Optimizing Sampling Protocol for Largemouth Bass and Bluegill in Small Impoundments

Jarrad T. Kosa,[1] *Lake Fisheries Research Section, Kentucky Department of Fish and Wildlife Resources, 1 Game Farm Road, Frankfort, KY 40601*

R. Scott Hale, *Inland Fisheries Research Unit, Ohio Division of Wildlife, 10517 Canal Road SE, Hebron, OH 43025*

Abstract: Fisheries managers need to minimize sampling effort required to provide statistically reliable data for cost effective monitoring and assessment. Shoreline electrofishing methods used to estimate abundance and size structure of largemouth bass (*Micropterus salmoides*) and bluegill (*Lepomis macrochirus*) may be affected by seasonal variability of littoral habitat use by these species. A fixed standard of 3 15-minute electrofishing samples did not provide CPUE estimates that we considered precise enough to consistently use for management decisions on 4 50- to 119-ha Kentucky impoundments. Due to intra-reservoir variability that resulted in occasional over-sampling and, more commonly, under-sampling, we proposed dynamic sample-size protocols that are unique to each system and derived from reservoir-specific variability. This approach is the equivalent of highly specific stratification by reservoir type and is more consistent with current reservoir-specific management and regulation trends.

Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 52:111–118

Standardized sampling methods are commonly used to compare abundance and size distributions of animal populations from similar habitats (Eberhardt 1978, Krebs 1989, Ney 1993). The Kentucky Department of Fish and Wildlife Resources currently uses a standard minimum effort of 3 15-minute electrofishing samples to estimate abundance and length distributions of largemouth bass and bluegill. These data are collected during a single evening between 1 April and 1 June with 2 dip netters, standardized gear, and specific target species to minimize variability. This study was conducted to determine if 3 electrofishing samples provided adequate precision and if the target window of time for sampling was appropriate for largemouth bass and bluegill in Kentucky impoundments.

1. Present address: Office of Energy Products, Federal Regulatory Commission, 888 First Street NW, Washington, D.C. 20426

The authors thank G. Buynak, B. Kinman, L. E. Miranda, D. Riecke and 2 anonymous reviewers for their editorial comments and manuscript review. K. Frey provided technical assistance. A special appreciation is extended to G. R. Wilde and S. Malvestuto who provided much insight regarding the statistical aspects of this study.

Methods

Littoral areas of 4 50- to 119-ha central Kentucky impoundments were sampled with shoreline electrofishing methods. All reservoirs were eutrophic (Ky. Div. Water 1994) with maximum depths of 9–15 m, mean depths of 3–6 m, and mid-summer Secchi disk transparencies <1 m. Fish communities were composed of largemouth bass, bluegill, *Lepomis* spp., channel catfish (*Ictalurus punctatus*), and the primary prey was gizzard shad (*Dorosoma cepedianum*).

Largemouth bass and bluegill were sampled bi-weekly by nocturnal electrofishing during 10 April to 8 June 1995. A Smith-Root model GPP 5.0 electrofishing unit with pulsed direct current (60 pulses/sec, 4–6 amperes) was operated from a 5-m aluminum boat. Two bow-positioned dippers collected only largemouth bass or only bluegill on alternate samples, and 6 successive samples were collected each night. The boat was driven at idle speed parallel to the shoreline from fixed-site starting points. Total length (nearest 1 mm) of each fish was measured immediately prior to release in an area away from the sample site. Bluegill were length-grouped as stock (<152 mm) or quality (≥152 mm), and largemouth bass were length-grouped as subadults (<254 mm), adults (≥254 mm), and preferred-length (≥381 mm). Surface water temperature (C) was measured immediately prior to the first sample each evening.

