INTERACTION BETWEEN INTRODUCED RAINBOW TROUT AND THREE NATIVE FISHES FOR FOOD RESOURCES IN AN OZARK STREAM

By

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CHAPTER I.

INTRODUCTION

This thesis is composed of one manuscript written in the format for submission to the Transactions of the American Fisheries Society. Chapter I is an introduction to the rest of the thesis. The manuscript is as follows; Chapter II, "Interaction between introduced rainbow trout and three native fishes for food resources in an Ozark stream."

CHAPTER II.

INTERACTION BETWEEN INTRODUCED RAINBOW TROUT AND THREE NATIVE FISHES FOR FOOD RESOURCES IN AN OZARK STREAM

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Abstract

We compared the gut contents of introduced rainbow trout (*Oncorhynchus mykiss*) to those of native bluegill (*Lepomis macrochirus*), shadow bass (*Ambloplites ariommus*), and smallmouth bass (*Micropterus dolomieu*) to assess the potential for competition for food and potential feeding acclimation in Brush Creek, Oklahoma, a small springfed stream on the Ozark Plateau. Trout diet was not associated with residence time in the stream, but seasonal effects were detected. Rainbow trout diet differed from all three native fishes in the two months of comparison (March and May). Some prey items were shared with native fishes, but Bray-Curtis similarity values were low in both months. The diet of bluegill was more similar to that of rainbow trout diet, than those of shadow bass and smallmouth bass. Rainbow trout contained relatively low numbers of animal items. This, together with warm summer temperatures probably explains the observed loss in lipid and weight content throughout the study. It is unlikely that exploitative competition for food resources occurred between rainbow trout and the three native fishes examined.

Introduction

Over 140 species and 24 families of fresh-water fish in North America have expanded their ranges through introduction (Moyle 1985). East of the Rocky Mountains, introduced fish represent nearly 10% of the species in most drainages, whereas in the western United States they often represent between 35 to 59% of the fish fauna. Non-native fishes have been introduced for a variety of reasons, including sport fish enhancement and creation, biological control of pests, release of unwanted aquarium fish, dumping of bait buckets, and escape from aquaculture facilities. Widespread environmental change has also contributed to ichthyofaunal changes (Moyle et al. 1986).

In managing fisheries, agencies have typically regarded introductions as successful if the target fishery is enhanced, with little regard to ecosystems or long-term effects (Courtenay et al. 1986). Impacts of fish introductions have ranged from subtle changes in community structure and function to extirpation of local fish populations. For fishery enhancement purposes, most introduced fish are transferred from hatcheries and typically are behaviorally different from wild fishes. Hatchery-reared rainbow trout (*Oncorhynchus mykiss*) are typically bred for high feeding and growth rates that may accompany greater aggression and competitive ability (Kinghorn 1983). For example, Bachman (1984) observed that hatchery brown trout engaged in more agnostic encounters and won more contests than wild fish. In a Minnesota stream, introduced brown trout (*Salmo trutta*) completely replaced brook trout (*Salvelinus fontinalus*) over a 15-year period (Waters 1983).

Throughout the Great Basin of western North America, cutthroat trout (*Salmo clarki*) have been replaced by more aggressive, hatchery-reared rainbow trout and brown trout (Moyle and Vondracek 1985). In Great Smokey Mountains National Park, Larson and Moore (1985) documented large reductions in the range of native brook trout coupled with expanded distribution of introduced rainbow trout. The length of stream occupied solely by brook trout declined 60% during a 40-year period. Vincent (1987) showed that rainbow trout introductions in two Montana streams were associated with a decreased biomass (49%) and increased movement of previously stocked brown trout. Other studies have examined effects of introduced trout on a microhabitat scale. Fausch and White (1981) found that brook trout moved into more favorable resting positions after removal of brown trout. DeWald and Wilzbach (1992) found that native brook trout lost weight and shifted microhabitat positions in the presence of brown trout in artificial streams.

Although extensive research has been conducted on interspecific interactions among introduced and native salmonids, there is limited information regarding interactions between introduced rainbow trout and native fishes in warmwater streams. A study in the Little Missouri River, Arkansas found that introduced rainbow trout exhibited little or no feeding, with food items such as corn, gravel, and trout pellets forming the majority of the diet (Ebert and Filipek 1991). The investigators suggested that introduced trout go through a fairly long acclimation period before beginning to feed. They also suggested that competition between smallmouth bass and rainbow trout was minimal, due to a lack of trout feeding on natural prey items, low post stocking survival, and decreased activity of smallmouth bass during winter stocking months. A more recent study in the same system documented that trout actively fed on a variety of invertebrates within 30 days of stocking, suggesting less acclimation time than previously thought (Metcalf et al. 1997). Other studies in coldwater streams have shown similar results, suggesting that trout adapted to a natural food diet following stocking (Lord 1934, Raney and Lachner 1942, Ersbak and Haase 1983, Bachman 1984, Dewald and Wilzbach 1992). However, it has been well documented in both warmwater and coldwater streams that growth and condition of hatchery-reared trout decrease following their release (Needham and Slater 1945, Miller 1958, Reimers 1963, Ersbak and Haase 1983, Metcalf et al. 1997) and that survival of stocked trout into the next season is rare. In Oklahoma, hatchery reared rainbow trout have been stocked into reservoir tailwaters; however, there has been increased demand by private angling groups for rainbow trout releases into streams of northeastern Oklahoma. Most of these streams have native fish populations common to the Ozark region and little is known regarding interactions between introduced rainbow trout and native fishes in these systems.

Our objectives were to 1) assess growth and condition of introduced rainbow trout in an Ozark stream to evaluate their potential for long-term survival and to 2) examine food habits of introduced rainbow trout and three native fishes (smallmouth bass (*Micropterus dolomieu)*), shadow bass (*Ambloplites* *ariommus*), and bluegill (*Lepomis macrochirus*) to assess diet overlap and the potential for resource competition.

Methods

Study Site

Brush Creek, Delaware County, Oklahoma, is a spring-fed Ozark stream with a well-developed riffle-pool sequence. It is approximately 8 km in length with a mean stream width of 8.9 m. Substrate is predominately gravel-cobble sized dolomitic limestone and there are deposits of fine materials in the backwaters and deep pools. Pools over 2 m in depth and formed primarily by bedrock lateral scours and, to a lesser extent, root-wad lateral scours are common. Temperatures are relatively constant at the headwaters where springs are abundant but become more variable downstream where springs are smaller and less common. The study site was a large, bedrock formed pool 45 m in length with an average width of 13 m and depth of 2.1 m. The pool was in the midsection of the stream where water temperatures were relatively variable. Average daily temperatures ranged from 6.5° C in winter to 23.5° C in late summer. The fish assemblage was typical of streams in this region and consisted primarily of central stoneroller (*Campostoma anomalum)*, cardinal shiner (*Luxilus cardinalis)*, southern redbelly dace (*Phoxinus erythrogaster*), creek chub (*Semotalis atromaculatus*), redspot chub (*Nocomis asper*), white sucker (*Catostomus commersoni),* orangethroat darter (*Etheostoma spectabile*), stippled darter (*Etheostoma punctulatum*) banded sculpin (*Cottus carolinae*), yellow bullhead (*Ictalurus natalis*), longear sunfish (*Lepomis megalotis*), bluegill (*Lepomis macrochirus*), green sunfish (*Lepomis cyanellus*), shadow bass (*Ambloplites ariommus*) smallmouth bass (*Micropterus dolomieu*), largemouth bass (*Micropterus salmoides*), and spotted bass (*Micropterus punctulatus*).

Field Sampling

We stocked 2500 rainbow trout at a rate of 500 trout per month from November 2000 through March 2001. Fish were weighed to the nearest gram, measured for total length, and tagged with floy tags before stocking. Floy tags were individually numbered and each monthly cohort was given a different tag color. Trout were sampled using a boat mounted Smith-Root 2.5 GPP electrofishing system (AC) between the hours of 0900 and 1000. We sampled trout at monthly intervals from November 2000 through August 2001 to examine diet and growth. All trout captured were identified by tag number and color and weighed to the nearest gram and total length was measured to the nearest millimeter. A representative sample (8-11) from each cohort was sacrificed for diet analysis. Stomachs were removed in the field and preserved in 10% formalin for stomach content identification in the lab. In total, 219 trout stomachs were collected and examined. Prey items were enumerated and identified to the lowest practical taxon. We identified fish remains to species, insects to family, and other invertebrates to order.

We sampled drifting invertebrates in January, March and May to determine seasonal shifts in prey availability. Four drift nets were placed directly upstream of the study site for one hour to collect drifting invertebrates.

Samples were placed in 10% formalin and brought to the lab for enumeration and identification.

