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ANNUAL PROGRESS REPORT

EVALUATION OF WALLEYE STOCKING PROGRAM

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Executive Summary

Walleye (Stizostedion vitreum) are an important sportfish and have attracted interest from both anglers and researchers. From these studies, it has become clear that success of walleye fry stockings is highly variable. Stocking success probably depends upon a variety of physical and biotic factors; previous work with walleye and other stocked sportfish has identified several factors which might influence stocking success of walleye in a given impoundment. One of the more important of these potential factors is forage base. As zooplankton are the first food eaten by walleye fry, fry stocking success may be related to zooplankton density and size composition at the time of stocking. Other important factors influencing success may include resident predators, physical-chemical conditions, and stocking stress.

Ten fry stockings were conducted in 1996; survival of walleye stocked as fry was low in all but two lakes. Walleye fry were collected in all study lakes except for Springfield, which historically has high fry survival. Catch-per-unit-effort ranged from 0.0 to 7.47 fish per hour. Survival to fall for walleye stocked as fry ranged from 0 to 0.9%. Across lakes, mean total length of walleye stocked as fry collected in fall sampling ranged from 160-258 mm. Total and macrozooplankton (cladoceran plus copepod) densities on lakes with walleye fry varied greatly. Total zooplankton density ranged from less than 50 organisms/liter to greater than 4000. Macrozooplankton was also variable and in most lakes ranged from 5 to over 500 organisms/liter. Relationships between prey availability and growth and survival were weak due to uniformly low survival of fry. We now have sufficient data to begin to assess relationships between zooplankton levels and fry survival across years.

Nineteen fingerling stocking evaluations were conducted in 1996. Mortality of walleye fingerlings 24 h following stocking ranged from 0 to 87%, with a mean of 13%. Catch-per-unit-effort of age-0 stocked fingerlings from fall electrofishing was greater than 1 fish/h in eleven of the nineteen fingerling stockings. Survival estimated for stocked fingerlings ranged from <1 to 5%. Like survival, growth of walleye fingerlings was highly variable. Average total length in fall ranged from 137-268 mm for 50 mm stocked fingerlings and 129-158 mm for 100 mm stocked fingerlings. Predation on walleye fingerlings by largemouth bass was below 1% in all but two lakes. Inshore fingerling stocking resulted in higher predation from largemouth bass than offshore stocking in Lake Kinkaid. Larger walleye primarily consumed lepomid sunfish and cyprinids. Zooplankton, ichthyoplankton, and benthic invertebrate densities varied considerably across our study lakes. Research conducted at Sam Parr suggests that benthic invertebrate density may not be an important factor influencing growth and survival. Relationships between these variables and growth and survival of stocked walleye will be examined across years.

We will continue to evaluate the role of forage base and predators in determining survival of stocked walleye. Stocking walleye from shore resulted in much higher predation when compared to walleye stocked offshore. Inshore and pelagic stockings will be continued for both fry and fingerlings to determine the importance of predation. Evidence obtained thus far indicates there is variability in forage populations among different lakes at the time when fingerlings are stocked and in the months following stocking. Our work will continue to evaluate advantages of matching walleye stockings to lakes which have optimum forage populations.

Job 101.1. Factors affecting survival and growth of walleye fry

OBJECTIVE: To evaluate factors affecting survival and growth of walleye fry stocked in impoundments

INTRODUCTION: Walleye (Stizostedion vitreum) are an extremely important sportfish and have attracted an increasing amount of interest from anglers and researchers over the past two decades (see literature summaries in Ebbers 1988, Davin et al. 1989). From these and other studies, it has become clear that success of walleye fry stockings is highly variable (Laarman 1978). Stocking success probably depends upon a variety of physical and biotic factors; previous work with walleye and other stocked sportfish has identified several factors which might influence stocking success of walleye fry in a given impoundment. One of the more important of these potential factors is forage base (Forney 1977, Li and Mathias 1982, Carline et al. 1986, Wahl and Stein 1988). As zooplankton are the first food eaten by walleye fry, fry stocking success may be related to zooplankton density and size composition at the time of stocking (Mathias and Li 1982, Hokanson and Lien 1986, Fox et al. 1989, Confer et al. 1990, Fox and Flowers 1990). Other important factors influencing success may include resident predators (Wahl and Stein 1989), physical-chemical conditions (Koonce et al. 1977), and stocking stress (Carmichael et al. 1984, Mather and Wahl 1989).

METHODS: Ten walleye fry stockings were conducted in eight impoundments during 1996 (Table 1). Major piscivores present in these impoundments in addition to walleye include largemouth bass Micropterus salmoides, smallmouth bass Micropterus dolomieui, yellow bass, white bass and hybrid white bass Morone spp., northern pike Esox lucius, muskellunge Esox masquinonge, various sunfish Lepomis spp., crappie Pomoxis spp., and catfish Ictalurus spp.. The lakes in many cases contain substantial aquatic vegetation including coontail Ceratophyllum demersum, water milfoil Myriophyllum spp., pondweed Potamogeton spp., and naiad Najas spp.. The maximum depth of these impoundments ranges from 8-24 m, and average depth from 4-8 m.

All fry for experimental stockings were reared at Jake Wolf Memorial and LaSalle fish hatcheries by the Illinois Department of Natural Resources. Fry were marked by immersion for 6 h in 500-mg/L oxytetracycline (OTC) in order to differentiate fry from fingerling stockings and to determine the extent of natural recruitment in the study lakes. In order to assess mortality due to stocking stress, subsamples from each fry stocking (N=100) were held in three plastic tubs (133 L) for 24 hours. Water temperature, dissolved oxygen, and turbidity were recorded at the time of stocking and at biweekly intervals thereafter. Secchi disc depth was recorded as a measure of turbidity. Zooplankton density and species composition were also sampled at biweekly intervals by making vertical tows with a 0.5-m diameter, 64µm mesh zooplankton net at six locations on each study lake. Samples were preserved in 4% Lugol's solution. In the laboratory, samples were adjusted to a constant volume (100 ml) and subsampled by 1-ml (1/100) aliquot. Numbers of major groups of zooplankton were identified, counted, and measured. Fall (September-November) electrofishing and trap net catch-per-unit effort (CPUE) were used as an index of walleye fry survival. All walleye collected were measured (nearest millimeter) to determine growth rates. Walleye were also given an upper caudal-fin clip, and modified Schnabel mark-recapture population estimates were calculated for walleye from fry and fingerling stockings when three or more recaptures were obtained.

The importance of fry predation was evaluated by collecting potential predators at inshore sites where known numbers of fry were released on lakes Springfield, East Fork, and Sara. All potential predators were preserved and returned to the laboratory for later analysis.

RESULTS: Mortality of fry associated with stocking stress ranged from 4 to 33% (Table 1). Mean surface water temperature at stocking was 15°C, but ranged as high as 23°C. Other factors that may contribute to stocking mortality are hauling time and fry condition. Relationships between these variables and stocking mortality will be explored further in future data analysis and final reports.

Survival of walleye stocked as fry was low in all but two lakes (Table 2). Walleye fry were collected in all of our study lakes except for Springfield, which historically has high fry survival. Catch-per-unit-effort ranged from 0.0 to 7.47 fish per hour. Survival to fall for walleye stocked as fry ranged from 0 to 0.9%. Across lakes, mean total length of walleye stocked as fry collected in fall sampling ranged from 160-258 mm. Based on the extensive effort expended to collect walleye on fry lakes in all years, survival of walleye stocked as fry appears to generally be poor. However, in some circumstances, survival of fry can be high.

Determination of zooplankton population density and composition on fry study lakes was completed, but the uniformly poor survival of fry made investigation of the influence of zooplankton on survival difficult. Total and macrozooplankton (cladoceran plus copepod) densities on lakes with measurable survival of walleye fry varied greatly. Total zooplankton density ranged from less than 50 organisms/liter to greater than 4000 (Figure 1). Macrozooplankton was also variable and in most lakes ranged from 5 to over 500 organisms/L. Lake Le-Aqua-Na, however, had macrozooplankton densities over 3000 organisms/L, comprising mostly of Bosminidae. Densities less than 50 zooplankters/L may be too low for efficient walleye fry foraging (Mayer and Wahl 1995).

RECOMMENDATIONS: Data collected thus far suggest water temperature at stocking can be an important factor influencing mortality. Results from additional future stockings will be used to assess the importance of other variables associated with stocking mortality such as hauling time and fry condition.

Survival of walleye stocked as fry is highly variable, but can be high in certain reservoirs and years. Identifying conditions when fry survival can be improved is important. There is considerable variability in zooplankton populations among different lakes at the time when fry are stocked. Split stockings of fry will be conducted in 1997 and should help us to evaluate the importance of prey availability. Our work will continue to evaluate if efforts should be made to match fry stocking to lakes which have optimum zooplankton populations on dates when fry are available. This work will include experimental stockings in small lakes where there is a higher likelihood of obtaining population estimates and where stocking time relative to peak zooplankton abundance can be controlled more closely. Lab experiments investigating relationships between zooplankton populations and walleye fry survival and growth have been completed (Mayer and Wahl 1995), and data from these experiments, in conjunction with data collected from walleye fry study lakes, will be useful in determining the best lakes and timing for stocking of walleye fry.

