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COMPARISONS OF CATCHES BY STANDARD LAKE SURVEY NETS WITH CATCHES BY MODIFIED NETS

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ABSTRACT

The catches of modified passive lake survey sampling nets differed sufficiently from those of standard nets to preclude interchanging them for lake survey or assessment purposes. The smallest mesh size of standard 76.2 m multimesh gill nets caught most species at higher rates than in the same mesh size of 30.5 m nets. Catches in the four largest mesh sizes of the two net types were more nearly similar but tended to be higher in the shorter net. Leading behavior appeared to influence the catches. About 40% of the total catch in 76.2 m nets was taken in the smallest mesh compared to 30% in the 30.5 m nets. Mean lengths for 5 of 13 species were significantly larger in the smallest mesh of the 76.2 m nets than those in the same mesh size of the shorter nets. No relationship could be detected between catch rates of the two gill net types and lake size. Monofilament gill nets outfished multifilament nets for almost every species except small bullhead but similar-sized fish were caught by both types of nets for most species. The catch composition in the two smallest meshes differed significantly between monofilament and multifilament gill nets. Single-frame trap nets caught six species at substantially higher rates than double-frame trap nets, especially bluegill and black bullhead. Double-frame trap nets sampled larger fish of most species than single-frame trap nets. The catch composition of the two types of trap net differed significantly. Modified gill nets and trap nets should be used only in circumstances where comparisons with previous surveys are not a consideration.

INTRODUCTION

The foundation of fish management in Minnesota is the periodic assessment of fish stocks. Accurate assessment of fish populations is essential to providing protection and management of the fisheries' resource. Standardized sampling gear has been used for these assessments and, with the exception of switching from cotton or linen to nylon twines, has changed little in the last 40 years.

There are some circumstances, however, where modified gill nets might be desirable, such as in small lakes that lack extensive littoral area. Other examples would be lakes with extremely high numbers of bullhead or yellow perch, or lakes where the significance of the numbers of game fish in the sample catches might be misconstrued and cause public relations problems. Shorter gill nets conceivably could be used to take smaller but equally significant samples that would maintain continuity with the historical data base and would be better suited to certain situations.

Baranov (1914) pioneered many of the sampling principles that are still valid today, including the concept of using multi-mesh gill nets to sample a considerable size range of a given species. Many variations in sampling net design have been examined, among them different twine diameter, amount of hang and mesh size. For example, Ridenhour and Di Costanzo (1956) found nylon gill nets to be more effective than cotton nets for catching most species, while Scidmore and Scheftel (1957) found nylon gill nets to be more effective for walleye only.

Some investigations have compared monofilament and multifilament twined gill nets. Monofilament twine was usually more effective. Collins (1979) concluded that monofilament was 1.8 times more effective for whitefish but less effective for rainbow smelt, white sucker, alewife, splake and burbot. Pristas and Trent (1977) found that larger catches for 8 of 12 species were taken in monofilament gill nets. Seasonal differences have also been observed. Salmon catches were greater in monofilament gill nets in warm seasons and smaller in cold ones, probably because of changes in net visibility caused by plankton blooms (Washington 1973). Blaxter et al. (1964) observed that herring, even in daylight, swam into monofilament gill nets nearly invisible to the human eye in water.

The color of netting material has also been examined. Except for Bonde (1965), who concluded that color was not a factor in catch differences between Minnesota and Ontario gill nets, most investigators have found color differences to be quite important. Catch rates differed significantly in gill nets of any of nine colors from catch rates in white ones (Jester 1977). He felt there may be visual reasons why larger largemouth bass were caught more readily in yellow nets and more nongame fish were caught in brown nets. Andreev (1955) felt that background light was important and recommended the use of darker nets in good light or clear water and lighter nets in turbid water or low light conditions.

Standard experimental gill nets used in Minnesota lake surveys are 76.2 m long and 1.8 m deep (Scidmore 1970). They consist of five 15.2 m sections of 19, 25, 32, 38, and 51 mm bar measure mesh, hung on a one-half basis. Webbing in the three smaller meshes is of Number 69 nylon. Number 104 nylon is used in the larger meshes. The standard trap net used is the 0.91 X 1.8 m double frame net with 12.2 m lead. Webbing is of 19 mm bar measure mesh of Number 15 or Number 18 cotton twine or braided nylon of comparable strength. Knotless nylon webbing may also be used.

The objective of this study was to determine if the sampling characteristics of modified nets were similar to those of standard lake survey assessment gear thus making them interchangeable when conditions warranted. Evaluations of three types of sampling gear modifications were made: (1) change in length of experimental gill nets to 30.5 m; (2) the use of monofilament webbing for gill nets; and (3) a change in the number and size of the frames (one 0.76 X 1.5 m instead of two 0.91 X 1.8 m) used in standard lake survey trap nets. In addition to providing flexibility in certain sampling situations, there would be some potential savings in construction and maintenance costs of the modified trap nets and some handling and storage advantages.

