Movement and Habitat Selection of Largemouth Bass in a Florida Steep-sided Quarry Lake

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Abstract: The movement and habitat selection of largemouth bass (*Micropterus salmoides*) was determined in a north-central Florida lake from 18 April 2002 to 1 May 2003 via radio telemetry. The study site was a steep-sided, 7-ha flooded limerock quarry, composed of six conjoined sub-basins. Twelve largemouth bass were internally implanted with radio transmitters (of no more than 18% of the total length of the fish). Limnetic areas were selected over littoral areas during the summer (May through October) and fall/winter (November through January) periods. Only one fish used littoral areas more than limnetic areas during this time. In the spring (February through April), habitat use switched. Sunken trees were the only structural habitat significantly used by largemouth bass ($P < 0.05$). Other structural habitats (aerators, feeders, fish attractors, and humps and boulders) had neutral preference values. Areas within 5 m of the shoreline were strongly avoided ($P < 0.05$). Home range was positively correlated with days sampled, but not total length and weight of fish. Home range varied from 0.56 to 4.84 ha, with means of 3.04 ha for all fish, and 4.09 ha for the five fish that were tracked over the entire study. No seasonal trends were evident in home range size. One fish established a separate home range from 9 January to 18 February 2003; after which it returned to its previous range. Fish exhibited constant movement during diel sampling periods, often moving between sub-basins. No day/night differences in movement or habitat preference were detected. It is speculated that the largemouth bass fed primarily on open water prey. Increasing structural habitat may not measurably increase angler catch rates for largemouth bass in steep-sided lakes where open water prey are the prin-

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cipal forage. Managers should focus their efforts on educating anglers to direct fishing effort to open areas to increase catch rates of largemouth bass.

Key words: radio telemetry, habitat selection, *Micropterus salmoides,* open water, littoral

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Habitat selection by largemouth bass (*Micropterus salmoides*) is an important consideration in fisheries management. Knowledge of preferred habitats can aid biologists in making management decisions. As ambush predators, largemouth bass typically use structural littoral habitats including: aquatic vegetation (Fish and Savitz 1983, Mesing and Wicker 1986, Killgore et al. 1989, Smith and Orth 1990), brushy habitat (Scott and Crossman 1973, Vogele and Rainwater 1975, Schlagenhoff and Murphy 1985, Betsill et al. 1986), shoreline (Lyons 1983, Wanjala et al. 1986), and docks/piers (Colle et al. 1989). Aquatic vegetation is the principal habitat available for the Florida largemouth bass (*M. s. floridanus*), which evolved in the shallow, highly vegetated waters of Florida and seems to prefer shallow water (Chew 1975). Largemouth bass also use open water areas in some situations (Wanjala et al. 1986, Colle et al. 1989). Colle et al. (1989) found that largemouth bass used open water areas after all submerged aquatic vegetation was removed from Lake Baldwin, a shallow Florida lake.

Quarry lakes are fairly common in Florida and throughout the United States and are often fished by anglers. Because quarry lakes often have nearly vertical walls, littoral habitat can be limited. There is a lack of research on habitat selection by largemouth bass in steep-sided systems with narrow littoral zones.

The home range of largemouth bass has been quantified by various authors (Warden and Lorio 1975, Fish and Savitz 1983), the size of which increases with fish size (Chappell 1974), length of time sampled, and water body size and morphometry. Largemouth bass have "activity centers" within their home range where they spend the majority of their time (Winter 1977, Doerzbacher 1980, Betsill et al. 1986, Boyer 1994). Other researchers noted that subsets of some populations exhibit random movement and do not have activity centers (Ball 1947, Moody 1960). This is most likely associated with open water use. It has been hypothesized that there are mobile and sedentary segments of some largemouth bass populations (Fetterolf 1952, Funk 1957, Moody 1960, Poddubnyi et al. 1974, Miller 1975). Factors leading to transient behavior may include selection of a limnetic species as its primary prey or lack of suitable habitat.

