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Sampling Channel Catfish with Tandem Hoop Nets in Small Impoundments

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Abstract.—Because populations of channel catfish *Ictalurus punctatus* have been difficult to sample in small impoundments, we determined whether tandem hoop net series (three nets tied in series and baited with cheese) fished for 3 d could effectively sample these populations. In 2000 we compared seasonal catch rates (catch per unit effort [CPUE], defined as the number of fish caught per series) and length frequencies (total length [TL]; mm) of channel catfish captured with two types of tandem series (long versus short bridles) and monitored the mortality of channel catfish along with the CPUE and mortality of bycatch in five lakes. Mean CPUE ranged from 12 to 194 fish/series for channel catfish and from 5 to 101 fish/series for bycatch among series types, lakes, and sampling periods. Mean CPUE for channel catfish and bycatch was similar between series types and did not consistently vary with sampling period. Length frequencies of channel catfish were usually similar between series types. Mortality was low for both channel catfish (0.3% of total catch) and bycatch (8%). In 2001, using short-bridled series, we assessed gear size bias in one lake; sampled 66 lakes that are stocked annually with channel catfish fingerlings at rates of 12, 37, or 74/ha; and estimated the sample sizes required for precise estimates of mean CPUE and accurate estimates of size structure. Hoop nets failed to capture channel catfish less than 250 mm TL in proportion to their abundance. Mean CPUE among 62 lakes ranged from 0.5 to 369.7 channel catfish/series and increased with stocking rate. Four lakes were excluded because of the high catch and mortality of turtles. Mean TL ranged from 276 to 463 mm among the lakes and decreased with stocking rate. For moderate precision (coefficient of variation [100·SE/mean] = 0.2) of mean CPUE, from 12 to nearly 50 series were required, and length measurements from 300 fish were necessary for accurate assessments of size structure. Tandem hoop netting provided adequate samples of channel catfish in most small impoundments, but obtaining precise estimates of CPUE may be difficult; moreover, turtle mortality can be problematic in some lakes.

Channel catfish *Ictalurus punctatus* are a popular sport fish in many small impoundments (<200 ha) in the Midwestern and southern United States. Catfish anglers in Missouri accounted for 21% of the total angling effort in small impoundments, second only to black bass *Micropterus* spp. anglers (Weithman 1991). Natural recruitment of channel catfish is usually very low in these impoundments, primarily because of predation by largemouth bass *M. salmoides* (Marzolf 1957; Krummrich and Heidinger 1973; Spinelli et al. 1985; Storck and Newman 1988), so populations are maintained by supplemental stocking. Large fingerlings (>175 mm total length; TL) are commonly stocked to reduce vulnerability to predation (Krummrich and Heidinger 1973; Storck and Newman 1988; Michaletz and Dillard 1999). These stockings represent a substantial investment of effort and money for many state agencies.

Despite the importance of these fisheries, little is known about channel catfish populations in small impoundments because they are difficult to sample. Several methods have been used to sample channel catfish in impoundments, including gill nets (Hanson 1986; Stevenson and Day 1986; Wilde 1995; Howell and Betsill 1999; Mitzner 1999; Santucci et al. 1999), hoop nets (Hanson 1986; Walker et al. 1996; Howell and Betsill 1999), trap nets (Marshall 1991), slat traps (Perry 1979; Hanson 1986; Santucci et al. 1994), wire fish traps (Perry and Williams 1987; Crumpton et al. 1988), electrofishing (Santucci et al. 1994, 1999; Dudash and Heidinger 1996), trot lines (Ste-

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venson and Day 1986; Santucci et al. 1994, 1999; Dudash and Heidinger 1996), trawls (Stevenson and Day 1986), and trammel nets (Ware 1967). In small impoundments, gill nets, trap nets, or electrofishing are the methods used most frequently to sample channel catfish (Michaletz and Dillard 1999). Of these three, gill nets may be the most effective (Robinson 1999; Santucci et al. 1999), but they can cause high mortality of captured fishes (Hubert 1983), can be highly size selective (Hubert 1983), and may not provide high catch rates of channel catfish (Mitzner 1999; Robinson 1999; Santucci et al. 1999; Michaletz 2001).

