North American Journal of Fisheries Management 23:462–469, 2003
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Comparison of the Species Composition, Catch Rate, and Length Distribution of the Catch from Trap Nets with Three Different Mesh and Throat Size Combinations

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Abstract.—Trap nets of varying design are commonly used to assess fish populations, but the effect of the design on gear selectivity is not well known. In particular, it may be advantageous to use multiple net designs with different mesh and throat sizes to maximize the catch of specific length-classes and to minimize the risk of predation on small fish by larger fish. We compared the species composition, catch rate, and length distribution of fishes caught by three trap net designs with dimensions differing only in mesh size and throat size (0.6-cm delta mesh and 3.8-cm × 3.8-cm square throats, 1.3-cm square mesh and 7.6-cm × 7.6-cm square throats, or 2.5-cm square mesh and 12.7-cm × 12.7-cm square throats). A total of 3,473 fish of 18 species were captured from Sandy Lake, Portage County, Ohio, during 24 sample dates from June to August 1999. The large net design had a significantly higher average number of species captured (mean = 11) than the medium or small net design (means = 9 and 8, respectively). Whereas nets with larger mesh and throat size combinations typically caught larger fish for the six most commonly captured species, only rarely did nets capture fish as large or as small as possible based on their physical dimensions. Specific length-classes of some species were not captured in the nets or were very net design specific, indicating a possible difference in trap net vulnerability of different ontogenetic stages. We conclude that data from trap nets with different mesh and throat sizes should not be directly compared with each other, and that multiple net mesh and throat sizes (or even multiple gear types) should be used when a more complete picture of fish length and abundance is desired.

Trap nets are commonly used to assess fish populations (Hubert 1996). While many trap-net designs have been described (e.g., using different mesh sizes, throat sizes and shapes, and heart dimensions), few studies have compared the catch among these designs. All commonly used fish sampling methods are biased with respect to species, size, or sex of the fish caught (Hubert 1996). Therefore, it is important to know the catch bias of sampling equipment so gear can be selected that will target the species, size, or sex of interest, or a combination of gear can be used to minimize the bias of samples of the overall fishery.

The minimum size of fish that can be captured by a trap net is ultimately set by mesh size. Accordingly, several studies have found that nets with smaller mesh tend to catch either smaller fish or more fish in small length-classes for several species: yellow perch *Perca flavescens* (Kraft 1990; Kraft and Johnson 1992), channel catfish *Ictalurus punctatus* (Hesse et al. 1982; Holland and Peters 1992), white crappie *Pomoxis annularis* (Willis et al. 1984; Jackson and Bauer 2000), Black crappie *P. nigromaculatus* (McInerny 1988; Jackson and Bauer 2000), and bluegill *Lepomis macrochirus* (Jackson and Bauer 2000). However, some studies have also found that differences in trap-net mesh size did not affect the length distribution of captured fish (white crappie, Willis et al. 1984; northern pike *Esox lucius*, Clark and Willis 1989). Studies have also found that trap-net mesh size affects catch per unit effort (CPUE) for channel catfish (Hesse et al. 1982; Holland and Peters 1992) and some length-classes of black crappie (McInerny 1988). However, no consistent relationship between trap-net mesh size and CPUE has been found for yellow perch (Kraft 1990) or northern pike (Clark and Willis 1989). We know of no study that has investigated the relationship between trap-net mesh size and fish size or CPUE for many fishes that are commonly captured in trap nets (e.g., redear sunfish *Lepomis microlophus*, pump-

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Received April 23, 2001; accepted July 22, 2002

