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DEPARTMENT OF NATURAL RESOURCES

RESEARCH

REPORT 146

MARCH 1988

ANALYSIS OF FISH TRAWLING DATA FROM LAKE WINNEBAGO, 1962-1981

By

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Bureau of Research

ABSTRACT

Data from 2,026 trawl hauls on Lake Winnebago, 1962-81, were assembled and analyzed to determine their usefulness in estimating trends in abundance of major fish taxa. The standardized gear for the 20-year period was a 12-ft otter trawl, and sampling on the 137,708-acre lake was conducted from June through October in most years.

Log-transformed mean catch per trawl haul (CPH) for young of the year, yearlings, and adults of major fish taxa proved to be the best method for testing the data set, which was unbalanced by sample numbers and frequencies over the study period. Statistically significant ($P < 0.05$) differences were observed in CPH between taxa, CPH between lake areas, and taxa by area interactions. Abundance indices of 8 major fish taxa were graphed for the 20-year sampling period, depicting abundance for summer (Jun-Aug), fall (Sep-Nov), and combined seasons.

Future trawl sampling should be conducted from July through October at 2-week intervals with at least 20 hauls per day (160 per year) taken in area 3 of Lake Winnebago. Based on the variances of the log-transformed CPH values for major taxa observed from 1962-81 in area 3, a yearly sample size of 47-193 trawl hauls is necessary, depending on the age group, to determine the geometric mean CPH to within 10% with a 90% confidence level.

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INTRODUCTION

Small otter trawls have been used successfully on Lake Winnebago since 1957 to sample fish throughout their first year of life. Trawling from 1957 through 1961 was directed toward testing gear and evaluating the suitability of various lake areas for trawling. In 1962 trawling gear and methodology were standardized. Fish samples have been collected in all suitable areas of the lake during most of the open water seasons since then. Trawl samples have been used to estimate relative abundance of Lake Winnebago fish populations and also as indicators of the survival of year classes through their first season.

The objectives of this study were: (1) to assemble the long-term data base resulting from the trawling effort into a workable computer file; (2) to analyze the 1962-81 data and determine its usefulness in estimating trends in the abundance of major Lake Winnebago fish taxa; and (3) to make recommendations based on these findings on how to improve future trawling effort.

Trawling with larger gear for the purpose of freshwater drum removal on Lake Winnebago has been conducted concurrently with this investigation. Results of the separate research into the effects of drum removal have been excluded from this report to avoid confusing the present data with the data collected using larger vessels (35-50 ft) and trawls (45-55 ft with 3-6 inch stretch mesh) (Priegel 1971, Otis 1988).

DESCRIPTION OF STUDY AREA

Lake Winnebago spans 137,708 surface acres and is ideally suited for trawling (Fig. 1) (Wirth 1957; Priegel 1965, 1966). Average and maximum depths are 15.5 ft and 21.0 ft, respectively; the flat bottom is primarily composed of organic silt or sand overlying a clay base. With the exception of rock reefs bordering the west shore and the south end of the lake, trawling obstacles are nearly nonexistent.

Lake Winnebago sustains a diversity of year-round sport fisheries, the most notable being for walleye, sauger, and white bass. It also supports the largest harvestable lake sturgeon population in North America. The lake is truly a multi-use system, encompassing many fishing, hunting, and boating interests, as well as providing a vast pool of water for downstream industry. Lake Winnebago is replenished by the Fox and Wolf river watersheds that extend over much of the state (Fig. 1). The lake is linked to the Great Lakes via a series of locks and dams on the lower Fox River.

In the late 1950s Lake Winnebago was arbitrarily divided into 6 trawling areas (Fig. 1). The areas were not designated for biological reasons or for any marked differences in habitat, but simply to make referrals to fish sampling locations easier. The 6 areas have become historical reference locations through general usage over the past 30 years.

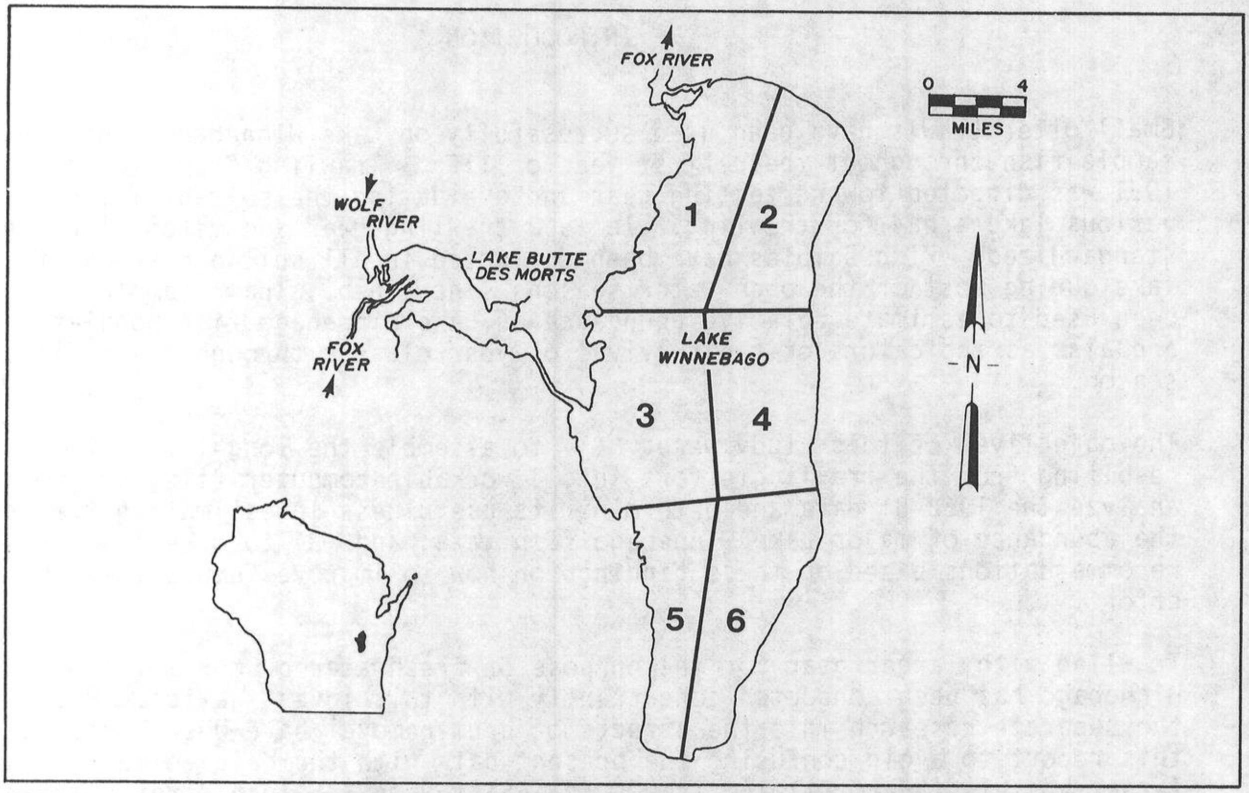


FIGURE 1. The Fox-Wolf River drainage basin and boundaries of the 6 trawling areas of Lake Winnebago.

METHODS

Field Sampling

The Wisconsin Department of Natural Resources Bureau of Research vessel "Tarred Twine," a 30-ft stern trawler, was used to conduct bottom trawl surveys during the entire 1962-81 sampling period (Fig. 2). Trawling was done during daylight hours about every 2 weeks from June through November using a 12-ft headline semiballoon otter trawl consisting of 1.5-inch stretch mesh wings and body and a 0.25-inch flat mesh cod liner. Wooden otter boards (1 by 12 by 24 inches) with a metal front and bottom runners were attached between the net wings and a 30-ft nylon bridle. One hundred feet of steel tow cable, wound by power winch, was used between the stern and bridle (Fig. 3). Engine speed from a 165-hp marine inboard was a constant 1,450 rpm, which produced an average 4-mph tow. Guillory et al. (1983) towed similar gear at about 3.5 mph with good success. Towing time was standardized at 7 minutes based on the number of fish that could be easily handled and the weight of the catch produced (Wirth 1957). Livingston (1976) noted that weight buildup in a trawl can limit effectiveness.

Seven-minute hauls were made 3-33 times each trawling day at depths of 14-19 ft. Table 1 gives the number of trawl hauls by month, area, and year from 1962-81. Data recorded in the field included: counts and identification of all fish, separation of fish into adult or young-of-the-year categories, trawling location, and general weather conditions. Air temperature data were obtained from the U.S. Weather Bureau office at Oshkosh. Water level data

TABLE 1. Distribution of bottom trawl hauls by month, area, and year for Lake Winnebago, 1962–81.

