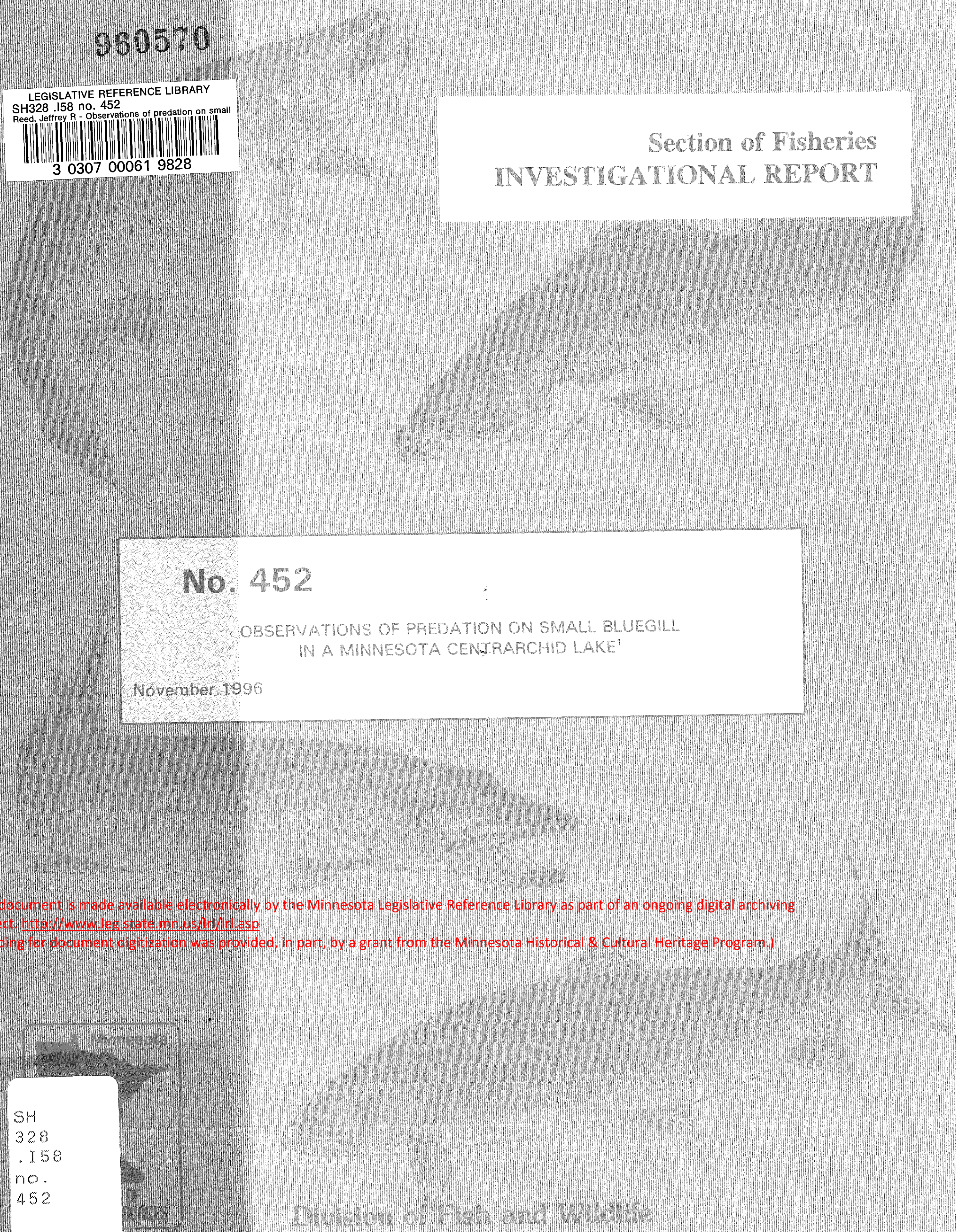
Section of Fisheries
# INVESTIGATIONAL REPORT



## No. 452

# OBSERVATIONS OF PREDATION ON SMALL BLUEGILL IN A MINNESOTA CENTRARCHID LAKE[1]

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# OBSERVATIONS OF PREDATION ON SMALL BLUEGILL IN A MINNESOTA CENTRARCHID LAKE[1]

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*Abstract*.--We examined the diets of fish species that had the potential to prey on young-of-the-year (YOY) and age-1 bluegill *Lepomis macrochirus* in a 270 ha Minnesota lake. Neither bowfin *Amia calva*, small or large northern pike *Esox lucius*, black crappie *Pomoxis nigromaculatus*, nor adult largemouth bass *Micropterus salmoides*, were observed to have eaten any YOY or age-1 bluegill in either of the two years of the study. Young-of-the-year northern pike, age-1 and age-2 largemouth bass, and yellow perch *Perca flavescens* consumed limited numbers of YOY and age-1 bluegill. Young-of-the-year bluegill were observed in a large portion of the YOY largemouth bass stomachs collected in 1995. Bioenergetic modeling indicated that age-2 walleye would consume the most YOY bluegill of any of the predators we examined. Yellow perch were the most commonly eaten fish in the diets of most predators. The high proportion of yellow perch in the diets of predators indicates that predator density manipulations aimed at increasing predation on small bluegill may not be successful. Managers wishing to decrease small bluegill abundance should manage lakes for predator diversity, both in terms of species and year classes.

