DISTRIBUTION AND HABITAT SELECTION OF LARGEMOUTH BASS IN A FLORIDA LIMEROCK PIT

By

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Abstract of Thesis presented to the Graduate School
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Major Department: Fisheries and Aquatic Sciences

Radio telemetry was used to determine the distribution and habitat selection of largemouth bass (*Micropterus salmoides*) in a north-central Florida lake from 18 April 2002 to 1 May 2003 so that management recommendations that would increase angler catch rates could be made. The study site (Kirkpatrick Lake, Alachua County, Florida) is a steep-sided, 7-ha flooded limerock quarry, and is 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) and tracked. Over the course of the study, the number of fish tracked was reduced to five as transmitters failed or ceased movement.

Pelagic areas were selected over littoral areas during the summer and fall/winter periods ($p = 0.022$). Only one fish utilized littoral areas more than pelagic areas during this period. In the spring (February through April), habitat use switched; littoral areas seemed to be selected over pelagic areas for four of five fish based on the preference values. However, no significance was found because of the low number of replicates

(n = 5). Sunken trees were the only structural habitat significantly utilized by largemouth bass ($p < 0.001$). Other structural habitats had generally neutral preference values. Areas within 5 m of the shoreline were strongly avoided ($p < 0.001$).

Home range was correlated with days sampled ($n = 12$, $r = 0.69$, $p = 0.01$), but not total length and weight of fish ($n = 5$, $r = 0.57$, $p = 0.31$; $n = 5$, $r = 0.52$, $p = 0.36$, respectively). 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.

Largemouth bass locations, observed during two diel tracking sessions, were consistent with weekly daytime data collected over the full term of the study. Fish exhibited constant movement during diel sampling periods, often moving between sub-basins. No day/night or spring/summer differences in movement or habitat preference were detected. There was no evidence of any diel on-shore/off-shore movement patterns.

Twenty mushroom-hat fish attracting devices (FADs) were suspended vertically into the lake at four sites on October 4, 2002. Although four of the five remaining largemouth bass utilized these FADs at least once, the neutral preference values indicate that the FADs were not a significant habitat for the largemouth bass.

Due to the selection of pelagic areas, except during the spawning season, 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 lakes where open water prey are the principal forage. Therefore, fisheries managers should focus their efforts on angler education in such lakes.

INTRODUCTION

Habitat selection by largemouth bass (*Micropterus salmoides)* is an important consideration in fisheries management. Knowledge of selected habitats can aid biologists in making management decisions. As ambush predators, largemouth bass typically utilize structural littoral habitat such as vegetation and woody debris, though they are sometimes found off-shore in deeper, open water. 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). Colle et al. (1989) found that the Florida largemouth bass utilized 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 utilized by anglers. There is a lack of research on habitat selection by largemouth bass in steep-sided systems that have a narrow littoral zone.

The home range of largemouth bass has been quantified by various authors (Warden and Lorio 1975; Fish and Savitz 1983), the size of which varies 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 the population exhibit random movement and do not have activity centers (Ball 1947; Moody 1960). It has therefore 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 a transient lifestyle may include differential prey selection or lack of suitable habitat.

One response by fisheries managers to a perceived lack of natural habitat is to supplement it with artificial habitat or 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 have a mobile lifestyle due to a lack of attractive habitat, then offering habitat may allow them to assume a more sedentary habit. This would allow the fish to be more accessible to anglers, who often fish near structural habitat. The purpose of this study was to determine the distribution and habitat selection of largemouth bass in a deep, steep-sided Florida lake and to assess changes in distribution after installation of artificial structure.

STUDY SITE DESCRIPTION

Kirkpatrick Lake is located in Alachua County, Florida, west of Gainesville (Figure 1). 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 11m. Giant bulrush (*Scirpus californicus*), alligator weed (*Alternanthera philoxeroides*), and cattails (*Typha latifolia*) are present but limited in abundance due to the lack of suitable shallow substrate. Southern naiad (*Najas guadalupensis*) is common in the littoral zone and grows to an average height of 0.3 m. The littoral zone extends to a mean depth of 3.5 m. Littoral zone width averages 10 m but ranges from 0 to 45 m. Six large trees have been submerged in the lake as structural habitat. 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). The lake is currently fertilized during the warm months to increase algal production and enhance fish production. Fish are also fed pelleted food. Secchi disk depths now range from less than 1m when the lake is fertilized (February to November) to over 3 m when the lake is not fertilized and water temperatures are lower. Sport fish in the lake include largemouth bass, hybrid striped bass (*Morone chrysops x Morone saxatilis*), bluegill (*Lepomis macrochirus*), warmouth (*Lepomis gulosus*), and redear sunfish (*Lepomis microlophus*). Prey species include 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 (*Ictalurus nebulosus*). Fishing pressure is light (2-3 fishing parties per week) because it is a private water body that has controlled access and a catch and release only fishing policy. Although large adult largemouth bass (> 406 mm TL) are often stocked into the lake, but are not routinely caught by anglers.