Month	Area	No. of Trawl Hauls Per Year																				Total For All Years
		1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	
June	1	13	5	5	4	5	0	0	0	6	0	0	0	10	0	0	0	0	0	0	0	48
	2	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10
	3	8	19	10	6	6	10	0	0	17	5	16	16	10	29	6	7	0	10	20	10	205
	4	4	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14
	5	5	6	5	0	0	0	0	0	7	0	5	0	0	0	5	9	0	10	20	2	74
	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	4	0	0	0	0	13
	All	40	40	20	10	11	10	0	0	30	5	21	16	20	29	20	20	0	20	40	12	364
July	1	16	8	10	0	0	0	0	0	5	4	2	10	0	12	0	4	0	3	0	0	74
	2	0	9	10	0	0	0	0	0	5	3	0	0	0	10	0	0	0	0	0	0	37
	3	14	10	0	7	10	17	0	12	10	17	14	10	10	0	0	26	0	17	20	20	214
	4	3	13	0	9	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	35
	5	0	0	0	1	0	3	0	0	0	3	16	0	15	10	0	0	0	0	20	20	88
	6	7	0	0	3	0	0	0	4	0	6	0	0	0	10	0	0	0	0	0	0	30
	All	40	40	20	20	10	20	0	16	20	33	32	20	25	52	0	30	0	20	40	40	478
August	1	10	4	0	13	3	0	10	0	0	0	8	0	0	0	12	0	0	0	0	0	60
	2	13	0	0	0	0	0	0	0	0	0	7	0	0	0	10	0	0	0	0	0	30
	3	9	16	13	7	10	10	37	0	10	13	0	5	0	26	17	0	10	8	20	10	221
	4	13	12	5	0	0	0	0	0	5	0	7	5	0	0	0	0	0	0	0	0	47
	5	2	0	2	0	4	0	0	0	4	0	0	0	0	0	0	0	9	7	20	10	58
	6	3	8	0	0	0	0	0	0	6	0	8	0	10	0	0	0	0	0	0	0	35
	All	50	40	20	20	17	10	47	0	25	13	30	10	10	26	39	0	19	15	40	20	451
September	1	15	0	0	0	0	0	0	0	7	4	0	0	0	0	0	0	0	0	0	0	26
	2	2	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	5
	3	9	15	10	10	19	0	0	0	16	31	20	8	17	0	40	20	0	7	30	20	272
	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	4	14
	5	4	5	0	0	1	0	0	0	0	13	0	7	0	0	0	10	0	9	30	10	89
	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	7
	All	30	20	10	10	20	0	0	0	23	48	20	15	20	0	40	40	0	16	60	41	413
October	1	0	15	4	4	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	36
	3	14	6	11	16	7	3	0	11	0	11	0	6	10	15	20	10	0	10	10	20	180
	4	2	9	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	26
	5	0	0	0	0	0	0	0	0	0	0	0	0	4	10	0	10	0	10	10	0	44
	6	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14
	All	30	30	20	20	10	3	0	11	0	11	0	6	14	25	20	20	0	20	20	40	300
November	3	0	0	0	0	10	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	20
	All	0	0	0	0	10	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	20
Season Total	1	54	32	19	21	11	0	10	0	18	8	10	10	10	12	12	4	0	3	0	10	244
	2	25	9	10	0	0	0	0	0	5	3	7	0	3	10	10	0	0	0	0	0	82
	3	54	66	44	46	62	40	37	23	53	77	50	45	57	70	83	63	10	52	100	80	1112
	4	22	44	10	9	0	0	0	0	5	0	7	5	0	10	0	10	0	0	0	14	136
	5	11	11	7	1	5	3	0	0	11	16	21	7	19	20	5	29	9	36	100	42	353
	6	24	8	0	3	0	0	0	4	6	6	8	0	10	10	9	4	0	0	0	7	99
	All	190	170	90	80	78	43	47	27	98	110	103	67	99	132	119	110	19	91	200	153	2,026

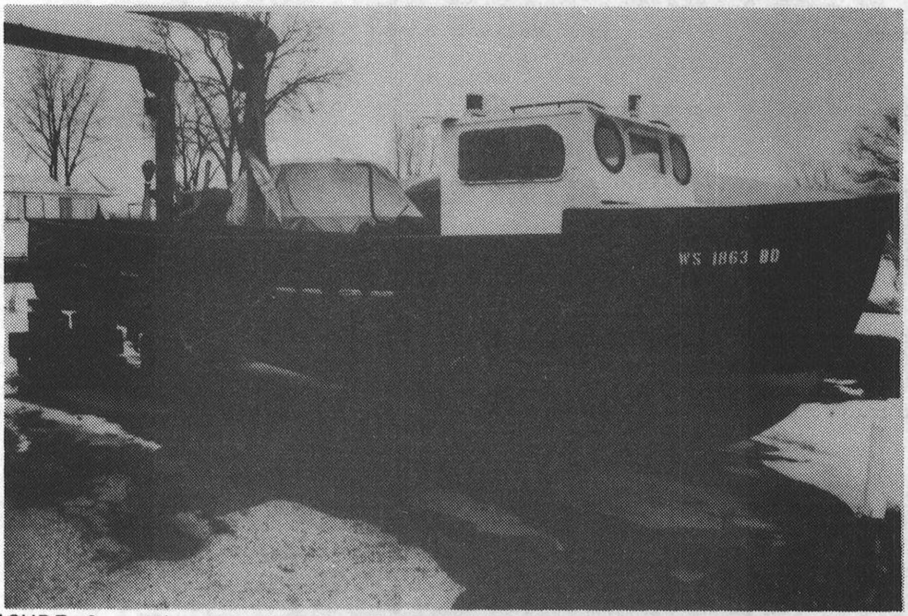


FIGURE 2. The 30-ft stern trawler "Tarred Twine" in dry dock.

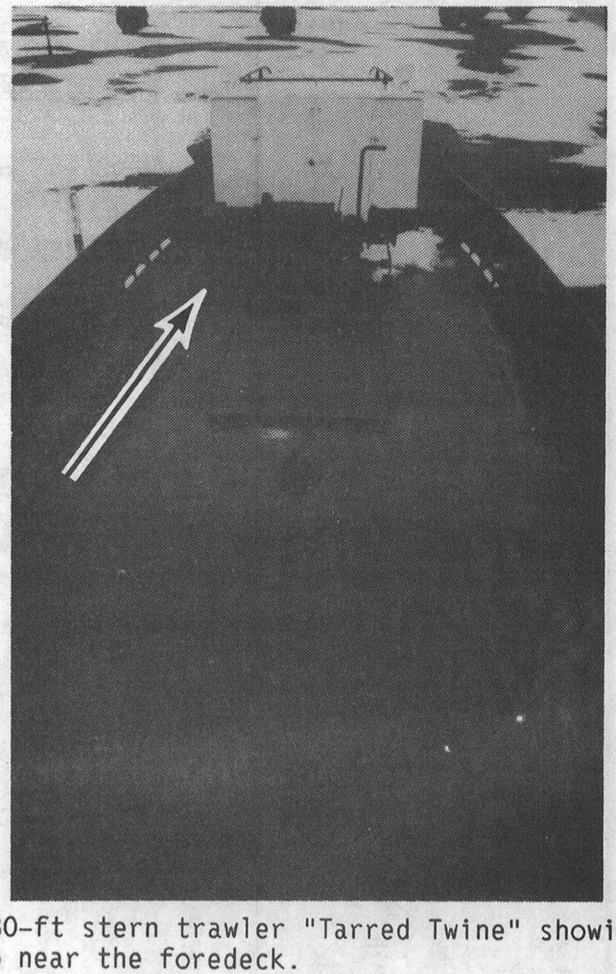


FIGURE 3. Deck of 30-ft stern trawler "Tarred Twine" showing winch positioned posterior to the cab near the foredeck.

were obtained from annual water resources data collected by the U.S. Geological Survey.

Data Analysis

Principal data analyses were based on 8 major Lake Winnebago fish species or taxonomic groupings, which by number constituted 99.6% of the total trawl catch from 1962-81 (Table 2). For the analyses, black and white crappie were combined as crappie; emerald, river, spottail, and pugnose shiner plus pugnose minnow were combined as minnow. The 8 major taxonomic categories are: trout-perch, freshwater drum, white bass, yellow perch, walleye, minnow, sauger, and crappie. All fish except walleye and sauger were classified as adults or young of the year. For walleye and sauger, yearlings were separated from adults to check second year survival of year classes of these important sport fishes (Table 3).

Lake Winnebago trawl data from 1962-81 were computer-filed and double-checked for accuracy against original field data sheets. The trawl catch data were normalized by transformation before parametric statistical analyses were performed. The $\log_{10}$ (Catch + 1) transformation was used.

Several authors have used the Poisson and negative binomial distributions to model fish trawling catch data (Taylor 1953, Roessler 1965, Clark 1974, Lenarz and Adams 1980). Taylor (1953) proposed a model for fish community population structures that includes specific distributions for different population parameters. In turn, each specific distribution suggests an appropriate normalizing transformation. In the Taylor model, the number of individuals of each species follows a negative binomial distribution. The appropriate transformation for a negative binomial variable is a function involving a parameter of the distribution (Taylor 1953, Clark 1974); however, the simpler log (Catch + 1) transformation is adequate for many trawling data sets (Taylor 1953, Haack and Muth 1980) and does not involve fitting a statistical distribution to the data.