DESCRIPTION OF STUDY LAKES

Evaluation of the modified sampling gear was conducted in 24 lakes ranging in size from 37 to 1,293 ha (Table 1). Most are hardwater farm-belt lakes near the Twin Cities, except for Jeanette and Bear Head lakes which are softwater lakes in the Precambrian shield region of northeastern Minnesota. Water chemistry parameters were typical of lakes in southern Minnesota with total alkalinities of about 150 mg/l $CaCO_3$ and pH of 7.0 - 8.0, except for the two softwater lakes. Based on values of total phosphorus, most of the lakes are eutrophic or hypereutrophic (Heiskary 1985) with only Bear Head Lake being considered to be mesotrophic. Secchi disc values were 2.0 - 10.0 m from readings taken at the time of netting each lake from June through September in 1983 and 1984. Except for Minniebelle and Bear Head lakes, the readings further verify the eutrophic conditions found in

Table 1. Lakes netted for lake survey gear evaluation, 1983-84.

Lake	County	Area (ha)	Maximum depth (m)	Mean secchi (ft)	Total P (µg/l)	Trophic status[a]	Type of evaluation[b]
Steiger	Carver	114	12.2	1.6	30	E	1
Waconia	Carver	1,293	11.3	1.2	43	E	1
Wasserman	Carver	112	12.5	0.6	70	E	1
Cedar	McLeod	865	2.4	0.5	99	E	1
Swann	McLeod	195	3.0	0.8	--	-	2,3
Winsted	McLeod	165	3.7	0.4	450	H	2,3
Belle	Meeker	419	7.6	1.3	59	E	1,2,3
Betsy	Meeker	74	7.6	0.7	973	H	1
Big Swan	Meeker	312	9.8	1.2	118	H	2
Clear	Meeker	285	5.2	1.8	111	H	1
Erie	Meeker	79	10.4	1.8	28	E	1
Jennie	Meeker	441	4.3	2.0	94	E	1
Manuella	Meeker	140	15.5	1.5	26	E	1
Minniebelle	Meeker	226	14.9	3.3	59	E	1,2
Richardson	Meeker	51	14.3	1.2	--	-	1
Spring	Meeker	81	9.1	0.7	1,023	H	2
Stella	Meeker	253	22.9	1.4	32	E	1
Washington	Meeker	1,021	5.2	1.1	42	E	1
Bear Head	St. Louis	280	14.0	3.8	13	M	2
Jeanette	St. Louis	258	4.6	1.7	43	E	2
Carl's	Scott	55	4.3	1.5	--	-	1
Collinwood	Wright	258	8.5	1.2	62	E	2,3
Dog	Wright	38	7.6	1.3	83	E	1,2
Union	Wright	37	10.7	1.4	--	-	1

[a] Trophic status: mesotrophic (M); eutrophic (E); hypereutrophic (H).

[b] Type of evaluation: 30.5 m vs 76.2 m gill nets (1); monofilament vs multifilament gill nets (2); single-frame vs double-frame trap nets (3).

most of the study lakes.

Fish populations of the 24 study lakes were varied with 20 species sampled during the evaluations (Table 2). Ecologically, most of the lakes are considered to be bass - panfish although many are stocked with walleye. Several of the lakes are marginal winterkill and have fish communities dominated by nongame species.

Table 2. List of species sampled during evaluations of lake survey sampling gear.

Species	Species code[a]	Scientific name
Bowfin	BOF	Amia calva
Northern pike	NOP	Esox lucius
Carp	CAP	Cyprinus carpio
White sucker	WTS	Catostomus commersoni
Black bullhead	BLB	Ictalurus melas
Yellow bullhead	YEB	Ictalurus natalis
Brown bullhead	BRB	Ictalurus nebulosus
Green sunfish	GSF	Lepomis cyanellus
Pumpkinseed	PMK	Lepomis gibbosus
Bluegill	BLG	Lepomis macrochirus
Smallmouth bass	SMB	Micropterus dolomieui
Largemouth bass	LMB	Micropterus salmoides
White crappie	WHC	Pomoxis annularis
Black crappie	BLC	Pomoxis nigromaculatus
Yellow perch	YEP	Perca flavescens
Walleye	WAE	Stizostedion vitreum
Freshwater drum	FRD	Aplodinotus grunniens

[a] Species code is used to identify species in subsequent tables in this report.

METHODS

Each type of net evaluated was compared with its standard counterpart. The first comparison made was between 30.5 m multimesh gill nets and the standard 76.2 m gill nets. The 30.5 m gill net was 1.8 m deep and consisted of five 6.1 m sections of 19, 25, 32, 38, and 51 mm bar measure mesh, hung on a one-half basis. During 1983, 65 paired sets were made. One net of each length was set in close proximity to its counterpart to ensure that both nets were fishing at the same depth and in the same habitat. Nets were set parallel to shore along the same depth contours (2.4 - 3.7 m) in an end-to-end orientation. Both nets of a pair were set with the sequence of mesh sizes aligned in the same direction so that the largest mesh size of one of the nets was always adjacent to the smallest mesh of the other net.

The paired nets were set in two ways to test for possible leading effects that might cause differences in CPUE. For 33 of the paired sets, the nets were tied together in essence making a single net 106.7 m long. The other 32 paired sets were made with a gap of approximately 3 m left between the nets.

