WATER QUALITY EFFECTS OF ABOVE-STREAM FISH FEEDERS IN LOW-NUTRIENT NORTH CAROLINA MOUNTAIN STREAMS

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[1] Presently the North Carolina Division of Water Quality, in the Department of Environment, Health, and Natural Resources.

ABSTRACT

From 1990-1993, pelletized fish food was added daily to 900-m stretches of four mountain streams by the North Carolina Wildlife Resources Commission, in an attempt to increase the standing crop and maximal size of wild trout. This report assesses water quality impacts of the feeders, through examinations of water chemistry and benthic invertebrate communities, as a companion paper to a separate report on the impact of feeding on the trout populations. Analyses of water chemistry (including five nutrient parameters: NH_3, NO_2, NO_3, PO_4, and total P) and benthic invertebrate bioindicators yielded no statistically significant impacts when each of the five nutrients and the benthic invertebrate index were considered separately. All waters, whether fed or unfed, were judged to be of high water quality by the benthic invertebrate index, which is taken to be a long-term integrator of water quality.

While none of the six of these metrics was statistically significant when considered alone, all six gave some indication of some impact, and a meta-analysis combining the six metrics yielded a statistically significant indication that the feeders had a subtle enriching impact. However, the increased nutrient levels, if present, were estimated to be small (about 0-30%) relative to the response of the main target trout species (about 100% increases in numbers and 400% increase in mass per unit area). We conclude that feeding at the intensity and spatial extent of the experiment can produce desired responses in the targeted trout populations without substantial local deterioration of water quality, but also note that expansion of the feeding program in intensity or spatial extent can be expected to produce water quality deterioration locally or in downstream areas, and that the feeding level at which water quality deterioration would become apparent is not known.

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SUMMARY AND CONCLUSIONS

Population growth and increased recreational development within the mountain region of North Carolina has increased demand on wild trout sport fisheries. Designated wild trout waters, dominated by rainbow trout (*Oncorhynchus mykiss*), are not presently stocked with hatchery-reared fish, so the fishery relies on natural reproduction and growth to maintain trout populations. These naturally low nutrient waters produce trout seldom exceeding 200 mm total length.

The North Carolina Wildlife Resources Commission (NCWRC) initiated a wild trout supplemental feeding project in 1990 on four North Carolina mountain streams (Borawa et al. 1995). The NCWRC project assessed whether addition of pelleted food would increase trout maximal size and standing stocks (grams/m^2) within 900-m fed sections of streams over a three-year period. The NCWRC study was directed at assaying the trout populations in the streams; this report evaluates possible effects of the feeders on the water quality of these streams.

Samples were collected in 1993, the final year of the three-year NCWRC project. In each of the four study watersheds, we chose four study sections: a section above (upstream of) the 900-m fed section, the fed section itself, a section below the fed section, and a nearby 'control stream' of similar size. This design enlarged upon the NCWRC study, in which trout populations were measured in the fed sections and one additional section per stream (a section above the fed section in two of the streams, and a section below the fed section in the other two streams). Primary emphasis was on bioassessment of macroinvertebrate communities by criteria established by the North Carolina Division of Environmental Management (NCDEM). In addition, we sampled nutrient concentrations (ammonia, nitrite, nitrate, dissolved reactive phosphorus, and total phosphorus) and other chemical parameters (pH, alkalinity, hardness, % oxygen saturation, and conductivity).

We detected no statistically significant impacts to water quality due to the supplemental feeding when each nutrient level was considered separately. Invertebrate community analysis, an long-term integrator of water quality, yielded bioclassifications of "excellent" for all samples except for two late-summer sections in one stream. While none of the six of these metrics was statistically significant when considered alone, all six gave some suggestion of some impact, and a meta-analysis combining the six metrics yielded a statistically significant indication that the feeders had a subtle enriching impact. However, the increased nutrient levels caused by the feeders, if present but statistically undetected in the individual analyses, were estimated to be small (about 0-30%) relative to the response of the main target trout species (about 100% increases in numbers and 400% increase in mass per unit area).

We conclude that feeding at the intensity and spatial extent of the experiment can produce desired responses in the targeted trout populations without substantial local deterioration of water quality. Because the water quality assessments were made in the third year of the feeders' input, and taken in a year with unusually low water flow, we feel that this conclusion is likely to be valid even if the feeding activity were extended to additional years with the same intensity, although we cannot strictly dismiss the possibility that deterioration of water quality would become apparent under some climatic circumstances, or over a longer time scale. Also, we also note that expansion of the feeding program in intensity or spatial extent can be expected to produce water quality deterioration locally or in downstream areas, and emphasize that the feeding levels at which water quality deterioration should become apparent are not known.

RECOMMENDATIONS

1. We recommend that feeding at the level used in the present study can be used without concern for substantial local deterioration of water quality.

2. We also recommend that expansion of the feeding program in either intensity (input per area per time) or spatial extent (length of stream reach or streams per drainage) be accompanied by a water quality assessment program. At a minimum, benthic invertebrate assays should be conducted.

3. We also judge that the recommendations in Borawa et al. (1995), which assesses the impact of the feeders on trout growth, are reasonable. In particular, the use of feeders with adjustable food input or use of hand feeding can avoid unnecessary nutrient input and food wastage.