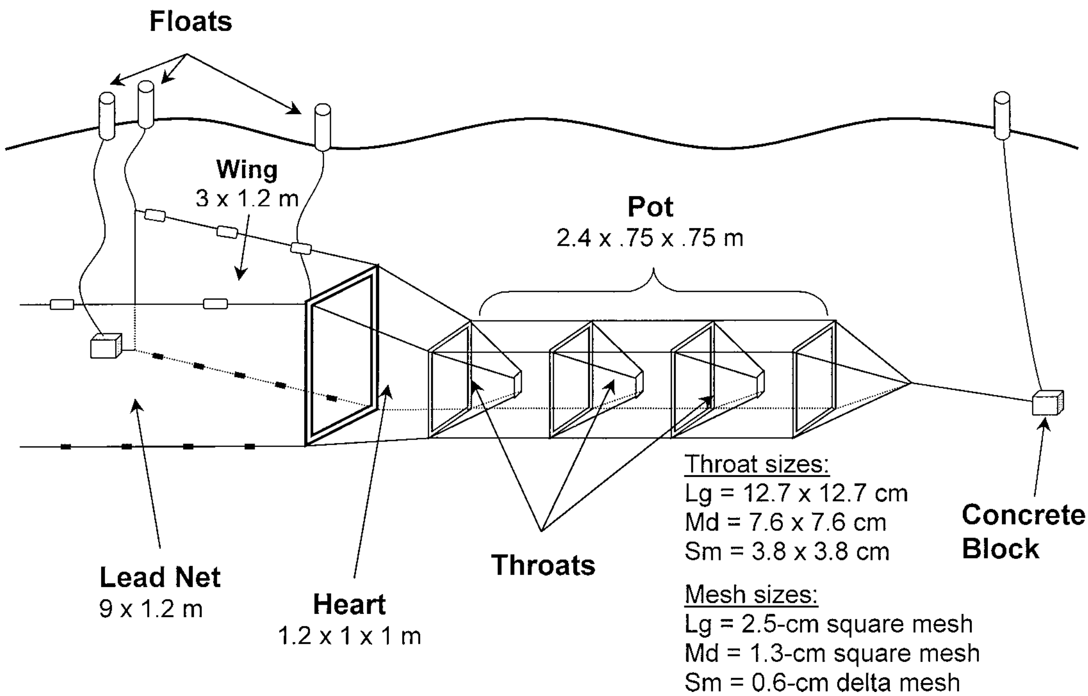

FIGURE 1.—Trap-net design used to test the effect of different mesh and throat size combinations on catch bias.

kinseed *Lepomis gibbosus*, brown bullhead *Ameiurus nebulosus*, and largemouth bass *Micropterus salmoides*). Additionally, we know of no study that has compared the minimum size of fish actually captured by a trap net with the minimum size a given mesh size could physically retain.

The maximum size of fish that can be captured by a trap net is ultimately set by the throat size of the net. However, we are unaware of any study that has investigated the relationship between throat size and fish size or CPUE. Theoretically, building trap nets with fine mesh size and large throats would maximize the range of fish sizes the net could catch. However, large throats may not be efficient at retaining small fish, and larger fish allowed into nets with large throats may prey on smaller individuals inside the net. Additionally, small mesh netting is heavy and expensive. Thus, it would seem most efficient to use multiple gear sizes and to vary mesh size and throat size together when using trap nets to sample fish of different sizes. However, with the limited information on the effects of mesh and throat size, this idea remains untested. Therefore, we compared the species composition, CPUE, and size distribution of fishes caught by three different trap-net designs of differing mesh and throat size.

Methods

Trap nets were designed so that only mesh and throat size varied among net types (Figure 1). The nets were constructed by sewing pieces of tar-treated nylon netting together with tar-treated #21 nylon twine. Square frames were constructed from 2.54- and 0.64-cm-diameter, schedule 20 polyvinyl chloride (PVC) pipes for the one heart and four pot frames, respectively. The first three pot frames contained square throats (Figure 1).

Two nets were constructed for each of the three mesh and throat size designs. Each pair of nets with the same mesh and throat size combination was attached together with a single 30-m lead net fastened to one side of each net's heart with 10.2-cm cable ties. The lead net was set perpendicular to the opening of each net. A wing net was then attached to the other side of the each net's heart with 10.2-cm cable ties and set at a 45° angle to the lead net. Leads and wings for each pair of nets were constructed from the same mesh as the nets. Floats (number 125 hard plastic, 12.7 cm long, 3.8-cm diameter) were hung on the top of the leads and wings every 91 cm. Lead weights (23.3 g) were hung on the bottom of the leads and wings every 37 cm, and the wings and leads were attached to the trap nets with 10.2-cm cable ties.

Each pair of nets was set in Sandy Lake, Portage County, Ohio, parallel to the southwest shoreline along the 1.8-m depth contour (approximately 1 m offshore from a fairly distinct deep vegetation line). The net pair was oriented as described by Hubert (1996), with the lead net parallel to shore and the opening of the two nets facing each other (opening perpendicular to the shore). The nets were set on June 18 and remained in the lake until August 19, 1999. The nets were sampled 24 times during this period and were usually emptied every 24 or 48 h (range, 19–124 h). Nets were always fished for the same length of time on a given sample date. All fish were identified to the lowest taxonomic level possible and released. On 14 sample dates, total lengths (mm) of all fish captured were also recorded.