Trout sacrificed in the months of February and March were frozen for subsequent lipid analysis. Lipid extractions followed Hamilton et al. (1992). We ground individual fish using a meat grinder and extracted 2-3 samples per fish for lipid analysis. Wet weights for each sample ranged from 2.5 to 3 g and were placed on weighed filter paper and dried in an oven at 75° C for approximately 12 hours. Dry weights of each sample were recorded and extracted in petroleum ether for 24 hours. After extraction, samples were air dried for 30 minutes then dried in an oven for one hour. Extracted dry weights were recorded, and lipid content was computed as the difference in weights before and after extraction. Results were expressed as mean percent lipid content for each cohort.

Bluegill, shadow bass, and smallmouth bass diets were examined in March and May of 2001 and compared to trout diets. In March and May, sample size was, respectively, 13 and 21 for bluegill, 12 and 27 for shadow bass, and 17 and 35 for smallmouth bass. We originally wanted to separate adult and juvenile smallmouth bass. Because of low sample size of juveniles (less than 10 captured over two years), we were only able to assess adult smallmouth bass diets. We used two non-lethal methods to remove prey items from native fishes. For bluegill and smaller shadow bass we used a stomach pump (Giles 1980), in which a plastic tube was inserted through the esophagus into the stomach and prey items were flushed out into a tray. For smallmouth bass and larger shadow bass, we used a glass tube (Van Den Avyle and Roussell 1980) that was inserted through the esophagus, into the stomach, and prey items were removed by either creating a vacuum, flushing water into the tube, or with a retractable claw remover (Dimond 1985). Different diameters of glass tubes were used depending on size of the esophagus.

Analysis

Rainbow Trout Growth. – Lipid content and weight change were used to assess growth of rainbow trout. Lipid content was analyzed on four cohorts in February and five cohorts in March with residence times ranging from zero days (hatchery fish) to 130 days. Linear regressions were used to assess if lipid content was related to residence time.

We analyzed weight change for fish stocked in November, December, February, and March. Each individually numbered trout was weighed prior to stocking and weighed upon recapture to determine the weight change since stocking. We used linear regression to determine weight change over time for each cohort. We compared slopes among cohorts using the GLM procedure in SAS to assess if date of stocking influenced growth rates.

Rainbow Trout Diet. – We compared diets among cohorts to determine if residence time in the stream influenced trout diets. We analyzed 4 cohorts on three separate sampling dates (February, March, and May). This allowed us to examine diets of fish that had resided in the stream from 7 to 180 days. We also combined cohorts and compared diets of rainbow trout among months (January, February, March, May, and August) to describe seasonal diet patterns.

We used the Bray-Curtis index to measure diet similarities among cohorts of trout (i.e., 7, 30, and 60 days residence time) and among seasons (Krebs 1989). This index ranges from 0 (indicating no similarity) to 100 (indicating identical diets). We used analysis of similarities (ANOSIM; Clark and Green 1988; McAleese 1997) to quantitatively compare differences among diets. This procedure computes all possible pairwise Bray-Curtis similarities among individual fish and then ranks them from lowest to highest. A test statistic (R) is computed by comparing average ranks within groups to those among groups (Clarke and Green 1988). The data is then repeatedly randomized and R is recalculated, resulting in a distribution of R values. The observed value of R is then compared to the distribution derived from the randomizations to determine the percentage of permutations that are greater than or equal to the observed value of R. If less than 5% of the randomizations were greater than or equal to the observed R, then we rejected the null hypothesis of no differences among groups. For diets showing differences between groups, we used Canonical Correspondence Analysis (CCA) with the CANOCO 4.0 (ter Braak and Smilauer 1998) program to examine dietary patterns. Canonical Correspondence Analysis is a multivariate, direct-gradient analysis that ordinates species according to measured environmental variables (ter Braak 1986). For the CCA, we used a square-root transformation of prey numbers to minimize the influence of large numbers of individuals in any one stomach and downweighted rare prey items to avoid an unduly large influence on the analysis that is common in CCA's (ter Braak and Smilauer 1998).

Native vs. Trout Diet Comparison. – We used analyses similar to those described above to compare diets of rainbow trout and native fishes (bluegill, shadow bass, and smallmouth bass) for March and May 2001. We used the Bray-Curtis index to measure diet similarities among species and ANOSIM to quantitatively compare differences in diets. CCA's were run to assess diet composition for all species.

Results

Trout Growth. - Lipid content significantly decreased with residence time for trout collected in February and March (slope = -0.0014, $p < 0.0001$ and slope = -0.0013, $p < 0.0001$, respectively, Figure 1). Trout weight also decreased over time for each cohort (Table 1, Figure 2). Total weight loss after stocking ranged from and average of 11 grams per fish (November cohort) to an average of 62 g per fish (March cohort) (Figure 2). The slope of the relationship was higher for March than for all other cohorts, affirming our hypothesis of increased weight loss during spring and summer (Table 1). The slope for the February cohort was greater than for November and December, implying that cohorts stocked closer to the summer had greater weight loss than those stocked earlier (Table 1). Fish stocked in November and December were the only cohorts with no difference in slope (Table 1).

Rainbow Trout Diet. – Seven days after stocking, 53% of trout had empty stomachs (Figure 3). After 30 days, only 14% of trout stomachs were empty and for trout in the stream for 60 days or more, percentage of empty stomachs was never higher than 13%, suggesting acclimation over time (Figure 3). Percentage of stomachs containing only non-animal items (mostly pebbles and leaves) showed no consistent association with residence time (Figure 3).

For trout with food items in their stomachs, residence time had little affect on diet composition. Only 4 of 18 possible comparisons differed significantly between residence times (Table 2). Cohorts sampled in February showed no effect of residence time (Table 2a). March samples showed relatively high similarities among cohorts (Table 2b), but fish sampled at 120 days after stocking differed significantly from fish sampled at 30 and 90 days (respectively, R = 0.156, P = 0.024 and R = 0.218, P = 0.006), suggesting relatively high overlap of prey items but different overall abundances of prey groups. Percent composition between 30 vs 90 and120 days showed relatively high overlap values (Table 3), but mean number of prey items eaten per fish was greater at 120 days than for 30 and 90 days (Table 3). This explains why Bray-Curtis values were relatively high for the two comparisons yet the diets differed significantly.

In May, only two of six comparisons differed from each other (Table 2c). Fish diets at 60 and 180 days were different (R = 0.469, P = 0.010) (Table 2c) and similarity was relatively low (21.73), suggesting that the percent composition of prey items differed between the two groups. Trout at 60 days fed primarily on ephemeropteran and plecopteran nymphs, pebbles and to a lesser extent on leaves and hemipterans (Table 4). In contrast, trout at 180 days fed primarily on hemipterans and gastropods (Table 4), resulting in low similarities and significantly different diets. Trout diets at 180 days were also different from trout diets at 150 days (R=0.259, P=0.026) and the similarity was relatively low. Trout at 150 days had a more even diet in which no prey item made up more than 17% of the diet (Table 4). Also, trout at 180 days averaged more prey items per fish compared to trout at 150 days. All other comparisons among cohorts showed no significant differences.

Most (14 of 18) comparisons among cohorts showed no significant differences; therefore, we grouped cohorts together for seasonal diet analysis of rainbow trout. All pairwise comparisons for January, February, March, May, and August showed significant differences from one another (Table 5). Canonical correspondence analysis indicated that pebbles comprised a large portion of trout diets for January and August samples (Figure 4, Table 6). Trout collected in January and August also had the lowest average number of prey items in their stomachs (1.26 and 1.10, respectively) compared to February, March, and May (5.41, 3.13, and 3.93, respectively). Correspondingly, drift-net samples showed species richness and abundance per net to be lowest in January (1 and 0.5, respectively) compared to March (13 and 8.5) and May (10 and 7.5) (Table 7). Drift samples were not obtained in February and August.

Trout diets in February and March were significantly different (Table 5), but, were in close proximity in the CCA biplot and similarity was relatively high between the two months (Table 5). The most commonly shared items were gastropods followed by isopods and heptageniids (Table 6). The significant difference in diets was attributable to abundances of prey items eaten in the two months, with average of 5.71 prey items per fish in February and 3.33 prey items in March.

Trout diets in May differed significantly from those in other months and had relatively similarities to those from other months. Trout in May fed primarily on hemipterans and unidentified ephemeropteran and plecopteran nymphs whereas in February and March gastropods and heptageniids were predominant items.

Trout diets in January and August differed significantly from each other and from other months. In January, mean number of prey items per fish was 3.53 with pebbles and leaves forming greater than 50% of the items (Table 6). Gastropods were the primary animal prey in January (Table 6). In August number of prey items per fish was low and greater than 50% of the items were pebbles and leaves (Table 6). Heptageniids, decapods, and fish were the primary animal prey in August (Table 6). Low species richness in January corresponded with low drift rates (Table 7).