Fish abundance, as indexed by the log-transformed mean catch per haul for young of the year, yearling, adult, and all of the 8 major taxonomic groups combined, was tested for differences in spatial and temporal distribution using analysis of variance (ANOVA). Trawls were initially grouped by years, months, and lake areas (Fig. 1), but missing cells made it necessary to combine months and lake areas or to work only with other more balanced subsets of the data. Simple correlation coefficients were used to compare catches in different areas by months and years. Proc GLM from the Statistical Analysis System (SAS) was used for the ANOVA and Proc CORR for the correlation analyses (SAS Inst. 1982). In the ANOVA, type III hypotheses were used for unbalanced data and type IV hypotheses for data with missing cells (Freund and Littell 1981).

RESULTS AND DISCUSSION

Effect of Unbalanced Sampling Design

The number of hauls was extremely unbalanced with respect to lake area, month, and year, with many missing cells (Table 1). The effect of this imbalance was to make the testing for differences between levels of these class variables

TABLE 2. Species list and number of individuals captured in Lake Winnebago bottom trawling, 1962-81.

Common Name	Scientific Name	No. Captured
Trout-perch	*Percopsis omiscomaycus* (Walbaum)	204,460
Freshwater drum	*Aplodinotus grunniens* Rafinesque	71,590
White bass	*Morone chrysops* (Rafinesque)	39,835
Yellow perch	*Perca flavescens* (Mitchill)	34,407
Walleye	*Stizostedion vitreum vitreum* (Mitchill)	10,316
Emerald shiner	*Notropis atherinoides* Rafinesque	7,575
Sauger	*Stizostedion canadense* (Smith)	3,743
Black crappie	*Pomoxis nigromaculatus* (Lesueur)	1,599
White sucker	*Catostomus commersoni* (Lacepede)	613
White crappie	*Pomoxis annularis* Rafinesque	192
Carp	*Cyprinus carpio* Linnaeus	179
Burbot	*Lota lota* (Linnaeus)	99
Bullhead (unsp.)	*Ictalurus* spp.	93
Channel catfish	*Ictalurus punctatus* (Rafinesque)	77
Yellow bass	*Morone mississippiensis* Jordan and Eigenmann	47
Quillback	*Carpiodes cyprinus* (Lesueur)	45
River shiner	*Notropis blennius* (Girard)	36
Lake sturgeon	*Acipenser fulvescens* Rafinesque	23
Chestnut lamprey	*Ichthyomyzon castaneus* Girard	22
Bluegill	*Lepomis macrochirus* Rafinesque	20
Silver lamprey	*Ichthyomyzon unicuspis* Hubbs and Trautman	20
Mottled sculpin	*Cottus bairdi* Girard	18
Logperch	*Percina caprodes* (Rafinesque)	18
Darter (unsp.)	*Ammocrypta*, *Etheostoma*, and *Percina* spp.	18
Redhorse (unsp.)	*Moxostoma* spp.	10
Gizzard shad	*Dorosoma cepedianum* (Lesueur)	7
Mooneye	*Hiodon tergisus* (Lesueur)	5
Spottail shiner	*Notropis hudsonius* (Clinton)	4
Northern pike	*Esox lucius* Linnaeus	2
Flathead catfish	*Pylodictis olivaris* (Rafinesque)	1
Pumpkinseed	*Lepomis gibbosus* (Linnaeus)	1
Pugnose shiner	*Notropis anogenus* Forbes	1
Pugnose minnow	*Notropis emiliae* (Hay)	1
	Total	375,247

TABLE 3. Size ranges used in computer coding to designate yearling walleye and sauger in Lake Winnebago, by month (all ranges inclusive).

Month	Species	Size Ranges	
		Inches	Millimeters
June	Walleye	4.5-8.8	114-224
	Sauger	4.5-8.2	114-208
July	Walleye	6.0-10.2	152-259
	Sauger	5.0-9.3	127-236
August	Walleye	7.0-10.5	178-267
	Sauger	6.0-9.8	152-249
September	Walleye	7.5-11.5	190-292
	Sauger	6.5-10.0	165-254
October	Walleye	8.5-11.9	216-302
	Sauger	7.0-11.1	178-282
November	Walleye	9.0-12.8	229-325
	Sauger	7.5-11.3	190-287

dependent on the sampling design. Ordinarily the presence of missing cells in a multi-way analysis of variance prevents a complete analysis (Freund and Littell 1981), particularly if there are interactions between levels of the missing cells. In addition, if the occurrence of a missing cell is somehow related to the dependent variable, then results will be biased even if no interaction is present.

Unfortunately, in the Winnebago trawl data both interactions and systematic relationships between trawling effort and actual catch rates were found. We initially observed that there was a large, nearly significant positive correlation ($\underline{r}$ = 0.68, $\underline{P}$ = 0.15) between mean catch in an area over all years and the total number of trawl hauls made in that area (Table 4). The number of hauls was a function of the number of years sampled, so it was possible that the correlation was related to some characteristic of the years that were not sampled. In fact, when the years were ranked by mean catch per haul, areas 2, 4, and 6 were sampled on the average only in years of lower abundance (Table 5). No relationship between particular months trawled and the catch rates was apparent.

Analysis of Abundance Data

We initially recognized that catch per haul differed between taxa, age groups, and years because of overall differences in abundance, differences in gear selectivity, and annual fluctuations in population abundance. Of more interest was whether the relative abundance of the different taxa varied between lake areas, different times of the year, and different years. Because of the unbalanced sampling design, it was impossible to examine temporal and spatial abundance variation simultaneously in all of the data.

To control for spatial variation and to reduce the number of missing cells, changes in fish abundance between months and years were examined in area 3 only. Area 3 was the most consistently sampled area, and there were 9 years in which trawls were made monthly from June to October (Table 1). Based on these years (1962, 1963, 1965, 1966, 1971, 1973, 1979, 1980, and 1981), we found highly significant interactions between taxa, months, and years in adults, yearlings, and young of the year ($\underline{P}$ < 0.01). When the analysis was repeated separately for each taxa and age group, month by year interactions were found for all taxa and age groups. These significant interactions indicated that there were disproportionate changes in species abundance between months and years. Comparisons of abundance indices based on catches pooled over temporal parameters would produce ambiguous results.

Analysis of spatial distribution variation was more difficult because only a few areas were usually sampled each month. The area by taxa interaction was studied by limiting comparisons to data sets that had trawl hauls in similar months and years. To keep enough samples, it was necessary to restrict this analysis to 5 separate pairwise comparisons of area 3 with each other area. Area 3 was chosen as the reference area because it contained the greatest number of trawl hauls. Differences between taxa main effects were highly significant in all the analyses. The patterns of significant interactions and area effects indicated that area 3 was most similar to areas 5 and 6 and least similar to areas 1, 2, and 4 (Table 6). For areas 1, 2, and 4, there were usually significant interaction effects with area 3, which suggested that taxa showed different relative abundances between areas even when the data were

TABLE 4. Trawling catch and effort summarized by area for Lake Winnebago, 1962-81.

Parameter	Mean Catch Per Trawl Haul (CPH) By Area					
	1	2	3	4	5	6
Mean total CPH	131.2	118.3	195.0	128.3	175.1	177.8
Mean adult CPH	28.2	22.0	40.1	33.2	42.8	40.5
Mean yearling CPH*	0.5	0.4	0.9	0.4	1.1	1.2
Mean YOY CPH	102.4	95.8	152.8	94.7	129.0	135.4
Mean no. taxa/haul	5.1	5.1	5.7	5.3	5.4	5.6
No. years out of 20 represented	16	9	20	10	18	12
No. hauls	244	82	1,112	136	353	99

* Only walleye and sauger in yearling category.

TABLE 5. Ranking of 6 Lake Winnebago areas by sampling year and by mean catch per trawl haul over all areas pooled. Absence of ranking for an area indicates no trawl data within that area in a given year. Mean rank of 10.5 (example: area 3) indicates no bias since all years contain samples.

Year	Mean Catch Per Trawl Haul	Rank	Rank For Each Area					
			1	2	3	4	5	6
1966	507.3	1	1		1		1	
1978	321.9	2			2		2	
1974	240.3	3	3	3	3		3	3
1965	235.5	4	4		4	4	4	4
1967	216.6	5			5		5	
1971	211.6	6	6	6	6		6	6
1964	204.4	7	7	7	7	7	7	
1975	193.9	8	8	8	8	8	8	8
1963	185.7	9	9	9	9	9	9	9
1981	178.4	10	10		10	10	10	10
1968	172.1	11	11		11			
1969	165.8	12			12			12
1979	148.8	13	13		13		13	
1973	144.1	14	14		14	14	14	
1980	140.2	15			15		15	
1962	132.7	16	16	16	16	16	16	16
1977	122.2	17	17		17	17	17	17
1976	120.6	18	18	18	18		18	18
1972	80.7	19	19	19	19	19	19	19
1970	55.9	20	20	20	20	20	20	20
Mean of available years		10.5	11.0	11.8	10.5	12.4	10.4	12.0

TABLE 6. F-statistics associated with area and area by taxa interaction effects, from pairwise analysis of variance comparisons between area 3 and every other area. Comparisons were restricted to months and years with trawls from both areas. A large F-statistic indicates a significant effect (** or *). A nonsignificant interaction indicates taxa catches were proportional between areas, and a nonsignificant area effect indicates overall catches between areas were similar.

