Movement and Behavior of Blue Catfish in Lake Wilson, Alabama

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Abstract: Twelve large (>6 kg) blue catfish (*Ictalurus furcatus*) were collected and surgically implanted with one-year radio transmitters near Wheeler Dam in Lake Wilson, Alabama, during April–May 2007. Fish were located every 14 days over an 11-month period; 10 fish survived for at least 90 days. Four fish remained in the area where they were tagged for the duration of the study. Six fish moved away from the Wheeler Dam tailrace of which four fish moved down river and likely inhabited depths beyond the effective range of our radio telemetry equipment. One radio-tagged catfish emigrated downstream from Lake Wilson into Pickwick Lake. Although some blue catfish in Lake Wilson made long migrations, a substantial proportion of tagged individuals (60%) remained sedentary and moved very little throughout the year. Blue catfish moved <30 m between 48% of biweekly tracking events and 38% of diel tracking locations. Water temperature was negatively related to movement rates and the probability of observing fish movement (>30 m).

Key words: blue catfish, telemetry, Tennessee River, movement

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Catfishes Ictaluridae are important sport fishes that are commonly sought by anglers across the United States (USFWS 2006). Catfishes are among the most popular species targeted by anglers in reservoirs; Miranda (1999) reported that harvest of these fishes occurred in 81% of the 349 U.S. reservoirs he examined and accounted for 16% of the total fish yield. Productive catfish fisheries dominated by harvest of blue catfish (*Ictalurus furcatus*) and channel catfish (*I. punctatus*) are located primarily in the central and southern United States, offering the greatest opportunities for management of these species (Miranda 1999).

In Alabama, popular catfish fisheries are found in most of the large reservoirs throughout the state, especially those on the Tennessee River. Until recently, little attention has been paid to these fisheries; however, Holley et al. (2009) confirmed that a productive and abundant blue catfish fishery existed in Lake Wilson, Alabama. Although harvest was considered low to moderate, the population was considered to be vulnerable to growth over fishing and consequent loss of "trophy-sized" catfish due to their slow growth rate (von Bertalanffy K = 0.081) and relatively long life span (maximum age = 25 years) (Holley et al. 2009). In response to these issues, the Alabama Division of Wildlife and Freshwater Fisheries imposed a statewide harvest limit of one catfish >864 mm per day. Lake Wilson is a relatively open system, subject to immigration and emigration (Pegg et al. 1997), and no data on blue catfish movement in this or similar systems is available. Movements of fish away from protected areas can influence the effectiveness of harvest restrictions (Hayes et al. 1997). Information on movement, behavior, and habitat preferences can be an important component to assist in fishery management decisions especially for inter-connected systems such as the reservoirs of the Tennessee River.

Blue catfish are thought to be highly migratory (Lagler 1956, Pflieger 1975, Graham 1999); however, the movement and behavior of this species has not been thoroughly investigated and may be highly variable among water bodies. Mark-recapture studies have indicated that blue catfish are highly mobile and movements of up to 78 km have been observed (Pugh and Schramm 1999, Timmons 1999). Grist (2002) utilized radio telemetry techniques to track blue catfish movement in Lake Norman, North Carolina, and reported 50% of radio-tagged blue catfish congregated in the Catawaba River during May, presumably to spawn. Some of these fish traveled up to 35 km to reach the river (Grist 2002).

The objective of this study was to observe by using radio telemetry the movement patterns of large (>6 kg) blue catfish in Lake Wilson, Alabama, and use this information to identify seasonal trends in blue catfish movement related to temporal or environmental variables. This data will improve our understanding of blue catfish ecology in a large impounded river system and may be used to improve management strategies.

Methods

This study was conducted on Lake Wilson, a 6,275 ha impoundment that stretches 24 km along the Tennessee River in north Alabama (Figure 1). Discharge from Wheeler Dam was variable and averaged 594 m^3/sec (range 127 to 2,462 m^3/sec) between May 2007 and April 2008 (J. Warren, Tennessee Valley Authority, unpublished data). Twelve large blue catfish (>6 kg) were captured