The number of 15-minute samples required for 2 levels of precision were determined for each sampling date on each lake. Two levels of precision were considered: (1) within 50% of the true median (±50%) and (2) within 25% of the true median (±25%). Both levels of precision were examined at the 95% confidence level and they correspond to standards established by Robson and Regier (1964) for preliminary surveys (±50%) and for management studies (±25%). Sample size was calculated as:

$$N = \frac{(Z^2 s_y{}^2)}{[\log_{10}(\text{RE} + 1)]^2}$$

where $Z = 1.96$, the ordinate of the normal curve at the 95% confidence level; s_y2 = variance of transformed data [$Y = \log_{10}(\text{CPUE} + 1)$]; and RE = relative error about the median CPUE (Gilbert 1987). This method uses variance of the log-transformed CPUE data to determine sample sizes (Gilbert 1987, Van Den Avyle et al. 1995). Mean CPUE (fish/hour) and the coefficient of variation of the mean ($CV_{\bar{x}} = SE/\bar{x}$ were calculated for all length categories of largemouth bass and bluegill. CPUE data were not normally distributed and therefore transformed with $Y = \log_{10}(X + 1)$, where X = CPUE, to normalize data and stabilize variance.

We sought to identify dates for estimating CPUE that would represent peak abundance and low sampling variability to minimize sampling effort and maximize data utility. We used regression and correlation approaches to explore relations between catch rates, sampling date, and water temperature. Temporal trends in littoral abundance for each species for each lake were examined through regression of mean CPUE on Julian date of each sample. Relations between temperature and mean CPUE of all length groups of largemouth bass and bluegill were evaluated using Pearson correlation coefficients. For all regressions and correlations, CPUE data were log-transformed [$\log_{10}$ (CPUE+1)] to normalize data and stabilize variances.

Results

Largemouth Bass

CPUE of all lengths of largemouth bass were highly variable across lakes and through time (Table 1). The $CV_{\bar{x}}$ ranged from 6 to 39% (mean = 14%) and was con-

Table 1. Number of 15-minute electrofishing samples required to estimate largemouth bass (all lengths) CPUE with confidence limits of ±25% and ±50% about the median in 4 Kentucky reservoirs. Limits were calculated based on a 95% level of confidence.

		Electrofishing		*N* required for a confidence limit of	
Reservoir	Water temperature (C)	Mean CPUE (fish/hour)	$CV_{\bar{x}}$ (%)	±25%	±50%
10–13 Apr					
A. J. Jolly	15.0	89	19	11	3
Bullock Pen	13.0	124	11	2	1
Linville	15.5	108	7	1	1
Willisburg	18.0	193	14	4	1
24–27 Apr					
A. J. Jolly	14.5	119	6	1	1
Bullock Pen	14.5	117	19	9	3
Linville	15.5	140	20	11	3
Willisburg	17.0	179	8	1	1
8–11 May					
A. J. Jolly	20.5	125	11	2	1
Bullock Pen	18.0	133	9	6	1
Linville	20.5	167	20	11	3
Willisburg	20.5	173	9	2	1
22–25 May					
A. J. Jolly	24.0	69	13	4	1
Bullock Pen	22.0	96	19	8	2
Linville	24.0	125	39	30	9
Willisburg	25.5	140	8	1	1
5–8 Jun					
A. J. Jolly	28.0	63	18	8	3
Bullock Pen	27.0	83	7	1	1
Linville	25.5	53	20	7	2
Willisburg	29.0	101	6	1	1

sistently highest at Linville Lake (mean $CV_{\bar{x}}$ = 21%). Largemouth bass CPUE was greater during the second and third sample periods (24–27 Apr and 8–11 May) than the earlier or later dates. Regression analyses suggested that littoral abundances declined through the sampling period at all lakes ($P \leq 0.10$).

The number of electrofishing samples required for acceptable precision varied considerably. Between 1 and 30 (mean = 6) samples were required to obtain precision of ± 25% and 1–28 (mean = 2) samples were required for precision of ± 50%. Fewer samples were required for the ± 25% level of precision during 24–27 April and 8–11 May (mean = 4.9, SE = 1.7), compared to the other sample periods (mean = 6.6, SE = 1.9).

Catch rates for subadults were 1.7 times less than for adults and suggested either size-selective sampling, variable year-class strength, or offshore aggregation of subadults. The $CV_{\bar{x}}$ for subadult catch rates ranged from 9% to 46% (mean = 24%), and 2–63 (mean = 15) samples were required to obtain a precision level of ± 25% and 1–19 (mean = 4) electrofishing samples were required for a precision level of ± 50%. Littoral abundance of adult largemouth bass peaked during April and early May. The $CV_{\bar{x}}$ ranged from 3% to 32% (mean = 16%), and 1–26 (mean = 7) samples were required for a precision level of ± 25% and 1–8 (mean = 2) to achieve a precision level of ± 50%.