Hoop nets set singly are commonly used to capture channel catfish in lotic systems (Hesse et al. 1982; Gerhardt and Hubert 1991; Michaletz and Dillard 1999) but are not effective in small impoundments (Hanson 1986; Robinson 1999; Michaletz 2001). In a recent study, however, Sullivan and Gale (1999) reported that tandem hoop nets (three nets tied in series) captured more channel catfish per effort than did gill nets in a 377-ha reservoir. Tandem hoop nets also were associated with less mortality of captured fish than were gill nets (Sullivan and Gale 1999) and may be a good alternative to gill nets. The reservoir sampled by Sullivan and Gale (1999) contained a self-sustaining channel catfish population with high natural recruitment, an environment considerably different from small impoundments, where natural recruitment is negligible and populations are maintained by stocking.

Our objective was to determine whether baited hoop nets fished in tandem could effectively sample channel catfish in small impoundments. Initially, we compared seasonal catch rates of channel catfish and bycatch (fishes other than channel catfish) and length frequencies of channel catfish captured in two types of tandem hoop nets (long versus short bridle). Mortality of channel catfish and bycatch were also recorded. Then, we assessed size bias of tandem hoop nets by sampling a channel catfish population of known size structure. Finally, tandem hoop nets were used to sample channel catfish in 66 lakes across the state of Missouri to evaluate the effectiveness of this method in providing adequate samples of channel catfish for population assessment.

Methods

Tandem hoop net comparisons.—Channel catfish in Blind Pony (65 ha), Edwin A. Pape (99 ha), Little Dixie (83 ha), Macon (81 ha), and Maple Leaf (57 ha) lakes were each sampled for 3 d twice in May–June and once in October 2000 with two types of tandem hoop net series. All five lakes are located in central Missouri and are stocked annually with large (mean TL = 230 − 250 mm) channel catfish fingerlings in late September to mid-October. Stocking rates during this study were 74 fingerlings/ha for Blind Pony Lake, 12/ha for Edwin A. Pape and Little Dixie lakes, 25/ha for Macon Lake, and 37/ha for Maple Leaf Lake. In addition to channel catfish, these shallow, eutrophic impoundments provide fisheries for largemouth bass, crappies *Pomoxis* spp., bluegills *Lepomis macrochirus*, and redear sunfish *L. microlophus*.

The two types of tandem hoop net series differed: One type (long bridles) contained 6-m bridles that separated consecutive nets (Walker et al. 1996; Sullivan and Gale 1999); the other type (short bridles) contained 1-m bridles. For both types, the cod end of one net was attached directly to a bridle attached to the mouth of the next net. Hoop nets were about 3.4 m long made up of seven fiberglass hoops about 0.8 m in diameter (hoop size slightly decreased from the mouth to cod end of the net) and constructed of 25-mm-bar mesh. Mesh with 25-mm-square openings appears to be optimal for sampling a broad size range of channel catfish (Hesse et al. 1982; Sullivan and Gale 1999). The hoop nets contained a fingered crowfoot-style throat on the second and fourth hoops. The rear throat (on fourth hoop) of all hoop nets was further constricted by tying the throat strings together about 15 cm from the cod end of the throat so that fish would be less likely to escape the net (Sullivan and Gale 1999). Without this modification, the opening of the rear throat was about 15–20 cm in diameter, which may allow many channel catfish to escape. Each net was baited with 4 kg of waste cheese, which usually increases catches of channel catfish (Perry 1979) and is more effective than other baits such as soybean chips and cottonseed cake (Perry and Williams 1987).

For each sampling trip, four series of each type were set at randomly selected locations in the littoral zone of each lake. Anoxic water below the thermocline was avoided to reduce fish mortality and increase catches. Nets were usually set parallel to shore, submerged brush piles, or flooded tree lines at water depths of 1–4 m. Steep slopes were avoided to prevent nets from collapsing or sliding into deeper water. An anchor with flukes that dug into the substrate was attached to the cod end of the rear net so that the hoop net series could be stretched tight. Additional weights were attached between the middle and front net and to the bridle on the front net so that the nets would not collapse or move. Sets were left undisturbed for 3 d before fish were retrieved and removed. Three-day soak durations were used because we anticipated lower densities of channel catfish than in the reservoir sampled by Sullivan and Gale (1999). Sullivan and Gale (1999) used 2-d samplings but suggested that longer soak durations may be necessary for lakes with lower channel catfish densities.