One response by fisheries managers to a perceived lack of physical habitat is to supplement it with artificial structure, which has been shown to attract and concentrate prey and sport fish (Hazzard 1937; Rodeheffer 1939, 1940, 1945; Manges 1959; Anderson 1964; La Roche 1972; Prince et al. 1975). This often results in higher catch rates for anglers (Prince et al. 1975, Wilbur 1978), which is often a goal of sport-fishery managers.

If largemouth bass are mobile due to a lack of attractive habitat, then providing habitat may allow them to become more sedentary. This would make the fish more accessible to anglers, who often fish near structural habitat. Conversely, if largemouth bass are mobile because they rely on open water prey, such as clupeids, adding structural habitat is not as likely to elicit the desired response. The purpose of this study was to determine the movement and habitat selection of largemouth bass in a deep, steep-sided Florida quarry lake.

Study Area

Kirkpatrick Lake is located in Alachua County, Florida, west of Gainesville. It is a flooded limerock quarry consisting of six conjoined sub-basins with a total surface area of approximately 7 ha. Much of the perimeter of the lake is comprised of 10- to 30-m vertical walls. This steep-sided lake has a mean depth of 6.5 m and a maximum depth of 11 m. Giant bulrush (*Scirpus californicus*), alligator weed (*Alternanthera philoxeroides*), and cattails (*Typha latifolia*) were present but limited in abundance due to the lack of suitable shallow substrate. Southern naiad (*Najas guadalupensis*) was common in the littoral zone and grew to an average height of 0.3 m. The littoral zone extended to a mean depth of 3.5 m, comprising 39.8% of the surface area of the lake. Littoral zone width averaged 10 m, but ranged from 0 to 45 m. Six large trees had been submerged in the lake as structural habitat. Four mushroom–hat fish attractor complexes (each composed of five individual fish attractors) were placed into the lake on 4 October 2002 (Thompson 2003). The lake was naturally oligotrophic based on water clarity (Forsburg and Ryding 1980), having secchi disk depths up to 6 m (Christy Horsburgh, Department of Fisheries and Aquatic Sciences, University of Florida, unpublished data). However, in recent years, 20 L of liquid 0-46-0 fertilizer was added annually to the lake to increase primary production and enhance fish production. Fish were also fed pelleted feed. Secchi disk depths ranged from less than 1 m when the lake was fertilized (February to November) to over 3 m when the lake was not fertilized and water temperatures were lower. Sport fish in the lake included largemouth bass, hybrid striped bass (*Morone chrysops* x *Morone saxatilis*), bluegill (*Lepomis macrochirus*), warmouth (*Lepomis gulosus*), and redear sunfish (*Lepomis microlophus*). Prey species included golden shiner (*Notemigonous chrysoleucas*), threadfin shad (*Dorosoma petenense*), gizzard shad (*Dorosoma cepedianum*), lake chubsucker (*Erimyzon sucetta*), eastern mosquitofish (*Gambusia holbrooki*), blue tilapia (*Oreochromis aureus*), and brown bullhead (*Ameiurus nebulosus*). Fishing pressure was light (2–3 fishing parties per week) because it is a private water body with controlled access and a strict catch and release fishing policy. Large adult largemouth bass (>406 mm total length) were often stocked into the lake, but were not routinely caught by anglers. Although the largemouth bass population in Kirkpatrick Lake is most likely comprised of intergrades (Thompson 2003), the percentage of northern sub-specific input is probably low. Phillip et al. (1983) estimated the percentage of the Florida largemouth bass subspecies genome to be approximately 96% for this region of Florida.

Methods

Eleven largemouth bass, weighing from 1.0 to 3.0 kg, were collected from both littoral and limnetic areas of the lake, including areas with and without structure. Fish were collected by pulsed-DC electrofishing on 16 April 2002 and implanted with Advanced Telemetry Systems (ATS) Model f1235 temperature-sensing radio transmitters (75 mm x 18 mm, 24 g). Transmitters had frequencies ranging from 48.411 to 48.825 MHz. One additional transmitter did not operate properly and had to be replaced. A twelfth fish was implanted on 7 May 2002 after the new transmitter arrived.

