Diel Differences in Electrofishing Catch in the Atchafalaya River Basin, Louisiana

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Abstract: Published reports indicate night electrofishing may be superior to day sampling to estimate density and diversity of collected fishes in some aquatic habitats. However, because shallow, highly turbid waters characteristic of river floodplains present fish detection, navigation, and safety concerns during night electrofishing, many southeastern floodplain sampling programs have focused on day electrofishing. We used paired day and night samples of fishes collected by transect (200 m distance for eight minutes) and point electrofishing (1 minute at four points spaced 25 m apart) to assess potential day electrofishing bias at four sites in the Atchafalaya River floodplain during fall and winter 2013. Analyses compared day and night estimates of overall catch-per-unit effort (CPUE) of bluegill (*Lepomis macrochirus*), largemouth bass (*Micropterus salmoides*), and black crappie (*Pomoxis nigromaculatus*), as well as species richness and assemblage evenness by electrofishing method. Point sampling at night resulted in greater overall and bluegill CPUEs, with transect electrofishing yielding greater nighttime richness and daytime largemouth bass CPUE. No differences were detected for estimates of black crappie CPUE, evenness, or between day and night assemblages for either sampling method. Selection of day or night electrofishing depends on sampling goals, habitat characteristics, particularly turbidity, and the electrofishing method employed, but our data indicate that daytime sampling provides acceptable estimates of fish assemblage structure in the Atchafalaya River floodplain.

Key words: sampling, rivers, Atchafalaya River, catch rate, species richness

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Electrofishing is a standard technique used to sample fishes in freshwater and oligohaline habitats throughout the United States (Pope et al. 2009, Reynolds and Kolz 2012). Metrics of interest, either within species (e.g., size structure; Paragamian 1989) or among species (e.g., richness, evenness; Pierce et al. 2001) have been found to vary between daytime and nighttime electrofishing samples. Although Pope et al. (2009) suggested that electrofishing be conducted at night, they also report similar daytime/nighttime catch-per-unit-effort (CPUE) values in turbid systems with Secchi depths <1 m.

The Atchafalaya River Basin (ARB; also Atchafalaya River Floodway system) consists of the Atchafalaya River and its adjacent floodplain bounded by the Old River Control Structure to the north, flood protection levees to the east and west, and the southern Wax Lake Outlet, which is the primary outflow into the Gulf of Mexico (Ruess 1982). The ARB is subdivided into water management units and is managed principally for flood control jointly by the U.S. Army Corps of Engineers and the Louisiana Department of Natural Resources with recreational and commercial fisheries as secondary interests (Alford and Walker 2013, Atchafalaya Basin Program 2013). Extensive oil and gas exploration and extraction (Carlson et al. 2012) and timber harvesting (Piazza 2014) have substantially altered the ARB with many active and abandoned wellheads, pipelines, and skidder lines throughout the floodplain. Moreover, active oil and gas exploration and extraction and timber harvesting operations rely on support from barges and large diesel crew boats that operate 24 hours a day resulting in periods of heavy boat traffic during shift changes throughout the day and night.

Within the ARB, a complex mosaic of seasonally and permanently inundated natural bayous and lakes, shallow swamps, and man-made canals provides habitat for fishes and invertebrates, and

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the spatial extent and water quality within these habitats are largely driven by the annual flood pulse of the Atchafalaya River (Sabo et al. 1999, Kaller et al. 2011, Pasco et al. 2016), which, in turn, strongly influences fisheries productivity (Alford and Walker 2013, Bennett and Kozak 2016). Although 396,200 ha of river and floodplain are within the ARB (Piazza 2014), spatial extent of inundation is highly variable among years and among different portions of the floodplain (7%–99%; Pasco et al. 2016). Hypoxia (dissolved oxygen < 2 mg L^{-1}) has long been recognized as a chief limiting factor for ARB floodplain aquatic habitats (Sabo et al. 1999, Kaller et al. 2011), as well as loss of deep water habitat from sediment accretion (Kroes and Kramer 2013). Inundation extent, connectivity with the Atchafalaya River, water temperature (Kaller et al. 2011, Pasco et al. 2016), and invasive aquatic plants (Kaller et al. 2015) influence hypoxia, ultimately limiting productivity of the system.

