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Electrofishing efficiency and its influence on stock assessment strategy[1/]

James B. Reynolds

Cooperative Fishery Research Unit[2/]

U. S. Fish and Wildlife Service

University of Missouri

Columbia, Missouri 65201

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Abstract

The field efficiency of boat electrofishing, mostly with 240 V AC at night, was studied in ponds and blocked coves of larger impoundments. After electrofishing, a toxicant was applied and most fish were collected. Electrofishing efficiency was estimated for various species and sizes of fish by calculating the percentage of the total collected which were captured by electrofishing. Largemouth bass, Micropterus salmoides, and bluegills, Lepomis macrochirus, were consistently most vulnerable (i.e., highest efficiency values) to electrofishing. Key determinants of efficiency were species, size of fish, population density, water temperature and transparency, cover, electrical current and catch-per-unit-effort. These factors are included in recommended procedures for standard electrofishing. Proportional stock density, the percentage of fish in a stock which are of quality size, can be estimated for largemouth bass from electrofishing samples. Sample size depends on the actual PSD of the stock, the confidence level (error) chosen and the confidence limit (precision) desired.

Introduction

Although an important development in fishery science and management, electrofishing continues primarily as a fish capture device. Its quantitative uses have been restricted mostly to estimates of relative abundance and population size by mark-recapture and, to a lesser extent, by depletion. Most of the recent literature treats equipment, techniques and fish response to electrical current (Friedman 1974).

Despite the importance of electrofishing and the reservoir of information, suprisingly little is known, quantitatively, about how well electrofishing samples represent the fish populations and stocks from whence they come. What is the actual efficiency of electrofishing in the field? What factors influence efficiency in a significant and predictable way? Can this information provide a sampling strategy for management decisions? These and other questions must be answered before the full value of electrofishing can be realized by fishery managers.

This paper summarizes the results of a two-year pilot study of electrofishing efficiency by the author and Unit graduate student Donald E. Simpson. Our purpose was to (1) quantify the efficiency of electrofishing in warm water impoundments, particularly for largemouth bass, Micropterus salmoides, (2) determine factors which affect efficiency and (3) develop a sampling strategy, including standards of procedure, for assessment of fish populations and stocks.

The probability sampling scheme was developed by A. S. Weithman, Unit graduate student. Biologists of the Central States Pond Management Work Group, Illinois Natural History Survey, Iowa Conservation Commission, Kansas Forestry, Fish and Game Commission, and U. S. Fish and Wildlife Service contributed data to this study. The Bass Research Foundation provided financial support.

Methods

It was not possible, within the time frame of this project, to investigate all types of electrical current, equipment and procedures. To determine the present usage of electrofishing equipment, a mail survey was conducted in early 1976. The results indicated that most biologists with boat electrofishing gear still use alternating current (AC) from 240 V generators with relatively simple electrode system design (Simpson and Reynolds 1977). Accordingly, our recommended electrofishing procedure was to electrofish one lap of the shoreline after sunset in the late summer or autumn, with 220-240 V AC, collecting all species and sizes of fish. We used one or two dip-netters and proceeded slowly instead of chasing fish. All captured fish were identified and measured. Meteorological and limnological measurements were recorded prior to electrofishing.

After electrofishing, a toxicant, usually rotenone, was applied and fish were collected for at least three consecutive days. The fish collection was assumed to represent the fish community. Electrofishing efficiency was calculated for each population (species) by expressing the number electrofished as a percentage of the number collected with the toxicant. Because all individuals are never collected, the efficiency values are overestimated; the bias is highest for small fish.

Linear and multiple regression methods were used to analyze the data. Analyses of efficiency were done by 4.0 inch (10 cm) length groups for largemouth bass, 3.0 inch (7.5 cm) groups for bluegills, *Lepomis macrochirus*. In all analyses, efficiency was considered the dependent or predicted variable.

Key Determinants of Electrofishing Efficiency

Factors which influence electrofishing efficiency fall into one of four general categories: fish characteristics, limnological characteristics, sampling conditions (i.e., time, season, weather) and electrofishing equipment and technique.

Fish characteristics

Efficiency varied greatly among species captured in small impoundments (Table 1). Centrarchids were most vulnerable to electrofishing, particularly largemouth bass; crappies (Pomoxis spp.) were the exception. Efficiency was also low for channel catfish (Ictalurus punctatus), bullheads (Ictalurus spp.), and golden shiners, (Notemigonus crysoleucas).