Because few walleye stocked as fry are typically collected in sampling during the first fall following stocking, those returned during future sampling will probably provide a better measure of survival and growth rates. By combining our multi-year data set on forage and predator densities in walleye fry study lakes with data on growth, survival, and harvest of walleye from these same bodies of water several years following stocking we may be better able to determine factors influencing fry stocking success.

Previous studies indicate that predation may have a major influence on walleye fry and fingerling stocking success. We are beginning to get good field estimates of fingerling predation mortality and now are attempting to collect data concerning the magnitude of predation on fry in impoundment stockings. Ney (1978) observed that predation could be a large component of first year mortality and cited cannibalistic walleye and other fish, leeches, diving beetles, and back swimmers as important predators of walleye fry. During 1997 we will attempt to estimate predation on fry by examining predator stomachs following stocking.

Job 101.2. Factors affecting survival and growth of walleye fingerlings

OBJECTIVE: To determine mechanisms affecting survival and growth of fingerling walleye after stocking in impoundments

INTRODUCTION: The success of walleye fingerling stocking, like that of fry stocking, has been highly variable (Laarman 1978). While Hauber (1983) indicated that fingerling stocking can be successful in increasing year class strength in some cases, the reasons for these successes are unknown. Variable success probably results from the interaction of a number of physical and biotic factors. Forage is probably one important factor influencing stocking success of walleye fingerlings. The temporal abundance and species composition of the forage base, as well as the size distribution of prey (relative to walleye size) may all play an important role (Smith and Pycha 1960, Forney 1974, Hauber 1983, Mandenjian et al. 1991).

Predation is also likely to have an impact on walleye fingerling stocking success. Recent evidence suggests predation can be an important source of mortality (Santucci and Wahl 1993). Size of stocked fish can affect susceptibility to predation (Hanson et al. 1986; Wahl and Stein 1989); predation is probably higher for small walleye fingerlings than for larger size groups (Santucci and Wahl 1993). The role of predator abundance and size distribution in determining mortality rates of stocked walleye has not yet been evaluated fully.

Physical-chemical conditions, including thermal stress at stocking, may also influence fingerling stocking success. Temperature may also be important in determining growth and survival during post-stocking periods. Serns (1982) found that density and growth of age-0 walleye in natural populations were related to June water temperatures; these relationships may also apply to stocked fingerlings.

METHODS: Nineteen fingerling stocking evaluations were conducted in eleven Illinois impoundments during 1996 (Table 3). Lake characteristics and fish populations are similar to those described for walleye fry study lakes in Job 101.1.

In order to assess mortality of walleye fingerlings due to stocking stress, subsamples of fish from each stocking were held in floating nets (4-m deep x 0.75-m diameter, 3.2-mm mesh) for 48 hours. The number of fingerlings alive and dead were counted after 24 and 48 h. A subsample of fish (N=50) were measured (total length (TL), mm) and weighed (g). All stocked walleye fingerlings less than 75-mm TL were marked by immersion for 6 h in 500-mg/L (OTC). Larger walleye were marked with a unique fin clip prior to stocking.

As with walleye fry, fall (September - December) electrofishing and trap-net CPUE were used as an index of walleye fingerling survival. All walleye collected were measured to determine growth rates. Stomach contents of fingerling walleye were examined by gastric flushing (Foster 1977) or by dissection. Walleye were given a caudal fin clip, and modified Schnabel mark-recapture population estimates were calculated for walleye from fingerling stockings when three or more recaptures were obtained.

Physical, chemical, and biotic conditions were monitored in all impoundments at the time of stocking, at bi-weekly intervals for the first two months following stocking, and at monthly intervals thereafter to evaluate their possible influence on walleye survival and growth. Water temperature, dissolved oxygen, and turbidity were determined as described in Job 101.1. Forage base and predator populations were also monitored at these same intervals. The role of forage base in determining growth and survival of walleye was evaluated by comparing walleye diets with the species composition, density, and size distribution of prey available in each impoundment. Zooplankton density and species composition were determined as described in Job 101.1. Benthic invertebrates were sampled using a Ponar or Ekman dredge. Samples were filtered through a #30 sieve, then preserved in a 70% ethanol and rose bengal solution. Benthic organisms were later removed and identified to lowest possible taxonomic group. Available forage fish were sampled using standard ichthyoplankton tows (0.5-m, 500-µm larval fish nets) and by standardized shoreline seining (9 x 1.5-m seine, 4-mm mesh). Forage fish were identified, counted, and measured to the nearest millimeter. Following each of the lake stockings, we determined losses of walleye to resident predators. Predators were collected by trap-netting and electrofishing standardized transects. All potential predators on walleye fingerlings were identified, measured (TL, mm), and given a distinct fin clip. Mark-recapture estimates of predator numbers were calculated as described for walleye fingerlings. Stomach contents of largemouth bass were examined using acrylic tubes (Van Den Avyle and Roussel 1980); walleye stomachs were examined using gastric flushing (Foster 1977). Numbers of walleye in predator stomachs were combined with population estimates of the number of predators to determine the total number of stocked walleye lost to predation.

RESULTS: Mortality of walleye fingerlings 24 h following stocking ranged from 0 to 87%, with a mean of 13% (Table 3). Unlike previous years, mortality of 50-mm stocked walleye fingerlings was not significantly related to lake surface temperature or to the difference between hatchery and lake temperature. However, relationships should develop after combining across years at the end of the study. As with fry, factors other than temperature may have a significant influence on stocking mortality.

Success in collecting stocked walleye fingerlings was variable. Catch-per-unit-effort of age-0 stocked fingerlings from fall electrofishing was greater than 1 fish/h in eleven of the nineteen fingerling stockings (Table 4). Survival estimated for stocked fingerlings ranged from

<1 to 5%. In eight other fingerling stockings sampled, CPUE of age-0 stocked fingerlings in fall electrofishing was less than 1.0 fish/h, indicating poor survival. This data is consistent with results from previous studies (Hauber 1983, Santucci and Wahl 1993, Buttner et al. 1991) and from previous years sampling in the current study, and indicates that stocked walleye fingerlings can experience mortality as high as 70-100% over a 3-4 month period.

Like survival, growth of walleye fingerlings was highly variable (Table 4). Across lakes, growth increment of walleye stocked as 50-mm fingerlings ranged from 80-218 mm, and total length in fall ranged from 137-268 mm. Growth was lowest on Lake Shelbyville which also had low total zooplankton and larval fish densities (Figure 1, Figure 2). Mean increment of walleye stocked as 100-mm fingerlings ranged from 25-47 mm; mean total length in fall for this group ranged from 129-158 mm. This range in growth is comparable to that reported for other walleye populations (Serns 1982, Buttner et al. 1991, Mandenjian et al. 1991), and demonstrates the variability that can occur among and within walleye populations. The apparent within-year growth advantage for early-stocked (50-mm) fish may translate into increased survival for these fish.

Differences in survival and growth of fingerling walleye among lakes have been attributed, in part, to differences in forage base among lakes (Forney 1974, 1976; Hauber 1983). Density of larval fish among walleye fingerling study lakes at the time of stocking (May-June) was variable, ranging from less than 1 to nearly 5 fish/m^3 (Figure 2). Measures of benthic invertebrate density at the time of stocking were more variable, ranging from 100 to over 10,000 benthic organisms/m^2 (Figure 3). Relationships with growth and survival between benthic invertebrate density and larval fish density will be assessed with data from all years at the end of the study.

Within-lake variability in forage abundance is probably also important in determining survival and growth of stocked walleye fingerlings. In Pierce Lake, relative survival of fingerlings stocked in late June was 1.6 times greater than that of fingerlings stocked in early June. Abundance of larval fish in late June was three times greater than that in early June. Although we expected this same pattern to be found in Sam Dale, better survival did not correspond with higher prey abundance. Late stocked walleye in Sam Dale were not collected in the fall despite higher larval fish densities at stocking, however, water temperatures were 11°C higher during the late stocking period. Higher temperatures may have had a negative influence on walleye survival and may have dampened the effect of forage availability.

Juvenile forage fish were collected by shoreline seining on all walleye study lakes. The dominant forage group collected in seine samples was centrarchids, followed by cyprinids and Atherinidae (Table 5). Diet of stocked walleye consisted primarily of Lepomis spp. and cyprinids on lakes where they were available, but percent occurrence of these forage groups in stomach samples was, in most cases, less than the corresponding occurrence in seine samples. On lakes in which they were available, percent occurrence of clupeids in diets was generally greater than their availability as measured in seine samples. Although shad were abundant in many of the lakes, few were collected by seining. On average, 19% of walleye stomachs examined were empty.

