

A STUDY OF THE WARMWATER FISHERIES
IN FOUR LAKES IN SOUTHEAST WISCONSIN

By

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Wisconsin Cooperative Fishery Research Unit

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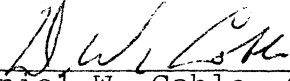
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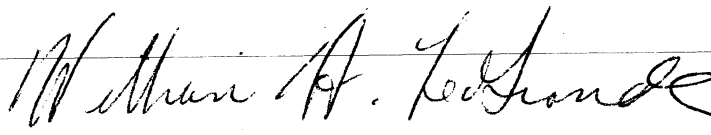
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ABSTRACT

Vital statistics were described for populations of largemouth bass (Micropterus salmoides) and panfish, mainly bluegill (Lepomis macrochirus), in Lakes Beulah (338 ha), Rockland (16 ha), Pretty (26 ha), and Browns (160 ha) in southeastern Wisconsin. Proportional stock density values for largemouth bass were below recommended management objectives (40-60%) in Beulah (13%), Rockland (13%), and Pretty (14%) Lakes, and within the objective range in Browns Lake (58%). Relative weight (a condition index) values for largemouth bass were satisfactory in all lakes except Browns Lake in fall. Largemouth bass growth in Rockland, Pretty, and Browns Lakes was similar to each other and the state average up to age 5. Growth of largemouth bass in Beulah Lake was similar to that in the other lakes and to the state average up to age 3, and significantly slower thereafter. Estimated total annual mortality rate of largemouth bass ranged from 52-79%. The exploitation rate (87%) of largemouth bass in Rockland Lake in 1980 was probably an overestimate. Population estimates of largemouth bass in Rockland Lake were 77 (for fish ≥ 130 mm long) and 37 (≥ 160 mm long) fish per hectare in spring and fall of 1980, and 46 (≥ 160 mm long) and 44 (≥ 160 mm long) fish per hectare

in spring and fall of 1981. The estimated standing stock of largemouth bass in Rockland Lake was 13 and 10 kg/ha in spring and fall of 1981.

Proportional stock density of bluegills was below recommended management objectives (20-40%) in Rockland (17%), Pretty (5%), and Browns (1%) Lakes, and within the objective range in Beulah Lake (40%). Condition of bluegills was satisfactory in Beulah and Rockland Lakes, and poor in Pretty and Browns Lakes. Bluegill growth in all lakes was significantly slower than the state average, and bluegills in Pretty and Browns Lakes grew significantly slower than those in Beulah and Rockland Lakes. Estimated total annual mortality rates of bluegills ranged from 39-77%.

Estimated fishing pressure in 1980 ranged from 107-348 hrs/ha. Catch of largemouth bass, bluegills, and all species combined ranged from 12-73, 132-459, 199-687 fish/ha, respectively. Corresponding harvest values ranged from 4-20, 37-210, and 79-301 fish/ha.

An index of abundance (number caught/hour of electrofishing and fyke netting combined) of bluegills 80-140 mm long was inversely correlated with proportional stock density, relative weight, and growth rate, and positively correlated with total annual mortality rate.

Community structure, measured by proportional stock density, did not meet the recommended management objective

in any lake.

Proportional stock density for largemouth bass and bluegills was positively correlated with various angling quality statistics.

Length limits established for largemouth bass in 1982 as a result of this investigation were a slot-length limit of 305-406 mm in Beulah and Rockland Lakes, and a minimum length limit of 406 mm in Pretty and Browns Lakes.

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INTRODUCTION

This study comprised the first two years (1980 and 1981) of a 6 - year evaluation of the effects of largemouth bass (Micropterus salmoides) length limits on the warmwater fisheries in four lakes in southeast Wisconsin.

The lakes were suspected of having overharvest of largemouth bass, resulting in too little predation pressure on panfish, resulting in unbalanced fish populations and an unsatisfactory sport fishery.

Objectives of this study were to: 1) describe vital statistics of largemouth bass and panfish, mainly bluegill (Lepomis macrochirus), populations, 2) assess problems in population and community structure, and 3) suggest management tactics that might improve the fisheries.

The following vital statistics were described: 1) length-frequency distributions, 2) the status of population and community structure, measured by the Proportional Stock Density index (Anderson 1976), 3) condition of largemouth bass and bluegill, measured by the Relative Weight index (Wege and Anderson 1978), 4) growth rates, 5) total annual mortality rates, 6) exploitation rate and population estimate of largemouth bass in one lake, and 7) fishing pressure (hrs/ha), catch (No./ha), and harvest (No./ha).

Study Lakes

The lakes studied were Beulah (338 ha), Pretty (26 ha), Browns (160 ha), and Rockland (16 ha), in Walworth, Waukesha or Racine counties, southeast Wisconsin (Appendices A and B). Beulah Lake has an inlet and outlet, and was raised 2.7 - 3.1 m by a mill dam built in the early 1840's, and reconstructed in 1910 - 1920 (George Boronow, Wisconsin DNR fish manager, personal communication). The others are seepage lakes; Browns and Rockland Lakes have a trickle outlet through a marsh, and Browns Lake has a dam (3.7 m wide) and a carp barrier (installed in 1972) across the outlet. The shoreline was completely developed around Browns and Pretty Lakes, mostly developed around Beulah Lake, and mostly undeveloped around Rockland Lake. Rockland Lake was the only lake without motorboats.

All lakes had hardwater (Appendix C) with potential for high productivity based on total alkalinity (Moyle 1946). Mean and maximum depths ranged from 2.4 - 5.2 m and 7.6 - 17.7 m, respectively.

Aquatic plants were abundant in all lakes except Pretty Lake. Submergent macrophytes grew on most of the lake bottoms in shallow water (< 4.6 m deep) in Beulah and Rockland Lakes. Emergent macrophytes (primarily

Scirpus spp.) grew along most of the edge of Rockland Lake. Browns Lake did not exceed 3.7 m in depth, except for a small depression (Appendix B), and submergent macrophytes grew to the surface throughout the lake, except in the depression. Aquatic plant - cutting machines were active throughout the summers on Beulah and Browns Lakes. Vegetation was scarce in Pretty Lake, except for a few beds of Chara spp., in the extensive shallow (<1.5 m deep), sandy fringe (Appendix B), and submergents occurred in deeper water (1.5-4.6 m deep).

All lakes contained a variety of fishes (Table 1). The largemouth bass and bluegill were the most abundant gamefish and panfish, respectively. A variety of minnows occurred in the lakes but were not adequately sampled in the present study.

Browns Lake was treated with rotenone and sand - formulated antimycin (George Boronow, Wisconsin DNR fish manager, personal communication) in 1971 to remove stunted panfish and carp (Schumacher and Rebicek 1977). Fishes stocked after treatment in 1971 - 1973 were northern pike (Esox lucius), walleye (Stizostedion vitreum vitreum), largemouth bass, smallmouth bass (Micropterus dolomieu), yellow perch (Perca flavescens), fathead minnow (Pimephales promelas), emerald shiner (Notropis atherinoides); and rainbow trout (Salmo gairdneri) to provide an immediate, short-term fishery (Table 2; Schumacher and Rebicek 1977). Fish surveys in 1972, 1973, and 1975 (methods included electro-fishing, fyke netting and minnow seining) indicated excellent

Table 1. Length range (mm) and sample size of fishes caught by electrofishing and fyke nets in 1980 and 1981, and by angling observed in creel survey in 1980, in Beulah, Browns, Pretty, and Rockland Lakes. S or F indicates that fish were caught in spring or fall electrofishing samples.

Species	Beulah		Browns		Pretty		Rockland	
	Electrofishing							
<u>Bluegill</u> <u>Lepomis macrochirus</u>	79-210 1970	S F	51-190 4983	S F	53-190 4231	S F	10-202 3647	S F
<u>Pumpkinseed</u> <u>Lepomis gibbosus</u>	51-180 159	S F	70-180 450	S F	71-201 313	S F	71-162 167	S F
<u>Yellow perch</u> <u>Perca flavescens</u>	20-230 394	S F	71-285 766	S F	109-244 56	S F	70-200 388	S F
<u>Green sunfish</u> <u>Lepomis cyanellus</u>	65-173 63	S F	101-169 32	S F	—		72-180 81	S F
<u>Warmouth</u> <u>Lepomis gulosus</u>	106-180 178	S F	—		74-156 243	S F	69-180 220	S F
<u>Largemouth bass</u> <u>Micropterus salmoides</u>	127-569 504	S F	127-518 383	S F	61-467 305	S F	74-526 1116	S F
<u>Northern pike</u> <u>Esox lucius</u>	251-610 4	S F	478-737 20	S F	330-744 11	S F	257-645 31	S F
<u>Walleye</u> <u>Stizostedion vitreum vitreum</u>	—		495-594 3		190-399 24	S F	—	
<u>Brown trout</u> <u>Salmo trutta</u>	140-594 23	S F	—		—		—	
<u>Bowfin</u> <u>Amia calva</u>	241-709 75	S F	—		—		229-597 137	S F
<u>Longnose gar</u> <u>Lepisosteus osseus</u>	330-879 7	S	—		—		—	
<u>Yellow bullhead</u> <u>Ictalurus natalis</u>	140-325 142	S F	91-320 448	S F	117-315 61	S F	127-315 111	S F
<u>Brown bullhead</u> <u>Ictalurus nebulosus</u>	178-315 138	S F	190-290 13	S F	160-323 54	S F	165-315 91	S F
<u>Black bullhead</u> <u>Ictalurus melas</u>	190 & 298 2	S F	127-297 195	S F	—		178-267 4	S F
<u>Rock bass</u> <u>Ambloplites rupestris</u>	188 1	S	—		91-216 32	S F	—	
<u>Black crappie</u> <u>Pomoxis nigromaculatus</u>	178-277 17	S F	137-274 12	S F	180-241 10	S F	135-257 56	S F
<u>Carp</u> <u>Cyprinus carpio</u>	—		597-683 3	S F	—		381-671 35	S F
<u>White sucker</u> <u>Catostomus commersoni</u>	292-467 4	S F	241-348 11	S F	275-538 7	S F	—	
<u>Grass pickerel</u> <u>Esox americanus vermiculatus</u>	124-320 376	S F	—		—		178-241 4	S F

Table 1 (continued)

Species	Beulah	Browns	Pretty	Rockland
Electrofishing (cont.)				
Lake chubsucker <u>Erimyzon sucetta</u>	102-287 S 523 F	—	—	76-290 S 130 F
Golden shiner <u>Notemigonus crysoleucas</u>	102-213 S 36	138-210 S 9	—	140-231 S 28 F
Total species	1	14	12	16
Total number caught	4,616	7,328	5,347	6,246
Fyke nets				
Bluegill	56-198 4739	51-193 19677	53-178 1704	51-190 797
Pumpkinseed	84-178 280	56-175 1192	79-193 270	56-150 21
Yellow perch	102-257 129	81-234 23	160 1	140-163 3
Green sunfish	66-170 135	56-193 180	—	66-124 12
Warmouth	66-173 200	—	76-180 239	58-150 29
Largemouth bass	102 & 384 2	76-173 8	84-140 6	—
Northern pike	—	615 1	307 1	—
Walleye	—	—	251 1	—
Brown trout	—	—	—	—
Bowfin	452 & 551 2	—	—	323-424 7
Longnose gar	437-640 3	—	—	—
Yellow bullhead	150-259 92	86-307 39	163-188 3	183-259 16
Brown bullhead	76-295 23	208-239 2	254-295 4	272-320 4
Black bullhead	249-295 3	239-241 3	—	—
Rock bass	196 & 239 2	—	89-254 20	—
Carp	—	—	—	—
White sucker	—	—	—	—
Grass pickerel	211-287 10	—	—	—
Lake chubsucker	122-234 29	—	—	218-292 7

Table 1 (continued)

Species	Beulah	Browns	Pretty	Rockland
Pyke net (cont.)				
Golden shiner	130-203 12	140-206 4	—	170-196 6
Horneyhead chub <u>Nocomis biguttatus</u>	163 1	—	—	—
Total species	17	10	10	11
Total number	5,639	21,249	2,249	905
Angling				
Bluegill	122-213 1938	57-206 662	122-186 72	99-198 418
Pumpkinseed	127-236 186	92-175 335	153-198 38	109-168 15
Yellow perch	107-277 228	92-277 33	—	109-191 72
Green sunfish	142-165 12	76-178 42	—	145 1
W. mouth	137-206 74	—	—	130-175 6
Largemouth bass	170-488 115	183-437 250	183-488 4	170-462 57
Northern pike	488 1	437-716 51	—	450-653 5
Walleye	—	589 1	—	—
Brown trout	218-361 67	—	—	—
Bowfin	411, 665, 729 3	—	—	362 1
Yellow bullhead	211-287 11	155-300 33	—	211-254 4
Brown bullhead	249-264 7	206-305 8	—	290, 297, 300 3
Black bullhead	—	185-287 89	—	—
Rock bass	163 & 203 2	—	—	—
Black crappie	117-284 13	—	188 & 201 2	117-264 82
Carp	—	—	—	411 1
Total species	13	10	4	12
Total number	2,657	1,504	116	665

Table 2. Fishes stocked in Browns, Beulah, and Pretty Lakes, 1967-1980; YGL means yearling, and FGL means fingerling.

Lake	Species	Period						
		1971	1972	1973	1978			
Browns	Northern pike	34 YLG	1,255,000 FRY	1,665,300 FRY				
	Walleye		2,500,000 FRY	50,340 FGL 3,199,000 FRY				
	Largemouth bass	28,377 FGL 30 Adult						
	Smallmouth bass		100,625 FRY					
	Rainbow trout		10,000 YLG (178-229 mm long)					
	Yellow perch		218 (76-127 mm long)					
	Fathead minnow		180,000	400,000				
	Emerald shiner			480,000				
	Black crappie				160 (178-229 mm long)			
	White crappie				40 (178-229 mm long)			
Beulah		1973	1974	1975	1976	1978	1979	1980
	Rainbow trout	30,007 (178-229 mm long)	210 (≥381 mm long) 7,000 (229 mm long) 15,000 (127-178 mm long) 3,000 (178 mm long)	16,001 (254 mm long)	12,000 (254-279 mm long)	6,000 (178 mm long)	6,000 (229 mm long) 4,500 (279 mm long)	
	Brown trout					6,000 (178 mm long)	6,000 (229 mm long)	15,700 (178 mm long)
Pretty		1967	1978	1979				
	Walleye	500		1,240 FGL				
	Largemouth bass		20,000 (76 mm long)					

survival of largemouth bass, good survival of northern pike and yellow perch, and poor survival of walleyes, smallmouth bass, fathead minnows, and emerald shiners (Schumacher and Rebicek 1977). Bluegills, pumpkinseeds (Lepomis gibbosus), and green sunfish (Lepomis cyanellus) were introduced from unknown sources after chemical treatment, for they were found in the fish surveys in 1973 and 1975. Black and white crappies (Pomoxis nigromaculatus and P. annularis) were stocked in Browns Lake in 1978 (Table 2; George Boronow, Wisconsin DNR fish manager, personal communication).

A panfish removal project was carried out in Pretty Lake in 1977 and 1978 because bluegills were abundant and growing slowly, and there were few large predators (Tills 1977). Some 120,460 fish were removed, of which 111,991 were bluegills.

Fishes stocked in Pretty Lake were walleyes in 1967 and 1979, and largemouth bass in 1978 (Table 2; George Boronow, personal communication).

Rainbow trout or brown trout (Salmo trutta) have been stocked from 1973 through 1980 (except 1977) in Beulah Lake to provide a two-story fishery each year (Table 2; George Boronow, personal communication).

Harvest regulations on largemouth bass in the study lakes from 1907 to the early 1950's included a 254-mm length limit and a maximum of 15 fish per day bag limit. In the early 1950's, the open season on largemouth bass was limited

to 20 June through 15 January, with a bag limit of 5 fish per day of at least 254 mm long. A study on largemouth bass in Browns Lake in 1953 indicated that an earlier season opening (i.e. first Saturday in May) and no minimum length limit were not detrimental to the bass population (Threinen and Mraz 1954). The 254-mm length limit was removed from largemouth bass statewide in 1954, and beginning in 1958, the bass season opened on the first Saturday in May. Harvest regulations on other fishes during this study included a bag limit of 5 northern pike in Pretty Lake and 2 in Beulah, Rockland and Browns Lakes; and 50 panfish (bluegills, pumpkinseeds, yellow perch, and black and white crappies) in aggregate for all lakes.

METHODS and MATERIALS

Sampling

Fish were caught by electrofishing, fyke netting, and angling (Table 1). Electrofishing was conducted at night (immediately after sunset) along shore with a boat-mounted 200 - 375 volt electroshocker (Novotny & Priegel 1971). Pulsed DC output was 2.5 - 3.0 amps. Boat speed alternated between 15 minutes of fast and slow electrofishing. Stunned fish were netted from the bow by two people and placed in a holding tank. One circuit of the shoreline of Rockland, Pretty and Browns Lakes was fished each survey. The southwest basin of Beulah Lake was sampled from the start to end location (about 100 ha) marked on Appendix B. Electrofishing was carried out on two nights in each spring and fall of 1980 and 1981 on Beulah, Pretty and Browns Lakes, and on four nights each on Rockland Lake (Table 3). Sampling effort was doubled on Rockland Lake to obtain sufficient data for a multiple census population estimate of largemouth bass. Shocking time was recorded so that catch per unit effort (CUE) could be calculated for each species.

Fyke nets were fished in June of 1980 and 1981

Table 3. Fish sampling methods and effort in 1980 and 1981. Effort is reported in hours for the electroshocker (DC), in net days for fyke nets and in hours/week for the creel survey. The number of fyke nets fished in each lake is in parenthesis after effort.

Year	Gear	Beulah Lake (338 ha)		Rockland Lake (16 ha)		Pretty Lake (25 ha)		Browns Lake (160 ha)	
		Total Effort	Dates sampled	Total Effort	Dates sampled	Total Effort	Dates sampled	Total Effort	Dates sampled
<u>1980</u>	electroshocker	4.0	21,28 May	4.2	20,29 May, 3,5 June	1.6	19 May 4 June	5.6	22,27 May
	Fyke nets	10(5)	24,25 June	4(2)	18,19 June	4(2)	25,26 June	10 (5)	18,19 June
	Creel Survey	32	20 May - 31 August	20	3 May - 28 September	8	20 May - 31 August	20	3 May - 28 September
	electroshocker	3.4	15,23 October	4.2	13,16,20,28 October	1.7	21,29 October	5.0	14,22 October
<u>1981</u>	electroshocker	3.6	19,27 May	3.7	13,18,26,28 May	1.6	2.,29 May	5.3	14,20 May
	Fyke nets	10(5)	9,10 June	8(4)	16,18,19 June	8(4)	11,12 June	8 (4)	16,17 June
	electroshocker	3.7	6,14 October	4.5	1,5,13 October 2 November	1.6	8,15 October	5.1	7,12 October

(Table 3). Two to 5 fyke nets of 19 mm (3/4") stretched mesh with a 15.2-m long lead were fished perpendicular to shore for 48 hrs.

Gamefishes (largemouth bass, northern pike, walleye and brown trout Salmo trutta) in electrofishing samples were counted, measured (mm), and weighed (g; in 1981 only); scale samples were collected and the fish released.

A subsample of panfishes (bluegill, pumpkinseed, yellow perch, green sunfish and warmouth Lepomis gulosus) were selected from electrofishing samples each spring and fall. Enough panfish were dip-netted from the holding tank, without regard to size to fill a 19-liter plastic container; about 10% formalin solution was added as a preservative; and the panfish were transported to a university laboratory for processing. Panfishes that were not preserved were counted and released. The preserved panfishes were counted, measured, and weighed, and scale samples were collected. ~~The spring 1980 panfish samples were accidentally allowed to dry so that weight data from that sample were of no value.~~

Fish captured in fyke nets were counted, measured, and released. Because one fyke net in Browns Lake (on 16 June 1981) contained about 7,000 fish, a subsample of 500 was selected from that net by removing fish, without regard to size, from various areas of the cod end of the net. Length and weight data, and scale samples were collected from a few fish in the fyke nets to increase the number of scale samples of small and large fishes.

Gear Selectivity Comparisons

Fyke net and electrofishing samples were compared on the basis of number, size range, and mean length of each species caught. Mean length of fish in spring and fall electrofishing, and fyke net samples (with a minimum of 35 fish) were compared with a two-sample t-test (Zar 1974; p. 105).

Proportional Stock Density

The Proportional Stock Density (PSD) index of Anderson (1976) was used to evaluate population and community structure. PSD was defined as the percent of "quality-size" fish in a "stock." PSD of largemouth bass, bluegill, pumpkinseed and yellow perch was calculated from the minimum stock- quality-size listed in Table 4.

For communities with a diversity of panfishes or game fishes, Anderson and Weithman (1978) suggested that predator and prey PSD's be calculated by weighting the PSD of each species according to its relative abundance. I calculated a prey PSD by weighting the PSD of each species by the number of stock-sized fish of the species in electrofishing samples. I used the formula of Snedecor and Cochran (1974) for a weighted mean,

$$P_W = \frac{PW}{W} ,$$

where P_W is the weighted mean prey PSD, P is the PSD for

Table 4. Minimum stock- and quality-size (mm long)
for largemouth bass, bluegills, pumpkinseeds, and
yellow perch.

Species	Stock-size	Quality-size
Largemouth bass	203	305
Bluegill	76	152
Pumpkinseed	76	152
Yellow perch	127	203

each prey species, and W is the weighting factor.

The largemouth bass was the only species used to calculate predator PSD because it was the only abundant predator species caught.

Relative Weight (W_r)

I used the W_r index of Wege and Anderson (1978) to evaluate the condition of bluegill and largemouth bass. W_r is a comparison between the weight (W) of a fish and a standard weight (W_s) for fish of the same length, determined from the formula, $W_r = W/W_s \times 100$ (Wege and Anderson 1978). Standard weights have been defined for largemouth bass and bluegill based on the extensive summary of length-weight data of Carlander (1977). Wege and Anderson (1978) grouped these data into 25-mm length intervals and calculated the 75th-percentile weight for each (i.e. 74% of the fish within the interval weighed less than the 75th-percentile). Values on a curve fitted to the 75th-percentile weight of each interval were adopted as the standard weights (W_s). Wege and Anderson (1978) suggested that suitable largemouth bass W_r may be 95-100% in late summer and fall, and Legler (1977) reported 90-95% as being satisfactory for bluegills. Hillman (1982) felt that these objective ranges seemed too narrow when considering communities which supported substantial numbers of large bluegills; he considered W_r of 90-105% as satisfactory for largemouth bass and bluegills. The lower bound that he used allowed for bass W_r 's that may have been influenced by a deficiency of stock-size bluegill prey. The upper bound allowed for mean bluegill W_r 's that were

substantially above the recommended range of Legler (1977).

I arbitrarily considered W_r of 90-105% to be satisfactory for largemouth bass and bluegills. Low W_r 's may indicate problems in obtaining food, and high W_r could be indicative of an abundance of food resources.

Problems associated with traditional condition indices are eliminated through use of W_r (Wege and Anderson 1978). Problems with condition indices, K or $C = W/L^3$ or $K_n = W/\hat{W}$ (Le Cren 1951), where W is the weight, L is the length, and $\hat{W}$ is a calculated mean weight for a certain length, based on the weight-length relationship in each population, are 1) different measurement units (metric or English) result in different values; 2) condition indices may vary widely among species (Wege and Anderson 1978); 3) many fishes change shape as they grow, and therefore, K or C change with changes in length (Le Cren 1951; Novinger 1973); and 4) tedious calculations are required to determine K_n . In contrast, W_r is simple to calculate, does not change with measurement units, can be readily compared among species, and standard weights compensate for changes in body form.

The W_r values of fish in various length groups (containing at least 5 fish) were compared among lakes with a Wilcoxon paired-sample test (Zar 1974; pp. 124-6).

Age, Growth, and Mortality

Age and growth statistics of largemouth bass, bluegills, and pumpkinseeds (in Browns Lake only) were determined from scale samples. A subsample of scales from 10 fish was selected randomly from those 10-mm length groups having more than 12 scale samples in spring and fall electrofishing samples. If there were 12 or fewer fish in a 10-mm length group, scales were read from all.

Scales were cleaned with a toothbrush and warm water, placed between 2 acetate slides (the slide that would receive the scale impression was warmed), and a roller press was used to produce an impression of the scale on the acetate. Scales were read on an Eberbach microprojector at 40X magnification. Annuli were recognized by spacing, cutting over, or marked disruptions of circuli. Scales were read twice or more until I was confident that they were aged correctly. A second opinion of scale age was obtained from experienced scale readers when I was doubtful.

The anterior scale radius was measured to each annulus and to the margin. The relationship of total fish length to scale margin was calculated from the empirical, functional GM regression (Ricker 1975) and used to back-calculate length at annulus formation.

The length-weight relationship, $W = aL^b$, was transformed to natural logarithms and fit by functional GM regression

(Ricker 1975).

Instantaneous rate of growth (G) was estimated from back-calculated lengths at annulus formation and from the slope (v) of the functional GM regression of weight on length.

Length at age of largemouth bass and bluegills were compared with a paired t-test (Zar 1974; p. 121) among lakes and to the state average (Snow 1969). Length increments were compared with a paired t-test, and instantaneous growth rates were compared among lakes with a Wilcoxon paired-sample test (Zar 1974; pp. 124-6).

Age frequency distributions were determined from length-frequency distributions according to the ratio of each age in each 10-mm length interval.

Total annual and instantaneous mortality (A and Z) and survival (S) rates were calculated from catch curves (Ricker 1975).

Population Estimates, Standing Stock, and Exploitation

Population estimates of largemouth bass in Rockland Lake were calculated by the mark and recapture method for fish larger than the minimum length in electrofishing samples. Electrofishing was conducted on four nights within a 4-week period each spring and fall. Bass were marked by clips of the caudal or pelvic fins. Chapman's modification of the Schnabel formula (Ricker 1975; equation 3.17) was used to

estimate population size. Limits of confidence (95%) were computed by treating R as a Poisson variable (Ricker 1975; p. 97); the confidence interval was calculated by substituting the upper and lower limits of R for R in the equation. The estimate of standing stock was the product of the population estimate and the mean individual weight of a fish.

The exploitation rate of largemouth bass in Rockland Lake in 1980 was calculated by dividing estimated harvest by the population estimate in 1980 (Ricker 1975; p. 264).

Creel Survey

A creel survey was conducted on the lakes in 1980. Browns and Rockland Lakes were surveyed from 3 May (the opening of the season) through 28 September, and Beulah and Pretty Lakes were surveyed from 20 May through 31 August. Shore and boat angling were stratified into early (0600-1400 hrs) and late (1400-2200 hrs) periods. All weekends and holidays, and 3 weekdays were censused so that 80 hrs per week were surveyed. The 3 weekdays and the early and late survey periods were selected randomly.

One clerk worked on Browns and Rockland Lakes, and another worked on Beulah and Pretty Lakes. One half of each survey period was devoted to Browns and Rockland Lakes so that each lake was surveyed 20 hrs/week. Beulah Lake was surveyed 32 hrs/week and Pretty Lake was surveyed 8 hrs/week (4 hours on one weekend day and on one weekday, the

periods selected at random).

Wisconsin Department of Natural Resources forms, Creel Census - Instantaneous Counts (form No. 3600-106) and Angler Interviewer (form No. 3600-114), were used to record creel survey data. Hourly instantaneous counts were obtained from one or two vantage points on Rockland, Pretty and Browns Lakes, and by traversing a transect entirely across Beulah Lake.

Anglers were interviewed on completion of their trip or toward the end of the survey period. Information recorded included: mode of fishing (boat or shore), number in party, time angler started fishing and time interviewed or ended fishing, species sought (if more than one, the percent of time applied to each species was recorded), and the number of each species caught and released.

On consent of anglers, creeled fish were counted, measured, weighed, and a scale sample was collected; all anglers were cooperative. A subsample of panfish was selected (about 10 - 60% of the time) when time did not conveniently allow examination of each fish. An attempt was made not to select certain sizes of fish in the subsample.

Estimated catch and harvest were the products of catch or harvest per unit effort from interviews and total effort from instantaneous counts.

Partial survey estimates of fishing pressure, catch,

and harvest of largemouth bass, bluegills, and of all species combined in May in Beulah and Pretty Lakes were corrected; i.e. increased to cover the entire month. These estimates were based on days surveyed from 20 May through 31 May. Fishing pressure, catch, and harvest of largemouth bass, bluegills, and all species combined for all of May were estimated from the proportion,

$$\frac{\text{Estimate for the last 12 days in May for Browns and Rockland Lakes}}{\text{Estimate for all of May for Browns and Rockland Lakes}} = \frac{\text{Estimate for the last 12 days in May for Beulah or Pretty Lakes}}{\text{Unknown estimate for all of May for Beulah or Pretty Lakes}}.$$

The estimates of catch and harvest of bluegills and all species combined for the last 12 days in May for Browns Lake were unrealistic and therefore were not included in the proportion.

RESULTS AND DISCUSSION

Gear Selectivity

Electrofishing produced 2 to 8 more species than fyke nets and the creel survey (Table 1). Sanderson (1960), Bocardy and Cooper (1963), and Reynolds and Simpson (1978) found electrofishing to be nearly as efficient in determining species composition as rotenone samples. Fyke nets in this study were not effective in capturing largemouth bass but were effective for bluegills, pumpkinseeds, green sunfish and warmouth.

Electrofishing and fyke nets yielded similar size ranges of bluegills, pumpkinseeds, yellow perch, warmouth and green sunfish (Figures 1-17), but fyke nets tended to select a greater proportion of the larger bluegills compared with electrofishing in spring (Figures 1-4). Mean length of bluegills captured in fyke nets was significantly greater than that of those caught by electrofishing in spring (t-tests, Appendix D).

In contrast, fyke nets selected a greater proportion of the smaller warmouth in Beulah and Pretty Lakes (Figures 12 and 14). Mean length of warmouth caught in spring electrofishing was significantly greater than that of warmouth caught in fyke nets (Appendix D).

Goedde (1980) also found fyke nets more selective for larger bluegills and for pumpkinseeds and yellow perch than

BEULAH LAKE

Bluegill

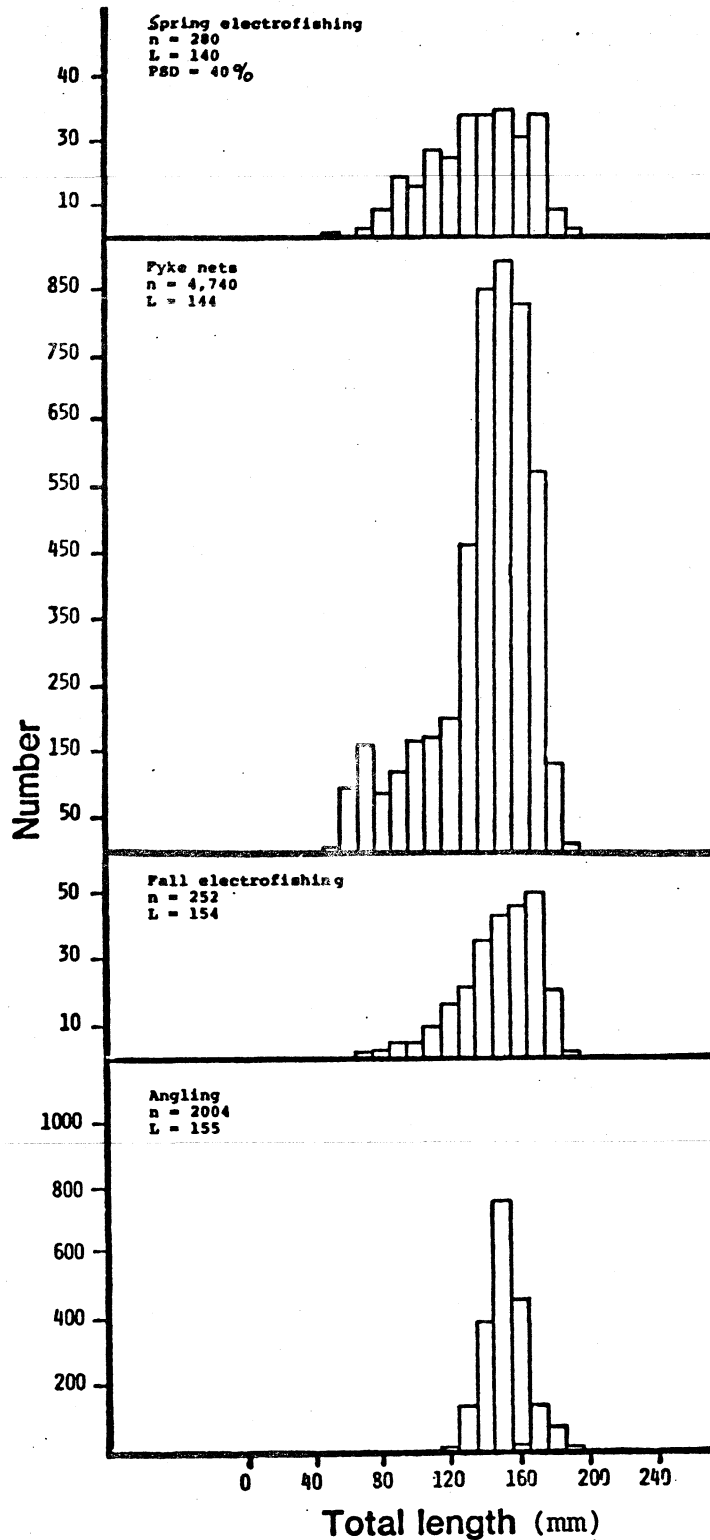


Figure 1. Length-frequency distribution of bluegills caught by electrofishing in spring and fall and fyke netting in June in 1980-1981, and angling in 1980, in Beulah Lake. L is the mean length.

Bluegill

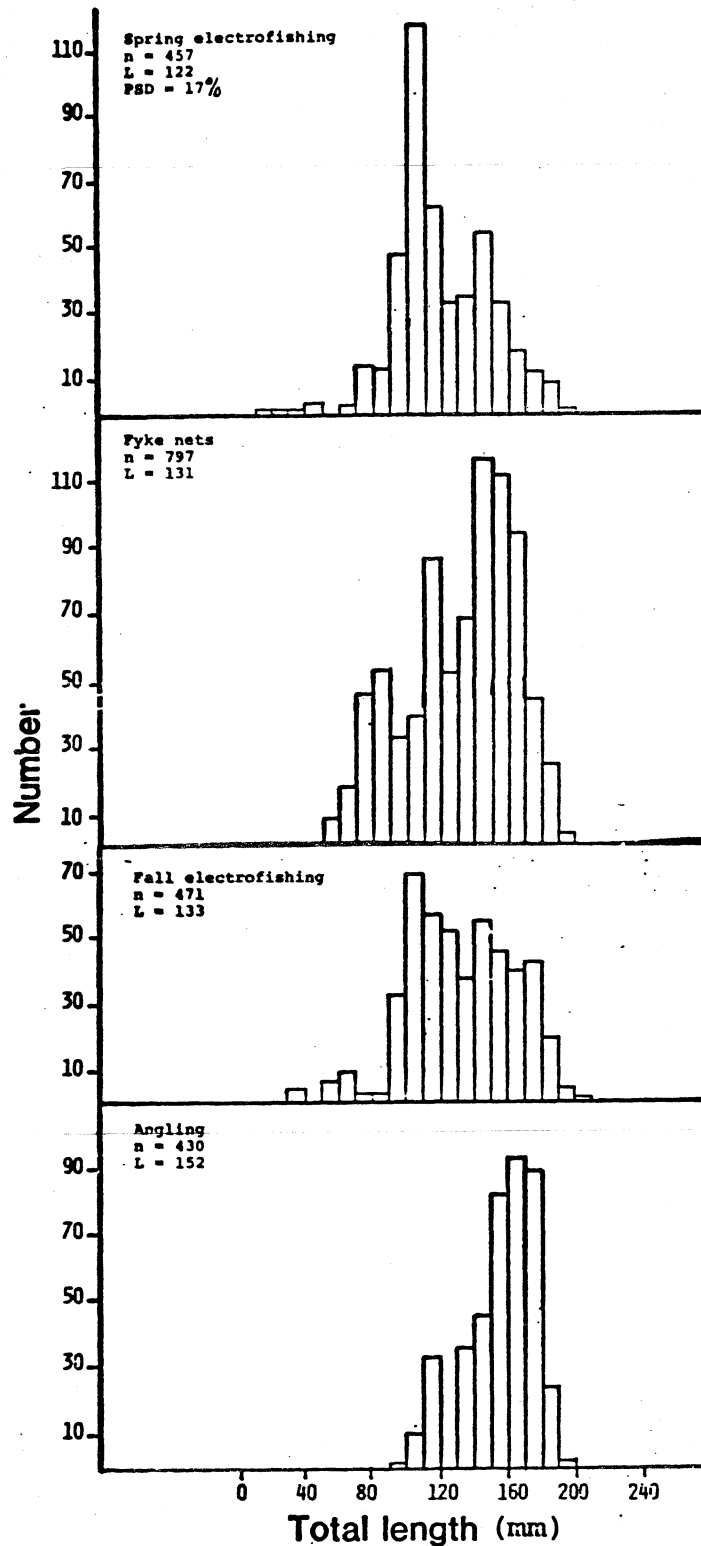


Figure 2. Length-frequency distributions of bluegills caught by electrofishing in spring and fall and fyke netting in June in 1980-1981, and by angling in 1980, in Rockland Lake. L is the mean length.