For the last two decades, reducing hypoxia and sediment accretion have been major objectives of water management within the ARB, and the U.S. Army Corps of Engineers and Louisiana Department of Natural Resources have implemented numerous projects to address these issues in the larger context of flood control. Recently, North American (Lapointe et al. 2006) and European (Copp 1989, Scholten 2003, Janáĉ and Jurajda 2007, Tomanova et al. 2013) fisheries scientists have used point electrofishing as an alternative to traditional transect electrofishing in riverine habitats. Point electrofishing involves holding the boat in the river at a sampling station as stationary as possible and applying the electrical current for a set period of time, often 10 sec (Scholten 2003), sometimes within a block net. By remaining stationary, point electrofishing reduces the chance of missing fish that surface while stunned after the boat has passed, as occasionally occurs during transect electrofishing in riverine systems. Advantages reported by point electrofishing practitioners include better estimates of fish catch, relative abundance, and fish-habitat associations in riverine habitats with less effort compared with single-pass transect electrofishing (Copp 1989, Scholten 2003, Lapointe et al. 2006, Janáĉ and Jurajda 2007, Tomanova et al. 2013); however, direct comparisons with other electrofishing methods are few (e.g., Teixeira-de Mello et al. 2014, Trumbo et al. 2016).

Given that the ARB consists of riverine and shallow, slow-moving or stagnant water habitats, point electrofishing may allow collection of better fisheries data. A previous study compared point versus transect electrofishing and concluded that although measures of diversity and fish size were similar between methods, species richness and catch of several species differed (Trumbo et al. 2016). Therefore, sampling since 2011 has included point and transect electrofishing to reduce bias in estimates of fish relative abundance and richness. However, concerns remain that biases may still be present because of potential difference in catch between day versus night sampling. Therefore, we began this project to determine if daytime point and transect electrofishing was collecting representative samples of the fish assemblages inhabiting the bayous, canals, and lakes that comprise the diversity of aquatic habitats in the ARB. To investigate this question, we collected paired daytime/nighttime samples within the ARB during 2013 to assess day versus night differences in: 1) total fish CPUE; 2) assemblage richness and diversity; and 3) CPUE of selected recreationally important fish taxa (Alford and Walker 2013, Piazza 2014, Benett and Kozak 2016).

Study Area

The study was conducted within the 29,000-ha Henderson Lake Water Management Unit in the ARB, Louisiana. Because each management unit within the ARB varies in physical habitat and water quality (Kaller et al. 2011, 2015), sites were selected within only this one management unit to reduce the potential confounding influences of unit-specific habitat and water quality. Moreover, because of night sampling hazards from active and abandoned wellheads and pipelines and heavy commercial boat traffic, the Henderson Lake Water Management Unit offered the safest possible routes between boat launches and sampling locations. Sites were selected from among long-term fish monitoring locations sampled by Louisiana State University from 2005–2015 as part of U.S. Army Corps of Engineers monitoring programs. Sites were permanently inundated channels generally characterized by shallow depths, turbid water, and extensive macrophyte beds, particularly water hyacinth (*Eicchornia crassipes*) and hydrilla (*Hydrilla verticillata*) (Walley 2007, Kroes and Kramer 2013, Kaller et al. 2015). Importantly, because not all of the Henderson Lake Water Management Unit is inundated even during the peak of the flood pulse (Pasco et al. 2016), sites included only permanent bodies of water that were inundated throughout the available sampling data (2005–2013) and were disconnected from the adjacent floodplain.