The second comparison made was between 30.5 m monofilament and 30.5 m multifilament twined gill nets during 1984. Paired sets of these types of nets were made in the same manner as the sets of 30.5 m and 76.2 m nets, except that a gap of 3 m was left between the nets in all pairs.

The third comparison was between single-frame and standard double-frame trap nets. The frames were made of 6 mm diameter steel rods in a rectangular configuration with dimensions of 0.76 m X 1.52 m for the single-frame trap nets and 0.91 m X 1.83 m for the double-frame trap nets. Both nets were constructed with standard 12.2 m leads, fiberglass hoops 0.76 m in diameter and 19 mm mesh nylon material.

Trap nets were set with the lead tied to a convenient object at the water's edge, such as a tree root, then extended at right angles to the shoreline and stretched tightly. Paired sets were made by setting one net of each type within 60-90 m of each other in the same type of habitat with similar bottom material and vegetation. Both nets of a pair were set and lifted within a few minutes of each other to equalize their fishing time. Sets for comparison of all gear types were 24 hours and were made under varying weather conditions between 1 June and 15 September 1983 and 1984.

Although it was recognized that gill net catches are seldom normally distributed (Moyle and Lound 1960), it was felt that sample sizes were large enough in most cases to use parametric methods for statistical analysis. Student's t-test (Snedecor and Cochran 1967) was used to compare catch per unit of effort (CPUE) of the paired sets for the three evaluations. Moyle (1949) concluded that the 80% probability level was about as high a statistical precision as could be practically achieved using passive gear to sample fish populations and paired catches in this study were tested at that level. Probabilities that exceeded the 95% level are indicated in the tabled data. Species composition of the modified nets was compared with that of the standard nets by contingency table analysis (Dowdy and Wearden 1983). Size structures of the catches were compared using the Kolmogorov-Smirnov goodness of fit test (Hollander and Wolfe 1973).

RESULTS

Gill net length

For 12 of 16 species in the 65 paired sets, no significant differences in CPUE were found between the 30.5 m and the 76.2 m gill nets (Table 3). The exceptions were white sucker, black bullhead, smallmouth bass and black crappie. Black crappie were caught at a higher rate in the 76.2 m nets, while the other three species were caught at higher rates in the 30.5 m nets.

When considered by mesh size, however, catches in the net types differed markedly (Table 3). In the 19 mm mesh, 14 of 16 species were caught at higher rates in the 76.2 m nets though only four of these

Table 3. Comparison of CPUE/30.5 m of 30.5 and 76.2 m multifilament gill nets, all lifts combined, 1983 (t-test, $p < 0.2$ underlined).

			Mesh size									
Net	All		19 mm		25 mm		32 mm		38 mm		51 mm	
length	30.5	76.2	30.5	76.2	30.5	76.2	30.5	76.2	30.5	76.2	30.5	76.2
Species												
BOF	0.05	0.04	--	0.09	0.15	--	--	0.03	--	0.03	0.08	0.06
NOP	2.89	3.13	1.46	2.40	3.54	3.54	4.54	5.66	4.00	3.29	0.92	0.74
CAP	0.29	0.38	0.08	0.12	0.08	0.15	0.38	0.37	0.46	0.34	0.46	0.92
WTS	0.82	0.49	0.31	0.22	0.38	0.12	0.77	0.37	0.77	0.46	1.85	1.26
BLB	7.12	5.31	2.77	4.03	11.46	7.14	11.85	7.51	9.23	6.95	0.31	0.92
YEB	2.05	2.28	1.85	3.45	2.08	0.83	2.00	2.40	3.08	4.18	1.23	0.52
BRB	1.34	0.99	0.15	0.55	0.54	0.15	3.15	1.66	2.46	2.58	0.38	--
PMK	1.15	1.48	0.62	1.14	2.23	2.37	2.54	3.05	0.38	0.83	--	--
BLG	1.65	1.93	1.31	2.09	1.77	2.77	2.31	3.02	2.46	1.57	0.38	0.22
SMB	0.31	0.10	--	0.06	0.23	--	0.38	0.12	0.46	0.18	0.46	0.15
LMB	0.18	0.18	0.38	0.37	--	0.09	0.15	0.09	0.15	0.15	0.23	0.22
WHC	2.34	2.73	4.85	7.11	1.69	1.26	1.31	1.82	3.69	3.38	0.15	0.09
BLC	6.31	8.42	16.62	27.20	4.54	5.54	6.08	6.22	3.69	2.68	0.62	0.46
YEP	4.02	4.61	16.31	19.82	3.15	2.83	0.54	0.25	0.08	0.12	--	0.03
WAE	1.74	1.59	0.38	0.86	1.08	0.86	2.23	1.45	2.08	2.22	2.92	2.58
FRD	0.45	0.46	--	0.09	0.08	0.06	--	0.31	0.85	0.58	1.31	1.26

differences were significant at $p < 0.2$. When catches of all species were combined, 40.8% of the total catch in 76.2 m nets was made in the 19 mm mesh compared to 28.8% in the 30.5 m nets. This difference was significant at the 95% level. In the larger meshes, most species were caught at higher rates in the 30.5 m nets but there were few consistent patterns to these catches. White sucker were caught at higher rates in all meshes of the 30.5 m nets.

