Evaluation of Largemouth Bass Minimum and Slot Length Limit Regulations

By

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Wisconsin Cooperative Fishery Research Unit

A Thesis

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

College of Natural Resources

UNIVERSITY OF WISCONSIN

Stevens Point, Wisconsin

December, 1984

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ACKNOWLEDGEMENTS

This study was supported by the Wisconsin Department of Natural Resources, and the Wisconsin Cooperative Fishery Research Unit, University of Wisconsin, Stevens Point.

Special thanks go to Dr. Daniel Coble, my committee chairman, for his suggestions and careful editing of this manuscript. I thank committee members Drs. Fred Copes and Jack Heaton for their advice and review of this manuscript. I also express sincere thanks to Dr. Fred Hilpert and Jeff Andrews for sharing their computer expertise.

I am grateful to all the Wisconsin DNR personnel who helped conduct the field work, especially George Boronow, for scheduling the electrofishing, fyke netting, and creel surveys. I am also grateful to the work study students who pressed scales and key punched data.

I am indebted to George and Lynn Boronow, and Randy Schumacher for their friendship and hospitality.

ABSTRACT

Beginning in 1982, minimum and slot length limit regulations for largemouth bass (Micropterus salmoides) were enforced on four lakes in southeast Wisconsin. Beulah and Rockland Lakes had a 305 - 406 mm slot length limit, and Pretty and Browns Lakes had a 406 - mm minimum length limit. Changes since 1980, in the largemouth bass and panfish, primarily bluegill (Lepomis macrochirus), populations and fisheries one year after imposition of the regulations were assessed.

Since the regulations, largemouth bass mortality decreased significantly in Pretty Lake, and mean length increased significantly in Rockland Lake. Bluegill Relative Weight (Wr) increased in all lakes but Pretty Lake, where it decreased significantly. Largemouth bass Wr remained in the satisfactory range (95-105%) in all the lakes. These changes were expected, and I think more time is necessary for the fishery to reflect post regulation conditions only.

There was little change in largemouth bass length - frequency distributions, and bluegill length frequencies shifted to smaller sizes in Beulah and Rockland Lakes, and to larger sizes in Pretty and Browns Lakes. The regulations did little to affect the growth rates of both largemouth bass and bluegills. There were no significant changes in bluegill mortality rates. Neither before, nor one year after the length limit regulations were in effect, did Proportional

Stock Density (PSD) of both predator and prey fall within recommended ranges.

Angler exploitation of largemouth bass in Rockland Lake decreased from 87% in 1980 to 31% in 1982.

Fishing pressure (hrs/ha) increased in 3 of the lakes in 1982, and the length limit regulations reduced the number of largemouth bass harvested from the protected size ranges. Mean length harvested, and catch and harvest rates of bluegills increased significantly for all lakes. However, these changes were inconsistent for largemouth bass.

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INTRODUCTION

In spring of 1980, the Wisconsin Cooperative Fishery Research Unit and the Wisconsin Department of Natural Resources began a study to improve the quality of fishing in four lakes in southeastern Wisconsin. It was believed that overharvest of largemouth bass (Micropterus salmoides) had resulted in the decline of quality size bass harvested and an unsatisfactory panfish fishery (George Boronow, Wisconsin Department of Natural Resource, fish manager, personal communication). All four lakes had unbalanced fish populations (Michaelis 1982). The hypothesis was that an increase in fishing quality would be accomplished by minimum and slot length limits on largemouth bass. Length limits would protect bass thereby increasing their predation on panfish.

Beulah, Rockland, Pretty and Browns Lakes were studied by Michaelis (1982), who described the fisheries in these lakes from Spring 1980 through Fall 1981, before length limit regulations were put into effect. On 1 May 1982, a 406 - mm minimum length limit was enforced on Pretty and Browns Lakes, and a 305 - 406 mm slot length limit on Beulah and Rockland Lakes. For the slot length limit, only largemouth bass less than 305 mm long or bass greater than 406 mm long could be legally harvested.

Objectives of my portion of the study (Spring 1982 - Fall 1983) were to: 1) describe any changes in the fish populations since the length limits went into effect and 2) determine the effects of the limits on angling.

Characteristics used to describe the largemouth bass and panfish, primarily bluegill (Lepomis macrochirus), populations were: 1) length - frequency distribution 2) Proportional Stock Density or PSD (Anderson 1976) 3) condition of largemouth bass and bluegill measured by the Relative Weight (Wr) index (Wege and Anderson 1978) 4) growth rate, 5) total annual mortality rate, and 6) fishing pressure (hrs/ha), catch (no/ha) and harvest (no/ha) rates. Also, population estimates and exploitation rates were calculated for largemouth bass in Rockland Lake.

Study Lakes

Lakes Beulah (338 ha), Pretty (26 ha), Browns (160 ha), and Rockland (16 ha) are in Walworth, Waukesha, and Racine counties, respectively (Appendices A,B). Beulah Lake was originally five distinct lakes, which were combined by the damming of the outlet stream in 1840 (Wisconsin Department of Natural Resources 1969). Residental development was heaviest around Pretty and Browns Lakes, intermediate at Beulah Lake, and mostly undeveloped at Rockland Lake.

Abundant aquatic vegetation occured in all lakes except Pretty Lake; all are hardwater and had diverse fish communities (Michaelis 1982; Appendix C). Largemouth bass was the major gamefish and bluegill, the most abundant panfish. A variety of minnows was present, but they were not adequately sampled.

Browns Lake was chemically treated in September, 1971, to remove stunted panfish and carp (Schumacher and Rebicek 1977). In May 1977 and 1978, a panfish removal project was conducted on Pretty Lake. Of the 120,460 fish removed, 93% were bluegills (Claggett 1979). Michaelis (1982) gave a more complete description of the study lakes.

Harvest regulations for largemouth bass in the study lakes included the size restrictions and a daily bag limit of five. Harvest regulations for other species of fish in the lakes were 50 panfish (bluegills, yellow perch, pumpkinseeds, and black and white crappies) in aggregrate for all lakes and a bag limit of five northern pike in Pretty

Lake and two in Beulah, Rockland and Browns Lakes. The fishing season for largemouth bass and northern pike was open from the first Saturday in May through 1 March. There was no season for panfish.

METHODS AND MATERIALS

Sampling

The lakes were sampled by electrofishing, fyke netting and creel survey (Table 1). Electrofishing (290 - 475 volts pulsed direct current) was conducted immediately after sunset with a boat - mounted electroshocker (Novotny and Priegel 1971) for two nights each spring and fall of the study except that: 1) because of generator problems during the Spring 1983 sampling, AC output (230 -250 volts) was also used (Table 1), and 2) spring sampling effort was doubled on Rockland Lake for a multiple census population estimate of largemouth bass. One lap of the shoreline was electrofished on Rockland, Pretty, and Browns Lakes during each sampling night. The southwest basin of Beulah Lake was sampled from the start to end locations (circumscribing about 100 ha) marked on Appendix B. Two people in the bow of the electroshocker netted stunned fish. The total time of electrofishing was recorded for calculation of catch per unit effort (CUE).

Fish were placed in a holding tank until processed. Largemouth bass, and the few northern pike, walleye, and brown trout caught were counted, weighed (g), and measured (total length, mm); scale samples were collected, and the fish were released. A sample of panfish was preserved (10% formalin) in a 19 liter plastic container. Panfish were netted from the holding tank without regard to size,and preserved; when the container was full, panfish in excess of those required to fill the container, were indentified, counted and released. The preserved panfish were weighed, measured, and scale samples were collected.

Four or five 1- m diameter fyke nets (19- mm stretched mesh) with a 15.2- m lead, were fished perpendicular to shore for 48 hours in June 1982 and May 1983 (Table 1). Captured fish were measured and released, and bluegills > 170 mm were also weighed, and scale samples collected. When more than a thousand panfish were caught in a fyke net, data were obtained from a net sample of those caught, i.e. of 1531 bluegill, 139 pumpkinseed, and 50 warmouth caught on 6 June 1982 in Pretty Lake, 1352, 88, and 46 were measured; and of 1013 bluegill caught in Browns Lake on 17 June 1982, 754 were measured.

Fyke netting and electrofishing were carried out concurrently in Spring 1983 for comparison of selectivity of the two kinds of gear. Lengths of fish in the fyke net and electrofishing samples were compared with a t - test.

Because Spring 1982 electrofishing data were obtained 12 days after the regulations went in effect, I considered Spring 1980, 81 and 82 to be pre- regulation data, and Spring 1983 electrofishing samples to be post- regulation data. For the fall samples, Fall 1980 and 1981 were pre- regulation, and Fall 1982 and 1983, post- regulation data.

Table 1. Fish sampling methods with effort recorded in hours for the electroshocker, net days for the fyke nets, and hours/week for the creel survey. Numbers in parenthesis are the number of fyke nets fished in each lake. Electrofishing was with pulsed direct current unless indicated otherwise.

		Beulah		Rockland		Pretty		Browns	
Year	Gear	Total Effort	Dates Sampled	Total Effort	Dates Sampled	Total Effort	Dates Sampled	Total Effort	Dates Sampled
1982	Electroshocker	3.9	20, 25 May	3.7	13, 17, 24 May 1 June	3.2	12, 27 May	4.4	18, 26 May
	Fyke nets	10 (5)	24, 25 June	8 (4)	15, 16 June	8 (4)	22, 23 June	8 (4)	17,18 June
	Creel survey	32	20 May - 31 August	20	1 May - 30 September	8	20 May - 30 September	20	1 May - 30 September
	Electroshocker	3.0	6, 13 October	2.5	4, 11 October	2.1	7, 14 October	4.7	5, 12 October
1983	Electroshocker	4.9	24[a] May 7 June	5.9	16,[a] 23,[a] 26 May 1, 6 June	2.9	31 May 9 June	8.4	17,[a] 25 May 8 June
	Fyke nets	10 (5)	7, 8 June	8 (4)	24, 25 May	8 (4)	9, 10 June	8 (4)	26, 27 May
	Electroshocker	4.5	12, 19 October	2.1	10, 17 October	4.0	13, 20 October	5.9	11, 18 October

a Alternating current

Proportional Stock Density

Proportional Stock Density or PSD is the percentage of quality - sized fish in a stock (Anderson 1976) and is calculated as:

$$PSD = \frac{\text{no. fish} > \text{minimum qualtiy size}}{\text{no. fish} > \text{minimum stock size}} \times 100.$$

PSD has been used to evaluate population and community structure (Anderson and Weithman 1978). I used the minimum stock and quality sizes (Table 2) defined by Anderson and Gutreuter (1983). Satisfactory PSD ranges for largemouth bass are 40 to 60 percent (Reynolds and Babb 1978). Novinger and Legler (1978) considered bluegill PSD's of 20 to 40 percent to be satisfactory when angling for both largemouth bass and bluegill is important.

I calculated community structure using a weighted mean prey PSD: Pw = PW/W' , where Pw is the weighted mean prey PSD, PW is the PSD for each prey species, and W is the number of stock - size fish of that species and W' is the number of stock - size fish of all prey species (Michaelis 1982). Predator PSD was not weighted because the largemouth bass was virtually the only predator caught. Novinger and Legler (1978) suggested at least 30 bluegills $\geq$ 80 mm be used to determine PSD. I weighed prey PSD if there were at least 30 fish in a sample.

Table 2. Minimum stock and quality size (mm) for largemouth bass, bluegills, pumpkinseeds,warmouths, green sunfish, and yellow perch.

Species	Stock - size	Quality - size
Largemouth bass	200	300
Bluegill	80	150
Pumpkinseed	80	150
Warmouth	80	150
Green sunfish	80	150
Yellow perch	130	200

Balance in fish communities may be evaluated by plotting prey PSD as a function of predator PSD in a tic-tac-toe graph (Anderson 1976; Anderson and Weithman 1978). The recommended PSD ranges for both predator and prey result in a center panel, formed by the intersecting lines, the objective area for a balanced fish community.

Relative Weight

Relative Weight or Wr was used to evaluate weight-length relations of largemouth bass $\geq$ 100 mm long and bluegills $\geq$ 80 mm long . Wr compares the actual weight (W) of a fish with a standard weight (Ws) for fish of the same length : Wr = W/Ws x 100 (Wege and Anderson 1978). A fortran program was developed which calculated Ws and computed mean Wr for each 10 - mm length group. Standard deviation and 95% confidence limits were also calculated. Regression equations used to determine standard weights (Ws) were: 1) largemouth bass, log Weight (g) = -5.316 + 3.191 log Length (mm) (Wege and Anderson 1978), and 2) bluegill, log Weight (g) = -5.374 + 3.316 log Length (mm) (Hillman 1982).

Wege and Anderson (1978) considered 95 - 100% to be a satisfactory Wr range for largemouth bass in late summer or early fall, and Legler (1977) reported 90 -95% satisfactory for bluegills. Hillman (1982) and Michaelis (1982) considered these ranges too narrow for diverse fish communities and concluded that Wr's of 90 - 105% were satisfactory for largemouth bass and bluegills. I considered Wr's of 90 - 105 % to be satisfactory.

Age, Growth, and Mortality

Scales from largemouth bass and bluegills, and from pumpkinseeds in Browns Lake only, were used to determine age. If there were more than 15 fish in a 10 - mm length group, a random sample of 10 fish was aged; otherwise, all scales were read.

Scales were cleaned, pressed on an acetate slide, and read on a microfiche reader (24x magnification). Usually four or more scales were pressed on each slide, and measurements of the anterior scale radius and annuli positions were recorded from the most legible scale.

The transformed length - weight relationship (log Weight = log a + b log Length) and a GM functional regression were used to calculate instantaneous growth (G) from back - calculated lengths at annulus formation (Ricker 1975). Instantaneous growth rates (G) between pre- and post-regulation data were compared with a Wilcoxon paired - sample test (Zar 1974: pp. 124 - 6).

Length at age of largemouth bass and bluegills were also compared with a paired t - test (Zar 1974; p. 121) between pre- and post- regulation data, and southeastern Wisconsin averages (Druckenmiller 1972).

Age frequency distributions were determined from 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

Chapman's modification of the Schnabel formula (Ricker 1975; equation 3.17) was used to estimate largemouth bass population size in Rockland Lake. Caudal or pelvic fins were clipped during spring electrofishing sampling, and fish were recaptured by eletrofishing in the same spring (May 1982 and 1983). No mark / recapture estimates were attempted in fall because few largemouth bass were caught then. Confidence limits (95%) were computed with R as a Poisson variable (Ricker 1975; p.97). Standing stock was the product of the population estimate and mean individual weight.

The exploitation rate of largemouth bass in Rockland Lake in 1982 was calculated by dividing estimated harvest (1982 creel survey) by the population estimate (Ricker 1975; p.264).

Creel Survey

Creel surveys were conducted on all study lakes in 1982. Rockland and Browns Lakes were surveyed from 1 May (the opening of the bass season) through 31 September. Beulah and Pretty Lakes were surveyed from 20 May through 31 August. All weekends and holidays, and 3 weekdays were censused each week except for Pretty Lake, which was creeled one weekend and one weekday. Angling (shore and boat) was stratified into early (0600 - 1400 hrs) and late (1400 - 2200 hrs) periods. The 3 weekdays and the early and late survey periods were selected at random.

One creel clerk worked on Beulah and Pretty Lakes. Beulah Lake was surveyed 32 hrs/week and Pretty Lake was surveyed 8 hrs/week; four hours each on one weekend day and one weekday, the periods and days randomly selected. Another creel clerk surveyed Rockland and Browns Lakes so that each lake was surveyed 20 hrs/week.

Hourly instantaneous counts were obtained from one or two vantage points on Rockland, Pretty, and Browns Lakes, and by the clerk traversing a transect entirely across Beulah Lake (George Boronow, DNR Fish Manager, personal communication). Anglers were interviewed between counts or at the end of the survey period. Information recorded included: mode of fishing (boat or shore), number in party, time spent fishing, species sought (If more than one, the percent applied to each species was recorded), and the number of each species caught and released. If a creel clerk encountered an illegal bass during the creel survey, it was returned to the water, but recorded as a bass harvested since the angler probably would have kept it had he or she not been stopped by the creel clerk.

With the angler's permission, creeled fish were counted, measured, and weighed. Scale samples were collected from largemouth bass. All anglers were cooperative. When time did not conveniently allow examination of each fish (about 35% of the time), a sample of panfish was selected without regard to size.

Estimated catch and harvest were the products of catch or harvest per unit effort from interviews and total effort from instantaneous counts (Hoey and Redmond 1974).

Because Beulah and Pretty lakes were surveyed for only part of May, estimates of fishing pressure, catch, and harvest for the period 20 - 31 May were extrapolated to cover the entire month, from the proportion,

$$\frac{\text{Est. for the last 12 days in May for Browns Lake}}{\text{Est. for the entire month of May for Browns Lake}} = \frac{\text{Est. for the last 12 days in May for Beulah or Pretty Lakes}}{\text{Unknown est. for the entire month of May for Beulah or Pretty Lakes.}}$$

The estimates of fishing pressure, catch, and harvest rates of largemouth bass, bluegills, and all species combined for the last 12 days in May for Rockland Lake were higher than for the other lakes, and therefore were not included in the proportion. Beulah and Pretty Lakes were not censused in September.

I compared the creel survey conducted in 1980, when there were no regulations, to the 1982 creel survey to record anglers response to the regulations.

RESULTS AND DISCUSSION

Gear Selectivity

Electrofishing produced more species than fyke nets and the creel survey (Appendix C), a result in agreement with that of Michaelis (1982). Although electrofishing and fyke nets yielded similar size ranges in my samples (Figures 1-4; Appendices D, E), fyke nets caught a greater proportion of larger bluegills than the electroshocker. When fyke netting and electrofishing were carried out concurrently in Spring 1983, mean lengths of bluegills, pumpkinseeds, green sunfish (except in Beulah Lake), and warmouth captured in fyke nets were significantly greater than those captured by electrofishing (Appendix F). Laarman and Ryckman (1980) stated that smaller fish were not adequately sampled in trap nets because of mesh size.

Michaelis (1982) considered spring electrofishing samples to be most representative of population size structures in the lakes because electrofishing catches contained size ranges similar to fyke net catches, and yielded a more typical pattern of decrease in number with increase in length. Reynolds and Simpson (1978) concluded that electrofishing was efficient to determine size - structure in fish communities, and that its efficiency is probably highest in spring when many fish are associated with warming, inshore waters.

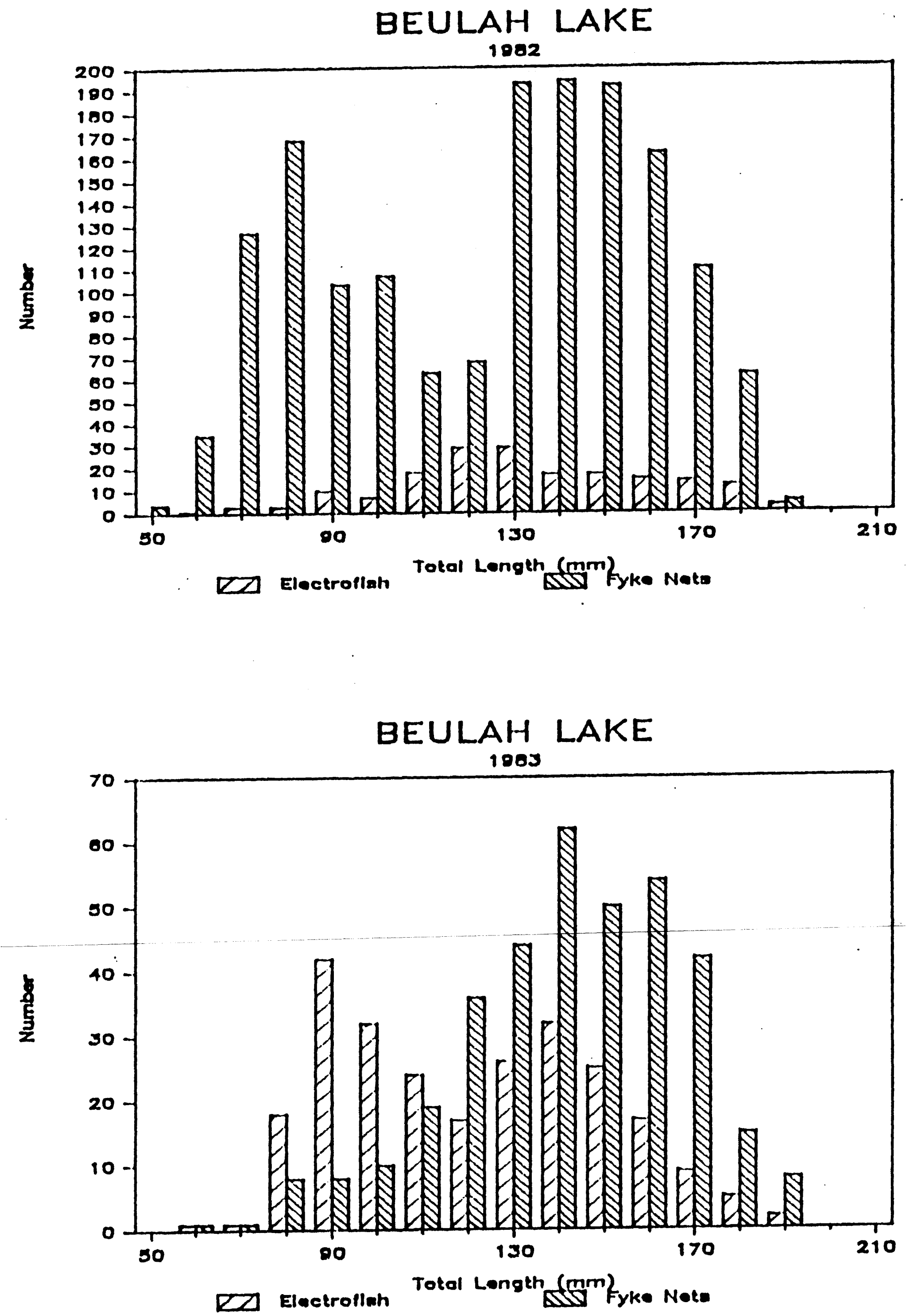
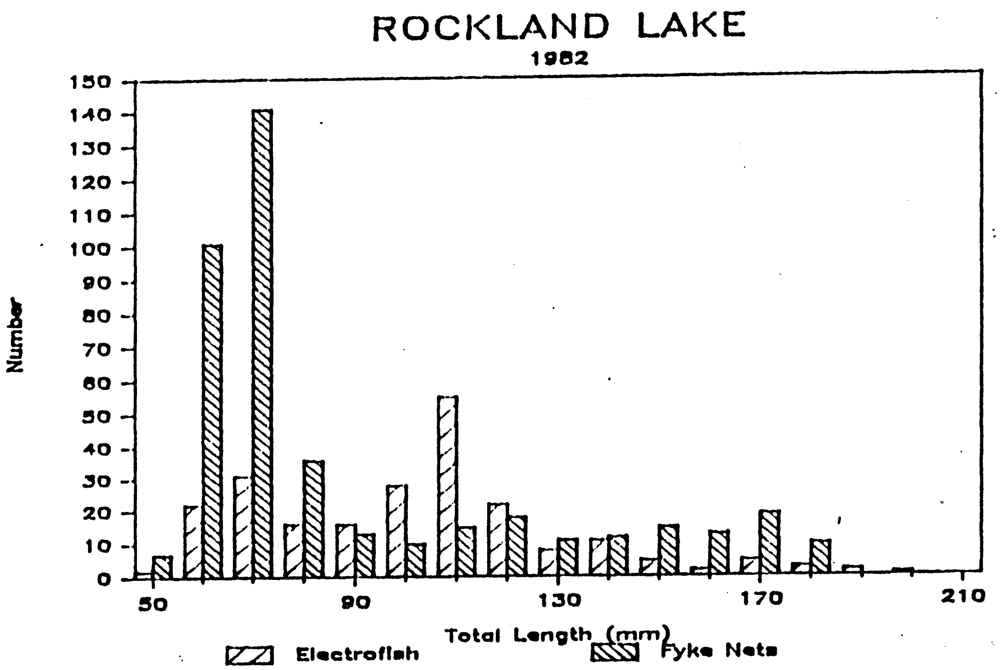


Figure 1. Length - frequency distributions of bluegills caught by spring electrofishing and fyke nets in 1982 and 1983 in Beulah Lake.