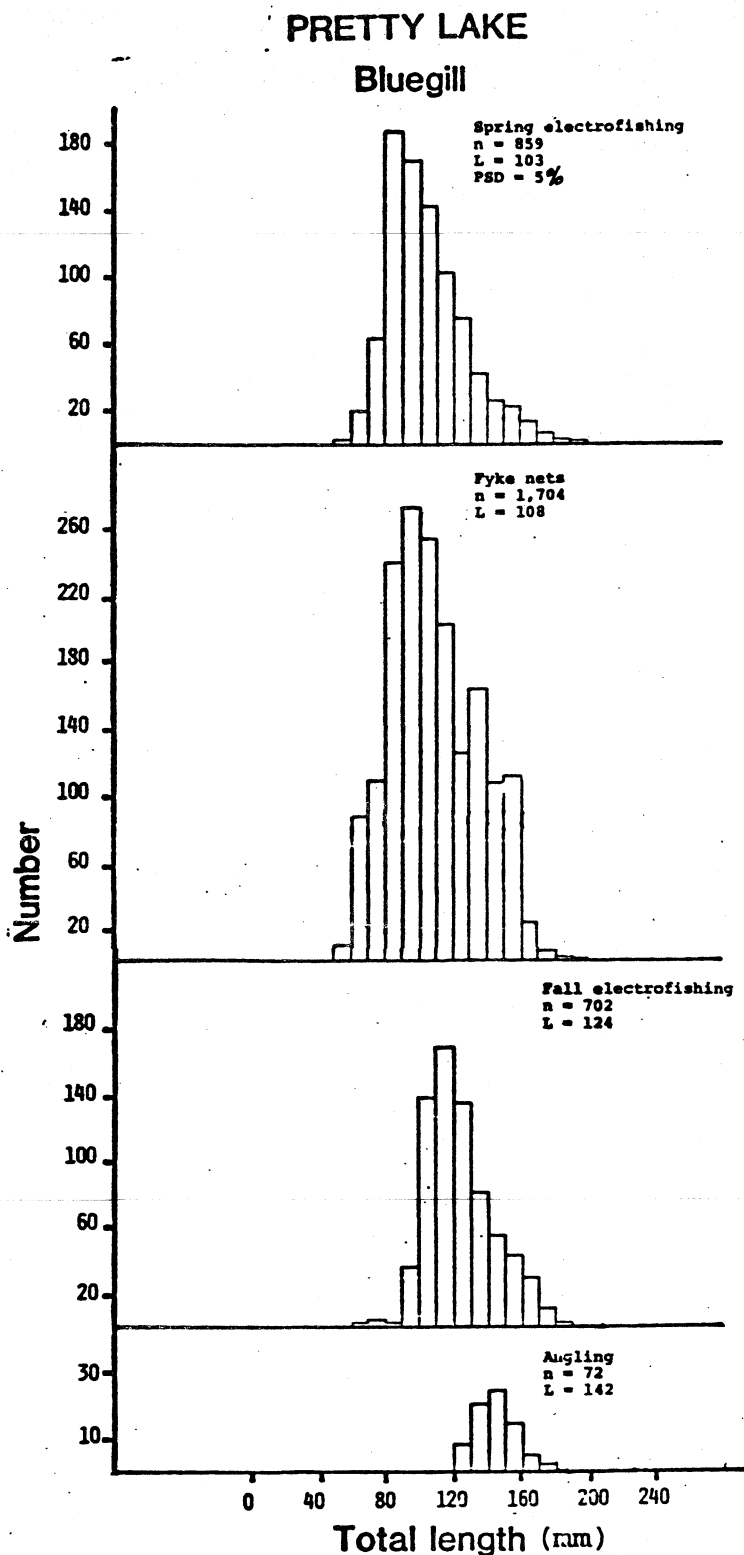


Figure 3. Length-frequency distribution of bluegills caught by electrofishing in spring and fall and fyke netting in June in 1980-1981, and by angling in 1980, in Pretty Lake. L is the mean length.

Browns Lake Bluegill

26

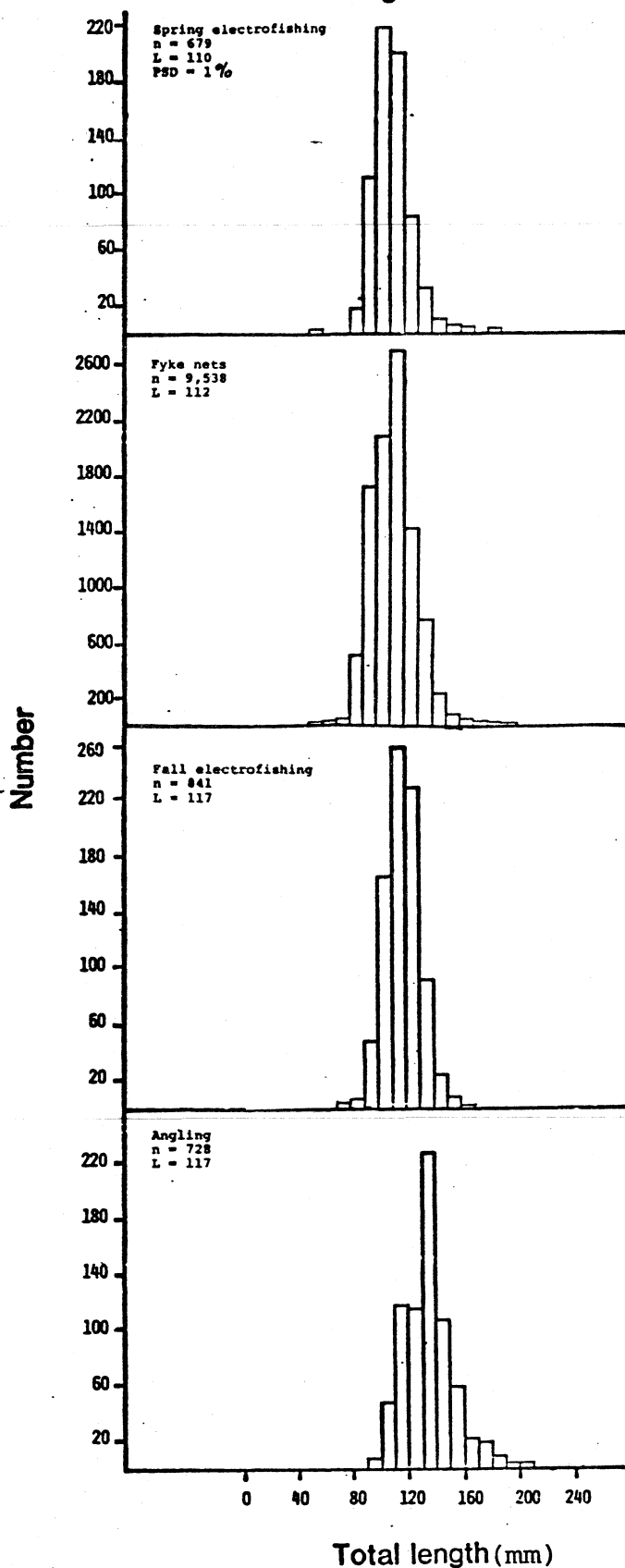


Figure 4. Length-frequency distribution of bluegills caught by electrofishing in spring and fall and fyke netting in June in 1980-1981, and by angling in 1980, in Browns Lake. L is the mean length.

BEULAH LAKE

Yellow perch

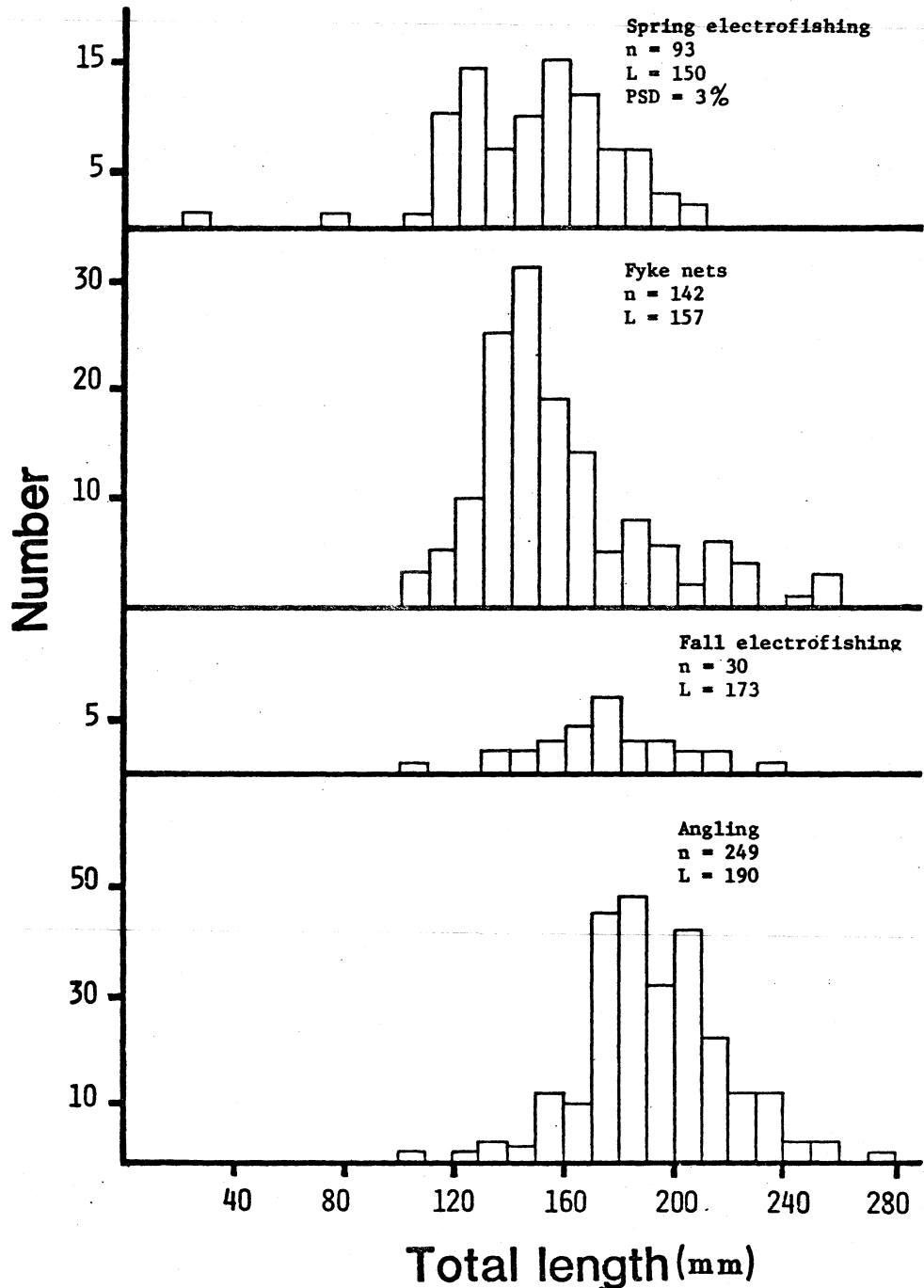


Figure 5. Length-frequency distribution of yellow perch caught by electrofishing in spring and fall and fyke netting in June in 1980-1981, and by angling in 1980, in Beulah Lake. L is the mean length.

ROCKLAND LAKE

Yellow perch

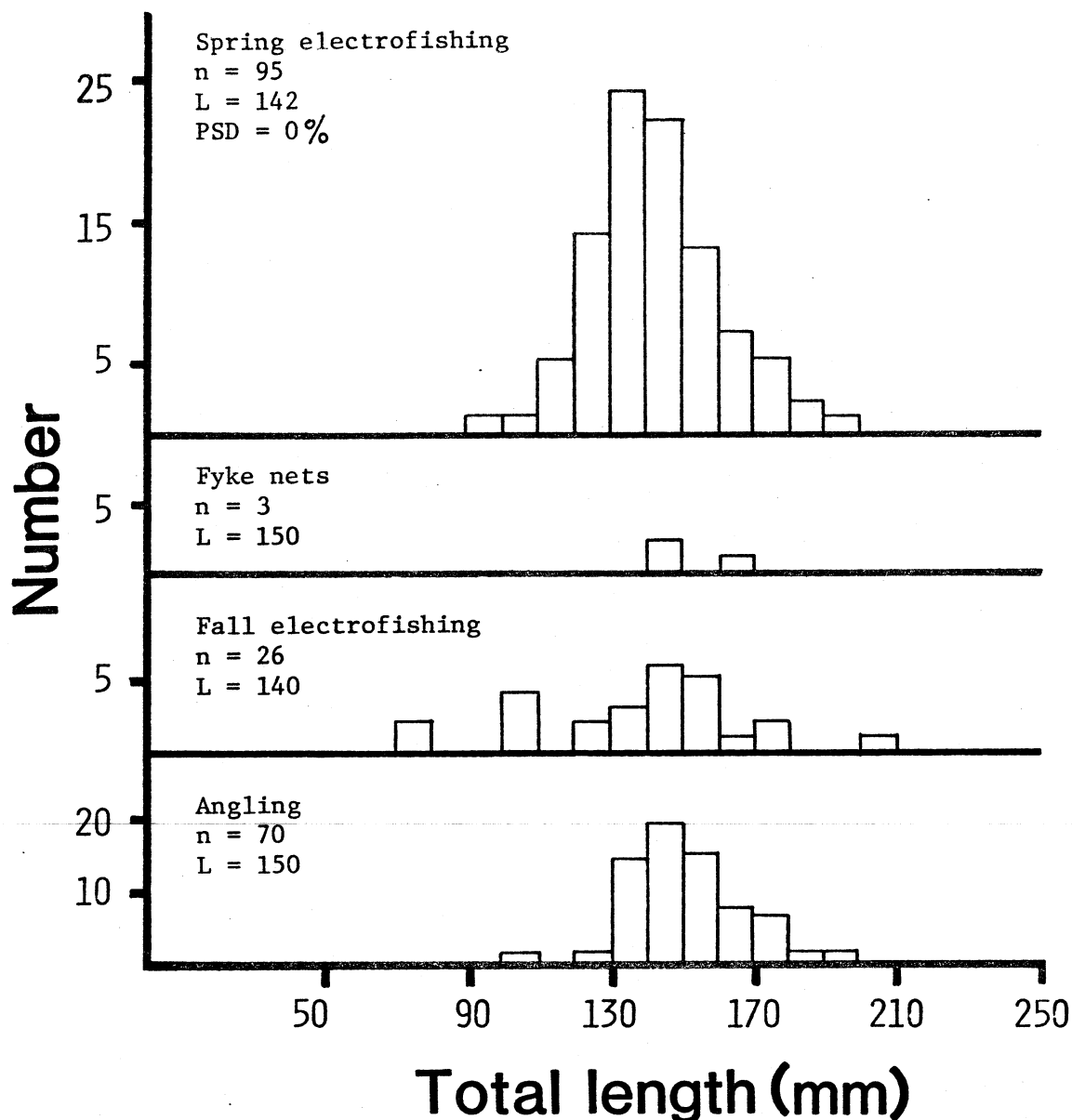


Figure 6. Length-frequency distribution of yellow perch caught by electrofishing in spring and fall and fyke netting in June of 1980-1981, and by angling in 1980, in Rockland Lake. L is the mean length.

BROWNS LAKE

Yellow perch

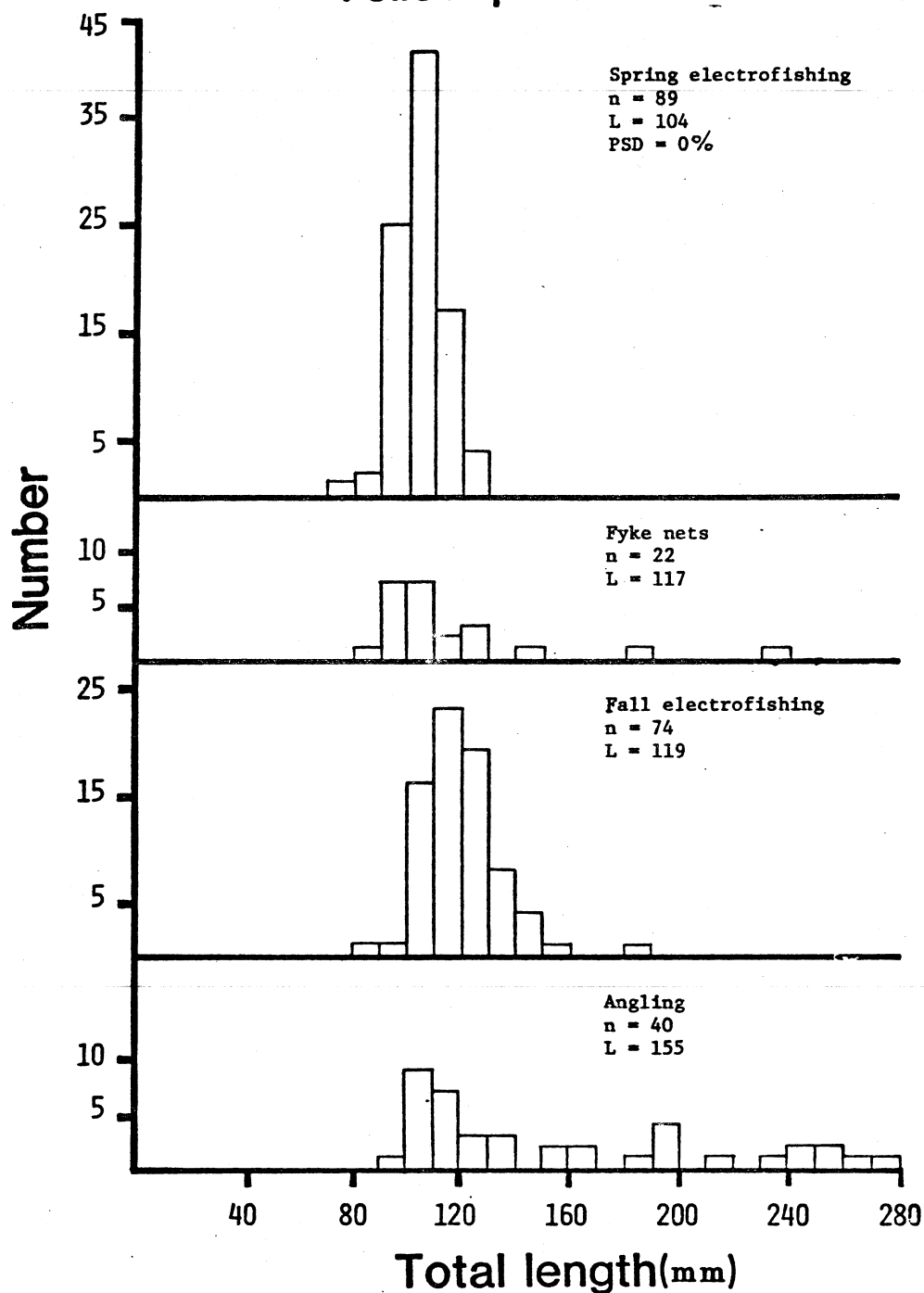


Figure 7. Length-frequency distribution of yellow perch caught by electrofishing in spring and fall and fyke netting in June in 1980-1981, and by angling in 1980, in Browns Lake. L is the mean length.

BEULAH LAKE

Pumpkinseed

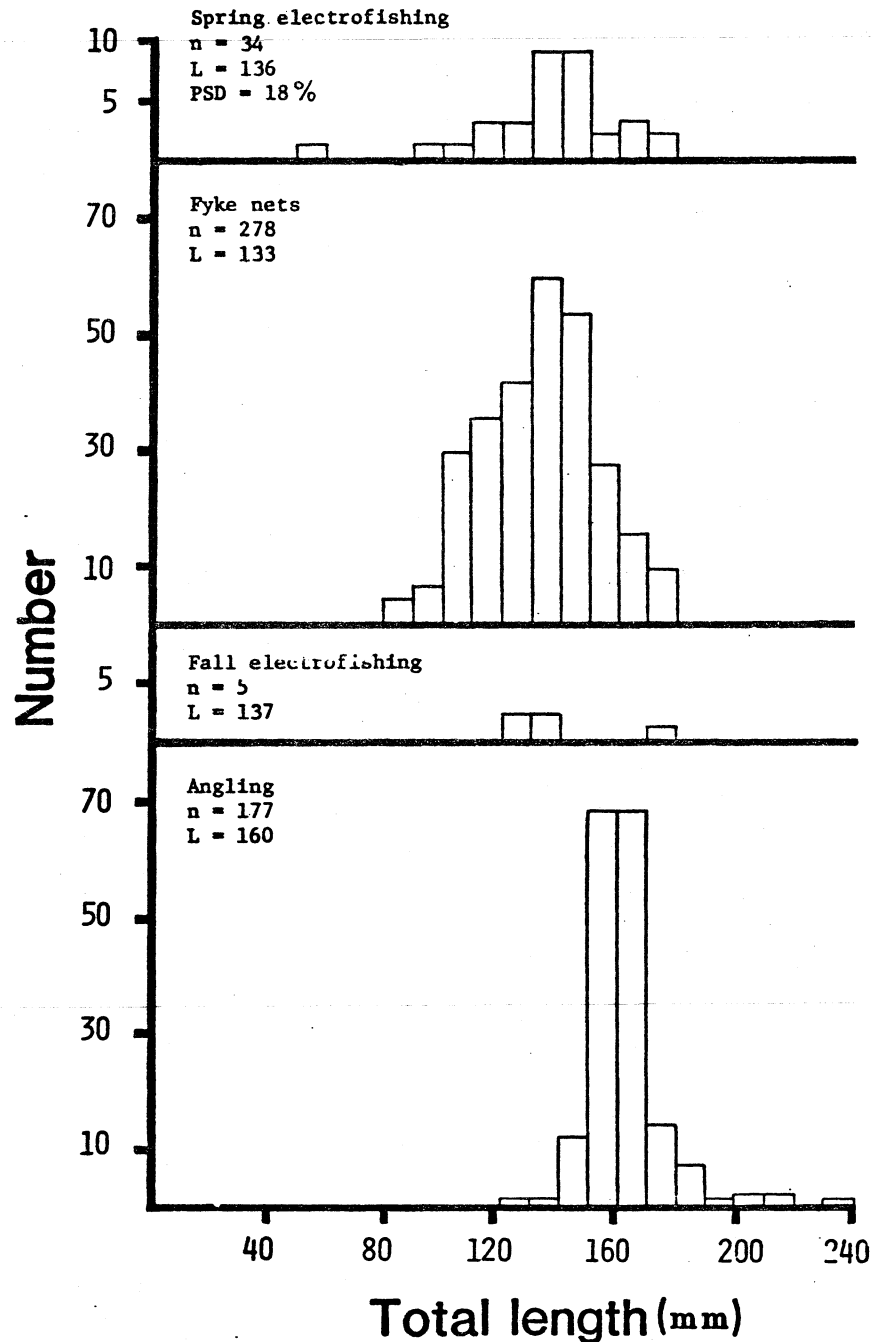


Figure 8. Length-frequency distribution of pumpkinseeds caught by electrofishing in spring and fall and fyke netting in June in 1980-1981, and by angling in 1980, in Beulah Lake. L is the mean length.

ROCKLAND LAKE

Pumpkinseed

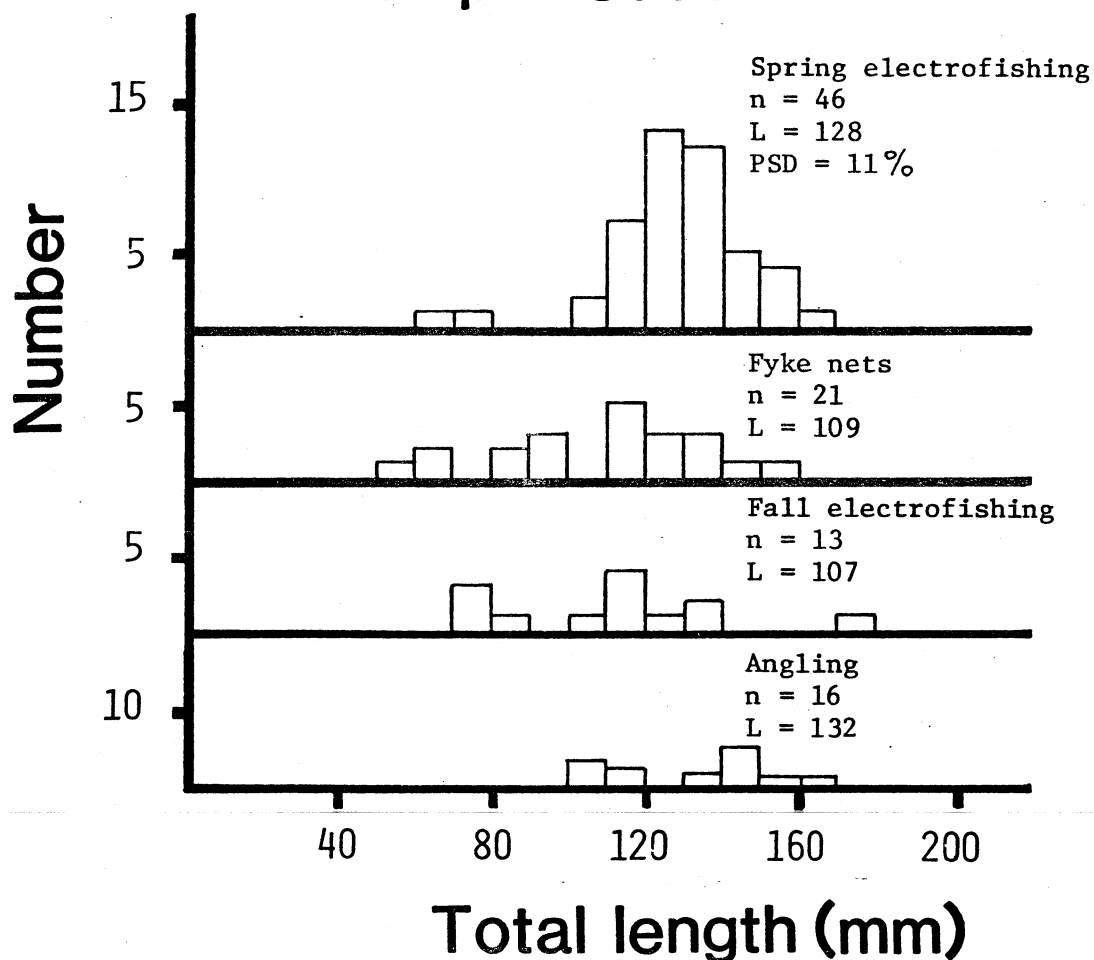


Figure 9. Length-frequency distribution of pumpkinseeds caught by electrofishing in spring and fall and fyke netting in June in 1980-1981, and by angling in 1980, in Rockland Lake. L is the mean length.

PRETTY LAKE

Pumpkinseed

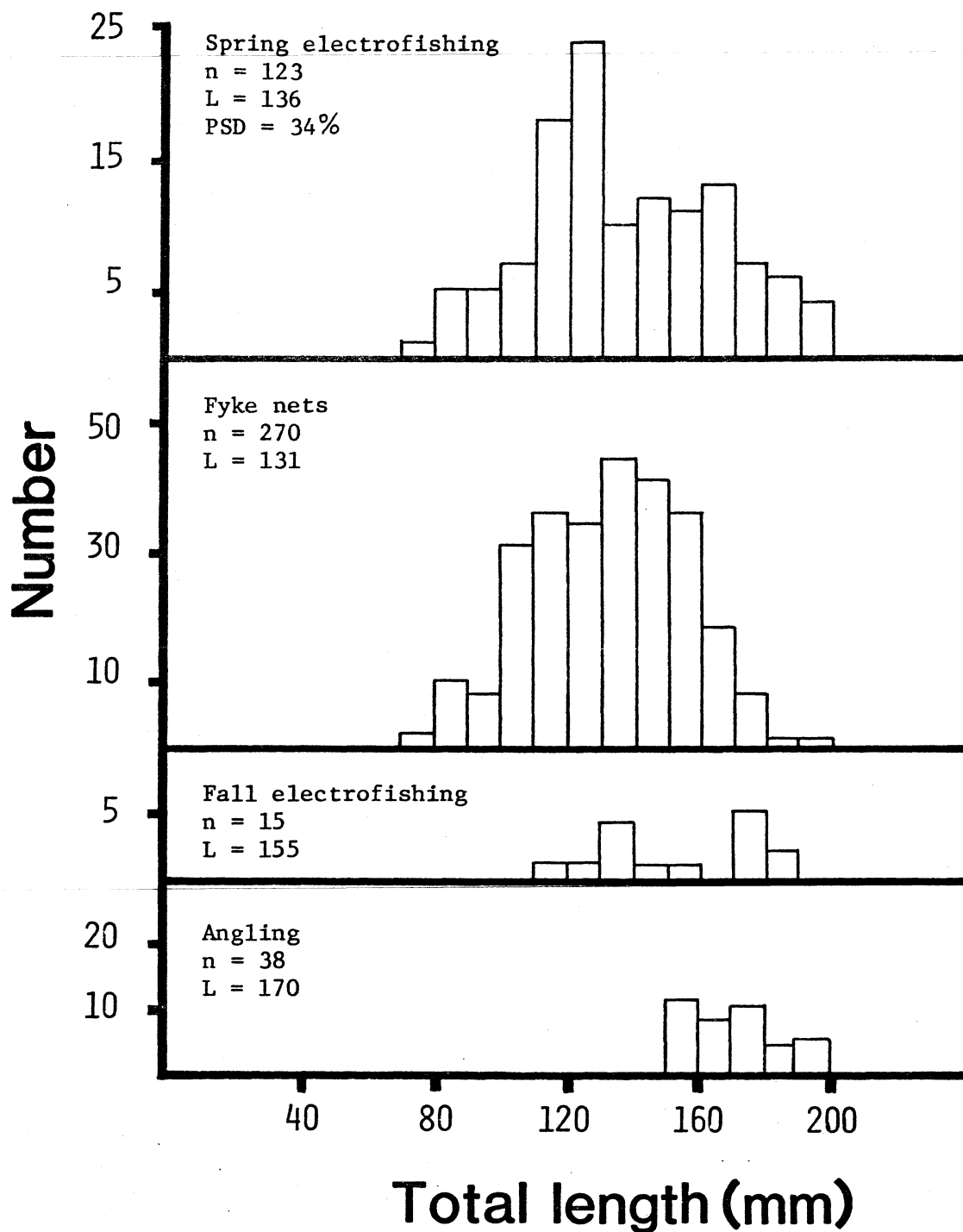


Figure 10. Length-frequency distribution of pumpkinseeds caught by electrofishing in spring and fall and fyke netting in June in 1980-1981, and by angling in 1980, in Pretty Lake. L is the mean length.

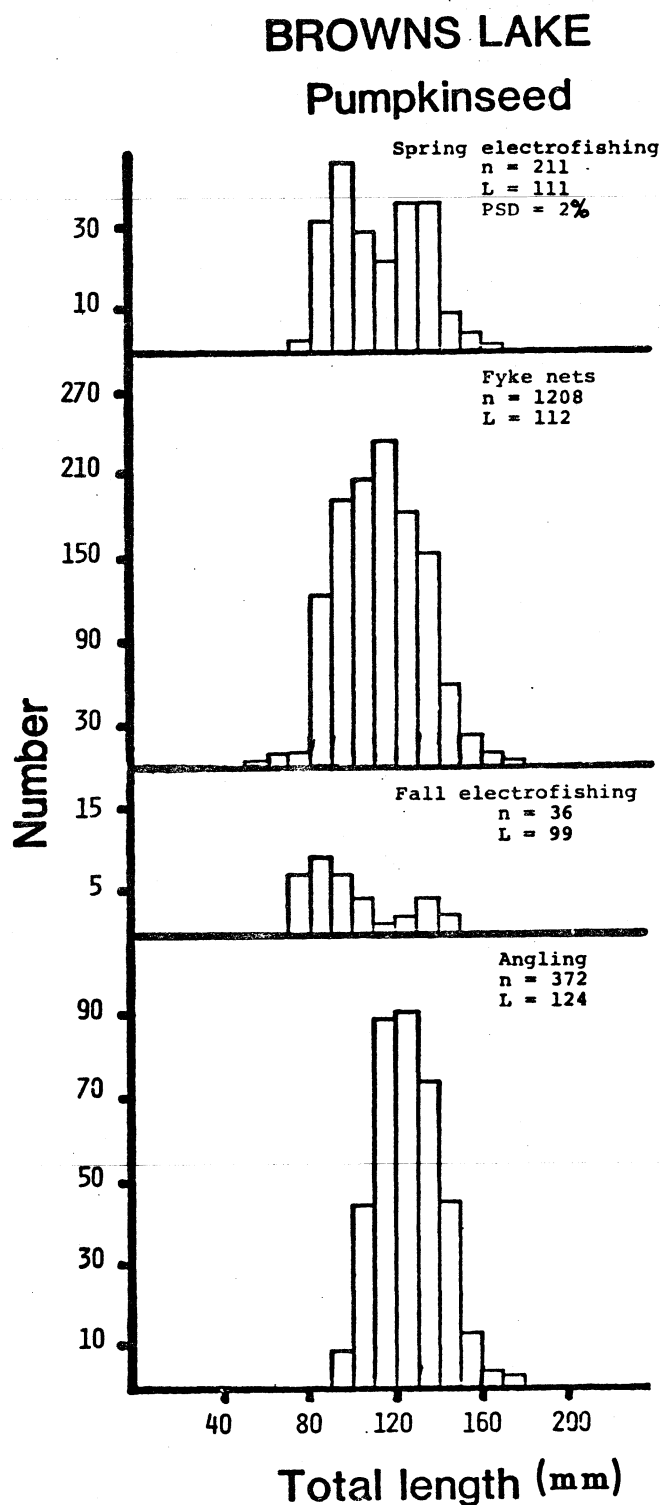


Figure 11. Length-frequency distribution of pumpkinseeds caught by electrofishing in spring and fall and fyke netting in June in 1980-1981, and by angling in 1980, in Browns Lake. L is the mean length.