No clear trend in seasonal abundance for preferred-length largemouth bass was apparent due to low CPUE and high variability. The $CV_{\bar{x}}$ ranged from 7% to 43% (mean = 25%). To obtain a precision level of ± 25%, 1–60 (mean = 14) samples were required, whereas 1–18 (mean = 4) samples were needed to achieve the ± 50% level of precision.

The water temperature ranged from 14.5 to 20.5 C during the period of peak littoral abundance of largemouth bass. Negative relations between temperature and mean CPUE of all lengths of largemouth bass combined were observed for A. J. Jolly ($P = 0.05$, $r^2 = 0.26$), Bullock Pen ($P = 0.07$, $r^2 = 0.23$) and Willisburg lakes ($P = 0.001$, $r^2 = 0.61$). Similarly, negative relations were observed between temperature and catch rate of subadults at A. J. Jolly ($P = 0.06$, $r^2 = 0.25$), Linville ($P = 0.07$, $r^2 = 0.23$) and Willisburg lakes ($P = 0.01$, $r^2 = 0.41$). Temperature and catch rates were not related for either adult or preferred-length bass.

Bluegill

Catch rates for all bluegill length groups were highly variable (Table 2). Catch rates for all sizes combined ($P \leq 0.05$) and for stock-length bluegill ($P < 0.05$) declined from early April through early June at all 4 study lakes. For all lengths combined, $CV_{\bar{x}}$ ranged from 4% to 37% (mean = 17%), from 1 to 37 (mean = 10) samples were required to obtain precision of ± 25% and 1–11 (mean = 3) samples were needed for precision of ± 50% (Table 2). For stock-length bluegill, the $CV_{\bar{x}}$ ranged from 5% to 43% (mean = 19%), from 1 to 41 (mean = 12) samples were needed to estimate abundance at ± 25% of the median and 1–12 (mean = 4) samples were required to estimate small bluegill abundance at ± 50% of the median.

Table 2. Number of 15-minute electrofishing samples required to estimate bluegill (all lengths) CPUE with confidence limits of ± 25% and ± 50% about the median in 4 Kentucky reservoirs. Limits were calculated based on a 95% level of confidence.

Reservoir	Water temperature (C)	Electrofishing Mean CPUE (fish/hour)	Electrofishing $CV_{\bar{x}}$ (%)	*N* required for a confidence limit of ±25%	*N* required for a confidence limit of ±50%
10–13 Apr					
A. J. Jolly	15.0	303	5	1	1
Bullock Pen	13.0	1,285	7	1	1
Linville	15.5	879	31	33	10
Willisburg	18.0	645	4	1	1
24–27 Apr					
A. J. Jolly	14.5	397	12	3	1
Bullock Pen	14.5	768	5	1	1
Linville	15.5	633	23	11	3
Willisburg	17.0	264	24	18	6
8–11 May					
A. J. Jolly	20.5	212	26	13	4
Bullock Pen	18.0	617	10	3	1
Linville	20.5	728	4	1	1
Willisburg	20.5	247	21	15	5
22–25 May					
A. J. Jolly	24.0	127	37	27	8
Bullock Pen	22.0	655	27	17	5
Linville	24.0	431	16	6	2
Willisburg	25.5	29	10	2	1
5–8 Jun					
A. J. Jolly	28.0	219	29	16	5
Bullock Pen	27.0	241	14	4	1
Linville	25.5	101	7	1	1
Willisburg	29.0	185	32	37	11

The littoral abundance of quality-length bluegills was highly variable at all lakes and decreased through the study period only in Linville ($P = 0.02$, $r^2 = 0.33$) and Willisburg lakes ($P = 0.007$, $r^2 = 0.44$). The $CV_{\bar{x}}$ ranged from 2% to 65% (mean = 28%) and 1–78 (mean = 24) samples were required to estimate abundance at ± 25% precision and 1–24 (mean = 7) samples were required for ± 50% precision.

