Temporal Comparisons of Electrofishing Efficacy for Largemouth Bass in a Small Puerto Rico Reservoir

Nick R. Peterson, *Department of Wildlife, Fisheries and Aquaculture, Mississippi State University, Mississippi State, MS 39762*

J. Wesley Neal, *Department of Wildlife, Fisheries and Aquaculture, Mississippi State University, Mississippi State, MS 39762*

Abstract: Largemouth bass (*Micropterus salmoides*) are the primary sport fish in Puerto Rico reservoirs and the majority of management efforts directed at this species primarily employ electrofishing in sampling activities. However, little attention has been given to evaluating electrofishing sampling efficiency in these systems. To evaluate differences in diel and seasonal electrofishing efficacy, largemouth bass were sampled in two diel periods (day: 0900–1500 h; night: 2100–0300 h) every three months over a three-year period in Lucchetti Reservoir, Puerto Rico, using a boom-mounted electrofisher. No overall statistical difference was observed between day and night electrofishing catch rates for stock-size (≥200 mm TL) largemouth bass in Lucchetti Reservoir ($F = 1.51$, df = 3, $P = 0.2222$), yet night catch rates were greater in 9 out of 12 samples. Monthly mean catch rates were lowest in May and highest in February. Length-frequency distributions differed between day and night samples in 3 out of 4 pooled sampling months (February, August, November; all $P \leq 0.0078$). If management objectives target high catch rates of largemouth bass, night electrofishing may be most efficient; however, length bias may be of concern and both day and night sampling may be necessary to accurately illustrate true population parameters.

Key words: *Micropterus salmoides,* small impoundment, diel sampling, sampling efficiency

Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 65:78–82

Electrofishing is the principal technique used for collecting largemouth bass (*Micropterus salmoides*); however, electrofishing efficiency has been shown to be controlled by a wide variety of physical, chemical, and biological factors including time of day, season, water temperature, conductivity, recruitment patterns, and habitat (Witt and Campbell 1959, Reynolds and Simpson 1978, Dumont and Dennis 1997, Gelos et al. 2010). Biases in electrofishing efficiency due to these factors have been observed to affect both catch rates and size distributions estimated by this gear (Burkhardt and Gutreuter 1995, Edwards et al. 1997, Sammons and Bettoli 1999, Schoenebeck and Hansen 2005, Hanson et al. 2008). Furthermore, behavior and habitat use of fishes can affect electrofishing efficiency both seasonally and over diel periods. For example, Sammons and Maceina (2005) found that largemouth bass were relatively sedentary and located offshore in deeper water during the day, but became more active at dusk and moved towards shoreline areas, where they remained during the night. Further, Waters and Noble (2004) found that under low water-conditions, largemouth bass were consistently found offshore and become more mobile.

Largemouth bass are the primary sport fish in Puerto Rico reservoirs (Neal et al. 2009), and population abundance and size-structure estimates are often obtained using electrofishing (Neal and Noble 2002, Neal et al. 2008). However, little attention has been given to evaluating efficiency of electrofishing sampling in these tropical systems. Therefore, the objectives of this study were to evaluate differences in diel and monthly electrofishing catch rates for largemouth bass, and to provide sampling recommendations for maximizing sampling efficiency in small Puerto Rico reservoirs.

Study Area

This study took place in Lucchetti Reservoir, a 108-ha impoundment in the mountain region of southwestern Puerto Rico. The area receives an average of 198 cm of rainfall annually and was originally tropical forest, although much of the landscape is now used for agriculture. The primary function of the reservoir is water storage for irrigation, but the creation of the Lucchetti Field Station and associated facilities by the Puerto Rico Department of Environmental and Natural Resources has improved recreational access and increased reservoir popularity among boating anglers (Churchill et al. 1995, Neal et al. 2009). The fish community in Lucchetti Reservoir consists of armored catfish (*Pterygoplichthys pardalis*), bluegill (*Lepomis macrochirus*), channel catfish (*Ictularis punctatus*), largemouth bass, marbled bullhead (*Amieurus nebulosus marmoratus*), Mozambique tilapia (*Oreochromis mossambicus*), redbreast tilapia (*Tilapia rendalli*), redear sunfish (*L. microlophus*), and threadfin shad (*Dorosoma petenense*) (Neal et al. 2009).