The selectiveness of electrofishing for larger fish is well-documented (Sullivan 1956; Junge and Libosvarsky 1965; Vibert 1967; Novotny and Priegel 1974). Selectivity for larger bass was evident in ponds and coves (Table 2; Figure 1); it may be even more pronounced than is apparent in view of the fact that rotenone capture efficiency for small bass is less than for larger ones (Henley 1967). Efficiency was highest for medium-size bluegills (Table 2). Electrofishing was more efficient for bass than bluegills; average efficiencies in ponds and coves combined were 9.1 and 0.8%, respectively.

Limnological characteristics

Water temperature significantly affects fish distribution and behavior, and, thus, electrofishing efficiency. Generally, efficiency for bass and bluegills decreased as temperature increased in the range of 70-85 F (21-29 C). As temperature increased, efficiency remained similar for intermediate sizes of both species, but declined for larger fish (Table 3). At higher temperatures, larger fish inhabit deeper water and are less vulnerable to electrofishing. The effectiveness of electronarcosis and subsequent flotation is also a function of temperature; for example, the percentage of bluegills collected by a pickup boat following an electrofishing boat on Lake of the Ozarks increased as water temperature decreased (A. Witt, personal communication).

In both ponds and coves, the efficiency for bass and bluegills decreased exponentially with increases in water transparency; Figure 2 depicts an example of the relationship among 12.0-15.9 inch (ca 30-40 cm) bass. Clear water probably causes fish movement to deeper waters, or increased avoidance capabilities, or both.

The effect of cover is important but difficult to quantify. Although cover was not evaluated in ponds and coves, its effect on bass capture efficiency was well demonstrated in experimental ponds. Almost 90% of the captures occurred in pond sections containing tire, stake or brush shelters (Figure 3). Cover apparently concentrates bass, making them more vulnerable to electrofishing. This aspect deserves further study.

Sampling conditions

Time of day and year could not be evaluated because of the restrictions of sample design: nighttime during late summer and autumn. Efficiency is undoubtedly lower during daytime (Loeb 1957; Witt and Campbell 1959; Kirkland 1965). Seasonal effects are realized through temperature changes and spawning activity. For this reason, efficiency is probably highest in spring when many fish are closely associated with warming, inshore waters.

Weather is an uncontrollable factor which was not evaluated. Events such as a cold front, storm or full moon may cause abrupt changes in fish distribution. These effects are subtle, however, and will require substantial amounts of data for valid analysis and interpretation.

Electrofishing equipment and technique

Methodology, like sampling conditions, were either random or fixed in their effects. Of the various factors in this category, the electrical current is probably the most influential. In a 1964 study in experimental ponds, Foster (Mo. Coop. Fish. Res. Unit, unpublished data) compared the efficiency of AC and unpulsed direct current (DC) for bass. The average efficiency with DC (19.1%) was higher than that with AC (13.3%). Size selectivity was similar for both current types (Figure 4).

Other determinants of efficiency

Certain factors seemed to affect efficiency, but small sample sizes and inconsistent results precluded definite conclusions. These included "learning" by fish exposed to electrical shock, dissolved oxygen, conductivity, bottom morphometry, amperage, electrode design, shoreline development and size of water body. Human factors, including netting efficiency, boat operation and crew experience, are difficult, if not impossible, to evaluate or control. Yet, these elements may account for significant portions of the variation in electrofishing efficiency. Additional data may eventually provide more dependable results.

Multiple regression analyses

When all dependent variables were simultaneously compared to electrofishing efficiency, only 50% of the total variation was explained. The only independent variable which consistently accounted for a significant amount of variation was catch-per-unit-effort (number caught/100 feet or 30.5 m of shoreline). Thus, despite the range of population densities encountered, the number of fish caught was the best indicator of efficiency. It is not yet possible, with the amount of available data, to estimate electrofishing efficiency, and, therefore, population size, based on a predictive equation which incorporates the various measurable determinants.

Stock Assessment

Although electrofishing efficiency for small fish is quite variable and unpredictable, it can be consistently high for fish of stock size. In many instances the most valid information available to a fishery manager concerns the stock within a population. Anderson (1976) has proposed Proportional Stock Density (PSD) as an index to evaluate the size structure, or balance, of a stock. PSD is the percentage of fish in the stock which are of quality size. For largemouth bass, stock size is $\geq$ 8.0 inches (20 cm) and quality size is $\geq$ 12.0 inches (30 cm). Reynolds and Babb (in preparation) recommend 40-60% PSD as balanced bass stocks in small impoundments, assuming actual density is not too low.

Although estimates of PSD from electrofishing samples are somewhat biased by size selectivity, the efficiency for all bass $\geq$ 8.0 inches (20 cm) is sufficiently similar to give close estimates of PSD (Figure 1). The sample size required to provide a valid estimate of PSD must be known. As sample size increases, the difference between electrofishing and actual PSD values decreases in small impoundments (Figure 5); apparently an electrofishing sample of 8-12 stock size bass will give an estimate of PSD within $\pm$ 10% at the 90% level of confidence. However, this applies only to small impoundments in which the bass stock was not balanced (30% > PSD > 70%); in those cases, assessment is an easier task because poor stock structure is relatively easy to detect.

