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Movements and Capture Efficiency of the Blue Catfish Ictalurus Furcatus,In Lake Dardanelle

Zachary S. Moran
Arkansas Tech University

MOVEMENTS AND CAPTURE EFFICIENCY OF THE BLUE CATFISH *ICTALURUS FURCATUS*, IN LAKE DARDANELLE

By

ZACHARY S. MORAN

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MOVEMENTS AND CAPTURE EFFICIENCY OF THE BLUE CATFISH
ICTALURUS FURCATUS, IN LAKE DARDANELLE

The evaluation committee hereby approves this thesis submitted by Zachary S. Moran in partial fulfillment of the requirements for the Degree of Master of Science.

____

Dr. Joseph N. Stoeckel Date
Thesis Advisor

____

Dr. John R. Jackson Date
Committee Member

____

Frank J. Leone Date
Committee Member

____

Dr. Jeff Robertson Date
Interim Dean of Graduate College

Permission

Title: Movements and capture efficiency of the Blue Catfish *Ictalurus punctatus* in Lake Dardanelle, Arkansas.

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Zachary S. Moran

Date

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….and thousands of catfish spines

Abstract

Standardizing low-frequency electrofishing procedures for sampling Blue Catfish *Ictalurus furcatus* has become a recent focus of fisheries biologists. Information on habitat use, value of chase boats, and duration and timing of samples could increase sampling efficiency. To asses these variables in Lake Dardanelle, Arkansas, I divided this reservoir into lacustrine, transition, and riverine zones. I used a systematic random sample design, and electrofisher, to collect 8,067 Blue Catfish from 458 samples between May and September 2016. I found: (1) The most efficient season to sample was the summer season when water temperatures were >25˚C; (2) CPUE was highest on channel edges in the lacustrine and transition zones >6 m deep, and wing dikes in the riverine zone; and (3) CPUE was higher during a 5 min sample than a 10 min sample. To assess the efficacy of a chase boat, I used a systematic random design to collect 4,312 Blue Catfish from 96 samples in the lacustrine, and riverine zones between September 2015 and May 2017. I found: (1) sample efficiency with a chase boat was higher than with a single electrofisher; (2) PSD did not differ between the gears; and (3) sampling for 10 min with a chase boat was more efficient than for 5 min in the lacustrine zone. To assess Blue Catfish habitat use in Lake Dardanelle, I collected telemetry data from groups of large (N=23, >775 mm) and small (N=20, 560-700 mm) Blue Catfish tagged between January and April 2016 and found: (1) Blue Catfish were located on deeper water main channel, and submerged channel edges in the lacustrine and transition zones, and scour holes formed by wing dikes in the riverine zone; and (2) the proportion of fish located by telemetry and captured by electrofishing in common habitats was similar.

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INTRODUCTION

"The Catfish is plenty good enough fish for everyone" ~ Mark Twain

Blue Catfish belong to the Division Teleostei, Subdivision Ostarioclupeomorpha, Superorder Ostariophysi, Order Siluriformes, and Family ictaluridae (Helfman et al. 1997). They are the largest of the ictalurid catfishes, and the third largest species of fish in the United States (Jenkins and Burkhead 1994; Graham 1999; VDGIF 2015). Their genus and species name is Greek for "forked cat", and refers to the species' deeply forked caudal fin, and congruent barbels (Graham 1999). Fossils of the first ictalurid catfish appeared during the Oligocene in Saskatchewan, Canada, and Blue catfish likely appeared in Texas during the Pliocene (Gayet and Meunier 2003).

Catfish are surrounded by a negative stigma, by some, marginalizing them as a dirty bottom feeder. Regarding Blue Catfish, this could not be further from the truth. Dressed in a metallic blue skin, Blue Catfish have a streamlined body designed for sustained, long distance swimming. Members of the ictalurid family possess highly attuned sensory organs including a lateral line, ampullae of lorenzini, weberian apparatus, and gustatory receptors covering their whiskery barbels (Bardach et al.1967; Altema 1971; Northcutt 2005). These adaptations allow them to thrive in the large river ecosystems of their native (Graham 1999), and non-native ranges (Schloesser et al. 2011; Greenlee et al. 2011).

Blue Catfish are highly sought after by commercial and recreational anglers because of their large size and high quality as a food fish (Graham 1999; Arterburn et al. 2002; Holley et al. 2009). Consequently, effective management of Blue Catfish is of

interest to state fisheries agencies (Graham 1999; Arterburn et al. 2002; Holley et al. 2009; Buckmeir and Schlechte 2009; Bodine et al. 2013). A major need for management of Blue Catfish populations is creation of standardized sampling procedures that can be used to compare unbiased samples (Bodine et al. 2013; Bonar et al. 2009; Buckmeier and Schlechte 2009). Bodine et al. (2013) demonstrated low-frequency electrofishing (LFE) at water temperatures ≥ 18 ºC to be an efficient method for sampling Blue Catfish. In addition, they found that 10 to 20 replicate samples, consisting of at least one fish, and a total of 200 to 800 fish accurately represented the size structures of most Blue Catfish populations. They recommended that samples be collected using a stratified random, or simple random sampling design in conjunction with one or more chase boats. Simple random and stratified random sampling protocols are suitable for fish randomly distributed in shallow habitats (Bonar et al. 2009; Miranda 2009), however, Blue Catfish may not be randomly distributed throughout their waterbodies. Thus, additional work on movement and habitat use by Blue Catfish could be useful for further refining standardized sampling protocols for Blue Catfish.

Peterson (2015) conducted an extensive literature review, and found only thirteen citations that provided original data on Blue Catfish habitat use, and none of them linked habitats used to capture efficiency of Blue Catfish. The first chapter of this thesis is focused on determining: (1) which habitats and longitudinal zones Blue Catfish in Lake Dardanelle use; (2) if “large” and “small” Blue Catfish use similar habitats; (3) if catch per unit effort (CPUE) of LFE samples correlates to habitat use patterns of Blue Catfish; and (4) which environmental and habitat characteristics are associated with higher CPUE, and if significant, how do they relate to fish locations.

Standardization of electrofishing procedures is often waterbody specific (Miranda 2009). The second chapter of this thesis addresses questions that can further improve a standardized LFE sampling protocol for Blue Catfish in Lake Dardanelle. Questions addressed include: (1) the most efficient time of the year to sample Blue Catfish; (2) which habitats and zones of the reservoir to sample; (3) whether size distributions differed by habitat and zone; (4) the utility of chase boats; (5) the sampling duration required to effectively sample; and (6) utility of a fish finder for increasing sample efficiency.

CHAPTER 1

MOVEMENTS AND CAPTURE EFFICIENCY OF THE BLUE CATFISH *ICTALURUS PUNCTATUS* IN LAKE DARDANELLE, ARKANSAS.

"Ten percent of the water holds ninety percent of the fish" ~ Dave Hughes

INTRODUCTION

Standardization of sampling procedures in fisheries science is essential for comparing data and trends across water bodies and among sample dates (Bonar and Hubert 2002; Reynolds and Kolz 2012). Standardized protocols consider the influence of gear, fish behavior, and the environment to minimize sampling bias (Bonar and Hubert 2002; Hayes et al. 2003; Sammons 2014). Minimization of sampling bias reduces sampling variability which improves sampling efficiency and reduces costs of sampling (Miranda 2009; Bonar et al. 2009). As a result, state and federal agencies have focused on standardizing sampling gear and protocols (Bonar et al. 2009). Most efforts have centered on developing high-frequency electrofishing procedures for centrarchid fisheries (Bonar et al 2009; Reynolds and Kolz 2012). However, contemporary standardized protocols for sampling ictalurids with low-frequency electrofishing (LFE) are being explored (Bodine et al. 2013).

Low-frequency electrofishing has become the primary method used to sample Blue Catfish *Ictalurus furcatus* (Brown 2007) because alternative methods are less effective and result in length biases (Buckmeir and Schlechte 2009; Evans et al. 2011; Gale et al. 1999; Vokoun and Rabeni 1999). For example, gill nets effectively capture Blue Catfish, but underrepresent 250 to 350-mm fish (Buckmeir and Schlechte 2009). Current LFE sampling protocols recommend using a stratified random, or simple random

sampling design, and use of a 5,000 to 9,000-watt generator to power a pulsator at output settings ranging from 7.5 to 30 pulses per second, 340 to 1000 volts (V), and 1 to 5 amps (A) (Bodine et al. 2013). The electrofishing boat can be used alone or in conjunction with chase boats which assist with the capture of distantly surfacing fish (Bodine et al 2013; Buckmeir and Schlechte 2009; Greenlee and Lim 2011; Schloesser et al. 2011). This protocol has generated representative size structure estimates of fish ranging in size from 200 to 1000 mm TL at water temperatures >18ºC (Bodine and Shoup 2010) when catch rates ranged from 23 to 373 fish/h (Buckmeir and Schlechte 2009; Bodine et al. 2011).

Standardized sampling protocols cannot substitute for an understanding of fish biology (Pope et al. 2010), and the randomized designs proposed for sampling Blue Catfish do not take advantage of possible differences in habitat use by size of fish or season. Telemetry studies on Blue Catfish have found them to be the most migratory of the ictalurid catfishes, and they have anecdotally been observed to group by size (Graham 1999; Pugh and Schramm 1999; Garret and Rabeni 2011). Grist (2002) found Blue Catfish to establish seasonal home ranges, and Garret and Rabeni (2011) demonstrated that Blue Catfish make seasonal spawning migrations. Blue Catfish have been found to be abundant on main channel habitats including wing dikes (Pflieger 1997), however most information on habitat use by Blue Catfish is purely anecdotal (Garret and Rabeni 2011). More objective information on habitat use would help clarify which habitats should be included, and what habitat characteristics should be considered when creating a sampling design for Blue Catfish.

I centered my research on determining: (1) which habitats and lake zones Blue Catfish use in Lake Dardanelle; (2) if "large" and "small" Blue Catfish use the same

habitats at the same rates; and (3) if electrofishing efficiency and proportion of fish present in a habitat was proportional; and (4) which environmental and habitat parameters on Lake Dardanelle influenced sampling efficiency. A better understanding of these factors should lead to a more efficient sampling protocol for Blue Catfish.

METHODS

Study area.—The Arkansas River is the second largest western tributary of the Mississippi River (Hocutt and Wiley 1986), and the sixteenth largest river in the United States in terms of discharge (USGS 1990). It flows 2,400 km from its source in the Rocky Mountains of Colorado to its confluence with the Mississippi River on Arkansas' border with Mississippi (Geik 2016). The watershed drains 417,000 km^2 (USGS 1990). The McClellan-Kerr Arkansas River Navigation System (MKARNS) was completed in 1971, and is made up of a series of 18 locks and dams, numerous wing dikes, and rip rap fortified banks, which are distributed over the lower 700 river kilometers (rkm) of the river. It provides commercial navigation, bank stabilization, flood control, and hydroelectric power generation (Limbird 1993).

Lake Dardanelle is a 13,900-ha pool (Pool 10) on the Arkansas River created in 1969 by the Army Corps of Engineers. It has a shoreline of 510 km, a volume of 656 million m^3, and a mean depth of 4.3 m (range to 16.5 m) (Rickett and Watson 1985). The pool is approximately 82.6 rkm long from Dardanelle Lock and Dam 10 to the Ozark-Jeta Dam Lock and Dam 12 (USACE 2014). Although the Dardanelle Dam has hydroelectric capabilities, water fluctuations are controlled within bounds that permit safe operation of a nuclear power plant.

For this study, I divided Lake Dardanelle into three zones (Figure 1) based on reservoir characterizations from Saji (2008). The uppermost sections of the pool is relatively narrow and extends from river kilometer 378.2 to river kilometer 412.0, and is comprised primarily of the river channel, natural river bank, and wing dikes. Channel width is typically less than 600 m in this section (riverine zone), and water velocities are higher than in the transition and lacustrine zones. The middle, or transition zone, extends from river kilometer 363.7 to river kilometer 378.2, and consists of a submerged main channel and channel edges, along with adjacent flats and multiple islands. The lowest or lacustrine zone extends from river kilometer 331.5 to river kilometer 363.7, and consists of the submerged main channel and channel edges, along with adjacent flats and bays. Two main tributaries, Illinois Bayou and Piney Creek, flow into the lower reach. Channel width in the transition and lacustrine zones range from 440 to 3,000 m.

Electrofishing site selection and procedure.— Monthly electrofishing samples were collected from May through September 2016 because LFE is less effective at water temperatures <18ºC (Bodine et al. 2013). I sampled five equidistant sites from each zone per week for the first three weeks of each month (15 sites per zone per month). Sites were sampled using a systematic random sampling design because it accounts for clustered populations along an environmental gradient (Strayer and Smith 2003). Sample starting points were selected at random each week for each zone. For example, when sampling the lacustrine zone (river kilometers 363.7 to 384.6), five 6.4-km long sections were created, and a random number generator was then used to select a number between 0 and 6.4 to serve as the starting point. If the number selected was 1.5, then samples were collected at 1.5, 7.9, 14.3, 20.7, and 27.1 rkm from the dam.

Three pelagic habitats were sampled in each zone because they are known to be inhabited by Blue Catfish (Graham 1999; Grist 2002; Lee 2009). In the lacustrine and transition zones, the three primary pelagic habitats were submerged channel, channel edge, and adjacent flats. In the riverine zone, main channel, channel edge, and wing dikes constituted the sampled habitats because flats were inconsequential. A Humminbird© Helix 7 KVD side scan fish finder was used to verify depths and that appropriate habitats were sampled.

Samples were conducted with a 5-m electrofishing boat equipped with a 7.5 Kilowatt (KW) inverter generator and Midwest Infinity© box that was set to maximize the effective field. Electrofishing settings were based on a pilot study conducted in the summer of 2015. Settings were standardized at: 15 pulses per second, duty cycle of 30%, and a voltage adjusted to create a 30 peak-amp output. Each habitat was sampled for 10 min following protocols listed in Bodine and Shoup (2013). Total length of each fish was measured to the nearest millimeter (mm). Current velocity, temperature, dissolved oxygen concentration, conductivity, Secchi disc depth, and depth were measured after each electrofishing run.

Transmitter selection, surgery, and fish collection.—Twenty-three "large" model CHP-87-XL Sonotronics (Tucson, Arizona) transmitters (length = 99 mm, diameter = 33.5 mm, weight = 34 g) with a 3-km tracking range and a 48-month battery life, and twenty "medium-sized" Sonotronics model CHP-87-L transmitters (length = 80 mm, diameter = 15.6 mm, weight = 12 g) with a 3-km tracking range and an 18-month battery life were placed into two size categories of Blue Catfish. Fish in the small size category ranged from 560 to 700 mm TL and 2.7 to 5.3kg in weight (Figure 3; Table 2). Fish in the

large category were greater than 774 mm TL (Figure 3; Table 3). Transmitters weighed less than 2% of the body weight of implanted fish (Bridger and Booth 2003). Transmitter frequency ranged from 70 to 83 kHz. Each transmitter generated a unique "ping" sequence and was inscribed with a telephone number and a request to call if found.

Surgery procedures followed those of Hart and Summerfelt (1975) with slight modifications. Blue Catfish were secured on a surgery board at a slight angle to allow access to the lateral side of the fish, while a sterilized surgical scalpel was used to make an incision up to 5 cm long on the side, 50 to 100 mm posterior of the pectoral girdle. A sterilized transmitter was then inserted in to the peritoneal cavity. The incision was closed with 5 to 10 staples from a Visistat 35W surgical staple gun (Mulford 1984). I pretested this procedure on 6 Blue Catfish that ranged from 535 to 670 mm, and held them in Arkansas Tech's aquaculture facility for 14 d, because they are notorious for expelling transmitters (Holbrook et al. 2013).

I attempted to capture an equal number of small and large fish from each zone using a combination of jug-lines, gill-nets, and LFE between February and April 2016. Jug line procedures followed those in Schmitt and Shoup 2013. An 8/0 circle hook, baited with freshly cut gizzard shad, was secured to a 20-m length of 136-kg breaking strain rope with a 1-kg weight on one end and a float on top. Gill nets (12.7 and 15.2-cm square-mesh-monofilament netting) ranged in length from 50 to 100- m and ranged in depth from 3.7- m (tied down to 2.4- m) to 7.3- m (tied down or hobbled to 5.5- m). Gill nets and jug lines were used until water temperatures reached 16 ºC at which time LFE became a viable capture method. Low-frequency procedures were the same as those used during the electrofishing sampling portion of this study.

Captured fish implanted with transmitters were energetic and free from sores or wounds. Fish that exhibited lethargy, deformity, or large open wounds were not implanted with transmitters. Prior to release, fish were given an intramuscular injection of antibiotics (liquamycin at 0.1 mg/kg fish mass) to reduce the risk of infection (Kennedy 2013).

Telemetry.—The entirety of Lake Dardanelle was actively tracked three times a week, for three weeks each month, from May through September 2016. Fish were located by stopping approximately every 0.5 km and scanning with a Sonotronics USR-08 ultrasonic receiver attached to a Sonotronics DH-4 directional hydrophone and/or a Sonotronics TH-2 omnidirectional hydrophone. I then used a directional hydrophone to pinpoint location of implanted fish. Global positioning system (GPS) coordinates were recorded when the signal from the directional hydrophone was of equal volume in all directions at a gain setting of ≤ 5 on the receiver (Barry 2007; Geik 2016). Water depth, surface water temperature, water velocity (1 m below the surface), time, and macrohabitat type were recorded for each set of coordinates. When locations of individual fish were unable to be pinpointed in a high-use area, all fish were assigned coordinates of the average location for that area. Average locations were determined by visually assessing the plot of all locations within a high-use area, and estimating the most representative central coordinates of each high-use area (Geik 2016). Macrohabitat type and surface water temperature were recorded for individuals assigned to average locations, but water depth and water velocity were not (Geik 2016). Implanted fish were considered dead or to have expelled transmitters if upstream movements were never detected. Fish considered dead were censored from telemetry analysis.

Habitat and zone use.— The percentage of fish relocations was calculated by dividing the number of relocations by the number of implanted fish, and the percentage per zone was calculated by dividing the number of fish relocated within a zone by the total number of relocations for the month. Habitat use within a zone was a function of relocations in a habitat within each zone and the number of all relocations within that zone. Relocations were further characterized as either “small” or “large” fish, and the percentages for all fish, as described above, were also made for these subgroups. Comparisons of zone usage by large versus small Blue Catfish by month and habitat usage within each zone by month were made with an Analysis of Proportions (ANOP).

Habitat use and electrofishing.—Percentages of Blue Catfish captured in each habitat by month, and for habitats within zones, were calculated similar to the above calculations for telemetered fish. Percentages of small (560-700 mm) and large (774-1140 mm) fish by zone and month, and within zones by habitat type were also calculated as above. Likewise, percentage of fish captured on each habitat of each zone were calculated by dividing the number of fish caught on a respective habitat by the total number of fish captured in that zone. To determine if catch rates of Blue Catfish were proportionate with zone use, I used an ANOP to compare percent zone use with percent captured for each month. Similarly, I compared percent of fish captured from each habitat with percent fish tracked with ANOP in each zone by month. Comparisons of zone usage by large versus small Blue Catfish by month and habitat usage within each zone by month were made with an ANOP for each month.

Environmental parameters and habitat characteristics.— The CPUE was calculated for each sample by multiplying the number of fish captured in 10 min by 6 to

create an estimate number of fish captured per hour. Young-of-the-year fish were not used in CPUE calculations because they can skew and create unrepresentative length frequency distributions (Maceina and Pereira 2007; Jackson and Noble 1995; Pope et al. 2010). Bodine et al. 2013 found that fish smaller than 200 mm may not be fully represented by LFE sampling, but I eliminated all age zero fish by estimating their maximum size which gradually changed through the sampling period. By examining gaps in length frequency distributions I removed lengths of age 0's estimated as <100 mm in July, <125 mm in August, and <150 mm in September (Isely and Grabowski 2007).

Low-frequency electrofishing, like many gears used to study fisheries, often produce samples with a large percentage of zeros (Bodine et al. 2013; Arab et al. 2008). Thus, Poisson distributions are common in datasets. To mitigate for the high number of zeros, I used a generalized linear model framework (McCullagh and Nelder 1989), with a quasi-Poisson regression (Ver Hoef and Boveng 2007) to identify relationships between the environmental variables and Blue Catfish CPUE on Lake Dardanelle. A quasi-Poisson was used in preference to a Poisson regression, because the dispersion factor associated with CPUE was > 1 (Maindonald and Braun 2014). A negative binomial regression was not used, because it gives less weight to larger values (Ver Hoef and Boveng 2007). To identify variables associated with high CPUE, I used a regression tree. I calculated variance inflation factors (VIF) using R (R Core Team 2014) to detect problems with multicollinearity. A VIF >3 was considered problematic (Zuur et al. 2007). I removed parameters with a VIF ≥ 3.

Depths associated with a CPUE > 120 were compared with the variables associated with fish relocations in the telemetry study. A CPUE of 120 was used because

it is the minimum catch rate recommended by Bodine et al. 2013 to accurately characterize the size distributions of a Blue Catfish population. I hypothesized there would be no difference in the variables values associated with fish locations and those associated with CPUE >120 fish/hour captured in each zone. I tested this hypothesis with a two-factor ANOVA for each zone with method and habitat as factors. A Tukey's honest significant difference (HSD) at a α=0.05 was used to determine differences.

I identified monthly Blue Catfish locations and sampling areas that resulted in catch rates greater than or equal to 120 fish/hour in each zone on Lake Dardanelle using ArcGIS 10.3 (ESRI, Redlands, California).

RESULTS

Surgery and tag retention.—Forty-three Blue Catfish were implanted with ultrasonic transmitters. Equal numbers of fish in the lacustrine, transition, and riverine zones proved difficult to obtain, and I ended up implanting 10 small fish and four large fish in the lacustrine, two small fish and 16 large fish in the transition, and eight small fish and three large fish in the riverine zone (Table 2; Table 3). Small catfish ranged in length from 560 to 700 mm TL (median length = 628 mm) and 2.13 to 5.30 kg in weight (median weight = 2.9 kg) (Table 2; Figure 3). Large catfish ranged from 774 to 1139 mm TL (median length = 902 mm) and 7.3 to 19.91 kg in weight (median weight =11.96) (Table 3; Figure 3). Water temperature at the time of capture for implanted fish ranged from 8.3 to 18 ^{o}C (median = 16.7 ^{o}C).

One hundred percent of fish retained transmitters in the tank study and no mortality occurred. Wounds exhibited minor inflammation around incision. In the field, one fish was found deceased, floating in the lacustrine zone, one fish either died or

expelled the transmitter, and seven fish were known to be harvested by commercial or recreational fisherman between the months of April and December 2016. The two deceased fish were both implanted with a CHP-87 XL transmitter. The fish found floating was in the small category, while the other fish was in the large category. Harvest rates of Blue Catfish on Lake Dardanelle were estimated at 16% (7/43). Maximum survival at the end of my study was 73%. All other fish were known to be alive at the end of study.

Habitat and zone use.—Approximately one-half of implanted fish were found during monthly tracking events from May through September, with a minimum of 47% in May and a maximum of 70% in July (Table 4 - Table 8). Fish were found to move freely between zones with 24-40% of implanted fish located outside the zone within which they were tagged during monthly tracking events. Fish were located primarily in the lacustrine (46%) and transition (37%) zones with only 14% of all locations recorded in the riverine zone. More fish were located in the lacustrine zone in June, July, and August, and in the transition in May and September. A maximum of 27% of locations occurred in the riverine zone in September. Channel edge habitat was the most used habitat in the lacustrine zone (≥ 70% of locations) and the transition zone (≥ 56% of locations). It was also highly used in the riverine zone (34% of locations) although wing dikes were used more regularly in this zone (55.6% of locations). Main channel habitat was also heavily used in the lacustrine zone (20% of locations) and the transition (23% of locations), but it was the least used habitat in the riverine zone (10% of locations). Adjacent flats were rarely used by Blue Catfish.

Habitat and zones used by "large" and "small" Blue Catfish summary.—Large fish were relocated at a slightly higher rate than small fish (62% vs 51%). Most large fish

were relocated in the transition zone (57% of locations) with fewer fish locations in the lacustrine zone (33% of locations) and riverine zone (10% of locations). Small fish were much more likely to be located in the lacustrine zone (68% of locations) than either the riverine (22% of locations) or transition (10% of locations) zone. Small fish (41%) were also much more likely to be found outside the zone in which they were tagged than were large fish (27%). Channel edge was the primary habitat used by large (≥75% of locations) and small (≥ 60% of locations) Blue Catfish in the lacustrine and transition zones. Wing dikes were the primary habitat used by both sizes of fish in the riverine zone (≥ 52% of locations), and main channel habitat was the second most used habitat in all zones, except no large fish were found in this habitat in the riverine zone. Channel edge habitat usage was similar to main channel habitat usage for small fish in the riverine zone (23.2% vs 24.4% of locations). Adjacent flats were used only by small catfish during the months of May and June.

Habitat and zones used by "large" and "small" Blue Catfish analysis.—There were no differences in the proportions of fish located by telemetry and those captured by LFE for either large or small Blue Catfish in the lacustrine, transition, or riverine zones during June, August and September (Table 11). The only differences in these proportions occurred in the lacustrine and transition zones in May, and the riverine zone in July (Table 11). There were no differences in the proportions of fish located by telemetry and those captured by LFE for either size class of implanted fish in any habitats in any of the zones from May through September (Table 12).

Electrofishing samples.—Between the months May and September, I collected 8,067 fish from 458 systematically-random sampled sites. Only 254 of these fish were

within the same size range of telemetered fish (Table 13; Table 14; Table 15). More small (195) fish were captured than large (59) fish (Table 14; Table 15). The majority of fish, similar in size to “implanted fish” (560 to 700 and >774 mm TL), were captured in the river (44%) and transition (40%) zones with the fewest captured in the lacustrine zone (16%) (Table 13). Most fish were captured in August and September from main channel (43%) and channel edge (57%) habitats in the lacustrine and transition zones, and channel edge (50%) and wing dike habitats in the river (45%) (Table 13). Very few fish were captured on adjacent flats in the lacustrine or transition zones or within the main channels in the riverine zone between May and September (Table 13).

Habitat and zone use and electrofishing comparison.—Proportions of catch and zone use by Blue Catfish were different in the riverine zone in every month except September (Table 16). In the lacustrine, proportions were different during June and August (Table 16). There was no difference in the proportions of zone use and catch in the transition zone from May through September (Table 16). Proportions of catch and habitat use were only different on main channel and channel edge habitats in the transition zone during July (Table 17).

Parameters associated with electrofishing efficiency and fish locations.—Variables classified by the regression tree to be associated with CPUE included month, depth, conductivity, and channel edge (habitat b) and wing dike (habitat d) habitats (Figure 4). The overall quasi-Poisson model proved significant in that R= 0.99, F = 2.11×10^5, df = 8, 447, P < 0.001. Compared to the month of May, CPUE in June decreased while it increased in July, August, and September (Table 18). Additionally, the model indicated CPUE increases with depth (Table 18). In comparison to flat habitats,

the model suggests that CPUE increases when sampling wing dikes and channel edges but decreased when sampling main channels (Table 18). Conductivity showed a positive relationship with CPUE, however, this factor was non-significant (Table 18)

Comparison of depths associated with fish location and fish captured.—A quasi-Poisson regression found the only significant environmental parameter positively associated with CPUE to be depth. Therefore, I only compared this parameter between fish locations, and CPUE>120 fish/hour.

In the lacustrine, depths associated with catch rates greater than 120 fish/hour ranged from 5 to 15 m (mean = 10.8 m, SE = 0.5; Figure 13) on main channels, 4.3 to 12 m (mean = 9.0 m, SE=0.6; Figure 13) on channel edges, and 1.3 to 5 m (mean=2.7 m, SE=0.3; Figure 13) on adjacent flats. Depths associated with Blue Catfish locations ranged from 4.7 to 14.3 m (mean = 10.6 m. SE = 0.4; Figure 13) on main channels, 4.1 to 17.60 m (mean = 10.5m, SE=0.3; Figure 13) on channel edges, and 3.5 to 5.4 m (mean = 4.9 m, SE = 0.7; Figure 13) on adjacent flats. No significant differences were found between the depths of habitats where fish were located and the depths of high efficiency samples (ANOVA: $F_{1, 116} = 0.41$, $P = 0.845$; Figure 13).

In the transition, depths associated with catch rates greater than 120 fish/hour ranged from 8.3 to 14 m (mean = 11.3 m, SE = 0.8; Figure 13) on main channels and 6.3 to 13.3 m (mean = 9.4 m, SE = 0.6; Figure 13) on channel edges. No samples exceeded catch rates of 120 fish/hour on adjacent flats. In the transition, depths associated with Blue Catfish locations ranged from 6.3 to 13.3 m (mean = 10.7 m, SE = 0.4; Figure 13) on main channels and 5.1 to 14.0 m (mean = 11.1 m, SE = 0.3; Figure 13) on channel edges. Only one fish was located on adjacent flats, and the depth associated with its

location was 4.3 m. No significant differences were found between the depths of habitats where fish were located and the depths of high efficiency samples (ANOVA: $F_{1, 147}$ = 0.90, P = 0.503).

In the riverine zone, depths associated with catch rates greater than 120 fish/hour ranged from 5 to 12 m (mean = 8.8 m, SE = 1.4; Figure 13) on main channels, 5.1 to 9.3 m (mean = 7.4 m, SE= 0.3; Figure 13) on channel edges, and 4 to 12.7 m (mean = 8.0 m, SE=0.6; Figure 13) on wing dikes. Depths associated with Blue Catfish locations ranged from 3.9 to 9.1 m (mean = 7.1, SE = 1.1; Figure 13) on main channels, 4.2 to 11.3 m (mean = 8.1 m, SE = 0.8; Figure 13) on channel edges, and 7.5 to 11.4 m (mean = 9.6, SE = 0.6; Figure 13) on wing dikes. No significant differences were found between the depths of habitats where fish were located and the depths of high efficiency samples (ANOVA: $F_{1, 120}$ = 0.018, P = 0.413).

DISCUSSION

Surgery and tag retention.—Transmitter retention and survival of implanted fish was very high in my study. My tagging methodology had high-survival and high retention in aquaculture trials. Other studies observed Blue Catfish to expel 27% of transmitters in the first 30 days (Holbrook et al. 2011). Results of my tank trials were similar to those of Gerber (2015) who also reported 100% retention and 100% survival in tank studies. During field trials, only two implanted Blue Catfish implanted died or expelled the transmitter. This meant approximately 95% of my fish were available to be tracked throughout my study.

I attribute high survival and transmitter retention rates to the use of lateral incisions and the use of staples to close the incisions. The use of surgical staples has

proven to be effective for surgeries of Striped Bass (Mulford 1984) and Paddlefish (Donabauer et al. 2009) but they have not previously been used for Blue Catfish surgeries. Staples have been shown to reduce the index of infection, exhibit higher retention, and have a 53% faster closure time than sutures (Swanberg et al. 1999). Similarly, I found surgical staples to be quick and easy to use. Incisions on implanted fish that were recaptured during sampling, or harvested, were fully healed with no trance of surgical staples. Fish recaptured during sampling, and harvested by, anglers were observed to have fully healed incisions with no remaining surgical staples. Gerber (2015) also used a lateral incision and found it to reduce the risk of tag loss compared to ventral incisions. Therefore, I recommend the use of surgical staples and a lateral incision in future tagging studies of Blue Catfish.

Habitat and zone use.—Fish demonstrated a high site fidelity in this study; less than 35 % of Blue Catfish moved outside of the zone they were originally tagged in during the months of May, June, July, and August. This supports the supposition by Garret and Rabeni (2011) that Blue Catfish have a home range. Site fidelity was described by Pugh and Schramm (1999) who found Blue Catfish in the lower Mississippi River (LMOR) to only move 5 to 12 km from their release site. Biologically this makes inherent sense as the lotic nature of Lake Dardanelle acts as a natural conveyor belt of food, and allows Blue Catfish to remain in areas that regularly concentrate forage.

Most locations of Blue Catfish were in the lacustrine and transition zones throughout my sample period. There was difficulty of detecting fish in the riverine zone due to noise associated with the more lotic nature of this zone (figure 9). Despite this, I did observe movements into the river zone during July, August, and September. Inter-

seasonal movements have been observed by Grist (2002) on Lake Norman, North Carolina, and could explain why more fish were located in the river zone during the later months. However, the overall majority of telemetered Blue Catfish were observed to remain within the zone they were originally tagged.

Blue Catfish heavily used channel edge and main channel habitats in the lacustrine and transition zones (Figure 12). Areas where the main channel was close to the shoreline that created steep drop-offs, and channel edges on outside bends were particularly heavily used (Figure 12; Figure 15). In the riverine zone, Blue Catfish also heavily used the channel edges of outside bends as well as scour holes associated with wing dikes (Figure 12; Figure 15). Use of channel habitats was also demonstrated by Peterson (2015) who found Blue Catfish to aggregate near the channel across seasons, and Pflieger (1999) found Blue Catfish in the scour holes of wing dikes. All of these are deep habitats that provide refuge from nearby high current, while acting as a supply of forage (McClain and Barry 2010).

Fish were only located on adjacent flats during May and early June, which is most likely linked to temperature and forage abundance (Peterson 2015). Warmer temperatures in shallow areas (Figure 10) during the spring season result in higher productivity and may provide more forage for Blue Catfish (Hall and Rudstam 1998). As Blue Catfish are poikilotherms, forays into warmer water on adjacent flats may help them meet metabolic needs (Kelsch and Neill 1990). It should be noted that Blue Catfish were absent from adjacent flats during the later months. A possible explanation is that adjacent flats may become too hot, and thus exceed temperature preferences of Blue Catfish (Beitinger et al. 2000).

*Habitat and zones used by "large" and "small" Blue Catfish.—*The majority of large fish were located in the transition zone for all sample months except July when more were located in the lacustrine zone. For the most part, larger fish were located within the zone in which they were tagged (mean in 83% of the time) with the largest departure occurring in June when 31% of the fish were located outside of the tagging zone. The majority of small Blue Catfish were located in the lacustrine zone during May, June, July, August, and September. Small Blue Catfish were observed to move outside of their original tagging zone more than large Blue Catfish (mean 41% vs 27%). Large and small Blue Catfish primarily used main channel and channel edge habitats in the lacustrine and transition zones, and wing dike and channel edge habitats in the riverine zone (Figure 15).