Differences in survival of fingerling walleye among lakes have also been attributed to variable predation pressure. There were a number of potential predators in the lakes including largemouth bass, smallmouth bass, adult walleye, crappie, yellow bass, white bass, northern pike, muskellunge, and tiger muskellunge. Micropterus spp. were abundant in all lakes and considered to be a likely predator on stocked fish (Wahl and Stein 1989). Walleye were found in bass stomachs following stocking on seven lakes (Table 6). Predation generally accounted for only a small percentage of observed mortality (less than 1%). Even though few largemouth bass stomachs contained walleye, the ones that did often contained more than one. For example, 47 walleye were consumed by only seven largemouth bass on Lake Kincaid, while the rest did not consume any walleye. Largemouth bass population estimates were not feasible on the largest lakes, but CPUE of bass on these lakes was similar to that on other lakes, and numbers of walleye per bass stomach on these larger lakes indicate that walleye mortality due to predation is probably low. Predation on walleye stocked both inshore and offshore was evaluated in Lake Bloomington and Lake Kincaid. Neither group was preyed upon by largemouth bass in Lake Bloomington. However, in Lake Kinkaid, stocking fingerlings from shore resulted in higher predation than stocking offshore (0.34 walleye per stomach compared to 0 walleye per stomach, respectively).

RECOMMENDATIONS: The current sampling and stocking schedule should be maintained next year. Evaluation of mortality at stocking will allow us to continue to examine the relationship of this portion of mortality to water temperature and size of stocked walleye. We will also continue to evaluate the role of forage base and predators, especially predators other than largemouth bass, in determining survival of stocked walleye. Stocking of fingerling walleye from shore has often resulted in higher mortality from predation. We will continue to examine the importance of stocking location in 1997 by monitoring predation on walleye stocked inshore and offshore as both fry and fingerlings. While predators appeared to play only a small role in determining survival, they may be somewhat more important than these initial numbers indicate. Santucci and Wahl (1993) reported mortality of intermediate-sized walleye fingerlings due to predators of as high as 28%. Additionally, walleye have been recovered from largemouth bass and other predator stomachs on several lakes more than a month following stocking. This suggests that, under certain circumstances, predation may influence survival of stocked walleye not only at the time of stocking, but throughout their entire first year. Predation on walleye fingerlings was also observed by northern pike, white bass, white crappie, and other walleye. Data concerning predation on walleye fingerlings, including data on predation by species other than largemouth bass, will be important in making recommendations regarding the appropriate predator populations in which to stock various sizes of walleye.

In addition, monitoring and assessment of factors influencing walleye growth in the years following stocking will be continued. This monitoring will be important, given the high variability in growth observed in the lakes studied. We should continue to closely monitor the adult walleye population in each of the study lakes, both to evaluate potential effects on subsequent stockings and because the success of walleye stockings may be more accurately evaluated in older age classes (Hauber 1983).

Evidence obtained thus far indicates there is variability in forage populations among different lakes at the time when fingerlings are stocked and in the months following stocking. Our work will continue to evaluate advantages of matching walleye stockings to lakes which have optimum forage populations. This work should include additional experimental stockings in lakes where stocking time relative to peak larval fish and benthic invertebrate abundance can be controlled more closely. Lab and pond experiments investigating relationships between forage populations and walleye fingerling survival and growth are producing results (see Job 101.4) that, in conjunction with data collected previously from walleye fingerling study lakes, will be useful in determining the best lakes and timing for these experiments.

Job 101.3. Size-specific survival, growth, and food habits of walleye fry and fingerlings

OBJECTIVE: To compare size-specific survival, growth, and food habits of walleye fry and fingerlings stocked in impoundments

INTRODUCTION: Two basic strategies have developed for stocking walleye to supplement natural populations or to add an additional fish species for the benefit of anglers. The first is to stock large numbers of walleye fry in hopes that, despite relatively poor survival to juvenile and yearling classes, a percentage of that stocking will survive and contribute to (or create) a strong year class. The second strategy is to stock smaller numbers of intermediate to advanced fingerlings in hopes that large size and increased survival will lead to strong year classes. In weighing these two options, considerations include hatchery production costs and relative survival of stocked walleye.

The most effective way to obtain conclusive evidence regarding the relative benefits of fry versus fingerling stocking is to obtain data from lakes where mixed-size stockings are conducted. In these situations, it can be expected that the physical, chemical, and biological conditions that dictate year-class strength will apply to both fry and fingerlings, allowing meaningful comparisons of differences in survival. In this job, mechanisms influencing post-stocking survival were evaluated in lakes where different size groups of walleye were stocked during the same year. Ultimately, data obtained in this portion of the study will be used to construct a bioeconomic model to investigate the survival and stocking success of different sizes of walleye as a function of costs of rearing.

METHODS: Both fry and fingerling stockings were conducted on East Fork Lake, Lake Le-Aqua-Na, Randolph County Lake, Ridge Lake, Lake Sara, Lake Shelbyville, and Lake Sterling (Tables 1 and 3). Stocking evaluations on these seven lakes were conducted as described in Jobs 101.1 and 101.2.

RESULTS: Mortality due to stocking stress was variable for both fry and fingerlings, ranging from 4-33% for fry and 0-87% for fingerlings. Fry and fingerling mortality were not related to water temperature at stocking, however, our sample size was small. Combined data over six years of the study should provide a clearer relationship between walleye survival and water temperature. Large fingerlings have been shown to be more resistant to temperature stress in laboratory evaluations. Temperature change from hatchery or hauling tank to lake may also be important in determining mortality of fry and small fingerlings. Handling stress and fish condition probably also play an important role, and additional data from lakes stocked with both fry and fingerlings will help to clarify these relationships.

Relative survival was higher for 50 mm stocked fish than for fry in all of our study lakes during 1996 (Table 7). On average, 50-mm fingerlings performed more than 140 times better than stocked fry (in terms of survival), and 100-mm fingerlings performed more than 150 times better than fry (Table 7).

Total length in fall of walleye stocked as fry (mean=200 mm) was similar to that of 50-mm fingerlings (mean=202 mm), but greater than that of 100-mm fingerlings (mean=143 mm). This pattern is similar to that observed in previous years of this study. This differential growth, with fish stocked as fry or 50-mm fingerlings generally being larger going into winter than fish stocked as large fingerlings, has the potential to influence foraging and survival in subsequent years. We will continue to investigate this pattern of growth with additional experimental stockings in subsequent segments of this study.

RECOMMENDATIONS: The current sampling schedule should be maintained; modifications described in Job 101.2 that are applicable to Job 101.3 should be adopted.

Job 101.4 Laboratory and pond experiments

OBJECTIVE: To evaluate the role of forage base and predators in determining the survival and growth of walleye fry and fingerlings in laboratory and pond experiments.

INTRODUCTION: Walleye fry consume zooplankton exclusively, but as they grow and their gape becomes less limiting, their diet broadens to include invertebrates and small fish. In general, walleye are piscivorous after reaching about 50 mm if forage fish are available. However, the availability of appropriately-sized forage fish is highly variable both across impoundments in any given year and from year-to-year within one impoundment. If appropriately-sized forage fish are unavailable or low in abundance when fingerling walleye are ready to switch to piscivory, reliance of benthos may be necessary for walleye fingerling survival.

We previously conducted walleye growth and survival experiments using juvenile walleye placed in bags. Some bags had access to the benthos and others did not. We added either no, low, or high densities of bluegill as additional forage for the walleye. We found that the growth of juvenile walleye was positively correlated with the amount of supplemental forage fish added. Next, we further investigated the importance of relative abundance of forage fish and benthos in walleye foraging in the laboratory. In addition, we also conducted experiments examining growth of juvenile walleye given different prey types to provide insight into the importance of prey type in walleye growth.

METHODS: *Bag experiments*--Detailed methods of the growth and survival experiments of juvenile walleye in bags with and without access to benthos have previously been described (see Clapp et al. 1996). Briefly, we placed 10 juvenile walleye (about 50 mm) into each of 24 bags (1- m diameter, 1.3 m deep) and provided them with different prey treatments (access to or restriction from benthos, and manipulated additional forage fish--either none, a low density, or a higher density) for 3 weeks after which we measured length, weight and calculated survival.

Foraging Behavior Experiments--These experiments were designed to offer juvenile walleye a prey choice from a continuum varying from just benthos to forage fish only, with intermediate combinations of benthos and fish. Prey organisms included benthos (fourth instar Chironomus sp. larvae) and forage fish (bluegill, 15 - 20 mm). Benthos density was held constant at 444 midge larvae/m^2, a density that is within density ranges found in the field. Bluegill density was either a high density (83/m^3) or a low density (28/m^3). Juvenile walleye (60 - 70 mm TL) were offered the following treatments: benthos only, low bluegill plus benthos, high bluegill plus benthos, and high bluegill density only. Each walleye was given each prey treatment in random order, 24 hours apart.

