EVALUATION OF FISH SAMPLING METHODS AND ROTENONE CENSUS

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ABSTRACT

During 1973 and 1974, 38 ponds in the north-central U.S. were studied by the Central States Pond Management Work Group. The fish in each pond were sampled by electrofishing and seining during late summer or early fall, then censused by rotenone poisoning shortly thereafter. This paper evaluates the effectiveness of these methods for management purposes. Rotenone census was most efficient when: surface temperature was at least 70 F (21 C); rotenone application was gradual with thorough mixing; and fish pickup lasted at least 3 days. Rotenone census was least efficient for small fish. The small seine was effective for capturing small ($<$ 3.0 inches or 7.5 cm) centrarchids, especially bluegill. Electrofishing efficiency was highest for largemouth bass and increased with bass length. The size structure of bass stocks can be estimated with an electrofishing sample of at least 8-12 stock-size bass (i.e., $\geq$ 8.0 inches or 20 cm). Management sampling of fish communities in small impoundments should include seining during summer to assess potential recruitment to stock, and electrofishing during spring or fall to determine stock size-structure. Partial rotenone census on high-priority impoundments may be desirable every 2 or 3 years to estimate density, biomass, and balance of fish communities.

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INTRODUCTION

In most situations, a complete census of a fish population or community is neither possible because of cost and logistics, nor desirable because of fish destruction. Fishery biologists rely instead on sampling to assess fish populations. Some studies have provided evaluations of sampling by a post-sampling census; examples are Krumholz (1944), Carlander and Lewis (1948), Fredin (1950), Carlander and Moorman (1956), Sanderson (1960), Lewis et al. (1962), Isaac and Bond (1963), Buck and Thoits (1965), Swingle et al. (1966), and Bennett and Brown (1969). Yet, much remains to be learned about the efficiency of various sampling gears.

This paper evaluates (1) the effectiveness of rotenone census in ponds studied by the Central States Pond Management Work Group (CSPMWG), and (2) the usefulness of the small seine and electrofishing boat for representative sampling of the fish communities. Details are also provided on sampling results as background for other papers in this symposium. Sampling methods are explained in a previous paper (Anderson et al. 1978). Results of rotenone census are discussed first to give more meaning to the evaluations of sampling which follow.

RESULTS

Rotenone Census

The 38 CSPMWG fish communities consisted mostly of bluegill and largemouth bass. On a combined basis, bluegill comprised 82% of the number and 65% of the weight collected; largemouth bass, 1% by number and 13% by weight; other species, 17% by number and 22% by weight. Species other than largemouth bass and bluegill made up 50% or more of the biomass in only five ponds (Anderson et al. 1978).

Total fish biomass collected from all ponds (Table 1) ranged from 94 to 717 lb/A (105 to 804 kg/ha). The average biomass recovered from ponds in 1974 was significantly higher than that from 1973 ponds (t test, $P < 0.01$). A breakdown of biomass into three groups — bluegill, bass and other species — indicated that the differences between years were mostly attributable to bluegill which dominated the total biomass and, therefore, its variation. The between-year differences were partly the result of an improved technique of rotenone application in 1974 (Anderson et al. 1978). The improved technique kept more fish, particularly small ones, stressed at the surface for a longer capture period. Other factors affecting biomass in CSPMWG ponds are considered by Hackney (1978).

Table 1. Biomass (lb/A) of fishes collected with rotenone from 38 CSPMWG study ponds.

Year of Collection	Largemouth Bass	Bluegill	Other Species	Total
1973 (n = 19)				
Minimum	6	17	0	94
Maximum	100	223	383	560
Mean	36	120	53	210
Median	37	119	36	194
1974 (n = 19)				
Minimum	0	73	0	132
Maximum	81	615	324	717
Mean	38	257	73	368
Median	37	277	30	341

Recovery efficiency, the percentage of marked fish recaptured during rotenone application, was not significantly different between years. Of 142 bluegill marked and released during 1973, 95 or 67% were recovered; of 571 in 1974, 377 or 66% were recovered. Recovery efficiency was 75% for 48 largemouth bass marked and released in 1973, and 73% for 138 in 1974. These between-year similarities in efficiency do not support the previous conclusions of higher efficiency in 1974 based on total biomass values. The discrepancy is probably due to sampling biases involved in fish marking procedure: marked fish were released in only 3 ponds in 1973, but in 14 ponds in 1974; only large fish were marked in both years, whereas the improved rotenone application technique mainly improved the capture of small fish.