Methods

Sampling

Because previous monitoring experience indicated that electrofishing in the ARB was ineffective during high water (i.e., floodplain inundation at 2.5 m, U.S. Geological Survey Butte LaRose gage 7381515), we conducted low-water daytime and nighttime electrofishing at four sites in the Henderson Lake Management Unit each month during September, November, and December 2013 for a total of 12 sampling events by each electrofishing method. At each site, fishes were sampled with a boat-mounted Smith Root 7.5 GPP electrofishing unit powered by a 5000-W generator with a DC output adjusted to approximately 700 volts and 9–12 amps. The daytime sampling methodology was similar to the description in Trumbo et al. (2016) and involved first selecting two 100-m reaches for each sampling method. One 100-m reach was selected and marked for transect electrofishing and an adjacent 100-m reach was selected and marked for point electrofishing. Point electrofishing was conducted at 25-m intervals along one 100-m reach. With the electrofisher power off, the boat was positioned at the point of sampling, and the boat was held as stationary as possible. The electrofisher was then powered on for 60 sec while all fishes were netted. The four sampling points were pooled for a combined 240 sec of electrofishing power-on time and a single point electrofishing sample. Following point electrofishing, transect electrofishing was conducted in the adjacent 100-m reach along both shorelines (200 m total) for 480 sec. All sampled fishes were identified and counted. Boat speed and reach length were standardized with a Garmin GPS unit during sampling. Transect electrofishing was always conducted away from the point electrofishing site to minimize fish movement or herding during transect sampling. At each reach, for both electrofishing methods, we measured site turbidity, depth, dissolved oxygen, and specific conductance with a YSI multi-probe. Sampling methodologies for transect and point sampling were identical during daytime and nighttime sampling, with night sampling occurring at the same site approximately 30 hours after day sampling (i.e., the evening of the day after daytime sampling).

Data Analysis

For each electrofishing method, we compared day and night estimates of overall density (catch-per-unit-effort [CPUE], fish min^{-1}), CPUEs of bluegill (*Lepomis macrochirus*), largemouth bass (*Micropterus salmoides*), and black crappie (*Pomoxis nigromaculatus*), as well as species richness and assemblage evenness per effort (either 480 sec for transect sampling or 240 sec for point sampling). We selected these three fish species because: 1) each fish is known to be well sampled by electrofishing in our long term data and in Louisiana Department of Wildlife and Fisheries fishery-independent electrofishing—unlike catfishes that are poorly represented in long term electrofishing datasets (Alford and Walker 2013, Bennett and Kozak 2016) and 2) these fish species attract considerable recreational fishing activity in the ARB (Holloway et al. 1998). Each analysis used a general linear mixed model with day or night as a fixed effect, turbidity, dissolved oxygen, water depth and specific conductance as fixed covariates, and sampling month as a random effect. Assumptions of the general linear mixed model were assessed for each model. Because distributions of CPUE are often skewed, generalized linear mixed models with log links and Poisson and negative binomial distributions were constructed for comparison of model fit ($\hat{c}$) with the general linear mixed models (Zuur et al. 2009). Models best satisfying assumptions and exhibiting a $\hat{c}$ closest to 1.0 were selected for interpretation. Point and transect electrofishing data were not pooled for analyses because low sample size limited model degrees of freedom and differences between methods have been previously described in this system by Trumbo et al. (2016). All analyses were performed in SAS/STAT (SAS Institute 2012). Importantly, all statistically significant and non-significant *P* values should be interpreted in the context of the generalized linear mixed model in that the *P* values are conditional on partitioning variance to inter-monthly differences in the response variable (the random effect) and holding the covariates constant (their means).

Results

Water conditions during sampling were typical of Henderson Lake in the late summer and fall (Table 1). Overall, collections yielded 2977 fishes representing 34 species with black bullhead (*Ameiurus melas*), shortnose gar (*Lepisosteus platostomus*), inland silverside (*Menidia beryllina*), and spotted bass (*Micropterus punctulatus*) collected only in daytime, and white crappie (*Pomoxis annularis*) collected only at night (Table 2). Transect electrofishing captured 29 and 28 species during the day and night, respectively, and point electrofishing captured 26 and 27 species during the day and night, respectively (Table 2). Collections were dominated by species with diverse habitat associations, including more pelagic gizzard shad (*Dorosoma cepedianum*) and threadfin shad (*D. petenense*), benthic smallmouth buffalo (*Ictiobus bubalus*) and bigmouth buffalo (*I. cyprinellus*), and strongly structure-oriented centrarchids like bluegill, warmouth (*Lepomis gulosus*), and redear sunfish (*Lepomis microlophus*).

During model fitting, several models exhibited good fit to the data ($\hat{c}$ near 1), and a few models exhibited an indication of overfitting ($\hat{c}$ much less than 1; Table 3). Although numerous solutions exist for overdispersion/underfitting ($\hat{c}$ much greater than 1), methods for addressing overfitting are limited to re-specification of model

Table 1. Means (± SE) of measured physicochemical variables from four sites and across three months in the Henderson Lake Water Management Unit of the Atchafalaya River Basin, Louisiana, 2013.