During the study, net pairs were rotated between three sampling locations on June 23 and June 30. All three sampling locations were adjacent to each other (the distance between the cod ends of adjacent net pairs was approximately 7 m) and had similar habitats. An analysis of CPUE and mean length using data taken for this and a concurrent study from June 19 to July 7 (all nets sampled an equal number of times in each location) indicated no significant sampling station effect (CPUE: $F_{2,27} = 0.424$, $P = 0.6585$; length: $F_{2,29} = 0.097$, $P = 0.9082$). Therefore, nets were not rotated again after this time. There were no significant differences in mean CPUE (small net type: $t = -0.30$, df = 23, $P = 0.7652$; medium net type: $t = -1.07$, df = 23, $P = 0.2883$; large net type: $t = 1.03$, df = 23, $P = 0.3073$) or mean fish length (small net type: $t = 0.73$, $P = 0.4724$; medium net type: $t = 0.25$, $P = 0.8045$; large net type: $t = 1.92$, $P = 0.0658$) between replicate nets with the same mesh and throat size. Therefore, the data from each pair of replicate nets were pooled for analysis.

Total length and body depth (measured as the maximum dorsal-ventral distance perpendicular to the anterior-posterior body axis) were measured on preserved bluegill, pumpkinseed, redear sunfish, largemouth bass, and black crappie that had been captured from Sandy Lake using the six trap nets during a concurrent study. A regression equation was generated for each species and used to estimate the body depth of fish captured in this study (Table 1). These body depth estimates were then compared with the mesh and throat sizes of the nets (measured as the diagonal distance when the net is pulled tight so that mesh and throat openings were square) to determine if the minimum and maximum fish lengths captured in each net were being constrained by the physical limitations of the net or by some other factor.

TABLE 1.—Length–body depth regression statistics for five of the most commonly captured species caught from Sandy Lake, Portage County, Ohio, from June 19 through August 19, 1999.

Species	r^2	n	Slope	Intercept
Bluegill	0.982	94	0.437	−7.46
Pumpkinseed	0.991	34	0.462	−8.08
Redear sunfish	0.969	15	0.425	−4.60
Largemouth bass	0.964	24	0.268	−2.96
Black crappie (>130 mm)	0.970	21	0.400	−8.24
Black crappie (<60 mm)	0.955	15	0.329	−2.49

The mean number of species and the total CPUE (1 unit effort = one net pair set for 24 h) captured by each net type was analyzed separately with a two-factor (net type × sample date) analysis of variance (ANOVA), using date as a blocking variable. Species composition (species-specific CPUE) from the three net types was then analyzed using a three-factor (species × net type × sample date) ANOVA, using date as a blocking variable. The most commonly captured species (≥5% of the total catch) on the dates that lengths were measured (bluegill, pumpkinseed, redear sunfish, brown bullhead, largemouth bass, and black crappie) were then analyzed separately using a two-factor (net type × date) ANOVA (with date as a blocking variable) to test for significant differences among net types in the mean of the minimum, median, and maximum lengths of fish caught from each sample. On days when fish length was recorded, no largemouth bass from large nets and no black crappie from small nets were caught. Therefore, these two net types were not part of the statistical analysis for these species. Data showing significant differences from ANOVA procedures were subsequently analyzed with Tukey's tests. Total and species-specific CPUE values were log transformed ($\log_e[X + 1]$) to correct for proportionality between means and standard deviations prior to analysis, and the significance of statistical results was determined ($P < 0.05$). All analyses were performed using the Proc Mixed procedure of the SAS Institute (1997).

Results

The three net pairs captured 3,473 fish of 18 species during the 24 sample dates. The mean number of species captured in the large net type (mean = 11.2) was significantly higher than in the medium (mean = 8.6; Tukey $P = 0.008$) or small (mean = 8.3; Tukey $P = 0.003$) net types ($F_{2, 46} = 7.50$, $P = 0.002$). The mean number of species captured in the medium and small net types was not significantly different (Tukey $P = 0.922$).