Water temperatures ranged from 13.0 to 20.5 C during the period of peak bluegill abundance. CPUE was inversely related to water temperature for all bluegill combined ($P \leq 0.05$) and stock-length bluegill ($P \leq 0.05$) at all lakes. However, catch rates of large bluegills and temperature were negatively related at Linville ($P = 0.01$, $r^2 = 0.37$) and Willisburg lakes ($P = 0.02$, $r^2 = 0.34$).

Discussion

The use of a fixed number of 3 electrofishing samples was an inefficient approach to monitoring abundance of largemouth bass and bluegill populations in small Kentucky impoundments. This protocol resulted in over-sampling in some cases and under-sampling in most cases. Universally increasing the minimum effort requirements may improve the precision of abundance estimates but unnecessarily increase sampling costs when fewer samples are adequate. Therefore, we recommend establishing reservoir-specific sample sizes based on reservoir-specific variability. Statewide or regional sample sizes are best applied where system-specific variability is unknown prior to the initial sampling effort (Cyr et al. 1992, Wilde 1995). Given the temporal and spatial differences in sample variances, managers need the flexibility to modify sampling effort even within a single system. Variability-based reservoir-specific sampling is likely the best approach for collecting statistically reliable data in a cost-effective way within these reservoirs.

Variability-based reservoir-specific sampling would allow managers greater adaptability as needs for precision change. While abundance estimates for both largemouth bass and bluegill, especially for specific length groups, occasionally required an unrealistic number of samples to attain precision greater than ±50%, this may be both lake- and time-specific. Therefore, managers should not feel constrained to the less precise standard of ±50%, recommended by Robson and Regier (1964) for preliminary surveys, particularly when attempting to detect changes in gross abundance. This level of precision is likely acceptable for initial investigations (Robson and Regier 1964, Johnson and Nielson 1983, Wilde and Fisher 1996); however, precision approaching ±25% is likely more desirable in most management settings.

Fisheries managers should also consider using the coefficient of variation of the mean, also referred to as the relative standard error (RSE = 100 × SE/mean), as a quick standard to evaluate the precision of their data in the field. The RSE has been used in fisheries research and management for assessing the precision of creel surveys and population estimates (Malvestuto et al. 1978, Knight and Malvestuto 1991, Cyr et al. 1992). Our data analyses and review of accepted precision levels support the establishment of a target RSE of 15%–20% for standardization purposes. For example, a target RSE of 15% indicates that the desired level of precision is ±30% of the mean at the 95% confidence level (Wilde and Fisher 1996).

We identified a sampling window of 3 weeks in which the availability of largemouth bass in all study sites was at consistently similar, high levels in small Kentucky reservoirs. Largemouth bass CPUE during the 24–27 April and 8–11 May sample periods was greater than the other 3 sample periods, although temperature was not a strong predictor for largemouth bass catch rates in our study. However, declining abundance for all lengths of largemouth bass during the study period suggested that water temperature or calendar date may be useful guidelines for standardizing sampling times.

We have also shown that catch rates of fish within specific length classes are often associated with much greater variability than when all lengths combined are considered. Managers must realize that more samples will be required when they seek precise abundance information for specific length groups.

Sampling to characterize the size structure of bluegill populations is difficult in general and this difficulty may increase during later months. Bluegill could not be sampled effectively in many cases with only 3 samples. Our data suggested that the sampling effort required to precisely estimate the size structure of bluegill populations was more than our current standard minimum of 3 samples. Fewer samples were required in April than in May and June. This is probably due to the decline in bluegill abundance along the shoreline in later months. We observed a similar pattern for stock-length bluegills. However, quality-length bluegills could only have been sampled at ±50% precision with ≤8 samples in April and often could not have been sampled adequately during the May and June sample dates without considerable effort.

Peak abundance periods of bluegill coincided with those of largemouth bass. Catch rates declined from early April through June for total and stock-length bluegill, but not for samples of quality length bluegill. Temperature was related to catch rates of bluegill but not largemouth bass. Seasonal fluctuations in the vulnerability of largemouth bass to shoreline electrofishing has been related to water temperature in other studies (Carline et al. 1984, Hall 1986). To predict peak abundance of both largemouth bass and bluegill in small impoundments, further research should focus on the relationships between fish availability and water temperature.