Native/Trout Diet Comparison. - The diet of rainbow trout differed from that of native fishes in both March and May (Table 8). Similarity values were relatively low, although, CCA analyses indicated some sharing of items between trout and natives. For the three native species examined, the bluegill diet was most similar to that of rainbow trout. In March, bluegill and trout shared many prey items (Figure 5), but only heptageniids, isopods, and decapods represented more than 2% of the diets (Table 9). Trout were the only species to feed on snails (Figure 5) and these made up 53% of their diets (Table 9).

Similarity values were higher between trout and bluegill in May than in March; however, diets still differed significantly. The increased similarity reflected reduced numbers of snails in trout diets (Table 9 and 10). Trout fed primarily on chironomids (42%) and dytiscids (17%) with other prey items forming 1% to 6% of the diet (Table 10). Only trout and bluegill fed on gastropods, Gomphidae, chironomid pupae, dytiscids, ephemeropterans, and hemipterans (Figure 6). Other prey items such as chironomids, baetids, and polycentropids were most abundant in bluegill and trout but were eaten by other native fishes as well. Chironomids were the most common prey item shared between bluegill and trout; however, the mean number per fish was quite different between the two species (Table 10). The total number of prey items per fish was also different between the two species (Table 10).

Shadow bass differed significantly from rainbow trout in March and May diets (Table 8). Shadow bass stomachs had five types of prey items, four of which were found in trout. Decapods contributed 54% of shadow bass diets and only 4% of trout diets (Table 9, Figure 5). Isopods had the highest overlap between shadow bass and trout (Table 9), but represented only 15% of shadow bass diets and 9% of trout diets. Trout fed on a wider range of prey items, resulting low similarly values in March. In May, shadow bass fed on a wider range of prey items than in March (Figure 6) resulting in higher similarity. Shadow bass still consumed decapods but also fed on ephemeropterans, plecopterans, perlodids, and amphipods (Figure 5). Decapods, amphipods, and chironomids represented 75% of shadow bass diets (Table 10) and only contributed 47% of trout diets. In May, chironomids were the most commonly shared prey (Table 10), with a greater number per stomach in trout.

Among the three natives, smallmouth bass were least similar to trout diet (Table 8). In March, smallmouth bass fed on only three taxa; decapods, isopods, and fish (Table 9). Decapods represented 85% of the items in smallmouth bass and contributed only 4% to the items in trout. The three prey items eaten by smallmouth bass formed only 16% of the trout diet in March, resulting in low similarity values and significantly different diets. In May, smallmouth bass were still relatively specialized, eating primarily decapods and to a lesser extent fish (Table 10) followed in abundance by baetids, perlodids, and ephemeropteran and plecopteran nymphs. Of the five prey items found in smallmouth, only decapods, baetiids, and ephemeropteran and plecopteran nymphs occurred in trout and they represented only 10% of the diet.

Discussion

Rainbow trout diet and growth

Shortly after stocking, over half of rainbow trout stomachs were empty, whereas after thirty days less than 15% had empty stomachs, suggesting trout had acclimated feeding activities. However, the level of feeding was low throughout the study. We found no relationship between trout diet and residence time (i.e., 30 days versus 60 days). Ersback and Haases (1983) documented an average of 18 prey items in wild brown trout stomachs and nine in those of stocked brook trout. Cada et al. (1987) examined diets of resident rainbow trout and documented an average of 12 prey items per stomach. We found an average of 4 food items per trout stomach and only 3 animal prey per stomach, suggesting that trout consumption in Brush Creek was relatively low.

Trout diets differed among months implying that season was a significant factor in determining the diet. In January and August, gut contents of trout had high proportions of non-prey items, whereas in February, March, and May, the diet was composed primarily of animal prey. The low numbers of animal prey in January and August probably reflects availability during these months. Correspondingly, only one invertebrate occurred in January drift net samples, whereas higher numbers occurred in March and May. Peaks in drifting invertebrates generally occur in spring and early summer and are lower in late summer through winter (Elliot 1965). Ebert and Filipek (1991) found primarily corn, trout pellets, and pebbles in stocked rainbow trout. However, they did not specify time of year and lack of animal prey might be explained by seasonal availability. In addition, Ebert and Filipek (1991) obtained their trout from local fisherman and corn is a commonly used bait. Metcalf et al. (1997) sampled diets in March through May in the Little Missouri River, Arkansas and found that introduced rainbow trout ate a variety of animal prey. Studies in other systems have also found animal prey in stocked trout (Lord 1934, Raney and Lachner 1942, Ersbak and Haase1983, Bachman 1984, Dewald and Wilzbachz 1992, and Metcalf et. al 1997) and begin feeding on unfamiliar prey within days of stocking (Ware 1971, Reirez et al. 1998).

We were concerned about potential piscivory by introduced rainbow trout on native fishes, particularly young-of-year smallmouth bass. Blinn et. al (1983) documented piscivory by rainbow trout on Colorado spinedace and suggested that the minnow was not accustomed to the presence of a predator and was not adapted to avoid predation. In Brush Creek, fish represented only a small proportion of the prey of rainbow trout, and none were identified as young-of-year smallmouth bass. Fish prey were cardinal shiners, southern red-belly dace, and stonerollers.

Rainbow trout declined steadily in weight and lipid levels following stocking. It is well known that trout condition declines following stocking (Needham and Slater 1945, Miller 1958, Reimers 1963, Ersbak and Haase 1983, Ebert and Filipek 1992). Although causative factors are not well understood. The decline of weight and lipids of trout in Brush Creek may reflect a combination of factors. Warm summertime temperatures may have led to weight loss by affecting food consumption and metabolic rates. Temperatures at the study site reached 23.5° C in summer, which is close to the thermal limit of 25° C for rainbow trout (Cherry et al. 1977) and high summertime mortality rates were observed (unpublished data). Trout densities at the stocking site slowly declined over summer and no trout were captured by September. However, throughout the summer and the following winter trout were observed in sites upstream of the stocking site where temperatures were cooler (unpublished data), suggesting that the warmer stream temperatures at the stocking site contributed to rapid weight loss during the summer.

Prey consumption by rainbow trout in Brush creek was low throughout the study. Klak (1941) suggested that introduced trout were not as efficient in obtaining food items as wild trout were. He noted that condition declined, despite the stream being rich in food. Similarly, Ersbak and Haase (1983) attributed weight loss and low survival of stocked trout to inefficiency in obtaining food. They suggested that hatchery-reared rainbow trout had higher bioenergetic demands than did wild trout and that this together with low prey consumption, resulted in declining condition and low survival. We cannot exclude such factors, but it seems in Brush Creek that warm summertime water temperature was a significant factor.

Low abundance of available prey likely affected trout weight loss during the winter when items such as pebbles and leaves were especially common in the stomachs. Cooper and Benson (1951) and Ellis and Gowing (1957) attributed growth rates to seasonal changes in prey availability and found increased growth and condition of trout when animal prey were abundant.

Decline of available habitat during the summer may have been another factor affecting weight loss in trout. Kurtz (1980) and Witworth and Strange (1983) found increased mortality during declines in suitable habitat. Kurtz (1980) suggested that suitable habitat was less available because of the formation of ice, causing increased population densities and higher mortalities. Similarly, Whitworth and Strange (1983) documented high mortality rates of trout in a second order Appalachian stream that they attributed to decreased available habitat and food during the winter. In our study, suitable habitat declined in the summer rather than in winter. Increased temperatures and negligible rainfall caused isolation of many deep-water habitats and reduction in flow over connecting riffles, and movement of trout and other native fishes between habitats was highly restricted. Miller (1958) attributed weight loss and high mortality to stress from social interaction between hatchery and resident trout. He suggested that trout exhausted themselves and either died of acidosis or starvation in streams occupied by resident trout, whereas mortality was lower in streams not occupied by resident trout. Increased population densities in Brush Creek may have heightened interactions among trout and natives such as smallmouth bass, shadow bass, and bluegill. In addition, hatchery-reared trout often are highly active and aggressive (Moyle 1969, Symons 1969, Mesa 1991), which would also cause higher bioenergetic demands. Our study did not examine behavior of trout in Brush Creek, so the potential role of behavioral interactions in highly speculative.