Higher surface temperatures significantly increased the recovery efficiency of marked bass ($r = 0.75$, $P < 0.01$) but not marked bluegill (Figure 1). Recovery efficiency was usually above 70% for bass and 50% for bluegill when surface temperature was 70 F (21 C) or more. Rotenone applications occurred when surface temperature was 67-88 F (19-31 C) in 32 ponds; 57-64 F (14-18 C) in the other six ponds. In most ponds, therefore, temperature was not an obstacle to high efficiency during rotenone census.

Table 2. Combined percentage of fishes captured by day in 12 CSPMWG ponds following rotenone application. Day 1 is the day of rotenone application.

Category	Day of Capture			
	1	2	3	4+
Weight (lb)				
All species	47	32	16	5
Bluegill	40	35	20	5
Largemouth Bass	70	9	14	7
Number of bluegill by length (inches)				
0.0-2.9	41	54	4	1
3.0-5.9	32	52	14	2
6.0-8.9	47	16	28	9
Number of bass by length (inches)				
0.0-3.9	51	28	18	3
4.0-7.9	51	16	23	10
8.0-11.9	64	9	17	10
12.0-15.9	63	13	15	9
16.0+	81	6	11	2

In 12 ponds fish captures were recorded daily for at least 4 days after rotenone application. Almost half of the total weight of fishes collected in these ponds was taken on the first day (Table 2). About a third of the biomass was collected the second day; only 5% was taken on the fourth and subsequent days. The total weight of bluegill collected followed a similar pattern. Bass biomass was high the first day, dropped substantially the second, then increased on the third due to dead bass that re-floated; weights were quite low thereafter.

The number of bass and bluegill collected was also influenced by time and, to a lesser extent, by individual size (Table 2). Most bluegill smaller than 6.0 inches (15 cm) were taken during the first 2 days whereas those 6.0 inches or greater were mostly taken on the first and third days. The effect of size on bass captures was even more striking: the relative difference between percentage recoveries on the first and second days increased with size; numbers increased for all but the smallest bass between the second and third days. Only medium size bass were collected in significant numbers on the fourth and subsequent days.

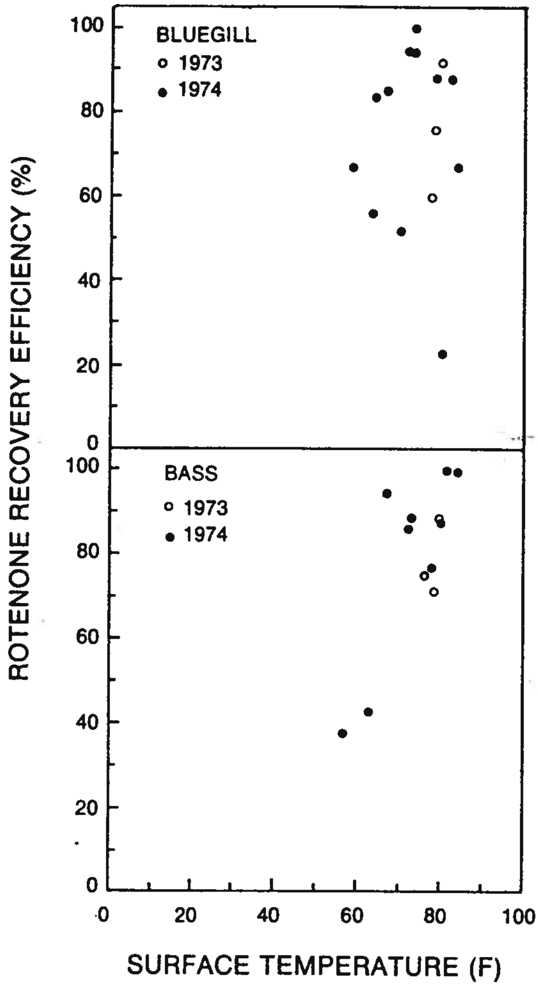


Figure 1. Rotenone recovery efficiency of marked fish as a function of surface water temperature in CSPMWG ponds. Only ponds that contained at least 4 marked bass or 12 marked bluegill are included.

Seining

The small seine was used to sample 29 ponds. According to sampling protocol, the 30,700 feet (9357 m) of shoreline in these ponds called for 307 quadrant seine hauls; 238 hauls, or an average of 1 every 129 feet (39 m) were actually taken.

