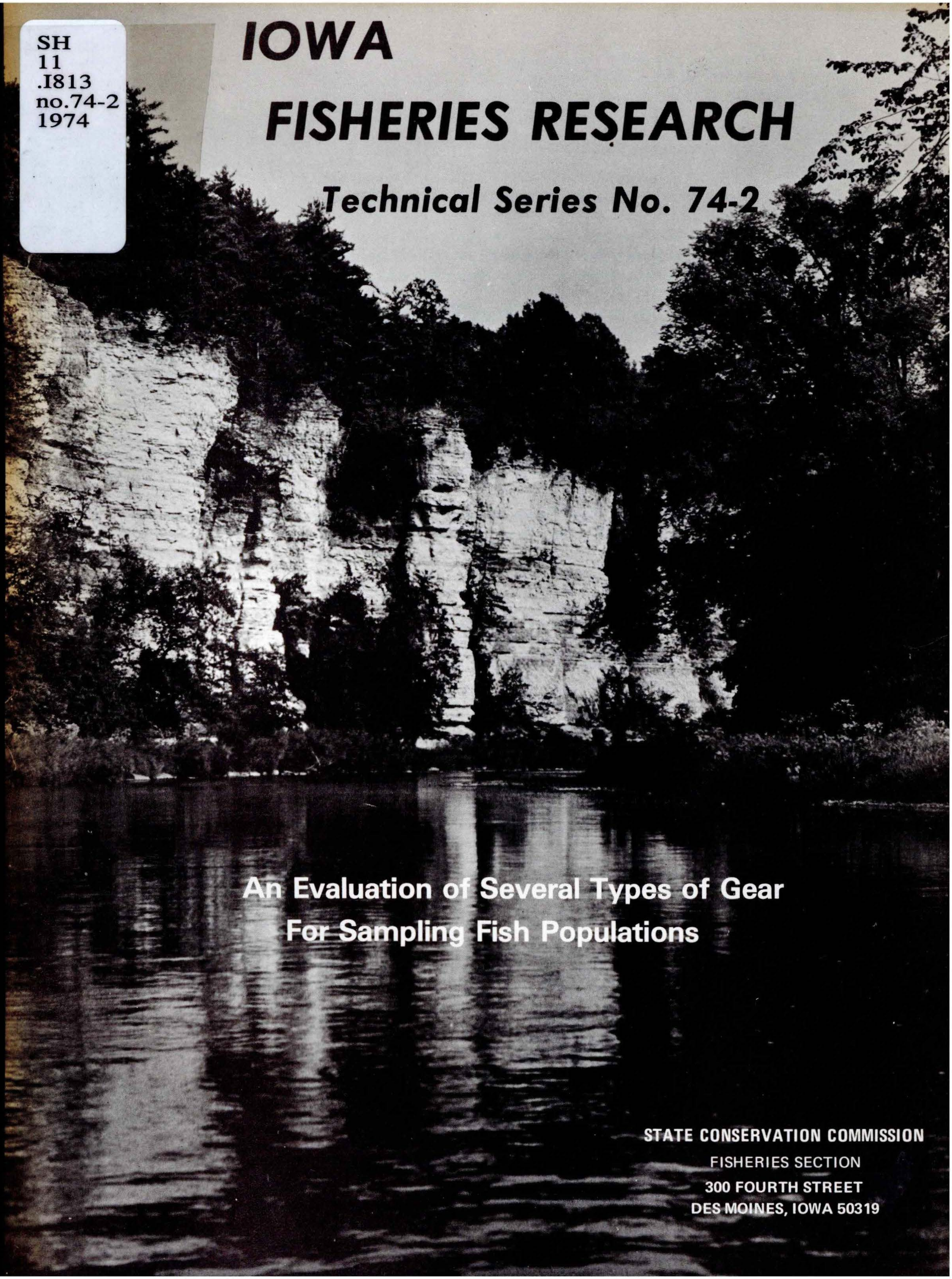
IOWA FISHERIES RESEARCH

Technical Series No. 74-2



An Evaluation of Several Types of Gear For Sampling Fish Populations

STATE CONSERVATION COMMISSION
FISHERIES SECTION
300 FOURTH STREET
DES MOINES, IOWA 50319

IOWA FISHERIES RESEARCH TECHNICAL SERIES

No. 72-1 - Vital Statistics of the Crappie Population in Coralville Reservoir with an Evaluation of Management. By Larry Mitzner.

No. 72-2 - Some Biological Characteristics of a Channel Catfish Population in the Lower Des Moines River with an Evaluation of Potential Commercial Harvest. By James Mayhew.

No. 72-3 - Population Studies of Bigmouth Buffalo in Coralville Reservoir with Special Reference to Commercial Harvest. By Larry Mitzner.

No. 72-4 - The Development of Commercial Food Fish Populations at Red Rock Reservoir During the First 3-Years of Impoundment. By James Mayhew.

No. 73-1 - SHAD - A Computer Program for the Computation of Age and Growth Statistics of Fish. By James Mayhew.

No. 74-1 - The Northern Pike Population in Brown's Lake, Iowa Following a Winterkill. By Kay Hill.

AN EVALUATION OF SEVERAL TYPES OF GEAR FOR SAMPLING FISH POPULATIONS•

Dick McWilliams

Larry Mitzner
Fisheries Research Biologists

and

James Mayhew
Supervisor of Fisheries Research

Technical Series 74-2
October, 1974

Fisheries Section

Jerry M. Conley
Superintendent of Fisheries

TABLE OF CONTENTS

LIST OF TABLES

ABSTRACT

Fish populations at Red Haw, Green Valley and Bobwhite Lakes, all man-made lakes, and Spirit Lake, a natural lake, were sampled with fyke nets, experimental gill nets and seine to measure the amount and sources of variation in apparent abundance of common fish species. Analysis of variance procedure was used to measure the variation due to yearly and monthly interval and net site location. A sampling regime was chosen for each type of gear with permanent sample sites and intervals in 1971-1973. The sample intervals were from April-September with 2-8 sites depending on the type of gear. By this approach the most common sources of variation encountered in sampling fish populations were identified. Habitat diversity and preference of fish species were most pronounced at Spirit Lake and apparent abundance was significantly different at net locations for all species. Conversely, sampling at man-made lakes showed there was considerably less variance in mean catch effort between net locations. Sampling interval was responsible for a major source of variation in catch effort of young fish in seine samples, while sampling interval was a less important source of variation for the other types of gear. Fyke net catches were less variable than seine samples except for walleye at Spirit Lake, and crappie and golden shiner at man-made lakes. Experimental gill nets were most effective for sampling channel catfish and golden shiner at man-made lakes, particularly Green Valley and Bobwhite Lakes, while bluegill and crappie were best sampled with fyke nets at man-made lakes. Fyke nets best sampled bullhead and yellow perch at Spirit Lake and experimental were quite ineffective for any species at Spirit Lake. Variance in catch effort was used to compute sample size for various levels of sampling accuracy and precision. Recommended levels of accuracy and precision were described. Preliminary surveys was 60% accuracy and .10 precision; intensive management, 80% accuracy and .05 precision; and research 90% accuracy and .05 precision. Examples of sample size computation were given to illustrate the method. Recommendations were proposed for use of conventional fish sampling gear with reference to sample site, interval and sample size.

INTRODUCTION

Sampling fish populations with seines, fyke nets and gill nets to determine changes or trends in apparent abundance is a basic tool in fisheries management and research. Reliable estimates of abundance are difficult to obtain primarily because of the lack of standardized sampling techniques and gear, and from a general dearth of knowledge about the sources of variation in catch other than changes in population abundance. Standardization of techniques and gear within a sampling regime is necessary to achieve precise estimates of relative abundance and other population parameters. Recognition and delineation of inherent sources of variation in catch per unit effort are also prerequisites for obtaining precise indices. The largest problem with these surveys seems to be some assurance that the samples are truly reflecting numerical population characteristics. If they are not, judgements and programs based on them are likely to be wrong, or at best unproductive.

Variability in the catch of fish with entrapment or encircling gear usually arises from two primary sources, differences in spatial and temporal distribution. Spatial variation is mainly attributable to the location of sampling sites and habitat preferences of fish, although the clumping of fish due to schooling or other natural nonrandom distribution cannot be discounted as an important source of sampling error. Temporal variations in catch effort are commonly due to daily or seasonal changes in fish activity and are usually associated with spawning activity, feeding movement or other activity which cause fish to be more or less vulnerable at one time or another.

Catch effort values bear some proportional relationship to population abundance and have been used as indicators of apparent abundance (Carlander, 1953). The reliability of catch data to derive relative abundance indices and to compare fish populations was found to be subject to considerable error by Moyle (1950). Moyle and Lound (1954) approached the problem of determining errors associated with catch means and medians of stationary net catches by using two statistical methods. The conclusion concerning errors associated with catch means was similar to Moyle's earlier work. The mean was considered most useful in describing apparent abundance of a fish population, with catch medians considered most effective for evaluating and comparing several fish populations. A sampling regime specifically designed to measure the amount of variation in catch success from several factors was discussed by Ridenhour (1960). The sampling design, based on a Latin square, took into account variation in the catch effort due to the time of day, year sampled and net location.