Diet comparison of trout and native fishes

Diets of rainbow trout and native fishes differed significantly in March and in May, although trout did share some prey items with all three native species examined. Differences in diet suggest that competition for food resources is minimal between rainbow trout and the native fishes examined. Ebert and Filipek (1992) also suggested minimal competition between introduced trout and smallmouth bass based on the lack of animal prey items in trout diets and low post-stocking survival. However, in our study and the study by Metcalf et al. (1997) trout fed on a variety of animal prey in addition to pebbles and leaves. Regardless, exploitative competition for food was not likely a significant factor in our study. However, trout did feed on prey items common to the native fishes examined. Thus, if food resources were limited and/or trout densities were sufficiently high, the competition for food resources might occur. Bachman

(1982) found that limited amount of available feeding positions for trout were limited because of social interactions and suggested that number of available feeding sites may determine the carrying capacity for trout. Although preferred feeding positions of trout and native fishes may not be similar, trout may interfere with native fishes by occupying suboptimal feeding positions when population density is high.

Our results indicate that, if food resources were limited, competition might be greatest between trout and bluegill. However, indirect effects could potentially be detrimental to other species such as smallmouth bass. Metcalf et. al. (1997) suggested that increased competition between trout and native insectivorous fishes (such as bluegill) could directly affect smallmouth bass recruitment by causing a decrease in young-of-year forage fish. None of the juvenile smallmouth bass sampled in our study contained young-of-year bluegill. Juvenile smallmouth bass diets were similar to trout diets, consisting primarily of ephemeropterans; however, we did not sample enough juveniles to analyze these data rigorously. Livingston and Rabeni (1991) found that young-of-year smallmouth bass in an Ozark stream feed primarily on ephemeroptera, chironomids, and fish.

Our study was not designed to assess interference competition between introduced trout and natives. Given the aggressive behavior of hatchery reared trout, it is possible that trout could potentially interfere with native fishes. Taniiguchi et al (1998) examined interactions among three fish species along a temperature gradient and found that brook trout and brown trout interfered with feeding and out competed creekchubs (*Semotalis atromaculatus*) at temperatures below 20° C. At 22° C creek chubs began to out-compete brook trout and gained an advantage over brown trout at 24° C. These results could have implications for the timing and location of trout stocking. Managers could potentially mitigate competitive interactions by stocking trout at temperatures when hatchery trout are at a disadvantage with native fishes.

Our study examined diets of only a few of the native species present. Insectivores such as darters, sculpins, and some cyprinids may have diets more similar to trout in Brush Creek, potentially resulting in competition for food resources. In addition, redear sunfish (*Lepomis microlophus*) feed primarily on snails and other small mollusks, similar to trout diets in Brush Creek. Redear were not found in Brush Creek, but they are common in the Ozark region (Robinson and Buchanan 1992).

Ebert and Filipek (1990) recommended that trout stockings not be conducted past the month of April to prevent potential competition with juvenile smallmouth bass. Metcalf et. al. (1997) recommended that stockings be terminated in March to allow invertebrate populations to recover. Our data suggest that trout in Brush Creek were not efficient at obtaining food items and probably did not significantly affect invertebrate populations in the stream. In Brush Creek, it seems unlikely that introduced trout would cause food resources to become limiting.

It is unknown if trout competitively interfere with native fishes for food resources in Brush Creek. The literature suggests that hatchery-reared trout are aggressive and often out-compete native trout, but, it is not clear whether this is a significant factor in interactions between hatchery-reared rainbow trout native fishes in Ozark streams. Laboratory studies and field observations and experiments would help clarify this question.

The long term effects of trout introductions in Ozark streams are not well understood. Introduced rainbow trout in our study consumed prey items at very low rates. However, if trout were stocked into cooler streams, where conditions may be more favorable for their long-term survival, they might feed on natural prey at higher rates, therefore, increasing the potential for competition.

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Table 1. Multiple comparison of weight change among four cohorts of stocked rainbow trout. Asterisk (*) indicates significant slope for that cohort ($p<0.05$). Different letters in the multiple comparison represent significantly different slopes ($p<0.05$).

Month Stocked	Duration Sampled	Slope	Multiple Comparison
November	November 1 - May 2	-0.10451*	a
December	December 4 - May 24	-0.11347*	a
February	February 4 - June 18	-0.25651*	b
March	March 4 - Aug 6	-0.42335*	c

Table 2. Bray-Curtis similarity values and ANOSIM R-statistics among different cohorts for the months of February (a), March (b) and May (c). Asterisks (*) indicates difference in diets at the α = 0.05 level for ANOSIM calculations.

February			
Days	Bray-Curtis Similarity	Observed R	P value
7 vs 30	42.52	-0.046	0.744
7 vs 60	54.06	0.076	0.161
7 vs 90	49.84	0.006	0.429
30 vs 60	34.47	-0.006	0.497
30 vs 90	52.63	-0.062	0.785
60 vs 90	38.89	0.084	0.139

March			
Days	Bray-Curtis Similarity	Observed R	P value
30 vs 60	48.00	0.118	0.061
30 vs 90	85.59	-0.078	0.963
30 vs 120	50.98	0.156*	0.024
60 vs 90	48.00	-0.003	0.446
60 vs 120	71.69	-0.078	0.906
90 vs 120	56.86	0.218*	0.006

May			
Days	Bray-Curtis Similarity	Observed R	P value
60 vs 90	50.44	-0.008	0.460
60 vs 150	43.35	-0.008	0.504
60 vs 180	21.73	0.469*	0.010
90 vs 150	53.82	-0.176	0.926
90 vs 180	59.98	0.084	0.249
150 vs 180	40.96	0.259*	0.026

Table 3. Mean number of prey items per fish and percent composition of prey items among different cohorts of rainbow trout for the month of March. Species richness values are given at the bottom of the table.

	Mean # prey itmes / Fish				Percent Composition			
Residence Time (Days)	30	60	90	120	30	60	90	120
Decapoda								
Astacidae		0.20		0.33		0.08		0.06
Isopoda								
Asellidae		0.30		0.89		0.12		0.16
Diptera								
Pupae		0.10		0.11		0.04		0.02
Chironomidae				0.11				0.02
Ephemeroptera								
Baetidae		0.10				0.04		
Heptageniidae	0.38	0.20	0.30	0.22	0.18	0.08	0.15	0.04
Unidentifiable				0.11				0.02
Plecoptera								
Perlodidae		0.20				0.08		
Ephem/Plecop Parts		0.10	0.10	0.22		0.04	0.05	0.04
Ephem/Plecop Nymphs	0.13				0.06			
Trichoptera								
Polycentropidae		0.10				0.04		
Arachnida								
Hydracarina			0.10	0.11			0.05	0.02
Gastropoda								
Fish Unidentifiable				0.33				0.06
Pleuroceridae	1.50	0.90	1.50	2.67	0.71	0.36	0.75	0.47
Leaves		0.20		0.56		0.08		0.10
Pebbles	0.13	0.10			0.06	0.04		
Total	2.13	2.50	2.00	5.67	1.00	1.00	1.00	1.00
Species Richness	3	9	4	10	3	9	4	10

Table 4. Mean number of prey items per fish and percent composition of prey items among different cohorts of rainbow trout for the month of May. Species richness values are given at the bottom of the table.

	Mean # prey items / Fish				Percent Composition			
Residence Time (Days)	60	90	150	180	60	90	150	180
Decapoda								
Astacidae				0.17				0.03
Isopoda								
Asellidae		0.14	0.60			0.03	0.13	
Diptera								
Pupa	0.86	0.14	0.60		0.17	0.03	0.13	
Other Unidentifiable				0.17				0.03
Ephemeroptera								
Baetidae		0.14				0.03		
Unidentifiable	0.14				0.03			
Plecoptera								
Unidentifiable	0.14	0.14			0.03	0.03		
Ephem/Plecop Nymphs	1.43	0.86	0.60	0.67	0.29	0.21	0.13	0.11
Hemiptera								
Hemiptera	0.43	1.29	0.80	4.00	0.09	0.31	0.17	0.63
Trichoptera								
Caddisfly Case			0.20				0.04	
Arachnida								
Hydracarina				0.17				0.03
Gastropoda								
Pleuroceridae		0.71	0.60	1.00		0.17	0.13	0.16
Fish Unidentifiable			0.20				0.04	
Cyprinidae			0.60				0.13	
Leaves	0.57	0.57		0.17	0.11	0.14		0.03
Pebbles	1.43	0.14	0.40		0.29	0.03	0.09	
Total	5.00	4.14	4.60	6.33	1.00	1.00	1.00	1.00
Species Richness	5	7	8	6	5	7	8	6

Table 5. Bray-Curtis similarity values and ANOSIM R-statistics of trout diets among different months. Asterisks (*) indicates difference in diets at the α = 0.05 level for ANOSIM calculations.