## Introduction

The problem of small, over-abundant or "stunted" bluegill *Lepomis macrochirus* has been considered a function of inadequate predator control of bluegill densities. Therefore, the goal of many fishery managers has been to manage for fish communities with adequate predator populations to restrict bluegill recruitment to levels that reduce competition and increase size structures. Most attempts to manage bluegill have focused on increasing the mortality of age-1 and age-2 fish (Kruse 1991). Based on concepts developed in small impoundments in the southeastern United States (Swingle 1950), largemouth bass *Micropterus salmoides* have been used as the primary tool for managing bluegill populations in midwestern impoundments. By maintaining adequate numbers of largemouth bass in these impoundments, predation alone can regulate

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bluegill numbers and increase their average size (Anderson 1976; Novinger and Legler 1978). Numerous attempts to increase largemouth bass numbers through size limit protection have also met with success in these systems (Redmond 1972; Hickman and Congdon 1972; and Hoey and Redmond 1972). In more northern latitudes, largemouth bass production was lower and the potential for bluegill to overpopulate increased (Modde and Scalet 1985).

Management of species other than largemouth bass to increase bluegill mortality has met with little success. No beneficial effects on bluegill mortality and growth were found in several Michigan lakes following walleye *Stizostedion vitreum* and northern pike *Esox lucius* introductions (Beyerle 1971; Beyerle 1978). Repeated stocking of walleye and muskellunge *Esox masquinongy* in a northern Wisconsin lake also failed to improve the bluegill size structure (Snow 1988). However, when stocked alone with bluegill in two other Wisconsin lakes, walleye were effective predators and significantly limited bluegill survival (Beard 1982).

Although a great deal of research effort has focused on the relationship between bluegill and various predators, much of it has been manipulative in nature. In other words, predators were stocked and the bluegill populations monitored for changes in density and/or growth. These manipulations may have been doomed to failure because a basic understanding of the predator-prey relationships that existed within these systems was lacking. This is particularly true in north-temperate lakes that are more complex ecosystems than impoundments of the midwest and southeast. The greatest declines in bluegill abundance in Minnesota lakes have been associated with poor young-of-the-year (YOY) survival (MNDNR, unpublished data), typically a result of unusually cool weather which reduced spawing success. Therefore, we felt predation on this cohort may have the greatest effect on year-class formation.

The objectives of this study were to identify the predators of YOY and yearling bluegill in a north-temperate lake and to determine which have the greatest potential for limiting bluegill survival.

## Study Area

Smith Lake (270 ha, Lake Class 31; Schupp 1992) is located 10 km southeast of Alexandria, Minnesota and is currently managed as a walleye - centrarchid fishery. Smith Lake has a maximum depth of 9.1 m and a large littoral area (127 ha) with dense beds of emergent and submergent vegetation. Smith Lake was chosen because it contained diverse populations of the predators we sought to evaluate (walleye, northern pike, largemouth bass, bowfin *Amia calva*, black crappie *Pomoxis nigromaculatus*, and yellow perch *Perca flavescens*). The bluegill population consisted of high densities of slow-growing individuals, which is typical of many bluegill populations in Minnesota.

## Methods

### *Diet Collection and Analysis*

Diet information from these predator species was collected at various intervals from May-October 1992 and May-September 1995. Electrofishing, gill nets (various mesh sizes and time duration), beach seines of various lengths and mesh sizes, and angling were used to collect fish for diet analysis. All fish were measured and most were weighed. A modified Seaburg stomach pump (Seaburg 1957) was used to dislodge food items from the stomachs of collected fish. Stomach items were identified to the lowest possible taxa. When possible, fish found in stomach samples were weighed, measured and aged, either by scale or otolith.

For diet analysis, largemouth bass were placed into four sample groups: YOY, age-1, age-2, and ≥ age 3; northern pike were placed into three sample groups: YOY < 434 mm, and ≥ 434 mm; and walleye were placed into two groups: age-2, and ≥ age-3. In general, northern pike ≥ 434 mm were age-2 and older. None of the other sampled predators were grouped by age or size. Summer sampling was divided into two periods, prior to 1 July and after 1 July. This division typically reflected the absence or presence of YOY bluegill in seine hauls. YOY bluegill collected in the seine hauls were weighed and measured.

*Bioenergetic Modeling*

Species specific models from the Wisconsin bioenergetic model (Hewett and Johnson 1992) were used to estimate consumption of YOY bluegill by sample group for northern pike, largemouth bass, yellow perch, and walleye. Consumption of bluegill was estimated only for the time period that they were observed in the predator's diet. Estimates were made based upon the growth observed for each cohort in 1995 and reflect the consumption of the "typical" individual in that cohort.