Comparisons of net pairs set with gaps or tied together revealed some differences in CPUE possibly caused by leading behavior of some species (Tables 4 and 5). Significant differences in catches between net lengths when pairs of nets were tied showed a more consistent

Table 4. Comparison of CPUE/30.5 m by mesh size of selected species in 30.5 m and 76.2 m multifilament gill nets for sets with nets tied together, 1983 (t-test, $p < 0.2$ underlined).

	Mesh size									
Net	19 mm		25 mm		32 mm		38 mm		51 mm	
length	30.5	76.2	30.5	76.2	30.5	76.2	30.5	76.2	30.5	76.2
Species										
NOP	1.06	2.06	4.09	3.70	4.09	5.27	3.94	3.64	1.21	0.67
WTS	0.45	0.30	0.61	0.12	1.06	0.61	2.06	0.79	1.82	1.39
BLB	1.82	4.12	8.94	8.97	9.09	7.70	10.76	7.33	0.30	1.33
YEB	1.21	4.61	1.97	0.97	1.67	1.82	2.12	3.03	0.76	0.67
BRB	0.15	0.18	0.61	1.21	2.73	0.73	2.42	1.88	0.45	--
PMK	0.61	1.33	2.42	2.97	2.12	3.39	0.15	0.97	--	--
BLG	1.82	1.88	1.67	3.09	1.82	2.97	3.03	2.00	0.45	0.18
WHC	4.39	8.73	1.97	1.46	1.52	1.88	3.94	3.94	0.15	0.12
BLC	17.12	30.61	4.85	5.88	4.24	5.39	2.42	2.73	1.06	0.61
YEP	17.73	20.42	2.88	3.09	0.61	0.30	--	0.12	--	--
WAE	0.15	1.15	1.06	1.03	2.42	1.70	2.27	2.61	3.18	3.39

Table 5. Comparison of CPUE/30.5 m by mesh size of selected species in 30.5 m and 76.2 m multifilament gill nets for nets set with a gap, 1983 (t-test, $p < 0.2$ underlined).

	Mesh size									
Net	19 mm		25 mm		32 mm		38 mm		51 mm	
length	30.5	76.2	30.5	76.2	30.5	76.2	30.5	76.2	30.5	76.2
Species										
NOP	1.88	2.75	3.97	3.38	5.00	6.06	4.06	2.94	0.62	0.81
WTS	0.16	0.13	0.16	0.13	0.47	0.13	0.47	0.13	1.88	1.12
BLB	3.75	3.94	14.06	5.25	14.69	7.31	7.66	6.56	0.31	0.50
YEB	2.50	2.25	2.19	0.69	2.34	3.00	4.06	5.38	1.72	0.38
BRB	0.16	0.94	0.47	0.19	3.59	2.62	2.50	3.31	0.31	--
PMK	0.63	0.94	2.03	1.75	2.97	2.69	0.63	0.69	--	--
BLG	0.78	2.32	1.88	2.44	2.81	3.06	1.88	1.12	0.31	0.25
WHC	5.31	5.44	1.41	1.06	1.09	1.75	3.44	2.81	0.16	0.06
BLC	16.09	23.69	4.22	5.19	7.97	7.06	5.00	2.62	0.16	0.31
YEP	14.84	19.19	3.44	2.56	0.47	0.19	0.16	0.13	--	0.06
WAE	0.63	0.56	1.09	0.69	2.03	1.19	1.88	1.81	2.66	1.75

pattern than for pairs set with a gap. Seven significant differences were observed in tied pairs and five of these occurred in the 19 mm mesh. The larger catches in the 19 mm mesh all occurred in the 76.2 m nets. In contrast, only three significant differences were observed in net pairs set with a gap.

There were no significant differences in composition of the catch for any mesh size of the two net lengths, however the proportions of the total catch taken in the 19 mm mesh of each net length were similar whether tied or gapped. Catches in the 19 mm mesh of the 76.2 m nets made up 42.2 and 39.5% in tied and gapped nets, respectively; in 30.5 m nets the respective percentages were 30.5 and 27.2. Catch rates of white sucker, white crappie and walleye were higher in all meshes of the tied sets of 76.2 m nets and in all but one mesh of the tied sets of 30.5 m nets.

The 30.5 m and 76.2 m nets appeared to sample fish of similar sizes for a given species. Where significant differences occurred, the 76.2 m nets sampled fish of greater mean TL in 8 of 10 cases (Table 6). Five of these occurrences were in the smallest mesh size and in all cases the larger fish were taken by the 76.2 m nets. There appeared to be no systematic differences between mean lengths of fish sampled by the larger meshes of the two net lengths.

Comparisons of length distributions were made for those species and mesh sizes where significant differences were found in mean TL for one or the other length of net. No significant differences in length distributions were found ($p < 0.2$) indicating that the 30.5 m and 76.2 m nets equally sampled fish of the same size ranges.

Analysis of covariance indicated that lake size was not a significant factor in the relative effectiveness of 30.5 m and 76.2 m gill nets.