Lucchetti Reservoir has been categorized from mesotrophic to eutrophic on the basis of nutrients, physical limnology, chlorophyll *a*, and phytoplankton biomass data. Water transparency is usually >1 m and generally fluctuates 0.75 to 2.0 m (Churchill et al. 1995). Water temperature and photoperiod has a typical annual range of

25 to 29 C and 11 to 13 h daylight, respectively (Gran 1995). The maximum depth is 22.2 m (Neal et al. 1999).

Methods

Lucchetti Reservoir was sampled for largemouth bass by electrofishing during day (0900 to 1500 h) and night (2100 to 0300 h) every three months between May 1998 and February 2001. The months sampled were chosen to distribute effort among months recognized for spawning (i.e., February and May, Ozen and Noble 2002) and young-of-year recruitment (November, Ozen 2002), including a transition period (August). Sampling was conducted using a boom-mounted electrofisher at 240-V pulsed DC with a target output of 3,000 W. Prior to sampling, six shoreline sites were randomly established. Before each sample period, three sites were randomly chosen for the day sample and the three remaining sites were used for the night sample. Each site was sampled for 900 sec of electrofishing time. All largemouth bass were collected and measured for total length (mm).

To avoid the effects of variable recruitment and gear bias, only stock-size largemouth bass (≥200 mm; Gabelhouse 1984) were used for catch per-unit-effort and length-frequency comparisons. Before analyses, mean catch per-unit-effort and total length values for each sampling date were log-transformed to stabilize the variance to mean ratios. Mean catch-per-unit effort from each diel sampling period was pooled by month across years and compared using the two-way analysis of variance (ANOVA, SAS Institute 2008). Length distributions from each diel sampling period was also pooled by month across years and analyzed with multiple two-way Kolmogorov-Smirnov tests and the NPAR1WAY procedure (SAS Institute 2008). Significance was established at an alpha level of $P \leq 0.05$.

Results

Collectively, no differences were observed between day and night electrofishing catch rates for largemouth bass in Lucchetti Reservoir ($F = 1.51$, $df = 3$, $P = 0.2222$); however, mean catch per-unit-effort was greater during night than day in 9 of 12 sample periods (Table 1). Overall, mean catch per-unit-effort was highest in February and lowest in May (Figure 1). Among months, no statistical differences were observed in mean catch per-unit-effort between diel sampling periods ($F = 5.24$, df $= 3$, $P = 0.0953$); however, pair-wise comparisons showed differences between August and February ($P = 0.0411$), February and May ($P = 0.0004$), and May and November ($P = 0.0093$).

Day and night samples appeared to collect different size classes of fish (Figure 2). Day sampling tended to catch smaller (< 300 mm TL) largemouth bass in February ($P < 0.0001$) but larger fish (> 300 mm

Table 1. Mean catch per-unit-effort data for stock length (≥200 mm; Gabelhouse 1984) largemouth bass collected with electrofishing during day (0900 to 1500 h) and night (2100 to 0300 h) over a three-year period from Lucchetti Reservoir, Puerto Rico. The number of samples for each sampling period is in parenthesis.

		Day		Night	
Year	Month	Mean	SE	Mean	SE
1998	May	16.47 (1)	–	21.47 (1)	–
	Aug	48.00 (3)	10.6	120.00 (1)	–
	Nov	53.49 (3)	5.96	89.50 (2)	50.50
1999	Feb	92.46 (2)	32.47	80.15 (2)	36.15
	May	31.27 (3)	11.87	93.51 (3)	4.26
	Aug	67.54 (3)	30.51	62.38 (3)	3.49
	Nov	102.66 (3)	13.53	65.61 (2)	51.77
2000	Feb	132.41 (3)	16.66	172.66 (3)	48.89
	May	58.33 (3)	33.58	89.83 (3)	31.24
	Aug	84.84 (3)	21.67	114.75 (2)	47.25
	Nov	147.33 (3)	32.67	192.50 (2)	7.50
2001	Feb	112.16 (3)	15.84	113.07 (2)	6.92