INTRODUCTION

The naturally low-nutrient status of many mountain streams flowing over crystalline bedrock in western North Carolina (Wallace et al., 1992) can be viewed as attractive from a water quality perspective, but has also been viewed as an impediment to recreational fisheries development in the mountain region (Habera and Strange 1993; Borawa et al. 1995). Beginning in 1990, the North Carolina Wildlife Resources Commission (NCWRC), in cooperation with North Carolina Trout Unlimited and the U.S. Forest Service, conducted a three-year study evaluating the impact of increased allochthonous input of food on the trout populations in four mountain streams (Borawa et al. 1995), with the aim of evaluating the impact of such feeding on the standing crop (mass per area) and size structure of rainbow trout *(Onchorhynchus mykiss*) and brown trout (*Salmo trutta*). Allochthonous input was increased in sections of the streams designated as "wild trout" waters by installing overhead, battery-powered, solar-activated feed dispensers, which discharge trout food (commercial trout food pellets) into the streams. By NCWRC policy, fisheries in designated "wild trout" waters rely on natural growth and reproduction by resident trout because such streams are not included in stocking programs using hatchery-reared trout. In each of the four replicate study streams, the set of nine feeders spaced 100 m apart were designed to dispense about 50 kg of food every 2 weeks, or about 1300 kg per year (Borawa et al. 1995). The NCWRC established and maintained the feeders, and measured population responses by the trout. Borawa et al. (1995) found that the food supplement provided its intended effect, producing dramatic increases in trout maximal size and trout population standing crop. Borawa et al. estimated that the feeders increased the standing crop of trout by >200%, and primarily by increasing the density of rainbow trout >254 mm total length.

The present report is a companion study to the study by Borawa et al. (1995), and reports on assays of measures of water quality in the study streams. While several studies have assessed supplemental feeding on growth of wild trout (North Carolina Wildlife Resources Commision 1968, Ratledge et al. 1972, England and Fatora 1974) or salmon (Mason 1976, Irvine and Bailey 1992), these studies did not employ the replicated experimental design employed in the present study (Borawa et al. 1995 and the present report), and the previous studies did not assess water quality impacts of the supplemental feeding.

The feeding in the NCWRC study began in late summer 1990 and ended in early fall 1993. Samples reported in the present paper were taken during May through August of 1993, i.e., in the final year of the three-year trial. We put primary emphasis on the composition of the macroinvertebrate community in the streams, as a biotic indicator likely to integrate over the three years of the study. Invertebrate collections were made at four sites in each of the four study drainages in May-June, and again in the July-August period with warmer temperatures and low-flow conditions. In addition, water samples were collected at each site on three occasions, to provide estimates of nutrient levels and other chemical parameters. Finally, we also collected fish samples by electrofishing, with the aim of applying a North Carolina Division of Environmental Management Index of Biotic Integrity (NCDEM IBI) for mountain streams. Each of these three metrics addresses a different part of the stream ecosystem and may integrate over different time scales. Our null hypothesis was that the supplemental feeding of wild trout had no impact on water quality, where water quality is operationally defined as being lower if nutrient concentration is raised, or if biotic indicators show a shift to more pollution-tolerant taxa.

METHODS

Study Sites

The four western North Carolina streams involved in the NCWRC feeding study were (Fig. 1): (1) Curtis Creek, McDowell County (35°42′33″N, 82°11′33″W); (2) South Toe River, Yancy County (35°44′05″N, 82°14′03″W), (3) Looking Glass Creek, Transylvania County (35°19′09″N, 82°47′30″W), and (4) Kimsey Creek, Macon County (35°04′18″N, 83°31′47″W). In addition to the four primary streams, four additional streams within the same drainage basin (one for each primary stream) were selected for an additional outside control. These were: (1) Catawba River (control for Curtis Creek), McDowell County (35°36′56″N, 82°14′30″W); (2) Upper Creek (control for South Toe River), Yancy County (35°43′53″N, 82°14′23″W); (3) Davidson River (control for Looking Glass Creek), Transylvania County (35°16′59″N, 82°49′32″W); and (4) Bearpen Creek (control for Kimsey Creek), Macon County (35°02′25″N, 83°30′21″W). Curtis Creek was accessed directly from FR (Forest Road) 482. Catawba River was accessed via a 4 km hike from the end of Catawba River Road. South Toe River and Upper Creek were accessed directly from FR 472. Looking Glass Creek was accessed directly from US 276, and Davidson River from FR 475. Kimsey Creek was accessed via a 5 km hike from Standing Indian Campground (FR 67), and Bearpen Creek directly from FR 67.

Boulder, rubble, and sand are the three principle substrate types in the study streams, with bedrock and silt deposits present within each stream as well (see Cady 1994 for details). The streams consisted primarily of small pools interspersed among longer stretches of riffle. Runs were absent and undercut banks were rare. Canopy vegetation consisted primarily of birch (*Betula* spp.), hemlock (*Tsuga canadensis*), and yellow-poplar (*Liriodendron tulipefera*) with a dense understory of rhododendron (*Rhododendron* sp.). All sections were second or third order except for the section of Curtis Creek above the feeders, which was first order (as defined by Strahler 1952). Sections ranged in width from 1 m (Curtis Creek), to approximately 8 m (South Toe River and Davidson River).

Study Design

The NCWRC had two study reaches on each of the four fed streams: one was a 900 m section with nine feeders each (the "Fed Section," to be abbreviated as "FS"), and the other was a 900 m section without feeders or with non-functional feeders suspended over the stream. In two of the streams, Curtis Creek and Kimsey Creek, the unfed study sections were downstream of the fed sections ("Below Feeders," or "BF"). In the other two streams, South Toe River and Looking Glass Creek, the unfed study sections established by the NCWRC were upstream of the fed sections ("Above Feeders," or "AF"). Each section was separated by a 450 m buffer zone intended to eliminate any feeder effects. Feeders were separated by 100 m and suspended approximately 3-4 m over the stream with a steel cable.

For the purposes of this study, we expanded on the NCWRC design. In the study reported here, each fed stream had an AF (Above Fed), FS (Fed Section), and BF (Below Fed) section,

(paste Fig. 1 here)

Figure 1. Location of the four study watersheds (asterisks) established by the North Carolina Wildlife Resources Commission (NCWRC), and enlarged illustration of one of the watersheds (South Toe River, Yancy County, North Carolina). Each of the four study watersheds contained four sampling sections: Above the Fed Section (AF), Fed Section (FS), Below the Fed Section (BF), and a reference "Control Stream" (CS).

rather than the FS and either an AF or BF in the NCWRC original design. AF, FS, and BF sections corresponded directly with NCWRC sections where sections were already established. In addition, in each study drainage, we added an additional "Control Stream," abbreviated as CS, each of which was selected based on their general similarity to the fed stream sections in that drainage. As an example of the design employed at all sites, Fig. 1 illustrates the physical design in South Toe River site; other sites had the same conceptual design.