## Results

Due to unusually cool summers in 1992 and 1993, bluegill reproduction in Smith Lake failed. The summers of 1994 and 1995 were much warmer than previous ones, with the bluegill population producing what appeared to be very large year-classes. In 1995, we caught our first YOY bluegill in seine hauls in mid-July and continued to see large numbers throughout the summer. Young-of-the-year bluegill averaged 9.2 mm in our first samples and reached a mean length of 36.4 mm by early September (Figure 1).

*Bowfin Diets*

Bowfin consumed adult bluegill in 1992 and 1995; however, no YOY or age-1 bluegill were observed in bowfin diets in either year. Yellow perch were the most commonly observed fish in 1992 diets while Iowa darters *Etheostoma exilis* and Johnny darters *E. nigrum* were the most common fish observed in 1995.

*Northern Pike Diets*

No YOY bluegill were observed in the stomachs of any size groups of northern pike in 1992 (Table 1); however, adult bluegill were the most commonly found diet item in large northern pike stomachs. Large northern pike also preyed upon black crappie, largemouth bass, darters, and yellow perch. The two collected YOY northern pike had eaten invertebrates. One of the three YOY northern pike sampled in 1995 had consumed a YOY bluegill. The diets of small northern pike in 1995 were dominated by yellow perch, with only one age-1 bluegill observed in the diet of a single small northern pike (Table 1). Diets of large northern pike consisted mainly of large items such as largemouth bass, other north-

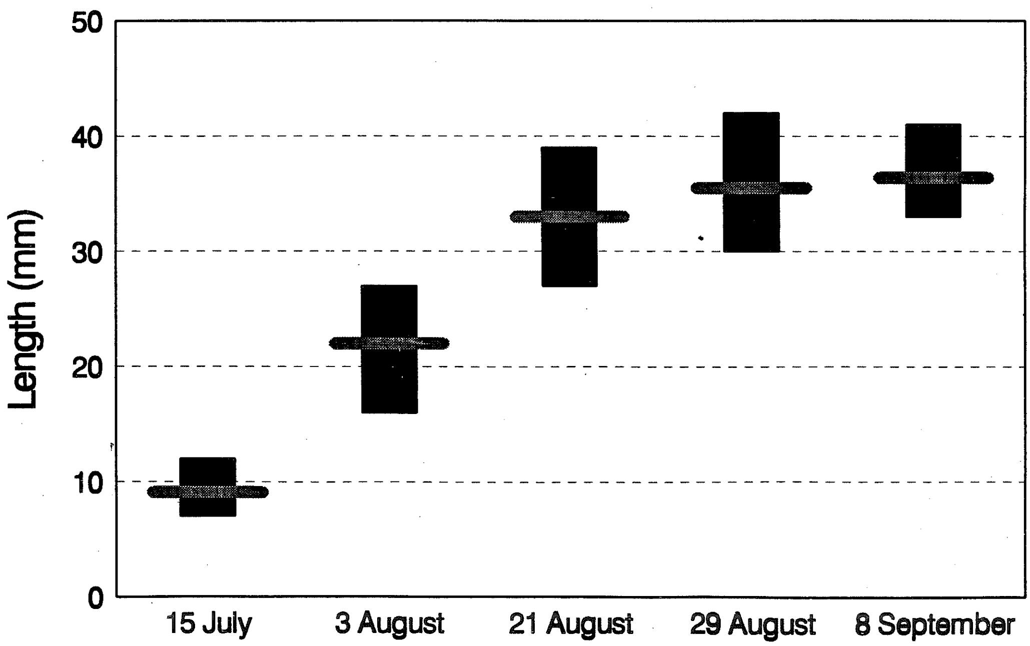


Figure 1. Mean length and range of young-of-the-year bluegill, Smith Lake, Minnesota, 1995.

Table 1. Frequency of diet items observed in northern pike stomachs, Smith Lake, Minnesota, 1992 and 1995.

| Item | 1992 YOY (n=2) (114-143 mm) | 1992 Small (n=0) | 1992 Adult (n=48) (434-604 mm) | 1995 YOY (n=3) (119-175 mm) | 1995 Small (n=36) (203-433 mm) | 1995 Adult (n=14) (434-888 mm) |
|---|---|---|---|---|---|---|
| Zygoptera | 2 | | | | | 1 |
| Unknown Cyprinid | | | | | 1 | |
| Northern pike | | | | | | 2 |
| YOY Bluegill | | | | 1 | | |
| Age-1 Bluegill | | | | | 1 | |
| Bluegill | | | 14 | | 1 | |
| YOY Black Crappie | | | 3 | | | |
| Largemouth Bass | | | 1 | | | 1 |
| Walleye | | | | | | 1 |
| YOY Yellow Perch | | | 3 | | 3 | |
| Yellow Perch | | | 1 | | 7 | 5 |
| Iowa Darter | | | | | 1 | 1 |
| Johnny Darter | | | 1 | | | |
| Unknown Fish | | | 11 | | 2 | 2 |
| Empty | | | 14 | 2 | 18 | 4 |

ern pike, yellow perch, and walleye. Unlike 1992, no bluegill were observed in the diets of large northern pike.