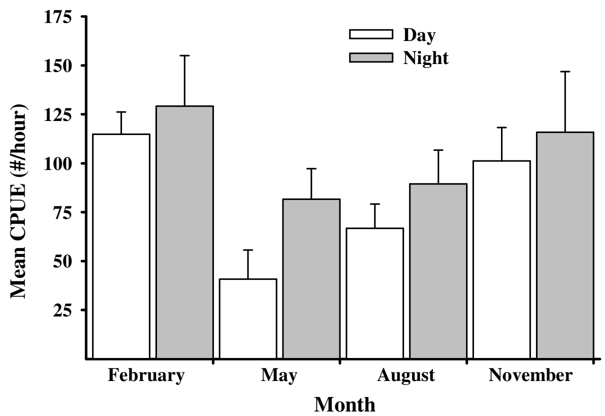

Figure 1. Mean catch-per-unit effort (number per hour of electrofishing; CPUE) by month for stock length (≥ 200 mm; Gabelhouse 1984) largemouth bass collected during day (0900 to 1500 h) and night (2100 to 0300 h) electrofishing in Lucchetti Reservoir, Puerto Rico. Monthly data are pooled across three years (May 1998 to February 2001). Error bars represent one standard error.

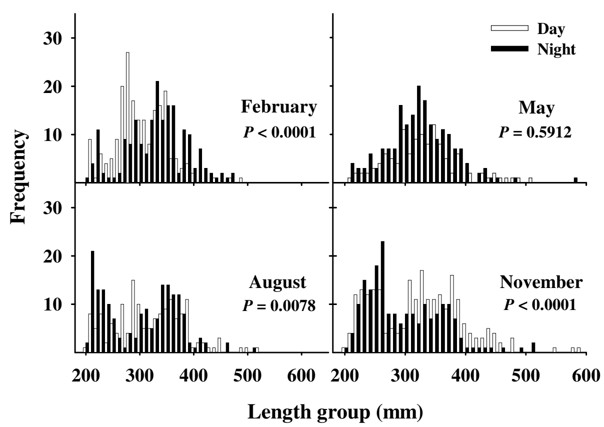

Figure 2. Length-frequency distributions by month for stock length (≥200 mm; Gabelhouse 1984) largemouth bass collected during day (0900 to 1500 h) and night (2100 to 0300 h) electrofishing in Lucchetti Reservoir, Puerto Rico. Monthly data are pooled across three years (May 1998 to February 2001).

TL) in November ($P < 0.0001$) than night sampling. August day sampling collected fewer of the smallest fish (< 260 mm TL) and more intermediate (270–300 mm TL) largemouth bass than night sampling ($P = 0.0078$).

Discussion

Although overall differences in diel catch rates were not evident in Lucchetti Reservoir, more fish were collected at night than day in 9 of 12 sampling periods. The lack of a significant difference might be a result of our sampling design or annual variation in diel catch rates. Regardless of the lack of statistical significance, mean night catch rates were on average 35% greater than mean day catch rates in all four sampling months when the data were pooled (Figure 2), suggesting that greatest electrofishing catch rates can be achieved by sampling during the night. This supports findings from temperate studies that reported greater largemouth bass catch rates at night (e.g., Gilliland 1987).

Observed differences in day versus night catch rates are most likely due to diel behavioral shifts and environmental factors. Nocturnal inshore movements of age-0 (Irwin and Noble 2000) and adult (Woodward and Noble 1999, Sammons and Maceina 2005) largemouth bass have been reported in temperate reservoirs of the continental United States. Malvestuto and Sonski (1990) hypothesized that largemouth bass followed bluegill feeding movements from the limnetic zone during the day to the littoral zone at night. A similar pattern was observed for telemetered largemouth bass in Lake Seminole (Sammons and Maceina 2005), which is a sunfish-dominated system (Sammons and Maceina 2006). Diet compositions for largemouth bass in Lucchetti Reservoir during the same time-frame as this electrofishing study found the most common prey items were threadfin shad and tilapia. However, diet composition varied among diel periods. During the day, threadfin shad composed 71% of largemouth bass diet by weight, while tilapia composed 22%; whereas at night threadfin shad composed only 55% of bass diet by weight, while tilapia composed 37% (Neal et al. 2001). It is possible that the diel differences in mean catch rates observed in Lucchetti Reservoir may have been influenced by diel changes in prey utilization, as threadfin shad prefer off-shore habitat while tilapia and sunfish tend to be littoral.