Large Blue Catfish may remain in certain areas due to location of spawning areas. Blue Catfish are thought to be cavity spawners, using undercut banks and root wads as places to lay their eggs (Graham 1999). I observed probable spawning areas in the transition below Spadra Creek, and across from Piney Creek in the lacustrine zone (Figure 15). These areas were located on outside bends, and consisted of steep, muddy banks. They are also where the majority of large Blue Catfish were located throughout my study period. These areas may therefore be useful for future brood stock collection, or when studying abundance of larger Blue Catfish.

*Habitat use and electrofishing.—*Blue Catfish behavior contributes to the difficulty of standardizing low-frequency electrofishing (Bodine et al. 2013). Gerber (2015) found them to form aggregations in specific areas which can be hard to identify, and sample on large open waterbodies. During my study, I collected the highest CPUE's

when sampling specific habitats. These “hotspots” were channel edges and main channels on outside bends, and deep scour holes on wing dikes. However, the underlying question when sampling these “hotspots” is whether they are actually being used by Blue Catfish or if high catch rates are result of a bias related to LFE. I found that catch rates of Blue Catfish were correlated with Blue Catfish locations. Blue Catfish do indeed use these “hotspots”, and the reason for increased catch rates is related to the presence of more fish. Fisheries managers should therefore consider incorporating deeper channel edges, main channels, and wing dike habitats in their future sample designs. Tools that are useful for identifying these hotspots are contour maps, and a fish finder.

Environmental parameters and habitat characteristics associated with electrofishing efficiency and fish locations.— Standardizing electrofishing is made extremely difficult due to a stochastic environment (Bonar and Hubert 2002; Reynolds and Kolz 2012). In order to compare data between and among waterbodies, it is imperative to understand how environmental factors influence the sampling gear. I found that higher catch rates are correlated with higher temperatures. Bodine and Shoup (2010) also report higher CPUEs when water was the warmest in Oklahoma reservoirs. Warmer temperatures in the summerr season are associated with lower flow and higher conductivities in Lake Dardanelle (Figure 8 and Figure 9). Thus, these factors are associated with higher CPUEs, and it is quite likely that some or all of them positively affect sampling efficiency (Hill and Willis 1994; Korman et al. 2011; Reynolds and Kolz 2012). Daugherty and Sutton (2005) found that high flow caused low-frequency sampling efficiency of Flathead Catfish to decrease. I observed that during the higher flow event in May that Blue Catfish would surface near inaccessible flooded structure, therefore

causing CPUEs to decrease. I observed increased catch rates with increased conductivities. This observation is similar to Justus (1994), however, he cautioned this efficiency may be correlated with warmer temperatures. Therefore I recommend that future research focus on how conductivity influences electrofishing sampling. Number of fish locations and CPUE were positively correlated with depth. Blue Catfish tended to be located on deeper habitats, and CPUE's were also higher. I recommend that managers consider depth when creating sample designs.

CONCLUSIONS

During this study, I found Blue Catfish in Lake Dardanelle use primarily channel edge and main channel habitats in the lacustrine and transition zones, and wing dike and channel edge habitats in the riverine zone. Large and small sizes of Blue Catfish used similar habitats. The CPUE of LFE samples correlates with the degree of habitat use of Blue Catfish indicating that the higher CPUEs are a reflection of higher densities of Blue Catfish, and not a habitat-associated sampling bias. That is, Blue Catfish CPUE's are proportional to the density of fish at the sample site. Higher CPUEs are obtained by sampling relatively deep (> 6m) main channel, channel edge and wing dike habitats in the summer.

Chapter 2

WHEN, WHERE, AND HOW MUCH EFFORT IS REQUIRED TO SAMPLE BLUE CATFISH?

"Efficiency is doing things right; effectiveness is doing the right things" ~ Peter Drucker

INTRODUCTION

When creating standard sampling procedures, it is recommended that managers identify a suitable sample frame and sample design for the study species (Bonar et al. 2009). Sample frames consider gear type and probable fish locations to identify where fish can be sampled effectively, while a sample design focuses on when, where, and how much effort is required to collect data for management purposes (Bonar et al. 2009). Contemporary studies on standardizing sample procedures for Blue Catfish have centered on the use of low-frequency electrofishing because it has been demonstrated to be an effective technique for studies on community structure, population dynamics, and ecological impacts (Brown 2007; Buckmeir and Schlechte 2009; Bodine and Shoup 2010; Kwak et al 2011; Greenlee and Lim 2011; Bodine et al. 2013; Schmitt et al. 2017). These studies recommend 10 to 20 stratified or simple random samples consisting of 200 to 800 fish, a sample duration of 5 to 10 min, use of a chase boat (a second boat with netters), and a water temperature above 18˚C. These procedures, are employed by Arkansas, Oklahoma, and Texas, because they have been shown to produce representative size structures with good efficiency and precision (Buckmeir and Schlechte 2009;Bodine et al. 2013). However, they are often waterbody specific because effectiveness is highly influenced by environmental factors and fish behavior (Bodine et al 2013). Therefore, before applying them to a waterbody they should be critically

evaluated to identify where efficiency can be improved, and monetary costs reduced (Bonar et al 2009; Miranda 2009).

Unlike species that are effectively stunned and captured at electric pulse frequencies of 60 to 120 Hz per second, Blue Catfish respond to low-frequency pulses by surfacing considerable distances from the electrodes (Bodine et al. 2013; Cailteux and Strickland 2009; Cunningham 2004; Vokoun and Rabeni 1999). Consequently, addition of a chase boat to collect distant fish, and those that surface behind the electrofisher, can increase the total catch per sample (Quinn 1988; Bodine et al 2013). Blue Catfish samples collected with chase boats, have produced non-biased length structures with catch rates up to 6,000 fish per hour (Bodine et al. 2011; Greenlee and Lim 2011). In the Missouri River, chase boats accounted for nearly 50% of Flathead Catfish captured (Robinson 1994). High proportions of the total catch of Flathead Catfish in lotic and lentic habitats were also collected by Cunningham (2004) and Daugherty and Sutton (2005) when using chase boats. However, an increase in catch rates of fish per hour by using chase boats comes at an increased cost of additional equipment, personnel, and monetary resources (Daugherty and Sutton 2005). Bodine et al. (2013) noted that the cost associated with additional man-hours is not often considered in calculations of CPUE of catfish when using a chase boat. Additionally, no studies have compared the size structures generated from a chase boat with those of the electrofisher. Therefore, despite their widespread use to capture Blue Catfish, chase boats may not improve efficiency (Cunningham 2004) or produce different size structures than a single electrofisher (Daugherty and Sutton 2005).

Another factor to consider when creating standard LFE procedures is knowing how long to sample. As mentioned previously, Blue Catfish have a tendency to surface varying distances away from the electrofisher. Standard sampling procedures account for this by recommending that samples last from 5 to 10 min to allow ample time to collect the distant surfacing fish. Shorter electrofishing samples have been shown to create similar mean lengths, account for more habitat variability, and result in smaller confidence limits compared to longer samples (Miranda et al. 1996). No studies evaluate CPUE and size structures of Blue Catfish from a 5 and 10 min LFE sample. A shorter sampling duration may reduce the costs of sampling, and prevent crew exhaustion (Bonar et al. 2009), however a longer sample may lead to higher LFE efficiency since Blue Catfish surface such great distances away from the electrofisher.

Fish sample data should be collected using protocols that account for gear biases, fish behavior, and environmental variation (Bonar et al. 2009; Miranda 2009; Koch et al. 2014). Bodine and Shoup (2010) found that sampling in water temperatures >18˚C on main lake points lead to the highest efficiency while Justus (1996) observed more Blue Catfish to be collected from large, deep, eddied pools when water temperatures were >22˚C. Furthermore, they postulated that fish behavior could highly influence when and where Blue Catfish are susceptible to capture. Few studies surrounding LFE have examined efficiency and size distributions collected from various habitats and seasons, and no studies have examined these factors on Lake Dardanelle. Knowledge of where Blue Catfish are concentrated and when to sample them can increase efficiency, and lead to selection of an appropriate sample design for the area of study.

To aid in the development of a standard LFE protocol for Blue Catfish in Lake Dardanelle, I focused this chapter on answering questions associated with sample frames and sample designs. I examined: (1) seasonality and how it relates to size structures and efficiency on Lake Dardanelle; (2) which zones and habitats to sample on Lake Dardanelle and how they relate to size structures and efficiency; (3) utility of a chase boat and how it relates to size structures and efficiency; (4) length of time needed to sample, and how it relates to size structures and efficiency; and (5) utility of a fish finder for increasing sample efficiency of Blue Catfish. The information from this study will help fisheries managers better understand how a standard LFE protocol may be applied to Lake Dardanelle.

METHODS

Study area.—The Arkansas River is the second largest western tributary of the Mississippi River (Hocutt and Wiley 1986), and the sixteenth largest river in the United States in terms of discharge (USGS 1990). It flows 2,400 km from its source in the Rocky Mountains of Colorado to its confluence with the Mississippi River on Arkansas' border with Mississippi (Geik 2016). The entire watershed drains 417,000 km^2 (USGS 1990). The McClellan-Kerr Arkansas River Navigation System (MKARNS) was completed in 1971; it is made up of a series of 18 locks and dams, numerous wing dikes, and rip rap fortified banks, which are distributed over the lower 700 km of the river. It provides commercial navigation, bank stabilization, flood control, and hydroelectric power generation (Limbird 1993).

Lake Dardanelle (Pool 10) was created as a result of the McClellan-Kerr navigation project. The lake has a surface area of roughly 16,200 ha, a shoreline of 510

km, a volume of 656 million m^3, and a mean depth of 4.3 m (range to 16.5 m) (Rickett and Watson 1985). It is approximately 82.6 river km long, extending from Dardanelle Lock and Dam to the Ozark-Jeta Lock and Dam (USACE 2014). Although the Dardanelle Dam has hydroelectric capabilities, water fluctuations are controlled primarily for operation of a nuclear power plant.

I divided Lake Dardanelle into three zones (Figure 1) based on information from Saji (2008). The upper (riverine) zone extends from river kilometer (km) 378.2-412; it is comprised of river channel, river bank, and wing dikes. The middle (transition) zone extends from river km 363.7-378.2; it consists of channel edges, main channels, many islands, and adjacent flats. The lower (lacustrine) zone extends from river km 331.5-363.7; it consists of main channels, channel edges, and adjacent flats. Channel width is typically less than 600 m in the riverine zone, and water velocities are typically higher than in the transition and lacustrine zones. Two large tributaries, Illinois Bayou and Piney Creek, flow into the lower reach. Channel width in the transition and lake ranges from 440 to 3000 m.

When and where to sample Blue Catfish in Lake Dardanelle.—Electrofishing samples were collected from May to September 2016. I selected these months because LFE has been shown to be ineffective in water temperatures <18ºC (Bodine et al. 2013). I divided these months into a spring (warm temperature, pre-spawn and spawn) period (May and June), and a summer (hot temperature, post-spawn) period (July, August, and September). I expected more movement of mature size fish during the spring period than during the summer period due to spawning-related movements (Lee 2009; Garret and Rabeni 2011).

Electrofishing samples were collected from each zone during the same week, for three weeks in each month. I used a systematic random sampling design because it accounts for clustered populations from an environmental gradient and I expected that sample densities might steadily increase/decrease along the longitudinal gradient (Strayer and Smith 2003). Five equally spaced sample sites, beginning at a random starting point, were sampled each week in each zone. For example, when sampling the lacustrine zone, the section was divided into five equidistant lengths of 6.4 km. A random number generator was then used to select a number between 0.0 and 6.4 to serve as a starting point. If the number selected was 1.5, then successive sample sites were located at river kilometers 7.9, 14.3, 20.7, and 27.1.

Since Blue Catfish may inhabit both littoral and pelagic environments (Graham 1999; Grist 2002; Lee 2009), I sampled three common open water habitats at each sample site (Table 2.1). In the lacustrine and transition zones, these were the mid-channel areas, channel edges, and adjacent flats. In the riverine zone flat habitats essentially were non-existent and so the third habitat type consisted of wing dikes. Wing dikes are a common habitat in the upper reaches of the pool, but not the mid or lower reaches. The sampling order in the lacustrine and transition zones was main/mid-channels, channel edge, and adjacent flat. In the riverine zone it was main channel, channel edge, and wing dike. Samples of the three habitat types at each sample site were spaced sufficiently far apart to ensure that samples were independent of each other. A Humminbird© Helix 7 KVD side scan fish finder was used to locate and keep samples within the targeted habitat types. The electrofisher consisted of a 5 m electrofishing boat equipped with a 60 HP outboard, a 7.5 KW inverter generator, and Midwest Infinity© control box. Standardized

electrofishing settings were based on a pilot study conducted in the summer of 2015 to identify the settings that produced the most fish per hour in Lake Dardanelle; 15 pulses per second, and a duty cycle of 30%. Voltage was adjusted to create a 30 peak-amp output. Habitats were sampled for 10 min following protocols listed in Bodine and Shoup 2013. Fish captured in the first 5 min were kept separate from those captured in the second 5 min. Together the combined samples composed a 10 min sample. Total length was recorded for each fish to the nearest millimeter.

Catch per unit effort (CPUE) was calculated seasonally for each zone, and each habitat with each zone. I modified my calculations of catch per-unit effort (CPUE) to account for samples saturated with misrepresentative sized fish. I removed fish I estimated to be age-0 size during post spawn months in July, August and September (Graham 1999). The length frequency method listed by Isely and Grabowski (2007), and published data from Grey and Collins (1970), and Boxrucker and Kuklinski (2008) suggested the lengths of age 0's in July to be 100 mm, 125 mm in August, and 150 mm in September. Therefore I excluded these sizes of fish when I calculated CPUE. I compared CPUE from each season using a Kruskal-Wallis test. A Kruskal-Wallis was used in preference to an Analysis of Variance (ANOVA) since distributions failed to adhere to tests for normality, and sample sizes were slightly unbalanced. If a Kruskal-Wallis indicated a significant difference, a Dunn's Test was used as a post-hoc to determine significant differences. I compared efficiency between zones by comparing each zone with a Kruskal-Wallis with a Dunn's test as a post-hoc during each season. I compared efficiency between habitats with each zone during each season with a Kruskal-Wallis test and a Dunn's test as a post-hoc.

Seasonal size distributions from each zone were compared with a Kolmogorov-Smirnov test. Size distributions from each zone were compared with a Kolmogorov-Smirnov test. Size distributions from each habitat within a zone were compared with a Kolmogorov-Smirnov test. Proportional size distributions (PSD) categories were calculated using methods described in Anderson and Neumann (1996). These categories were Quality (PSD-Q), Preferred (PSD-P), memorable (PSD-M), and trophy (PSD-T). A two-factor ANOVA was used to compare PSD on each zone of Lake Dardanelle with PSD and season as factors. I compared PSD from each zone by season with a two-factor ANOVA with PSD and zone as factors. I compared PSD from each habitat within each zone with a two-factor ANOVA with habitat and PSD as factors. A Tukey honest significant difference (HSD) was used if a significant difference was found to identify differences in groups.

Chase boat efficiency and size structures. —Chase boat sampling trials were scheduled between May and June when water temperatures were <22˚C, and the summer season between August and September when water temperatures were >28˚C. Sampling occurred in the lower (lacustrine) zone and upper (riverine) zone. The middle (transition) zone was used as a buffer zone between the lacustrine and riverine zones, and consequently was not sampled (Figure 2). Four equidistant sample sites were established in each zone and subsequently sampled using a systematic random sample design. Habitats in the lacustrine zone were main/mid-channel, channel edge, and adjacent flats. In the river, adjacent flats became unavailable, and were substituted for wing dikes. Sample sites within each equidistant section were spaced so the previous sample would not conflict with future samples.

The electrofisher consisted of a 5-m electrofishing boat equipped with a 60 HP outboard, a 7.5 KW inverter generator, and a Midwest Infinity© control box. Standardized electrofishing settings were based on a pilot study conducted in the summer of 2015 to identify the settings that produced the most fish per hour in Lake Dardanelle; 15 pulses per second, and a duty cycle of 30%. Voltage was adjusted to create a 30 peak-amp output. The chase boat consisted of a 5 m metal-hulled boat equipped with a 50 HP outboard and railing. Two netters were standardized for each boat.

Habitats were sampled for 10 min following protocols listed in Bodine and Shoup 2013. Blue Catfish were separated into two live-wells on the electrofisher and chase boat based on if they were captured in the first 5-min or second 5-min sample time. Fish from both live-wells were treated as catch from a 10 min sample. A timekeeper on the electrofisher signaled the chase boat with a flag at the beginning of electrofishing, the 5 min mark, and when time elapsed. Fish were counted and measured to the nearest mm before release. The chase boat crew collected fish that were unavailable (to the sides or behind) to the electrofisher crew.

Catch per unit effort was calculated for the chase boat as catch per person-per hour (CPUE/person-hour) so as to account for additional effort. A Wilcoxon signed-rank test was used to compare CPUE/person-hour of the electrofisher and electrofisher and chase boat combined during the spring and summer season. A Wilcoxon signed-rank was used in preference to a paired t-test since data were not normal and jointly sampled from the same population. Size distributions created by the electrofisher and were compared to those created with an electrofisher and chase boat combined using a Kolmogorov-Smirnov test. Seasonal PSD were compared using a two-way ANOVA with gear

(electrofisher/chaseboat) and PSD (quality, preferred, memorable, trophy) as factors. Tukey's HSD was used to determine differences between groups of PSD and gear.

Sampling time.—CPUE was calculated for the first five min and 10 min. I compared the first 5 min of a sample with 10 min using a Wilcoxon signed-rank test in each zone on Lake Dardanelle. Size distributions from the first 5 min and 10 min were compared in each zone with a Kolmogorov-Smirnov test. In each zone on Lake Dardanelle I compared PSD from the first 5 min with a 10 min sample using a two factor ANOVA with sample time and PSD as factors. Tukey's HSD was used to determine where differences existed between sample time and PSD groups.

Utility of a fish finder.—At each sample site, after determining depth of habitat, I also noted whether any fish were marked on the fish finder. I calculated the CPUE for each habitat for samples for which fish were detected on the fish finder prior to sampling, and for those samples for which no fish were detected. Analysis of this data was observational to determine whether use of a fish finder is associated with higher catch rates.

RESULTS

Electrofishing summary.—During my field season, I collected 8,067 Blue Catfish from 458 samples. Of the 8,067 Blue Catfish, 563 of them were estimated as age zeros, and subsequently excluded from analysis. Catch rates ranged from 0 to 1056 fish/hour. Fish sizes ranged from 84 to 1120 mm. The highest CPUE occurred on channel edge and wing dike habitats during the summer season (Table 20; Figure 34). Samples collected from the lacustrine zone resulted in the highest CPUE (Table 21; Figure 35), however, more large fish were collected in the transition and river zones (Figure 36). The lowest

catch rates for the transition, riverine, and lacustrine zones occurred during the spring season (Table 20; Figure 35).

Chase Boat summary.—During the chase boat portion of this study, I collected 4,312 Blue Catfish from 96 systematically sampled habitats. Of these 4,312 Blue Catfish, 1,054 fish were estimated to be age zeros, and were excluded from analysis. Chase boat crews captured 1,920 Blue Catfish ranging from 152 to 940 mm while electrofisher crews captured 1,338 fish ranging from153 to 855 mm. Catch rates ranged from 0 to 846 fish/hour with the electrofisher, and 0 to 1200 fish/hour with a chase boat (Figure 35). Sampling with the electrofisher plus a chase boat in the summer season was more efficient than sampling in the spring season (Table 23; Figure 35), and led to capture of more and larger fish.

When to sample Blue Catfish in Lake Dardanelle.—Catch per unit effort was observed to increase overall during the summer season (Figure 23), however, efficiency decreased on flat habitats in the transition and lacustrine zones during the summer season (Table 20; Figure 34). Spring and summer season CPUE's obtained from each zone differed significantly at an $\alpha = 0.05$ (Table 25; Figure 37), however CPUE's from flats in the lacustrine zone, and channel edges and wing dikes in the riverine zone were not found to statistically differ (Table 26; Figure 34).

A greater number of large fish were collected during the summer season (Figure 25). Subsequently, seasonal comparisons of size distributions collected from each zone were found to differ significantly at $\alpha = 0.05$ (Table 27; Figure 38; Figure 39). Seasonal size distributions collected from the nine different habitats were found to differ except flats from the transition (Table 2.10; Figure 2.9).

Proportional size distributions collected from Dardanelle's zones did not differ significantly by season in the lacustrine (ANOVA: $F_{3, 172}$ = 1.48, *P* = 0.223) or riverine (ANOVA: $F_{3, 148}$ = 0.71, *P* = 0.547) zone (Figure 40). However, the transition zone was marginally non-significant (ANOVA: $F_{3, 140}$ = 0.2.66, *P* = 0.051), and Tukey's HSD indicated a difference in the number of quality sized fish at $p < 0.05$. Seasonal PSD's were found to significantly differ on main channels in the lacustrine (ANOVA: $F_{3, 52}$ = 3.24, *P* = 0.030) and transition zones (ANOVA: $F_{3, 44}$ = 3.74, *P* = 0.018) (Figure 41). Tukey's HSD found differences to exist between quality sized fish at $p<0.05$. PSD's collected from other habitats in the riverine, transition, and lacustrine zones did not differ seasonally (Figure 2.11).

Sampling efficiency in zones and habitats of Lake Dardanelle.—Catch per unit effort was highest in the lacustrine zone during the spring and summer season (Table 29; Figure 35). CPUE's collected from the transition and riverine zones did not differ statistically at $\alpha<0.05$ (Table 29). The CPUE was highest on channel edges and wing dikes in the riverine zone, and highest on main channels and channel edges in the transition and lacustrine zones (Table 30; Figure 34). The CPUE from main channels and channel edges in the lacustrine, transition and river did not differ significantly during the summer season (Table 30; Figure 34), however, adjacent flats were found to be statistically lower than channel edges and main channels in the lacustrine and transition zones. CPUE from wing dikes were statistically higher than channel edges and main channels in the summer season (Table 30; Figure 34).

Size distributions and proportional stock distribution in zones and habitats of Lake Dardanelle. —Size distributions collected during the spring and summer seasons

from each zone differed statistically (Table 31; Figure 38; Figure 39). However, size distributions from riverine habitats (Figure 42), and main channels and channel edges in the transition (Figure 43) and lacustrine (Figure 44) zones in the spring season did not differ (Table 32). Size distributions collected from all habitats in the summer season differed statistically (Table 32).

PSD's collected from lacustrine, transition and riverine zones were found to differ during the spring (ANOVA: $F_{6, 204}$ =4.91, P <0.001) and summer seasons (ANOVA: $F_{6, 256}$ = 12.14, P <0.001) (Figure 40). A Tukey's HSD found differences of quality sized fish at the p<0.05 level between the lacustrine and transition, and the lacustrine and riverine zones during both seasons. Quality sized fish did not differ between the transition or riverine zone during either season. All other PSD categories did not differ between zones for either season.

PSD's differed in habitats of the transition zone (ANOVA: $F_{6, 60}$ = 3.90, P = 0.002) during the spring season, and lacustrine zone (ANOVA: $F_{6, 96}$ = 9.48, P <0.001) during the summer season. A Tukey's HSD indicated quality sized fish to differ between flats and channel edges, and flats and main channels in the lacustrine zone. In the transition, quality sized fish from flats differed from channel edges, but did not differ from main channels. All other size categories from the lacustrine and transition zones did not differ. PSD's from habitats in the riverine (ANOVA: $F_{6, 60}$ = 0.28, P = 0.946) and lacustrine (ANOVA: $F_{6, 60}$ = 0.84, P = 0.548) zones in the spring season, and transition (ANOVA: $F_{6, 64}$ = 0.81, P = 0.568) and riverine (ANOVA: $F_{6, 72}$ = 1.35, P = 0.245) habitats in the summer season did not differ (Figure 41).

*Chase boats: CPUE comparison.—*The CPUE of the electrofisher and chase boat combined was significantly higher than a single electrofisher in the riverine and lacustrine zone during the spring and summer season (Table 33). CPUE/person-hour of the chase boat and electrofisher combined was significantly higher than a single electrofisher in the riverine and lacustrine zone during the spring and summer season (Table 33)

*Chase boats: PSD and size distribution comparison.—*Utility of an electrofisher and chase boat combined led to the capture of more, larger fish than a single electrofisher (Figure 47). Compared to a single electrofisher, overall size distributions created with the electrofisher and chase boat combined were significantly different in the lacustrine and riverine zones during the spring and summer season (Table 37; Figure 47). However, a two factor ANOVA found no significant differences in PSD between a single electrofisher, and a chase boat and electrofisher combined in the lacustrine (ANOVA: $F_{3,40}$ = 0.77, P = 0.302) and riverine (ANOVA: $F_{3,40}$ = 0.66, P = 0.580) zones during the spring season (Figure 48). During the summer season, no significant differences in PSD's created between a single electrofisher, and an electrofisher and chase boat combined in the lacustrine (ANOVA: $F_{3,40}$ = 0.16, P = 0.925) and riverine ($F_{3,40}$ = 0.55, P = 0.653) zones were noted (Figure 48).

S*ampling time: Single electrofisher.—*Samples that lasted for 10 min led to the capture of an additional 1,770, 833, and 1,026 additional fish in the lacustrine, transition, and riverine zones respectively (Table 35; Figure 49). CPUE's generated from a 10 min sample were lower than those in a 5 min sample in the lacustrine, transition, and riverine zones (Table 35; Table 36; Figure 50). Size distributions created during a 5 and 10 min

sample were found to be statistically different in the lacustrine, transition, and riverine zones (Table 37; Figure 49; Figure 51). Samples that lasted for 10 min captured more, large fish, however average PSD's decreased (Table 35; Table 36; Figure 52). A two factor ANOVA found no significant differences between PSD from 5 min and 10 min samples in the lacustrine (ANOVA: $F_{3,352}$ = 0.06, P = 0.979), transition (ANOVA: $F_{3,280}$ = 0.00, P = 1.00) and riverine ($F_{3,304}$ = 0.04, P = 0.791) zones (Figure 52).

Sampling time: Electrofisher and chase boat.—Samples that lasted for 10 min led to the capture of 1,680 and 321 additional fish in the lacustrine and riverine zones respectively (Table 38; Figure 53). CPUE's generated from a 10 min sample were observed to increase in the riverine and lacustrine zones (Table 38; Table 40; Figure 54). Size distributions created during a 5 and 10 minute sample with a chase boat were found to differ in the lacustrine zone, but were similar in the riverine zone (Table 38; Figure 55). Samples that lasted for 10 min led to the capture of more, large fish in the lacustrine and riverine zones (Figure 55). PSD's generated from a 10 min sample were observed to decrease in the lacustrine zone with quality sized fish, and preferred sized fish in the riverine zone (Table 38; Figure 55). Samples that lasted for 10 min led to an increase in PSD in the riverine zone, and PSDM in the lacustrine zone (Table 38; Figure 55). A two factor ANOVA found no significant differences between PSD from 5 min and 10 min samples in the lacustrine (ANOVA: $F_{3,88}$ = 0.04, P = 0.989). A two factor ANOVA found no significant differences between PSD from 5 min and 10 min samples in the lacustrine (ANOVA: $F_{3,88}$ = 0.04, P = 0.989) and riverine (ANOVA: $F_{3,88}$ = 0.16, P = 0.924) zones.

Utility of a fish finder.—The CPUE at sites where fish were recorded on the depth finder prior to sampling averaged 3.7 times higher than the sites where no fish were

detected prior to sampling. At least one fish was detected before 315 samples, and no fish were detected prior to 181 samples. The greatest increase in CPUE was for the main channel (8.7 times) and the lowest was for flats (2.3 times). The CPUEs for dike and channel edge habitats were 3.7 times greater when fish were detected prior to sampling. PSDs were generally higher when fish were detected prior to sampling.

DISCUSSION

When to sample Blue Catfish in Lake Dardanelle.—Sample efficiency was highest during the summer season when water temperatures were ≥ 25˚C. These findings are similar to those of Bodine et al. (2013) who found CPUE of LFE increased with temperature. However, CPUE was observed to decrease on adjacent flats in the lacustrine and transition zones during the summer season. A possible explanation for higher catch rates on adjacent flats in the spring season could be due to fish behavior. Blue Catfish commonly occupied flats habitat in the spring, but not during the summer. Warmer temperatures on the flats may have attracted Blue Catfish because they are poikilotherms and rely on environmental factors to regulate homeostasis (Graham 1999). Likewise, adjacent flats in the summer season may have exceeded Blue Catfish temperature preferences thus causing them to migrate to deeper, cooler habitats (Graham 1999). Another possibility, could be due to abundance of forage. Although I did not specifically investigate forage abundance on adjacent flats, warmer temperatures during the spring season could have resulted in higher productivity than that found in the cooler, deep habitats (Hall and Rudstam 1998). As a result, an abundance of forage on adjacent flats in the spring season may have attracted Blue Catfish to this habitat in the spring.

Sampling efficiency in zones and habitats of Lake Dardanelle.—I found efficiency to be highest in the lacustrine zone. This differs from the findings of Bodine and Shoup

(2010) who reported increased catch rates at the uppermost end of their sample areas. A potential reason for higher catch rates in the lacustrine may be presence of forage. Lewis and Magoulick (2002) found Zebra Mussels *Dreissena polymorpha*, to comprise over 50% of Blue Catfish diets during summer months. The low-flow conditions, and increased autochthonous production, in this zone creates a perfect environment for zebra mussel proliferation, and thus presence of Blue Catfish (Gagen and Stoeckel 1995). The lacustrine zone also provides a favorable habitat to another prey item for Blue Catfish, Gizzard Shad *Dorosoma cepedianum* (Lewis and Magoulick 2002). The combined presence of these two forage items could explain why catch rates of Blue Catfish was higher in the lacustrine zones.

Channel edges in the lacustrine and transition zones, and wing dikes in the riverine zone produced the highest catch rates. Channel edges where bends from the preexisting river channel created deep holes along muddy banks were particularly productive. Deeper wing dikes with large scour holes were also more efficient to sample than shallow wing dikes. These results are similar to those of Bodine and Shoup (2010), found that sampling channel habitats resulted in the highest efficiency. Managers may therefore increase their efficiency by including channel edge habitats, and wing dikes in their sample designs.

Size distributions and proportional stock distribution in zones and habitats of Lake Dardanelle. —Evaluating size structure of a fish population is one of the most common analyses conducted by fisheries biologists (Neumann et al. 2012). Stock density indices provide an easily calculated numerical descriptor of length frequency data (Neumann et al. 2012). Size of recruitment to the fishery and spawning stock are of

particular interest (Neumann et al. 2012). I found that sampling channel edges and main channels in the lacustrine and transition zones, and wing dikes in the riverine zone, resulted in the capture of more fish within the quality, preferred, and memorable size classes. By including these habitats in a sample design, managers are more likely to collect samples consisting of PSD's representative of the population.

Interpretation of size distribution data is often subjective, and can only occur with knowledge of how, when, and where the data were collected (Neumann and Allen 2007). In this study, the summer months proved to be the most efficient time to sample and the size range of fish collected was the widest at that time. The lacustrine produced the greatest abundance of fish and the lowest PSD's because it harbored a larger proportion and number of quality size and smaller fish. Flats in particular, held a preponderance of smaller size fish compared to other habitats. The overall PSD for all seasons can be expected to provide reasonable estimates of the true PSD for Lake Dardanelle. Sampling channel habitat produces the same estimate and the highest CPUE suggesting that systematic sampling of channel edge habitat through the length of the pool may be the best method to sample Blue Catfish in Lake Dardanelle.

Chase boats.—Utility of a chase boat resulted in increased catch rates and capture of larger fish. This is a similar finding to those of Robinson (1994) and Cunningham (2004) who demonstrated the utility of chase boats when sampling Flathead Catfish, a species that has a similar reaction to low-frequency pulses as Blue Catfish. Low-frequency pulses elicit unique surfacing responses in Blue Catfish with fish often surfacing 30-60 s after power is applied from the electrofisher (Corcoran 1979). There, they remain briefly on the surface before submerging (Bodine and Shoup 2010). During

this time, fish are not completely immobilized and retain the ability to swim and, frustratingly, avoid capture. Large Blue Catfish especially seemed to sense the approaching electrofisher more than small Blue Catfish. They did not repeat this behavior when a chase boat approached which could mean they sense the electrical outputs of the electrofisher. Additionally, I anecdotally observed power outputs were more precise when a chase boat was used. Every time the electrofisher would accelerate to capture a distant surfacing fish, the surface area of the anodes would decrease resulting in decrease of electrofisher power output. A chase boat allowed the electrofisher to maintain consistent power output throughout the duration of a sample by collecting the distantly surfacing fish. A chase boat requires twice the amount of effort to operate in comparison to a single electrofisher. This additional effort is often ignored when managing Blue Catfish (Bodine et al. 2013). Despite the additional effort required for its operation, catch rates were still significantly higher than that of a single electrofisher. Therefore, I recommend the use of a chase boat for growth and population estimate studies that require a large amount of fish be collected.

Use of a chase boat led to the increased capture of larger fish. However, there was no difference in PSDs created with its use. Conversely, overall size structures were different in the lacustrine, but not in the river. As aforementioned, smaller fish were more present in the lacustrine zone than the riverine which explains why there were differences in the lacustrine, but not the riverine zone. Chase boats may not be required for studies on size structure, if the management questions focus strictly on PSDs. However if the studies focus on overall size distributions, a chase boat should be used because it increases catch of larger fish.

S*ampling duration*. — I found CPUE to be significantly higher in the first 5 min of sampling than during a 10-min sample in the lacustrine and transition zones, but was not higher in the riverine zone. During my study, I observed Blue Catfish to surface 30-60 s after power application. After approximately 3 min, fish began to recuperate from the pulses of the electrofisher and resurface. Larger fish tended to surface later than small fish, although they still surfaced within the first 5 min of sampling. As the electrofisher moved along a habitat, Blue Catfish would continue to surface, typically in lower densities. This explains why efficiency was higher in the first 5 min than the second min. When a chase boat was used, sampling for 10 min resulted in higher CPUE than a 5 min sample. A possible explanation is the chase boat is more mobile than the electrofisher and is able to collect more fish during longer samples. Overall, size structures from 5 min were different than 10 min, but PSD indices were not. Thus, similar PSDs are produced in 5 min and 10 min samples. When a chase boat was used size distributions from 5 min were similar to those from a 10 min in the riverine zone, but were different in the lacustrine zone. Similar size structures can therefore be collected whether samples last for 5 or 10 min. I recommend that managers consider a 5 min sample when creating their sample designs for Lake Dardanelle as sampling for 5 min was overall more efficient, and resulted in similar PSD's to a 10 min sample.