Variable	September	November	December
Temperature (°C)	31.45 (± 0.21)	17.54 (± 0.34)	10.90 (± 0.29)
Dissolved oxygen (mg L^{-1})	4.99 (± 0.59)	12.54 (± 0.50)	9.95 (± 0.75)
Depth (m)	0.06 (± 0.05)	1.31 (± 0.80)	0.21 (± 0.06)
pH	7.48 (± 0.09)	7.96 (± 0.06)	7.95 (± 0.06)
Specific conductance (mS cm^{-1})	0.26 (± 0.01)	0.33 (± 0.02)	0.23 (± 0.02)
Turbidity (NTU)	8.28 (± 1.31)	11.41 (± 1.26)	43.20 (± 19.3)

Table 2. Total fish sampled by species during daytime and nighttime sampling using transect and point electrofishing from four sites in the Henderson Lake Water Management Unit of the Atchafalaya River Basin, Louisiana, 2013.

		Transect		Point	
Species	**Common name**	**Night**	**Day**	**Night**	**Day**
Ameiurus natalis	Brown bullhead	1	1	0	0
Americas melas	Black bullhead	0	0	0	1
Amia calva	Bowfin	4	29	2	11
Anchoa mitchelli	Bay anchovy	1	2	1	0
Aphredoderus sayanus	Pirate perch	2	2	2	1
Aplodinotus grunniens	Freshwater drum	0	1	5	2
Cyprinus carpio	Common carp	1	0	0	1
Dorosoma cepedianum	Gizzard shad	75	59	58	23
Dorosoma petenense	Threadfin shad	75	36	69	41
Fundulus chrysotus	Golden topminnow	2	4	4	2
Gambusia affinis	Mosquitofish	0	6	3	0
Hyophthalmichthys molitrix	Silver carp	5	0	1	2
Ictalurus furcatus	Blue catfish	1	1	1	0
Ictalurus punctatus	Channel catfish	1	0	2	0
Ictiobus bubalus	Smallmouth buffalo	24	26	29	28
Ictiobus cyprinellus	Bigmouth buffalo	8	6	10	16
Labidesthes sicculus	Brook silverside	2	61	14	5
Lepisosteus oculatus	Spotted gar	95	66	36	24
Lepisosteus ossues	Longnose gar	5	5	0	0
Lepisosteus platostomus	Shortnose gar	0	1	0	0
Lepomis gulosus	Warmouth	28	24	30	21
Lepomis humilis	Orangespotted sunfish	11	11	17	17
Lepomis macrochirus	Bluegill	142	134	254	140
Lepomis megalotis	Longear sunfish	2	2	6	0
Lepomis microlophus	Redear sunfish	18	22	30	34
Lepomis miniatus	Redspotted sunfish	7	8	6	8
Menidia beryllina	Inland silverside	0	1	0	1
Micropterus punctulatus	Spotted bass	0	2	0	1
Micropterus salmoides	Largemouth bass	75	140	44	63
Mugil cephalus	Striped mullet	8	6	6	1
Notemigonus crysoleucas	Golden shiner	3	10	5	3
Polyodon spathula	Paddlefish	1	1	1	0
Pomoxis annularis	White crappie	5	0	11	0
Pomoxis nigromaculatus	Black crappie	66	7	80	12
Total		837	724	853	563

Table 3. Comparisons of model fit ($\hat{c}$) for generalized linear mixed models evaluated for day and night electrofishing comparisons. Models best satisfying assumptions and exhibiting a closest to 1.0 were selected for interpretation and are shaded in gray. CPUE is catch per unit effort (fish min^{-1}).