Miranda and Boxrucker (2009) recommended that most standardized electrofishing sampling should be conducted during the day, but noted that night electrofishing should be used when water transparency exceeds 1 m. Transparency in Lucchetti Reservoir is usually >1 m, suggesting that night electrofishing would be more effective than day electrofishing for conducting standardized sampling programs in this reservoir. Dumont and Dennis (1997) reported that water transparency explained diel variability in electrofishing catch rates in four of eight instances in which differences in catch rates were observed. In reservoirs with high turbidity, electrofishing catch rates of largemouth bass tend to be more similar between night and day sampling (e.g., Bennett and Brown 1969).

Monthly patterns in electrofishing catch rates were observed in Lucchetti Reservoir, with the greatest and lowest mean catch rates in February and May, respectively. This contradicts the pattern generally observed in temperate waters, where largemouth bass tend to be in deeper water during the late-winter pre-spawn period and then move shallower in the spring and are more vulnerable to electrofishing gear (Pope et al. 2009). Because water temperature (typical annual range 25 to 29 C) and photoperiod (11 to 13 h daylight) patterns are fairly consistent in Puerto Rico, spawning in Lucchetti Reservoir often commences as early as December or January and may be protracted over six months with peak spawning typically in February or March (Gran 1995, Waters 1999, Ozen and Noble 2002). This could explain the high catch rates in February, when male and female largemouth bass move shallow to spawn, and the low catch rate in May, when post-spawn largemouth bass may have moved off-shore to replenish energy reserves by feeding on threadfin shad (Waters 1999).

Another explanation for monthly differences in catch rates could be annual patterns in growth and gear-recruitment. In Lucchetti Reservoir, rapid (1.25 mm/d; Neal et al. 2002) growth of age-0 fish spawned between January and June leads to recruitment to stock size by November or for certain February, contributing to the greater catch rates during these months.

Differences in length-frequency distributions were observed in three out of four months sampled. Pooled by month, all months but May showed diel differences in length frequency distributions, yet the direction of these differences was not consistent throughout the year. Gilliland (1987) reported diel differences between day and night-collected length frequencies during the fall, but noted no diel differences during the spring. In May, all largemouth bass in Lucchetti Reservoir have recruited to stock-size, but no age-0 fish have recruited. As mentioned above, largemouth bass may have moved offshore in May to recover from spawning (Waters 1999), resulting in the observed lower catch rates. This movement would likely be size-specific, whereas larger fish are more likely to have moved offshore than smaller fish. This would provide a smaller size-range of fish available for sampling in May compared to other months, reducing the opportunity to detect differences in diel length frequency distributions. Diel differences in other months may be due to larger fish moving inshore at night, except in May, when they remained offshore to recover from spawning.

This study demonstrated how largemouth bass catch rates can vary temporally, and supported the importance for implementing standardized electrofishing protocols for this species in Puerto Rico. Diel differences in electrofishing catch-rates suggested that time of day and month should be carefully considered when establishing sampling protocols. For assessment purposes, the current protocol of standardized day sampling could be continued in order to maintain continuity with historical data sets. However, night electrofishing would be more efficient for large-scale collection efforts such as mark-recapture studies. Furthermore, mark-recapture electrofishing to estimate abundance of stock-size and larger largemouth bass is best conducted in February, because most age-0 fish are still very small and most age-1 fish are stock size (200 mm; Gabelhouse 1984) or larger at this time of year. Thus, by sampling in February there is no need to account for recruitment to stock size between marking efforts and recapture efforts for the population estimate. However, if the goal of the sampling is to measure recruitment, sampling in later months may be preferred.

Day and night electrofishing samples should not be used interchangeably for standardized sampling programs in Puerto Rico, due to likely diel differences in efficiency that may affect both catch-rate and size structure estimates. However, given that both day and night sampling have differential biases associated with them, combining day and night sampling may more accurately illustrate true population parameters. Because the physicochemical environments of most Puerto Rico reservoirs are relatively homogenous, our results may be extended to unstudied Puerto Rico systems of similar size to Lucchetti Reservoir. Furthermore, habitat heterogeneity can affect the determination of stock structure indices, therefore an SDI and a better evaluation of the distance of shoreline sampled may need to be considered in future electrofishing events.