On retrieval, fish were removed from the nets, counted by species, and mortalities were recorded. Channel catfish were measured for TL (nearest mm), and all live fish were released immediately after processing. Catches were recorded separately for each net within a series but were pooled by series for analysis, and catch per unit effort (CPUE) was expressed as the number of channel catfish or bycatch caught per series.

Analysis of variance (ANOVA) was used to compare $\log_e$(CPUE + 1) of channel catfish and bycatch among series types, lakes, and sampling periods. The three sampling periods corresponded to the first, second, and third time the lakes were sampled. Catch data were transformed to normalize data and stabilize variances. All possible interaction terms were also included in the ANOVA. Length frequencies of channel catfish were compared between series types for each lake and sampling period with Kolmogorov–Smirnov (K–S) tests (PROC NPAR1WAY; SAS Institute 1989), with probabilities adjusted for multiple comparisons by the Bonferroni procedure. For these and all following statistical analyses, the significance level was set at $P \leq 0.05$.

Size bias of sampling gear.—A population of channel catfish was created in Sterling Price Lake (10 ha) by stocking 1,054 pond-reared individuals (mean TL = 340 mm, range = 156−529 mm) on May 1, 2001. Before stocking, each fish was marked by removal of the adipose fin, and measured (TL) so that the number and size structure of the population was known. The fish had never been exposed to baited hoop nets. Sterling Price Lake is a shallow, eutrophic impoundment in central Missouri having a fish community similar to those in the other study lakes. The stocked channel catfish were given 2 weeks to acclimate to the lake and distribute themselves around it. No mortality was observed at the time of stocking but anglers harvested an unknown number of fish during the acclimation period. Conservation agents estimated 100–200 adipose-clipped channel catfish were harvested during the period. On May 14, 2001, six short-bridled tandem hoop net series were set at randomly selected locations in the littoral zone and fished for 3 d. Nets were set and retrieved as previously described. All captured channel catfish were checked for fin clips and measured for TL. The length frequency of channel catfish with fin clips captured by hoop nets was compared with the length frequency of the known population by a K–S test. Significant differences in the two length frequencies indicated a potential size bias of the sampling method.

Statewide sampling.—Channel catfish populations in 66 small impoundments across the state of Missouri were sampled for 3 d with short-bridled tandem hoop net series during mid-May to late June 2001. These lakes had been stocked with channel catfish fingerlings at either 12/ha (low), 37/ha (medium), or 74/ha (high) annually since 1998. In fall 2000, however, five lakes that should have been stocked at 74/ha were mistakenly stocked at 86–148/ha. The number of tandem series used to sample the lake varied with surface area of the lake; four series were used in lakes with surface area less than 20.2 ha, six series in those equal to or greater than 20.2 but less than 60.7 ha, and eight series for those of 60.7 ha or more. Nets were set and retrieved as described previously except that turtles were removed from nets daily in one lake. All channel catfish were counted and measured for TL. Bycatch and mortality of captured fishes were not routinely recorded. An ANOVA followed by pairwise comparisons was used to determine whether mean CPUE ($\log_e$-transformed) and mean TL differed among the groups of lakes stocked at different rates. Few individuals were collected in some lakes, so lakes were included in the analysis of mean TL only if 30 or more individuals were measured. Because we assumed that stocking increases abundance, we expected CPUE to increase with stocking rate. We also expected mean TL to be related inversely to stocking rate; lakes with higher stocking rates should contain populations with greater portions of smaller (younger) individuals.