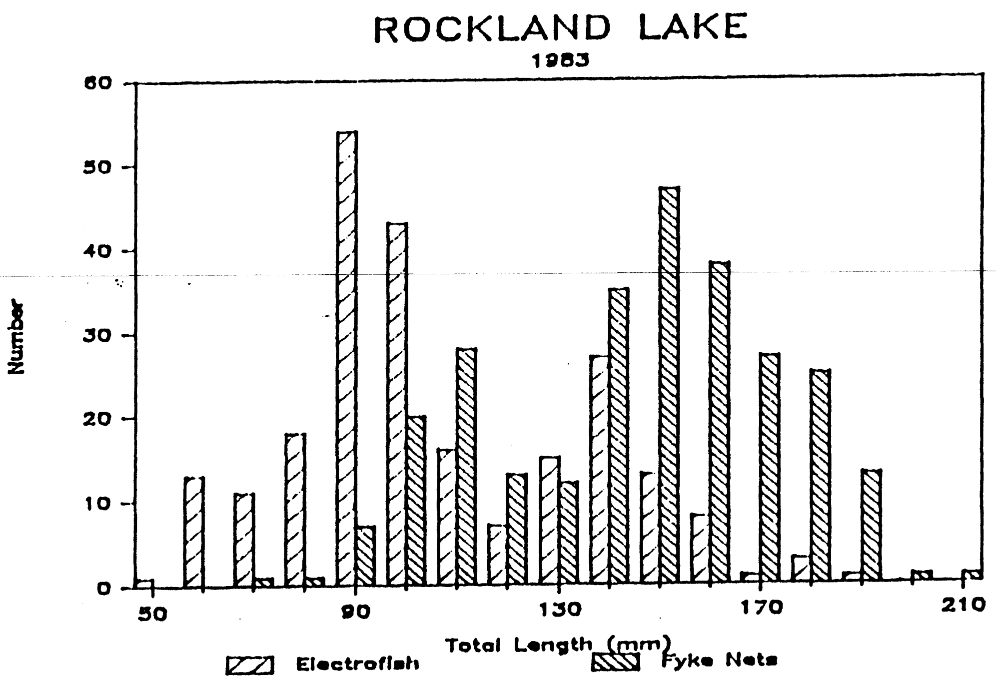
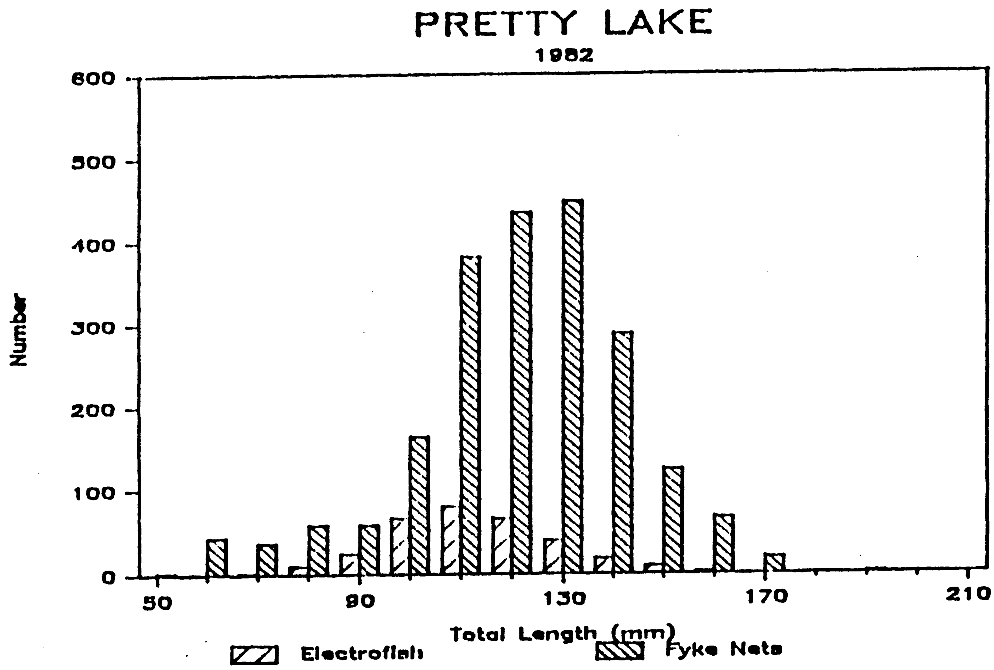


Figure 2. Length - frequency distributions of bluegills caught by spring electrofishing and fyke nets in 1982 and 1983 in Rockland Lake.



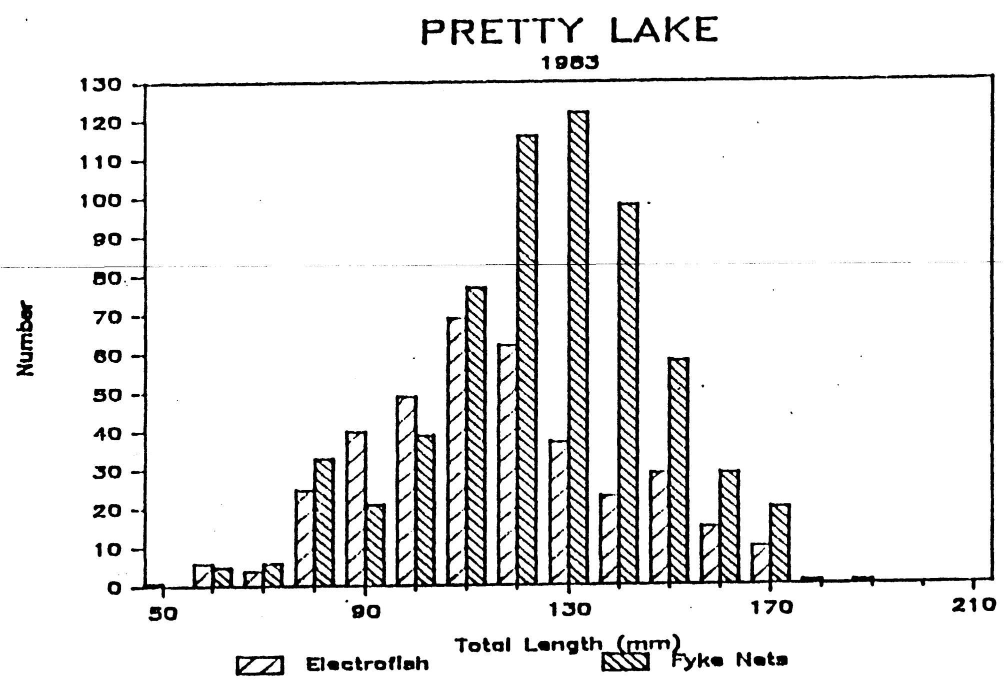
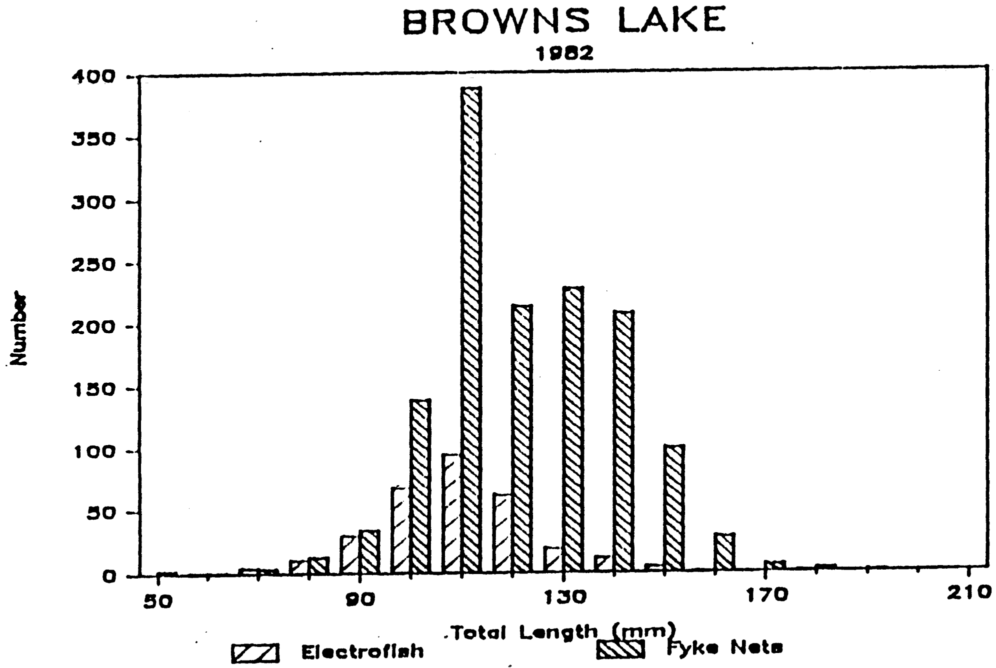


Figure 3. Length - frequency distributions of bluegills caught by spring electrofishing and fyke nets in 1982 and 1983 in Pretty Lake.



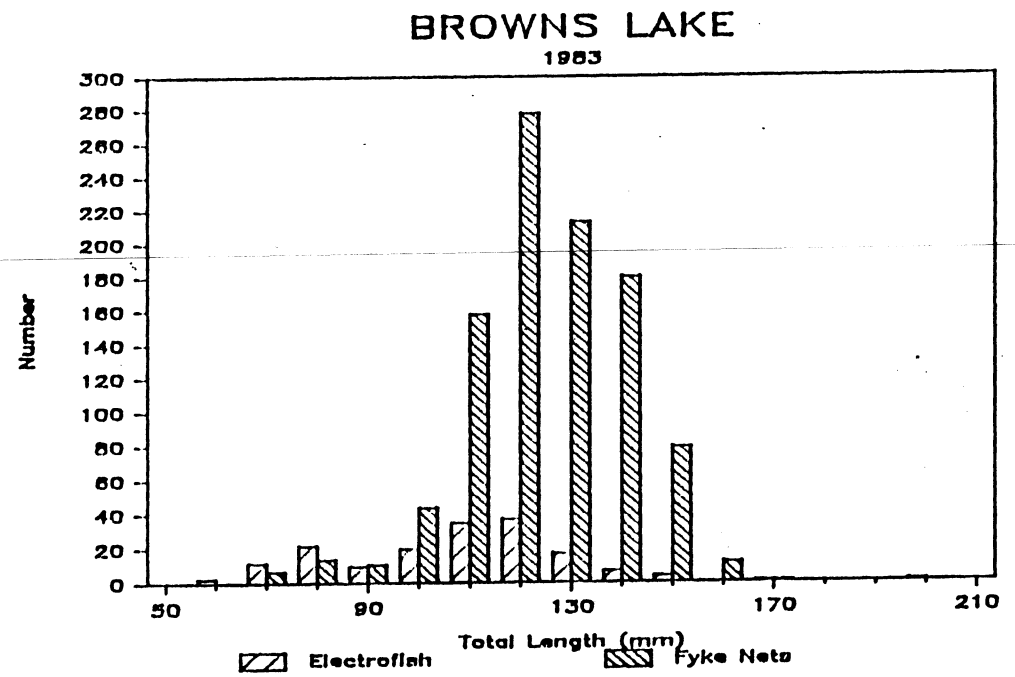


Figure 4. Length - frequency distributions of bluegills caught by spring electrofishing and fyke nets in 1982 and 1983 in Browns Lake.

I used spring electrofishing samples to compare length - frequency distributions, calculate PSD, Wr, and mortality rates. Spring and fall electrofishing samples were combined to determine growth rates, and index of abundance (CUE).

Length - Frequency Distributions

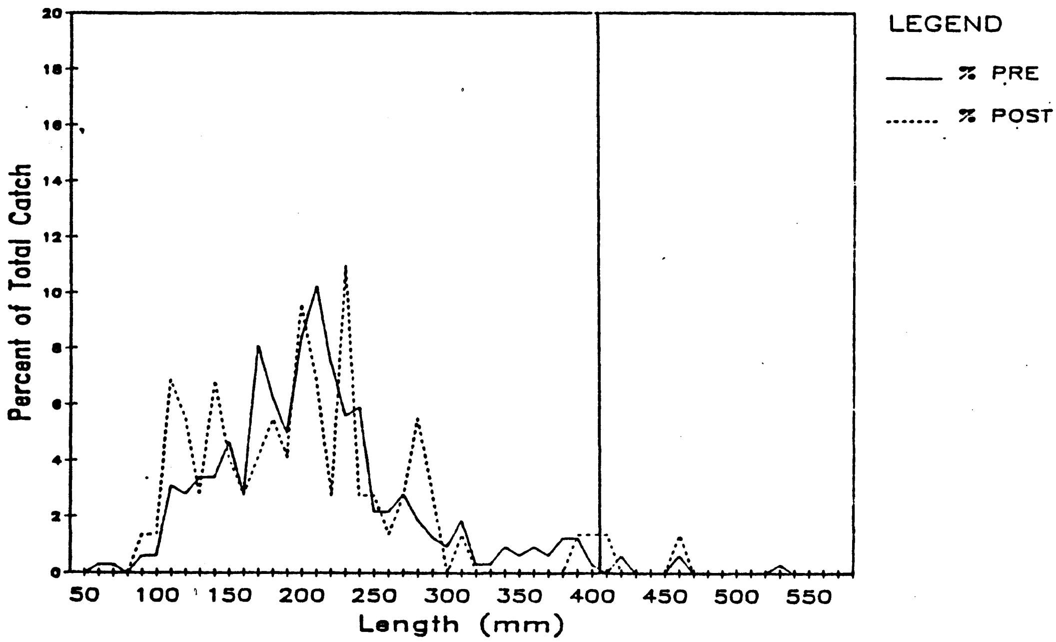
Largemouth bass

In general, there was little change in length frequency distributions since the impostion of the length limit regulations (Figures 5-6; Appendix G). Rockland Lake was the only lake in which mean length changed (214 to 236 mm) significantly (Appendix H). Perhaps more time is necessary for changes in the length structure of largemouth bass populations to be evident.

In Pretty Lake, length frequency distributions were similar for pre- and post- regulation periods, but in Browns Lake the percentage of both small and large bass increased (Figure 5). The former was probably a new year class, and the latter appeared to be a shift of pre- regulation largemouth bass of 320 to 370 mm to lengths greater than 400 mm. Fishing pressure on Browns Lake declined 25 percent (Creel Survey section), and apparently many largemouth bass larger than the minimum length limit were not harvested.

For lakes with the slot length limit, there was little

PRETTY LAKE



BROWNS LAKE

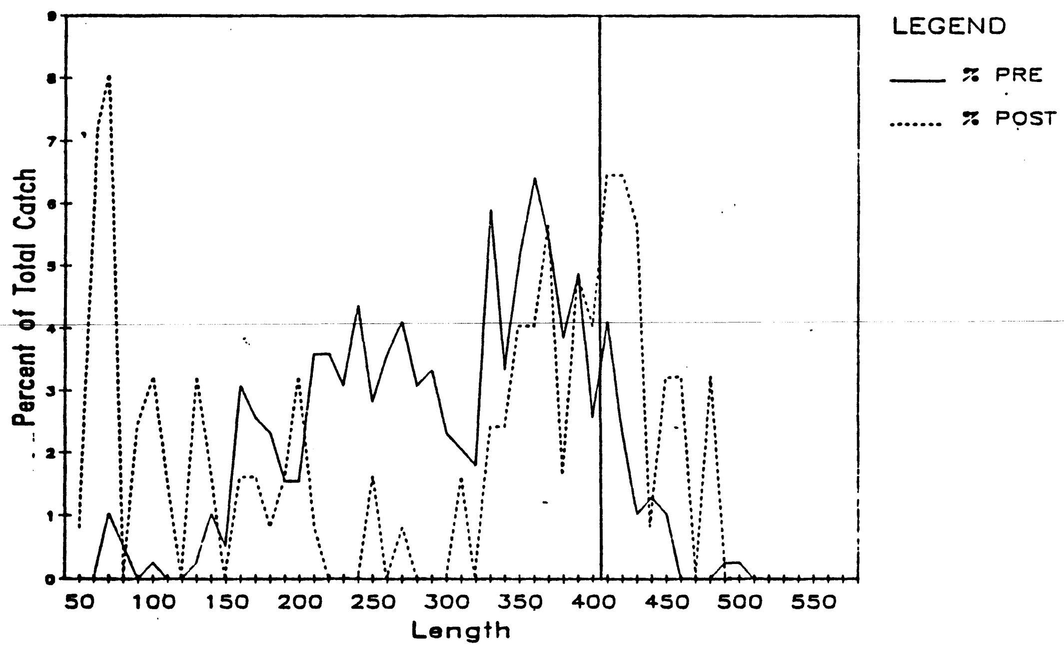
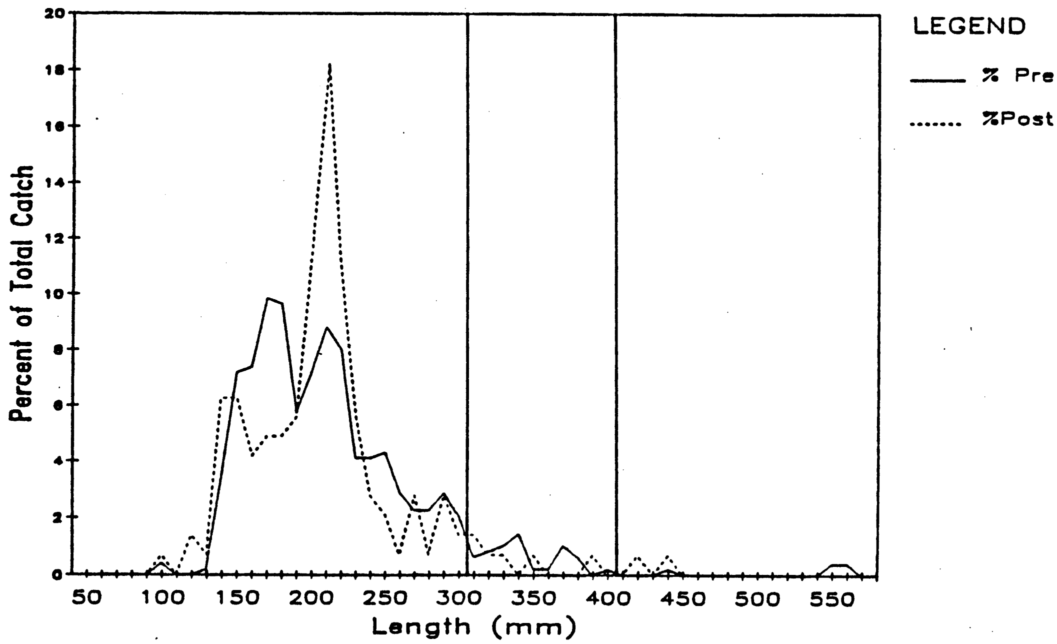


Figure 5. Length - frequency distributions of largemouth bass as a percent of the total catch for spring pre and post regulation electrofishing samples in Pretty and Browns Lakes. The minimum length limit (406 mm) is represented by the vertical line.

BEULAH LAKE



ROCKLAND LAKE

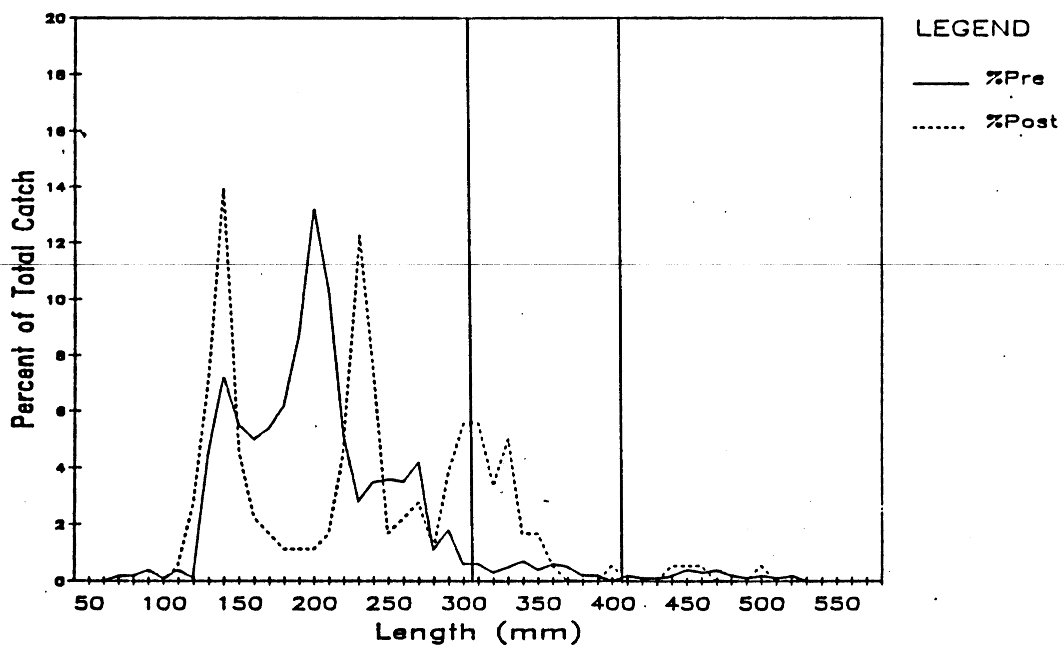


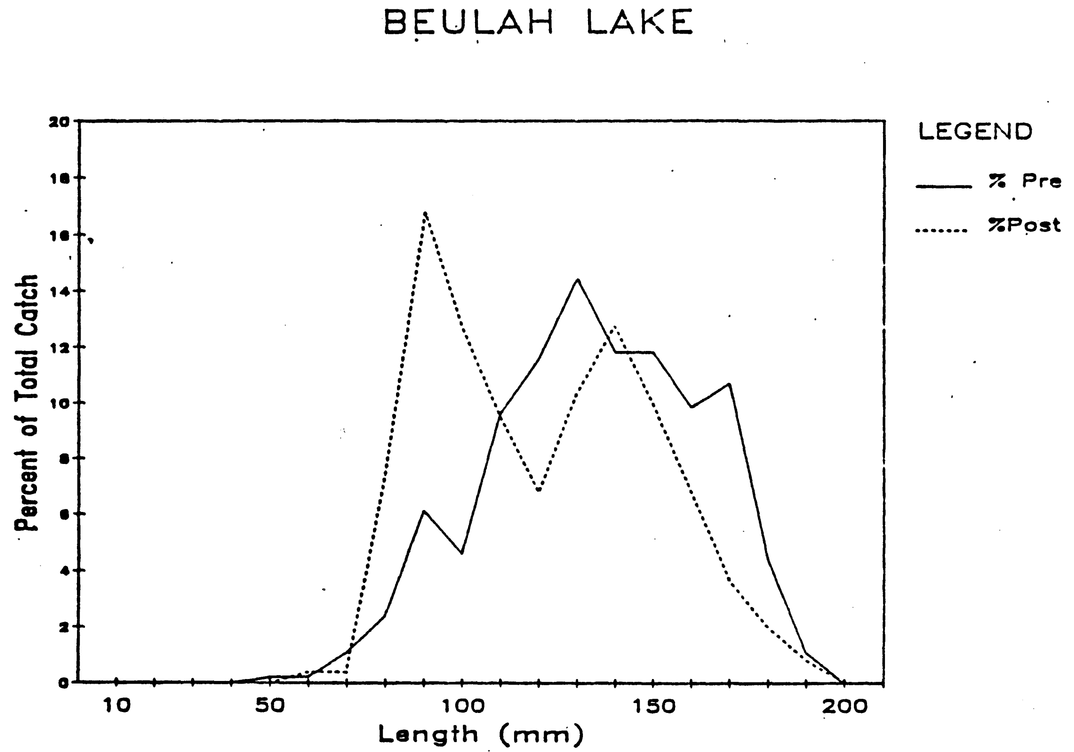
Figure 6. Length - frequency distributions of largemouth bass as a percent of the total catch for spring pre and post regulation electrofishing samples in Beulah and Rockland Lakes. The protected size range (305-406 mm) is between the vertical lines.

change in the percent of bass in the protected length range in Beulah Lake, and an increase of 19% in Rockland Lake (Figure 6).

