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Sampling Characteristics of Enclosure Fish Traps

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Abstract

Traps that enclose quickly a known area of water, enclosure traps, appear to be effective devices for sampling small fishes in shallow marshes. Three trap designs, a 1-m² drop trap, a 1-m² throw trap, and a 2.25-m² throw trap, were compared. The drop trap was inferior in sampling accuracy and precision and in ease of use. The two throw traps had similar sampling characteristics, but the larger, 2.25-m², trap required a larger field crew and more time to sample a unit area than did the smaller throw trap. The precision of the 1-m² throw trap in the Everglades was such that 20 or fewer samples were required in nearly 75% of the sampling situations. The trap had an accuracy of about 73% of true fish density. It showed no bias against particular fish species, but a bias against fish larger than 20 mm occurred in one of three tests. Their precision, accuracy, and logistical efficiency make small throw traps useful for some studies of fishes in shallow marshes.

The dynamics of fish populations in shallow marshes are less well understood than those of fish in rivers, lakes, streams, or ponds, even though marshes account for a large proportion of freshwater habitats. To a considerable extent, marsh fishes have been little studied because methods for quantitatively sampling them are poorly developed.

In recent years, several attempts have been made to devise and use trapping devices suitable for shallow-water fishes (Kjelson and Johnson 1973; Wegener et al. 1973; Kushlan 1974a; Kjelson et al. 1975; Aneer and Nellbring 1977; Gilmore et al. 1978), especially in south Florida marshes (Kushlan 1974b, 1976, 1980; Kushlan et al. 1975; Ogden et al. 1976). A common feature of these "enclosure traps" is that they surround a fixed area of water surface by being thrown, dropped, or otherwise inserted into the water column. Despite the increasing use of enclosure traps, their sampling characteristics have not been studied in detail. Most designs have specific sampling drawbacks, and, from a previous analysis of several such traps (Kushlan 1974a), I concluded that the most precise data on shallow-water fish communities could be obtained by using portable, open-bottom traps. Subsequent modifications resulted in the development of three enclosure-trap designs, a 1-m² drop trap, a 2.25-m² throw trap, and a 1-m² throw trap. Each trap is thrown or dropped into the water, and fish caught within are removed with a dip net. The sampling characteristics of these traps are analyzed in this paper with special emphasis on what I judged to be the most satisfactory trap, a 1-m² throw trap.

Methods

The 1-m² drop trap was supported by a quadrapod of aluminum conduit. Two square frames of galvanized iron pipe 1 m on a side formed the top and bottom. They were connected by 3-mm mesh nylon netting material to provide an enclosure 1 m deep. Each corner of the top frame was secured above the water to a quadrapod leg so that the lower frame could reach the marsh bottom. To set the trap, the lower frame was raised by a block and tackle to the level of the top frame and secured there. The trap dropped into the water when the lower frame was released. The trap required time to set up and to allow for re-equilibration of fish after their initial disturbance.

The 1-m² throw trap consisted of a box-like frame constructed of pipe with 3-mm netting material on four sides (Fig. 1). The trap was 1 m wide and 0.5 m tall. The 25-mm galvanized pipe frame was joined by side arm elbows and unions. A modified frame that could be collapsed during transport consisted of 9.5-mm diameter pipe attached to the bottom that slid inside a 25-mm aluminum pipe attached to the top. When the trap was fully opened, the two vertical pipes were secured with pins inserted through matching holes. I found that such a collapsible construction weakens the trap and rarely seems necessary. Similar traps made of 25-mm polyvinyl chloride pipe and of 25-mm aluminum pipe failed after short periods because the joints cracked under stress. The trap was thrown by one person. Additional equipment necessary included dip nets, generally two mesh sizes used sequentially, and collecting bottles with preserving medium. The trap is readily transported, and we regularly move such traps by van, truck, airboat, and helicopter.

The 2.25-m² throw trap was identical in shape and construction to the smaller throw

FIGURE 1.—*Operation of 1-m^2 throw trap.*

trap. Each side of this trap was 0.5 m tall by 1.5 m wide. It was thrown by two persons, each standing on opposite sides of the trap.