Acknowledgments

We thank the personnel of the Puerto Rico Department of Natural and Environmental Resources (DNER), Division of Marine Resources and Division of Reserves and Refuges. Additionally, numerous North Carolina State University employees also provided assistance including, but not limited to, Dan Ashe, Grisel Rodriguez-Ferrer, Felix Del Toro, and Diana Mora-Pinto. We also thank Mississippi State University employees Don Jackson, Peter Allen and Steve Miranda for sharing their analytical and statistical expertise. Funding was provided through Federal Aid in Sport Fish Restoration under Puerto Rico DNER Projects F-41-2 and F-53.

Literature Cited

Bennett, C. D. and B. E. Brown. 1969. A comparison of fish population sampling techniques on Lake Raymond in Gary, Oklahoma. Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners 22:424–444.

Burkhardt, R. W. and S. Gutreuter. 1995. Improving electrofishing catch consistency by standardizing power. North American Journal of Fisheries Management 15:375–381.

Churchill, T. N., R. L. Noble, J. E. Gran, and A. R. Alicea. 1995. Largemouth bass recruitment in Lucchetti Reservoir. Puerto Rico Department of Natural and Environmental Resources, Federal Aid in Sport Fish Restoration, Final Report, Project F-16, Study 2, San Juan.

Dumont, S. C. and J. A. Dennis. 1997. Comparison of day and night electrofishing in Texas reservoirs. North American Journal of Fisheries Management 17:939–946.

Edwards, C. M., R. W. Drenner, K. L. Gallo, and K. E. Rieger. 1997. Estimation of population density of largemouth bass in ponds by using mark-recapture and electrofishing catch per effort. North American Journal of Fisheries Management 17:719–725.

Gabelhouse, D. W., Jr. 1984. A length-categorization system to assess fish stocks. North American Journal of Fisheries Management 4:273–285.

Gelos, M., F. Teixeira-de Mello, G. Goyenola, C. Iglesias, C. Fosalba, F. Garcia-Rodriguez, J. P. Pacheco, S. Garcia, M. Meerhoff. 2010. Seasonal and diel changes in fish activity and potential cascading effects in subtropical shallow lakes with different water transparency. Hydrobiologia 646(1):173.

Gilliland, E. 1987. Evaluation of Oklahoma's standardized electrofishing in calculating population structure indices. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies 39:277–287.

Gran, J. E. 1995. Gonad development and spawning of largemouth bass in a tropical reservoir. Master's thesis. North Carolina State University, Raleigh.

Hanson, K. C., C. T. Hasler, S. J. Cooke, C. D. Suski, D. P. Philipp. 2008. Intersexual variation in the seasonal behaviour and depth distribution of a freshwater temperate fish, the largemouth bass. Canadian Journal of Zoology 86(8):801.

Irwin, E. R. and R. L. Noble. 2000. Diel distribution of age-0 largemouth bass, *Micropterus salmoides*, in B. E. Jordan Lake, North Carolina (USA) and its relation to cover. Ecology of Freshwater Fish 9:229–235.

Malvestuto, S. P. and A. J. Sonski. 1990. Catch rate and stock structure: a comparison of daytime versus nighttime electric fishing on West Point Reservoir, Georgia, Alabama. Pages 210–218 *in* I. G. Cowx, editor. Developments in electric fishing. Blackwell Scientific Publications, Oxford, UK.

Miranda, L. E. and J. Boxrucker. 2009. Warmwater fish in large standing waters. Pages 29–42 *in* S. A. Bonar, W. A. Hubert, and D. W. Willis, editors. Standard methods for sampling North American freshwater fishes. American Fisheries Society, Bethesda, Maryland.

Neal, J. W., C. G. Lilyestrom, and T. J. Kwak. 2009. Factors influencing tropical island freshwater fishes: species, status, and management implications in Puerto Rico. Fisheries 34(11):546–554.