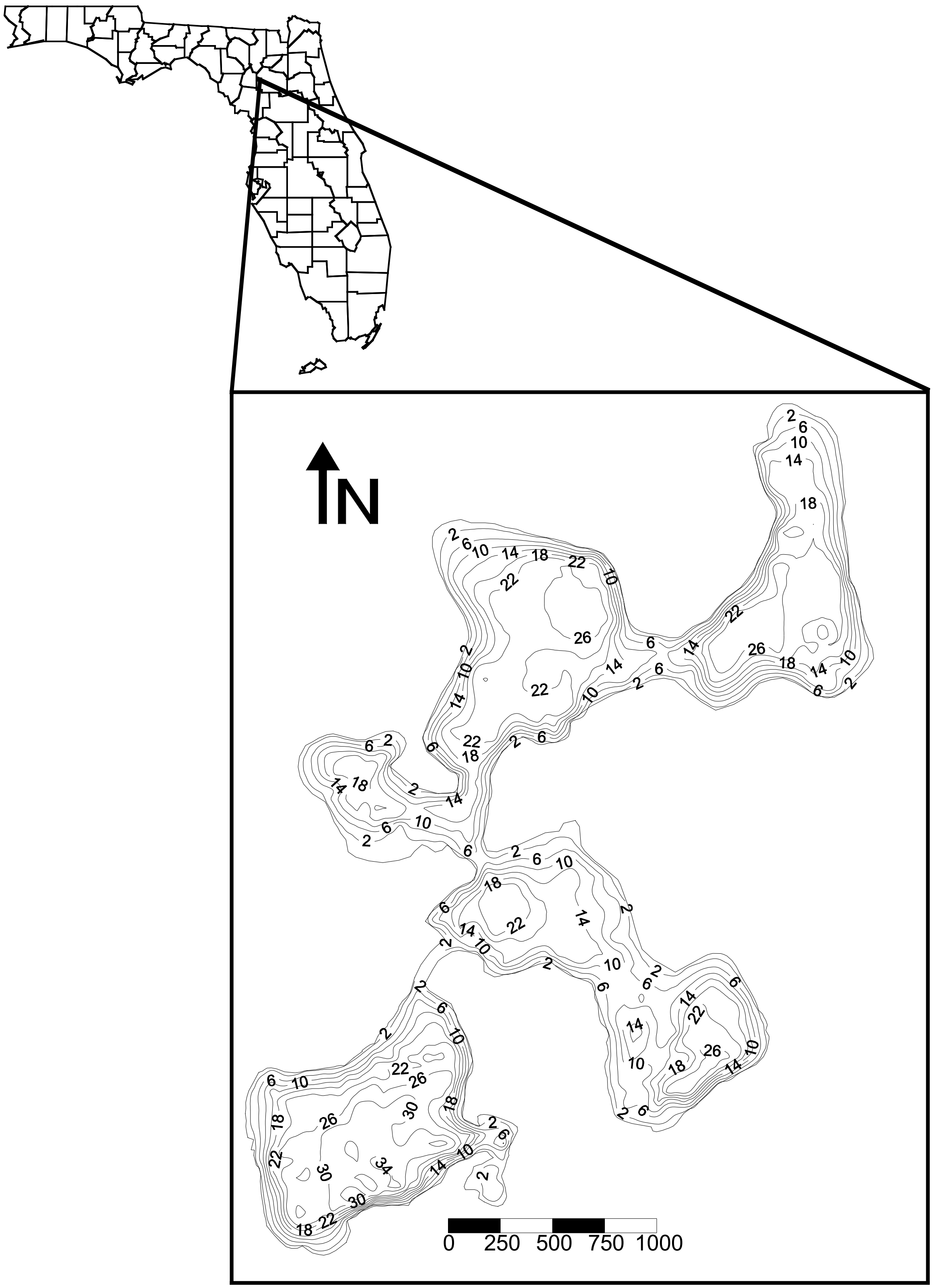

Figure 1. Kirkpatrick Lake location and bathymetric map (from Florida LAKEWATCH). Depth contours and distances are in feet.