Age Group	Effect	Comparison 3 vs. 1	3 vs. 2	3 vs. 4	3 vs. 5	3 vs. 6
Adults	Area	47.55**	6.10*	35.40**	1.17	5.63*
	Interaction	14.20**	9.16**	4.17**	1.63	1.71
YOY	Area	13.46**	14.60**	0.10	1.04	0.41
	Interaction	9.63**	5.16**	8.22**	4.30**	1.81
Total	Area	35.35**	12.28**	12.56**	2.13	3.45
	Interaction	9.94**	5.39**	5.69**	3.16*	1.27

** $P < 0.01$.
* $0.01 < P < 0.05$.

approximately balanced across years and seasons. This analysis suggested that the lake could be divided into two general areas made up of areas 3, 5, and 6 and areas 1, 2, and 4.

The pairwise comparisons between areas were based on trawl hauls pooled over months and years even though temporal interactions were known to be present in the data. By pooling areas as suggested above and arbitrarily grouping months into summer (Jun, Jul, and Aug) and fall (Sep, Oct, and Nov) seasons, it was possible to do an overall analysis of temporal and spatial variability with most of the data. After pooling samples from areas 3, 5, and 6 into a southwest zone and areas 1, 2, and 4 into a northeast zone, only 5 years remained with more than one missing cell (Table 7). After deleting data from these 5 years (1967, 1968, 1969, 1978, and 1980), the remaining 15 years of data were subjected to an overall analysis of year, season, and taxa effects. The overall significance of all the two-way interactions involving taxa (Table 8) verified that relative abundance of taxa varies between zones, seasons, and years in a nonproportional fashion.

Examination of the actual sums of squares associated with each ANOVA (Table 3) shows that many of the interaction effects were small compared to the overall differences associated with taxa, age groups, and years. Thus, we were tempted to consider the effects as practically negligible and merely products of a large number of samples. However, the proliferation of significant interactions at all stages of the analyses suggests that either fish movements are statistically nonpredictable or that the unbalanced sampling design has introduced substantial bias into the analysis. The only safe generalization is that the lake could be divided into 2 geographic zones (Table 7), but that each zone should at least be sampled during both seasonal periods (preferably each month since the grouping into periods was arbitrary and not motivated by patterns in the data) to produce a statistically accurate picture of fish abundance levels.

TABLE 7. Distribution of trawl hauls for summer (Jun-Aug) and fall (Sep-Nov) seasons in northeast (areas 1,2,4) and southwest (areas 3,5,6) zones for Lake Winnebago, 1962-81.

	No. of Trawl Hauls			
	Northeast Zone		Southwest Zone	
Year	Summer	Fall	Summer	Fall
1962	82	19	48	41
1963	61	24	59	26
1964	30	9	30	21
1965	26	4	24	26
1966	8	3	30	37
1967			40	3
1968	10		37	
1969			16	11
1970	21	7	54	16
1971	7	4	44	55
1972	24		59	20
1973	15		31	21
1974	10	3	45	41
1975	32		75	25
1976	22		37	60
1977	4	10	46	50
1978			19	
1979	3		52	36
1980			120	80
1981	___	24	72	57
Total	355	107	938	626

Analysis of Area 3 as an Index Location

Although the above analyses indicated that substantial interactions sometimes exist between taxa abundances in different areas at different times of the year and even between years, we decided to examine the idea of designating area 3 as an index location and also to evaluate the potential bias and error that could result. Most trawling effort was concentrated in area 3 over the past 20 years and it is doubtful that sufficient funding and personnel exist to permit an annual comprehensive survey of the lake.

The monthly mean catch per haul in area 3 was highly correlated with the monthly mean catch per haul over all areas sampled for all taxa and age groups (Table 9). This was not surprising, however, because the total mean catch was primarily based on area 3 hauls (Table 4). Of more interest was whether the catch in area 3 was similar to the catch in other areas during the same months and years. For adults and young of the year, area 3 was most similar to area 5 when correlations were averaged over the 8 index taxa (Table 9). Catches in area 3 were least similar to catches in areas 2 and 6. For yearling walleye and sauger, catches were most similar between areas 3 and 6 and least similar between areas 3 and 2. Mean correlations for yearlings ranged from 0.8960 to 0.1013 indicating a range of similarities between areas. All mean correlations were positive, however, indicating general similarities between areas in overall catches.

TABLE 8. Analysis (ANOVA) of interactions for years with one or less missing cells for Lake Winnebago trawl data, 1962-81. Areas and months are pooled.

Dependent Variable: Log 10 Total Catch

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	PR > F
Model	164	3524.49	21.49	104.21	0.0001
Error	13355	2754.11	0.21		
Corrected Total	13519	6278.60			

Source	Degrees of Freedom	SAS Type IV SS	F Value	PR > F
Taxa	7	1377.81	954.45	0.0001
Year	14	178.59	61.86	0.0001
Season	1	0.31	1.53	0.2166
Zone	1	43.31	210.03	0.0001
Taxa*Year	98	641.26	31.73	0.0001
Taxa*Season	7	177.42	122.91	0.0001
Taxa*Zone	7	28.26	19.58	0.0001
Year*Season	14	66.44	23.01	0.0001
Year*Zone	14	55.34	19.17	0.0001
Season*Zone	1	0.15	0.71	0.4005

Dependent Variable: Log 10 Adult Catch

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	PR > F
Model	164	1615.82	9.85	89.79	0.0001
Error	13355	1465.39	0.11		
Corrected Total	13519	3081.21			

Source	Degrees of Freedom	SAS Type IV SS	F Value	PR > F
Taxa	7	584.78	761.35	0.0001
Year	14	67.61	44.01	0.0001
Season	1	0.48	4.36	0.0367
Zone	1	20.37	185.67	0.0001
Taxa*Year	98	368.28	34.25	0.0001
Taxa*Season	7	21.67	28.21	0.0001
Taxa*Zone	7	19.10	24.86	0.0001
Year*Season	14	25.12	16.35	0.0001
Year*Zone	14	11.40	7.42	0.0001
Season*Zone	1	0.02	0.21	0.6488

Dependent Variable: Log 10 Yearling Catch

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	PR > F
Model	62	40.51	0.65	23.62	0.0001
Error	3317	91.75	0.03		
Corrected Total	3379	132.26			

Source	Degrees of Freedom	SAS Type IV SS	F Value	PR > F
Taxa	1	3.38	122.22	0.0001
Year	14	11.06	28.57	0.0001
Season	1	0.11	3.99	0.0457
Zone	1	0.70	25.35	0.0001
Taxa*Year	14	5.77	14.90	0.0001
Taxa*Season	1	0.43	15.58	0.0001
Taxa*Zone	1	0.21	7.64	0.0058
Year*Season	14	5.56	14.35	0.0001
Year*Zone	14	2.56	6.62	0.0001
Season*Zone	1	0.04	1.39	0.2385

Dependent Variable: Log 10 Young-of-Year Catch

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	PR > F
Model	164	3067.03	18.70	97.09	0.0001
Error	13355	2572.46	0.19		
Corrected Total	13519	5639.50			

Source	Degrees of Freedom	SAS Type IV SS	F Value	PR > F
Taxa	7	1221.23	905.72	0.0001
Year	14	124.39	46.13	0.0001
Season	1	0.45	2.33	0.1272
Zone	1	14.25	73.99	0.0001
Taxa*Year	98	598.01	31.68	0.0001
Taxa*Season	7	277.53	205.83	0.0001
Taxa*Zone	7	20.16	14.95	0.0001
Year*Season	14	45.27	16.79	0.0001
Year*Zone	14	39.27	14.56	0.0001
Season*Zone	1	0.47	2.42	0.1200

TABLE 9. Correlations between log 10 mean catch per haul in area 3 against other areas in months and years with trawls in both areas. (Number of months suitable for comparison and the 5% critical value for testing are given.)