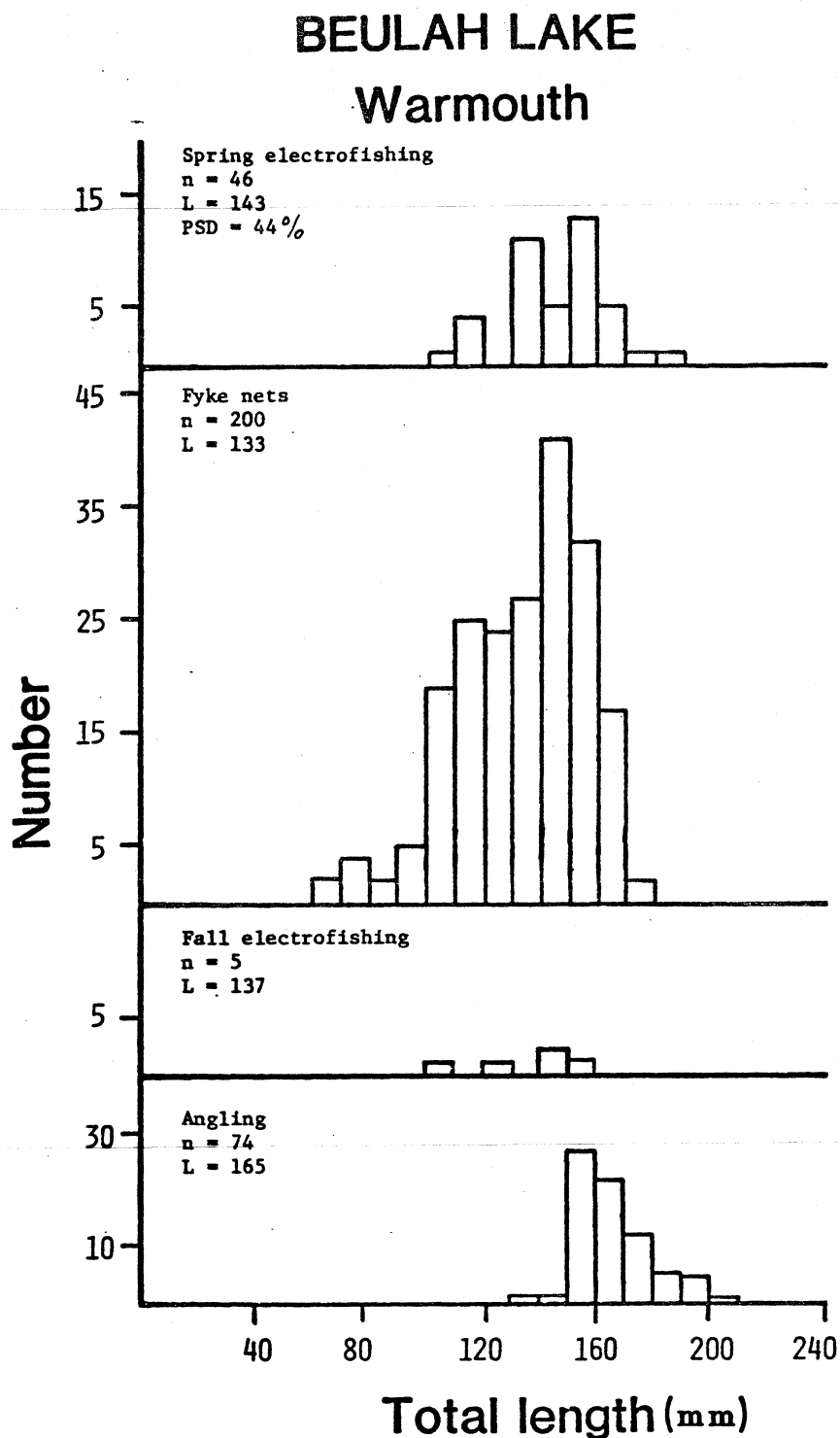


Figure 12. Length-frequency distribution of warmouth caught by electrofishing in spring and fall and fyke netting in June in 1980-1981, and by angling in 1980, in Beulah Lake. L is the mean length.

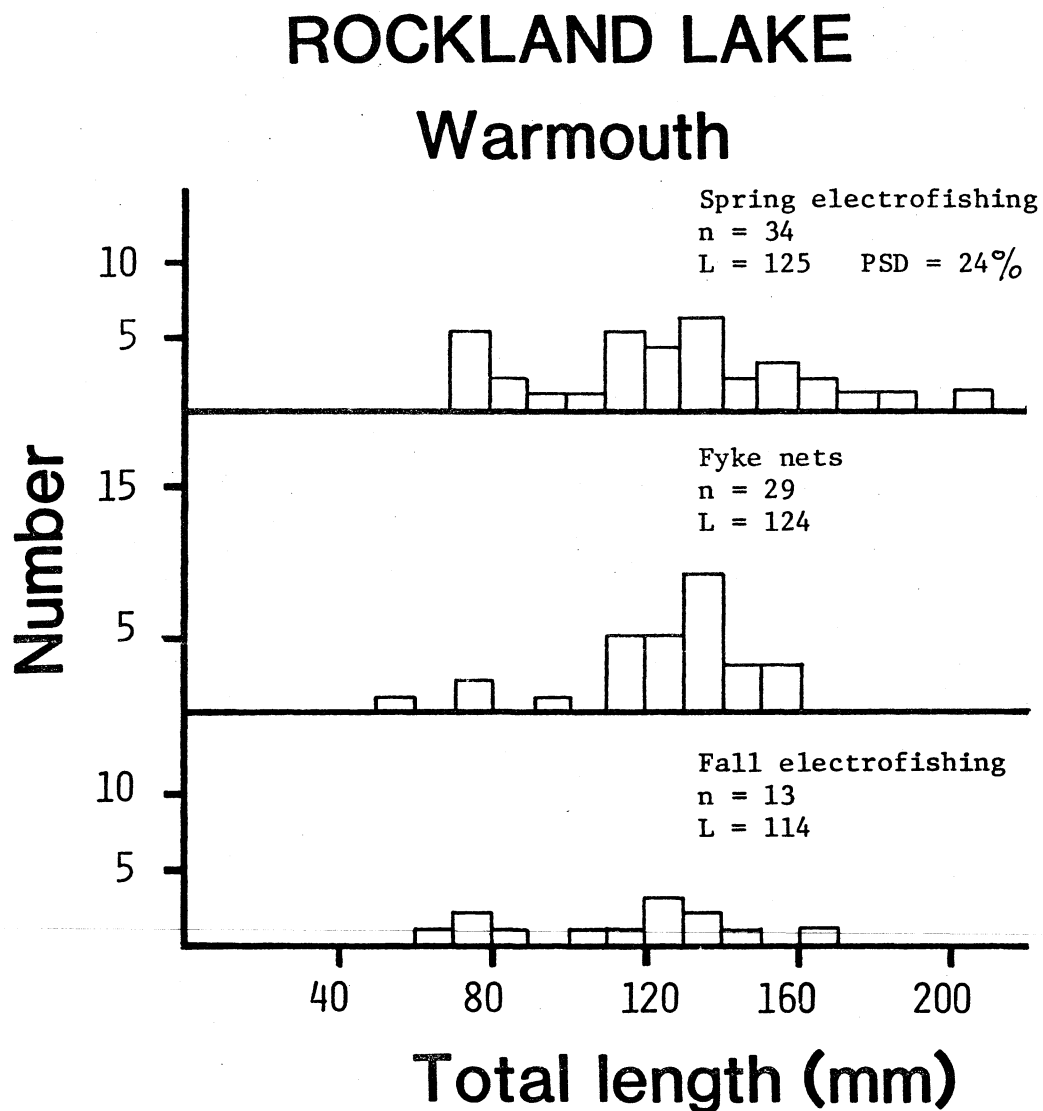


Figure 13. Length-frequency distribution of warmouth caught by electrofishing in spring and fall and fyke netting in June 1980-1981, and by angling in 1980, in Rockland Lake. L is the mean length.

PRETTY LAKE

Warmouth

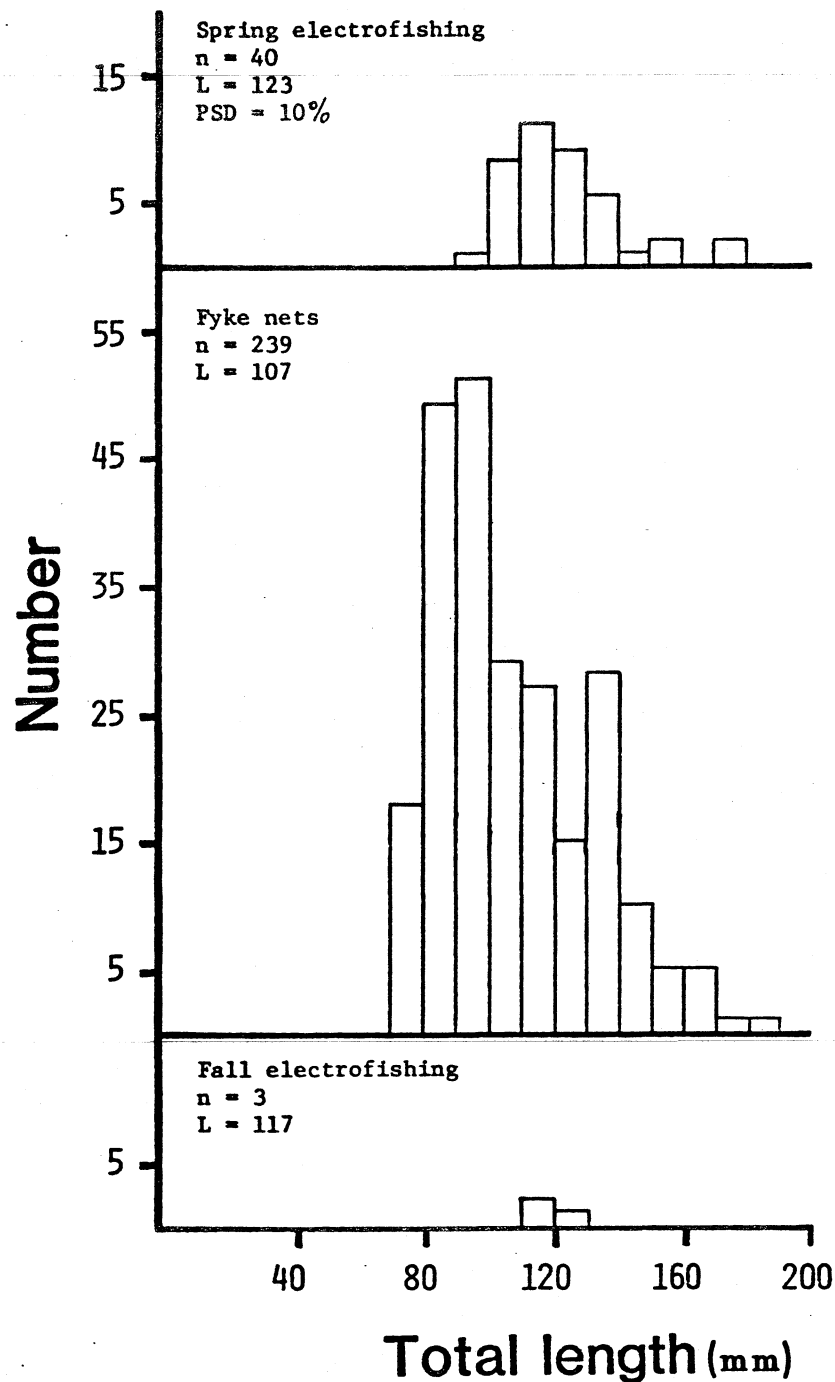


Figure 14. Length-frequency distribution of warmouth caught by electrofishing in spring and fall and fyke netting in June in 1980-1981, and by angling in 1980, in Pretty Lake. L is the mean length.

BEULAH LAKE

Green sunfish

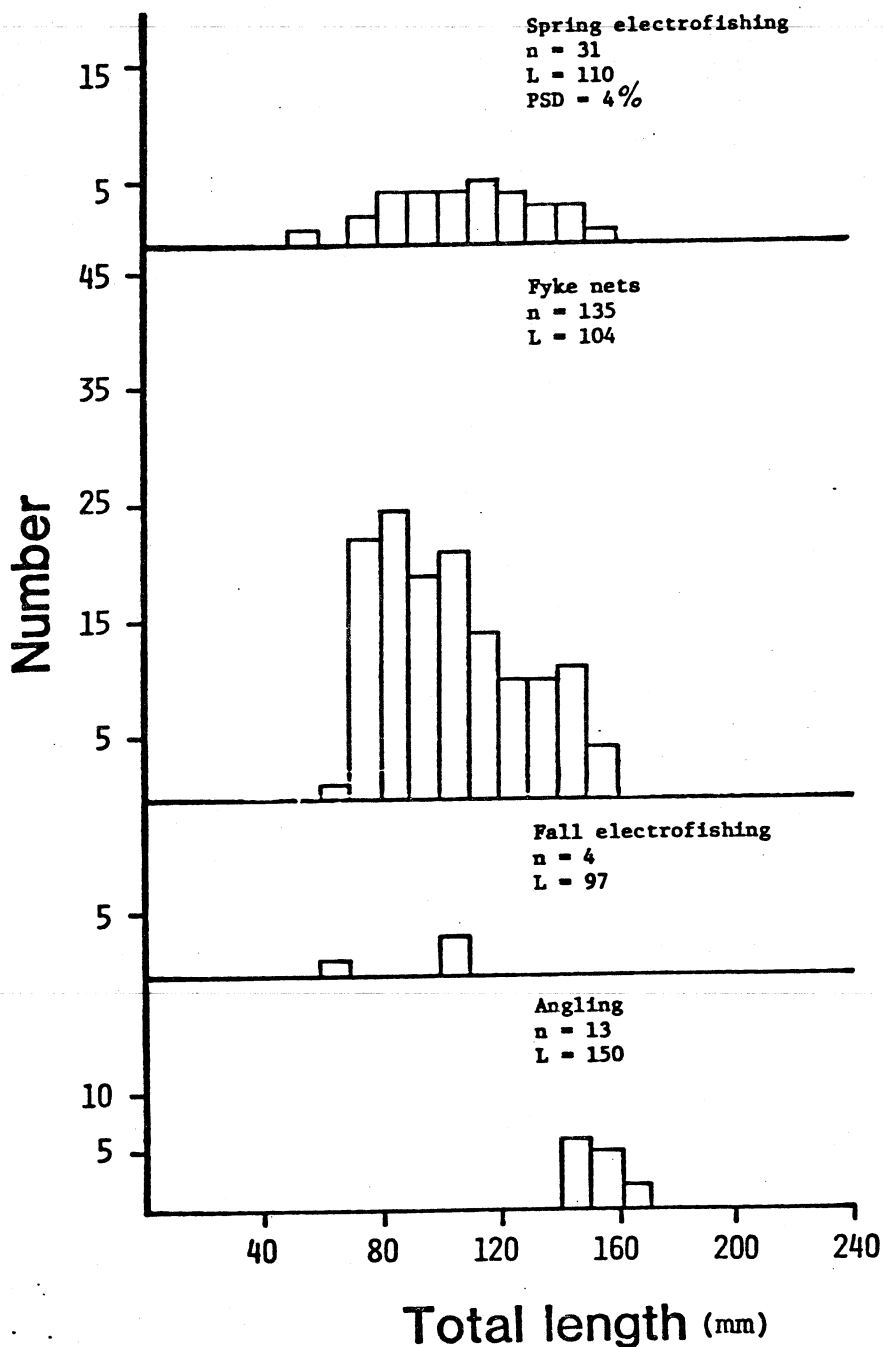


Figure 15. Length-frequency distribution of green sunfish caught by electrofishing in spring and fall and fyke netting in June in 1980-1981, and by angling in 1980, in Beulah Lake. L is the mean length.

ROCKLAND LAKE

Green sunfish

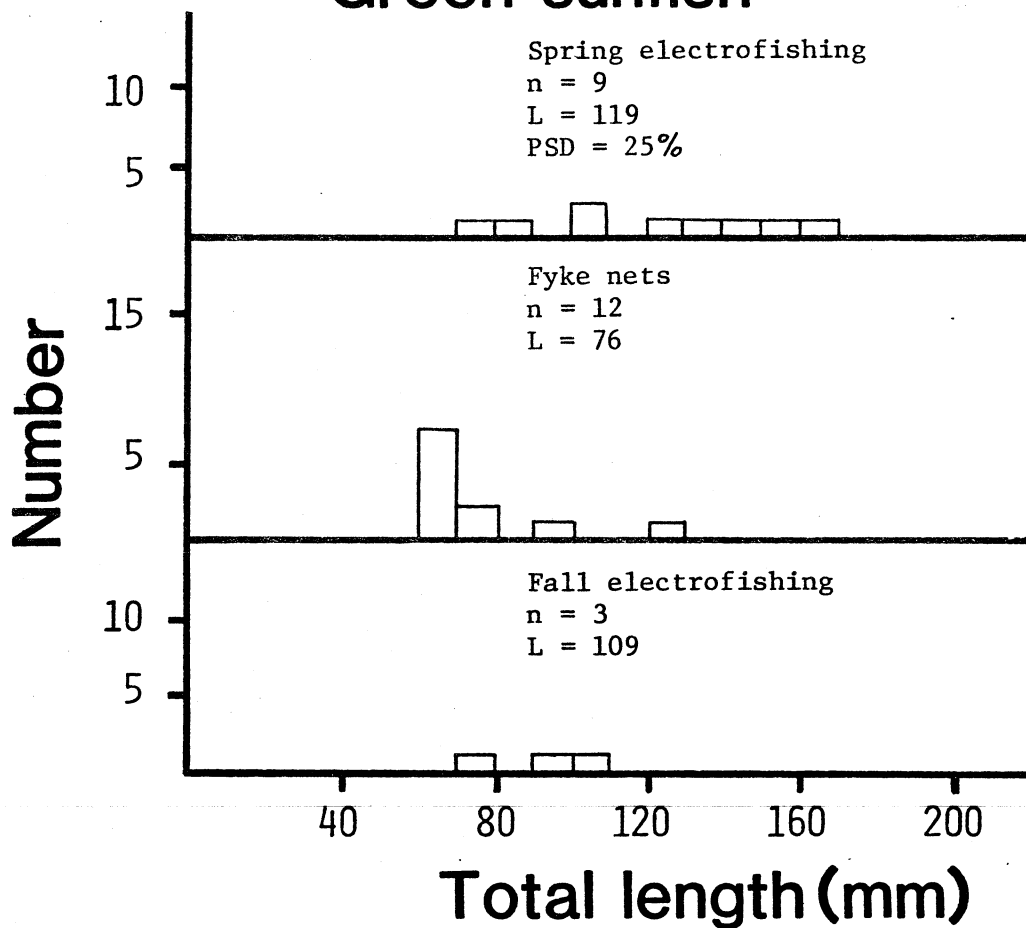


Figure 16. Length-frequency distribution of green sunfish caught by electrofishing in spring and fall and fyke netting in June in 1980-1981, and by angling in 1980, in Rockland Lake. L is the mean length.

BROWNS LAKE

Green sunfish

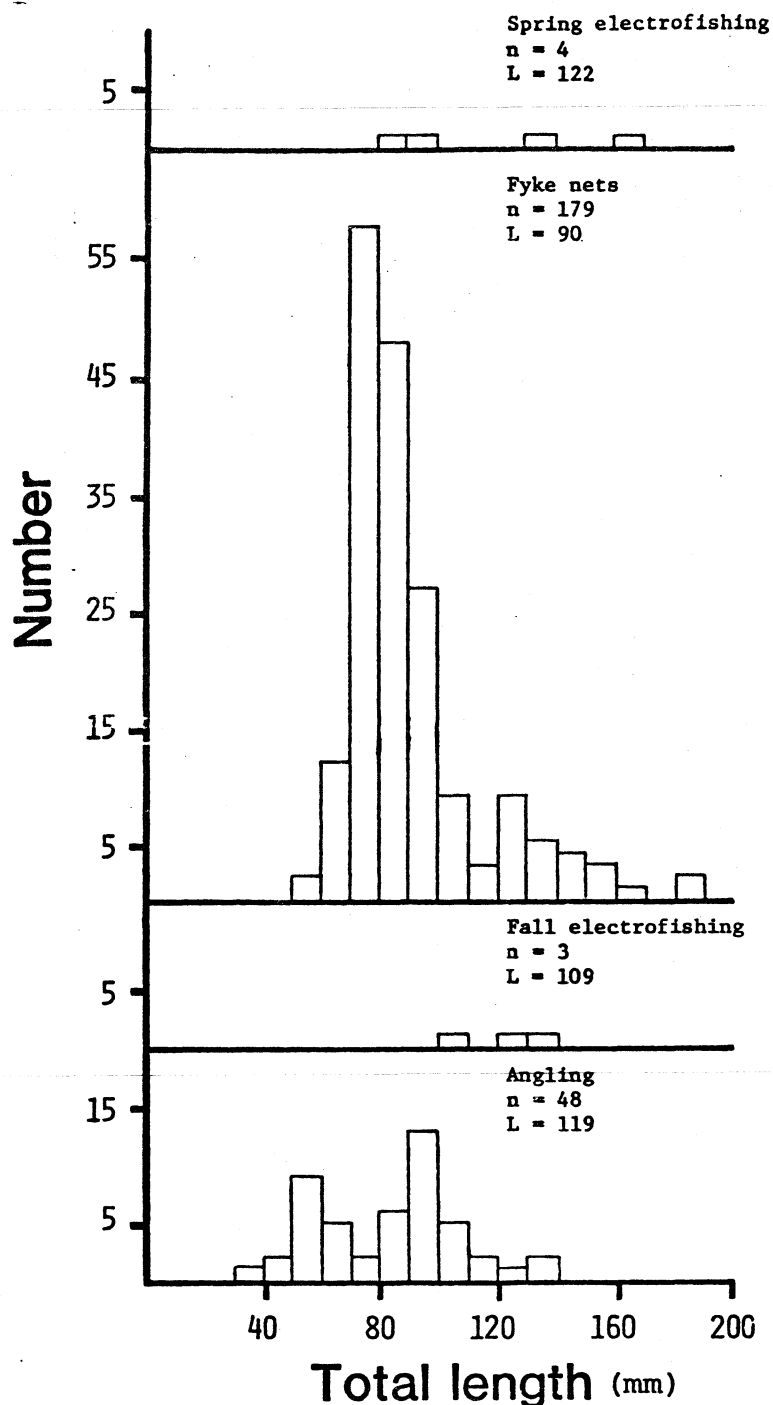


Figure 17. Length-frequency distribution of green sunfish caught by electrofishing in spring and fall and fyke netting in June in 1980-1981, and by angling in 1980, in Browns Lake. L is the mean length.

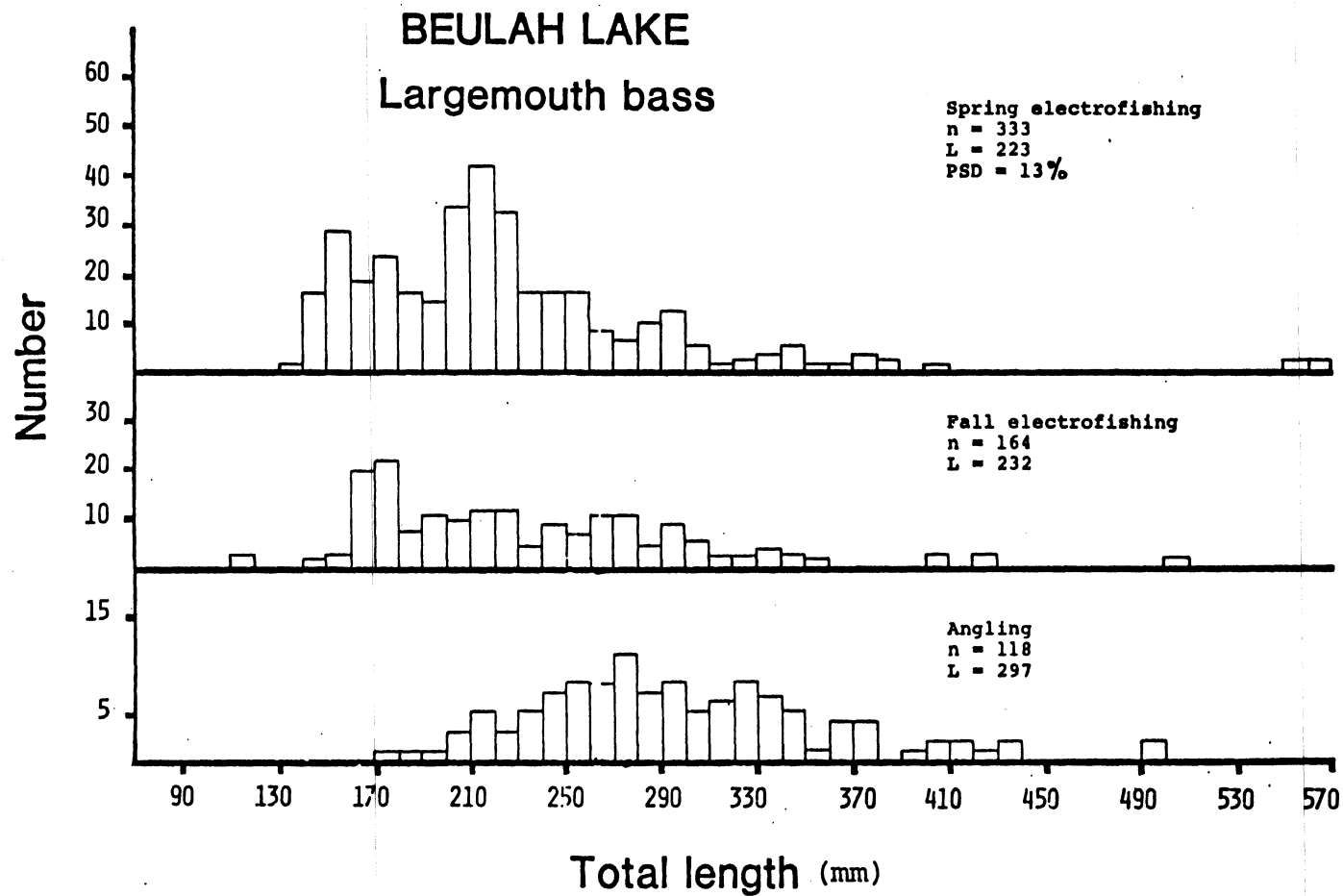


Figure 18. Length-frequency distribution of largemouth bass caught by electrofishing in spring and fall in 1980-1981, and by angling in 1980, in Beulah Lake. L is the mean length.

ROCKLAND LAKE

Largemouth bass

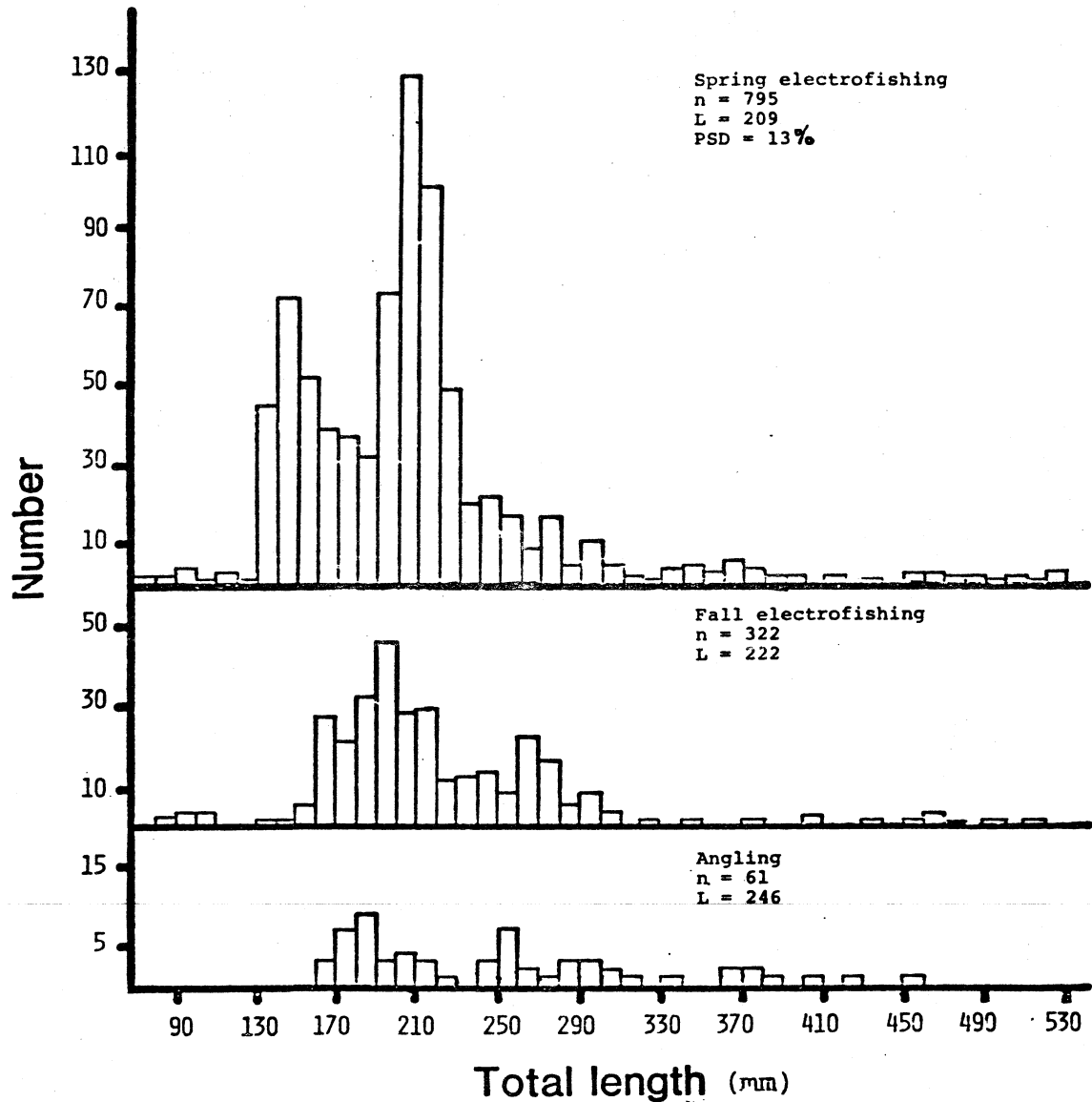


Figure 19. Length-frequency distribution of largemouth bass caught by electrofishing in spring and fall in 1980-1981, and by angling in 1980, in Rockland Lake. L is the mean length.

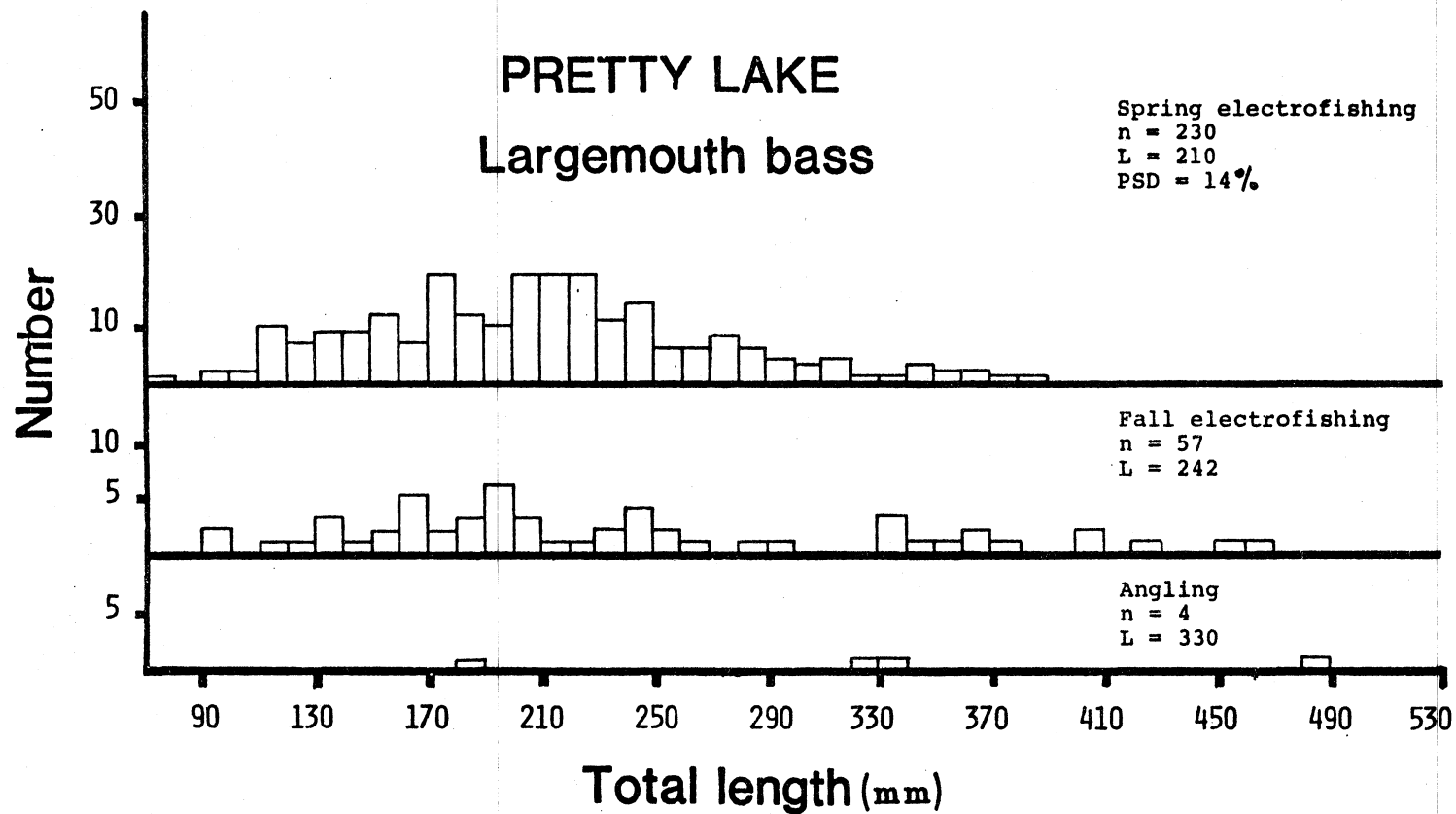


Figure 20. Length-frequency distribution of largemouth bass caught by electrofishing in spring and fall in 1980-1981, and by angling in 1980, in Pretty Lake. L is the mean length.

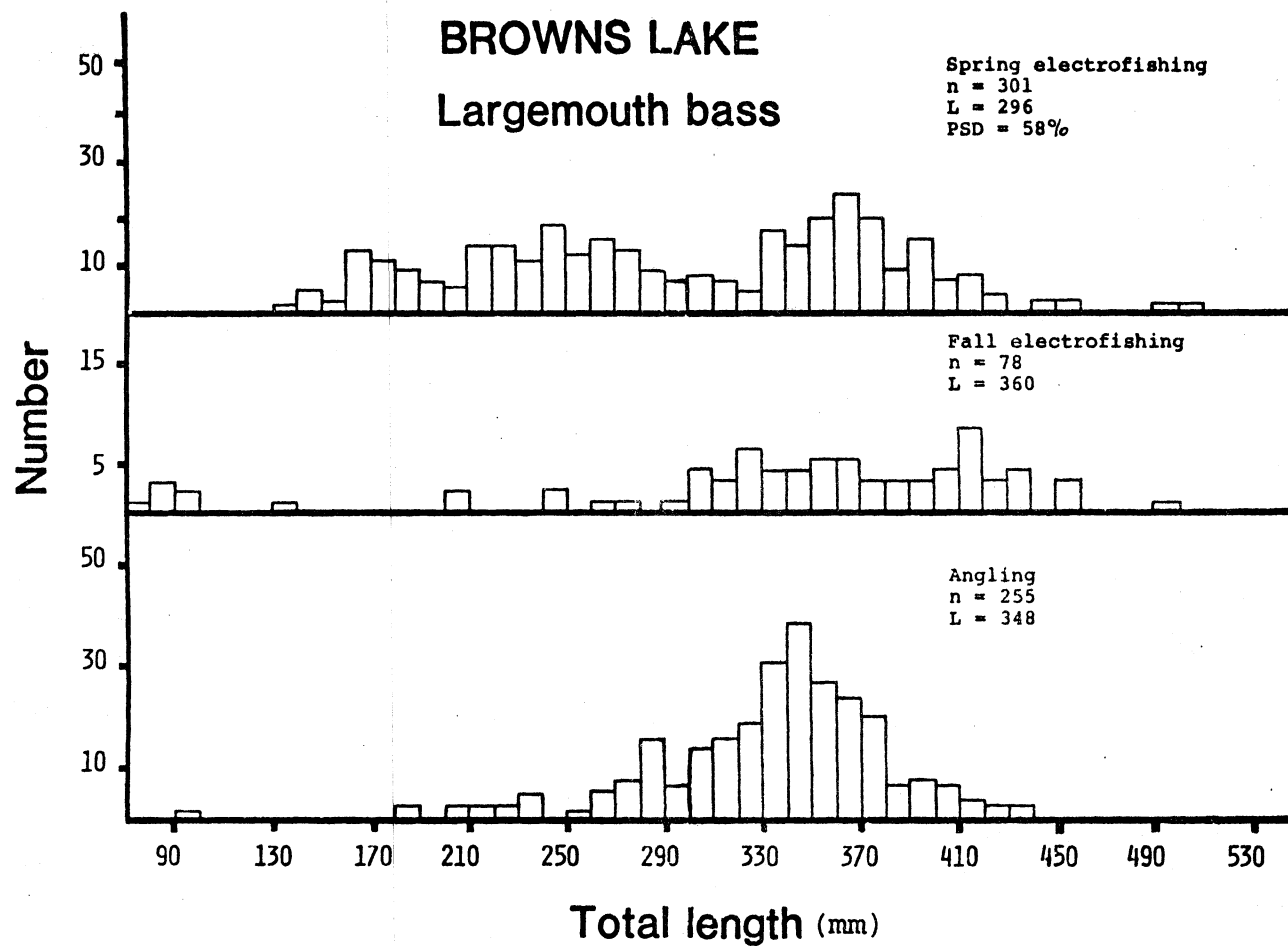


Figure 21. Length-frequency distribution of largemouth bass caught by electrofishing in spring and fall in 1980-1981, and by angling in 1980, in Browns Lake. L is the mean length.

electrofishing. He reasoned that relatively greater catches of large panfish in the fyke nets compared with the electroshocker could be caused by: 1) lower vulnerability of small than large panfish to fyke nets, or 2) lower vulnerability of the large panfish to electroshocking. Reynolds and Simpson (1978) thought that larger bluegill may inhabit deeper water making them less vulnerable to electrofishing. However, Goedde (1980) reported that the larger pumpkinseed and yellow perch also were more vulnerable to fyke nets. Goedde (1980) concluded that electrofishing catches were most representative of the size structure of the fish populations in his study because: 1) electrofishing catches contained sizes of panfish covering the entire length range of fishes caught in traps and fyke nets and 2) electrofishing is generally considered to be more, not less, efficient for larger than smaller fishes, especially largemouth bass (Sullivan 1956; Reynolds and Simpson 1978).