Total CPUE was significantly higher in the large net (mean = 21.4, SE = 3.5) than in the medium (mean = 11.2, SE = 2.2; Tukey $P < 0.001$) and small (mean = 9.3, SE = 1.0; Tukey $P < 0.001$) net types ($F_{2, 46} = 15.23$, $P < 0.001$). Total CPUE of the medium and small nets were not significantly different (Tukey $P = 0.835$).

Species-specific CPUE was significantly different among net types (significant net type × species interaction, $F_{16, 598} = 10.27$, $P < 0.001$; Figure 2). Bluegill had the highest CPUE relative to other species in the three net types. Other species that had a high CPUE in one or two net types had a low CPUE in the other(s).

For the six most commonly captured species, large nets generally caught significantly larger fish (minimum, median, and maximum total length; Figure 3; Table 2). However, there were no significant differences between the three net types in the minimum or median length of black crappie ($P = 0.367$ and 0.420 for minimum and median length, respectively) and largemouth bass ($P = 0.108$ and 0.548 for minimum and median length, respectively), or the maximum length of the largemouth bass ($P = 0.398$) caught. Additionally, there were no significant differences between the medium and large net types with any of the three length metrics for redear sunfish or brown bullhead. There were also no significant differences between medium and large nets in the median and maximum lengths of pumpkinseed caught. Medium nets caught the widest range of fish lengths for species appearing in all three net types (Figure 3; Table 2).

Using length–body depth regression statistics for each species (Table 1), we determined that, in most cases, the mesh size of all three net types could have retained smaller fish than were captured in the samples (Figure 3). Throat sizes of all three net types would have allowed the capture of larger fish than were actually captured (Figure 3), a pattern that was most pronounced in the larger net types.

Discussion

Because the actual species composition and length distribution of the fish populations in Sandy Lake are unknown, it is not possible to determine if the nets caught fish in proportion to their abundance or if they were biased to specific species or length-classes. However, we assume each pair of nets was interacting with the same fish populations for three reasons. First, there were no significant sampling location effects. Second, the different net types were periodically rotated between sampling locations during the first part of the study. Third, the sampling stations were adjacent to each other and had no obvious habitat differences. Because the samples were collected over 2 months, it is also likely that the length distribution of fishes changed during the study or that fish may have changed their behavior relative to the trap nets with experience or seasonally based behavior (Hamley and Howley 1985; Cross et al. 1995). But, because the different net types were sampled on the same dates and the ANOVA procedure accounted for variability attributable to date, seasonal changes in length distribution or trap-net avoidance would not bias the results of the net design comparison.

The three net types caught different species and had different species-specific CPUE and length distributions. Using all three net types together would therefore provide a more complete picture of the abundance and size structure of the fishery than using any one design by itself. This is consistent with the findings of other studies that have demonstrated an effect of trap-net mesh size on CPUE and the lengths of captured fish (Hesse et al. 1982; McInerny 1988; Holland and Peters 1992). We are unaware of any study that has documented the effect of different throat sizes on the catch of trap nets. Nonetheless, we expect that smaller throats would improve the retention of smaller fish and exclude larger predators that could bias the samples through selective predation.

Even using the three trap net types to target different length-classes, our data imply that trap nets provide a skewed view of fish length distribution for some species. Some species had length-classes that were not captured by any of our nets. For some species (i.e., large largemouth bass and small black crappie), individuals in the length-classes not captured by our trap nets were captured in littoral zone seining samples or were caught by anglers—often near the trap nets (D. Shoup, personal observation). Therefore, it is most likely these fish length-classes were present but avoided the nets. Other researchers have captured certain length-classes of adult largemouth bass (Roach 1942; Latta 1959) and juvenile crappie (McInerny 1988; Miranda et al. 1996; Allen et al. 1999) that were not captured in our nets. This discrepancy