Response Variables

Three metrics used to identify potential water quality impacts due to the feeders. These were analyses of: (1) water chemistry, especially nutrient concentration; (2) benthic macroinvertebrate communities; and (3) fish communities. An attempt was also made to measure algal growth in the study streams, but was unsuccessful due to loss of replicates due to spates and human disturbance.

Sampling efforts for the FS concentrated at the most downstream feeder, because the effect of the feeders might be expected to accumulate across a 900 m fed section with the nine feeders 100 m apart. Samples were also taken in the AF, BF, and CS sections at the farthest downstream area of each section. The methods all followed typical protocols for studies of this type, as detailed below.

Chemical analyses. Water samples were collected three times over the sampling period at each section on each of the four pairs of study streams. These sampling periods corresponded to an early (late May), middle, and late (August) sample to examine variation over time; we anticipated the possibility that signs of water quality deterioration such as low dissolved oxygen or elevated ammonia might be more pronounced in the late summer (August) when water temperature would be expected to be higher than earlier, and water flow rates might be low. The chemical parameters ammonia (NH_3-N ppm), nitrite ($NO_2^=$-N ppb), nitrate (NO_3^--N ppm), dissolved reactive phosphate (DRP) ($PO_4^{\equiv}$-P ppb), total phosphorus (total P ppm), pH, alkalinity (as ppm $CaCO_3$), and hardness (as ppm $CaCO_3$) were assayed at each sampling period. Dissolved oxygen (ppm O_2, expressed as percent saturation), conductivity (micromhos/cm), water temperature (^oC), and stream discharge (m^3/sec, measured at the time of sample collection, using a flowmeter placed at 0.6 of water depth) were also measured. Total nitrogen was not included in our analyses, because an unexplained precipitate was reported in some of those assays.

Water samples were collected during morning hours by inverting a submerged one liter bottle in the stream, placing the bottle in crushed ice, and transporting the sample to the USDA/NCSU Mountain Horticulture, Crops, Research, and Extension Center (Fletcher, NC) for immediate processing and analysis of ammonia, nitrate, nitrite, dissolved reactive phosphate, and total phosphorus. All other chemical and physical parameters were measured directly in the field using titration procedures or portable meters. All laboratory chemical analyses were conducted with spectrophotometric procedures, except ammonia which was analyzed using an ammonia probe. Calibration was performed via preparation of solutions of known concentration.

Invertebrate communities. Invertebrate samples were collected two times, early (late May-June) and late (July-early August), from each site over the sampling period. This allowed

determination of water quality for a period when maximal invertebrate densities should be present (late spring and early summer), and for a time when more stressful seasonal conditions may have more of an impact on invertebrate communities (late summer).

All habitat types were intensively sampled following methods described in Lenat (1988). These types of collections use: (1) two, one m^2, 500 μm mesh kick nets for riffles; (2) three, 30 cm^2 base, 200 μm mesh Surber sampler for soft sediments; (3) one, 600 μm mesh, 14 l sieve buckets for leaf or coarse particulate organic matter (CPOM); (4) 5-10, 800 μm mesh dip nets for deep pools and under banks and logs; (5) ten large rocks (approximately 20 cm^2) that could be easily lifted from the stream and brushed free of attached organisms over a pan; and (6) fine bristle brushes for removing organisms from submerged rocks and logs as part of an intensive 15 minute survey of areas that could not be readily sampled with the conventional equipment described earlier. Sieve buckets were filled at least one-third full (water drained) with leaf particles and other organic debris.

Invertebrate samples were field picked from a pan of water held in sunlight for a minimum of two hours. No visual aides were used during field picking procedures. Invertebrate samples were preserved in 90 percent ethanol. Samples were transported to Clark Laboratories (Department of Zoology, NCSU) for identification and enumeration. Exceptions to this method of preservation were the Kimsey Creek and Bearpen Creek samples which were collected as whole samples and preserved in 7% formalin to allow more complete biomass estimates as part of another study. The keys and taxonomic references of Wiggins (1977), Brigham et al. (1982), Wiederholm (1983), Merritt and Cummins (1984), Stewart and Stark (1988), and several unpublished keys developed by NCDEM personnel were used to identify collected invertebrates to the lowest taxonomic level possible.

Following processing in the laboratory, invertebrate data were entered into the NCDEM invertebrate biomonitoring model to project a bioclassification ranking (1 = poor, 5 = excellent) for each site at a given time. The NCDEM model is fully described elsewhere (Lenat 1988, North Carolina Division of Environmental Management 1991), and we briefly summarize the procedure here. The procedure results in a Bioclass rating, based on two sub-components: the EPT (Ephemeroptera, Plecoptera, and Trichoptera) value based on the number of species of Ephemeroptera, Plecoptera, and Trichoptera, and a BI (Biotic Index, not to be confused with Bioclass) value, which is a broader index based on abundances of invertebrate taxa (including insects but also other taxa) and the pollution tolerance of each taxon. For the EPT score in the NC mountain region, more than 43 EPT taxa present in a sample yields a score of five and decreases as the number of EPT species present decreases, with corrections for stream size, to a minimum of 1. The BI score utilizes a database with pollution tolerances assigned to each invertebrate taxon (species or higher taxonomic level for some groups). The Biotic Index (BI) is the output of a weighted average tolerance rating of all invertebrates in the sample based on their abundance in a standard collection Tolerant species have higher tolerance values, so higher abundances of tolerant species yield a higher BI value; BI values less than 4.0 in the mountain region are considered to indicate excellent water quality, and BI values higher than 7.05 are dominated by pollution-tolerant taxa and indicate very poor water quality. A conversion is then made to scale the BI value into the same units as the EPT score: 5 is the highest score and is associated with sites with the highest water quality (low BI scores, <4.0, receive this highest

rating of 5), and 1 indicates poor water quality (high BI scores, >7.05). The arithmetic mean of these two scores obtained from the EPT and BI subcomponents (each ranging from 1 to 5) is then computed and results in an assignment to a Bioclass. Bioclass scores of $\geq$ 4.5 receive an "excellent" water quality rating; < 4.5 a "good" rating; and so on. EPT values were adjusted for stream size by NCDEM procedures (Lenat 1991).