The primary objective of this study was to measure the amount and sources of variation in the catch of fish in a comprehensive sampling program using drag seines, fyke nets and gill nets. The catch effort statistic could also form the base for the development of relative abundance estimates for common fish species. Four lakes were chosen that represented different types of waters managed for sport fisheries in the state. Preliminary experimental sampling was initiated with drag seines and fyke nets in 1971 and continued for three consecutive years. Gill net fish sampling started in 1972 and terminated the following year. Location of sampling stations in each lake were established in the first year and remained in the same place throughout the study. Sampling dates were also maintained each year of experimental netting. The catch statistics were analyzed in a fashion to identify the unique contribution to total catch variance for years, location and sampling interval.

DESCRIPTION OF THE LAKES

Fish populations were sampled at Spirit Lake, a natural lake located in northwest Iowa, and at Red Haw Lake, Green Valley Lake and Bobwhite Lake, man-made impoundments in southern Iowa. Spirit Lake was representative of most natural lakes. Red Haw Lake, Green Valley Lake and Bobwhite Lake were representative of three types of man-made impoundments, classified by physical and chemical parameters.

Spirit Lake is the largest natural lake in Iowa containing 2,300 ha (5,600 a). It is a shallow, eutrophic lake with a maximum depth of 7.3 m (25 ft). The basin is bowl-shaped and has gradually sloping sides, rocky shoals, several prominent reefs and extensive areas of muck bottom. The lake is homothermous in summer months with adequate dissolved oxygen to support fish life at all depths. The watershed is approximately 15,000 ha (38,000 a) and flat to gently rolling, with much of the land in small grain row crop production.

The lake classification systems developed by Mayhew (1973) and Mitzner (1974) were used in this study to select groups of man-made lakes. The classification segregated lakes in three groups, and one lake was chosen from each class.

Red Haw Lake was characteristic of Group I lakes. Located in Lucas County near Chariton it contains 29 ha (75 a) and a maximum depth of 12 m (40 ft). The steep-sided basin is protected from wind by surrounding hills and mature timber. Thermal stratification occurs from May through October, with the metalimnion from 2-5 m (6.5-16 ft) deep, but normally about 3 m (10 ft) deep. Dissolved oxygen is depleted in the hypolimnion to < 3 mg/l. The watershed contains 725 ha (1,790 a).

Green Valley Lake in Union County near Creston represented Group II lakes. The lake is Y-shaped with surface area of 154 ha (380 a). The basin has gradually sloping sides with a maximum depth of 7.4 m (25 ft). Temporary thermal stratification occurs only during periods of light surface wind. The lake is unprotected by surrounding topography or vegetation and prevailing winds along the lake axis are partially responsible for disrupting thermal stratification. Intensive agricultural practices in the watershed and resultant silt inflow causes turbidity to range to 25 cm (10 in) Secchi disk reading.

Bobwhite Lake is a 40 ha (98 a) municipal water supply for Allerton in Wayne County and is a typical Group III impoundment. The basin is shallow with a maximum depth of 5.2 m (16 ft). Thermal stratification is absent, but in the summer dissolved oxygen is partially depleted below 3 m (10 ft). Erosion in the intensively farmed watershed is common with high silt turbidity a chronic problem.

Several factors were considered in selecting sampling locations for gear in the study lakes. First, sites were distributed over all areas of the lakes. Secondly, sites were chosen so each gear type would fish effectively and excluded dam-faces and extreme shallows. Finally, a variety of habitat was selected, including a variety of bottom slopes, soil types and plant communities at each lake. Time intervals selected for fish sampling were generally paced evenly through the summer and early autumn.

DESCRIPTION OF SAMPLING METHODS AND GEAR

Seines, fyke nets and experimental gill nets used in this study were identical to those commonly used by most fisheries biologists for population sampling. All fish captured were counted and released.

SEINE SAMPLES

Two sizes of drag seines were used in the study, both with 6.35 mm (1/4 in) woven bar mesh. Dimensions of the seine used in Spirit Lake was 152 m (500 ft) long, containing five 30.5 m (100 ft) sections. The outside sections were 1.8 m (6 ft) deep, inside sections were 2.4 m (8 ft) deep and a single center section bag was 3.7 m (12 ft) deep. Seine hauls in the man-made lakes were made with a 15.2 m (50 ft) by 1.5 m (5 ft) common sense drag seine.

Sampling at Spirit Lake was conducted at 8 different locations (Figure 1) during 6 biweekly periods, commencing 1-15 June each year. Standardization of the hauls was accomplished by holding one end of the seine near shore, then laying the seine out in a half-circle configuration and retrieving directly toward shore.

In man-made lakes, seine sampling was conducted monthly from July through September. Four sites were selected at each lake (Figure 1). Seine hauls were made parallel to the shoreline covering a length of approximately 20 m.

FYKE NET SAMPLING

Fyke nets, also called pound nets, were of two sizes. At Spirit Lake frames were .76 x 1.5 m (2 1/2 x 5 ft) with .61 m (2 ft) hoops and 15.2 m (50 ft) leads. Fyke nets used in man-made lakes had .61 m x 1.22 m (2 ft x 4 ft) frames with .61 m (2 ft) hoops and 12.2 m (40 ft) leads. The leads were hung using either polycore or cork float lines and lead-core lead lines. Web dimensions on all nets was 25 mm (1 in) bar mesh. Sets were made with the leads perpendicular to shore.

Sampling at Spirit Lake commenced on 1-15 June each year and continued for 6 biweekly intervals. Eight sites were selected for netting at the same location as the seine sites (Figure 1).

At the man-made lakes, sampling was conducted each year during 6 monthly intervals, April through September. Four locations (Figure 1) were sampled at each lake during each interval; again all net leads were set perpendicular to shore.

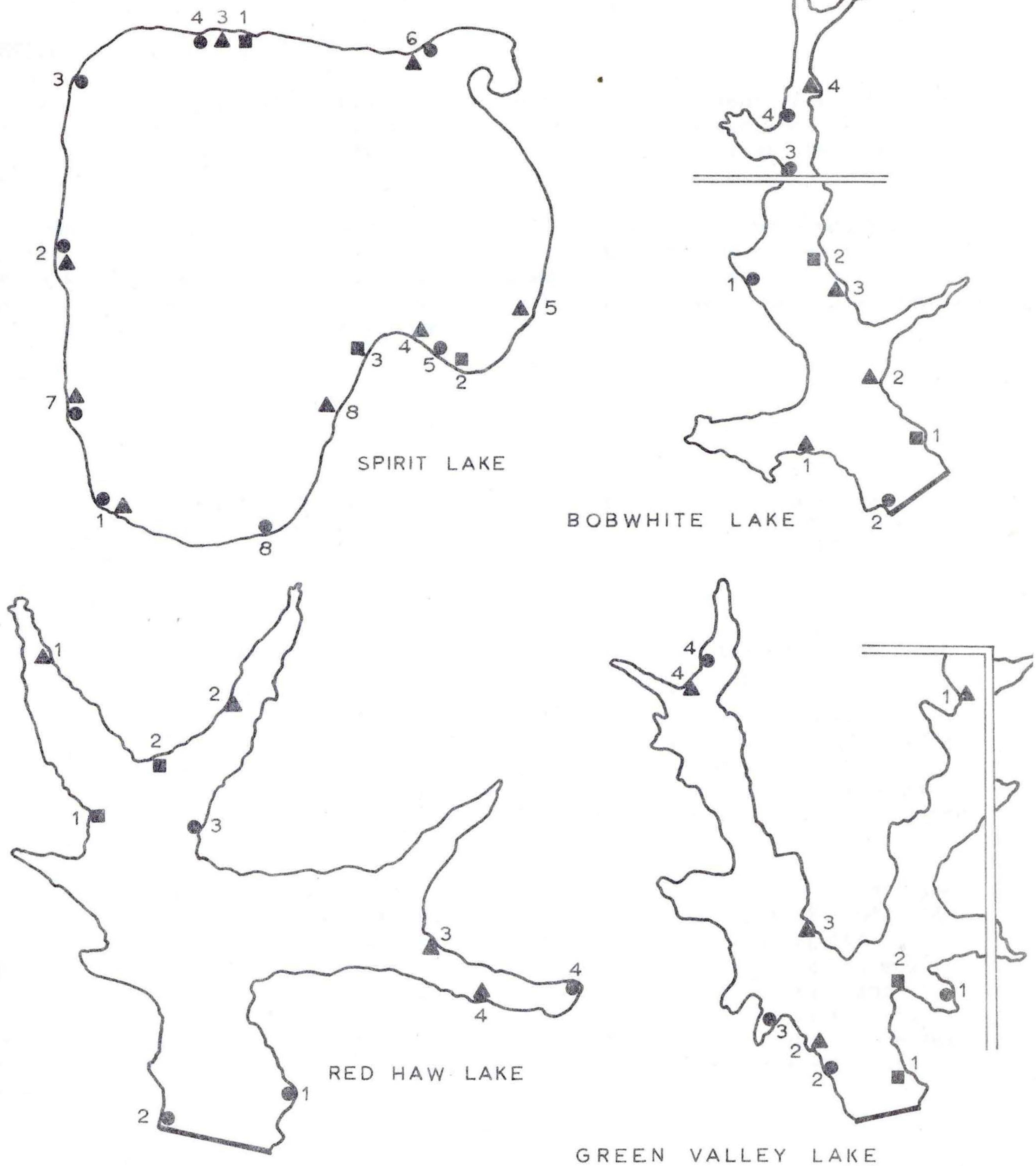


Figure 1. Location of sampling stations at the four lakes. Solid circles denote seine station, solid triangles are fyke net stations and solid squares are gill net stations.