Assuming that electrofishing efficiency for stock and quality size bass is sufficiently similar to be considered equal, it is possible to estimate stock sample size for various values of PSD and confidence limits. The binomial distribution applies to estimates of PSD since fish in the stock must be either (1) less than quality size, or (2) quality size:

$$p \pm (1.645 \sqrt{pq/n} + \tfrac{1}{2} n)$$

where n = number of stock-size fish sampled
p = PSD expressed as a decimal fraction
q = 1.0 - p
1.645 = t value at 90% confidence level

Confidence limits (precision) for PSD estimates depend on sample size (n), confidence level (error) chosen, and the actual PSD of the stock (Figure 6). Confidence limits around a PSD estimate decrease as the sample size increases and as the chosen confidence level decreases. For a given sample size and specified confidence level, confidence limits are widest when actual stock PSD is 40-60% and decrease symmetrically as actual PSD approaches 0 or 100%.

Management Sampling Strategy

Electrofishing efficiency, particularly for largemouth bass, could not be predicted with reasonable confidence using the data from the pilot study. However, key factors which influence efficiency were quite evident. These are included in a recommended procedure for electrofishing assessment of fish populations and stocks.

Spring is probably the best season to obtain good electrofishing samples. As shallow waters warm, fish of all sizes, but particularly adults, are closely associated with shoreline habitat. Surface temperature should be above 60 F (16 C) to increase efficiency; ranges of spawning temperature should also be considered. Sampling should be done soon after dusk when most predators are feeding near shore. Electrical current is more efficient as DC or pulsed DC than AC, but is relatively unimportant if one type is consistently used. Water transparency, amperage output, weather conditions and extent of cover should be observed and recorded. One lap of shoreline is the most complete unit of effort; additional or partial laps should be recorded separately. In larger waters bodies, shoreline distance and time should both be recorded as units of effort. Dip netters should be experienced and cognizant of the need to collect <u>all</u> fish possible, regardless of species and size. The second best season for electrofishing assessment is the autumn after shoreline temperature is decreased from summer maximia, and a larger segment of the fish community moves shoreward at night.

Most freshwater predators (e.g., micropterine centrarchids, percids and esocids are vulnerable to electrofishing during spring seasons. These are excellent opportunities to assess, stock balance, effective reproduction (i.e., relative abundance of age I fish) and population size structure (i.e., length frequency). Under standard procedures, catch-per-unit-effort provides the best estimates of relative abundance. Electrofishing is probably least size-selective among stock sizes for most predator species. Therefore, PSD is a valuable index for making management decisions based on electrofishing samples. The smaller samples required to detect unbalanced stocks work to the advantage of the fishery manager; correct assessment of poor stock condition is more important than incorrect assessment of a balanced stock.

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Table 1. Efficiency of electrofishing for detecting and sampling populations of common species in 27 Central States Pond Management Work Group ponds. Populations were defined by rotenone recovery of at least 30 individuals (from Simpson 1978).

Species	Number of populations	Detection[a] success (%)	Combined[b] efficiency (%)
Bluegill	27	100	0.5
Largemouth bass	24[c]	96	5.6
Green sunfish *Lepomis cyanellus*	9	67	0.3
Crappie *Pomoxis* sp.	8	25	0.3
Redear sunfish *L. microlophus*	4	100	0.9
Channel catfish *Ictalurus punctatus*	5	20	0.4
Bullhead *Ictalurus* sp.	5	20	1.1
Golden shiner *Notemigonus crysoleucas*	5	20	0.1

a Percentage of populations from which at least one individual was taken during electrofishing.

b (Total captured in all ponds ÷ total recovered in all ponds) x 100

c Includes two ponds with less than 30.

Table 2. Efficiency of AC electrofishing for capturing different length groups of largemouth bass and bluegill (from Simpson 1978). SD = standard deviation.

Length group (in)	Ponds		Coves		Combined	
	Mean	SD	Mean	SD	Mean	SD
Largemouth bass	(n=31)		(n=15)		(n=46)	
≤ 3.9	2.1	3.9	3.0	3.9	2.4	3.9
4.0-7.9	7.9	9.9	16.8	15.9	11.1	13.0
8.0-11.9	12.8	13.8	11.5	7.4	12.3	11.8
12.0-15.9	15.3	19.2	22.9	33.5	17.9	24.9
≥ 16.0	18.1	27.4	20.8	29.2	18.9	27.4
All lengths	10.3	11.6	5.5	5.4	8.6	10.0
Bluegill	(n=29)		(n=7)		(n=36)	
≤ 2.9	0.8	1.3	1.4	1.7	0.9	1.4
3.0-5.9	2.2	3.3	3.4	3.4	2.5	3.3
≥ 6.0	1.3	1.8	1.5	1.7	1.4	1.7
All lengths	1.0	1.5	2.2	2.4	1.2	1.7

Table 3. Average efficiency of electrofishing for capturing largemouth bass and bluegill in ponds and coves under different ranges of surface water temperature. Standard deviation is indicated in parentheses (from Simpson 1978).

