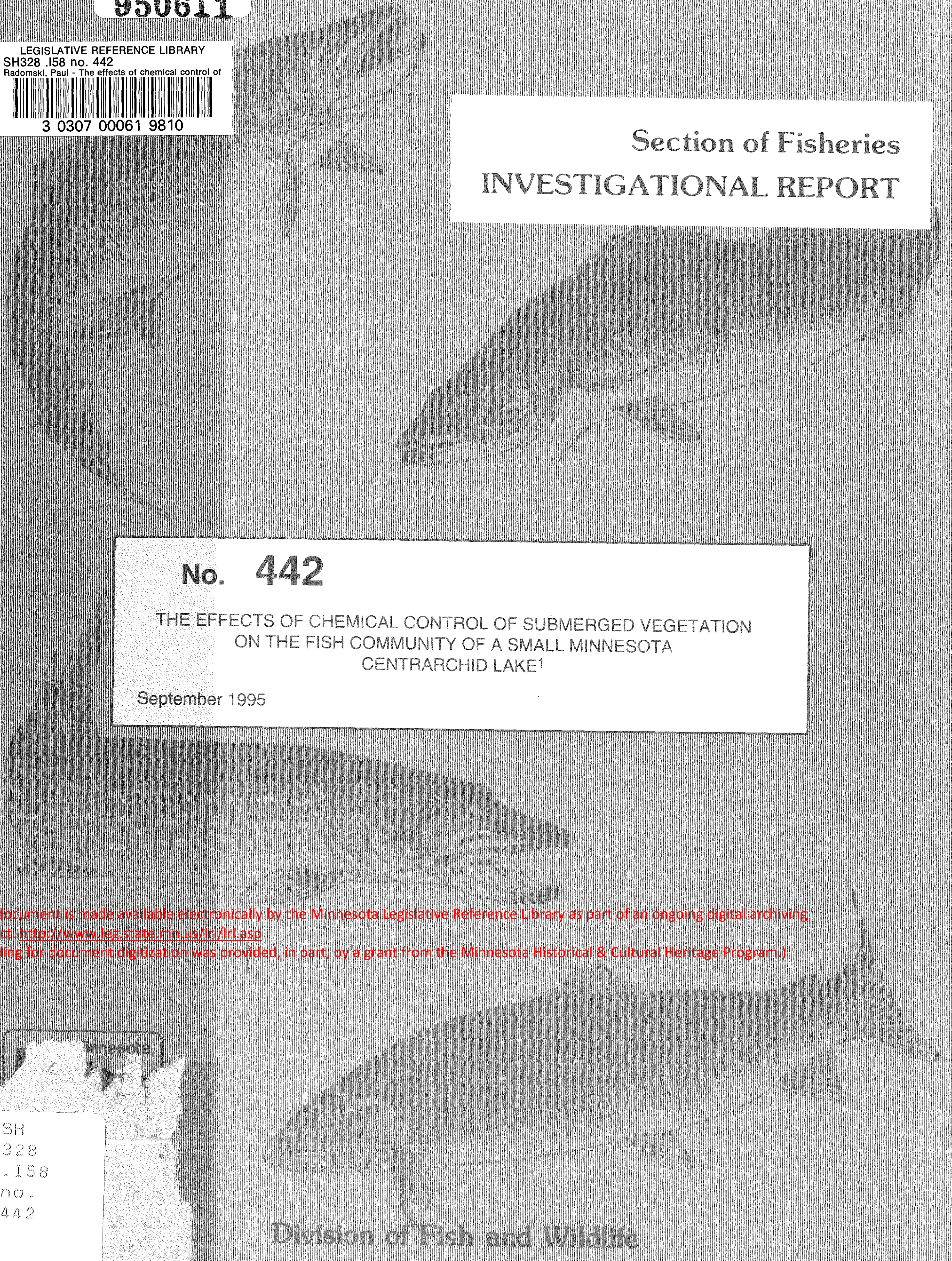

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THE EFFECTS OF CHEMICAL CONTROL OF SUBMERGED VEGETATION ON THE FISH COMMUNITY OF A SMALL MINNESOTA CENTRARCHID LAKE[1]

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Abstract.--A whole-lake application of endothall herbicide was evaluated as a fisheries management tool to enhance bluegill growth and size structure. A single treatment in 1992 eliminated submergent vegetation in 10 ha Little Horseshoe Lake, but bluegill size structure and growth were not altered during the following two years. Summer water temperature apparently had a greater effect on bluegill and largemouth bass growth than the abundance of submerged vegetation. Improving bluegill populations by increasing predation through submerged vegetation reduction shows little promise as a fish management tool.

Introduction

Chemical control of submerged macrophytes to provide recreational benefits is a common practice in Minnesota lakes. The effect of these control efforts on fish communities has not been extensively studied in Minnesota. If reductions in densities of submerged vegetation enhance sport fish populations, then vegetation management could become a valuable tool for fisheries managers. Conversely, if vegetation management efforts negatively influence fish communities, vegetation management goals could conflict with fisheries management objectives.

Aquatic plants characterize fish habitat to a large extent (Engel 1990). Bluegill *Lepomis macrochirus* seek vegetated areas for food and to avoid predators. Vegetation acts as a growth substrate for invertebrates, and bluegill will feed extensively on epiphytic macroinvertebrates (Schramm and Jirka 1989). Submerged vegetation density and species composition can also affect fish species interactions (Savino and Stein 1982), and thus may influence the composition and size structure of the

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fish community (Crowder and Cooper 1979). Plant cover can provide bluegill with an effective refuge from predators such as largemouth bass *Micropterus salmoides* and northern pike *Esox lucius*. Bluegill select areas of dense vegetation when bass are present (Gotceitas and Colgan 1987), and increases in plant density generally decrease rates of bluegill capture by piscivores (Savino and Stein 1989).

Vegetation may influence the size structure of bluegill populations. Dense vegetation, which reduces predation and increases competition, may result in slow growing bluegill (Engel 1985) and poorly conditioned largemouth bass (Colle and Shireman 1980). Small, slow growing bluegill are a problem for many fisheries managers trying to improve angler satisfaction in north-temperate regions (Kruse 1991; Wisconsin Department of Natural Resources 1992; Schneider 1993).