EXPERIMENTAL GILL NET SAMPLING

Experimental gill nets contained five, 9 m (30 ft) sections of 13 (1/2), 19 (3/4), 25 (1), 32 (1 1/4) and 38 mm (1 1/2) inch bar measure, No. 104 nylon twine. The nets were 1.8 m (6 ft) deep and had polycore float and lead-core lead lines.

Sampling at Spirit Lake started 16-30 June each year and continued for 5 biweekly periods at three locations (Figure 1). Nets were set perpendicular to shore with the smallest mesh set nearest the shore. In man-made lakes, two locations were established in each lake (Figure 1). Nets were set for 6 monthly intervals from April through September.

ANALYSIS OF NUMERICAL CATCH DATA

Sources of variation in the catch effort for each sampling gear were determined by factorial analysis of variance. Numerical counts of fish were transformed by

$$Y_{ijk} = \log_{10}(X_{ijk} + 1)$$

where Y_{ijk} was the transformation of $X_{ijk} + 1$, and X_{ijk} was the numerical catch in the k^{th} sampling interval at the j^{th} net location in the i^{th} year. Transformation was necessary to achieve uniformity in the variance among residuals. Examination of the empirical cumulative distribution of residuals by full normal probability plotting of data collected in 1971 revealed normality was a reasonable assumption after transformation. Further deviate plotting was not repeated since data collected in 1972 and 1973 were distributed similar to those the previous year.

Residual mean squares were the unbiased estimated error for the transformed catch data after deviations due to year, location, sampling intervals and interactions were accounted for in the random effects model. For testing the significance of the main factors and interactions, the error mean square was derived by pooling the station-sampling interval and year station-sampling interval interactions. Neither of these interactions were of practical value in the overall analysis. Sources of variation and the expected mean square for each are listed in Table 1. The minimum level of significance for all tests was set at 95%.

FINDINGS

Sampling of fish populations with the three types of gear produced a list of 36 species (Appendix A) of which black bullhead, crappie, channel catfish, largemouth bass, bluegill, walleye, yellow perch, warmouth bass, and golden shiner were used to evaluate catch statistics. Thirty-three species were caught at Spirit Lake, 14 at Red Haw Lake, 13 at Green Valley Lake and 10 at Bobwhite Lake.

Table 1. Expected mean squares and component coefficients for factorial analysis of variance in the catch of fish in experimental netting.[a]

Source of variation		df	Parameter estimated
Year	(y = 2-3)	1-2	$\sigma^2_{YSP} + 6 - 18s\,\sigma^2_{YP} + 4 - 36p\,\sigma^2_{YS} + 2 - 6ps\,\sigma^2_{YS}$
Site	(s = 2-8)	1-7	$\sigma^2_{YSP} + 6 - 48y\,\sigma^2_{SP} + 4 - 36p\,\sigma^2_{YS} + 2 - 6py\,\sigma^2_{S}$
Y x S		1-14	$\sigma^2_{YSP} + 2 - 36p\,\sigma^2_{YS}$
Period	(p = 3-6)	2-5	$\sigma^2_{YSP} + 6 - 48y\,\sigma^2_{SP} + 6 - 36s\,\sigma^2_{YP} + 3 - 6sy\,\sigma^2_{P}$
Y x P		2-12	$\sigma^2_{YSP} + 6 - 18s\,\sigma^2_{YP}$
S x P		2-35	$\sigma^2_{YSP} + 6 - 48y\,\sigma^2_{SP}$
	(residual)		
Y x S x P		2-70	σ^2_{YSP}
Total (corrected)		11-143	

[a]The number of observations within years ranged from 2 to 3, site from 2 to 8 and periods from 3 to 6, derivation of the df followed the usual n-1 procedure.

SEINE SAMPLING

Spirit Lake. Yellow perch, walleye, black crappie and spottail shiner were caught in adequate numbers for statistical evaluation. All were age 0 fish, except spottail shiner, which were not aged, but the sample was assumed to contain both juvenile and adult fish.

The overall mean catch effort (C/E) of age 0 yellow perch in the seine samples was 3,983 and ranged from 3,022 in 1971 to 5,002 in 1973 (Table 2). There was no significant difference in apparent abundance of young perch ($P > .05$) between years. The difference in mean C/E of young perch between sampling sites showed a highly clustered distribution ($P < .01$) with the catch ranging from 1,491 at station 8 to 5,936 at station 7 (Table 3). Young perch were caught in early June samples, but their density was quite low, averaging 2 per haul. Later sampling reflected an accelerated increase in abundance reaching the maximum density of 7,225 per haul by mid-July, then declining to 3,034 by late August. The highly significant F ratio ($P < .01$) for the year-station interaction indicated quite large variability in catch means existed at the different sampling stations although there was little variation between years. High catches of yellow perch at a particular sampling station did not

Table 2. Mean catch effort of fish in seine haul samples at Spirit Lake, 1971-73.

Species	Year		June 1-15	June 16-30	July 1-15	July 16-31	August 1-15	August 16-31	Mean
Y perch	1971		0	1,279	8,387	2,105	2,806	3,556	3,022
	1972		6	1,024	7,270	7,475	5,303	2,465	3,924
	1973		0	1,088	5,690	12,094	8,060	3,081	5,002
		Mean	2	1,130	7,116	7,225	5,390	3,034	3,983
Walleye	1971		0	55	24	3	10	4	16
	1972		64	668	154	28	8	2	154
	1973		2	30	30	28	11	15	19
		Mean	22	251	69	19	10	7	63
B crappie	1971		0	42	27	143	201	372	131
	1972		0	0	100	789	1,414	611	486
	1973		0	< 1	0	2	27	38	11
		Mean	0	14	42	311	547	341	209
S shiner	1971		137	9	12	69	125	895	208
	1972		3	< 1	8	1,165	3,882	252	885
	1973		30	132	32	18	681	749	274
		Mean	57	47	17	417	1,562	632	455

Table 3. Factorial analysis of variance in the catch of age 0 fish in seine haul samples at Spirit Lake, 1971-73.

Source of variation	Y perch	Walleye	B crappie	S shiner
Year	NS	**	**	NS
Station	**	**	**	**
Interval	**	**	**	**
Year x station	**	NS	**	*
Year x interval	NS	**	**	*

*Significant at the 95% level.

**Significant at the 99% level.

necessarily mean C/E remained high at the station in successive years. Catch effort means for the year-station class ranged from a minimum of 408 at station 2 in 1971 to a maximum of 12,829 at station 4 in the last year.

The mean overall C/E of young walleye in seine samples was 63 fish per haul. Yearly means were 16 in 1971, 154 in 1972 and 19 in 1973, which were significantly different at the 99% level. Multiple range testing revealed the catch in 1972 was significantly higher ($P < .01$) than other years. Difference in mean catch effort of young walleye at the eight sampling locations was highly significant ($P < .01$) with values ranging from 6 at station 2 to 154 at station 3. Seasonal distribution of catch means for age 0 walleye was 22 per haul in early June, increasing in late June to 251 per haul, followed by a rapid decline to 7 per haul in the last sampling interval. The nonsignificant year-station interaction indicated although there was unequal distribution of young walleye along the shore, the mean number taken at sampling stations each year was nearly equal. The highly significant ($P < .01$) difference for the year-interval showed inflections in the catch curves did not occur at the same sampling intervals each year, but varied considerably and was probably due to the dates of spawning. Mean C/E for the year-interval interaction ranged from no walleye in period one in 1971 to 608 in period 2 the second year.

Overall mean catch of age 0 black crappie was 209 per haul, ranging from 11 in 1973 to 486 in 1972. Variation in the catch was significantly different at the 99% level and indicated the 1972 year class was much stronger than in 1971 or 1973. Catch effort at individual sampling stations showed highly significant differences ($P < .01$) varying from 46 at station 8 to 498 at station 5. Distribution of the catch by sampling interval showed age 0 crappie were usually not captured until mid-June when average C/E was 14 per seine haul. There was a systematic increase to a mean of 547 at the first interval in August, and declined to an averageof 341 in the last interval. Highly significant ($P < .01$) differences in mean C/E for the year-station and year-interval classes showed the numerical abundance of 0-age crappie varied widely between sampling stations and intervals in different years. High catches at one station or interval were apparently not repeated in successive years.

Catch means for the year-station classes varied from < 1 age 0 crappie at station 7 in 1973 to 1,161 in 1972 at station 4. Highest catches always occurred at the latter station during all years. The year-interval interaction means ranged from no fish in the first sampling period in all years to 1,414 in 1972 during the fifth interval. The most important disparity was that age 0 crappie were absent from seine hauls until the third sampling interval in 1973.

Catch means for spottail shiner in the seine samples were 208 in 1971, 885 in 1972, and 274 in 1973, with an overall average of 455. Despite the large difference in 1972 compared to the other years, the values were not significantly different ($P > .05$). Distribution of spottail shiner in Spirit Lake was highly segregated, ranging from 17 at station 8 to 1,272 at station 4. The difference in the seasonal distribution of the catch was also highly significant ($P < .01$) indicating a large portion of the catch were young fish. Catch distribution was bimodal with a mean of 57 fish per haul in the early summer samples that declined to a low of 17 per haul in the third period. This mode was followed by an increase to the maximum C/E mean of 1,562 in the fifth interval followed by a decline to 632 in the last period giving further credence to the postulation that young fish entered the catch later in the summer. Significant variation ($P < .05$)

for both first order interactions revealed catch success varied considerably between sampling stations each year and during the same intervals each year. The minimum C/E mean for the year station interaction was < 1 spottail shiner at station 8 in 1972 while the maximum C/E mean was 3,543 at station 3 in 1972. Year-interval class means ranged from < 1 fish in the second interval in 1972 to 3,882 in the fifth period. Obviously, a large portion of the significant variation in C/E mean for spottail shiner occurred in 1972 when both maximum and minimum catch values were recorded.