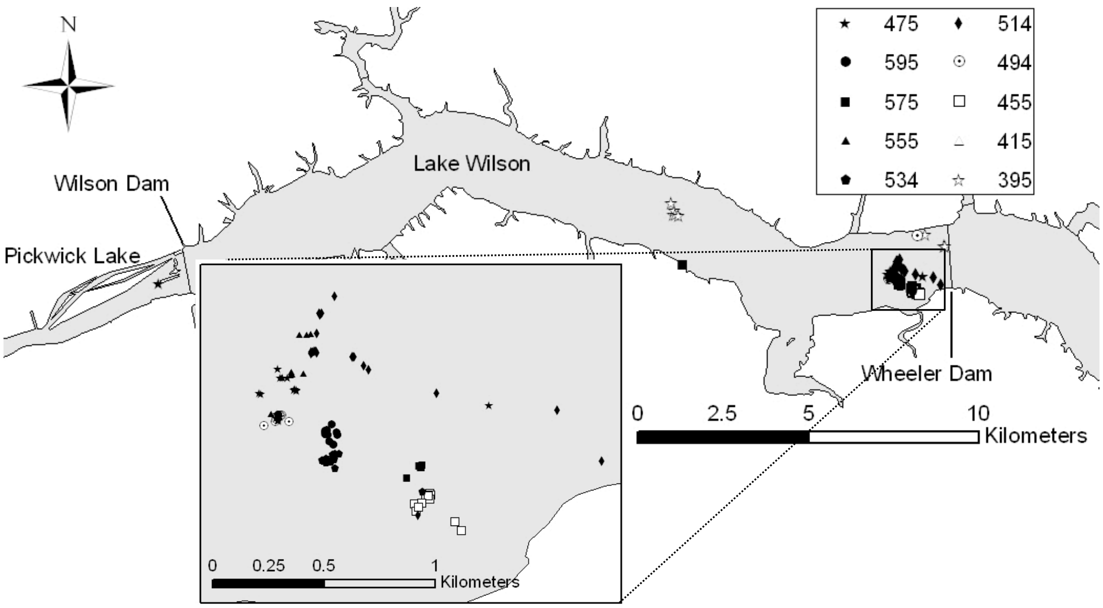

Figure 1. Map of Lake Wilson, Alabama, including relocations of individual catfish from biweekly tracking events between May 2007 and April 2008. The inset shows the Wheeler Dam tailrace where most relocations occurred.

during the day using low-pulse (15 pps) DC electrofishing in April and May 2007. Our ability to capture large blue catfish and the cost associated with tagging and tracking limited our sample size. Fish were collected in the Wheeler Dam tailrace using one electrofishing boat and one chase boat. Immediately after capture, fish were weighed to the nearest 10 g, measured to the nearest mm (TL), and anaesthetized with MS-222 in a 150-L livewell. Radio transmitters (model F1850B, Advanced Telemetry Systems, Isanti, Minnesota) fitted with mortality sensors were surgically implanted into each fish's body cavity following the modified procedure described by Siegwarth and Pitlo (1999). Transmitters were cylindrical with a 17 mm diameter and 72 mm length and weighed 27 g. Transmitters were surgically attached to the fish's cleithrum bone to avoid transmitter expulsion (Seigwarth and Pitlo 1999). We attached transmitters to the cleithrum as a precaution because transmitter expulsion rates are not available for blue catfish. Once the surgical procedure was complete, fish were held in a 150-L livewell until full recovery from the anesthesia and subsequently released at the site of capture.

Tagged fish were relocated from April 2007 to April 2008 by boat using a directional Yagi antenna (ATS model) once every 14 d. Beginning in October 2007, fish were located every 6 h for a 24-h period to determine diel movements. Once the boat was positioned directly over a fish, the location was recorded using a WAAS-enabled handheld GPS (Lowrance iFinder, Tulsa, Oklahoma) which was accurate to within 2 m. From surveys conducted with known-location transmitters prior to fish implantation, detectable distance from the transmitter was about 35 m at a depth of 27 m and 45 m at a depth of 9 m (Maceina et al. 2008). When fish were not located in the Wheeler Dam tailrace, the entire reservoir was searched by boat; on one occasion in April 2008, an aerial survey was conducted to search a 290-km section of the Tennessee River including major tributaries between the Pickwick Dam tailrace in Tennessee and Lake Guntersville in northeast Alabama. The aerial survey was conducted by airplane (Cessna 172) with dual antennas affixed to the wing struts. Tracking was ended in April 2008 when transmitter batteries were suspected to have expired.