Tests of the traps were conducted in the marshes of the Everglades and shallow marine flats of southern Florida. The marsh tests were all conducted in medium to sparse herbaceous vegetation dominated by species of *Eleocharis*, *Panicum*, and *Utricularia*. Because the nature of the plant cover, particularly its density and height, affects trapping characteristics, marsh type was held as constant as possible among the tests. The marine site was an open turtle grass bed (*Thalassia* sp.). No test of the effects of various plant covers was made.

To compare the precision and ease of use of all three traps, the three traps were operated between 19 and 25 times at the same time in the same area. Fish were extracted by dip net and preserved. The number of fishes in each trap and the time required for a specified number of people to empty the trap completely were recorded. In the laboratory, fishes were identified and their standard lengths measured. After the initial comparative test, the precision of the 1-m^2 throw trap was tested in a series of eight sampling episodes (seven in Everglades marsh and one in a marine grass flat) over one year. Each sampling episode consisted of 20 samples taken on one day. Based on these results a regular sampling program using this trap was initiated and the 60 subsequent sets of samples taken over two and a half years provided additional data on trap precision under normal operating conditions.

The accuracy of the 1-m^2 throw trap was determined by sampling within three large block netted areas. The blocknets had the same netting material as was used for the trap and were held up by poles 2 m apart. To allow for re-equilibration of the fish beneath the net, we waited one hour before remotely dropping the bottom of the blocknet. The bottom was imbedded into the sediment by weights while the top edge remained attached to poles and floats. After the blocknet was down, 20 throw trap samples were taken inside. Fish caught in the traps were identified, their standard lengths were measured, and they were then returned alive to the enclosure. When sampling was completed, the entire blocknetted area was treated with rotenone. Dead and dying fish were collected over that day and the next two days. The block nets erected to study the accuracy of the fish trap were used at low (3 fish/m^2), medium (9 fish/m^2), and high (33 fish/m^2) fish densities. Twenty samples were taken within each of three block nets, so that we had time to sample and poison on a single day.

The number of samples (N) required to provide a statistically adequate sample was calculated by the equation, $N = t_\alpha^2 s^2/L^2$, where t is Student's statistic for the selected confidence level α, s^2 is the variance of the sample, and L is the allowable error (Snedecor and Cochran 1967). In this study α was 0.05, so t^2 was approximately 4. L was set at 20% based on the usual densities of the fish populations studied. Overall mean densities in the Everglades fluctuated around 10 fishes per m^2, and the accuracy needed was about two fish. When the average density was less than 10 fish/m^2, L was set at 1 fish. Standard parametric and nonparametric statistical tests were used (Siegel 1956; Sokal and Rohlf 1969). "Electivity" (E) or selectivity of the traps for fish size was analyzed by the expression $E = (P - S)/(P + S)$, where P = proportion of fish of a given length category in the population, and S = proportion of fish in that length category in the samples (Ivlev 1961).

Results and Discussion

Comparison of Enclosure Traps

Of the two 1-m^2 traps, the drop-trap samples had a higher variability than the throw-trap samples; coefficients of variability (CV = 100[mean]/SD) were 91% and 38%, respectively. The variability of the drop-trap samples taken was so great that to detect 20% differences

TABLE 1.—*Fish sampling statistics for three types of enclosure traps. Values within a row without a letter in common are significantly different (t-tests, P ≤ 0.05).*

	1-m^2 drop trap	1-m^2 throw trap	2.25-m^2 throw trap
Samples taken	25	23	19
Density (mean number of fish/m^2, ± SD)	6.4 ± 5.82 a	11.0 ± 4.21 b	12.6 ± 4.70 b
Species (mean fish species/m^2, ± SD)	2.0 ± 0.93 a	2.9 ± 0.95 b	2.0 ± 0.40 a
Mean length (mm/18 m^2, ± SD,N)	18 ± 4.8,108 a	18 ± 5.9,141 a	19 ± 5.9,191 a
Mean time (2 operators, minutes/m^2)	15.3	16.0	18.5
Mean time (3 operators, minutes/m^2)		10.2	11.2
Samples needed to detect a 20% difference in density ($\alpha = 0.05$)	82	15	14
Samples needed to detect a one-species difference in species/m^2 ($\alpha = 0.05$)	4	4	1
Samples needed to detect a 1-mm difference in length ($\alpha = 0.05$)	15	13	5

in density would require 82 replicates, or 21 hours of sampling (at 15.3 minutes per trap, excluding set up time). The throw trap, catching significantly more fish and more species and requiring fewer replicates and therefore, less field time (Table 1), was unquestionably the superior sampling method of the two.