Length group (in.)	Surface temperature (F) ≤ 69	70-79	≥ 80
Bass n=	7	14	21
≤ 3.9	0.8 (1.4)	4.0 (5.2)	1.8 (3.0)
4.0-7.9	9.5 (12.1)	7.1 (6.8)	14.2 (15.8)
8.0-11.9	15.4 (10.3)	10.9 (12.1)	12.3 (12.4)
12.0-15.9	25.0 (14.3)	28.0 (32.2)	8.7 (18.3)
≥ 16.0	39.0 (38.5)	27.0 (30.1)	6.7 (14.1)
All lengths	12.1 (11.5)	8.6 (10.1)	7.3 (9.6)
Bluegill n=	9	14	13
≤ 2.9	0.6 (1.0)	0.9 (1.2)	1.1 (1.8)
3.0-5.9	1.7 (1.0)	2.7 (3.6)	2.7 (4.0)
≥ 6.0	2.7 (2.6)	1.2 (1.3)	0.8 (1.2)
All lengths	0.6 (0.4)	1.4 (1.7)	1.4 (2.3)

Figure Titles

1. Average electrofishing efficiencies in ponds and coves for largemouth bass in 4.0-inch length groups (from Simpson 1978).

2. Influence of water transparency on electrofishing efficiency for largemouth bass 12.0-15.9 inches long (from Simpson 1978).

3. Number of bass captured by electrofishing in experimental ponds with and without artificial structures (from Simpson 1978).

4. Comparison of efficiencies of AC and DC electrofishing for capture of largemouth bass in experimental ponds (from Simpson 1978).

5. Error or difference between electrofishing and actual PSD values as a function of number of stock-size bass sampled in ponds studied by the Central States Pond Management Work Group. Straight line is regression formula: log(Error) = 1.68 - 0.08(Sample Size); r = -0.78. Curved lines are 90% confidence limits (from Simpson 1978).

6. Confidence limits (± %) as a function of PSD for varying sample size of stock-size fish. A, n=10; B, n=25; C, n=50; and D, n=100 (from Weithman et al., in prep.).