We attempted to capture fish over a broad size range so that transmitter weights would be no more than 2% of the body weight (Mesing and Wicker 1986). Transmitter size was more important than weight during implantation of largemouth bass in Kirkpatrick Lake. Although Ross and McCormick (1981) recommend transmitters weigh less than 2% of the weight of the fish, it has been shown that fish quickly adapt to transmitter weights of 2.4% to 4.3% of body weight (Crumpton 1982, Connors 2002). The transmitter was 2.5% of the body weight and 17.8% of the total length for the smallest fish in this study. Although a smaller fish could have been used based on transmitter weight, we found insertion and suturing difficult when the transmitter was greater than 20% of the total length of the fish (using practice specimens prior to initiating this study) because of the physical constraints of the abdominal cavity. Because most internal radio transmitters are cylindrical, transmitter length can be used to estimate the minimum size fish needed for implantation. Also, length of a fish does not fluctuate seasonally like weight. Based on our experience, transmitter length should be no more than 18% of the total length of the fish.

Fish handling procedures were recommended by Dr. Allen Riggs, College of Veterinary Medicine, University of Florida. Surgical tools and transmitters were disinfected with 95% ethyl alcohol before use. Each fish was individually anesthetized in a 51-L aerated cooler containing 150-mg L^{-1} MS-222 solution. After a fish lost equilibrium, total length (TL) and weight were measured before moving the fish for surgery to a 95-L aerated cooler containing 100-mg L^{-1} MS-222 solution. Both solutions were buffered at a rate of two parts sodium bicarbonate to one part MS-222. While in the second cooler, the fish was placed into a wooden trough such that its head was submerged while the area of operation was out of the water. A 20- to 25-mm vertical incision was made 25 to 30 mm anterior of the anus. The transmitter was inserted into the body cavity and the incision was closed with a single row of four to five stitches through both the peritoneum and integument using size 3-0 reverse cutting needles and monofilament suture material (Fluorofil, Schering-Plough, Union, New Jersey). Antibiotic topical ointment (Panalog) was rubbed onto the incision to help prevent infection. Two Floy T-bar internal anchor tags were inserted between the dorsal pterygiophores of each fish. The fish was then placed into a cooler of fresh water for recovery before being released at the site of its capture. Total handling time for each fish was 20 to 30 minutes.

Two signs were placed near the boat ramp and picnic area of this private lake advising anglers to immediately release tagged fish unharmed at the site of capture. At least one tagged fish was caught and released back into the lake by an angler during this study.

Each fish was located weekly from 1 May 2002 to 1 May 2003 (unless the transmitter failed or ceased movement) with an ATS Model R2000 receiver and a loop antenna. Radio-tracking was performed using a 3-m jon boat propelled by an electric trolling motor to minimize disturbance to the fish. Random sampling times were varied between 0700 and 2100 hours to reduce bias associated with time of day. Fish located near vertical walls were triangulated parallel and perpendicular to the wall to eliminate false locations due to signal reflection. Latitude and longitude were determined directly above the location of the fish with a global position system (GPS), along with the time of day. Because GPS readings could not always be taken due to the steepness of the rock walls, all locations were also marked on a detailed bathymetric map developed by Florida LAKEWATCH (Department of Fisheries and Aquatic Sciences, University of Florida, Gainesville) in November 2000. Pulse rate (seconds per 100 pulses) was measured for each transmitter with a stopwatch.

Dissolved oxygen and temperature profiles were measured, with a Yellow Springs Instruments Model 58 dissolved oxygen/temperature meter, in every sub-basin in which a radio-tagged fish was located. The recorded pulse rate of each transmitter was then compared with the calibration curve, supplied with each transmitter, to obtain the temperature of each fish. This temperature was then compared with the temperature profile of the sub-basin to approximate the depth of each fish.

