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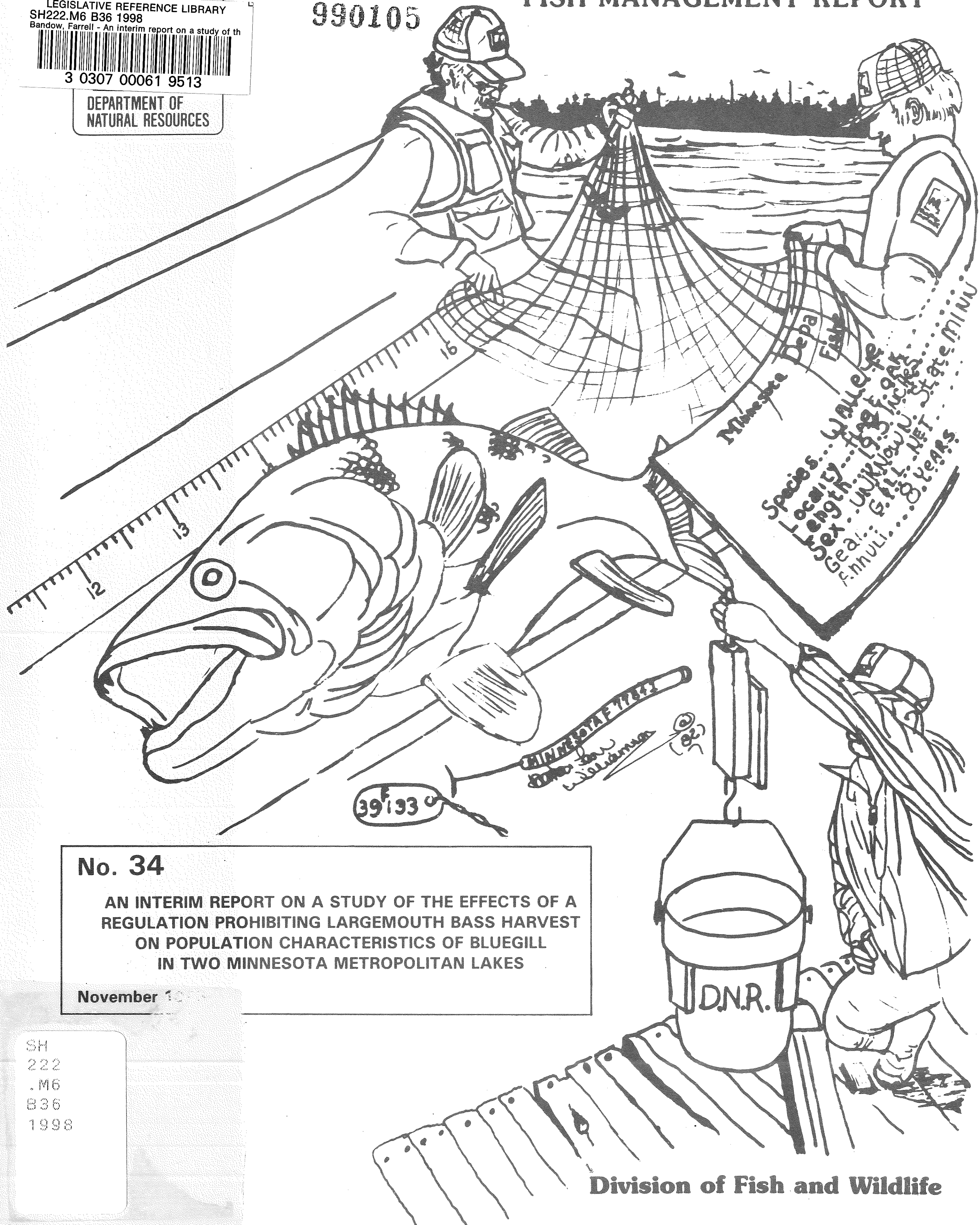


## No. 34

## AN INTERIM REPORT ON A STUDY OF THE EFFECTS OF A REGULATION PROHIBITING LARGEMOUTH BASS HARVEST ON POPULATION CHARACTERISTICS OF BLUEGILL IN TWO MINNESOTA METROPOLITAN LAKES

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# An Interim Report on a Study of the Effects of a Regulation Prohibiting Largemouth Bass Harvest on Population Characteristics of Bluegill in Two Minnesota Metropolitan Lakes[1]

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*Abstract.*—After three years of preliminary sampling in four centrarchid lakes, a regulation prohibiting harvest of largemouth bass *Micropterus salmoides* was implemented on two of the lakes. The objective was to increase the average size of panfish (primarily bluegill *Lepomis macrochirus*) available to anglers by limiting recruitment through increased predator abundance. Noncompliance with the regulation was observed during creel surveys. Largemouth bass harvest estimates declined only 68% in one lake and 88% in the other during the first 2 years of regulation compared with the previous 3 years. Spring population estimates have not yet provided conclusive evidence of increased largemouth bass abundance. The only notable changes in bluegill population characteristics were increases in growth rates and fish quality in one of the experimental lakes. That, however, began before the regulation was implemented.

## Introduction

Many Minnesota anglers express dissatisfaction with the small panfish they catch. Slow growth of panfish, as a result of overpopulation, is frequently a major cause and is of special concern to fisheries managers. The problem occurs statewide, and is particularly important in the St. Paul-Minneapolis metropolitan area and surrounding counties where high fishing pressure exacerbates it. Panfish (primarily sunfish *Lepomis spp*. and crappie *Pomoxis spp*.) were usually the species anglers indicated they sought most in summer creel surveys of 28 metropolitan area lakes (Shodeen and Tureson 1975; Tureson 1978a; Tureson 1978b; Gilbertson 1979) and 12 Rice and Le Sueur County lakes (Belford 1989; Pittman 1989). Efforts to alleviate the problem by panfish removal, macrophyte removal, predator stocking, and selective treatment with fish toxicant have had poor or inconsistent results (Scidmore 1960; Davis 1979; Cross et al. 1992; Radomsk1 et al. 1995). Those procedures also have high labor or material costs.

High densities of small, slow-growing bluegill *Lepomis macrochirus* have been described as merely symptoms of another problem—too few predators, usually largemouth bass *Micropterus salmoides* (Ming 1974; Ming

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and McDannold 1975). Anderson (1974) suggested that bass overharvest may be the most serious problem limiting the sustained quality of fishing in most public waters that have satisfactory bass habitat. Several authors have reported overharvest of bass leading to bluegill overpopulation and poorer fishing (Graham 1974; Hickman and Congdon 1974; Rasmussen and Michaelson 1974; Ming and McDannold 1975; Anderson 1976; Novinger and Legler 1978).

Restrictions on largemouth bass harvest are frequently contemplated for reducing bluegill recruitment and promoting faster growth. Reduced bag limits, unless extremely restrictive, have little potential for reducing bass overharvest (Hackney 1974; Redmond 1974). Minimum length limits on largemouth bass improved bluegill population structure in several midwestern ponds and reservoirs (Anderson 1974; Hickman and Congdon 1974; Rasmussen and Michaelson 1974; Ming and McDannold 1975; Novinger and Legler 1978). They, however, frequently result in accumulation of small bass behind the size limit and reduced growth rates of that species (Farabee 1974; Hickman and Congdon 1974; Rasmussen and Michaelson 1974; Ming and McDannold 1975). Slot length limits may alleviate that problem by allowing harvest of small bass and protecting fish at sizes where they were still reasonably abundant, fast growing, and effective predators (Anderson 1976). Reduced growth rates of bass, however, are less important when bluegill is the species of primary concern.

Few evaluations of largemouth bass harvest restrictions have been done at latitudes similar to Minnesota's. Using growth data from Oklahoma and Montana, Modde and Scalet (1985) simulated bluegill and largemouth bass populations, and found bluegill two times more vulnerable to largemouth bass predation in Oklahoma. A wider range of sizes and a greater proportion of the southern bluegill population were vulnerable to largemouth bass predation than was the case in the north because of latitudinal differences in growth rates of the two species relative to one another.

Size and species composition of the prey base undoubtedly affects the outcome of predator-prey interactions. Predation by largemouth bass may not sufficiently control bluegill or crappie recruitment if preferred prey of other species are abundant in the community (Timmons et al. 1980; Carline et al. 1984; Reed and Parsons 1996). This means that experiments are necessary to test the effectiveness of special regulations in Minnesota, and that regulations must be based on local ecological and demographic characteristics.

Two studies conducted at latitudes similar to Minnesota's suggest that bluegill fishing might be improved by restrictive regulations on largemouth bass harvest. Following implementation of regulations restricting largemouth bass harvest on four Wisconsin lakes, Lundquist (1990) noted increases in relative weight and mean length of angler harvested bluegill. Although the harvest improved, expected changes in electrofishing catch per unit effort, mean length of sampled bluegill, and growth rates did not occur. For another Wisconsin Lake, Otis (1990) reported increases in proportional stock density of bluegill following implementation of a regulation protecting predators (primarily largemouth bass). The changes were achieved partially through increased numbers of 150 mm and longer fish in the population and partially through decreased numbers of 80-150 mm fish.

This is an interim report of a study scheduled for completion in the year 2001. The study objective is to determine if a regulation protecting all largemouth bass from harvest can improve predator/prey balance and yield 20% increases in mean lengths of angler-harvested bluegill in two St. Paul-Minneapolis metropolitan area lakes.

## Study Lakes

Four lakes in the St. Paul-Minneapolis metropolitan area were chosen for the study on the basis of similarities in size, classification, morphology, fish species assemblages, and close proximity to one another. Lake areas and maximum depths are as follows: Ann Lake, 47 hectares; 14 m—Bavaria Lake, 66 hectares; 20 m—Pierson Lake, 125 hectares; 12 m—Zumbra Lake, 72 hectares; 18 m. The lakes, all in Carver County, are in Class 24 of the MNDNR lake classification system (Schupp 1992). Bluegill is the principal panfish species and largemouth bass is the principal predator species. The only intensive fish management that occurs is stocking of northern pike-muskellunge (*Esox lucius x E. masquinongy*) hybrids in Pierson Lake every third year.

Based on the results of the first 2 years of a 3-year preliminary sampling phase, Ann and Bavaria lakes were selected for the experimental regulation, while Pierson and Zumbra lakes would serve as reference lakes. The regulation, requiring the immediate release of all largemouth bass caught in Ann and Bavaria lakes, was implemented at the opening of the 1995 fishing season.