Managers can control sample time and duration. Variance has been shown to decrease as sample duration and catch increase; however, short duration samples (5 and 10 minutes) may result in less total effort when travel time between sample sites is <30 minutes (Miranda et al. 1996). Furthermore, Hardin and Connor (1992) point out that increasing the sample duration results in sampling diverse habitats during the same sample which may have unpredictable effects. Stratification by habitat may be a viable option; however, the habitat delineation required increases management and research costs and therefore may not be feasible for management agencies.

Our results indicated that the minimum number of 3 electrofishing samples rarely provided adequate precision to describe largemouth bass or bluegill abundance in small Kentucky impoundments. We recommend that managers of small largemouth bass-bluegill impoundments base electrofishing sample sizes on system-specific variability rather than a universal and fixed number of electrofishing samples. In addition, sources of variability must be better understood in order to more effectively stratify samples by abiotic factors. This will ultimately help field biologists reduce the cost of obtaining statistically precise data.

Literature Cited

Carline, R. F., B. L. Johnson, and T. J. Hall. 1984. Estimation and interpretation of proportional stock density for fish populations in Ohio impoundments. North Am. J. Fish. Manage. 4: 139–154.

Cyr, H., J. A. Downing, S. LaLonde, S. B. Baines, and M. L. Pace. 1992. Sampling larval fish populations: choice of sample size and number. Trans. Am. Fish. Soc. 121:356–368.

Eberhardt, L. L. 1978. Appraising variability in population studies. J. Wildl. Manage. 42:207–238.

Gilbert, R. O. 1987. Statistical methods for environmental pollution monitoring. Van Nostrand Reinhold, New York, N.Y. 320pp.

Hall, T. J. 1986. Electrofishing catch per hour as an indicator of largemouth bass density in Ohio impoundments. North Am. J. Fish. Manage. 6:397–400.

Hardin, S. and L. L. Connor. 1992. Variability of electrofishing crew efficiency, and sampling requirements for estimating reliable catch rates. North Am. J. Fish. Manage. 12:612–617.

Johnson, D. L. and L. A. Nielsen. 1983. Sampling considerations. Pages 1–21 *in* L. A. Nielsen and D. L. Johnson, eds. Fisheries techniques. Am. Fish. Soc., Bethesda, Md.

Kentucky Division of Water. 1994. Kentucky report to congress on water quality. Commonwealth Ky. Nat. Resour. and Environ. Protection Cabinet, Div. Water, Frankfort. 298pp.

Knight, S. S. and S. P. Malvestuto. 1991. Comparison of three allocations of monthly sampling effort for the roving creel survey on West Point Lake. Am. Fish. Soc. Symp. 12:97–101.

Krebs, C. J. 1989. Ecological methodology, 3rd ed. Harper Collins Publ., New York, N.Y. 654pp.

Malvestuto, S. P., W. D. Davies, and W. L. Shelton. 1978. An evaluation of the roving creel survey with nonuniform probability sampling. Trans. Am. Fish. Soc. 107:255–262.

Miranda, L. E., W. D. Hubbard, S. Sangare, and T. Holman. 1996. Optimizing electrofishing sample duration for estimating relative abundance of largemouth bass in reservoirs. North Am. J. Fish. Manage. 16:324–331.

Ney, J. J. 1993. Practical use of biological statistics. Pages 137–158 *in* C. C. Kohler and W. A. Hubert, eds. Inland fisheries management in North America. Am. Fish. Soc., Bethesda, Md.

Robson, D. S. and H. A. Regier. 1964. Sample size in Petersen mark-recapture experiments. Trans. Am. Fish. Soc. 93:215–226.

Van Den Avyle, M. J., G. R. Ploskey, and P. W. Bettoli. 1995. Evaluation of gill-net sampling for estimating abundance and length frequency of reservoir shad populations. North Am. J. Fish. Manage. 15:898–917.

Wilde, G. R. 1995. Gill net sample size requirements for temperate basses, shads, and catfishes. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 47:588–595.

——— and W. L. Fisher. 1996. Reservoir fisheries sampling and experimental design. Am. Fish. Soc. Symp. 16:397–409.