The 238 hauls captured 18,117 fish of 14 species. Of these, 16,754 (92.5%) were bluegill and only 172 (0.9%) were largemouth bass. The small seine was 100% successful in detecting the presence of bluegill in the ponds, moderately successful for largemouth bass and green sunfish, and poor for golden shiner and channel catfish (Table 3). The presence of other species was too infrequent to evaluate detection success by the small seine.

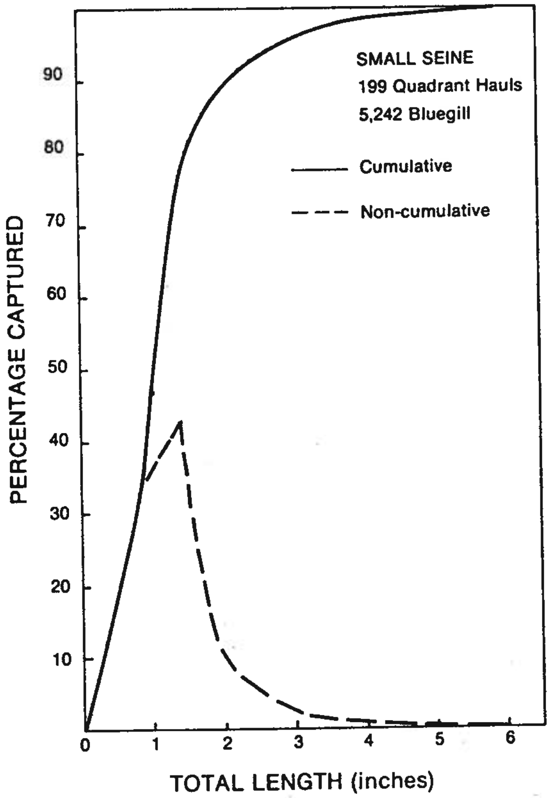
Table 3. Success of species detection by small seine sampling.

Species	Number of Ponds: Species present[a]	Number of Ponds: Species sampled	Detection success (%)
Bluegill	29	29	100
Largemouth bass	28	19	68
Green sunfish	12	7	58
Golden shiner	10	1	10
Channel catfish	15	1	7

[a]As determined by rotenone census.

All bluegill captured by seining in 27 ponds were measured to the nearest 0.5 inch (1 cm). These pooled data provided a length-frequency curve (Figure 2) which indicated that approximately 96% of the bluegill were < 3.0 inches (7.5 cm) long; 90% were < 2.0 inches (5 cm) long. Although not a selectivity curve, Figure 2 gives support to the conclusion that the small seine is effective for capturing only small bluegill (i.e., < 3.0 inches). Only 181 bass were caught by seining in 18 ponds; 81% were < 3.0 inches.

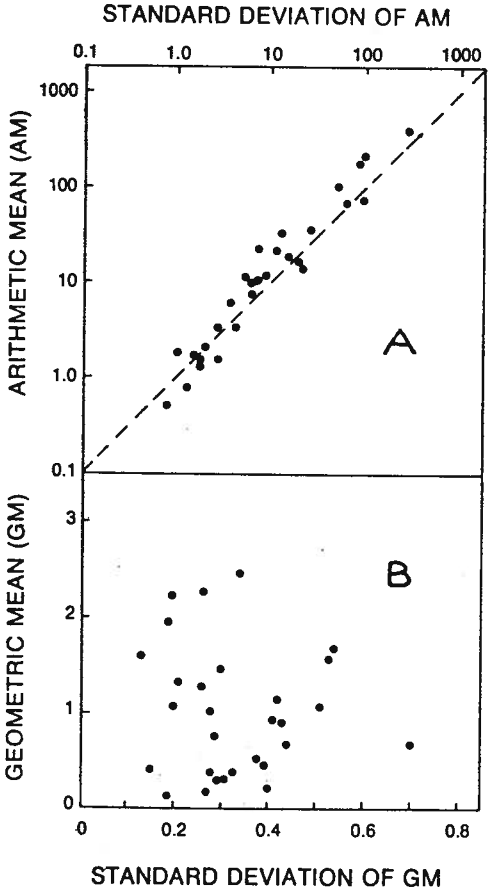
Figure 2. Relative length frequency of bluegill captured by seining in 27 CSPMWG ponds.