## Methods

Largemouth bass were sampled by boom shocker several times in each lake before the spawning season each spring from 1992 through 1997 for mark-recapture population estimates. All bass were measured to the nearest millimeter total length, weighed to the nearest gram, and scale samples were collected for age-growth analysis. The left pelvic fin was removed from each largemouth bass captured in 1992. From 1993 through 1997, a numbered t-bar anchor tag was attached to each bass 200 mm and longer. Secondary marks of various fin punches were also administered each year.

Spring abundance of largemouth bass in each lake was estimated by the Chapman modification of the Petersen method (Ricker 1975) from pooled marking and pooled recapture data. The 1992 estimates were derived by selecting the sample with the most recaptures as the recapture segment and all previous samples combined as the marking segment. Thereafter, as individual fish were recognizable, samples were pooled into marking and recapture segment combinations that maximized R. When ties occurred, the product MC was maximized.

Panfish were sampled in July with trap nets at the same lake sites each year. Trap nets were 12.7 mm square measure mesh with 10.7 m leads. All fish were measured to the nearest millimeter total length and weighed to the nearest gram. Scale samples were collected from up to 10 fish per centimeter interval of each species.

Unweighted back-calculations of lengths at age of bluegill and largemouth bass were done by the Fraser-Lee method using standard intercepts of 20 mm for each species (Carlander 1982). Differences in back-calculated annual growth increments and back-calculated lengths at age were tested with two-sample t-tests using $P \leq 0.05$ as the level of significance. Unequal variances were assumed in all tests.

Proportional stock densities (Anderson 1976) and relative stock densities of preferred size fish were calculated using the standard lengths for stock, quality, and preferred sizes proposed by Gabelhouse (1984).

Randomized roving creel surveys were conducted on each lake from mid- to late April to mid-November 1992 through 1996 by a single clerk working 8 h days, 5 d a week. All weekend days were workdays. Surveys were stratified by early and late shifts, by weekday and weekend-holiday, and by month. One clerk sampled two lakes during either the early or late shift each workday and spent approximately 3.5 h on each lake. Four equally spaced activity counts were made at each lake. Between activity counts, the clerk interviewed fishing parties and recorded the number of fishing lines, trip lengths, numbers of each species harvested or released, and as time permitted, recorded total lengths. Incomplete fishing trip interviews were updated to complete trip interviews whenever possible.

## Results

*Creel Survey and Angler Attitudes*

The regulation requiring immediate release of largemouth bass sharply reduced harvest of the species, but did not eliminate it (Table 1).

Table 1. Estimates of angler harvest from mid-April to mid-November 1992 through 1996. Scientific names of species are listed in Table 2.

| | Ann Lake[a] | | | Bavaria Lake[a] | | | Pierson Lake | | | Zumbra Lake | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | Number | SE | Number per hectare | Number | SE | Number per hectare | Number | SE | Number per hectare | Number | SE | Number per hectare |
| **1992** | | | | | | | | | | | | |
| Bowfin | | | | | | | 7 | 9 | 0.1 | 16 | 15 | 0.2 |
| Northern pike | 15 | 12 | 0.3 | 45 | 21 | 0.7 | 167 | 65 | 1.3 | 82 | 31 | 1.1 |
| Tiger muskie[b] | | | | | | | 22 | 20 | 0.2 | | | |
| Carp | | | | | | | | | | 34 | 34 | 0.5 |
| Bullhead[c] | | | | 15 | 15 | 0.2 | 54 | 33 | 0.4 | 47 | 46 | 0.7 |
| Sunfish[d] | 1,216 | 978 | 25.9 | 3,068 | 1,123 | 46.7 | 3,218 | 668 | 25.7 | 361 | 155 | 5.0 |
| Largemouth bass | 138 | 78 | 2.9 | 172 | 74 | 2.6 | 395 | 129 | 3.2 | 597 | 204 | 8.3 |
| Black crappie | 387 | 352 | 8.2 | 370 | 210 | 5.6 | 362 | 184 | 2.9 | 171 | 73 | 2.4 |
| All species | 1,756 | 1,042 | 37.3 | 3,669 | 1,145 | 55.9 | 4,225 | 709 | 33.8 | 1,309 | 275 | 18.1 |
| **1993** | | | | | | | | | | | | |
| Northern pike | 20 | 12 | 0.4 | 20 | 15 | 0.3 | 90 | 36 | 0.7 | 440 | 108 | 6.1 |
| Bullhead | 6 | 6 | 0.1 | | | | | | | | | |
| Sunfish | 6,264 | 1,666 | 133.2 | 11,032 | 2,475 | 168.0 | 2,437 | 673 | 19.5 | 5,255 | 2,380 | 72.7 |
| Largemouth bass | 224 | 71 | 4.8 | 538 | 265 | 8.2 | 310 | 97 | 2.5 | 636 | 175 | 8.8 |
| Black crappie | 883 | 596 | 18.8 | 1,846 | 453 | 28.1 | 624 | 308 | 5.0 | 187 | 83 | 2.6 |
| Yellow perch | 84 | 49 | 1.8 | 172 | 96 | 2.6 | | | | 21 | 14 | 0.3 |
| All species | 7,480 | 1,772 | 159.1 | 13,608 | 2,531 | 207.2 | 3,461 | 748 | 27.7 | 6,539 | 2,390 | 90.5 |
| **1994** | | | | | | | | | | | | |
| Bowfin | | | | | | | 7 | 6 | 0.1 | | | |
| Northern pike | | | | 26 | 13 | 0.4 | 71 | 26 | 0.6 | 340 | 91 | 4.7 |
| Bullhead | 40 | 22 | 0.8 | | | | | | | 198 | 103 | 2.8 |
| Sunfish | 3,080 | 929 | 65.5 | 9,066 | 2,472 | 137.4 | 1,797 | 595 | 14.4 | 6,184 | 1,267 | 85.9 |
| Largemouth bass | 203 | 80 | 4.3 | 219 | 66 | 3.3 | 274 | 151 | 2.2 | 422 | 94 | 5.9 |
| Black crappie | 106 | 35 | 2.3 | 2,877 | 748 | 43.6 | 1,669 | 682 | 13.4 | 242 | 90 | 3.4 |
| Yellow perch | 37 | 19 | 0.8 | 216 | 120 | 3.3 | | | | | | |
| All species | 3,466 | 946 | 73.7 | 12,403 | 2,914 | 187.9 | 3,818 | 971 | 30.5 | 7,386 | 1,331 | 102.6 |
| **1995** | | | | | | | | | | | | |
| Bowfin | | | | | | | | | | 3 | 3 | |
| Northern pike | 9 | 8 | 0.2 | 86 | 47 | 1.3 | 196 | 64 | 1.6 | 408 | 116 | 5.7 |
| Carp | | | | | | | 10 | 9 | 0.1 | 36 | 29 | 0.5 |
| Bullhead | 61 | 39 | 1.3 | 9 | 9 | 0.1 | | | | 582 | 237 | 8.1 |
| Sunfish | 3,604 | 1,406 | 76.7 | 7,362 | 1,775 | 111.5 | 1,644 | 537 | 13.2 | 5,021 | 1,452 | 69.7 |
| Largemouth bass | 58 | 30 | 1.2 | 31 | 25 | 0.5 | 298 | 80 | 2.4 | 517 | 156 | 7.2 |
| Black crappie | 1,477 | 667 | 31.4 | 2,439 | 861 | 36.9 | 375 | 152 | 3.0 | 139 | 42 | 1.9 |
| Yellow perch | 226 | 163 | 4.8 | 25 | 22 | 0.4 | | | | 5 | 5 | 0.1 |
| All species | 5,435 | 1,852 | 115.6 | 9,951 | 2,300 | 150.8 | 2,523 | 531 | 20.2 | 6,712 | 1,661 | 93.2 |

Table 1. Continued.

| Species | Ann Lake Number | Ann Lake SE | Ann Lake Number per hectare | Bavaria Lake Number | Bavaria Lake SE | Bavaria Lake Number per hectare | Pierson Lake Number | Pierson Lake SE | Pierson Lake Number per hectare | Zumbra Lake Number | Zumbra Lake SE | Zumbra Lake Number per hectare |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1996** | | | | | | | | | | | | |
| Northern pike | 51 | 25 | 1.1 | 173 | 70 | 2.6 | 276 | 72 | 2.2 | 100 | 51 | 1.4 |
| Carp | | | | | | | 13 | 9 | 0.1 | 19 | 15 | 0.3 |
| Golden shiner | 11 | 10 | 0.2 | | | | | | | | | |
| Bullhead | 358 | 257 | 7.6 | 8 | 8 | 0.1 | | | | 13 | 11 | 0.2 |
| Sunfish | 2,551 | 1,093 | 54.3 | 7,777 | 1,547 | 117.8 | 3,400 | 1,180 | 27.2 | 5,182 | 1,769 | 72.0 |
| Largemouth bass | 64 | 42 | 1.4 | 45 | 28 | 0.7 | 514 | 205 | 4.1 | 350 | 173 | 4.9 |
| Black crappie | 54 | 44 | 1.2 | 1,419 | 479 | 21.5 | 376 | 142 | 3.0 | 333 | 159 | 4.6 |
| Yellow perch | 161 | 131 | 3.4 | 14 | 9 | 0.2 | | | | | | |
| All species | 3,249 | 1,170 | 69.1 | 9,437 | 1,743 | 143.0 | 4,579 | 1,030 | 36.6 | 5,997 | 1,963 | 83.3 |
| **1992-1994 averages** | | | | | | | | | | | | |
| Sunfish | 3,520 | | 74.9 | 7,722 | | 117.3 | 2,484 | | 19.9 | 3,933 | | 54.5 |
| Largemouth bass | 188 | | 4.0 | 310 | | 4.7 | 326 | | 2.6 | 552 | | 7.6 |
| **1995-1996 averages** | | | | | | | | | | | | |
| Sunfish | 3,077 | | 65.5 | 7,570 | | 114.7 | 2,522 | | 20.2 | 5,101 | | 70.8 |
| Largemouth bass | 61 | | 1.3 | 38 | | 0.6 | 406 | | 3.3 | 434 | | 6.0 |

[a] Immediate release of largemouth bass required beginning May 1995.
[b] Northern pike X muskellunge
[c] Black bullhead, yellow bullhead, and brown bullhead
[d] Bluegill (primarily), pumpkinseed, green sunfish, and hybrid sunfish

Table 2. Scientific names of species listed in Table 1.

| Common name | Scientific name |
|---|---|
| Bowfin | *Amia calva* |
| Northern pike | *Esox lucius* |
| Muskellunge | *Esox masquinongy* |
| Carp | *Cyprinus carpio* |
| Golden shiner | *Notemigonus crysoleucas* |
| Black bullhead | *Ameiurus melas* |
| Yellow bullhead | *Ameiurus natalis* |
| Green sunfish | *Lepomis cyanellus* |
| Pumpkinseed | *Lepomis gibbosus* |
| Bluegill | *Lepomis macrochirus* |
| Largemouth bass | *Micropterus salmoides* |
| Black crappie | *Pomoxis nigromaculatus* |
| Yellow perch | *Perca flavescens* |

Under the regulation in 1995 and 1996, on average, estimates of largemouth bass harvest from Ann and Bavaria lakes declined 68 and 88% from pre-regulation years, respectively. For the same periods, bass harvest was up 25% at Pierson Lake and down 21% at Zumbra Lake. The proportion of angling parties interviewed at Ann Lake in 1996 and 1997 that illegally harvested largemouth bass was 3.2% (Table 3). That was a decline of 73% from the 12% of parties that had harvested bass legally before the regulation was implemented. At Bavaria Lake, 2.1% of the parties illegally harvested bass—a decline of 76%.