Seasonal Comparison			
Month	Bray-Curtis Similarity	Observed R	P Value
Jan vs Feb	38.96	0.381*	0.001
Jan vs Mar	39.44	0.399*	0.001
Jan vs May	31.89	0.306*	0.001
Jan vs Aug	57.59	0.420*	0.001
Feb vs Mar	65.39	0.125*	0.007
Feb vs May	28.37	0.389*	0.001
Feb vs Aug	34.54	0.299*	0.004
Mar vs May	28.58	0.394*	0.001
Mar vs Aug	29.38	0.440*	0.003
May vs Aug	26.56	0.168*	0.005

Table 6. Mean number of prey items per fish and percent composition of prey items in diets of rainbow trout among different months. Species richness values are given at the bottom of the table.

	Mean # prey items / Fish					Percent Composition				
	Jan	Feb	Mar	May	Aug	Jan	Feb	Mar	May	Aug
Decapoda										
Astacidae		0.55	0.50	0.04	0.20		0.10	0.15	0.01	0.08
Isopoda										
Asellidae	0.05	1.25	0.25	0.22		0.01	0.22	0.08	0.05	
Diptera										
Pupae		0.04	0.04	0.37			0.01	0.01	0.08	
Chironomidae			0.02					0.01		
Other Unidentifiable				0.04					0.01	
Ephemeroptera				0.04					0.01	
Baetidae		0.08	0.02	0.04			0.01	0.01	0.01	
Heptageniidae	0.05	0.63	0.21		0.30	0.01	0.11	0.06		0.13
Unidentifiable		0.18	0.06				0.03	0.02		
Plecoptera										
Perlodidae		0.08	0.04				0.01	0.01		
Unidentifiable		0.06	0.04	0.07			0.01	0.01	0.02	
Ephem/Plecop Parts	0.11	0.45	0.08		0.10	0.03	0.08	0.02		0.04
Ephem/Plecop Nymphs		0.10	0.04	0.85	0.10		0.02	0.01	0.18	0.04
Hemiptera										
Hemiptera	0.05	0.06		1.48		0.01	0.01		0.31	
Odonata										
Gomphidae		0.02	0.02				0.00	0.01		
Trichoptera										
Polycentropidae		0.16	0.04				0.03	0.01		
Caddisfly Case		0.18		0.04			0.03		0.01	
Arachnida										
Hydracarina			0.04	0.04				0.01	0.01	
Gastropoda										
Pleuroceridae	1.00	1.53	1.69	0.56	0.10	0.28	0.27	0.51	0.12	0.04
Pelecypoda										
Pisidiidae		0.06					0.01			
Fish Unidentifiable			0.06	0.04	0.10			0.02	0.01	0.04
Cyprinidae				0.11	0.20				0.02	0.08
Leaves	0.68	0.22	0.15	0.33	0.10	0.19	0.04	0.05	0.07	0.04
Pebbles	1.58	0.08	0.04	0.48	1.20	0.45	0.01	0.01	0.10	0.50
Total	3.53	5.71	3.33	4.74	2.40	1.00	1.00	1.00	1.00	1.00
Animal prey items/fish	1.26	5.41	3.08	3.78	0.80	.	.	.	.	.
Species Richness	5	16	16	14	7	5	16	16	14	7

Table 7. Species richness (SR) and abundance of prey items per drift net for January, March and May.

	SR	# Drift items/net/hr
January	1	0.5
March	13	8.5
May	10	7.8

Table 8. Bray-Curtis similarity values and ANOSIM R-statistics of fish among rainbow trout (RBT), bluegill (BGL), shadow bass (SHD) and smallmouth bass (SMB). Asterisks (*) indicates difference in diets at the $\alpha = 0.05$ level for ANOSIM calculations.

	Bray-Curtis Similarity	Observed R	P Value
March			
RBT vs. BGL	28.42	0.344*	0.001
RBT vs. SHD	22.35	0.102*	0.002
RBT vs. SMB	10.60	0.392*	0.001
May			
RBT vs. BGL	54.35	0.205*	0.001
RBT vs. SHD	30.39	0.411*	0.001
RBT vs. SMB	11.11	0.680*	0.001

Table 9. Mean number of prey items per fish and percent composition of prey items in diets of bluegill (BGL), smallmouth bass SMB, shadow bass (SHD) and rainbow trout (RBT) in March. Species richness values are given at the bottom of the table.

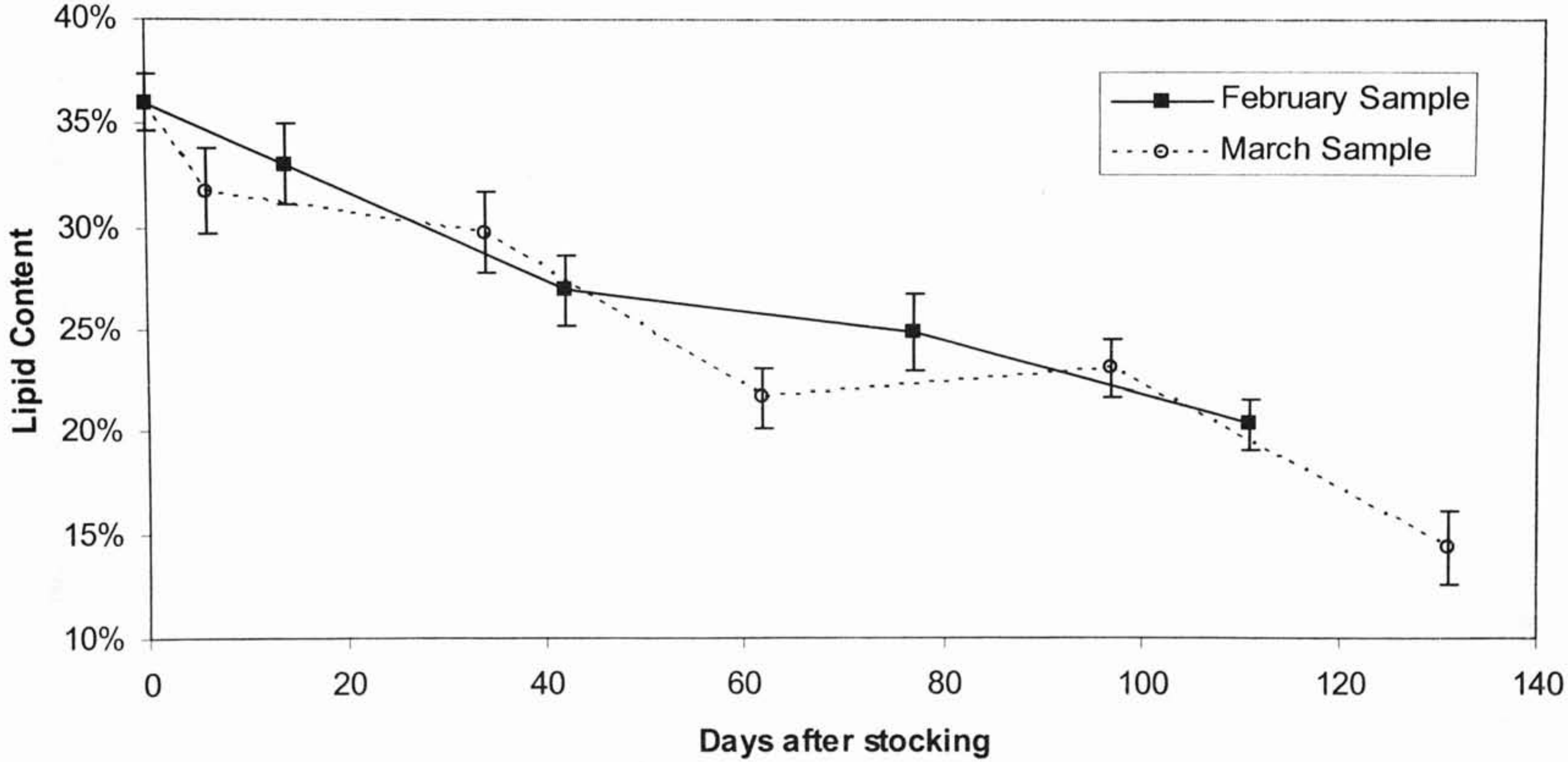
	Mean # Prey Items / Fish				Percent Composition			
Taxon	BGL	SHD	SMB	RBT	BGL	SHD	SMB	RBT
Amphipoda	2.38	0.13						
Gammaridae					0.22	0.08		
Decapoda								
Astacidae	0.44	0.88	1.21	0.13	0.04	0.54	0.85	0.04
Isopoda								
Asellidae	1.63	0.25	0.05	0.28	0.15	0.15	0.04	0.09
Diptera								
Pupae				0.05				0.02
Chironomidae	0.13			0.03	0.01			0.01
Ephemeroptera								
Baetidae	0.25			0.03	0.02			0.01
Heptageniidae	1.81	0.13		0.26	0.17	0.08		0.09
Unidentifiable	0.13	0.25		0.03	0.01	0.15		0.01
Plecoptera								
Perlodidae				0.05				0.02
Ephem/Plecop Parts	0.06			0.10	0.01			0.03
Ephem/Plecop Nymphs	0.06			0.03	0.01			0.01
Hemiptera								
Hemiptera	0.13				0.01			
Trichoptera								
Polycentropidae	0.88			0.03	0.08			0.01
Arachnid								
Hydracarina	2.88			0.05	0.26			0.02
Gastropoda								
Pleuroceridae				1.56				0.53
Pelecypoda								
Pisidiidae	0.19				0.02			
Fish Unidentifiable			0.16	0.08			0.11	0.03
Leaves				0.23				0.08
Pebbles				0.05				0.02
Total	10.94	1.63	1.42	2.97	1	1	1	1
Species Richness	13	5	3	14	13	5	3	14

Table 10. Mean number of prey items per fish and percent composition of prey items in diets of bluegill (BGL), smallmouth bass SMB, shadow bass (SHD) and rainbow trout (RBT) in May. Species richness values are given at the bottom of the table.