Bluegills

There were no consistent patterns of change in the length frequency distributions for bluegills since the regulations went into effect. Length frequencies shifted to smaller sizes in Beulah and Rockland Lakes, and to larger sizes in Pretty and Browns Lakes (Figures 7-8). Mean lengths changed significantly in 3 of the lakes (Appendix H); they decreased in Beulah and Rockland Lakes (140 to 128 mm, 116 to 112 mm, respectively), and increased in Pretty Lake (108 to 120 mm).

Possible reasons for a lack of a consistent increase in length of bluegills are: 1) variation in year class strength, 2) the regulations were insufficient to cause an increase, and 3) insufficient time for the effects of the regulations to be evident. Novinger and Legler (1978) recommended decreasing largemouth bass harvest using high minimum length limits and severe creel limits when bluegill PSDs are lower than 20%. Three of the lakes had bluegill PSDs below 20% (see PSD section), and stricter regulations may be necessary. Reed (1982) suggested that evaluation of the effect of regulations on fishing quality should not be attempted until the



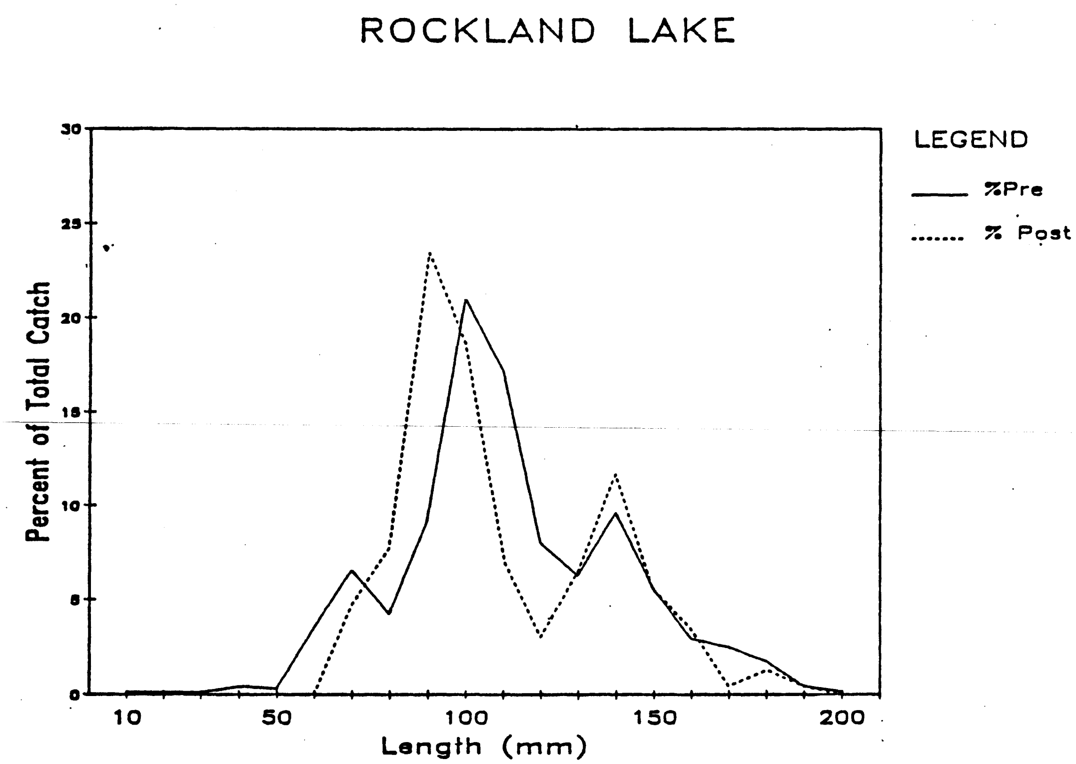
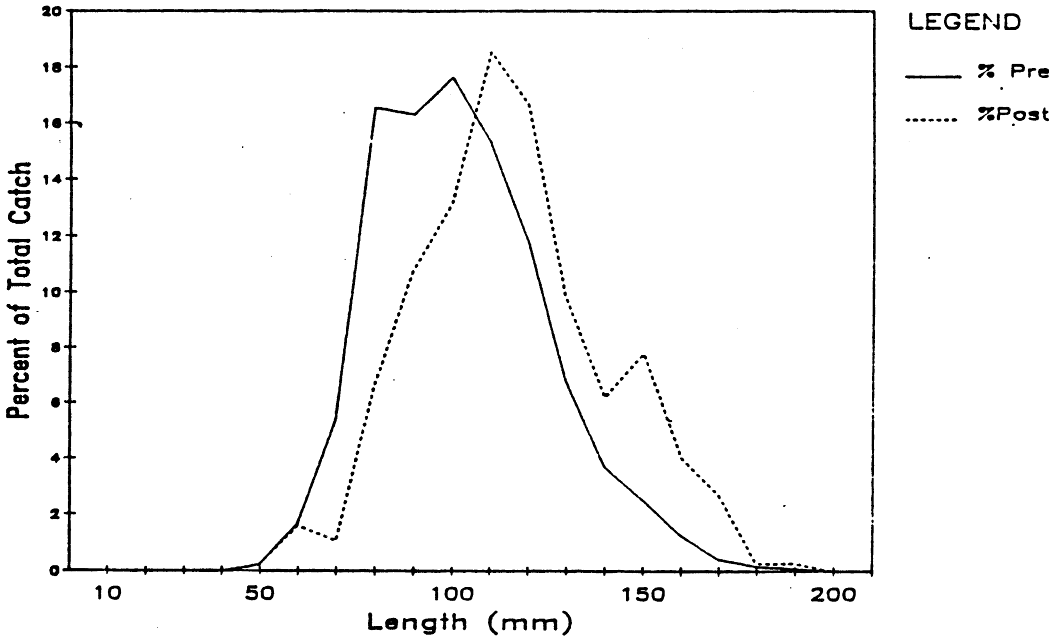


Figure 7. Length - frequency distributions of bluegills as a percent of the total catch for spring pre and post electrofishing samples in Beulah and Rockland Lakes.

PRETTY LAKE



BROWNS LAKE

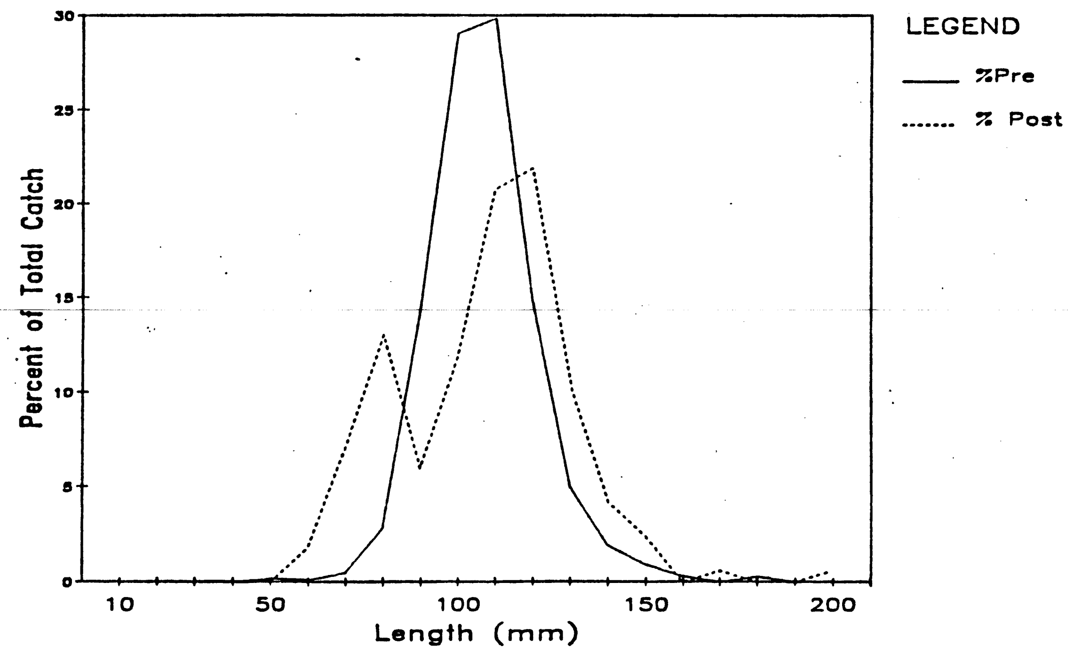


Figure 8. Length - frequency distributions of bluegills as a percent of the total catch for spring pre and post electrofishing samples in Pretty and Browns Lakes.

regulation had been in effect for at least five years. More time for the evaluation of the length limit regulations would seem advisable.

Index of Abundance

The length limit regulations had little effect on the index of abundance, or catch per unit effort (CUE), for largemouth bass and bluegills (Appendix I). For largemouth bass, CUE changed significantly in Rockland and Pretty Lakes only (Appendices J,K). In Rockland Lake, the mean CUE decreased, but the CUE for bass in the protected range increased, which coincides with the change in the length - frequency distribution (Figure 6). The CUE for largemouth bass in Pretty Lake decreased significantly. I cannot explain this change; the length - frequency distributions were similiar for pre and post regulation electrofishing samples of largemouth bass in Pretty Lake. There were no significant changes in CUE for bluegills (Table 3; Appendix I).

Hence, on the basis of electrofishing CUE data, the only expected change in fish populations evident so far in this project was for largemouth bass in Rockland Lake.

Table 3. Comparison of bluegills pre (1980 -1982) and post (1983) regulation electrofishing sample CUE's (fish/hour) with a t- test (Li 1969; p. 100). All statistical tests at the 0.05 level of significance.

Lake	Period	Mean CUE	Calculated t	d.f.	Significant difference
Beulah	Pre	291	0.946	5	no
	Post	256			
Rockland	Pre	360	1.231	6	no
	Post	311			
Pretty	Pre	694	0.192	5	no
	Post	721			
Browns	Pre	542	0.054	2	no
	Post	528			

Proportional Stock Density

Largemouth bass

Along with the increase in mean length, and CUE for largemouth bass in Rockland Lake, there was a corresponding increase in PSD (Table 4). I would expect largemouth bass PSD's in Rockland Lake to increase since there was an increase in the percentage of larger bass in the post regulation electrofishing samples (Figure 6). Changes in largemouth bass PSDs were similar to changes in length frequency distributions. In Browns Lake, low numbers of fish of stock - size before the length limit yielded a high PSD. After the regulations were in effect, there were both low numbers of stock - size bass and an increase in quality - size bass (Figure 5). Hence, PSD increased even more (62 to 90%), well beyond the recommended ranges. In Beulah and Pretty Lakes, PSDs remained vitually the same (Table 4).

Bluegill

Overall changes in bluegill PSDs were inconsistent one year following the length limit regulations (Spring 1983). Pretty Lake PSD for bluegills increased from 5 to 16%, while Beulah Lake PSD decreased from 38 to 23%, and PSDs in Rockland and Browns Lakes were stable (Table 4). Again, changes that occurred in bluegill post- regulation PSDs were in the same direction as the changes in length frequency distributions.

Table 4. Pre (1980-1982) and post (1983) largemouth bass and bluegill spring PSD's and temperature (°C) in the study lakes.

Species	Lake	Pre PSD	°C	Post PSD	°C
Largemouth bass	Beulah	17	18	11	20
	Rockland	13	21	41	19
	Pretty	19	21	13	20
	Browns	62	20	90	21
Bluegill	Beulah	38	18	23	20
	Rockland	15	21	13	19
	Pretty	5	21	16	20
	Browns	2	20	4	21

Table 5. Daily largemouth bass PSD (from electrofishing) and temperature (°C) in Rockland Lake in Spring 1983.

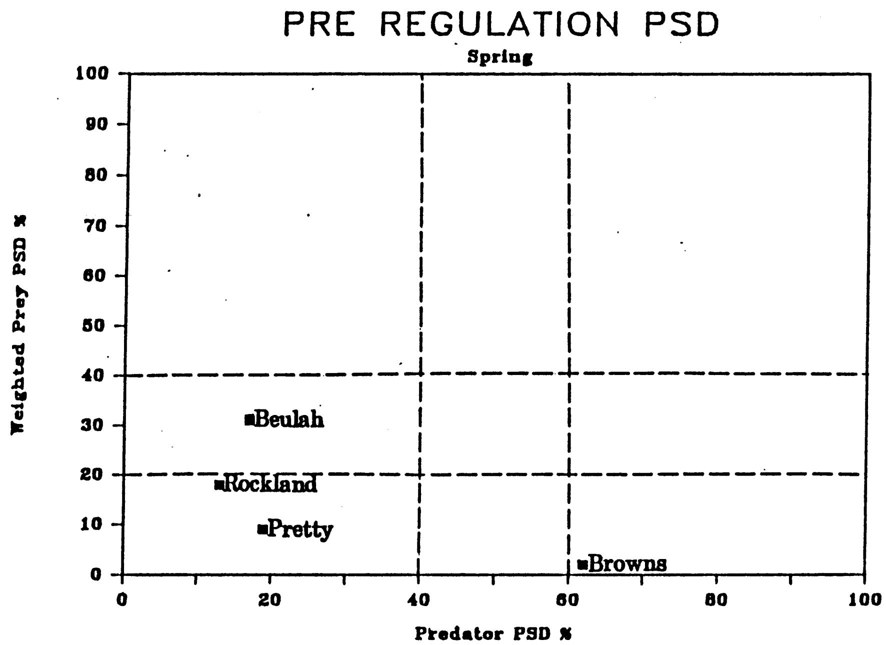
Date	PSD	°C
16 May	35	15
23 May	75	18
26 May	38	19
1 June	37	20
6 June	36	20

Largemouth bass plus Bluegill

Neither before, nor one year after imposition of the length limit regulations, did PSDs of both predator and prey fall within the recommended ranges in any lake (Figure 9). PSD of bluegills in Beulah Lake were satisfactory both before and after the regulations. Largemouth bass PSD in Rockland Lake was satisfactory since the regulations

Proportional Stock Density is a population structure index, and may be influenced by recruitment, growth, and mortality. Carline, Johnson, and Hall (1984) used a computer simulation model to show that PSD increases linearly with survival and curvilinearly with growth. Variations in recruitment can cause large fluctuations in PSD; a large year class would decrease PSDs when the fish were stock - size, and it would increase PSDs when the fish grew to quality - size. I think that the usefulness of PSD is limited because PSD describes relative, not absolute abundance (Gablehouse 1984). A low PSD could be caused by high mortality of quality - size fish or by a large year class of stock - size fish without such high mortality (Michaelis 1982). I prefer to have additional data, e.g. length - frequency distributions, and growth and mortality rates to interpet changes in fish populations.

Water temperature may also affect PSDs. Carline, Johnson, and Hall (1984) concluded that when largemouth bass were collected with electrofishing gear, spring PSDs were positively related to water temperature. However, in my



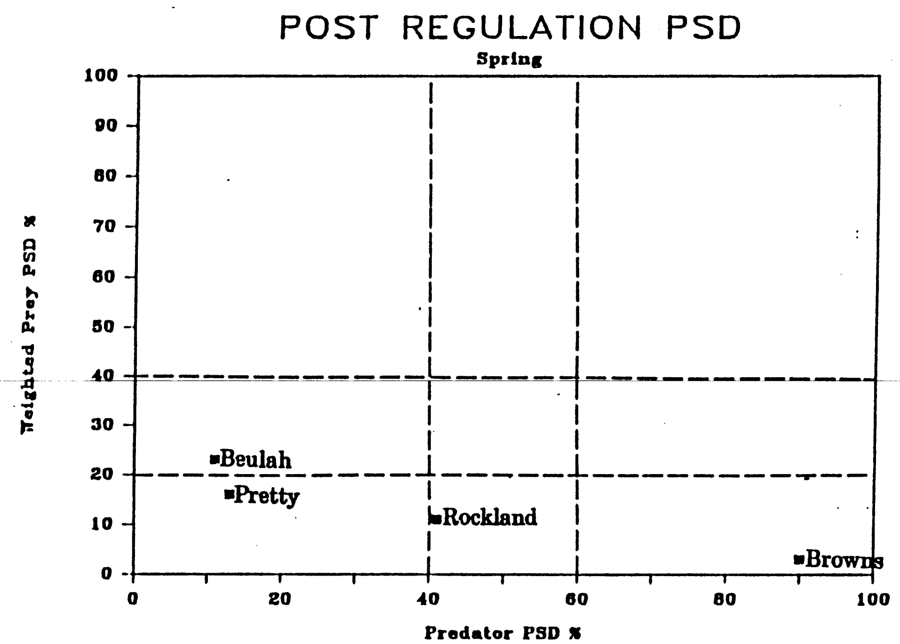


Figure 9. Spring pre (1980-1982) and post (1983) predator and prey PSD's for the study lakes.

study, there were no straightforward relationships between water temperature and PSD (Tables 4,5).

Relative Weight

Largemouth bass

Relative Weight of largemouth bass were within the recommended ranges of 90 to 105% in all the lakes before and after the imposition of the regulations (Figures 10-11). Changes in Relative Weight for largemouth bass were inconclusive. Relative Weight did not change in Browns Lake, but it changed significantly in the other lakes, increasing in Beulah and Pretty, and decreasing in Rockland Lakes (Appendix L). I would not expect much change in Wr for largemouth bass. The purpose of the regulations is to protect largemouth bass to increase predation on an abundant (panfish) food resource, which was believed to be ample both before and after the regulations.

I cannot explain the significant changes in Wr. Because the changes were in both directions, and because I would not expect Wr to change greatly, I suspect that the changes were fortuitous.

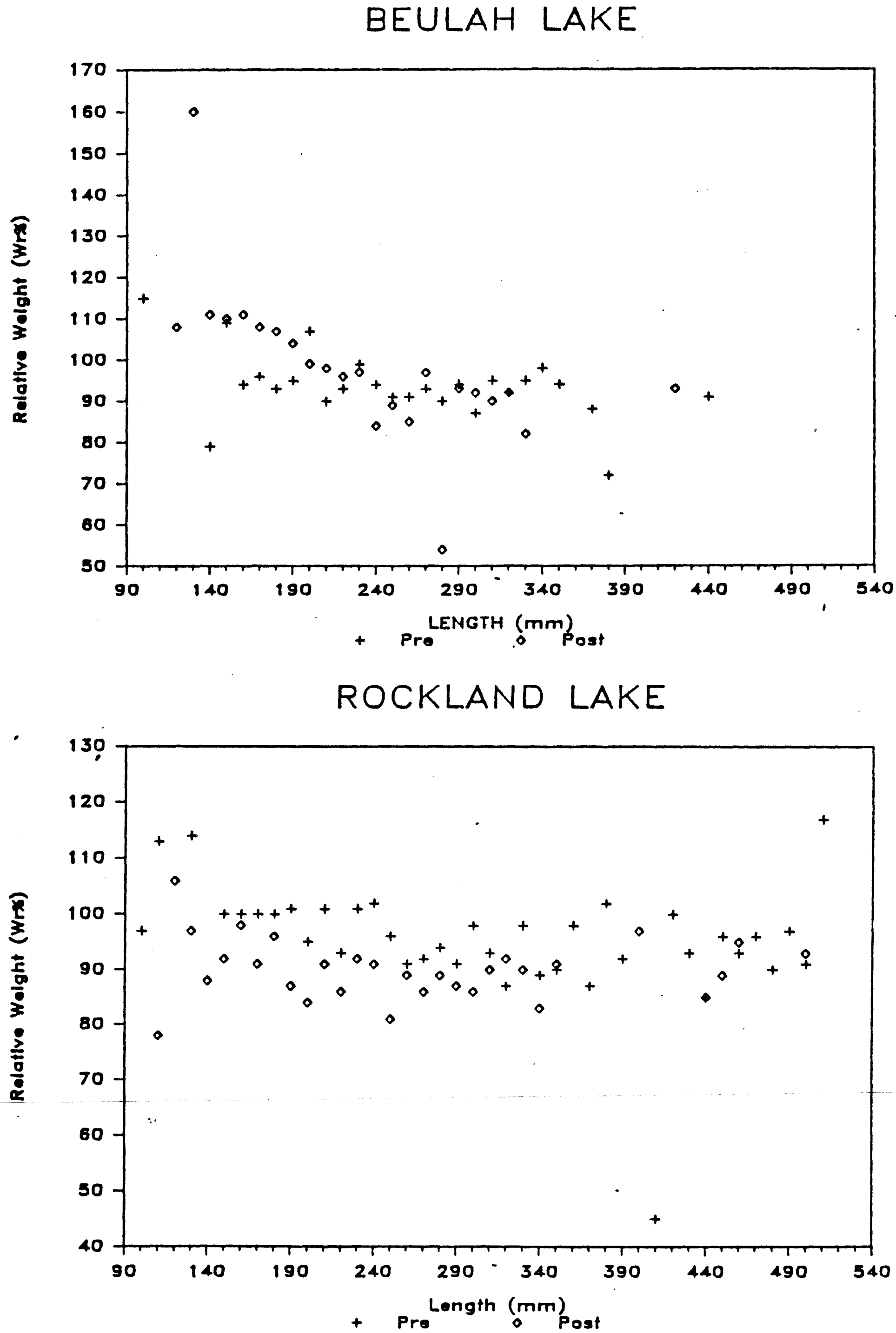


Figure 10. Pre and post regulation mean Relative Weight of largemouth bass in 10-mm length groups in Beulah and Rockland Lakes.

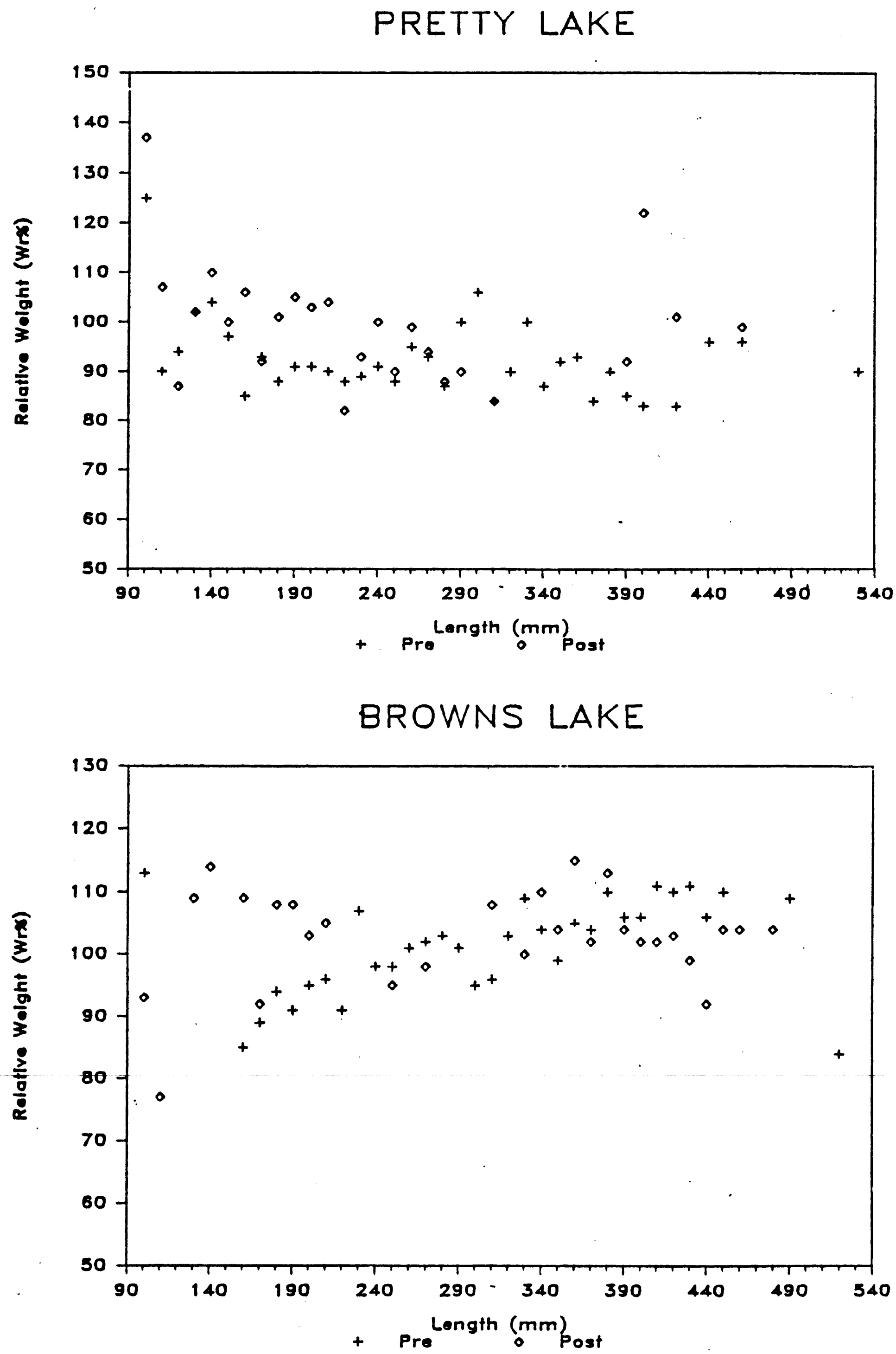


Figure 11. Pre and post regulation mean Relative Weight of largemouth bass in 10-mm length groups in Pretty and Browns Lakes.