A single juvenile walleye was placed into a holding area separated by a plexiglas divider from the rest of the aquarium (72 L) 24 hours before running an experiment. To acclimate forage fish, bluegill were netted into a floating corral in the experimental arena for 24 hours prior to experimentation. Four ice cube trays were filled with wet vermiculite and two plastic plants were place randomly in each tray. In trials with benthos, using forceps, two chironomid larvae were placed into each compartment of each tray. The ice cube trays were gently lowered into the experimental arena and allowed to settle for one hour before beginning the experiment. To begin an experiment, the forage fish and walleye were released and visual observation began. We recorded the pursuit of bluegill and strikes and captures of both prey types. At 5 minute intervals we recorded the location of the walleye (either high or low in the water column) and the number of bluegill high or low in the water column and whether they were dispersed or congregated. After 1 hour the walleye was corralled back into the holding area and the prey were removed from the tank.

Growth experiments--In these experiments, juvenile walleye (45-52 mm) were fed either zooplankton, benthos, or bluegill ad libitum to determine if prey type influenced their growth. We weighed and measured two walleye and then placed them into a 38-L aerated aquaria. We had eight replicate tanks for each of three treatments. Appropriate prey were added in the following densities: 500 zooplankters/L, 385 midge larvae/m^2, and 79 bluegill/m^3. Prey densities were checked five times daily. Zooplankton was subsampled using a plastic tube and the density was supplemented when the density fell below 200 zooplankters/L. We initially stocked a density of 153 large midge larvae/m^2 into each tank. Although the number of midge larvae available at each time interval varied, we ensured that there was a surplus of at least ten visible larvae per tank at all times. We initially stocked a density of 46 bluegill (15-20 mm)/m^3 into each tank. At subsequent time intervals, we replaced consumed bluegill with an equal number of new bluegill so that 46/m^3 was a maximum density available to walleye. After 5 days, all walleye were again weighed and measured and the experiment was terminated.

RESULTS: *Bag experiments*--The majority of the results of the walleye bag experiments have been given previously (see Clapp et al. 1996). Briefly, we found that growth of juvenile walleye was positively correlated with the amount of forage fish added. Access to benthos had no effect on growth. Survival was not affected by forage treatment. We have now also processed walleye stomachs collected during the experiment (Figure 4). Fish dominated the diets of walleye in the high forage fish density treatment. Benthos, fish and zooplankton were all important in the diets of walleye receiving low forage fish density. Benthos was more important than zooplankton in the diets of walleye receiving no forage fish. But in both the low and no forage fish treatments, walleye consumed more benthos in the treatment that had no access to benthos than the treatment which did have access to benthos. Thus, we were unsuccessful in our attempt to restrict access to benthos.

Foraging behavior experiments--Juvenile walleye preferred bluegill over chironomid larvae. Walleye searched for and pursued bluegill throughout the experiment. Walleye generally had a higher efficiency on chironomids when fish were present compared to when they were absent (Figure 5). In the presence of forage fish, walleye foraged for chironomid larvae only when they actually saw a larvae, while in the absence of forage fish, walleye foraged more generally and did not only attack visible larvae. Walleye selected prey in proportion to the relative abundances of each prey type present (see Figure 6). Thus, the most chironomids were eaten when only chironomids were available. Much fewer were eaten when fish were also available at a low density, and even fewer were eaten when fish were available at a high density. Likewise, the number of bluegill eaten increased when their relative abundance in the environment was higher. In this manner, bluegill replaced chironomids as prey as they became more available.

Growth experiments--Walleye fed bluegill gained the most weight of all three prey types. Those fed chironomids gained more weight than those fed zooplankton (Figure 7). So, though all walleye were fed ad libitum, prey type influenced growth of walleye.

In the bag experiments, we showed that juvenile walleye growth is positively correlated with forage fish density. We found no additional advantage to including benthos in walleye diets, but these results are inconclusive since benthos was still eaten in our no benthos treatment. The foraging behavior experiments showed that juvenile walleye preferred bluegill to benthos, but that as forage fish were less abundant, they foraged more heavily on benthos. This preference for forage fish when walleye reach 50-60 mm is likely explained by larger mouth gapes, and was reflected in the results of our growth experiments. Walleye of this size grew better when they can feed completely on forage fish than when having to rely on either just benthos or zooplankton.

RECOMMENDATIONS: These combined experiments emphasize that the quality and amount of prey available to juvenile walleye is important in determining their growth. High forage fish abundance will lead to faster walleye growth. We would predict that reliance upon benthos when forage fish abundance is low would decrease juvenile walleye growth. Therefore, maximum walleye growth would occur where abundances of appropriately-sized forage fish is high. These results will be very helpful in interpreting our field data on the importance of prey availability in determining growth and survival of stocked walleye.

Job 101.5 Analysis and reporting

OBJECTIVE: To prepare annual and final reports which develop management guidelines for stocking walleye in Illinois impoundments.

RESULTS AND RECOMMENDATIONS: Relevant data were analyzed and reported in individual jobs of this report (see Job 101.1-101.4).

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Table 1. Summary of experimental walleye fry stockings in Illinois impoundments in 1996. Area is impoundment area in hectares. Temperature change is the difference between hatchery temperature and lake temperature at stocking. Stocking mortality was determined by holding fry (N=100) in each of three plastic tubs for 24 h following stocking.

Lake (Area)	Stocking Date	Number per Hectare	Lake Temperature (·C)	Temperature change (·C)	Stocking mortality (%)
East Fork (379)	4/27/96$_a$	1,273	14.2	-2.5	6.0
	4/27/96$_b$	1,273	14.2	-2.5	6.0
Le-Aqua-Na (16)	4/17/96	2,713	10.0	-5.6	33.0
Randolph Co (26)	4/26/96	2,500	16.0	+2.0	8.2
	5/10/96	2,500	22.8	+7.2	21.1
Ridge (6)	5/10/96	3,333	20.5	+8.3	5.5
Sara (237)	4/28/96$_a$	1,266	14.3	+0.2	14.8
	4/28/96$_b$	1,266	14.3	+0.2	14.8
Shelbyville (4,455)	4/26/96	1,750	---	---	---
	5/10/96	168	17.2	+5.0	20.9
Springfield (1,715)	4/26/96	1,574	14.0	-1.8	19.5
Sterling (53)	4/16/96	1,396	8.0	-7.6	3.6

a = stocked offshore; b = stocked inshore

Table 2. Fall (September-November) 1996 catch per unit effort and growth of stocked walleye fry. Increment is the growth since stocking of fish collected, based on an average size of 6 mm at stocking.

Lake	Fall mean TL (mm)	Increment (mm)	Number examined (# collected)	CPUE (fish/h)	Population estimate (% survival)
East Fork (Inshore)	186	180	3 (11)	1.03	56 (0.9)
(Offshore)	---	---	0	---	---
Le-Aqua-Na	182	176	1 (3)	0.38	3 (<1)
Randolph (Early)	227	221	3 (3)	0.23	---
(Late)	194	188	1 (1)	0.01	---
Ridge	258	252	14 (17)	4.14	---
Sara (Inshore)	215	209	9 (10)	0.68	10 (<1)
(Offshore)	209	203	6 (6)	0.41	6 (<1)
Shelbyville	160	154	79 (137)	7.47	516 (<1)
Springfield	---	---	0	---	---
Sterling	185	179	2 (6)	0.27	6 (<1)

Table 3. Summary of experimental walleye fingerling stockings in Illinois impoundments in 1996. Area is impoundment area in hectares. Total lengths of a subsample (N=50-100) of walleye were measured prior to stocking. Temperature change is the difference between hatchery temperature and lake temperature at stocking. Stocking mortality was determined by holding fingerlings (N=30-40) in each of three cages for 24 h following stocking.

Lake (Area)	Stocking date	Mean TL (mm)	Number per hectare	Lake Temperature (·C)	Temperature change (·C)	Stocking mortality (%)
Bloomington (250)	6/04/96$_a$	40	51	17.2	-0.6	1.0
	6/04/96$_b$	45	51	17.2	-0.6	1.0
East Fork (379)	6/11/96	43	99	21.8	+1.9	1.3
Kinkaid (1,114)	6/05/96$_a$	~50	23	26.3	+7.0	5.3
	6/05/96$_b$		23	26.3	+7.0	5.3
	6/11/96$_a$		13	---	---	---
	6/11/96$_b$		13	---	---	---
Le-Aqua-Na (16)	6/11/96	47	109	17.0	-1.5	2.4
	8/13/96	104	71	26.7	+5.0	0.0
Pierce (66)	6/05/96	46	61	18.0	-1.0	0.0
	6/18/96	43	61	24.0	+5.0	1.1

Table 3. continued...