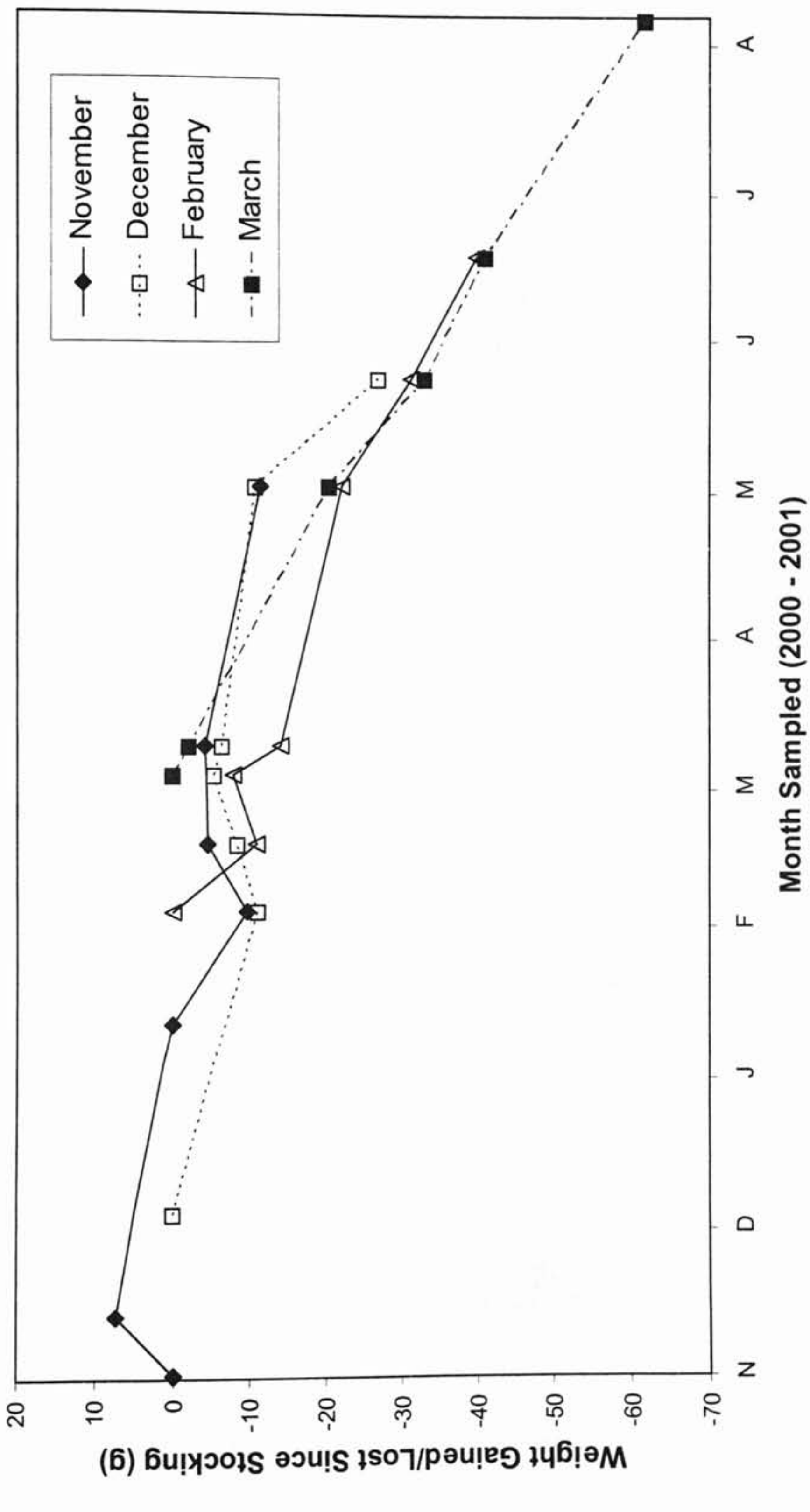
	Mean # Prey Items / Fish				Percent Composition			
	BGL	SHD	SMB	RBT	BGL	SHD	SMB	RBT
Amphipoda								
Gammaridae	6.06	0.80		0.10	0.17	0.20		0.01
Decapoda								
Astacidae	0.22	1.40	0.92	0.40	0.01	0.36	0.67	0.04
Isopoda								
Asellidae	1.61	0.20		0.10	0.05	0.05		0.01
Coleoptera								
Dytiscidae	0.44			1.50	0.01			0.17
Psephenidae				0.10				0.01
Diptera								
Pupae	0.17			0.50	0.00			0.06
Chironomidae	21.61	0.73		3.80	0.62	0.19		0.42
Culcidae	0.67				0.02			
Ephemeroptera								
Baetidae	1.11	0.07	0.08	0.30	0.03	0.02	0.06	0.03
Ephemerellidae				0.10				0.01
Heptageniidae	0.28	0.07			0.01	0.02		
Unidentifiable	0.22			0.10	0.01			0.01
Plecoptera								
Perlodidae	0.28	0.27	0.08		0.01	0.07	0.06	
Unidentifiable				0.10				0.01
Ephem/Plecop Parts	0.06	0.20				0.05		
Ephem/Plecop Nymphs	0.22	0.07	0.08	0.30	0.01	0.02	0.06	0.03
Hemiptera								
Hemiptera	0.78			0.30	0.02			0.03
Odonata								
Gomphidae				0.20				0.02
Trichoptera								
Polycentropidae	0.17	0.07		0.30		0.02		0.03
Arachnida								
Hydracarina	0.61				0.02			
Gastropoda								
Pleuroceridae				0.50				0.06
Fish Unidentifiable		0.07	0.23			0.02	0.17	
Pebbles				0.30				0.03
Total	34.50	3.93	1.38	9.00	1	1	1	1
Species Richness	16	11	5	15	16	11	5	15