During my sample season, I found it was possible to collect fifteen 10 min samples per day. By reducing samples to 5 minutes, 30 samples per day would be feasible. Bodine et al. (2013) recommend a minimum of 200 fish be captured to describe size structures of a Blue Catfish population. I found average catch rates to be 156 fish/h on channel edges and 132 fish/h on wing dikes. It would therefore be possible to collect

over 200 fish in 70 min of sampling these two habitats. Managers may maximize efficiency by sampling channel edges and wing dike longitudinally on Lake Dardanelle with samples lasting 5 min at each sample site.

Utility of a fish finder.—Greater CPUEs when fish are detected with a fish finder prior to sampling suggests that greater efficiencies can be achieved by traveling along a habitat prior to sampling until at least one fish is marked on a fish finder. This procedure could be incorporated into a stratified random sampling design. That is, sample sites can be selected with the longitudinal stratified random approach used in this study, with the electrofisher moving from selected sites upstream and sampling not commencing until at least one fish is detected. Based on the results of this study, this procedure has the potential to more than triple capture efficiency

Conclusions

Standardized sampling procedures should consider gear, fish behavior, and environment so as to minimize bias during sampling (Bonar and Hubert 2002; Hayes et al. 2003; Sammons 2014). Blue Catfish in Lake Dardanelle, are located more frequently in deeper main channel, channel edge, and wing dike habitats. Small and large fish (see Chapter 1) both used channel edge main channel, and wing dike habitats proportionately. Small fish use adjacent fats in the spring, however, when temperatures rise, they move to deeper habitats. Proportions of fish captured by ELF by habitat were similar to the proportions to which they are located in those habitats by telemetry; Channel edges and wing dike habitats >6 m in depth are positively associated with CPUE. Sampling during the summer season is more efficient than sampling in the spring season. Size distributions in the riverine and transition zones do not differ across seasons, whereas there are significantly

more stock size fish in the lacustrine zone. Use of a chase boat improved efficiency, however size structures are similar between samples. Sampling for 5 min with a single electrofisher is more efficient than 10 min with a single electrofisher, but when a chase boat is used, a 10 min sample is more efficient. There was no significant difference between PSDs calculated from a 5 min or 10 min of sample when a single electrofisher, or an electrofisher and chase boat combined.

Management Summary and Recommendations

- The telemetry portion of this study illustrates that Blue Catfish habitually occupy types of habitats; the same habitats where CPUE is highest. That is, Blue Catfish capture rates by LFE are proportionate to the amount of time that they occupy specific habitats.
- Channel edge, main channel, and scour holes associated with dikes, when associated with depths > 6 m all produce relatively high CPUEs for Blue Catfish when sampled with LFE.
- Flats are used by smaller-size fish during the spring, but not during the summer. Larger-size Blue Catfish are not associated with flats.
- Smaller-size Blue Catfish are more prevalent in the lacustrine zone compared to the transition and riverine zones in Lake Dardanelle.
- Larger-size Blue Catfish are relatively well associated with all zones in Lake Dardanelle, with slightly lower numbers found in the lacustrine zone compared to the transition and riverine zones.

- Relatively high PSDs and CPUEs are associated with channel edge and wing dike habitats. Channel edge habitat extends the length of the pool whereas dike habitat is located almost entirely in the riverine zone.
- A longitudinal stratified random sampling approach that incorporates samples of channel edge habitat appears to be the most efficient strategy for obtaining accurate measures of Blue Catfish PSDs in Lake Dardanelle.
- Samples 5 min in duration produce comparable, but slightly higher PSD values and CPUE when compared to samples of 10 min duration.
- Use of chase boat approximately doubles the catch of Blue Catfish per minute, but PSDs are similar whether a chase boat is used or not used.
- CPUE per boat crew is approximately the same when a chase boat or only an electrofishing boat is used.
- CPUE can be increased by a factor of three when Blue Catfish are sampled at sites where fish are detected with a fish finder before sampling commences.
- To obtain a sample size of 200 stock size fish, channel edges of Lake Dardanelle can be sampled for approximately 70 min.
- To monitor Blue Catfish populations in Lake Dardanelle, I suggest a stratified random approach to sampling along channel edges for the length of the reservoir. Moving upstream from the starting point, sampling duration should be 5 min. This procedure should produce approximately 20 samples, 100 min of sampling, and 290 fish per day using this method.

Sampling for Blue Catfish in Lake Dardanelle should take place in either July, August, or September when water temperatures are >25˚C. Water levels should be at normal pool and wind speeds should be low. I recommend use of metal-mesh nets (shad nets) because spines often make removal of Blue Catfish from traditional multi-strand mesh nets difficult. One large opening net should be kept on each boat should a large Blue Catfish surface. Lake Dardanelle should be divided into an upper and lower zone, with the midway point being at Spadra Creek Recreation Area. A stratified random or systematic random sampling method should be used. Strata should consist of channel habitats >6 m. Systematic random samples should be limited to channel habitats >6 m deep. Shallow, flat habitats should be excluded from sample designs. A chase boat should be used in addition to an electrofisher when sampling, and samples should last for 5 min. Ten samples should be collected from the lower zone, and 10 samples should be collected from the upper zone. The electrofisher should be equipped with a side scan and down imaging fish finder unit. Once the electrofisher arrives at the designated sample location, it should circle the area until centered over the highest density of fish indicated by the unit. Power should be applied once this spot has been located. Electrofisher settings should be set so as to produce 200 V, 30 peak amps, and >6,000 W with a duty cycle of 15 pps.

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TABLE 1.—Descriptions of zones and four macrohabitat types sampled in Lake Dardanelle, Arkansas River, Arkansas.

Habitat Type	Code	Description
Riverine		Extends from river km 378-412. Typically has flow year round. Consists of main channel, channel edge, and wing dike habitats.
Transition		Extends from river km364-378. Flow begins to slow down in this area. Consists of main channel, channel edge, and flat habitats. This area has more islands compared to the lacustrine and river zones.
Lacustrine		Extends from river km 331-364. There is little flow in this area during the late summer compared to the spring. Consists of main channel, channel edge, and flat habitats.
Adjacent Flats	Flat	Waters adjacent to the main channel that are typically less than 3 m deep. Are connected to the channel edge.
Main channel	Main	The area impounded by Dardanelle Dam that typically has current at normal river levels (20,000 - 50,000 cfs) and is generally deeper than 3 m. Includes navigation channels and area that is not impounded by Dardanelle Dam
Channel Edge	Edge	The slope edge of the main channel, can be a steep or soft gradient. Generally deeper than 3 m.
Wing Dikes	Dike	The areas within 20 m of a wing dike and downstream dike fields.

TABLE 2.—Tagging dates in 2016, location, and status of "small" (560-700 mm) Blue Catfish.

ID	Date	Zone	Size[a]	Length (mm)	Weight (kg)	Last Tracked	Status[b]
201	2/21	Lacustrine	L	560	2.7	5/27/2017	L
205	4/9	Transition	L	575	2.13	3/32/2017	L
223	4/16	Riverine	X	613	3.13	6/2/2016	H
254	3/21	Lacustrine	L	613	2.61	3/21/2016	H
222	4/16	Riverine	L	614	2.72	4/16/2017	L
210	4/10	Riverine	L	620	3.52	4/13/2017	L
236	3/23	Lacustrine	X	620	2.81	5/13/2017	L
199	2/22	Lacustrine	X	620	2.72	4/2/2017	L
217	4/9	Riverine	L	623	3.26	3/12/2017	L
213	4/10	Riverine	L	627	3.35	5/20/2017	L
234	3/23	Lacustrine	X	630	2.75	4/5/2017	L
202	4/9	Riverine	L	631	2.67	3/21/2017	L
215	3/11	Lacustrine	L	650	3.15	6/3/2017	L
230	4/16	Riverine	X	656	3.24	7/17/2016	L
233	4/10	Riverine	X	659	2.78	7/12/2016	H
225	3/25	Lacustrine	X	675	3.77	10/25/2016	H
229	4/16	Transition	X	685	4.15	7/28/2016	L
221	3/25	Lacustrine	X	690	4.69	4/14/2017	L
204	2/26	Lacustrine	L	698	4.7	3/11/2017	L
218	2/26	Lacustrine	X	700	5.3	3/15/2017	L

[a]L=large size, X=extra-large size transmitter.
[b]L=living, H=harvested, D=died from unknown causes

TABLE 3.—Tagging dates in 2016, location, and status of "large" (774-1139 mm) Blue Catfish.

ID	Date	Zone	Size[a]	Length (mm)	Weight (kg)	Last Tracked	Status[b]
216	4/10	Riverine	L	774	7.19	8/27/2016	H
235	4/17	Transition	X	806	8.05	11/4/2016	L
253	4/16	Transition	L	819	7.78	10/11/2016	L
198	4/16	Transition	X	822	8.41	11/5/2016	L
200	4/16	Transition	L	825	7.87	11/5/2016	L
220	4/21	Lacustrine	X	828	9.32	8/22/2016	L
207	4/21	Lacustrine	L	834	8.89	11/4/2016	L
231	4/24	Transition	X	847	8.28	11/9/2016	L
203	4/21	Transition	L	852	9.63	8/27/2016	L
238	4/17	Riverine	X	853	10.03	11/6/2016	H
212	4/16	Transition	X	858	11.93	11/5/2016	L
237	4/17	Transition	X	877	10.94	11/5/2016	L
55	4/29	Transition	X	902	11.96	n/a	H
232	4/1	Riverine	L	915	9.29	3/4/2017	L
197	4/21	Lacustrine	X	920	11.43	8/5/2016	L
62	5/3	Transition	X	920	11.77	5/17/2016	D
219	4/21	Transition	X	925	12.93	11/5/2016	L
206	4/15	Lacustrine	L	935	10.91	8/5/2016	L
214	4/21	Transition	L	944	11.79	11/5/2016	L
227	4/17	Transition	X	955	15.54	8/28/2016	L
224	4/21	Transition	X	1043	13.72	6/2/16	L
123	4/29	Transition	X	1070	16.61	7/31/16	D
228	4/24	Transition	X	1139	19.91	10/2/16	L

[a]L=large size, X=extra-large size transmitter.
[b]L=living, H=harvested, D=died from unknown causes

TABLE 4.—Large (L) and small (S) fish locations in May. Star represents original tagging location. Refer to Table 1 for habitat descriptions.

Size	ID	Lacustrine			Transition			Riverine		
		Main	Edge	Flat	Main	Edge	Flat	Main	Edge	Dike
L	62					1*				
L	197		*			1				
L	198					1*				
L	203					1*				
L	206		1*							
L	212					1*				
L	214					1*				
L	216					1				*
L	220		1*							
L	227					1*				
L	231					1*				
L	232					1			*	
S	199		*	1						
S	213	1								*
S	215		1*							
S	217									1*
S	218	1	2*							
S	222		1						*	
S	223						1		*	
S	230		1						*	

TABLE 5.—Large (L) and small (S) fish locations in June. Star represents original tagging location. Refer to Table 1 for habitat descriptions.

Size	ID	Lacustrine			Transition			Riverine		
		Main	Edge	Flat	Main	Edge	Flat	Main	Edge	Dike
L	123		2			1*				
L	197		2*							
L	198					2*				
L	200		1			*				
L	203					2*				
L	207		1*							
L	212				1	*				
L	214		1			1*				
L	219		2			*				
L	220	1	*							
L	224					1*				
L	228					2*				
L	231					2*				
L	235					1*				
L	237		2			*				
L	238								1*	1
S	199	1	1*						1	
S	201		1*							
S	202					1	*			
S	213					1				*
S	215		1*							
S	217	2*								
S	218		2*							
S	221	1		*						
S	222		1	2		*				
S	225		2	*						
S	230		1						*	
S	233									1*
S	234		2	1*						

TABLE 6.—Large (L) and small (S) fish locations in July. Star represents original tagging location. Refer to TABLE 1 for habitat descriptions.

Size	ID	Lacustrine			Transition			Riverine		
		Main	Edge	Flat	Main	Edge	Flat	Main	Edge	Dike
L	197		1*							
L	198				2	1*				
L	200	1	2*							
L	203				1	2*				
L	206		1*			2				
L	207		1*							
L	212				2	1*				
L	214				1	1*				
L	216		1							*
L	219				1	2 *				
L	220		2	*						
L	227	1				*				
L	231					2*				
L	232		1			1*				
L	235		1			*				
L	237		2			*				
L	238								*	2
S	199		1*							
S	202						*		1	
S	205					1*				
S	217	2*								
S	218		2*							
S	221		1	*						
S	222		1			*				
S	225	1	2	*						
S	229					*				2
S	230		1					1	*	
S	233									1*
S	234	1		*						1
S	236			*				1	2	

TABLE 7.—Large (L) and small (S) fish locations in August. Star represents original tagging location. Lacustrine, Transition, and Riverine represent the zones on Lake Dardanelle. Refer to TABLE 1 for habitat descriptions

Size	ID	Lacustrine			Transition			Riverine		
		Main	Edge	Flat	Main	Edge	Flat	Main	Edge	Dike
L	197		1*							
L	198					1*				
L	200		1*							
L	203					1*				
L	206	1	*			2				
L	207		1*							
L	214					1*				
L	216				1					*
L	219				1	2 *				
L	227					*				1
L	231				1	*				
L	232		1			*				
L	238								*1	
S	199		1*							
S	202						*	1		
S	213				1					*
S	217	2*								
S	218		1 *							
S	221	1		*						
S	222		1			*				
S	225		1	*						

TABLE 8.—Large (L) and small (S) fish locations in September. Star represents original tagging location. Lacustrine, Transition, and Riverine represent the zones on Lake Dardanelle. Refer to TABLE 1 for habitat descriptions.

Size	ID	Lacustrine			Transition			Riverine		
		Main	Edge	Flat	Main	Edge	Flat	Main	Edge	Dike
L	198				1	*				
L	200		*			1				
L	207		1*							
L	212				1	*				
L	214				1	*				
L	216					1				*
L	219					1*				
L	231					*			1	
L	232					1*				
L	233									1*
L	235		1			*				
L	237				1	*				
L	238								*1	
S	199		*							1
S	202						*		1	
S	205		1			*				
S	215	1	*							
S	217	*								1
S	218		1*							
S	221		1	*						
S	222		1			*				
S	236			*		1				

TABLE 9.—Proportion analysis comparing large and small fish locations in each zone by month.

Month	Habitat	χ^2	*P*
May	Lacustrine	4.59	0.032
	Transition	7.08	0.008
	Riverine	0.04	0.834
Jun	Lacustrine	1.21	0.271
	Transition	3.49	0.061
	Riverine	<0.01	1.00
Jul	Lacustrine	<0.01	1.00
	Transition	3.72	0.054
	Riverine	4.62	0.032
Aug	Lacustrine	1.77	0.184
	Transition	3.13	0.077
	Riverine	<0.01	1.00
Sep	Lacustrine	2.32	0.128
	Transition	0.17	0.676
	Riverine	0.02	0.882

TABLE 10.—Proportion analysis comparing monthly locations of large and small fish in each habitat within zones on Lake Dardanelle. Refer to TABLE 1 for habitat descriptions.

Month	Habitat	Lacustrine		Transition		Riverine	
		χ^2	*P*	χ^2	*P*	χ^2	*P*
	Main	<0.01	1.00	N/A	N/A	N/A	N/A
May	Edge	0.03	0.863	2.23	0.136	N/A	N/A
	Flat/Dike	<0.01	1.00	2.23	0.136	N/A	N/A
	Main	0.25	0.620	<0.01	1.00	N/A	N/A
Jun	Edge	2.05	0.152	<0.01	1.00	0	1.00
	Flat/Dike	0.76	0.385	N/A	N/A	0	1.00
	Main	0.47	0.495	N/A	N/A	<0.01	1.00
Jul	Edge	0.47	0.495	<0.01	1.00	<0.01	0.936
	Flat/Dike	N/A	N/A	N/A	N/A	0.41	0.521
	Main	0.04	0.836	0.09	0.766	N/A	N/A
Aug	Edge	0.04	0.836	<0.01	1.00	N/A	N/A
	Flat/Dike	N/A	N/A	N/A	N/A	N/A	N/A
	Main	<0.01	1.00	<0.01	1	N/A	N/A
Sep	Edge	<0.01	1.00	<0.01	1	0.15	0.693
	Flat/Dike	N/A	N/A	N/A	N/A	0.47	0.494

TABLE 11.—Comparison of proportions of large and small fish located by telemetry to proportions of large and small fish captured by electrofishing in each zone.

Month	Zone	χ^2	*P*
May	Lacustrine	4.59	0.032
	Transition	7.08	0.008
	Riverine	0.04	0.834
Jun	Lacustrine	1.21	0.271
	Transition	3.49	0.061
	Riverine	<0.01	1.00
Jul	Lacustrine	14.03	1.00
	Transition	0.93	0.336
	Riverine	5.14	0.023
Aug	Lacustrine	1.77	0.184
	Transition	3.13	0.077
	Riverine	<0.01	1.00
Sep	Lacustrine	0.01	0.919
	Transition	0.74	0.389
	Riverine	0.22	0.640

TABLE 12.—Proportion analysis comparing monthly locations of large and small fish in each habitat within a zone. No fish detections is represented by the acronym NFD.

Month	Habitat	Lacustrine		Transition		Riverine	
		χ^2	*P*	χ^2	*P*	χ^2	*P*
	Main	<0.01	1.00	NFD	NFD	NFD	NFD
May	Edge	0.03	0.863	2.23	0.136	NFD	NFD
	Flat/Dike	<0.01	1.00	2.23	0.136	<0.01	1.00
	Main	0.25	0.620	<0.01	1.00	NFD	NFD
Jun	Edge	2.05	0.152	<0.01	1.00	<0.01	1.00
	Flat/Dike	0.76	0.385	NFD	NFD	<0.01	1.00
	Main	0.47	0.495	NFD	NFD	<0.01	1.00
Jul	Edge	0.47	0.495	<0.01	1.00	<0.01	0.936
	Flat/Dike	NFD	NFD	NFD	NFD	0.41	0.521
	Main	0.04	0.836	0.09	0.766	<0.01	1.00
Aug	Edge	0.04	0.836	<0.01	1.00	<0.01	1.00
	Flat/Dike	NFD	NFD	NFD	NFD	<0.01	1.00
	Main	<0.01	1.00	<0.01	1	NFD	NFD
Sep	Edge	<0.01	1.00	<0.01	1	0.15	0.693
	Flat/Dike	NFD	NFD	NFD	NFD	0.47	0.494

TABLE 13.—Number and capture locations of fish 575-700 and 774-1139 mm by month. Refer to TABLE 1 for habitat descriptions.

Month	Lacustrine			Transition			Riverine			Total
	Main	Edge	Flat	Main	Edge	Flat	Main	Edge	Dike	
May	2	8	0	2	14	2	1	8	5	42
Jun	0	0	0	2	7	0	0	5	3	17
Jul	3	7	0	22	9	1	4	15	9	71
Aug	2	2	0	13	13	0	3	13	37	83
Sep	6	9	0	3	8	0	1	11	3	41
Total	13	26	0	42	51	3	9	52	57	254

TABLE 14.—Number and capture locations of fish 575-700 mm by month. Refer to TABLE 1 for habitat descriptions.

Month	Lacustrine			Transition			Riverine			Total
	Main	Edge	Flat	Main	Edge	Flat	Main	Edge	Dike	
May	1	5	0	1	7	2	1	5	5	27
Jun	0	0	0	1	5	0	0	4	3	13
Jul	3	6	0	18	7	1	4	11	9	59
Aug	2	2	0	9	9	0	2	11	29	64
Sep	5	6	0	3	6	0	1	8	3	32
Total	11	19	0	32	34	3	8	39	49	195

TABLE 15.—Number and capture locations of fish 774-1139 mm by month. Refer to TABLE 1 for habitat descriptions.

Month	Lacustrine			Transition			Riverine			Total
	Main	Edge	Flat	Main	Edge	Flat	Main	Edge	Dike	
May	1	3	0	1	7	0	0	3	0	15
Jun	0	0	0	1	2	0	0	1	0	4
Jul	0	1	0	4	2	0	0	4	0	12
Aug	0	0	0	4	4	0	1	2	8	19
Sep	1	3	0	0	2	0	0	3	0	9
Total	2	7	1	10	17	0	1	13	8	59

TABLE 16.—Proportion analysis comparing large and small fish captured with fish locations in each zone.

Month	Zone	χ^2	*P*
May	Lacustrine	2.22	0.136
	Transition	0.08	0.779
	Riverine	5.16	0.023
Jun	Lacustrine	16.69	<0.001
	Transition	1.84	0.175
	Riverine	10.35	0.001
Jul	Lacustrine	<0.01	1.00
	Transition	3.72	0.054
	Riverine	4.62	0.032
Aug	Lacustrine	23.81	<0.001
	Transition	0.63	0.427
	Riverine	19.65	<0.001
Sep	Lacustrine	2.32	0.128
	Transition	0.17	0.676
	Riverine	0.22	0.640

TABLE 17.—Proportion analysis comparing both size classes of captured and telemetered fish. The acronym D-NC means fish were detected, but no fish were captured. The acronym N-NC, means no fish were detected and no fish were captured. Refer to TABLE 1 for habitat descriptions.

Month	Habitat	Lacustrine		Transition		Riverine	
		χ^2	*P*	χ^2	*P*	χ^2	*P*
May	Main	0	1.00	N-NC	N/A	<0.01	1.00
	Edge	0	1.00	1.89	0.169	<0.01	1.00
	Flat	0	1.00	<0.01	1.00	0.02	0.881
Jun	Main	D-NC	N/A	0.17	0.679	N-NC	N/A
	Edge	D-NC	N/A	0.17	0.679	<0.01	1.00
	Flat	D-NC	N/A	N-NC	N/A	<0.01	1.00
Jul	Main	<0.01	1.00	4.39	0.036	<0.01	1.00
	Edge	0	1.00	5.43	0.019	1.27	0.260
	Flat	N-NC	N/A	<0.01	1.00	0.862	0.353
Aug	Main	<0.01	1.00	0.16	0.689	0.43	0.510
	Edge	<0.01	1.00	0.16	0.689	<0.01	1.00
	Flat	N-NC	N/A	N- NC	N/A	0.46	0.496
Sep	Main	0.51	0.475	0.11	0.742	<0.01	1.00
	Edge	0.51	0.475	0.11	0.742	0.26	0.608
	Flat	N -NC	N/A	N-NC	N/A	0.71	0.401

TABLE 18.—Results for the posterior densities of the model coefficients for the Quasi-Poisson model for Blue Catfish CPUE. The results shown are the mean, SD, median, and lower and upper bounds for the 95% credible interval for the posterior densities of the model random effects. The levels of the categorical variables set to zero to define dummy variables. Variables are month (May, June, July, August, September), conductivity, depth, and habitat type. Refer to TABLE 1 for habitat descriptions.

Coefficient	Mean	Standard Error	*P*	Lower bound 95% CI	Upper bound 95% CI
Intercept	3.4413	0.1983	<0.001	3.04	3.82
June	-0.4802	0.2269	0.034	-0.94	-0.05
July	0.2534	0.1667	0.129	-0.07	0.58
August	0.7252	0.1707	<0.001	0.39	1.06
September	0.7250	0.1632	<0.001	0.41	1.04
Depth	0.0807	0.0187	<0.001	0.04	0.12
Conductivity	0.0007	0.0005	0.163	<0.01	<0.01
Edge	0.4381	0.2140	0.041	0.11	0.98
Mains	-0.1933	0.2377	0.417	-0.65	0.28
Dike	0.5429	0.2239	0.016	0.02	0.87

TABLE 19.—Variance inflation factors from the following parameters: Conductivity, Depth, June, July, August, September, main channels, channel edges, and wing dikes. Refer to TABLE 1 for habitat descriptions.

Coefficient	VIF
June	0.036
July	0.048
August	0.047
September	0.049
Depth	0.023
Conductivity	0.016
Edge	0.024
Main	0.011
Dike	0.051

TABLE 20.—Summary of samples from each habitat within each zone by season. Refer to TABLE 1 for habitat descriptions.

Season	Zone	Habitat	Fish *n*	Sample *n*	Effort (h)	Median CPUE (fish/h)
Spring	Riverine	Main	40	22	3.6	3
		Edge	204	22	3.6	42
		Dike	298	25	4.2	51
	Transition	Main	84	22	3.6	12
		Edge	225	22	3.6	48
		Flat	122	19	3.2	36
	Lacustrine	Main	163	23	3.8	24
		Edge	464	23	3.8	72
		Flat	314	23	3.8	48
Summer	Riverine	Main	350	28	4.7	48
		Edge	482	27	4.5	108
		Dike	815	30	5.0	112
	Transition	Main	384	23	3.8	60
		Edge	704	24	4.0	117
		Flat	64	21	3.5	12
	Lacustrine	Main	979	35	5.8	132
		Edge	1438	34	5.7	195
		Flat	374	33	5.5	12

TABLE 21.—Summary of number of fish captured and median CPUE for each zone by season.

Season	Zone	Fish *n*	Sample *n*	Effort (h)	Median CPUE (fish/h)
Spring	Riverine	542	69	11.5	18
	Transition	431	69	11.5	36
	Lacustrine	941	63	10.5	48
Summer	Riverine	1647	85	14.2	72
	Transition	1152	68	11.3	51
	Lacustrine	2791	103	17.2	114

TABLE 22.—Summary of number of fish captured in the spring and summer season by a single electrofisher (EF) and an electrofisher plus a chase boat combined (EF+CB) from the riverine and lacustrine zones.

Gear	Season	Zone	Fish *n*	Sample *n*	Effort (h)	Median CPUE	Median CPUE fish/person-h
EF	Spring	Riverine	75	24	4	13	4
		Lacustrine	453	24	4	43	14
	Summer	Riverine	212	24	4	42	14
		Lacustrine	1203	24	4	144	48
EF+CB	Spring	Riverine	217	24	4	36	6
		Lacustrine	1028	24	4	108	18
	Summer	Riverine	548	24	4	84	14
		Lacustrine	2519	24	4	402	67

TABLE 23.—Comparison of CPUE among zones by season.

Season	Zone	Wilcoxon W-statistic	*P*
Spring	Riverine	69	11.5
	Transition	69	11.5
	Lacustrine	63	10.5
Summer	Riverine	85	14.2
	Transition	68	11.3
	Lacustrine	103	17.2

TABLE 24.—Comparison of CPUE between seasons by habitat within zones. Refer to TABLE 1 for habitat descriptions.

Zone and habitat	Wilcoxon W-Statistic	*P*
Riverine Main	483	<0.001
Riverine Edge	369	0.150
Riverine Dike	369	0.150
Transition Main	427	<0.001
Transition Edge	415	<0.001
Transition Flat	111	0.016
Lacustrine Main	655	<0.001
Lacustrine Edge	542	0.014
Lacustrine Flat	274	0.077

TABLE 25.—Comparison of size distributions between seasons by zone.

Zone	Kolmogorov-Smirnov D-Statistic	*P*
River	0.19	<0.001
Transition	0.27	<0.001
Lake	0.19	<0.001

TABLE 26.—Comparison of size distributions between seasons by habitat and zone. Refer to TABLE 1 for habitat descriptions.

Zone and habitat	Kolmogorov-Smirnov D-Statistic	*P*
Riverine Main	0.33	<0.001
Riverine Edge	0.18	<0.001
Riverine Dike	0.15	<0.001
Transition Main	0.31	<0.001
Transition Edge	0.35	<0.001
Transition Flat	0.15	0.261
Lacustrine Main	0.19	<0.001
Lacustrine Edge	0.24	<0.001
Lacustrine Flat	0.13	0.003

TABLE 27.—Comparison of CPUE among zones by season. Dunn's test comparison is sequential in the following order: Riverine-Transition; Transition-Lacustrine; Lacustrine-Riverine.

Season	Zone	Median CPUE	Kruskal Wallis χ^2	Dunn's *P*
	Riverine	18		0.011
Spring	Transition	36	8.16	0.398
	Lacustrine	48		0.005
	Riverine	72		0.006
Summer	Transition	51	7.28	0.248
	Lacustrine	114		0.026

TABLE 28.—Comparison of CPUE among habitats by season. Dunn's test comparison is sequential in the following order: Main-Edge; Edge-Flat; Flat-Main or Dike-Main. Refer to TABLE 1 for habitat descriptions.

Season	Zone	Habitat	Median CPUE	Kruskal Wallis χ^2	Dunn's *P*
Spring	Riverine	Main	3	24.17	<0.001
		Edge	42		0.367
		Dike	51		<0.001
	Transition	Main	12	12.80	<0.001
		Edge	48		0.067
		Flat	36		0.027
	Lacustrine	Main	24	7.63	0.003
		Edge	72		0.071
		Flat	48		0.098
Summer	Riverine	Main	48	5.05	0.068
		Edge	108		0.252
		Dike	112		0.014
	Transition	Main	60	35.17	0.034
		Edge	117		<0.001
		Flat	12		<0.001
	Lacustrine	Main	132	29.24	0.081
		Edge	195		<0.001
		Flat	12		<0.001

TABLE 29.—Kolmogorov-Smirnov comparison of size distributions between each zone by season. Comparison is sequential in the following order: Riverine - Transition; Transition - Lacustrine; Lacustrine - Riverine.

Season	Zone	Kolmogorov-Smirnov D-Statistic	*P*
Spring	Riverine	0.44	<0.001
	Transition	0.42	<0.001
	Lacustrine	0.43	<0.001
Summer	Riverine	0.14	<0.001
	Transition	0.21	<0.001
	Lacustrine	0.44	<0.001

TABLE 30.—Kolmogorov-Smirnov comparison of size distributions among habitats in each zone by season. Comparison is sequential in the following order: Main-Edge; Edge-Flat; Flat- Main or Dike-Main in the riverine zone. Refer to TABLE 1 for habitat descriptions.

Season	Zone	Habitat	Kolmogorov-Smirnov D-Statistic	*P*
Spring	Riverine	Main	0.11	0.751
		Edge	0.07	0.679
		Dike	0.15	0.456
	Transition	Main	0.16	0.077
		Edge	0.34	<0.001
		Flat	0.25	0.003
	Lacustrine	Main	0.08	0.377
		Edge	0.15	<0.001
		Flat	0.16	0.008
Summer	Riverine	Main	0.18	<0.001
		Edge	0.08	0.048
		Dike	0.18	<0.001
	Transition	Main	0.09	0.031
		Edge	0.14	0.021
		Flat	0.21	0.016
	Lacustrine	Main	0.09	<0.001
		Edge	0.15	<0.001
		Flat	0.14	<0.001

TABLE 31.—Comparison of CPUE and catch/person-h from the electrofisher and chase boat by season.

Statistic	Spring riverine	Summer riverine	Spring lacustrine	Summer lacustrine
V-statistic for CPUE	0	0	0	2.5
P	<0.001	<0.001	<0.001	<0.001
V-statistic for catch/person-h		58.5	54	44
P	0.015	0.016	0.006	0.008

TABLE 32.—Mean proportional size distributions (PSD) created with a single electrofisher (EF) and an electrofisher and chase boat combined (EF+CB) from the lake and river during the spring and summer season. PSD categories obtained from Anderson and Neumann 1996. PSD categories are quality = PSD, preferred = PSD-P, memorable = PSD-M.

Gear	Season	Zone	PSD	PSD-P	PSD-M
EF	Spring	Riverine	23	2.0	0
		Lacustrine	8.5	0	0
	Summer	Riverine	9	0	0
		Lacustrine	20	1	0
EF+CB	Spring	Riverine	15	1	0
		Lacustrine	3.6	0	0
	Summer	Riverine	13	1	0
		Lacustrine	13	0.4	0.1

TABLE 33.— Median CPUE and mean average proportional size distributions (PSD) created from sampling for 5 min and 10 min in the lacustrine, transition, and riverine zones on Lake Dardanelle. PSD categories obtained from Anderson and Neumann 1996. PSD categories are quality = PSD, preferred = PSD-P, memorable = PSD-M.

Duration	Zone	Fish *n*	CPUE	PSD	PSD-P	PSD-M
5	Lacustrine	2223	54	3.9	0.1	<0.01
	Transition	905	30	15	1.9	0.4
	Riverine	1234	30	18	0.7	0.1
10	Lacustrine	3993	30	3.7	0.1	<0.01
	Transition	1738	18	15	1.9	0.5
	Riverine	2260	18	17	0.4	0.1

TABLE 34.—Wilcoxon signed rank test (WSR) and Kolmogorov-Smirnov (KS) comparison of CPUE and size distributions from 5 and 10 min samples from the lake, river and transition zones on Lake Dardanelle.

Statistics	Lacustrine	Transition	Riverine
V-statistic of WSR test	7905	3487	4707
P	<0.001	0.039	0.057
D-statistic of KS test	0.15	0.17	0.16
P	<0.001	<0.001	<0.001

TABLE 35.—Median CPUE (fish/h) and mean proportional size distribution (PSD) created from sampling in 5 min and 10 min in the lacustrine and riverine zones on Lake Dardanelle with an electrofisher and chase boat combined. PSD categories obtained from Anderson and Neumann 1996. PSD categories are quality = (PSD), preferred = (PSD-P), memorable = (PSD-M), and trophy = (PSD-T).

Duration	Zone	Fish *n*	CPUE	PSD	PSD-P	PSD-M	PSD-T
5	Lacustrine	1867	150	9.7	0.2	0	0
	Riverine	444	42	12.9	1.4	0	0
10	Lacustrine	3547	231	8.3	0.2	0.04	0
	Riverine	765	48	14	0.7	0	0

TABLE 36.—Wilcoxon signed rank test (WSR) and Kolmogorov-Smirnov (KS) comparison of CPUE and size distributions from 5 and 10 min samples with an electrofisher and chase boat combined from the lake, river and transition zones on Lake Dardanelle.

Statistics	Riverine	Lacustrine
V-statistic of WSR test	144	66
P	<0.001	<0.001
D-statistic of KS test	0.07	0.21
P	0.158	<0.001

TABLE 37.—Catch per unit effort (fish/h) and proportional size distributions (PSD) created when fish were noted on a fish finder and when no fish were noted in each zone of Lake Dardanelle. PSD categories obtained from Anderson and Neumann 1996. PSD categories are quality = (PSD), preferred = (PSD-P), and memorable = (PSD-M).