In Minnesota, Cross et al. (1992) evaluated reducing submerged vegetation to improve the size structure and growth of bluegill, largemouth bass, and northern pike. In two central Minnesota lakes, they mechanically harvested about 8% of the submerged vegetation. Density, size structure, and growth of these three species were not significantly affected by reduced vegetation, with the exception of young-of-the-year largemouth bass, where growth increased. They concluded that removal of small areas of submerged vegetation was not an effective fisheries management tool. Conversely, localized mechanical harvesting did not have deleterious effects on the fish community.

The objective of this project was to evaluate the effects of whole-lake chemical control of submerged vegetation on the fish community of a small centrarchid lake. Fish community responses were examined by analyzing growth and size structure of bluegill, largemouth bass, and northern pike before and after treatment. We tested the hypothesis that removal of submerged vegetation would increase growth and improve population size structure of bluegill, largemouth bass, and northern pike.

Study Lakes

Two central Minnesota (Crow Wing County) lakes were selected--Little Horseshoe Lake for chemical treatment and East Twin Lake as a reference lake. Little Horseshoe Lake is small (10 ha) with a maximum depth of 9 m. Aquatic plants were common to a depth of 4.5 m and covered about 40% of the lake. This lake had lush submergent summer growth dominated by Robbins' pondweed *Potamogeton robbinii*. Other submerged plant species included *P. natans* and *P. zosteriformis*. East Twin Lake is a 13 ha lake with a maximum depth of 8.5 m. Submerged vegetation occurs around the entire shoreline. East Twin Lake has a diverse submerged plant community consisting of *P. robbinii, P. amplifolius, P. natans, P. zosteriformis, P. richardsonii, Elodea canadensis, Vallisneria americana*, and *Najas flexilis*. Both lakes are mesotrophic; total phosporus was less than 0.02 mg/l when the study began.

Both lakes had similar fish community composition, with similar abundances of bluegill, black crappie *Pomoxis nigromaculatus*, largemouth bass, and northern pike. Previous Department of Natural Resources (DNR) fisheries assessments had indicated good size structure of northern pike, but dense populations of slow growing bluegill. No public access existed on either lake, and angling exploitation was light.

Methods

Aquathol K®, an endothall herbicide, was applied to Little Horseshoe Lake in June 1992. The littoral area of the lake (4.5 ha) was treated once with 600 l of herbicide. The application goal was a treatment concentration of 5.0 mg/l to kill submerged aquatic vegetation (primarily Robbins' pondweed) to a depth of 2.5 m. Herbicide concentrations slightly exceeded the target concentration, with a mean concentration of 6.28 mg/l observed on the day of treatment (Table 1). Granular 2,4-D was applied three times in one bay on the lake to eliminate stands of watershield *Brasenia*

Table 1. Mean residue concentrations (mg/l) in water sampled from Little Horseshoe Lake after herbicide treatment.

Time	Endothall	Aquathol K
Day of treatment	2.53	6.28
8 days after treatment	0.42	1.03

schreberi; one treatment occurred in 1992 and two treatments were applied in 1993.

The Little Horseshoe Lake fish community was sampled before and after elimination of submerged vegetation. Pretreatment sampling of fish began in 1990 and continued annually until completion of the project in 1994. East Twin Lake was sampled the same years. Fish were collected from both lakes using gill nets, trap nets, a large seine, and electrofishing. To estimate relative abundance, we sampled fish with standard Minnesota summer trap net surveys and fall seining (50.3 m long, 4.3 m deep, and 19.1 mm mesh leads with a 6.4 mm mesh bag). Three seining stations were established on each lake, and the lakes were seined in early September. The seine was laid out parallel to shore and then pulled directly to shore, covering approximately 0.3 ha. Catches were randomly subsampled to obtain fish lengths and scales from bluegill, largemouth bass, black crappie, and pumpkinseed *Lepomis gibbosus*.

Fish scales were aged and scale increments were digitized to construct growth records. We applied ANOVA using the linear modeling system of Weisberg (1993), because it partitions variation in scale data between age and year effects. The year effects represent the growth index that we subjected to further analyses with climate data (obtained from the DNR Division of Forestry, Brainerd weather station). Old fish (>8 years) were excluded from this analysis due to uncertainty in aging.

The size structure of the bluegill population was assessed with trap net proportional stock density (Anderson and Weithman 1978). Confidence intervals were approximated as presented by Gustafson (1988). The Kolmogorov-Smirnov test was used to examine differences between length frequency distributions. Bluegill year-class strength was determined by a simple aggregative catch-per-unit-effort (CPUE) index using the average CPUE by age from all available years as the comparison CPUE (Carlander et al. 1960).

We collected monthly samples of aquatic vegetation in plots along established transect lines using SCUBA gear from May through September (1991-1994) for both lakes. Three transect areas were established per lake, and divers collected samples at two plots along each transect. The plants were gathered off the bottom within a three-sided frame so data could be quantified on a per area basis. For each plot, plants were sorted by species, and weighed (wet weight, roots excluded). Monthly water samples were also collected from May through September (1990-1994).

Results and Discussion

Vegetation

The single whole-lake treatment with endothall in 1992 eliminated submergent vegetation in Little Horseshoe Lake through 1994 (Table 2). For floating-leaf vegetation, a reduction of approximately 60% in areal coverage was achieved by periodic treatments with 2,4-D granules over a two-year period. Prior to treatment in Little Horseshoe Lake, submerged vegetation had a density of about 2,000 g/m^2. After treatment, a thick (0.1 to 0.6 m) layer of detritus, consisting of decomposing Robbins' pondweed, inhibited aquatic plant emergence from the lake shoal soils. One year after treatment, water lily seedlings were observed colonizing the devegetated littoral area. Only several individual submergent plants were observed after August 1992 in Little Horseshoe Lake. East Twin Lake had a dense and diverse aquatic plant community throughout the study, and both lakes had substantial areas of floating-leaf and emergent vegetation.

Water Chemistry

Water clarity was lower after elimination of submerged vegetation in Little Horseshoe Lake (Table 3). Secchi disk transparencies

Table 2. Mean littoral macrophyte biomass (g/m^2) by month in Little Horseshoe and East Twin lakes, 1991-1994. CV=coefficient of variation; NS=not sampled.