METHODS

Transmitter Implantation

Eleven largemouth bass, weighing from 1.0 to 3.0 kg, were collected from the lake by electrofishing (300 V, 7A, DC pulse) on 16 April 2002 and implanted with Advanced Telemetry Systems (ATS) Model f1235 temperature-sensing radio transmitters (75 mm x 18 mm, 24 g). These transmitters had radio frequencies ranging from 48.411 to 48.825 MHz. One 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 two percent of the body weight (Mesing and Wicker 1986). 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 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 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 into the dorsal pterigiophores and a small piece of the right pelvic fin was clipped from 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 a an angler during this study. Fin samples were sent to the A. E. Woods Fish Hatchery (Texas Parks and Wildlife Department) in San Marcos, Texas for DNA analysis.

Radio-Tracking

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 johnboat propelled by an electric trolling motor to minimize disturbance to the fish. Sampling times were randomly varied between 0700 and 2100 hrs 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. A GPS reading was taken directly above the location of the fish 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, FL) in November 2000. Prevailing weather conditions (% clouds, precipitation, and wind) were recorded to note any behavioral changes due to weather. Pulse rate (seconds/100 pulses) was measured for each transmitter with a stopwatch.

Dissolved Oxygen/Temperature Sampling

Dissolved oxygen/temperature profiles were recorded, 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.

Habitat Mapping

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 (Figure 2). 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 (Figure 3). Pelagic areas (> 3.5 m depth) included open water, fish feeders, aerators, large sunken trees, and

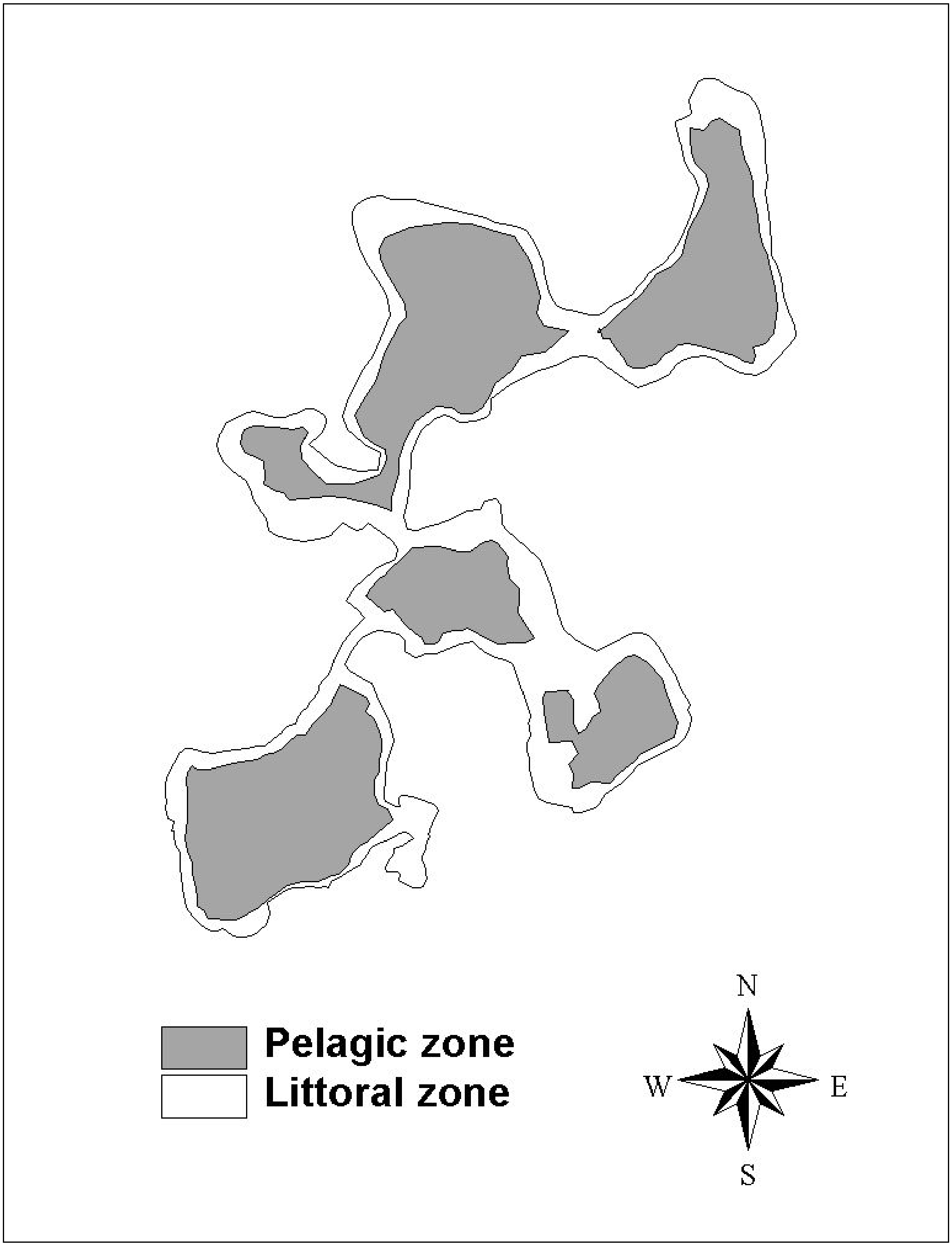

Figure 2. Pelagic and littoral zones in Kirkpatrick Lake, Florida. The littoral zone extended to the 3.5-m depth contour, May 2002 to May 2003.