Once each fish was located, water depth (m) and temperature (C) were recorded. Hourly and daily average discharge from Wheeler Dam was obtained from the Tennessee Valley Authority. The average daily discharge for dates when fish were located was used for weekly tracking comparisons and the mean discharge of the six hours prior to each location was used for diel comparisons. Lunar phase was calculated as lunar illumination or the proportion of the moon illuminated by the sun on a given night. Blue catfish locations were plotted and distances between locations were measured in ArcGIS 9.1 (ESRI 2005). Seasonal classifications were based on month: spring (March, April, May), summer (June, July, August), fall (September, October, November), and winter (December, January, February). Seasons included similar numbers of observations for the individuals tracked and months were assigned to seasons based on mean monthly water temperatures.

Movement rates were calculated as the total observed distance

Table 1. Transmitter number, total length, weight, number of days the fish was tracked , and general description of fate of each blue catfish tagged in Lake Wilson.
* indicates tracking was not continuous.

Tag number	TL (mm)	Wt (kg)	Days tracked	Fate
455	842	8.68	336	remained in tailrace for entire 336 d study
475	845	6.98	345*	remained in tailrace until January 2008, was located in Pickwick Lake in April 2008
494	892	8.90	183	remained in tailrace until contact was lost in October 2007
415	902	10.52	140	moved downstream September 2007 before contact was lost
514	946	15.28	336	remained in tailrace for entire 336 d study
375	1047	17.36	28	died
555	1084	17.98	140	remained in tailrace until contact was lost in September 2007
575	1124	19.74	168	moved downstream in October 2007 before contact was lost
595	1144	25.18	336	remained in tailrace for entire 336 d study
534	1183	24.52	336	remained in tailrace for entire 336 d study
395	1192	23.66	45	died
436	1215	24.02	310*	moved downstream 14 days after tagging and was harvested by an angler in March 2007

moved between relocations, divided by the time lapse between locations. Because movement data was not normally distributed, data were transformed to $\log_{10}$ values prior to analysis (Rogers and White 2007). Differences in weekly movement rates among seasons were tested using a repeated-measures mixed-model ANOVA (SAS Institute 2003) and temperature was included as a covariant in the model. Restricted maximum likelihood was used to estimate variance components (Littell et al. 2006) and a first-order autoregressive covariance structure was specified because observations taken closer together in time were assumed to be more highly correlated than observations taken farther apart in time (Swihart and Slade 1985, Rodgers and White 2007).

The effects of temperature, discharge, lunar phase, time of location, and seasons on diel movement rates were also tested using a repeated-measures mixed-model ANOVA (SAS Institute 2003). Restricted maximum likelihood was used to estimate variance components and we used corrected Akaike's Information Criteria (AIC_c) to identify the most parsimonious models (Burnham and Anderson 2002). AIC_c was used because our sample size was low compared to the number of variables in the model (Burnham and Anderson 2002).

To account for a substantial proportion of observed movements being minimal or negligible (≤30 m) we augmented mixed model analysis with a non-parametric approach to analyzing movements. Movements were classified into two categories: movement (movements >30 m) and non-movement (movements ≤30 m). Thirty meters was used as the point of reference for classification because it was the average diameter of the clusters of locations around the point where each fish was primarily located. This was determined by measuring the diameter of the smallest possible circle to encompass at least 50% of points for each individual. The effects of temperature, discharge, and season on the probability of observing movement were tested using logistic regression (SAS Institute 2003) and the method of generalized estimating equations was used to account for correlations among observations of the same fish. First order auto-regressive covariance structure was specified because we assumed observations taken closer together in time were more highly correlated. In addition, Pearson correlations between water temperature and the proportion of observed movements >30m were determined for weekly and diel data. All statistical tests were considered significance at $P \leq 0.1$ because low sample size diminished the power of our analysis and type II error was a concern (Peterman 1990).

Results

Twelve fish implanted with radio transmitters ranged in size from 842 to 1,192 mm TL and 6.98 to 25.18 kg wet weight (Table 1). Two radio-tagged blue catfish died within 90 days of tagging. One fish was harvested by an angler and another fish moved outside Lake Wilson. The fate of the remaining four fish was unknown. Extensive boat searches concentrated in Lake Wilson and the aerial search of the Tennessee River indicated that fish with functioning transmitters were either no longer in the area searched or at depths too great for signal detection. As a result, a total of 277 locations were recorded from 10 tagged blue catfish and included in the analysis.