Year	Mean Biomass (g/m^2) May	Jun	Jul	Aug	Sep
L. Horseshoe Lake					
1991	1267	2397	NS	2317	2029
CV	0.41	0.32	NS	0.42	0.50
1992	2725	2028	867	0	0
CV	0.16	0.18	1.34	--	--
1993	NS	0	4*	0	0
CV	NS	--	2.45	--	--
1994	0	0	0	0	0
CV	--	--	--	--	--
E. Twin Lake					
1991	920	941	NS	1975	1483
CV	1.10	0.98	NS	1.07	1.69
1992	529	365	323	621	NS
CV	2.11	1.37	1.40	1.02	NS
1993	NS	1059	1865	2212	1006
CV	NS	2.29	1.87	0.84	1.56
1994	274	1078	817	2938	1329
CV	1.76	1.75	1.31	1.06	1.72

* Seedlings of Nymphaeaceae

Table 3. July water characteristics of Little Horseshoe and East Twin lakes, 1990-1994.

Year	1990	1991	1992	1993	1994
Little Horseshoe Lake					
Secchi disk transparency (m)	3.8	3.8	3.5	2.3	2.7
Chlorophyll *a* (ug/l)	6.0	5.0	15.4	12.6	8.3
Total phosphorus (mg/l)	0.012	0.005	0.024	0.027	0.038
East Twin Lake					
Secchi disk transparency (m)	5.3	3.5	3.5	3.3	3.5
Chlorophyll *a* (ug/l)	3.3	0.1	7.4	4.1	4.2
Total phosphorus (mg/l)	0.008	0.005	0.022	0.013	0.011

declined from a mean of 3.7 m to 2.5 m. Comparing the periods 1990-1991 and 1992-1994, both lakes had generally higher concentrations of chlorophyll *a* and total phosphorus. Little Horseshoe Lake, however, had higher total phosphorus concentrations after chemical treatment (Table 3). These results can be explained by decomposing plants releasing nutrients after herbicide treatment, resulting in increased algal production with lower water clarity (Engel 1990).

Bluegill

The relative abundance of bluegill, as measured by various gears, did not change substantially in either Little Horseshoe or East Twin lakes during the study (Tables 4-6). Bluegill dominated the fish biomass in both lakes. During the five years of trap netting (1990-1994), bluegill CPUEs were high, indicating large and dense populations (Table 4). At Little Horseshoe Lake, bluegill trap net CPUE increased linearly, while bluegill seine CPUE fluctuated around 500 fish/haul. Other investigators have documented changes in dominance of various fish species after elimination of vegetation. Bettoli et al. (1993) hypothesized that diet flexibility allowed bluegill to persist at high densities after elimination of submerged vegetation by grass carp *Ctenopharyngodon idella*, though abundances of other fish species were altered. Generally, elimination of submerged vegetation has produced few consistent or predictable changes in fish community structure (Bailey 1978).

Observed changes in bluegill numbers can be explained by variation in year-class strength (Figure 1). In Little Horseshoe Lake, the 1988 and 1989 year-classes were strong, and the 1990 through 1992 year-classes were weak. The 1988 and 1989 year-classes recruited to trap nets during the study resulting in higher CPUEs in Little Horseshoe Lake. In East Twin Lake, the 1990 and 1991 year-classes were strong, and the 1992 year-class was weak. In both lakes, weak year-classes followed strong year-classes.

Bluegill year-class strength was apparently determined before early September, when seining occurred, and was unrelated to the abundance or density of submerged vegetation in Little Horseshoe Lake (Table 7). Bluegill young-of-the-year seine CPUE was highest in 1993 for Little Horseshoe Lake, while no bluegill from the 1992 cohort were ever collected. The summer of 1992 was the coolest

Table 4. Catch per unit of effort (CPUE) of fish sampled by trap nets. Species are abbreviated as follows: northern pike-NOP, pumpkinseed-PMK, bluegill-BLG, largemouth bass-LMB, black crappie-BLC, yellow perch-YEP. N = number of nets.

Little Horseshoe Lake

		CPUE (number/net)					
Year	N	OP	PMK	BLG	LMB	BLC	YEP
1990	2	1.0	0.0	22.0	0.0	1.0	0.0
1991	3	0.3	0.7	44.7	0.3	1.0	1.3
1992	3	1.0	5.7	61.7	0.7	1.0	0.0
1993	3	0.0	5.0	73.3	0.7	5.0	0.0
1994	3	0.3	2.3	86.0	0.0	7.0	0.3

		CPUE (kg/net)					
Year	N	NOP	PMK	BLG	LMB	BLC	YEP
1990	2	1.13	0.00	1.00	0.00	0.22	0.00
1991	3	0.25	0.03	1.40	0.04	0.36	0.06
1992	3	1.80	0.50	2.09	0.19	0.18	0.00
1993	3	0.00	0.53	2.17	0.54	0.51	0.00
1994	3	1.03	0.29	2.83	0.00	1.08	0.02

East Twin Lake

		CPUE (number/net)					
Year	N	NOP	PMK	BLG	LMB	BLC	YEP
1990	3	0.4	0.0	73.7	0.7	9.7	0.0
1991	3	2.0	0.0	143.7	1.0	8.7	1.0
1992	3	1.0	0.0	62.0	0.3	3.3	0.0
1993	3	0.3	0.0	51.7	1.3	2.7	0.0
1994	3	0.0	0.0	56.0	1.0	8.7	0.0

		CPUE (kg/net)					
Year	N	NOP	PMK	BLG	LMB	BLC	YEP
1990	3	0.13	0.00	4.53	0.20	0.90	0.00
1991	3	0.74	0.00	6.37	0.27	0.72	0.09
1992	3	1.42	0.00	3.72	0.07	0.37	0.00
1993	3	0.22	0.00	4.34	0.41	0.32	0.00
1994	3	0.00	0.00	3.16	0.38	0.66	0.00

Table 5. Catch per unit of effort (CPUE) for the most common fish sampled by fall seining. Species are abbreviated as follows: northern pike-NOP, pumpkinseed-PMK, bluegill-BLG, largemouth bass-LMB, black crappie-BLC, yellow perch-YEP. N = number of net hauls.