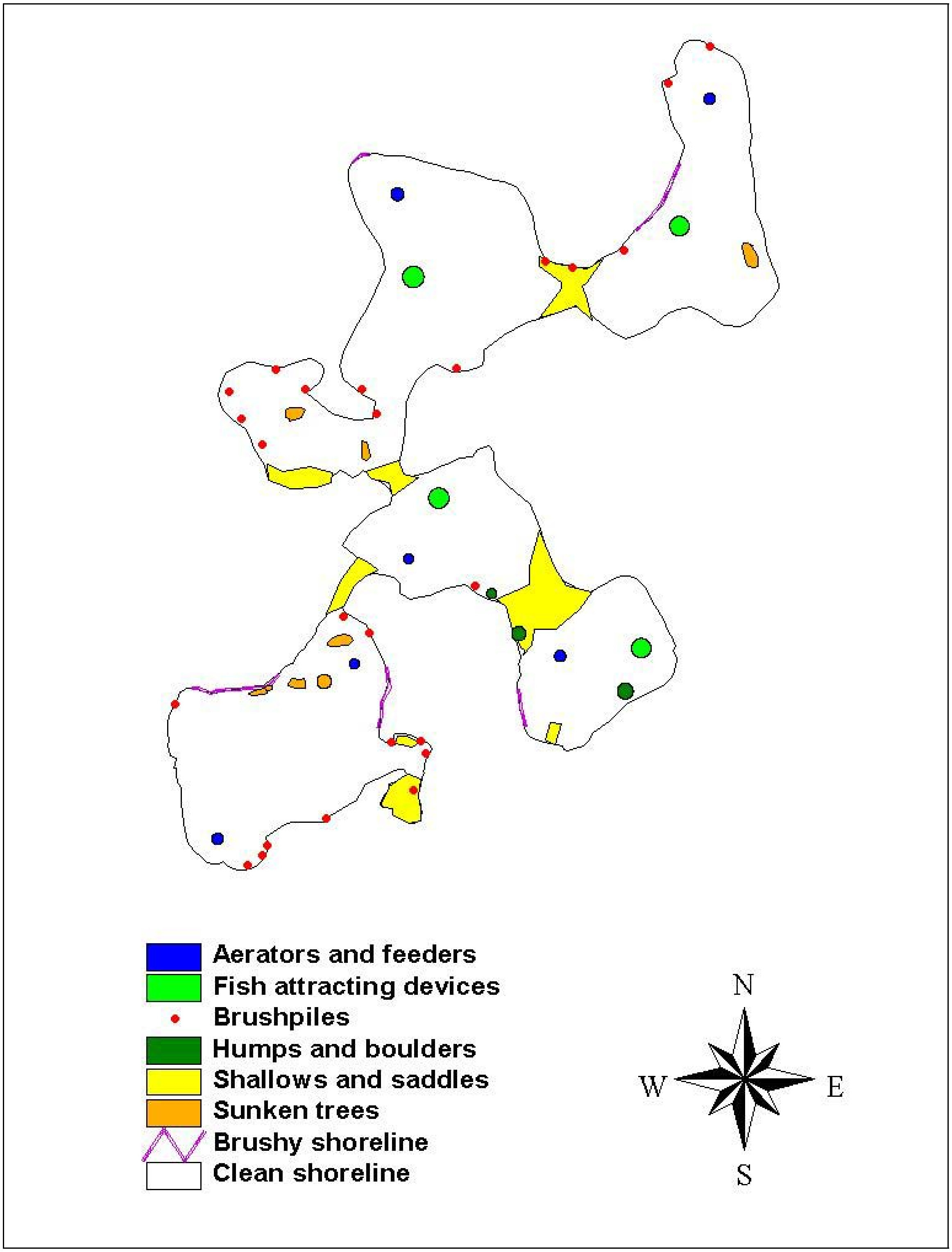

Figure 3. Distribution of habitats and fish attracting device installation sites for Kirkpatrick Lake, Florida, May 2002 to May 2003.

fish attracting devices (FADs). These habitats were visually marked in the winter, when water clarity was high, and drawn onto the bathymetric map. 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 utilizing a particular habitat when it was within 5 m of the habitat. Maps showing the location fixes for each fish were then overlaid onto the habitat map to count the number of locations per habitat.