Statistical analysis of chemical and macroinvertebrate data. Multi-way ANOVA procedures, using SAS© (1990) statistics software program (proc ANOVA protocol), were used to compare differences between sections and dates for the macroinvertebrate indices (BI, EPT, and Bioclass) and the chemical variables. Of primary interest was the test for differences between corresponding sections (AF, FS, BF, and CS) across all streams and dates. For the invertebrate samples, the analysis was based on a 4x4x2 split-plot design with factors corresponding to four streams, four sections, and two dates. For chemical variables, the design was 4x4x3, because samples were analyzed for three dates.

Table 1 shows the theoretical model of a split-plot design as it pertains to this study. In this example, blocks are represented by streams; streams are treated as a random effect in the analysis, and replication is at the level of the stream (N = 4 replicates). The fixed effects, section and date, are compared in the analysis by using the mean square error from the stream by section and stream by date interactions, respectively, as the error term (denominator) to generate F-values (Steel and Torrie 1980). Table 2 illustrates the outcome of these procedures in an ANOVA table for the chemical parameter ammonia. Any statistically significant outcomes (with α = .05 defining statistical significance) were compared with least significant difference (LSD) procedures.

Fish Communities. Fish samples were collected once from each site during the sampling period (4 basins, each with 4 sites, or 16 collections). Fish collections in the NCWRC study sections (the FS in each study stream, plus either the AF or BF in each study stream, for a total of 8 collections) were directed by the NCWRC; collections were made by electroshocking (Borawa et al. 1995). In addition, we collected fish samples using the same procedures in the remaining 8 sites.

Sections were blocked at each end with one-quarter inch mesh (6 mm) seines and sampled with gas-powered, backpack electroshockers. Three-pass-depletion procedures were used to sample fish populations. Collected fish were immediately anesthetized in tricaine methanesulfonate. Fish were identified to species, weighed to nearest 0.1 g, and measured to the nearest mm, and were immediately revitalized and released following processing. Unidentified fish were preserved in ten percent formalin and transported to Clark Laboratories for further identification using Menhinick (1991).

Table 1. The "split-plot in space and time" design (ANOVA) used for statistical analyses, depicting sources of variation, degrees of freedom (df), and expected values of the mean squares for the analysis of chemical parameters. Streams represent blocks and are random; sections and dates are fixed factors. Adapted from Steel and Torrie (1980).

Sources of Variation	df	Expected Values
Streams, R	r-1	$\sigma^2 + ab\sigma_R^2$
Sections, A	a-1	$\sigma^2 + b\sigma_{AR}^2 + rb\phi_A$
Error (a), RA	(r-1)(a-1)	$\sigma^2 + b\sigma_{AR}^2$
Dates, B	b-1	$\sigma^2 + a\sigma_{BR}^2 + ra\phi_B$
Error (b), RB	(r-1)(b-1)	$\sigma^2 + a\sigma_{BR}^2$
AB	(a-1)(b-1)	$\sigma^2 + \sigma_{ABR}^2 + r\phi_{AB}$
Error (c), RAB	(r-1)(a-1)(b-1)	$\sigma^2 + \sigma_{ABR}^2$

Table 2. Example of ANOVA table (for ammonia).

Source	df	Sum of Squares	Mean Square	F	p-value
Stream (R)	3	0.0153	0.0051	-	-
Section (A)	3	0.0323	0.0108	1.48	0.2842
R*A	9	0.0655	0.0073	-	-
Date (B)	2	0.0101	0.0051	0.16	0.8527
R*B	6	0.1859	0.0310	-	-
A*B	6	0.0889	0.0148	1.83	0.1492
R*A*B	18	0.1455	0.0081		
Total	47	0.5437			

RESULTS

Weather conditions in the summer of 1993 were considered to be unusually hot and dry for the mountain region (James Borawa, North Carolina Wildlife Resources Commission, personal communication). Water temperature (Fig. 2) increased over the course of the study period, and water flow declined (Fig. 3). The water conditions in the Late-July/Early-August samples represented high-temperature/low-flow conditions at which we anticipated water quality deterioration, if present, to be most pronounced.

Chemical Parameters

Nitrogen and phosphorus were of primary interest because of their potential eutrophic effects. None of the five chemical parameters involving these elements (ammonia, nitrite, nitrate, DRP, total phosphorus) showed a statistically significant ($p < .05$) difference between sections over the course of the sampling period (Table 3). Statistical significance was present for nitrite and total phosphorus between dates (Table 3). There was a marked decrease in nitrite levels after the first sampling period; least significant difference (LSD) procedures yielded significantly higher average nitrite levels in the first period compared to both the second and third sampling periods ($p < 0.001$ in each case). Total phosphorus showed a statistically significantly increase in the third sampling period compared to the first and second periods ($p < 0.001$ in each caseThere were no statistically significant differences present in the interaction of section by date comparisons for any of the nutrient parameters (Table 3). Least Significant Difference tests specifically comparing the Above Fed (AF) section with the Fed Section (FS) also failed to reveal any statistically significant differences, whether making the comparison across all dates combined, or examining each date individually (Table 3).