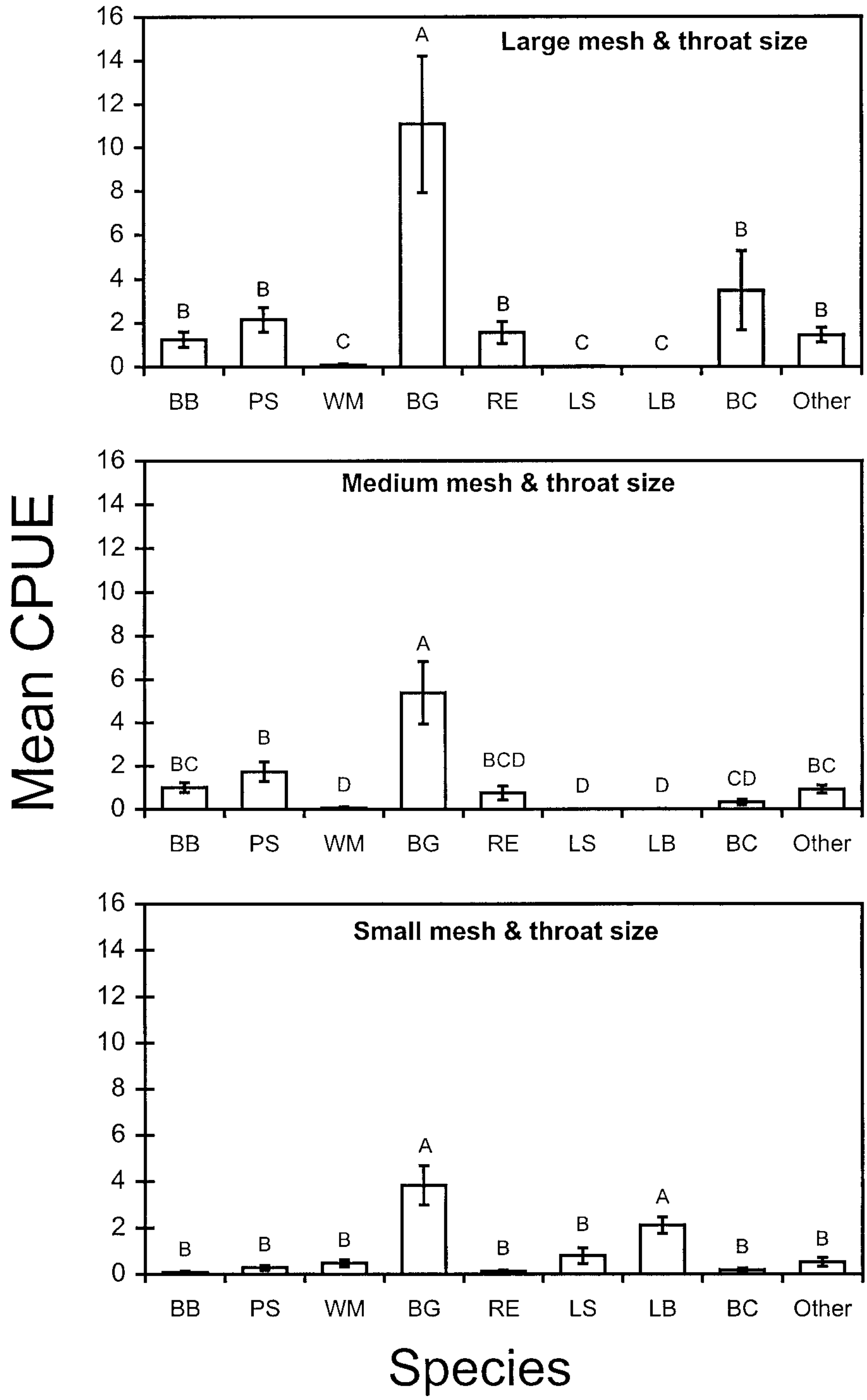

FIGURE 2.—Mean catch per unit effort (24 h) for trap nets with three different mesh and throat size combinations fished in Sandy Lake, Portage County, Ohio, from June 19 through August 19, 1999. Abbreviations are: BB = brown bullhead, PS = pumpkinseed, WM = warmouth, BG = bluegill, RE = redear sunfish, LS = *Lepomis* spp., LB = largemouth bass, YP = yellow perch, BC = black crappie, and Other = other species, which included black bullhead *Ameiurus melas,* white crappie, walleye *Stizostedion vitreum,* golden shiner *Notemigonus crysoleucas,* green sunfish *Lepomis cyanellus,* yellow bullhead *Ameiurus natalis,* gizzard shad *Dorosoma cepedianum,* orangespotted sunfish *Lepomis humilis,* grass pickerel *Esox americanus vermiculatus,* and golden redhorse *Moxostoma erythrurum.* Error bars indicate 1 SE, letters indicate significant differences (Tukey $P < 0.05$) among species within each net type.