Bluegill

Changes in Wr of bluegills were somewhat encouraging. If increase predation thinned bluegill populations leaving fewer fish to feed on the same food base, Wr would be expected to increase. Relative Weight increased significantly in Beulah, Rockland, and Browns Lakes (Figures 12-13; Appendix L). However, bluegill Wr were in the recommended ranges only in the former two lakes.

Wr decreased significantly in Pretty Lake, which I cannot explain, and the increase in Browns Lake was not sufficient to bring Wr into the recommended range (Appendix L).

The unexpected change in Wr in Pretty Lake coupled with the lack of change in bluegill CUE (Table 3) since the imposition of the regulations, advises caution in attributing the change in Wr to the length limit regulations. Again, perhaps more time is necessary for clearer cause and effect changes to become evident.

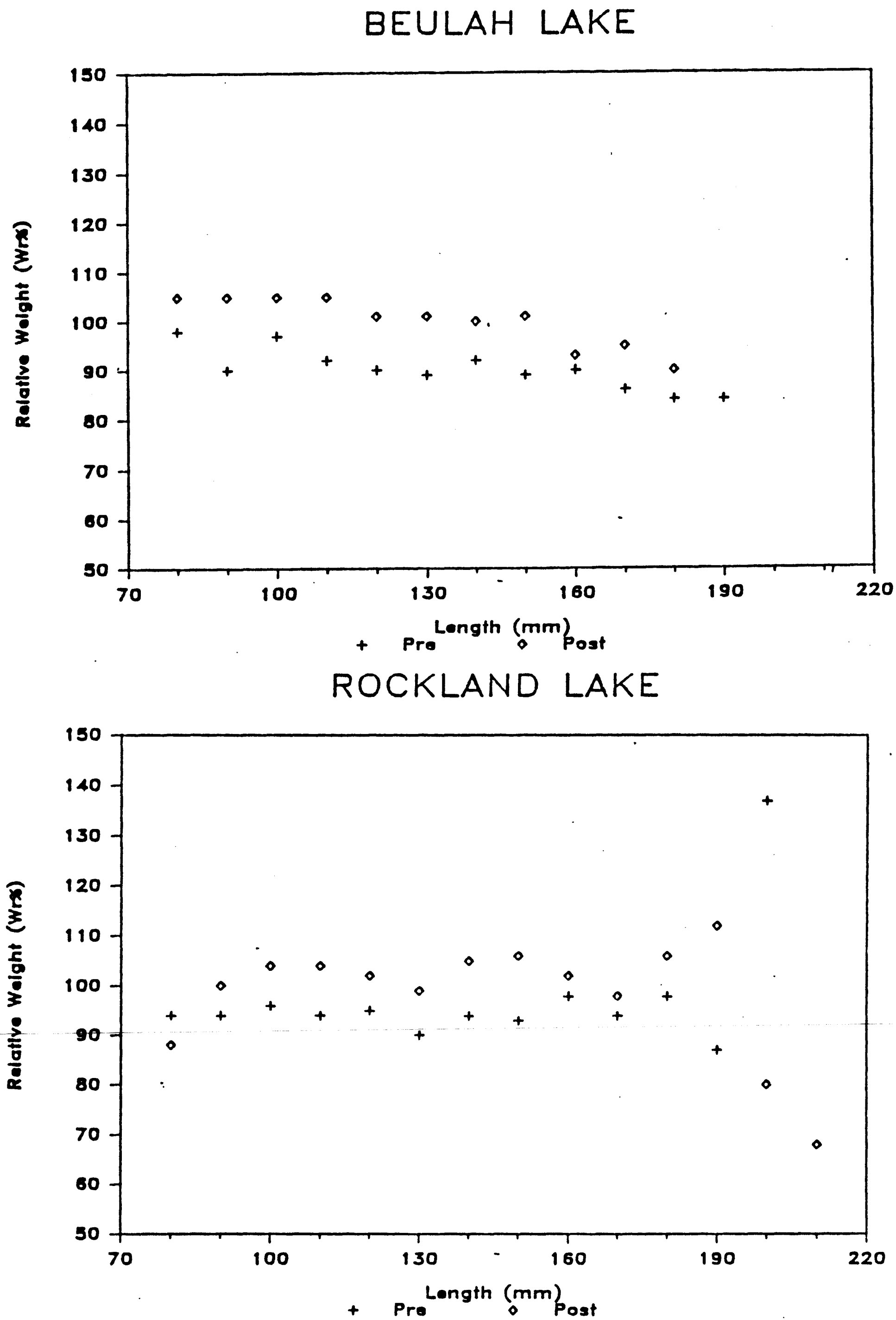
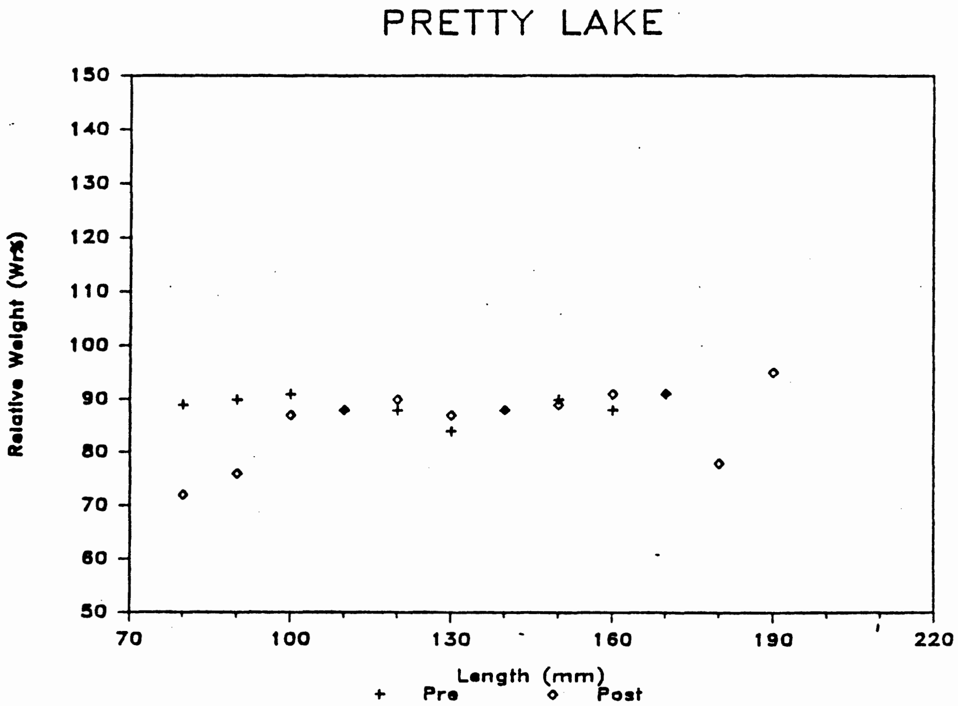


Figure 12. Pre and post regulation Relative Weight of bluegills in 10-mm length groups in Beulah and Rockland Lakes.



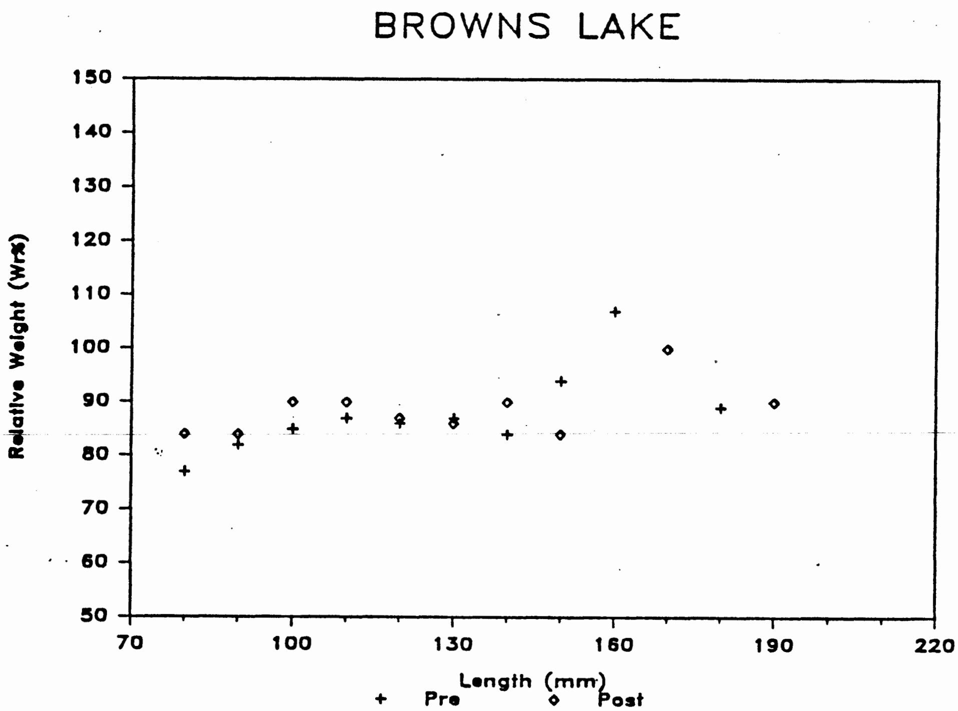


Figure 13. Pre and post regulation Relative Weight of bluegills in 10-mm length groups in Pretty and Browns Lakes.

Growth

Largemouth bass

The length limit regulations should not effect the growth rates of largemouth bass since there is an abundant food source. Growth did not change in three of the lakes during the year (1983) following the regulations. Because instantaneous growth rates and length increments were determined from the last two annuli on scales, they were affected only by conditions in 1982 and 1983. Growth rate in Beulah Lake was significantly lower after the length limit regulation (Table 6; Appendix M). The slower growth rate of largemouth bass in Beulah Lake may be attributed to low bluegill abundance (Table 3) or a high proportion (86%) of bass less than 250 mm long (Figure 6) or both. This reduced growth rate is not consistent with the change in Wr of largemouth bass in Beulah Lake, for post- regulation Wr increased significantly (Appendix L).

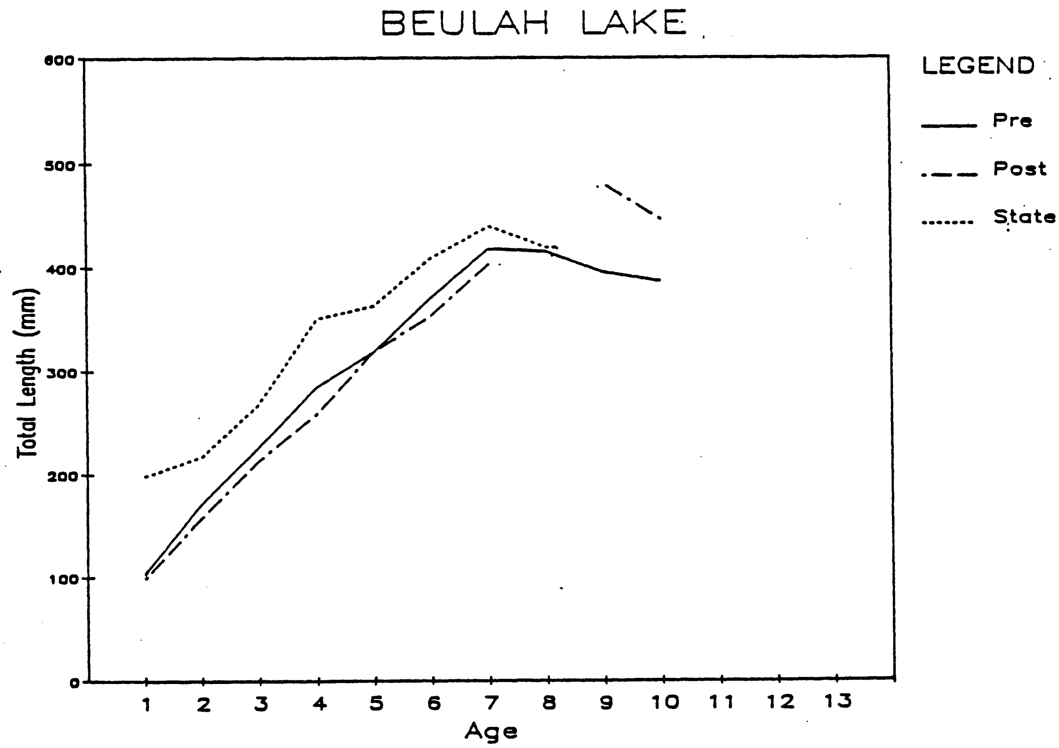
Length at age for largemouth bass in Beulah and Browns Lakes were significantly less than the Southeastern Wisconsin average (Figures 14-15;Appendices N,O). This observation is difficult to interpet with the Wr data. Relative Weights were higher in these two lakes than in Pretty and Rockland Lakes (Appendix L). Food may have been less available to bass in Beulah and Browns Lakes than in the other two lakes. The CUE for bluegills in Beulah Lake was low, and Browns Lake had more submerged vegetation than the other lakes that could provide cover for bluegills.

Table 6. Instantaneous growth rates (G) compared with a Wilcoxon paired - sample test (Zar 1974; p. 124-126) between pre (1980-1982) and post (1983) regulation largemouth bass, bluegills,and pumpkinseed (Browns Lake only) samples. All statistical tests were at the 0.05 level of significance; N is the number of pairs.

Species	Lake	T	N	Significant difference
Largemouth bass	Beulah	0	6	yes [a]
	Rockland	8	7	no
	Pretty	6	7	no
	Browns	7	8	no
Bluegill	Beulah	5	7	no
	Rockland	13	8	no [b]
	Pretty	0	7	yes
	Browns	11	7	no
Pumpkinseed	Browns	9	6	no

a Pre-regulation sample had the larger value.

b Post-regulation sample had the larger value.



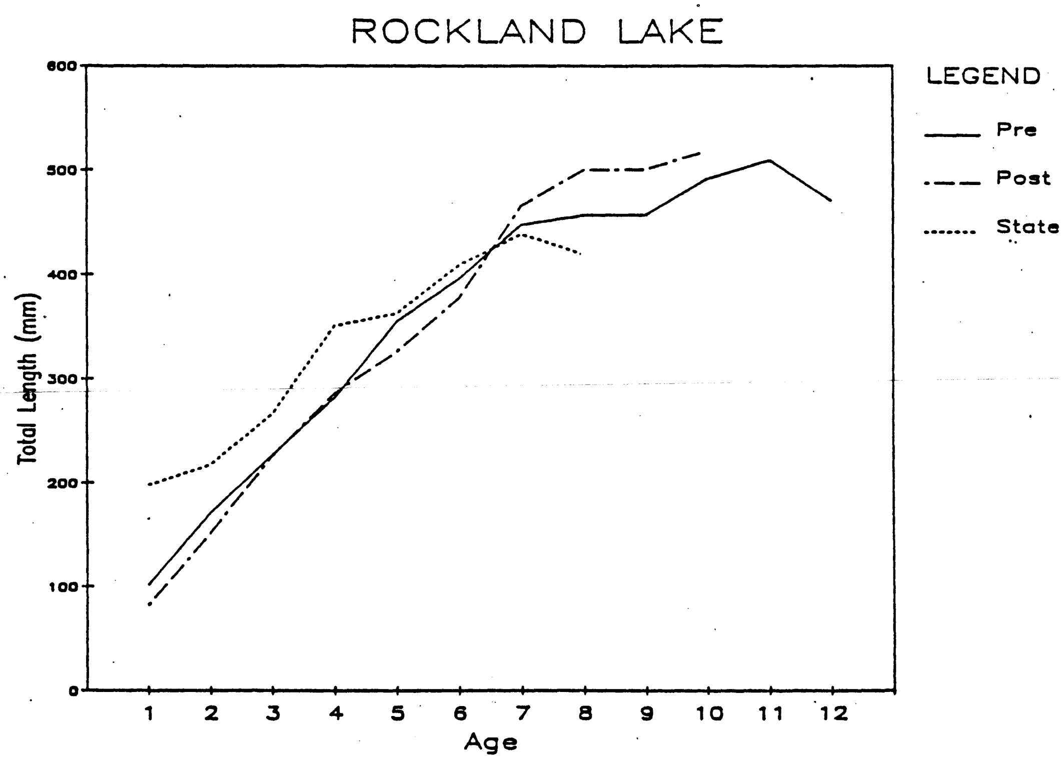


Figure 14. Total length (mm) at age of pre and post regulation largemouth bass in Beulah and Rockland Lakes; and the southeastern Wisconsin average (Druckenmiller 1972).

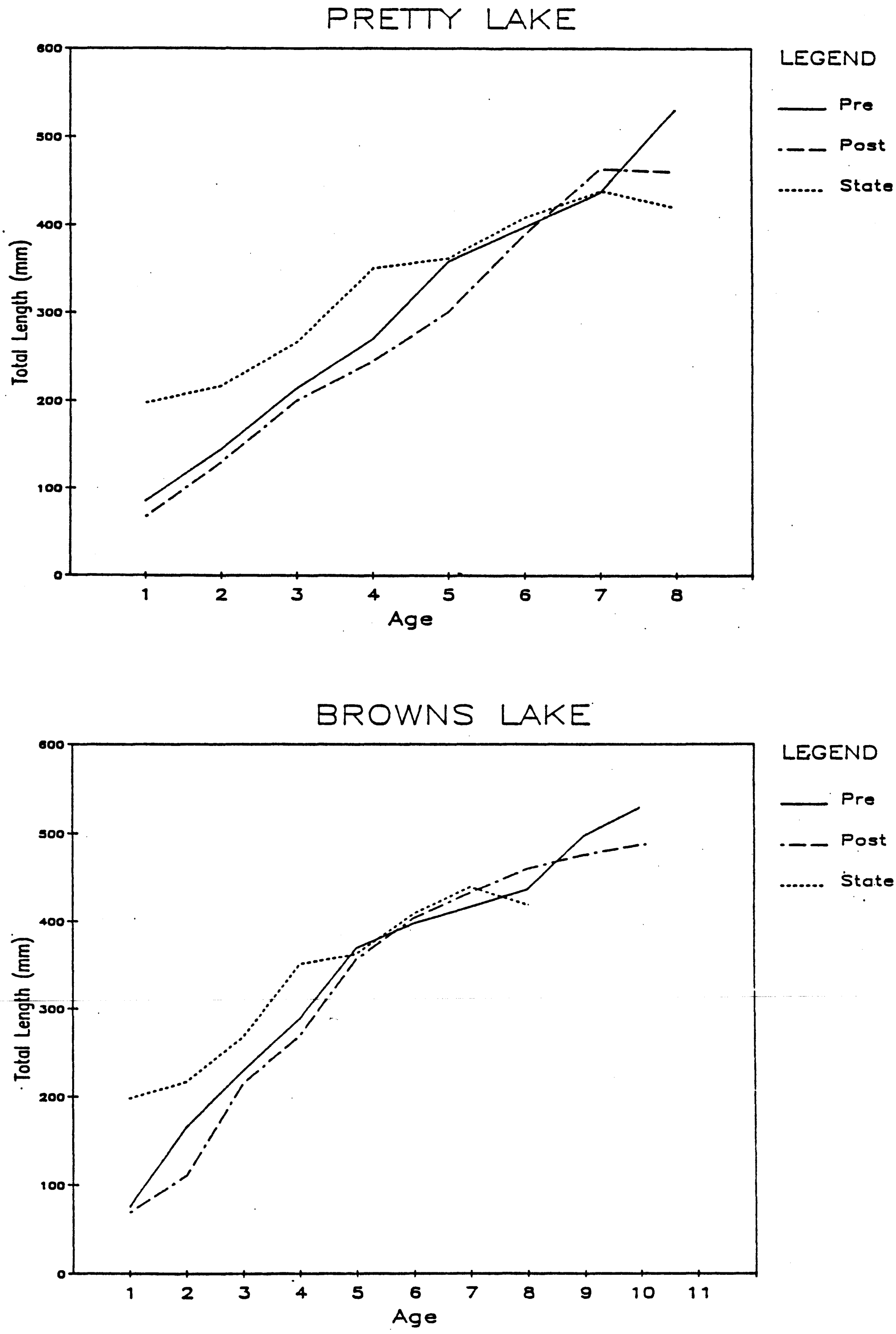


Figure 15. Total length (mm) at age of pre and post regulation largemouth bass in Pretty and Browns Lakes; the southeastern Wisconsin average (Druckenmiller 1972).

Bluegill

If the length limit regulations thinned the bluegill populations, I would expect growth rates to increase. However, there were no significant changes in bluegill abundance, and the regulations did little to affect the growth rate of bluegills. Only in Pretty Lake was there a significant change, an increase (Table 6), but change in growth was not consisent with change in Wr. Post- regulation Wr of bluegills in Pretty Lake decreased (Appendix L). Since bluegill CUE's have remained the same follwing the imposition of the length limit regulations, and the significant changes in the growth rate and Wr in Pretty Lake were in opposite directions, I suspect these changes may not be related to the length limit regulations. There was no change in the post-regulation growth rate for pumpkinseeds in Browns Lake (Table 6).

Length at age for bluegills in all lakes and pumpkinseed in Browns Lake were less than the Southeasetern Wisconsin average (Figures 16-17; Appendices N,O). Less than satisfactory growth rate is characteristic of unbalanced fish populations (Anderson 1973).