Little Horseshoe Lake

		CPUE (number/haul)					
Year	N	NOP	PMK	BLG	LMB	BLC	YEP
1990	1	7.0	17.0	692.0	18.0	24.0	4.0
1991	2	4.0	6.3	421.5	13.0	6.5	2.0
1992	3	1.3	6.2	742.7	11.3	0.0	0.0
1993	3	1.0	2.3	457.5	46.3	1.3	0.5
1994	2	0.0	2.0	250.0	65.0	0.0	0.0

		CPUE (kg/haul)					
Year	N	NOP	PMK	BLG	LMB	BLC	YEP
1991	2	2.15	0.05	5.33	0.33	0.43	0.03
1992	3	2.07	0.67	14.87	0.12	0.00	0.00
1993	3	0.46	0.09	7.77	0.35	0.001	0.003
1994	2	0.00	0.11	5.90	0.75	0.00	0.00

East Twin Lake

		CPUE (number/haul)					
Year	N	NOP	PMK	BLG	LMB	BLC	YEP
1991	2	4.0	0.0	1166.0	20.0	59.0	5.9
1992	3	2.7	0.0	734.9	43.5	110.3	7.4
1993	3	1.3	0.0	662.1	6.0	14.3	9.3
1994	3	5.7	0.0	640.3	21.3	13.3	36.3

		CPUE (kg/haul)					
Year	N	NOP	PMK	BLG	LMB	BLC	YEP
1991	2	1.24	0.00	3.22	2.82	2.03	0.06
1992	3	1.57	0.00	6.58	0.39	0.77	0.04
1993	3	0.60	0.00	5.32	0.67	0.78	0.12
1994	3	1.41	0.00	5.30	0.99	0.58	0.26

Table 6. Catch per unit of effort (CPUE; number/net) of fish sampled by gill net at Little Horseshoe Lake. Species are abbreviated as follows: northern pike-NOP, bluegill-BLG, largemouth bass-LMB, black crappie-BLC, yellow perch-YEP. N=number of nets.

Year	N	NOP	BLC	BLG	LMB	YEP
1990	2	16.0	9.5	6.0	0.5	0.0
1994	2	10.5	8.5	2.0	0.5	1.5

Table 7. Catch per unit of effort (CPUE; number/haul) for young-of-the-year bluegill (BLG) and largemouth bass (LMB) sampled by fall seining. NA=not available.

	L. Horseshoe		E. Twin	
Year	BLG	LMB	BLG	LMB
1990	NA	15.0	NA	NA
1991	18.0	11.0	579.5	12.0
1992	0.0	9.0	81.5	32.0
1993	123.8	44.7	105.5	1.0
1994	65.0	64.5	383.0	18.0

summer in the last 12 years, and elsewhere young-of-the-year bluegill were also rare (Dennis Schupp, personal communication). Clark and Lockwood (1990) found that bluegill reproductive success was negatively correlated with density of small bluegill. In northern Wisconsin, Beard (1982) stated that fry mortality during the time of dispersal from the nest may have the most influence on year-class strength. He also correlated late spawning with weak year-class strength. Thus, water temperature may have a direct effect on bluegill young-of-the-year production in the northern part of its range. Intraspecific competition and water temperature were likely the most important factors influencing bluegill abundance and year-class fluctuations in Little Horseshoe Lake.

Bluegill size structure did not change significantly after the elimination of vegetative cover in Little Horseshoe Lake, where trap net PSDs ranged from 7.6 to 28.4 (Figure 2). PSDs less than 20 are regarded as populations with poor size structure (Gabelhouse 1984). Yearly fluctuation of PSDs were the result of variable recruitment (Figure 1). East Twin bluegill PSDs ranged from 36.9 to 75.5; the low value resulted from recruitment of the 1990 and 1991 year-classes to trap nets in 1994. The size of young-of-the-year bluegill was similar between the two lakes over the years, suggesting abiotic factors controlled first-year growth of bluegill (Figure 3).

Largemouth Bass

Largemouth bass young-of-the-year CPUE was higher, and there were greater size

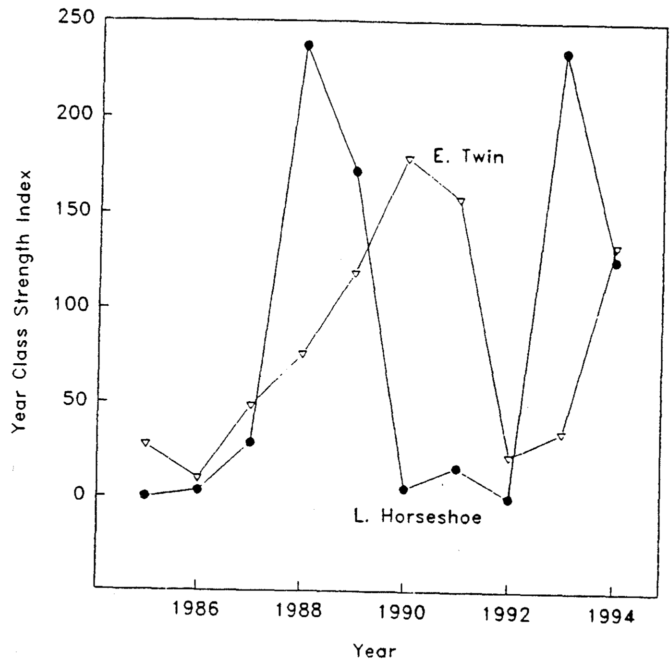


Figure 1. Bluegill year-class strength indices for L. Horseshoe and E. Twin lakes.

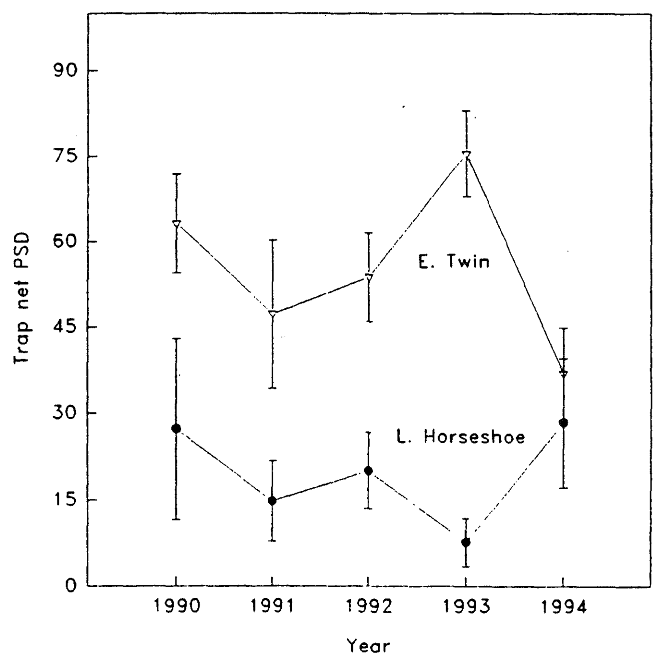


Figure 2. Proportional stock densities (PSD) of bluegill captured in summer trap nets for L. Horseshoe and E. Twin lakes. Error bars represent approximate 95% confidence intervals.