Table 6. Comparison of mean TL of species sampled by 30.5 m and 76.2 m multifilament gill nets, mesh sizes separate, set type (gapped or tied) combined, 1983. Significantly larger values (t-test, $p < 0.05$) underlined. Number sampled in parentheses.

					Mesh size					
Net	19 mm		25 mm		32 mm		38 mm		51 mm	
Length	30.5	76.2	30.5	76.2	30.5	76.2	30.5	76.2	30.5	76.2
Species										
NOP	476.6	428.4	452.2	434.8	483.4	471.4	549.6	532.3	675.7	688.7
	(17)	(73)	(41)	(108)	(59)	(184)	(53)	(106)	(12)	(23)
CAP	594.0	386.0	626.0	337.8	373.5	339.8	309.8	296.3	427.3	379.1
	(1)	(4)	(1)	(5)	(4)	(12)	(6)	(11)	(6)	(29)
WTS	176.3	205.3	246.6	220.0	306.5	269.0	359.3	347.0	432.8	446.8
	(4)	(6)	(5)	(4)	(10)	(12)	(10)	(13)	(24)	(40)
BLB	153.7	162.8	189.7	186.4	227.8	228.6	255.8	258.6	310.3	313.6
	(35)	(130)	149)	(231)	(154)	(243)	(120)	(227)	(4)	(30)
YEB	233.5	264.3	239.7	221.7	264.1	260.7	278.5	286.1	326.7	334.0
	(24)	(122)	(27)	(27)	(26)	(78)	(40)	(136)	(16)	(21)
BRB	272.5	236.7	241.7	246.0	255.5	258.6	262.7	264.6	275.5	--
	(2)	(7)	(7)	(5)	(40)	(54)	(33)	(84)	(4)	--
PMK	97.6	102.5	124.2	123.8	145.4	146.2	156.8	166.1	--	--
	(8)	(34)	(27)	(71)	(33)	(97)	(5)	(28)	--	--
BLG	102.9	113.7	128.2	117.6	153.4	153.6	172.2	174.6	202.5	207.4
	(15)	(61)	(20)	(86)	(29)	(91)	(30)	(49)	(4)	(7)
LMB	131.6	173.0	--	--	214.5	199.5	254.0	258.4	340.5	363.7
	(5)	(12)	--	--	(2)	(4)	(2)	(5)	(2)	(7)
WHC	127.3	130.6	170.0	164.8	213.6	215.4	231.1	232.1	286.5	291.7
	(49)	(220)	(21)	(40)	(17)	(56)	(48)	(108)	(2)	(3)
BLC	117.7	121.5	166.4	165.7	196.1	192.6	211.8	213.1	256.9	270.0
	(219)	(775)	(58)	(175)	(78)	(201)	(46)	87)	(8)	(15)
YEP	153.2	156.1	189.6	190.4	233.9	--	242.0	265.5	--	--
	(193)	(453)	(37)	(89)	(7)	--	(1)	(4)	--	--
WAE	280.0	360.8	295.9	326.2	467.9	435.1	467.4	461.8	491.9	492.3
	(5)	(28)	(14)	(29)	(29)	(46)	(26)	(71)	(39)	(85)
FRD	--	--	183.0	340.5	--	--	295.0	328.5	345.2	346.3
	--	--	(1)	(2)	--	--	(11)	(19)	(16)	(41)

Monofilament vs multifilament gill nets

Monofilament gill nets clearly outfished multifilament nets for most species when all mesh sizes were combined (Table 7). Catch rates were significantly higher for northern pike, carp, white and black crappie, and walleye. In addition, catches of white sucker, black and

Table 7. Comparison of monofilament and multifilament gill net CPUE/30.5 m, 1984.

	Mesh size											
	All		19 mm		25 mm		32 mm		38 mm		51 mm	
Net type[a]	MO	MU	MO	MU	MO	MU	MO	MU	MO	MU	MO	MU
Species												
NOP	4.22^{b}	3.11	2.82^{b}	1.09	5.64	4.36	7.46^{c}	5.36	4.45	3.82	0.73	0.91
CAP	2.56^{c}	1.73	2.64^{b}	0.55	0.82	1.00	0.36	0.27	3.00	2.00	6.00	4.86
WTS	2.75	2.22	0.45	1.73	0.91	1.64	2.27	2.36	5.46^{b}	2.00	4.64	3.36
BLB	20.69	22.29	14.00	33.72^{b}	23.18	31.18	44.46	31.00	20.28	14.36	1.55	1.18
YEB	4.42	4.22	0.82	2.82^{b}	0.45	3.68^{b}	4.36	5.91	13.82	6.82	2.64	1.36
BRB	1.45	1.22	0.36	0.45	0.36	1.36	1.18	0.82	4.81	3.33	--	0.27
PMK	0.85	1.15	0.36	0.36	0.36	1.45^{c}	2.18	2.00	1.27	1.91	0.09	--
BLG	0.49	0.53	0.27	0.18	0.36	1.09	0.18	0.18	1.09	0.82	0.55	0.36
LMB	0.20	0.20	0.36	0.09	0.18	0.82	0.27	--	0.09	0.09	0.09	--
WHC	1.11^{c}	0.73	0.36	0.27	1.18^{c}	0.36	1.82^{c}	0.64	1.45	1.64	0.73	0.73
BLC	22.18^{b}	9.09	44.28	21.36	28.54^{b}	10.18	26.72^{b}	8.46	9.46	4.45	1.91^{c}	1.00
YEP	5.51	4.00	18.89	12.94	7.00	5.64	1.82	1.3	0.18	0.45	--	--
WAE	2.40^{b}	0.93	1.36^{c}	0.64	1.73^{c}	0.82	3.45^{b}	1.00	3.64^{c}	1.55	1.82^{b}	0.64