The bathymetric map of Kirkpatrick Lake was copied into ArcView GIS 3.2 as a base-map for habitat and location mapping. ArcView was used to measure habitat areas, count locations per habitat, and generate digital maps of the lake and its habitats. The littoral zone was defined as the area from the shoreline out to the 3.5 m depth contour, the mean maximum depth of rooted aquatic vegetation. Littoral areas included clean shoreline, brushy shoreline (shoreline that had terrestrial bushes growing out into the water), humps, boulders, small brush-piles (such as single Christmas trees submerged into the lake), shallows (relatively flat areas that were less than 2 m deep), saddles (littoral areas between sub-basins), and other non-structural areas. Limnetic areas (>3.5 m depth) included open water, fish feeders, aerators, large sunken trees, and fish attracting devices (FADs). These habitats were visually marked in the winter, when water clarity was high, and drawn onto the bathymetric map (Fig. 1). These habitats were then redrawn onto the base-map using ArcView. A 5-m buffer was placed around structural habitats (humps, boulders, brushpiles, trees, aerators, feeders, and FADs). A fish was considered to be using a particular habitat when it was within 5 m of the habitat. This 5-m distance was selected to minimize disturbance of fish potentially changing their behavior patterns and because at this distance in the clear water, the individual habitats could easily serve as a reference for the fish. Maps showing the location fixes for each fish were then overlaid onto the habitat map to count the number of locations per habitat.

Annual and seasonal home ranges were calculated with ArcView using the smallest convex-polygon method (Winter 1977). Outliers were removed from the in-

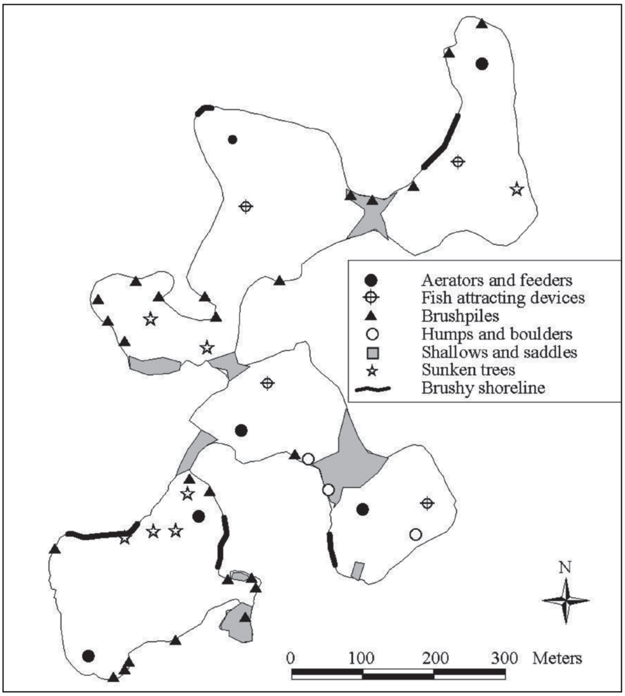

Figure 1. Distribution of habitats and fish attracting device installation sites for Kirkpatrick Lake, Florida, May 2002 to May 2003.

dividual home range estimates if they occurred as single locations in a sub-basin and were not along travel routes. The sampling year was broken up into three seasons. The summer season included all sampling dates from May through October 2002. Fall/winter sampling dates were from November 2002, when the lake started to destratify, through January 2003. Spring sampling dates were from February through May 2003 (the typical spawning period for largemouth bass in north Florida). Annual and seasonal habitat selection were determined from a modification of Strauss' (1979) linear index of food selectivity, $L = r_i - p_i$; where r_i is the percent use of habitat i and p_i is the percent availability of habitat i (Mesing and Wicker 1986). Habitat preference values can range from –1 (avoidance) to +1 (preference). The Wilcoxon signed rank test (Hollander and Wolfe 1973) was used to determine if mean L values were significantly different from zero ($\alpha = 0.05$).

Diel sampling was conducted on 22 August 2002 and 17 April 2003 to determine if habitat use and movements were equivalent between day and night. Sampling began at 0700 hours and ended at approximately 0300 hours. Each fish was located every four hours during diel sampling and its position marked on the bathymetric map. GPS readings were not taken during diel sampling because of potential effects on fish movements. For each time period, pulse rate was recorded for each fish and a dissolved oxygen/temperature profile was recorded for each sub-basin in which a fish was located.