Sample size estimation.—We estimated the number of tandem hoop net series required for various levels of precision of CPUE by using procedures outlined in Wilde (1995). Mean ($\bar{x}$) and variance (s^2) of CPUE for channel catfish from the study lakes in 2000 (May–June data only) and 2001 were $\log_e$-transformed, and a linear regression equation was developed to predict variance from mean CPUE (Cyr et al. 1992). The regression equation was then back-transformed to a linear scale and

TABLE 1.—Least-square mean catch per unit effort (CPUE; number of fish/series) and 95% confidence limits (CL), mean total length (mm; range), and number of measured individuals (N) for channel catfish and least-square mean CPUE (95% CL) and mortality (%) for bycatch captured by tandem hoop nets (long- and short-bridled series combined) for five Missouri lakes during May–June and October 2000. Sample size equals eight series except that one series on June 27 for Maple Leaf Lake was excluded due to an improper set. Kolmogorov–Smirnov (K–S) test P-values are given for comparisons of length frequencies of channel catfish captured with long- and short-bridled series. To assure an experimentwise $\alpha = 0.05$, P-values ≤ 0.0033 (indicated by asterisks) are considered significant.

		Channel catfish				Bycatch	
Lake	Period (Date)	Mean CPUE (95% CL)	Mean length (range)	N	K–S test P-value	Mean CPUE (95% CL)	Mortality (%)
Blind Pony	1 (May 15)	83 (48–146)	385 (230–680)	843	0.31	58 (32–108)	6
	2 (Jun 12)	82 (47–145)	397 (242–662)	791	0.23	6 (4–13)	17
	3 (Oct 2)	94 (54–166)	416 (263–632)	897	0.36	15 (9–30)	35
Edwin A. Pape	1 (Jun 5)	129 (74–227)	428 (226–745)	1,113	0.20	26 (14–49)	13
	2 (Jun 26)	84 (48–149)	400 (235–732)	791	0.68	7 (5–15)	11
	3 (Oct 16)	71 (41–127)	375 (210–759)	697	0.001*	14 (8–27)	8
Little Dixie	1 (May 30)	24 (14–44)	368 (232–860)	244	0.0002*	42 (23–78)	16
	2 (Jun 20)	48 (28–86)	379 (234–668)	583	0.08	22 (12–41)	8
	3 (Oct 10)	6 (4–13)	425 (260–660)	140	0.03	44 (24–82)	1
Macon	1 (May 22)	11 (7–21)	368 (212–623)	101	0.20	84 (46–156)	5
	2 (Jun 19)	23 (14–43)	392 (224–574)	245	0.003*	28 (16–53)	4
	3 (Oct 9)	47 (27–83)	399 (206–656)	428	0.76	15 (9–29)	7
Maple Leaf	1 (Jun 6)	29 (17–53)	397 (210–630)	323	0.04	37 (20–68)	4
	2 (Jun 27)	27 (15–51)	388 (223–648)	216	0.84	32 (17–63)	1
	3 (Oct 17)	134 (77–237)	407 (227–740)	1,218	0.0007*	5 (3–11)	32

corrected for transformation bias to produce means rather than medians of predicted variances by using equations in Wilde (1995). Sample size (N) was then predicted for different levels of precision ($CV_{\bar{x}}$) and mean CPUE by the equation (Cochran 1977):

$$N = s^2\bar{x}^{-2}CV_{\bar{x}}^{-2},$$

where $CV_{\bar{x}}$ is the coefficient of variation of the sample mean.

We also estimated the number of fish (N_f) required for length measurements to accurately represent the size structure of the portion of a population vulnerable to our sampling method following procedures in Vokoun et al. (2001). Because N_f varies with population size-structure (Vokoun et al. 2001), we used data from two channel catfish populations with vastly different size structures so that the potential range in N_f could be determined. Because sample sizes exceeded 1,000 for both lakes, we assumed that the length frequencies developed from these samples accurately reflected the size structure of the population. We used these length frequencies, constructed with 25-mm intervals, as standards to compare with other length frequencies constructed from 16 sample sizes from 50 to 1,500 fish (50, 100, 200, 300, . . . 1,300, 1,400, and 1,500). For each population, 100 computer-generated samples were drawn, with replacement, for the 16 sample sizes (50–1,500 fish) and these samples were compared with the population by calculating, for each sample size, a mean squared difference (MSD). Small MSD values indicated that the generated size-structure estimates were similar to that of the population. Bootstrapping was used to estimate the variability of MSD from the 100 MSD estimates per sample size. A 90% inclusive data band was established from the 5th and 95th percentile MSDs.