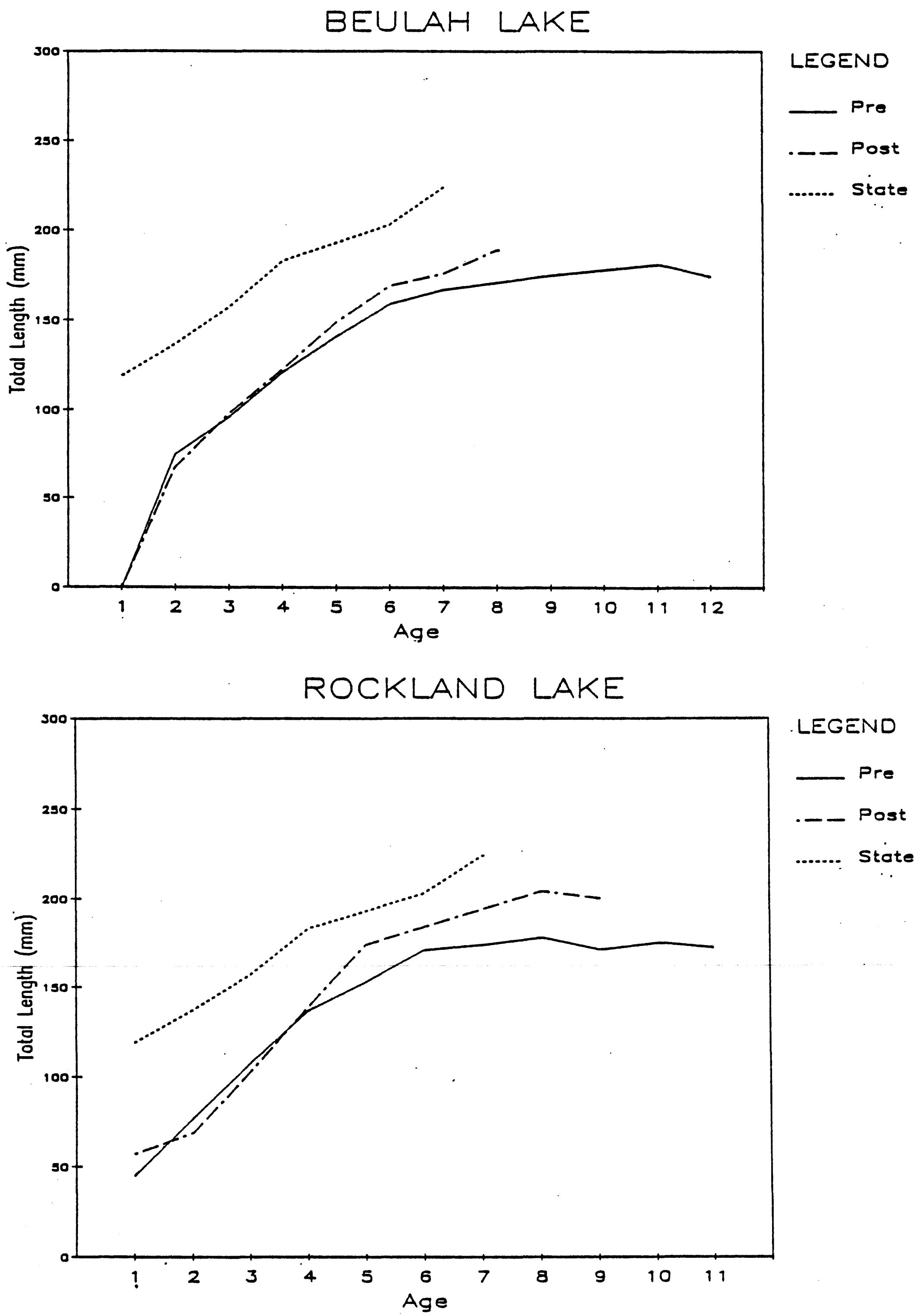
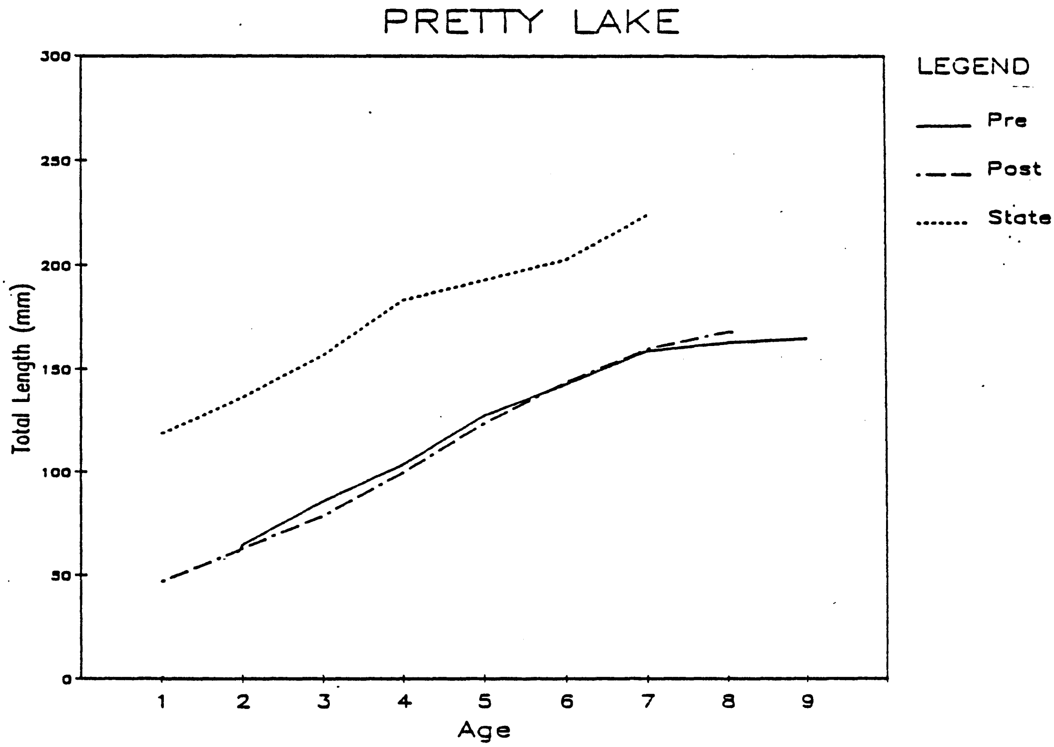


Figure 16. Total length (mm) at age of pre and post regulation bluegills in Beulah and Rockland Lakes; and the southeastern Wisconsin average (Druckenmiller 1972).



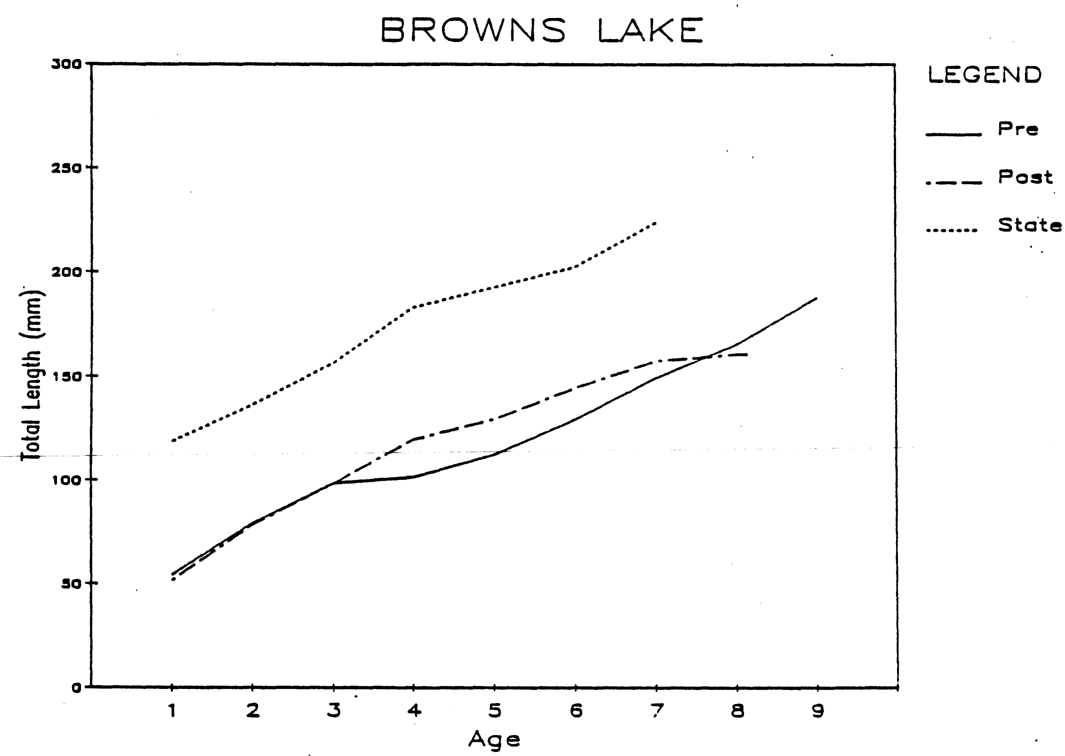


Figure 17. Total length (mm) at age of pre and post regulation bluegills in Pretty and Browns Lakes; and the southeastern Wisconsin average (Druckenmiller 1972).

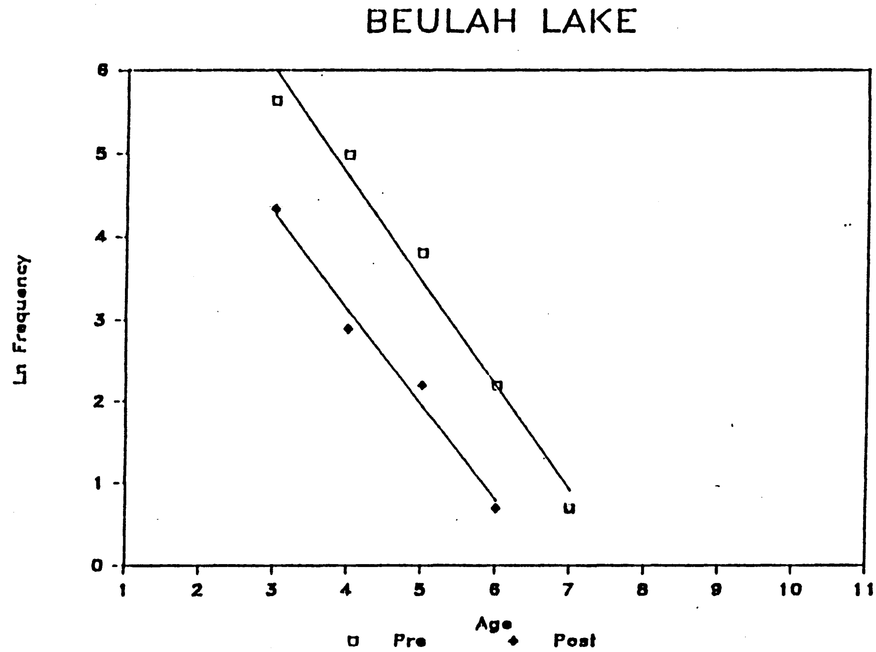
Mortality

Largemouth bass

Mortality rates of largemouth bass would be expected to decrease after imposition of the length limit regulations. Post regulation mortality did decrease in all lakes (Figures 18-19; Table 7), but the decrease was significant only for Pretty Lake. (Appendices P,Q). Because the catch curves covered a span of 5 or more years, e.g. ages 3 - 7, the post regulation catch curves would be influenced by conditions before the change in regulations (Figures 18-19). More time will be necessary for post regulation catch curves to reflect only conditions after imposition of the length limit regulations.

Bluegill

If length limit regulations increases abundance of largemouth bass, bluegill mortality rates should increase. However, there was no significant change in bluegill mortality rates (Figures 20-21; Appendix P). Again, more time will be required for post regulation catch curves to reflect only post regulation conditions.



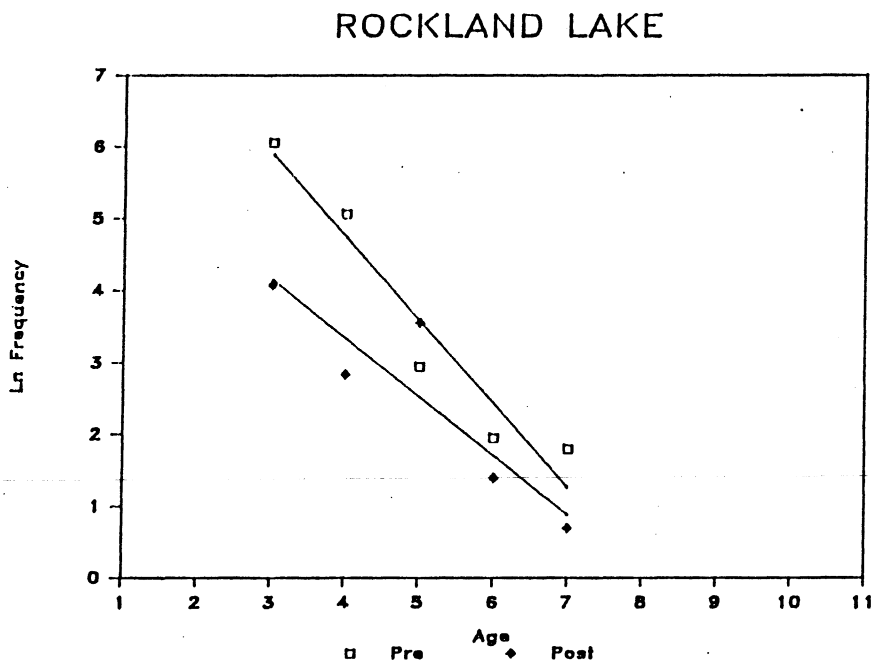
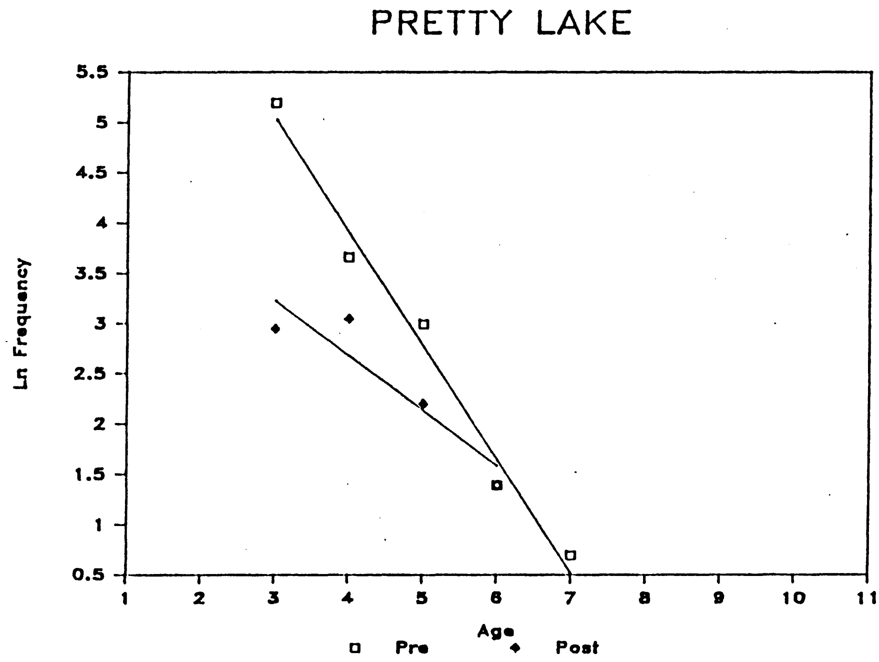


Figure 18. Catch curve of spring pre and post regulation electrofishing samples for largemouth bass in Beulah and Rockland Lakes.



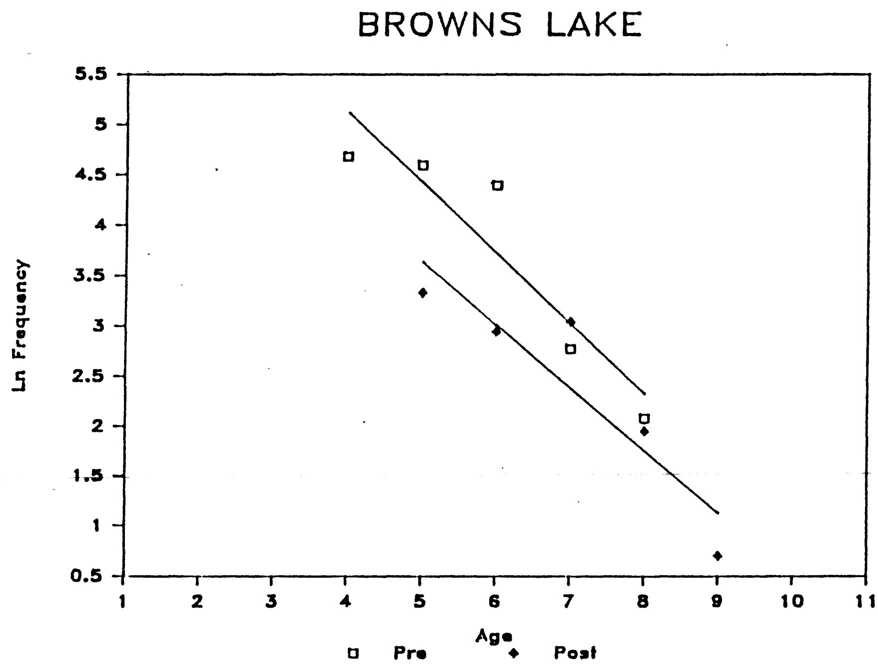


Figure 19. Catch curve of spring pre and post regulation electrofishing samples for largemouth bass in Pretty and Browns Lakes.

Table 7. Total annual and instantaneous mortality (A and Z), and survival (S) rates of largemouth bass, bluegills, and pumpkinseeds (Browns Lake only) for pre (1980-1982) and post (1983) regulation electrofishing samples. r is the correlation coefficient.

Lake	Period	A (%)	Z	S (%)	r	Ages	n
			Largemouth bass				
Beulah	Pre	72	1.270	28	0.989	3-7	483
	Post	69	1.161	31	0.991	3-6	105
Rockland	Pre	69	1.165	31	0.964	3-7	617
	Post	56	0.821	44	0.906	3-7	117
Pretty	Pre	68	1.128	32	0.991	3-7	245
	Post	42	0.552	58	0.925	3-6	53
Browns	Pre	50	0.703	50	0.928	4-8	312
	Post	47	0.628	53	0.916	5-9	77
			Bluegills				
Beulah	Pre	42	0.544	58	0.966	4-11	402
	Post	44	0.572	56	0.929	3-8	264
Rockland	Pre	55	0.809	44	0.982	3-8	564
	Post	64	1.027	36	0.942	3-6	242
Pretty	Pre	74	1.364	26	0.989	5-8	472
	Post	83	1.748	17	0.871	5-7	263
Browns	Pre	76	1.420	24	0.962	5-8	645
	Post	49	0.680	51	0.982	4-7	109
			Pumpkinseed				
Browns	Pre	72	1.291	27	0.981	5-8	198
	Post	58	0.864	42	0.957	3-7	135

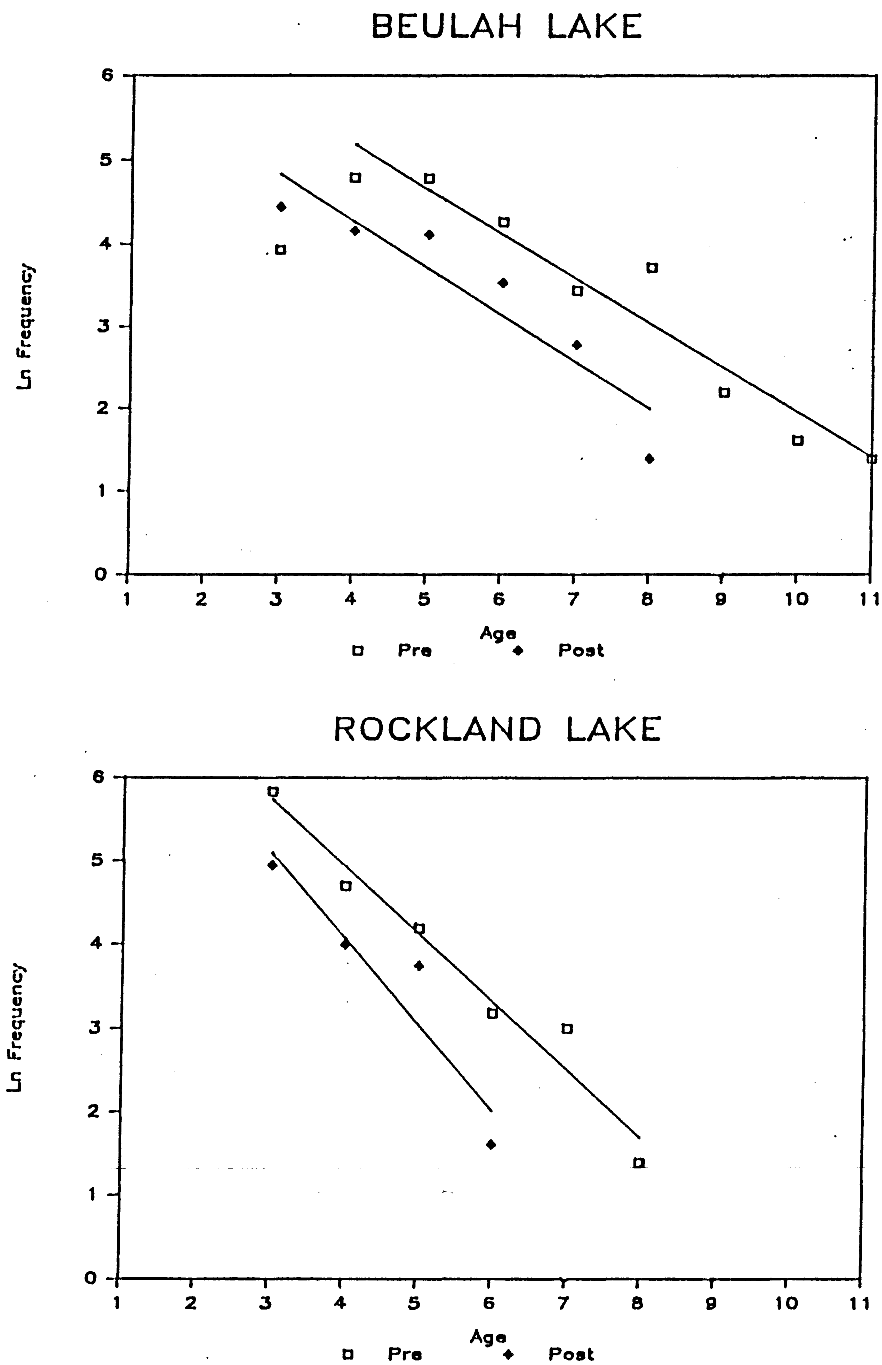
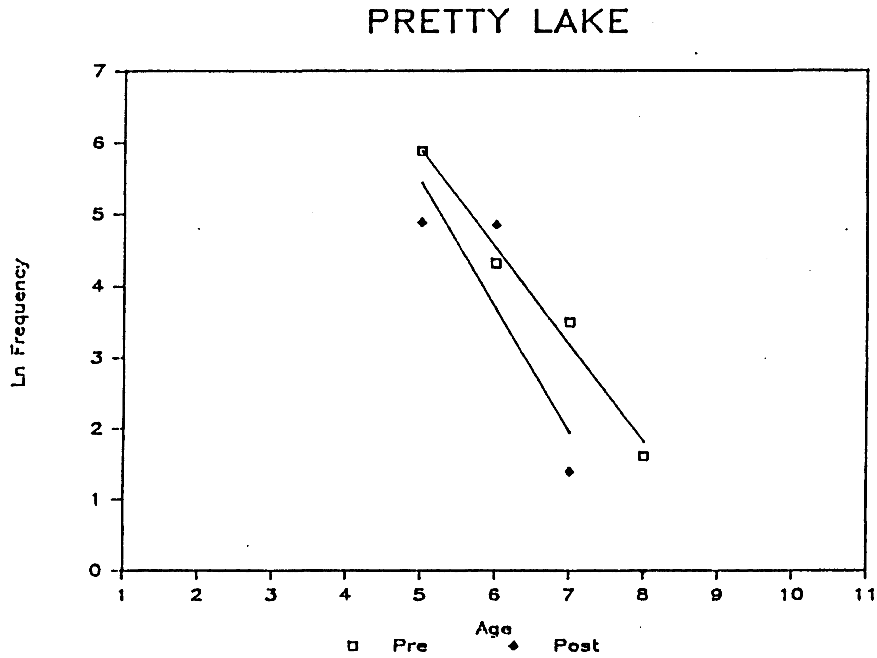


Figure 20. Catch curve of spring pre and post regulation electrofishing samples for bluegills in Beulah and Rockland Lakes.



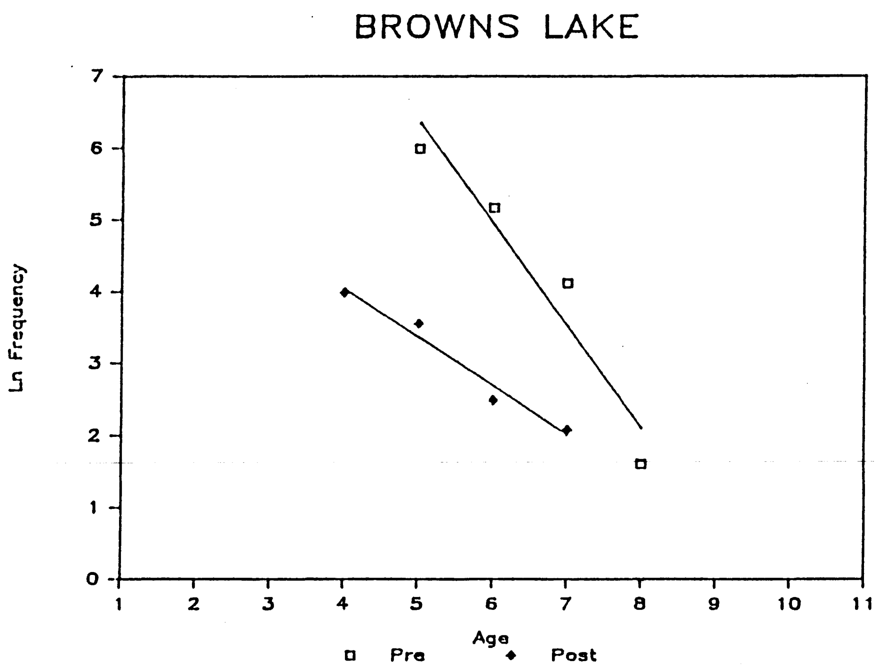


Figure 21. Catch curve of spring pre and post regulation electrofishing samples for bluegills in Pretty and Browns Lakes.