Zone	Fish noted	CPUE	PSD	PSD-P	PSD-M
Lacustrine	No	14	2.5	0.0	0.0
Lacustrine	Yes	40	6.3	0.5	0.0
Transition	No	3.6	8.1	0.0	0.0
Transition	Yes	24	22.2	2.6	0.5
Riverine	No	5	9.2	0.6	0.0
Riverine	Yes	25	16.3	0.8	0.3

TABLE 38.—Catch per unit effort (fish/h) and proportional size distributions created when fish were noted on a fish finder and when no fish were noted in each habitat of Lake Dardanelle. PSD categories obtained from Anderson and Neumann 1996. PSD categories are quality = (PSD), preferred = (PSD-P), and memorable = (PSD-M). Refer to TABLE 1 for habitat descriptions.

Habitat	Fish noted	CPUE	PSD	PSD-P	PSD-M
Dike	No	12	5.4	0.0	0.0
Dike	Yes	40	19.8	1.5	0.9
Flat	No	11	2.8	0.0	0.0
Flat	Yes	13	23.8	4.8	0.0
Edge	No	7	5.0	5.0	0.0
Edge	Yes	35	15.5	1.4	0.2
Main	No	4	12.1	0.0	0.0
Main	Yes	28	9.5	0.8	0.0

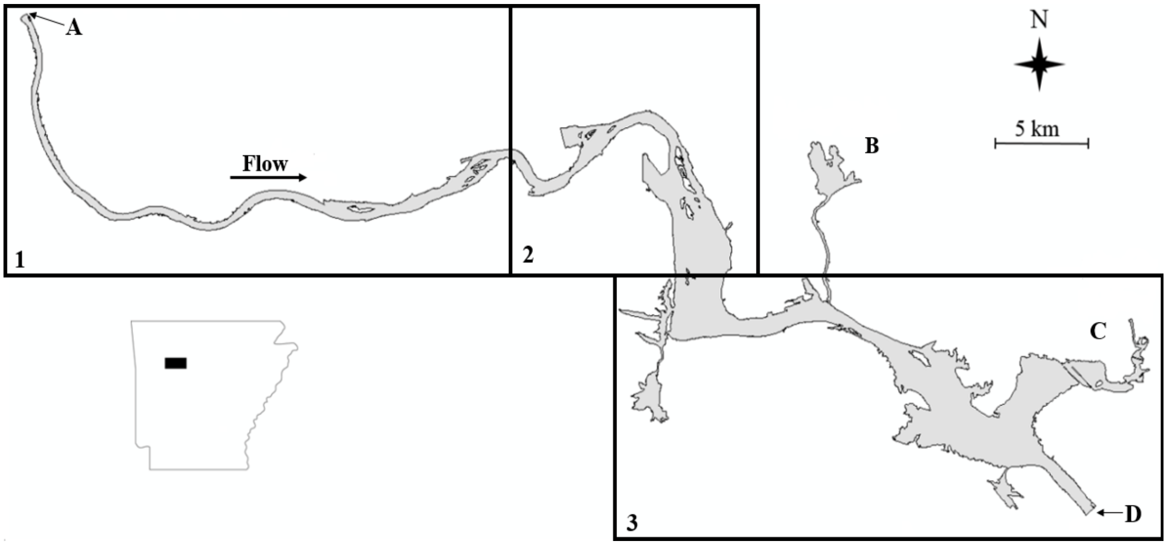

FIGURE 1.—Sample areas on Lake Dardanelle, Arkansas used during the single electrofisher portion of this study. Number 1) represents the river, 2) the transition, and 3) the lacustrine zone. Letter A) represents Ozark-Jeta Dam, B) Piney Creek, C) Illinois Bayou, and D) Dardanelle Dam.

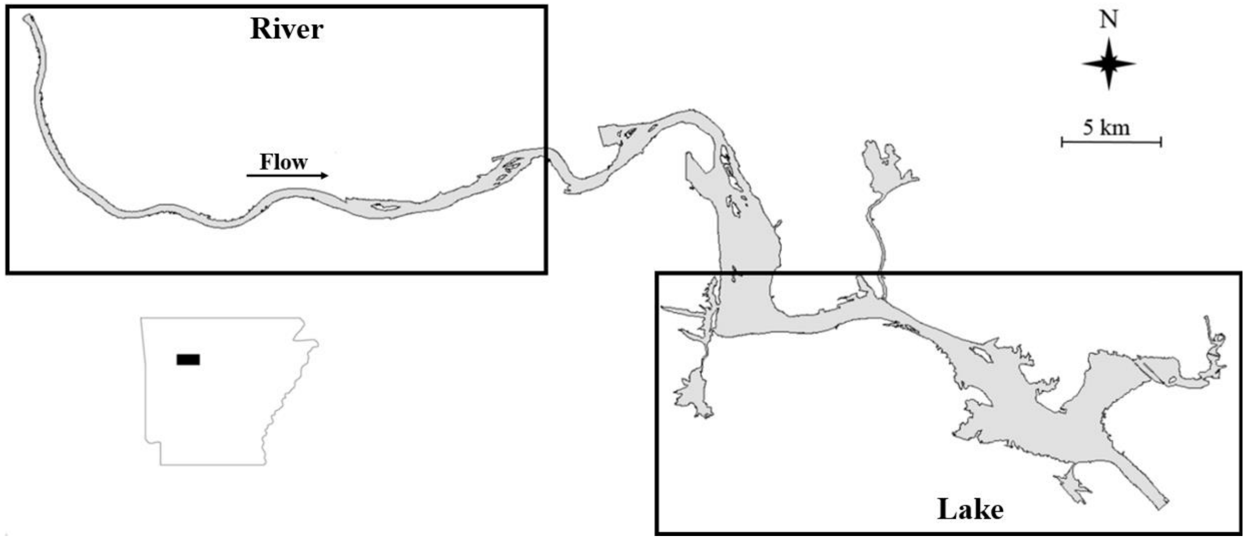

FIGURE 2.—Sample areas on Lake Dardanelle, Arkansas used during the chase boat portion of this study.

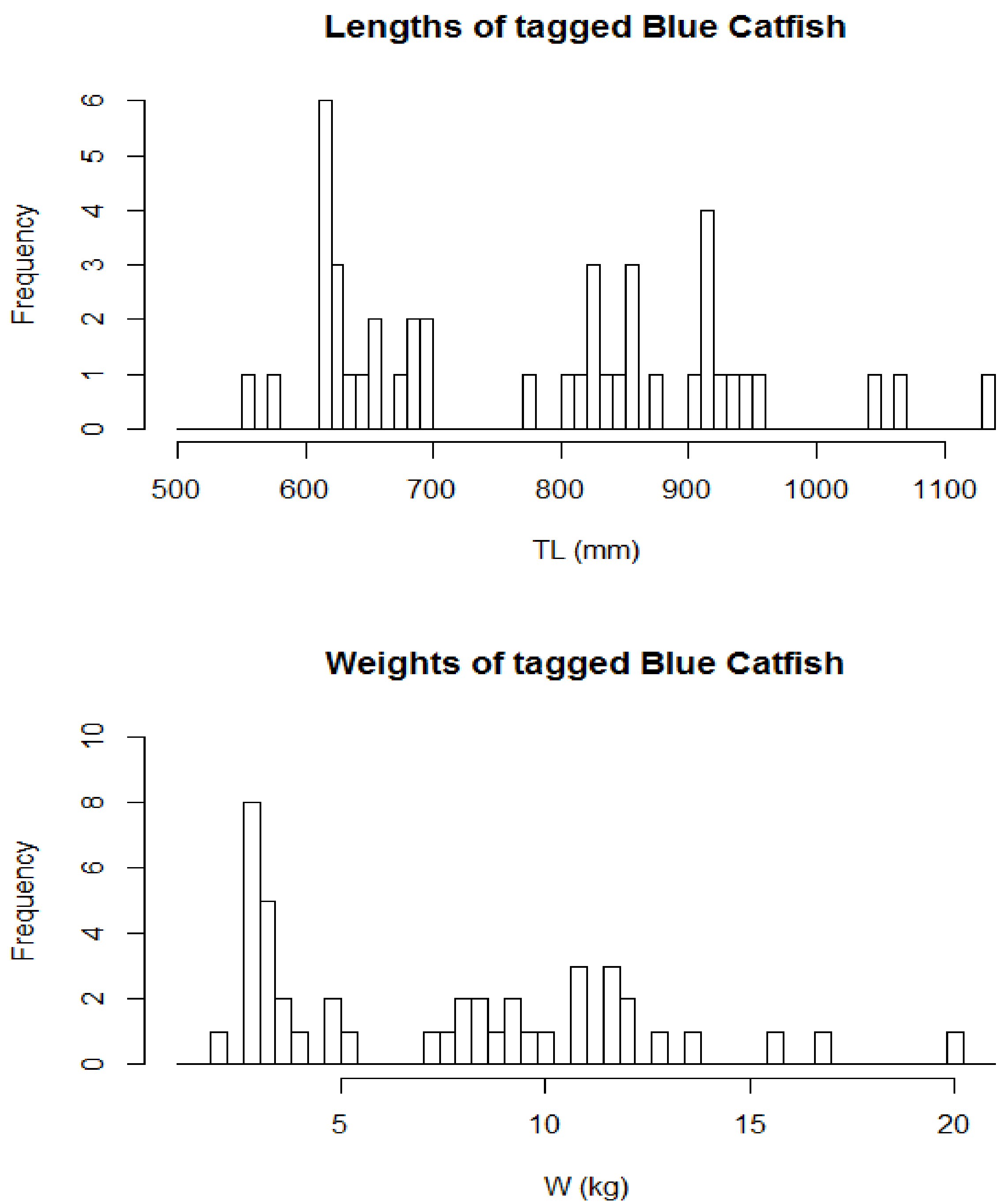

FIGURE 3.—Histograms of total length (TL) and weight (W) of Blue Catfish implanted with transmitters.

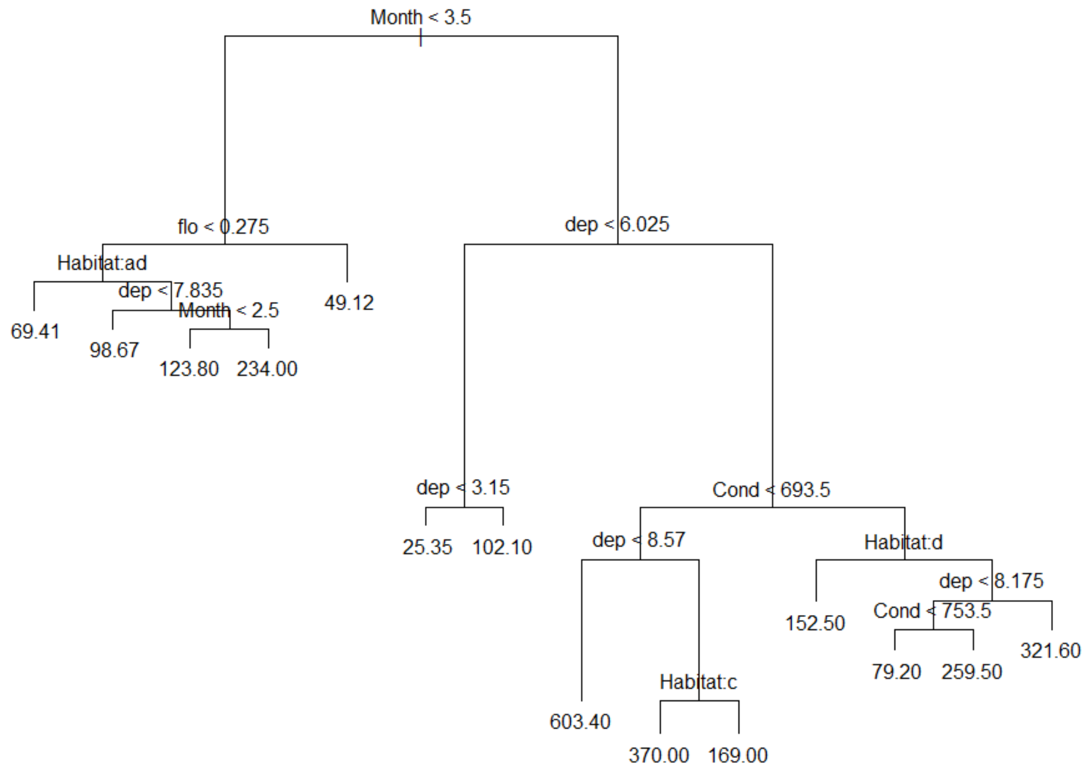

FIGURE 4.—Regression tree indicating significance of variables and their association with CPUE on Lake Dardanelle. Months were categorized as the following: May= (1), June= (2), July= (3), August= (4), and September= (5). Habitats were categorized as flats= (a), channel edges= (b), main channels= (c), and wing dikes= (d). Abbreviations for conductivity, depth, and flow are (Cond), (dep), and (flo) respectively. No association with CPUE was found with the factor zone, temperature, or secchi depth.

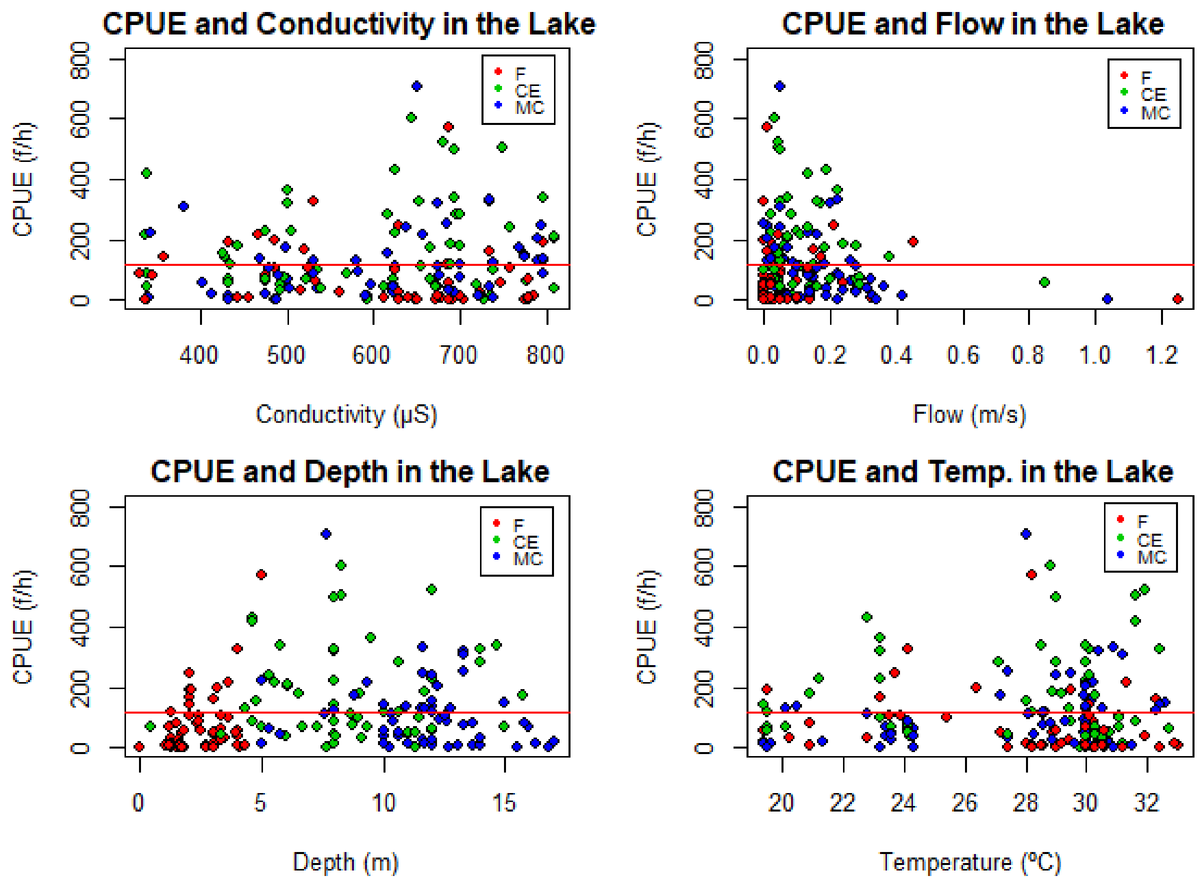

FIGURE 5.—Scatterplots showing relationships between CPUE and conductivity, flow, depth, and temperature in the lake. The horizontal red line indicates a CPUE of 120 fish per hour (fish/h) which is the minimum catch rate needed to fulfill requirements recommended in Bodine et al. (2013). F=Flat, CE=Edge, MC=Main.

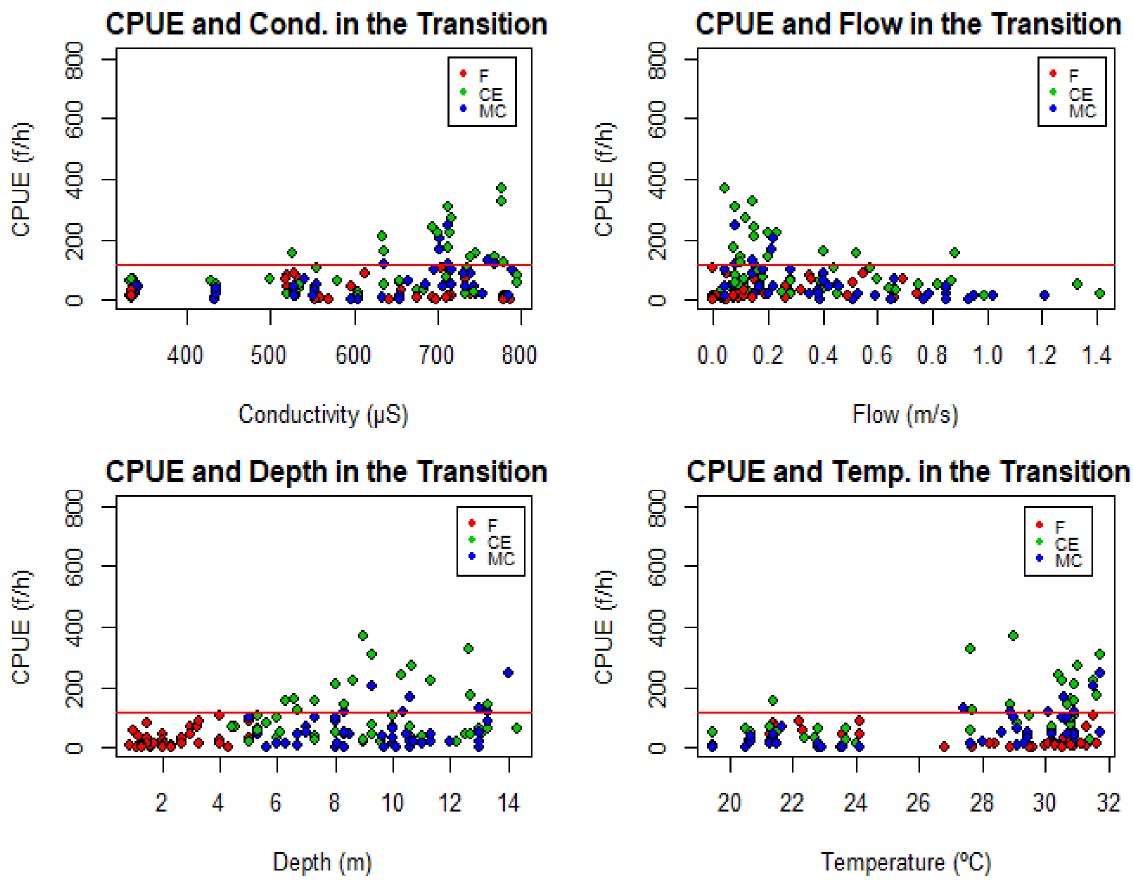

FIGURE 6.—Scatterplots showing relationships between CPUE and conductivity, flow, depth, and temperature in the transition. The horizontal red line indicates a CPUE of 120 fish per hour (fish/h) which is the minimum catch rate needed to fulfill requirements recommended in Bodine et al. (2013). F=Flat, CE=Edge, MC=Main.

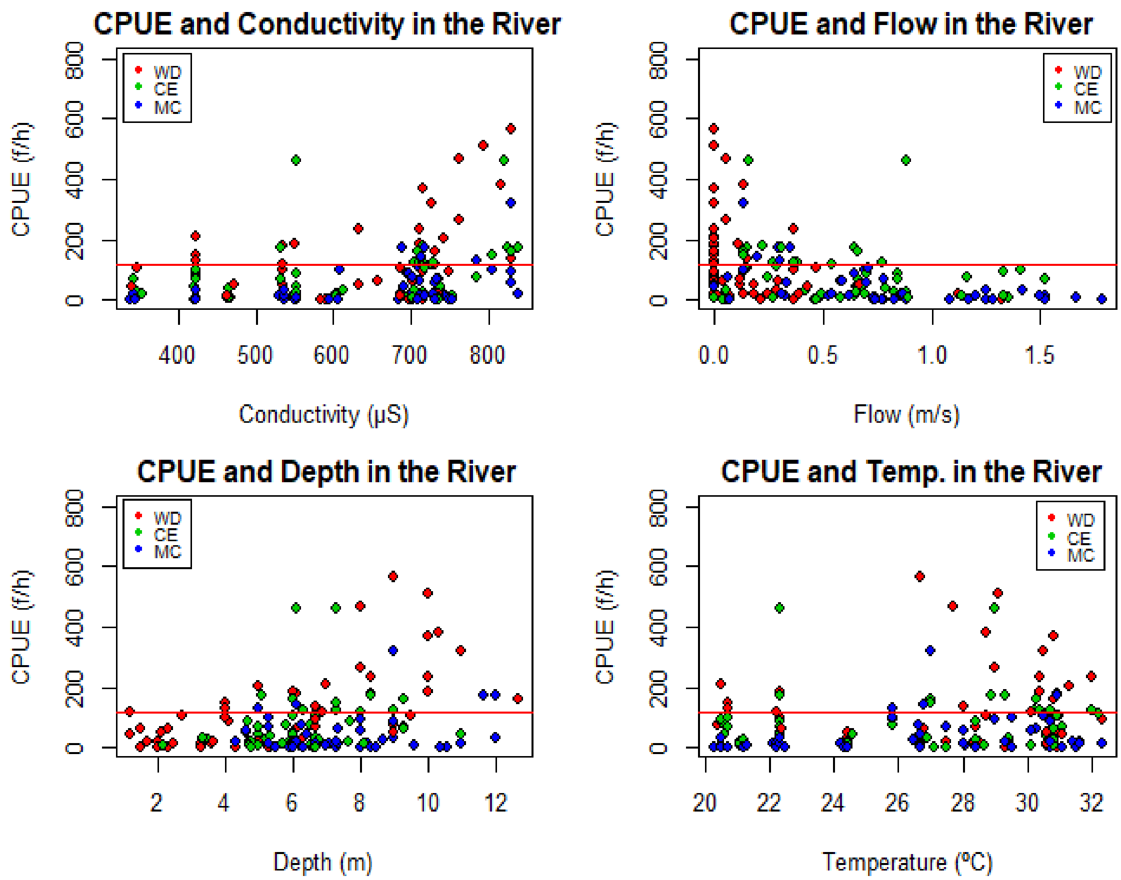

FIGURE 7.—Scatterplots showing relationships between CPUE and conductivity, flow, depth, and temperature in the river. The horizontal red line indicates a CPUE of 120 fish per hour (fish/h) which is the minimum catch rate needed to fulfill requirements recommended in Bodine et al. (2013). WD=Dike, CE=Edge, MC=Main.

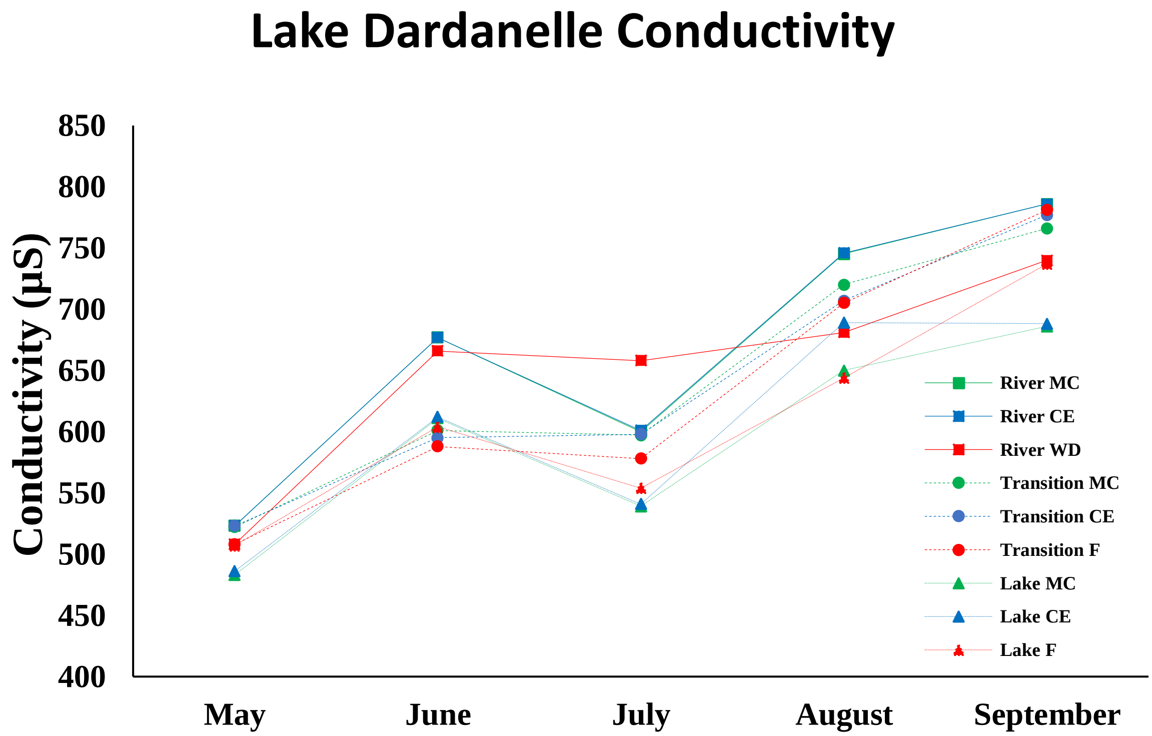

FIGURE 8.—Conductivities on Lake Dardanelle by month. Solid lines with squares represent the river, dashed lines with circles the transition, and dots with triangles the lake. Red represents wing dyke and flats, blue represents Channel edge, and green represents the main channel.

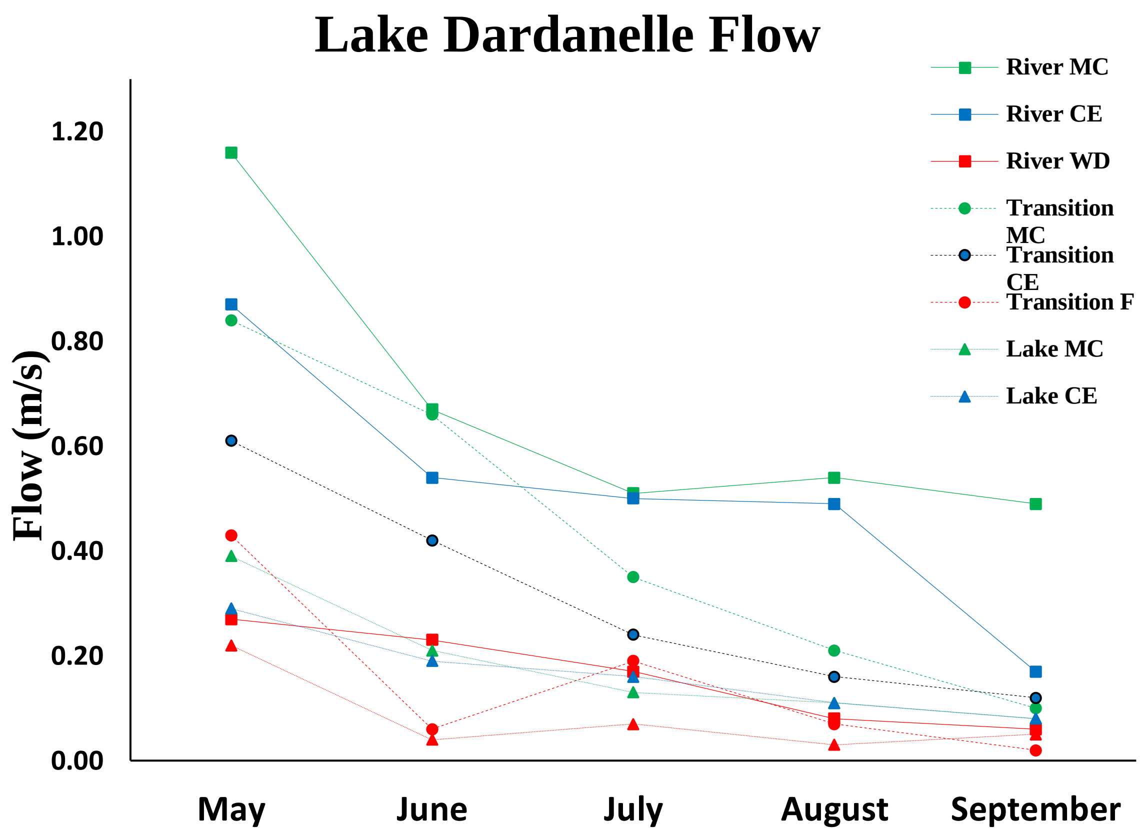

FIGURE 9.—Flow on Lake Dardanelle by month. Solid lines with squares represent the river, dashed lines with circles the transition, and dots with triangles the lake. Red represents wing dyke and flats, blue represents Channel edge, and green represents the main channel.

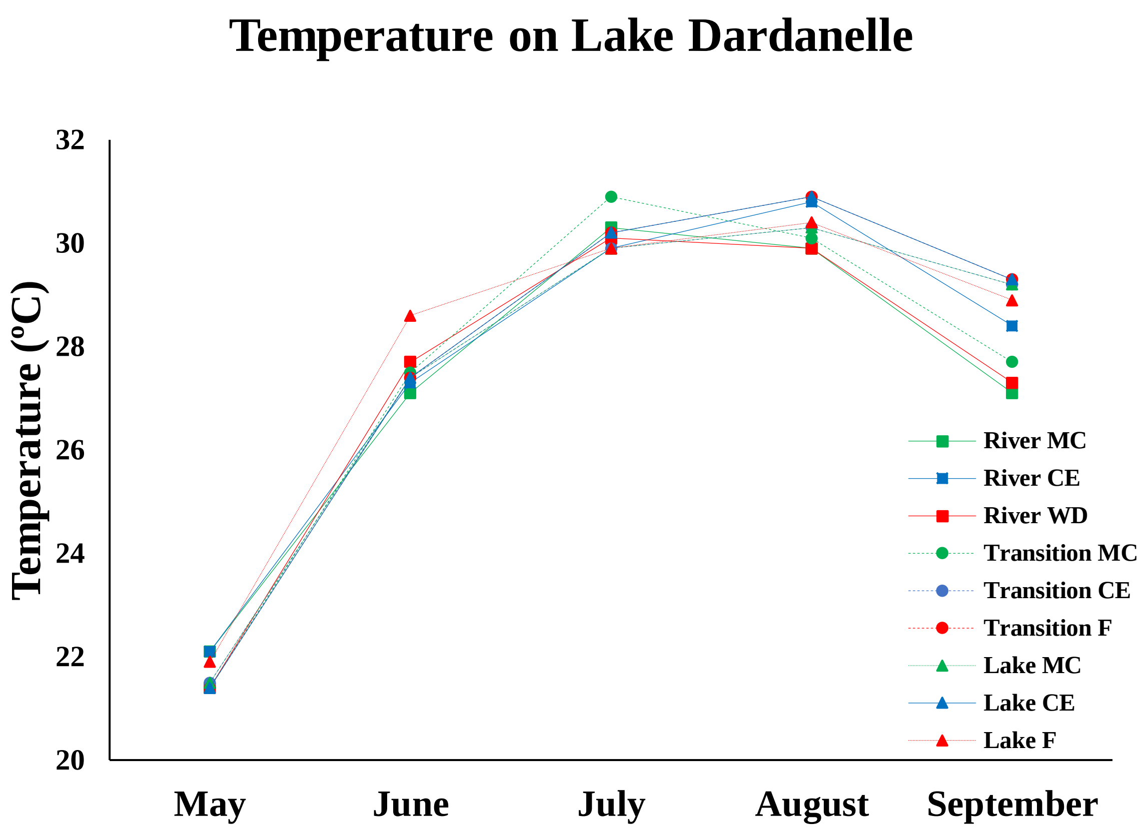

FIGURE 10.—Temperature on Lake Dardanelle by month Solid lines with squares represent the river, dashed lines with circles the transition, and dots with triangles the lake. Red represents wing dyke and flats, blue represents Channel edge, and green represents the main channel.