Figure Captions

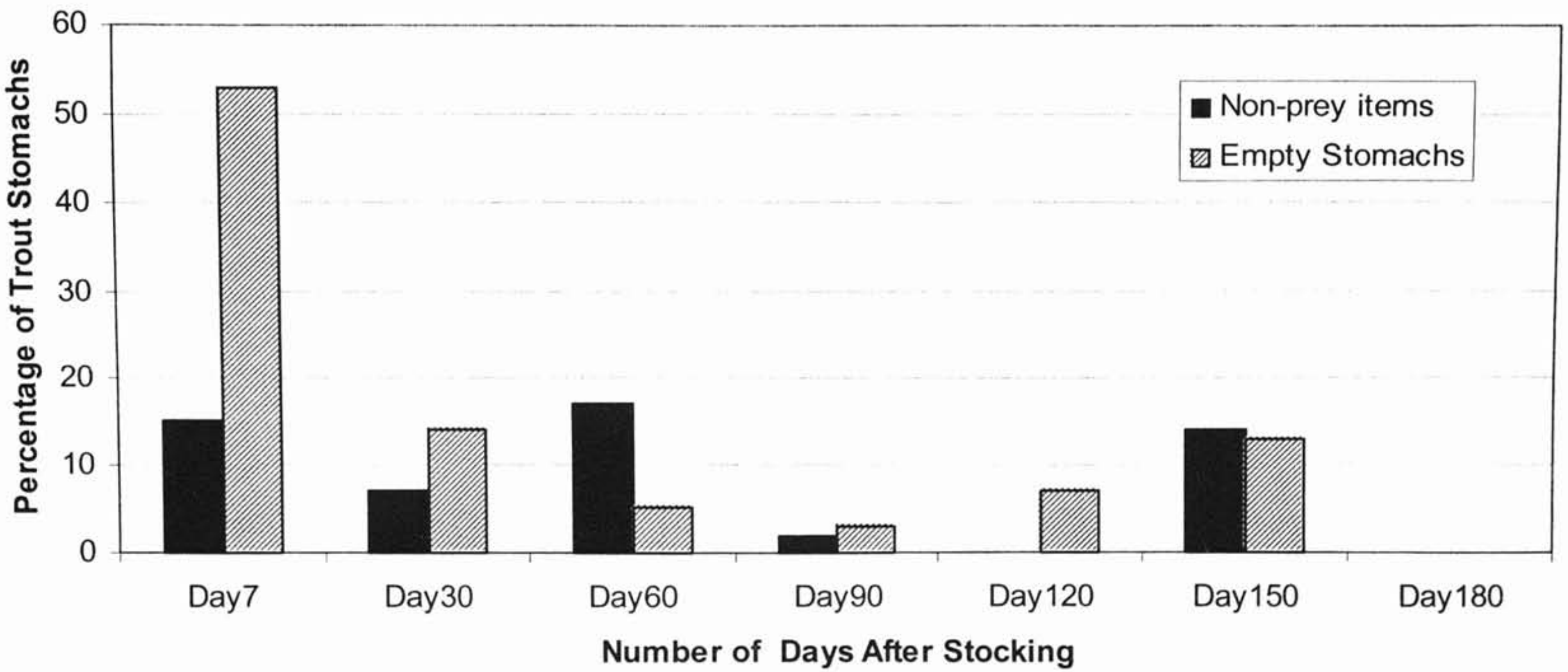
1. Percent lipid composition of rainbow trout at different residence times for February and March.
2. Weight change of four different cohorts of rainbow trout after stocking.
3. Percentage of empty stomachs for rainbow trout with different residence times in the stream.
4. CCA biplot relating prey items to trout diets at different months. Solid circles indicate prey items and open diamonds indicate trout at particular months
5. CCA biplot for March 2001, relating prey items to rainbow trout, bluegill, shadow bass, and smallmouth bass. Solid circles indicate prey items and open diamonds indicate fish species (environmental variables plotted as centroids).
6. CCA biplot for May 2001, relating prey items to rainbow trout, bluegill, shadow bass and smallmouth bass. Solid circles indicate prey items and open diamonds indicate fish species (environmental variables plotted as centroids). All prey items plotted on the dotted line were fed on by only rainbow trout and bluegill.



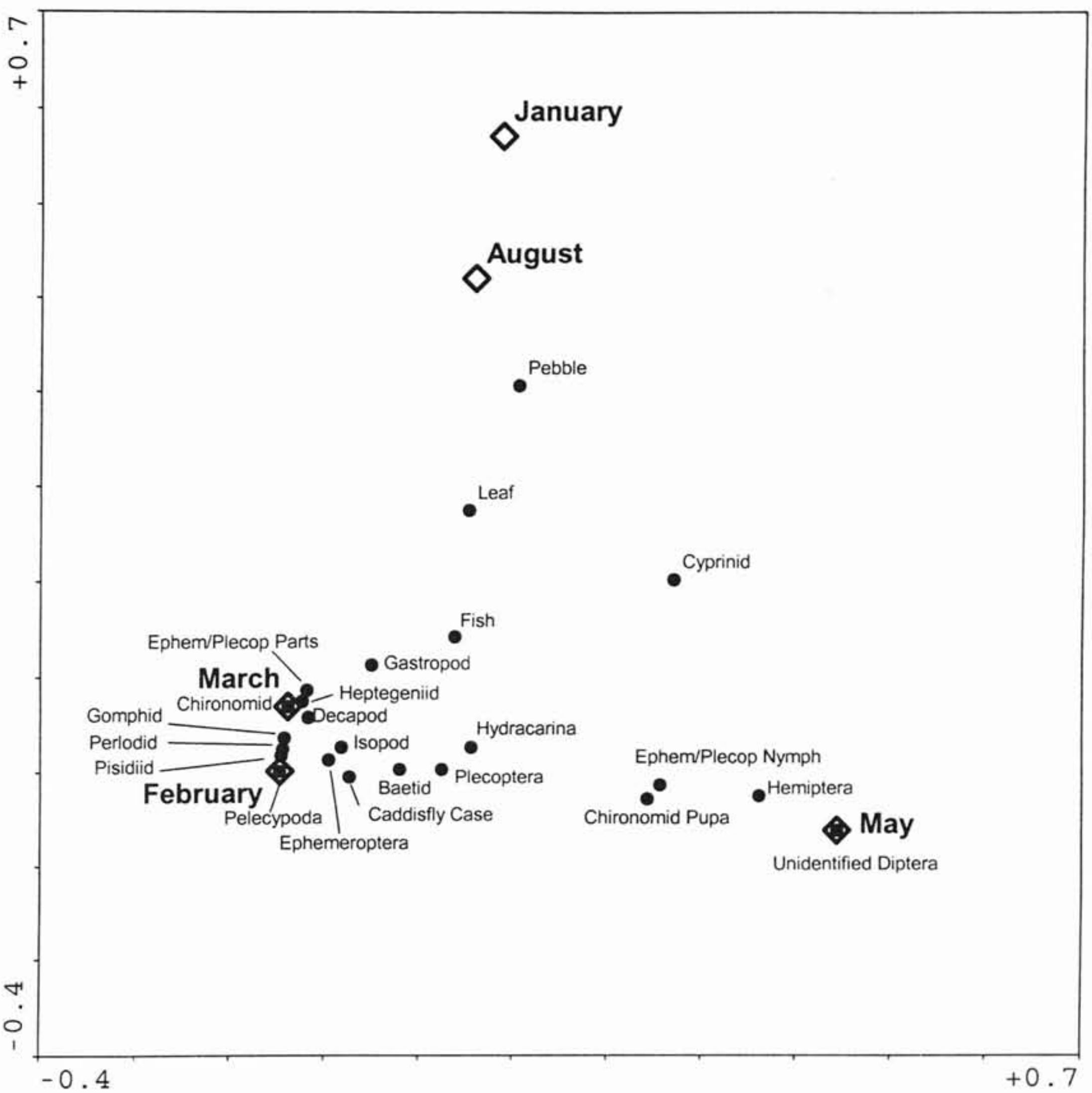
February Sample
March Sample
Lipid Content
40%
35%
30%
25%
20%
15%
10%
0
20
40
60
80
100
120
140
Days after stocking