Red Haw Lake. Bluegill and largemouth bass were the only fish species captured in sufficient numbers for statistical treatment. Bluegill were separated into age groups 0 and I with separate analysis for each group. The largemouth bass were all young fish.

Overall catch mean of age 0 bluegill was 135 fish per haul, with yearly averages of 16 in 1971, 124 in 1972 and 264 in 1973 (Table 4). The increase in relative abundance was significant at the .01 level of probability (Table 5). Catch effort at the four sampling stations ranged from 84 at station 1 to 163 at station 4 ($P > .05$). The lack of significant difference between the sampling station means indicated rather uniform distribution of young bluegill resulting from the rather uniform type of habitat around the shoreline of the lake. Difference in catch success by interval was highly significant ($P < .01$) increasing steadily from 18 fish per haul in July to 283 in September. The highly significant ($P < .01$) year-interval class showed in addition to increasing catch success by interval, mean C/E values were different during each sampling interval in successive years. Means for the first order interaction ranged from no fish in the first interval in 1971 to 631 in the third period in 1973.

Catch means of age I bluegill were 7 in 1971, < 1 in 1972 and 68 in 1973, with an overall mean of 25 per haul. Catch means between years were significantly different at the 99% level. Nonsignificant ($P > .05$) differences between station means indicated continued homogenous distribution of age I bluegill, with catch means of individual stations ranging from 3 at station 1 to 36 at station 4. Catch success for sampling intervals was identical in July and August with 4 fish per haul, but in September the C/E mean increased to 67 ($P > .05$). The highly significant ($P < .01$) year-interval interaction indicated the seasonal catch mean of yearling bluegill was not the same in all years. No fish were caught during the second and third sampling periods in 1972 while the maximum mean value catch of 198 appeared in period 3 during 1973.

The mean overall C/E of age 0 largemouth bass was 2 fish per haul with a range of < 1 fish in 1971 to 5 in 1972. The samples showed the 1972 year class was significnatly more numerous than either of the other years. Nonsignificant ($P > .05$) differences among sampling stations indicated bass were distributed rather evenly along the shore with C/E averages ranging from 1 at station 3 to 4 at station 1. Mean catch during the season decreased from 3 in July to 1 in August, followed by an increase to 2 in September ($P < .05$). There was a constant mean catch success of age 0 bass at all sampling stations during identical intervals each year ($P > .05$).

Green Valley Lake. Age 0 bluegill, age 0 white crappie and golden shiner were caught in sufficient numbers for analysis in seine samples.

Table 4. Mean catch effort of fish in seine haul samples at Red Haw Lake, 1971-73.

Species	Year		July	August	September	Mean
Age 0 bluegill	1971		0	13	37	16
	1972		36	153	183	124
	1973		18	143	631	264
		Mean	18	103	283	135
Age 1 bluegill	1971		9	7	4	7
	1972		1	0	0	< 1
	1973		2	5	198	68
		Mean	4	4	67	25
Age 0 Lm bass	1971		< 1	< 1	< 1	< 1
	1972		9	2	5	5
	1973		0	< 1	2	1
		Mean	3	1	2	2

Table 5. Factorial analysis of variance in the catch of bluegill and largemouth bass in seine haul samples at Red Haw Lake, 1971-73.

Source of variation	Age 0 Bluegill	Age 1 Bluegill	Age 0 Lm bass
Year	**	**	**
Station	NS	NS	NS
Interval	**	NS	NS
Year x station	NS	NS	NS
Year x interval	**	**	**

**Significant at the 99% level.

Yearly mean catch of young bluegill declined precipitously from 54 fish per haul in 1971 to 1 fish in 1972 increasing slightly to 4 per haul in 1973 (Table 6). The overall catch mean was 19 fish per haul. The decline in relative abundance between 1971 and 1972-73 was highly significant (Table 7). Average catch effort values by station ranged from 16 fish at station 3 to 21 at station 2, which were nonsignificant at the .05 level of probability. Seasonal mean catch success increased significantly ($P < .05$) from 3 fish per haul in July to 35 per haul in September. There were nonsignificant differences in catch means for the year-station and year-interval classes.

The overall mean catch of white crappie by seine was 38 per haul. Yearly catch means were 4 in 1971, 111 in 1972, and 1 in 1973. The highly significant difference ($P < .01$) in relative abundance was due mostly to high catch effort values in 1972. Mean catch effort at the sampling stations ranged from 8 fish per haul at station 2 to 97 at station 11. There was wide variation between station location, but the means were not significantly different ($P > .05$) showing a nearly homogenous distribution of crappie along the shore. Differences in catch success during the three month sampling period was highly significant ($P > .01$). The mean catch decreased progressively from 111 in July to 1 in September. The highly significant ($P > .01$) year-interval interaction indicated the magnitude of differences in mean C/E during the sampling intervals was not constant each year. Year-interval class means ranged from no crappie captured in the last two sampling intervals of 1973 to 319 in the first period in 1972.

The overall mean catch of golden shiner in the seine samples was 14 with averages of 18, 25, and < 1 fish per haul in 1971-73, respectively. Differences in apparent abundance was highly significant ($P < .01$) due to the low catch in the last year. Nonsignificant ($P > .05$) differences between the sampling stations showed almost even distribution of golden shiner in all habitats which ranged from 11 fish at station 1 to 17 fish at station 2. Mean seasonal catch success of golden shiner was 28 in July seine samples, declining to 6 in August and 9 in September. Catch success between month samples was significantly different at the 99% level. The highly significant ($P < .01$) F ratio for the year-interval classes indicated in addition to highly significant catch periodicity, abundance changed within each monthly sample regardless of the year in which the sample was collected. Minimum C/E means for this class was no fish in the last three monthly samples of 1973, while the maximum was 54 per haul in the first sampling interval in 1972.

Bobwhite Lake. Bluegill and largemouth bass catches were numerically adequate for statistical treatment of seine samples. Catch data of two age groups of bluegill, 0 and 1, and age 0 largemouth bass were analyzed.

The overall catch mean of bluegill young was 25 per haul, with averages of 23 in 1971, 39 in 1972, and 12 in 1973 (Table 8). Changes in apparent abundance were highly significant ($P < .01$) and the strongest year class of bluegill occurred in 1972 (Table 9). Catch success means between sampling stations ranged from 19 fish at station 3 to 36 fish at station 4, with nearly equal distribution of young bluegill in shallow water ($P > .05$). Sampling interval catch means were nearly constant with 26 captured in July, 27 in August and 22 in September. Non significant differences among all first order interactions indicated mean C/E values remained constant for all sampling stations and intervals each year.

Table 6. Mean catch effort of fish in seine samples at Green Valley Lake, 1971-73.

Species	Year	July	August	September	Mean
Bluegill	1971	7	61	94	54
	1972	0	0	2	1
	1973	< 1	3	8	4
	Mean	3	21	35	19
W crappie	1971	12	0	0	4
	1972	319	11	3	111
	1973	2	0	0	1
	Mean	111	4	1	38
G shiner	1971	31	11	13	18
	1972	54	7	13	25
	1973	0	1	0	< 1
	Mean	28	6	9	14

Table 7. Factorial analysis of variance in the catch of fish in seine haul samples at Green Valley Lake, 1971-73.

Source of variation	Bluegill	W crappie	G shiner
Year	**	**	**
Station	NS	NS	NS
Interval	**	**	**
Year x station	NS	NS	NS
Year x interval	NS	**	**

**Significant at the 99% level.

Table 8. Mean catch per effort of fish in seine haul samples at Bobwhite Lake, 1971-73.

Species	Year	July	August	September	Mean
Age 0 bluegill	1971	26	31	12	23
	1972	39	41	39	39
	1973	13	8	15	12
	Mean	26	27	22	25
Age 1 bluegill	1971	2	0	1	1
	1972	3	1	0	1
	1973	6	1	8	5
	Mean	3	1	3	2
Age 0 Lm bass	1971	3	1	1	1
	1972	2	1	< 1	1
	1973	0	1	2	1
	Mean	2	1	1	1

Table 9. Factorial analysis of variance in the catch of fish in seine haul samples at Bobwhite Lake, 1971-73.

Source of variation	Age 0 Bluegill	Age 1 Bluegill	Age 0 Lm bass
Year	**	**	NS
Station	NS	NS	NS
Interval	NS	NS	NS
Year x station	NS	NS	NS
Year x interval	NS	NS	NS

**Significant at the 99% level.

Age 1 bluegill had an overall mean C/E of 2 fish per seine haul. Yearly averages were 1, 1, and 5 with the increase in relative abundance in 1973 highly significant (P < .01). Average catch effort at the four sampling stations ranged from 1 at station 2 to 4 per haul at station 4 (P > .05). Seasonal catch distribution was not significantly different between monthly sampling intervals (P > .05). Mean catch effort was 3 in July, < 1 in August, followed by an increase to 3 fish per haul in September. No significant difference was noted for the first order interactions.