Four of ten fish remained in the Wheeler Dam tailrace for the entire 336-d study. Four fish moved out of the tailrace and initially moved downstream (Table 1, Figure 1). These fish moved into areas of the reservoir in which water depths exceeded the effective detection depth of our radio telemetry equipment. When fish were located in downstream portions of Lake Wilson, they were always found near the bank or on submerged humps in shallower water. One fish moved downstream within 14 days of tagging, two additional fish moved downstream in fall 2007, and one fish moved downstream in January 2007. In addition to the fish located down-

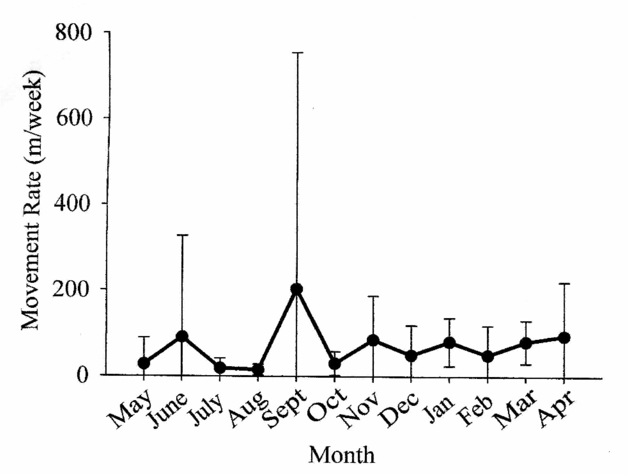

Figure 2. Mean monthly movement rates (m/week) of blue catfish observed between May 2007 and April 2008. Error bars represent one SD.

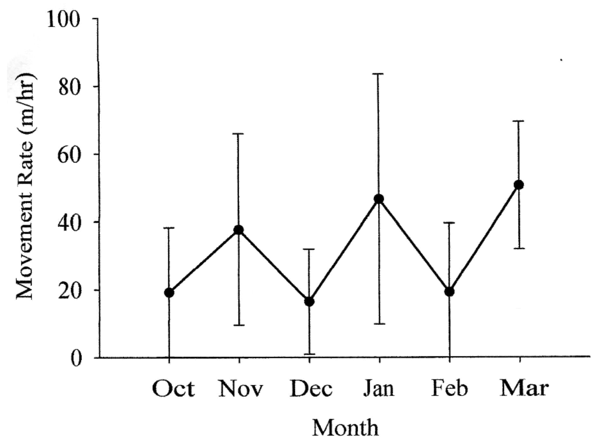

Figure 4. Mean monthly movement rates (m/h) of blue catfish based on diel tracking events between October 2007 and April 2008. Error bars represent one standard deviation.

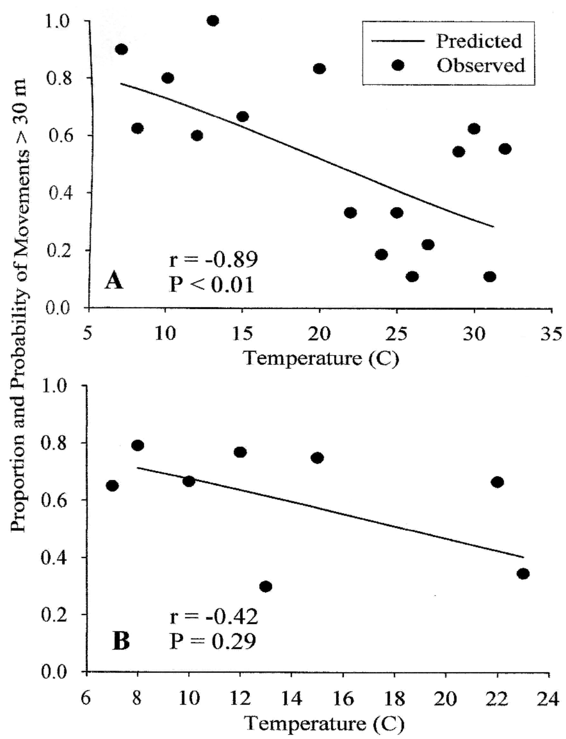

Figure 3. Predicted and observed movements (>30 m) of large blue catfish between bi-weekly tracking events from May 2007 to April 2008 (3A) and between diel tracking relocations taken every 6 h over 24-h periods bi-weekly from October 2007 to April 2008 (3B). Observed values represent proportions of fish movements >30 m from 1 C temperature groups. The predictions are from a logistic regression that modeled the probability of observing movement (>30 m) in terms of water surface temperature.

stream, two fish disappeared from the Wheeler Dam tailrace in fall 2007, and we were unable to obtain any further information on the locations of these fish.