The average number of small bluegill captured in the haul series from each pond was approximately equal to and highly correlated with ($r = 0.96$, $P < 0.01$) its standard deviation (Figure 3A). Thus, the catches of small bluegill were not normally distributed, but positively skewed. Normal distributions are required for valid use of common statistical tests. To achieve normality, the number of small bluegill caught in each seine haul was transformed to $\log_{10}(X_i + 1)$ where X_i equals the number caught in any haul (Steel and Torrie 1960, p. 157). For each haul series, a geometric mean ($GM = \Sigma [\log_{10}(X_i + 1)]/n$, where n = number of hauls) of the number of small bluegill per haul was calculated. The geometric means were poorly correlated with ($r = 0.04$), and thus independent of, their standard deviations (Figure 3B) — an indication of normality. The logarithmic transformation apparently achieved a normal distribution of seine haul data. Brown (1965) drew the same conclusion about seine data for bluegill in an Alabama pond.

The densities (number/A) of small bluegill were poorly correlated with the GM catches in seine hauls ($r = 0.23$, $P > 0.10$). A significant correlation resulted between GM catches and numbers of small bluegill per 100 feet (30.5 m) of shoreline ($r = 0.41$, $P < 0.05$). The higher correlation is likely the result of small bluegill being distributed near the shoreline. Despite the higher correlation, the GM catch per haul accounted for only 17% of the total variation in shoreline abundance. Much of the unexplained variation is probably due to highly variable seining and rotenone capture efficiencies of small bluegill. If, on the average, fewer than 10 small bluegill are captured per haul in a series ($GM < 1.0$) the shoreline abundance is probably less than 400 per 100 feet of shoreline; if an average of 10 or more are caught per haul ($GM \geq 1.0$), shoreline abundance is probably more than 400 (Figure 4).

Figure 3. Relationship between the average and standard deviation of catch of small bluegill in each seine haul series for 27 CSPMWG ponds; A— untransformed data; B— transformed data.



Each of the 29 seine haul series provided an estimate of the number of seine hauls required to estimate the true shoreline abundance of small bluegill within ± 10% at the 90% level of confidence. The Stein two-stage method was used (Steel and Torrie 1960, p. 86). The required number of seine hauls in each pond was divided into shoreline length to give a required distance between seine hauls. The required distance between hauls was highly dependent on sampling variability, expressed as coefficient of variation for GM ($r = 0.89$, $P < 0.01$). The coefficient of variation for GM must be 14 or less if the distance between hauls is to be 100 feet (30.5 m) or more. In most ponds, sampling variability was too high for 100 feet (30.5 m) to suffice as the distance between seine hauls (Figure 5).

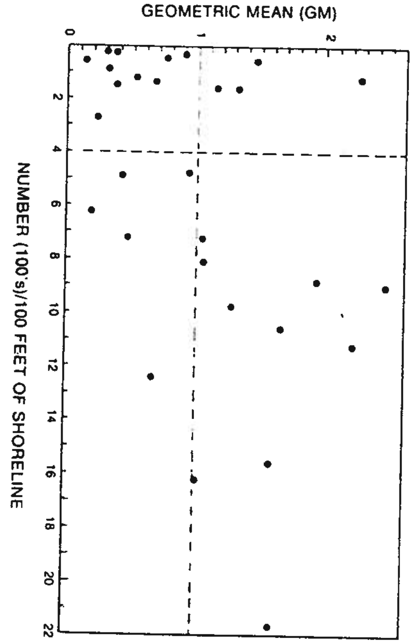


Figure 4. Geometric mean catch per seine haul of small bluegill as a function of their shoreline abundance, determined by rotenone census.

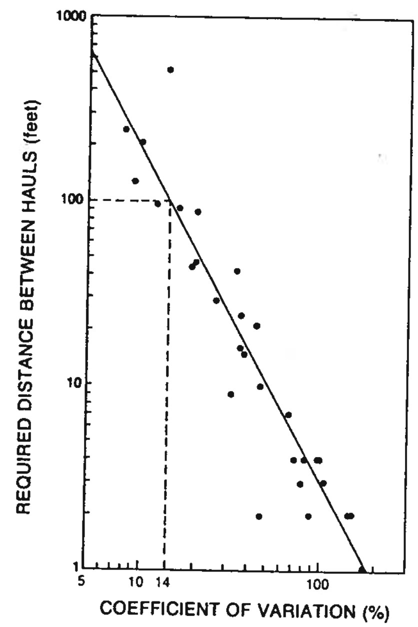


Figure 5. Effect of sampling variability, expressed as coefficient of variation of GM on the distance required between seine hauls to estimate the true shoreline abundance of small bluegill within ± 10%, assuming a 0.10 confidence level.