Age Group	Species	Correlation Coefficients of Area 3 With: Total Catch	Area 1	Area 2	Area 4	Area 5	Area 6	Mean
Adults	Trout-perch	0.9598*	0.7115*	0.1752	0.6967*	0.7940*	0.3177	0.6091
	Drum	0.9436*	0.4394*	0.7046	0.7897*	0.7984*	0.5498	0.7042
	White bass	0.9300*	0.5875*	0.2058	0.6651*	0.5866*	0.5823	0.5929
	Yellow perch	0.9293*	0.7325*	0.6605	0.7414*	0.6596*	0.7340*	0.7429
	Walleye	0.9158*	0.6489*	0.7241*	0.7066*	0.5510*	0.2727	0.6365
	Minnow	0.9910*	0.3395	-0.1429	-0.1341	0.8565*	-0.1257	0.2974
	Sauger	0.9221*	0.6069*	0.6799	0.5725*	0.4382*	0.3664	0.5977
	Crappie	0.9411*	-0.0672	0.0131	0.0000	0.8665*	0.9051*	0.4431
	Mean	0.9416*	0.4999*	0.3775	0.5047*	0.6938*	0.4503	0.5780
Yearlings	Walleye	0.9490*	0.2662	0.3676	0.6725*	0.6202*	0.8754*	0.6251
	Sauger	0.9679*	0.6335*	-0.1650	0.9383*	0.8363*	0.9165*	0.6879
	Mean	0.9585*	0.4499*	0.1013	0.8054*	0.7283*	0.8960*	0.6565
Young of year	Trout-perch	0.9769*	0.7592*	0.6126	0.8284*	0.8623*	0.6168*	0.7760
	Drum	0.9762*	0.8791*	0.7268*	0.8722*	0.8198*	0.7855*	0.8433
	White bass	0.9180*	0.6977*	0.3808	0.7777*	0.5682*	0.2008	0.5905
	Yellow perch	0.9285*	0.6995*	0.8963*	0.5783*	0.8060*	0.0461	0.6591
	Walleye	0.8725*	0.4516*	0.0840	-0.0692	0.7890*	0.1672	0.3825
	Minnow	0.9741*	0.5404*	0.0000	-0.0084	0.9118*	0.7660*	0.5307
	Sauger	0.9814*	0.8361*	0.1271	0.3505	0.7014*	0.5575	0.5923
	Crappie	0.9701*	0.8580*	0.4977	0.8554*	0.7716*	0.1514	0.6840
	Mean	0.9497*	0.7152*	0.4157	0.5231*	0.7788*	0.4114	0.6323
Number of months compared		85	29	8	16	39	11	
5% critical value for testing		0.2170	0.3670	0.7070	0.4970	0.3250	0.6020	

*Significant correlations (greater than the 5% critical value).

Although most correlations were large and positive, it was apparent that some species and some age groups within species were not well-indexed by the catch in area 3 (Table 9). Catches of minnow and crappie adults and walleye young of the year in other areas were only moderately related to index catches in area 3. On the other hand, catches of drum young of the year in area 3 were fairly similar to other areas.

Overall Trends in Relative Abundance

Although significant interactions exist in comparisons of taxa abundance between months and years, we graphed year-to-year and within-season changes in mean catch per haul (CPH) for qualitative comparison of relative abundance (Fig. 4 and 5). In Figure 4 yearly means were further separated by summer (Jun, Jul, Aug) and fall (Sep, Oct, Nov).

Trends of abundance over time can usually be attributed to timing of strong year classes (Fig. 4). However, mean seasonal CPH does not always provide a sound estimate of species year class strength because daily mortality varies during the first summer of life (Walburg 1976). Low catches for many young-of-the-year species early in a season are likely due to poor gear effectiveness for fish at these small sizes (Fig. 5). For young of the year descending best fit lines later in the season reflect the relative seasonal mortality of many Lake Winnebago species.

Despite the data base limitations previously discussed in this report, relative abundance indices portrayed in Figures 4 and 5 were examined in a series of more detailed analyses. Stepwise multiple regressions were used to correlate indices of abundance with spring water levels, spring and summer air temperatures, and other taxa abundance. The methods and the results of these analyses are not treated in detail in this report, but are available upon request. Here it is pertinent to note their existence and to use them to suggest several general hypotheses for further study as more information becomes available from continued trawl sampling. These results and suggested hypotheses are:

(1) Young-of-the-year yellow perch daily survival was positively correlated with young-of-the-year white bass abundance suggesting either a predator-prey relationship or a predator-buffering relationship.

(2) There was a positive correlation between adult yellow perch abundance and young-of-the-year yellow perch abundance suggesting a stock-recruitment relationship. Weak stock-recruitment relationships were found in white bass and freshwater drum.

(3) Young-of-the-year walleye and sauger abundances were primarily related to spring temperatures and water levels. Walleye yearling abundance was negatively correlated with predator abundance and positively correlated with young-of-the-year abundance, especially walleye. Thus, while walleye young-of-the-year abundance seemed to be largely controlled by physical factors, walleye yearling abundance was more dependent on biological interaction.

(4) A positive correlation between young-of-the-year and adult trout-perch abundance suggested a stock-recruitment relationship. Abundance of young-of-the-year trout-perch was negatively correlated with spring temperatures and positively correlated with water levels, indicating that abiotic factors may be important in controlling trout-perch reproductive success.

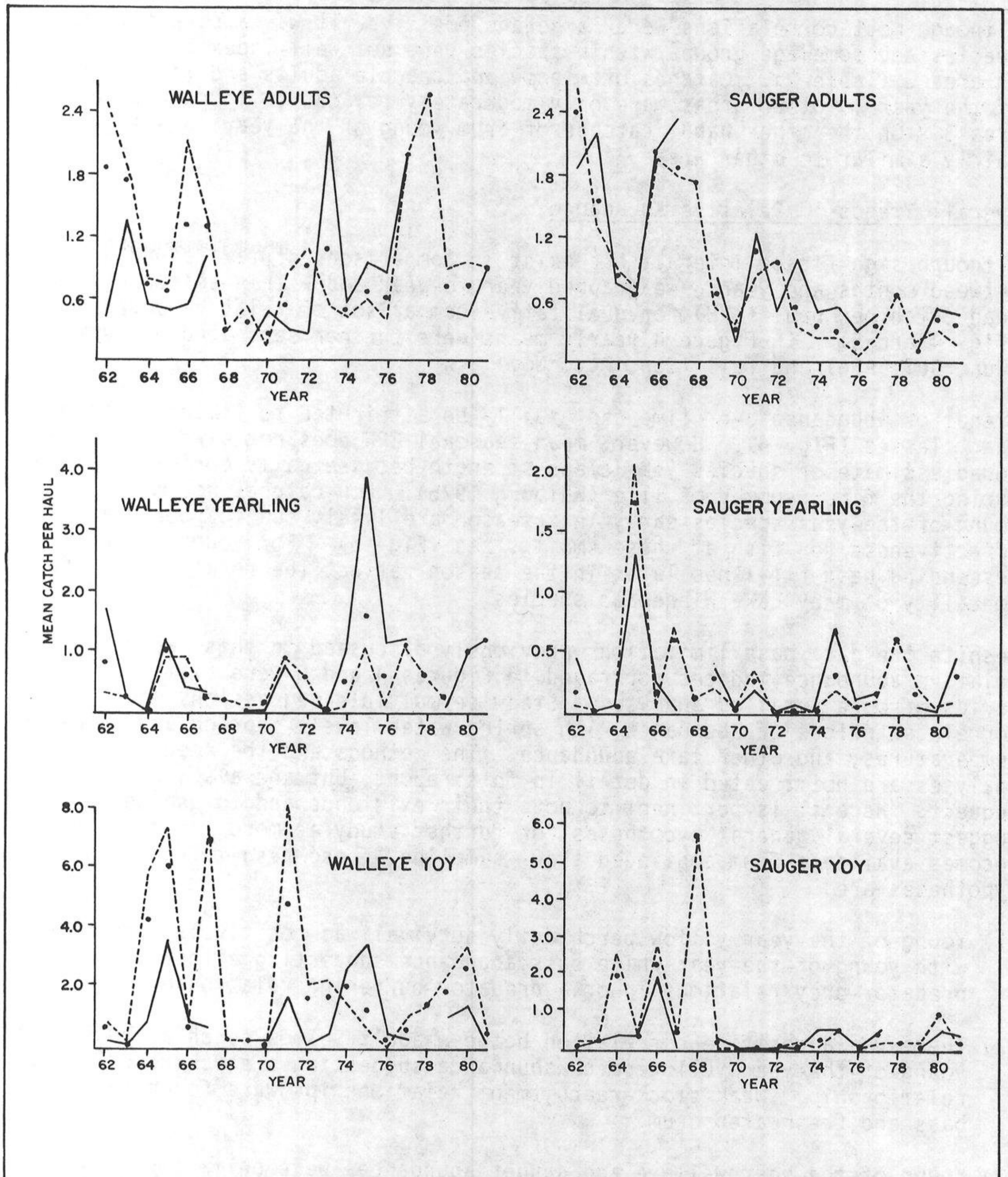


FIGURE 4. Mean number of fish/standardized trawl haul captured in Lake Winnebago, 1962-81. Each of the 18 graphs depicts one of the 8 major taxa and its size classification of adults, yearlings, or young of the year (YOY). Dashed lines represent summer samples from June, July, and August. Solid lines represent fall samples from September, October, and November. Dots represent yearly means. There were no fall samples in 1968 and 1978. Note that the divisions of each x-axis (years) are the same while those on the y-axis (mean catch per haul) vary considerably between figures.