Results

Tandem Hoop Net Comparisons

Mean CPUE of channel catfish ranged from 12 to 194 fish/series among series types, lakes, and sampling periods. Log-transformed CPUE did not vary significantly among series types ($F = 0.24$; df = 1, 89; $P = 0.63$) or sampling periods ($F = 0.92$; df = 2, 89; $P = 0.40$). Log-transformed CPUE did differ significantly among lakes ($F = 18.51$; df = 4, 89; $P < 0.0001$), but differences were inconsistent among sampling periods (lake × sampling period interaction: $F = 6.99$; df = 8, 89; $P < 0.0001$). All other interactions were not significant (lake × series type: $F = 1.05$; df = 4, 89; $P = 0.39$; series type × sampling period: $F = 0.36$; df = 2, 89; $P = 0.70$; lake × series type × sampling period: $F = 0.90$; df = 8, 89; $P = 0.52$). Because series type differences were not significant, CPUE data for the two set types were combined (Table 1).

Mean lengths of channel catfish captured by hoop nets ranged from 343 to 439 mm among series types, lakes, and sampling periods. Length frequencies of captured channel catfish differed significantly between series types for 4 of 15 comparisons (Table 1). Because length frequencies were usually similar between series types, length data for the two types were combined (Table 1).

Channel catfish mortality was observed on only two occasions. Three (0.4% of total catch) mortalities were found in hoop nets in Blind Pony Lake in May. Twenty-three (10.5%) mortalities were found in Maple Leaf Lake in late June. For all lakes and periods, mortality was 0.3% of the total catch.

Bycatch mean CPUE ranged from 5 to 101 fish/series among series types, lakes, and sampling periods. Bycatch consisted mostly of crappies, bluegills, redear sunfish, and sunfish hybrids. Log-transformed CPUE differed significantly among lakes (F = 4.76; df = 4, 89; P = 0.0016) and sampling periods (F = 19.74; df = 2, 89; P < 0.0001), but differences were inconsistent among lake and sampling period combinations (lake × sampling period interaction: F = 4.15; df = 8, 89; P < 0.0003). Differences in log-transformed CPUE were nearly significant between series types (least square means = 18.6 fish/series for short-bridle and 25.7 fish/series for long-bridle: F = 3.79; df = 1, 89; P = 0.055). All interactions other than lake × sampling period were not significant (lake × series type: F = 1.21; df = 4, 89; P = 0.31; series type × sampling period: F = 1.49; df = 2, 89; P = 0.23; lake × series type × sampling period: F = 0.82; df = 8, 89; P = 0.59). Because series type was not significant, CPUE data for the two types were combined (Table 1). Mortality of bycatch ranged from 1% to 35% among all lakes and sampling periods (Table 1) and was 8% overall.

Size Bias of Sampling Gear

Approximately 15% (N = 157) of the stocked channel catfish (N = 1,054) were captured by tandem hoop nets. In addition, 106 channel catfish (mean TL = 427 mm, range = 232–612 mm) not from the stocking (no mark) were captured. The length frequency of fin-clipped channel catfish (mean TL = 359 mm) captured with hoop nets differed significantly from that of the stocked fish (mean TL = 340 mm; K–S test, P = 0.001; Figure 1). No fin-clipped channel catfish smaller than 250 mm TL were captured in tandem hoop nets. If we exclude fish smaller than 250 mm, length frequencies of stocked channel catfish and those captured with fin clips were not significantly different (K–S test, P = 0.42) and the mean length of stocked fish (mean TL = 358 mm) was nearly identical to that of those captured in hoop nets.

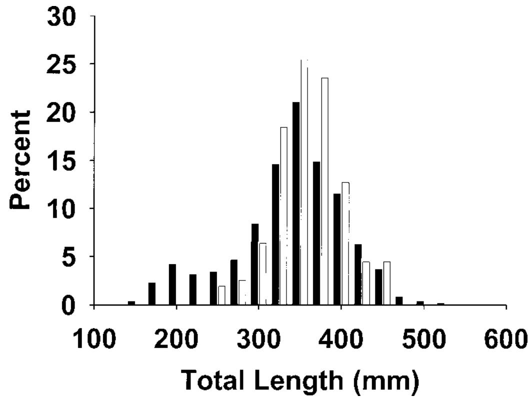

FIGURE 1.—Length frequencies (grouped in 25-mm intervals) of channel catfish captured by hoop nets (open bars) and those of the known population (solid bars) for Sterling Price Lake, Missouri, on May 17, 2001. Sample size was 157 for hoop net catches and 1,054 for the population.