———, ———, and R. L. Noble. 2008. Tropical reservoir fisheries in Puerto Rico: adaptive management through applied research. Pages 681–697 *in* M. S. Allen, S. Sammons, and M. J. Maceina, editors. Balancing fisheries management and water uses for impounded river systems. American Fisheries Society, Symposium 62, Bethesda, Maryland.

——— and R. L. Noble. 2002. Growth, survival, and site fidelity of Florida and intergrade largemouth bass stocked in a tropical reservoir. North American Journal of Fisheries Management 22:528–536.

———, ———, C. G. Lilyestrom, N. M. Bacheler, and J. C. Taylor. 2001. Freshwater sportfish community investigations and management. Puerto Rico Department of Natural and Environmental Resources, Federal Aid in Sport Fish Restoration, Final Report, Project F-41, Study 2, San Juan.

———, ———, ———, T. N. Churchill, A. R. Alicea, D. E. Ashe, F. M. Holliman, and D. S. Waters. 1999. Freshwater sportfish community investigations and management. Puerto Rico Department of Natural and Environmental Resources, Federal Aid in Sport Fish Restoration, Final Report, Project F-41, Study 2, San Juan.

———, ———, and T. N. Churchill. 2002. Timing of largemouth bass supplemental stocking in a tropical reservoir: impacts on growth and survival. Pages 691–701 *in* D. P. Philipp and M. S. Ridgway, editors. Black Bass: Ecology, Conservation, and Management. American Fisheries Society, Bethesda, Maryland.

Ozen, O. 2002. Population dynamics of largemouth bass in Lucchetti Reservoir, Puerto Rico. Doctoral Dissertation, North Carolina State University, Raleigh.

——— and R. L. Noble. 2002. Relationship between water level fluctuations and largemouth bass spawning in a Puerto Rico reservoir. Pages 213–220 *in* D. P. Philipp and M. S. Ridgway, editors. Black bass: ecology, conservation, and management. American Fisheries Society, Symposium 31, Bethesda, Maryland.

Pope, K. L., R. M. Neumann, and S. D. Bryan. 2009. Warmwater fish in small standing waters. Pages 13–27 *in* S. A. Bonar, W. A. Hubert, and D. W. Willis, editors. Standard methods for sampling North American freshwater fishes. American Fisheries Society, Bethesda, Maryland.

Reynolds, J. B. and D. E. Simpson. 1978. Evaluation of fish sampling methods and rotenone census. Pages 11–24 *in* G. D. Novinger and J. G. Dillard, editors. New approaches to the management of small impoundments. American Fisheries Society, North Central Division, Special Publication 5, Bethesda, Maryland.

Sammons, S. M. and P. W. Bettoli. 1999. Spatial and temporal variation in electrofishing catch rates of three species of black bass (*Micropterus* spp.) from Normandy Reservoir, Tennessee. North American Journal of Fisheries Management 19:454–461.

——— and M. J. Maceina. 2005. Activity patterns of largemouth bass in a subtropical US reservoir. Fisheries Management and Ecology 12:331–339.

——— and ———. 2006. Changes in diet and food consumption of largemouth bass following large-scale hydrilla reduction in Lake Seminole, Georgia. Hydrobiologia 560:109–120.

SAS Institute. 2008. SAS procedures guide, version 9.2. SAS Institute, Cary, North Carolina.

Schoenebeck, C. W. and M. J. Hansen. 2005. Electrofishing catchability of walleyes, largemouth bass, smallmouth bass, northern pike, and muskellunge in Wisconsin lakes. North American Journal of Fisheries Management 25:1341–1352.

Waters, D. S. 1999. Spawning season and mortality of adult largemouth bass (*Micropterus salmoides*) in a tropical reservoir. Master's thesis. North Carolina State University, Raleigh.

——— and R. L. Noble. 2004. Spawning season and nest fidelity of largemouth bass in a tropical reservoir. North American Journal of Fisheries Management 24:1240–1251.

Witt, A. and R. S. Campbell. 1959. Refinements of equipment and procedures in electrofishing. Transactions of the American Fisheries Society 88:33–35.

Woodward, K. O. and R. L. Noble. 1999. Over-winter movements of adult largemouth bass in a North Carolina Reservoir. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies 51:113–122.