[a] monofilament (MO); multifilament (MU).

[b] t-test, $p < 0.05$.

[c] t-test, $p < 0.20$.

yellow bullhead, and pumpkinseed differed significantly in some mesh sizes. Walleye were caught at significantly higher rates in all mesh sizes of monofilament nets. Bullhead and pumpkinseed were the only species caught at significantly higher rates in any mesh size of multifilament gill nets.

No significant differences in catch composition could be detected between the net types when they were examined without regard to mesh size. Catch compositions in the 19 mm and 25 mm meshes, however, did differ significantly (Chi-square, $p < .05$). Differences in catches of black bullhead and black crappie in the 19 mm mesh and black crappie in the 25 mm mesh contributed most to the respective Chi-square values. Black crappie comprised 32.2 percent of the total number of fish caught by monofilament gill nets but only 20.7 percent caught by multifilament nets. Black bullhead comprised 43.3 percent of the catch in multifilament nets.

Mean TL of fish captured by the two net types did not differ significantly for most species and mesh sizes (Table 8). In cases where length differences were significant, mean TL was larger in monofilament nets in 7 of 11 instances. Larger carp were taken in all meshes of the multifilament nets while larger white sucker were taken in all meshes of the monofilament nets. In only one mesh size for each species, however, were these differences significant.

Comparisons of length distributions were made for those species and mesh sizes where significant differences in mean TL (Table 8) were found for one or the other type of net. Differences in length distributions between net types that may have been significant were observed for black bullhead sampled in 25 mm mesh ($p = 0.023$) and black

Table 8. Comparison of mean TL of species sampled by monofilament and multifilament gill nets, mesh sizes separate, 1984. Significantly larger values (t-test $p < 0.05$) underlined. Number sampled in parentheses.

	Mesh size									
	19 mm		25 mm		32 mm		38 mm		51 mm	
Net type[a]	MO	MU	MO	MU	MO	MU	MO	MU	MO	MU
Species										
NOP	447.2	461.0	450.3	418.5	484.0	501.4	538.9	550.3	645.1	651.2
	(29)	(10)	(59)	(45)	(81)	(59)	(49)	(41)	(8)	(10)
CAP	473.4	496.0	330.7	494.3	392.5	503.0	325.8	330.9	379.7	388.0
	(29)	(6)	(9)	(3)	(4)	(3)	(33)	(22)	(65)	(53)
WTS	278.0	173.1	254.1	234.3	286.2	278.9	356.3	338.1	440.6	436.3
	(5)	(17)	(10)	(8)	(23)	(24)	(60)	(22)	(53)	(38)
BLB	145.7	138.0	187.7	193.8	216.8	220.1	255.2	257.2	267.5	237.9
	(131)	(325)	(135)	(175)	(237)	(178)	(169)	(139)	(17)	(13)
YEB	248.4	255.2	184.5	238.2	224.5	256.3	267.7	272.4	319.2	316.6
	(9)	(31)	(4)	(38)	(48)	(65)	(139)	(75)	(29)	(15)
BRB	257.3	270.8	259.0	259.6	262.8	255.7	275.1	269.4	--	296.3
	(4)	(5)	(4)	(7)	(13)	(9)	(59)	(35)	--	(3)
PMK	110.5	106.3	120.0	123.0	149.7	146.6	157.6	158.9	131.0	--
	(4)	(3)	(4)	(6)	(21)	(21)	(14)	(20)	(1)	--
BLG	94.5	97.5	134.0	144.5	174.5	190.0	186.2	173.0	206.8	208.3
	(2)	(2)	(3)	(4)	(2)	(2)	(12)	(9)	(6)	(4)
LMB	200.5	--	212.5	178.0	228.3	--	255.0	248.0	348.0	--
	(4)	--	(2)	(1)	(3)	--	(1)	(1)	(1)	--
WHC	189.0	195.0	187.3	192.0	223.4	239.6	239.6	220.3	281.9	272.6
	(4)	(2)	(13)	(4)	(20)	(7)	(16)	(18)	(8)	(7)
BLC	130.4	125.0	166.8	159.1	189.3	188.9	210.1	202.0	241.0	252.1
	(186)	(110)	(212)	(86)	(292)	(91)	(104)	(49)	(21)	(11)
YEP	166.9	163.0	199.4	196.0	235.3	244.3	--	--	--	--
	(180)	(123)	(74)	(64)	(20)	(15)	--	--	--	--
WAE	241.4	287.2	319.8	330.1	345.6	377.0	427.3	447.8	489.6	482.6
	(15)	(6)	(18)	(9)	(38)	(10)	(40)	(17)	(18)	(7)

[a] monofilament (MO); multifilament (MU).

crappie sampled in 38 mm mesh ($p = 0.088$). Distributions were similar for all other species and mesh sizes.