<u>Home Ranges and Habitat Selection</u>

Annual and seasonal home ranges were calculated with ArcView using the smallest convex-polygon method (Winter 1977). Outliers were removed from the individual 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 2002 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 2003 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 ($\alpha(2) = 0.05$).

Diel Sampling

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 hrs and ended at approximately 0300 hrs. Each fish was tracked every four hours during diel sampling and its location 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.

Fish Attracting Device Study

Twenty mushroom-hat FADs were suspended vertically into the lake at four sites (Figure 3) on 4 October 2002. They were constructed using 150-L plastic trash cans. After the bottom was cut out, the remaining cylinder was cut vertically to make two arc-shaped pieces. These pieces along with the lid were used to construct one four-tiered structure. Holes were drilled in the center of these pieces and 10-mm diameter nylon rope threaded through the holes (with three 0.6-m segments of 38-mm diameter PVC pipe placed in between as spacers). The top and bottom pieces were secured with several knots in the rope. Each FAD was anchored with a 20x20x40-cm concrete block. Five dense 15x20-cm Styrofoam floats were used to float each structure. Each FAD was 2-m long from the lowest piece to the top of the floats. Depth was adjusted on site so that the bottom of each FAD was no deeper than 3 m below the water surface (the shallowest observed depth that the water became anoxic). This meant that the top of each FAD was 1 m underwater and thus less visible to anglers. FADs were placed in open water near funnels of recorded fish travel. Each site consisted of five FADs placed approximately 2 m apart in a pentagon formation. Radio-tagged fish were located three times each week for two weeks prior to FAD placement and three times each week for four weeks thereafter to quantify any changes in habitat use. Afterwards, normal weekly sampling was resumed for the remainder of the study.

RESULTS

General

At first, all 12 radio-tagged largemouth bass were identified to be the Florida subspecies based on the analysis of microsatellite DNA loci *Lma* 0012, *Mdo* 0006, and *Mdo* 0004 (Texas Parks and Wildlife Department, unpublished data) . Preliminary data from the Texas Parks and Wildlife Department suggested that these loci were diagnostic between northern and Florida largemouth bass. Subsequent analysis by the Texas Parks and Wildlife Department found that these loci were not diagnostic. Further analysis was performed on seven intrapseudogenic loci, which preliminary data show to be completely fixed for either northern or Florida largemouth bass. Results from this analysis indicate that eleven of the fish sampled were intergrades and one (Fish 704) was pure Florida strain (Texas Parks and Wildlife Department, unpublished data). No DNA could be extracted from the twelfth fish. Because of these conflicting results, largemouth bass were not designated to subspecies for this study.

Tagged largemouth bass were successfully located, on average, over 99% of the time. Five fish (471, 684, 725, 764, and 825) most likely died, or possibly shed their transmitters, when their movements ceased during the course of the study (Table 1). It is unlikely that the transmitters were shed since the first cessation of movement came 3.5 months after transmitter implantation (Allen Riggs, personal communication). Efforts to instigate movement, if the fish was 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, greater than 375 mm TL, were observed per week in Kirkpatrick Lake. This pattern of finding a few larger dead largemouth bass over an extended period during the hotter months is consistent with largemouth bass virus (Wes Porak, Florida Fish and Wildlife Conservation Commission, personal communication) and, speculatively, may be 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, 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 (at depths up to 5.5 m) for the remainder of the study.

Table 1. Size distribution and tagging information for largemouth bass in Kirkpatrick Lake, Florida.

Fish number	Total length (mm)	Weight (g)	Tagging date	Last observation[1]	Number of observations	Number of attempts	Location rate (%)
411	556	2950	16-Apr-02	1-May-03	66	66	100.00
471	446	1265	16-Apr-02	22-Aug-02	16	16	100.00
501	422	979	16-Apr-02	1-May-03	65	66	98.48
561	448	1248	16-Apr-02	30-Aug-02	21	21	100.00
684	459	1267	16-Apr-02	26-Oct-02	37	38	97.37
704	483	1409	16-Apr-02	18-Sep-02	24	24	100.00
725	512	2193	16-Apr-02	7-Aug-02	14	14	100.0
744	475	1322	16-Apr-02	1-May-03	65	66	98.48
764	523	2203	7-May-02	22-Aug-02	13	13	100.00
784	455	1357	16-Apr-02	21-Apr-03	65	66	98.48
804	444	1161	16-Apr-02	1-May-03	66	67	98.51
825	466	1358	16-Apr-02	6-Sep-02	22	22	100.00
						Overall rate (%):	99.28

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

Habitat Selection

Pelagic areas were utilized more than twice as often as littoral areas (from the shoreline to the 3.5 m depth contour) by the largemouth bass (Table 2). Other utilized habitats included sunken trees while shoreline areas were avoided.