Figures 4-6 show the estimates of ammonia, nitrite, and nitrate over time for each section (section mean ± SE). Ammonia and nitrate are reported as parts-per-million (ppm); nitrite is reported as parts-per-billion (ppb) of nitrogen. Elevated ammonia levels are suggested in the FS sections on the first sampling period (Fig. 4), but this suggestion was not consistent over time, and not statistically significant. Nitrite levels show a decreasing trend for all sections over time (Fig. 5). Nitrate levels varied little across time (Fig. 6).

Figures 7 and 8 show dissolved reactive phosphorus (DRP) and total phosphorus over time for each section (section mean ± SE). While there were suggestions of some differences among sections on some dates, overall there was no statistically significant differences among sites.

Other measurements (pH, alkalinity, hardness, % oxygen saturation, and conductivity) revealed no significant differences overall between sections (pH: $p=0.72$, alkalinity: $p=0.61$, hardness: $p=0.79$, % O_2 saturation: $p=0.99$, conductivity $p=0.69$). Table 4 lists means and one standard error for each of these measures at each section for the three sampling periods.

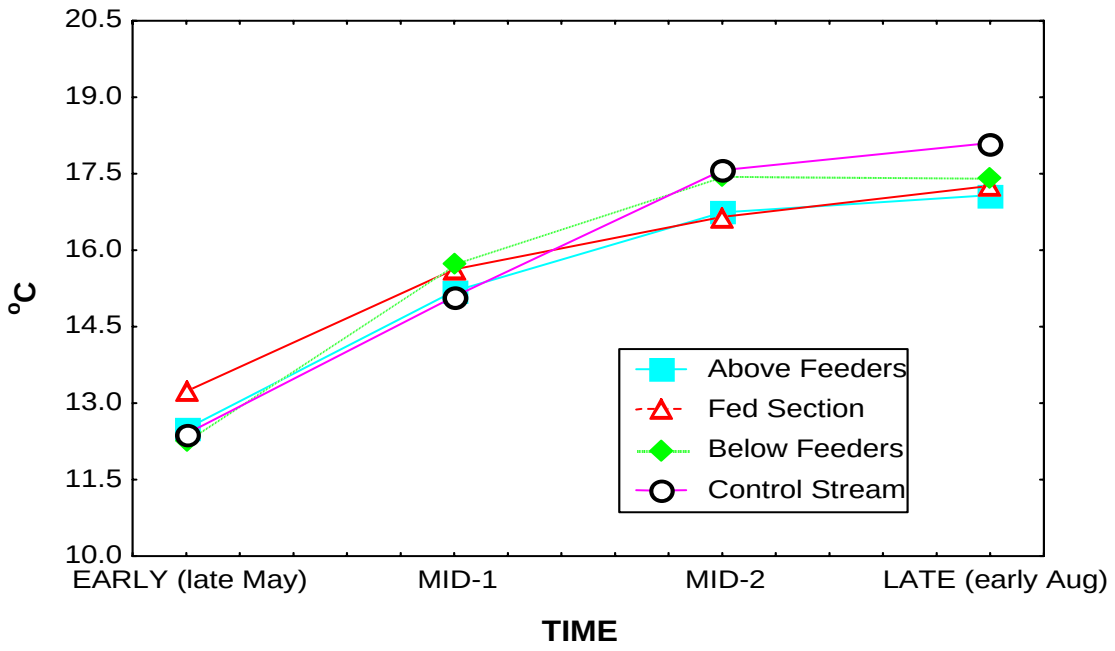

Figure 2. Water temperatures, averaged across all four study drainages.

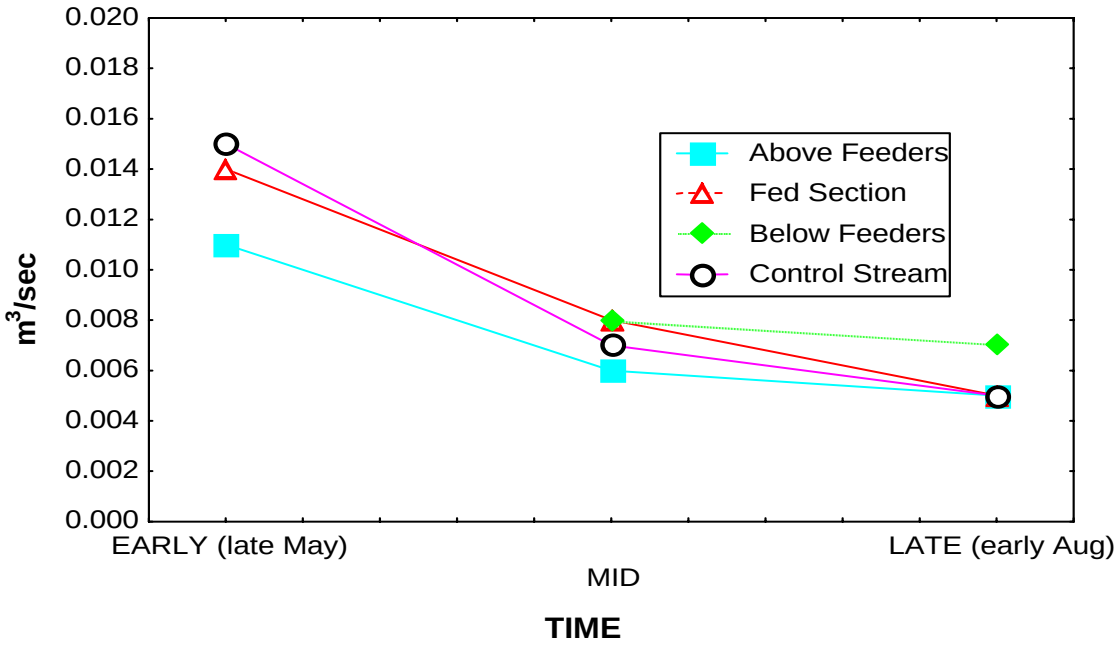

Figure 3. Average discharges, averaged across the four study drainages. The data point for the Below Feeders site on the Early sample is off the scale at 0.047, due to one high reading.