The overall mean for age 0 largemouth bass was slightly more than 1 fish per haul. Mean catch each year was also 1 fish per haul (P > .05). Sampling station mean C/E showed a uniform catch ranging from a mean of 1 at station 4 to 2 bass per haul at station 1 (P > .05). Seasonal distribution of the catch was nearly constant, varying by only one fish per haul from July through September (P > .05). Catch means for the first order interactions were not significant.

FYKE NET SAMPLING

Spirit Lake. Adult black bullhead, yellow perch and walleye were taken in sufficient numbers to permit statistical analysis of the fyke net samples. The catch effort values were expressed as fish per net day (FND) where a net day was defined as a single net unit set over night during a one day period.

The overall mean C/E of black bullhead was 148 FND (Table 10). Average catch means by year decreased from 329 FND in 1971 to 92 FND in 1972 and 23 FND in 1973. Catch effort means between years was highly significant (P < .01) indicating the decrease in relative abundance over the study was of meaningful proportions (Table 11). Catch success means at the eight sampling stations ranged from 98 FND at station 5 to 206 FND at station 1. Significant (P < .01) differences between the station means showed bullhead distribution was not equal in all areas of Spirit Lake with highest catch values occurring at stations 1 and 2. Early June samples produced the highest C/E means of 341 FND followed by lowered catches in early July to 42 FND. Success increased steadily thereafter to 151 and 141 FND during the August intervals. The highly significant (P < .01) year-interval interaction showed inflections in the catch curve did not occur during the same interval each year. C/E means for these interactions ranged from 728 for the first period in 1971 to 6 for period 3 in 1973.

Mean yellow perch C/E in fyke nets was 8, 8, and 7 FND during the three years (P > .05). Apparently the numerical abundance of adult perch remained stable during this study. Mean C/E for the sampling stations ranged from 2 FND at station 5 to 12 FND at station 6. The analysis of variance showed these means were significantly different (P < .01). Perch were unequally distributed among lake habitats, and were most abundant at station 1. Catch success of perch increased gradually during June and early July, from 9 to 11 FND, followed by a decline to 5 FND in late August. Highly significant differences (P < .01) in mean C/E for the year-interval interaction showed changes in the catch curves occurred at different times during consecutive years. Highest catches was recorded in period 3 (19 FND) in 1971 and period 2 (11 FND) in 1972 compared to period 1 (18 FND) in 1973.

Table 10. Mean catch effort of fish in fyke net samples at Spirit Lake, 1971-73.

Species	Year	June 1-15	June 16-30	July 1-15	July 16-31	August 1-15	August 16-31	Mean
B bullhead	1971	728	209	43	193	423	376	329
	1972	222	147	78	59	19	29	92
	1973	73	21	6	9	10	18	23
	Mean	341	126	42	87	151	141	148
Y perch	1971	2	11	19	11	4	4	8
	1972	7	11	9	6	9	7	8
	1973	18	7	6	1	5	3	7
	Mean	9	10	11	6	6	5	8
Walleye	1971	1	4	6	6	3	2	3
	1972	< 1	3	2	2	2	1	2
	1973	< 1	< 1	1	1	2	1	1
	Mean	< 1	2	3	3	2	2	2

Table 11. Factorial analysis of variance in the catch of fish in fyke net samples at Spirit Lake, 1971-73.

Source of variation	B bullhead	Y perch	Walleye
Year	**	NS	**
Station	**	**	NS
Interval	**	**	**
Year x station	NS	NS	NS
Year x interval	**	**	NS

**Significant at the 99% level.

The overall C/E mean of walleye in the fyke nets was 2 FND. Average C/E by year was 3 in 1971, 2 in 1972, and 1 FND in 1973 with the difference significant at the .01 level of probability. Catch effort for the eight sampling stations ranged from 1 FND at station 4 to a high of 3 FND at station 2 ($P > .05$). Seasonal catch was unimodal, increasing from < 1 FND in early June to 3 FND in early July, declining gradually to 2 FND during the last interval in August. Neither first order interactions were significant.

Red Haw Lake. Bluegill, black crappie, black bullhead and warmouth bass were caught in sufficient numbers to permit analysis.

Yearly averages of adult bluegill were 6 FND in 1971, 5 FND in 1972 and 5 FND in 1973 (Table 12). The difference between these means was not significant ($P > .05$) indicating a rather stable population of adult bluegill (Table 13). Catch effort at the four sampling stations ranged from 2 FND at station 1 to 10 FND at station 3. Although the range in mean C/E of bluegill between stations was quite wide, the analysis of variance showed the difference was not significant at the 95% level. Catch success for the monthly samples interval was bimodal. First, catch increased from 4 FND in April to 7 FND in May, followed by a decrease to 2 FND in June. The second mode occurred in August when C/E increased to 9 FND, followed by a decrease to 3 FND in September. First order interactions were not significant ($P < .05$) indicating rather constant mean C/E at all stations during the same sampling interval each year.

Black crappie overall catch mean in fyke nets was 4 FND varying only from 5 FND in 1971 to 3 FND in 1972 ($P > .05$). Station 3 was the most successful netting site for black crappie with a mean of 7 FND. Lowest catch mean was at station 2 where success was 2 FND. Catch means at the different sampling stations were nonsignificant ($P > .05$). Catch success by sampling interval was bimodal, with means of 1 FND in April, 3 FND in May followed by a decline to 1 FND in June. The second mode appeared in September when success increased to a mean of 8 FND. Analysis of variance showed monthly catch means were significantly different ($P < .05$), but neither first order class interaction was significant ($P > .05$).

Catch means of black bullhead ranged from 1 FND in 1971 and 1972 to 2 FND in 1973 ($P > .05$). Mean catch success at the four sampling stations also varied only a small amount ranging from 1 FND at station 4 to 2 FND at station 3 ($P > .05$). Seasonal catch success decreased at a significant rate ($P < .05$) from 3 FND in April to 1 FND in September. Catch effort mean values for bullhead were nearly constant for all sampling stations during the sampling intervals each year.

The overall average C/E of warmouth was 1 FND with maximum average catch values of 2 in 1971 and 1973. Mean C/E in 1972 was < 1 FND warmouth. There was also little variation in catch effort values between stations with the indices ranging from 1 FND at station 4 to 2 FND at station 2. Difference in seasonal catch success was significant ($P < .05$) with the C/E means decreasing from 3 FND in April to < 1 FND in July. In September average catch increased slightly to 1 FND.

Green Valley Lake. Black crappie and white crappie were the most numerous fish caught in fyke nets at Green Valley Lake and were used for statistical data treatment.

Table 12. Mean catch effort of fish in fyke net samples at Red Haw Lake, 1971-73.

Species	Year	April	May	June	July	August	September	Mean
Bluegill	1971	4	12	1	3	9	6	6
	1972	5	4	3	11	5	2	5
	1973	3	4	3	8	11	< 1	5
	Mean	4	7	2	7	9	3	5
B crappie	1971	1	1	< 1	2	12	11	5
	1972	1	1	2	3	3	8	3
	1973	< 1	8	1	1	7	5	4
	Mean	1	3	1	2	7	8	4
Bullhead	1971	4	2	1	< 1	1	1	1
	1972	1	1	1	2	1	1	1
	1973	5	5	2	1	1	1	2
	Mean	3	3	1	1	1	1	2
Warmouth	1971	4	< 1	1	< 1	1	2	2
	1972	1	< 1	< 1	0	< 1	< 1	< 1
	1973	4	5	< 1	< 1	< 1	0	2
	Mean	3	2	< 1	< 1	1	1	1

Table 13. Factorial analysis of variance in the catch of fish in fyke net samples at Red Haw Lake, 1971-73.

Sources of variation	Bluegill	B crappie	B bullhead	Warmouth
Year	NS	NS	NS	*
Station	NS	NS	NS	NS
Interval	NS	*	NS	*
Year x station	NS	NS	NS	NS
Year x interval	NS	NS	NS	NS

*Significant at the 95% level.

The overall mean C/E of black crappie was 13 FND (Table 14). Catch means for the three years were 14 FND in 1971, 16 FND in 1972 and 8 FND in 1973. Changes in catch indices were significantly different at the 95% level (Table 15). Ranges in catch effort averages at the four sampling stations were 11 FND at station 4 and 15 FND at station 1. Analysis of variance showed no difference in C/E means between net locations ($P < .05$) indicating black crappie had little habitat preference and were fairly uniformly distributed. Seasonal catch success means increased from 19 FND in April to 22 FND in May; the catch decreased gradually from May through September when the mean catch was 5 FND. Both first order interactions were nonsignificant at the 95% level, indicating the mean C/E values were nearly constant at all stations during sampling interval each year.

Average catch effort for white crappie was 17, 52, and 62 FND for 1971-73 with an overall mean of 44 FND. Significant ($P < .05$) differences in relative abundance were due mainly to the low catch success in 1971. Average C/E between sampling areas ranged from 23 FND at station 1 to 64 FND at station 3, but these differences were not significant. Catch success during the six monthly intervals increased from a mean of 51 FND in April to a mean of 87 FND in May, followed by declining success to a mean of 13 FND in August, and a slight increase to a mean of 16 FND in September. The difference in catch success of crappie between months was significant ($P < .05$).