Figure 1

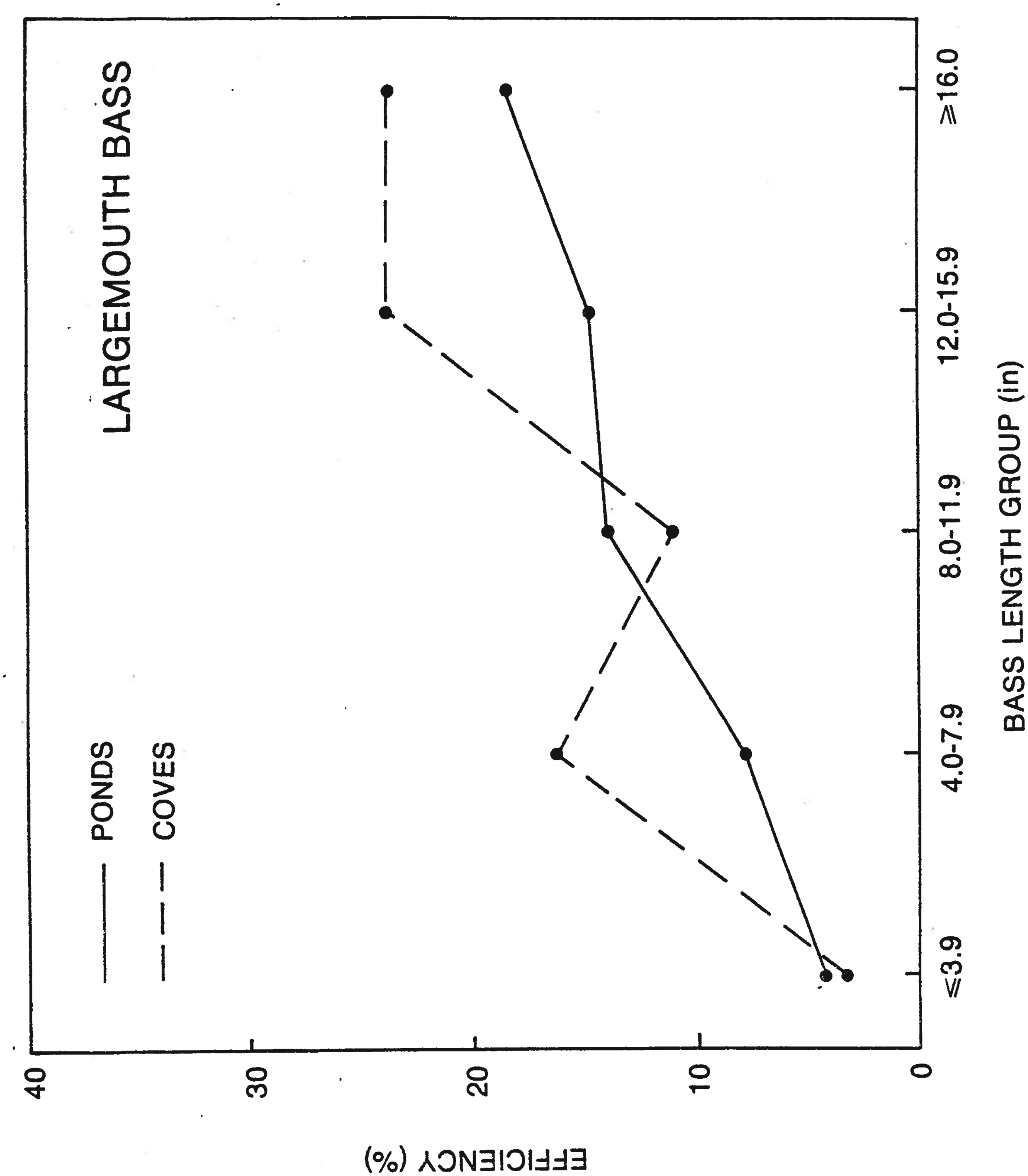

LARGEMOUTH BASS
PONDS
COVES
EFFICIENCY (%)
0
10
20
30
40
BASS LENGTH GROUP (in)
≤3.9
4.0-7.9
8.0-11.9
12.0-15.9
≥16.0

Figure 2

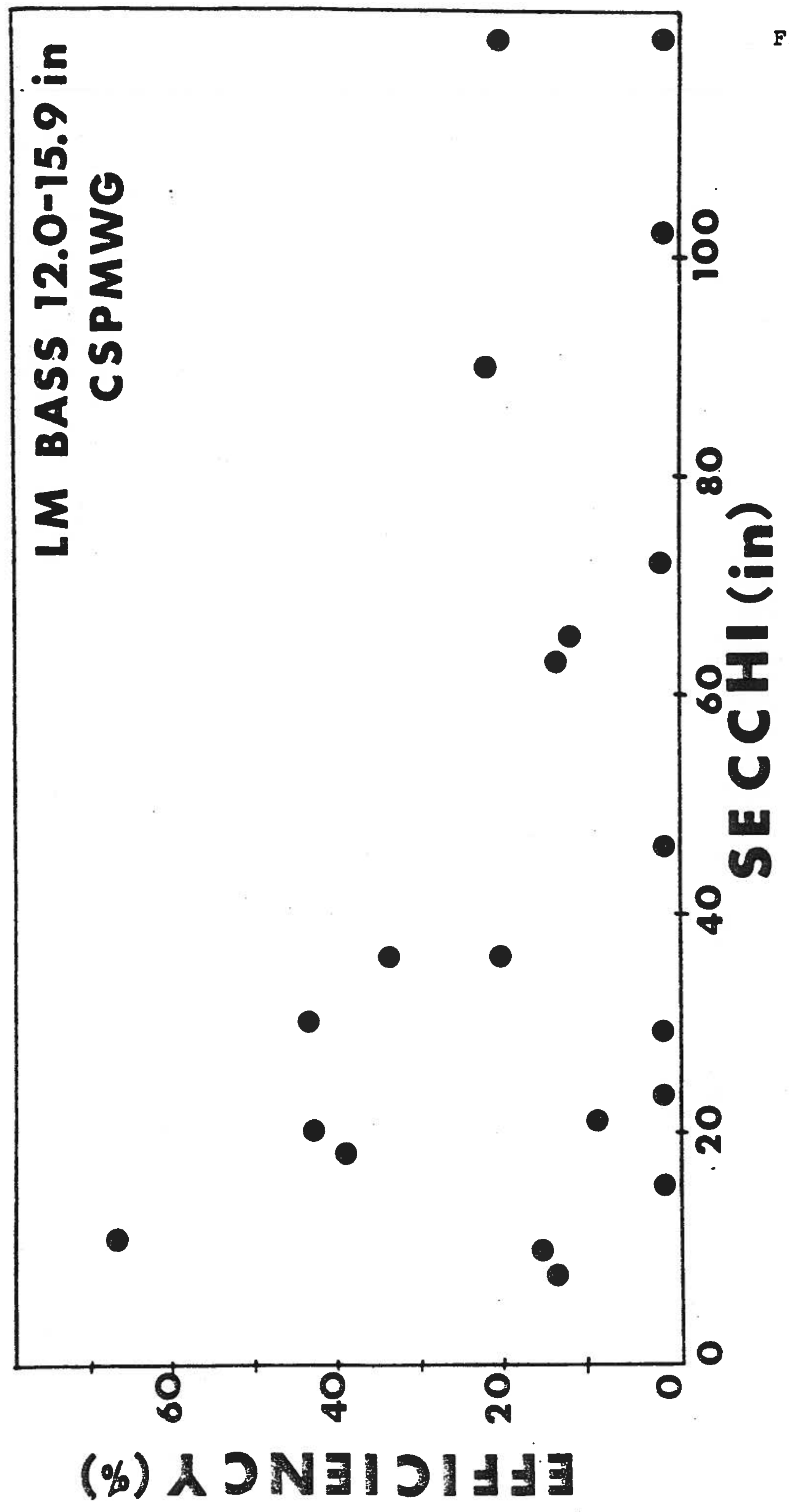

LM BASS 12.0-15.9 in
CSPMWG
SECCHI (in)
EFFICIENCY (%)
0
20
40
60