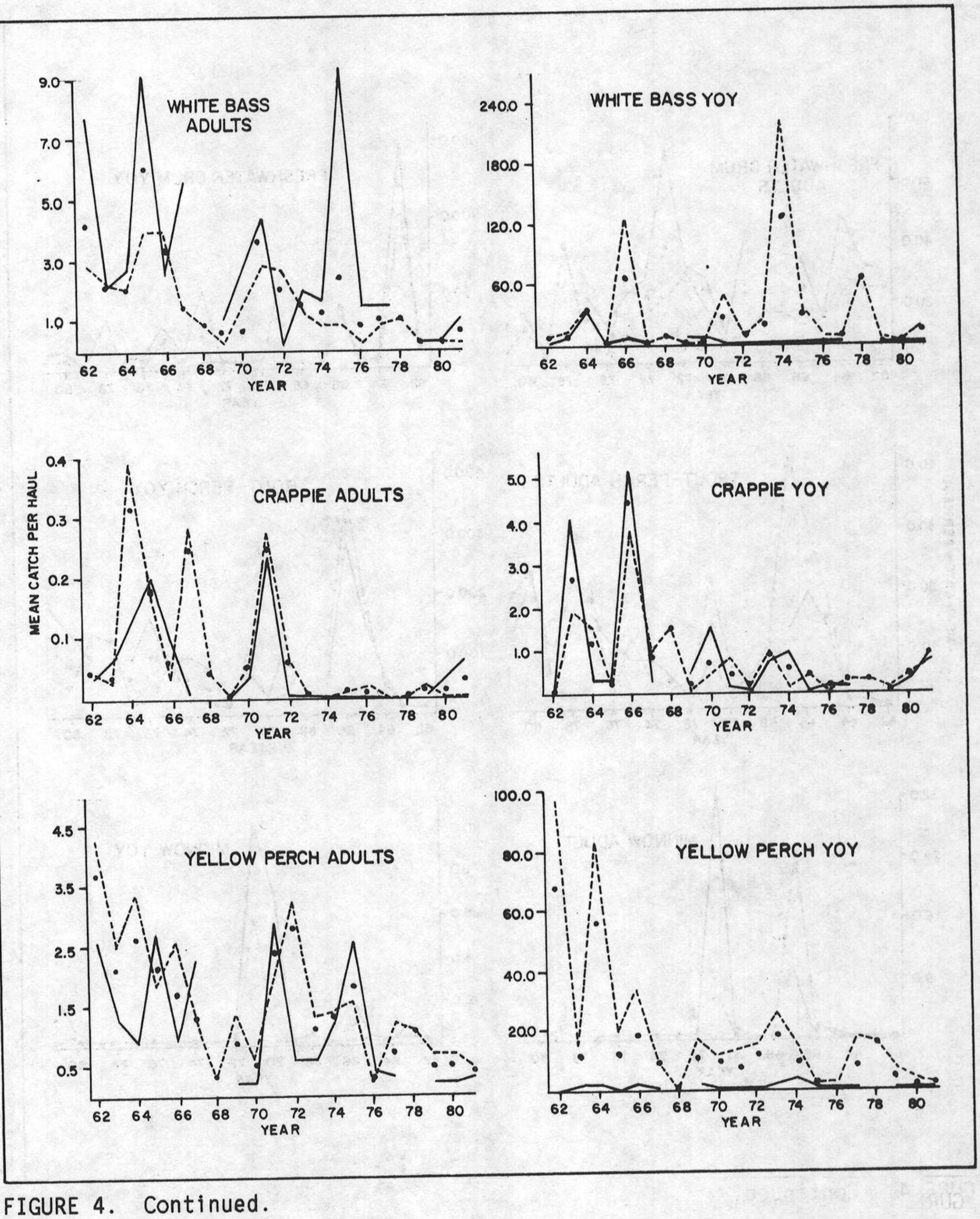


FIGURE 4. Continued.

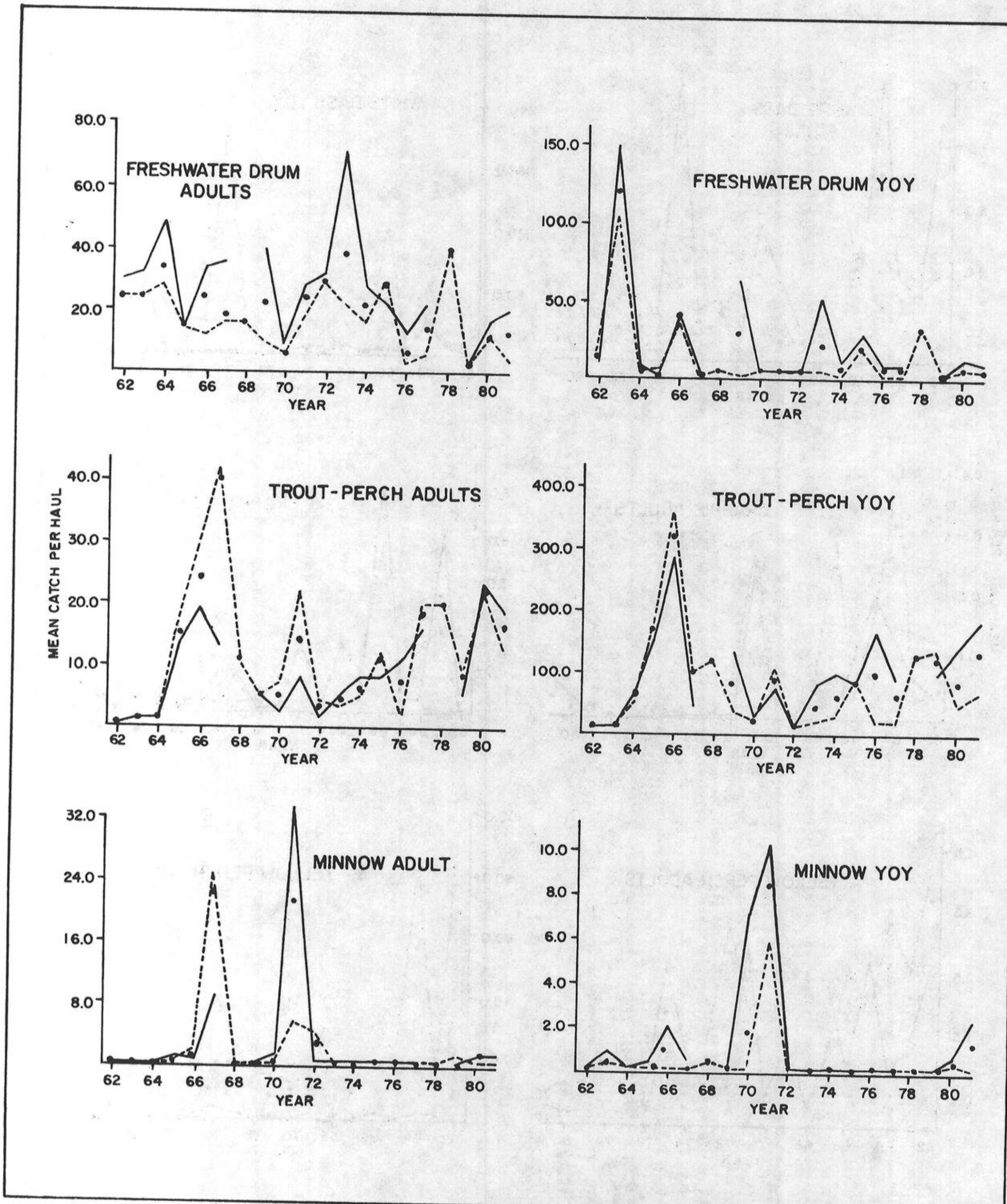


FIGURE 4. Continued.