Bobwhite Lake. Numerical catches of black crappie, white crappie and bluegill in fyke net samples were analyzed.

The overall mean C/E of black crappie was 8 FND with yearly averages of 7, 16 and 1 FND (Table 16). These values were statistically different at the .01 level of probability (Table 17). Mean C/E at the sampling stations ranged from 4 FND at station 1 to 14 FND at station 4, with significantly ($P < .05$) more crappie being taken at the latter location. Difference in monthly catch means was also significant ($P < .05$). Mean catch success in April was 9 FND with a sharp decrease to 2 FND in May, followed by an increase in July to 20 FND. By September mean C/E decreased to 5 FND. The year-interval interaction was also significant ($P < .05$). The maximum mean C/E value in 1971 was recorded in August with 13 FND. The following year the maximum mean catch was in July with 48 FND, although the mean in April was 24 FND. In 1973, the maximum value of 2 FND was recorded in May samples.

White crappie C/E average during the study was 98 FND. Catch means by years were 72 FND in 1971, 155 FND in 1972, and 66 FND in 1973. The significant ($P < .05$) change in relative abundance was due to the higher catch values in 1972. Station C/E means ranged from 76 FND at station 2 to 120 FND at station 3. Analysis of variance showed these means were not statistically different ($P > .05$). Catch success for the seasonal intervals was quite sporadic, with the highest mean C/E, 181 FND, reported in May and the lowest mean C/E of 41 occurring in August. However, the difference in catch periodicity was not significant at the .05 level of probability. Neither first order class interaction was significant indicating mean C/E remained fairly constant at all stations during sampling each year.

The overall C/E mean of bluegill was 6 FND ranging from 5 FND in 1973 to 8 FND in 1972. Catch success means at the four sampling stations ranged from 4 FND at station 2 to 9 FND at station 4. Catch effort values for monthly periods showed no seasonal trend with the catches alternating systematically

Table 14. Mean catch effort of fish in fyke net samples at Green Valley Lake, 1971-73.

Species	Year	April	May	June	July	August	September	Mean
B crappie	1971	11	15	29	14	7	11	14
	1972	26	39	5	10	12	4	16
	1973	19	14	4	4	5	2	8
	Mean	19	22	13	9	8	5	13
W crappie	1971	14	20	36	12	5	15	17
	1972	31	171	32	32	23	24	52
	1973	108	71	155	19	10	9	62
	Mean	51	87	74	21	13	16	44

Table 15. Factorial analysis of variance in the catch of fish in fyke net samples at Green Valley Lake, 1971-73.

Source of variation	B crappie	W crappie
Year	*	*
Station	NS	NS
Interval	NS	*
Year x station	NS	NS
Year x interval	NS	NS

*Significant at the 95% level.

Table 16. Mean catch per effort of fish in fyke net samples at Bobwhite Lake, 1971-73.

Species	Year	April	May	June	July	August	September	Mean
B crappie	1971	1	2	7	11	13	6	7
	1972	24	2	4	48	9	10	16
	1973	2	2	2	2	0	0	1
	Mean	9	2	4	20	7	5	8
W crappie	1971	115	137	47	40	63	29	72
	1972	214	321	105	146	26	118	155
	1973	66	85	86	96	33	31	66
	Mean	132	181	80	94	41	59	98
Bluegill	1971	4	3	8	3	13	3	6
	1972	7	3	11	9	15	2	8
	1973	2	3	12	12	3	1	5
	Mean	5	3	10	8	10	2	6

Table 17. Factorial analysis of variance in the catch of fish in fyke net samples at Bobwhite Lake, 1971-73.

Source of variation	B crappie	W crappie	Bluegill
Year	**	*	NS
Station	**	NS	NS
Interval	*	NS	NS
Year x station	NS	NS	NS
Year x interval	*	NS	NS

*Significant at the 95% level.

**Significant at the 99% level.

between high and low values. The lowest C/E mean occurred in the last interval with 2 FND and the maximum mean values were 10 FND in June and August. No significant variations due to any of the factorial component was measured for bluegill sampling with fyke nets at Bobwhite Lake.

EXPERIMENTAL GILL NET SAMPLING

Spirit Lake. Only two fish species, yellow perch and black bullhead, were captured in sufficient numbers for evaluation of experimental gill net samples.

The overall mean C/E of yellow perch in gill nets was 44 FND with yearly catch means of 38 FND in 1972 and 51 FND in 1973 (Table 18). Analysis of variance showed the difference between these means was not significant at the 95% level (Table 19). Mean catch at the three netting sites ranged from 27 FND at station 1 to 50 FND at station 3. The statistical difference between stations was also not significant ($P > .05$). Catch effort among the five biweekly sampling intervals showed little fluctuation. Numerical abundance in the samples ranged from a mean of 48 FND in late June to 39 FND in early August ($P > .05$).

Table 18. Mean catch effort of fish in experimental gill nets at Spirit Lake, 1972-73.

Species	Year		June	July		August		Mean
			16-30	1-15	16-31	1-15	16-31	
Y perch	1972		40	36	32	31	50	38
	1973		57	54	59	47	38	51
		Mean	48	45	45	39	44	44
B bullhead	1972		95	86	83	86	75	85
	1973		170	113	99	43	51	95
		Mean	132	99	91	65	63	90

Table 19. Factorial analysis of variance in the catch of fish in the experimental gill net samples at Spirit Lake, 1972-73.

Sources of variation	Y perch	B bullhead
Year	NS	NS
Stations	NS	NS
Interval	NS	NS
Year x station	NS	NS
Year x interval	NS	NS

Black bullhead mean C/E was 85 FND in 1972 and 95 FND in 1973 ($P > .05$). Fish were fairly evenly distributed among stations with C/E means ranging from 67 FND at station 3 to 108 FND at station 2. Catch effort means for bullhead declined steadily from late June at 132 FND to 63 FND in late August. None of the main factors were found to cause significant variation in catch success in experimental gill nets.

Red Haw Lake. Experimental gill net catches were high for golden shiner and yellow perch with the catch of other species too small for statistical treatment.

Golden shiner overall mean C/E was 27 FND (Table 20). Variance in catch effort between years was quite large ranging from a mean of 16 FND in 1973 to 38 FND the previous year, but the difference was not significant at the 95% level (Table 21). Shiners were caught in nearly equal abundance at all sampling stations, with mean C/E of 34 FND at station 1 and 22 FND at station 2 ($P > .05$). There were significant ($P < .05$) changes in catch periodicity, increasing from an average C/E of 29 FND in April to 87 FND in May, followed by a substantial decrease to 12 FND in June. After that, mean catch increased from 4 FND in July to 23 FND in September. Neither of the first order interactions were significant sources of variation in catch effort ($P > .05$).

Catch effort of yellow perch in the gill net samples averaged 10 FND and varied from 9-11 FND. The constant mean catch success values indicated a stable population of yellow perch existed in the lake. Difference in mean C/E between net locations was not significant ($P > .05$) ranging from 11 FND at station 1 to 9 FND at station 2. Variation in monthly catch success followed no trend. Mean catch decreased first from 22 FND in April to 7 FND in May with higher success in June when the catch mean was 13 FND. During July and August, mean C/E was 3 and 5 FND, and increased to 11 FND in September. These differences were highly significant ($P < .01$). The highly significant difference of year-interval classes showed inflections in the catch curves occurred at different sample intervals each year. Highest mean catch success in 1971 (32 FND) was recorded in April, while mean C/E in 1972 was greatest (20 FND) in the June net samples.

Table 20. Mean catch per effort of fish in experimental gill net samples at Red Haw Lake, 1972-73.

Species	Year		April	May	June	July	August	September	Mean
G shiner	1972		37	120	19	12	8	35	38
	1973		20	55	5	8	1	10	16
		Mean	29	87	12	10	4	23	27
Y perch	1972		32	7	7	1	7	15	11
	1973		12	7	20	5	3	7	9
		Mean	22	7	13	3	5	11	10

Table 21. Factorial analysis of variance in the catch of fish in the experimental gill net samples at Red Haw Lake, 1972-73.

Sources of variation	G shiner	Y perch
Year	NS	NS
Station	NS	NS
Interval	*	**
Year x station	NS	NS
Year x interval	NS	**

*Significant at the 95% level.

**Significant at the 99% level.

Green Valley Lake. White crappie, channel catfish, golden shiner and walleye were captured in sizeable numbers and were adequate to permit analysis of experimental gill net samples.

Overall mean white crappie C/E for the study was 47 FND (Table 22). Yearly averages were 58 FND in 1972 and 36 FND in 1973 with no significant ($P > .05$) change in apparent abundance (Table 23). Mean catch effort for sampling locations ranged from 38 FND at station 1 to 55 FND at station 2. Similar catch means were noted for white crappie at all stations ($P > .05$). Monthly catch

Table 22. Mean catch per effort of fish in experimental gill net samples at Green Valley Lake, 1972-73.

Species	Year		April	May	June	July	August	September	Mean
W crappie	1972		12	44	59	68	84	83	58
	1973		21	43	80	34	20	16	36
		Mean	17	43	69	51	52	49	47
G shiner	1972		23	42	44	24	7	69	35
	1973		27	2	8	1	1	0	6
		Mean	25	22	26	12	4	35	20
C catfish	1972		6	2	4	2	6	3	4
	1973		1	1	6	4	4	3	3
		Mean	4	2	5	3	5	3	3
Walleye	1972		10	4	3	5	8	9	6
	1973		5	4	5	3	2	3	3
		Mean	7	4	4	4	5	6	5

Table 23. Factorial analysis of variance of the catch of fish in experimental gill net samples at Green Valley Lake, 1972-73.