Single vs double-frame trap nets

Major differences were found between catch rates of single and double-frame trap nets. Catches of 8 of 15 species differed significantly (t-test, $p < 0.05$) and for 7 of these, higher CPUEs were observed in single-frame trap nets (Table 9). The catch rate of bluegill in single-frame nets was nearly triple that in double-frame nets. Black crappie and black bullhead were also caught at much higher rates in single-frame nets. More than 80% of the catches in both net types consisted of bluegill, black crappie and black bullhead. Carp was the only species caught at a significantly higher rate in double-frame nets.

Species composition differed significantly in the two trap net types (Chi-square = 16.26, 4 d.f., $P < 0.01$). The difference in bluegill catches accounted for 74% of the Chi-square value.

Significantly larger mean total lengths were found for 5 of 13 species captured in double-frame trap nets (Table 10). Yellow perch was the only species for which mean TL was larger in single-frame nets.

Length frequency distributions differed significantly for several species captured in the two trap net types. The differences were significant ($P < 0.05$) for yellow perch, black crappie, black and brown bullhead, and white crappie. With the exception of yellow perch, larger individuals of these species appeared to be more vulnerable to double-frame trap nets.

DISCUSSION

None of the modified sampling nets had the same catch characteristics as its standard counterpart. The differences between catches of the paired sets were greater for the monofilament vs multifilament gill nets and the single-frame vs double-frame trap nets than for the 30.5 m vs 76.2 m gill nets.

Initial inspection might lead one to believe that the 30.5 m and

Table 9. Comparison of CPUE per trap net lift for single-frame and double-frame trap nets, 1984.

Species	Single-frame trap nets	Double-frame trap nets
Bowfin	0.74^{b}	0.41
Northern pike	0.39	0.51
Carp	0.75	1.40^{a}
White sucker	1.65	1.01
Black bullhead	46.91^{b}	26.99
Yellow bullhead	0.94^{a}	0.14
Brown bullhead	1.71^{a}	0.77
Pumpkinseed	3.79	2.58
Bluegill	19.22^{a}	6.64
Green sunfish	0.99	0.78
Largemouth bass	0.06	0.05
White crappie	2.46	1.99
Black crappie	26.32^{a}	14.44
Yellow perch	2.36^{a}	0.95
Walleye	0.26	0.19

[a] t-test, $P < 0.05$.
[b] t-test, $P < 0.20$.

Table 10. Comparison of mean TL of species sampled by single-frame and double-frame trap nets, 1984. Number sampled in parentheses.

Species	Single-frame	Double-frame
Northern pike	498.2 (28)	500.9 (34)
Carp	445.3 (57)	470.5^{a} (102)
White sucker	278.3 (125)	295.4 (71)
Black bullhead	214.7 (857)	219.2^{a} (746)
Yellow bullhead	232.7 (71)	239.0 (9)
Brown bullhead	252.4 (130)	275.6^{a} (56)
Pumpkinseed	136.2 (258)	131.9 (124)
Bluegill	139.8 (497)	141.1 (305)
Green sunfish	117.4 (76)	119.8 (57)
White crappie	231.0 (188)	251.4^{a} (144)
Black crappie	179.6 (844)	189.3^{a} (605)
Yellow perch	171.7^{a} (178)	158.1 (67)
Walleye	319.1 (20)	347.4 (14)

[a] t-test, $P < 0.05$.

76.2 m gill nets had virtually the same catch characteristics because CPUE was not significantly different between the two for 12 of 16 sampled species. When examined by mesh size, however, fundamental differences became apparent. Catches of 14 of 16 species sampled by the 19 mm mesh were substantially higher in the 76.2 m nets. These differences may have been caused by behavioral responses of the smaller individuals of each species to the smallest mesh size. Larger members of the same species caught in larger mesh sizes were more often taken in greater numbers by the 30.5 m nets. Perhaps the smaller fish were more prone to following along a net before attempting to pass through and thus often bypassed the smallest mesh of the shorter nets. Conversely, it almost appears that the larger number of fish caught in the smaller mesh of the longer net would have been caught in the larger mesh of the smaller net. This could be a behavior pattern where a fish will only follow along a net so far before it will try to pass through.

The biasing effects of leading behavior on sampling with nets have been recognized by other investigators. Larkin (1963, 1964) felt that experiments to compare selectivities of different nets may be biased if these nets were tied end-to-end in a single gang. Certain positions in the gang may be more favorable than others and the catch of one net may be reduced by competition with an adjacent, more efficient net. He also felt that large fish may lead along a small-meshed net until they encounter and are captured by a larger mesh. He suggested that this leading can be minimized by leaving gaps between the nets. Therefore, gill net pairs in this study were set tied together and with a gap between to evaluate these potential leading effects.