Statewide Sampling

Although channel catfish were sampled in 66 lakes, only 62 were used for analysis; sampling in 4 lakes in the southeastern portion of the state was hampered by large catches and high mortality of turtles. Dead turtles floated the nets and probably reduced the sampling efficiency for channel catfish. Turtle catches were not routinely quantified but were much lower, typically fewer than 10 (total catch), in the other study lakes.

Overall, a grand mean of 90.5 channel catfish was caught per tandem hoop net series, and mean CPUE ranged from 0.5 to 369.7 fish/series among lakes. Log-transformed mean CPUE varied among lakes with the same stocking rate (Table 2) but varied significantly with stocking rate (F = 6.32; df = 2, 59; P = 0.003). Log-transformed mean CPUE in lakes with the high stocking rate were significantly greater than those with medium (P = 0.047) and low stocking rates (P = 0.0008). Log-transformed mean CPUE did not differ between lakes with medium and low stocking rates (P = 0.11).

Tandem hoop nets captured channel catfish ranging from 168 to 747 mm TL. Mean TL of channel catfish ranged from 276 to 463 mm among lakes and varied significantly with stocking rate (Table

TABLE 2.—Least-square mean catch per unit effort (CPUE; number of fish/series) and 95% confidence limits (CL) and mean total length (mm) and 95% CL of channel catfish captured during May–June 2001 with tandem hoop nets in Missouri lakes stocked at 12, 37, and 74 fingerlings/ha per year; *N* equals the number of lakes.

Stocking rate	CPUE		Length	
	N	Mean (95% CL)	*N*	Mean (95% CL)
12	22	19 (10–37)	17	389 (372–407)
37	22	41 (21–78)	20	370 (354–386)
74	18	109 (53–225)	18	346 (329–363)

2; $F = 6.41$; df = 2, 52; $P = 0.0032$). Mean TL for lakes with low stocking rates was significantly larger ($P = 0.0008$) than for high stocking rates but was not significantly different ($P = 0.11$) than for medium stocking rates. Mean TL for lakes with medium stocking rates was also significantly larger ($P = 0.04$) than for high stocking rates.

Minimum Sample Size

The required number of tandem hoop net series for a given precision decreased with increased mean CPUE from 0 to 10 fish/series and then approached an asymptote for mean CPUE of 100/series or greater (Figure 2). The relationship between $\bar{x}$ and s^2 used to estimate sample size was highly significant ($\log_e(s^2) = 0.223 + 1.746[\log_e(\bar{x})]$; $r^2 = 0.91$, df = 70, $P < 0.0001$). For $CV_{\bar{x}} = 0.1$ (not shown in Figure 2), the required number of series always exceeded 40 series, even for the greatest mean CPUE observed (369.7 fish/series). For the overall grand mean CPUE of 90.5 fish/series for the 62 study lakes in 2001, the required number of series equaled 59 for $CV_{\bar{x}} = 0.1$, 15 for $CV_{\bar{x}} = 0.2$, 7 for $CV_{\bar{x}} = 0.3$, 4 for $CV_{\bar{x}} = 0.4$, and 3 for $CV_{\bar{x}} = 0.5$.

The accuracy of length frequency data exhibited an asymptotic relationship with sample size (Figure 3). Increases in sample size resulted in large decreases in MSD below 300 fish, but increases in sample size to more than 300 fish resulted in little decrease in MSD. Population size structure influenced the accuracy of the estimates. At a given sample size, size-structure estimates were more accurate for a population with a heterogeneous size structure (Edwin A. Pape Lake) than one with a homogeneous size structure (Hamilton City Reservoir).