Though fyke nets tended to select the larger bluegills in this study, they selected similar size pumpkinseeds (except in Rockland Lake) and the smaller warmouth in Beulah and Pretty Lakes compared to spring electrofishing. I do not know whether differences in size between fyke net and spring electrofishing catches were caused by gear selectivity or growth of bluegill; the fyke nets were fished 2 to 4 weeks after electrofishing.

Spring and fall electrofishing generally yielded the same species and similar size ranges (Table 1; Figures 1-21), but mean length of samples in fall was usually larger than in spring, and fall samples often provided fewer fish (Figures 1-21). Mean length of fall samples (with $n \geq 35$) was significantly greater than in spring, except for largemouth bass in Beulah Lake (no significant difference) and pumpkinseeds in Browns Lake (significantly greater in spring); i.e. 2 exceptions out of 10 comparisons (Appendix D). Fall electrofishing probably yielded larger fish because of seasonal growth.

Electrofishing catch per unit of effort (CUE) for largemouth bass, pumpkinseeds and yellow perch (except Browns Lake in fall of 1981) was consistently lower in fall than in spring (Table 5). CUE for bluegills (except for Rockland Lake in fall of 1980) was greater in fall than spring. However, spring bluegill catches always exceeded 100 fish (Appendix E). CUE for green sunfish and warmouth was not consistently greater in spring or fall (Table 5).

I consider the spring electrofishing samples to be most representative of the size structure of fish populations in this study in spring because: 1) electrofishing catches contained size ranges similar to fyke net catches, and 2) electrofishing, better than fyke net data, yielded a typical pattern of decrease in number with increase in length.

Because of these reasons and because sample sizes were usually larger in spring than fall, comparisons among fish population in the remainder of this thesis (except for

Table 5. Catch per unit effort (CUE) of fishes in electrofishing (number/hr) and fyke net (number/net day) samples from the four study lakes, and the calculation of the index of abundance of bluegills 80-140 mm long. Effort is reported for electrofishing (hours) and fyke nets (net days) at the bottom of each column unless indicated otherwise.

Species	BEULAH LAKE						ROCKLAND LAKE					
	Electrofishing				Fyke nets		Electrofishing				Fyke nets	
	1980		1981		1980 June	1981 June	1980		1981		1980 June	1981 June
	Spring	Fall	Spring	Fall			Spring	Fall	Spring	Fall		
Largemouth bass	41.0	22.1	48.6	24.3	0.1	0.1	78.6	41.4	125.7	32.7	--	--
Bluegill	189.8	265.6	280.0*	438.0**	387.2	86.7	294.8	260.2	209.6***	720.0**	106.0	46.6
Pumpkinseed	34.5	1.8	27.5*	6.0**	16.6	11.3	14.8	5.7	23.3***	15.0**	2.5	1.4
Yellow perch	53.0	30.9	122.5*	48.0**	2.5	10.4	44.1	13.8	41.9***	9.0**	0.3	0.3
Green sunfish	12.0	1.2	17.5*	6.0**	11.2	2.3	2.1	0.5	5.2***	3.0**	--	1.5
Wormouth	31.0	5.9	65.0*	12.0**	13.5	6.5	12.1	7.1	32.6***	42.0**	1.8	2.8
Black crappie	1.0	1.8	1.9	--	1.2	0.5	4.8	2.9	3.3***	6.0**	--	0.4
Walleye	--	--	--	--	--	--	--	--	--	--	--	--
Northern pike	--	0.3	--	0.3**	--	--	0.2	4.3	1.1	6.0	--	--
Black bass	0.3	--	--	--	0.1	0.1	--	--	--	--	--	--
Brown bullhead	12.5	7.1	20.0*	5.41**	0.9	1.4	--	--	--	--	--	--
Yellow bullhead	7.5	4.1	17.5*	15.0**	0.5	4.7	5.7	5.0	10.0	15.0**	1.5	1.3
Black bullhead	0.3	--	--	0.3**	--	0.3	0.5	0.5	--	--	--	--
Brown trout	1.0	2.9	0.3	2.2	--	--	7.6	1.4	11.4	2.7	0.3	0.4
White sucker	--	1.2	0.6	--	--	--	--	--	--	--	--	--
Bowfin	4.8	3.2	2.5*	12.0**	0.1	0.1	9.1	9.5	4.6	12.0**	1.0	0.4
Grass pickerel	17.5	17.7	37.5*	33.0**	0.3	0.7	1.0	1.2	1.9	2.9	--	--
Longnose gar	0.8	--	1.1	--	--	0.3	--	--	--	--	--	--
Lake chubsucker	46.3	31.5	80.1*	135.0**	1.0	1.9	11.0	3.1	5.14	9.0**	--	--
Horneyhead chub	--	--	--	--	--	0.1	--	--	--	--	--	--
Golden shiner	6.75	--	2.5*	--	0.4	0.8	1.4	1.4	2.7	3.0	0.3	0.6
Carp	--	--	--	--	--	--	4.3	1.2	3.0	0.2	--	--
Effort	4	3.4	3.6	3.7	10	10	4.2	4.2	3.7	4.5	4	8

*Based on a 10 and 14 minute shocking period.

**Based on a 10 minute shocking period.

***Based on a 2.7 hr shocking period.

#Based on a 2.8 hr shocking period.

Table 5 (continued)

BROWNS LAKE												
Species	PRETTY LAKE				BROWNS LAKE							
	Electrofishing				Fyke nets				Electrofishing			
	1980 Spring	1980 Fall	1981 Spring	1981 Fall	1980 June	1981 June	1980 Spring	1980 Fall	1981 Spring	1981 Fall	1980 June	1981 June
Largemouth bass	47.8	12.4	52.7	23.1	1.0	0.3	30.2 ^d	4.6	25.7	10.8	0.6	0.3
Bluegill	572.5	712.4	546.9	1032.0 ^{ee}	285.5	70.3	319.3 ^d	432.6	396.3 ^{ee}	212.0 ^{ee}	567.2	1750.6
Pumpkinseed	56.3	7.1	122.5	9.4	20.5	23.5	81.4 ^d	10.4	47.8 ^{ee}	30.0 ^{ee}	74.9	95.4
Yellow perch	17.5	5.9	6.3	2.5	6.3	--	67.5 ^d	37.5	77.4 ^{ee}	345.0 ^{ee}	2.0	0.4
Green sunfish	--	--	--	--	--	--	1.8 ^d	3.2	2.8 ^{ee}	9.0 ^{ee}	14.3	4.6
Warmouth	72.5	12.9	46.9	96.0 ^{ee}	16.8	21.5	--	--	--	--	--	--
Black crappie	1.3	1.8	0.6	2.5	--	--	--	0.4	3.0 ^{ee}	3.0 ^{ee}	--	--
Walleye	3.6	2.4	6.9	1.9	0.3	--	--	0.6	--	--	--	--
Northern pike	0.6	1.2	--	5.0	0.3	--	0.4 ^d	1.4	0.4	1.8	0.1	--
Black bass	--	0.5	16.3	3.1	2.5	1.3	--	--	--	--	--	--
Brown bullhead	5.6	--	26.3	0.6 ^{ee}	--	0.5	2.9 ^d	--	0.4	0.6	0.1	0.1
Yellow bullhead	7.5	--	22.5	6.1	0.3	0.3	30.7 ^d	14.8	47.7	3.0 ^{ee}	2.0	2.4
Black bullhead	--	--	--	--	--	--	32.1 ^d	3.8	7.9	8.6	--	0.4
Brown trout	--	--	--	--	--	--	--	--	--	--	--	--
White sucker	1.9	--	1.3	1.3	--	--	0.2	0.2	1.7	--	--	--
Bowfin	--	--	--	--	--	--	--	--	--	--	--	--
Grass pickerel	--	--	--	--	--	--	--	--	--	--	--	--
Longnose gar	--	--	--	--	--	--	--	--	--	--	--	--
Lake chub	--	--	--	--	--	--	--	--	--	--	--	--
Hornhead chub	--	--	--	--	--	--	--	--	--	--	--	--
Golden shiner	--	--	--	--	--	--	1.8 ^d	--	0.8	--	0.4	--
Carp	--	--	--	--	--	--	0.2	0.4	--	--	--	--
Effort	1.6	1.7	1.6	1.6	4	8	5.6	5.0	5.3	5.1	10	8

Calculation of the Index of Abundance of Bluegills 80-140 mm Long, 1980 plus 1981.											
				Mouth		Rockland		Pretty		Browns	
Electrofishing											
Sum of CUE's				1172.3		1484.6		2863.8		2340.0	
Percent of fish 80-140 mm				34		60		81		96	
CUE of fish 80-140 mm				398.9		890.8		2319.7		2265.6	
Fyke nets											
Sum of CUE's (in fish/hr)				19.7		6.4		14.9		96.6	
Percent of fish 80-140 mm				25		42		74		95	
CUE of fish 80-140 mm				5.1		2.7		11.0		91.8	
Total CUE of fish 80-140 mm long in electrofishing and fyke net samples (Index of abundance)				404.0		893.5		2330.7		2357.4	

growth and creel survey) are based on spring electrofishing data only.

Proportional Stock Density (PSD) and Mean Length

Community structure, evaluated by the PSD index did not meet recommended management objectives (Anderson 1976) for predators and prey in any lake.

Population length structure was compared among lakes on the basis of Proportional Stock Density (PSD) and mean length. Anderson (1976) described PSD as an index for evaluating fish population structure in terms of length. PSD was defined as the percentage of quality-size fish in a stock (see Methods Section for values of stock - and quality-size for each species) and is readily determined from length frequency distributions. Recommended management objectives to achieve a sustained quality fishery were PSD ranges of 40 through 60% for largemouth bass (Reynolds and Babb 1978) and 20 through 40% for bluegills (Novinger and Legler 1978) when largemouth bass were of primary importance in a mixed fishery.

Anderson and Weithman (1978) felt that the PSD concept could be applied to any predator and prey species. They developed PSD indices for coolwater species and suggested management objectives of 30 through 50% for panfish (yellow perch) and 30 through 60% for gamefish (northern pike, muskellunge Esox masquinongy, walleye, and smallmouth bass Micropterus dolomieu).

I found PSD useful for identifying problems-and comparing fish population length structures among lakes although PSD has been criticized. Carline and Savino (1981) concluded that PSD was not likely to monitor the interactive effects of growth, mortality and recruitment. Based on their results, growth rate had the most influence on the size structure of a population, and effects of an increase in growth rate on PSD's might not have been apparent if recruitment had been poor. Also, PSD describes relative, not absolute, abundance. A low PSD could be caused by high mortality of quality-size fish or by a large year class(es) of stock-size fish (smaller than quality size) without such high mortality. Goedde (1980) felt that PSD ranges given as management objectives in previous studies were probably not best for Mid and Allen Lakes because community composition in those lakes was more complex than a simple largemouth bass/bluegill community, and yellow perch play the role of both predator and prey. Diverse communities also occurred in the lakes in this study, and yellow perch and black crappie probably were predator and prey.

Largemouth Bass

Only Browns Lake had a substantial number of quality-size largemouth bass (Figures 18 - 21). PSD and mean length of largemouth bass in Browns Lake was 58% and 296 mm (Figure 21). In contrast, PSD of largemouth bass in Beulah, Pretty and

Rockland Lakes was 13, 14 and 13%; corresponding mean lengths were 223, 210 and 208 mm (Figures 18-20). An appreciable number of bass smaller than quality-size occurred in Beulah and Rockland Lakes but not in Pretty and Browns Lakes.

One year class comprised over half of the quality-size largemouth bass in Browns Lake. Analysis of spring 1980 age-frequency (Appendix F) and length at age (Table 6). data indicated that age 5 bass comprised 56% of the quality-size bass in Browns Lake. This strong year class (1975) may have been produced by the fry, fingerling and adult largemouth bass that were stocked in 1971 - 1972 following chemical treatment of Browns Lake in 1971 (Schumacher and Rebicek 1977). Alternatively, the variation in year class strength of largemouth bass in Browns Lake may not have been related to the chemical treatment; Mraz (1964) reported that the largemouth bass population in Browns Lake in 1953 - 1957 was subject to large variation in year class strength.

Bluegill

Beulah and Rockland Lakes had a greater proportion of quality-size bluegills than Pretty and Browns Lakes (Figures 1-4). Mean length of bluegills in Beulah and Rockland Lakes was 140 and 122 mm; PSD was 17% in Rockland Lake, and, at 40% in Beulah Lake, it reflected a larger proportion of quality-size fish. An abundance of stock, and few quality-size bluegills,

Table 6. Mean back-calculated total length (mm) at age of largemouth bass and bluegills in Beulah, Rockland, Pretty, and Browns Lakes, and pumpkinseeds in Browns Lake, in 1980-1981, and of largemouth bass in Browns Lake in 1953, 1955, and 1957 combined (Mraz 1964); and empirical total length at age of largemouth bass and bluegills in Pretty Lake in 1977-1978 (Claggett 1979); and the Wisconsin state average (Snow 1969).

Species	Lake	1	2	3	4	5	6	Age 7	8	9	10	11	12	13
Largemouth	Beulah	82.6	159.9	223.1	270.3	298.9	339.1	346.7	370.6	391.8	462.1	538.0	552.2	564.8
	SD	4.3	6.3	7.3	12.3	21.0	33.5	24.7	48.4	81.6	84.9	0	0	0
	n	387	385	304	130	57	27	15	9	5	2	1	1	1
	Rockland	64.1	147.5	226.2	283.9	349.9	377.8	406	409.1	436.5	450.2	463.5	461.6	
	SD	7.2	9.5	13.5	26.2	29.4	26.3	34.3	22.0	6.5	4.9	7.5	---	
	n	399	377	268	87	43	30	22	15	12	9	4	1	
	Pretty	88.0	151.0	227.9	300.2	351.6	406.3	434.9						
	SD	4.5	11.7	9.7	13.9	23.9	2.7	0.3						
	n	259	255	180	50	19	10	5						
	Browns	73.3	150.0	228.7	303.9	356.4	376.1	384.9	405.0	398.8	395.3	402.4	409.6	418.2
(1953,1955 & 1957 combined)	SD	9.1	14.7	19.2	17.8	12.4	10.7	12.5	12.5	21.3	---	---	---	---
	n	399	397	378	250	157	86	24	11	2	1	1	1	1
	Browns	86	168	231	282	318	353	396						
	n	4499	4243	3324	2010	919	375	84						
	Pretty	121	180	230	295	353	384	420	488	---	---	498		
(1977-1978)	n	9	48	52	39	31	23	9	4			2		
	State Average (1955-67)	79	160	231	315	333	373	424						
Bluegill	Beulah	33.9	60.8	89.5	115.9	136.8	150.5	157.8	162.1	168.8	174.0	176.4	162.3	
	SD	1.3	1.3	2.1	2.9	3.8	6.3	5.9	4.0	5.0	6.1	11.6	---	
	n	263	263	262	225	174	120	83	54	30	17	5	1	
	Rockland	40.8	64.5	90.9	118.6	136.8	156.1	160.7	164.2	164.7	165.8	172.0		
	SD	1.2	4.0	7.3	11.9	6.2	12.4	9.2	9.2	6.1	2.3	0.1		
	n	343	332	294	212	126	85	47	25	12	5	2		
	Pretty	41.5	58.7	78.0	100.3	120.9	138.6	151.1	158.2	171.0				
	SD	1.0	1.4	1.6	2.5	3.7	2.8	2.5	2.7	0.1				
	n	303	303	290	244	171	108	58	18	5				
	Browns	42.4	63.9	79.3	98.3	117.0	133.4	151.2	166.8	186.4				
(1977-1978)	SD	2.3	4.5	6.8	7.4	7.6	8.3	7.8	8.8	0.1				
	n	225	223	219	217	194	121	49	18	6				
	Pretty	---	66	85	114	132	148	142						
State Average (1955-67)	n		1	12	30	48	11	1						
	State Average (1955-67)	38	79	109	142	165	183	201	203	211				
Pumpkinseed	Browns	49.9	67.4	78.1	93.8	112.4	122.9	128.2	124.1					
	SD	1.7	5.2	4.1	1.4	2.4	3.7	5.3	0.1					
	n	164	163	148	139	120	61	16	2					
State Average (1955-67)		46	73	114	127	155	168							

occurred in Pretty and Browns Lakes. Mean lengths, respectively were 103 and 110 mm and PSD's were 5 and 1%.

Yellow Perch

Quality-size yellow perch were rare in all lakes (Figures 5 - 7). The PSD of yellow perch was 3 and 0% in Beulah and Rockland Lakes, and mean lengths were 150 and 142 mm. In Browns Lake all yellow perch sampled were smaller than the minimum stock-size (130 mm), and the mean length was 104 mm. Few yellow perch were caught in Pretty Lake (Table 1; Appendix E).

Pumpkinseed

Only Pretty Lake had pumpkinseeds with a PSD within the objective range of 20 - 40% (Figures 8-11). Mean length of pumpkinseeds in Pretty Lake was 136 mm, and the PSD was 34%. The PSD of pumpkinseeds in Beulah, Rockland and Browns Lakes was 18, 11 and 2%, and corresponding mean lengths were 136, 128 and 111 mm.

Warmouth and Green Sunfish

Minimum stock - and quality-sizes have not been developed for warmouth and green sunfish. Because these fishes grow to lengths similar to bluegills and pumpkinseeds, I used minimum stock - and quality-sizes of 76 and 150 mm to calculate PSD's of warmouth and green sunfish.

The PSD of warmouth was within the objective range in Rockland Lake but above and below it in Beulah and Pretty Lakes (Figures 12-14). Mean length of warmouth in Rockland Lake was 125 mm, and PSD was 24%. PSD was 43% in Beulah Lake, 10% in Pretty Lake, and mean lengths were 143 and 123 mm. Warmouth were not captured in Browns Lake.

Electrofishing yielded few green sunfish in Rockland and Browns Lakes and none in Pretty Lake (Figures 15-17). Few quality-size green sunfish were caught in Beulah Lake; PSD and mean length were 4% and 110 mm.

Community Structure

Anderson (1976) evaluated community structure by plotting PSD's of largemouth bass (predator) and bluegills (prey) on what he termed a tic-tac-toe graph. Parallel vertical and horizontal lines defined the objective ranges for predators and prey (Figure 22). The center panel, formed by these intersecting lines, was the most desirable area of community structure.

None of the lakes that I studied had predator and prey PSD's that fell in the center panel of the tic-tac-toe graph (Figure 22). Values for Rockland and Pretty Lakes were below the recommended management objectives for both predators and prey. Beulah Lake values fell in the objective range for prey but below it for predators, and Browns Lake values were within the objective range for predators but below it for prey.

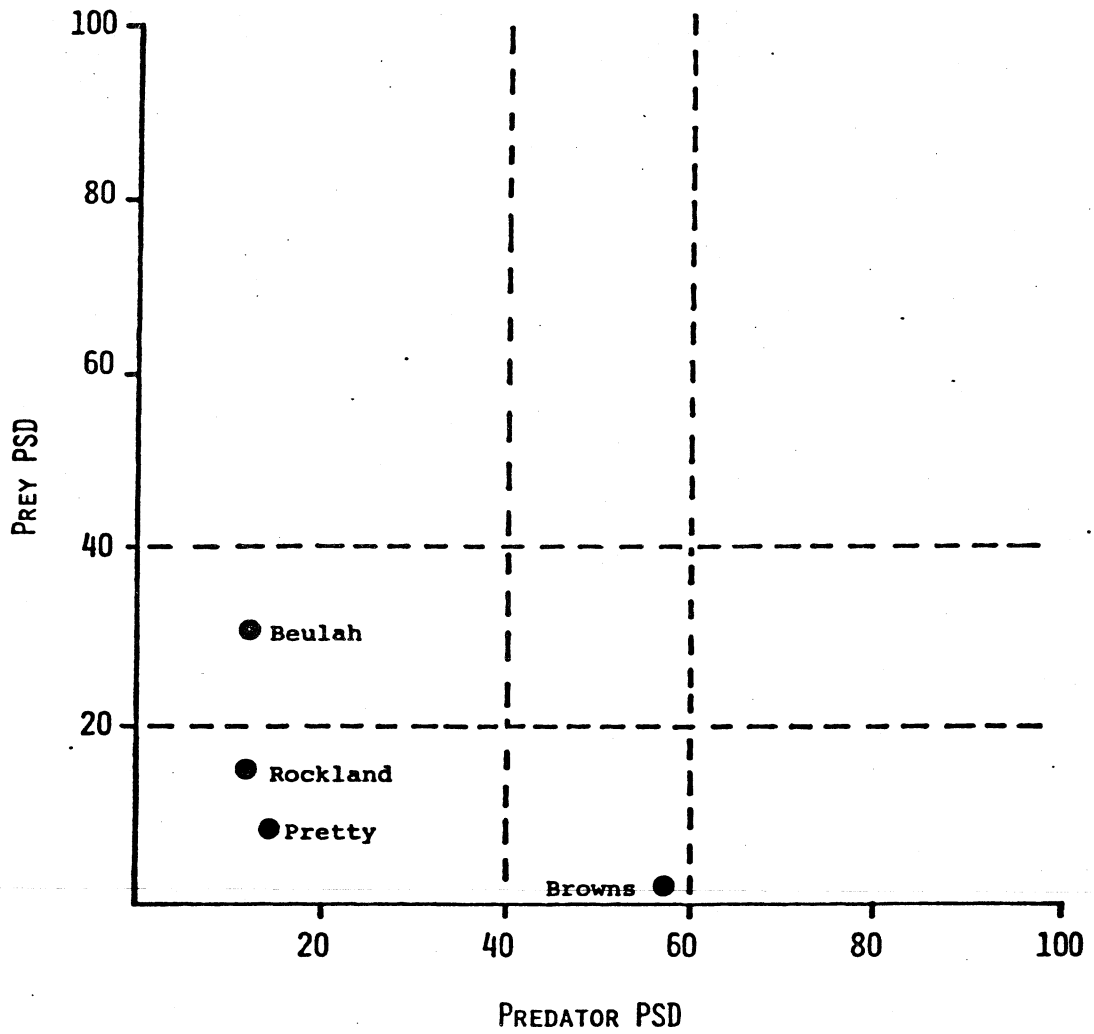


Figure 22. Prey vs predator PSD for the four study lakes in 1980-1981.

The bluegill was the most abundant panfish in the four lakes (Table 5). When prey PSD was calculated from bluegill data only, the results were similar to those with combined, weighted, prey PSD's.

Relative Weight

Differences in condition of largemouth bass among lakes were difficult to interpret. Bluegills were in best condition (heaviest for their length) in Beulah Lake, followed, in order, by Rockland Lake, Pretty Lake, and Browns Lake.

Largemouth Bass W_r in Spring

Results of comparing spring 1981 W_r 's (Figure 23) among the lakes with a Wilcoxon paired-sample test indicated that largemouth bass (< 260 mm) in Rockland Lake were significantly heavier than those in Pretty and Beulah Lakes (Table 7). I cannot explain this difference; it may be fortuitous. Different results may have been obtained if sample size was large enough to include size groups greater than 260 mm in the paired-sample test. Largemouth bass ranging from 350-440 mm in Browns Lake had the highest W_r values of any bass (Figure 23). The W_r 's for these fish could not be compared with the Wilcoxon test because adequate numbers of fish of the same length were not captured in the other lakes.

Spring vs Fall W_r of Largemouth Bass

Mean W_r of largemouth bass was satisfactory in spring and fall (except in Browns Lake in fall). It ranged from 93-109% in the four lakes. Compared to spring, fall W_r values averages 3-9% higher in Pretty, Browns and Beulah Lakes, and 2% lower in Rockland Lake (Appendix H). Though sample sizes were too small for statistical comparison, W_r of large bass ($300 \leq \text{bass} < 430$ mm) in Browns Lake and

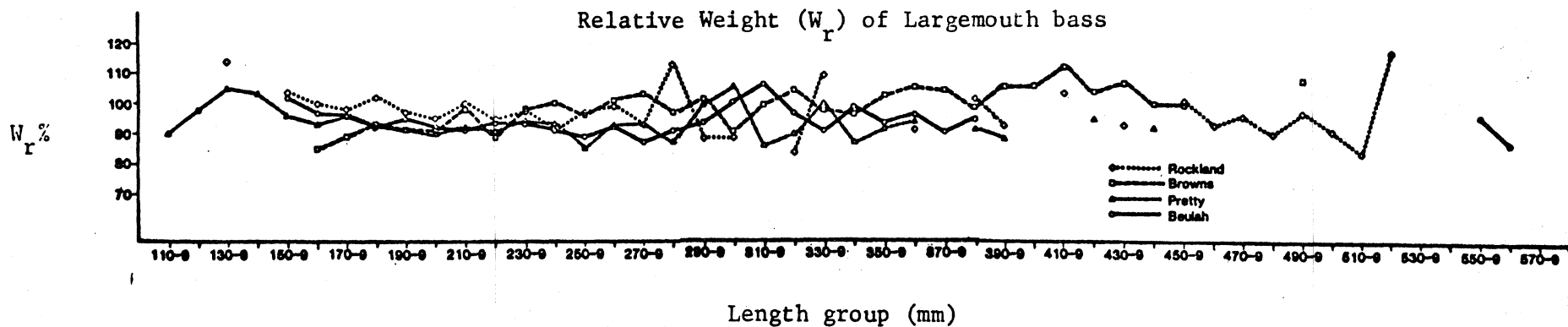


Figure 23. Mean Relative Weight (W_r) of largemouth bass in 10-mm length groups in the four study lakes in spring 1981.

Table 7. Mean Relative Weight (W_r) of bluegills and largemouth bass (<260 mm) in 10-mm length groups (containing at least 5 fish) compared with a Wilcoxon paired-sample test (Zar 1974; p. 124-6) among the lakes in spring of 1981. All statistical tests were at the 0.05 level of significance. Where a significant difference occurred, the first sample had the larger value.

Species	Samples compared	T	n	Significant difference	No significant difference
Bluegill	Beulah vs Rockland	0	7	X	
	Beulah vs Pretty	0	7	X	
	Beulah vs Browns	0	6	X	
	Rockland vs Pretty	1	7	X	
	Rockland vs Browns	0	6	X	
	Pretty vs Browns	1	7	X	
Largemouth bass	Rockland vs Beulah	0	10	X	
	Beulah vs Pretty	4	7		X
	Beulah vs Browns	3	6		X
	Rockland vs Pretty	1.5	8	X	
	Rockland vs Browns	12	7		X
	Pretty vs Browns	2	6		X

smaller bass ($140 \leq \text{bass} < 190$ mm) in Beulah Lake in fall were consistently larger than in spring (Appendix H).

Enough bass ranging from 160 - 250 mm were sampled in Rockland Lake in spring and fall of 1981 for statistical comparison of that length range of the population. No significant difference was found.

Bluegill W_R in Spring

Comparison of bluegill W_R among lakes in spring of 1981 indicated that Beulah Lake bluegill were significantly heavier than those in Rockland, Pretty and Browns Lakes; Rockland Lake bluegill were significantly heavier than those in Pretty and Browns Lake; and Pretty Lake bluegill were significantly heavier than those in Browns Lake (Table 7 and Figure 24).

W_R vs Index of Abundance

The abundance of small bluegills (80 - 140 mm long) was inversely correlated with W_R . I calculated an index of abundance of bluegills of 80 to 140 mm by combining catch per unit of effort values for electrofishing and fyke nets (Table 5). The index of abundance was highest in Browns Lake (2357 fish/hr, next highest in Pretty Lake (2331 fish/hr), next in Rockland Lake (894 fish/hr) and least in Beulah Lake (404 fish/hr). Corresponding W_R 's of bluegill (80 - 140 mm long) in these lakes were 83, 88, 92 and 97% (Appendix I).

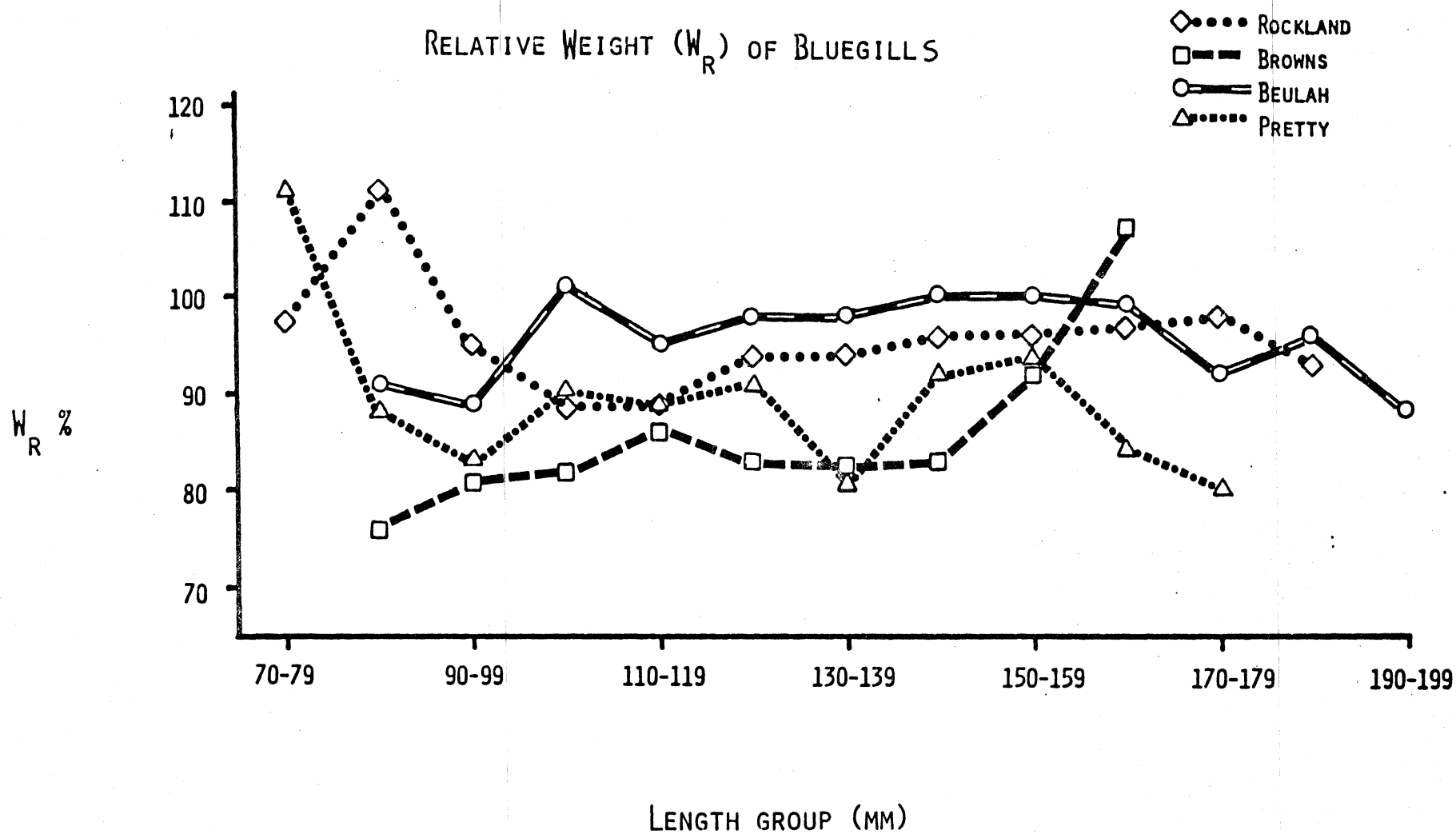


Figure 24. Mean Relative Weight (W_R) of bluegills in 10-mm length groups in the four study lakes in spring 1981.

This correlation between condition and index of abundance suggests that bluegill condition was inversely related to bluegill density.

The abundance of small bluegills (80 - 140 mm long) may have been related to the condition of large largemouth bass (≥ 350 mm) in Browns Lake. These largemouth bass had the highest W_r values of any bass (Figure 23), and Browns Lake had a large number of small bluegills (index of abundance of 2357 fish/hr) as potential food (Figure 4).

Spring vs Fall W_r of Bluegill

Bluegills were not consistently heavier in spring or fall. Separate comparisons of bluegill W_r in spring 1981 with the falls of 1980 and 1981 (Wilcoxon paired-sample test) indicated that bluegills in Beulah and Pretty Lakes were significantly heavier in spring than in fall (Table 8). However, the same tests indicated no significant difference between spring and fall W_r 's for bluegills in Browns and Rockland Lakes. Mean W_r of bluegill samples in spring (1981) averaged 2 - 12% higher in Rockland, Beulah and Pretty Lakes, and 1% lower in Browns Lake than fall W_r (1980 and 1981 combined; Appendix I).

Table 8. Mean Relative Weight (W_r) of bluegills in 10-mm length groups compared with a Wilcoxon paired-sample test (Zar 1974; pp. 124-126) among spring and fall electrofishing samples. All statistical tests were at the 0.05 level of significance. Where a significant difference occurred, the first sample had the larger value.

Lake	Samples compared	T	n	Significant difference	No significant difference
Beulah	Spring 1981 vs Fall 1981	1	8	X	
Rockland	Spring 1981 vs Fall 1981	4	8		X
Pretty	Spring 1981 vs Fall 1981	0	8	X	
Browns	Spring 1981 vs Fall 1981	10.5	7		X
Beulah	Spring 1981 vs Fall 1980	0	7	X	
Rockland	Spring 1981 vs Fall 1980	8.5	8		X
Pretty	Spring 1981 vs Fall 1980	3	8	X	
Browns	Spring 1981 vs Fall 1980	3	6		X
Beulah	Fall 1980 vs Fall 1981	7.5	7		X
Rockland	Fall 1980 vs Fall 1981	1	10	X	
Pretty	Fall 1980 vs Fall 1981	5	8		X
Browns	Fall 1980 vs Fall 1981	4.5	6		X

Growth

Growth of largemouth bass was slowest in Beulah Lake, and similar in the other lakes (Figure 25). In Browns Lake growth of largemouth bass was the same in 1980-1981 as in the 1950's, and in Pretty Lake it was the same in 1980-1981 as in 1977-1978. Bluegills grew faster in Beulah and Rockland Lakes than in Pretty and Browns Lakes (Figure 26), and in Pretty Lake, growth of bluegills was slower in 1980-1981 than in 1977-1978.