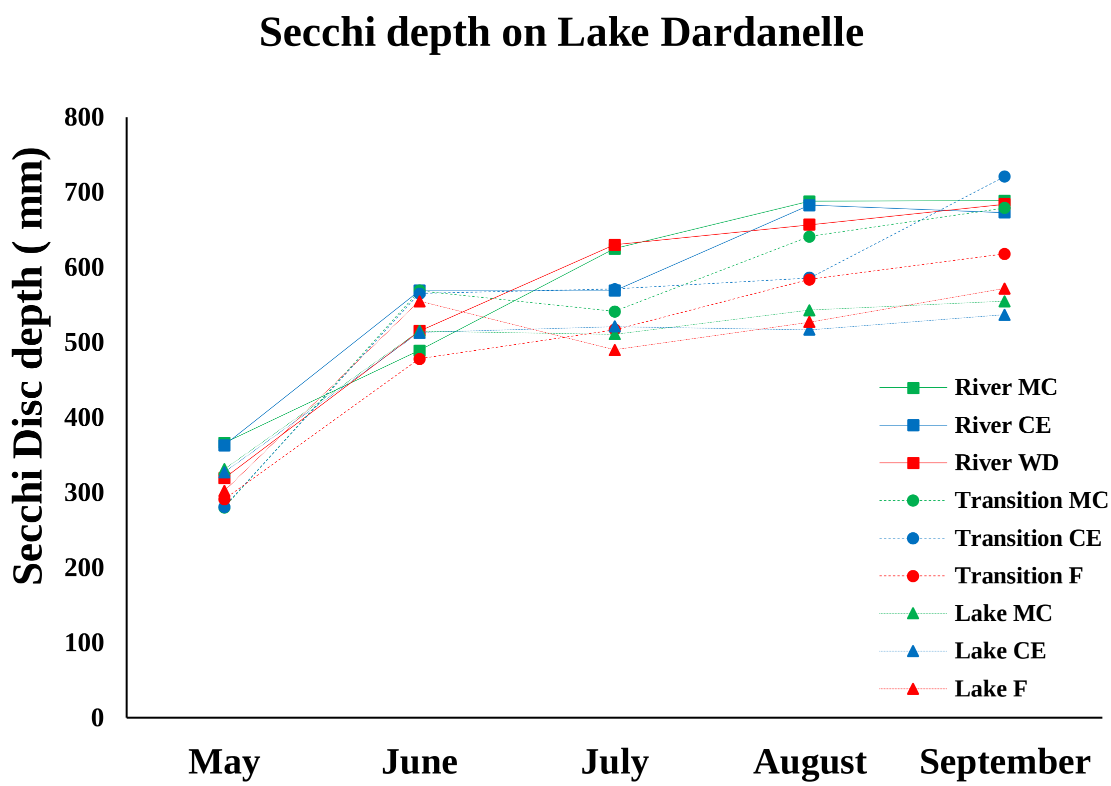

FIGURE 11.—Secchi disk depth on Lake Dardanelle by month. Solid lines with squares represent the river, dashed lines with circles the transition, and dots with triangles the lake. Red represents wing dyke and flats, blue represents Channel edge, and green represents the main channel.

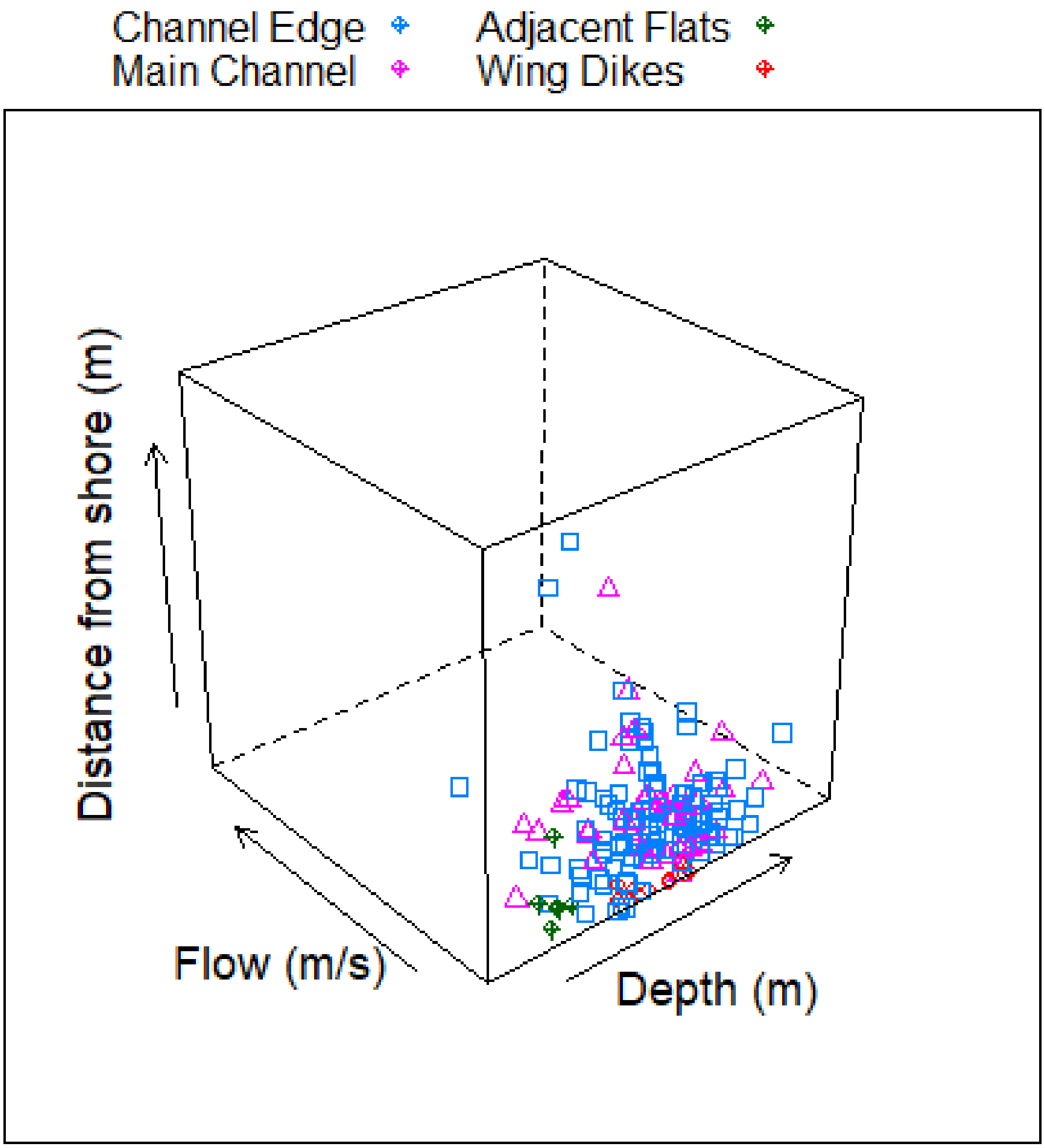

FIGURE 12.—Cloud plot illustrating Blue Catfish locations on habitats throughout Lake Dardanelle between May and September.

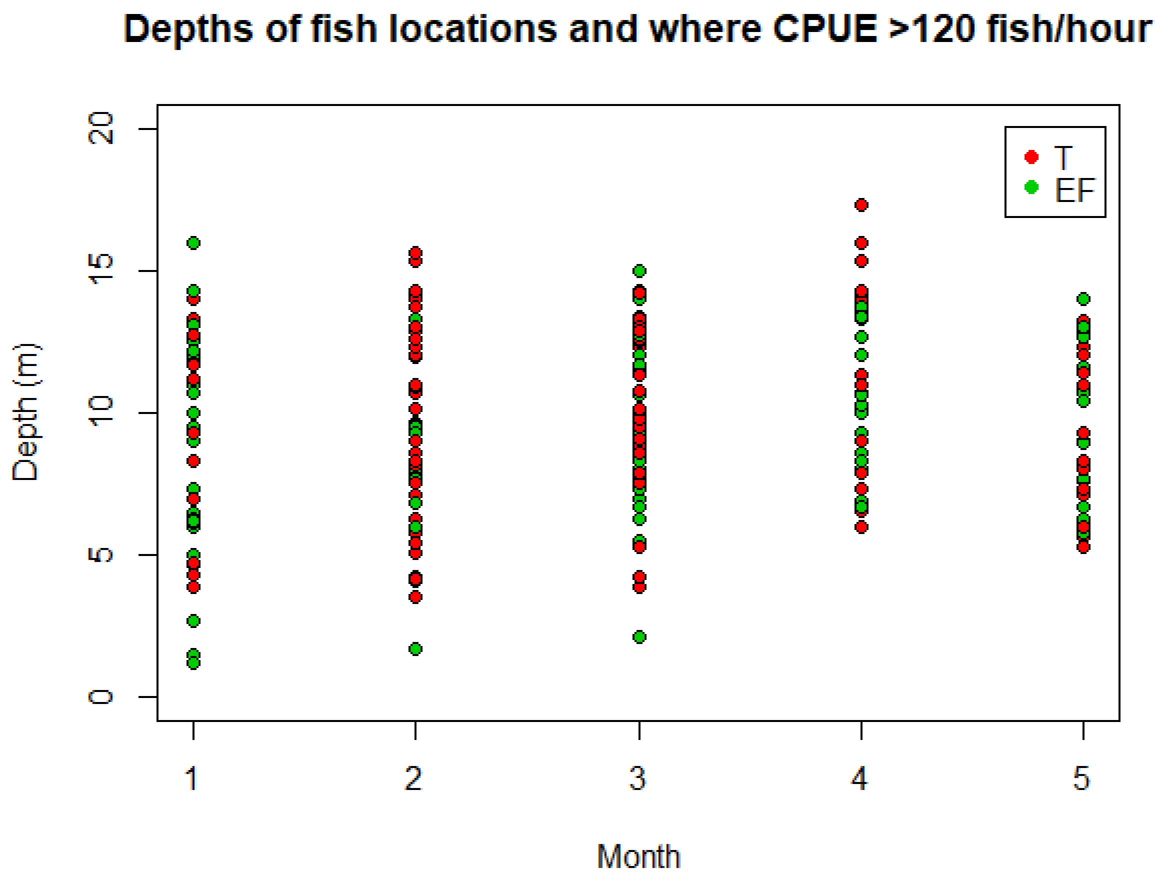

FIGURE 13.—Depths of fish located, and samples where efficiency exceeded 120 fish per hour (fish/h). Categories for month are May= (1), June= (2), July = (3). August = (4), and September = (5). Red dots are depths of habitat where fish tracked were (T), and green dots are depths of habitat where fish were captured at a rate of 120 fish/hour (EF).

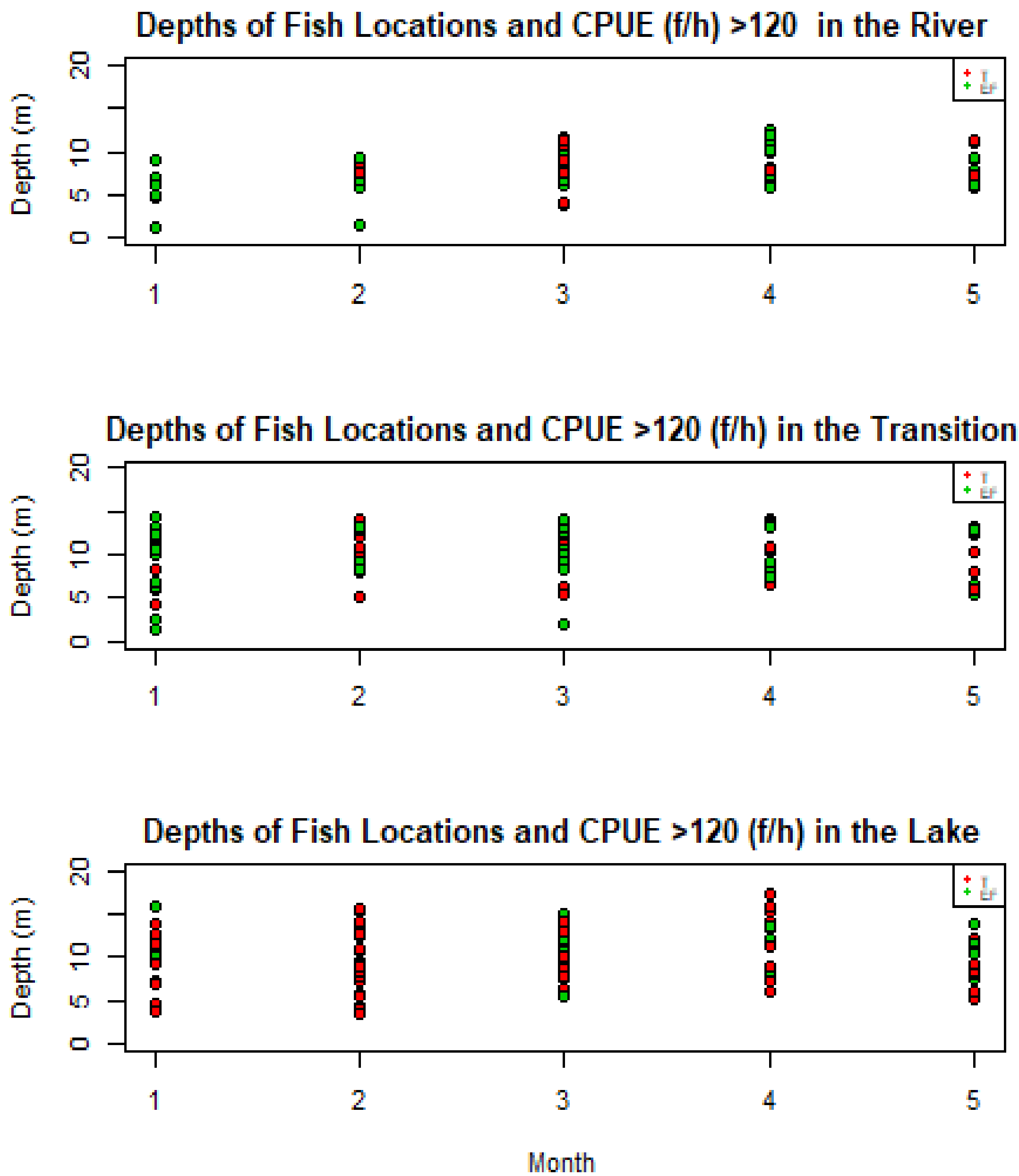

FIGURE 14.—Depths of fish located, and samples where efficiency exceeded 120 fish per hour (fish/h) in the river, transition, and lake zones. Categories for month are May= (1), June= (2), July = (3). August = (4), and September = (5). Red dots are depths of habitat where fish tracked were (T), and green dots are depths of habitat where fish were captured at a rate of 120 fish/hour (EF).

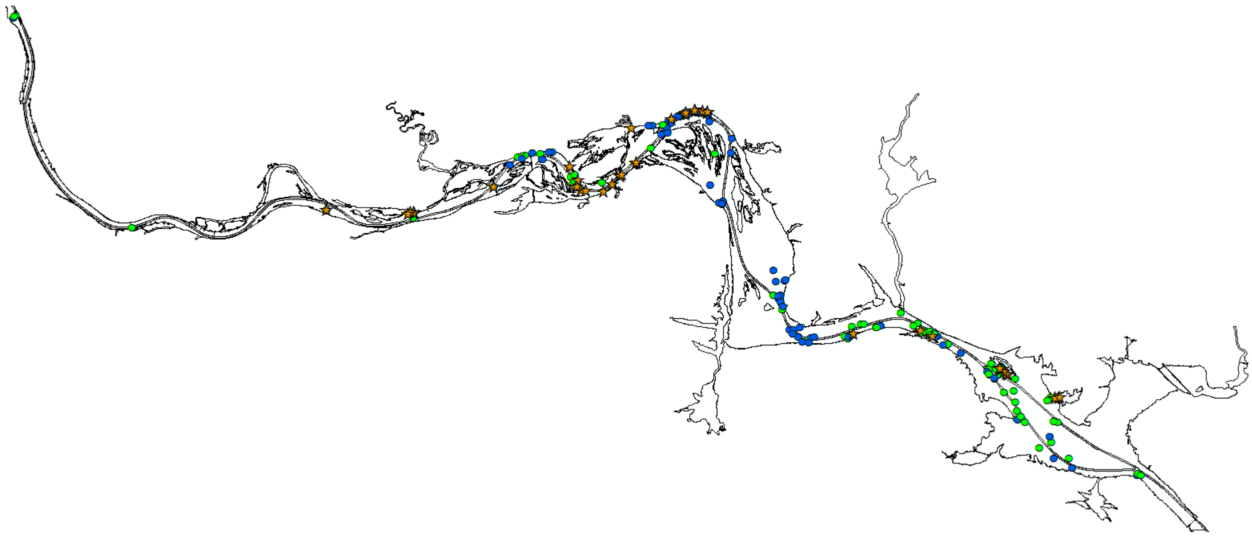

FIGURE 15.—Large (blue dots) and small (green dots) fish locations on Lake Dardanelle between the months of May and September. Gold star represents original tagging location.

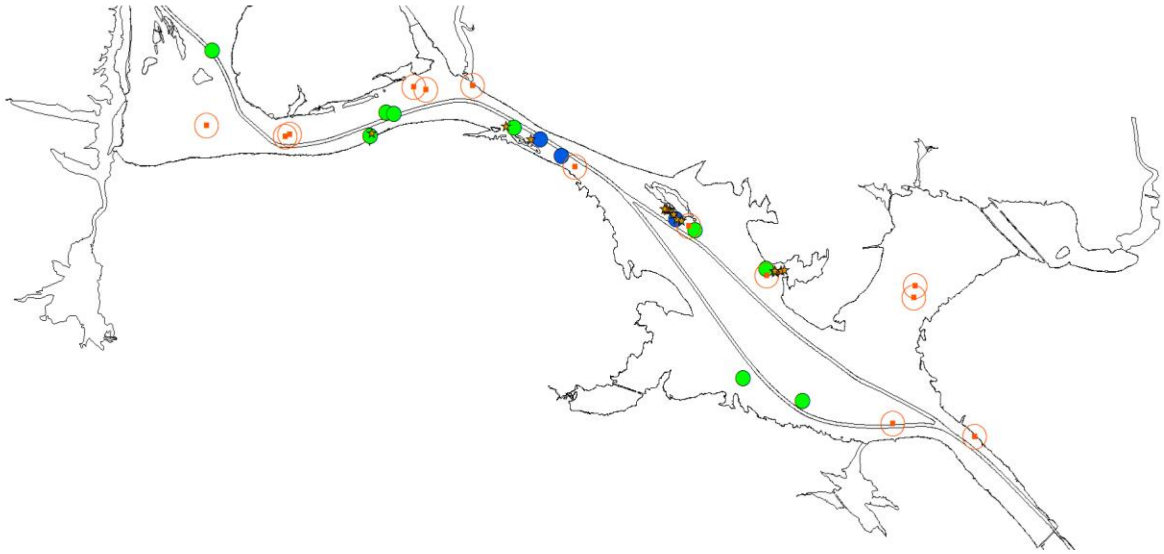

FIGURE 16.—Fish locations in the lacustrine zone of Dardanelle in May. Blue circles represent large fish, green circles represent small fish, and red circles represent samples with CPUE >120 fish/hour and at least one fish longer than 560 mm. Gold stars represent original tagging locations of small and large fish.

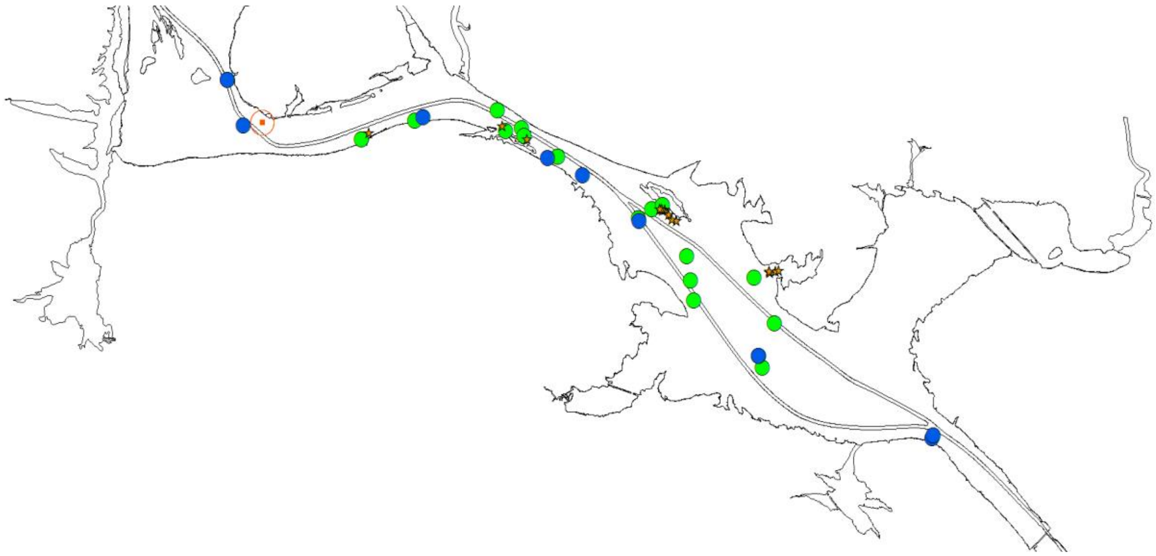

FIGURE 17.—Fish locations in the lacustrine zone of Dardanelle in June. Blue circles represent large fish and green circles represent small fish. No samples were collected with CPUE>120 and one fish longer than 560 mm. Gold stars represent original tagging locations of small and large fish.

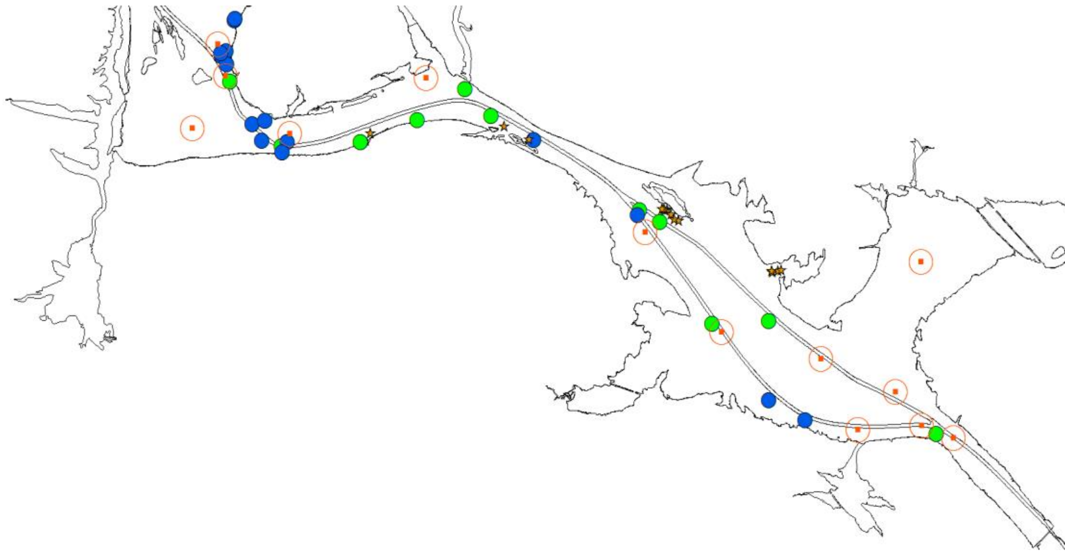

FIGURE 18.—Fish locations in the lacustrine zone of Dardanelle in July. Blue circles represent large fish, green circles represent small fish, and red circles represent samples with CPUE >120 fish/hour and at least one fish longer than 560 mm. Gold stars represent original tagging locations of small and large fish.

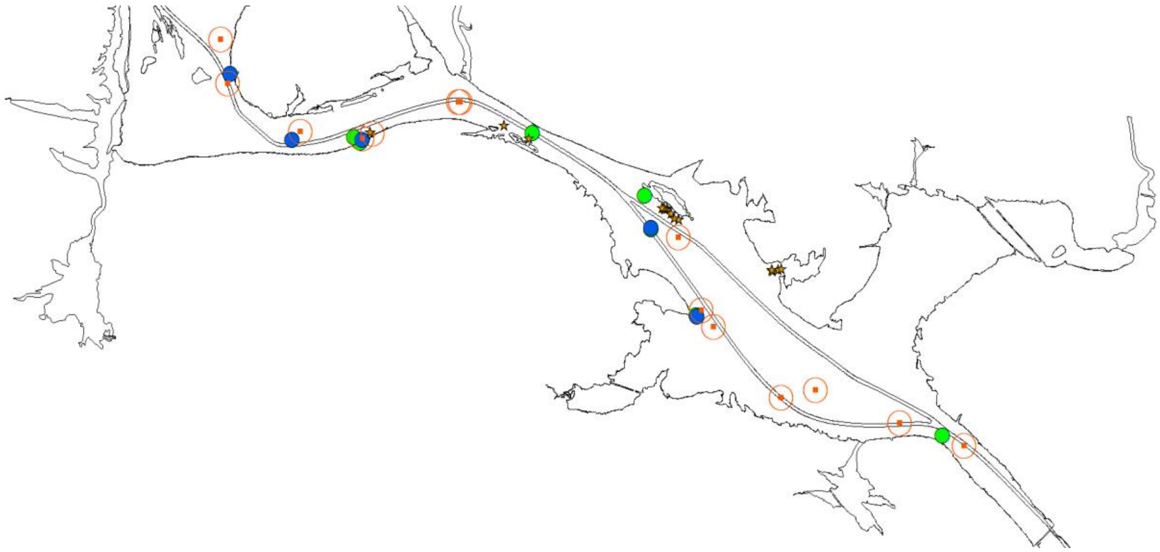

FIGURE 19.—Fish locations in the lacustrine zone of Dardanelle in August. Blue circles represent large fish, green circles represent small fish, and red circles represent samples with CPUE >120 fish/hour and at least one fish longer than 560 mm. Gold stars represent original tagging locations of large and small fish.

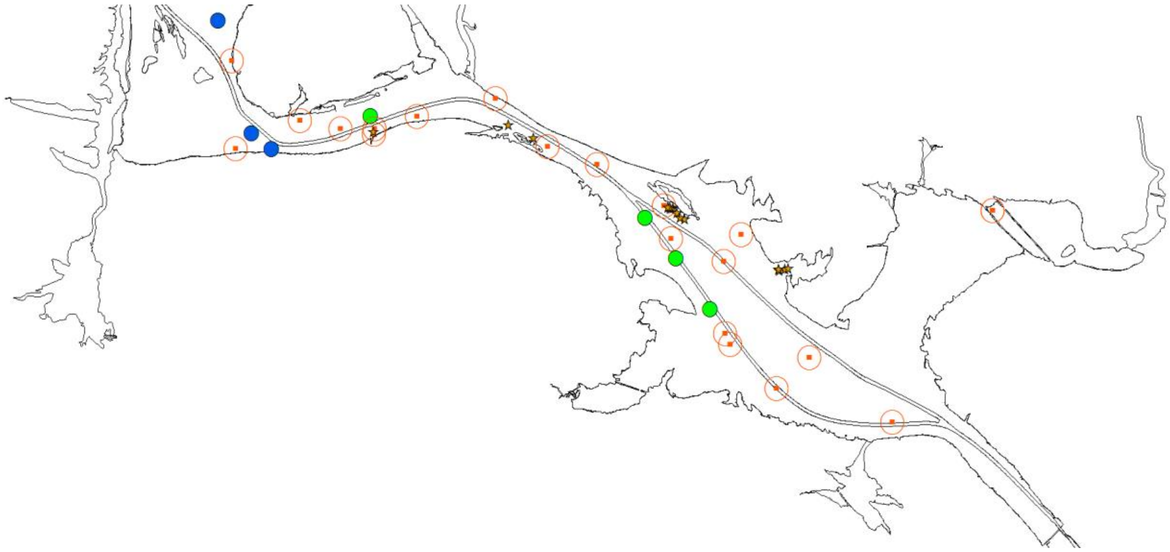

FIGURE 20.—Fish locations in the lacustrine zone of Dardanelle in September. Blue circles represent large fish, green circles represent small fish, and red circles represent samples with CPUE >120 fish/hour and at least one fish longer than 560 mm. Gold stars represent original tagging locations of large and small fish.

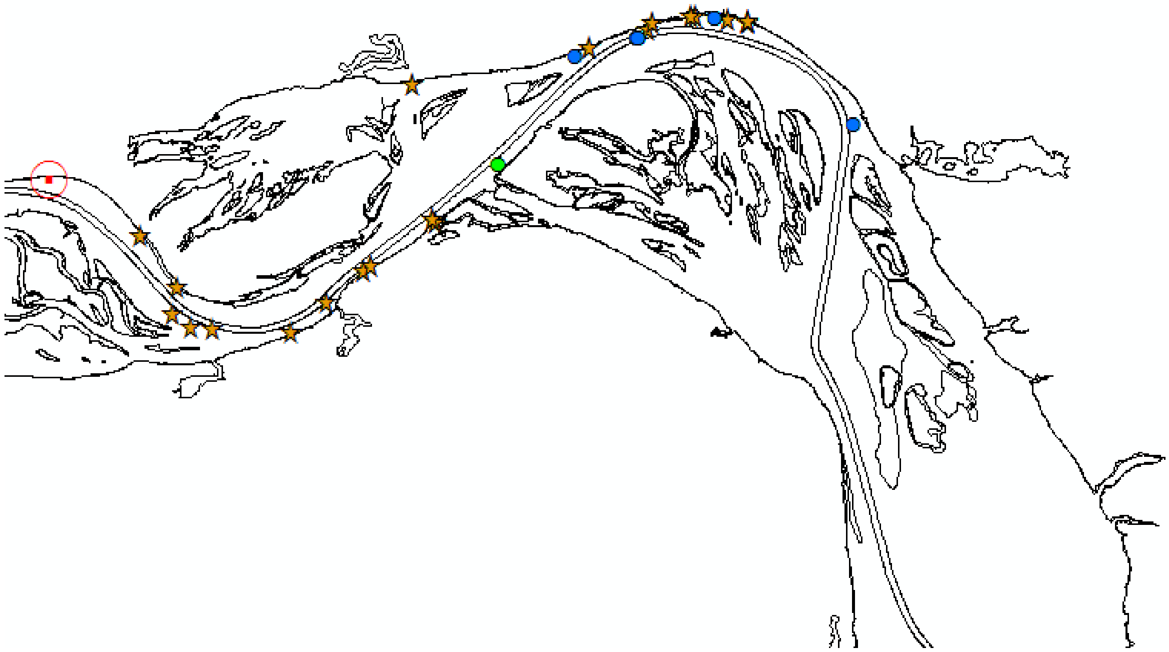

FIGURE 21.—Fish locations in the transition zone of Dardanelle in May. Blue circles represent large fish, green circles represent small fish, and red circles represent samples with CPUE >120 fish/hour and at least one fish longer than 560 mm. Gold stars represent original tagging locations of large and small fish.

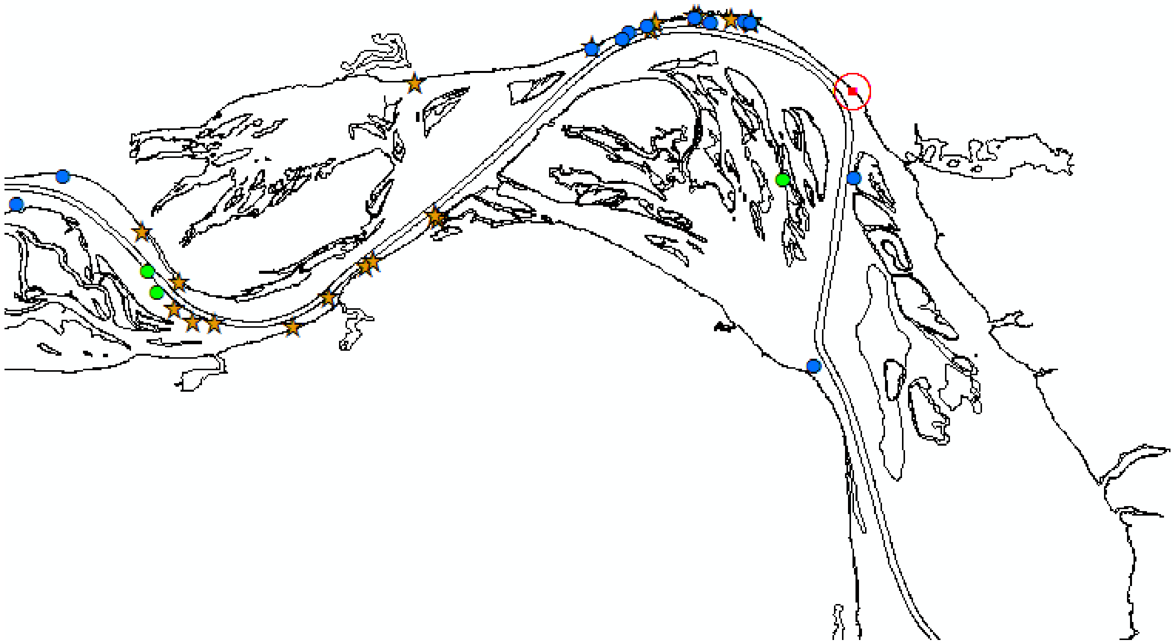

FIGURE 22.—Fish locations in the transition zone of Dardanelle in June. Blue circles represent large fish, green circles represent small fish, and red circles represent samples with CPUE >120 fish/hour and at least one fish longer than 560 mm. Gold stars represent original tagging locations of large and small fish.

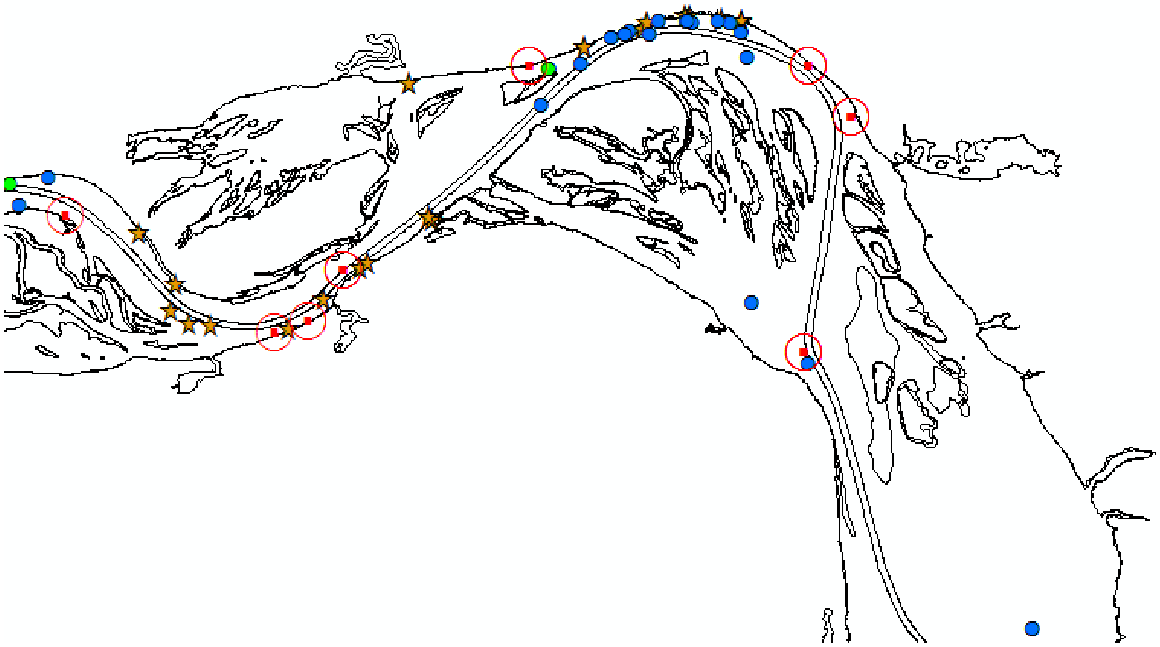

FIGURE 23.—Fish locations in the transition zone of Dardanelle in July. Blue circles represent large fish, green circles represent small fish, and red circles represent samples with CPUE >120 fish/hour and at least one fish longer than 560 mm. Gold stars represent original tagging locations of large and small fish.