*Black Crappie Diets*

No YOY or age-1 bluegill were observed in black crappie diets in either year. Invertebrates, mainly chironomids and other dipterans, were the staple of black crappie diets in 1992. Substantially fewer black crappie were sampled in 1995. Cyprinids were the most frequently observed diet item in 1995.

*Largemouth Bass Diets*

Young-of-the-year bluegill were found most frequently in the diets of YOY largemouth bass in 1995. Although diets of YOY largemouth bass collected in 1992 (n=19) consisted mainly of invertebrates, three contained fish (which were not identifiable) (Table 2). The diet data collected in 1995 differed greatly because 92% of the YOY largemouth bass with food in their stomachs had eaten fish. The majority of fish consumed by YOY largemouth bass were YOY bluegill (68%). Unidentifiable fish remains composed 23% of the YOY largemouth bass diets while black crappie and brook stickleback *Culea inconstans* each composed 2% (Table 2). Although 44% of the YOY largemouth bass collected in 1995 had empty stomachs, this was more frequent later in the summer. The increase in the number of empty stomachs in late summer corresponded to a sharp decrease in the number of YOY bluegill eaten by YOY bass.

Much like the 1995 YOY cohort, age-1 largemouth bass collected in 1995 consumed fish far more frequently than the same age class did in 1992. Most age-1 largemouth bass sampled in1992 (n=6) had eaten invertebrates, mainly adult and larval dipterans. A single yellow perch was the only fish found in the diets of age-1 largemouth bass (Table 3). Age-1 largemouth bass in 1995 showed a strong preference for YOY yellow perch. Fifty-three percent of the age-1 largemouth bass that had consumed fish ate YOY yellow perch, and 27% (n=14) had eaten more than one perch. Cannibalism of YOY largemouth bass was very common in mid-June, but it accounted for only 8% of the fish in the diets. Unidentified fish composed 30% of the fish portion of the diet. Many of these unidentified fish were larval fish from the June sampling period. Two YOY and one age-1 bluegill were observed during the late sampling period.

Table 2. Frequency of diet items observed in YOY largemouth bass stomachs, Smith Lake, Minnesota, 1992 and 1995.

| Item | 1992 (n=19) (37-45 mm) | 1995 (n=118) (37-102 mm) |
|---|---|---|
| Cladocera | 7 | 1 |
| Amphipoda | 3 | 4 |
| Diptera | | |
| Chironomidae | 5 | 4 |
| Other Diptera | 3 | |
| Ephemeroptera | | 3 |
| Anisoptera | | 1 |
| Stickleback | | 1 |
| YOY Black Crappie | | 1 |
| YOY Bluegill | | 45 |
| Unknown Fish | 3 | 14 |
| Empty | 7 | 52 |

Two YOY bluegill were found in age-2 largemouth bass stomachs in 1992 while none were found in 1995. Most of the age-2 largemouth bass sampled in 1995 had eaten darters which could not be identified to species (Table 3). A single age-1 bluegill was observed in the 1995 diet collections.

Bluegill were not found in any of the 122 adult largemouth bass stomachs we examined. As was the case with younger cohorts, adult largemouth bass sampled in 1992 consumed more invertebrates (43%) than those sampled in 1995 (23%) (Table 4). Ninety-five percent of the adult largemouth bass collected in 1995 had consumed some type of fish compared to 66% in 1992. Cyprinids were the most commonly found fish in largemouth bass stomachs in 1992 (32%), but in 1995 yellow perch were the most commonly identifiable fish (22%). Unidentifiable fish composed 35 and 22% of the fish portion of the largemouth bass diets in 1992 and 1995, respectively. Largemouth bass collected in 1992 were found to prey upon YOY black crappie (16%) and yellow perch (19%).

*Walleye Diets*

In both years, age-2 walleye were common in the electrofishing samples, but their diets varied considerably between the two years. The age-2 walleye collected in 1992 preyed primarily upon invertebrates, particularly adult dipterans. The few fish they did eat were cyprinids (Table 5). The age-2 walleye collected in 1995 preyed

Table 3. Frequency of diet items observed in age-1 and age-2 largemouth bass stomachs, Smith Lake, Minnesota, 1992 and 1995.

| Item | 1992 Age-1 (n=6) (81-170 mm) | 1992 Age-2 (n=6) (221-301 mm) | 1995 Age-1 (n=135) (80-204 mm) | 1995 Age-2 (n=5) (230-290 mm) |
|---|---|---|---|---|
| Ephemeroptera | 1 | | 1 | |
| Zygoptera | | | 5 | |
| Anisoptera | | | 4 | |
| Hemiptera | | | | 1 |
| Diptera | 5 | 2 | | |
| YOY Northern Pike | | | 1 | 1 |
| Unknown Cyprinid | | 2 | 2 | 1 |
| Bullhead | | | 2 | |
| YOY Largemouth Bass | | | 8 | |
| YOY Bluegill | | 2 | 2 | |
| Age-1 Bluegill | | | 1 | 1 |
| YOY Yellow Perch | 1 | 1 | 52 | 1 |
| Unknown Darter | | | 4 | 4 |
| Unknown Fish | | | 30 | |
| Empty | | | 31 | |