Evidence of leading behavior by individual species was inconclusive for this study. None of the species were consistently caught in higher numbers in the tied sets for each net length or in the longer net of each paired set. The higher proportion of the total catch in the 19 mm mesh of the 76.2 m nets, whether tied or gapped, suggests that most fish did lead to some extent along the smallest mesh. For the four larger meshes, total catches tended to be higher in the 30.5 m nets whether gapped or tied. Catches in the larger meshes of the 76.2 m net tended to be higher in the tied sets suggesting that there may be a threshold net length where leading behavior becomes a factor. Pairs of nets set with a gap between most closely simulated normal sampling conditions.

The subject of fish reaction to nets is complex and has many implications for evaluations of this type. Besides leading effects, schooling behavior may play an important role. Ochiai and Asano (1955) found that schooling minnows (*Orizias latipes*) approached nets more freely than lone fish did. Also, visibility can affect net selectivity because fish reaction to nets may change with size. Steinberg (1964) found that more visible nets caught a smaller proportion of large perch and postulated that larger, older fish approached nets more cautiously because they were better able to see the nets. Visual sensitivity and acuity may improve as a fish grows because the density of cones in its eye declines less rapidly than the image area increases (Hester 1968). Even low visibility may not guarantee fish in the net. Leggett and Jones (1971) found that ultrasonically tagged American shad (*Alosa sapidissima*) avoided drift nets even on dark moonless nights, presumably detecting net vibrations through their lateral line systems.

The comparison of monofilament and multifilament gill nets confirmed findings of other investigators that monofilament nets generally outfish those made of multifilament twine. It is believed that monofilament nets are less visible under certain conditions of water clarity and fish are less likely to detect them and turn away (Steinberg 1964; Washington 1973; Collins 1979). Even though monofilament material was stiffer to handle and did not entangle fish as badly as multifilament, most species were caught at substantially higher rates in it. The only species for which this was not true were black and yellow bullhead caught in the two smallest mesh sizes. Monofilament nets were either more visible to the smaller bullhead which were then able to avoid them or else the multifilament nets were less detectable for some reason. If visibility is the key to net avoidance for at least some species and monofilament nets are more difficult to see, then bullhead must rely less on sight and more on other means, such as the lateral line sensory system, to avoid them. Conversely, other sampled fish groups (centrarchids, esocids and percids) were caught more frequently in the less visible nets, indicating that eyesight was their primary means of sensory perception.

Different behavioral responses apparently caused the dissimilar catch rates between single and double-frame trap nets. Intuitively, one would not expect single-frame trap nets to outfish their counterparts by such large margins for several species. Centrarchids especially seemed to prefer the single-frame nets. Physically, the single-frame nets are somewhat smaller than the double-frame nets but mesh size (19 mm) and size of the pocket (five 0.76 m hoops) are essentially the same for both net types.

Since the size of most caught species was rather small (mean TL < 300 mm) and could easily enter either type of net, the observed differences in total lengths sampled by the two types of trap net were surprising. Although more individuals of six species were sampled in single-frame trap nets, the double-frame nets seemed to be selective for larger fish of five different species. The fact that trap nets are selective for size as well as species was noted by Latta (1959) and Laarman and Ryckman (1980), and was not particularly surprising. The unusual aspect is that above the smallest size of fish retained in the 19 mm mesh there is no apparent physical characteristic of the double-frame nets that should retain larger individuals than those in single-frame nets. Apparently some difference in behavior causes this size selectivity to occur. Perhaps the larger members of a species are more active in satisfying their food or other requirements than smaller individuals. Watt (1956) suggested that the greater amount of movement of larger fish of a species makes them more prone to capture, a concept he illustrated with data from recaptures of smallmouth bass. Even though physically similar to a single-frame trap net, a double-frame net may appear to be more suitable cover. If a larger fish is more active than a smaller one, it may encounter more pairs of nets and have more opportunity to select what appears to be better cover.

MANAGEMENT IMPLICATIONS

None of the gear modifications tested in this study should be substituted for their standard counterparts for lake surveys or other assessments where comparisons with previous surveys or with a historical data base is important. Catches in the 19 mm mesh of the standard 76.2 m gill nets were substantially higher than those in

30.5 m nets for several species. Conversely, catches in the four larger meshes tended to be higher in the 30.5 m nets. Significantly larger fish of five species were also caught in the 19 mm mesh of the standard length gill nets. Monofilament gill nets clearly outfished their multifilament counterparts and the catch composition differed significantly in the two smaller meshes. Catch rates of seven species were significantly higher in single-frame than in double-frame trap nets, catch composition differed, and significantly larger fish of five species were caught in double-frame nets. These differences in catch characteristics invalidate any direct comparisons between catches by standard gear and by the modified nets.

Caution should also be used when comparing growth rates of fish captured by different gears. Faster growing individuals of a given year class are recruited first to any passive fishing gear or mesh size. Since the selectivity of each of the net types compared in this study differed, it is likely that growth rates calculated from the fish caught would also differ from gear to gear.

The modified gill nets and trap nets tested in this study should be used only in special circumstances where comparisons with previous surveys are not a consideration.

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