Blue catfish moved on average 67 m/week (SD = 204); however, the median monthly movement rate was 17 m/week and only 4% of observed movement rates exceeded 200 m/week. When longer movements were observed, fish generally returned to the previous location. Forty-eight percent of catfish movements were ≤30 m between bi-weekly tracking events. Although seasonal differences in movement rates were not evident ($F = 0.06$, df = 3, 21, $P = 0.98$, Figure 2), water temperature had a significant effect ($F = 2.82$, df = 1, 119, $P = 0.096$) on weekly movement rates based on mixed model analysis. In addition, the probability of observing movement >30 m increased as temperature decreased (slope = –0.09, SE = 0.05, $Z = -1.96$, $P = 0.05$, Figure 3A) based on logistic regression. The relationship between movement and water temperature was also significant based on Pearson correlation (r = –0.89, $P < 0.001$).

Four blue catfish were tracked over a 24-h period on nine occasions between October 2007 and March 2008. Movement rates averaged 30 m/hr (SD = 26) and did not vary among months ($P = 0.55$, Figure 4) or between day and night ($P = 0.67$). However, temperature, time of location, discharge, and lunar phase were all included in at least one of the four models relating environmental variables to fish movement rates based on AIC_c values (Table 2). Temperature appeared to be the most important factor related to blue catfish movement rates and based on the model blue catfish movement rates were greater at cooler water temperatures. Only 37% of movements observed over 6-h periods exceeded 30 m. The probability of observing movement >30 m increased as water tem-

Table 2. Test statistics of four models describing hourly movement rates of blue catfish. Models were selected from 12 candidate models including, time of location, discharge, lunar phase, and water temperature using AIC_c selection criteria.

Effect	Estimate	*t*	*P*	AIC_c
intercept	2.21	4.13	0.006	293.4
temp	-0.94	-2.43	0.05	
discharge	-0.04	-0.59	0.58	
lunar	-0.37	-1.62	0.16	
intercept	3.10	4.52	0.004	294.1
temp	-0.95	-2.50	0.05	
discharge	-0.03	-0.44	0.68	
lunar	-0.45	-1.90	0.12	
time	-0.20	-2.04	0.11	
intercept	2.98	4.22	0.006	294.3
temp	-0.97	-2.54	0.04	
discharge	-0.07	-1.16	0.30	
time	-0.17	-1.62	0.16	
intercept	2.25	4.09	0.007	294.3
temp	-0.97	-2.50	0.05	
discharge	-0.07	-1.17	0.29	

perature decreased (slope = –0.09, SE = 0.29, $Z = -3.03$, $P = 0.003$, Figure 3B) based on logistic regression. However, the relationship between observing movements >30 m and water temperature was not significant based on Pearson's correlation ($r = -0.42$, $P = 0.29$).

Discussion

Forty percent of radio-tagged blue catfish remained in the Wheeler Dam tailrace for the entire 11 month study. However, 60% of radio-tagged fish left the tailrace and many were observed moving downstream or were located downstream later in the study. Funk (1976) reported that many species of fish in Missouri streams included mobile and sedentary populations. The concept that mobile and sedentary individuals exist in a population (Funk 1976) was supported by our results for blue catfish. Lagler (1956) suggested that blue catfish make seasonal migrations upstream in the spring and downstream in the fall. Four of the six fish that left the Wheeler Dam tailrace did so in September and October 2007. Similarly, 50% of blue catfish radio tagged in Lake Norman, North Carolina, made long (>30 km) seasonal migrations, but this occurred during spring to the headwaters of the reservoir while the remaining 50% exhibited site fidelity year round (Grist 2002). The movements of nearly half of the fish we tracked support the premise that at least some of the population makes a seasonal downstream migration in the fall, although we did not observe upstream migration in spring as Grist (2002) observed. Tracking was terminated in April 2008 when transmitters were suspected to expire, thus a spring migration may have occurred but was not observed.