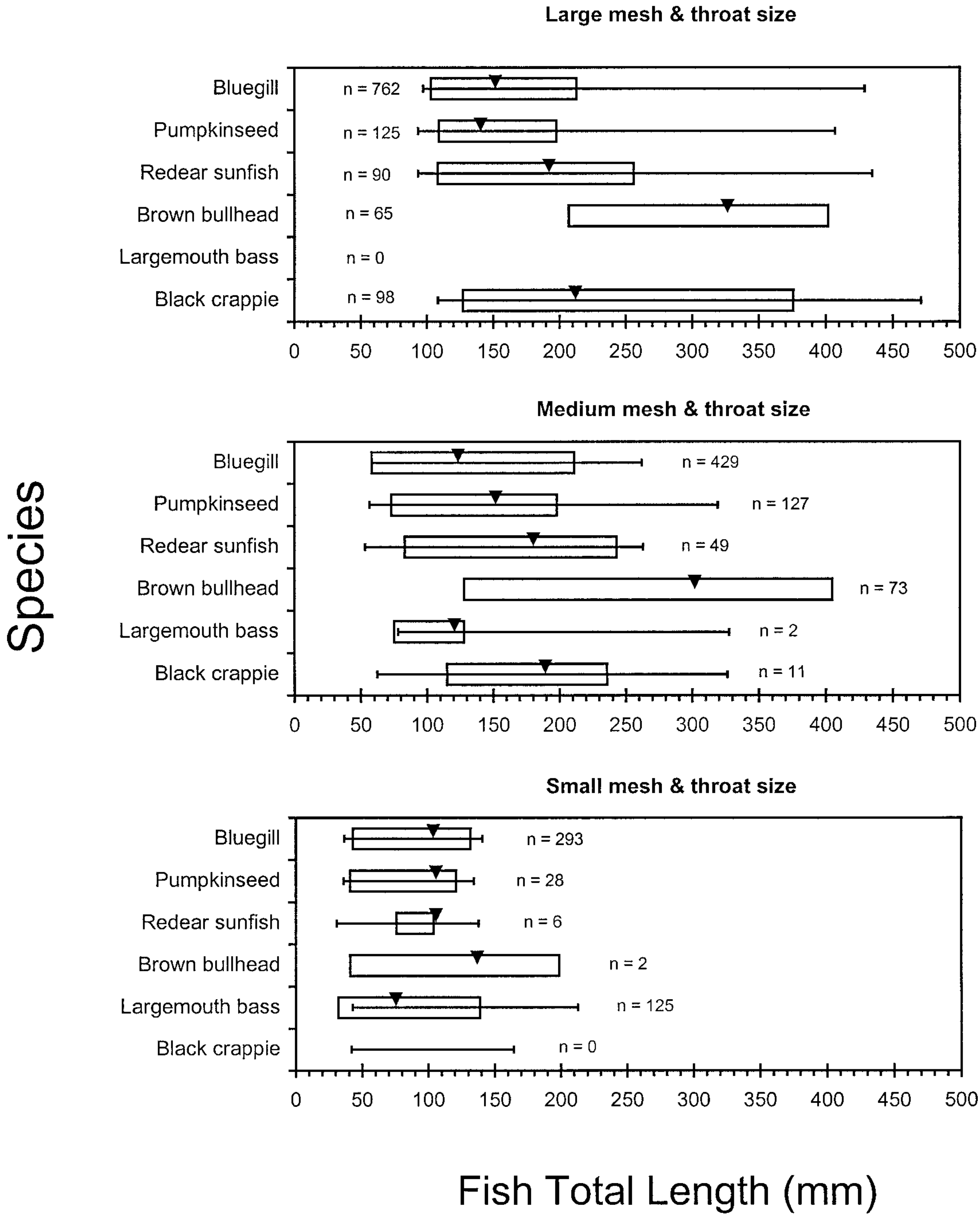

FIGURE 3.—Lengths of the six most commonly captured species (≥5% of the total catch) caught from Sandy Lake, Portage County, Ohio, in trap nets with three mesh and throat size combinations. The white bar indicates the range of fish lengths captured. Triangles indicate the median length. ‘‘Error bar’’ lines indicate the range of lengths the trap-net type could capture based on mesh size and throat size of the net in relation to fish body depths (the total length–body depth relationship for each species is based on regression information in Table 1). Lines indicating the range of fish lengths the trap net could capture are not given for largemouth bass in the large net and brown bullhead in all net types because the regression data did not include enough fish to accurately estimate these values. The number of individuals of each species captured in each net type is also given.