Except for the inexplicably low bluegill harvest from Zumbra Lake in 1992, sunfish (primarily bluegill) provided the bulk of the summer angler harvest on all study lakes in all years (Table 1). Excluding Zumbra Lake in 1992, average pre-regulation and post-regulation sunfish harvest was similar at all lakes.

The regulation did not appreciably affect fishing pressure on the experimental lakes (Table 4). In 1995, the estimate of angling effort on Bavaria Lake was down 19 to 30% from pre-regulation estimates. In 1996, effort rose 17%, and on average, post-regulation effort on Bavaria Lake was 19% lower than pre-regulation effort. For the same periods, angling effort declined 8% on Pierson Lake and 6% on Zumbra Lake. Change was negligible at Ann Lake, where on average, post-regulation estimates exceeded pre-regulation estimates by 2%.

Most anglers appeared to accept the regulation, however, the extent to which catch-and-release anglers might have supplanted harvest anglers after the regulations were implemented is unknown. During the first 2 years of regulation, 94% of respondents at Ann Lake and 95% at Bavaria Lake said they favored the regulation if it would yield larger panfish. Three percent at Ann Lake and 2% at Bavaria Lake opposed the regulation, and 3% at each lake had no opinion.

Species preferences of anglers interviewed at Bavaria Lake did not differ appreciably after the regulation was imposed (Table 5). Some notable changes in preferences occurred at Ann Lake where, in 1995, the proportion of bass angling parties declined 13 to 26% from pre-regulation years, then, in 1996, rose 78% and was 31 to 55% higher than in pre-regulation years. The proportion of parties seeking panfish at Ann Lake in 1996 was lower than in any previous year.

*Largemouth Bass Population Estimates*

Largemouth bass population estimates for the experimental lakes yielded conflicting results (Table 6). The 1997 spring abundance estimate of largemouth bass longer than 200 mm in Ann Lake was lower than all previous estimates, while the 1997 Bavaria Lake estimate was higher than all previous estimates. In 1997, the Ann Lake estimate ranged 9 to 41% lower than pre-regulation estimates (through 1995), while the 1997 Bavaria Lake estimate ranged 49 to 134% higher than pre-regulation estimates. On average, the 1996 and 1997 post-regulation estimates for Ann Lake differed from the pre-regulation estimates by a minus 17%. The difference was a plus 52% for Bavaria Lake, a plus 15% for Pierson Lake, and a minus 48% for Zumbra Lake.

*Age and Growth*

In spring 1995, when the regulations were implemented, Bavaria Lake bluegill at

Table 3. Observations during creel surveys of legal and illegal harvest of largemouth bass.

| Year | Ann Lake: Number of parties interviewed | Ann Lake: Number of parties that harvested largemouth bass | Ann Lake: Percent of parties that harvested largemouth bass | Bavaria Lake: Number of parties interviewed | Bavaria Lake: Number of parties that harvested largemouth bass | Bavaria Lake: Percent of parties that harvested largemouth bass |
|---|---|---|---|---|---|---|
| | | | **Legal harvest** | | | |
| 1992 | 113 | 9 | 8.0 | 159 | 11 | 6.9 |
| 1993 | 135 | 17 | 12.6 | 170 | 16 | 9.4 |
| 1994 | 168 | 24 | 14.3 | 192 | 19 | 9.9 |
| | | | **Illegal harvest** | | | |
| 1995 | 113 | 4 | 3.5 | 130 | 2 | 1.5 |
| 1996 | 135 | 4 | 3.0 | 162 | 4 | 2.5 |
| | | | **Pooled observations** | | | |
| Legal | 416 | 50 | 12.0 | 521 | 46 | 8.8 |
| Illegal | 248 | 8 | 3.2 | 292 | 6 | 2.1 |

Table 4. Estimates of summer angling effort from 1992 through 1996.

| Year | Ann Lake: Hours | Ann Lake: SE | Ann Lake: Hours/ hectare | Bavaria Lake: Hours | Bavaria Lake: SE | Bavaria Lake: Hours/ hectare | Pierson Lake: Hours | Pierson Lake: SE | Pierson Lake: Hours/ hectare | Zumbra Lake: Hours | Zumbra Lake: SE | Zumbra Lake: Hours/ hectare |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1992 | 4,248 | 696 | 90 | 7,870 | 1,148 | 120 | 10,043 | 1,616 | 80 | 6,256 | 980 | 87 |
| 1993 | 7,175 | 1,193 | 153 | 8,662 | 1,061 | 132 | 6,304 | 1,020 | 50 | 7,981 | 910 | 110 |
| 1994 | 5,923 | 726 | 126 | 9,225 | 1,119 | 140 | 7,584 | 1,229 | 61 | 10,192 | 1,115 | 141 |
| 1995 | 5,331 | 994 | 113 | 6,413 | 788 | 97 | 6,762 | 1,198 | 54 | 8,487 | 1,018 | 118 |
| 1996 | 6,433 | 729 | 137 | 7,514 | 1,144 | 114 | 7,910 | 1,055 | 63 | 6,896 | 971 | 96 |
| 1992-94 average | 5,782 | | 123 | 8,586 | | 131 | 7,977 | | 64 | 8,143 | | 113 |
| 1995-96 average | 5,882 | | 125 | 6,963 | | 105 | 7,336 | | 59 | 7,691 | | 107 |

ages 4 through 6 and Ann Lake bluegill at ages 4 and 5 were larger, on average, than bluegill of similar ages in the reference lakes (Table 7, Figure 1). That was a substantial change in the status of Bavaria Lake bluegill relative to reference lake bluegill which, in 1992, were larger or similar in size. In 1992, the mean length of age-4 bluegill was significantly less in Bavaria Lake than in the two reference lakes in two-sample t tests ($P$s$<0.030$), and mean lengths did not differ at ages 5 and 6 ($P$s$>0.370$). All were below statewide means for Class 24 lakes (Tomcko and Pierce 1997). By 1995, mean lengths of Bavaria Lake bluegill at ages 4 through 6 exceeded those in the reference lakes by 17 to 28 mm ($P$s$\leq 0.050$) and were well above statewide means.

The status of mean lengths of bluegill in Ann Lake relative to the reference lakes did not change appreciably from 1992 to 1995. An 11 mm margin favoring age-4 Ann Lake bluegill over age-4 Pierson Lake bluegill in 1992 was significant ($P=0.006$), but a 10 mm margin in 1995 was not ($P=0.221$). Contrastingly, a 9 mm margin favoring age-4 Ann Lake bluegill over age-4 Zumbra Lake bluegill in 1992 was not significant ($P=0.105$), but a 21 mm margin in 1995 was ($P<0.001$).

The latter, the only notable change in relative status of Ann Lake bluegill, was caused, not by change in Ann Lake bluegill, but by a 14 mm decline in the mean length of Zumbra Lake bluegill ($P=0.029$). Mean lengths of age-5 fish in Ann Lake and the reference lakes did not change appreciably between 1992 and 1995, and the Ann Lake fish were significantly larger by 10 to 12 mm both years ($Ps<0.020$). Between 1992 and 1995, mean lengths of age-6 bluegill increased by 7 to 9 mm in all three lakes, and Ann Lake means did not differ from the reference lake means in either year ($Ps>0.320$).

Age 6 fish in 1995 were of the 1989 year class which grew relatively fast in Bavaria Lake in 1992, 1993, and 1994 at ages 3, 4, and 5 (Table 8, Figure 1). Mean annual growth increments of bluegill were 6 to 17 mm larger in Bavaria Lake than in the reference lakes, and the differences were significant in two-sample t tests ($Ps<0.050$). The only significant case of faster growth of the 1989 year class in Ann Lake was at age 3 in 1992, when Ann Lake bluegill outgrew their counterparts in Zumbra Lake ($P<0.001$),

Samples sizes from the 1990 bluegill cohort (age 5 in 1995) in Bavaria Lake were

Table 5. Percent responses from fishing parties when asked what fish they were seeking. Up to two responses were recorded.

| Year | Number of interviews | Bass | Pike | Sunfish[a] | Crappie[b] | Panfish[c] | Other[d] | No preference |
|---|---|---|---|---|---|---|---|---|
| | | | | **Ann Lake** | | | | |
| 1992 | 113 | 42 | 6 | 5 | 7 | 44 | | 22 |
| 1993 | 134 | 36 | 13 | 23 | 6 | 53 | | 20 |
| 1994 | 168 | 40 | 7 | 39 | 20 | 58 | | 18 |
| 1995 | 112 | 31 | 9[e] | 42 | 17 | 61 | 1 | 23 |
| 1996 | 135 | 56 | 19 | 27 | 9 | 37 | | 13 |
| | | | | **Bavaria Lake** | | | | |
| 1992 | 159 | 31 | 16 | 8 | 16 | 53 | | 21 |
| 1993 | 170 | 30 | 6 | 26 | 16 | 72 | | 10 |
| 1994 | 193 | 21 | 12 | 44 | 30 | 69 | | 16 |
| 1995 | 130 | 29 | 12 | 42 | 22 | 65 | | 9 |
| 1996 | 162 | 23 | 20 | 37 | 28 | 64 | | 11 |
| | | | | **Pierson Lake** | | | | |
| 1992 | 215 | 28 | 29[e] | 11 | 7 | 52 | | 9 |
| 1993 | 125 | 30 | 31[e,f] | 14 | 11 | 46 | | 15 |
| 1994 | 161 | 26 | 35[e] | 24 | 21 | 43 | | 16 |
| 1995 | 146 | 47 | 47[e,f] | 18 | 12 | 34 | 1 | 8 |
| 1996 | 185 | 49 | 48[f] | 22 | 8 | 32 | 1 | 7 |
| | | | | **Zumbra Lake** | | | | |
| 1992 | 134 | 60 | 27 | 1 | 6 | 18 | | 13 |
| 1993 | 163 | 53 | 40 | 15 | 8 | 30 | | 7 |
| 1994 | 229 | 45 | 34 | 29 | 10 | 36 | 1 | 7 |
| 1995 | 209 | 44 | 34 | 26 | 11 | 37 | 1 | 11 |
| 1996 | 158 | 51 | 34 | 20 | 11 | 28 | 1 | 12 |