Tailrace or riverine areas of reservoirs may be the preferred spawning habitat for blue catfish (Graham 1999, Grist 2002). Based on angler harvest of blue catfish in this system, this population may concentrate in the Wheeler Dam tailrace during spring and summer months (Holley et al. 2009) during spawning (Graham 1999). Blue catfish spawn once temperatures reach about 22–23 C (Tave and Smitherman 1982) which occurred in Lake Wilson in May. The probability of observing blue catfish moving was low when temperatures exceeded 20 C. Blue catfish may not reach sexual maturity until about 590 mm TL (Perry and Carver 1973); all of the fish tracked in this study exceeded 840 mm. All blue catfish tracked in this study were captured in the Wheeler Dam tailrace during spring and most of these fish remained in the tailrace until at least September or October.

Larger blue catfish (>6 kg) that resided in the tailrace displayed sedentary behavior with strong homing tendencies, especially at warmer temperatures. The location and area of fish home ranges may be related to forage, habitat availability, sex, or social interactions (Savitz et al. 1983, Wendel and Kelsch 1999, Hansen and Closs 2005). Prey mobility, or lack of mobility, could influence blue catfish movement. For example, blue catfish have been reported to feed heavily on mussels (Grist 2002, Eggleton and Schramm 2004) which are primarily sedentary. Additional research is necessary to determine why some large blue catfish remained in the tailrace while others exhibited greater mobility.

Although only 10 fish were successfully tracked and information on fish which moved into deeper water was limited, our results represent the first information on movement and behavior of this species in the Tennessee River. This information should be used to improve the study design of future research on blue catfish. In large, deep systems the use of ultrasonic or a combination of acoustic and radio telemetry should be considered for this species so fish can be relocated in deep water. The modified internal attachment procedure (Siegwarth and Pitlo 1999), in which transmitters are attached to the cleithrum to prevent expulsion, was used to successfully attach transmitters, and mortality was low. Further research is needed to determine the most efficient attachment technique for this species. Twenty-four hour tracking was conducted from October 2007 to April 2008; therefore, diel behavior of fish during summer months was not observed. However, our limited results represent the only information available on the diel movements of blue catfish and indicate 24-h tracking is essential to describe the behavior of this fish.

At least one radio-tagged fish emigrated from Lake Wilson into Pickwick Lake. Although only one large blue catfish was documented outside Lake Wilson, the fates of four other fish were unknown when the study ended and emigration from Lake Wilson may have been higher than observed. Regulations protecting large blue catfish in individual reservoirs may be less effective if immigration and emigration rates are high.

In Lake Wilson, some blue catfish were highly mobile, while others remained in the Wheeler Dam tailrace for then entire 336-d study. The majority of movement data was collected from the more sedentary group of fish, thus we likely underestimated movement rates of the entire population. Our results provide a base upon which future research is needed to better understand the movement and behavior of large blue catfish.

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Literature Cited

Burnham, K. P. and D. R. Anderson. 2002. Model selection and multimodel inference: a practical information-theoretic approach, 2nd edition. Springer, New York, New York.

Eggleton, M. A. and H. L Schramm, Jr. 2004. Feeding ecology and energetic relationships with habitat of blue catfish, *Ictalurus furcatus*, and flathead catfish, *Pylodictis olivaris*, in the lower Mississippi River, U.S.A. Environmental Biology of Fishes 70:107–121.

Environmental Systems Research Institute, Inc. (ESRI). 2005. ArcGIS 9.1. Redlands, California.

Funk, J. L. 1957. Movement of stream fishes in Missouri. Transactions of the American Fisheries Society 85:39–57

Graham, K. 1999. A review of the biology and management of blue catfish. Pages 37–49 *in* E. R. Irwin, W. A. Hubert, C. F. Rabeni, H. L. Schramm, Jr., and T. Coon, editors. Catfish 2000: Proceedings of the International Ictalurid Symposium. American Fisheries Society, Symposium 24, Bethesda, Maryland.

Grist, J. D. 2002. Analysis of a blue catfish population in a southeaster reservoir: Lake Norman, North Carolina. Master's thesis. Virginia Polytechnic Institute and State University, Blacksburg.

Hansen, E. A. and G. P. Closs. 2005. Diel activity and home range size in relation to food supply in a drift-feeding stream fish. Behavioral Ecology 16(3):640–648.

Hayes, M. C., L. F. Gates, and S. A. Hirsch. 1997. Multiple catches of smallmouth bass in a special regulation fishery. North American Journal of Fisheries Management 17:182–187.