TABLE 2.—Means of the minimum, median, and maximum length (total length; mm) of fish captured in each sample by trap nets with three different mesh and throat size combinations. The six species listed were the most frequently captured (≥5% of total catch) by the nets in Sandy Lake, Portage County, Ohio, from June 19 through August 19, 1999. Net types that were significantly different in the Tukey's test ($P < 0.05$) are indicated by a less than symbol (<) between means.

Species	Length	Net mesh and throat size					ANOVA results	
		Small		Medium		Large	*F*	*P*
Bluegill	Maximum	117	<	166	<	189	56.6	<0.001
	Median	84	<	107	<	134	73.9	<0.001
	Minimum	58	<	67	<	113	156.2	<0.001
Pumpkinseed	Maximum	93	<	162		167	84.8	<0.001
	Median	88	<	135		142	48.0	<0.001
	Minimum	83	<	103	<	122	14.5	<0.001
Redear sunfish	Maximum	87	<	188		205	19.7	<0.001
	Median	87	<	164		179	32.7	<0.001
	Minimum	87	<	143		149	13.4	0.001
Brown bullhead[a]	Maximum	120	<	330		367	11.6	0.001
	Median	120	<	292		319	13.1	0.033
	Minimum	120	<	254		261	6.5	0.014
Largemouth bass[b]	Maximum	100		102			1.9	0.398
	Median	55		102			11.1	0.186
	Minimum	43		102			34.1	0.108
Black crappie[c]	Maximum			196	<	273	14.0	0.020
	Median			175		200	1.4	0.304
	Minimum			149		161	1.7	0.267

[a] Only two brown bullheads were captured in the small net on dates when lengths were recorded.

[b] Largemouth bass were not captured in the large net and only two individuals were captured in the medium net on dates when lengths were recorded.

[c] Black crappies were not captured in the small net on dates when lengths were recorded.

could be due to some design feature of the nets used or to a difference in the behavior of the fish in the lakes sampled. Regardless, it is clear that trap nets may not adequately sample all sizes of some species, even with multiple net types. This is consistent with the conclusions of other studies (Latta 1959; Yeh 1977; Hayes 1989; Miranda et al. 1990; Weaver et al. 1993; Jackson and Harvey 1997) indicating that multiple gear types are necessary to obtain a complete picture of a fishery (but see caution by Jackson and Harvey 1997).

Large nets caught more fish than the other two types. Therefore, based on our results, nets with larger mesh and throat size should be used when catching the greatest number of fish is paramount. While we are unaware of any other study that has compared both mesh and throat size, studies investigating mesh size alone have found either no effect of mesh size on CPUE (Kraft 1990) or that nets with smaller mesh sizes had the largest CPUE (Hesse et al. 1982; Holland and Peters 1992). It is possible that the small throat size on our small mesh net prevented this net from having a higher CPUE than the larger net types. While the large mesh and throat size nets had the highest CPUE, it is important to note that this design did not capture fish as small as the other net types and may therefore give a biased view of species composition and size distribution if used by itself.

Within the range of fish lengths captured by each net design, all three net types appeared to function similarly with respect to the relative CPUE of specific length-classes. Length-class modes for each species often occurred in all three net designs, except for length-class modes that were too large or too small to be captured in a given net type. However, because nets typically did not capture fish as large or as small as would have been physically possible, researchers should be careful about conclusions based on the catch of fish that are close to the physical limits of the net design used. We, therefore, recommend using trap-net designs that overlap slightly with respect to the minimum and maximum physical constraints of each design.

Our results demonstrate that trap-net design can affect the number of species captured, total CPUE, species-specific CPUE, and the length distribution of the catch. Therefore, catches from nets with different designs should not be directly compared, and researchers should select one or more net designs that are compatible with their research objectives. Multiple mesh and throat size designs may provide a more complete picture of the fish community, but other types of gear may also be necessary to capture specific length-classes or species.