Largemouth bass

Largemouth bass growth was similar in all lakes and to the state average (Snow 1969) for ages 1 through 3 (Figure 25). For ages 1 through 9, largemouth bass in Beulah Lake grew significantly slower than bass in the other lakes and the state average (Appendix J). Length of bass in Beulah Lake at ages 10 - 12 were determined from 2 fish only (Appendix N). Slower growth of bass of ages 4 through 9 may have been related to the lower abundance of small bluegills in Beulah Lake; the index of abundance of bluegills (80 - 140 mm long) in Beulah Lake (404 fish/hr) was lowest among the four lakes.

Length at age for largemouth bass in Pretty, Browns

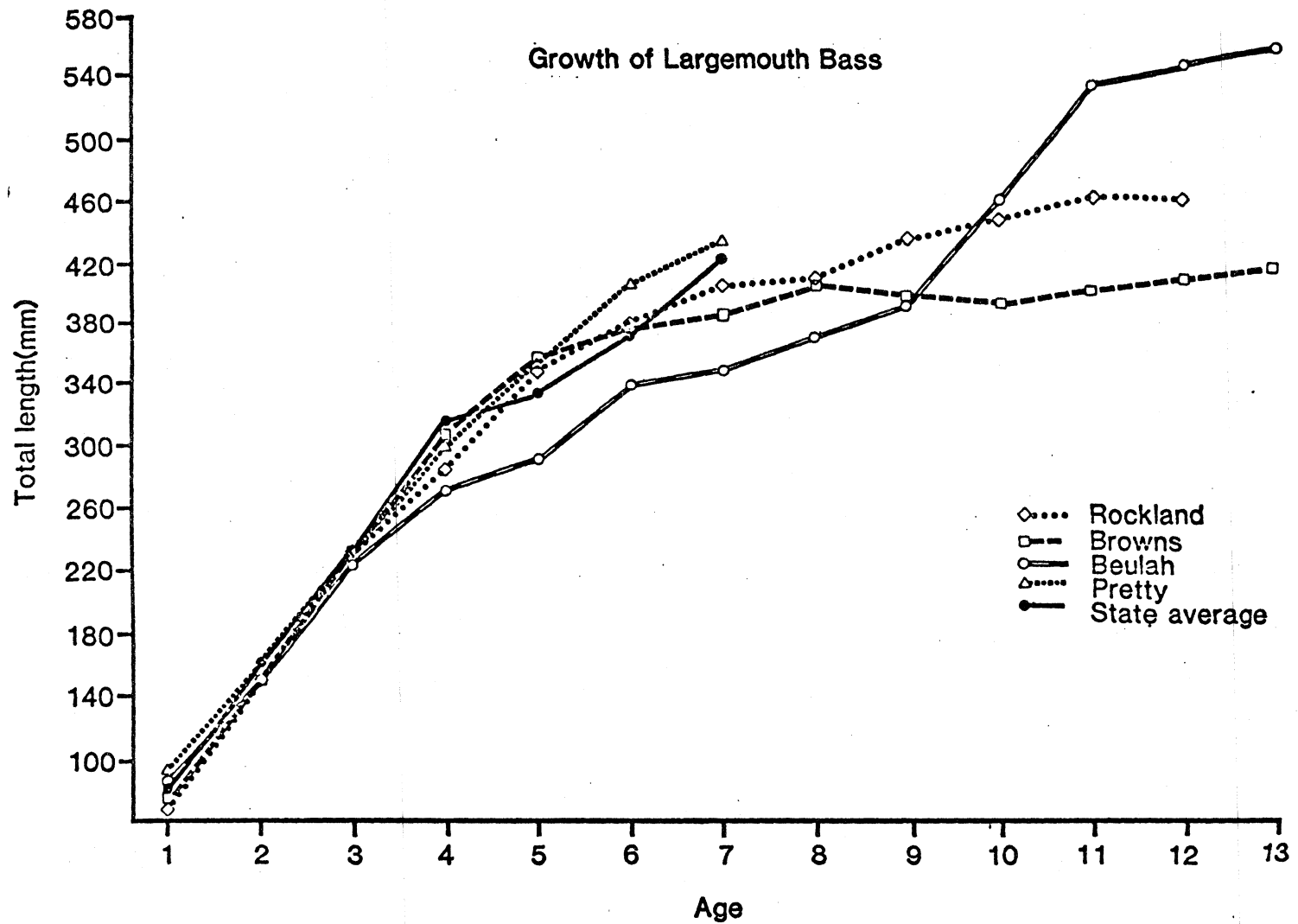


Figure 25. Total length at age of largemouth bass in the four study lakes in 1980-1981 and the state average (Snow 1969).

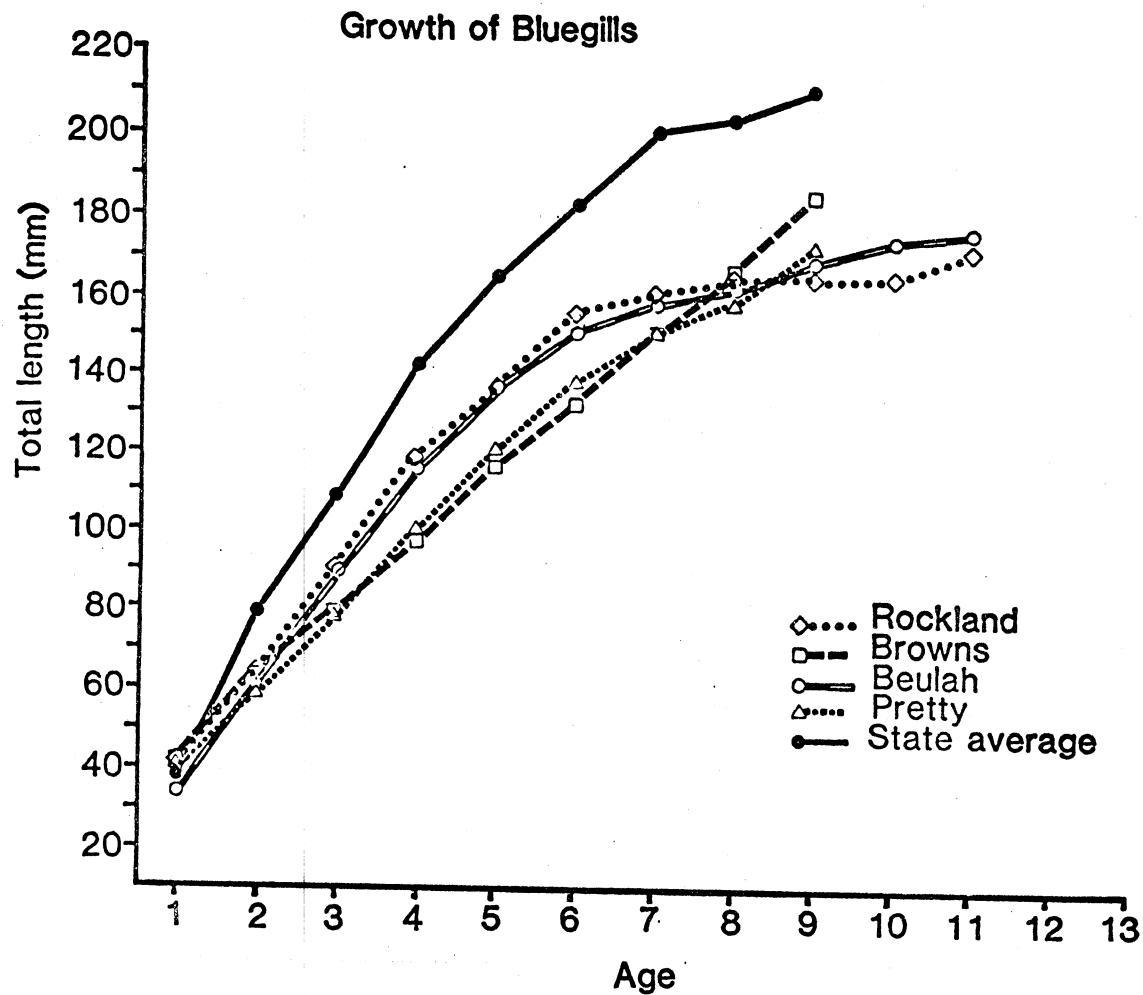


Figure 26. Total length at age of bluegills in the four study lakes in 1980-1981 and the state average (Snow 1969).

and Rockland Lakes were similar to each other and the state average at ages 3 - 5, but largemouth bass in Pretty Lake were longer than any other bass at ages 6 and 7, and, though not readily apparent in Figure 25, were significantly longer at ages 1 - 7 than bass in Rockland Lake (Appendix J). Largemouth bass reached quality-size (≥ 300 mm) after age 3 in Pretty and Browns Lakes and age 4 in Beulah and Rockland Lakes (Table 6). The index of abundance of bluegills (80 - 140 mm long) was higher in Pretty and Browns Lakes than in Beulah and Rockland Lakes.

Growth of largemouth bass in Browns Lake in 1980-81 was the same as in the 1950's. Mraz (1964) reported total length at age of largemouth bass of ages 1 through 7 in Browns Lake in 1953, 1955 and 1957. I calculated an average length at age for those years combined (Table 6), and then compared it to length at age in 1980-1981 with a paired t-test; no significant difference was found (Appendix J).

Growth of largemouth bass in Pretty Lake was the same in 1980-1981 as in 1977-1978. Claggett (1979) reported total length at age of bass in Pretty Lake in 1977 and 1978. I calculated an average length at age for those years combined (Table 6), and then compared it to length at age in 1980 and 1981 for ages 1 through 7 with a paired t-test; no significant difference was found (Appendix J).

Only 2 of the 12 comparisons of length increments and instantaneous growth rates (G) of largemouth bass (Appendix K) among lakes were significantly different (Appendices L and M). Largemouth bass in Rockland Lake had higher G values than in Pretty Lake and greater length increments than in Beulah Lake. Instantaneous growth rates and length increments were determined from the last two annuli on scales, and therefore were affected by the most recent environmental conditions.

Bluegill

Growth of bluegills in Pretty and Browns Lakes was slower than that of bluegills in Beulah and Rockland Lakes (Figure 26). Although bluegills in all lakes were of similar length to age 2, at ages 3 - 7, those in Pretty and Browns Lakes were significantly shorter than bluegills of the same ages in Beulah and Rockland Lakes (Appendix J). Bluegill reached quality-size (150 mm) after age 5 in Beulah and Rockland Lakes and age 6 in Pretty and Browns Lakes (Table 6).

This difference in growth among lakes was probably density related. Bluegills of ages 3 - 7 in Pretty and Browns Lakes ranged from 80 - 150 mm long, the lengths that formed the peaks of abundance observed on bluegill length-frequency histograms (Figures 3 and 4). Index of

abundance was greater for bluegill of 80 - 140 mm in Pretty and Browns Lakes than in the other lakes (Table 5), and their relative weight was lower than in the other lakes (relative weight subsection).

Bluegills in all lakes grew significantly slower (Figure 26; Appendix J) than the state average (Snow 1969). Goedde (1980) reported bluegills growing faster in Mid Lake and slower in Allen Lake, both in Wisconsin, than the Wisconsin state average. Allen Lake had a higher density of small bluegills than Mid Lake. Growth of bluegills in Rockland and Beulah Lakes was similar to that of bluegills in Allen Lake (1974-1976) to age 6 and slower thereafter.

Growth of bluegills in Pretty Lake was significantly slower in 1980-1981 than in 1977-1978. Claggett (1979) calculated total length at age of bluegills in Pretty Lake in 1977-1978. I calculated an average length at age for those years combined (Table 6), and then compared it to length at age in 1980 and 1981 for ages 3 - 6 with a paired t-test (Appendix J). I can only speculate on a reason for the recent slower growth of bluegills in Pretty Lake.

Results of statistical comparisons of length increments and instantaneous growth rates of bluegills (Appendix K) among the lakes were mostly inconsistent (Appendices L and M). However, the analyses did indicate that length increments and instantaneous growth rates of bluegills in

Rockland Lake were significantly greater than in Pretty and Browns Lakes.

Pumpkinseeds in Browns Lake grew significantly slower than the state average (Snow 1969; Appendix J). Pumpkinseeds, as bluegills in Browns Lake, had a low PSD (2%).

Bias in Back-calculation of Age

Most of my y - intercept values for the empirical, functional regression of total length on scale radius were realistic (Appendix N). Carlander (1982) proposed that standard y - intercept values be used for back-calculation of growth to reduce error caused by variation among empirical y - intercept values. He recommended standard y - intercepts of 20 mm for largemouth bass and bluegills, and 25 mm for pumpkinseeds. Two of my 9 calculated y - intercept values differed substantially (> 9 mm) from his recommendations: intercepts of 7 mm for largemouth bass in Rockland Lake and of 40 mm for largemouth bass in Pretty Lake (Appendix N). The effect of erroneous intercept values is greater the younger the fish (Carlander 1982). Hence, I probably tended to underestimate lengths of young bass in Rockland Lake and overestimate lengths of young bass in Pretty Lake. These biases would tend to affect estimates of growth rate (length increment, instantaneous growth rate) of young bass in the direction of overestima-

- tion in Rockland Lake and underestimation in Pretty Lake.

Length of largemouth bass of age 1 was highest in Pretty Lake and lowest in Rockland Lake (Figure 25), and length increments and instantaneous growth rates of bass of age 1 were lowest in Pretty Lake and highest in Rockland Lake (Appendix K). The larger length of bass of age 1 in Pretty Lake and the smaller value in Rockland Lake could be attributed to the biased y - intercept values. That bias probably also caused instantaneous growth rate and length increment of bass of age 1 to be lower in Pretty Lake and higher in Rockland Lake.

Mortality

Higher annual mortality rates of largemouth bass corresponded with low PSD's. Estimated total annual mortality rates of largemouth bass in Pretty, Beulah, Rockland and Browns Lakes were 79, 68, 66 and 52%, respectively, for the ages indicated (Table 9). Corresponding PSD values were 14, 13, 13 and 58%.

The lower mortality rate in Browns Lake was a result of the greater proportion of older largemouth bass in that lake compared with the others (Figures 18 - 21). Higher survival of bass ages 5 - 9 (Table 10) may be a reflection of a large food supply in the form of the greater number of small bluegills in Browns Lake than in the other lakes (Figures 1-4 ; Table 5). Alternatively, the largemouth bass in Browns Lake have a history of variation in year class strength (Mraz 1964). The greater proportion of bass of ages 5 - 9 in Browns Lake than in the other lakes may or may not have been a result of high survival after chemical treatment in 1971.

My annual mortality rates are within the published range of 35 - 89% for exploited largemouth bass populations (Goedde 1980; Appendix O).

Annual mortality rates of bluegills corresponded with PSD, W_r , and growth rate. Estimated total annual mortality rates for bluegills in Browns, Pretty, Rockland and Beulah Lakes were 77, 71, 63 and 39%, respectively, for the ages indicated (Table 9).

Table 9. Total annual and instantaneous mortality (A and Z), and survival (S) rates of largemouth bass, bluegills, and pumpkinseeds (in Browns Lake only) in spring 1980 and 1981 combined electrofishing samples from the four study lakes. r is the correlation coefficient.

Species	Lake	A%	Z	S%	r	Ages	n
Largemouth bass	Beulah	67.5	1.12	32.5	.98	3-6	229
	Rockland	66.0	1.08	34.0	.93	3-7	456
	Pretty	79.0	1.56	21.0	.99	3-6	159
	Browns	51.8	0.73	48.2	.94	3-9	296
Bluegill	Beulah	38.8	0.49	61.2	.98	5-11	180
	Rockland	63.0	0.99	37.0	.97	5-9	102
	Pretty	70.9	1.24	29.1	.99	5-9	239
	Browns	77.4	1.49	22.6	.96	5-8	563
Pumpkinseed	Browns	77.1	1.48	22.9	.99	6-8	75

Table 10. Age frequency distributions (%) of largemouth bass and bluegills in Beulah, Rockland, Pretty, and Browns Lakes, and pumpkinseeds in Browns Lake, in spring electrofishing samples in 1980-1981. N is the sample size.

Species	Lake	<u>Age</u>														Total
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	
Largemouth bass	Beulah	0	98	176	35	12	6	0	1	1	1	0	0	2		332
	Rockland	19	307	398	34	14	5	5	0	3	6	4	1			796
	Pretty	3	69	133	18	7	1									231
	Browns	0	7	99	72	65	43	8	8	1						303
Bluegill	Beulah	0	1	39	62	73	38	25	26	9	5	4				282
	Rockland	4	28	228	94	57	22	18	4	1						452
	Pretty	0	21	354	244	160	45	28	5	1						858
	Browns	2	4	22	89	366	138	55	4							678
Pumpkinseed	Browns	0	0	0	36	100	62	10	3							211

Bluegills in Browns and Pretty Lakes, with the two highest mortality rates, had poor length structure and higher index of abundance (PSD's of 1 and 5%; Figures 1-4 ; Table 5), lowest relative weight (Figure 24), and slowest growth rate (Figure 26). Beulah Lake bluegills, with the lowest annual mortality rate, had the best population length structure and lowest index of abundance, were in best condition, and grew faster than bluegill in Pretty and Browns Lakes.

These annual mortality rates for bluegills, except in Beulah Lake, were similar to published rates for other exploited populations which ranged from 60-82% (Goedde 1980; Appendix O). The annual mortality rate of bluegills in Beulah Lake (39%) was similar to the rate calculated for unexploited bluegills (30%) in Mid Lake (Goedde and Coble 1981). I cannot explain why bluegill in Beulah Lake would have a lower mortality rate than bluegill in the other lakes.

Pumpkinseeds in Browns Lake had an estimated total annual mortality rate of 77% for ages 6 through 8; which fell within the published range of 59-88% for exploited populations (Goedde 1980; Appendix O).

Population Estimates, Standing Stocks and
Exploitation of Largemouth Bass in Rockland Lake

The estimated largemouth bass population (Schnabel estimate) was larger in spring than in fall in 1980, and similar in spring and fall of 1981 (Table 11). Estimates were 77 (for fish ≥ 130 mm long) and 37 (for fish ≥ 160 mm long) fish per hectare in spring and fall of 1980. The larger spring estimate may be due to the greater length range of fish included in the estimate in spring. Estimated population size was 46 (≥ 160 mm long) and 44 (≥ 160 mm long) fish per hectare in spring and fall of 1981 and corresponding standing stocks were 13 and 10 kg/ha (Table 11). The mean standing stock of largemouth bass in North American lakes and reservoirs containing largemouth bass has been reported to be 16.8 kg/ha (Bennett 1971). My population estimates and standing stocks were within published ranges of 5-405 fish/ha and 4-116 kg/ha (Appendix P).

Angler exploitation of largemouth bass in Rockland Lake was estimated to be 87% for the summer (3 May through 28 September) of 1980 (Table 11). Estimated population size (spring 1980) and harvest of largemouth bass ≥ 170 mm long (the minimum length kept by anglers) were 23 and 20 fish/ha (Table 11; Appendix Q).

This exploitation rate was probably an overestimate

Table 11. Schnabel population estimate, 95% confidence interval (CI), standing stock and mean individual weight, and exploitation rate (1980 only) of large-mouth bass in Rockland Lake in spring and fall of 1980 and 1981.

Period	Population size (No/ha) & minimum length(mm)	95% CI	Standing stock (kg/ha)	Mean individual weight (g)
Spring 1980	77 (≥ 130)	54 - 113	---	---
Spring 1980	23 (≥ 170)	14 - 37	---	---
Fall 1980	37 (≥ 160)	24 - 62	---	---
Spring 1981	46 (≥ 160)	38 - 57	13	291
Fall 1981	44 (≥ 160)	25 - 83	10	226

Estimated exploitation rate (u)

$$u = \frac{\text{estimated harvest in summer of 1980}}{\text{population estimate in spring of 1980}} = \frac{20 \text{ No/ha}}{23 \text{ No/ha}} = \quad \times 100 = 87\%$$

because it was higher than the estimated total annual mortality rate (66%; Table 9) and the published range of exploitation rates of largemouth bass (12-65%; Appendix R). It could have resulted from an overestimate of harvest. However, I could find no evidence that harvest was overestimated. Rockland Lake was easily creel surveyed because it had but one public access point, and it was the smallest lake surveyed.

An overestimate of exploitation also could result from an underestimate of population size. This bias does not seem likely in the present case because the method of obtaining the population estimates (fish caught with the same gear, electrofishing, for marking and recapture) is more likely to lead to overestimation than to underestimation. A condition that must be met for accurate population estimates is that the marked fish be as vulnerable to the gear as unmarked fish (Ricker 1975). This condition would not occur if the same gear were used to catch fish for marking and recapture, and the released, marked fish subsequently avoided the gear. Jacobs and Swink (1982) reported that most attempts to estimate abundance of various species of fish in two Kentucky tailwaters from electrofishing alone were unsuccessful because too few marked fish were recaptured. The authors felt that fish captured during the first electrofishing run avoided recapture, and in one instance, longear sunfish

(Lepomis megalotis) originally captured over nests were observed swimming away from the boat during recapture attempts 24 hours later. Fewer recaptures would tend to increase a population estimate.

In conclusion, I probably overestimated the exploitation rate of largemouth bass in Rockland Lake, but I cannot identify a reason for the bias. In any event, the estimate, 87%, even though probably inflated, in relation to the estimated total annual mortality rate of largemouth bass in Rockland Lake, 66%, suggests that fishing mortality comprised a large proportion of total mortality. A high exploitation rate would leave few old, large largemouth bass in a population. Few quality-size bass (≥ 305 mm long) were caught in Rockland Lake in fall 1980 and spring 1981 electrofishing samples (Appendix S); PSD's were 10 and 8%.

Even though my method of obtaining population estimates (fish caught by electrofishing both for marking and recapture) may lead to overestimation, I have no evidence that it did. Moreover, overestimation of populations did not occur in two other studies. Schneider (1971) found the opposite bias when he used electrofishing for both marking and recapture. His population estimates were consistently lower than those obtained from trap nets or from the combined effort of both gears. Also, Jesien (1977) found little difference in population estimates for the white sucker (Catostomus commersoni)

calculated from electrofishing data alone and estimates obtained when electrofishing was used for marking and angling for recapture.

Creel Survey

Fishing Pressure

Fishing pressure or effort was highest in Rockland Lake (348 hrs/ha), lowest in Pretty Lake (107 hrs/ha), and it generally decreased over the survey period (Figure 27; Appendix T). Fishing pressure on Beulah and Browns Lakes was 151 and 187 hrs/ha. Mraz (1964) reported fishing pressure on Browns Lake of 185 and 156 hrs/ha in 1953 and 1955. Pressure estimates for these four lakes were within the published range of 32-577 hrs/ha (Appendix U). The primary target of anglers was largemouth bass in Beulah, Browns and Rockland Lakes (Table 12). Largemouth bass fishing comprised 46 to 62% of the total fishing effort on these lakes. Bluegill and pumpkinseed were of equal and primary importance to anglers on Pretty Lake, and comprised 63% of the total fishing effort. The secondary target of anglers was bluegills in Beulah and Rockland Lakes (28 and 36% of total effort), northern pike in Browns Lake (16%) and largemouth bass in Pretty Lake (25%).

Catch (the number caught) and Harvest (the number kept)

Catch per unit area (number/ha) of largemouth bass, bluegills, and of all species combined was higher in Rockland

ANGLING PRESSURE BY MONTH, 1980

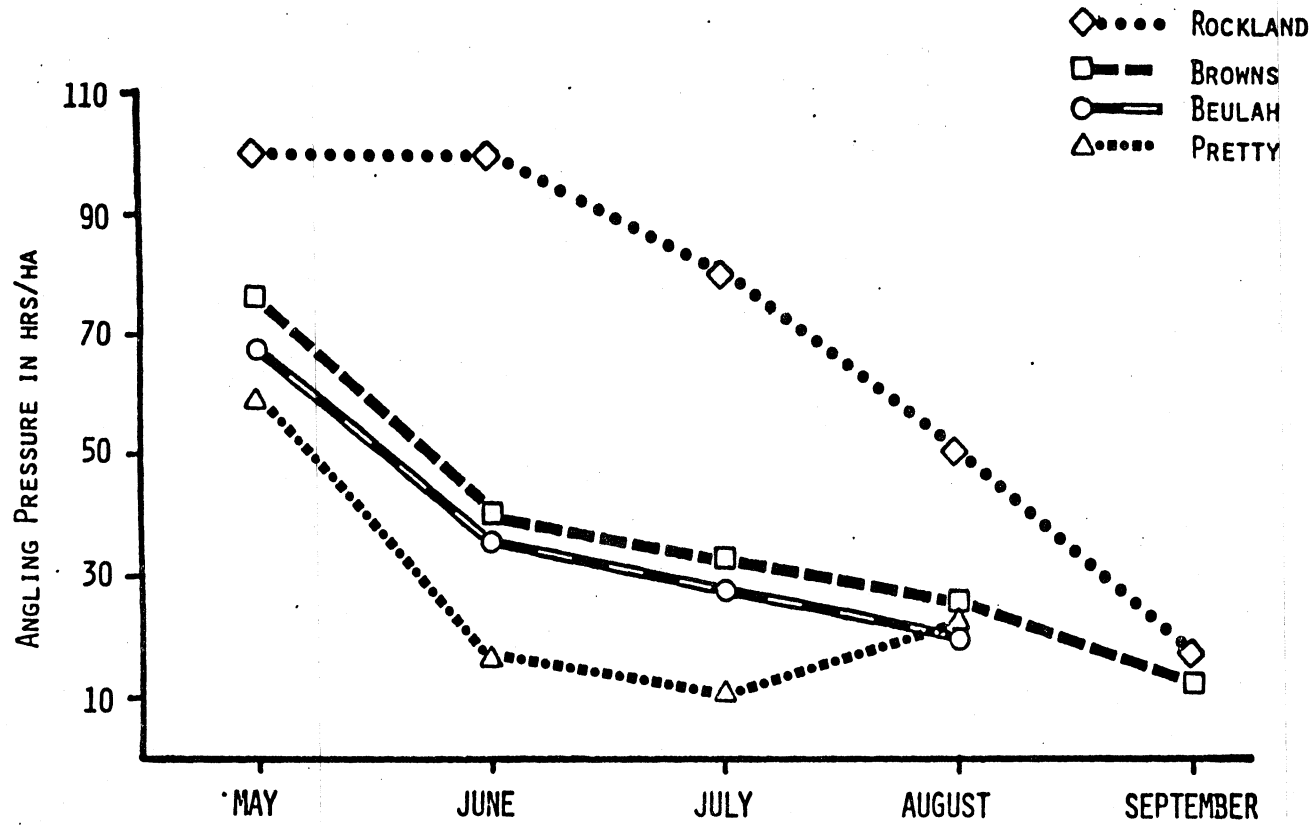


Figure 27. Monthly angling effort (pressure) in the four study lakes in 1980.

Table 12. Estimated fishing effort (hrs/ha) and percent of total effort applied to each species in the four study lakes.

Species	Beulah (338 ha)		Browns (160 ha)		Pretty (26 ha)		Rockland (16 ha)	
	Effort	Percent of total effort	Effort	Percent of total effort	Effort	Percent of total effort	Effort	Percent of total effort
Largemouth bass	78.1	51.7	116.6	62.1	26.7	25.0	162.6	46.0
Bluegill	42.1	27.9	25.7	13.7	39.5	37.0	125.0	35.9
Pumpkinseed	3.5	2.3	10.8	5.7	27.7	26.0	3.9	1.1
Yellow perch	3.5	2.3	1.9	1.0	--	--	18.2	5.2
Northern pike	15.9	10.5	30.4	16.2	10.7	10.0	17.4	5.0
Brown trout	5.7	3.8	--	--	--	--	--	--
Black crappie	1.7	1.1	0.6	0.3	3.6	3.4	24.4	7.0
Walleye	--	--	0.4	0.2	--	--	--	--
Black bullhead	--	--	0.2	0.1	--	--	--	--
Yellow bullhead	--	--	0.1	0.04	--	--	--	--
Bullhead unspecified	--	--	1.9	1.0	--	--	--	--

Lake, where fishing pressure was highest, than in the others, and it generally declined throughout the season in Rockland Lake (Figures 28-30). Highest values (June) were 20 and 139 fish/ha for largemouth bass and bluegills in Rockland Lake and 240 fish/ha for all species combined in Pretty Lake in May. The higher catch of all species combined in Pretty Lake in May was probably due to the catch rate of pumpkinseeds (4.83 fish/hour; Appendix V) for the period surveyed (20-31 May). This rate comprised 67% of the catch rate of all species combined in Pretty Lake in May, and was 19-268 times greater than the catch rate of pumpkinseeds in the other lakes. Anglers were observed catching pumpkinseeds on nests in late May; a time when they are more vulnerable to angling. Alternatively, this catch rate may be inaccurate because of the small amount of creel survey effort (8 hrs/week) devoted to Pretty Lake.

Mean values of catch/area for the season in Rockland Lake were 15, 92 and 137 fish/ha/month (Appendix Q) for largemouth bass, bluegills and all species combined, respectively. Comparable mean values in the other three lakes combined were 5, 34 and 67 fish/ha/month. Published seasonal mean catch values were 3-60, 1.4-98 and 4-116 for largemouth bass, bluegills and all species combined (Appendix U). Mean values calculated for the lakes in this study were within these published ranges, except for all species combined in Rockland Lake, which was higher, and also the value for bluegill in Rockland Lake was near the top of the published

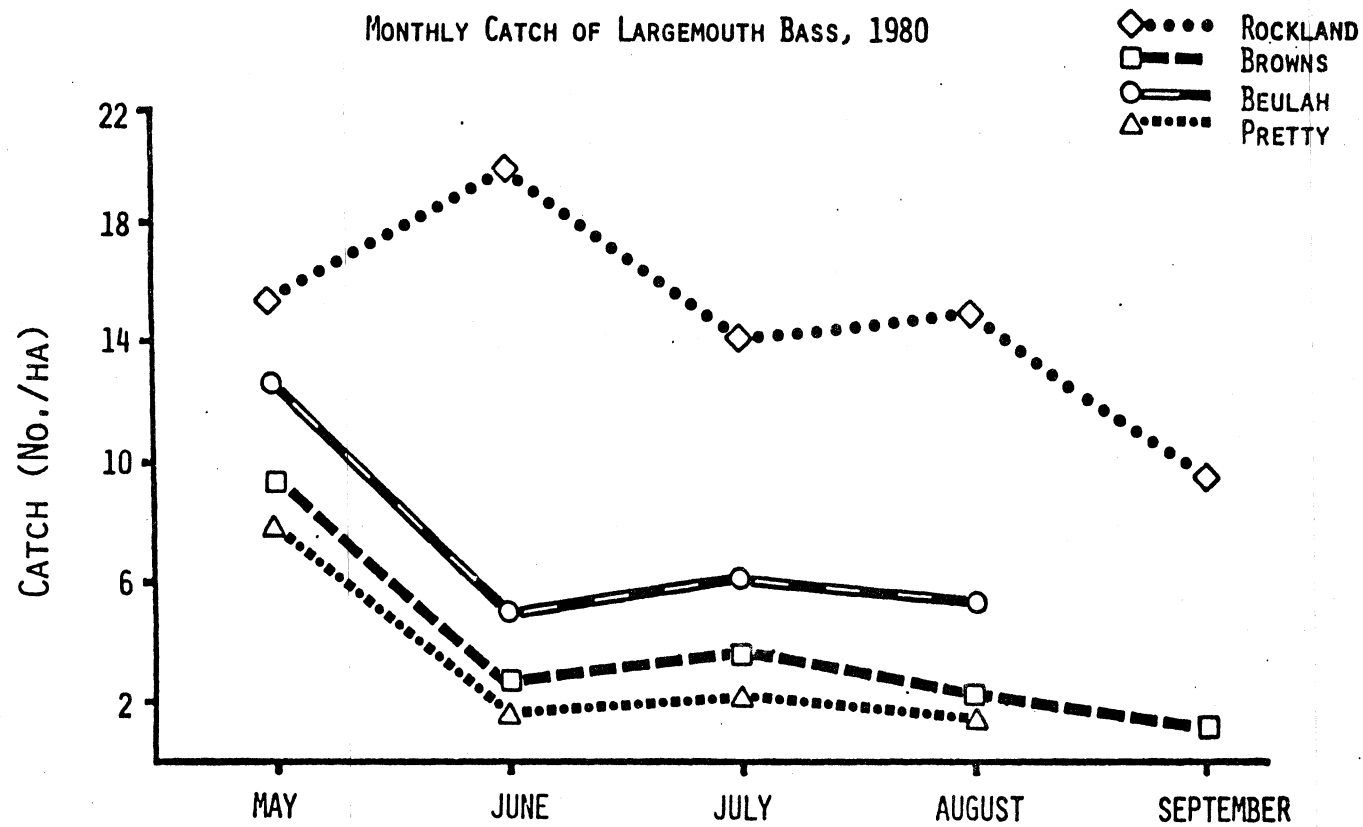


Figure 28. Monthly catch of largemouth bass in the four study lakes in 1980.

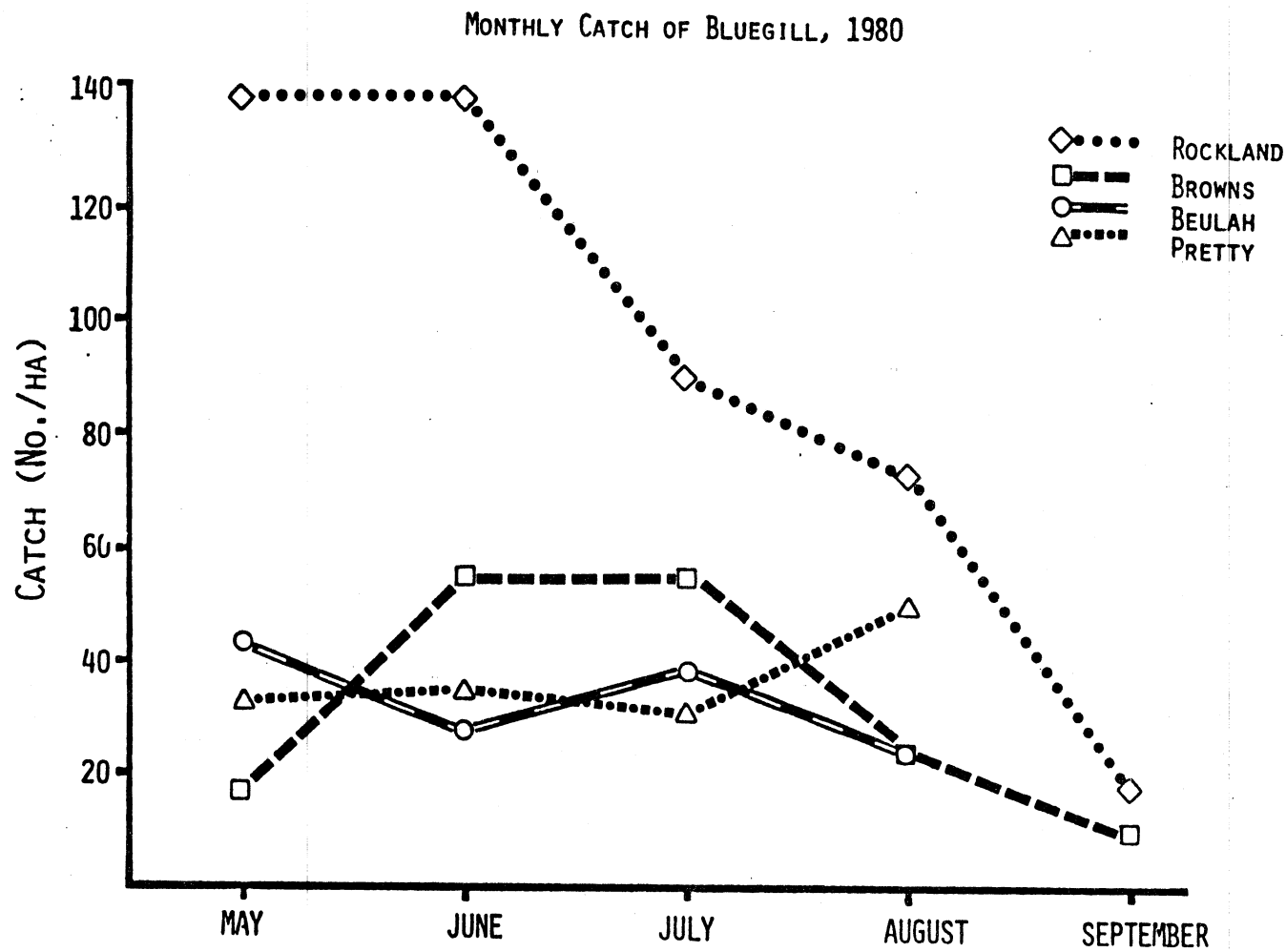


Figure 29. Monthly catch of bluegills in the four study lakes in 1980.