Source of variation	W crappie	G shiner	C catfish	Walleye
Year	NS	**	NS	**
Station	NS	*	**	NS
Interval	NS	NS	*	NS
Year x station	NS	NS	NS	NS
Year x interval	NS	**	*	NS

*Significant at the 95% level.

**Significant at the 99% level.

success means increased gradually from 17 FND in April to 69 FND in June, followed by an overall decrease to 49 FND in September ($P > .05$). Neither first order interactions were significant at the 95% level.

Yearly catch means of golden shiner were 35 FND in 1972 and 6 FND in 1973, with an overall mean of 20 FND. The decrease in apparent abundance was highly significant ($P < .01$). Variation in catch success means between the two sampling areas was also significant ($P < .05$). Catch effort at station 1 was 14 FND, while at station 2 it was 7 FND, indicating shiners were not randomly distributed along the shoreline. Catch success means decreased between April and May samples from 25 FND to 22 FND followed by a slight increase to 26 FND in June. Most of the fish were captured in September when mean C/E increased to 35 FND. July and August had lowest mean C/E values with 12 and 4 FND. Range in catch means between months was rather large, but not significant ($P > .05$). The F value for the year-interval classes was significant at the .01 level of probability ($P < .01$) revealing catch success varied considerably during the same sampling intervals each year. The highest mean catch value in 1972, 69 FND, was recorded in September compared to 27 FND recorded in April, 1973.

Catch effort means of channel catfish at Green Valley Lake in gill nets was 4 FND in 1972 and 3 FND in 1973 ($P > .05$). The numerical catch of catfish between sampling stations was significantly different ($P < .01$) with means of 2 FND at station 1 and 5 FND at station 2. Catch effort means alternated monthly between high and low catches. April was high with a mean of 4 FND, while May was low with 2 FND, followed by 5 FND in June and August and 3 FND in July and September. The significant difference ($P < .05$) for the year-interval interaction showed seasonal catch means did not occur during the same interval each year. The maximum catch mean of 6 FND was noted during April in 1972 while the identical catch mean occurred in June of 1973.

The catch effort mean for walleye in gill net samples was 5 FND. Yearly averages ranged from 6 FND in 1972 to 3 FND in 1973, and were significantly different ($P < .01$) showing a decrease in walleye relative abundance of 50%. Location catch success means were 5 FND at station 1 and 4 FND at station 2 ($P > .05$). Seasonal mean catch success was 7 FND in April followed by decreasing success to 4 FND in July, then increasing to 6 FND in September. The lower mean catch rate in midsummer was not significantly different ($P > .05$) from other months. Neither first order class interactions were significant sources of variation in mean catch success at the 95% level.

Bobwhite Lake. Channel catfish, golden shiner, black bullhead and white crappie were the only fish species caught in adequate numbers to permit numerical evaluation of experimental gill net catches.

Channel catfish C/E mean was 5 FND during the entire study (Table 24). Catch mean in the first year was 6 FND compared with 3 FND in 1973, with the decrease in apparent abundance significant at the 95% level (Table 25). Station C/E means were 4 FND at station 1 and 5 FND at station 2 with no difference in catch between the sampling areas ($P > .05$). Catch success by interval showed little variation, with a slight increase from a mean of 4 FND in April to 6 FND in May, followed by declining values to 4 FND in July. A slight decrease occurred in September to a mean of 3 FND. Catch effort was nearly constant at each sampling station during the sampling intervals each year.

Table 24. Mean catch per effort of fish in experimental gill net samples at Bobwhite Lake, 1972-73.

Species	Year		April	May	June	July	August	September	Mean
C catfish	1972		6	9	9	5	5	4	6
	1973		3	3	2	4	7	1	3
		Mean	4	6	5	4	6	3	5
G shiner	1972		234	92	57	72	29	48	88
	1973		34	21	31	15	13	1	19
		Mean	134	56	44	43	21	24	54
B bullhead	1972		10	6	7	11	8	5	8
	1973		6	1	2	2	7	4	3
		Mean	8	3	5	6	7	4	5
W crappie	1972		67	86	29	155	21	118	79
	1973		50	21	56	34	19	17	33
		Mean	58	53	42	95	20	67	56

Table 25. Factorial analysis of variance in the catch of fish in the experimental gill net samples at Bobwhite Lake, 1972-73.

Source of variation	C catfish	G shiner	B bullhead	W crappie
Year	*	**	**	**
Station	NS	NS	NS	NS
Interval	NS	**	NS	*
Year x station	NS	NS	NS	NS
Year x interval	NS	NS	NS	NS

*Significant at the 95% level.

**Significant at the 99% level.

Black bullhead had an overall mean C/E of 5 FND during the study, while the average values each year were 8 FND in 1972 and 3 FND in 1973. The decrease in mean C/E was significant at the 99% level. Catch effort for netting sites was 5 FND at station 1 and 6 FND at station 2. Seasonal mean catch success decreased from 8 FND in April to 3 FND in May, increased steadily to 7 FND in August and decreased to 4 FND in September. A similar catch distribution was recorded both years ($P > .05$).

The mean C/E of white crappie was 56 FND with yearly averages of 79 FND in 1972 and 33 FND in 1973. The considerable decline in catch was significant at the .01 level of sampling probability. The mean catch at station 1 was 49 FND compared with 62 FND at station 2 ($P > .05$). Mean catch success decreased from 58 FND in April to 42 FND in June, followed by a large increase in July to 95 FND. Catch effort in August decreased to 20 FND, then increased to 67 FND in September. The analysis of variance for crappie catch effort showed mean monthly C/E values were significantly different ($P < .05$). Catch success at the different sampling stations during the same months each year was similar.

DISCUSSION AND RECOMMENDATIONS

Findings in this study involving some causes for variations in the catch of fish with sampling gear were in many ways similar to those reported by other investigators (Moyle, 1950; Moyle and Lound, 1954; Ridenhour, 1960). Foremost were the facts that apparent abundance of fish populations between years could be compared by using mean catch effort and the samples were subject to quite large variations. The main questions resolved included determination if variations were actually due to changes in apparent abundance or directly related to sampling error. Both factors concomitantly prevailed many times; then the problem was to identify which was more important.

The study approach was to develop lengthy fish population sampling regimes using common types of gear used in several types of Iowa lakes and separate the unique contribution of several known variables to catch effort means. The gear evaluated included two stationery types, one which captured fish by entanglement (gill net) and the other by entrapment (fyke net); and one encircling (drag seine) type. Each gear had certain advantages and disadvantages in manual use, which are rather well known and shall not be discussed at length in this report. Each type also had different effectiveness in diverse habitats.

The sampling design and analytical procedure delineated the contribution of the main factors; sampling years, net location and netting interval to total variation in catch effort. Most important was variation in catch success between sampling years since this variable identified changes in relative abundance, including year class strength for age 0 fishes. The reliability of catch effort statistics were greatly enhanced when variability due to sampling location and interval was controlled or at least accounted for in the analysis.

There are numerous causes for variations in catch effort of fish with the sampling devices tested other than changes in numerical abundance. Both gill nets and fyke nets rely wholly upon fish movement for capture and stimuli that either accelerate or attenuate movement proportionately change catch success.

Mayhew (1973) reported this occurred commonly with channel catfish caught with baited hoop nets and associated periodic changes in the intensity of movement with seasonal spawning activity and paternal nest protection along with feeding activity.

Catch effort in shallow waters along shorelines, which was primarily sampled by all gear, was grossly affected by nonrandom spatial distribution associated with the habitat preference of fish and also clumping from schooling. In some instances the actual physical characteristics of the sampling site was also important, particularly where bottom slope, rough substrate, or dense submergent vegetation hindered effectiveness of the gear. Habitat diversity and preference of the different fish species were most pronounced in Spirit Lake. Catch effort means were significantly different at the eight sampling stations for all fish species. For instance, in seine hauls young perch were most numerous at station 8, young walleye at station 3, young crappie at station 5 and spottail shiner at station 4. For fyke net samples the physical characteristics of the sites may have been more important, since minimum catch means of the three fish species captured were recorded at station 5, which was located near an area of gently sloping bottom with shallow water depths, but dense stands of emergent vegetation. Fyke nets in the man-made lakes showed that the sampling location was a consistent source of variation in numerical catch success. Habitat diversity was not evident in these lakes and the similarity in catch means for nearly all types of gear at individual lakes indicated that even when habitat preference prevailed not many types were available for selection. Although the seine sampling in this study was conducted in daylight, the effects of schooling of fish might be minimized by sampling in darkness, especially for sight schooling fish such as spottail shiner.