Table 4. Frequency of diet items observed in age-3 and older largemouth bass, Smith Lake, Minnesota, 1992 and 1995.

| Item | 1992 (n=64) (314-489 mm) | 1995 (n=58) (321-510 mm) |
|---|---|---|
| Hirudinae | | 2 |
| Amphipoda | | 1 |
| Diptera | 8 | |
| Chironomidae | 1 | |
| Zygoptera | 4 | 3 |
| Anisoptera | 1 | 1 |
| Trichoptera | 5 | 4 |
| Rana spp. | 3 | 2 |
| Northern Pike | | 1 |
| Unknown Cyprinid | 10 | 2 |
| Spottail Shiner | | 8 |
| Creek Chub | | 1 |
| Bullhead | | 1 |
| YOY Black Crappie | 5 | |
| Pumpkinseed | | 1 |
| Yellow Perch | 6 | 14 |
| Iowa Darter | | 5 |
| Unknown Fish | 11 | 8 |
| Empty | 24 | 20 |

mainly on age-1 yellow perch, although YOY bluegill were found in the diets of three individuals collected in August. Three YOY bluegill were found in one large walleye; however, age-1 yellow perch composed the bulk of the larger walleye diets. Larger bluegill were found in the diets of large walleye in both years; however, this occurrence was rare.

*Yellow Perch Diets*

Yellow perch that we collected in 1995 were far more piscivorous (49%) than those collected in 1992 (29%) (Table 6). Yellow perch were observed to prey upon YOY bluegill in both years, but the occurrence was uncommon. The presence of fish in yellow perch diets appeared to be independent of yellow perch length, as small yellow perch (<150 mm) were as likely to consume fish as were larger perch.

*Bluegill Consumption*

Consumption of bluegill varied greatly from May through September and was affected

Table 5. Frequency of diet items observed in age-2 and older walleye stomachs, Smith Lake, Minnesota, 1992 and 1995.

| Item | 1992 Age-2 (n=12) (170-237 mm) | 1992 Older (n=16) (329-572 mm) | 1995 Age-2 (n=18) (187-312 mm) | 1995 Older (n=20) (302-722 mm) |
|---|---|---|---|---|
| Diptera | 8 | | | |
| Zygoptera | | 1 | 2 | 1 |
| Trichoptera | 1 | | | 1 |
| Unknown Cyprinid | 2 | | 3 | 1 |
| Spottail Shiner | | | 1 | |
| YOY Bluegill | | | 3 | 1 |
| Bluegill | | 2 | | 1 |
| YOY Black Crappie | | 1 | | |
| YOY Yellow Perch | | 3 | 1 | 0 |
| Yellow Perch | | | 8 | 11 |
| Unknown Fish | | | 2 | |
| Empty | 2 | 9 | 4 | 6 |

Table 6. Frequency of diet items observed in yellow perch stomachs, Smith Lake, Minnesota, 1992 and 1995.

| Item | 1992 (n=55) (140-221 mm) | 1995 (n=80) (102-265 mm) |
|---|---|---|
| Hirudinae | | 1 |
| Gastropoda | | 2 |
| Pelecypoda | 5 | 4 |
| Cladocera | 3 | |
| Amphipoda | 3 | 10 |
| Trichoptera | 1 | 9 |
| Ephemeroptera | | 1 |
| Zygoptera | 4 | 7 |
| Anisoptera | | 3 |
| Diptera | 14 | 1 |
| Chironomidae | 38 | 1 |
| Unknown Cyprinid | 3 | 2 |
| Spottail Shiner | | 2 |
| YOY Bluegill | 1 | 2 |
| Age-1 Bluegill | 1 | |
| YOY Black Crappie | 1 | |
| YOY Yellow Perch | | 3 |
| Iowa Darter | | 15 |
| Unknown Fish | 3 | 9 |
| Empty | 24 | 21 |

by predator size. Estimates of YOY bluegill (g) consumed by predators indicated that age-2 walleye and largemouth bass < 3 years of age ate the most YOY bluegill (Figure 2). Young-of-the-year northern pike were estimated to consume 11.4 g of YOY bluegill per individual/season during late summer. Age-4 yellow perch consumed the fewest YOY bluegill, an estimated 4.3 g/individual/season. The consumption of YOY bluegill by YOY, age-1, and age-2 largemouth bass was estimated to be 37.5, 27.5, and 24.5 g/individual/season, respectively. The majority of YOY bluegill consumption by YOY largemouth bass occurred before the end of August (Figure 3). Conversely, age-1 and age-2 largemouth bass consumed the majority of YOY bluegill later in the summer and into early fall. Age-2 walleye consumed the most YOY bluegill, (72.4 g/individual/season) (Figure 2). More than one-half of the YOY bluegill consumed by age-2 walleye were eaten between late August and mid-September (Figure 3).