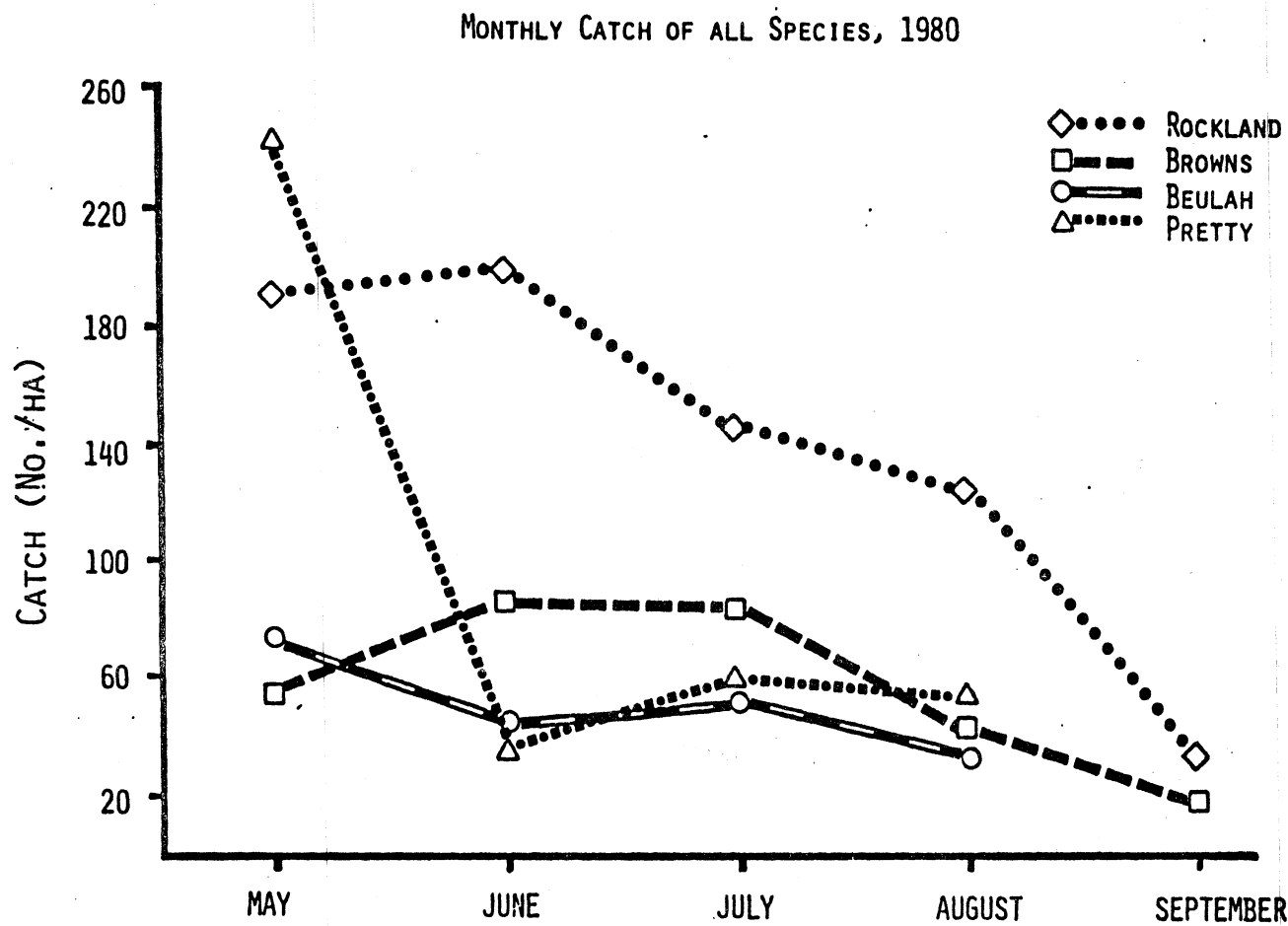


Figure 30. Monthly catch of all species combined in the four study lakes in 1980.

range. The catch in Rockland Lake may have been related to the greater fishing effort in Rockland Lake than in the other lakes (Figure 27).

Bluegills dominated angler creels in each lake and comprised 39 to 75% of the total harvest (Table 13). Pumpkin-seeds comprised a large percentage (38%) of the fish creeled in Pretty Lake. Percent of largemouth bass in the total harvest was highest in Browns Lake (14%) and ranged from 4 - 7% in the remaining lakes.

Various angling quality statistics were correlated with PSD values in spring 1980. The following variables were generally positively correlated with PSD: 1) percent of a species in the total harvest, 2) mean length of fish harvested, 3) harvest rate (number/hr), 4) percent of quality-size fish in the harvest, and 5) percent of catch harvested (Figure 31). The relationships between the angling variables and PSD were generally curvilinear, i.e. as PSD increased, its apparent effect on a variable decreased. PSD and variables 1 - 5 for bluegills were highest in Beulah Lake and lowest in Browns Lake, except for the percent of bluegills in the total harvest which was lowest in Pretty Lake.

Correlations between PSD and variables 1 - 5 were not so consistent for largemouth bass as for bluegills (Figure 31). PSD and variables 1 - 5 were highest for largemouth bass in Browns Lake. Also PSD, harvest rate, and percent of

Table 13. Estimated catch (number/ha), harvest (number/ha), percent of catch harvested, and percent of a species in the total harvest of fishes in the four study lakes in 1980. Estimates for largemouth bass, bluegills, and all species combined in Beulah and Pretty Lakes were corrected to cover the entire month of May. Estimates for the other fishes in those lakes are based on the days surveyed from 20 May through 31 August.

Species	Beulah (338 ha)				Browns (160 ha)				Pretty (26 ha)				Rockland (16 ha)			
	Catch	Harvest	Percent of catch harvested	Percent of a species in the total harvest	Catch	Harvest	Percent of catch harvested	Percent of a species in the total harvest	Catch	Harvest	Percent of catch harvested	Percent of a species in the total harvest	Catch	Harvest	Percent of catch harvested	Percent of a species in the total harvest
All combined	198.96	98.95	49.7	---	282.1	78.51	27.8	---	384.27	114.18	29.7	---	687.01	301.19	43.8	---
Largemouth bass	28.87	3.55	12.3	3.6	18.78	11.06	58.9	14.1	12.40	4.28	34.5	3.7	73.30	20.02	27.3	6.6
Northern pike	1.08	0.02	1.9	0.02	4.36	1.87	42.9	2.4	---	---	---	---	9.27	1.88	20.3	0.6
Brown trout	1.73	1.71	67.6	1.8	---	---	---	---	---	---	---	---	---	---	---	---
Bluegill	132.38	74.06	55.9	74.8	160.38	37.01	23.1	47.1	145.96	44.96	30.8	39.4	459.47	210.62	45.8	69.9
Yellow perch	10.80	6.98	63.7	7.3	10.44	2.33	22.3	3.0	---	---	---	---	61.34	24.49	39.9	8.1
Pumpkinseed	10.3	6.07	58.9	6.4	61.34	17.06	27.8	21.7	124.3	43.31	34.8	42.9	12.34	6.08	49.3	2.0
Black crappie	1.28	0.50	39.1	0.5	---	---	---	---	23.34	9.14	39.2	9.1	62.23	32.86	52.8	10.9
Green sunfish	1.74	0.76	43.7	0.8	7.92	1.89	23.9	2.4	---	---	---	---	---	---	---	---
Walleye	---	---	---	---	0.08	0.08	100.0	0.1	---	---	---	---	---	---	---	---
Yellow bullhead	0.26	0.26	100.0	0.3	0.22	0.22	100.0	0.3	---	---	---	---	---	---	---	---
Rock bass	0.34	0.06	17.6	0.1	---	---	---	---	---	---	---	---	---	---	---	---
Warmouth	3.93	2.58	65.6	2.7	---	---	---	---	---	---	---	---	5.3	2.4	45.3	0.8
Brown bullhead	0.14	0.14	100.0	0.1	0.53	0.53	100.0	0.7	---	---	---	---	0.61	0.61	100.0	0.2
Bullhead unspecified	---	---	---	---	6.84	5.38	78.7	6.9	---	---	---	---	2.79	2.15	77.1	0.7
Black bullhead	---	---	---	---	3.18	1.00	31.4	1.3	---	---	---	---	---	---	---	---
Carp	---	---	---	---	---	---	---	---	---	---	---	---	0.25	0.25	100.0	0.1

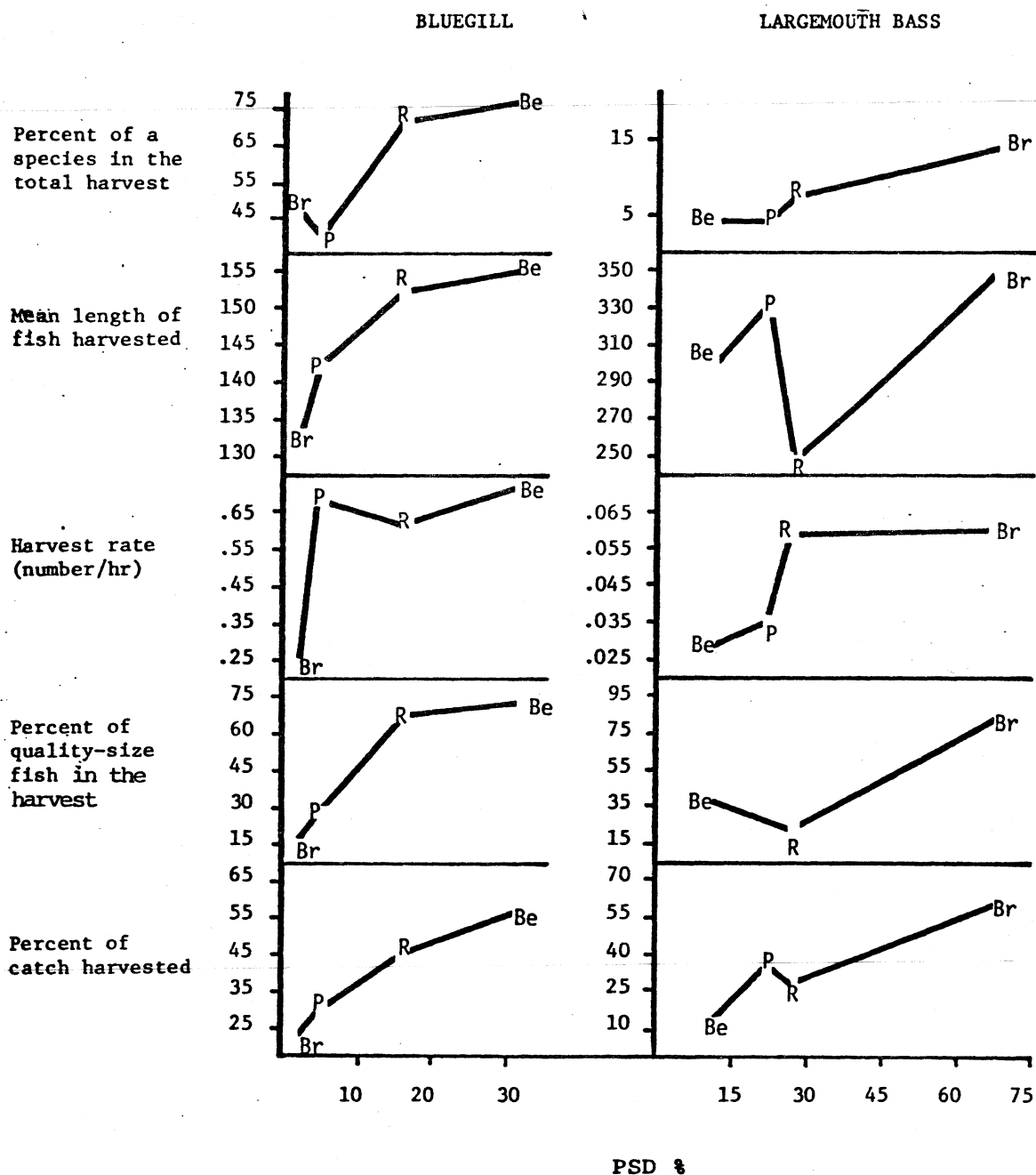


Figure 31. PSD versus the percent of a species in the total harvest, mean length of fish harvested, harvest rate, percent of quality-size fish in the harvest, and percent of catch harvested for bluegills and largemouth bass in the four study lakes in 1980.

- catch harvested were lowest in Beulah Lake. However, mean length and percent of quality-size largemouth bass in the creel, but not PSD, were lowest in Rockland Lake.

Many small largemouth bass were available to anglers on Rockland Lake in 1980. Analysis of the length-frequency distributions in spring and fall of 1980 (Appendix S) and of length at age data (Table 6) for largemouth bass indicated that a strong 1978 year class was present in Rockland Lake in 1980. These smaller fish, averaging 148 mm at age 2, probably account for the smaller mean length and lower percentage of the harvest that was quality-sized bass for Rockland Lake. These bass did not decrease the PSD because they were shorter than the minimum stock-size (203 mm). I found no evidence of a strong year class of 1, 2 or 3 year-old bass present in 1980 in the other lakes.

The anglers' catch of largemouth bass in Browns Lake in 1980 was similar to that in 1953, and greater than the catch in 1955. The creel surveys in 1980, 1953 and 1955 were about 5 months long. Mraz and Threinen (1955) reported the catch of largemouth bass in Browns Lake to be 16.7 and 7.8 fish/ha in 1953 and 1955; the catch in 1980 was 18.6 fish/ha. The authors felt that the decline in catch of bass from 1953 to 1955 was a result of a decrease in fishing pressure in 1955, and possibly the rejection of the bass by anglers after the novelty of the "no size limit" (effec-

tive in 1953) had worn off (Mraz and Threinen 1955).

There were more larger bass harvested in 1980 than in 1953. Quality-size largemouth bass (≥ 305 mm) comprised 81% and 25% of those harvested in 1980 and 1953, respectively, and corresponding mean lengths were 348 and 272 mm. More larger bass were present in 1980 probably because of the large 1975 year class (Proportional Stock Density and Mean Length section), which, at age 5 averaged, 356 mm long (Table 6).

Management

Length limits were established for largemouth bass in the study lakes in 1982.

Few quality-size (≥ 305 mm) largemouth bass occurred in Beulah, Rockland and Pretty Lakes (PSD's of 13, 13 and 14%). Estimated total annual mortality rates of largemouth bass in Beulah (68%), Rockland (66%), and Pretty (79%) Lakes were greater than 60% of the published rates (Appendix O). The exploitation rate of largemouth bass in Rockland Lake (87%) was higher than the published range of 12 - 65%. Estimated fishing pressures in Rockland and Browns Lakes were greater than 77 and 64% of the published values (Appendix U).

Few quality-size bluegills occurred in Rockland, Pretty, and Browns Lakes (PSD's of 17, 5 and 1%). Bluegills in the study lakes were growing slower than the state average (Growth section), and bluegills were in poor condition in Pretty and Browns Lakes (W_r values of 88 and 84%). Estimated total annual mortality rates of bluegills in Browns and Pretty Lakes (77 and 71%) were near the upper limit (82%) of the published range.

The rationale of the length limits was to protect bass to increase predation pressure on bluegills. Increased predation could decrease the number of bluegills and thereby improve their growth and condition.

A slot-length limit of 305 - 406 mm was established for largemouth bass in Beulah and Rockland Lakes. The purposes were to; 1) protect quality-size bass for at least 2 years of their life at a time when they exhibit a high absolute annual weight gain, and 2) to allow harvest of surplus bass of less than quality-size. Beulah and Rockland Lakes contained a greater proportion of bass of less than quality-size than the other lakes (Figures 18 and 19), and therefore may be able to support harvest of the smaller bass. A minimum length limit for largemouth bass in Beulah and Rockland Lakes may have tended to stock-pile small bass causing slow growth.

A minimum length limit of 406 mm was established for largemouth bass in Pretty and Browns Lakes. These lakes contained low proportions of bass of less than quality-size (Figures 20 and 21). This length limit may increase the number of all bass less than the limit.

Past fish management tactics on Browns and Pretty Lakes were not successful. Browns Lake was chemically treated in 1971 to remove stunted panfish (primarily bluegills) and carp (Schumacher and Rebicek 1977). An electrofishing survey, following chemical treatment, indicated that the treatment was successful (Piening 1972). The present study indicated that bluegills in Browns Lake were again slow-growing and abundant.

Bluegills in Pretty Lake were growing slowly in 1977-78; their length at each age was much smaller than Snow's (1978) averages for northern Wisconsin lakes (Claggett 1979). A panfish removal project was conducted in 1977 and 1978 in an attempt to improve bluegill growth. About 96,000 panfish (91,200 were bluegills) were removed in May 1977, and about 24,460 panfish (20,791 bluegills) in May 1978. Claggett (1979) reported that the removal of panfish in 1977 was not successful in increasing growth of bluegills by May of 1978, and because fewer bluegills were removed in 1978, he anticipated little effect by 1979. In 1980 and 1981 (present study) their growth was even slower than in 1977-1978, their relative weight was poor (Figure 24), and their PSD was low (5%).

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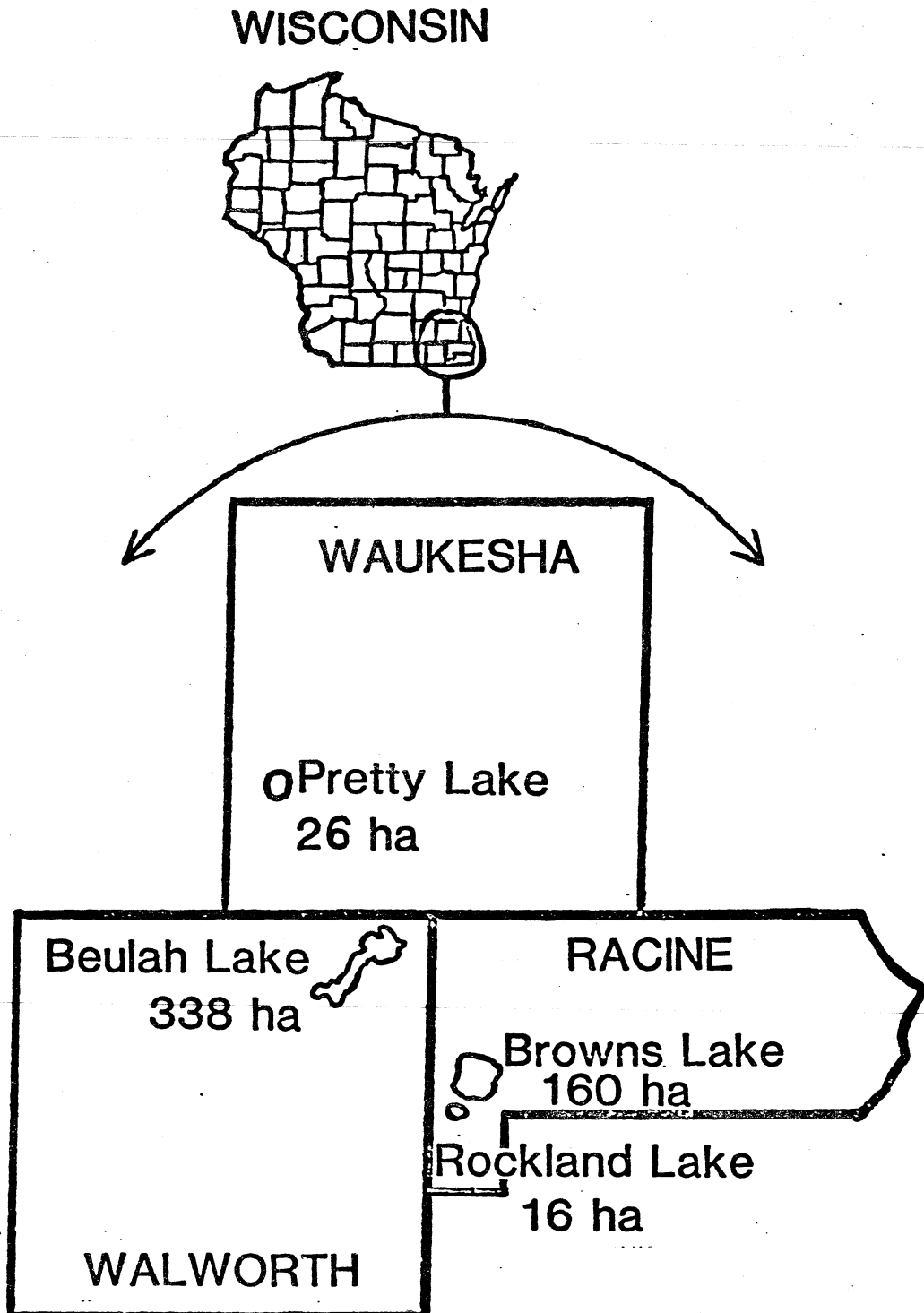
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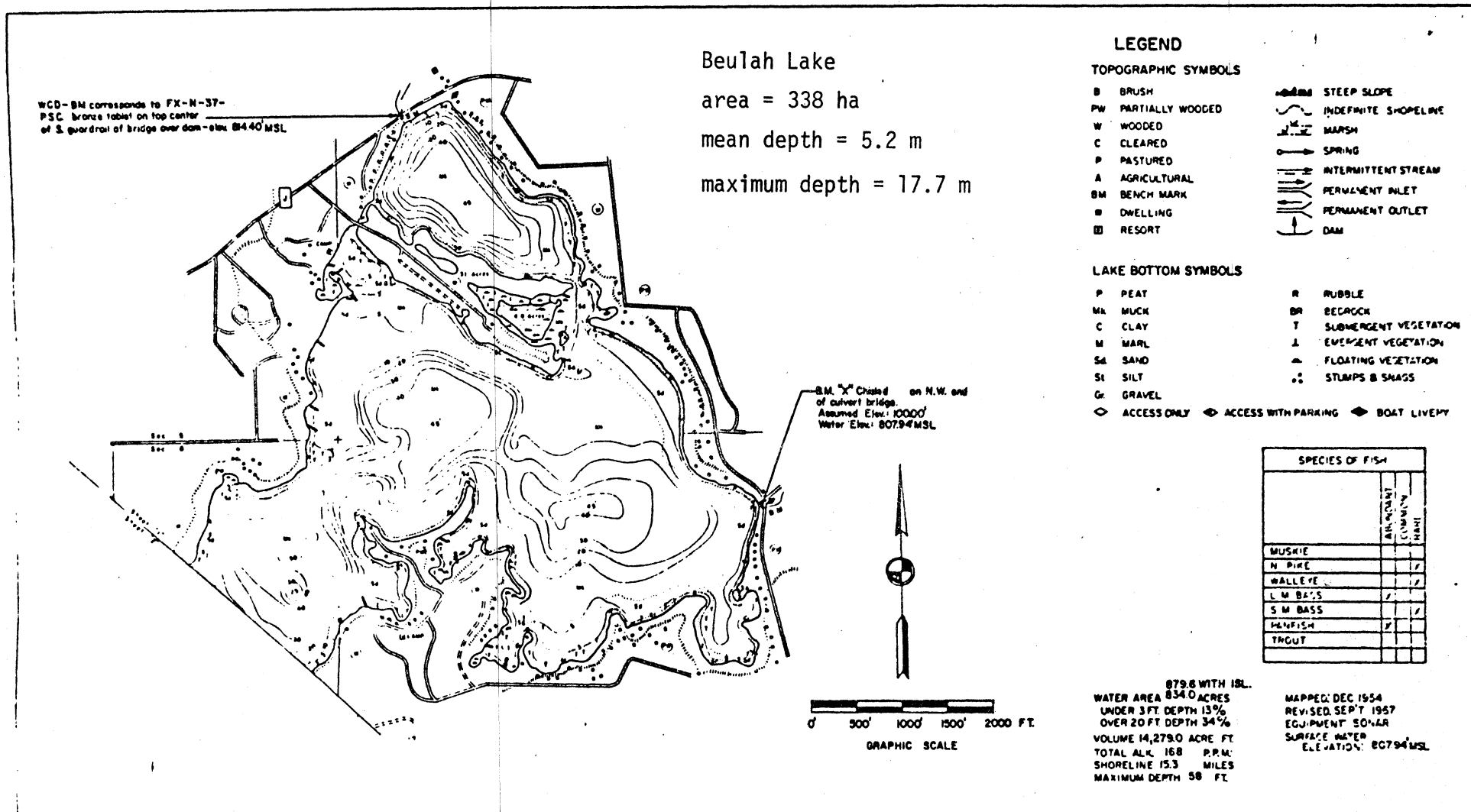
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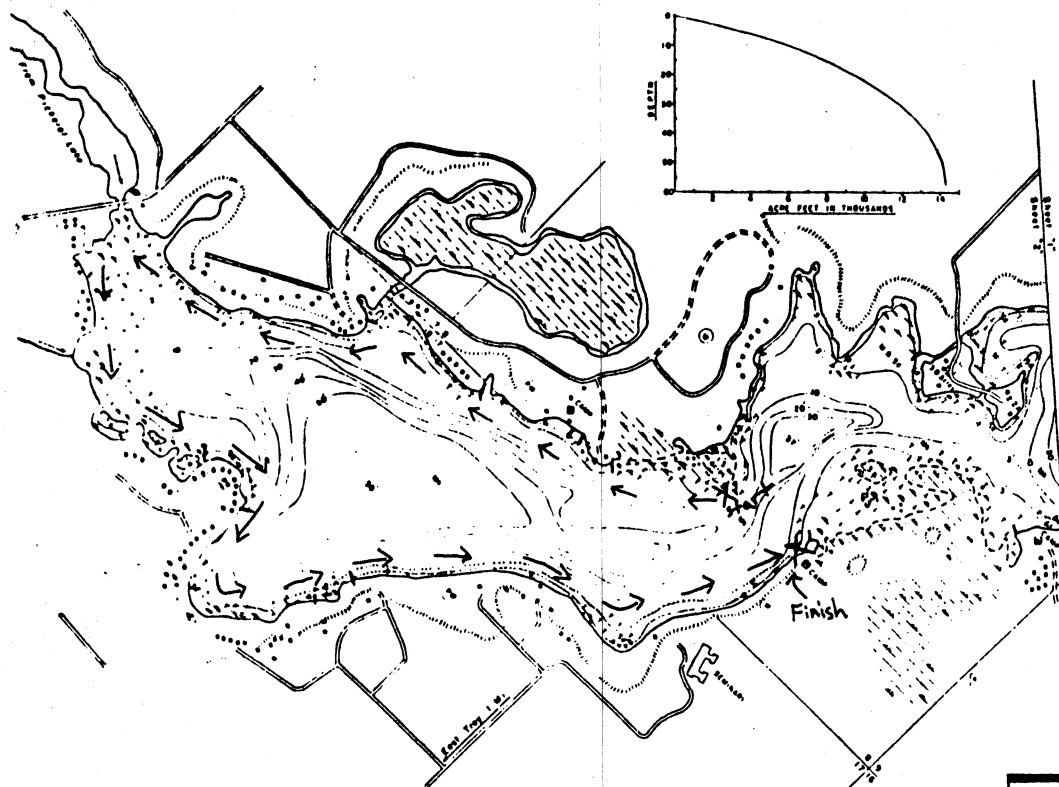
Appendix A

Location of the four study lakes in three counties in southeast Wisconsin.



Appendix B. Hydrographic maps of Beulah, Rockland, Pretty and Browns Lakes. Arrows in Beulah Lake show area electrofished.

Beulah Lake (continued) southwest basin



NOTE: SEE MAP I FOR
BENCHMARK DESCRIPTION.

LEGEND

TOPOGRAPHIC SYMBOLS

- B BRUSH
- PW PARTIALLY WOODED
- W WOODED
- C CLEARED
- P PASTURED
- A AGRICULTURAL
- BM BENCHMARK
- DW DWELLING
- R RESORT
- STEEP SLOPE
- INDEFINITE SHOVEL NE
- WASH
- SPRING
- INTERMITTENT STREAM
- PERMANENT INLET
- PERMANENT OUTLET
- DAM

LAKE BOTTOM SYMBOLS

- P PEAT
- ML MUCK
- C CLAY
- M MARL
- SA SAND
- SI SILT
- G GRAVEL
- R RUBBLE
- BP BEDROCK
- T SUBMERGENT VEGETATION
- E EMERGENT VEGETATION
- F FLOATING VEGETATION
- S STUMPS & SNAGS
- ACCESS ONLY
- ACCESS WITH PARKING
- BOAT LIFT

SPECIES OF FISH			
	ABUNDANT	COMMON	RARE
MUSKIE			
N. P. FISH			
WALLEYE			
L. W. BASS			
S. W. BASS			
PANFISH			
TROUT			

0 500' 1000' 1500' 2000 FT.
GRAPHIC SCALE

879.6 WITH ISL
WATER AREA 834.0 ACRES
UNDER 3 FT DEPTH 13%
OVER 20 FT DEPTH 34%
VOLUME 14,279.0 ACRE FT
TOTAL ALK. 168 P.P.M.
SHORELINE 15.3 MILES
MAXIMUM DEPTH 58 FT.

MAILED, DEC. 1954
REVISED SEPT. 1957
EQUIPMENT SONAR
SURFACE WATER
ELEVATION 8079.4 MG.

Rockland Lake

mean depth = 3.1 m

area = 16 ha

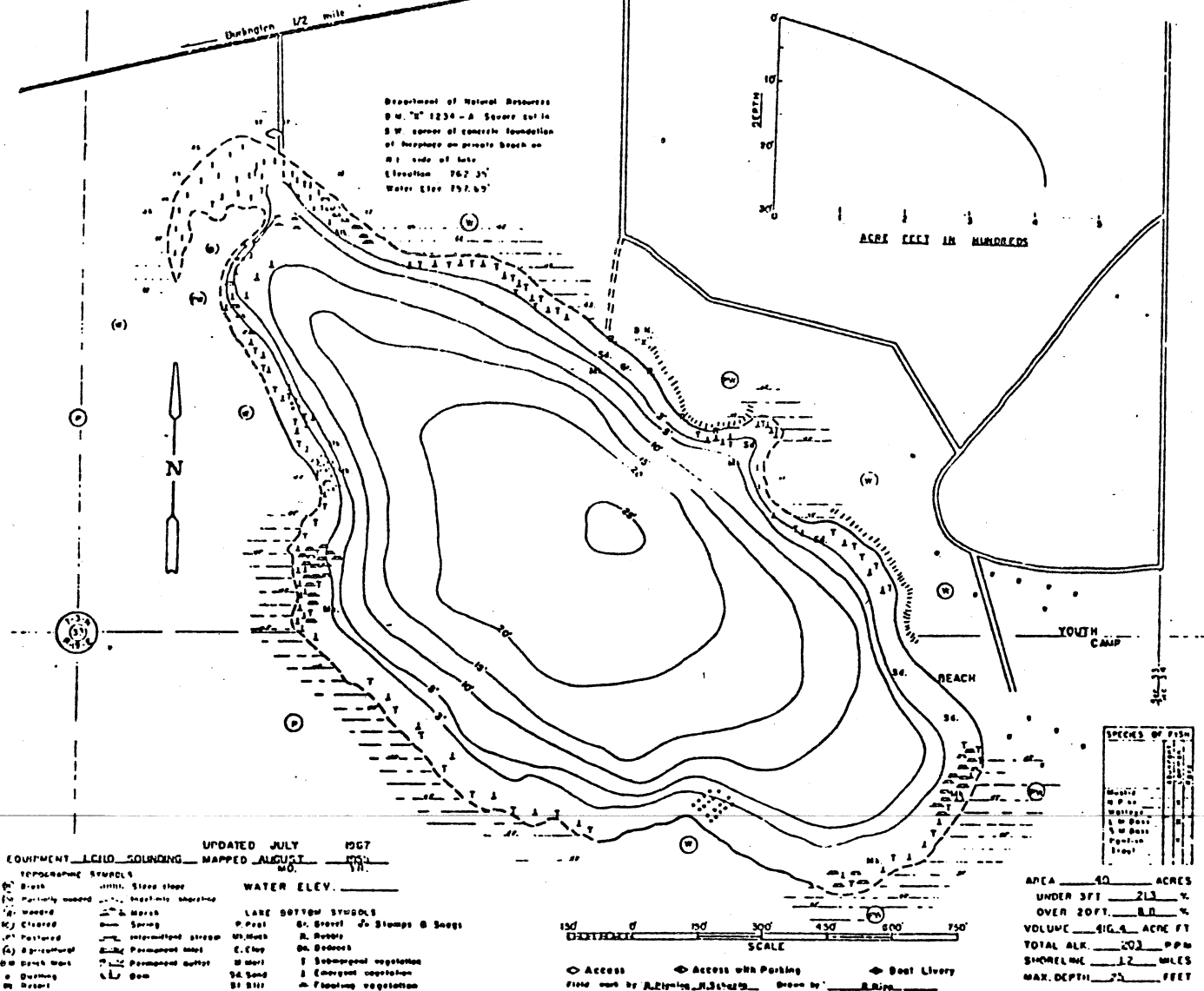
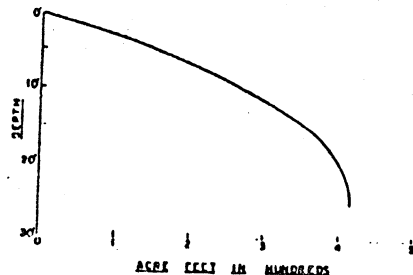
maximum depth = 7.6 m

STATE OF WISCONSIN
DEPARTMENT OF NATURAL RESOURCES

LAKE SURVEY MAP

ROCKLAND LAKE
HARCIN COUNTY
SEC. 33 T. 3 N. R. 1 E.