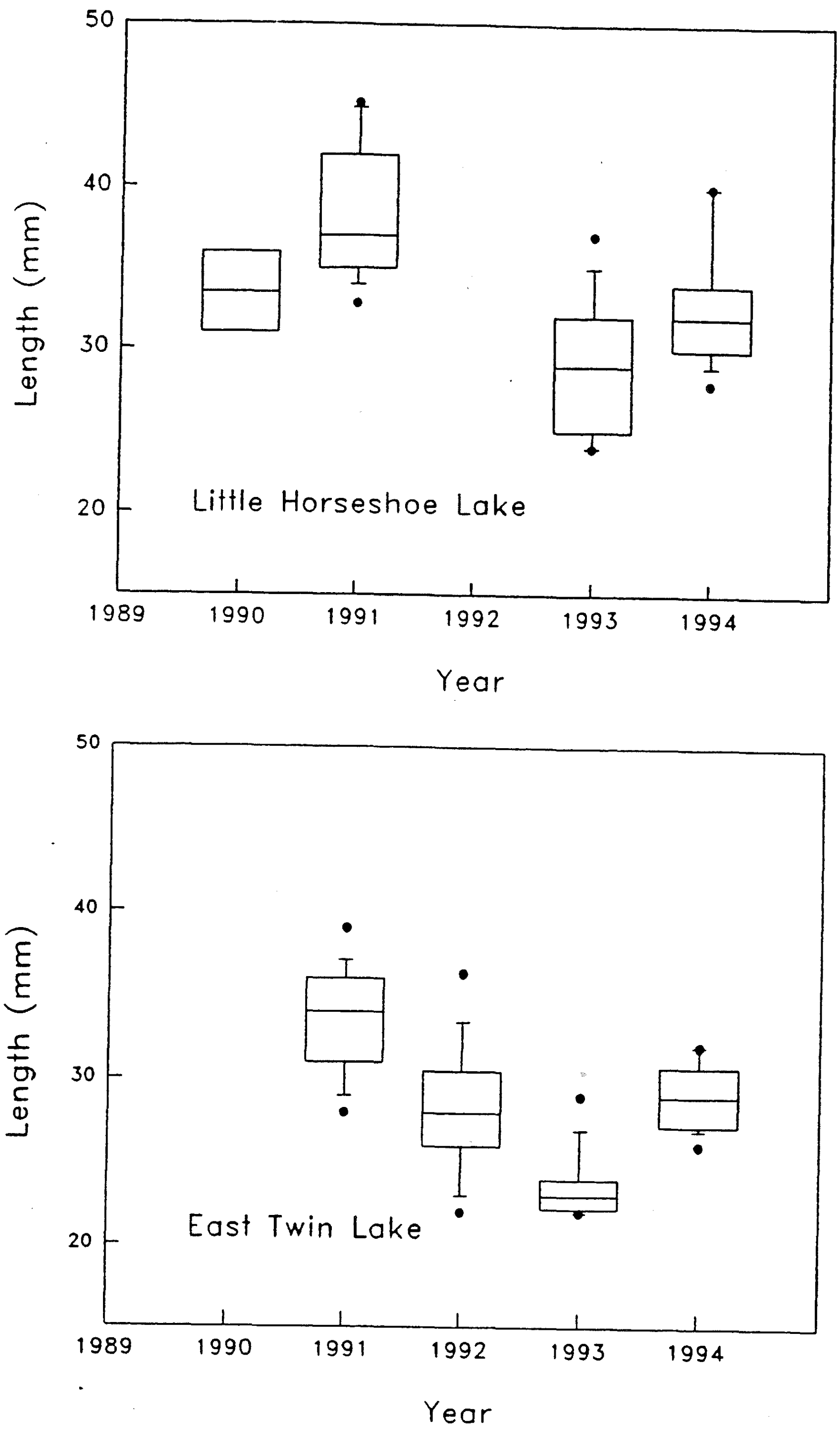
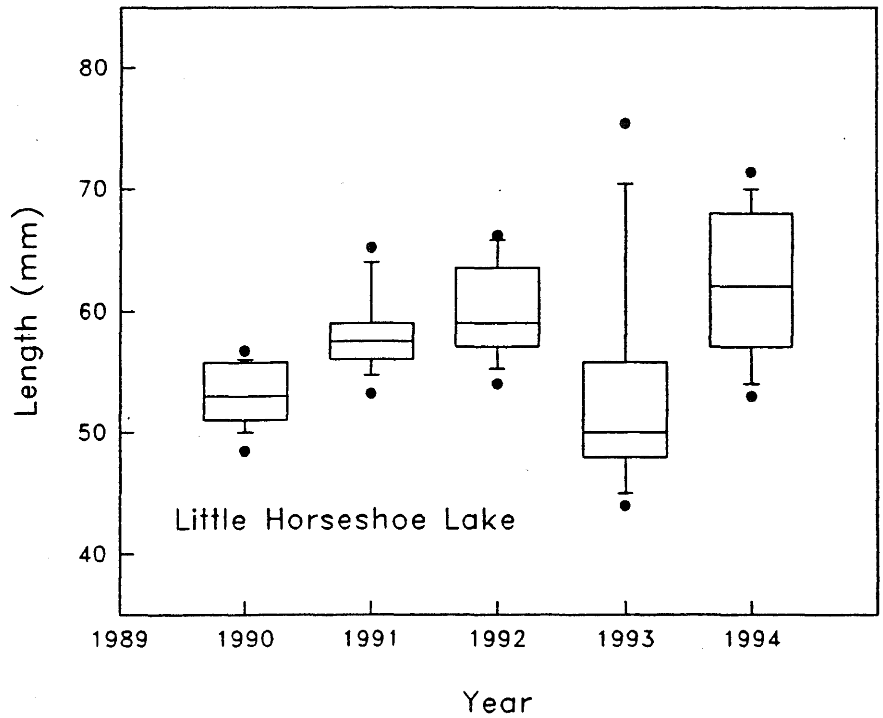


Figure 3. Median total lengths of young-of-the-year bluegill sampled by fall seining. Data are the median (solid horizontal line), 25th and 75th percentiles (box), 10th and 90th percentile (capped vertical lines, and 5th and 95th percentile (solid dots) of total length. No young-of-the-year bluegill were found in the 1992 seine hauls at Little Horseshoe Lake.