[a] Sunfish and bluegill
[b] Crappie and black crappie
[c] Panfish, sunfish, bluegill, crappie, and black crappie
[d] Bullhead, carp, and walleye
[e] Includes muskellunge
[f] Includes muskellunge and northern pike-muskellunge hybrid

Table 6. Numbers of recaptures (R) and spring population estimates ($\hat{N}$) with 95% confidence limits of largemouth bass 200 mm and longer. The 1992 estimates were derived by selecting the sample with the most recaptures as the recapture segment and all previous samples as the marking segment. For the 1993 through 1997 estimates, data were pooled into sample combinations that maximized R. When ties occurred, the product MC was maximized.

| | Ann Lake | | | | Bavaria Lake | | | | Pierson Lake | | | | Zumbra Lake | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | R | $\hat{N}$ | Lower limit | Upper limit | R | $\hat{N}$ | Lower limit | Upper limit | R | $\hat{N}$ | Lower limit | Upper limit | R | $\hat{N}$ | Lower limit | Upper limit |
| 1992 | 4 | 571 | 255 | 1,428 | 5 | 729 | 344 | 1,683 | 6 | 2,374 | 1,178 | 5,193 | 5 | 1,397 | 660 | 3,223 |
| 1993 | 5 | 851 | 402 | 1,964 | 2 | 520 | 190 | 1,300 | 3 | 1,431 | 584 | 3,578 | 5 | 2,241 | 1,059 | 5,172 |
| 1994 | 5 | 752 | 355 | 1,736 | 12 | 464 | 274 | 838 | 6 | 2,942 | 1,460 | 6,435 | 14 | 2,094 | 1,282 | 3,611 |
| 1995 | 6 | 555 | 276 | 1,215 | 11 | 705 | 408 | 1,321 | 11 | 2,418 | 1,402 | 4,533 | 20 | 1,644 | 1,085 | 2,615 |
| 1996 | 16 | 632 | 398 | 1,053 | 24 | 754 | 515 | 1,149 | 8 | 3,173 | 1,700 | 6,491 | 24 | 933 | 637 | 1,422 |
| 1997 | 12 | 503 | 298 | 909 | 7 | 1,085 | 564 | 2,284 | 8 | 2,113 | 1,132 | 4,323 | 8 | 994 | 533 | 2,033 |

Table 7. Mean back-calculated total lengths (TL) of bluegill at age. Back-calculations were to the most recent annuli only.

| | Year sampled | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1992 | | | 1993 | | | 1994 | | | 1995 | | | 1996 | | | 1997 | | |
| Lake | *N* | TL | SE | *N* | TL | SE | *N* | TL | SE | *N* | TL | SE | *N* | TL | SE | *N* | TL | SE |
| **Age 1** | | | | | | | | | | | | | | | | | | |
| Ann | 26 | 48 | 0.9 | 0 | | | 1 | 39 | | 20 | 48 | 1.3 | 33 | 47 | 0.9 | 17 | 45 | 1.0 |
| Bavaria | 18 | 48 | 0.7 | 4 | 39 | 1.9 | 5 | 38 | 1.6 | 40 | 43 | 0.9 | 29 | 40 | 0.9 | 14 | 44 | 1.0 |
| Pierson | 0 | | | 0 | | | 0 | | | 6 | 43 | 1.7 | 4 | 47 | 1.6 | 0 | | |
| Zumbra | 2 | 41 | 1.9 | 0 | | | 7 | 38 | 1.4 | 28 | 51 | 1.1 | 25 | 49 | 1.0 | 0 | | |
| **Age 2** | | | | | | | | | | | | | | | | | | |
| Ann | 12 | 73 | 1.5 | 14 | 81 | 2.0 | 0 | | | 0 | | | 18 | 82 | 1.3 | 17 | 80 | 1.3 |
| Bavaria | 12 | 68 | 0.9 | 18 | 80 | 1.4 | 15 | 69 | 0.8 | 16 | 70 | 1.3 | 44 | 75 | 1.4 | 12 | 67 | 1.8 |
| Pierson | 4 | 61 | 2.1 | 1 | 50 | | 0 | | | 1 | 85 | | 20 | 85 | 2.4 | 2 | 77 | 4.2 |
| Zumbra | 22 | 66 | 1.2 | 3 | 58 | 1.9 | 0 | | | 6 | 83 | 7.3 | 36 | 78 | 1.5 | 23 | 77 | 1.5 |
| **Age 3** | | | | | | | | | | | | | | | | | | |
| Ann | 22 | 97 | 1.8 | 13 | 100 | 2.1 | 22 | 105 | 1.7 | 1 | 93 | | 1 | 107 | | 29 | 116 | 2.0 |
| Bavaria | 13 | 83 | 0.8 | 2 | 106 | 4.5 | 40 | 105 | 2.0 | 18 | 98 | 1.7 | 6 | 99 | 7.2 | 31 | 115 | 1.9 |
| Pierson | 27 | 93 | 1.9 | 10 | 88 | 3.3 | 12 | 79 | 1.5 | 0 | | | 0 | | | 7 | 99 | 3.5 |
| Zumbra | 3 | 107 | 3.8 | 22 | 82 | 1.4 | 10 | 83 | 4.1 | 1 | 77 | | 9 | 114 | 6.2 | 26 | 106 | 1.6 |
| **Age 4** | | | | | | | | | | | | | | | | | | |
| Ann | 25 | 129 | 2.7 | 22 | 122 | 1.2 | 13 | 138 | 3.5 | 21 | 127 | 2.1 | 4 | 124 | 5.7 | 3 | 145 | 6.9 |
| Bavaria | 20 | 106 | 1.5 | 14 | 122 | 2.0 | 4 | 135 | 7.9 | 36 | 134 | 2.3 | 14 | 131 | 3.4 | 5 | 142 | 3.8 |
| Pierson | 15 | 118 | 2.8 | 40 | 116 | 1.9 | 31 | 109 | 3.4 | 8 | 117 | 7.3 | 0 | | | 4 | 119 | 1.5 |
| Zumbra | 6 | 120 | 4.5 | 19 | 108 | 1.9 | 29 | 106 | 1.7 | 15 | 106 | 2.1 | 1 | 108 | | 1 | 136 | |
| **Age 5** | | | | | | | | | | | | | | | | | | |
| Ann | 8 | 146 | 2.7 | 16 | 141 | 2.1 | 20 | 142 | 2.5 | 16 | 148 | 3.6 | 14 | 156 | 3.9 | 9 | 162 | 4.2 |
| Bavaria | 14 | 136 | 3.8 | 11 | 139 | 3.4 | 17 | 158 | 3.1 | 9 | 156 | 6.3 | 25 | 154 | 2.6 | 11 | 157 | 2.8 |
| Pierson | 12 | 136 | 2.4 | 6 | 143 | 2.2 | 40 | 134 | 2.5 | 38 | 136 | 2.4 | 15 | 129 | 3.2 | 3 | 112 | 1.6 |
| Zumbra | 18 | 137 | 2.1 | 15 | 126 | 1.4 | 19 | 140 | 2.7 | 39 | 136 | 3.0 | 12 | 128 | 3.4 | 1 | 126 | |
| **Age 6** | | | | | | | | | | | | | | | | | | |
| Ann | 7 | 152 | 2.3 | 19 | 156 | 1.9 | 11 | 157 | 3.1 | 14 | 160 | 2.4 | 9 | 170 | 3.0 | 23 | 161 | 2.3 |
| Bavaria | 24 | 148 | 2.3 | 24 | 154 | 2.0 | 19 | 167 | 3.3 | 17 | 179 | 2.2 | 14 | 174 | 3.1 | 25 | 171 | 2.0 |
| Pierson | 7 | 148 | 2.3 | 17 | 153 | 1.9 | 1 | 146 | | 15 | 157 | 4.5 | 29 | 131 | 2.3 | 14 | 134 | 2.2 |
| Zumbra | 11 | 151 | 2.8 | 10 | 137 | 2.4 | 12 | 150 | 3.4 | 13 | 158 | 2.8 | 31 | 143 | 1.9 | 26 | 149 | 1.6 |

Table 7. Continued.

| | Year sampled | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1992 | | | 1993 | | | 1994 | | | 1995 | | | 1996 | | | 1997 | | |
| Lake | N | TL | SE | *N* | TL | SE | *N* | TL | SE | *N* | TL | SE | *N* | TL | SE | *N* | TL | SE |
| | | | | | | | | | **Age 7** | | | | | | | | | |
| Ann | 0 | | | 3 | 170 | 2.8 | 0 | | | 4 | 168 | 4.5 | 1 | 177 | | 5 | 167 | 4.8 |
| Bavaria | 1 | 156 | | 14 | 172 | 1.8 | 3 | 165 | 4.4 | 3 | 175 | 5.8 | 8 | 182 | 3.3 | 5 | 183 | 2.4 |
| Pierson | 7 | 160 | 2.9 | 9 | 165 | 2.3 | 0 | | | 1 | 182 | | 17 | 159 | 1.6 | 23 | 143 | 2.8 |
| Zumbra | 5 | 154 | 3.4 | 15 | 153 | 3.2 | 14 | 163 | 3.9 | 4 | 165 | 2.3 | 1 | 151 | | 11 | 158 | 1.8 |
| | | | | | | | | | **Age 8** | | | | | | | | | |
| Ann | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | |
| Bavaria | 0 | | | 0 | | | 0 | | | 0 | | | 1 | 170 | | 3 | 189 | 8.5 |
| Pierson | 1 | 162 | | 3 | 174 | 2.9 | 0 | | | 0 | | | 0 | | | 17 | 164 | 1.5 |
| Zumbra | 1 | 164 | | 8 | 157 | 3.3 | 1 | 173 | | 5 | 179 | 1.5 | 1 | 160 | | 0 | | |
| | | | | | | | | | **Age 9** | | | | | | | | | |
| Ann | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | |
| Bavaria | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | | 1 | 193 | |
| Pierson | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | |
| Zumbra | 0 | | | 3 | 166 | 4.8 | 1 | 166 | | 1 | 195 | | 0 | | | 0 | | |
| | | | | | | | | | **Age 10** | | | | | | | | | |
| Ann | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | |
| Bavaria | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | |
| Pierson | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | |
| Zumbra | 0 | | | 0 | | | 0 | | | 1 | 176 | | 0 | | | 0 | | |