Lake (Area)	Stocking date	Mean TL (mm)	Number per hectare	Lake Temperature (·C)	Temperature change (·C)	Stocking mortality (%)
Randolph Co (26)	6/11/96	48	100	27.3	---	0.0
	8/15/96	118	63	30.6	+1.2	87.3
	8/22/96	125	63	29.0	+1.0	0.0
Ridge (6)	6/05/96	~50	117	21.0	---	---
	8/22/96	--	67	30.5	+5.5	20.1
Sam Dale (78)	6/11/96	45	50	21.1	+1.1	7.1
	6/17/96	44	50	32.0	+10.0	12.0
Sara (237)	6/05/96	45	99	22.7	+4.6	0.0
Shelbyville (4,455)	6/13/96	52	3	25.6	+5.0	24.5
	6/14/96	52	3	26.0	+5.0	31.0
	6/17/96	~52	1.6	---	---	---
	7/11/96	62	21	29.0	+4.0	53.3
Sterling (53)	6/11/96	48	51	18.5	-1.5	5.0
	8/20/96	93	35	27.3	+2.0	0.0

a = stocked offshore b = stocked inshore

Table 4. Fall (September-November) catch per unit effort and growth of stocked walleye fingerlings. Increment is the growth since stocking. Number examined refers to number of fish examined for OTC marks. CPUE refers to electrofishing-caught fish only.

Lake	Length at stocking (mm)	Fall mean TL (mm)	Increment (mm)	Number examined (# collected)	CPUE (fish/ h)	Population estimate (% survival)
Bloomington (Inshore)	40	226	186	15 (27)	2.53	---
(Offshore)	45	223	178	8 (15)	1.40	---
East Fork	43	182	139	64 (228)	21.43	1,110(3.0)
Kinkaid (Inshore)		---	---	0	0	---
(Offshore)	45	194	149	2 (2)	0.16	---
Le-Aqua-Na	47	161	114	17 (44)	5.57	48 (2.8)
	104	129	25	28 (28)	3.54	56 (4.9)
Pierce (Early)	46	224	178	9 (21)	0.93	45 (1.1)
(Late)	43	226	183	14 (33)	1.46	69 (1.7)
Randolph Co	48	199	151	11 (12)	0.90	---
	122	158	36	4 (4)	0.30	---
Ridge	~50	268	218	2 (3)	0.73	---
	~100	147	47	10 (10)	2.44	---
Sam Dale (Early)	45	207	162	15 (16)	1.79	---
(Late)	44	---	---	0	0	---
Sara	45	225	180	27 (29)	1.98	19 (0.1)

Table 4. continued...

Lake	Length at stocking (mm)	Fall mean TL (mm)	Increment (mm)	Number examined (# collected)	CPUE (fish/ h)	Population estimate (% survival)
Shelbyville	57	137	80	77 (134)	7.30	503
Sterling	48	195	147	28 (77)	3.50	77 (2.9)
	93	139	46	21 (21)	0.96	31 (1.7)

Table 5. Percent occurrence of forage fish in seine (S) or blocknet (B) samples and walleye diets (D) in each study lake. Number examined for seines and blocknet is the total number of individuals collected in shoreline sampling between May and October in each year. Number examined for diet samples is number of walleye stomachs examined during this same time period. Percent of stomachs empty is shown in parentheses. Other fish includes primarily cyprinids and unidentified fish; other non-fish are primarily insects and zooplankton.

Lake	Sample type	Number (% empty)	Forage Group				
			Centrarchidae	Atherinidae	Clupeidae	Other (fish)	Other (non-fish)
Bloomington	(S)	410	94	0	3	2	0
	(D)	130(30)	9	0	49	35	7
East Fork	(S)	4,232	95	0	<1	2	3
	(D)	115(0)	85	1	4	4	6
Kinkaid	(S)	1,204	59	0	1	40	0
	(D)	7(0)	71	0	29	0	0
Le-Aqua-Na	(S)	2,484	99	0	0	<1	0
	(D)	123(41)	52	0	0	32	15

Table 5. continued...

Lake	Sample type	Number (% empty)	Forage Group				
			Centrarchidae	Atherinidae	Clupeidae	Other (fish)	Other (non-fish)
Pierce	(S)	6,505	57	34	<1	10	0
	(D)	709(28)	36	6	11	23	23
Randolph Co	(S)	717	97	0	0	1	2
	(D)	29(0)	38	0	0	7	55
Ridge	(S)	1,572	99	0	0	<1	0
	(D)	20(65)	57	0	0	29	14
Sam Dale	(S)	4,136	85	2	6	8	<1
	(D)	28(0)	36	21	7	32	4
Sara	(S)	986	64	0	<1	36	<1
	(D)	61(0)	16	2	80	2	0
Shelbyville	(S)	211	31	9	16	43	0
	(D)	101(3)	27	50	12	11	0
Springfield	(S)	2079	63	9	6	22	0
	(D)	123(32)	4	2	65	29	0
Sterling	(S)	765	14	21	0	65	0
	(D)	503(33)	22	10	0	54	14

Table 6. Numbers of stocked walleye fingerlings consumed by largemouth bass during the week following stocking. Walleye total length (TL, mm) is mean length of fingerlings at stocking. Minimum bass total length is the size of largemouth bass capable of consuming stocked walleye (based on a predator:prey ratio of 0.57). Population estimates are fall, modified-Schnabel estimates. Percentage walleye consumed is the percentage of the total number of stocked walleye consumed by largemouth bass.

Lake	Walleye length (TL, mm)	Minimum largemouth bass length (TL, mm)	Largemouth bass population estimate	Number of LMB examined	Walleye per stomach	Percent walleye consumed
Bloomington	40	70	2,990	87	0.00	0
	45	79	2,990	87	0.00	0
East Fork	43	84	8,441	262	0.09	2.03
Kinkaid (Inshore)	45	79	---	137	0.34	---
(Offshore)	45	79	---	137	0.00	---
Le-Aqua-Na	47	82	107	121	0.00	0
	104	182	107	25	0.00	0
Pierce	46	81	1,706	71	0.00	0
	43	75	1,706	43	0.00	0
Randolph Co.	48	84	3,128	119	0.01	1.20
	118	207	3,128	75	0.08	15.16
	125	219	3,128	173	0.03	5.70
Ridge	50	88	291	0	0.00	0
	100	175	291	16	0.00	0

Table 6. continued...

Lake	Walleye length (TL, mm)	Minimum largemouth bass length (TL, mm)	Largemouth bass population estimate	Number of LMB examined	Walleye per stomach	Percent walleye consumed
Sam Dale	45	79	7,484	254	0.004	0.77
	44	79	7,484	230	0.000	0
Sara	45	79	10,115	144	0.013	0.56
Shelbyville	57	100	---	16	0.190	---
Sterling	48	84	143	55	0.000	0
	93	163	143	39	0.077	0.40

Table 7. Relative survival of walleye fry, 50-mm fingerlings, and 100-mm fingerlings stocked in eleven Illinois impoundments.

Lake	Size Group	Number stocked	Number collected	Relative survival
Bloomington	Inshore(50mm)	12,700	27	1.8
	Offshore	12,700	15	1
East Fork	Fry	965,000	11	1
	50 mm	37,400	228	550
Kinkaid	Inshore(50mm)	40,000	0	---
	Offshore	40,000	2	---
Le-Aqua-Na	Fry	43,400	3	1
	50 mm	1,736	44	367
	100 mm	1,139	28	356
Pierce	Early (50mm)	4,055	21	1
	Late	4,000	33	1.6
Randolph Co.	Fry	130,000	4	1
	50 mm	2,600	12	150
	100 mm	1,650	4	79
Ridge	Fry	20,000	17	1
	50 mm	700	3	5.0
	100 mm	400	10	29
Sam Dale	Early (50mm)	3,880	16	---
	Late	3,880	0	---
Sara	Fry	600,000	16	1
	50 mm	23,400	29	46
Sara	Offshore(Fry)	300,000	6	1
	Inshore	300,000	10	1.7
Shelbyville	Fry	8.55mil	137	1
	50 mm	130,786	134	64
Sterling	Fry	74,000	6	1
	50 mm	2,690	77	353
	100 mm	1,850	21	140