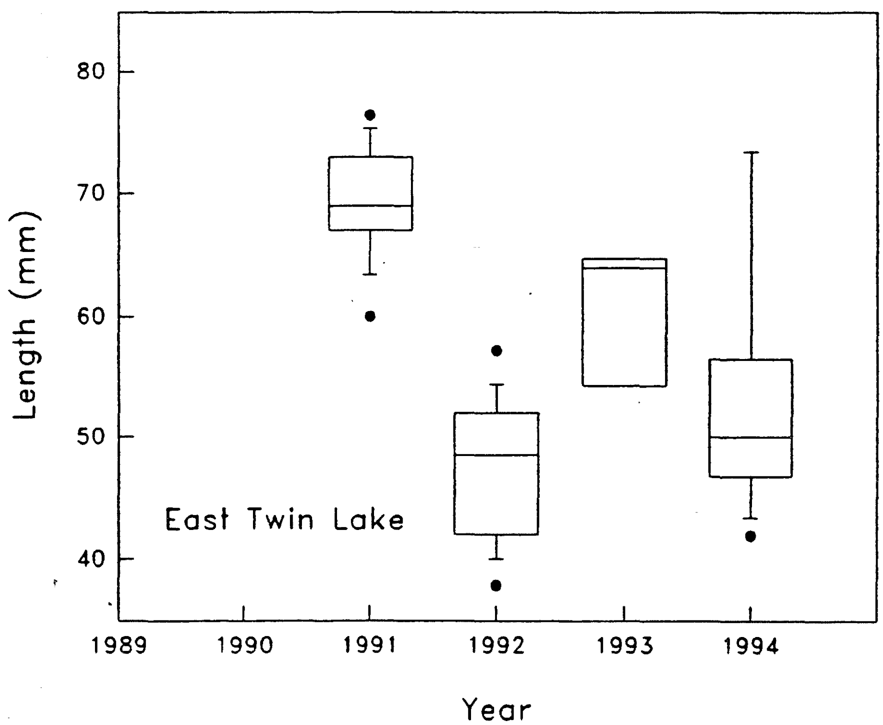


Figure 4. Median total lengths of young-of-the-year largemouth bass sampled by fall seining. Data are represented as in Figure 3.

ranges observed in years with no submerged vegetation in Little Horseshoe Lake (Table 7, Figure 4). There were no trends in largemouth bass young-of-the-year abundance or size in East Twin Lake. Furthermore, we detected no changes in adult largemouth bass abundance. Cross et al. (1992) observed an increase in first-year growth of bass with partial removal of submerged vegetation. Bettoli et al. (1992) found that piscivory in young-of-the-year largemouth bass started earlier in environments without submerged vegetation, which resulted in faster growth. Vegetation removal may improve first-year growth, and thus could improve recruitment; however, the benefits of vegetation removal for largemouth bass remain uncertain. Durocher et al. (1984) found no significant correlation between submerged vegetation coverage and abundance of small largemouth bass; however, they did find a significant positive relationship between submerged vegetation coverage (up to 20%) and abundance of large bass. Bettoli et al. (1993) observed a decline in juvenile largemouth bass CPUE after vegetation removal, but noted a decrease in seine catchability due to increases in bass growth. They did not detect any significant changes in adult bass abundance following vegetation removal. Bain and Boltz (1992) found no evidence that localized herbicide treatments changed the abundance, size structure, or movement of largemouth bass.

Northern Pike

There were no significant changes in the length frequencies of northern pike from gill nets in Little Horseshoe Lake ($P > 0.05$; Figure 5). We also were unable to detect any changes in abundance (Table 6).

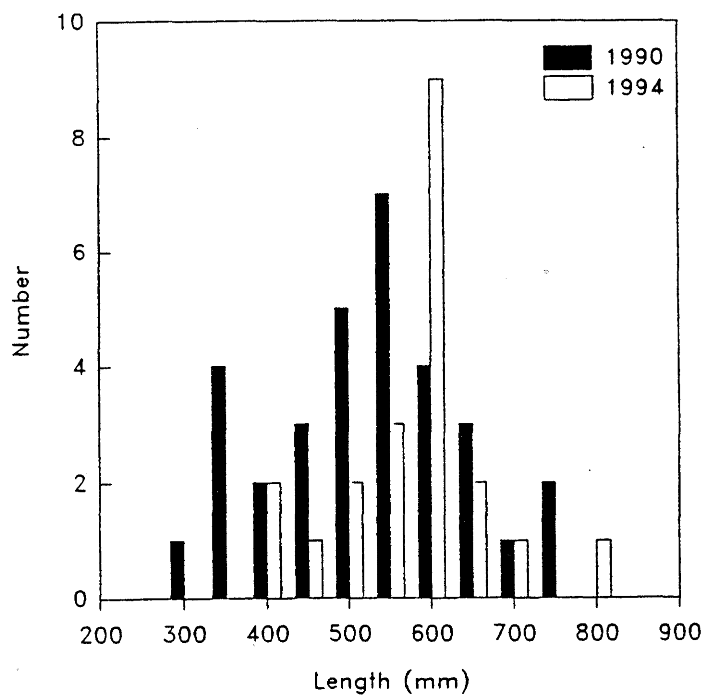


Figure 5. Length distributions of northern pike captured by gill nets in Little Horseshoe Lake in 1990 and 1994.

Factors Affecting Growth

Bluegill and largemouth bass growth were apparently related more to water temperature than to abundance of submerged vegetation. Growth indices of bluegill, largemouth bass, and black crappie from Little Horseshoe Lake were significantly positively correlated with July mean air temperature ($P<0.05$, Table 8). At Little Horseshoe Lake, 68% of the variability in the bluegill growth index was explained by July mean air temperature. At East Twin Lake, the bluegill growth index was also correlated with July mean air temperature. Although slower growth generally occurred after chemical treatment of submerged vegetation (Figures 6-7), inspection of the residuals of the fitted July temperature-growth index model by year for bluegill and largemouth bass revealed no pattern after treatment (Figure 8). Observed growth was neither consistently higher or lower than the predicted growth after the elimination of submerged vegetation. Thus

Table 8. Correlations between July mean air temperatures and growth coefficients of four fish species from two central Minnesota lakes. NA=not available.