Variability of the samples of the differently sized throw traps was nearly identical (CV for $1\text{-m}^2 = 38\%$; CV for $2.25\text{-m}^2 = 37\%$), and the smaller trap required only one more sample than the larger trap (Table 1). Neither the mean number of fish caught per square meter nor the mean size of trapped fish was significantly different between those two traps (Table 1). The throw traps differed significantly only in the number of species caught per square meter. Unexpectedly, the smaller trap caught more species (Table 1).

Ease and time required for use are primary criteria in choosing a sampling device; the shorter the sampling time, the more useful the trap. The larger trap required more sampling time per square meter than the smaller trap, whether two or three operators were involved. For this reason, and because there was no statistical advantage, I concluded that the 1-m^2 throw trap is the better sampling device. This trap can be thrown by one person (Fig. 1), although two operators allow more efficient removal of fish. In the test data for determination of fish density (Table 1), two people could gather the requisite 15 samples in 4 hours. With travel time in the Everglades allowed for, this sampling regimen can be accomplished in a day in the field.

The number of samples required for an adequate estimate of fish density was more than sufficient to detect a one-species difference in number of species caught and a 1-mm difference in mean length of fish caught (Table 1). As a result, the calculation of the number of samples required can be based on density alone.

It is possible to determine readily necessary sample size in the field. The sample size, with constant α and L (0.05 and 20% error, respectively in our work), is a function of the coefficient of variation. For example:

$$\begin{aligned} N &= t_\alpha^{\,2}s^2/L^2 \\ &= 4s^2/(0.2\cdot \text{mean})^2 \\ &= 100(s/\text{mean})^2 \\ &= 100\text{CV}^2. \end{aligned}$$

The coefficient of variation can be computed easily on a portable calculator. Alternatively, a graph of CV on N can be developed beforehand for a given α and L. For a calculated CV, N can be read from the graph after a few samples (my standard is seven) have been taken, permitting effective use of field time.

Precision of the 1-m² Throw Trap

Most of the initial eight field trials of the small throw trap required a logistically reasonable number of samples (Table 2). However, the variances in two cases were impractically high. One field crew could not take the 29 or 36 samples in one day, although two crews could have done so. For the criteria used, CV should be no higher than 0.5. One sample (number 8, Table 2) was taken to study trap characteristics at relatively low fish density. With means on the order of two fish, 0.2 × the mean is only 0.4 fish. In this application, a dif-

TABLE 2.—*Samples taken to analyze precision of 1-m² throw traps.*

Sample	Number of samples taken	Mean density (fish/m², ± SD)	Number of samples required to detect a 20% difference
1	20	7.5 ± 4.02	29
2	20	9.7 ± 3.66	15
3	20	10.4 ± 5.33	19
4	20	9.3 ± 3.28	13
5	20	8.5 ± 3.55	18
6	20	10.0 ± 4.78	23
7	20	7.8 ± 4.64	36
8	25	2.4 ± 1.87	14[a]

[a] 0.2 × mean is less than one fish; therefore, accuracy is set to nearest whole fish (1).

ference of less than a fish was too small to be a practical distinction. When the accuracy criterion was set to detect a difference of one fish, a practical number of samples was required.

These data suggested that the precision of the 1-m² trap usually was adequate for quantitative studies, and I began using the trap in my ongoing studies of Everglades fish populations. Over 2.5 years, nearly 75% of 60 sampling episodes required fewer than 20 samples (Table 3).