Discussion

A recent survey of fisheries management agencies revealed the need for more effective sampling methods for catfishes in small impoundments and other waters (Michaletz and Dillard 1999). Traditional methods such as gill nets, single hoop nets, trap nets, and electrofishing have not provided adequate samples of channel catfish in many small impoundments (Marshall 1991; Howell and Betsill 1999; Mitzner 1999; Robinson 1999; Santucci et al. 1999; Michaletz 2001). Our results indicated that tandem hoop nets effectively sampled channel catfish in most study impoundments in Missouri and should be effective in other states as well. This method usually produced a reasonable number of channel catfish with minimal effort, provided unbiased size-structure estimates for fish of 250 mm

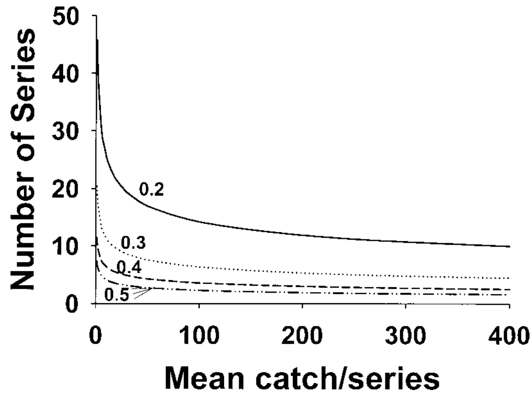

FIGURE 2.—Relationships between the number of tandem hoop net series (*N*) required for various levels of precision (coefficient of variation [$CV_{\bar{x}} = 100 \cdot SE/mean$] values of 0.2, 0.3, 0.4, and 0.5) and mean catch of channel catfish/series. Curves were derived from the equation $N = 1.832\bar{x}^{-0.254}\ CV_{\bar{x}}^{-2}$.

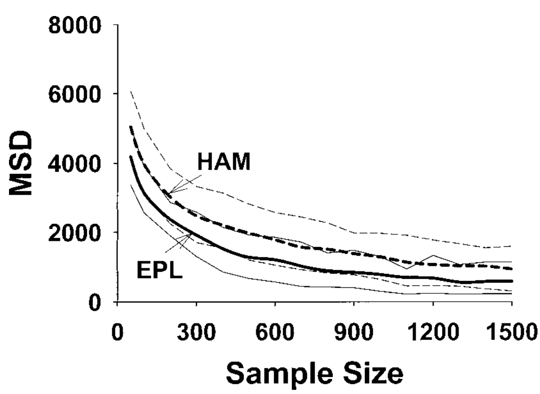

FIGURE 3.—Relationship between mean squared difference (MSD [dashed and solid bold lines] ± 90% inclusive data band [dashed and solid light lines]) and sample size for Hamilton City Reservoir (HAM) and Edwin A. Pape Lake (EPL), Missouri, respectively.

TL or longer and caused little mortality of captured channel catfish and bycatch. The average 3-d series in 2001 captured about 90 channel catfish, similar to catches (adjusted for differences in soak duration) reported by Sullivan and Gale (1999). If eight series were used, then about 720 channel catfish would have been collected at this average catch rate. With three persons, eight series can be set in less than 2 h, and the series can be retrieved and the fish processed in less than 8 h. In contrast, it would have taken about 200 or more trap net, single hoop net, or gill net sets to capture the same number of channel catfish based on average catch rates reported by Marshall (1991), Howell and Betsill (1999), Mitzner (1999), Robinson (1999), Santucci et al. (1999), and Michaletz (2001) and 180 h or more of electrofishing based on the catch rates reported by Santucci et al. (1999).

Acquiring precise estimates of mean CPUE would require substantial effort for most lakes, a common reality for most sampling programs (Hardin and Connor 1992; Neumann et al. 1995; Van Den Avyle et al. 1995; Wilde 1995). For moderate precision ($CV_{\bar{x}} = 0.2$), 12 to nearly 50 series were required for the range of mean CPUE found in the study lakes, similar to the number of gill nets required for Texas reservoirs (Wilde 1995). More precise estimates ($CV_{\bar{x}} = 0.1$) required 40 or more series. Although it may be possible to set that many nets, net saturation might occur in smaller lakes, which could reduce the mean CPUE. Moreover, that amount of effort probably would require several days of netting and a large number of nets. For most management purposes, it may not be feasible to devote the effort and expense necessary to obtain precise estimates of mean CPUE.