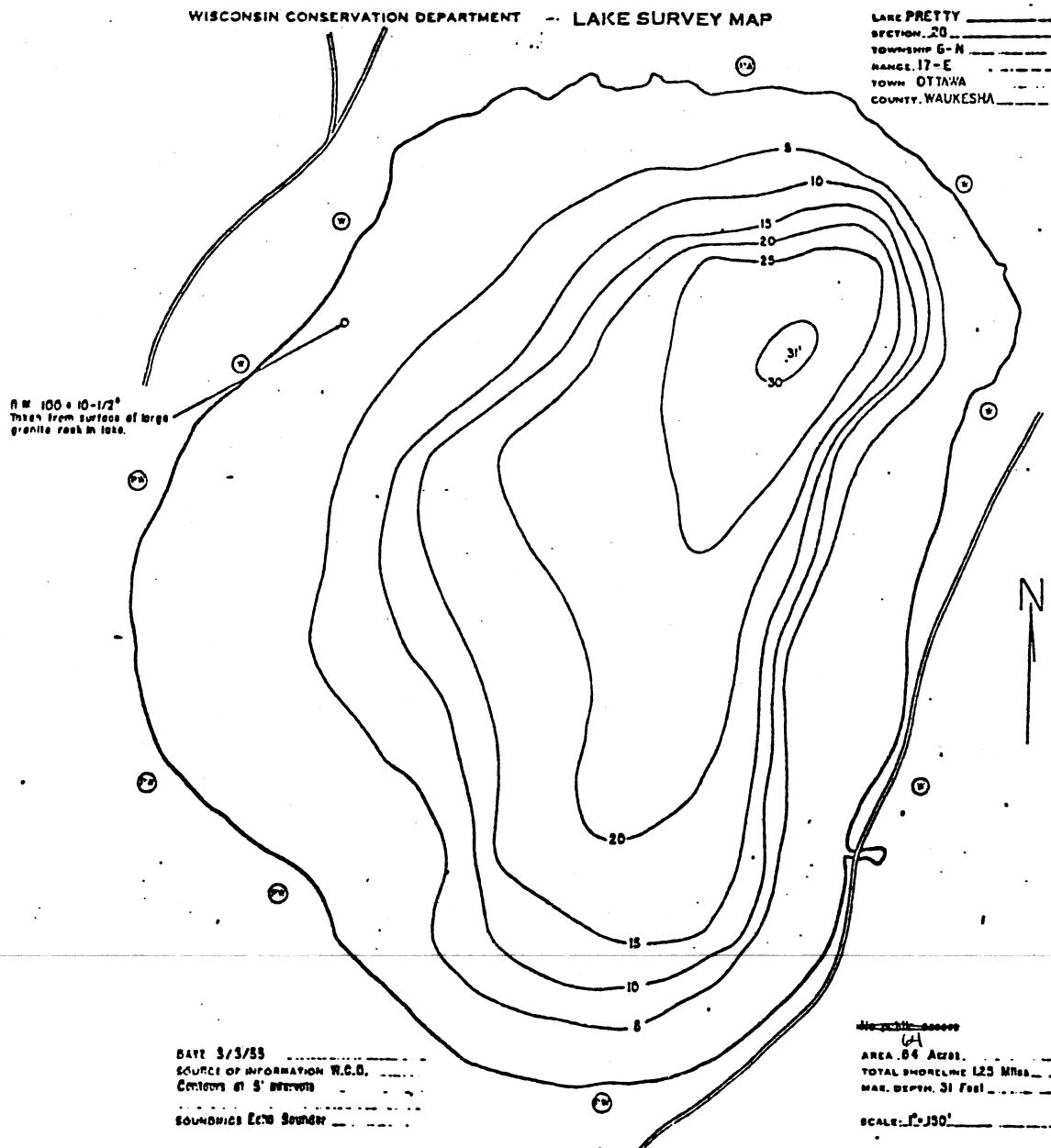
Department of Natural Resources
B.M. "A" 1234 - A Square set in
S.W. corner of concrete foundation
of barge on private beach on
N.E. side of lake
Elevation 762.35'
Water Elev 757.65'



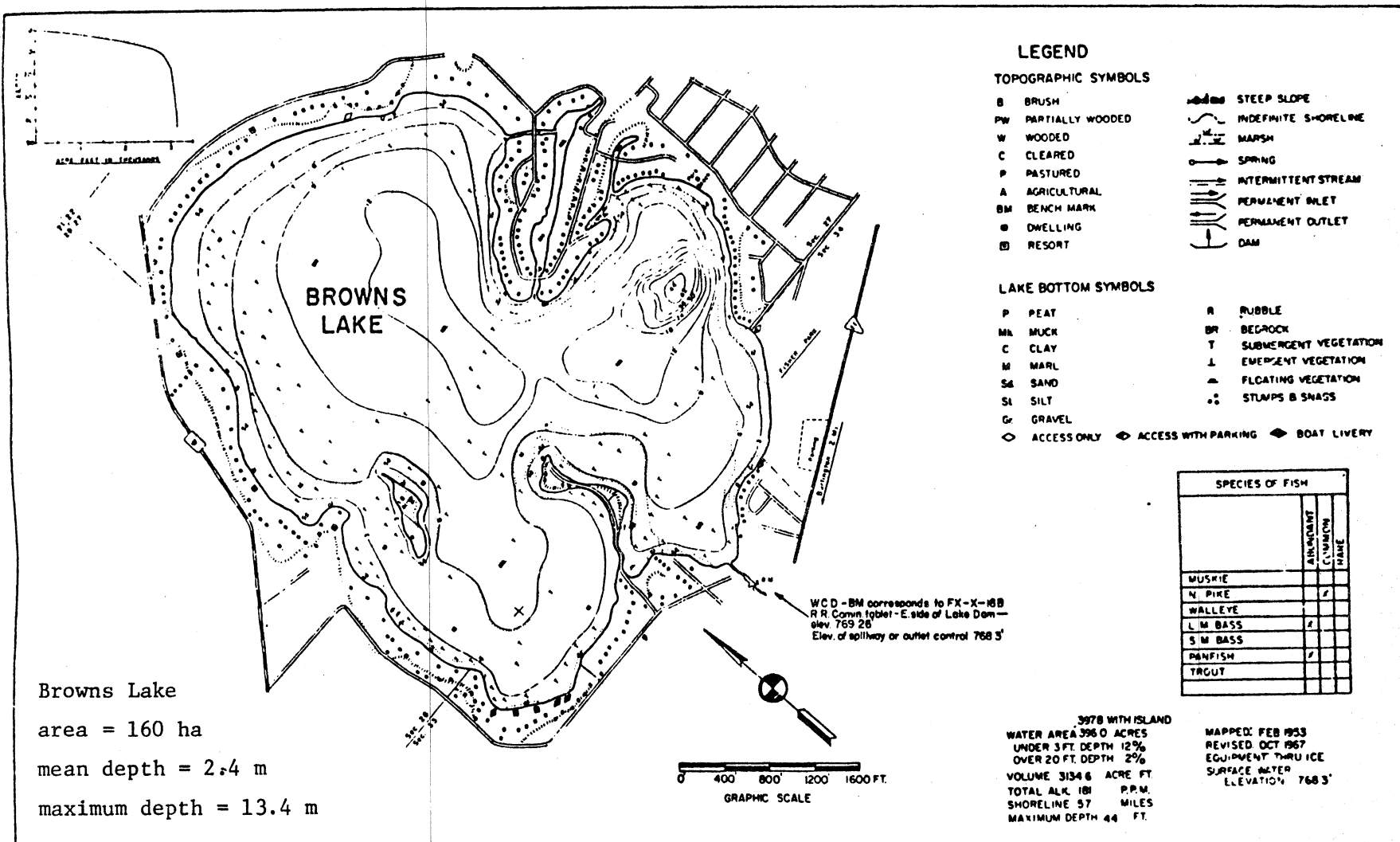
Appendix B (continued)

Pretty Lake
area = 26 ha

mean depth = 3.7 m
maximum depth = 9.5 m



Appendix B (continued)



Appendix B (continued)

Appendix C

Composition of water samples from the four study lakes. All units are mg/l unless indicated otherwise.

	Browns Lake				Rockland Lake			Beulah Lake			Pretty Lake				
Date:	IV/13/81				IV/13/81			IV/6/66	IX/12/66	IX/12/65	III/14/80			IV/17/80	
Depth:	0.3	1.8	6.7	13.4	0.3	3.7	7.3	0.9	2.7	6.4	0	6.1	9.5	0	9.1
Analysis															
pH (units)	--	--	--	--	--	--	--	8.3	8.1	8.0	8.2	8.1	8.2	8.3	8.4
Turbidity (NTU*)	0.8	0.8	0.8	1.3	1.1	1.5	1.5	--	--	--	--	--	--	--	--
Color	17	29	20	52	39	35	46	--	--	--	--	--	--	--	--
SO ₄	34	33	34	38	11	13	17	26.3	29.3	28.0	--	--	--	--	--
Conductivity (mho/cm)	535	525	525	525	545	525	525	379	410	410	380	400	420	360	360
Alkalinity	156	152	156	156	214	218	218	182	200	203	128	136	140	142	140
Total Hardness	260	216	232	216	252	260	--	--	--	--	--	--	--	--	--
Ca ⁺⁺ Hardness	100	88	88	92	112	112	116	29.3	18.0	19.2	22	25	26	37	37
Dissolved Oxygen	9.2	9.6	8.7	8.3	9.1	8.5	7.4	--	--	--	13.2	5.4	1.1	11.3	10.9
Chemical Oxygen Demand	22	23	21	26	35	28	28	--	--	--	--	--	--	--	--
Ortho-P	.022	.020	.016	.030	.001	.001	.001	0.12	--	0.07	.004	.004	.005	.004	.004
Total-P	.046	.050	.054	.070	.024	.032	.030	--	0.11	0.10	.02	.02	.02	.02	.02
NH ₄ -N	0	.07	--	0	0	--	0	--	--	--	0.21	0.36	0.60	0.15	0.19
NO ₂ /NO ₃ -N	0.14	0.21	--	0	0.14	--	0	--	--	--	0.11	0.14	0.12	0.15	0.19
Kjeldahl-N	0.84	1.82	--	0.70	0.98	--	1.96	--	--	--	0.6	0.6	0.5	0.6	0.6
Cl ⁻	52	54	--	54	33	--	32	2.5	4.0	4.2	16	17	18	14	14
Total Residue	310	327	--	323	321	--	300	--	--	--	--	--	--	--	--
Filtrable Residue	294	274	--	320	292	--	292	--	--	--	--	--	--	--	--
Nonfiltrable Residue	10	30	--	40	32	--	30	--	--	--	--	--	--	--	--
Na ⁺	20	20	21	21	12	11	11	3.4	3.1	3.1	8	8	8		
K ⁺	0.8	1.2	.9	1.1	4.5	4.6	4.6	1.5	1.3	1.3	1.6	1.6	1.8	1.5	1.5
Mg	--	--	--	--	--	--	--	28.8	27.6	28.3	24	24	26	22	22
Total Fe	--	--	--	--	--	--	--	.01	.01	.04	--	--	--	--	--

Mean length (L) of fish compared with a two-sample t-test (Zar 1974; p. 105) among fyke net and electrofishing samples. All statistical tests were at the 0.05 level of significance.

Species	Lake	Sample	L	n	SD	t	df	Significant difference	No significant difference	
Fyke Nets vs Spring Electrofishing										
Bluegill	Beulah	Fyke	144	4740	28.1	2.524	5,017	X		
		Spring	140	279	27.4					
	Rockland	Fyke	131	797	32.6	5.419	1,246	X		
		Spring	122	451	26.1					
	Pretty	Fyke	108	1704	25.8	4.783	2,560	X		
		Spring	103	858	22.5					
	Browns	Fyke	112	9538	15.9	2.273	10,215	X		
		Spring	110	679	13.7					
Pumpkinseed	Beulah	Fyke	113	278	19.6	1.018	311		X	
		Spring	136	35	23.3					
	Pretty	Fyke	131	270	23.0	1.837	391		X	
		Spring	136	123	28.3					
	Browns	Fyke	113	1208	19.3	0.772	1,417		X	
		Spring	111	211	20.0					
	Yellow perch	Fyke	157	142	31.6	1.848	232		X	
		Spring	150	92	26.0					
Wormouth	Beulah	Fyke	133	200	22.6	2.875	244	X		
		Spring	143	46	17.6					
	Pretty	Fyke	107	239	23.5	4.226	277	X		
		Spring	123	40	18.2					
	Spring Electrofishing vs Fall Electrofishing									
	Bluegill	Beulah	Spring	140	279	27.4	6.497	529	X	
			Fall	154	252	22.4				
		Rockland	Spring	122	451	26.1	6.104	916	X	
Fall			133	467	30.2					
Pretty		Spring	103	858	22.5	18.757	1,558	X		
		Fall	124	702	19.5					
Browns		Spring	110	679	12.7	10.382	1,519	X		
		Fall	117	36	22.1					
Pumpkinseed	Browns	Spring	111	211	20.0	3.463	245	X		
		Fall	99	36	22.1					
Yellow perch	Browns	Spring	104	89	9.2	8.066	161	X		
		Fall	119	74	15.3					
Largemouth bass	Beulah	Spring	223	333	64.3	1.490	495		X	
		Fall	232	164	63.3					
	Rockland	Spring	209	787	55.2	3.216	1,101	X		
		Fall	222	316	59.9					
	Pretty	Spring	210	227	55.3	3.167		X		
		Fall	242	55	94.9					
	Browns	Spring	296	301	80.1	6.261	370	X		
		Fall	360	71	64.7					

Appendix E

Length-frequency distributions of bluegills, pumpkinseeds, yellow perch, green sunfish, and warmouth in electrofishing samples in spring and fall of 1980 and 1981 from the four study lakes.

BEULAH LAKE																				
Length group (mm)	Bluegill				Pumpkinseed				Yellow perch				Green sunfish				Warmouth			
	Spring 1980	Fall 1980	Spring 1981	Fall 1981	Spring 1980	Fall 1980	Spring 1981	Fall 1981	Spring 1980	Fall 1980	Spring 1981	Fall 1981	Spring 1980	Fall 1980	Spring 1981	Fall 1981	Spring 1980	Fall 1980	Spring 1981	Fall 1981
0-9	1																			
20-29									1											
50-59	1				1								1							
60-69											1				1					
70-79	2			1									2							
80-89	7	1		2									4							
90-99	14	4		4		1							3	1						
100-109	9	5	1	3		1			1	1			4		1	2		1		1
110-119	16	10	1	8	2	1			10				4	1			3	1		
120-129	15	9	7	9	2	1		2	13	1			3	1			5			1
130-139	22	15	18	3	3	6	1	1	7		1	1	2	1			7	4		
140-149	24	13	16	19	6	3			7	3	1	1		3			4	1	1	1
150-159	21	16	21	22	1	1			9	6	2	1	1				7	6		1
160-169	15	15	27	19	2	1			7	5	1	3					4	1		
170-179	11	24	27	23	1	1	1		4	4	2	5					1			
180-189	3	5	11	9					3	6	1	2						1		
190-199	1	1		1					2	1		3								
200-209									2		1	1								
230-239												1								
Total	162	118	129	123	18	16	2	3	66	27	10	20	27	7	1	3	31	15	1	4

Appendix E (continued)

ROCKLAND LAKE																				
Length group (mm)	Bluegill				Pumpkinseed				Yellow perch				Green sunfish				Wormouth			
	Spring 1980	1981	Fall 1980	1981	Spring 1980	1981	Fall 1980	1981	Spring 1980	1981	Fall 1980	1981	Spring 1980	1981	Fall 1980	1981	Spring 1980	1981	Fall 1980	1981
0-9																				
10-19	1																			
20-29	1																			
30-39	1		3	1																
40-49	3																			
50-59			2	4																
60-69	1	1	5	4		1														1
70-79	10	4	1	1		1	1	2			1	1		1	1			5	2	
80-89	11	2		2			1							1				2	1	
90-99	31	16	5	27					1							1		1		
100-109	90	26	5	63	2		1		1					2	1			1	1	
110-119	47	16	10	46	4	3	1	3	5			4						5	1	
120-129	15	18	24	27	8	5	1		13	1		2		1			1	3	3	
130-139	15	20	19	18	7	5	1	1	14	10	3		1					6	2	
140-149	30	25	19	35	3	2			10	12	5	1		1				2	1	
150-159	19	14	24	21	2	2		1	2	11	3	2		1			1	2		
160-169	15	3	17	22		1				7	1		1					2	1	
170-179	8	4	14	28						5	1	1						1		
180-189	4	5	6	13						2								1		
190-199	1		1	3						1										
200-209				1								1					1			
210-219																				
Total	303	154	155	316	26	20	6	7	46	49	14	12	2	7	2	1	3	31	13	

Appendix E (continued)

		P R E T T Y L A K E														
Length group (mm)	Bluegill				Pumpkinseed				Yellow Perch				Warmouth			
	Spring		Fall		Spring		Fall		Spring		Fall		Spring		Fall	
	1980	1981	1980	1981	1980	1981	1980	1981	1980	1981	1980	1981	1980	1981	1980	1981
0-9	1															
50-59	2															
60-69	19			1												
70-79	60	2		2	1											
80-89	175	10		1	4	1										
90-99	120	48	22	16	2	3								1		
100-109	64	78	55	82	1	6					1		5	3		
110-119	41	60	44	124	3	15		1					6	5		2
120-129	43	31	32	102	8	16		1					8	1		1
130-139	23	17	34	47	3	7	2	2	2				5	1		
140-149	14	11	28	27	3	9		1	2		1		1			
150-159	11	9	28	14	5	6	1				2		1	1		
160-169	8	4	14	16	3	10					1					
170-179	4	1	4	7	3	4	2	3	3		2		2			
180-189	2		1	1	4	2		2	5		1					
190-199	1				3	1			2			1				
230-239										1						
240-249										1						
Total	588	271	262	440	43	80	5	10	14	2	6	3	28	12	0	3

Appendix E (continued)

BROWN S LAKE																
Length group (mm)	Bluegill				Pumpkinseed				Yellow perch				Green sunfish			
	Spring		Fall		Spring		Fall		Spring		Fall		Spring		Fall	
	1980	1981	1980	1981	1980	1981	1980	1981	1980	1981	1980	1981	1980	1981	1980	1981
0-9																
10-19																
20-29																
30-39																
40-49																
50-59	2															
60-69																
70-79				4	2			7	1							
80-89	12	5	1	6	31			9	2		1			1		
90-99	71	41	9	39	33	12		7	15	10	1			1		
100-109	115	104	65	101	21	7	1	3	26	14	7	9				1
110-119	70	130	167	92	16	5		1	9	8		23				
120-129	27	56	103	127	25	10	1	1	2	2		19			1	
130-139	10	20	37	56	20	15	2	2				8	1		1	
140-149	2	5	9	15	6	3	1	1				4				
150-159	3	1	3	5	4							1				
160-169	2	1	1	1	1									1		
170-179																
180-189	2															
Total	316	363	395	446	159	52	5	31	55	34	9	65	3	1	2	1

Appendix F

Age frequency distributions (%) of largemouth bass and bluegills in Beulah, Rockland, Pretty, and Browns Lakes, and pumpkinseeds in Browns Lake, in individual and combined electrofishing samples in spring and fall of 1980-1981. N is the sample size for each period.

Species	Lake	Period	1	2	3	4	5	6	Age 7	8	9	10	11	12	13	14	N
Largemouth bass	Beulah	Spring 1980-81	0.0	29.4	52.9	10.4	3.5	1.8	0.0	0.3	0.3	0.3	0.0	0.3	0.6	0.3	333
		Spring 1980-81 & Fall 1980	0.2	26.1	50.9	14.0	4.8	1.8	0.0	0.7	0.2	0.2	0.0	0.2	0.5	0.2	408
		Spring 1981	0.0	27.2	55.2	10.7	2.9	2.3	0.0	0.0	0.0	0.0	0.0	0.6	0.6	0.6	173
		Spring 1980	0.0	33.1	49.4	9.4	4.4	1.3	0.0	0.6	0.6	0.6	0.0	0.0	0.6	0.0	160
		Fall 1980	1.3	10.7	43.3	30.7	10.0	1.3	0.0	2.7							75
	Rockland	Spring 1980-81	2.4	38.6	50.1	4.3	1.8	0.6	0.6	0.0	0.4	0.7	0.4	0.1			795
		Spring 1980-81 & Fall 1980	3.1	34.7	52.1	5.9	1.4	0.7	0.7	0.0	0.3	0.7	0.4	0.1			969
		Spring 1980	1.5	66.1	24.4	2.7	3.2	0.3	0.6	0.0	0.3	0.9					330
		Spring 1981	1.7	7.3	81.3	5.8	0.7	0.7	0.7	0.0	0.4	0.4	0.9	0.2			465
		Fall 1980	5.2	11.5	63.8	16.7	0.0	1.1	1.1	0.0	0.0	0.6					174
	Pretty	Spring 1980-81	1.3	29.8	57.6	7.8	3.0	0.4									230
		Spring 1980-81 & Fall 1980	1.6	29.3	57.0	9.0	2.8	0.4									251
		Spring 1981	0.0	34.0	78.0	7.0											119
		Spring 1980	2.7	31.5	48.6	9.9	6.3	0.9									111
		Fall 1980		28.6	52.4	19.0											21
	Browns	Spring 1980-81	0.0	2.3	32.7	23.8	21.6	14.3	2.5	2.5	0.3						301
		Spring 1980-81 & Fall 1980	0.0	2.2	30.9	23.3	21.6	16.7	2.3	2.8	0.3						324
		Spring 1981	0.0	0.0	31.0	32.5	3.6	18.6	5.8	4.7	0.7						137
		Spring 1980	0.0	4.3	34.8	17.1	34.1	8.5	0.6	0.6							164
		Fall 1980	0.0	0.0	8.7	17.4	17.4	47.8	4.3	4.3							23

Appendix F (continued)

Species	Lake	Period	1	2	3	4	5	6	Age 7	8	9	10	11	12	13	14	N
Bluegill	Beulah	Spring 1980-81	0.0	0.4	14.0	22.0	26.0	13.4	8.8	9.1	3.0	1.8	1.4				279
		Spring 1980-81 & Fall 1980	0.0	0.3	9.6	16.8	23.2	15.4	12.4	10.2	5.5	4.7	1.6	0.5			408
		Spring 1981	0.0	0.0	11.0	22.5	23.1	21.1	7.7	9.1	2.6	0.9	2.0				118
		Spring 1980	0.0	0.6	15.5	21.1	29.8	8.7	9.6	9.0	2.8	2.2	0.6				161
		Fall 1980				5.4	15.5	20.3	19.0	11.0	13.2	11.6	1.6	2.3			129
	Rockland	Spring 1980-81	0.9	6.2	50.1	20.5	12.5	4.9	4.0	0.8	0.2						455
		Spring 1980-81 & Fall 1980	1.5	5.4	37.3	28.5	12.9	6.7	4.5	2.1	0.7	0.3	0.2				610
		Spring 1981	0.0	4.5	39.0	42.1	5.1	6.0	2.5	0.7							154
		Spring 1980	1.3	8.0	55.5	7.3	17.4	4.3	4.7	1.0	0.5						301
		Fall 1980	3.2	3.9	7.1	43.2	13.2	12.6	6.1	6.3							155
	Pretty	Spring 1980-81	0.0	2.4	41.3	28.4	18.6	5.2	3.3	0.6	0.1						858
		Spring 1980-81 & Fall 1980	0.0	1.9	27.2	36.4	17.9	9.8	4.9	1.4	0.5						1120
		Spring 1981	0.0	0.0	8.9	49.1	32.5	7.4	1.5	0.7	0.4						271
		Spring 1980	0.0	3.6	63.9	12.1	11.5	4.3	4.1	0.5							587
		Fall 1980				41.2	12.4	27.7	10.1	6.3	2.3						262
	Browns	Spring 1980-81	0.3	0.6	3.2	13.1	53.8	20.3	8.1	0.5							679
		Spring 1980-81 & Fall 1980	0.2	0.4	1.9	7.7	49.2	33.4	6.9	0.4							1074
		Spring 1981	0.0	1.1	5.8	0.0	47.4	32.8	12.1	0.8							363
		Spring 1980	0.6	0.0	0.0	33.2	32.7	9.2	4.3								316
		Fall 1980				1.8	34.2	59.6	4.4								395
Pumpkinseed	Browns	Spring 1980-81				17.2	47.3	29.4	4.6	1.5							211
		Spring 1980-81 & Fall		10.1	6.1	13.4	37.9	25.5	5.7	1.4							247
		Spring 1981					42.3	42.3	11.5	3.8							52
		Spring 1980				26.1	48.7	23.3	1.9								159
		Fall 1980-81		38.9	25.0	8.3	8.3	11.1	8.3								36

Appendix G

Prey PSD's weighted by the number of stock-sized fish in electrofishing samples from the four lakes in spring 1980-1981. Prey species included bluegill, pumpkinseed, yellow perch, warmouth, and green sunfish in Beulah and Rockland Lakes; bluegill, pumpkinseed, yellow perch, and warmouth in Pretty Lake; and bluegill and pumpkinseed in Browns Lake. PSD's for individual species are from Appendix Y.

<u>Lake</u>	<u>Weighted prey PSD</u>
Rockland	$\frac{17(440) + 11(45) + 0(74) + 24(33) + 25(8)}{440 + 45 + 74 + 33 + 8} = 15$
Pretty	$\frac{5(808) + 34(122) + 13(16) + 10(40)}{808 + 122 + 16 + 40} = 9$
Beulah	$\frac{40(277) + 18(33) + 3(63) + 44(46) + 0(28)}{277 + 33 + 63 + 46 + 28} = 31$
Browns	$\frac{2(677) + 2(209)}{677 + 209} = 2$

Appendix H

Mean Relative Weight ($W_r\%$) of largemouth bass in 10-mm length groups from electrofishing samples in spring and fall of 1981. A subsample of 10 fish was selected randomly from length groups containing more than 21 scale samples. The mean W_r of a population was calculated by weighting the W_r of fish in each length group by the number of fish in the group.

Length group. (mm)	Beulah				Rockland				Pretty				Browns			
	Spring		Fall		Spring		Fall		Spring		Fall		Spring		Fall	
	W_r	n	W_r	n	W_r	n	W_r	n	W_r	n	W_r	n	W_r	n	W_r	n
100 - 109	--	--	--	--	--	--	--	--	125	1	--	--	--	--	--	--
110 - 119	--	--	120	1	112	3	--	--	90	1	115	1	--	--	--	--
120 - 129	--	--	--	--	--	--	--	--	98	3	--	--	--	--	--	--
130 - 139	--	--	--	--	114	2	--	--	105	4	102	2	--	--	--	--
140 - 149	--	--	106	1	--	--	--	--	103	4	--	--	--	--	--	--
150 - 159	102	4	106	1	103	2	98	1	96	9	--	--	--	--	--	--
160 - 169	97	10	102	16	100	10	104	16	93	4	104	4	85	1	--	--
170 - 179	96	18	98	16	98	15	101	13	96	12	--	--	89	3	--	--
180 - 189	92	10	99	4	102	16	103	12	92	9	89	2	93	4	--	--
190 - 199	95	9	102	5	97	10	99	6	91	7	89	3	91	4	--	--
200 - 209	92	21	88	2	95	10	97	5	90	16	105	1	91	5	101	1
210 - 219	91	21	96	1	100	10	93	1	92	16	95	1	98	9	--	--
220 - 229	93	17	90	3	94	10	97	3	91	11	93	1	89	7	--	--
230 - 239	93	3	--	--	97	9	89	7	94	5	101	1	98	8	--	--
240 - 249	91	10	99	2	91	9	92	10	93	8	84	2	100	11	94	1
250 - 259	89	9	91	2	97	15	95	6	85	1	84	1	96	7	--	--
260 - 269	92	7	93	7	99	3	89	21	93	4	127	1	101	8	--	--
270 - 279	87	3	91	3	93	1	93	16	93	1	--	--	103	6	99	1
280 - 289	91	6	96	2	113	1	88	2	87	2	83	1	97	3	--	--
290 - 299	94	8	98	3	89	4	90	4	100	2	90	4	102	4	106	1
300 - 309	101	2	91	3	89	5	80	1	106	1	--	--	91	6	111	3

Appendix H (continued)

Length group (mm)	Beulah				Rockland				Pretty				Browns			
	Spring		Fall		Spring		Fall		Spring		Fall		Spring		Fall	
	W _r	n	W _r	n	W _r	n	W _r	n	W _r	n	W _r	n	W _r	n	W _r	n
310 - 319	107	1	--	--	--	--	--	--	86	1	--	--	100	1	102	2
320 - 329	97	2	92	1	84	1	--	--	90	2	--	--	105	3	113	5
330 - 339	91	1	102	2	110	1	--	--	100	1	99	3	98	1	101	3
340 - 349	99	4	91	1	--	--	86	1	87	1	93	1	97	5	111	4
350 - 359	94	1	89	1	--	--	--	--	92	2	91	1	103	3	105	2
360 - 369	97	1	--	--	92	3	--	--	94	1	90	2	106	9	111	4
370 - 379	91	1	--	--	--	--	87	1	--	--	94	1	105	9	114	2
380 - 389	95	1	--	--	102	1	--	--	92	3	--	--	99	4	119	1
390 - 399	--	--	--	--	93	2	--	--	89	1	--	--	106	10	113	2
400 - 409	--	--	88	1	--	--	--	--	--	--	99	2	106	4	111	2
410 - 419	--	--	--	--	103	2	--	--	--	--	94	1	112	6	110	4
420 - 429	--	--	99	1	--	--	--	--	95	1	91	1	104	3	115	2
430 - 439	--	--	--	--	93	1	--	--	--	--	--	--	107	1	110	3
440 - 449	--	--	--	--	--	--	--	--	92	3	--	--	100	1	--	--
450 - 459	--	--	--	--	101	2	101	1	--	--	100	1	100	2	107	3
460 - 469	--	--	--	--	93	1	94	2	--	--	102	1	--	--	--	--
470 - 479	--	--	--	--	96	1	100	1	--	--	--	--	--	--	--	--
480 - 489	--	--	--	--	90	1	--	--	--	--	--	--	--	--	--	--
490 - 499	--	--	--	--	97	1	--	--	--	--	--	--	108	1	114	1
500 - 509	--	--	101	1	91	2	--	--	--	--	--	--	--	--	--	--
510 - 519	--	--	--	--	84	1	80	1	--	--	--	--	--	--	--	--
520 - 529	--	--	--	--	117	1	--	--	--	--	--	--	--	--	--	--
550 - 559	96	2	--	--	--	--	--	--	--	--	--	--	--	--	--	--
560 - 569	87	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Total	174		80		146		132		137		35		149		47	
Mean W _r -	93		98		97		95		94		97		100		109	

Appendix I

Mean Relative Weight (W_r %) of bluegills in 10-mm length groups from electrofishing samples in fall of 1980, and spring and fall of 1981. A subsample of 10 fish was selected randomly from length groups containing more than 12 scale samples. The mean W_r of a population was calculated by weighting the W_r of fish in each length group by the number of fish in the group.

Length group (mm)	Beulah						Rockland						Pretty						Browns					
	1980		1981		1981		1980		1981		1981		1980		1981		1981		1980		1981		1981	
	Fall	n	Spring	n	Fall	n	Fall	n	Spring	n	Fall	n	Fall	n	Spring	n	Fall	n	Fall	n	Spring	n	Fall	n
70 - 79	--	--	--	--	72	1	--	--	98	4	--	--	--	--	111	2	69	2	--	--	--	--	88	4
80 - 89	--	--	91	1	79	2	--	--	111	2	85	2	76	3	88	10	53	1	--	--	76	5	84	6
90 - 99	--	--	89	4	94	4	102	5	95	11	87	10	85	10	83	10	61	10	87	9	81	10	82	10
100 - 109	90	1	101	5	96	3	103	5	89	10	88	10	78	11	90	10	72	10	83	9	82	11	89	10
110 - 119	94	1	95	11	96	8	96	11	89	10	94	10	79	10	89	10	73	10	87	10	86	10	81	10
120 - 129	95	7	98	8	89	9	97	10	94	10	91	10	83	10	91	10	76	10	87	10	83	10	81	10
130 - 139	91	10	98	10	86	3	96	10	94	10	89	10	86	10	81	9	75	10	85	9	82	12	79	10
140 - 149	89	10	100	10	87	10	97	10	96	11	88	10	77	10	92	11	76	10	81	9	83	5	76	10
150 - 159	88	10	100	10	86	9	94	10	96	10	88	10	76	10	94	10	80	10	86	3	92	1	83	5
160 - 169	86	10	99	10	86	10	94	10	97	3	88	10	77	10	84	5	79	10	91	1	107	1	81	1
170 - 179	83	9	92	10	88	11	90	10	98	4	88	11	78	4	80	1	83	7						
180 - 189	78	11	96	5	81	9	87	6	93	5	88	12					80	1						
190 - 199			88	1	71	1	90	1			87	3												
200 - 209											90	1												
Totals	69		85		80		88		90		109		88		83		91		60		65		76	
Mean W_r =	87		97		87		95		94		89		80		88		74		86		84		83	
Mean W_r of fish 80-140 mm long =			97						92				88								83			

Appendix J

Length at age compared with a paired t-test (Zar 1974; p. 121) among samples and with the Wisconsin state averages. All statistical tests were at the 0.05 level of significance. Where a significant difference occurred, the first sample had the larger value.

Species	Samples compared	t	df	Ages	Significant difference	No Significant difference
Bluegill	Beulah vs Rockland	0.915	9	1-10		X
	Beulah vs Pretty	2.376	8	1-9	X	
	Beulah vs Browns	0.942	8	1-9		X
	Rockland vs Pretty	3.123	8	1-9	X	
	Rockland vs Browns	1.363	8	1-9		X
	Pretty vs Browns	1.042	8	1-9		X
	State average vs Beulah	6.513	8	1-9	X	
	State average vs Rockland	5.169	8	1-9	X	
	State average vs Pretty	6.184	8	1-9	X	
	State average vs Browns	5.298	8	1-9	X	
	Beulah vs Rockland	2.712	4	3-7		X
	Beulah vs Pretty	7.362	4	3-7	X	
	Beulah vs Browns	5.702	4	3-7	X	
	Rockland vs Pretty	9.258	4	3-7	X	
	Rockland vs Browns	6.426	4	3-7	X	
	Pretty vs Browns	1.607	4	3-7		X
	Pretty 1977-78 vs Pretty 1980-81	6.865	3	3-6	X	
Pumpkinseed						
	State average vs Browns	3.156	5	1-6	X	
Largemouth bass	Rockland vs Beulah	2.548	8	1-9	X	
	Pretty vs Beulah	2.490	6	1-7	X	
	Browns vs Beulah	2.673	7	108	X	
	Pretty vs Rockland	3.152	6	1-7	X	
	Rockland vs Browns	0.412	7	1-8		X
	Pretty vs Browns	1.574	6	1-7		X
	State average vs Beulah	2.555	6	1-7	X	
	State average vs Rockland	1.428	6	1-7		X
	State average vs Pretty	1.015	6	1-7		X
	State average vs Browns	0.843	6	1-7		X
	Browns 1980-81 vs Browns 1953-57	0.649	6	1-7		X
	Pretty 1980-81 vs Pretty 1977-78	0.418	6	1-7		X

Appendix K

Length increments (mm) and instantaneous growth rates (G) of bluegills and largemouth bass in the four study lakes, and pumpkinseeds in Browns Lake.

Species	Lake	1-2	2-3	3-4	4-5	5-6	6-7	Age 7-8	8-9	9-10	10-11	11-12	12-13
<u>Length increments</u>													
Bluegill	Beulah	28.6	29.4	27.9	23.1	17.2	10.7	7.5	6.4	6.1	5.8	6.6	
	n	1	37	51	54	37	29	24	13	12	4	1	
	Rockland	27.3	30.4	35.7	28.5	26.8	14.8	10.6	11.4	9.4	8.6		
	n	38	82	86	41	38	22	13	7	3	2		
Pretty	27.9	21.5	15.7	16.2	12.5	10.1	8.5	7.5					
	n	4	2	23	73	72	31	12	6				
Browns	27.9	17.1	15.9	18.9	12.8	8.9	9.6						
	n	15	9	19	59	45	14	2					
Pumpkinseed	Browns	27.9	17.1	15.9	18.9	12.8	8.9	9.6					
	n	15	9	19	59	45	14	2					
Largemouth bass	Beulah	83.3	65.2	50.4	31.7	37.7	30.5	21.5	18.2	12.6	--	--	12.6
	n	81	174	73	30	12	6	5	2	1			1
	Rockland	86.4	81.7	54.7	45.9	36.7	41.3	12.4	20.1	18.6	19.6	9.3	
	n	109	181	44	13	8	7	2	3	5	3	1	
Pretty	57.8	73.2	52.2	39.7	37.6	26.1							
	n	75	130	31	9	5	5						
Browns	74.0	80.3	80.4	41.2	28.8	21.0	16.9	12.9	--	--	--		8.6
	n	19	128	93	71	62	13	9	1				1
<u>Instantaneous growth rates</u>													
Bluegill	Beulah	2.121	1.307	0.905	0.616	0.393	0.226	0.160	0.129	0.118	0.109	0.139	
	n	1	37	51	54	37	29	24	13	12	4	1	
	Rockland	1.640	1.202	1.014	0.733	0.560	0.298	0.206	0.225	0.186	0.167		
	n	38	82	86	41	38	22	13	7	3	2		
Pretty	0.714	0.601	0.545	0.463	0.365	0.231	0.138	0.107					
	n	13	46	73	63	50	40	13	5				
Browns	1.428	0.8181	0.657	0.548	0.358	0.248	0.188	0.143					
	n	4	2	23	73	72	31	12	6				
Pumpkinseed	Browns	1.523	0.733	0.674	0.659	0.395	0.256	0.294					
	n	15	9	19	59	45	14	2					
Largemouth bass	Beulah	2.257	1.078	0.643	0.361	0.344	0.297	0.190	0.177	0.101	--	--	0.072
	n	81	174	73	30	12	6	5	2	1			1
	Rockland	2.503	1.354	0.686	0.401	0.302	0.297	0.108	0.142	0.129	0.132	0.063	
	n	109	181	44	13	8	7	2	3	5	3	1	
Pretty	1.632	1.231	0.600	0.397	0.301	0.191							
	n	75	130	31	9	5	5						
Browns	2.320	1.433	1.073	0.386	0.254	0.183	0.136	0.102	--	--	--		0.067
	n	19	128	93	71	62	13	9	1				1

Appendix L

Length increments compared with a paired t-test (Zar 1974; p. 121) among samples. All statistical tests were at the 0.05 level of significance. Where a significant difference occurred, the first sample had the larger value.