Table 3. Nutrient summary. (a) Mean and SE. (b) p-values for the total design (4 sections, 3 dates); $p < .05$ indicates statistical significance. (c) Least Significant Difference comparisons of the Above Fed Section versus the Fed Section. Overall, no statistically significant differences were found among stream sections; nitrite and phosphorus showed change across time (dates).

	(a) Mean [SE]				(b) p-values for the total design (4 sections, 3 dates)			(c) p-values for Least Significant Difference comparisons of the Above Fed Section vs the Fed Section			
									Individual dates		
Nutrient	Above Feeders	Fed Section	Below Feeders	Control Stream	Section	Date	Section*Date interaction	All dates combined	Early	Mid	Late
Ammonia (ppm)	0.0935 [0.025)	0.1148 [0.025]	0.0884 [0.025]	0.1543 [0.025]	0.2842	0.8527	0.1492	0.6312	0.5045	0.9068	0.9581
Nitrite (ppb)	0.4919 [0.116]	0.5347 [0.116]	0.3424 [0.116]	0.3149 [0.116]	0.4873	0.0052	0.2625	0.8181	0.6509	0.8208	0.8208
Nitrate (ppm)	0.1093 [0.017]	0.1444 [0.017]	0.1420 [0.017]	0.1448 [0.017]	0.4022	0.4634	0.2838	0.3141	0.6974	0.6126	0.4806
DRP (ppb)	2.6825 [0.845]	2.8517 [0.845]	3.6592 [0.845]	2.7717 [0.845]	0.8339	0.2819	0.8123	0.8966	0.8269	0.4456	0.4456
Total Phosphorus (ppm)	0.0747 [0.006]	0.0791 [0.006]	0.0878 [0.006]	0.0875 [0.006]	0.3276	0.0075	0.6559	0.9364	0.4880	0.4266	0.9147

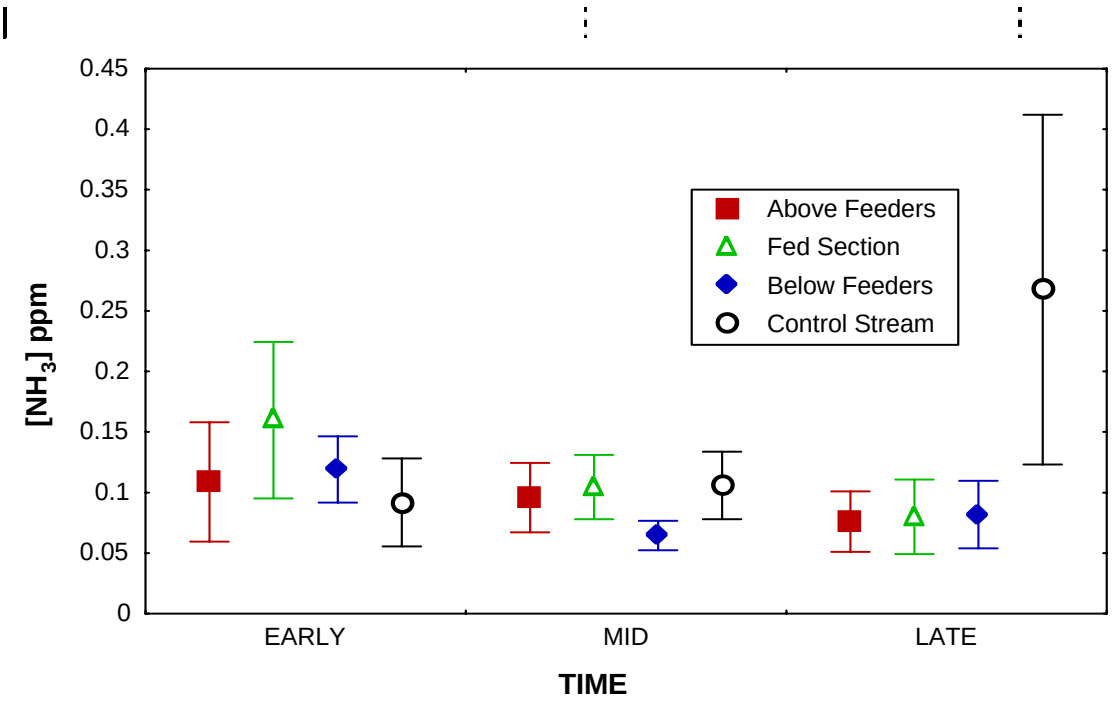

Figure 4. Ammonia levels (mean ± SE). Each point is the mean of the values from each of the four study drainages.