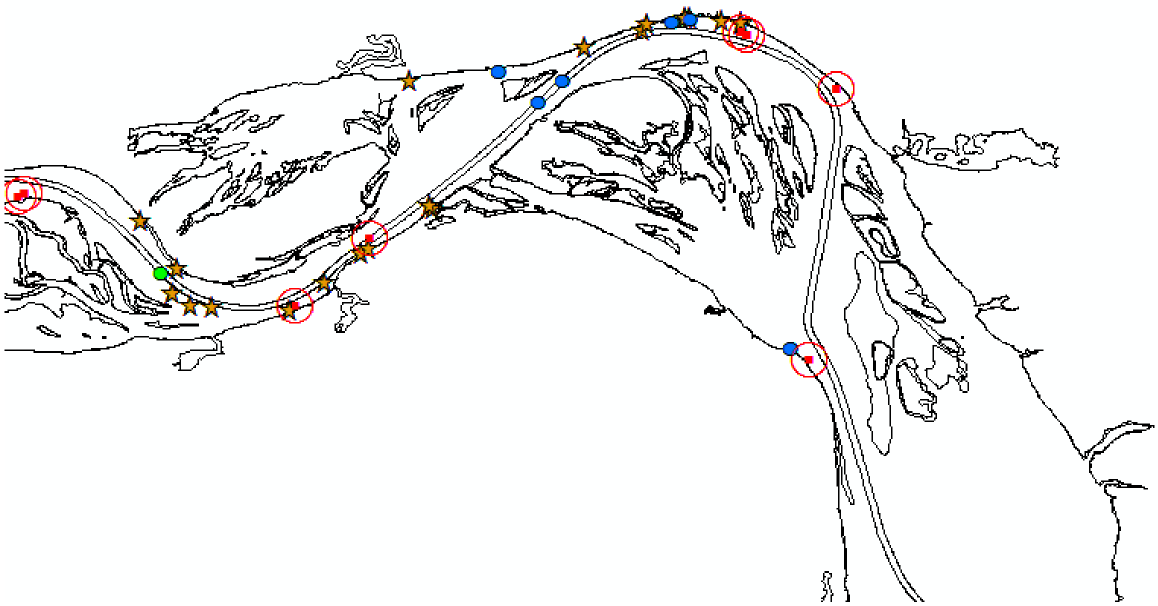

FIGURE 24.—Fish locations in the transition zone of Dardanelle in August. Blue circles represent large fish, green circles represent small fish, and red circles represent samples with CPUE >120 fish/hour and at least one fish longer than 560 mm. Gold stars represent original tagging locations of large and small fish.

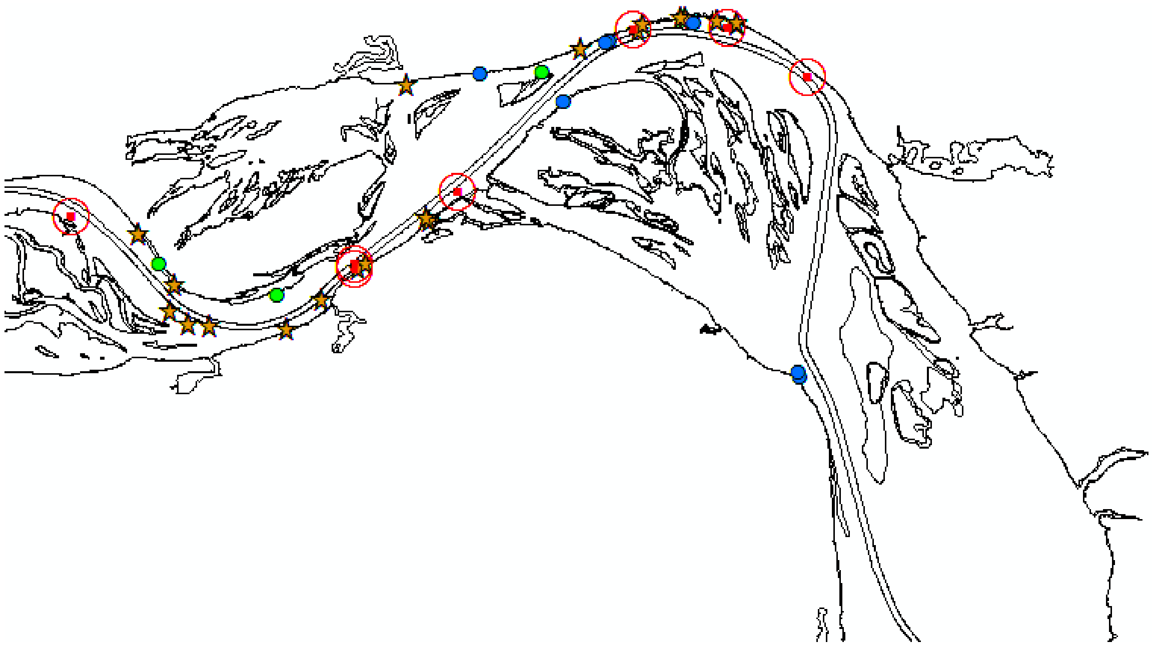

FIGURE 25.—Fish locations in the transition zone of Dardanelle in September. Blue circles represent large fish, green circles represent small fish, and red circles represent samples with CPUE >120 fish/hour and at least one fish longer than 560 mm. Gold stars represent original tagging locations of large and small fish.

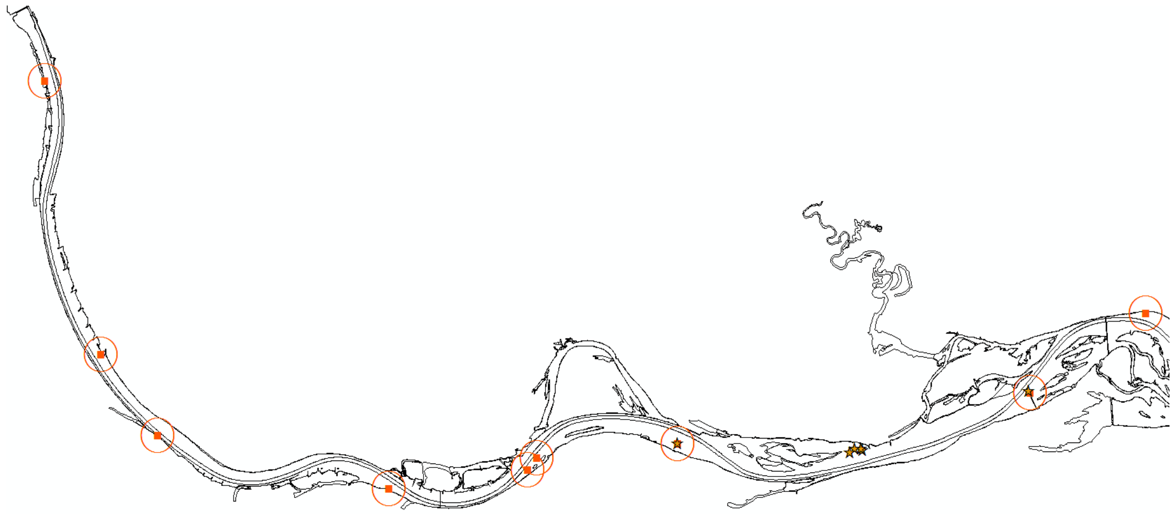

FIGURE 26.—Samples with CPUE >120 fish/hour and at least one fish longer than 560 mm. Gold stars represent original tagging locations of large and small fish. No fish were actively tracked in this zone during May.

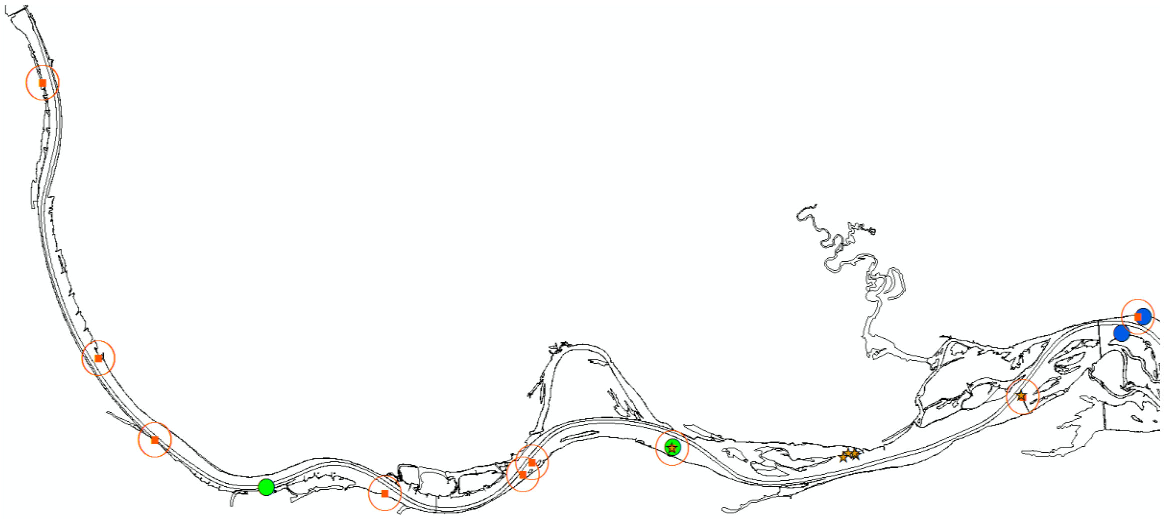

FIGURE 27.—Fish locations in river zone of Dardanelle in June. Blue circles represent large fish, green circles represent small fish, and red circles represent samples with CPUE >120 fish/hour and at least one fish longer than 560 mm. Gold stars represent original tagging locations of large and small fish.

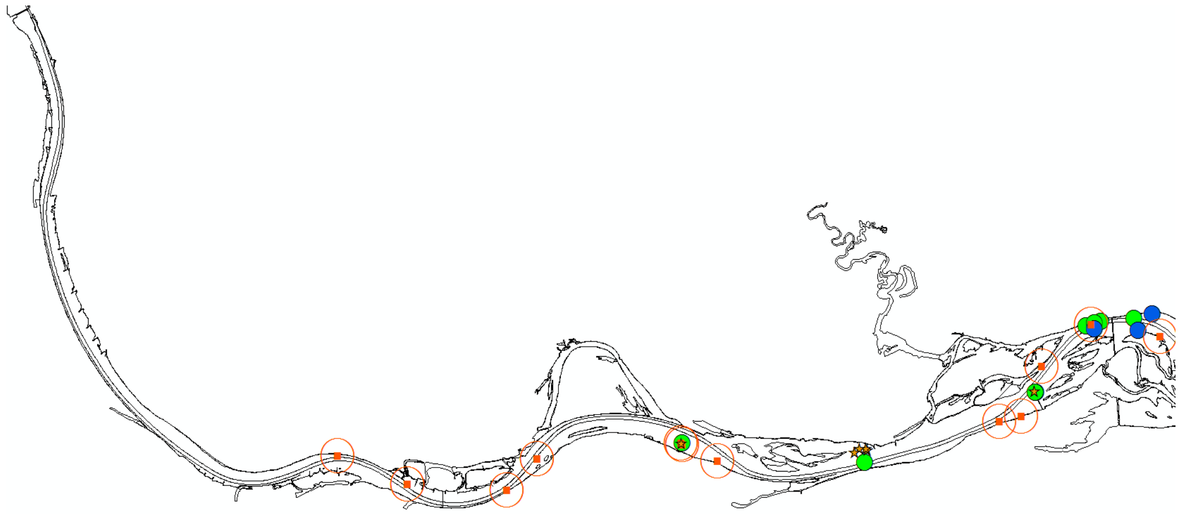

FIGURE 28.—Fish locations in river zone of Dardanelle in July. Blue circles represent large fish, green circles represent small fish, and red circles represent samples with CPUE >120 fish/hour and at least one fish longer than 560 mm. Gold stars represent original tagging locations of large and small fish.

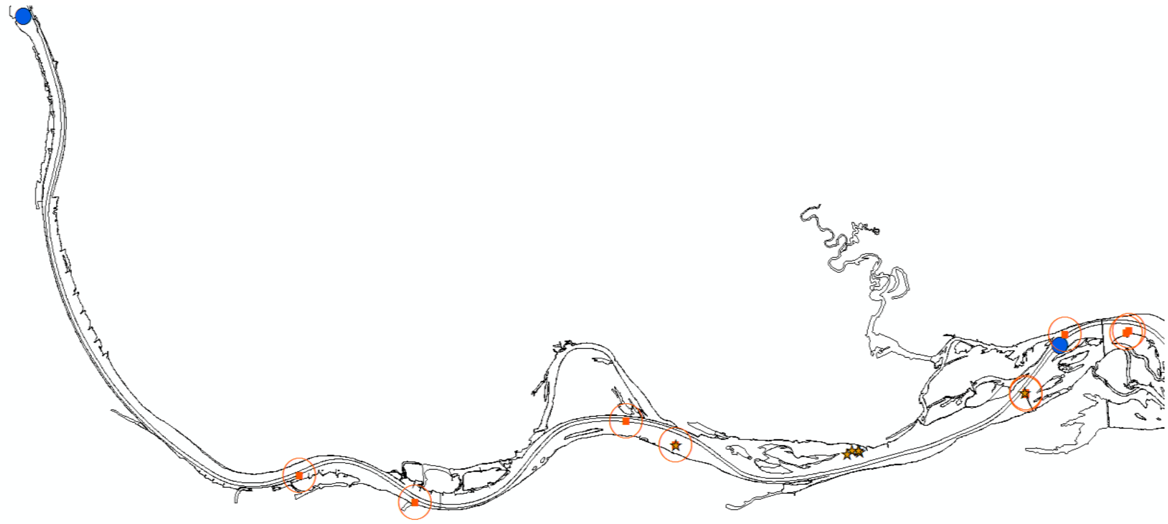

FIGURE 29.—Fish locations in river zone of Dardanelle in August. Blue circles represent large fish, green circles represent small fish, and red circles represent samples with CPUE >120 fish/hour and at least one fish longer than 560 mm. Gold stars represent original tagging locations of large and small fish.

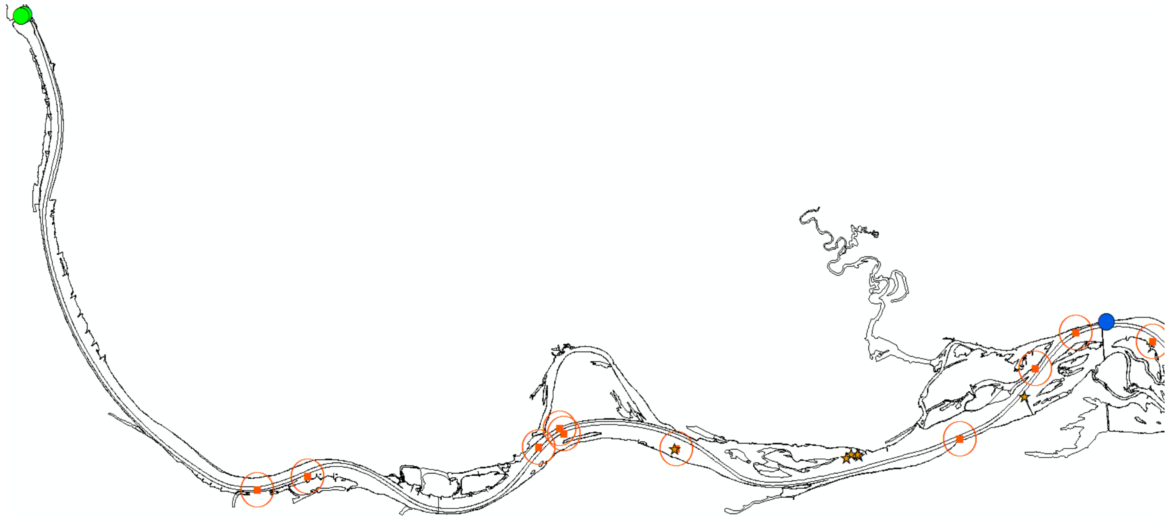

FIGURE 30.—Fish locations in river zone of Dardanelle in September. Blue circles represent large fish, green circles represent small fish, and red circles represent samples with CPUE >120 fish/hour and at least one fish longer than 560 mm. Gold stars represent original tagging locations of large and small fish.

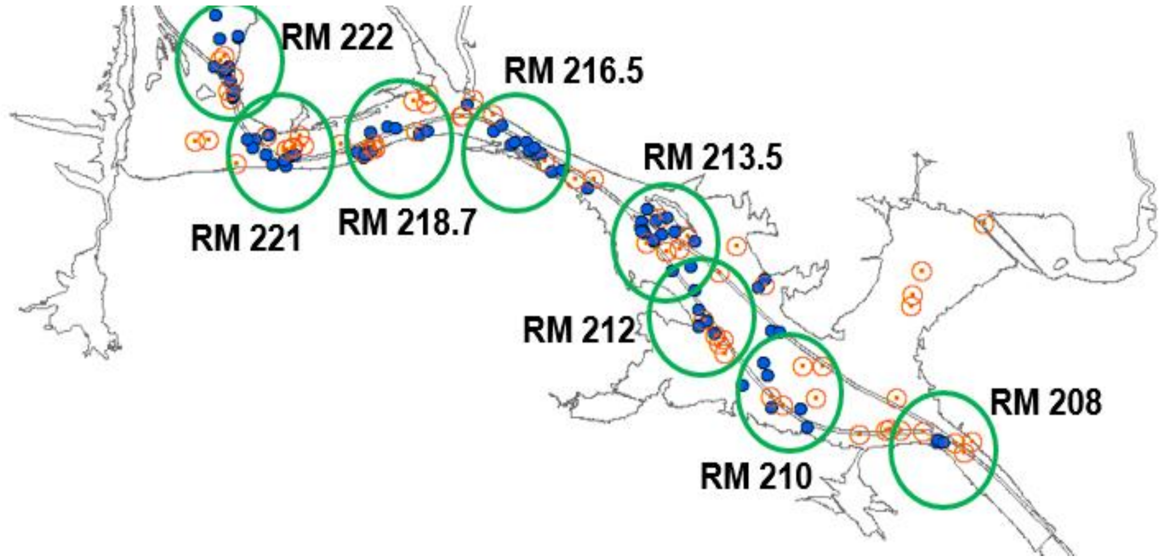

FIGURE 31.—Fish locations (blue dots) and areas of high CPUE (red circles) and associated River Mile (RM) in the lacustrine zone.

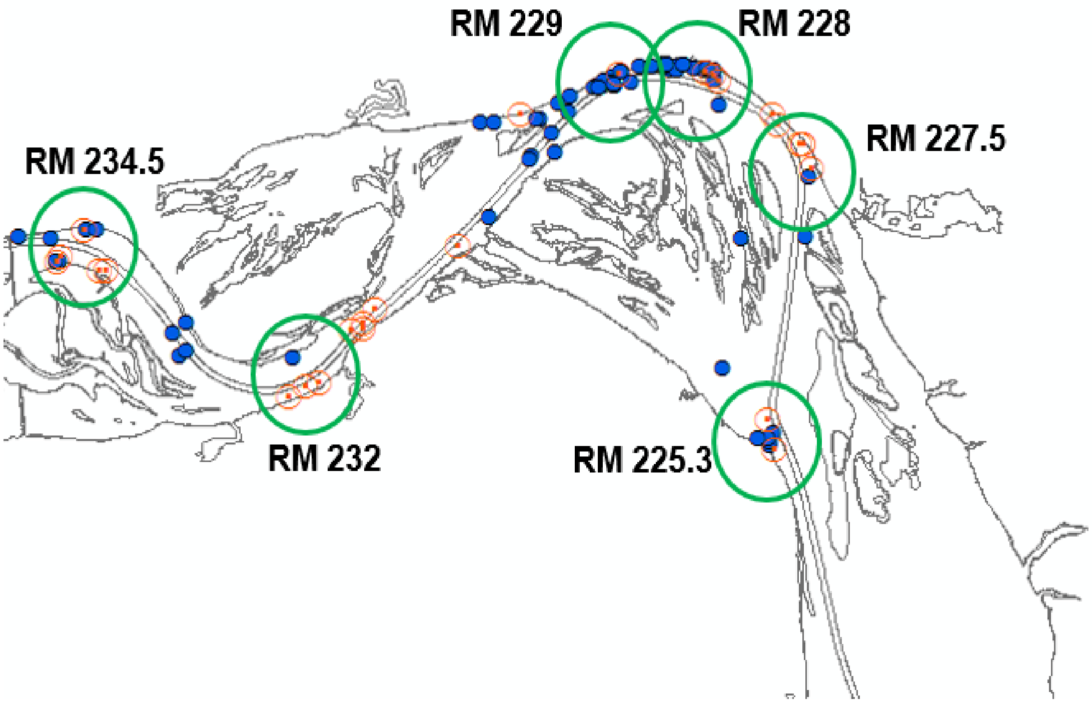

FIGURE 32.—Fish locations (blue dots) and areas of high CPUE (red circles) and associated River Mile (RM) in the transition zone.

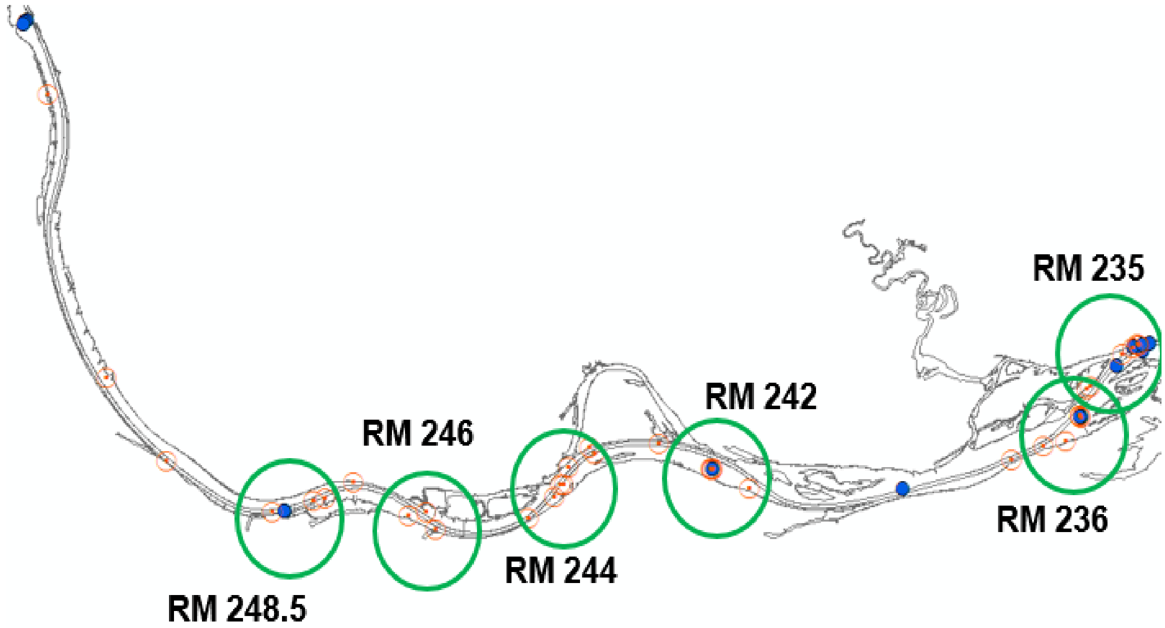

FIGURE 33.—Fish locations (blue dots) and areas of high CPUE (red circles) and associated River Mile (RM) in the riverine zone.

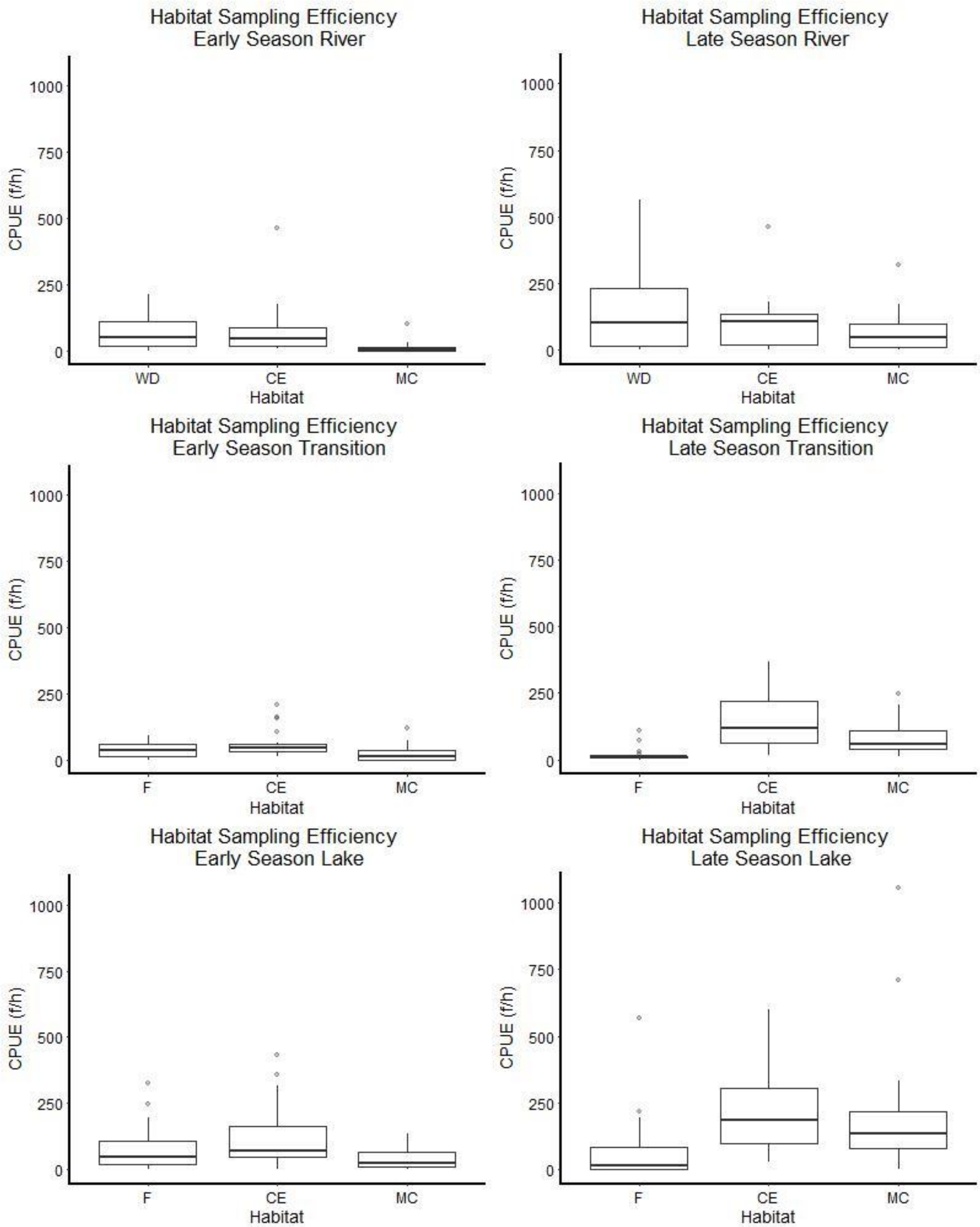

FIGURE 34.—Sample efficiency from each habitat within each zone by season. Refer to TABLE 1 for habitat descriptions.

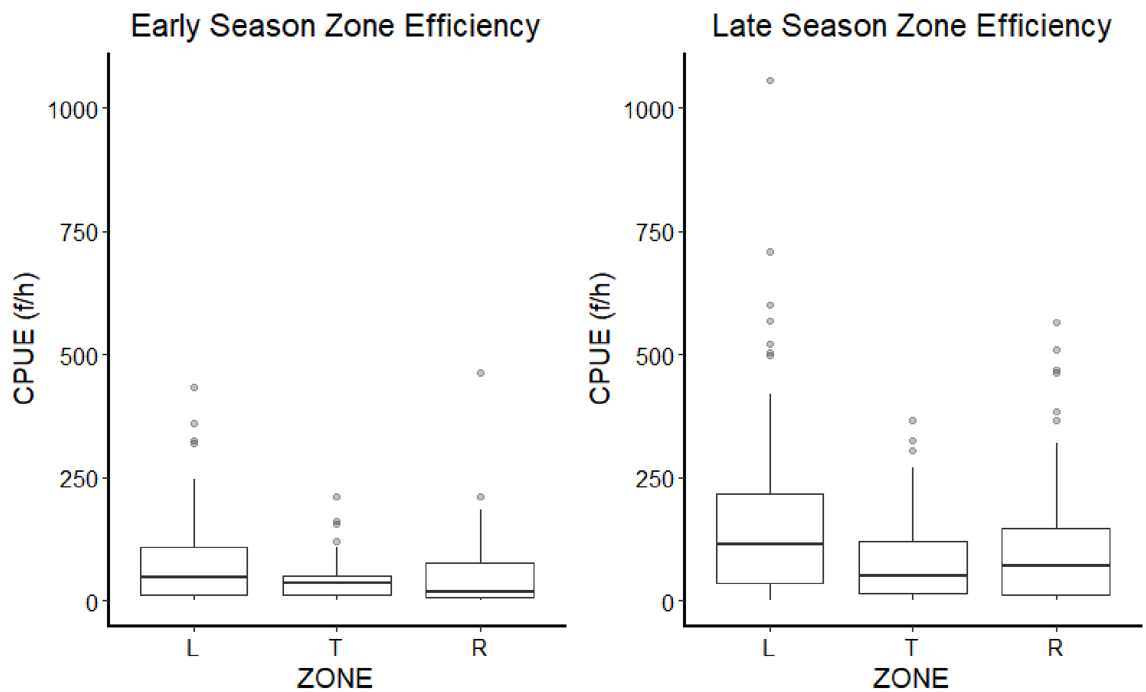

FIGURE 35.—Boxplots of catch per unit effort (CPUE (fish/h)) of Blue Catfish sampled during the spring and summer season in the lacustrine (L), transition (T), and riverine (R) zones. Refer to TABLE 1 for habitat descriptions.

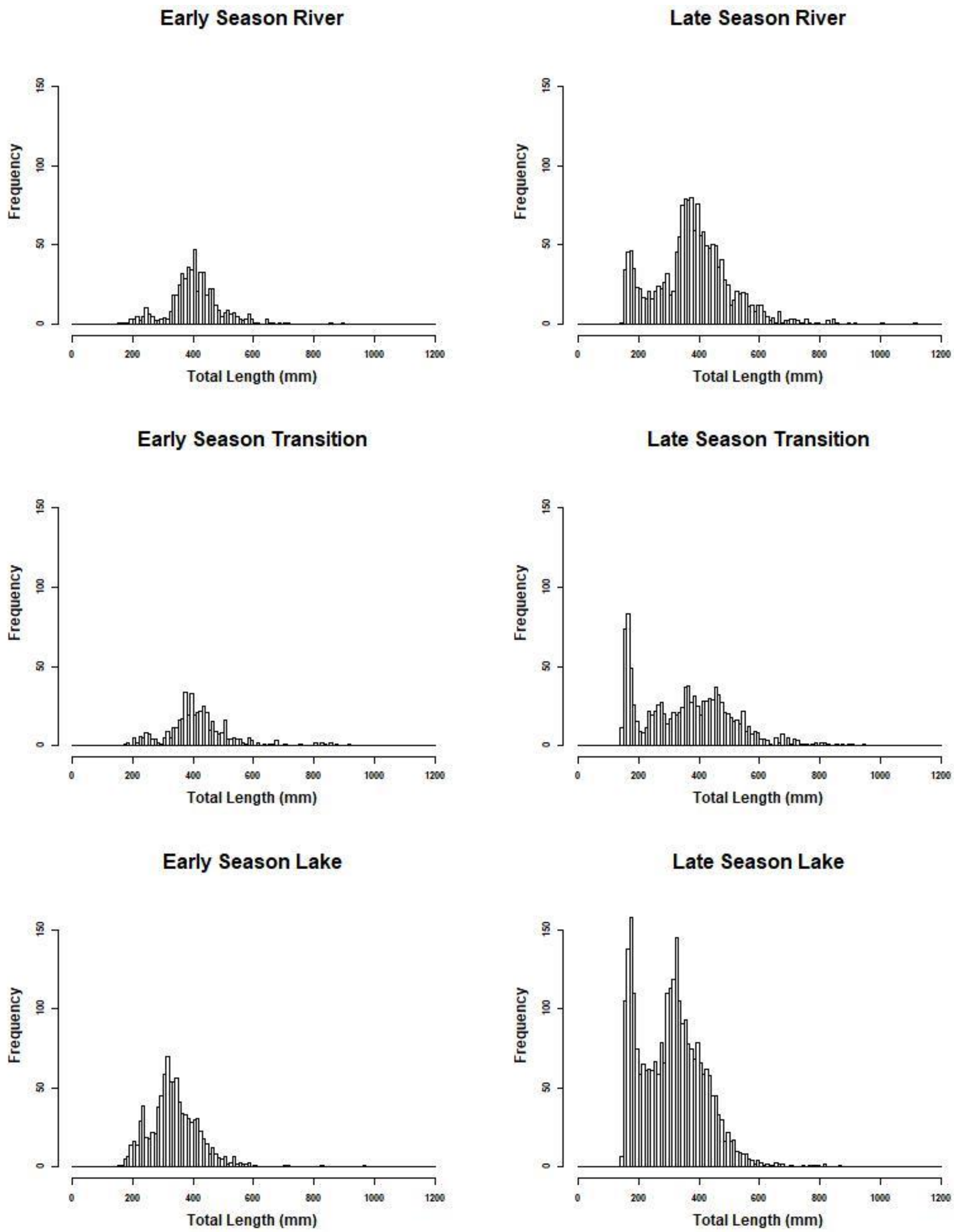

FIGURE 36.—Length frequency histograms of Blue Catfish captured from the riverine, transition and lacustrine zones during the spring and summer seasons.