Species	Samples compared	t	df	Ages	Significant difference	No significant difference
Bluegill	Rockland vs Beulah	4.740	6	2-9	X	
	Beulah vs Pretty	0.318	6	2-9		X
	Beulah vs Browns	1.731	5	3-9		X
	Rockland vs Pretty	2.985	7	1-9	X	
	Rockland vs Browns	3.306	5	3-9	X	
	Pretty vs Browns	3.787	5	3-9	X	
Largemouth bass	Rockland vs Beulah	2.836	5	1-7	X	
	Beulah vs Pretty	0.403	5	1-7		X
	Beulah vs Browns	0.544	6	1-8		X
	Rockland vs Pretty	2.309	5	1-7		X
	Rockland vs Browns	0.545	5	1-7		X
	Pretty vs Browns	1.153	5	1-7		X

Appendix M

Instantaneous growth rates (G) compared with a Wilcoxon paired-sample test (Zar 1974; p.124-126) among bluegill and largemouth bass samples. All statistical tests were at the 0.05 level of significance, and N was the number of pairs. Where a significant difference occurred, the first sample had the larger value.

Species	Samples compared	T	N	Significant difference	No significant difference
Bluegill	Beulah vs Rockland	4	7		X
	Beulah vs Pretty	1	7	X	
	Beulah vs Browns	6	6		X
	Rockland vs Pretty	0	8	X	
	Rockland vs Browns	0	7	X	
	Browns vs Pretty	1	7	X	
Largemouth bass	Beulah vs Rockland	3.5	6		X
	Beulah vs Pretty	6	6		X
	Beulah vs Browns	11	7		X
	Rockland vs Pretty	0	6	X	
	Rockland vs Browns	5	6		X
	Pretty vs Browns	6	6		X

Appendix N

Empirical, functional GM regression (Ricker 1975) of total length (mm) on scale radius for largemouth bass, bluegills, and pumpkinseeds, and the number of fish of each age sampled in the four study lakes. Standard y-intercepts proposed by Carlander were 20 mm for largemouth bass and bluegills, and 25 mm for pumpkinseeds.

Species	Lake	Regression equation		
		y	y-intercept (mm)	slope
Largemouth bass	Beulah	y =	11.70	+ 1.58 x
	Rockland	y =	6.70	+ 1.55 x
	Pretty	y =	39.91	+ 1.43 x
	Browns	y =	28.72	+ 1.43 x
Bluegill	Beulah	y =	18.15	+ 1.10 x
	Rockland	y =	20.14	+ 1.08 x
	Pretty	y =	22.15	+ 1.16 x
	Browns	y =	25.74	+ 1.02 x
Pumpkinseed	Browns	y =	31.94	+ 0.84 x

Number of fish of each age															
		Age													Total
		1	2	3	4	5	6	7	8	9	10	11	12	13	
Largemouth bass	Beulah	2	81	174	73	30	12	6	5	2	1			1	387
	Rockland	22	109	181	44	13	8	7	2	3	5	3	1		398
	Pretty	4	75	130	31	9	5	5							259
	Browns	2	19	128	93	71	62	13	9	1				1	399
Bluegill	Beulah	0	1	37	51	54	37	29	24	13	12	4	1		263
	Rockland	11	38	82	86	41	38	22	13	7	3	2			343
	Pretty	0	13	46	73	63	50	40	13	5					303
	Browns	2	4	2	23	73	72	31	12	6					225
Pumpkinseed	Browns	1	15	9	19	59	45	14	2						164

Appendix O

Estimates (%) of total annual mortality (A), annual expectation of death by natural causes (v), and annual exploitation rates (u) for largemouth bass, bluegills and pumpkinseeds from several lakes.

Lake and Location	A	v	u	Source
Largemouth bass				
Fort Smith, Ark.	38	6	32	Cole 1966
Sutherland, Calif.	70	34	36	La Faunce et. al. 1964
Merle Collins, Calif.	71-92	11-56	36-65	Rawstron & Hashagen 1972
Folsom, Calif.	89	49	40	Rawstron 1967
Ridge, Ill.	35-40	5-11	25-30	Bennett 1954
Gordy, Ind.	60	24	36	Gerking 1952
Whitmore, Mich.	42	20	22	Cooper & Shafer 1954
Sugarloaf, Mich.	70	35	35	Cooper & Latta 1954
Dollar, Mich.	--	--	36	Patriarche 1959
Gladstone, Minn.	61	47	14	Maloney et. al. 1962
Murphy Flowage, WI.	48	21	27	Snow 1978b
Bluegill				
Muskellunge, Ind.	60	41	19	Ricker 1945
Shoe, Ind.	71	46	24	Ricker 1945
Spear, Ind.	77	41	36	Ricker 1955
Gordy, Ind.	82	47	35	Gerking 1952
Sugarloaf, Mich.	66	41	25	Cooper & Latta 1954
Dollar, Mich.	--	--	36	Patriarche 1959
Escabana, WI.	--	--	33	Kempinger et. al. 1975
Pumpkinseed				
Spear, Ind.	88	--	--	Ricker 1955
Muskellunge, Ind	80	--	--	Ricker 1945
Dollar, Mich.	--	--	20	Patriarche 1959
Escanaba, WI.	--	--	13-41	Kempinger et. al. 1975
Murphy Flowage, WI.	59-87	--	--	Snow 1978b

*From Goedde 1980, Appendix L

Appendix P

Estimated population size, 95% confidence interval (CI), and standing stock and mean individual weight of largemouth bass in various lakes.

Lake and Location	Surface area (ha)		Estimated number (No./ha) and size (mm long)	95% CI (No./ha)	Standing stock (kg/ha)	Mean Individual weight (g)	Source and Method*
Rockland, WI	16	May 1980	77 (≥ 130)	54-113	---	---	Present Study A
"		May 1980	23 (≥ 170)	14-37	---	---	" "
"		Oct. 1980	37 (≥ 160)	24-62	---	---	" "
"		May 1981	46 (≥ 160)	38-57	13	291	" "
"		Oct. 1981	44 (≥ 160)	25-83	10	226	" "
Mid., WI	4.7	May 1976	36 (≥ 100)	17-74	13	343	Goedde 1980 A
"		May 1979	40 (≥ 100)	13-196	10	260	" "
Ross, OH	58	Oct. 1979	24 (≥ 170)	17-34	---	---	Carlisle and Savino 1981 A or B
"		April 1980	32 (≥ 170)	25-41	6	173	" "
"		Oct. 1980	23 (≥ 170)	13-50	---	---	" "
Browns, WI	160	Sept. 1953	139 (≥ 150)	---	37	266	Mraz and Threinen 1958 A
Gladstone, MN	19	1958	289 (≥ 150)	262-322	---	---	Maloney, Schupp and Scidmore 1962 C
Sugarloaf, MI	73	Oct. 1948	24 (≥ 150)	---			Cooper 1951 C
"		May 1949	5 (≥ 150)	---	3 year average=7	622	" "
"		May 1950	7 (≥ 150)	---			" "
Fife, MI	233	June 1950	8 (≥ 150)	---	4	560	" "
Cold Springs, IA	6.5	May-Sept. 1981	405 (≥ 125)	363-447	20	---	Hill 1982a, B

Standing stock estimated from cove rotenone samples

Viking, IA	74	July 1981-June 1982	103 (≥ 150)	Hill 1982b
Anita, IA	55	" "	116 (≥ 150)	"
Don Williams, IA	60	" "	29 (≥ 150)	"
Manteno, IA	6	" "	51 (≥ 150)	"
Arrowhead, IA	6	" "	15 (≥ 150)	"

*Methods: A = Schnabel

Appendix Q

Monthly catch (number/ha) and harvest (number/ha) of fishes in the four study lakes in 1980. Browns and Rockland Lakes were surveyed from 3 May through 28 September 1980, and Beulah and Pretty Lakes were surveyed from 20 May through 31 August. Catch and harvest values for largemouth bass, bluegills, and all species combined in Beulah and Pretty Lakes in May were corrected to cover the entire month.

	Beulah		Browns		Pretty		Rockland	
	catch	harvest	catch	harvest	catch	harvest	catch	harvest
Largemouth bass								
May	12.60	1.40	9.19	5.32	7.60	2.80	15.29	8.00
June	4.76	0.68	2.69	1.43	1.45	0.48	19.76	4.08
July	6.19	0.57	3.48	2.01	2.00	1.00	13.97	3.03
August	5.32	0.90	2.22	1.45	1.35	--	14.88	3.90
September	--	--	1.20	0.85	--	--	9.40	1.01
Total	28.87	3.55	18.78	11.06	12.4	4.28	73.30	20.02
Mean catch/month	7.20		3.76		3.1		14.66	
Bluegill								
May	42.80	12.00	16.65	1.67	32.3	1.30	138.74	69.99
June	27.93	21.53	55.19	10.02	33.77	17.37	139.30	66.63
July	38.02	28.60	54.67	14.88	30.99	10.79	89.53	27.70
August	23.63	11.93	23.97	7.37	48.90	15.50	73.46	38.92
September	--	--	9.90	3.07	--	--	18.44	7.38
Total	132.38	74.06	160.38	37.01	145.96	44.96	459.47	210.62
Mean catch/month	33.10		32.10		36.50		91.89	

Appendix Q (continued)

	Beulah		Browns		Pretty		Rockland	
	catch	harvest	catch	harvest	catch	harvest	catch	harvest
Pumpkinseed								
May	3.85	1.39	19.78	4.01	98.50	37.41	1.86	1.17
June	3.23	2.46	16.46	3.36	--	--	3.54	1.64
July	2.42	1.73	17.85	4.90	24.00	4.20	1.00	0.32
August	0.80	0.49	9.85	2.90	1.81	1.70	5.68	2.69
September	--	--	5.40	1.89	--	--	0.26	0.26
Total	10.30	6.07	69.34	17.06	124.30	43.31	12.34	6.08
Northern pike								
May	0.33	--	0.53	0.23	--	--	1.93	0.61
June	0.25	--	0.61	0.28	--	--	4.71	0.63
July	0.34	0.02	1.94	0.70	--	--	1.36	0.64
August	0.16	--	0.76	0.33	--	--	--	--
September	--	--	0.52	0.33	--	--	1.27	--
Total	1.08	0.02	4.36	1.87	--	--	9.27	1.88
Yellow perch								
May	2.24	0.83	2.80	0.55	--	--	1.93	1.93
June	4.17	3.17	4.17	0.79	--	--	3.62	1.09
July	2.47	1.78	1.16	0.32	--	--	27.28	7.66
August	1.92	1.10	2.16	0.62	--	--	25.34	12.55
September	--	--	0.15	0.05	--	--	3.17	1.26
Total	10.80	6.88	10.44	2.33	--	--	61.34	24.49

Appendix Q (continued)

	Beulah		Browns		Pretty		Rockland	
	catch	harvest	catch	harvest	catch	harvest	catch	harvest
	Green sunfish				Carp			
May	1.27	0.47	1.02	0.21			--	--
June	--	--	3.84	0.79			--	--
July	0.26	0.18	1.62	0.44			--	--
August	0.21	0.11	0.70	0.21			0.25	0.25
September	--	--	0.74	0.24			--	--
Total	1.74	0.76	7.92	1.89			0.25	0.25
	Warmouth							
May	0.64	0.24	--	--	--	--	0.31	0.31
June	2.18	1.66	--	--	--	--	1.18	0.55
July	0.55	0.38	--	--	--	--	2.00	0.64
August	0.56	0.30	--	--	--	--	1.81	0.90
September	--	--	--	--	--	--	--	--
Total	3.93	2.58	--	--	--	--	5.30	2.40
	Black crappie							
May	1.11	0.50	--	--	23.34	9.14	27.82	16.86
June	--	--	--	--	--	--	25.21	12.28
July	0.03	--	--	--	--	--	8.30	3.27
August	0.14	--	--	--	--	--	0.90	0.45
September	--	--	--	--	--	--	--	--
Total	1.28	0.50	--	--	23.34	9.14	62.23	32.86

Appendix Q (continued)

	Beulah		Browns		Pretty		Rockland	
	catch	harvest	catch	harvest	catch	harvest	catch	harvest
Brown bullhead								
May	--	--	0.53	0.53	--	--	0.61	0.61
June	--	--	--	--	--	--	--	--
July	0.08	0.08	--	--	--	--	--	--
August	0.06	0.06	--	--	--	--	--	--
September	--	--	--	--	--	--	--	--
Total	0.14	0.14	0.53	0.53	--	--	0.61	0.61
Yellow bullhead				Bullhead unspecified				
May	--	--	--	--			1.32	1.32
June	0.06	0.06	0.11	0.11			0.32	--
July	0.14	0.14	--	--			0.64	0.32
August	0.06	0.06	--	--			0.51	0.51
September	--	--	0.11	0.11			--	--
Total	0.26	0.26	0.22	0.22			2.79	2.15
Brown trout		Bullhead unspecified						
May	0.59	0.59	0.53	0.03				
June	0.37	0.37	1.16	1.10				
July	0.28	0.28	2.27	1.71				
August	0.49	0.47	2.55	1.99				
September	--	--	0.33	0.28				
Total	1.73	1.71	6.84	5.38				

Appendix Q (continued)

	Beulah		Browns		Pretty		Rockland	
	catch	harvest	catch	harvest	catch	harvest	catch	harvest
	Rock bass		Black bullhead					
May	--	--	2.88	0.70				
June	0.03	0.03	--	--				
July	0.17	0.03	--	--				
August	0.14	--	--	--				
September	--	--	0.30	0.30				
Total	0.34	0.06	3.18	1.00				
			Walleye					
May			0.08	0.08				
June			--	--				
July			--	--				
August			--	--				
September			--	--				
Total			0.08	0.08				
			All species combined					
May	71.60	19.70	53.89	13.66	239.6	63.00	189.84	100.79
June	42.97	29.98	84.31	17.92	35.32	17.90	197.71	86.76
July	50.97	33.85	82.90	24.95	57.21	16.06	144.12	43.57
August	33.42	15.42	42.28	14.87	52.14	17.22	122.81	60.16
September	--	--	18.68	7.11	--	--	32.53	9.91
Total	198.96	98.95	282.1	78.51	384.27	114.18	687.01	301.19
Mean catch/month	49.74		56.41		96.07		137.40	

Appendix R

Exploitation rate (u) of largemouth bass in several lakes.

Lake	State		u(%)	Source
Browns	WI		12	Mraz and Threinen 1955
Ridge	IL		25-30	Bennett 1954
Altoona	GA		17	Kirkland 1965
Clear	CA		20	Kimsey 1956
Gladstone	MN		15	Maloney et.al. 1962
Bischoff	IN		39	Ball 1974
Sugarloaf	MI		26	Cooper and Latta 1954
Mollenkramer	IN		47	Ball 1974
Fort Smith	AR		32	Cole 1966
Sutherland	CA		36	La Faunce et.al. 1964
Oliver	IN		17	Gerking 1956
Gordy	IN		36	"
Shoe	IN		20	Richardson 1942
Folsom	CA		40	Rawstrom 1967
Snowden	MD		57	Manning 1951
Merle Collins	CA	1965	36	Rawstrom and Hashagen 1972
"	"	1966	45	" "
"	"	1967	62	" "
"	"	1968	65	" "
"	"	1969	65	" "

Appendix.S

Length-frequency distributions of largemouth bass in electrofishing samples in spring and fall of 1980 and 1981 from the four study lakes.

Length group (mm)	Beulah				Rockland				Browns				Pretty			
	Spring		Fall		Spring		Fall		Spring		Fall		Spring		Fall	
	1980	1981	1980	1981	1980	1981	1980	1981	1980	1981	1980	1981	1980	1981	1980	1981
60 - 69												1				
70 - 79					1	1	1					1	1			
80 - 89					2		2					3				
90 - 99					3	1	2	1				2	2		2	
100 - 109						1	3						1	1		
110 - 119			1	1		3							9	1		2
120 - 129					1								4	3	1	
130 - 139	1				43	2	1		1			1	4	5	1	2
140 - 149	16			1	72			1	4				5	4	1	
150 - 159	24	4	2		50	2	4	1	2				3	9	2	
160 - 169	8	10	2	17	27	12	11	16	11	1			3	4	1	4
170 - 179	5	18	4	16	17	20	9	15	7	3			7	12	2	
180 - 189	5	11	3	4	11	21	20	12	4	4			3	9	1	2
190 - 199	5	9	5	5	6	67	40	6	2	4			4	6	3	3
200 - 209	12	21	7	2	3	125	24	4		5	1	1	1	18	2	1
210 - 219	20	21	9	2	4	96	28	1	4	9			5	14		1
220 - 229	16	16	7	4	2	47	5	6	6	7			9	10		1
230 - 239	13	3	4		8	12	5	8	2	8			6	5	1	1
240 - 249	6	10	4	4	13	9	2	12	6	11	1	1	6	8	2	2
250 - 259	7	9	4	3	12	5	2	7	4	7			6		1	1
260 - 269	1	7	3	8	6	3		24	6	8	1		3	3		1
270 - 279	3	3	7	3	15	2		17	6	6		1	7	1		
280 - 289	3	6	2	2	4	1	3	4	5	3			4	2		1
290 - 299	4	8	5	3	4	7	4	4	3	3		1	4		1	

Appendix S (continued)

Length group (mm)	Beulah				Rockland				Browns				Pretty			
	Spring		Fall		Spring		Fall		Spring		Fall		Spring		Fall	
	1980	1981	1980	1981	1980	1981	1980	1981	1980	1981	1980	1981	1980	1981	1980	1981
300 - 309	3	2	2	3		5	2	2	3	4		3	3			
310 - 319		1	1	1	2				5	1	2	2	4			
320 - 329		2	1	1		1	1		4		1	5	1			
330 - 339	2	1	1	2	3	1			12	4	1	3	1			3
340 - 349	1	4	1	1	5			1	11	2		4	2	1		1
350 - 359		1		1	3				16	2	3	2		2		1
360 - 369		1			2	4			14	9	1	4	1	1		2
370 - 379	2	1			4			1	10	8	1	2	1			1
380 - 389	1	1			1	1			5	3	2	1	1			
390 - 399						2			5	9	1	2				
400 - 409	1		1	1			2		3	3	2	2				2
410 - 419						2			1	6	4	4				1
420 - 429			1	1						3	1	2				1
430 - 439						1	1				1	3				
440 - 449									1	1						
450 - 459					1	2		1		2		3				1
460 - 469					2	1	2	2								1
470 - 479					1	1		1								
480 - 489					1	1										
490 - 499						1	1			1		1				
500 - 509				1		2			1							
510 - 519						1		1								
520 - 529					1	2										
550 - 559		2														
560 - 569	1	1														
Total	160	173	75	89	330	465	174	148	164	137	23	55	111	119	21	36

Appendix T

Estimated monthly fishing effort (hrs/ha) in the four study lakes in 1980. Browns and Rockland Lakes were surveyed from 3 May through 28 September, and Beulah and Pretty Lakes were surveyed from 20 May through 31 August. Estimates for Beulah and Pretty Lakes in May were corrected to cover the entire month.

	Beulah (338 ha)	Browns (160 ha)	Pretty (26 ha)	Rockland (16 ha)
May	66.6	75.9	57.8	101.3
June	35.6	39.9	16.7	99.5
July	28.3	33.4	10.7	79.8
August	20.5	25.5	21.5	50.6
September	--	13.1	--	16.91
Total	151.0	187.8	106.7	348.1

Appendix U

Angling effort, and catch per month of all species combined (ALL), largemouth bass (LMB), and bluegills (BLG) in various lakes.

Lake	Area (ha)	Period surveyed	Angling Effort (hrs/ha)	Catch (number/ha/month)			Source
				ALL	LMB	BLG	
Beulah WI	338	20 May - 31 August 1980	108	50	7	33	Present Study
Browns "	160	3 May - 28 September 1980	187	56	4	32	" "
Pretty "	26	20 May - 31 August 1980	69	96	3	37	" "
Rockland "	16	3 May - 28 September 1980	348	137	15	92	" "
Ross OH	58	1 April - 30 September 1977	577	--	25	84	Carline and Savino 1981
"	"	12 June - 6 September 1978	310	--	--	89	" "
"	"	1 April - 30 September 1979	508	--	24	48	" "
"	"	1 April - 30 September 1980	519	--	18	52	" "
Keshena WI	9.9	5 May - 9 September 1978	71	--	--	--	Kniefcik 1980
La Belle WI	9.3	5 May - 9 September 1978	40	--	--	--	" "
Browns WI	160	16 May - 9 October 1953	185	--	3	--	Mraz 1964
"	"	30 April - 30 September 1955	156	--	2	--	" "
Little Dixie MO	83	1 April - 15 October 1961	118	--	--	--	Heman, Campbell & Redmond 1969
" "	"	1 April - 15 October 1962	105	--	--	--	" " " "
" "	"	1 April - 15 October 1963	113	--	--	--	" " " "
" "	"	1 April - 15 October 1964	159	--	--	--	" " " "
Linwood MN	310	15 May - 31 October 1952	142	--	--	--	Lux and Smith 1960
"	"	15 May - 31 October 1953	127	--	--	--	" " "
Clearwater MO	668	30 May - 30 November 1949	109	12	--	--	Patriarche and Campbell 1957
"	"	30 May - 30 November 1950	149	13	--	--	" " "
Big Creek IA	344	1 April - 1 September 1974	339	--	60	--	Paragamian 1982
"	"	1 April - 1 September 1975	410	--	39	--	" "
"	"	1 April - 1 September 1976	408	--	14	--	" "
Gordy IN	11.5	2 June - 4 September 1950	230	116	--	98	Gerking 1952
Merle Collins CA	405	15 March - 30 September 1966	43	4	3	1.4	Hashagen 1973

Appendix V

Estimated monthly catch and harvest rate (number/ha) based on all hours of fishing for each species caught by angling in the four study lakes. Browns and Rockland Lakes were surveyed from 3 May through 28 September, and Beulah and Pretty Lakes were surveyed from 20 May through 31 August.

	Beulah		Browns		Pretty		Rockland	
	catch rate	harvest rate	catch rate	harvest rate	catch rate	harvest rate	catch rate	harvest rate
Largemouth bass								
May	0.286	0.043	0.121	0.070	0.199	0.100	0.151	0.079
June	0.134	0.019	0.068	0.036	0.087	0.029	0.199	0.041
July	0.219	0.020	0.104	0.060	0.188	0.094	0.175	0.038
August	0.259	0.044	0.087	0.057	0.063	--	0.294	0.077
September	--	--	0.092	0.065	--	--	0.566	0.060
Bluegill								
May	1.140	0.455	0.219	0.022	0.995	0.057	1.370	0.691
June	0.784	0.604	1.385	0.251	2.028	1.043	1.400	0.670
July	1.344	1.011	1.635	0.445	2.908	1.013	1.122	0.347
August	1.150	0.581	0.941	0.289	2.278	0.722	1.451	0.769
September	--	--	0.757	0.234	--	--	1.090	0.436
Pumpkinseed								
May	0.163	0.059	0.260	0.053	4.826	1.834	0.018	0.012
June	0.091	0.070	0.413	0.084	--	--	0.036	0.016
July	0.085	0.061	0.534	0.147	2.251	0.394	0.013	0.004
August	0.039	0.024	0.387	0.114	0.084	0.079	0.112	0.053
September	--	--	0.413	0.145	--	--	0.015	0.015

Appendix V (continued)

	Beulah		Browns		Pretty		Rockland	
	catch rate	harvest rate	catch rate	harvest rate	catch rate	harvest rate	catch rate	harvest rate
Northern pike								
May	0.014	--	0.007	0.003	--	--	0.019	0.006
June	0.007	--	0.015	0.007	--	--	0.047	0.006
July	0.012	0.001	0.058	0.021	--	--	0.017	0.008
August	0.008	--	0.030	0.013	--	--	--	--
September	--	--	0.040	0.025	--	--	0.075	--
Yellow perch								
May	0.095	0.035	0.037	0.007	--	--	0.019	0.019
June	0.117	0.089	0.104	0.020	--	--	0.037	0.011
July	0.087	0.063	0.035	0.010	--	--	0.432	0.096
August	0.093	0.054	0.085	0.024	--	--	0.501	0.248
September	--	--	0.011	0.004	--	--	0.188	0.075
Green sunfish								
May	0.054	0.020	0.013	0.004			--	--
June	--	--	0.096	0.020			--	--
July	0.009	0.006	0.048	0.013			--	--
August	0.010	0.005	0.028	0.008			0.005	0.005
September	--	--	0.057	0.018			--	--

Appendix V (continued)

	Beulah		Browns		Pretty		Rockland	
	catch rate	harvest rate	catch rate	harvest rate	catch rate	harvest rate	catch rate	harvest rate
Warmouth								
May	0.027	0.010	--	--	--	--	0.003	0.003
June	0.061	0.047	--	--	--	--	0.012	0.005
July	0.019	0.014	--	--	--	--	0.025	0.008
August	0.027	0.015	--	--	--	--	0.036	0.018
September	0.044	0.027	--	--	--	--	--	--
Black crappie								
May	0.047	0.021	--	--	1.144	0.448	0.275	0.166
June	--	--	--	--	--	--	0.253	0.123
July	0.001	--	--	--	--	--	0.104	0.041
August	0.007	--	--	--	--	--	0.018	0.009
September	--	--	--	--	--	--	--	--
Brown bullhead								
May	--	--	0.007	0.007			0.006	0.006
June	--	--	--	--			--	--
July	0.003	0.003	--	--			--	--
August	0.003	0.003	--	--			--	--
September	0.002	0.002	--	--			--	--

Appendix V (continued)

	Beulah		Browns		Pretty		Rockland	
	catch rate	harvest rate	catch rate	harvest rate	catch rate	harvest rate	catch rate	harvest rate
Yellow bullhead								
May	--	--	--	--				
June	0.002	0.002	0.003	0.003				
July	0.005	0.005	--	--				
August	0.003	0.003	--	--				
September	0.003	0.003	0.008	0.008				
	Brown trout		Bullhead unspecified				Bullhead unspecified	
May	0.025	0.025	0.007	0.004			0.013	0.013
June	0.010	0.010	0.029	0.028			0.003	--
July	0.010	0.010	0.068	0.051			0.008	0.004
August	0.024	0.023	0.100	0.078			0.010	0.010
September	--	--	0.025	0.021			--	--
	Rock bass		Black bullhead					
May	--	--	0.038	0.009				
June	0.001	0.001	--	--				
July	0.006	0.001	--	--				
August	0.007	--	--	--				
September	--	--	0.023	0.023				

Appendix V (continued)

	Beulah		Browns		Pretty		Rockland	
	catch	harvest	catch	harvest	catch	harvest	catch	harvest
	rate	rate	rate	rate	rate	rate	rate	rate
	Walleye							
May			0.001	0.001				
June			--	--				
July			--	--				
August			--	--				
September			--	--				
	All species combined							
May	1.851	0.658	0.710	0.180	7.164	2.439	1.874	0.995
June	1.207	0.842	2.133	0.449	2.115	1.072	1.987	0.1872
July	1.801	1.196	2.482	0.747	5.347	1.501	1.806	0.546
August	1.630	0.752	1.658	0.583	2.425	0.801	2.427	1.189
September	--	--	1.426	0.543	--	--	1.924	0.586

Appendix W

Length-frequency distributions of bluegills, pumpkinseeds, yellow perch, green sunfish and warmouth in fyke net samples in June of 1980 and 1981 from the four study lakes.

B E U L A H L A K E										
Length group (mm)	Bluegill		Pumpkinseed		Yellow perch		Green sunfish		Warmouth	
	1980	1981	1980	1981	1980	1981	1980	1981	1980	1981
50 - 59	2	1								
60 - 69	89	6					1			2
70 - 79	143	16					19	3	4	
80 - 89	70	17	3	1			21	3	1	1
90 - 99	66	54	4	2			16	3	1	4
100 - 109	94	74	23	6	1	2	19	2	8	11
110 - 119	118	55	26	9	1	4	13	1	21	4
120 - 129	143	58	25	16	3	7	7	2	19	5
130 - 139	351	109	31	28	6	19	10		10	4
140 - 149	712	136	31	22	6	25	5	6	26	15
150 - 159	775	115	11	16	5	14	1	3	22	10
160 - 169	711	115	8	7	1	13			10	7
170 - 179	484	86	4	5	1	4				2
180 - 189	106	24			1	7				
190 - 199	9	1				6				
200 - 209						1				
210 - 219						6				
220 - 229						4				
240 - 249						1				
250 - 259						3				
Total	3873	867	166	112	25	116	112	23	135	65

Appendix W (continued)

R O C K L A N D L A K E										
Length group (mm)	Bluegill		Pumpkinseed		Yellow perch		Green sunfish		Warmouth	
	1980	1981	1980	1981	1980	1981	1980	1981	1980	1981
50 - 59		8		1						1
60 - 69		17		2				7		
70 - 79	9	37						2		2
80 - 89	4	49	1	1				1		
90 - 99	7	26	2	1				1		1
100 - 109	21	18								
110 - 119	59	27	4	1					1	4
120 - 129	34	18	1	2				1	3	2
130 - 139	42	26	1	2					2	7
140 - 149	73	43	1		1	1				3
150 - 159	84	27		1					1	2
160 - 169	63	31				1				
170 - 179	20	24								
180 - 189	7	18								
190 - 199		4								
Total	424	373	10	11	1	2	0	12	7	22

Appendix W (continued)

P R E T T Y L A K E								
Length group (mm)	Bluegill		Pumpkinseed		Yellow perch		Warmouth	
	1980	1981	1980	1981	1980	1981	1980	1981
50 - 59	10							
60 - 69	63	24						
70 - 79	72	36	1	1			4	14
80 - 89	188	51	5	5			6	43
90 - 99	202	69	6	2			6	45
100 - 109	149	104	11	20			10	19
110 - 119	118	84	11	25			10	17
120 - 129	83	42	12	22			8	7
130 - 139	101	62	11	33			14	14
140 - 149	66	40	10	31			4	6
150 - 159	68	43	11	25			1	4
160 - 169	19	4	3	15	1		3	2
170 - 179	3	3	1	7			1	
180 - 189				1				1
190 - 199				1				
Total	1142	562	82	188	1	0	67	172

Appendix W (continued)

B R O W N S L A K E								
Length group (mm)	Bluegill		Pumpkinseed		Yellow perch		Green sunfish	
	1980	1981	1980	1981	1980	1981	1980	1981
50 - 59	5	1	2				25	
60 - 69	13	5	2	7			8	4
70 - 79	26	6	6	4			44	10
80 - 89	477	11	110	14	1		39	9
90 - 99	1584	120	130	62	7		24	3
100 - 109	1485	580	128	78	6	1	9	
110 - 119	1094	1590	147	88	2		3	
120 - 129	446	957	107	76	2	1	6	3
130 - 139	338	410	78	76			4	1
140 - 149	122	110	29	31		1	1	3
150 - 159	39	35	5	17			1	2
160 - 169	18	23	4	5			1	
170 - 179	15	8	1	1				
180 - 189	7	9			1			2
190 - 199	3	1						
Total	5672	3866	749	459	20	2	142	37

Appendix X

The spring 1980 PSD(%), percent of the catch that was harvested, percent of quality-sized fish in the harvest, mean length (mm) of fish harvested, harvest rate (number/ha), and percent of total harvest of bluegills and largemouth bass in the four study lakes.

Species	Lake	Spring 1980 PSD	Percent of catch harvested	Percent of quality-sized fish harvested	Mean length of fish harvested	Harvest rate	Percent of total harvest
Bluegill	Beulah	32	56	73	155	.718	75
	Rockland	16	46	67	152	.607	70
	Pretty	5	31	28	142	.688	39
	Browns	2	23	15	132	.232	47
Largemouth bass	Beulah	11	12	41	297	.028	4
	Rockland	27	27	23	246	.058	7
	Pretty	22	34	--*	330	.035	4
	Browns	68	59	81	348	.059	14

*only 5 fish were sampled

Appendix Y

Proportional Stock Density (PSD%) of fishes in the four study lakes in spring, fall, and combined spring samples in 1980 and 1981.

Species	Lake	1980		PSD Fall	No. in stock	1981		PSD Fall	No. in stock	PSD Combined Spring 1980 & 1981		No. in stock
		PSD Spring	No. in stock			PSD Spring	No. in stock					
Largemouth bass	Beulah	11	96	13	60	14	121	28	43	13		217
	Rockland	27	97	10	81	8	335	9	96	13		432
	Pretty	22	65	0	7	6	65	61	23	14		130
	Browns	68	133	87	23	46	125	91	47	58		258
Bluegill	Beulah	32	160	66	128	52	117	60	123	40		277
	Rockland	16	288	43	144	17	152	29	307	17		440
	Pretty	5	537	18	262	5	271	9	438	2		677
	Browns	2	314	1	395	1	363	1	448	2		677
Pumpkinseed	Beulah	24	17	50	2	13	16	0	3	18		33
	Rockland	8	26	0	5	16	19	25	4	11		45
	Pretty	45	42	60	5	29	80	50	10	34		122
	Browns	3	157	0	5	0	52	0	25	2		209
Yellow perch	Beulah	5	41	11	9	0	22	5	20	3		63
	Rockland	66	3	8	12	20	30	--	--	24		33
	Pretty	0	14	17	6	100	2	0	3	13		16
Wormouth	Beulah	39	31	0	1	53	15	25	4	44		46
	Rockland	66	3	8	12	20	30	--	--	24		33
	Pretty	11	28	--	--	8	12	0	3	10		40
Green sunfish	Beulah	0	21	0	1	0	7	0	3	0		28
	Rockland	50	2	0	2	17	6	0	1	25		8

Appendix Z

Mean length (mm) and weight (g) of each species of fish examined in the harvest in the four study lakes.

	Largemouth bass	Brown trout	Northern pike	Walleye	Bluegill	Pumpkinseed	Yellow perch	Black crappie	Warmouth	Green sunfish	Rockbass	Yellow bullhead	Brown bullhead	Black bullhead	Carp
Beulah															
Mean length	297	251	490	--	155	160	190	216	165	150	183	259	259	--	--
Mean weight	408	191	567	--	109	118	145	186	122	91	141	277	816	--	--
n	115	67	1	--	1938	186	228	13	74	12	2	11	7	--	--
Browns															
Mean length	348	--	577	594	132	124	155	--	--	119	--	216	246	234	--
Mean weight	663	--	1194	2041	41	41	73	--	--	54	--	177	259	209	--
n	250	--	51	1	662, 661*	335	33	--	--	42	--	33	33	8	89
Pretty															
Mean length	330	--	--	--	142	170	--	196	--	--	--	--	--	--	--
Mean weight	717	--	--	--	82	136	--	113	--	--	--	--	--	--	--
n	4	--	--	--	72, 71*	38, 29*	--	2	--	--	--	--	--	--	--
Rockland															
Mean length	246	--	592	--	152	132	150	208	150	145	--	231	295	--	414
Mean weight	286	--	1239	--	82	59	41	145	91	113	--	200	340	--	1787
n	57	--	5	418	15	72	82	6	1	--	4	3	3	--	1

*Sample size for weight estimate