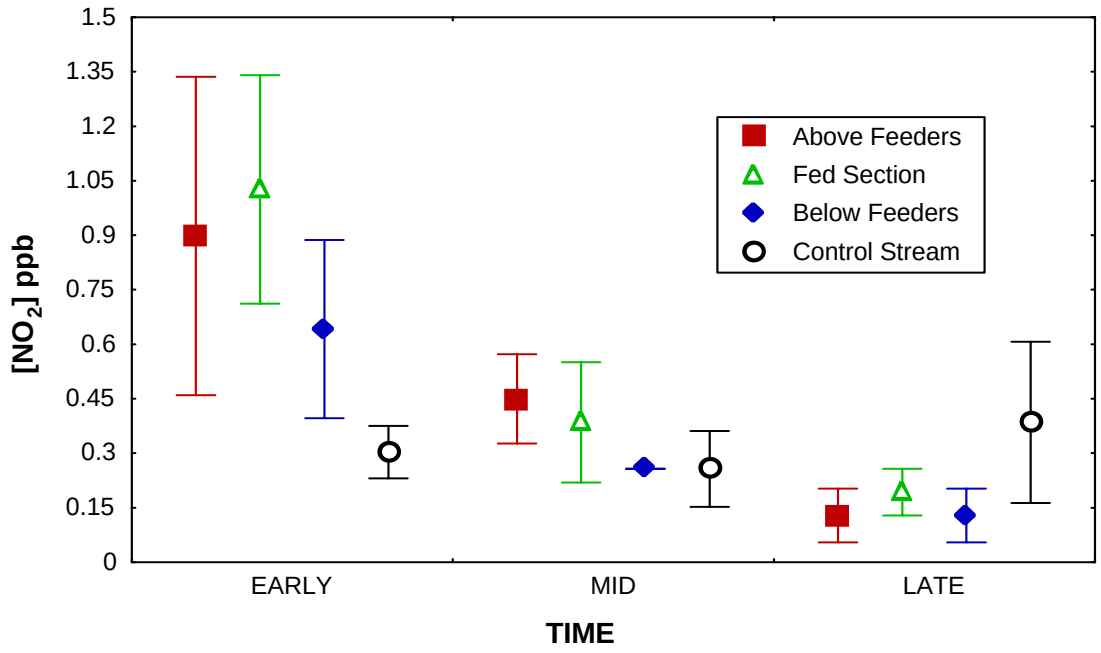

Figure 5. Nitrite levels (mean ± SE).

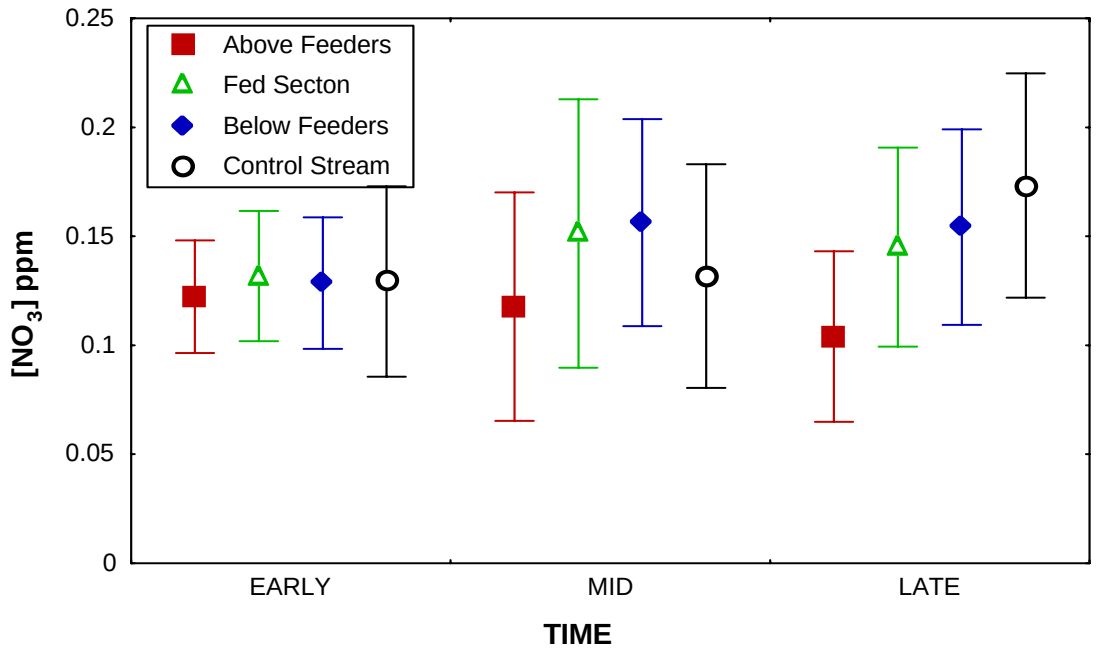

Figure 6. Nitrate levels (mean ± SE).

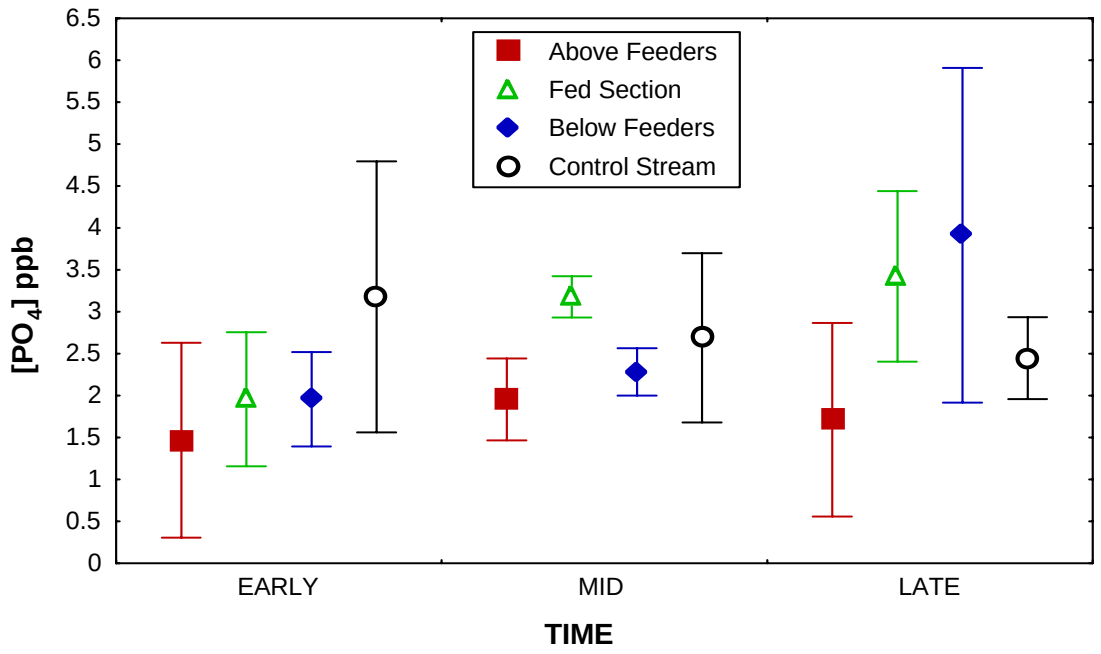

Figure 7. Dissolved reactive phosphorus (mean ± SE).