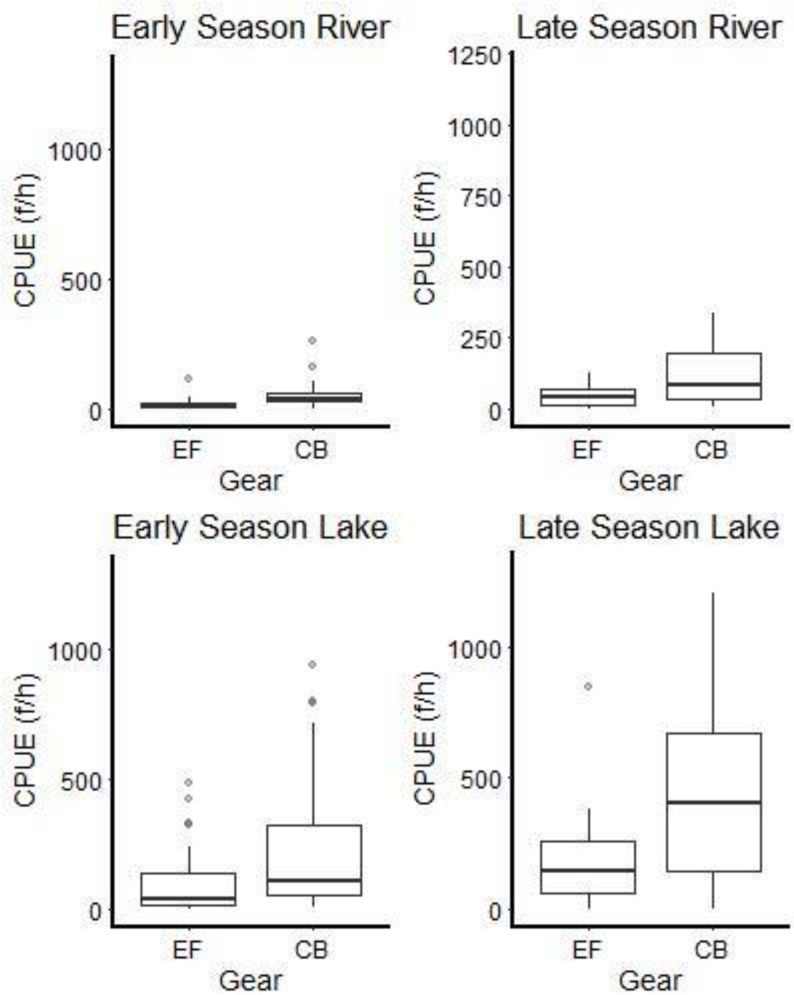

FIGURE 37.—Boxplots of catch per unit effort (CPUE (fish/h)) of Blue Catfish sampled with a single electrofisher (EF), and a chase boat and electrofisher combined (CB) from the river and lacustrine zones during spring and summer seasons.

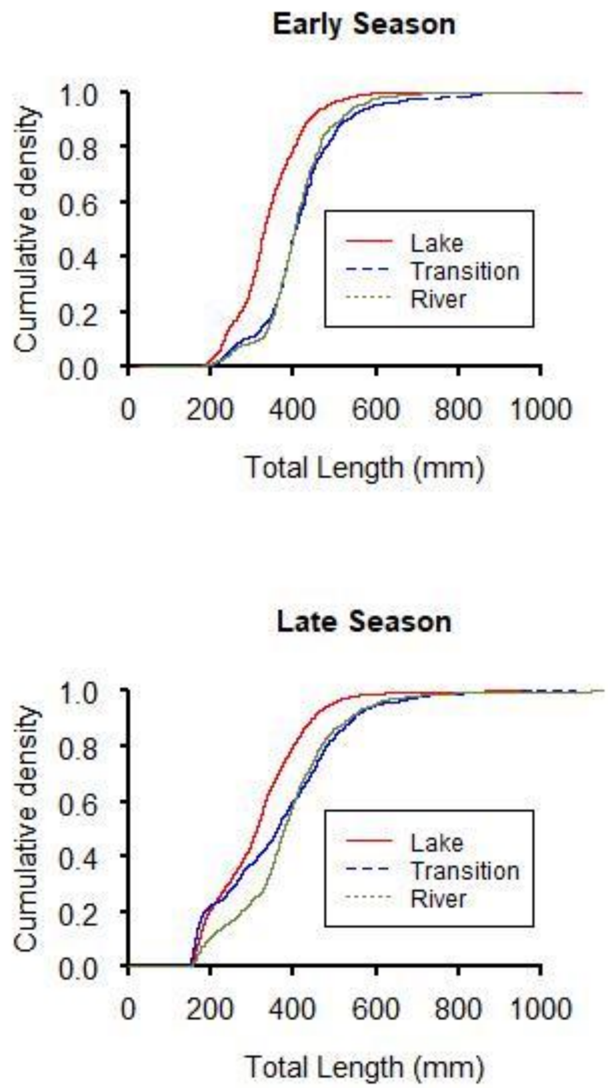

FIGURE 38.—Empirical cumulative distribution functions of Blue Catfish captured from Lake Dardanelle from the lacustrine, transition, and riverine zones during the spring and summer seasons.

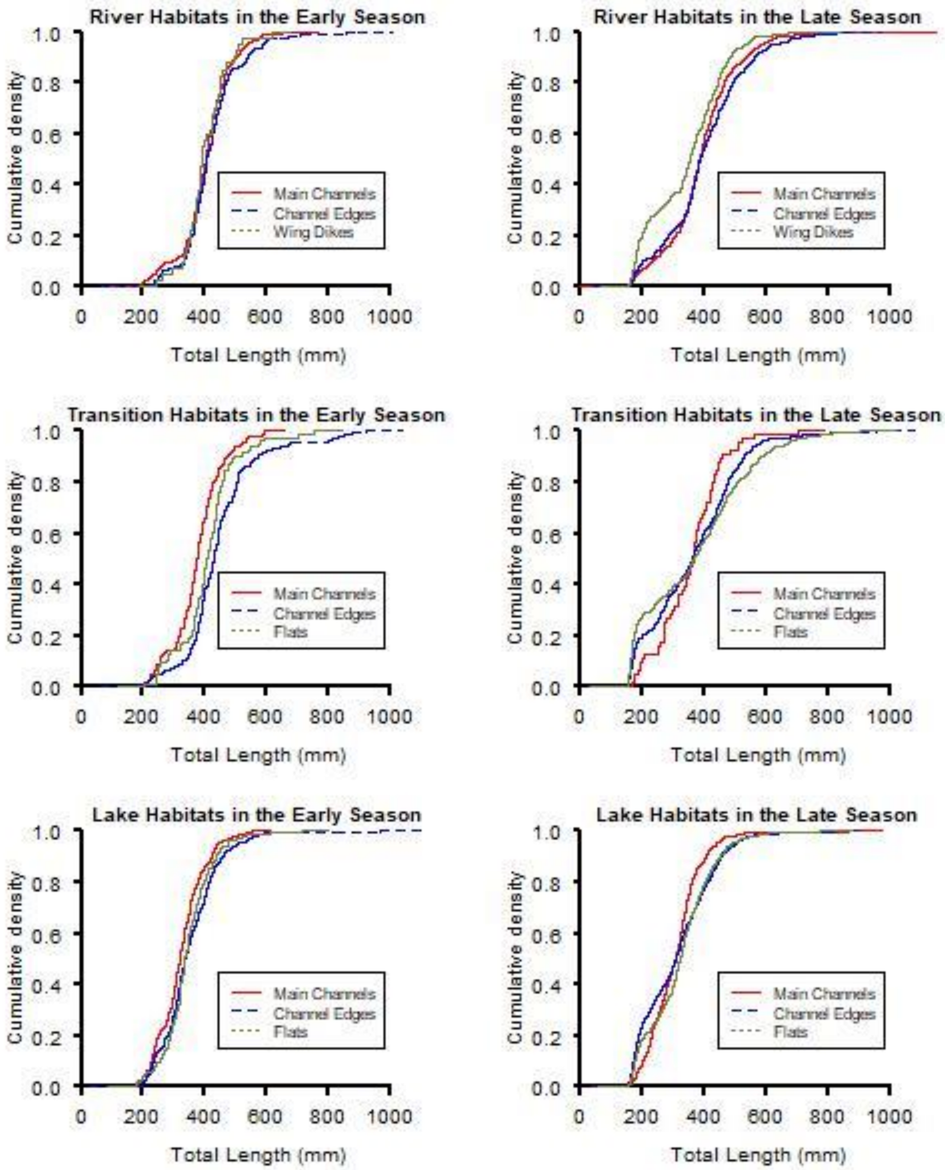

FIGURE 39.—Empirical cumulative distribution functions of Blue Catfish captured from Lake Dardanelle from habitats in the lacustrine, transition, and riverine zones during the spring and summer seasons.

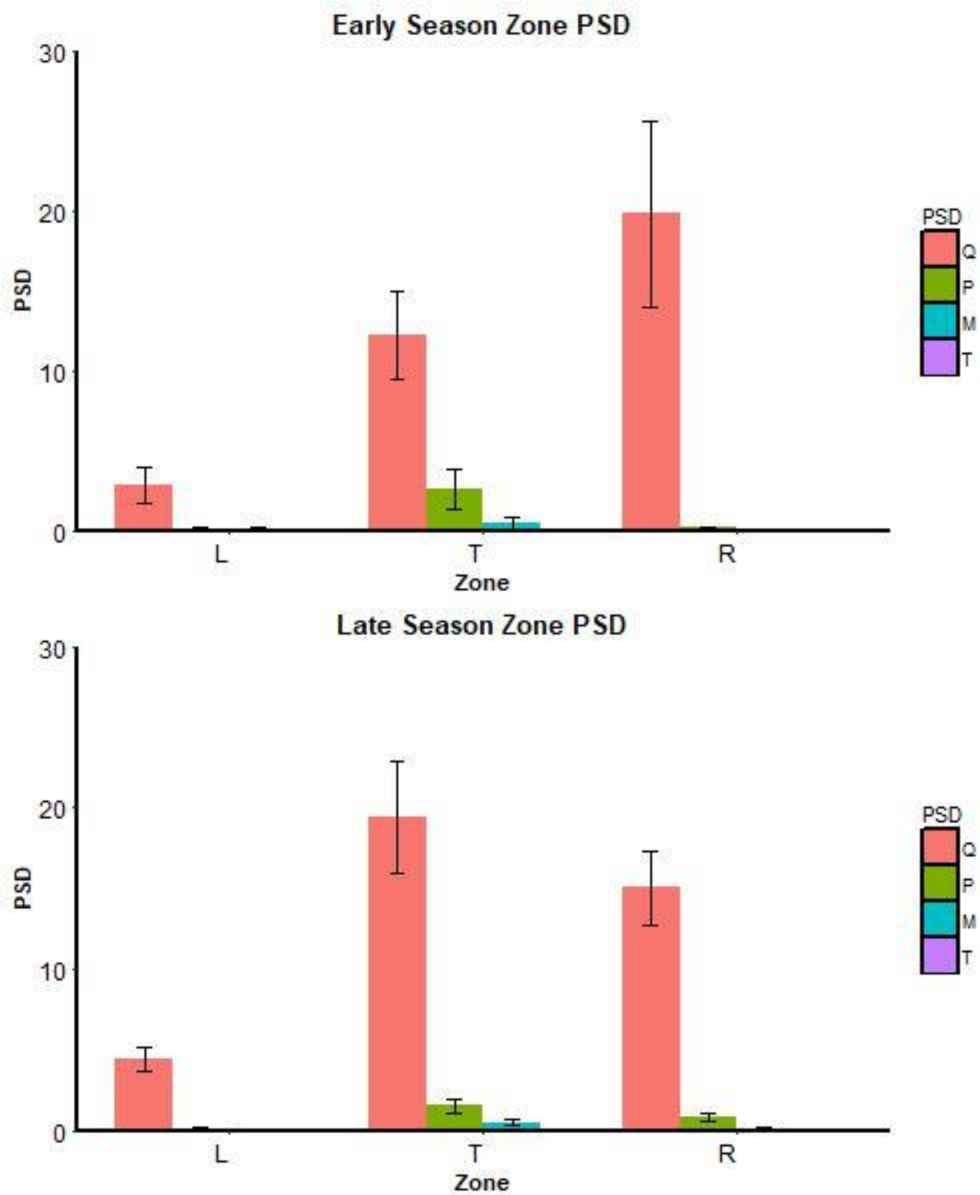

FIGURE 40.—Proportional size distributions (PSD) of Blue Catfish captured from lacustrine (L), transition (T) and riverine (R) zones during the spring and summer seasons. PSD categories are quality (Q), preferred (P), memorable (M), and trophy (T).

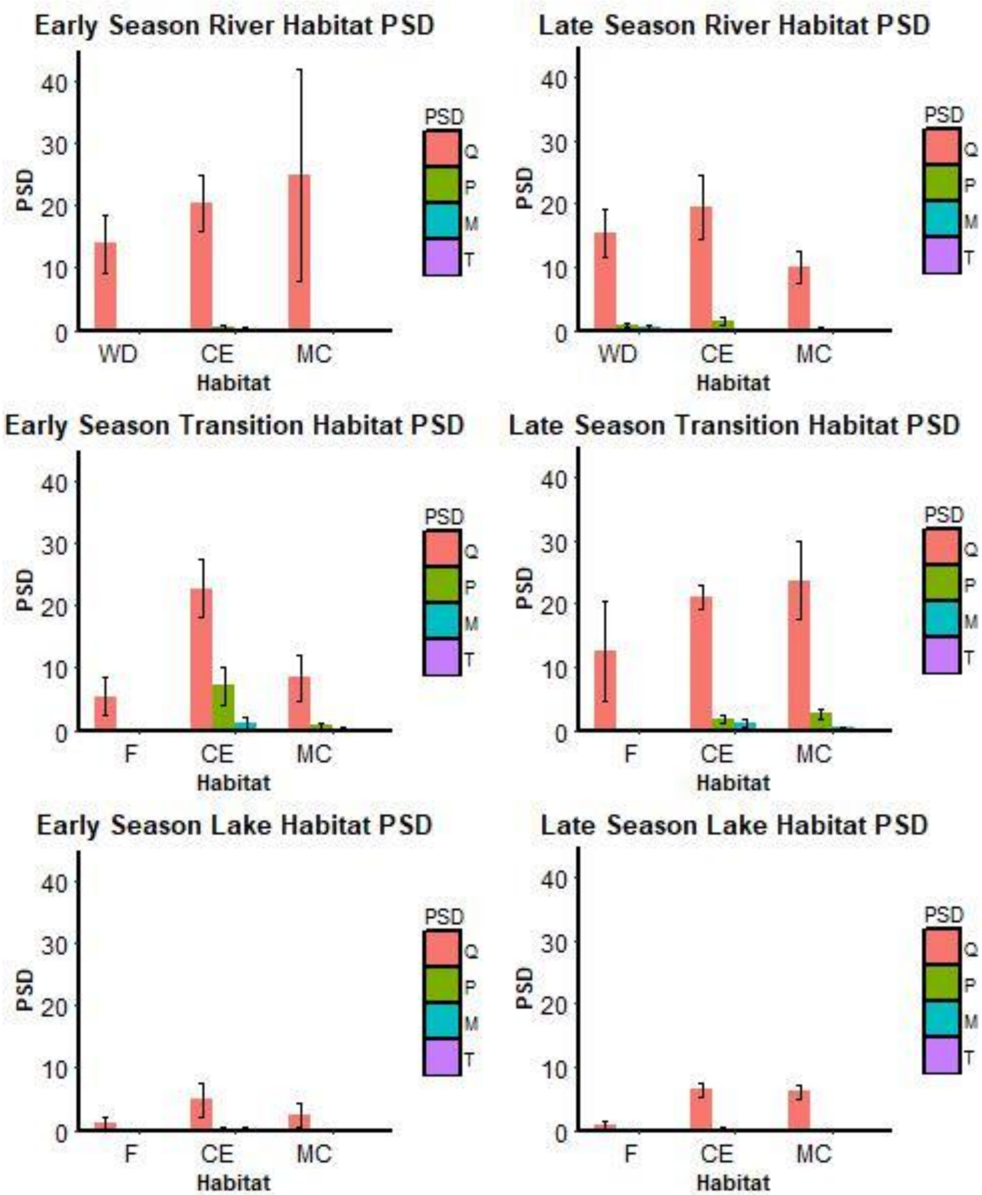

FIGURE 41.—Proportional size distributions (PSD) of Blue Catfish captured from main channel (MC), channel edge (CE), flats (F), and wing dike habitats (Dike) during the spring and summer seasons. PSD categories are quality (Q), preferred (P), memorable (M), and trophy (T). Refer to TABLE 1 for habitat descriptions.

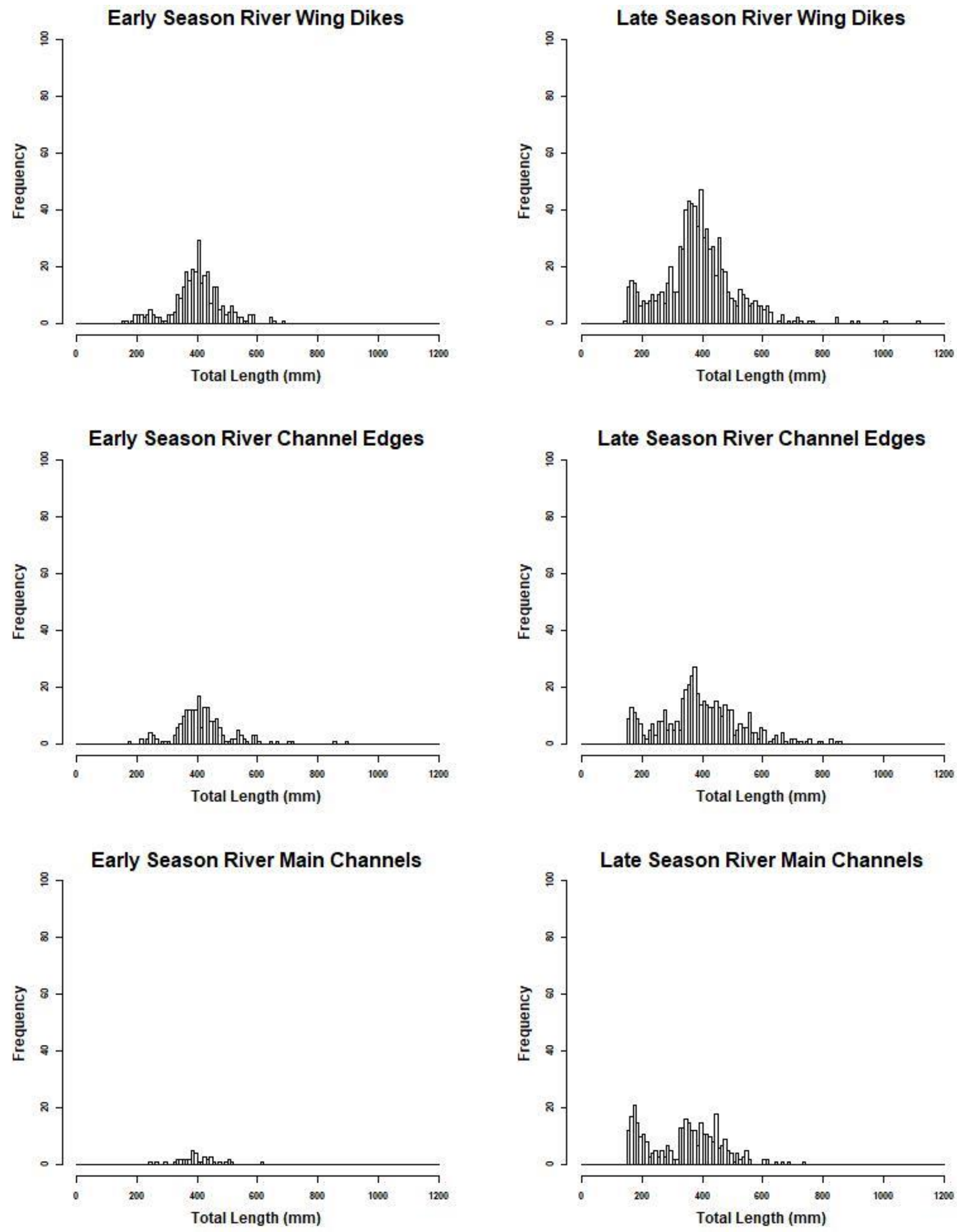

FIGURE 42.—Length frequency histograms of Blue Catfish captured from main channel, channel edge, and wing dike habitats in the riverine zone during the spring and summer seasons.

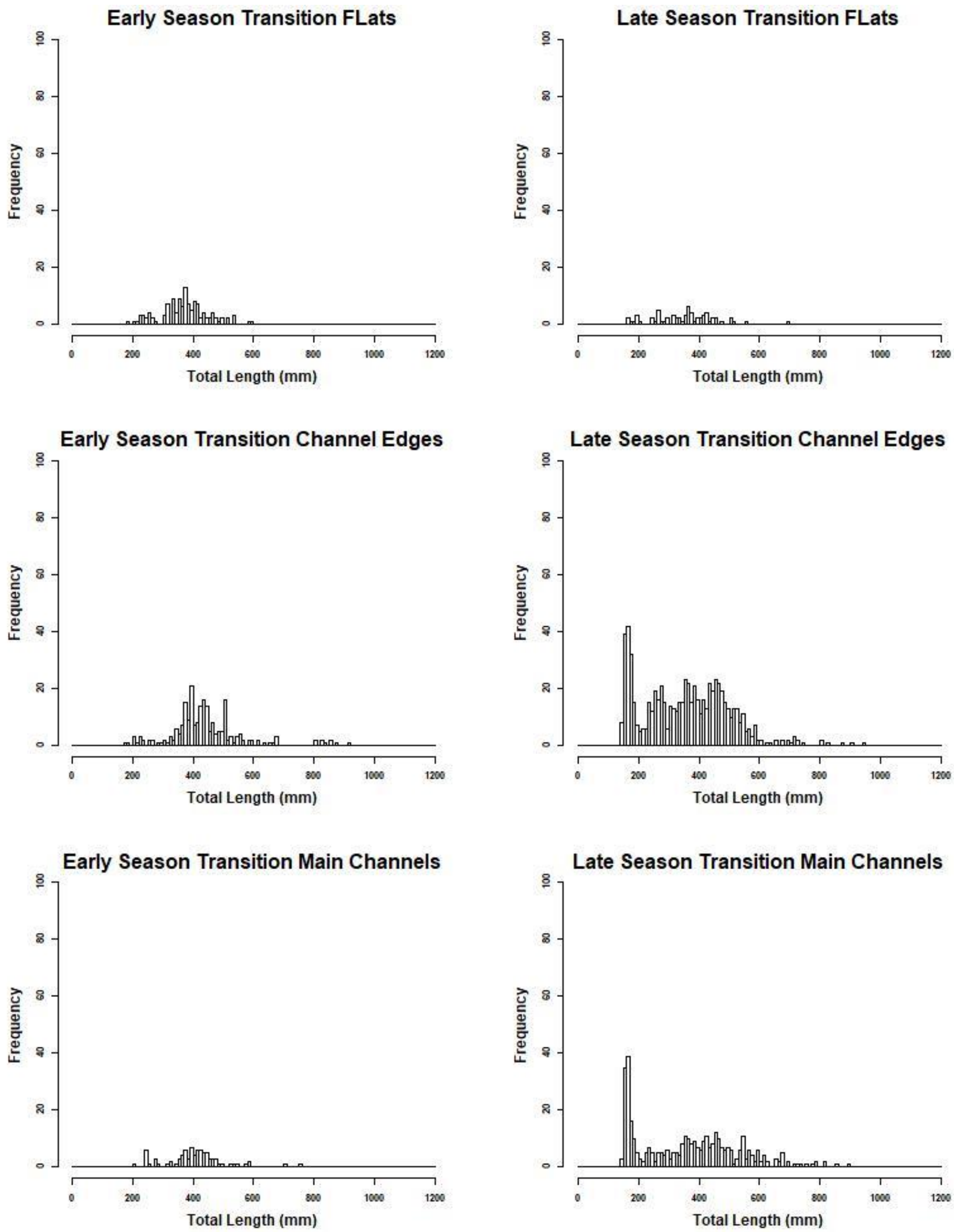

FIGURE 43.—Length frequency histograms of Blue Catfish captured from main channel, channel edge, and adjacent flat habitats in the transition zone during the spring and summer seasons.

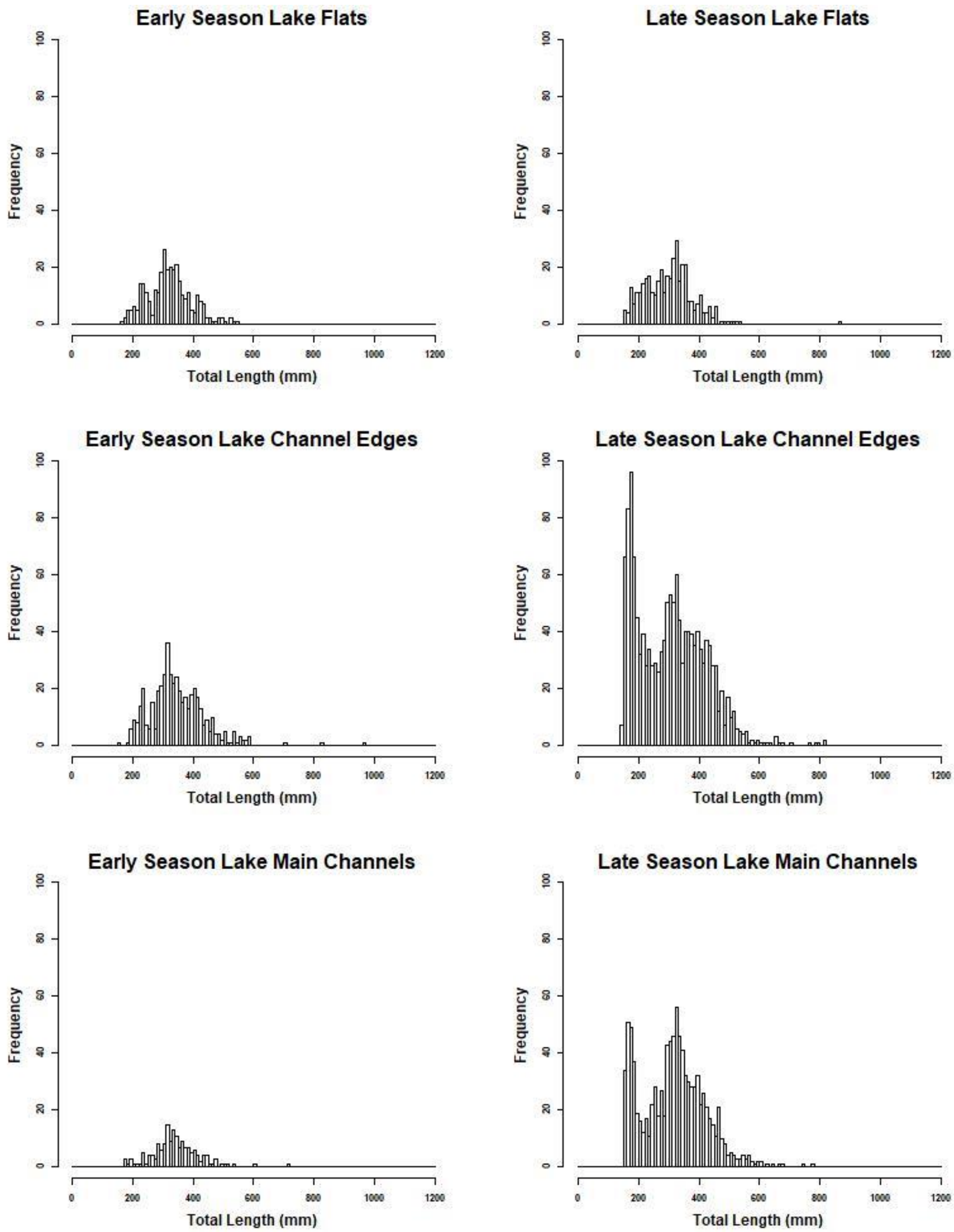

FIGURE 44.—Length frequency histograms of Blue Catfish captured from main channel, channel edge, and adjacent flat habitats in the lacustrine zone during the spring and summer seasons.

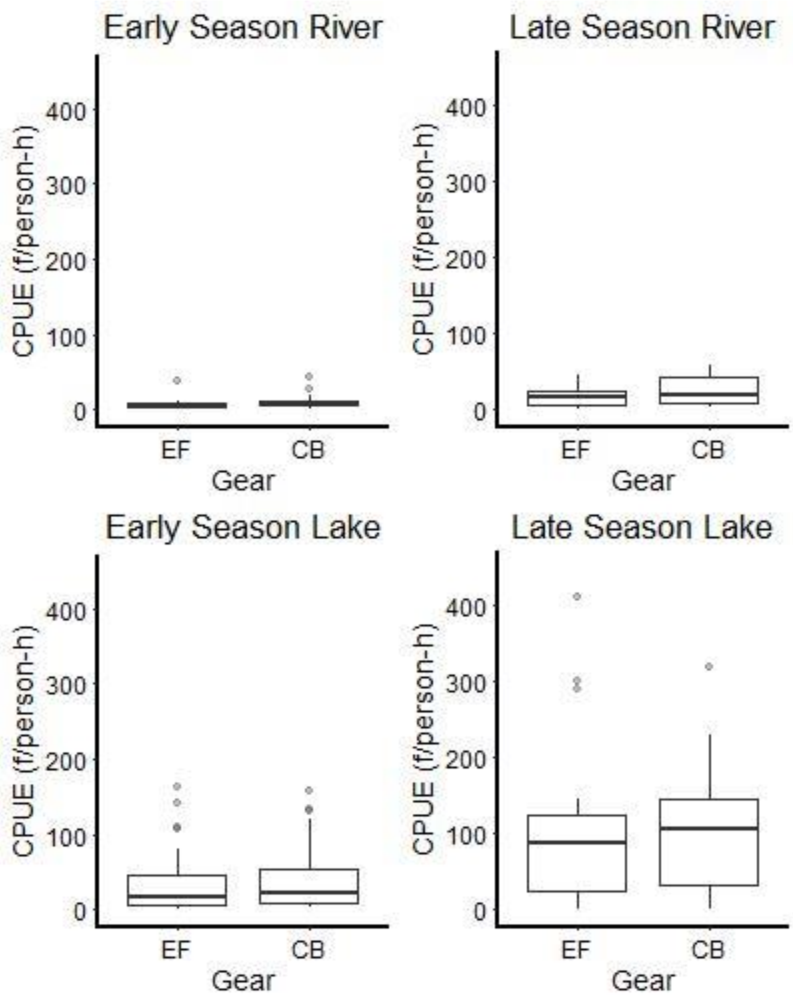

FIGURE 45.—Boxplots of catch per unit effort per person hour (CPUE f/person-h) of Blue Catfish sampled with a single electrofisher (EF), and a chase boat and electrofisher combined (CB) from the riverine and lacustrine zones during spring and summer seasons.

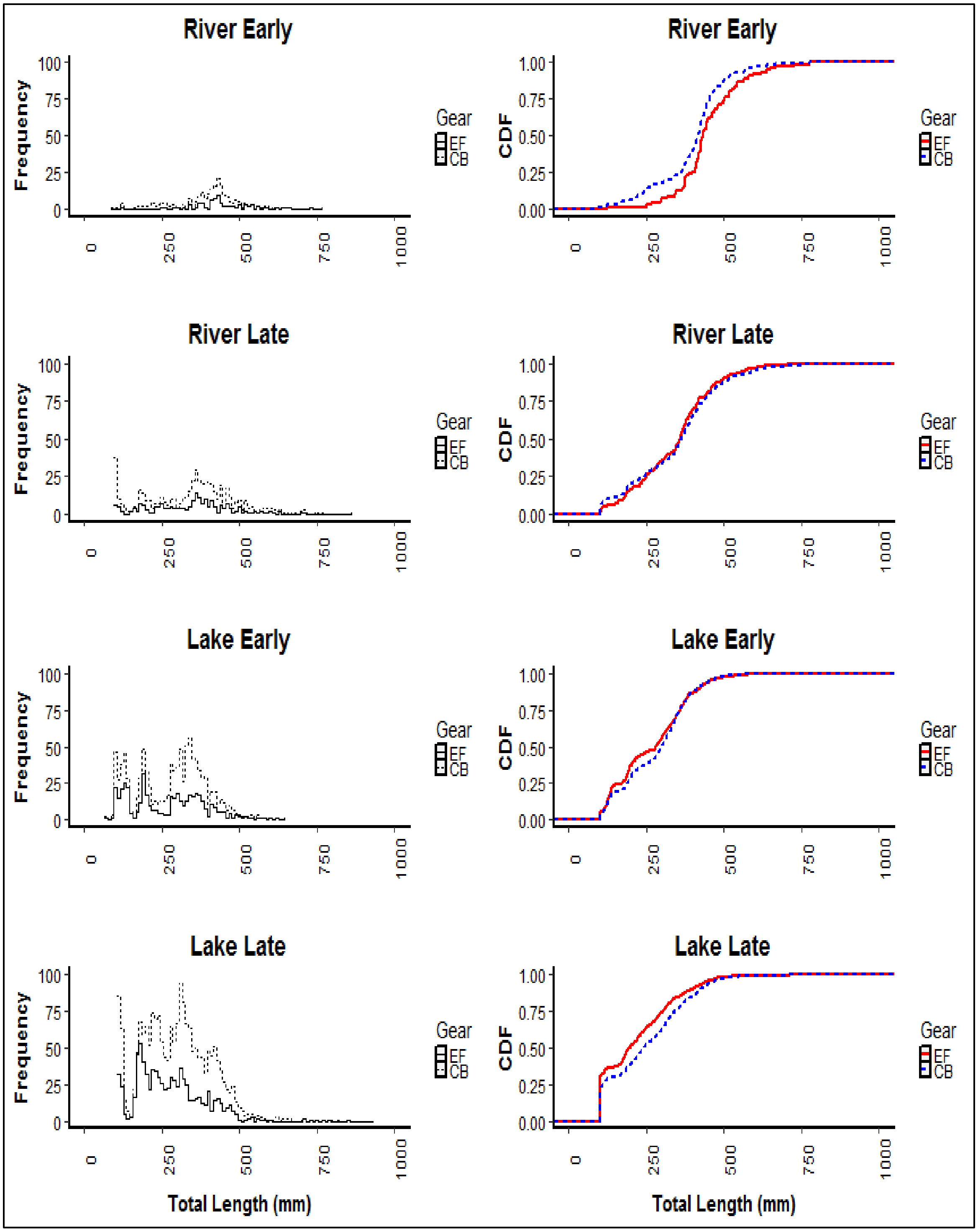

FIGURE 46.—Length frequency histograms, and empirical cumulative distribution functions (CDF) of a single electrofisher, and a chase boat and electrofisher combined. In the length frequency histograms, catch from the electrofisher is the solid black line, and the electrofisher and chase boat combined is the dashed line. The red solid line represents a single electrofisher, and the dashed blue line represents the electrofisher and chase boat combined.