Results

Tagged largemouth bass were successfully located on average over 99% of the time. Five transmitters (471, 684, 725, 764, and 825) became stationary during the course of the study, indicating that the fish most likely died or possibly shed their transmitters (Table 1). It is unlikely that the transmitters were shed since the first cessation of movement came 3.5 months after transmitter implantation (A. Riggs, University of Florida, personal communication). Efforts to instigate movement, if the fish were alive but inactive, were unsuccessful. Further efforts to recover the transmitters or fish carcasses were also unsuccessful. Transmitters in four of the five fish ceased movement in August and early September. During this time period, one to two dead, untagged largemouth bass, >375 mm TL, were observed per week. This pattern of finding a few large dead largemouth bass over an extended period during the hotter months is consistent with largemouth bass virus (W. Porak, Florida Fish and Wildlife Conservation Commission, personal communication) and, speculatively, may have been the cause of these deaths. Two fish (561 and 704) either experienced transmitter failure or were removed from the lake by poachers. Another transmitter (Fish 744) stopped pulsing on 17 April 2003, so depth could no longer be calculated. However, the transmitter continued to emit a tone and the fish could be located for the duration of the study.

Dissolved oxygen concentrations were less than 2 mg L^{-1}, at water depths below 4.2 m, from the start of radio-tracking until the lake destratified on 14 November 2002. Observed oxygen concentrations did not drop below 2 mg L^{-1} (at depths up to 5.5 m) for the remainder of the study. Temperature data from the transmitters were often inconsistent with the data from the temperature profiles. Thirty percent of the temperature calculations from the transmitter calibration curves were higher

Table 1. Tagging information and home range for largemouth bass in Kirkpatrick Lake, Florida.

Fish number	Length (mm)	Weight (g)	Home range (ha)	Tagging date	Last observation[a]	Observations/ attempts
411	556	2950	4.57	16 Apr 2002	1 May 2003	66/66
471	446	1265	0.56	16 Apr 2002	22 Aug 2002	16/16
501	422	979	3.49	16 Apr 2002	1 May 2003	65/66
561	448	1248	2.64	16 Apr 2002	30 Aug 2002	21/21
684	459	1267	1.82	16 Apr 2002	26 Oct 2002	37/38
704	483	1409	2.42	16 Apr 2002	18 Sep 2002	24/24
725	512	2193	2.08	16 Apr 2002	7 Aug 2002	14/14
744	475	1322	4.30	16 Apr 2002	1 May 2003	65/66
764	523	2203	3.79	7 May 2002	22 Aug 2002	13/13
784	455	1357	4.84	16 Apr 2002	21 Apr 2003	65/66
804	444	1161	3.27	16 Apr 2002	1 May 2003	66/67
825	466	1358	2.74	16 Apr 2002	6 Sep 2002	22/22

a. First observation was 1 May 2002 for all fish except 764 which was 18 May 2002.

Table 2. Mean values of the linear selection index L for habitat use by largemouth bass in Kirkpatrick Lake, Florida, from 1 May 2002 to 1 May 2003. Positive values indicate preference; negative values indicate avoidance. Values with asterisks (*) are significantly different (*P* < 0.05) from zero.

Season	Littoral zone	Brushy shore	Clean shore	Brush piles	Shallows/ saddles
Summer	–0.09*	–0.09*	–0.84*	–0.03*	–0.11*
Fall/Winter	–0.14	–0.10*	–0.87*	-0.03*	–0.10
Spring	0.14	–0.10*	–0.80*	–0.02	0.09

Season	Limnetic zone	Sunken trees	Aerators/ feeders	Fish attracting devices	Humps/ boulders
Summer	0.09*	0.08*	0.00	–0.01	0.00
Fall/Winter	0.14	0.06	0.07	0.03	0.02
Spring	–0.14	0.05*	0.02	0.03	0.00

than the measured surface water temperatures. For this reason, derived depth estimates were not used.

Habitat Selection

Overall, largemouth bass used limnetic areas more than twice as often (68.4% of the fish locations and 60.2% of total lake area) as littoral areas (31.6% of fish locations and 39.8% of total lake area). A commonly used habitat included sunken trees (11.5% of fish locations and 3.4% of available habitat), while shoreline areas were avoided (6.7% of fish locations).