TABLE 3.—*Frequency distribution of the number of samples required for the 1-m² throw trap, based on 60 sets of samples taken in the Everglades ($\alpha = 0.05$; acceptable error = 20% of the mean).*

Samples required	Frequency (%)
1–10	40
11–20	32
21–30	13
31–40	8
41–50	3
51–60	0
61–70	3

Accuracy of the 1-m² Throw Trap

In all three tests of accuracy, the samples tended to underestimate true fish density (Table 4), but the deviation was significant only at the highest population density ($t = 5.95$; $P < 0.05$). For the low- and medium-density tests, 20 samples were insufficient to detect a 20% difference by parametric analysis (31 and 32 samples required, respectively). However, the samples did not differ from the population densities by the nonparametric Kolmogorov-Smirnov test ($P > 0.05$). Significantly different or not, the sample estimates were a fairly consistent fraction (70–76%) of the true fish densities. Thus, the accuracy of the traps in the Everglades can be considered to be about 73%. For some purposes, such a conversion factor could be used, with caution, to estimate fish standing stock.

Accuracy of the trap for determining species richness and the sizes of fish may be important for some applications. In all three tests, the

TABLE 4.—*Sampling accuracy of the 1-m² throw trap under three conditions of fish density. Asterisks (*) denote sample values significantly different from population values (*t-test*, P < 0.05).*

	Test 1	Test 2	Test 3
Test conditions			
Number of samples	20	20	20
Enclosure area (m²)	368.7	190	232.3
Fish density (fish/m²)			
Population density	3.4	9.4	33.2
Sample mean ± SD	2.6 ± 2.83	6.6 ± 3.94	24.1 ± 6.64*
Accuracy (% of population density)	76	70	73
Fish length (mm)			
Number fish in enclosure	1,263	1,791	7,715
Population mean length ± SD	19.9 ± 7.30	19.6 ± 6.67	20.8 ± 10.80
Number fish in sample	53	132	482
Sample mean length ± SD	20 ± 8.4	17 ± 6.7*	15 ± 8.0*
Number of species			
Species in enclosure	11	16	10
Species in samples	7	12	8
Species in population having a density > 1/20 m²	0	1	0

mean length of fish in the population was about 20 mm (Table 4). In two of the tests, the sample mean length underestimated the population mean length. Such a size bias might be caused either by the larger fish being able to escape a falling trap or by their being relatively scarce. In test 2 (medium density), all fishes that were greater than 40 mm long occurred at a density of 0.019/m^2, or 0.4 fish per 20 m^2. Thus, the 20 samples taken did not cover a sufficient area to expect to catch one of these large fishes except by chance. The case was the same in test 1 (low density). In test 3, however, large fishes were more common, so the rareness of large fish was not the only explanation for a bias in the results of this test. The bias applies to fish larger than 20 mm in the test situation. Although the electivity of the throw trap was -0.4 for fish over 20 mm, the electivity was 0 for fish 11–20 mm, and the trap provided a good sample of these smaller-sized fishes.

The samples obtained most of the species (64–80%) present in the enclosure (Table 4). Of the species not caught, all but one occurred at densities of less than 1 fish per 20 m^2. In test 2, no warmouth (*Lepomis gulosus*) was captured although the density of this species was 1.2 fish/20 m^2, and one fish could have been expected to be caught. With this exception, the trap appeared to miss only those species too rare to be expected to be caught in the area covered.

Conclusion

The 1-m^2 throw trap required a logistically reasonable number of samples in most cases. In 3 tests, the accuracies of the 1-m^2 trap for estimating density were similar, encouraging confidence in applying a correction factor for determination of standing stock. The 1-m^2 trap appeared biased against some larger fishes, because they were rare and because they might have been able to avoid the trap. The potential influence of any such bias must be considered when the technique is applied. The trap sampled adequately the sizes of fish that dominate the Everglades fish community, and it adequately sampled the species present, missing only the rare ones.

Thus, such a 1-m^2 throw trap seems worthy of consideration in similar applications. As in all sampling studies, the nature of the population to be sampled should be considered. The density of vegetation in the sampling habitat is also an important consideration in sampling accuracy, as are the sizes and trap-avoidance behaviors of the particular species being studied. Preliminary tests should be performed for each application. Nonetheless, to overcome the problems that have inhibited the study of marsh fishes to date, enclosure traps may provide a realistic approach for future quantitative work in shallow vegetated habitats.

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