Electrofishing

Standard electrofishing methods were used on 27 of the 38 ponds. Electrofishing efficiency for a given species was defined as the percentage of the total population captured by electrofishing one lap of the shoreline. Because the population data were not corrected for incomplete captures during rotenone application, the values for electrofishing efficiency are maximum estimates, especially for small fish. Combined efficiency is the percentage of the total number of fish captured in all ponds, and average efficiency is the mean of efficiencies in each pond.

Electrofishing was reliable for detecting populations of largemouth bass, bluegill, and redear sunfish, and generally indicated the presence of green sunfish (Table 4). Only two of nine crappie populations were sampled, but average crappie density in the other seven ponds was high—221/A. Electrofishing was inefficient for sampling populations of channel catfish, bullheads, and golden shiner.

Size selectivity of electrofishing was clearly evident for largemouth bass (Figure 6). Average efficiency increased in a linear fashion from 1.7% for bass less than 4.0 inches (10 cm) to 19.3% for bass 16.0 inches (41 cm) or longer. Largemouth bass were the fish most susceptible to capture (Table 4); the combined efficiency for all size groups was 5.6%.

Table 4. Success of species detection and efficiency of electrofishing in 27 CSPMWG ponds.

Species	Number of Ponds: Species present[a]	Species sampled	Detection success (%)	Combined efficiency (%)
Bluegill	27	27	100	0.5
Largemouth bass	26	23	88	5.6
Redear sunfish	5	4	80	0.9
Green sunfish	12	6	50	0.4
Crappie (both species)	9	2	22	0.3
Golden shiner	9	1	11	0.1
Bullhead (all species)	9	1	11	1.1
Channel catfish	13	1	8	1.1

[a]As determined by rotenone census

Figure 6. Efficiency of electrofishing as a function of total length for largemouth bass in 27 CSPMWG ponds.

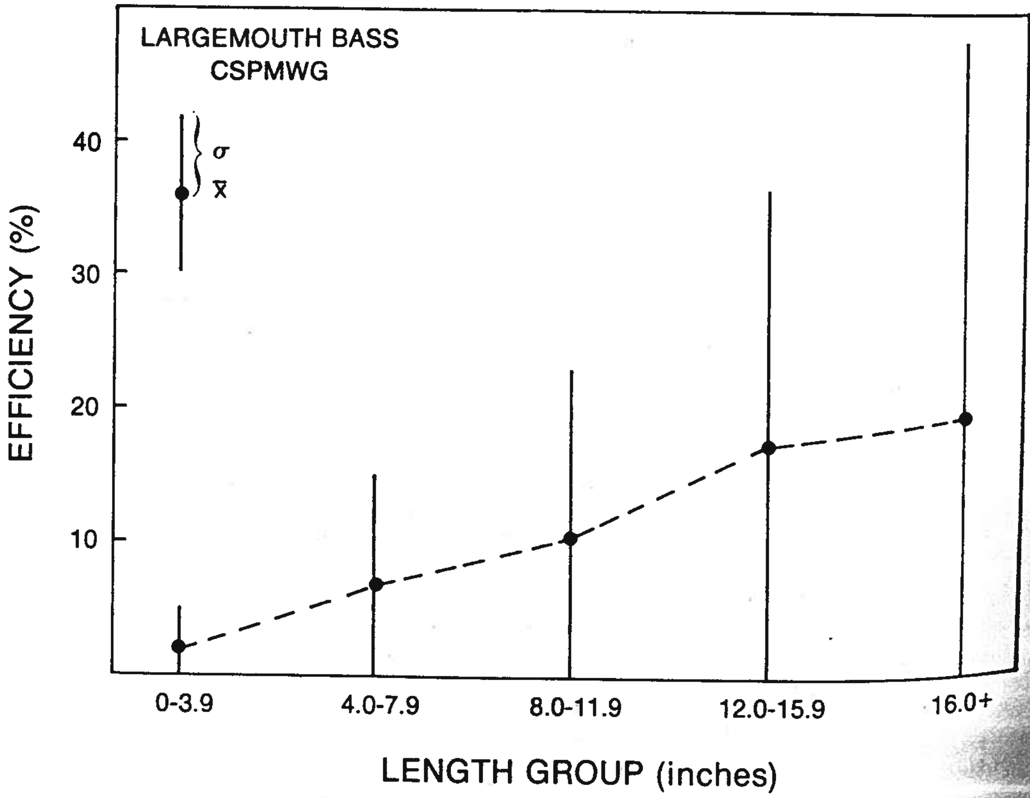


Table 5. Correlations of numbers of fish caught by electrofishing 100 feet (30.5m) of shoreline with numbers per 100 feet shoreline actually present[a] for largemouth bass in 4-inch (10 cm) length groups and bluegill in 3-inch (8 cm) length groups in 27 CSPMWG ponds. Coefficients are given only when significant at the 90% confidence level.