Structural habitats were not heavily used by largemouth bass (Table 2). Sunken trees were the only structural habitat significantly ($P < 0.05$) used by largemouth bass (summer and spring). Other structural habitats, such as aerators, feeders, fish attractors, and humps and boulders, had neutral L-values (summer, fall/winter, and spring; $P > 0.05$). Brushy and clean areas, within 5 m of the shoreline, were strongly avoided during each of the three seasons ($P < 0.05$). Brush piles were also avoided in the summer and fall/winter seasons ($P < 0.05$).

Limnetic areas were positively selected over littoral areas during the summer ($P < 0.05$). Only one fish (784) used littoral areas (L = 0.13) more than limnetic areas (L = –0.13) during the summer. During the fall/winter period, the lake destratified and the dissolved oxygen and temperature readings became uniform. Positive L-values for open water were higher (L = 0.14) than in the summer (L = 0.09), indicating increased use of open water areas. This preference reversed in the spring, when littoral areas (L = –0.14) seemed to be selected over limnetic areas (L = 0.14). Fish 411, the largest fish in the study and possibly a female, used open water areas most of the time (L = 0.16, 0.31, and 0.21 for the summer, fall/winter, and spring, respectively).

Home Range

For this study, home range was defined as the area through which a fish traveled during the study period (Burt 1943). One outlier was removed from each of the home range estimates of Fish 471, 501, and 684. Home range estimates varied from 0.56 to 4.84 ha, with a mean of 3.04 ha for all fish (Table 1). Home range was positively correlated with days sampled ($N = 12$; r = 0.69; $P = 0.01$). Knowing this, we wished to determine if fish size affected home range. By analyzing data from only those fish that were observed for the full duration of the study, home range was found not to be correlated with total length and weight ($N = 5$, r = 0.57, $P = 0.31$; $N = 5$, r = 0.52, $P = 0.36$, respectively), and mean home range increased to 4.09 ha.

No seasonal trends were evident in home range size. Fish 804 established a separate winter home range primarily in the southernmost sub-basin from 9 January to 18 February 2003, after which, it returned to its summer-spring range in the three northern sub-basins of the lake.

Diel Sampling

Largemouth bass locations, observed during both diel tracking sessions, were consistent with weekly daytime data collected during the course of the study. No differences in movement or habitat preference were detected between day and night samples. Fish exhibited constant movement (often between sub-basins) during diel sampling periods. No fish was found in the same location more than two consecutive times. There was no evidence of any diel on-shore/off-shore movement patterns among the fish.

Discussion

Several studies have documented seasonal use of off-shore areas by largemouth bass in the winter after lake destratification (Warden and Lorio 1975, Prince and Maughan 1979, Betsill 1986, Woodward and Noble 1997). Most of these offshore locations involved structural habitat. In our study, limnetic areas were used night and day, and year-round, except during the spawning season. The majority of locations in our lake were in the open water limnetic zone not associated with any structural habitat. Wanjala (1986), Mesing and Wicker (1986), and Colle et al. (1989) also found use of the open water limnetic zone by largemouth bass. It may be argued, or at least it can not be ruled out based on this study, that the habitat enhancements may provide refuge and food for bait fish, which attract the largemouth bass to the limnetic zone. In this scenario, the enhancements would, in fact, prove beneficial.

It is a common perception that only mid-size (250–400 mm TL) largemouth bass use the open water limnetic zone with any regularity. Wanjala (1986) concluded that largemouth bass >380 mm TL in an Arizona lake could not forage effectively in open water because of their bulky body shape. However, fish up to 556 mm TL used open water regions of Kirkpatrick Lake. Mesing and Wicker (1986) and Colle et al. (1989) radio-tracked largemouth bass up to 615 mm and 499 mm TL, respectively, that used open water most of the time. Findings of this study and those of other Florida studies indicate that big largemouth bass readily use open water.