By the simple statistical procedures presented in the study plus multiple range testing for least significant difference values, sampling sites can be systematically combined reducing the number required when no difference exists between catch means. However, some precaution is necessary before combining stations to make sure significant interaction with sample year is absent. Assurance that inflections in catch means for individual sampling stations in all years are similar is prerequisite before a number of stations can be combined. Accordingly, the number of fyke net stations for yellow perch in Spirit Lake could be reduced from eight to four by combining stations 1, 4, 7 and 8; and stations 2 and 3. Stations 5 and 6 must be maintained at the same locations. Interaction between the year station classes was nonsignificant with the catch means for the first set of combined sites (stations 1, 4, 7 and 8) always greatest and station 5 always the lowest regardless of year. In contrast, the seine haul sites at Spirit Lake for age 0 yellow perch could not be combined although multiple range testing showed catch means at stations 3, 4, 5 and 6 were statistically alike because the year station interaction was significant, and the magnitude of the catch mean in one year did not mean similar values occurred in other years. Catch effort mean at station 3 was higher than any other sampling station in 1973, but ranked near the lowest in 1971. Modes in the catch curve occurring at different sampling intervals are also likely to cause significant differences in the interaction classes.

Sampling interval was a major source of variation in catch effort, especially for drag seine samples of young fish populations. Significant difference in catch means were recorded for all fish species with seines in all lakes. The reason for the large variation in the abundance of young fish population is quite obvious. In early samples prior to spawning there simply were no fish present. Later in the season they reached maximum density, usually followed by a systematic decline from mortality. In sampling regimes with small mesh seines it is imperative that several intervals, preferably evenly spaced, are included to minimize the affects of catch periodicity. Spawning date and the first appearance of young in the samples caused significant variations in year interval interactions and required evaluation before sampling intervals are combined in order to lessen the sample number.

Catch means by sampling interval in the fyke nets and gill nets was considerably less variable than seine samples; however, significant differences were noted for several fish species. The most pronounced variation was recorded for walleye in fyke net samples at Spirit Lake, and for crappie and golden shiner in man-made lakes. Experimental gill nets were not effective for determination of year class strength nor evaluating the effects of other factors on catch success in natural lakes. Samples for yellow perch and black bullhead indicated no significant differences in mean catch effort due to any of the main factors tested, where sampling with seines and fyke nets showed significant differences truly existed in apparent abundance as well as that due to other factorial components. Experimental gill nets were more suited for use in man-made lakes, detecting significant differences in the abundance of walleye and golden shiner at Green Valley Lake and channel catfish, white crappie, black bullhead and golden shiner in Bobwhite Lake. Gill nets were somewhat less effective to detect changes in abundance in Red Haw Lake.

Seine hauls, because of the small mesh size, was the only effective gear for sampling young fish and small forage fish species. This method was highly productive for evaluation of year class abundance for yellow perch, walleye, black crappie and spottail shiner in natural lakes; and bluegill and largemouth bass in the man-made lakes. Little disparity existed in the effectiveness of seine hauls to sample fish populations in the three different types of artificial lakes. For instance, at Bobwhite Lake and Red Haw Lake, the seine haul data indicated a very strong year class of bluegill occurred in 1972. The following year the samples also showed this year class, age I, remained most numerous, and substantiated the reliability of seining for determination of year class abundance for small sized fish.

Fyke nets were most effective for evaluating changes in relative abundance of adult populations, but variations due to station and sampling interval were more pronounced than with gill net or seine hauls. The gear was most effective for evaluation of walleye and bullhead population abundance in natural lakes and bluegill and crappie in man-made lakes, particularly in lakes where basin slope was not extraordinarily steep, such as Green Valley and Bobwhite Lakes.

One of the most important elements to consider in experimental fish population sampling is the sample size required to achieve certain levels of accuracy and precision. Using conventional procedures sample size can be computed from the function

$$N = \frac{(t^2)(s^2)}{(a\ \bar{y})^2}$$

where, N is the sample size, t is the level of precision obtained from a standard t table, s^2 is the sample variance, a is the level of accuracy, and $\bar{y}$ is the mean sample catch effort. The analysis of variance requires normal distribution of the catch data. Normality was achieved by transformation of the catch counts and determined subjectively by full normal plotting of the residuals. The catch effort data were logarithmic transformed because standard deviations were usually proportional to catch means.

As an example, the following was computed for catch data using fyke nets in Spirit Lake. Sample values were: $s^2 = .121$; $\bar{y} = .743$; $t = 1.96$ (.05 level of precision at 143 df); and the level of accuracy = 10% or .10. Solving for N,

$$N = \frac{(1.96)^2(.121)}{[(.10)(.743)]^2} = 84.5 \text{ or } 85 \text{ fyke net days.}$$

Further sample size options at different levels of accuracy and precision can be determined iteratively. Table 26 lists the number of samples required for accuracy levels of 50-95% and precision at the .05-.40 levels for the above regime.

Table 26. Sample size in net days required to achieve various levels of accuracy and precision using transformed data for yellow perch caught in fyke nets at Spirit Lake.

Level of accuracy (%)	Level of precision .05	.10	.20	.30	.40
95	221	166	125	94	62
90	85	60	36	24	16
80	21	15	9	6	4
70	9	7	4	3	a
60	5	a	a	a	a
50	3	a	a	a	a

[a]Less than 3 net days required.

Choice of sample size actually remains that of the investigator where manipulating the levels of accuracy and precision depends mainly upon intended use of the data analysis. Sample size does not need to be as accurate and precise for preliminary fishery inventory work as for intensive management or research work. The following levels are suggested for different types of fisheries investigations: preliminary surveys, 60% accuracy and .10 precision; intensive management, 80% accuracy and .05 precision; and research, 90% accuracy and .05 precision. Using the previous Spirit Lake data for yellow perch, the number of fyke net samples required would be 3 for preliminary survey, 21 for intensive survey and 85 for research.

The most effective fish sampling gear would have the highest catch effort, smallest variance and lowest sample size. Results of this study showed quite clearly that all of these attributes in a single type of gear for each species are probably unattainable. Not only does the manual gear operation produce variability in catch success, but fish activity was an important source of error. The best approach to this problem seems to be fish sampling programs that utilize the most effective type of gear to minimize the effects of uncontrollable variables. The following suggestions are presented to make catch statistics in fish sampling gear more meaningful to several types of lakes in Iowa.

1. For samples of all age and size groups, use of all three gear is suggested, The most valid and comparable catch statistics with any two types of gear would be seine hauls and gill nets in man-made lakes and seine hauls and fyke nets in natural lakes.

2. Seine hauls were ineffective in sampling adult fish population regardless of the seine dimensions.

3. Fyke nets and experimental gill nets could not be used for sampling populations of young fish.

4. All types of habitat in the lakes should be sampled to minimize the preference of different fish species. Sampling stations can be combined when catch means are not significantly different except when catch statistics on consecutive years are different.

5. Sampling should extend over a lengthy period of time to minimize the effects of temporal variation, particularly for young fish.

6. The three types of gear used in the study adequately determined differences in year class strength and changes in apparent abundance.

7. Sample size should be calculated to prevent under sampling, which will not describe population characteristics, and over sampling, which is wasteful.

LITERATURE CITED

Carlander, K. 1953. Use of gill nets in studying fish populations, Clear Lake, Iowa. Iowa Acad. Sci., 60:621-625.

Mayhew, J. 1973. Some relationships between morphometry and thermal stratification in some Iowa lake basins. Proc. Iowa Acad. Sci., 80(4): 162-166.

__________. 1973. Variations in the catch of channel catfish and carp in baited hoop nets. Proc. of Iowa Acad. Sci., 80(3):136-139.

Mitzner, L. 1974. Life history and dynamics of largemouth bass in man-made lakes. D-J Rpt. 503-1. Iowa Cons. Comm. 26 pp.

Moyle, J. 1950. Gill nets for sampling fish populations in Minnesota waters. Trans. Amer. Fish. Soc., 79:195-204.

__________ and R. Lound. 1960. Confidence limits associated with means and medians of series of net catches. Trans. Amer. Fish. Soc., 89(1):53-58.

Ridenhour, R. 1960. Development of a program to sample young fish in a lake. Trans. Amer. Fish. Soc., 89(2):185-192.

ACKNOWLEDGEMENTS

The authors appreciate the fine assistance of many people during the investigation. Those most closely associated with the study were Terry Jennings who was project leader at Spirit Lake in 1971 and had an integral part in planning the investigation. Richard Davidson, Tom Molamphy and Steve Schutte were field leaders responsible for collecting and compiling catch statistics. Richard Davidson drew the figures and Mrs. Kathy Schlutz typed the manuscript. All did a fine job and the authors thank them.

APPENDIX A

Species caught in all sampling gear at Spirit Lake, Red Haw Lake, Green Valley Lake and Bobwhite Lake.

GREEN VALLEY LAKE

Walleye, *Stizostedion vitreum*
Yellow perch, *Perca flavescens*
Black bullhead, *Ictalurus melas*
Channel catfish, *Ictalurus punctatus*
Black crappie, *Pomoxis nigromaculatus*
White crappie, *Pomoxis annularis*
Largemouth bass, *Micropterus salmoides*
White bass, *Morone chrysops*
Yellow bass, *Morone interruptus*
Bluegill, *Lepomis macrochirus*
Green sunfish, *Lepomis cyanellus*
Carp, *Cyprinus carpio*
Golden shiner, *Notemigonus crysoleucas*

BOBWHITE LAKE

Black bullhead, *Ictalurus melas*
Channel catfish, *Ictalurus punctatus*
Black crappie, *Pomoxis nigromaculatus*
White crappie, *Pomoxis annularis*
Largemouth bass, *Micropterus salmoides*
Bluegill, *Lepomis macrochirus*
Green sunfish, *Lepomis cyanellus*
White sucker, *Catostomus commersoni*
Carp, *Cyprinus carpio*
Golden shiner, *Notemigonus crysoleucas*