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

Estimated largemouth bass population density (no./ha) in Rockland Lake has decreased since 1980. Population estimates were 77, 46, 39, and 38 in springs 1980, 1981, 1982, and 1983 respectively. The population estimate in 1980 and the subsequent decline is probably the result of a strong 1979 year class. Michaelis (1982) reported an appreciable number of bass smaller then quality size in Rockland Lake in 1980 and 1981. The estimated standing stock (kg/ha) of largemouth bass was similar in the springs of 1981-1983 (Table 8).

Angler exploitation of largemouth bass in Rockland Lake decreased during the first year of the slot length limit regulation. The estimated angler exploitation of largemouth bass in 1982 was 31% (Table 8). In 1980, when there were no regulations, angler exploitation was estimated to be 87% (Table 8). I expected angler exploitation to decrease since a portion of the bass population is protected. The length - frequency distribution of largemouth bass in Rockland Lake (Figure 6) shows an increase in the number of bass in the protected size range which is consistent with the decrease in exploitation.

Table 8. Schnabel population estimate (no./ha), 95% confidence interval (CI), standing stock, and mean individual weight of largemouth bass in Rockland Lake in Spring, 1980-1983. Estimated exploitation rate (u) for 1980 and 1982.

Period	Population size	Minimum length (mm)	95% CI	Standing stock (kg/ha)	Mean individual weight (g)	u (%)
Spring 1980	77	>130	54-113	---	---	87
Spring 1981	46	>160	38- 57	13	291	---
Spring 1982	39	>135	28- 58	10	266	31
Spring 1983	38	>130	24- 54	12	310	---

Creel Survey

Summary

In general, fishing pressure or effort (hrs/ha), increased in 3 of the 4 lakes during the first year of the length limit regulations (1982). Mean length (mm) harvested, and catch and harvest rates (no/ha) of bluegills increased for all lakes. Data were not so consistent for largemouth bass. Mean length (mm) of largemouth bass harvested increased in 2 lakes, and decreased in the other 2 lakes. Catch rate (no/ha), which I expected to increase since anglers would be releasing protected bass, decreased in all but one lake. The length limit regulations did reduce the number of largemouth bass harvested from the protected size ranges.

Fishing Pressure

Anglers response (measured by fishing pressure) to the length limit regulations was encouraging. Fishing pressure increased 42, 6, and 112% in Beulah, Rockland, and Pretty Lakes respectively; and decreased 25% in Browns Lake from 1980 to 1982 (Table 9). These changes were significant for all lakes except Rockland Lake (Appendix R). The data for Pretty Lake were subject to more error than the other lakes because of the small amount of creel survey time for that lake, 8 hours per week compared to 20 - 32 hours for the other lakes. The decline in fishing pressure for Browns Lake

Table 9. Estimated fishing pressure (hrs/ha) in the study lakes during the 1980 and 1982 creel surveys, and the percent change from 1980 to 1982.

Lake	1980	1982	Percent change
Beulah	151	215	42
Rockland	348	370	6
Pretty	107	227	112
Browns	187	141	-25

may have been related to the length limit regulations. Browns Lake had been known as a good bass, but poor panfish lake. The high minimum length limit might have discouraged anglers from fishing Browns Lake.

Angler effort increased for bluegills since the length limit regulaions went into effect. Anglers significantly spent more time fishing for bluegills on all the lakes except Browns Lake, where fishing pressure declined in 1982 (Table 10; Appendix R).

Catch and Harvest

Largemouth bass

Catch and harvest rates (no./ha) of largemouth bass in the first summer of the length limit regulations (Table 11) did not change as expected. With bass in the protected ranges being caught and released, I would expect catch rates to increase. Catch rates significantly increased only in Pretty Lake (Table 11; Appendix R), where the data were suspect because of the minimal creel effort there.

No increase in catch rates could be caused by a shift in angler preference to panfish fishing, which occurred in Beulah and Rockland Lakes (Table 10). I cannot explain the lack of an increase in catch rates for largemouth bass in Browns Lake.

For lakes with the minimum length limit (406mm) regulation, I would expect harvest rates to decrease since a

Table 10. Estimated fishing pressure (hrs/ha) applied to largemouth bass and bluegills during the 1980 and 1982 creel surveys, and the Chi - square analysis (Li 1969; p.458).

Species	Lake	1980 Effort[a]	1982 Effort[a]	χ^2	Significant difference
Largemouth bass	Beulah	78	64	0.69	no
	Rockland	163	102	7.28	no
	Pretty	27	110	24.72	yes
	Browns	117	68	6.79	no
Bluegills	Beulah	42	131	22.51	yes
	Rockland	125	209	10.56	yes
	Pretty	39	83	7.93	yes
	Browns	26	45	2.31	no

a Michaelis (1982).

large portion of the population is protected from harvest. The harvest rate of largemouth bass did decrease significantly in Browns Lake (Table 11; Appendix R). There was no significant change in the harvest rate for Pretty Lake, where creel effort was small (Table 11).

On the lakes with a slot length limit regulation (Beulah and Rockland), harvest rates could increase or decrease, depending on the portion of bass within and outside the slot. There was no change in harvest rate in Rockland and Beulah Lakes (Table 11; Appendix R).

Mean length (mm) of largemouth bass in the harvest should increase in minimum length limit lakes (Browns and Pretty). If year class strength were reasonably stable, it should decrease in the slot length limit lakes (Beulah and Rockland). These expectations were realized in Beulah and Browns Lakes, in which changes in mean length were significant (Table 11; Appendix S). For the other two lakes, sample size was small, especially for Pretty Lake where only 4 bass were seen in both 1980 and 1982 creel surveys (Appendix S).

The anticipated changes for largemouth bass could occur only if anglers obeyed the regulations. However, not all anglers obeyed the regulations. The percentage of largemouth bass harvested in 1980 that would have been in the protected size ranges, had they been in effect, were 37, 18, 75, and 99 in Beulah, Rockland, Pretty, and Browns Lakes respectively (Table 12). In 1982, the percentage of largemouth bass that

Table 11. Estimated largemouth bass catch and harvest rates (no./ha), mean length (mm) of largemouth bass harvested in 1982, and percent change from 1980 to 1982.

Lake	1980[a]	1982	Change	Significant difference
Beulah				
catch	28.8	25.8	-11	no
harvest	3.6	8.0	122	no
mean length	298.0	242.0	-19	yes
Rockland				
catch	73.3	40.9	-44	yes
harvest	20.0	12.3	-39	no
mean length	245.0	252.0	3	no
Pretty				
catch	12.4	37.3	201	yes
harvest	4.3	2.6	-40	no
mean length	330.0	325.0	-2	no
Browns				
catch	18.8	13.7	-27	no
harvest	11.1	1.2	-89	yes
mean length	330.0	356.0	8	yes

a Michaelis (1982)

were harvested (seen in the creel) in the protected size ranges were 1, 4, 50, and 49 in the same lakes(Table 12). In Pretty and Browns Lakes, mean lengths of largemouth bass harvested in 1982, which should have exceeded 406 mm, were 325 mm and 356 mm respectively (Table 11). These results indicate that the length limit regulations reduced the number of largemouth bass harvested that were in the protected ranges, but they did not eliminate such harvest.

Regulations are only as good as their acceptance by anglers (Anderson 1976). Angler use has increased, the number of largemouth bass harvested in the protected size ranges has decreased, and anglers are catching and keeping larger bluegills. Paragamian (1984) stressed the importance of public education to increase angler compliance. Signs are posted at the public accesses on all four lakes explaining the regulations; and bass groups, lake associations, and the local press are kept informed on the study (George Boronow, DNR Fish Manager, personal communication).

Table 12. Number of largemouth bass seen in the 1980 and 1982 creel surveys, and number and percent of bass harvested in the protected size ranges. The size ranges were not protected in 1980.

Year	Lake	Number creeled	Number in protected size range	Percent harvested in protected size range
1980	Beulah	115	43	37
	Rockland	57	10	18
	Pretty	4	4	75
	Browns	251	248	99
1982	Beulah	233	3	1
	Rockland	46	2	4
	Pretty	4	2	50
	Browns	35	17	49

Bluegills

Interpretation of the changes in the bluegill fisheries is difficult. If the length limit regulations effectively increased predation by largemouth bass on bluegills, the catch rate of bluegills should decrease. However, there was no change in bluegill abundance (Table 3), and catch rates of bluegills increased significantly in all lakes (Table 13; Appendix R). Catch rate of bluegills could increase if angling effort for bluegills increased. Fishing pressure and angling effort did increase on three of the lakes (Tables 9, 10). I cannot explain why bluegill catch rates increased on Browns Lake.

A reduction in bluegill density should increase growth rates, which should result in an increase in harvest rates and mean length of bluegills harvested. Although harvest rates and mean length of bluegills harvested in 1982 follwed this scenario (Table 13; Appendix S), I cannot explain why. Anglers were catching and keeping larger bluegills since the regulations went into effect, but the reason(s) is not readily evident because there was no change in bluegill CUE (Table 3), and growth rates increased significantly only in Pretty Lake (Table 6).

Table 13. Estimated bluegill catch and harvest rates (no./ha), and mean length of bluegills harvested in 1982, and percent change from 1980 to 1982.

Lake	1980[a]	1982	Change	Significant difference
Beulah				
catch	132.3	318.6	141	yes
harvest	74.1	189.1	155	yes
mean length	155.0	166.0	7	yes
Rockland				
catch	459.5	548.8	19	yes
harvest	210.6	291.3	38	yes
mean length	152.0	163.0	7	yes
Pretty				
catch	146.0	583.7	300	yes
harvest	45.0	259.8	477	yes
mean length	143.0	147.0	3	yes
Browns				
catch	160.4	224.5	40	yes
harvest	37.0	80.1	117	yes
mean length	132.0	140.0	6	yes

a Michaelis (1982)

SUMMARY

Of all the expected changes in the largemouth bass and bluegill fisheries, only these were significant one year after the length limit regulations were in effect:

1. Mean length and CUE of largemouth bass in the protected range from spring electrofishing samples increased in Rockland Lake.

2. Largemouth bass mortality decreased in Pretty Lake.

3. Bluegill growth rates increased in Pretty Lake.

4. Wr of bluegills increased in Beulah, Rockland, and Browns Lakes.

5. Mean length of bluegills from spring electrofishing samples increased in Pretty Lake.

The unexpected significant changes were:

1. Mean length of bluegills from spring electrofishing decreased in Beulah and Rockland Lakes.

2. The CUE for largemouth bass in Pretty Lake decreased.

3. Largemouth bass Wr increased in Beulah and Pretty Lakes, and decreased in Rockland Lake.

4. Bluegill Wr decreased in Pretty Lake.

5. Largemouth bass growth rates decreased in Beulah Lake.

Probably more time is necessary for more of the expected changes to occur, e.g. decrease in largemouth bass mortality and bluegill abundance, an increase in bluegill mortality and growth rates, and an increase in mean length of both largemouth bass and bluegills. Some of these changes may not occur with the present regulations. The extent to which desired changes occur will determine if this project is continued without change, with modifications, or discontinued.

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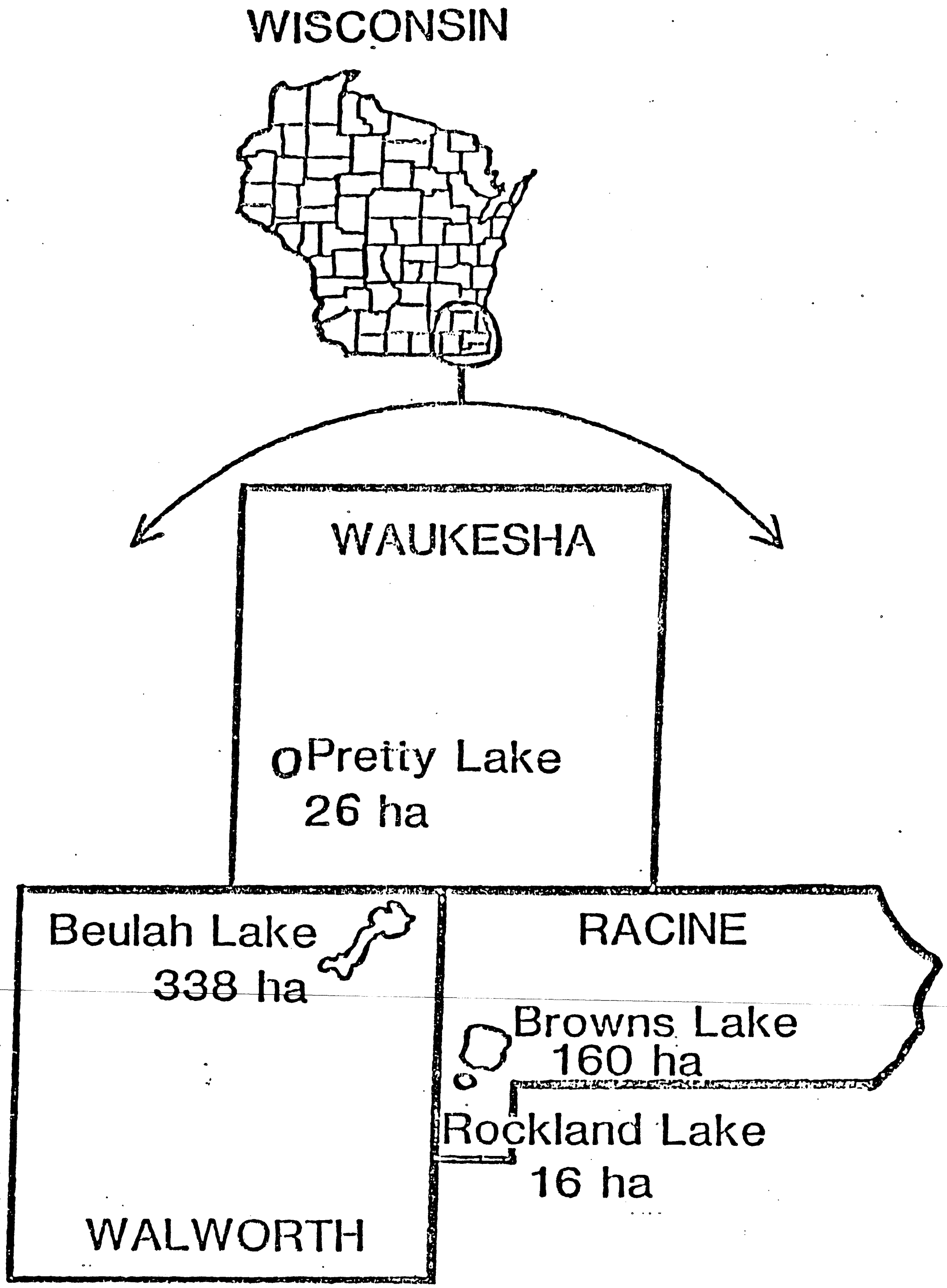
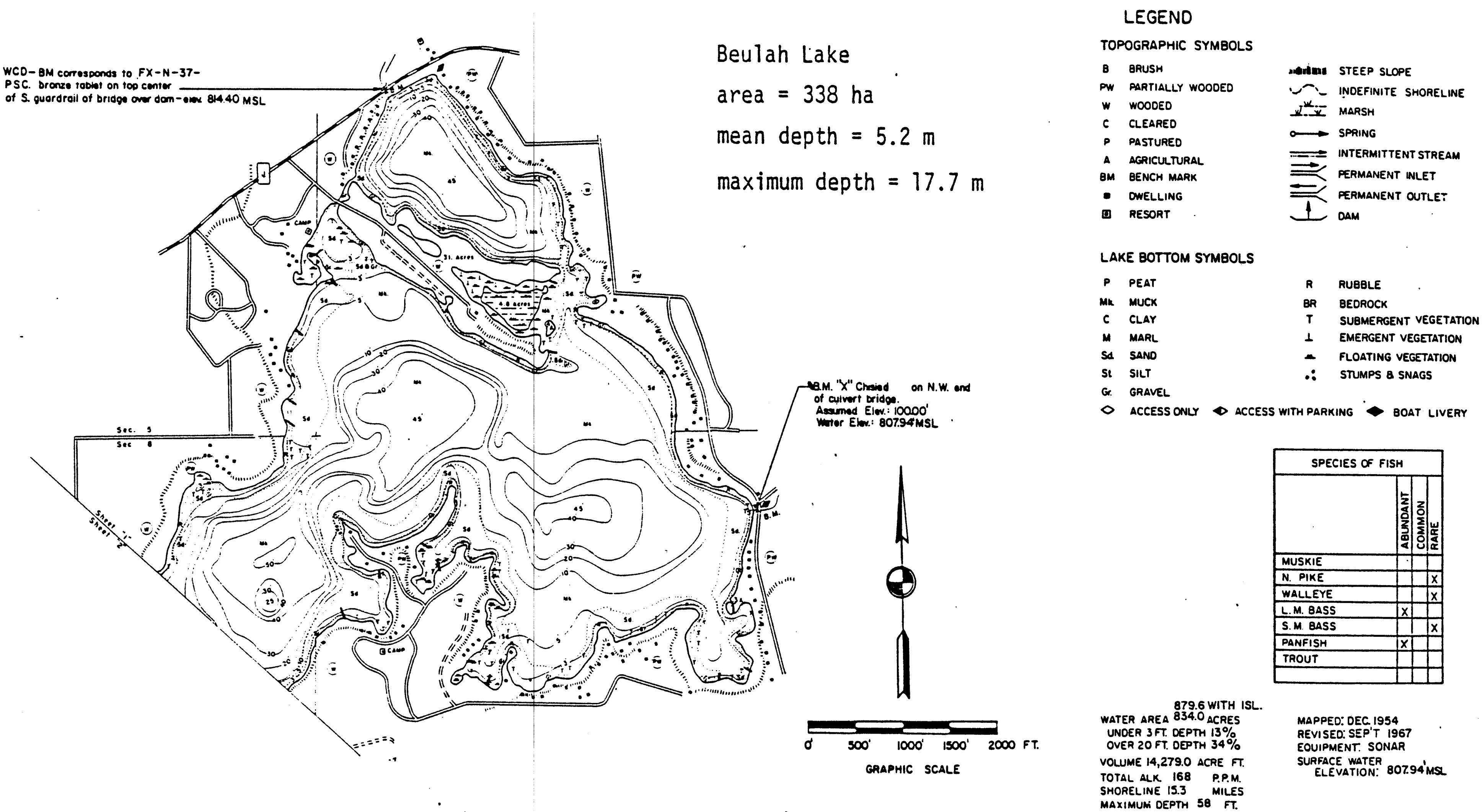


Appendix A

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

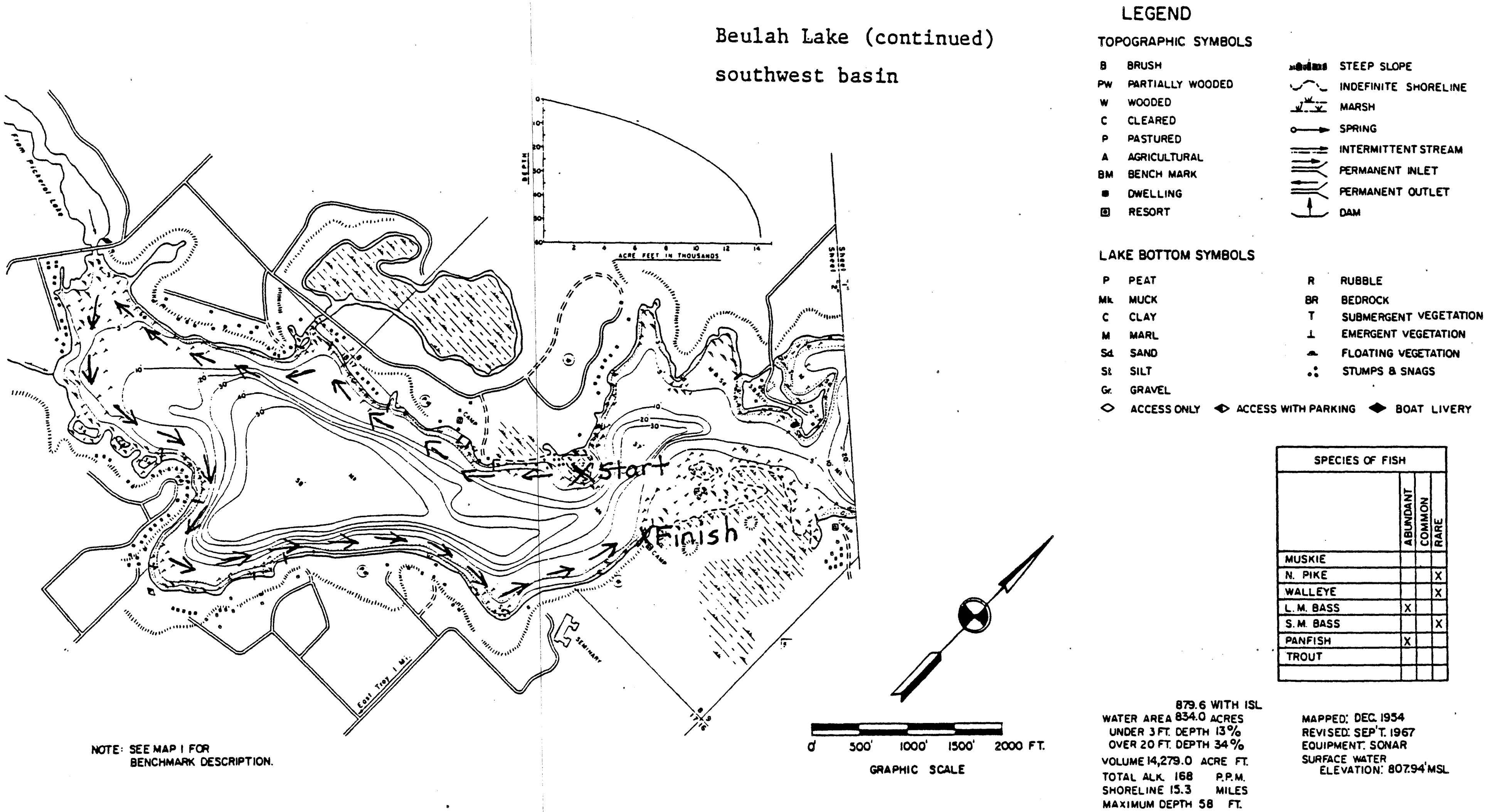


SPECIES OF FISH	ABUNDANT	COMMON	RARE
MUSKIE			
N. PIKE			X
WALLEYE			X
L. M. BASS	X		
S. M. BASS			X
PANFISH	X		
TROUT			

Appendix B. Hydrographic maps of Beulah, Rockland, Pretty and Browns Lakes.

Beulah Lake (continued)

southwest basin



Arrows in Beulah Lake show area electrofished.