Table 2. Percent habitat use by largemouth bass and percent habitat available in Kirkpatrick Lake, Florida, between 1 May 2002 and 1 May 2003.

Habitat type	% Use	% Available
Pelagic zone	68.4	60.2
Littoral zone	31.6	39.8
Pelagic habitats		
Sunken trees	11.5	3.4
Aerators/feeders	2.8	2.2
Fish attracting devices	5.5	2.5
Open water	48.6	52.1
Littoral habitats		
Brushpiles	0.5	3.0
Humps/boulders	1.6	1.3
Shallows/saddles	7.4	15.4
Non-structural	22.1	20.1
Shoreline		
Brushy	0.2	9.5
Clean	6.5	90.5

Structural habitats were not heavily utilized by largemouth bass in Kirkpatrick Lake (Tables 3 and 4). Sunken trees were the only structural habitat significantly utilized by largemouth bass ($p < 0.001$, Table 5). Other structural habitats had generally neutral *L*-values. Areas within 5 m of the shoreline were strongly avoided ($p < 0.001$).

Pelagic areas were selected over littoral areas during the summer and fall/winter periods ($p = 0.022$). Only one fish (784) utilized littoral areas more than pelagic areas during this period. 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 than in the summer, indicating increased use of open water areas.

Littoral areas seemed to be selected over pelagic areas in the spring. *L*-values were positive for four of the five remaining fish but no significance was found because of the low number of replicates (n=5). Fish 411, the largest fish in the study and possibly a female, seemed to utilize open water areas most of the time.

Table 3. Values of the linear selection index *L* for littoral 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.

Fish number	Littoral zone	Brushy shore	Clean shore	Brush piles	Humps/ boulders	Shallows/ saddles
			Summer			
411	-0.16	-0.10	-0.90	-0.03	0.04	-0.10
471	-0.20	-0.10	-0.90	-0.03	-0.01	-0.15
501	-0.21	-0.10	-0.88	-0.03	-0.01	-0.15
561	0.00	-0.10	-0.90	-0.03	-0.01	-0.15
684	-0.26	-0.10	-0.82	-0.03	0.04	-0.04
704	-0.14	-0.05	-0.82	0.01	-0.01	-0.11
725	-0.09	-0.10	-0.83	-0.03	-0.01	-0.15
744	0.00	-0.10	-0.77	-0.03	-0.01	-0.15
764	-0.01	-0.10	-0.83	-0.03	-0.01	-0.08
784	0.13	-0.10	-0.88	-0.03	0.01	-0.05
804	-0.02	-0.10	-0.82	-0.03	-0.01	-0.10
825	-0.07	-0.10	-0.76	-0.03	0.04	-0.01
			Fall/Winter			
411	-0.31	-0.10	-0.81	-0.03	0.17	-0.15
501	-0.30	-0.10	-0.90	-0.03	-0.01	-0.15
744	-0.22	-0.10	-0.81	-0.03	-0.01	-0.15
784	0.33	-0.10	-0.90	-0.03	-0.01	0.12
804	-0.22	-0.10	-0.90	-0.03	-0.01	-0.15
			Spring			
411	-0.21	-0.10	-0.85	-0.03	0.05	0.03
501	0.04	-0.10	-0.73	-0.03	-0.01	0.03
744	0.33	-0.10	-0.72	0.04	-0.01	0.11
784	0.40	-0.10	-0.84	-0.03	-0.01	0.38
804	0.13	-0.10	-0.85	-0.03	-0.01	-0.10

Table 4. Values of the linear selection index *L* for pelagic 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.

Fish number	Pelagic zone	Sunken trees	Aerators/ feeders	Fish attracting devices[1]
		Summer		
411	0.16	0.02	-0.02	0.07
471	0.20	0.23	0.05	-----
501	0.21	0.28	0.06	-0.03
561	0.00	0.07	-0.02	-----
684	0.26	-0.01	0.01	-0.03
704	0.14	0.23	-0.02	-----
725	0.09	-0.03	-0.02	-----
744	0.00	0.10	0.00	-0.03
764	0.01	0.04	-0.02	-----
784	-0.13	-0.01	0.03	-0.03
804	0.02	0.05	0.03	-0.03
825	0.07	0.01	-0.02	-----
		Fall/Winter		
411	0.31	0.06	0.25	-0.03
501	0.30	-0.03	0.08	0.07
744	0.22	0.15	-0.02	0.16
784	-0.33	-0.03	-0.02	-0.03
804	0.22	0.15	0.07	-0.03
		Spring		
411	0.21	0.03	0.10	0.11
501	-0.04	0.09	0.04	-0.03
744	-0.33	0.03	-0.02	-0.03
784	-0.40	0.03	-0.02	-0.03
804	-0.13	0.08	-0.02	0.10

[1] Fish without an *L*-value were no longer being located when the fish attracting devices were deployed.