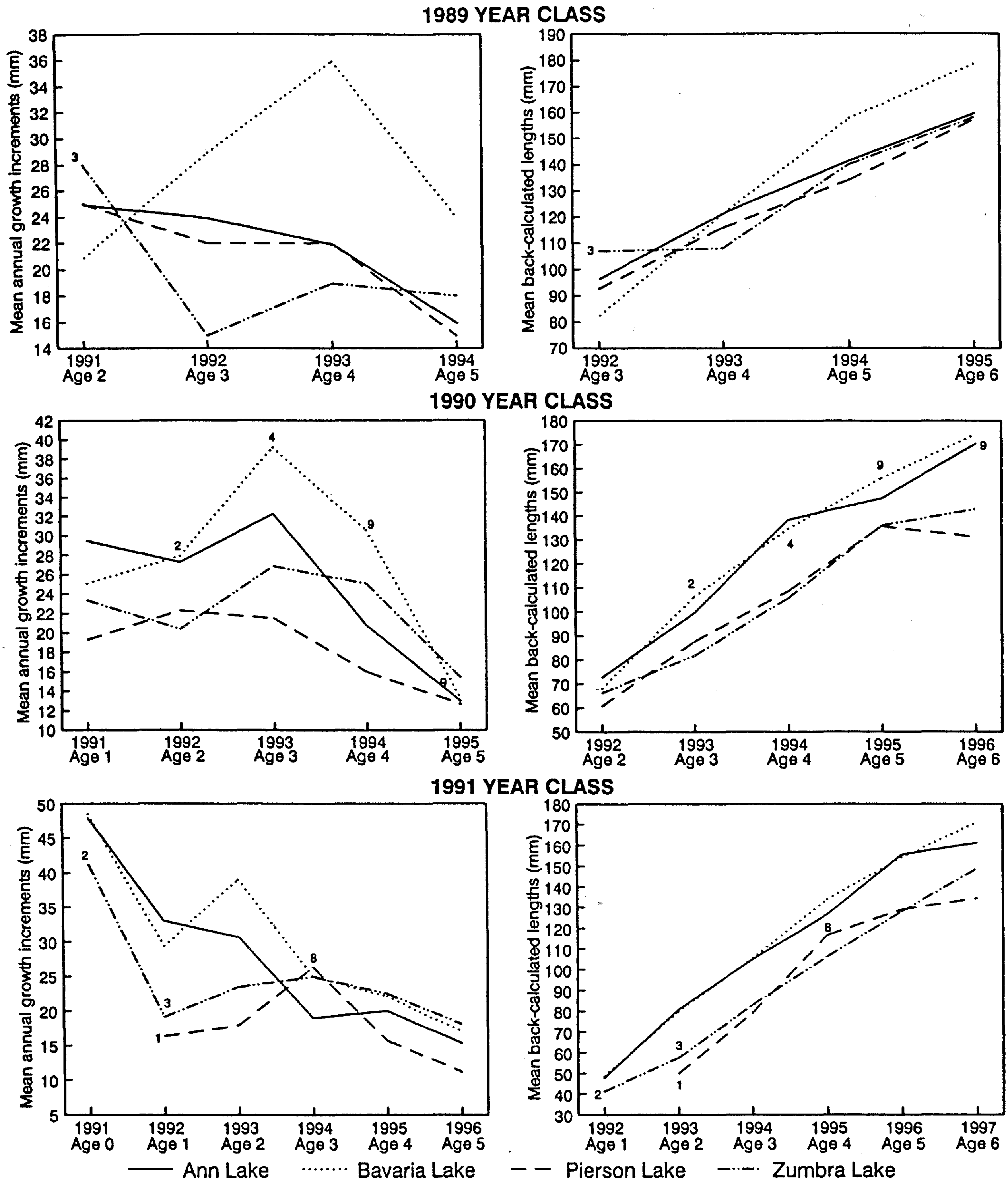


Figure 1. Mean annual growth increments and mean lengths at age of bluegill ages 2 through 6 of the 1989 year class, ages 1 through 6 of the 1990 year class, and ages 0 through 6 of the 1991 year class. Growth increments were derived from back-calculations to the two most recent annuli, and lengths are back-calculations to the most recent annuli. Sample sizes less than 10 are indicated in the panels.

Table 8. Mean annual growth increments (AGI in mm) of bluegill at age during the years 1991 through 1996. Increments were derived from back-calculations to the two most recent scale annuli.

| | Growth year | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1991 | | | 1992 | | | 1993 | | | 1994 | | | 1995 | | | 1996 | | |
| Lake | N | AGI | SE | *N* | AGI | SE | *N* | AGI | SE | *N* | AGI | SE | *N* | AGI | SE | *N* | AGI | SE |
| | | | | | | | | | **Age 0** | | | | | | | | | |
| Ann | 26 | 48 | 0.9 | 0 | | | 1 | 39 | | 20 | 48 | 1.3 | 33 | 47 | 0.9 | 17 | 45 | 1.0 |
| Bavaria | 18 | 48 | 0.7 | 4 | 39 | 1.9 | 5 | 38 | 1.6 | 40 | 43 | 0.9 | 29 | 40 | 0.9 | 14 | 44 | 1.0 |
| Pierson | 0 | | | 0 | | | 0 | | | 6 | 43 | 1.7 | 4 | 47 | 1.6 | 0 | | |
| Zumbra | 2 | 41 | 1.9 | 0 | | | 7 | 38 | 1.4 | 28 | 51 | 1.1 | 25 | 49 | 1.0 | 0 | | |
| | | | | | | | | | **Age 1** | | | | | | | | | |
| Ann | 12 | 29 | 0.7 | 14 | 33 | 1.1 | 0 | | | 0 | | | 18 | 37 | 0.8 | 17 | 34 | 0.9 |
| Bavaria | 12 | 25 | 0.7 | 18 | 29 | 0.9 | 15 | 31 | 0.7 | 16 | 34 | 1.0 | 44 | 32 | 0.8 | 12 | 29 | 0.9 |
| Pierson | 4 | 19 | 0.3 | 1 | 16 | | 0 | | | 1 | 31 | | 20 | 35 | 1.1 | 2 | 33 | 2.5 |
| Zumbra | 22 | 23 | 0.9 | 3 | 19 | 0.6 | 0 | | | 6 | 39 | 4.8 | 36 | 31 | 0.8 | 23 | 31 | 0.9 |
| | | | | | | | | | **Age 2** | | | | | | | | | |
| Ann | 22 | 25 | 1.4 | 13 | 27 | 1.8 | 22 | 31 | 0.7 | 1 | 24 | | 1 | 30 | | 29 | 35 | 1.1 |
| Bavaria | 13 | 21 | 1.0 | 2 | 28 | 5.5 | 40 | 39 | 1.0 | 18 | 30 | 1.2 | 6 | 31 | 4.5 | 31 | 41 | 1.0 |
| Pierson | 27 | 25 | 1.1 | 10 | 22 | 1.5 | 12 | 18 | 0.9 | 0 | | | 0 | | | 7 | 25 | 1.6 |
| Zumbra | 3 | 28 | 4.7 | 22 | 20 | 0.7 | 10 | 23 | 1.5 | 1 | 20 | | 9 | 34 | 2.7 | 26 | 30 | 0.8 |
| | | | | | | | | | **Age 3** | | | | | | | | | |
| Ann | 25 | 23 | 1.2 | 22 | 24 | 1.1 | 13 | 32 | 2.8 | 21 | 19 | 1.2 | 4 | 22 | 3.4 | 3 | 27 | 2.0 |
| Bavaria | 20 | 18 | 0.5 | 14 | 29 | 1.7 | 4 | 39 | 7.1 | 36 | 25 | 1.1 | 14 | 27 | 1.2 | 5 | 38 | 2.1 |
| Pierson | 15 | 22 | 1.5 | 40 | 22 | 0.8 | 31 | 22 | 1.2 | 8 | 26 | 4.5 | 0 | | | 4 | 21 | 1.4 |
| Zumbra | 6 | 21 | 1.8 | 19 | 15 | 1.1 | 29 | 27 | 0.9 | 15 | 25 | 1.3 | 1 | 35 | | 1 | 18 | |
| | | | | | | | | | **Age 4** | | | | | | | | | |
| Ann | 8 | 23 | 1.6 | 16 | 20 | 1.2 | 20 | 22 | 1.4 | 16 | 21 | 2.1 | 14 | 20 | 1.5 | 9 | 20 | 2.8 |
| Bavaria | 14 | 19 | 1.2 | 11 | 19 | 0.8 | 17 | 36 | 2.4 | 9 | 31 | 4.4 | 25 | 22 | 1.7 | 11 | 26 | 2.2 |
| Pierson | 12 | 21 | 2.0 | 6 | 19 | 1.2 | 40 | 22 | 1.1 | 38 | 16 | 1.1 | 15 | 16 | 1.7 | 3 | 14 | 1.6 |
| Zumbra | 18 | 20 | 1.4 | 15 | 15 | 0.8 | 19 | 19 | 1.6 | 39 | 25 | 0.8 | 12 | 23 | 1.4 | 1 | 22 | |
| | | | | | | | | | **Age 5** | | | | | | | | | |
| Ann | 7 | 18 | 1.1 | 19 | 18 | 0.8 | 11 | 21 | 1.8 | 14 | 16 | 1.7 | 9 | 13 | 1.2 | 23 | 15 | 1.2 |
| Bavaria | 24 | 14 | 0.6 | 24 | 16 | 0.7 | 19 | 23 | 2.6 | 17 | 24 | 2.5 | 14 | 13 | 1.1 | 25 | 17 | 1.0 |
| Pierson | 7 | 17 | 0.7 | 17 | 15 | 0.7 | 1 | 19 | | 15 | 15 | 1.5 | 29 | 13 | 0.7 | 14 | 11 | 1.1 |
| Zumbra | 11 | 20 | 0.9 | 10 | 14 | 0.8 | 12 | 16 | 2.4 | 13 | 18 | 1.3 | 31 | 15 | 1.1 | 26 | 18 | 1.1 |