Species	Little Horseshoe	East Twin
Bluegill	0.82*	0.59*
Pumpkinseed	0.54	NA
Largemouth Bass	0.81*	0.47
Black Crappie	0.77*	0.29

* $P<0.05$

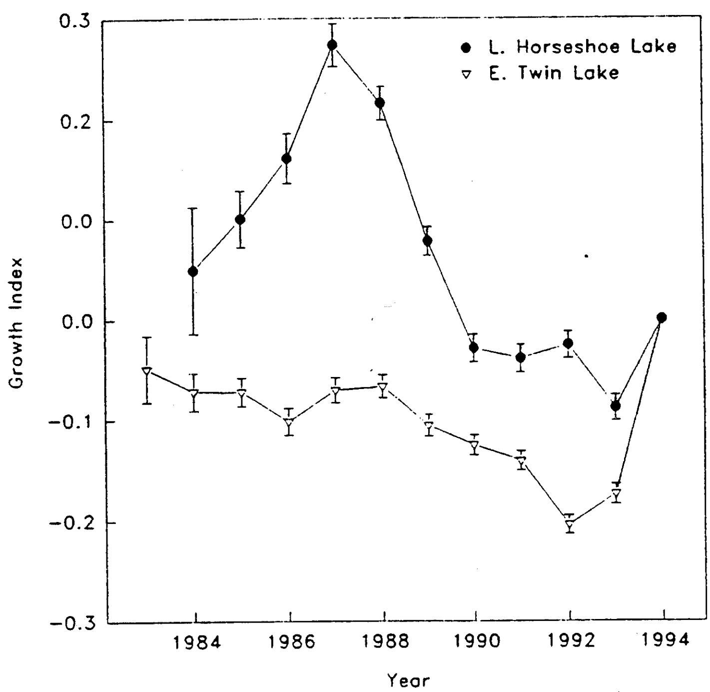


Figure 6. Growth series for bluegill from two lakes derived from Weisberg model. Error bars represent standard error.

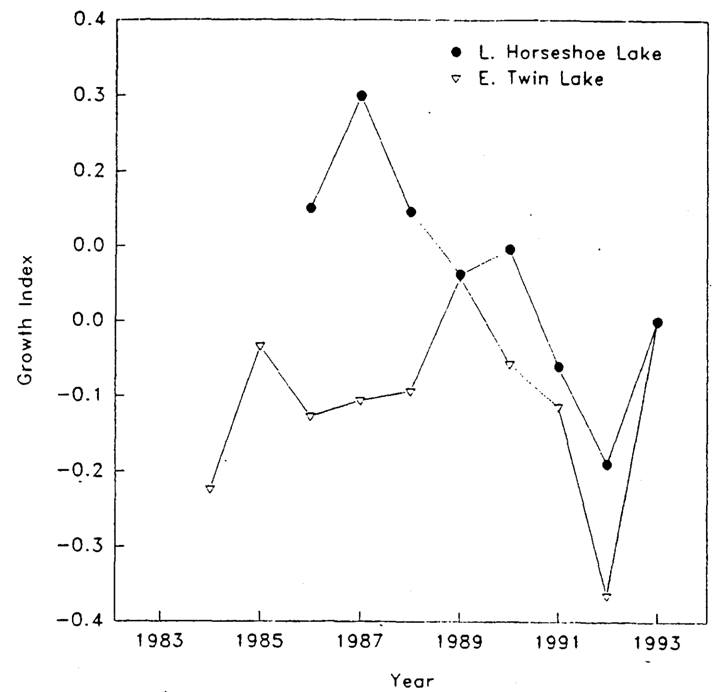


Figure 7. Growth series for largemouth bass from two lakes derived from Weisberg model. Error bars represent standard error.

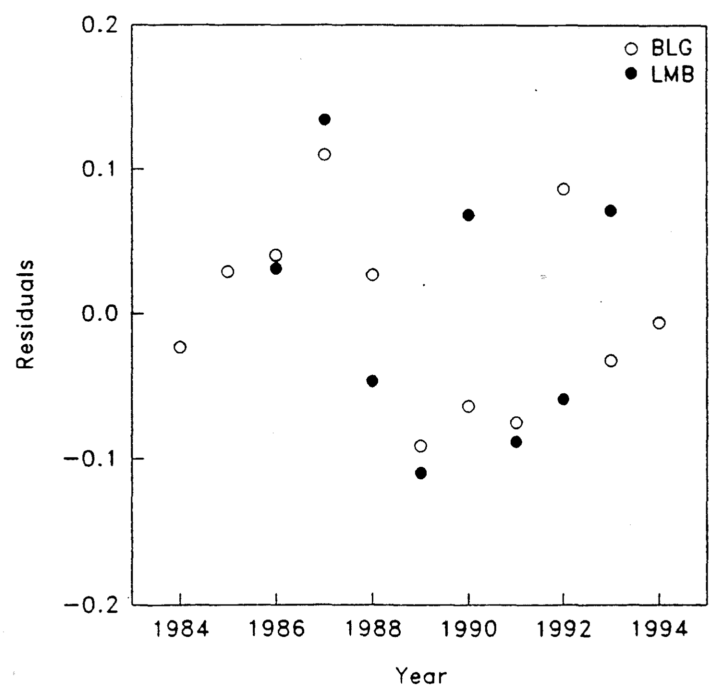


Figure 8. Temperature-growth model residuals by year for L. Horseshoe Lake bluegill (BLG) and largemouth bass (LMB)

we could not conclude that abundance of submerged vegetation was an important factor controlling growth rates of bluegill and largemouth bass. Theiling (1990) found a negative correlation between bluegill growth and total aquatic vegetation coverage for 30 Michigan lakes. Snow and Staggs (1994) found no relationships between vegetation parameters and bluegill growth. Both bluegill density and submerged vegetation have been shown to influence bluegill growth (Clark and Lockwood 1990; Theiling 1990), but species near the limit of their native range may be more influenced by thermal habitat, especially in small lakes like those in this study (Shuter and Post 1990).