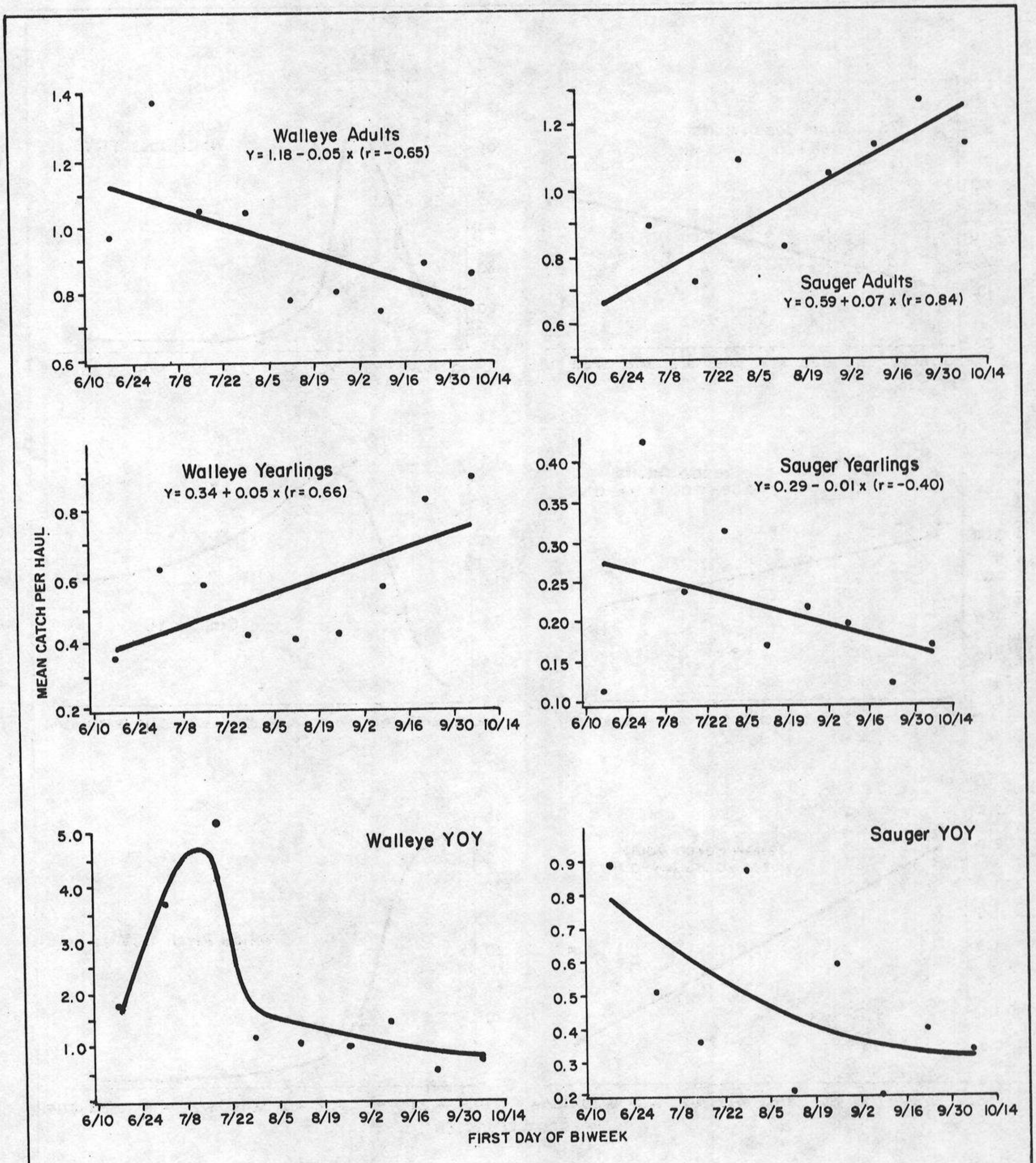
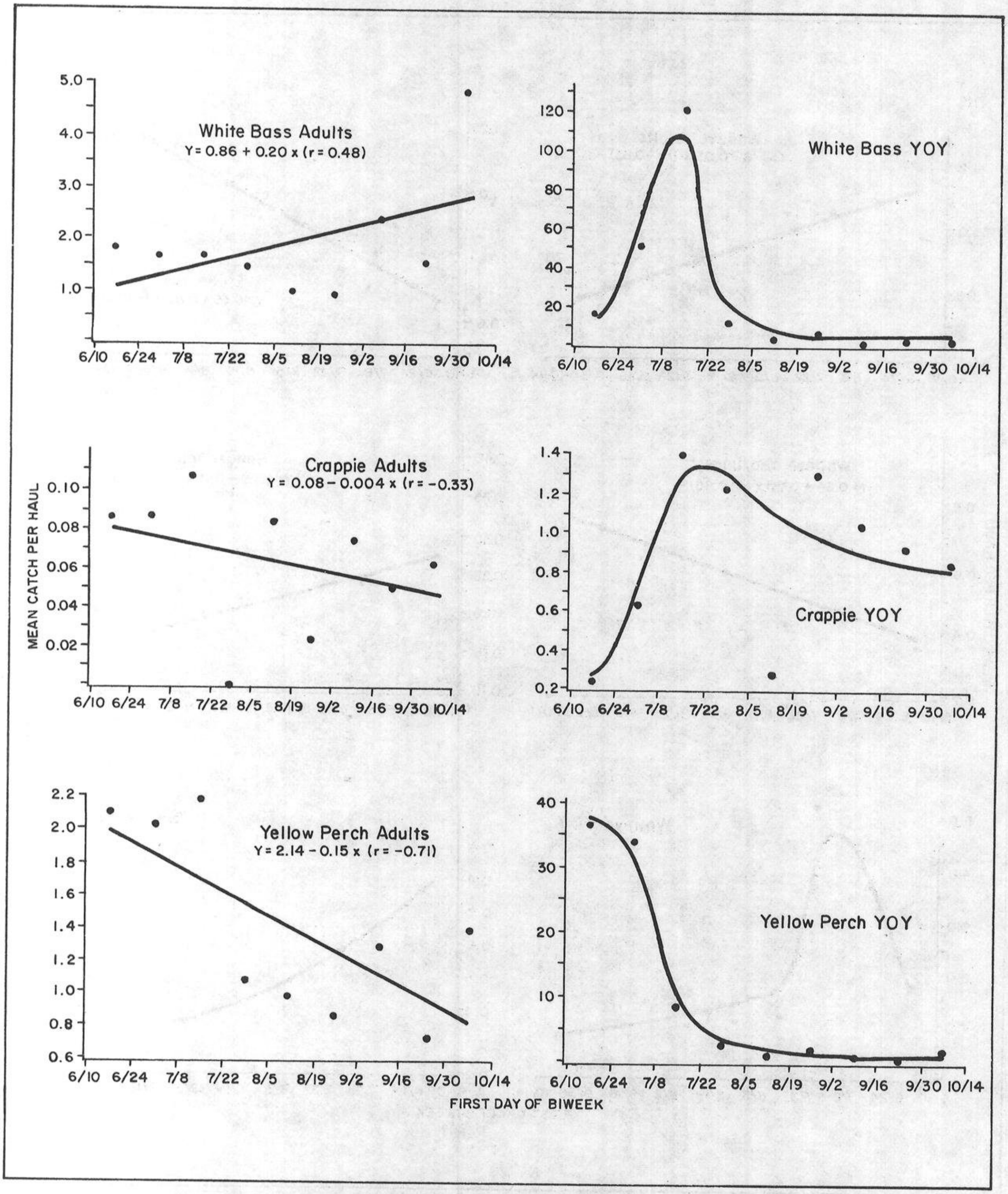


FIGURE 5. Mean number of fish per standardized trawl haul summarized by 2-week means during the open water seasons in Lake Winnebago, 1962-81. For young of the year, lines are best fit lines by eye, whereas lines for yearlings and adults are regression lines. All lines are based on the 9 bimonthly mean data points. Note that the divisions of each x-axis (date) are the same, while those on the y-axis (mean catch per haul) vary considerably between figures.



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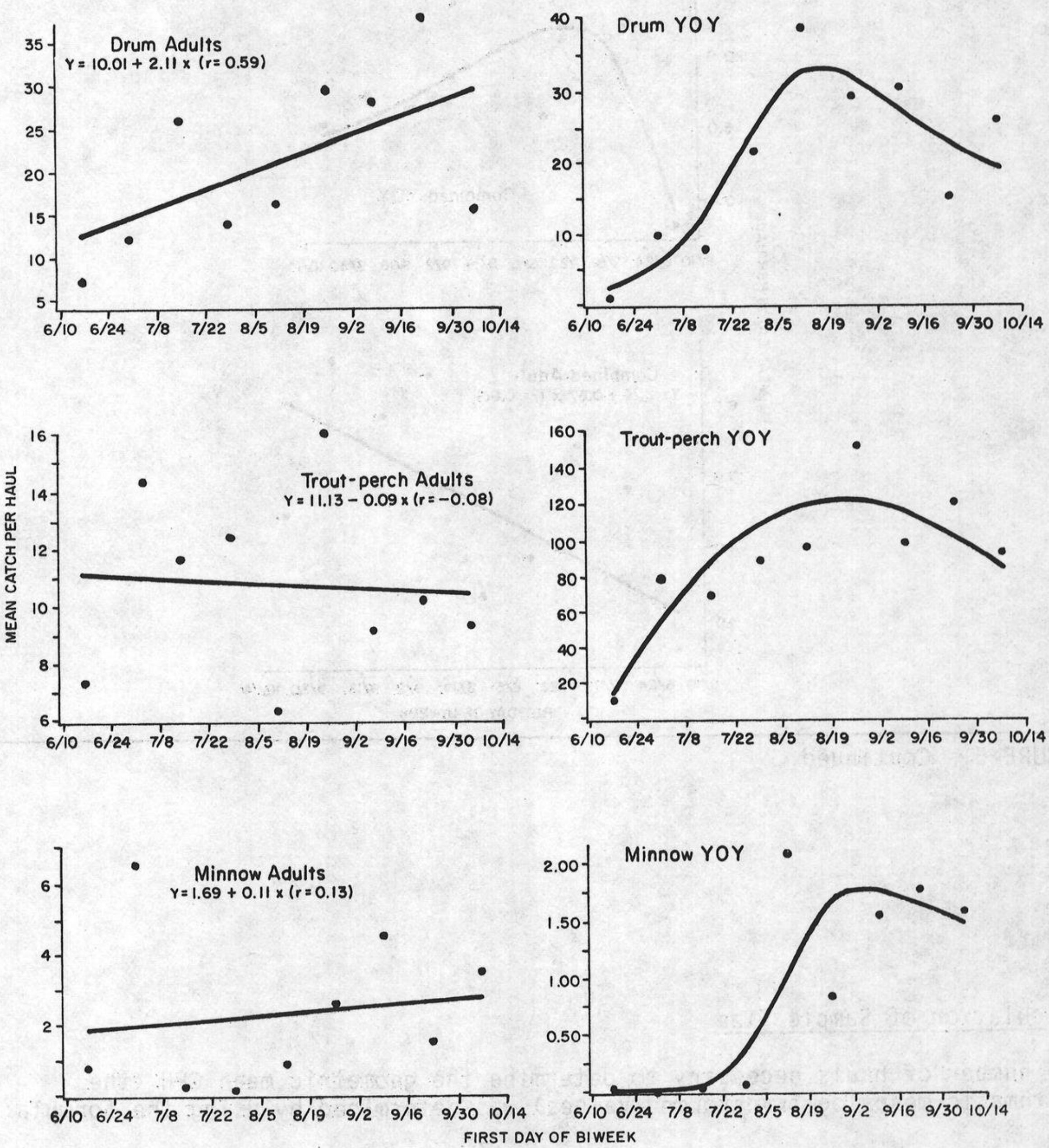