## DISCUSSION

The successful use of predation to control bluegill recruitment has been used in small impoundments and in some cases natural water bodies. Based upon our diet analysis of predators in a single lake, the successful management of YOY and age-1 bluegill numbers in some north-temperate lakes through predator density manipulation appears tenuous. Predation on YOY and age-1 bluegill was largely limited to YOY largemouth bass with lesser amounts consumed by YOY northern pike, age-1 and age-2 largemouth bass, age-4 yellow perch, and age-2 walleye. The larger predators such as bowfin, large northern pike, adult largemouth bass, or adult walleye had eaten no age-1 or YOY bluegill and seemed to prefer larger prey items. It appears to be energetically inefficient for these larger sized species to feed on small bluegill (Diana 1987). Cyprinids, age-1 largemouth bass, northern pike, medium-sized bluegill and particularly yellow perch were more common in large predator diets than were YOY or age-1 bluegill. Similar diets for these large predators have been reported from other Minnesota lakes. For example, in nearby Maple Lake, yellow perch were found in 70% of the northern pike with food in their stomachs (Seaburg and Moyle 1963). Similarly, yellow perch composed 100% of the fish found in walleye diets sampled from Maple Lake. Yellow perch constituted 47 and 90% of northern pike and walleye diets, respectively, in Horseshoe Lake (Schupp 1979). In addition to the aforementioned predators, we did not observe any small bluegill in the diets of black crappie. However, diet analysis of black crappie sampled from Grove Lake, Minnesota, contained notable numbers of sunfish (Seaburg and Moyle 1963).

Although small bluegill constituted a small portion of their diets, the total consumption by YOY northern pike, age-1 largemouth bass, age-2 largemouth bass, age-4 yellow perch, and age-2 walleye could represent a substantial number of bluegill. Although rarely observed, cannibalism of YOY walleye in Oneida Lake, New York, resulted in a substantial consumption and affected recruitment (Chevalier 1973). Similarly, although they composed only 6.7% of the yellow perch diet, Beard (1982) calculated that over one-

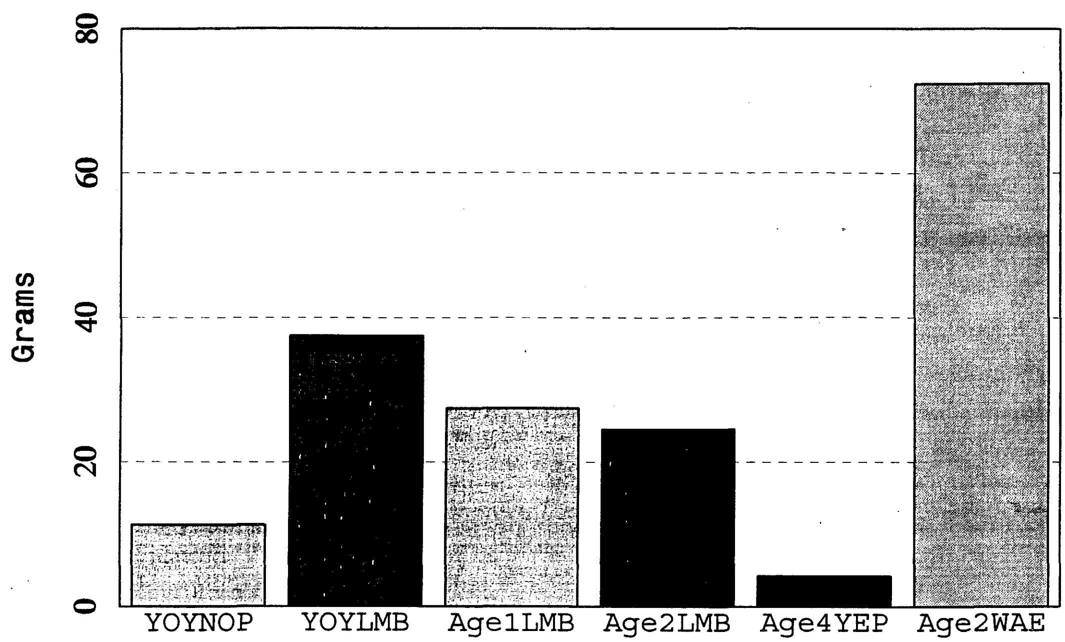


Figure 2. Estimated individual consumption of young-of-the-year bluegill by young-of-the-year northern pike (YOYNOP), young-of-the-year largemouth bass (YOYLMB), age-1 (Age1LMB)and age-2 (Age2LMB) largemouth bass,age-4 yellow perch (Age4YEP), and age-2 walleye (Age2WAE) from May through September, Smith Lake, Minnesota.