The mean home range of 3.04 ha for the largemouth bass in Kirkpatrick Lake is larger than means reported for largemouth bass in larger systems ([1.06 ha] Winter 1977, [<0.5 ha] Nieman and Clady 1980, [1.0 and 1.4 ha] Mesing and Wicker 1986, [1.37 and 1.73 ha] Boyer 1994, [2.11 ha] Woodward and Noble 1997). The larger home range size in Kirkpatrick Lake probably reflects the more mobile lifestyle of open water fish. Colle et al. (1989) found a larger mean of 21 ha in the off-shore component of largemouth bass in 80-ha Lake Baldwin, Florida. This may be because the fish had to range further to forage effectively based on the larger size and simpler morphometry of Lake Baldwin.

Fish 804 established a separate winter home range and then returned to its prior home range before spawning season. This agrees with Woodward and Noble's (1997) findings for Jordan Lake, North Carolina, where four of eleven adult largemouth bass established separate winter home ranges and returned to prior home ranges in early spring. This had only been observed previously in sub-adult largemouth bass (Woodward 1996).

There was considerable overlap in largemouth bass home ranges in Kirkpatrick Lake. One fish was located very near another fish on several occasions. This indicates possible shoaling activity. Large shoals of mobile largemouth bass were observed on three different occasions. These shoals contained 20 to 30 fish that ranged in size from an estimated 300 to 425 mm TL. Shoaling behavior in predatory fish is commonly associated with foraging activity for open water prey. Betsill (1983) and Wildhaber (1985) found a lack of overlap in individual home ranges of largemouth bass in two small Texas impoundments. This indicates the largemouth bass normally did not occupy the same areas and possibly defended territories. There were no limnetic prey species present in these impoundments; sunfish were the primary forage (Betsill 1983, 1985). Structural habitat may be a more important component of largemouth bass behavior when the primary forage is littoral species such as sunfish.

Structural habitat was not extensively used by largemouth bass in Kirkpatrick Lake based on the preference values. Largemouth bass were often observed in open water chasing shad to the surface. Angling efforts verified that these fish were largemouth bass. Therefore, limnetic clupeids are most likely the primary forage for largemouth bass in the lake. Diet studies should be conducted to test this hypothesis. Increasing structural habitat may not measurably increase angler catch rates for largemouth bass in lakes where open water prey are the principal forage.

Sunfish may not be as abundant or utilized in Kirkpatrick Lake to the extent that they are in most other systems for two reasons. Based on observation, there seems to be a lack of suitable spawning substrate for adult sunfish and refuge from predation for their young; this would reduce overall production of adequately-sized prey. The fish in the lake are occasionally fed with floating fish feed and many of the sunfish present are too large to be consumed by most largemouth bass. If production of young sunfish were increased, largemouth bass would likely use littoral areas more often.

Although FADs were offered as habitat to attract largemouth bass and possibly alter their habits from actively hunting in open water to ambush predation, this did not occur in any of the five fish radio-tracked after FAD deployment. Detecting a change in habit depends on what mechanisms are driving the largemouth bass to use open water. If largemouth bass use open water because structural habitat is limited, adding habitat could allow some fish to revert to ambush predation, assuming a source of forage is available near the habitat. However, if fish use open water as a means of procuring limnetic prey, increasing structural habitat probably will not alter the food base and therefore will be less likely to elicit a response in the behavior of the largemouth bass. Although it potentially only takes one fish to illustrate a shift in habit, the probability of detecting a change in a natural system is low. Therefore, behavioral questions such as this may best be answered in an experimental setting, where environmental variables can be better controlled.

Management Implications

Fisheries managers should consider the behavioral ecology of the largemouth bass as well as the human dimensions of the anglers before implementing habitat enhancement strategies. Although much time and effort has been spent planting bulrush and putting brush piles, trees, and FADs into Kirkpatrick Lake, the results from this study indicate that most of these habitats were not significantly used by largemouth bass. Since habitat manipulations may not be cost-effective (based on use by largemouth bass) in steep-sided lakes where open water prey are the principal forage, fisheries managers should focus their efforts on educating anglers to direct their fishing effort in open water areas to increase their catch rates of largemouth bass.

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