Table 5. 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/Winter	-0.10*	-0.09*	-0.85*	-0.03*	-0.10*
Spring	0.14	-0.10	-0.80	-0.02	0.09

Season	Pelagic zone	Sunken trees	Aerators/ feeders	Fish attracting devices	Humps/ boulders
Summer/Winter	0.10*	0.07*	0.02	0.01	0.01
Spring	-0.14	0.05	0.02	0.03	0.00

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 (Table 6). Home range was correlated with days sampled ($n = 12$; $r = 0.69$; $p = 0.01$). After equalizing the number of observations by removing the fish that were not located for the duration of the study, total length and weight were not correlated with home range ($n = 5$, $r = 0.57$, $p = 0.31$; $n = 5$, $r = 0.52$, $p = 0.36$, respectively), and mean home range increased to 4.09 ha.

Seasonal home ranges were calculated for the five fish that were located for the duration of the study (Table 7). Mean home range was 2.82, 2.23, and 2.72 ha for the summer, fall/winter, and spring periods, repectively. 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 2003 to 18 February 2003, after which, it returned to its spring/summer 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 day/night or spring/summer differences in movement or habitat preference were detected. Fish exhibited constant movement during diel sampling periods. No fish was found in the same location more than two consecutive times. Movement between sub-basins was common for both the spring and summer sampling dates (Table 8). There was no evidence of any diel on-shore/off-shore movement patterns among the fish.

Table 6. Number of observations and home range (ha) for largemouth bass in Kirkpatrick Lake, Florida, from 1 May 2002 to 1 May 2003.

Fish number	Number of observations	Home range (ha)
411	66	4.57
471	16	0.56
501	65	3.49
561	21	2.64
684	37	1.82
704	24	2.42
725	14	2.08
744	65	4.30
764	13	3.79
784	65	4.84
804	66	3.27
825	22	2.74
mean		3.04

Table 7. Seasonal home ranges for largemouth bass in Kirkpatrick Lake, Florida, from 1 May 2002 to 1 May 2003.

Fish number	Summer home range (ha)	Winter home range (ha)	Spring home range (ha)
411	3.59	1.38	2.74
501	1.11	1.99	3.47
744	2.85	3.36	2.84
784	4.53	3.07	2.28
804	2.01	1.38	2.25
mean	2.82	2.23	2.72

Fish Attracting Device Utilization

After FAD deployment, four of the five remaining fish utilized a FAD at least once (8 out of 146 observations). However, preference values were generally neutral and the FADs were not a significant habitat for the largemouth bass. Largemouth bass selected sunken trees over FADs, based on the preference values.

Table 8. Number and percent of follow-up largemouth bass locations that were in a different sub-basin during two diel sampling dates in Kirkpatrick Lake, Florida, on 22 August 2002 and 17 April 2003. Fish were located every four hours. Four observations per fish per sampling date.

Fish	22/23 August 2002	17/18 April 2003[1]	Total	% of total
411	0	1	1	12.5
501	0	2	2	25.0
561	2	----	2	25.0
684	2	----	2	25.0
704	3	----	3	37.5
744	2	2	4	50.0
784	2	3	5	62.5
804	3	0	3	37.5
825	0	----	0	0.0

[1] Fish without a value were no longer being located when the second diel sampling was performed.

DISCUSSION

General

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 locations were oriented to structural habitat. Pelagic areas were utilized night and day, and year-round, except during the spawning season, in Kirkpatrick Lake. The majority of these locations were in the open water limnetic zone not associated with any structural habitat. Mesing and Wicker (1986), Wanjala (1986), and Colle et al. (1989) also found utilization of the open water limnetic zone by largemouth bass.

It is a common perception that only mid-size largemouth bass utilize the open water limnetic zone with any regularity. Wanjala (1986) concluded that largemouth bass longer than 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 utilized 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 utilized open water most of the time. This indicates that big largemouth bass are capable of feeding efficiently in open water when it is energetically productive to do so.