Acknowledgments

This research was supported in part by Sigma Xi, the International Research Society. We are indebted to Brian Blake, Pam Brutsche, Jennifer Cline, Neil Coulter, Xueqing Gao, Mike Harris, Veronica Mattson, John McGrevey, Chris Norton, Frank Sams, Tracie Shoup, and Hong Wang for their assistance in sampling the trap nets. We would also like to thank the owners and residences of Sandy Lake for access to the study site. We thank Michael C. McInerny and two anonymous reviewers for their comments on earlier versions of this manuscript.

References

Allen, M. S., M. M. Hale, and W. E. Pine. 1999. Comparison of trap nets and otter trawls for sampling black crappie in two Florida lakes. North American Journal of Fisheries Management 19:977–983.

Clark, S. W., and D. W. Willis. 1989. Size structure and catch rates of northern pike captured in trap nets with two different mesh sizes. Prairie Naturalist 21: 157–162.

Cross, T. K., M. C. McInerny, and D. H. Schupp. 1995. Seasonal variation in trap-net catches of bluegill in Minnesota lakes. North American Journal of Fisheries Management 15:382–289.

Hamley, J. M., and T. P. Howley. 1985. Factors affecting variability of trapnet catches. Canadian Journal of Fisheries and Aquatic Sciences 42:1079–1087.

Hayes, J. W. 1989. Comparison between a fine mesh trap net and five other fishing gears for sampling shallow-lake fish communities in New Zealand. New Zealand Journal of Marine and Freshwater Research 23:321–324.

Hesse, L. W., G. Zuerlein, B. Newcomb, and L. A. DeVore (Retelsdorf). 1982. The relationship of hoopnet mesh size to channel catfish catches. Pages 40–43 *in* E. T. Mahaney, editor. The Missouri River channel catfish. Nebraska Game and Parks Commission, Technical Series 11, Lincoln.

Holland, R. S., and E. J. Peters. 1992. Differential catch by hoop nets of three mesh sizes in the lower Platte River. North American Journal of Fisheries Management 12:237–243.

Hubert, W. A. 1996. Passive capture techniques. Pages 157–192 *in* B. R. Murphy and D. W. Willis, editors. Fisheries techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Jackson, D. A., and H. H. Harvey. 1997. Qualitative and quantitative sampling of lake fish communities. Canadian Journal of Fisheries and Aquatic Sciences 54:2807–2813.

Jackson, J. J., and Bauer, D. L. 2000. Size structure and catch rates of white crappie, black crappie, and bluegill in trap nets with 13-mm and 16-mm mesh. North American Journal of Fisheries Management 20: 646–650.

Kraft, C. 1990. Effects of fykenet mesh size on legal and sublegal catch in the green bay commercial yellow perch fishery. Wisconsin Department of Natural Resources, Fisheries Management Report 146, Madison.

Kraft, C. E., and B. L. Johnson. 1992. Fyke-net and gillnet size selectivities for yellow perch in Green Bay, Lake Michigan. North American Journal of Fisheries Management 12:230–236.

Latta, W. C. 1959. Significance of trap-net selectivity in estimating fish population statistics. Papers of the Michigan Academy of Science, Arts, and Letters 44:123–138.

McInerny, M. C. 1989. Evaluation of trapnetting for sampling black crappie. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies 42(1988):98–106.

Miranda, L. E., J. C. Holder, and M. S. Schorr. 1992. Comparison of methods for estimating relative abundance of white crappie. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies 44(1990):89–97.

Miranda, L. E., M. S. Schorr, M. S. Allen, and K. O. Meals. 1996. Description of a floating trap net for sampling crappies. North American Journal of Fisheries Management 16:457–460.

Roach, L. S. 1942. Fish population of Buckeye Lake as determined by trap nets. Ohio Journal of Science 42:237–245.

SAS Institute. 1997. SAS/STAT software: changes and enhancements through release 6.12. SAS Institute, Cary, North Carolina.

Weaver, M. J., J. J. Magnuson, and M. K. Clayton. 1993. Analyses for differentiating littoral fish assemblages with catch data from multiple sampling gears. Transactions of the American Fisheries Society 122: 1111–1119.

Willis, D. W., D. W. Gablehouse, Jr., and T. D. Mosher. 1984. Comparison of white crappie catches in three types of trap nets. Kansas Fish and Game Commission, Comprehensive Planning Option, Project FW-9-P-2, Emporia.

Yeh, C. F. 1977. Relative selectivity of fishing gear used in a large reservoir in Texas. Transactions of the American Fisheries Society 106:309–313.