80
100
0
20
40
60

Figure 3

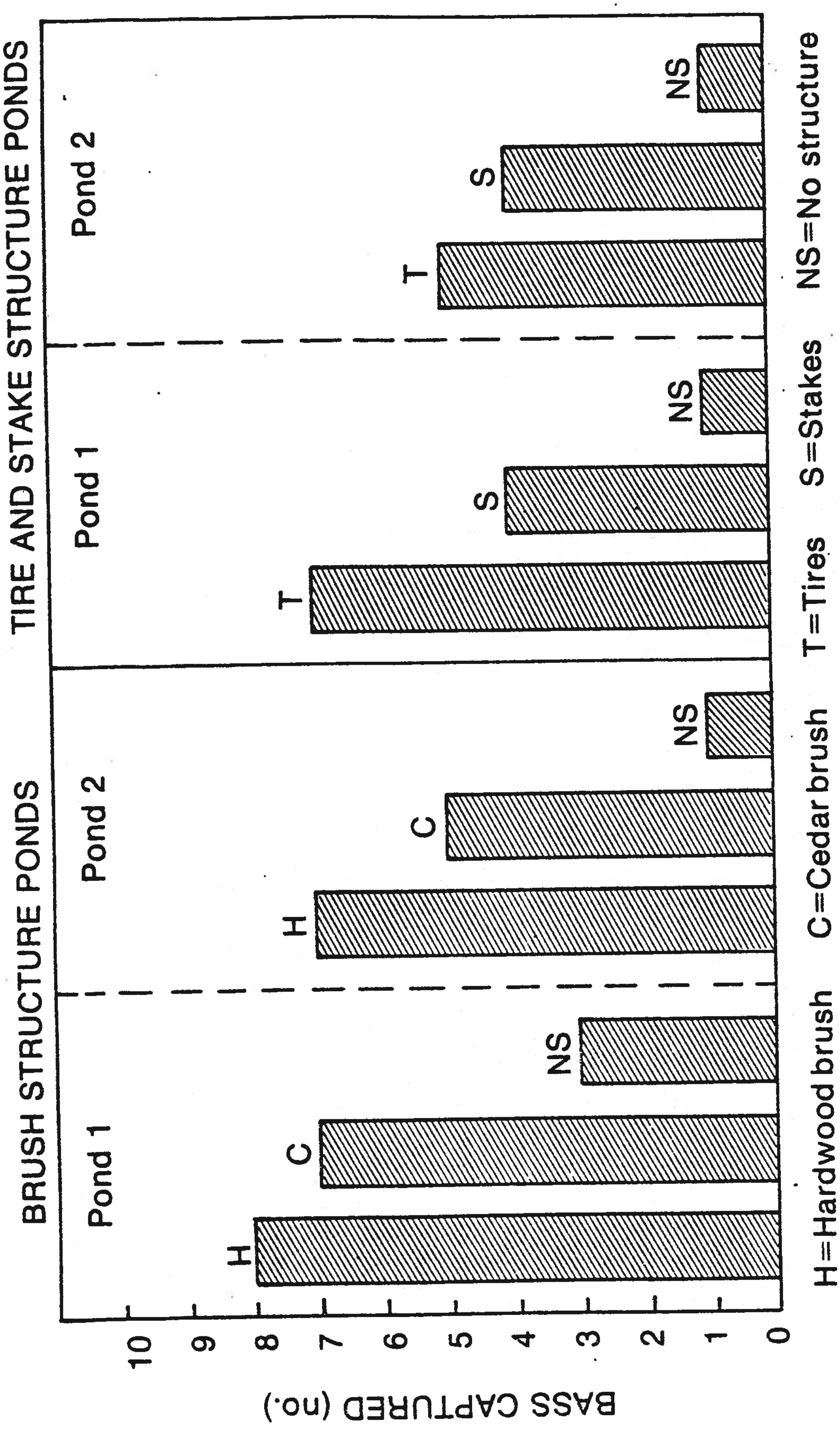

BRUSH STRUCTURE PONDS
TIRE AND STAKE STRUCTURE PONDS
Pond 1
Pond 2
Pond 1
Pond 2
H
C
NS
H
C
NS
T
S
NS
T
S
NS
BASS CAPTURED (no.)
0
1
2
3
4
5
6
7
8
9
10
H=Hardwood brush
C=Cedar brush
T=Tires
S=Stakes
NS=No structure