Holley, M. P., M. D. Marshall, and M. J. Maceina. 2009. Fishery and population characteristics of blue catfish and channel catfish in Lake Wilson, Alabama. North American Journal of Fisheries Management 29:1183–1194.

Maceina, M. J., M. D. Marshall, M. P. Holley, and R. W. Hunter. 2008. An evaluation of the recreational catfish fishery in Wilson Reservoir, Alabama. Final Report to Alabama Department of Conservation and Natural Resources, Montgomery.

Miranda, L. E. 1999. A typology of fisheries in large reservoirs of the United States. North American Journal of Fisheries Management 19:536–550.

Lagler, K. F. 1956. Freshwater Fishery Biology, 2nd edition. W. C. Brown Company Publishers, Dubuque, Iowa.

Littel, R. C., G. A. Milliken, W. W. Stroup, R. D. Wolfinger, O. Schnabenberger, 2006. SAS for Mixed Models, 2nd edition. SAS Institute Inc., Cary, North Carolina.

Pegg, M. A., P. W. Bettoli, and J. B. Layzer. 1997. Movement of saugers in the lower Tennessee River determined by radio telemetry, and implications for management. North American Journal of Fisheries Management 17:763–798.

Perry, W. G. and D. C. Carver. 1973. Length at maturity and total length-collarbone length conversions for channel catfish, *Ictalurus punctatus*, and blue catfish, *Ictalurus furcatus*, collected from the marshes of the southwest Louisiana. Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners 26:541–553.

Peterman, R. M. 1990. Statistical power analysis can improve fisheries research and management. Canadian Journal of Fisheries and Aquatic Sciences 47:2–15.

Pflieger, W. L. 1975. The fishes of Missouri. Missouri Department of Conservation, Jefferson City, Missouri.

Pugh, L. L. and H. L. Schramm, Jr. 1999. Movement of tagged catfishes in the Lower Mississippi River. Pages 193–197 *in* E. R. Irwin, W. A. Hubert, C. F. Rabeni, H. L. Schramm, Jr., and T. Coon, editors. Catfish 2000: Proceedings of the International Ictalurid Symposium. American Fisheries Society, Symposium 24, Bethesda, Maryland.

Rogers, K. B. and G. C. White. 2007. Analysis of movement and habitat use from telemetry data. Pages 625–676 *in* C. S. Guy and M. L. Brown, editors. Analysis and interpretation of freshwater fisheries data. American Fisheries Society, Bethesda, Maryland.

SAS Institute. 2003. SAS Institute, Inc. Cary, North Carolina.

Savitz, J., P. A. Fish, and R. Weszely. 1983. Effects of forage on home-range size of largemouth bass. Transactions of the American Fisheries Society 112:772–776.

Siegwarth, G. L. and J. M. Pitlo, Jr.1999. A modified procedure for surgically implanting radio transmitters in channel catfish. Pages 287–292 *in* E. R. Irwin, W. A. Hubert, C. F. Rabeni, H. L. Schramm, Jr., and T. Coon, editors. Catfish 2000: Proceedings of the International Ictalurid Symposium. American Fisheries Society, Symposium 24, Bethesda, Maryland.

Swihart, R. K. and N. A. Slade. 1985. Testing for independence of observations in animal movements. Ecology 66:1176–1184.

Tave, D. and R. O. Smitherman. 1982. Spawning success of reciprocal hybrid pairings between blue and channel catfish with and without hormone injection. Progressive Fish-Culturalist 44(2):73–74.

Timmons, T. J. 1999. Movement and exploitation of blue and channel catfish in Kentucky Lake. Pages 187–191 *in* E. R. Irwin, W. A. Hubert, C. F. Rabeni, H. L. Schramm, Jr., and T. Coon, editors. Catfish 2000: Proceedings of the International Ictalurid Symposium. American Fisheries Society, Symposium 24, Bethesda Maryland.

U.S. Fish and Wildlife Service (USFWS). 2006. National survey of fishing, hunting, and wildlife-associated recreation. Washington, D.C.

Wendel, J. L. and S. W. Kelsch. 1999. Summer range and movement of channel catfish in the Red River of the North. Pages 203–214 *in* E. R. Irwin, W. A. Hubert, C. F. Rabeni, H. L. Schramm, Jr., and T. Coon, editors. Catfish 2000: Proceedings of the International Ictalurid Symposium. American Fisheries Society, Symposium 24, Bethesda, Maryland.