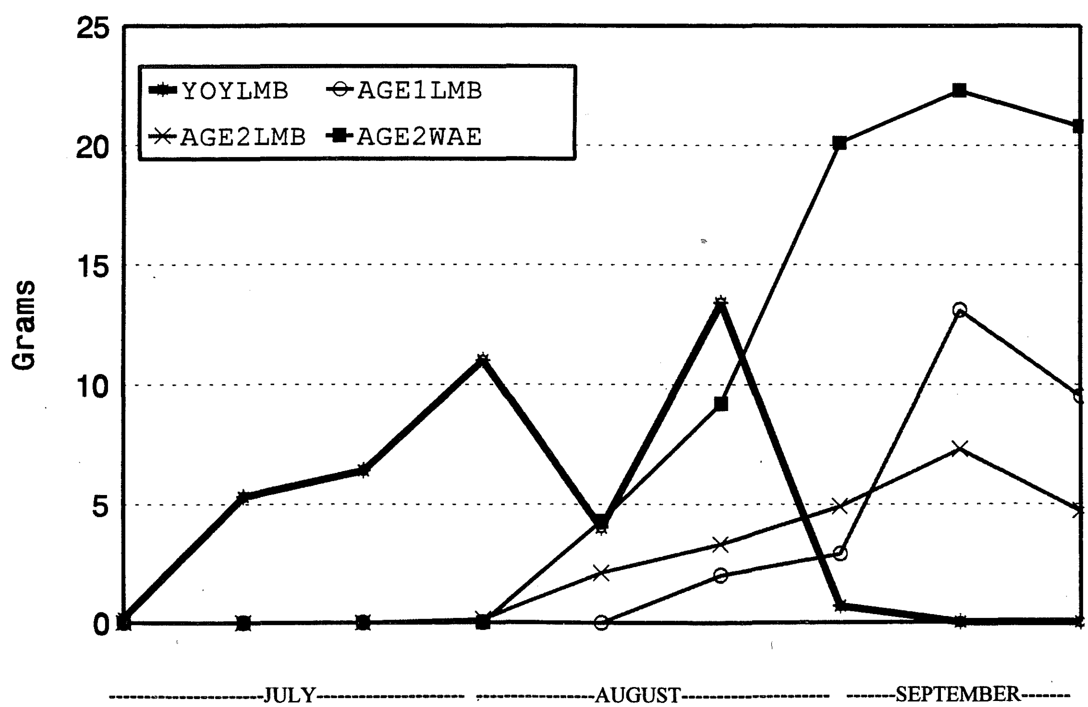


Figure 3. Seasonal consumption patterns of young-of-the-year bluegill by young-of-the-year largemouth bass (YOYLMB), age-1 and age-2 largemouth bass (AGE1LMB and AGE2LMB)and age-2 walleye (AGE2WAE), Smith Lake, Minnesota.

half of the YOY bluegill could be consumed by yellow perch. The bioenergetic model suggests that this could also be occurring in Smith Lake, particularly with age-2 walleye. Although YOY bluegill constituted only 14% of the age-2 walleye diets, each walleye was estimated to consume 72.4 g/individual/season of YOY bluegill, nearly three times more than age-1 largemouth bass. Although the observed growth of age-1 largemouth bass was greater than age-2 walleye (131 vs. 115 g/individual/season), and the amount of YOY bluegill in their respective diets was nearly identical, walleye physiology may have allowed for greater predation. Walleye digestive rates have been shown to be substantially faster than largemouth bass (Seaburg and Moyle 1963). They found largemouth bass needed 21 hours to digest 70% of a known volume of yellow perch, while 75% of the yellow perch force-fed to walleye had been digested in only 17 h. Young-of-the-year walleye readily utilize YOY bluegill as prey, and can drastically reduce their numbers (Beard 1982).

Management aimed at increasing small walleye abundance to reduce YOY bluegill recruitment is potentially confounded by the high cost of maintaining artificially high walleye densities and abundant alternative prey items. The fact that walleye preferred YOY yellow perch may limit the usefulness in reducing YOY bluegill survival. We observed declining numbers of YOY yellow perch in Smith Lake through the summer that corresponded to the shift in the age-2 walleye diet from YOY yellow perch to YOY bluegill. It appears that using small walleye in Smith Lake to consume YOY bluegill may depend on the abundance of YOY yellow perch. Also cost effectiveness and outside factors effecting year class strength may prevent increasing and maintaining walleye density to high enough levels to regulate bluegill recruitment. Natural reproduction in these systems is usually limited, and stocking fingerlings is costly and rarely produces the large year classes that would be required to reduce bluegill recruitment (Parsons et al. 1994). Based on Li's (1995 ) work on stocking success and the negative effects of a strong year class on the two adjacent year classes, it does not appear that high density walleye fry stocking is a viable option to controlling YOY bluegill.

Despite a great deal of research indicating that sustaining high numbers of age-1 to age-3 (150 to 300 mm) largemouth bass as the key to producing quality bluegill fisheries (Novinger and Legler 1978; Davies 1987; and Guy and Willis 1990), our observations and modeling in Smith Lake indicate that largemouth bass are less likely to consume YOY bluegill than are walleye. As with walleye, the presence of YOY yellow perch apparently buffers the effects of predation on the bluegill populations. Only after YOY yellow perch abundance declined in mid-August did largemouth bass prey upon YOY bluegill. Prior to that decline in 1995, age-1 and age-2 largemouth bass primarily ate yellow perch. Because the predator-prey relationship between largemouth bass and bluegill is not as direct in systems like Smith Lake as it is in small impoundments (Swingle 1950), management directed at improving bluegill populations by increasing largemouth bass populations is problematic.