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 in the same spot as 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 pelagic prey species present in these impoundments; sunfish were the primary forage (Betsill 1983; Wildhaber 1985). Habitat may be a more important component of the life history of largemouth bass when the primary forage are littoral species such as sunfish.

Structural habitat was not utilized extensively 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, pelagic clupeids are most likely the primary forage for largemouth bass in the lake. Diet studies should confirm this. 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 utilized in Kirkpatrick Lake to the extent they are in most other systems for two reasons. Based on observation, there seems to be a lack of suitable spawning substrate for sunfish; this would reduce overall production of adequately-sized prey. The fish in the lake are also fed with floating fish food 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 utilize 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. The odds of detecting a change in habit depend on what mechanisms are driving the largemouth bass to utilize open water. If largemouth bass utilize 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. If the fish utilize open water as a means of procuring pelagic prey, however, 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 odds of detecting a change in a natural system are low. Therefore, behavioral questions such as this may best be answered in an experimental setting, where environmental variables can be better controlled.

Genetics

Adult largemouth bass from area lakes have been stocked into Kirkpatrick Lake for the last several years (Dr. Dan Canfield, Jr., Department of Fisheries and Aquatic Sciences, University of Florida). It is unknown where the fish first stocked into the lake originated. These fish would likely have the most input on the genetics of the current population. Kirkpatrick Lake lies between the Suwannee River, Florida, and Orange Lake, Florida. The percentage of the Florida largemouth bass subspecies genome was estimated to be 96.25% for the Suwannee River population and 97.5% for the Orange Lake population (Phillip et al. 1983). This indicates that while largemouth bass populations in this region are intergraded, the percentage of northern subspecific input is low. Because of the conflicting results from microsatellite genetic analysis, further genetic testing is necessary to determine the percentage of Florida subspecific input on largemouth bass in Kirkpatrick Lake. Although no direct comparisons between the northern and Florida largemouth bass subspecies were made in this study, subspecific information may be useful to future researchers as more and more largemouth bass studies are performed at the subspecies level.

Transmitters

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 the percent 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. Since 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.

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 than the surface water temperatures. This could have been due to changes in the transmitters. Since depth was not an important part of this study, the data were only used to illustrate general trends. In retrospect, the money used to purchase the temperature-sensing feature would have been better spent buying extra transmitters as insurance against transmitter loss or failure.

Management Implications

Although much time and effort has been spent planting bulrush and putting brushpiles, trees, and FADs into Kirkpatrick Lake, the results from this study indicate that most of these habitats were not significantly utilized by largemouth bass. Thus, increasing structural habitat may not measurably increase angler catch rates, by attracting/concentrating adult largemouth bass, in lakes where open water prey are the principal forage.

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. The shoreline was the most often fished area by anglers in Kirkpatrick Lake (Daniel E. Canfield, Jr., personal communication) while the largemouth bass were found mostly in open water areas. In order to increase catch rates, it is necessary that either the anglers fish open water areas more often or the largemouth bass utilize littoral areas more often. Littoral habitat use by largemouth bass may be increased if production of littoral prey, such as sunfish, is increased. In addition to liming/fertilization programs, fish production in quarry lakes may possibly be increased with habitat manipulations that create more shallow, flat areas for spawning. Marked FADs placed into open water may have an indirect positive effect on angler catch rates by attracting anglers to under fished open water areas. Since habitat manipulations may not be cost-effective (based on utilization by largemouth bass) in lakes where open water prey are the principal forage, fisheries managers should focus their efforts on angler education.

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BIOGRAPHICAL SKETCH

Troy McDaniel Thompson, Jr. was born in Martinsville, Virginia, on 2 June 1975. He spent most of his spare time hunting and fishing in a three-county area of Virginia known as "the moonshine capital of the world." In 1993, he graduated from Fieldale-Collinsville High School knowing that he wanted a career in fisheries or wildlife management. After two years of classes at Patrick Henry Community College, Troy transferred to the Virginia Polytechnical Institute and State University in 1995. After being told that there were twice as many wildlife graduates as fisheries graduates, but the same number of jobs available for each, he did the math and decided on a career in fisheries. In May 1998, he graduated cum laude with a Bachelor of Science in Forestry and Wildlife with a concentration in fisheries. In July 1998, he began working as a technician for the Virginia Department of Game and Inland Fisheries in Forest, VA. It took him three short years to realize that working ¾ time with no benefits was not the career apex he had in mind when he left Virginia Tech. In August 2001, Troy enrolled as a graduate student under Dr. Chuck Cichra in the Department of Fisheries and Aquatic Sciences at the University of Florida to pursue a graduate degree. He will receive his Master of Science degree in December 2003. With increased knowledge, skills, and abilities, Troy hopes to pursue a research/management position as an agency biologist.