Figure 4

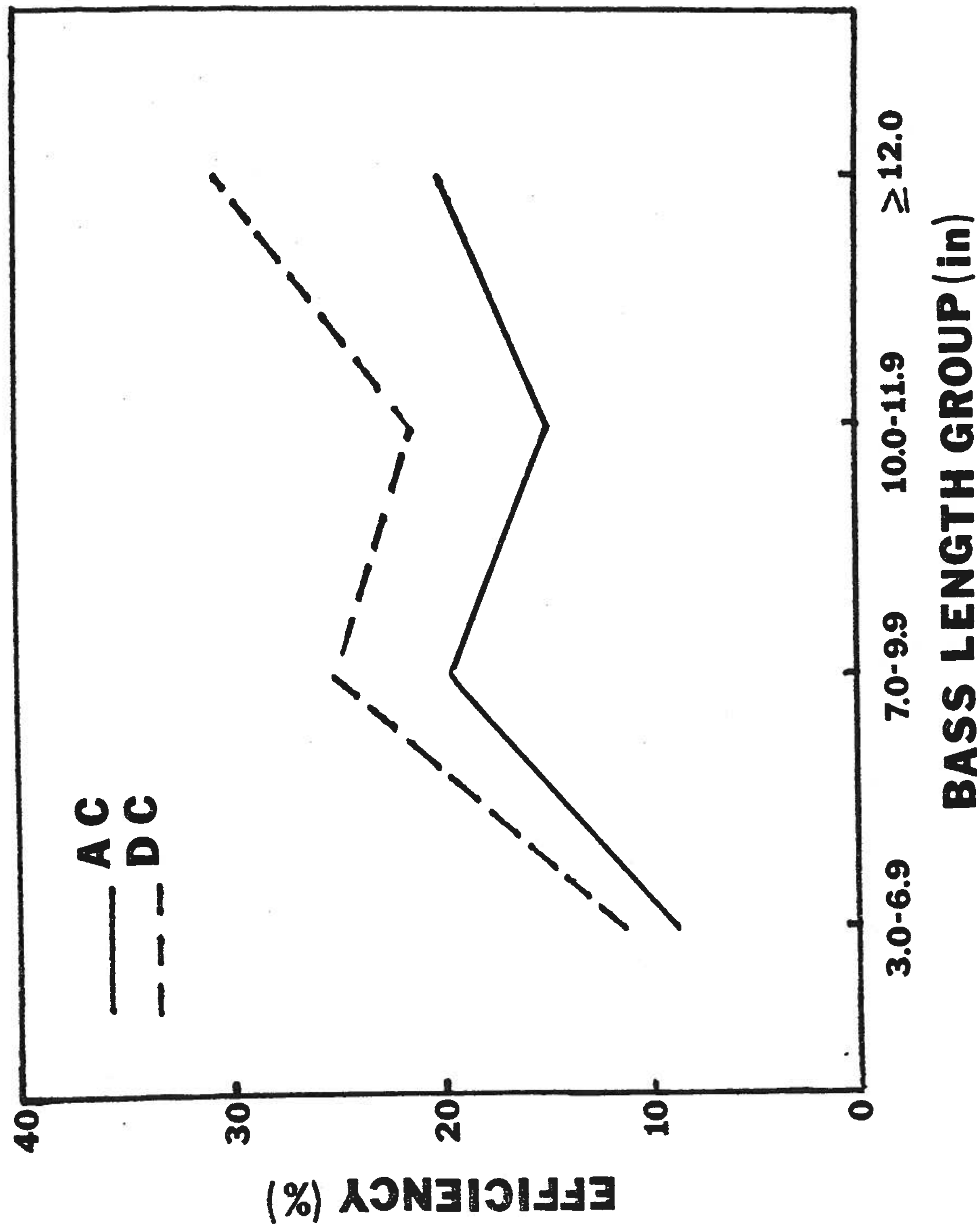
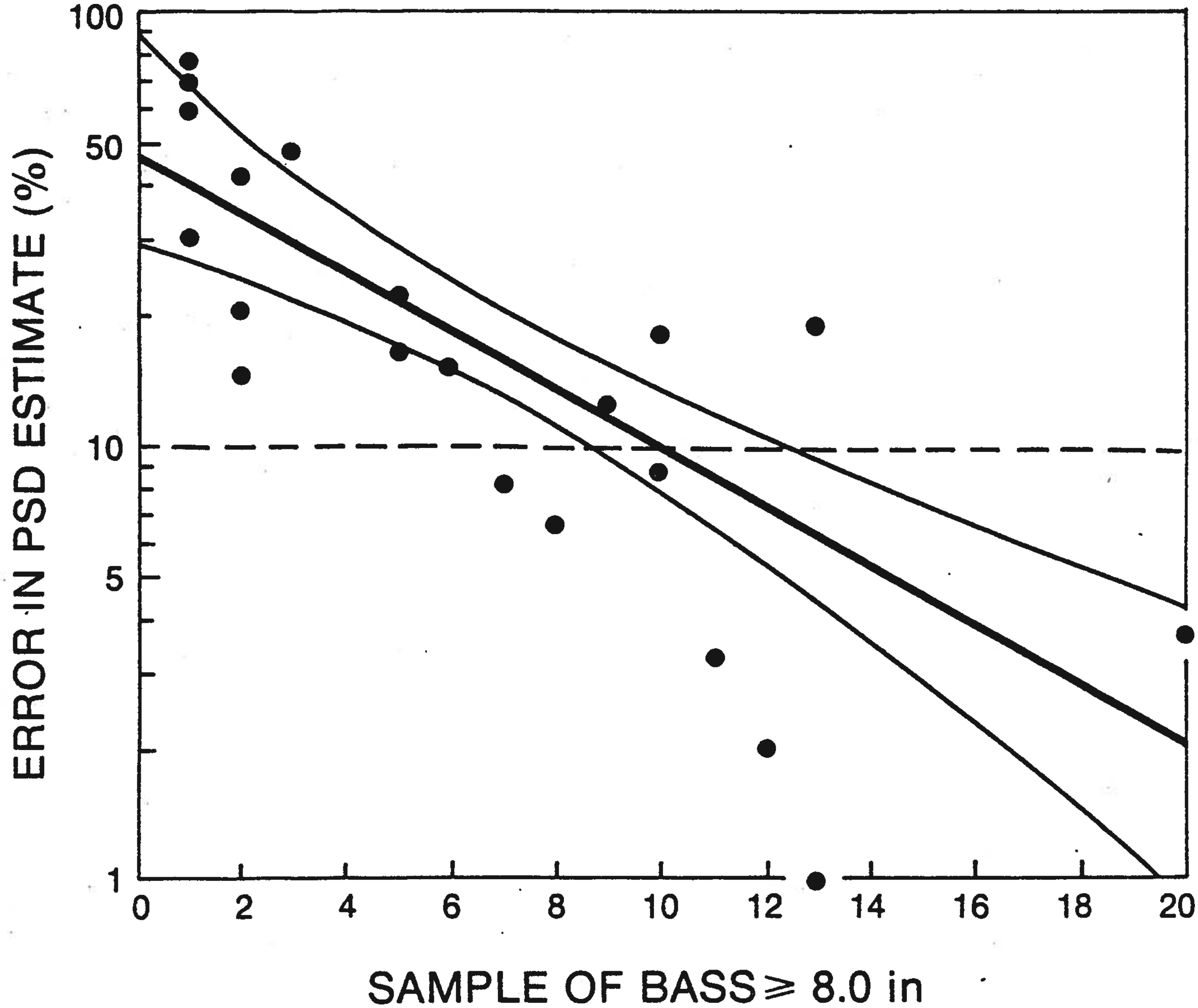

AC
DC
EFFICIENCY (%)
0
10
20
30
40
3.0-6.9
7.0-9.9
10.0-11.9
≥12.0
BASS LENGTH GROUP (in)

Figure 5


100
50
10
5
1
ERROR IN PSD ESTIMATE (%)
0
2
4
6
8
10
12
14
16
18
20
SAMPLE OF BASS ≥ 8.0 in