The use of northern pike to control panfish populations has been proven to be ineffective and even counter-productive (Anderson and Schupp 1986; Goeman et al. 1990). Our results also suggest that northern pike predation is insufficient to improve bluegill populations, and as with other predators YOY yellow perch made up the bulk of their diets. Larger northern pike preyed on larger bluegill; however, this does little to reduce recruitment and probably has little chance to improve bluegill size structure. Furthermore, it is questionable if the numbers of large northern pike needed to reduce bluegill numbers can be produced in lakes similar to Smith Lake (Jacobson 1992). Due to previous unsuccessful manipulations of northern pike populations and our diet data, we do not recommend any management activities that would increase northern pike densities with the intention of increasing bluegill predation.

It has been suggested that a predator-prey interaction may exist between yellow perch and bluegill which could influence bluegill abundance and size structure (Anderson and Schupp 1986; and Goeman et al. 1990). Beard (1982) reported that fingerling yellow perch do prey upon YOY bluegill and can consume great numbers of bluegill fry. Young-of-the-year bluegill have been observed in the stomachs of angler-caught yellow perch from Pelican Lake, Minnesota (B.G.Parsons, personal observation). Our observations further support the fact that yellow perch can be piscivorous at all sizes; however, diet analysis and bioenergetics modeling provided no evidence that this was the case in Smith Lake. The role of yellow perch as predators needs to be better defined.

The predator-prey relationship between largemouth bass and bluegill was limited to young-of-the-year of each species. The only predators we observed to consume numerous YOY bluegill were YOY largemouth bass. This may have been an unusual occurrence as YOY largemouth bass in a Wisconsin lake did not prey upon bluegill (Beard 1982). Several investigators report piscivory by YOY largemouth bass does not occur until they reach lengths of 41-51 mm (Keast and Webb 1966; Newburg 1969; and Holland and Chambers 1971). Newburg and Schupp (1986) observed YOY largemouth bass growth in Lake Geneva, Minnesota for seven years and only once did growth of YOY largemouth bass approach the growth we observed in Smith Lake. The growth we observed in 1995 was substantially greater than that in 1992 when invertebrates dominated the YOY largemouth bass diets. Warm water temperatures likely provided ideal growing conditions and allowed YOY largemouth bass to reach lengths of 45-55 mm by mid-July. Therefore, members of the 1995 cohort were large enough to be able to prey upon YOY bluegill from mid-July through mid-August. In many years, this window of opportunity for YOY largemouth bass is much shorter or non-existent and limits their usefulness as a predator. In years when early growth is not good or when bluegill are not present in large numbers, they are forced to consume invertebrates for the entire summer, and growth remains slow (Shelton et al. 1979; Timmons et al. 1980). Moreover, even in a year such as 1995 when YOY largemouth bass growth was exceptional, YOY bluegill grew fast enough that by the end of the summer, predation by YOY largemouth bass was limited to only the smallest members of the bluegill cohort.

Managing largemouth bass numbers and size structure with the goal of improving bluegill size structure is currently gaining favor in natural lakes of the upper Midwest. However, this strategy is based upon a relationship that may be more complex or even non-existent in some north-temperate lakes. Largemouth bass in Smith Lake, Maple Lake, and Horseshoe Lake ate substantially more yellow perch than bluegill (current study; Seaburg and Moyle 1963; and Schupp 1980, respectively). Age-3 and older largemouth bass in our study ate few bluegill; therefore, high minimum size or slot limits designed to increase bass numbers and size are unlikely to directly affect bluegill populations. Creel surveys of lakes similar to Smith Lake indicate that the harvest of largemouth bass < 300 mm was low (Kessler 1990). Size restrictions designed to protect these smaller fish and increase predation are unlikely to succeed, particularly if yellow perch densities are high. Perhaps the best management strategy for largemouth bass in lakes similar to Smith Lake is to insure adequate spawning habitat so that when optimal-growth conditions occur, as they did in 1995, production of fast-growing YOY is high.

## Management Recommendations

1. Because predator-prey relationships are not well defined in many Minnesota lakes, diet analysis and bioenergetic modeling should be incorporated into any management action designed to increase predator densities in order to decrease bluegill abundance.

2. Walleye may prey sufficiently on YOY bluegill if yellow perch densities are low. An evaluation of fry stocking in systems similar to Smith Lake may be warranted.

3. Unless diet information indicates that largemouth bass are preying on YOY and age-1 bluegill, regulations designed to increase largemouth bass population density should not be represented as being able to improve bluegill size structure.

4. Unless yellow perch densities are low and harvest of largemouth bass ≤ 300 mm is high, regulations designed to increase predation on bluegill by protecting largemouth bass are unlikely to work.

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