FIGURE 5. Continued.

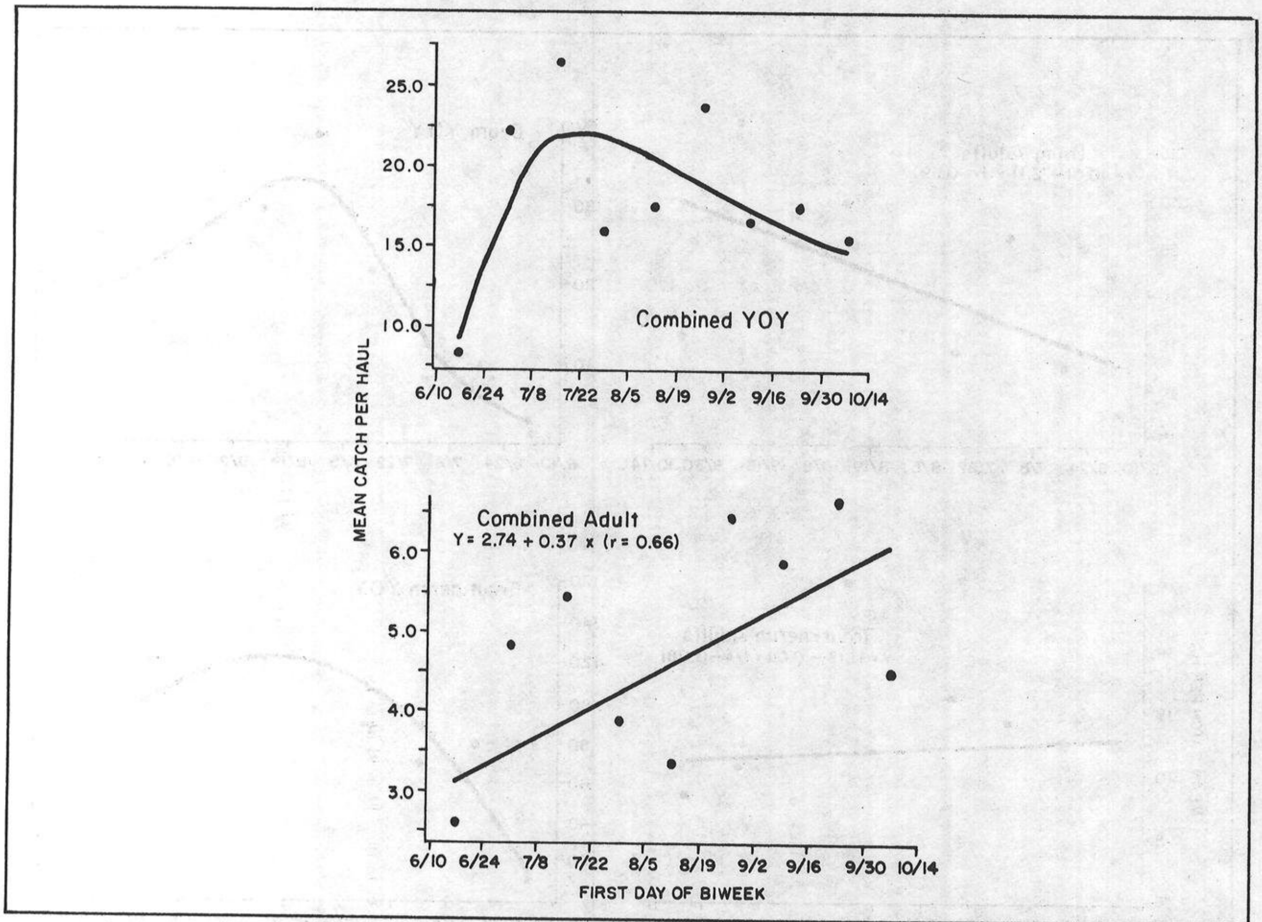

FIGURE 5. Continued.

Calculation of Sample Size

The number of hauls necessary to determine the geometric mean CPH (the arithmetic mean log-transformed values) was determined by using the formula:

$$N = \frac{Z_{\alpha}^2 \, S^2}{(\log_{10} k)^2}$$

where Z_{α} is the standard normal curve value corresponding to cumulative frequency of α, S^2 is the variance of the log-transformed values, and k is a constant determined by the desired precision. If it is desired to know the geometric mean to within 10% with α = 90% confidence, then Z = 1.65 and k = 1.1. Using values of S taken from the 1962-81 area 3 samples, calculated sample sizes differed by taxa but averaged 178 for adults, 47 for yearlings, and 193 for young of the year (Table 10).

TABLE 10. Sample size necessary to determine the geometric mean CPH to within 10% with a 90% confidence level, based on the observed variances from 1962-81 in area 3 only.

Species	Age Group	1962-81 Variance	Necessary Sample Size (No. Trawl Hauls)
Walleye	Adults	0.049	78
	Yearlings	0.041	66
	YOY	0.068	108
Sauger	Adults	0.047	75
	Yearlings	0.017	28
	YOY	0.020	32
White bass	Adults	0.071	113
	YOY	0.105	167
Yellow perch	Adults	0.070	112
	YOY	0.118	188
Drum	Adults	0.230	366
	YOY	0.144	229
Trout-perch	Adults	0.202	321
	YOY	0.272	433
Mean	Adults		178
	Yearlings		47
	YOY		193

MANAGEMENT IMPLICATIONS

Clearly, limited and intermittent trawling in all of the 6 areas of Lake Winnebago will not provide consistent, precise data necessary for the future needs of this large, multi-species system. Fish samples from trawling need to be stratified by year, time period, and lake location in order to get satisfactory comparisons of trends in abundance. Although the season and geographic zone groupings used in this report provided adequate stratification levels, the more specific month and area levels are preferred. If fiscal constraints will not allow for a rigorous, structured series of samples in each lake area in each month/year, then limiting the sampling effort to one area is the most practicable solution.

Testing of the 1962-81 trawl data has shown that significant differences exist in most comparisons of mean CPH between areas, months, seasons, and years. Many of these differences, however, might be explained by the lack of balanced systematic sampling. If equal numbers of samples can be taken at the same times and places each year, then differences would be more likely due to species abundance changes and not to any sampling bias.

Future trawling in Lake Winnebago should be redirected for maximum homogeneity of data. Haack and Muth (1980) recommended "primary stations" for their Lake Erie trawling because these areas are: (1) consistent producers of young fish, (2) representative of important nearby fishing areas, (3) in a major current pathway, and (4) easily accessible. Area 3 (see Fig. 1) would be the best choice for future trawling in Lake Winnebago as it best satisfies Haack and Muth's definition of a primary station. That is, area 3 appears to be the best area for producing consistent young-of-the-year fish catches with mean

CPH's greater than those in any of the other lake areas (see Table 4), it is an important fishing area, the Fox River enters Lake Winnebago in this area, and the trawler "Tarred Twine" is moored there for easy accessibility.

Additionally, area 3 has been trawl-sampled in all 20 years of this study, and it has the greatest total number of trawl samples. Future trawl sampling in area 3 should consist of 20 hauls per day at 2-week intervals beginning the first week in July and continuing through October each year. This annual effort would amount to a minimum of 160 trawl hauls in area 3 and would approach necessary sample size for 90% confidence (Table 10).

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