Largemouth bass		Bluegill	
Length (inches)	Correlation coefficient (r)	Length (inches)	Correlation coefficient (r)
0.0-3.9	0.68	0.0-2.9	0.39
4.0-7.9	0.52	3.0-5.9	0.40
8.0-11.9	0.70	6.0+	0.48
12.0-15.9	0.60	All sizes	NS
16.0+	NS		
All sizes	0.44		

[a]rotenone census/shoreline length x 100

Efficiency for bluegill was much less than for bass. Electrofishing took only 0.5% of the populations (Table 4), and did not show consistent size selectivity (Figure 7). The decline in capture efficiency for larger bluegill was probably the result of these fish being deeply distributed in most ponds.

Despite the wide variety of conditions in the ponds, correlations of electrofishing catch per 100 feet (30.5 m) of shoreline with abundance (rotenone census) per unit shoreline for bass and bluegill were generally significant at the 90% confidence level (Table 5). This suggests that electrofishing is a fairly reliable indicator of abundance for largemouth bass and bluegill.

Figure 7. Efficiency of electrofishing as a function of total length for bluegill in 27 CSPMWG ponds.

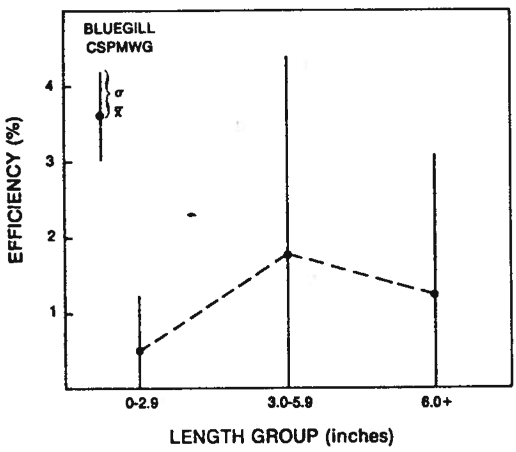


Table 6. Correction factors for various sizes of largemouth bass and bluegill (assuming 1.0 for bass ≥ 16.0 inches) to compensate for species and size selectivity of electrofishing. Multiply the number caught in each length group times the correction factor to estimate the true relative abundance. See text for further explanation.

Largemouth bass		Bluegill	
Length (inches)	Factor	Length (inches)	Factor
0.0-3.9	4.5	0.0-2.9	36.8
4.0-7.9	2.3	3.0-5.9	10.2
8.0-11.9	1.3	6.0+	12.3
12.0-15.9	1.3		
16.0+	1.0		

Electrofishing samples did not directly represent the relative abundance of the two species because average efficiency (all sizes) was nearly 15 times greater for bass than for bluegill. Because of size selectivity, direct analysis of populations based on electrofishing results in overestimates of large bass and underestimates of large bluegill. Correction factors (Table 6) can be applied to numbers of bass and bluegill of various lengths in an electrofishing sample. The result is a more realistic appraisal of size structure within, and relative abundance between, the two populations. These factors apply only to samples obtained by night electrofishing with alternating current in ponds during late summer and early autumn.

Electrofishing samples can also be used to assess the structure of largemouth bass stocks. Proportional Stock Density (PSD) is an index which Anderson (1976) proposed for bass stock assessment. PSD is the percentage of individuals in a stock which are quality size. For largemouth bass, Anderson defined those ≥ 8.0 inches (20 cm) as stock and those ≥ 12.0 inches (30 cm) as quality size; he recommended that bass PSD be 45-65% to achieve and sustain high angling quality.

PSD can be estimated directly from bass length data in an electrofishing sample. Because of slightly higher efficiencies for bass ≥ 12.0 inches (30 cm), estimates of PSD by electrofishing were generally higher than the true PSD as determined by rotenone census in CSPMWG ponds (Figure 8). The accuracy of electrofishing estimates of bass PSD increased as the number of stock-size bass in the sample increased (Figure 9). Samples of 8 to 12 stock-size bass *apparently* provide a PSD estimate which is within 10% of the population PSD at the 90% confidence level.