Accurate size-structure and age and growth information may be more important to fisheries managers than precise CPUE data. We found that 300 fish should provide sufficient information for a relatively accurate description of the size structure of the portion of the population vulnerable to the sampling method, similar to results of Vokoun et al. (2001), and should provide sufficient age and growth information as well. We captured at least 300 channel catfish in 34 of the 62 lakes sampled in 2001, using four to eight tandem hoop net series. For some lakes with low catch rates, it may not be possible to increase effort enough to capture 300 or more fish. However, smaller sample sizes may be adequate for providing age and growth information and for computing size structure indices such as proportional stock density (PSD). Anderson and Neumann (1996) suggested that at least 100 stock-sized fish be used to estimate PSD.

Length frequencies of channel catfish captured in tandem hoop nets may accurately reflect the size structure of the sampled population except for fish shorter than 250 mm TL. In most lakes, fish of this size would be products of recent stockings because natural recruitment is usually negligible (Marzolf 1957; Storck and Newman 1988) and most agencies stock channel catfish fingerlings at sizes of 175–250 mm TL (Michaletz and Dillard 1999). We found no size bias of the tandem hoop nets for fish larger than 250 mm TL. However, the population we created did not contain individuals larger than 550 mm TL, so size biases for large fish may exist. Although we could not determine whether size bias occurs for large fish, fish larger than 700 mm TL were captured in several lakes.

Mortality of channel catfish was usually low in 3-d tandem hoop nets. In our tandem hoop net comparisons in 2000, only 26 (0.3%) of the 8,639 channel catfish captured were dead. Sullivan and Gale (1999) reported no mortality of channel catfish in tandem hoop nets. Mortality of channel catfish was also low in most of the lakes during 2001. However, in a few instances, mortality was high because nets had been placed in the hypolimnion, where dissolved oxygen concentrations were low. To avoid high mortality, nets should always be placed in epilimnetic waters having sufficient dissolved oxygen.

Tandem hoop nets sometimes captured large numbers of bycatch, but mortality was usually less than 20%. In contrast, gill nets commonly capture large numbers of bycatch and the mortality of these fishes can be high (Santucci et al. 1999; Sullivan and Gale 1999; Michaletz 2001). Bycatch can be more easily removed from hoop nets than from gill nets. One disadvantage of using hoop nets, however, was the capture of turtles, many of which died, as reported by Sullivan and Gale (1999). The capture of turtles was not a significant concern in most lakes, high catches (hundreds) and mortality of turtles were serious problems in some lakes in southeastern Missouri. Hoop netting should be avoided in lowland lakes and swamps that contain large turtle populations.

Our analyses revealed differences in mean CPUE and mean TL among lakes stocked with channel catfish fingerlings at different rates, which met our expectations that mean CPUE should increase with stocking rate and that mean TL should decrease. Our results provide further support for the proposition that data collected with tandem hoop netting reflect actual population characteristics. Mean CPUE and mean TL varied considerably among lakes stocked at the same rate, which may have been caused by differences in growth and survival rates or differences in gear vulnerability of channel catfish among lakes. In particular, angler harvest of channel catfish can vary greatly among lakes (Hubert 1999) and lead to differences in survival and growth through density-dependent mechanisms.

On the basis of results from 2000, we chose to use short-bridled series fished in May and June to sample channel catfish populations in 2001. Short-bridled series were easier to set in confined areas and provided catches similar to long-bridled series. May and June sampling was chosen because fall stockings of channel catfish fingerlings complicated comparisons among study lakes in 2000. Although no seasonal differences in CPUE were evident in 2000, CPUE in some lakes was greatest in the fall because of the capture of recently stocked fingerlings. In Missouri, fingerlings are stocked in late September to mid-October, so fall sampling could occur before, during, or after stockings. While the sampling of a lake could be scheduled to occur either before or after stocking, it may be difficult to sample several lakes within the appropriate time frame. Sampling in September could lead to lower catch rates and survival of captured fish because of high water temperatures and low dissolved oxygen content. Sampling after stocking in October may be less effective because of rapidly falling water temperatures in late October. Sampling in May and June avoids complications of recently stocked fish and provides an assessment of the population for the fishing season. Sampling prior to high water temperatures and low dissolved oxygen conditions likely improves catch rates and reduces mortality of captured fishes.

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