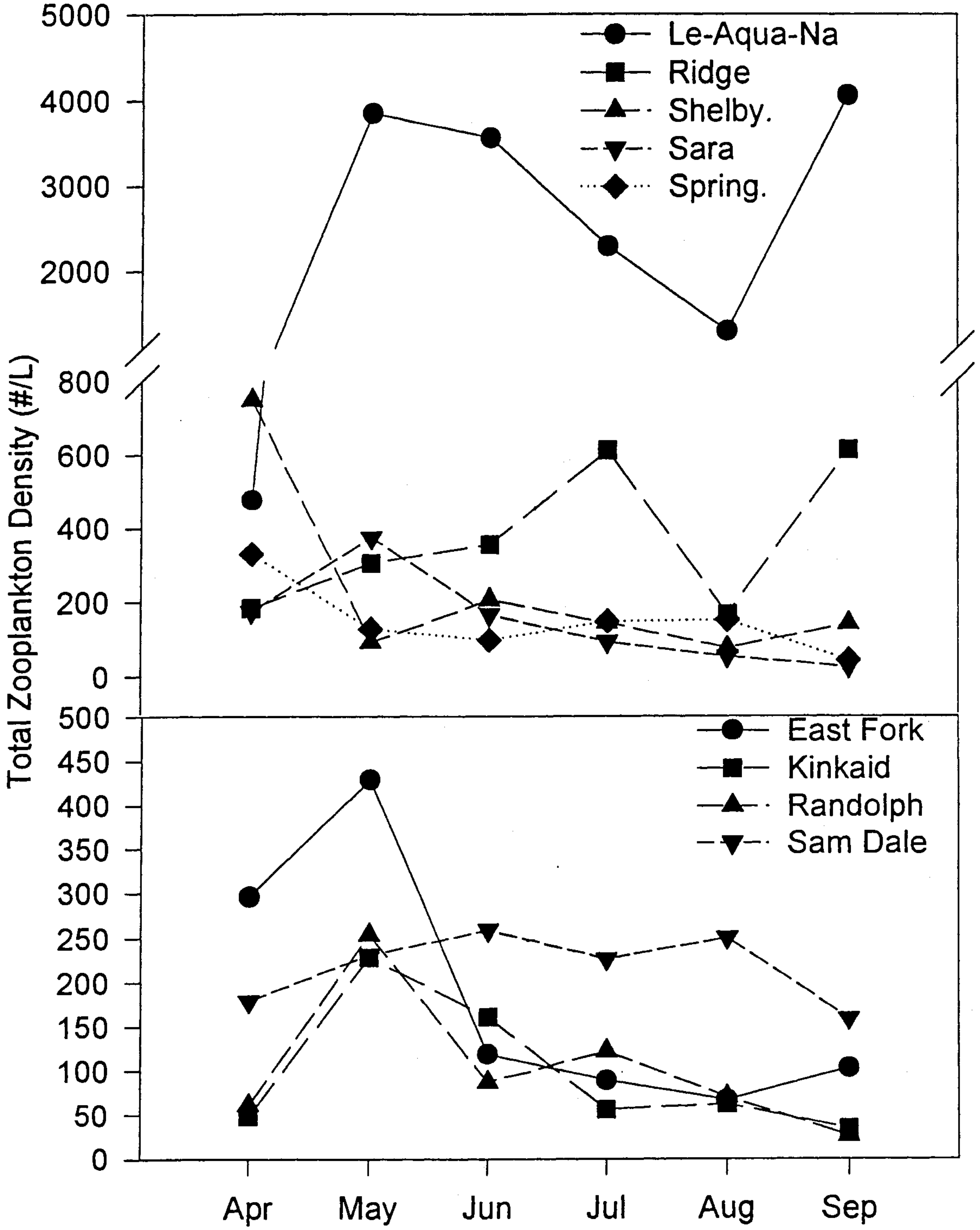

Figure 1. Total zooplankton density on nine walleye study lakes. Total includes crustacean and rotifer densities.