Conclusions

High-density bluegill populations may have slow growth and poor size structure (Figure 9); however, altering submerged vegetative cover may not improve bluegill populations. In this study, water temperature influenced bluegill dynamics more than the abundance of submerged vegetation. Bluegill appear quite flexible in habitat use and behavior in response to predators (Werner et al. 1977; Savino and Stein 1989). Bluegill in Little Horseshoe Lake may have altered their distribution in the littoral area, perhaps by using floating-emergent vegetation cover and abandoning the devegetated regions of the littoral area. Conrow et al. (1990) found extensive use of floating-emergent vegetation habitat by young bluegill. If bluegill were using shallow emergent cover, foraging success of largemouth bass and northern pike may not have changed with the elimination of submerged vegetation (Savino and Stein 1989).

These results indicate that growth, mortality, and natality were not greatly influenced by vegetation removal during the study period, or the consequences of removal have a lag-time greater than the study period. Hinch and Collins (1993) suggest a time span of up to seven years may be necessary to detect the influence of altered recruitment or mortality on the entire fish community. Additionally, this study had an unreplicated perturbation design. Such designs have difficult analysis problems (Stewart-Oaten et al. 1992; Smith et al. 1993). Since we relied on standard DNR lake survey sampling gear and monitored for only three years, the study could only detect large changes in the fish community that might have occurred within that time span. We have, however, come to a better understanding regarding the short-term resilient capabilities of fish populations when exposed to substantial habitat change, and also can better project what additional experimentation may prove fruitful in enhancing bluegill populations.

Management Implications

Improving bluegill populations by increasing predation through submerged vegetation removal shows little promise as a fish management tool based on the results of this study. The removal of extensive beds of submergents did not decrease bluegill recruitment. Water temperature apparently had a more profound influence on bluegill dynamics in Little Horseshoe Lake than did the abundance of submerged vegetation. The best potential for producing larger bluegill in small lakes with abundant vegetation probably involves restricting fishing harvest. Additional important elements in a successful management scheme include at least one major bluegill predator and appropriate timing of attempts to alter mortality and predatory rates through management. The bluegill predator should be characterized by high population density and slow growth (Schneider 1993). Management should be applied, as much as possible, during warm summers when recruitment and growth are likely to be higher.

Controlling submerged vegetation with herbicides did not alter fish population characteristics during the study period, nor did it result in any detected deleterious effects. Though such treatments apparently hold little promise for use as fish management tools, regulated submerged vegetation management for recreational purposes appears acceptable from a fish management viewpoint. The reality is that lakes have an inherent capacity to produce fish which is not readily altered.

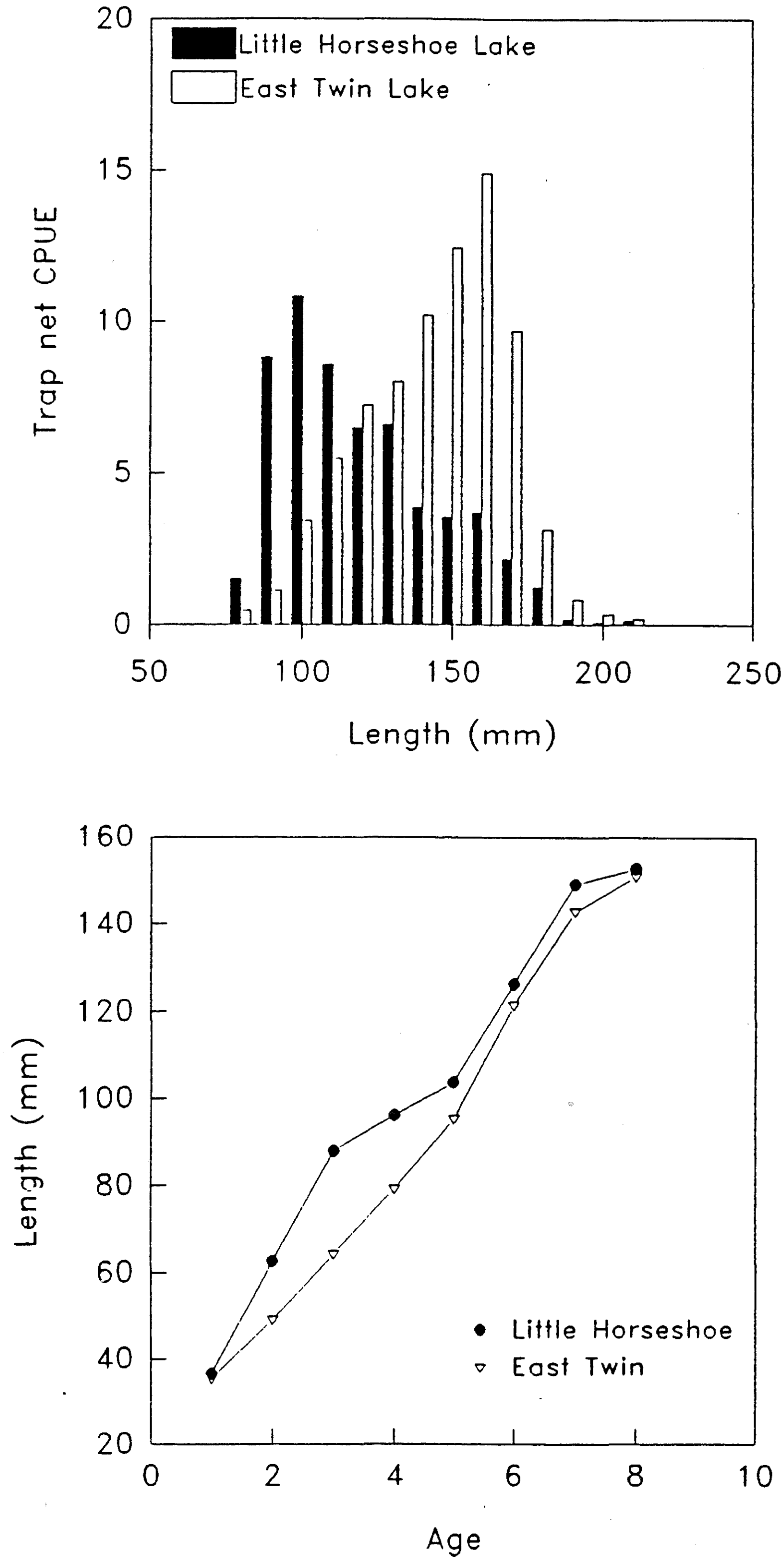


Figure 9. Average (1990-1994) bluegill trap net CPUE by length, and average (1990-1994) bluegill length-at-age for Little Horseshoe and East Twin lakes.

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