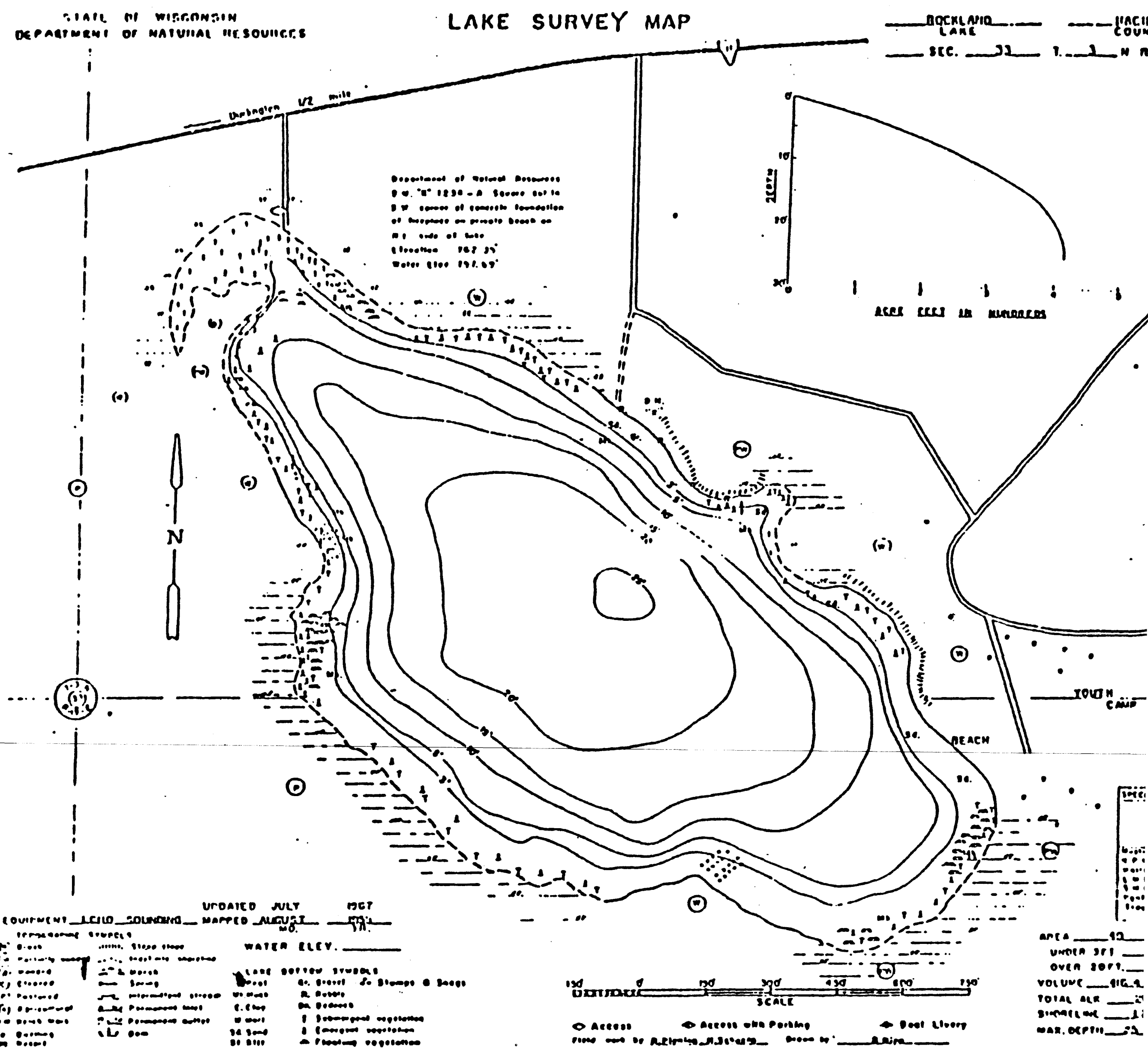
Appendix B (continued)

Rockland Lake

area = 16 ha

mean depth = 3.1 m

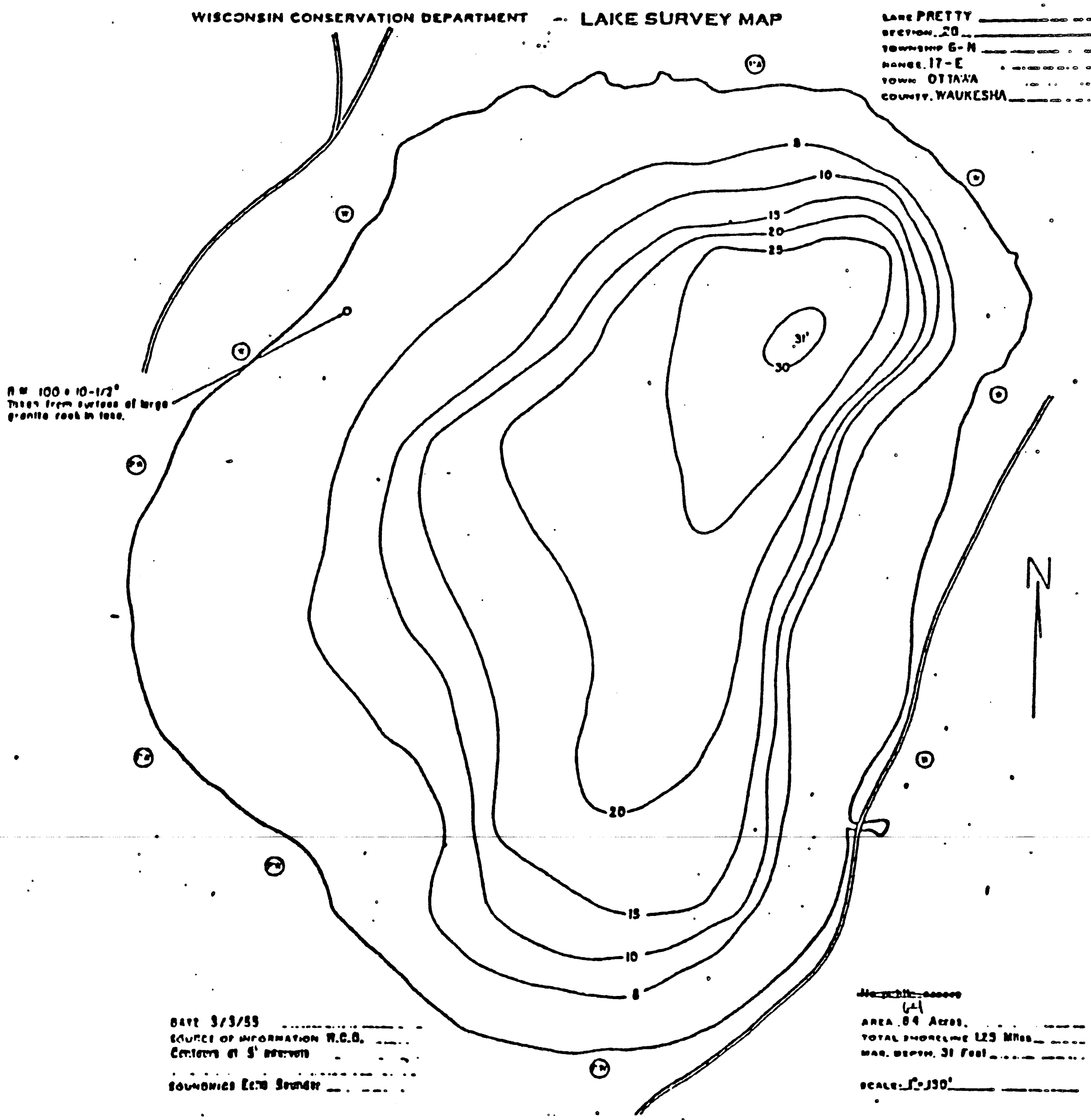
maximum depth = 7.6 m



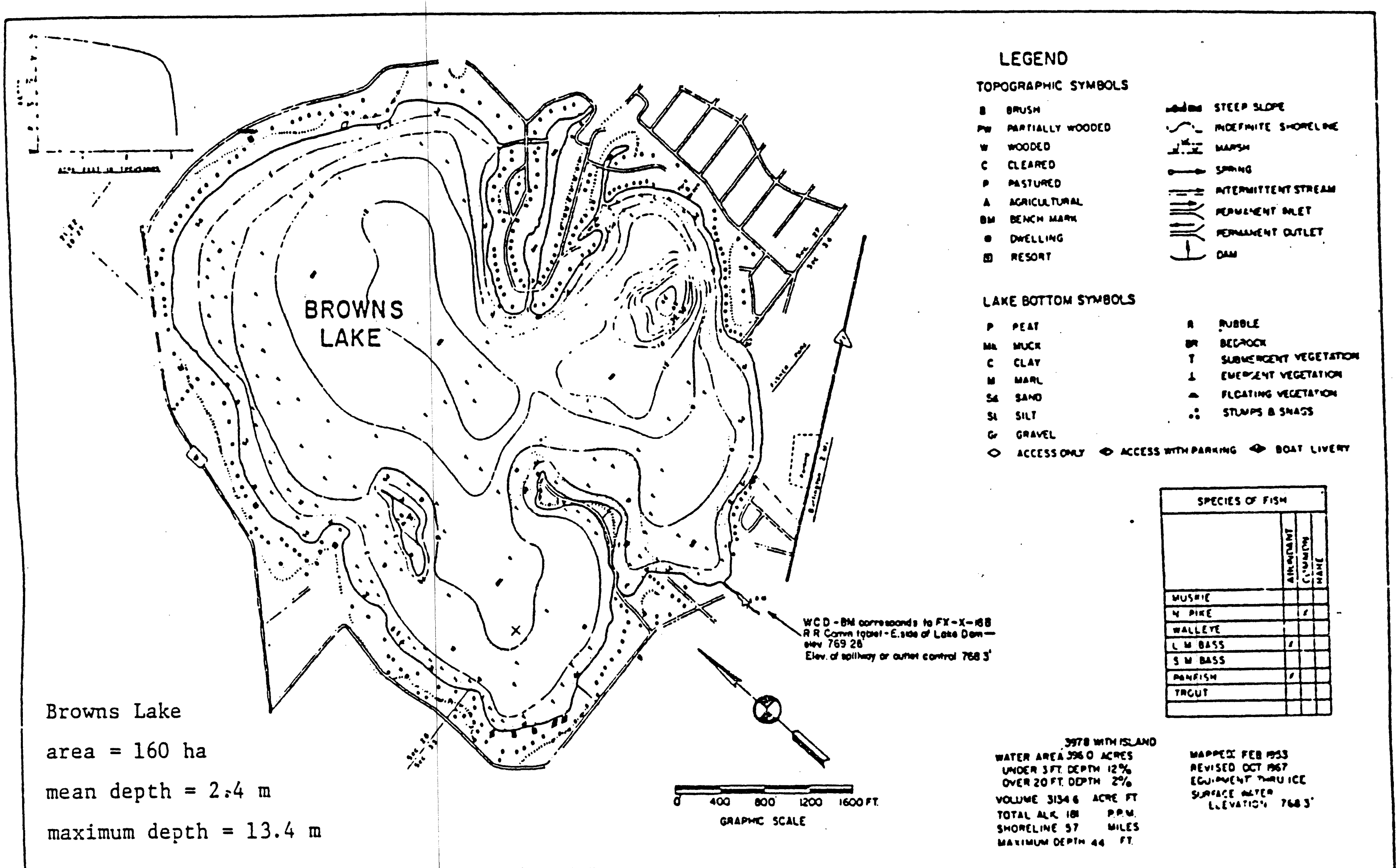
Appendix B (continued)

Pretty Lake mean depth = 3.7 m

area = 26 ha maximum depth = 9.5 m



Appendix B (continued)



Browns Lake

area = 160 ha

mean depth = 2.4 m

maximum depth = 13.4 m

Appendix B (continued)

Appendix C. Common and scientific names of species caught by electrofishing (E), fyke nets (F), and angling (A) during Spring 1982 to Fall 1983 in the four study lakes.

Gear	Common name	Scientific name
E, F, A	Bluegill	*Lepomis macrochirus*
E, F, A	Pumpkinseed	*Lepomis gibbosus*
E, F, A	Yellow perch	*Perca flavescens*
E, F, A	Green sunfish	*Lepomis cyanellus*
E, F, A	Warmouth	*Lepomis gulosus*
E, F, A	Largemouth bass	*Micropterus salmoides*
E, F, A	Northern pike	*Esox lucius*
E, F	Walleye	*Stizostedion vitreum vitreum*
E	Brown trout	*Salmo trutta*
E, F	Bowfin	*Amia calva*
E, F	Longnose gar	*Lepisosteus osseus*
E, F, A	Yellow bullhead	*Ictalurus natalis*
E, F, A	Brown bullhead	*Ictalurus nebulosus*
E, F, A	Black bullhead	*Ictalurus melas*
E, F, A	Rock bass	*Ambloplites rupestris*
E, F, A	Black crappie	*Pomoxis nigromaculatus*
E	Carp	*Cyprinus carpio*
E, F	White sucker	*Catostomus commersoni*
E, F	Grass pickeral	*Esox americanus*
E, F	Lake chubsucker	*Erimyzon sucetta*
E, F	Golden shiner	*Notemigonus crysoleucas*
E	White crappie	*Pomoxis annularis*

Appendix D. Length-frequency distributions of bluegills, pumpkinseeds, yellow perch, green sunfish, and warmouth in electrofishing samples in spring and fall of 1982 and 1983 from the four lakes.

BEULAH LAKE

Length group (mm)	Bluegill Spring 1982	Bluegill Spring 1983	Bluegill Fall 1982	Bluegill Fall 1983	Pumpkinseed Spring 1982	Pumpkinseed Spring 1983	Pumpkinseed Fall 1982	Pumpkinseed Fall 1983	Yellow perch Spring 1982	Yellow perch Spring 1983	Yellow perch Fall 1982	Yellow perch Fall 1983	Green sunfish Spring 1982	Green sunfish Spring 1983	Green sunfish Fall 1982	Green sunfish Fall 1983	Warmouth Spring 1982	Warmouth Spring 1983	Warmouth Fall 1982	Warmouth Fall 1983
60 - 69	1	1	3										1	1						
70 - 79	3	1	1			1							2	3						
80 - 89	3	18	17	1						1			3	5						
90 - 99	10	42	20	1									4	1				1		
100 - 109	7	32	7	2		4			1	3			8	2				1		
110 - 119	18	24	12	11		2				2	1		3	2			3	6	1	
120 - 129	29	17	18	11		5	7			3	1	1	3	3			3	2	2	1
130 - 139	29	26	23	32	2	6	1	1		3		2	5	2		1	4	6		1
140 - 149	17	32	37	29	1	6	1	2	2								5	4	3	
150 - 159	17	25	41	48		2	2		3	2							5	3	1	
160 - 169	15	17	31	22		3	1		3		1						1	2		
170 - 179	14	9	16	19		1			1		3						3		1	
180 - 189	12	5	7	11					1								1		2	2
190 - 199	3	2	2	2					1		3		1							
200 - 209									1		1									
210 - 219																				
220 - 229											2									
230 - 239										1	2									
240 - 249											1									
250 - 259									1											
260 - 269											1									
270 - 279																				
280 - 289																				
290 - 299																				
300 - 309											1									
Total	178	251	235	189	3	30	12	3	14	15	17	3	30	19	0	1	25	25	10	4

Appendix D (continued)

ROCKLAND LAKE

Length group (mm)	Bluegill Spring 1982	Bluegill Spring 1983	Bluegill Fall 1982	Bluegill Fall 1983	Pumpkinseed Spring 1982	Pumpkinseed Spring 1983	Pumpkinseed Fall 1982	Pumpkinseed Fall 1983	Yellow perch Spring 1982	Yellow perch Spring 1983	Yellow perch Fall 1982	Yellow perch Fall 1983	Green sunfish Spring 1982	Green sunfish Spring 1983	Green sunfish Fall 1982	Green sunfish Fall 1983	Warmouth Spring 1982	Warmouth Spring 1983	Warmouth Fall 1982	Warmouth Fall 1983
30 - 39				1																
40 - 49				1																
50 - 59	2	1	2	4												1				
60 - 69	22	13	16	20	6								3			1			1	1
70 - 79	31	11	9	11	11		2	2	1				6	1		2	1		2	
80 - 89	16	18	19	50	15	2	1		3	1			2	2				1		3
90 - 99	16	54	36	56	6	1	3	1		3			1				1	3	3	2
100 - 109	28	43	30	14	5	4	10	2	2	9	1		3	2	1	2	14	9	4	1
110 - 119	55	16	9	43	13	19	5	1	4	5	2	2					11	5	2	5
120 - 129	22	7	18	45	11	8	5	1	8	5	1	2					3	5	2	3
130 - 139	8	15	39	27	5	7	3	2	9	6	1	1	2				1	6	5	2
140 - 149	11	27	42	19	1	5	2	1	1	3	2						7	3		
150 - 159	5	13	24	17	1	2				2	3	4					5	2	1	
160 - 169	2	8	7	23					1		3	2					2		2	1
170 - 179	5	1	8	11						1	1						2	1		1
180 - 189	3	3	3	8						1							2	1		
190 - 199	2	1	1	2					1											
200 - 209	1								1											
210 - 219																				
Total	229	231	263	352	74	48	31	10	31	36	14	11	17	5	1	6	49	36	22	19

Appendix D (continued)

PRETTY LAKE

Length group (mm)	Bluegill Spring 1982	Bluegill Spring 1983	Bluegill Fall 1982	Bluegill Fall 1983	Pumpkinseed Spring 1982	Pumpkinseed Spring 1983	Pumpkinseed Fall 1982	Pumpkinseed Fall 1983	Yellow perch Spring 1982	Yellow perch Spring 1983	Yellow perch Fall 1982	Yellow perch Fall 1983	Green sunfish Spring 1982	Green sunfish Spring 1983	Green sunfish Fall 1982	Green sunfish Fall 1983	Warmouth Spring 1982	Warmouth Spring 1983	Warmouth Fall 1982	Warmouth Fall 1983
30 - 39				1																
40 - 49																				
50 - 59	1	1	1	3																
60 - 69	1	6	7	8																
70 - 79	2	4	26	27		1														3
80 - 89	11	25	57	35		1					1									1
90 - 99	25	40	49	51		2		1		1		3					1		1	2
100 - 109	67	49	70	85	4	1				1		3					1			6
110 - 119	81	69	112	68	3	1	1					5					1		5	2
120 - 129	66	62	106	84	4	3	1										7		3	5
130 - 139	40	37	66	65	5	4		1				1					2	1	2	3
140 - 149	19	23	32	36	9	2	1					2					1			
150 - 159	10	29	25	26	13	5			1											1
160 - 169	3	15	1	9	4	1	1					1								
170 - 179		10	1	5	5			1	1			2								
180 - 189		1	1	2	2			2				1					1			
190 - 199		1			1					1										
200 - 209																				
210 - 219												1								
Total	326	372	554	505	50	21	4	5	2	3	1	19	0	0	0	0	14	1	11	23

Appendix D (continued)

BROWNS LAKE

Length group (mm)	Bluegill Spring 1982	Bluegill Spring 1983	Bluegill Fall 1982	Bluegill Fall 1983	Pumpkinseed Spring 1982	Pumpkinseed Spring 1983	Pumpkinseed Fall 1982	Pumpkinseed Fall 1983	Yellow perch Spring 1982	Yellow perch Spring 1983	Yellow perch Fall 1982	Yellow perch Fall 1983	Green sunfish Spring 1982	Green sunfish Spring 1983	Green sunfish Fall 1982	Green sunfish Fall 1983	Warmouth Spring 1982	Warmouth Spring 1983	Warmouth Fall 1982	Warmouth Fall 1983
30 - 39																				
40 - 49			4																	
50 - 59			2	1																
60 - 69	1	3	8	5	1	2														
70 - 79	5	12	19	43	10	36	1	1		2						1				
80 - 89	11	22	21	61	15	37	7	1		4			2	3						
90 - 99	30	10	14	37	21	66	8	4	1	1		2		5	1	2				
100 - 109	68	20	31	37	10	23	15	9	18	3		4		1						
110 - 119	95	35	58	33	7	15	17	16	41	30	5	14		1		1				
120 - 129	62	37	85	52	5	13	8	13	17	45	4	25					1			
130 - 139	19	17	49	52	4	7	4	12	10	34	4	18								
140 - 149	12	7	32	24	11	4	2	1	2	26		8								
150 - 159	5	4	23	9		7			1	3		1	1							
160 - 169			6	5					1	3										
170 - 179		1								2					1					
180 - 189	1												1							
190 - 199			1																	
200 - 209		1																		
210 - 219									1		1									
220 - 229																				
230 - 239											1									
240 - 249											1									
Total	309	169	353	359	84	210	62	57	92	153	16	72	4	10	2	4	1	0	0	0

Appendix E. Length - frequency distributions of bluegills, pumpkinseeds, yellow perch, green sunfish, and warmouth in fyke net samples in 1982 and 1983 from the four study lakes.

BEULAH LAKE

Length group (mm)	Bluegill		Pumpkinseed		Yellow perch		Green sunfish		Warmouth	
	1982	1983	1982	1983	1982	1983	1982	1983	1982	1983
50 - 59	4						1			
60 - 69	35	1					13	4	2	
70 - 79	127	1	2				10	3	2	
80 - 89	168	8	7				12	1		1
90 - 99	103	8	2			1	15	1	2	2
100 - 109	107	10	9	3		1	23	2	4	
110 - 119	63	19	6	12			24	3	5	5
120 - 129	68	36	9	17			13	5	7	4
130 - 139	193	44	21	18			7	1	10	11
140 - 149	194	62	20	13			7	1	7	10
150 - 159	192	50	7	26			3	1	3	7
160 - 169	162	54		14			2		6	6
170 - 179	110	42		1			1		4	9
180 - 189	62	15	1	2					1	4
190 - 199	5	8	1	1						1
200 - 209										
Total	1593	358	85	107	0	2	131	22	53	60

Appendix E (continued)

ROCKLAND LAKE

Length group (mm)	Bluegill 1982	Bluegill 1983	Pumpkinseed 1982	Pumpkinseed 1983	Yellow perch 1982	Yellow perch 1983	Green sunfish 1982	Green sunfish 1983	Warmouth 1982	Warmouth 1983
50 - 59	7						1			
60 - 69	101						12			
70 - 79	141	1					21		3	
80 - 89	36	1	7				6		3	
90 - 99	13	7	4		1		2		2	2
100 - 109	10	20	3	1					2	
110 - 119	15	28	2						3	
120 - 129	18	13	1	2						2
130 - 139	11	12	2	2	1				1	1
140 - 149	12	35	1	5	1				1	1
150 - 159	15	47					1		1	2
160 - 169	13	38							4	2
170 - 179	19	27							2	
180 - 189	10	25				1				
190 - 199		13							1	
200 - 209		1								
210 - 219		1								
Total	421	269	20	10	3	1	43	0	23	10

Appendix E (continued)

PRETTY LAKE

Length group (mm)	Bluegill 1982	Bluegill 1983	Pumpkinseed 1982	Pumpkinseed 1983	Yellow perch 1982	Yellow perch 1983	Green sunfish 1982	Green sunfish 1983	Warmouth 1982	Warmouth 1983
50 - 59	3		1							
60 - 69	44	5	6							
70 - 79	37	6	2							2
80 - 89	59	33	7	1					6	4
90 - 99	59	21	5	1					22	5
100 - 109	165	39	15	3					22	3
110 - 119	383	77	22	4					11	7
120 - 129	436	116	24	9					5	3
130 - 139	449	122	34	23					5	3
140 - 149	289	98	33	23	1				1	1
150 - 159	125	58	10	22					2	2
160 - 169	67	29	14	18					1	
170 - 179	20	20	4	10					1	
180 - 189	1		1	1						1
190 - 199	2								1	
200 - 209										
Total	2139	624	178	115	1	0	0	0	77	31

Appendix E (continued)

BROWNS LAKE

Length group (mm)	Bluegill 1982	Bluegill 1983	Pumpkinseed 1982	Pumpkinseed 1983	Yellow perch 1982	Yellow perch 1983	Green sunfish 1982	Green sunfish 1983	Warmouth 1982	Warmouth 1983
50 - 59	3		7				1			
60 - 69	1		42							
70 - 79	4	7	81	1			5	2		
80 - 89	13	14	244	14			11	4		
90 - 99	34	11	77	12			9	3		
100 - 109	139	44	69	32			5	4		
110 - 119	388	158	59	59			1	9		
120 - 129	214	278	52	29		2		6		
130 - 139	228	213	98	23	1			1		
140 - 149	208	180	115	16	1			1		
150 - 159	100	79	41	4	2			1		
160 - 169	28	12	4	4				1		
170 - 179	6	1								
180 - 189	3					1				
190 - 199	1					1				
200 - 209										
Total	1370	997	889	194	4	4	32	32	0	0

Appendix F. Mean length (mm) of panfish compared with a t- test (Li 1969; p. 100) between fyke nets and electrofishing samples (n > 10). All statistical tests were at the 0.05 level of significance.