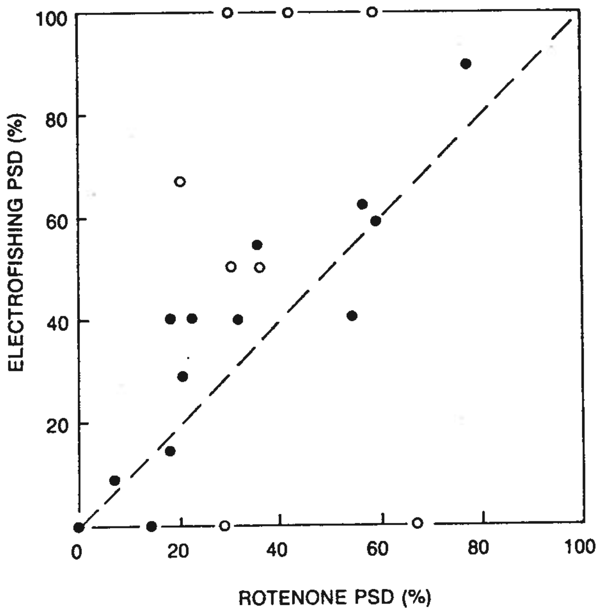
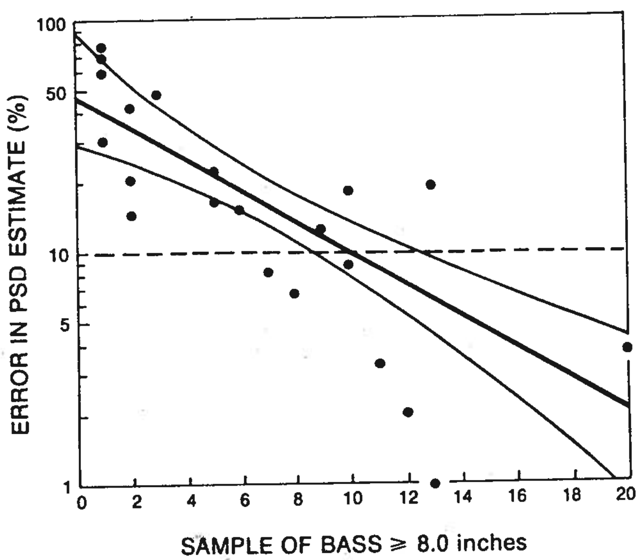


Figure 8. Relationship between Proportional Stock Density (PSD) of largemouth bass estimated by electrofishing and determined by rotenone census in CSPMWG ponds. Points close to the dashed line represent accurate estimates. Open circles represent estimates based on small samples (i.e., ≤ 3 stock-size bass captured by electrofishing).

Figure 9. Semi-logarithmic plot of the number of stock-size bass in electrofishing samples versus the absolute difference between PSD values from electrofishing sample and rotenone census. The linear regression line is described by $\log_{10}$ [Error in PSD Estimate] = 1.68-0.07 [Sample Size] with correlation of -0.70. Curved lines represent 90% confidence intervals.



DISCUSSION

The efficiency of fish capture by rotenone in the CSPMWG ponds was always less than 100%, such efficiency is unlikely in any field operation. For example, in 11 coves of Lake Cumberland, Kentucky, 26% of the number and 5% of the weight of fishes sank to the bottom and remained there during 3 days of rotenone collection; of the lost fish, 91% were less than 3 inches (7.5 cm) long (Henley 1967). Under most circumstances it is difficult to determine the actual efficiency because it varies with temperature, depth, cover, species, individual fish size and rotenone application technique (Carlander and Lewis 1948; Carter 1958; Henley 1967; and Parker 1970). Therefore, we and the authors of other papers in this symposium have not attempted to expand population data using recovery efficiencies for marked fish. Instead, we view the rotenone census data as minimum estimates and urge the reader to evaluate our analyses and interpretations accordingly.