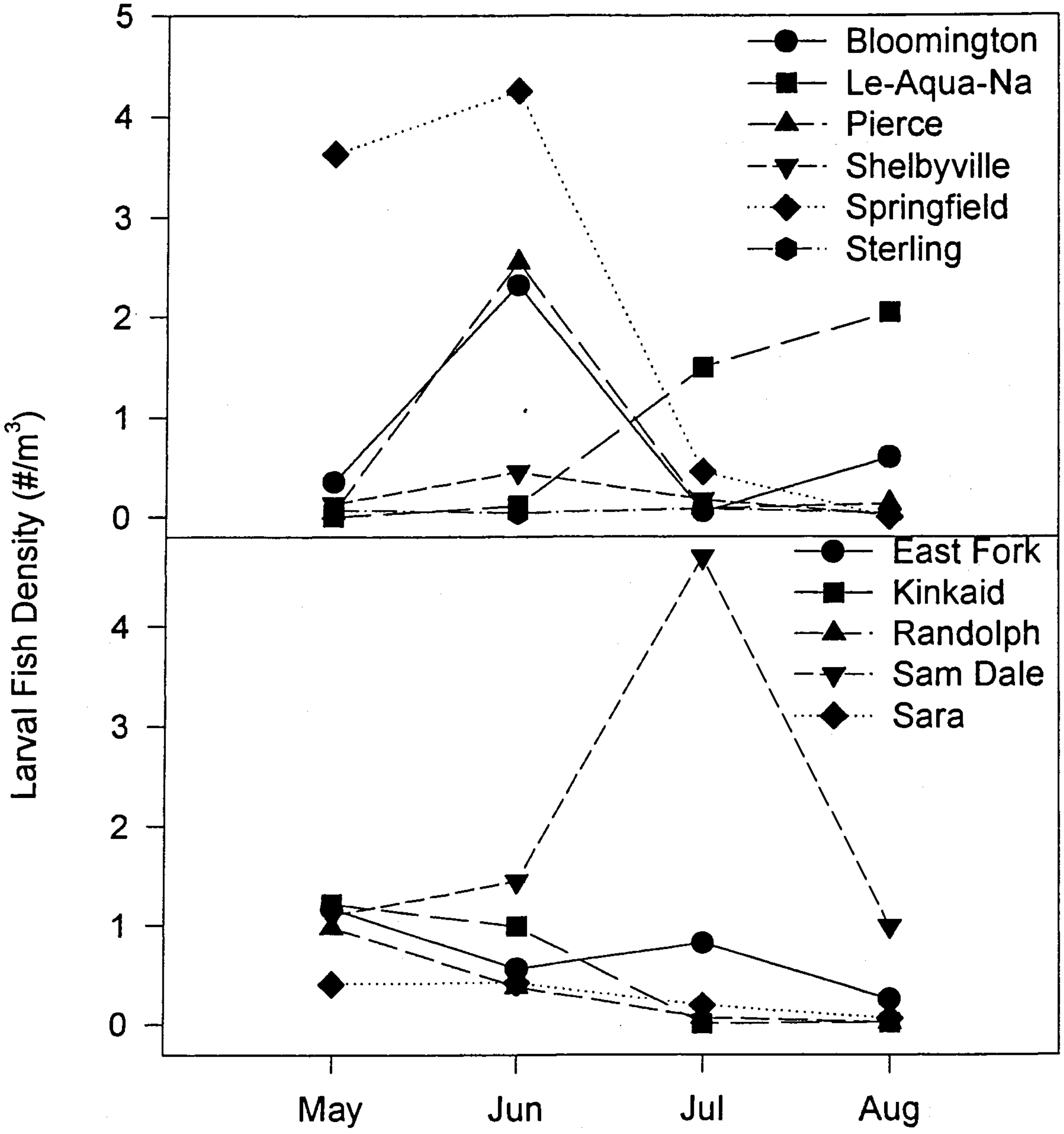

Figure 2. Total larval fish density on eleven walleye study lakes

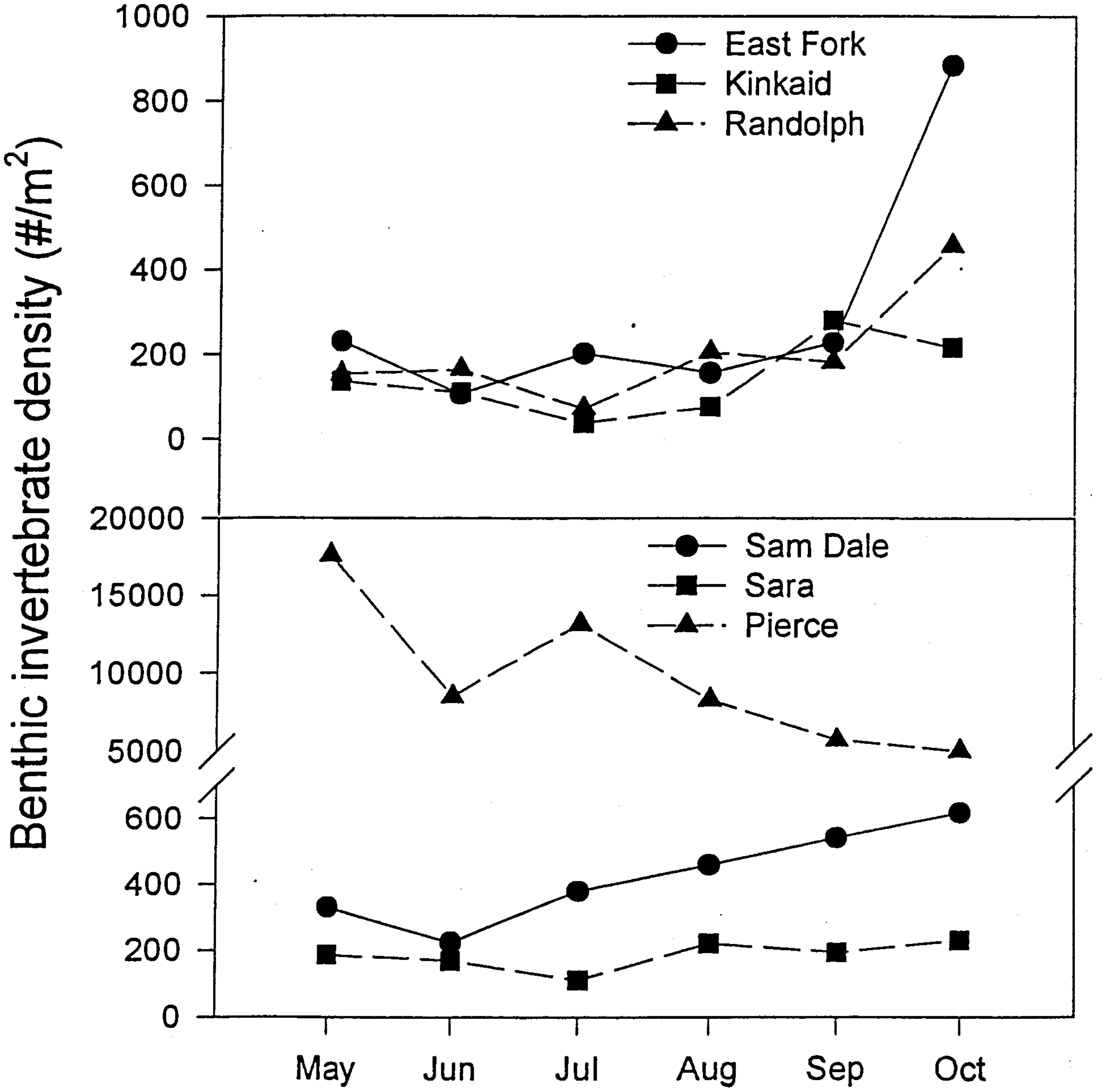

Figure 3. Total benthic invertebrate density on six walleye study lakes.

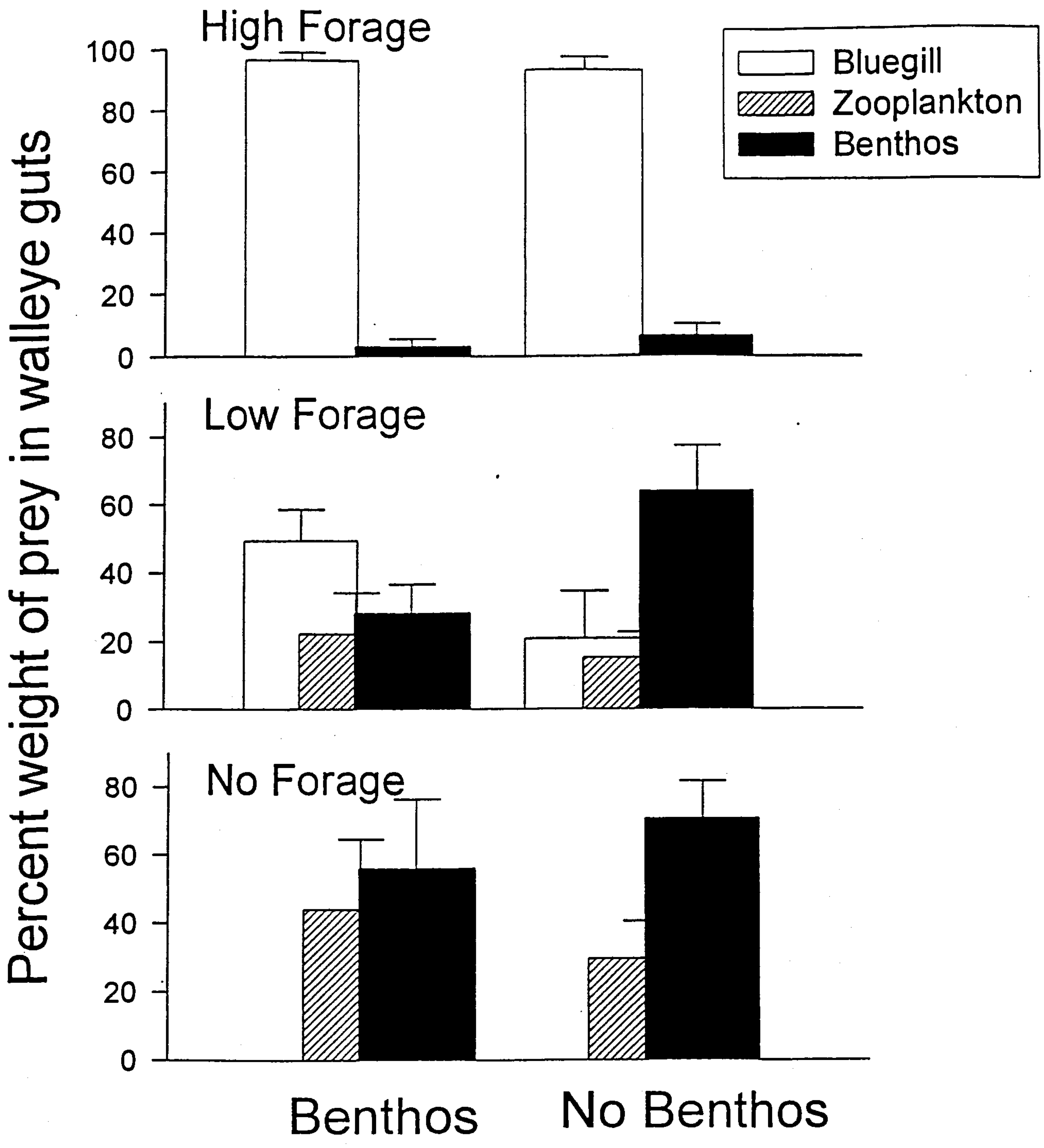

Figure 4. Stomach contents, by weight, of fingerling walleye fed three levels of forage fish and either having access to or being restricted from consuming benthos. Vertical bars represent standard errors.

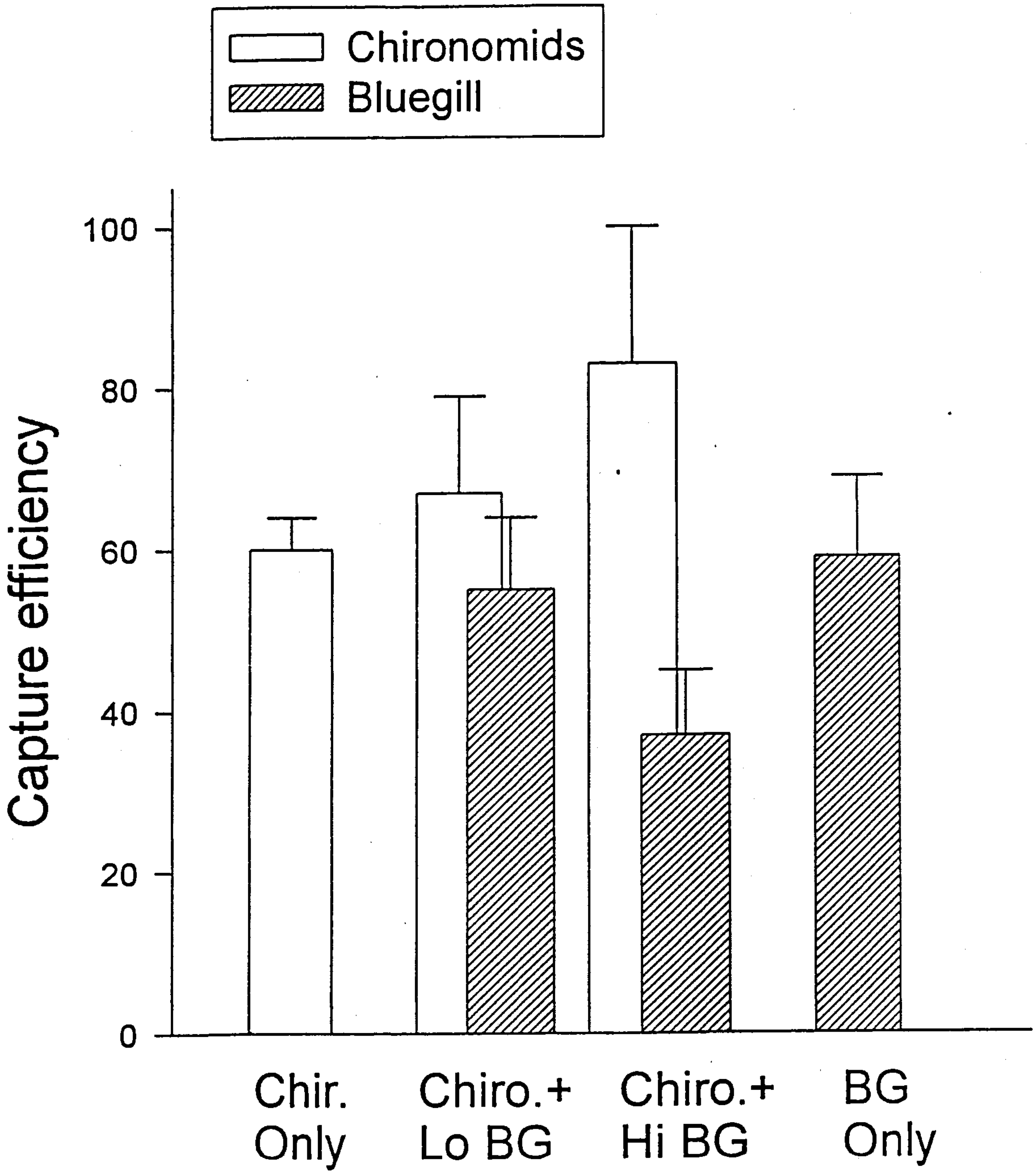

Figure 5. The capture efficiency (captures/strike) of juvenile walleye during foraging behavior experiments. Treatments included: chironomid larvae only, bluegill only, or a combination of taxa with a low and high density of bluegill. Vertical bars represent ± 1 SE.