Species	Lake	Gear	Mean length	Standard deviation	n	Calculated t	d.f.	Significant difference
			1982 Fyke nets and spring electrofishing					
Bluegill	Beulah	Fyke	129	34.6	1593	3.591	27	yes
		Electro	139	28.0	178			
	Rockland	Fyke	94	36.3	421	4.610	28	yes
		Electro	107	29.9	229			
	Pretty	Fyke	126	21.2	2139	6.642	25	yes
		Electro	118	17.3	326			
	Browns	Fyke	127	17.7	1361	11.198	24	yes
		Electro	114	15.8	309			
Pumpkinseed	Rockland	Fyke	103	19.4	20	0.461	15	no
		Electro	100	23.1	74			
	Pretty	Fyke	129	25.5	178	4.691	22	yes
		Electro	147	22.2	50			
	Browns	Fyke	107	27.6	889	0.949	19	no
		Electro	104	22.6	84			
Green sunfish	Beulah	Fyke	106	25.3	131	0.401	21	no
		Electro	108	26.7	31			
	Rockland	Fyke	76	14.9	43	2.426	10	yes
		Electro	88	22.3	17			
Warmouth	Beulah	Fyke	133	28.6	53	1.966	18	no
		Electro	145	19.9	25			
	Rockland	Fyke	125	38.7	23	0.444	20	no
		Electro	128	27.0	49			
	Pretty	Fyke	110	21.0	77	2.946	16	yes
		Electro	128	20.5	14			

Appendix F (continued)

1983 Fyke nets and spring electrofishing								
Species	Lake	Gear	Mean length	Standard deviation	n	Calculated t	d.f.	Significant difference
Bluegill	Beulah	Fyke	147	24.8	358	9.958	26	yes
		Electro	125	28.0	249			
	Rockland	Fyke	150	27.9	269	15.042	28	yes
		Electro	112	28.7	231			
	Pretty	Fyke	130	22.4	624	5.878	25	yes
		Electro	121	24.8	372			
	Browns	Fyke	130	15.7	997	12.593	21	yes
		Electro	112	22.6	169			
Pumpkinseed	Beulah	Fyke	142	19.0	107	2.098	17	yes
		Electro	134	22.1	30			
	Rockland	Fyke	135	13.3	10	2.456	10	yes
		Electro	122	15.7	48			
	Pretty	Fyke	146	18.8	115	3.608	19	yes
		Electro	129	25.8	21			
	Browns	Fyke	118	18.1	194	10.350	18	yes
		Electro	98	20.1	210			
Green sunfish	Beulah	Fyke	104	28.3	22	0.483	16	no
		Electro	100	22.5	19			
	Browns	Fyke	112	21.3	32	2.414	12	yes
		Electro	95	9.43	10			
Warmouth	Beulah	Fyke	148	24.5	60	2.712	17	yes
		Electro	133	18.7	25			

Appendix G. Length - frequency distributions of largemouth bass in electrofishing samples in spring and fall of 1982 and 1983 from the study lakes.

Length group (mm)	Beulah Spring 1982	Beulah Spring 1983	Beulah Fall 1982	Beulah Fall 1983	Rockland Spring 1982	Rockland Spring 1983	Rockland Fall 1982	Rockland Fall 1983	Pretty Spring 1982	Pretty Spring 1983	Pretty Fall 1982	Pretty Fall 1983	Browns Spring 1982	Browns Spring 1983	Browns Fall 1982	Browns Fall 1983
50 - 59														1		
60 - 69											4			9	14	3
70 - 79							1	3			2		4	10	2	5
80 - 89							1						2		4	2
90 - 99				2				1		1				3	7	2
100 - 109	2	1		1				1		1			1	4	11	
110 - 119					1	1	1			5	3			2	7	2
120 - 129		2	1			5	2		2	4	4	1			1	1
130 - 139		1	1			13	15		2	2	1	3		4	1	
140 - 149	1	9	8			25	10	2	2	5	2	3		2	3	
150 - 159	7	9	9	4	3	8	1	3	3	3		2			1	1
160 - 169	18	6	4	10	11	4	4	9	2	2	1	1		2	2	2
170 - 179	25	7		3	17	3	2	7	7	3				2	1	1
180 - 189	31	7	5	6	30	2		5	8	4		2	1	1	2	2
190 - 199	14	8	7	7	14	2	1	7	6	3	2	2		2	2	1
200 - 209	2	16	17	10	4	2	1	12	8	7	1	1	1	4	2	
210 - 219	2	26	22	13	2	3	3	14	14	5	3	2	1	1		4
220 - 229	7	16	16	5	2	8	6	7	5	2	1	2	1			2
230 - 239	4	8	5	16	8	22		4	7	8		2	2			1
240 - 249	4	4	5	8	13	13	4	4	1	2	1	1			1	
250 - 259	5	3	2	9	19	3		1	1	2	2	3		2	2	1
260 - 269	6	1	1	11	26	4	1	1	1	1		1			2	5
270 - 279	5	4	4	7	25	5	2	2		2	2	3	4	1	2	3
280 - 289	2	1	1	6	6	2				4	1	1	4			4
290 - 299	2	4		2	7	7	2	1		2		2	7		1	1

Appendix G (continued)

Length group (mm)	Beulah Spring 1982	Beulah Spring 1983	Beulah Fall 1982	Beulah Fall 1983	Rockland Spring 1982	Rockland Spring 1983	Rockland Fall 1982	Rockland Fall 1983	Pretty Spring 1982	Pretty Spring 1983	Pretty Fall 1982	Pretty Fall 1983	Browns Spring 1982	Browns Spring 1983	Browns Fall 1982	Browns Fall 1983
300 - 309	5	2	3	2	1	10	3				3	1	2		1	2
310 - 319	2	2	2	2	4	10	3		2	1			2	2	2	2
320 - 329	2	1	1		1	6	1						3			2
330 - 339	2	1	2	1	1	9	2	2			1	1	7	3	4	1
340 - 349	2		1	1	2	3	1					1		3	7	
350 - 359		1		2	1	3							2	5	8	
360 - 369				1		1	1		1			1	2	5	8	1
370 - 379	2				1			2	1			1	3	7	5	1
380 - 389	1		1	2					3		2		7	2		3
390 - 399		1		3					4	1			5	6	3	
400 - 409						1			1	1		1	4	5	3	1
410 - 419													9	8	3	5
420 - 429		1			1				2	1		1	6	8	6	1
430 - 439													4	7	4	5
440 - 449	2	1			2	1	1						3	1	3	
450 - 459					1	1							2	4		1
460 - 469						1			2	1	1			4		
470 - 479					2											1
480 - 489				1				1						4		1
490 - 499								1								
500 - 509						1					1					
510 - 519							1									
520 - 529								1								
530 - 539									1							
Total	155	143	118	135	205	179	70	91	86	73	38	39	89	124	125	70

Appendix H. Mean length (mm) of largemouth bass and bluegills compared with a t- test (Li 1969; p. 100) between spring pre (1980 - 1982) and post (1983) regulation electrofishing samples. All statistical tests were at the 0.05 level of significance.

Species	Lake	Period	Mean length	Standard deviation	n	Calculated t	d.f.	Significant difference
Largemouth bass	Beulah	Pre	220	54.4	487	1.268	142	no
		Post	214	62.6	143			
	Rockland	Pre	214	80.0	1000	3.553	178	yes
		Post	236	65.6	179			
	Pretty	Pre	217	75.1	322	0.984	72	no
		Post	208	70.5	73			
	Browns	Pre	305	146.5	390	1.154	123	no
		Post	290	86.0	124			
Bluegill	Beulah	Pre	140	28.5	457	6.132	250	yes
		Post	128	27.6	251			
	Rockland	Pre	116	28.7	686	2.439	230	yes
		Post	112	29.2	231			
	Pretty	Pre	108	24.8	1184	9.631	371	yes
		Post	120	22.1	372			
	Browns	Pre	112	22.6	988	0.241	160	no
		Post	111	14.4	161			

Appendix I. Catch pre unit effort (CUE) of largemouth bass and bluegills for electrofishing (no./hr) and fyke net (no./hr) samples from the four lakes in Spring 1980 - Fall 1983.

Electrofishing

Species	Year	Beulah Spring	Beulah Fall	Rockland Spring	Rockland Fall	Pretty Spring	Pretty Fall	Browns Spring	Browns Fall
Largemouth bass	1980[a]	41.0	22.1	78.6	41.4	47.8	12.4	30.2	4.6
	1981	48.6	24.3	125.7	32.7	52.7	23.1	25.7	10.8
	1982	38.5	75.8	56.0	63.1	28.1	36.0	18.0	137.1
	1983	59.9	61.1	189.7	88.2	49.6	26.9	44.9	24.8
Bluegills	1980[a]	189.8	265.6	294.8	260.2	572.5	712.4	319.3	432.6
	1981	280.0	438.0	209.6	720.0	546.9	1032.0	396.3	1212.0
	1982	282.0	648.4	315.0	765.0	606.0	2006.8	378.0	1003.1
	1983	439.9	447.7	614.9	795.4	1244.6	1076.4	284.5	266.4

Fyke nets

Species	Year	Beulah	Rockland	Pretty	Browns
Bluegills	1980[a]	16.1	4.4	11.9	23.6
	1981	3.6	1.9	2.9	72.9
	1982	6.7	2.3	11.1	8.5
	1983	1.5	1.4	3.3	5.2

a Michaelis (1982)

Appendix J. Index of abundance or CUE (fish/hour) from electrofish
for all largemouth bass and largemouth bass in the protected size
ranges for pre (1980 - 82) and post (1983) regulation samples.

	Slot Length Limit (305 - 406 mm)			
	Beulah Lake		Rockland L	
	Pre	Post	Pre	Pos
Sum of CUE's	174.5	196.8	334.4	341
Average CUE	34.9	32.8	66.9	37
Percent of fish 305 - 406 mm	8.0	8.0	4.3	17
CUE of fish 305 - 406 mm	14.0	15.6	14.4	57
Average CUE of fish 305 - 406 mm	2.8	2.6	2.9	6

	Minimum Length Limit (406 mm)			
	Pretty Lake		Browns Lake	
	Pre	Post	Pre	Post
Sum of CUE's	164.1	112.5	89.3	206.
Average CUE	32.8	18.8	17.9	29.
Percent of fish 305 - 406 mm	98.0	98.0	87.0	87.
CUE of fish 305 - 406 mm	160.8	110.3	77.7	180.
Average CUE of fish 305 - 406 mm	32.1	18.4	15.6	25.

Appendix K. Comparison of all largemouth bass CUE's (fish/hour) and CUE's of protected bass from pre (1980 - 1982) and post (1983) regulation electrofish samples with a t- test (Li 1969; p. 100). All statistical tests at the 0.05 level of significance.

Lake	Period	Mean CUE	Calculated t	d.f.	Significant difference	Mean protected CUE	Calculated t	d.f.	Significant difference
Beulah	Pre	34.9	0.558	5	no	2.8	0.417	5	no
	Post	32.8				2.6			
Rockland	Pre	66.9	6.447	8	yes	2.9	2.536	8	yes
	Post	37.9				6.4			
Pretty	Pre	32.8	4.389	5	yes	32.1	4.448	5	yes
	Post	18.8				18.2			
Browns	Pre	17.9	1.039	6	no	15.6	0.946	6	no
	Post	29.5				25.8			

Appendix L. Mean pre (1980-1982) and post (1983) regulation Relative Weight (Wr) for largemouth bass ($\geq$ 100 mm) and bluegills ($\geq$ 80 mm) compared with a t- test (Li 1969; p. 100). All statistical tests were at the 0.05 level of significance.

Species	Lake	Period	Wr	Standard deviation	n	Calculated t	d.f.	Significant difference
Largemouth bass	Beulah	Pre	95	6.6	285	7.670	49	yes
		Post	100	6.7	139			
	Rockland	Pre	97	6.2	336	12.849	68	yes
		Post	90	4.5	179			
	Pretty	Pre	91	5.0	212	8.926	58	yes
		Post	99	9.3	72			
	Browns	Pre	103	6.1	209	0.419	59	no
		Post	103	6.4	101			
Bluegill	Beulah	Pre	90	2.9	258	38.325	21	yes
		Post	102	4.0	249			
	Rockland	Pre	94	3.1	261	16.298	25	yes
		Post	101	5.6	209			
	Pretty	Pre	89	2.1	404	8.686	20	yes
		Post	86	5.7	361			
	Browns	Pre	85	2.8	367	7.391	18	yes
		Post	87	2.7	154			

Appendix M. Pre (1980-1982) and post (1983) regulation instantaneous growth rates (G) of largemouth bass and bluegills in the study lakes, and pumpkinseed in Browns Lake.

		Beulah Lake				Rockland Lake			
		Pre		Post		Pre		Post	
Species	Ages	G	n	G	n	G	n	G	n
Largemouth bass	1-2	2.197	135	1.399	80	2.523	160	2.062	120
	2-3	1.056	218	0.712	154	1.310	205	1.116	107
	3-4	0.674	135	0.512	60	0.795	108	0.804	29
	4-5	0.441	52	0.415	23	0.390	17	0.423	45
	5-6	0.440	14	0.255	9	0.302	10	0.366	8
	6-7	0.314	8	0.238	4	0.285	8	0.232	3
	7-8	0.188	5			0.192	5	0.144	1
	8-9	0.175	2	0.183	1	0.141	3		
	9-10	0.100	1	0.141	1	0.128	5	0.108	2
	10-11					0.131	3		
	11-12					0.062	1		
	12-13	0.071	1						
Bluegill	1-2	1.567	8	1.308	5	1.752	80	1.807	56
	2-3	1.300	46	1.078	69	1.434	120	1.456	130
	3-4	0.913	78	0.689	68	1.118	100	1.094	121
	4-5	0.644	77	0.592	81	0.784	50	0.650	64
	5-6	0.410	59	0.397	57	0.581	40	0.361	11
	6-7	0.240	33	0.281	25	0.308	24	0.298	3
	7-8	0.207	34	0.243	4	0.215	13	0.294	4
	8-9	0.127	13			0.236	7	0.220	1
	9-10	0.166	12			0.195	3		
	10-11	0.106	4			0.174	2		
	11-12	0.137	1						

Appendix M (continued)

Species	Ages	Pretty Lake Pre G	Pretty Lake Pre n	Pretty Lake Post G	Pretty Lake Post n	Browns Lake Pre G	Browns Lake Pre n	Browns Lake Post G	Browns Lake Post n
Largemouth bass	1-2	1.757	83	1.169	39	2.211	25	1.091	53
	2-3	1.219	176	1.007	36	1.514	134	1.588	49
	3-4	0.628	51	0.659	42	1.125	126	1.149	23
	4-5	0.459	21	0.486	18	0.428	96	0.539	59
	5-6	0.370	7	0.188	5	0.277	88	0.286	42
	6-7	0.199	4	0.341	3	0.208	19	0.183	34
	7-8	0.156	1	0.194	1	0.138	9	0.173	8
	8-9					0.103	1	0.157	2
	9-10							0.069	1
	10-11								
	11-12								
	12-13								
Bluegill	1-2	0.765	15	1.339	21	1.785	16	1.553	81
	2-3	0.639	56	1.050	60	0.726	26	0.759	52
	3-4	0.558	93	0.838	52	0.636	36	0.597	50
	4-5	0.444	100	0.686	63	0.534	80	0.514	45
	5-6	0.382	65	0.626	111	0.371	93	0.512	41
	6-7	0.246	43	0.515	31	0.272	38	0.409	22
	7-8	0.149	13	0.544	1	0.212	13	0.385	3
	8-9	0.115	5			0.144	6		
	9-10								
	10-11								
	11-12								
Pumpkinseed	1-2					1.434	33	1.187	25
	2-3					0.761	33	0.868	67
	3-4					0.659	27	0.654	67
	4-5					0.648	76	0.457	18
	5-6					0.397	51	0.404	10
	6-7					0.260	14	0.272	3
	7-8					0.298	2		

Appendix N. Total length (mm) at age of largemouth bass and bluegills in the four study lakes, and pumpkinseed (Browns Lake) for pre (1980-1982) and post (1983) regulation periods; and the southeastern Wisconsin average (Druckenmiller 1972).

Species	Lake	Period	Age 1	2	3	4	5	6	7	8	9	10	11	12	13
Largemouth bass	Beulah	Pre	104	172	227	285	319	371	418	415	395	386			567
		Post	99	158	214	259	319	354	403		481	446			
	Rockland	Pre	102	171	227	282	355	396	448	457	457	491	509	470	
		Post	82	151	225	286	326	377	466	500		518			
	Pretty	Pre	86	145	215	271	359	398	437	531					
		Post	68	130	201	246	302	389	464	460					
	Browns	Pre	76	166	230	289	370	398	417	437	498				513
		Post	69	111	216	269	357	404	433	460	476	488			
	S.E. Wis. Average		198	217	267	351	363	409	439	419					
Bluegill	Beulah	Pre		75	96	121	141	159	167	171	175	178	181	174	
		Post		67	98	123	149	169	176	189					
	Rockland	Pre	45	77	108	137	153	171	174	178	171	175	172		
		Post	57	69	103	139	174	184	194	204	200				
	Pretty	Pre		65	86	104	128	143	159	163	165				
		Post	47	63	79	100	124	144	160	168					
	Browns	Pre	55	80	99	102	113	130	150	166	188				
		Post	52	79	99	120	130	145	158	161					
	S.E. Wis. Average		119	137	157	183	193	203	224						
Pumpkinseed	Browns	Pre	66	79	93	100	119	128	134	119					
		Post		80	103	120	127	142	154						
	S.E. Wis. Average		117	127	142	155	163								

Appendix O. Comparison between length at age of post (1983) regulation largemouth bass, bluegills, and pumpkinseed (Browns Lake), and the southeast Wisconsin average (Druckenmiller 1973) with a paired t- test (Zar 1974; p.121). All statistical tests were at the 0.05 level of significance. Where significant changes occurred, the southeast Wisconsin average had the larger value.

Species	Lake	Calculated t	d.f.	Ages	Significant difference
Largemouth bass	Beulah	6.952	6	1-7	yes
	Rockland	1.459	7	1-8	no
	Pretty	2.339	7	1-8	no
	Browns	2.381	7	1-8	yes
Bluegill	Beulah	9.924	5	2-6	yes
	Rockland	5.565	6	1-7	yes
	Pretty	23.013	6	1-7	yes
	Browns	42.060	6	1-7	yes
Pumpkinseed	Browns	14.430	3	2-5	yes

Appendix P. Number of largemouth bass, bluegills, and pumpkinseeds (Browns Lake only) in each age class from pre and post regulation electrofishing samples, and the regression equations used for the catch curves shown in Figures 18-21.

	Largemouth bass							
	Beulah		Rockland		Pretty		Browns	
Age class	Pre	Post	Pre	Post	Pre	Post	Pre	Post
1	2	0	20	0	3	0	4	20
2	245	35	391	60	77	19	13	11
3	280	76	427	59	180	19	105	7
4	147	18	158	17	39	21	108	9
5	45	9	19	35	20	9	99	28
6	9	2	7	4	4	4	81	19
7	2	1	6	2	2	0	16	21
8	1		3	1	1	1	8	7
9	1		3				1	2
10	1	1	6					
11			4					
12			1					
13	2							

Beulah	Pre	$Y = 9.80 - 1.27\ X$, for ages 3-7, where X is age class and Y is log abundance of the age class.
	Post	$Y = 7.75 - 1.16\ X$, for ages 3-6.
Rockland	Pre	$Y = 9.38 - 1.16\ X$, for ages 3-7.
	Post	$Y = 6.62 - 0.82\ X$, for ages 3-7.
Pretty	Pre	$Y = 8.42 - 1.13\ X$, for ages 3-7.
	Post	$Y = 4.88 - 0.55\ X$, for ages 3-6.
Browns	Pre	$Y = 7.92 - 0.70\ X$, for ages 4-8.
	Post	$Y = 6.79 - 0.63\ X$, for ages 5-9.

Appendix P (continued)

Bluegill

Age class	Beulah Pre	Beulah Post	Rockland Pre	Rockland Post	Pretty Pre	Pretty Post	Browns Pre	Browns Post
1	0	0	4	1	0	0	2	1
2	9	2	116	26	25	10	16	36
3	51	85	340	141	368	43	125	24
4	121	64	110	54	320	58	201	54
5	120	61	66	42	359	132	402	35
6	71	34	24	5	75	127	176	12
7	31	16	20	1	33	4	62	8
8	41	4	4	4	5		5	
9	9		1	1	1			
10	5							
11	4							

Beulah Pre $Y = 7.35 - 0.54 X$, for ages 4-11.
Post $Y = 6.55 - 0.57 X$, for ages 3-8.

Rockland Pre $Y = 8.17 - 0.81 X$, for ages 3-8.
Post $Y = 8.19 - 1.03 X$, for ages 3-6.

Pretty Pre $Y = 12.69 - 1.36 X$, for ages 5-8.
Post $Y = 14.19 - 1.75 X$, for ages 5-7.

Browns Pre $Y = 13.46 - 1.42 X$, for ages 5-8
Post $Y = 6.77 - 0.68 X$, for ages 4-7.

Pumpkinseed

Age class	Browns Pre	Browns Post
1	0	2
2	19	73
3	34	88
4	44	33
5	117	6
6	68	5
7	10	3
8	3	

Pre $Y = 11.49 - 1.29 X$, for ages 5-8.
Post $Y = 6.82 - 0.86 X$, for ages 3-7.

Appendix Q. The regression equations between pre (1980-1982) and post (1983) regulation largemouth bass. bluegills, and pumpkinseeds (Browns Lake) compared with a t- test (Zar 1974; p.228). All statistical tests were at the 0.05 levl of significance.

Species	Lake	Calculated t	d.f.	Significant difference
Largemouth bass	Beulah	0.599	5	no
	Rockland	1.170	6	no a
	Pretty	3.200	5	yes
	Browns	0.325	6	no
Bluegill	Beulah	0.248	10	no
	Rockland	0.951	6	no
	Pretty	2.746	3	no
	Browns	2.379	4	no
Pumpkinseed	Browns	2.163	5	no

a Pre-regulation mortality was significantly greater.

Appendix R. Chi - Square analysis (Li 1969; p.458) of angling pressure (hrs/ha), and largemouth bass and bluegills catch and harvest rates (no./ha) from 1980 and 1982 creel surveys. All statistical tests were at the 0.05 level of significance.

Lake	χ^2	Significant difference
Angling pressure		
Beulah	11.2	yes
Rockland	0.7	no
Pretty	43.2	yes
Browns	6.4	yes
Largemouth bass catch rate		
Beulah	0.2	no
Rockland	9.0	yes
Pretty	12.8	yes
Browns	0.8	no
Largemouth bass harvest rate		
Beulah	1.3	no
Rockland	2.0	no
Pretty	1.3	no
Browns	8.2	yes
Bluegill catch rate		
Beulah	77.5	yes
Rockland	7.9	yes
Pretty	262.8	yes
Browns	11.0	yes
Bluegill harvest rate		
Beulah	50.2	yes
Rockland	12.8	yes
Pretty	151.6	yes
Browns	15.8	yes

Appendix S. Mean length (mm) of largemouth bass and bluegills harvested in compared with a t- test. All tests were at the 0.05 level of significance.

Species	Lake	Year	Mean length	Standard deviation	n	Calculated t	d.f.	Significant difference
Largemouth bass	Beulah	1980	298	2.43	115	9.13	346	yes
		1982	242	1.98	233			
	Rockland	1980	245	2.83	57	0.59	101	no
		1982	252	1.76	46			
	Pretty	1980	330	4.90	4	0.05	6	no
		1982	325	5.42	4			
	Browns	1980	330	1.72	251	2.48	284	yes
		1982	356	4.69	35			
Bluegill	Beulah	1980	155	0.48	1948	24.22	4179	yes
		1982	166	0.64	2233			
	Rockland	1980	152	0.79	418	8.68	1433	yes
		1982	163	0.79	1047			
	Pretty	1980	143	0.48	72	2.04	325	yes
		1982	147	0.72	255			
	Browns	1980	132	0.69	670	11.77	2351	yes
		1982	140	0.54	1683			