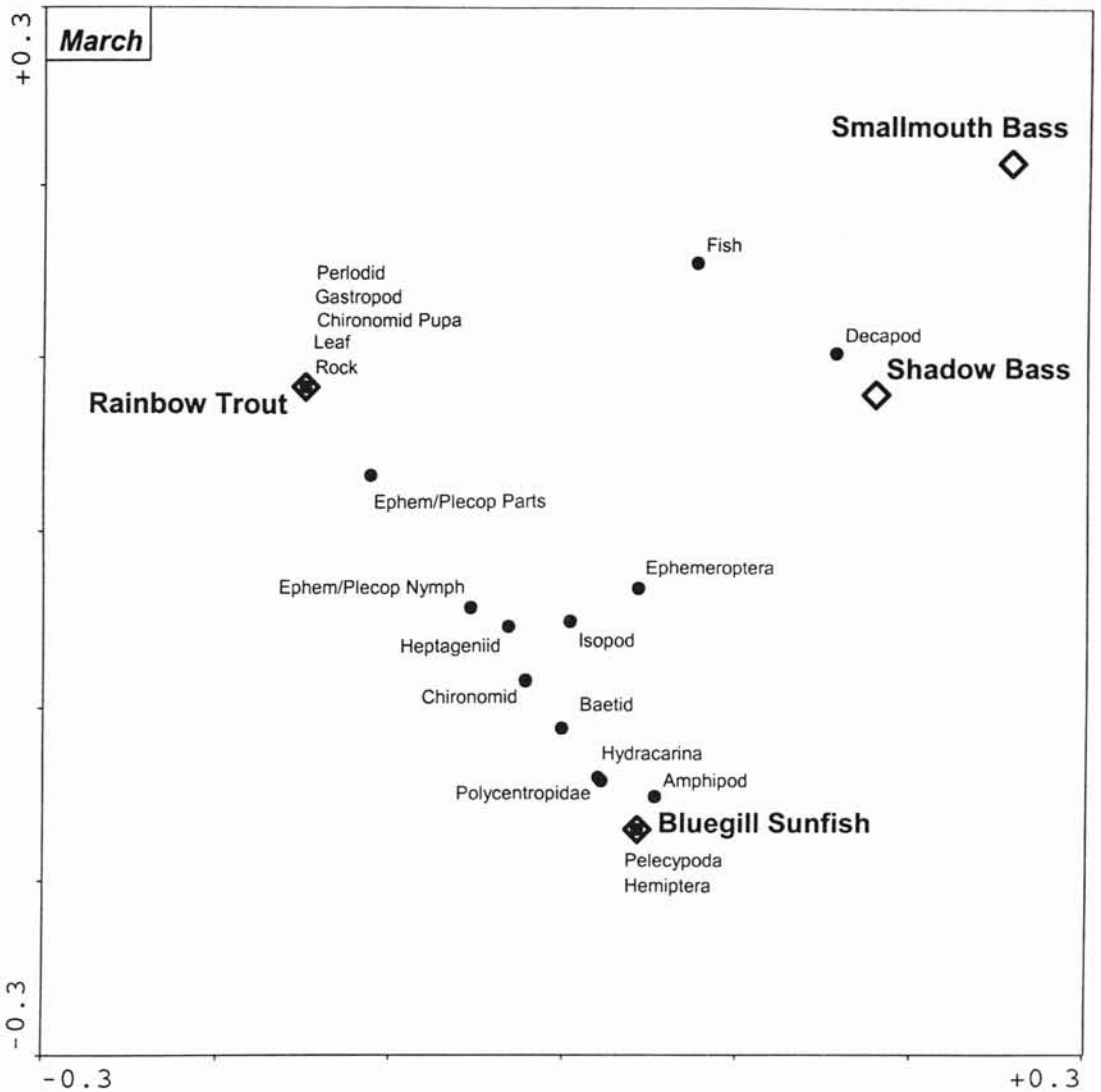


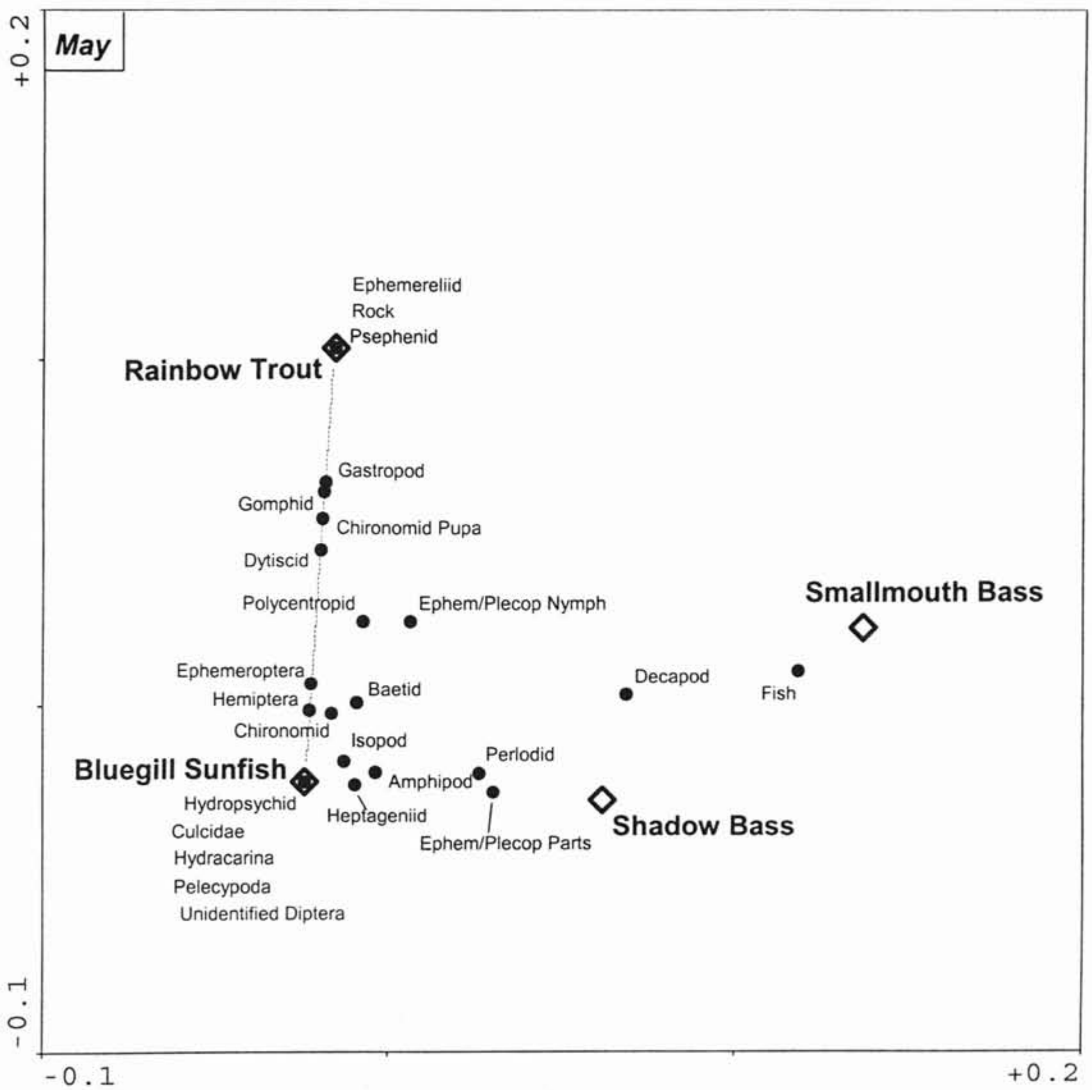
Weight Gained/Lost Since Stocking (g)
20
10
0
-10
-20
-30
-40
-50
-60
-70
N
D
J
F
M
A
M
J
J
A
Month Sampled (2000 - 2001)
November
December
February
March



Percentage of Trout Stomachs
60
50
40
30
20
10
0
Non-prey items
Empty Stomachs
Day7
Day30
Day60
Day90
Day120
Day150
Day180
Number of Days After Stocking


+0.7
-0.4
-0.4
+0.7
January
August
Pebble
Leaf
Cyprinid
Fish
Ephem/Plecop Parts
Gastropod
March
Heptegeniid
Chironomid
Decapod
Gomphid
Perlodid
Pisidiid
Isopod
Hydracarina
February
Baetid
Plecoptera
Pelecypoda
Caddisfly Case
Ephemeroptera
Ephem/Plecop Nymph
Hemiptera
Chironomid Pupa
May
Unidentified Diptera


March
+0.3
-0.3
-0.3
+0.3
Smallmouth Bass
Fish
Perlodid
Gastropod
Chironomid Pupa
Leaf
Rock
Decapod
Shadow Bass
Rainbow Trout
Ephem/Plecop Parts
Ephemeroptera
Ephem/Plecop Nymph
Heptageniid
Isopod
Chironomid
Baetid
Hydracarina
Amphipod
Polycentropidae
Bluegill Sunfish
Pelecypoda
Hemiptera


May
+0.2
-0.1
-0.1
+0.2
Ephemereliid
Rock
Psephenid
Rainbow Trout
Gastropod
Gomphid
Chironomid Pupa
Dytiscid
Polycentropid
Ephem/Plecop Nymph
Smallmouth Bass
Ephemeroptera
Hemiptera
Baetid
Decapod
Fish
Chironomid
Isopod
Perlodid
Bluegill Sunfish
Amphipod
Hydropsychid
Heptageniid
Shadow Bass
Culcidae
Ephem/Plecop Parts
Hydracarina
Pelecypoda
Unidentified Diptera

VITA 2

Daniel Brooks Fenner

Candidate for the Degree of

Master of Science

Thesis: INTERACTION BETWEEN INTRODUCED RAINBOW TROUT AND THREE NATIVE FISHES FOR FOOD RESOURCES IN AN OZARK STREAM

Major Field: Wildlife and Fisheries Ecology

Biographical:

Education: Graduated from Putnam City High School, Oklahoma City, Oklahoma in May, 1993; attended Phillips University, Enid, Oklahoma from September 1993 to May 1997 before transferring to Oklahoma State University, Stillwater, Oklahoma in August 1997. Receive Bachelor of Science degree in Zoology from Oklahoma State University in December 1999. Completed the requirements for the Master of Science degree with a major in Wildlife and Fisheries Ecology at Oklahoma State University in August, 2002.

Experience: Employed by the University of Oklahoma Health Sciences Center as an Animal Technician II from May 1994 to May 1997. Employed by Laboratory Animal Resources, Oklahoma State University as an animal technician from March 1998 to May 1999. Employed by the Oklahoma Cooperative Fish and Wildlife Research Unit, Oklahoma State University as an undergraduate and as a graduate research assistant from October 1998 to January 2002.

Professional Memberships: American Fisheries Society, American Society of Ichthyologist and Herpetologists, Southwestern Association of Naturalist.