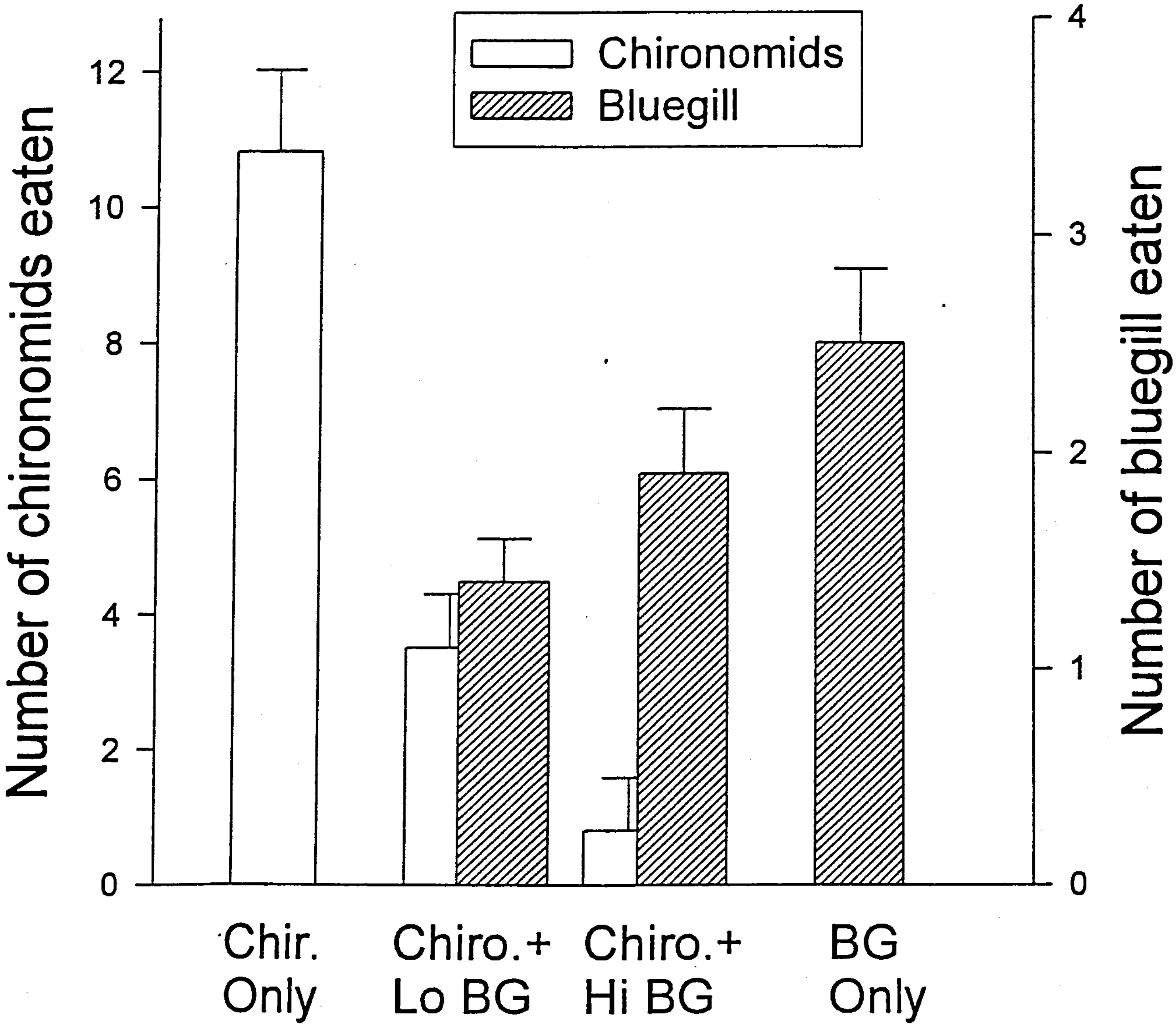

Figure 6. The number of chironomid larvae and bluegill eaten by juvenile walleye during foraging behavior experiments. Vertical bars represent ± 1 SE.

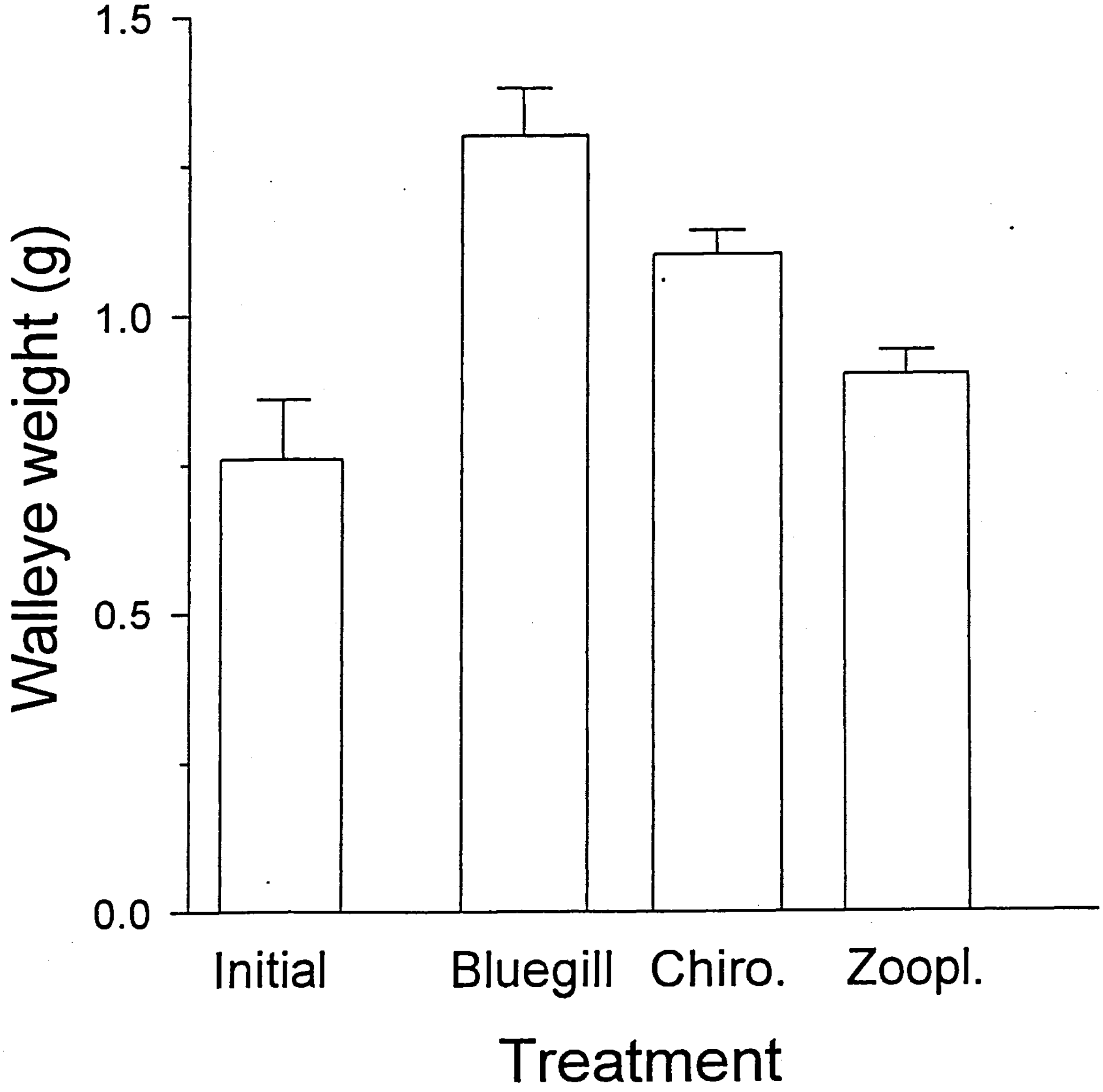

Figure 7. Weight of juvenile walleye before and after growth experiment. Walleye were fed either: bluegill, chironomid larvae, or zooplankton. Vertical bars represent ± 1 SE.