Table 8. Continued.

| | Growth year | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1991 | | | 1992 | | | 1993 | | | 1994 | | | 1995 | | | 1996 | | |
| Lake | *N* | AGI | SE | *N* | AGI | SE | *N* | AGI | SE | *N* | AGI | SE | *N* | AGI | SE | *N* | AGI | SE |
| | | | | | | | | **Age 6** | | | | | | | | | | |
| Ann | 0 | | | 3 | 14 | 1.0 | 0 | | | 4 | 13 | 2.0 | 1 | 13 | | 5 | 9 | 0.3 |
| Bavaria | 1 | 19 | | 14 | 16 | 0.8 | 3 | 18 | 5.4 | 3 | 12 | 2.2 | 8 | 13 | 2.1 | 5 | 9 | 1.2 |
| Pierson | 7 | 15 | 0.7 | 9 | 14 | 1.2 | 0 | | | 1 | 14 | | 17 | 14 | 0.7 | 23 | 11 | 1.0 |
| Zumbra | 5 | 15 | 1.0 | 15 | 14 | 1.0 | 14 | 20 | 1.9 | 4 | 20 | 3.9 | 1 | 12 | | 11 | 17 | 1.2 |
| | | | | | | | | **Age 7** | | | | | | | | | | |
| Ann | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | |
| Bavaria | 0 | | | 0 | | | 0 | | | 0 | | | 1 | 13 | | 3 | 10 | 3.5 |
| Pierson | 1 | 11 | | 3 | 13 | 0.5 | 0 | | | 0 | | | 0 | | | 17 | 8 | 0.4 |
| Zumbra | 1 | 22 | | 8 | 13 | 1.1 | 1 | 17 | | 5 | 13 | 2.4 | 1 | 7 | | 0 | | |
| | | | | | | | | **Age 8** | | | | | | | | | | |
| Ann | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | |
| Bavaria | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | | 1 | 14 | |
| Pierson | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | |
| Zumbra | 0 | | | 3 | 11 | 1.0 | 1 | 16 | | 1 | 9 | | 0 | | | 0 | | |
| | | | | | | | | **Age 9** | | | | | | | | | | |
| Ann | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | |
| Bavaria | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | |
| Pierson | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | |
| Zumbra | 0 | | | 0 | | | 0 | | | 1 | 15 | | 0 | | | 0 | | |

small, and the only significant comparison was a 15 mm growth advantage over Pierson Lake bluegill at age 4 in 1994 ($P$=0.011). The 1990 year class in Ann Lake grew relatively fast at ages 2 and 3 in 1992 and 1993. They outgrew counterparts in Pierson Lake both years ($Ps$<0.050). Only the 7 mm advantage over Zumbra Lake in 1992 was significant ($P$=0.003).

The 1991 cohorts (age 4 in 1995) in both experimental lakes exhibited good growth at age 1 in 1992, and in spite of the small sample size (3) from Zumbra Lake in 1992, the differences were significant ($Ps$<0.001). The faster growth in the experimental lakes at age 2 in 1993 was also significant ($Ps$<0.001).

By 1997, no solid evidence existed to suggest that the regulations were yet effective. The amount of valid growth analysis possible from 1995 to 1997 is limited by small sample sizes as a result of low abundance of the 1992 and 1993 year classes—ages 2 and 3 in 1995 and ages 4 and 5 in 1997 (Table 9). Age-3 bluegill in Bavaria Lake were longer in 1997

Table 9. Percent bluegill distribution by year class in summer trap net samples from 1992 through 1997. Values were apportioned with an age-length key according to age distributions of sub-samples of aged fish.

| | Year class | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lake | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 |
| | | | | | | | **1992** | | | | | | |
| Ann | | | 7 | 8 | 36 | 28 | 6 | 15 | | | | | |
| Bavaria | | 1 | 28 | 15 | 20 | 13 | 6 | 18 | | | | | |
| Pierson | 1 | 10 | 13 | 29 | 26 | 19 | 2 | | | | | | |
| Zumbra | 2 | 11 | 20 | 29 | 8 | 3 | 24 | 2 | | | | | |
| | | | | | | | **1993** | | | | | | |
| Ann | | | 3 | 43 | 26 | 20 | 5 | 4 | | | | | |
| Bavaria | | | 13 | 38 | 16 | 15 | 2 | 13 | 3 | | | | |
| Pierson | | 1 | 5 | 21 | 15 | 52 | 4 | [a] | | | | | |
| Zumbra | | 6[b] | 15 | 17 | 24 | 22 | 15 | 1 | | | | | |
| | | | | | | | **1994** | | | | | | |
| Ann | | | | | 19 | 40 | 26 | 15 | | 1 | | | |
| Bavaria | | | | 5 | 24 | 21 | 5 | 33 | 10 | 3 | | | |
| Pierson | | | | | 2 | 55 | 38 | 5 | | | | | |
| Zumbra | | | 2[b] | 13 | 14 | 23 | 35 | 8 | | 5 | | | |
| | | | | | | | **1995** | | | | | | |
| Ann | | | | | 6 | 22 | 26 | 32 | 1 | | 14 | | |
| Bavaria | | | | | 1 | 7 | 6 | 26 | 7 | 7 | 46 | | |
| Pierson | | | | | [a] | 20 | 70 | 8 | | [a] | 1 | | |
| Zumbra | | | | 3[b] | 3 | 15 | 55 | 15 | [a] | 3 | 7 | | |
| | | | | | | | **1996** | | | | | | |
| Ann | | | | | | 1 | 7 | 11 | 3 | 1 | 16 | 61 | |
| Bavaria | | | | | 1 | 8 | 15 | 25 | 8 | 2 | 22 | 20 | |
| Pierson | | | | | | 22 | 43 | 27 | | | 7 | 1 | |
| Zumbra | | | | | 1 | 2 | 39 | 13 | 1 | 11 | 23 | 10 | |
| | | | | | | | **1997** | | | | | | |
| Ann | | | | | | | 8 | 30 | 12 | 3 | 23 | 10 | 14 |
| Bavaria | | | | | | 4[b] | 9 | 47 | 17 | 4 | 14 | 2 | 3 |
| Pierson | | | | | | 23 | 41 | 24 | 2 | 5 | 4 | [a] | |
| Zumbra | | | | | | | 14 | 34 | 1 | 1 | 32 | 17 | |

[a] Less than 0.5%

[b] Totals of age-8 and older bluegill.

than in 1995 ($P<0.001$), and age-3 bluegill in all lakes were larger in 1997 than in 1994 ($Ps<0.002$). None of the differences in age-4 and age-7 bluegill between 1995 and 1997 were significant. Age-5 bluegill in Ann Lake were longer in 1997 ($P=0.020$) than in 1995 while bluegill in Pierson Lake were shorter ($P<0.001$). Age-6 bluegill in Bavaria, Pierson, and Zumbra lakes were shorter in 1997 than in 1995 ($Ps<0.015$).

Bavaria Lake was the only one of the four lakes where largemouth bass did not exhibit slower growth at some of the ages 2 through 7 in 1996 as compared with the years 1991 through 1994 combined (Figure 2). In two-sample t tests, the only significant difference in Bavaria Lake was a mean increment 5 mm larger at age 5 in 1996 ($P=0.039$). Bass grew significantly slower in 1996 at ages-5 through 7 in Ann and Pierson lakes and at ages-6 and 7 in Zumbra Lake ($Ps<0.022$).

*Fish Quality*

Trends in bluegill abundance indices for Ann and Bavaria lakes conflicted (Figure 3). Trap net catches of bluegill 80 mm and longer in the two lakes were very similar in 1992, but thereafter, they followed opposite trends through 1996. The bluegill catch in Ann Lake peaked in 1993, then it declined steadily through 1996. In Bavaria Lake, on the other hand, the catch was lowest in 1993, and then it steadily increased through 1997. Meanwhile, catches in the reference lakes fluctuated in unison and gradually increased through 1996.

Beginning in 1993, the larger lengths at age of bluegill in Bavaria Lake were generally reflected in the length distributions of the trap net catch with relatively large proportions of fish 170 mm and longer present (Figure 4). By 1997, 67% of bluegill 80 mm and longer in the Bavaria Lake catch were in that largest size group. That seems to imply low abundance of smaller, younger fish as future recruits to the fishery, however, this was from a catch of 517 fish—92% larger than the largest previous trap net catch in Bavaria Lake.

In 1992, length distributions of bluegill harvested by anglers from all four lakes were similar, and mean lengths, in the range of 163 to 166 mm, were nearly identical (Figure 5; Table 10). After 1992, quality of the harvest from Bavaria and Zumbra lakes rose sharply in terms of mean lengths and proportions of bluegill 170 mm and longer. That relatively high quality (with mean lengths in the proximity of 180 mm) persisted through 1996 at Bavaria Lake and through 1995 at Zumbra Lake. Compared with Bavaria Lake trap net catches, the Zumbra Lake trap net catches poorly reflected the dominance of bluegill 170 mm and longer in the angler harvest from 1993 through 1995 (Figure 4).

Until 1996, when the quality of the Ann Lake harvest rose abruptly, mean lengths of bluegill from Ann and Pierson lakes remained mostly in the 160s mm range. During that period, however, bluegill 170 mm and longer were better represented in the Ann Lake harvest than in the Pierson Lake harvest. The Pierson Lake harvest from 1993 through 1996 was heavily dominated by bluegill in the 140-169 mm range. Quality of largemouth bass populations, as characterized by indices of relative stock density of preferred length fish (≥380 mm) in electrofishing catches, was persistently high in all lakes throughout the study period (Table 11). However, in spite of the relatively rapid growth of Bluegill in Bavaria Lake few grew to preferred lengths of 200 mm and longer for that species.

## Discussion

Results of the study, to date, are inconclusive. No concrete evidence has emerged to imply that the regulations implemented in 1995 protecting largemouth bass from harvest in Ann and Bavaria lakes are acting to change population structures of largemouth bass or bluegill.