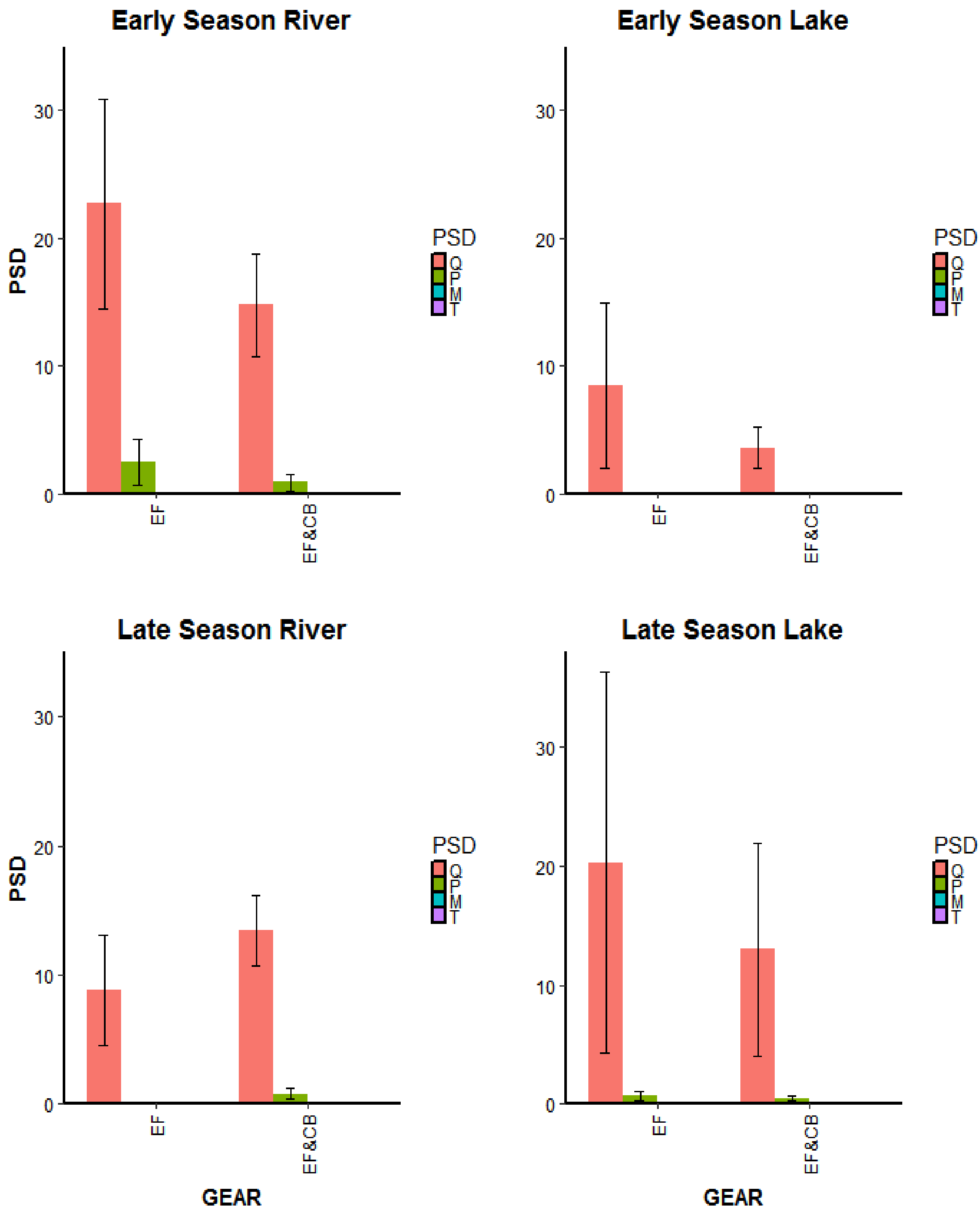

FIGURE 47.—Bar graph indicating proportional size distribution (PSD) created with a single electrofisher (EF) and an electrofisher and chase boat combined (EF&CB) from the lacustrine and riverine zones during the spring and summer season. PSD categories obtained from Anderson and Neumann 1996. PSD categories are quality = (PSD), preferred = (PSD-P), memorable = (PSD-M), and trophy = (PSD-T).

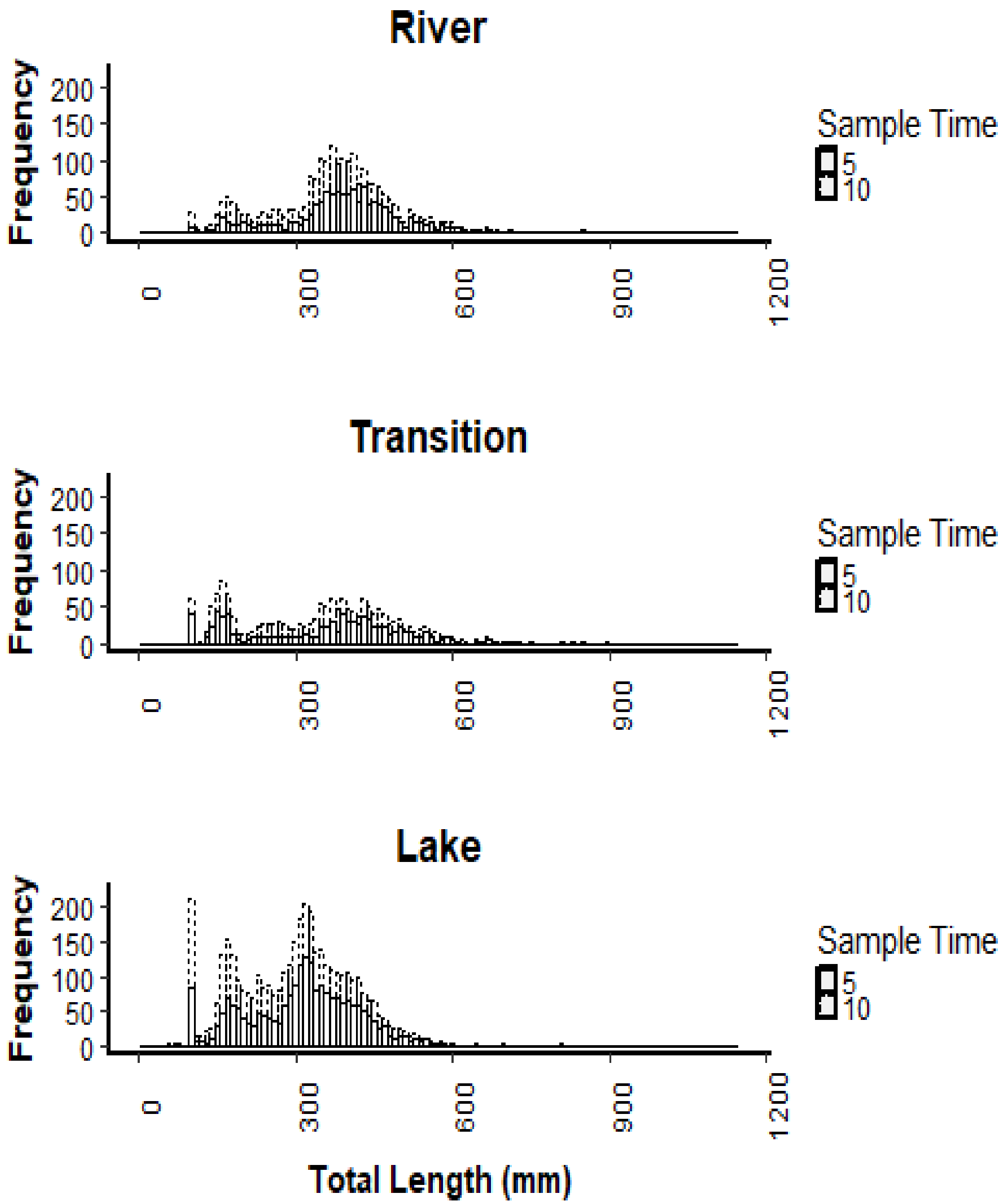

FIGURE 48.—Length frequency histograms of Blue Catfish captured during 5 and 10 min sample times from the lacustrine, transition, and riverine zones. Solid and dashed line represent 5 and 10 min sample times respectively.

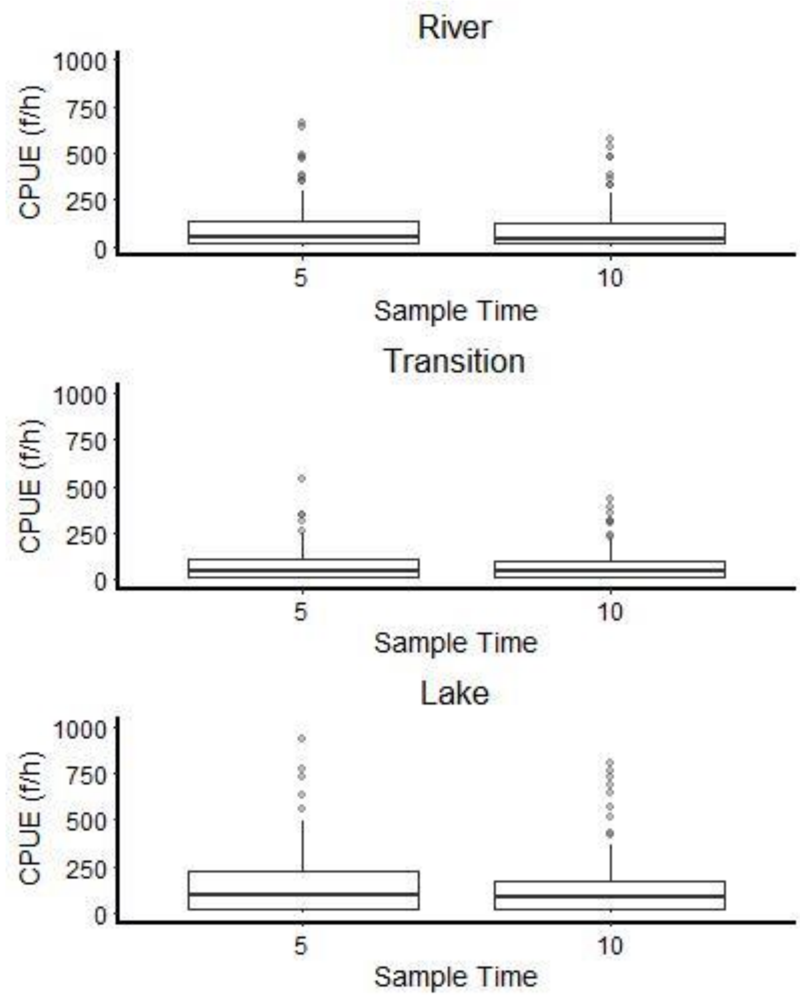

FIGURE 49.—Boxplots of catch per unit effort (CPUE (fish/h)) of Blue Catfish sampled with a single electrofisher (EF) from the lacustrine, transition, and riverine zones from 5 and 10 min sample time.

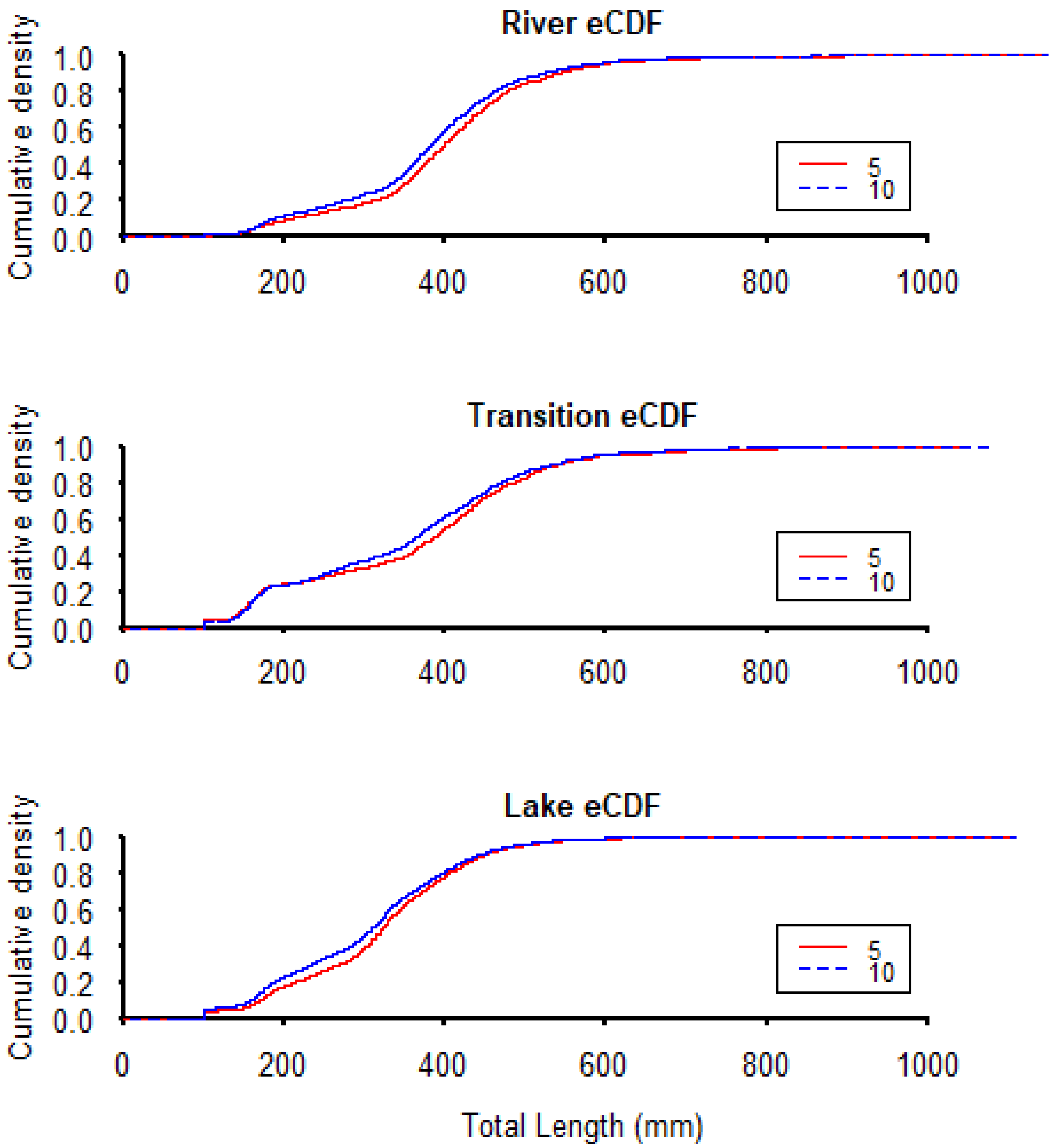

FIGURE 50.—Empirical cumulative distribution functions of Blue Catfish captured during 5 and 10 min sample times from the lacustrine, transition, and riverine zones. Solid red, and dashed blue represent 5 and 10 min sample times respectively.

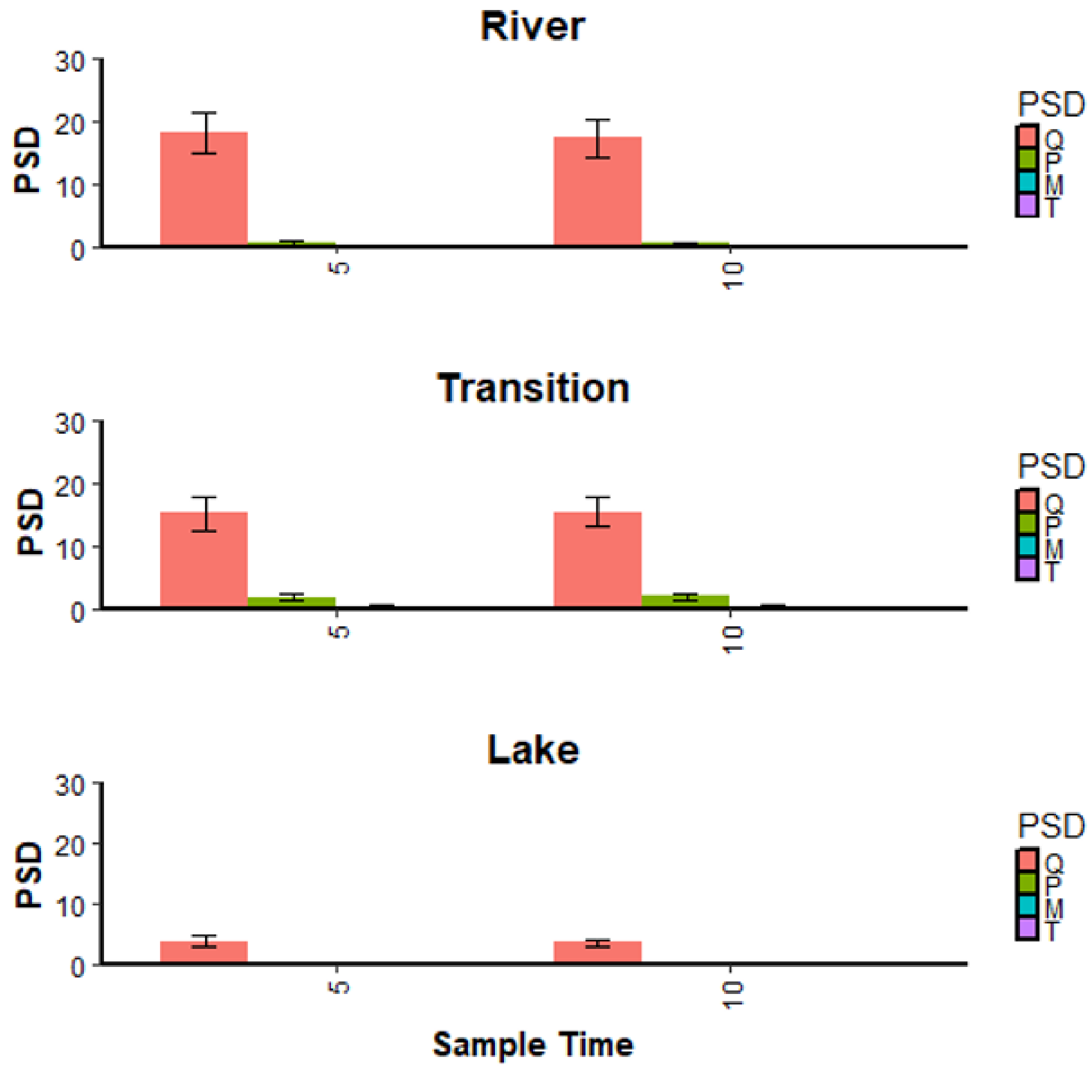

FIGURE 51.—Bar graph indicating proportional size distribution (PSD) created with a single electrofisher (EF) during 5 and 10 min sample times from the lacustrine, transition, and riverine zones. PSD categories obtained from Anderson and Neumann 1996. PSD categories are quality = (PSD), preferred = (PSD-P), memorable = (PSD-M), and trophy = (PSD-T).

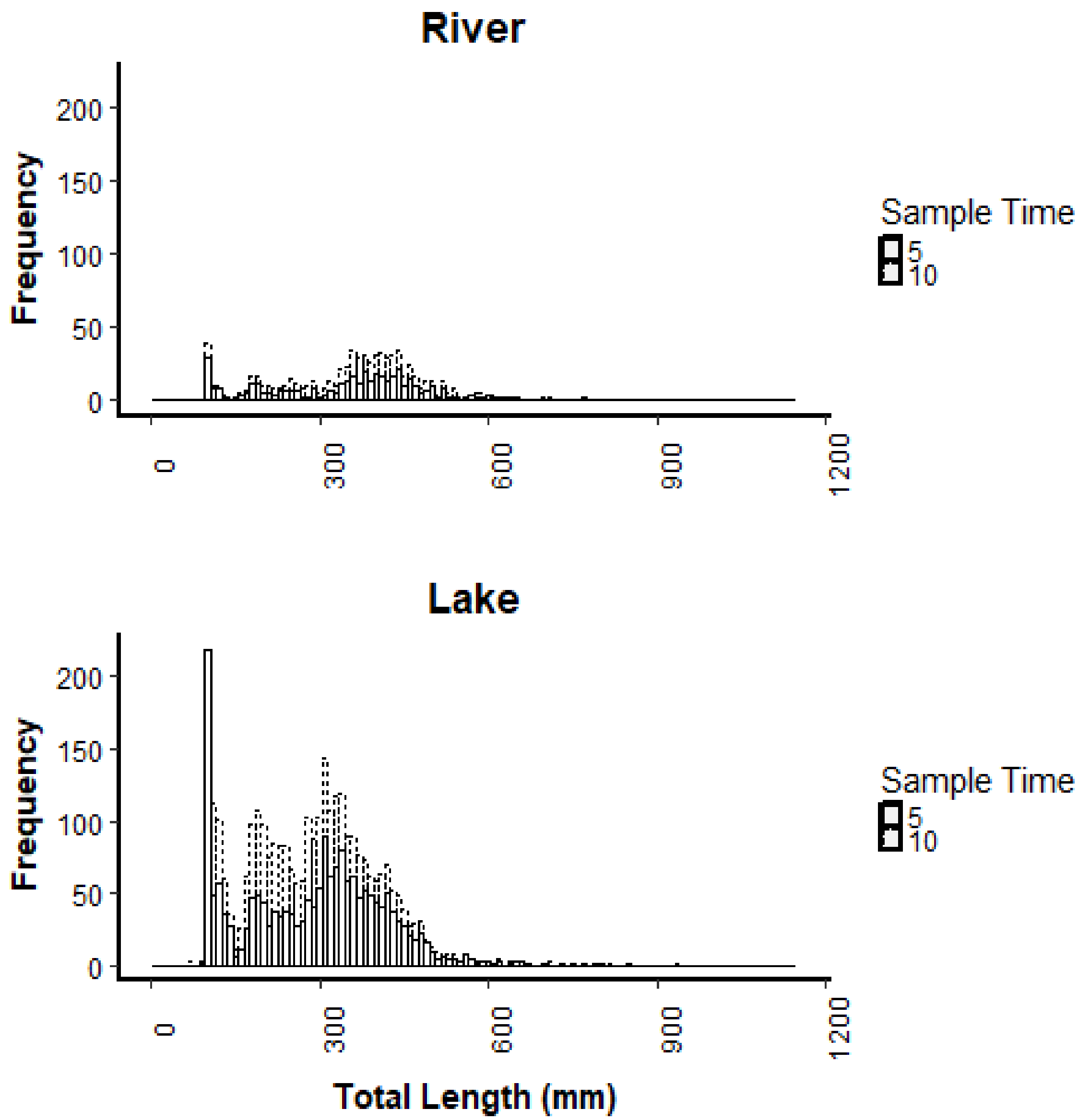

FIGURE 52.—Length frequency histograms of Blue Catfish captured with a chase boat and electrofisher combined during 5 and 10 min sample times in the lacustrine and riverine zones. Solid and dashed line represent 5 and 10 min sample times respectively.

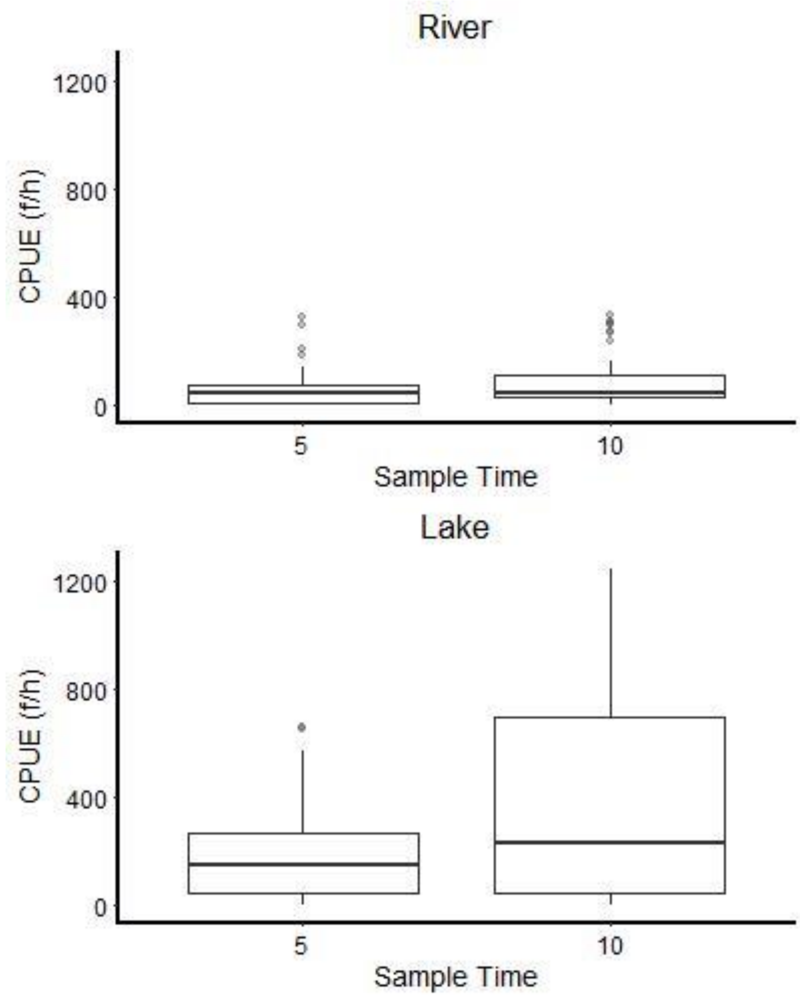

FIGURE 53.—Boxplots of catch per unit effort (CPUE (fish/h)) of Blue Catfish sampled with a chase boat and electrofisher combined during 5 and 10 min sample times from the riverine and lacustrine zones.

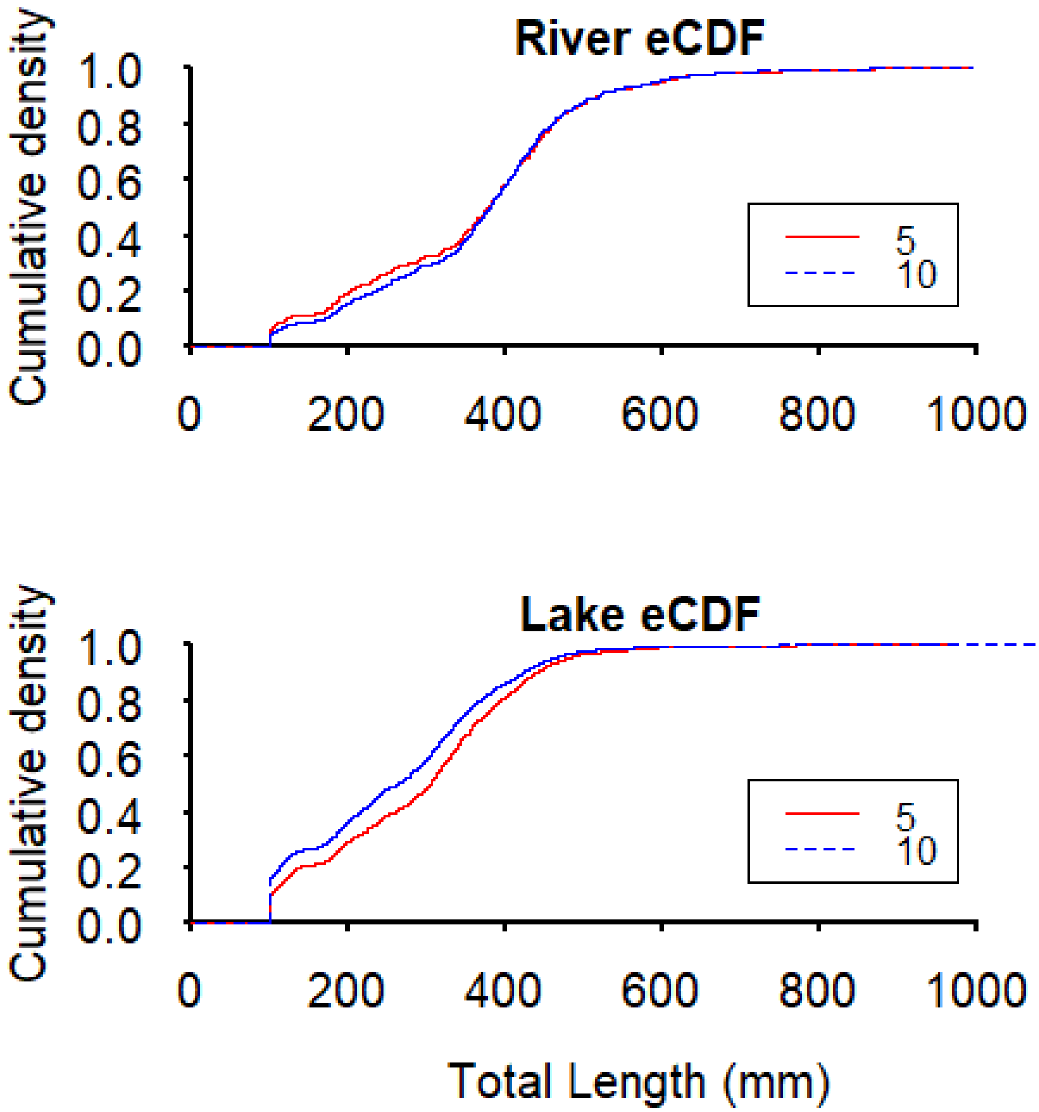

FIGURE 54.—Empirical cumulative distribution functions of Blue Catfish captured a chase boat and electrofisher combined during 5 and 10 min sample times. Solid red, and dashed blue represent 5 and 10 min sample times respectively.

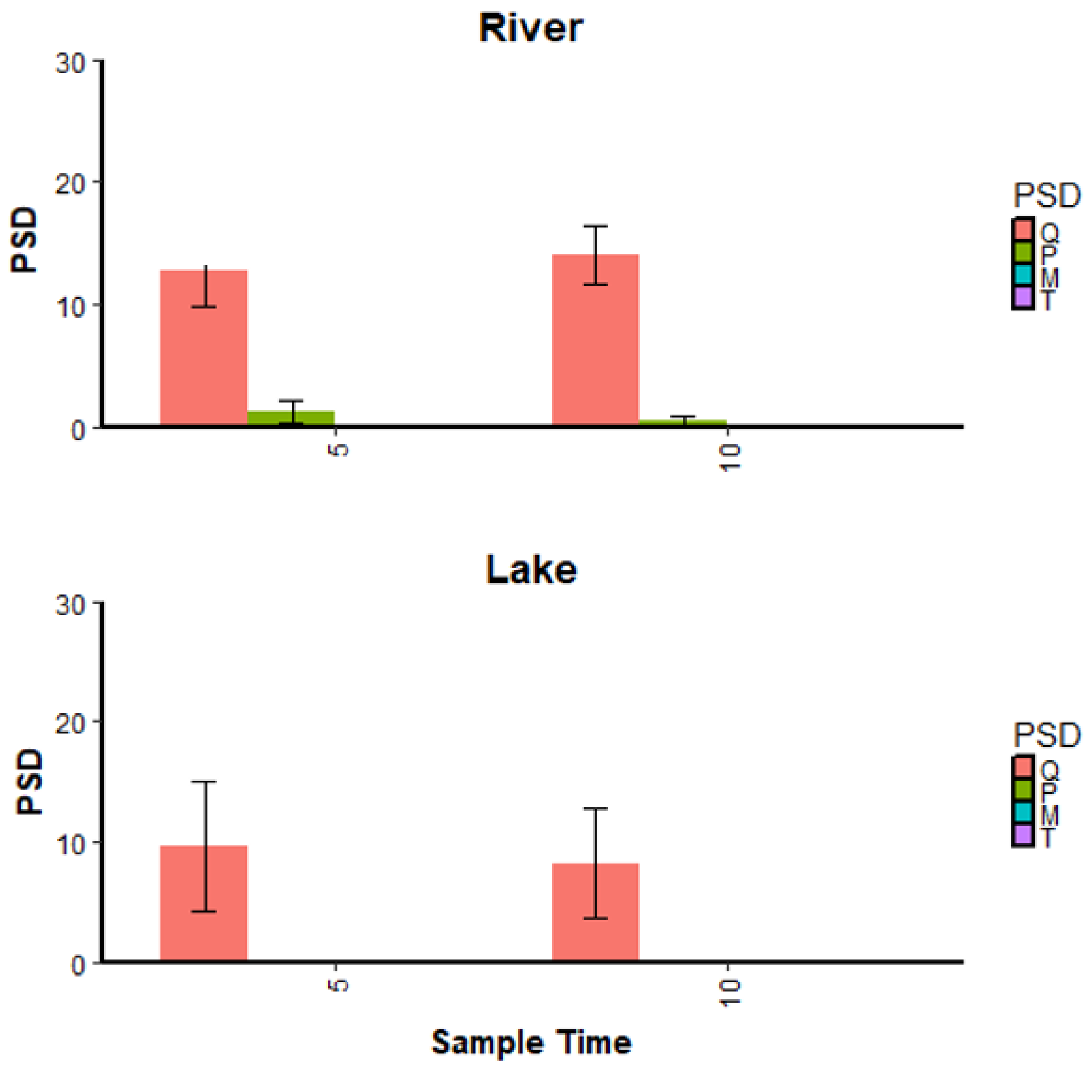

FIGURE 55.—Bar graph indicating proportional size distribution (PSD) created with a chase boat and electrofisher combined during 5 and 10 min sample times from the lake and river. PSD categories obtained from Anderson and Neumann 1996. PSD categories are quality = (PSD), preferred = (PSD-P), memorable = (PSD-M), and trophy = (PSD-T).