Comparison	**General linear mixed model (identity link, normal probability distribution)**	**Log link, Poisson probability distribution**	**Log link, negative binomial probability distribution**	**Log link, gamma probability distribution**
Point overall CPUE	0.25	0.30	0.30	**0.36**
Transect overall CPUE	0.00	0.02	0.02	**0.36**
Bluegill point CPUE	160.76	8.53	**1.06**	Not estimable
Bluegill transect CPUE	69.36	3.97	**1.00**	Not estimable
Largemouth bass point CPUE	3.07	**0.64**	0.64	0.14
Largemouth bass transect CPUE	28.67	2.64	**1.07**	0.30
Black crappie point CPUE	49.55	**5.90**	Not estimable	Not estimable
Black crappie transect CPUE	6.30	1.35	**0.99**	0.14
Point richness	8.88	**0.76**	0.76	0.07
Transect richness	3.33	**0.36**	0.36	0.03
Point evenness	0.00	0.01	0.01	**0.02**
Transect evenness	0.00	0.01	0.01	**0.02**

Table 4. Comparisons of night and day transect and point electrofishing means (95% CL) for total fish per minute (CPUE; fish min^{-1}), bluegill CPUE, largemouth bass CPUE, black crappie CPUE, richness per 480 sec (transect) or 240 sec (point), and evenness per 480 sec (transect) or 240 sec (point). Statistically significant comparisons are indicated by shading

Response variable	**Day transect electrofishing**	**Night transect electrofishing**
Total CPUE	6.80 (± 2.57)	6.72 (± 1.56)
Bluegill CPUE	11.17 (± 5.61)	11.83 (± 4.85)
Largemouth bass CPUE	**11.67 (± 4.81)**	**6.25 (± 2.54)**
Black crappie CPUE	0.58 (± 0.52)	5.5 (± 3.5)
Richness	**10.83 (± 1.43)**	**12.67 (± 1.6)**
Evenness	0.44 (± 0.03)	0.47 (± 0.03)
	Day point electrofishing	**Night point electrofishing**
Total CPUE	**11.72 (± 2.59)**	**17.78 (± 3.12)**
Bluegill CPUE	**5.29 (± 1.42)**	**2.92 (± 0.92)**
Largemouth bass CPUE	0.92 (± 0.29)	1.31 (± 0.33)
Black crappie CPUE	0.25 (± 0.13)	1.67 (± 0.72)
Richness	10.83 (± 1.46)	13.08 (± 2.02)
Evenness	0.45 (± 0.03)	0.45 (± 0.03)

structure, usually removal of covariates, or selection of an alternative analysis. In this case, because the models were not developed for predictive purposes, we followed the usually advised practice of ignoring overfitting in empirical modeling (Kéry and Royle 2016). Species richness for transect electrofishing was higher at night ($F = 6.35$; df = 1,16; $P = 0.02$), and for point electrofishing, overall CPUE ($F = 5.91$; df = 1,16; $P = 0.03$) and bluegill CPUE were also higher at night ($F = 5.96$; df = 1,16; $P = 0.03$). In contrast, largemouth bass CPUE was higher during the day ($F = 6.31$; df = 1,16; $P = 0.02$) for transect electrofishing. Catch rates and assemblage structure indices were similar between day and night sampling regardless of method for all other comparisons (Table 4). The observed difference in black crappie CPUE between day and night sampling was not statistically significant ($P > 0.05$), and was largely driven by a single sampling site when an unusually large number of black crappie were sampled.

Discussion

Many studies have reported increased electrofishing catches during night sampling relative to day sampling in rivers and lakes (Paragamian 1989, Sanders 1992, McInerny and Cross 2000, Hardie et al. 2006, but see Van Zee et al. 1996, McInerny and Cross

2004). We attempted to ensure collection of representative samples of ARB littoral fishes by incorporating both transect and point electrofishing in our monitoring efforts, but sampling had been limited to daytime, primarily for safety reasons. Sample composition differences existed between these two sampling protocols (Trumbo et al. 2016), but the present study indicated differences in daytime/nighttime assemblage composition within each method were not substantial. Therefore, our study indicated that daytime electrofishing provided reasonable estimates of catch and assemblage composition relative to nighttime sampling, for ARB littoral fishes. Indeed, some species (e.g., largemouth bass and bowfin [*Amia calva*]) seemed to be more vulnerable to daytime electrofishing. White crappie was only collected at night, but is generally uncommon relative to black crappie in the ARB and has been previously sampled there by daytime electrofishing (Troutman et al. 2007, Trumbo et al. 2016).