Care should be taken to increase rotenone capture efficiency whenever possible. Surface temperature should be at least 70 F (21 C). Application should proceed slowly after pond waters have been mechanically mixed; this maximizes the time that fish are stressed at the surface. Rotenone census apparently requires at least 3 consecutive days of fish pickups. Of 1,868 lb (847 kg) of fishes collected by rotenone in 11 coves in Lake Cumberland, Kentucky, 64, 25, and 11% were picked up on the first, second and third days, respectively (Henley 1967); our results are similar. Dense beds of submerged vegetation should be eradicated or the pond water level reduced prior to rotenone application if the census is to provide reliable data on small fishes. Fish of all sizes and species should be meticulously collected.

Rotenone census in a pond destroys all or most of the fish. In the CSPMWG ponds, the method was used as a research technique. Unfortunately, it is all too frequently used as a management technique after the manager or pond owner assumes that nothing else will work. We view it as a costly last resort. Other papers in this symposium discuss more positive approaches to fishery management in small impoundments.

The small seine seemed effective in capturing small centrarchids, particularly bluegill, but little else. By late summer and early autumn most age-0 largemouth bass were 3.0 inches (7.5 cm) or longer and had outgrown their vulnerability to seine capture. The small seine may be suitable for assessing abundance of age-0 bass during early summer when most individuals of the new year class are smaller than 3.0 inches.

The small seine is suitable for assessment of potential recruitment to bluegill stock; however, assessments should be restricted to individuals smaller than 3.0 inches. Normal distribution statistics should not be used on actual numbers, only on logarithmic transformations. If the geometric mean of a series of quadrant hauls is less than 1.0, or if the number of small bluegill in each haul is consistently less than 10, the shoreline abundance of small bluegill is probably low. If GM is more than 1.0, or each haul consistently captures 10 or more small bluegill, their abundance is likely high. To estimate the true geometric mean of shoreline abundance of small bluegill with ± 10%, assuming $P < 0.10$ of being wrong, the coefficient of variation for GM should be less than 15% in order to avoid an unreasonable amount of sampling. The coefficient of variation may be reduced by taking more seine samples and assuring that each haul is taken in a thorough, deliberate fashion. If sampling variability is still too high, seine catches will be useful only to detect the presence of age-0 bluegill as outlined by Swingle (1950).

Electrofishing with alternating current is an efficient method for capturing largemouth bass. Efficiency increases with size as Sullivan (1956) pointed out for stream fishes, but few studies have quantified it. Electrofishing efficiency is much lower and less predictable for bluegill. Future research should attempt to quantify factors other than fish size which affect electrofishing efficiency. Such information would provide a method to directly estimate bass population size, reducing the need for mark-recapture studies (Lewis et al. 1962).

Electrofishing can and should be used for more than collecting fish and documenting relative capture rates. We encourage fishery managers to use it to assess the structure of largemouth bass stocks, especially in small impoundments. Night electrofishing one lap of shoreline appears to be useful as a standard method.

PSD can be calculated from electrofishing samples, but one must assume that stock-size bass in both length groups (i.e. $<$ and $\geq$ 12 inches or 30 cm) are equally vulnerable to capture. This assumption implies that both groups are near shore and have negligible differences in response to electrical current. Spring may be the best time to assess bass stocks by this method because most bass are near shore (Ziebell and McClain 1977). In small impoundments, late summer and early fall is probably the next best sampling period because thermal stratification and low dissolved oxygen restrict bass to a shoreward distribution.

Sample size to estimate PSD depends not only on stock density and chosen confidence level, but also on the actual PSD. As PSD approaches 50%, sample size must increase to maintain a given confidence level (A.S. Weithman, Missouri Cooperative Fishery Research Unit, personal communication). In the CSPMWG ponds, PSD of most bass stocks were less than 40% (Figure 8). Fewer stock-size bass were therefore required to safely predict true PSD. The sample size of 8-12 bass previously recommended should be considered a minimum sample size, not a fixed one.

The CSPMWG study results can be used to set strategy and tactics for management sampling of small impoundments. In the spring, as shallow waters become warm and fish move shoreward, electrofishing should be used to assess centrarchid populations in general, and bass stocks in particular. A small seine is useful to assess reproduction and potential recruitment to stock, but only during summer when bluegill and bass are less than 3.0 inches. Rotenone is useful to estimate density, biomass, and size structure of the fish community. However, to avoid total community destruction, a cove, embayment, or corner of the impoundment should be censused after partitioning by block net. The best time to sample with rotenone is spring or early summer, shortly after shallow water temperature is above 70 F (21 C). Although expensive and time consuming, rotenone samples once every 2 or 3 years on high-priority impoundments may be worthwhile — at least until electrofishing or other methods are further refined for stock and population assessment.

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