Population estimates of largemouth bass 200 mm and longer, to date, provide no indication of increasing bass abundance in Ann Lake, but suggest that a trend of rising abundance in Bavaria Lake may have begun. With the imprecise nature of lake population estimates, it may take steady and substantial population increases to yield detectable trends and

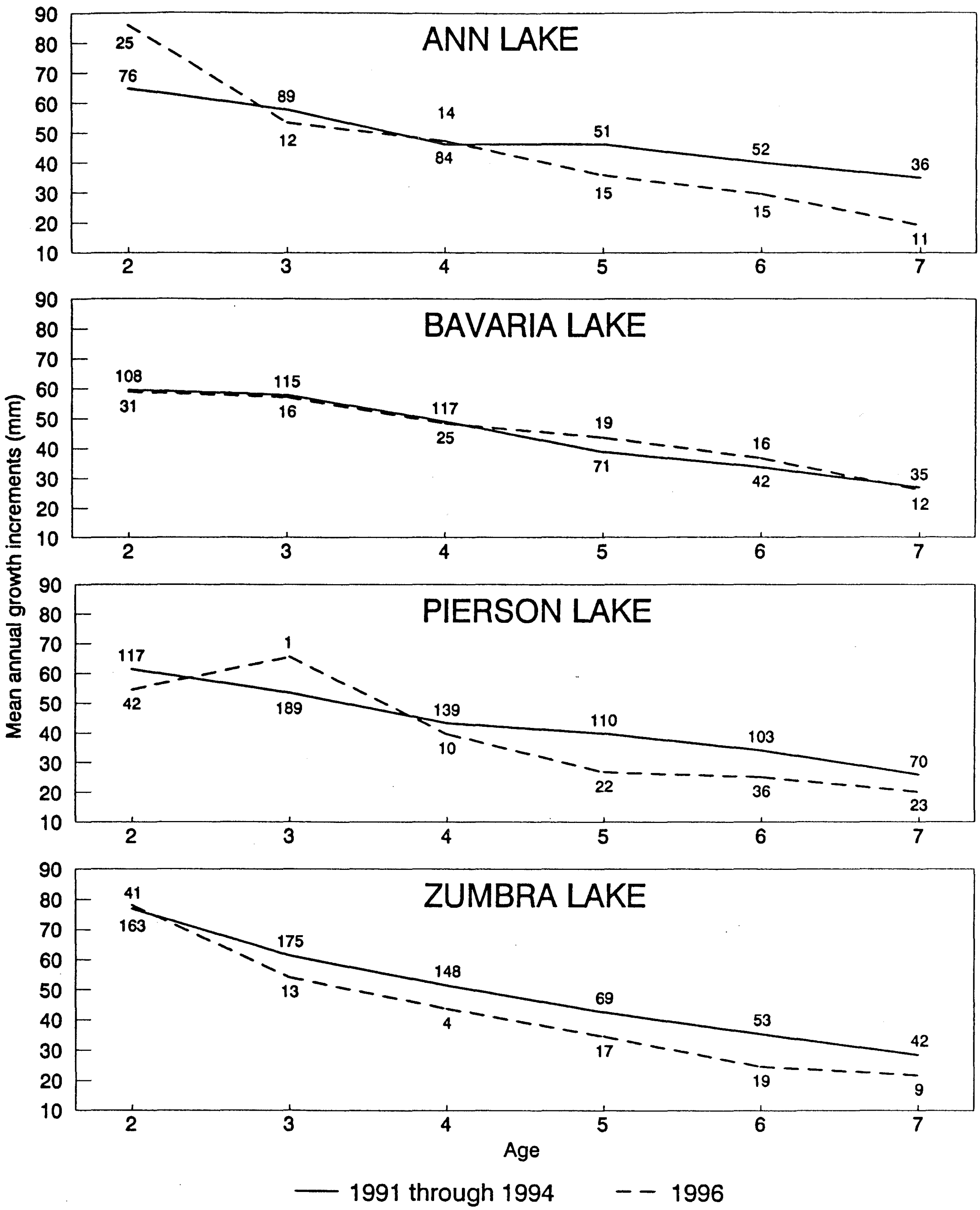


Figure 2. Mean annual growth increments of ages-2 through 7 largemouth bass during the years 1991 through 1994 (pooled) and 1996. Increments were derived from back-calculations to the two most recent scale annuli. Sample sizes are shown in the panels.

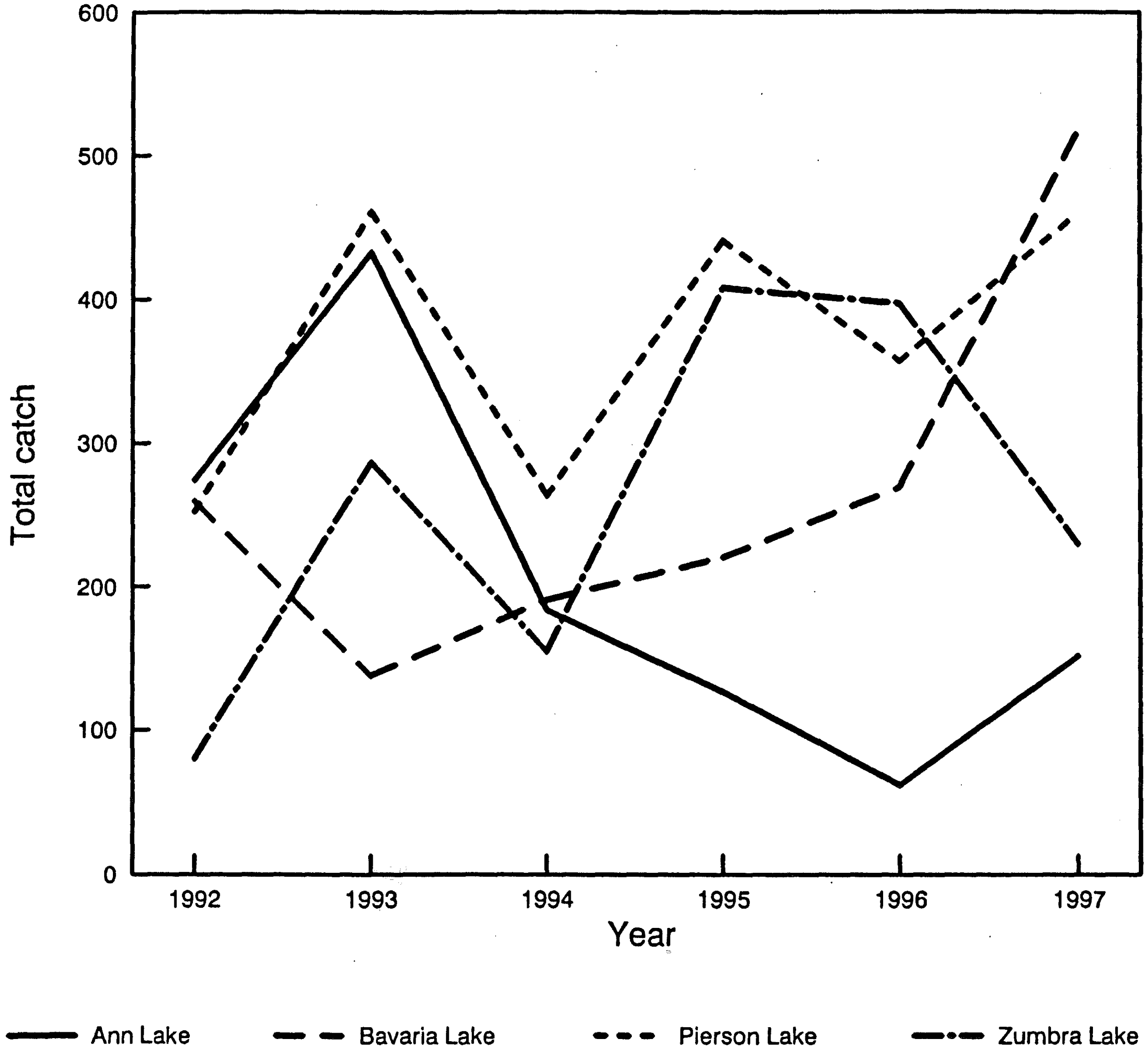


Figure 3. Trap net catches of bluegill 80 mm and longer during the years 1991 through 1997.