Interestingly, there have been no indications of crepuscular and nocturnal movements (and hence greater nighttime densities) of fishes in the Henderson Lake floodplain reported in either lotic or lentic habitats (e.g., Sanders 1992, Pierce et al. 2001, Wolter and Freyhof 2004, Hardie et al. 2006). The permanently-inundated habitats within Henderson Lake water management unit are quite shallow (mean 0.5 ± 0.3 SE m; Kaller et al. 2011, Pasco et al. 2016) and limited in spatial extent with only 32.3% (95% CL 13%–68%) of the 29,000-ha area flooded on average during peak flood and much less available (~8700 ha) during seasonal low water (Pasco et al. 2016). The area also is frequently covered with dense aquatic vegetation that reduces available dissolved oxygen (Walley 2007, Kaller et al. 2015) and often experiences widespread flooding and temperature induced hypoxia (Kaller et al. 2011, Pasco et al. 2016). Further, deeper areas of Henderson Lake are frequently hypoxic (dissolved oxygen <2.0 mg L^{-1}) for much of the year (Kaller et al. 2011). Thus, lack of fish movement may simply be due to a lack of available habitats within the system which was also suggested by Doerzbacher (1980) in relation to very limited movements and home ranges of largemouth bass during low water in the ARB. Low movement could be a seasonal phenomenon related to life history strategies (i.e., greater movement in pre- and post-spawning situations, such as greater summer spawning associated movements and limited fall/winter movements of spotted gar (*Lepisoteus oculatus*) in the ARB as reported by Snedden et al. [1999]); however, given the poor ability to electrofish during high water in this system, evaluating seasonal movements would require additional gear, such as gill nets, and would be outside the scope of this effort. Additionally, the abundance of predators in this system, particularly gars, largemouth bass, bowfin, and crappies, likely minimized advantages of moving away from littoral cover in terms of risk and reward, regardless of diel period or the quality of that cover. Finally, it is important to note that this study only sampled 12 total events at four sites in a system of approximately 8700-ha during low water. Effort was limited because of the concerns over safety while sampling at night in this "working swamp." Possibly, some locations that were not sampled have sufficient heterogeneity in depth, dissolved oxygen level, and aquatic plant coverage to offer opportunity for diurnal movement for some species of fishes. Moreover, again given the limited effort, some species poorly represented in the catch may exhibit movements that the low sample size did not detect. However, our data suggest that the most common fishes in the catch used the same habitats during the night or day in this system.

An additional factor likely contributing to the overall success of daytime electrofishing in the ARB is turbidity, which is often elevated in this system. None of the other physical or chemical parameters (particularly dissolved oxygen; Sabo et al. 1999) appeared to have been of sufficient magnitude to have affected survival or movement of ARB littoral fishes during the study. Turbidity averaged 20 NTUs (about 0.3 m Sechhi disk depth) during the study, but was often higher. For reference, the Louisiana Department of Environmental Quality (2011) set a maximum criterion of 50 NTU for bayous and 25 NTUs for designated scenic streams and outstanding natural resources, suggesting that Henderson Lake exceeded optimal turbidity in terms of water quality. Previous studies found that mean Secchi disk depths ranged from 0.47 to 0.65 m in Henderson Lake during the fall (W. E. Kelso, unpublished data). Pope et al. (2009) stated that the effectiveness of daytime and nighttime electrofishing is often similar in turbid waters, and results of several studies support this contention (Van Zee et al. 1996, Pierce et al. 2001, Speas et al. 2004). In terms of assemblage composition and total number of fish collected with each sampling method, our results support these findings. Given the typical turbidities, shallow depths, and abundant submerged structure in the Henderson Lake floodplain, the vulnerability of littoral fishes to electrofishing gear appeared to be quite similar, regardless of diel period.

Our results are not intended to discount the effectiveness of nighttime electrofishing for collecting littoral fishes. In many systems, onshore/offshore diel movements and low turbidities preclude daytime electrofishing as an effective collection method to determine fish assemblage structure (e.g., Sanders 1992, Pierce et al. 2001) or population metrics (e.g., Paragamian 1989). However, in the more eutrophic, shallow, lowland systems of the southeastern United States such as the ARB, daytime electrofishing can provide adequate data for monitoring fish assemblage changes through time, with many logistical advantages and greater sampling safety in structurally complex and commercially active habitats. Thus, selection of day or night electrofishing may depend on sampling goals, habitat characteristics, particularly turbidity, and the electrofishing method employed.

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