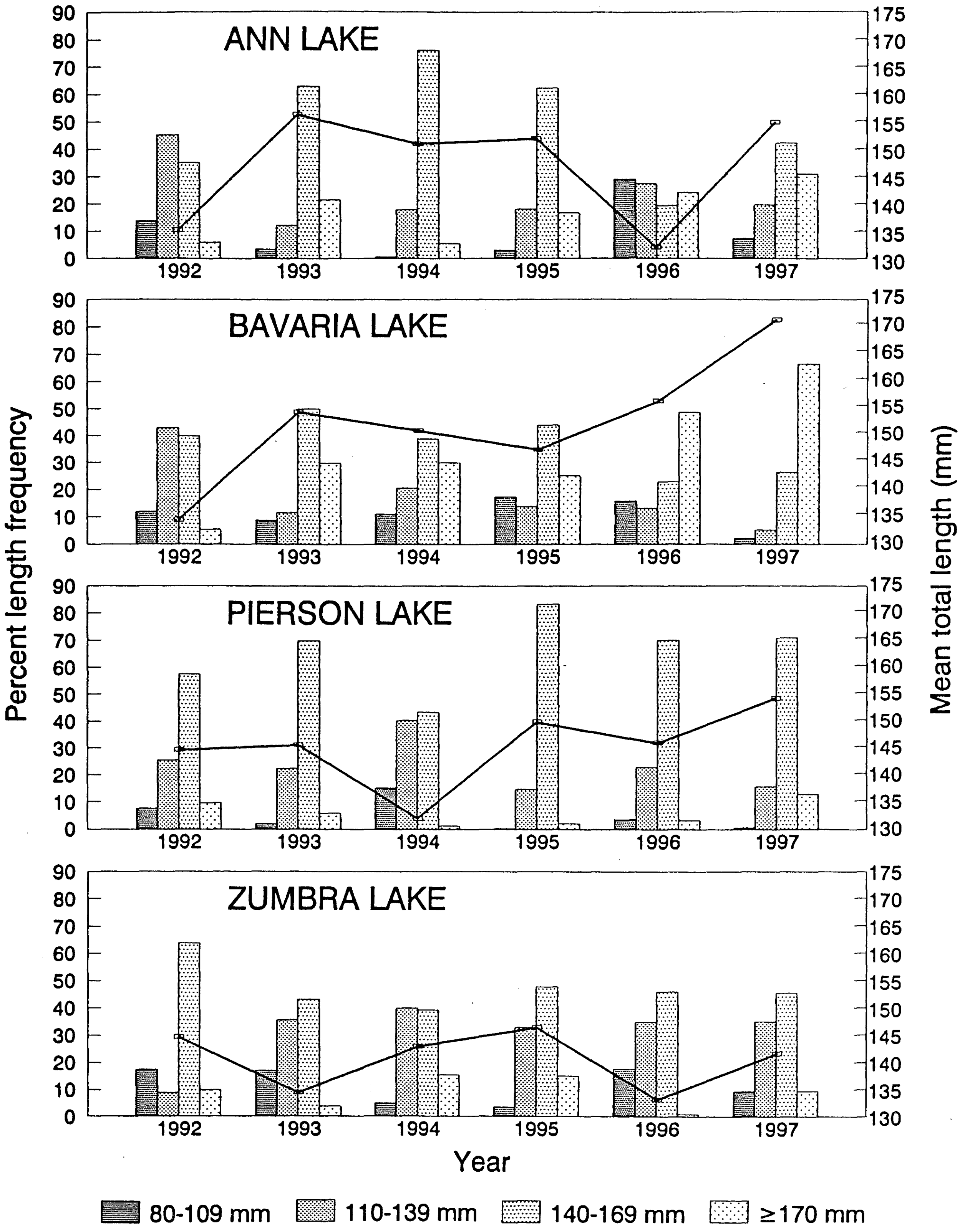


Figure 4. Percent length distributions (bars) and mean total lengths (lines) of bluegill 80 mm and longer sampled with trap nets.

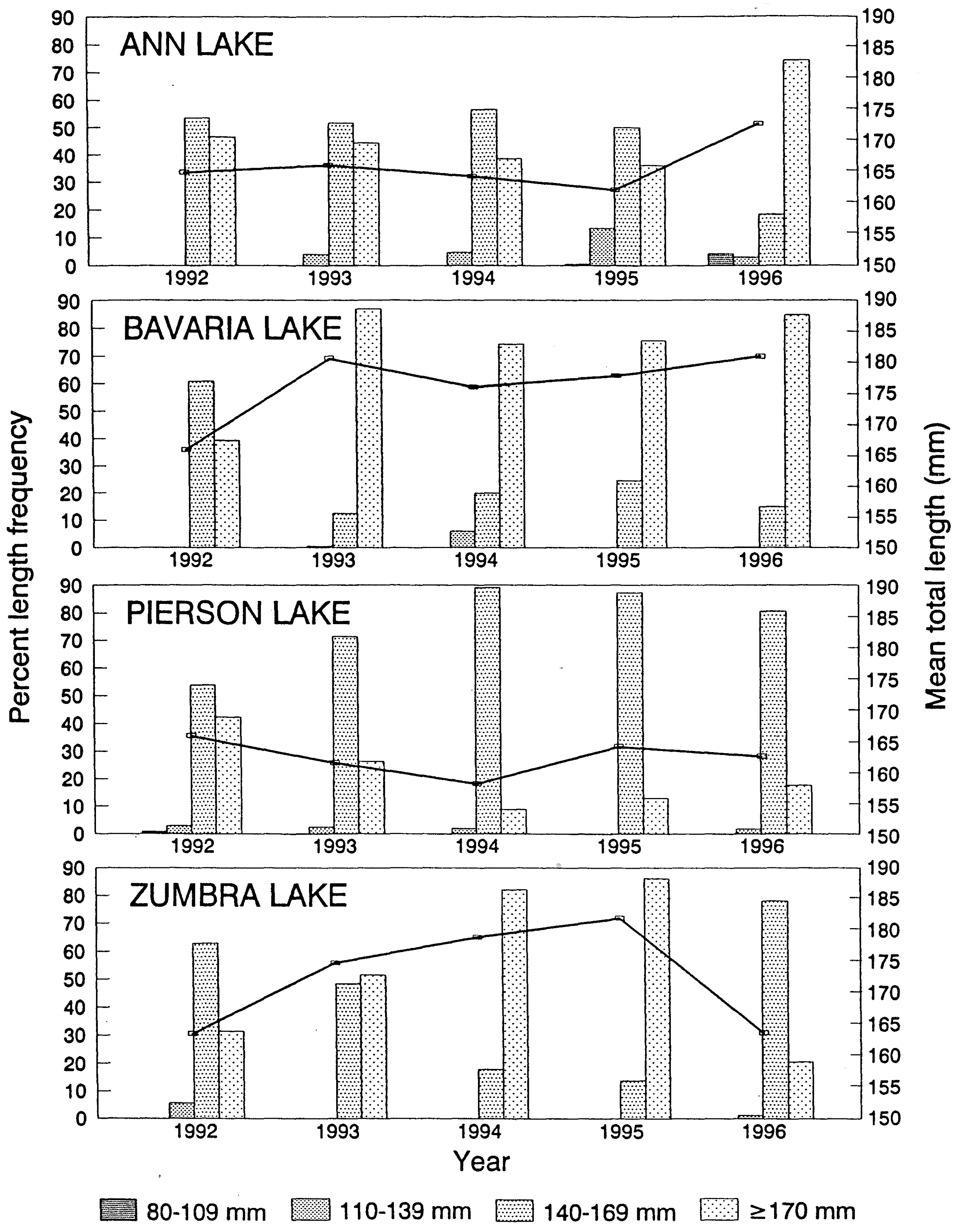


Figure 5. Percent length frequency distributions (bars) and mean total lengths (lines) of angler-harvested bluegill.

Table 10. Total length (mm) summaries of bluegill harvested by anglers, 1992-1996.

| | Year | | | | |
|---|---|---|---|---|---|
| | 1992 | 1993 | 1994 | 1995 | 1996 |
| | | | **Ann Lake** | | |
| *N* | 43 | 126 | 173 | 180 | 168 |
| Minimum | 142 | 111 | 124 | 107 | 95 |
| Maximum | 184 | 183 | 198 | 192 | 201 |
| Mean | 165 | 166 | 164 | 162 | 173 |
| SD | 12.4 | 12.3 | 13.1 | 17.0 | 20.2 |
| | | | **Bavaria Lake** | | |
| *N* | 153 | 350 | 201 | 196 | 625 |
| Minimum | 141 | 130 | 123 | 145 | 136 |
| Maximum | 192 | 207 | 211 | 213 | 208 |
| Mean | 166 | 181 | 176 | 178 | 181 |
| SD | 9.6 | 10.9 | 17.9 | 13.9 | 11.4 |
| | | | **Pierson Lake** | | |
| *N* | 315 | 42 | 56 | 132 | 176 |
| Minimum | 99 | 131 | 139 | 146 | 138 |
| Maximum | 222 | 194 | 179 | 201 | 177 |
| Mean | 166 | 161 | 158 | 164 | 162 |
| SD | 15.0 | 13.6 | 9.3 | 10.8 | 8.7 |
| | | | **Zumbra Lake** | | |
| *N* | 54 | 95 | 314 | 151 | 261 |
| Minimum | 133 | 155 | 153 | 155 | 130 |
| Maximum | 180 | 211 | 219 | 221 | 210 |
| Mean | 163 | 175 | 179 | 182 | 164 |
| SD | 10.4 | 12.9 | 11.5 | 12.0 | 11.0 |

provide convincing evidence of increased largemouth bass abundance in the regulated lakes should that occur.

Although the regulation sharply reduced largemouth bass harvest from the experimental lakes, considerable illegal harvest was occurring and that is a serious concern. The true scope of unlawful activity was undoubtedly higher than that observed in the creel survey because willful violators will tend to avoid survey clerks or conceal their catch. Depending upon severity, illegal harvest can increase the time frame for fulfillment of potential benefits—particularly critical in our circumstance where response from bluegill populations is the ultimate goal—or it can cause serious reduction in benefits (Gigliotti and Taylor 1990). Others have expressed concern with noncompliance with special regulations (Glass and Maughan 1984; Paragamian 1984; Pierce and Tomcko 1997).

Since the study began, Bavaria Lake has produced a relatively high quality bluegill fishery in terms of growth rates, body size, and angler harvest. However, those conditions existed before the regulation was implemented, and it cannot be determined, at this time, if it is helping to sustain them. The faster growth of bluegill in Bavaria Lake, beginning in 1992, apparently led to a relatively high proportion of bluegill 170 mm and longer in trap net samples and the angler harvest. That condition has continued through sustained high fishing pressure and harvest.

Although few bluegill have grown to the standard preferred length of 200 mm proposed by Gabelhouse (1984), the Bavaria Lake fishery likely would be considered high quality by most panfish anglers in today's environment of high fishing pressure and common scarcity of 170 mm plus bluegill. The prevailing standardized stock indices are useful for characterizing populations. They are probably are not sensitive enough to evaluate management activities and set realistic goals for many bluegill populations in northern latitudes under present-day conditions, unless it is desirable to establish trophy fisheries by eliciting large sacrifices from anglers with maximum or high slot length limits.

Anglers fishing Zumbra Lake also harvested large numbers of bluegill 170 mm and longer—exceeding 80% of the harvest—in 1994 and 1995. However, that condition was not sustained as the abundance of those larger fish declined sharply in the Zumbra Lake creel and trap net samples in 1996.

Abundance of bluegill in the 1992 and 1993 year classes is low in the study lakes, and in 1998, those groups will comprise 5 and 6 year old fish that usually contribute a large part of the angler harvest. The result could be a temporary decline in fishing quality unless the void is filled by rapid growth of recruiting fish.

Herbicide applications to Bavaria and Zumbra lakes in attempts to eradicate exotic milfoil have added intractable variables to the study that impede analyses of fish community interactions related to experimental regulation.

Repercussions from such perturbations to centrarchid communities can be severe. The 1996 and 1997 largemouth bass abundance estimates for Zumbra Lake—a reference lake with no regulation change—were substantially lower than previous estimates and could be reflecting direct or indirect effects of an application of the herbicide fluridone in 1994 that virtually eliminated all macrophytes in the lake. The absence of macrophytes also may have influenced angler vulnerability of larger bluegill leading to the high proportion of those fish in the Zumbra Lake angler harvest in 1994 and 1995. Although 2,4-D applications to the entire littoral zone of Bavaria Lake in 1992 and 1993 were much less destructive, they did cause unaccountable change in plant communities, and may be implicated in the improved quality of the bluegill fishery in that lake.

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