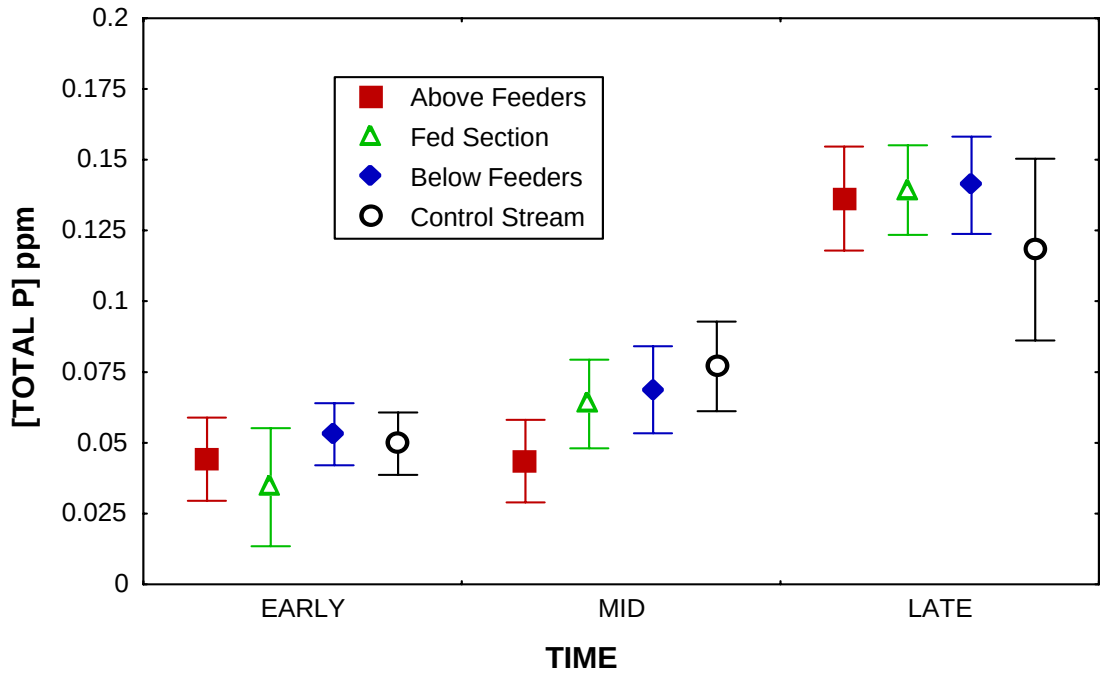

Figure 8. Total phosphorus (mean ± SE).

Table 4. Summary of additional chemical and physical measurements. Measurements averaged over all streams by dates. Data are means ± SE

EARLY

Measure	Above Feeders	Fed Section	Below Feeders	Control Stream
pH	7.08 ± 0.26	6.95 ± 0.17	6.98 ± 0.15	6.98 ± 0.23
Alkalinity (ppm $CaCO_3$)	3.50 ± 0.46	4.50 ± 0.94	4.50 ± 0.82	5.86 ± 2.63
Hardness (ppm $CaCO_3$)	5.00 ± 1.00	5.38 ± 0.95	5.13 ± 1.01	6.50 ± 2.50
% O_2 Saturation	92.3 ± 3.25	95.9 ± 4.45	96.6 ± 3.04	91.7 ± 5.39
Conductivity (μohmos/cm)	8.15 ± 1.03	9.75 ± 0.86	9.75 ± 0.48	13.3 ± 5.62

MID

Measure	Above Feeders	Fed Section	Below Feeders	Control Stream
pH	6.95 ± 0.27	7.00 ± 0.24	6.85 ± 0.26	6.90 ± 0.29
Alkalinity (ppm $CaCO_3$)	5.13 ± 0.97	4.88 ± 0.92	5.38 ± 0.56	7.50 ± 2.87
Hardness (ppm $CaCO_3$)	5.50 ± 0.96	5.50 ± 0.75	5.38 ± 0.56	7.50 ± 2.87
% O_2 Saturation	94.4 ± 3.38	96.0 ± 3.55	94.9 ± 3.08	96.4 ± 4.02
Conductivity (μohmos/cm)	10.5 ± 0.98	10.3 ± 0.86	9.75 ± 0.86	14.3 ± 5.30

LATE

Measure	Above Feeders	Fed Section	Below Feeders	Control Stream
pH	6.80 ± 0.22	6.75 ± 0.16	6.75 ± 0.19	6.60 ± 0.14
Alkalinity (ppm $CaCO_3$)	5.88 ± 1.25	5.38 ± 1.23	5.25 ± 1.25	8.81 ± 3.02
Hardness (ppm $CaCO_3$)	5.75 ± 1.18	5.25 ± 0.96	5.50 ± 0.96	7.50 ± 2.87
% O_2 Saturation	95.6 ± 4.94	91.4 ± 3.91	92.2 ± 4.28	94.6 ± 4.92
Conductivity (μohmos/cm)	12.0 ± 1.00	12.3 ± 1.13	14.3 ± 0.86	16.5 ± 6.44

Invertebrate Community Response

The NCDEM Bioclass model yielded "excellent" ratings from almost all invertebrate samples collected (Table 5). The only exceptions were the Curtis Creek BF and CS sections for the late samples that yielded "good" results. The "good" rating in the Curtis Creek CS section (Control Stream, in this case Catawba River) cannot be attributed to the feeders, because the Control Stream did not receive waters that were influenced by the feeders; the Catawba River, unlike the other collection sites, was turbid on most visits, and the rating may reflect sediment loading from an unknown source. While the "good" rating in the Curtis Creek BF section for the late sample might suggest an impact of the feeders, we note that the BF ratings in the other streams remained at the "excellent" level, and also that we noted at the time of that collection that recreational use (swimming, wading) by persons camping nearby was evident, unlike any of our other collections.

Although almost every sample yielded an "excellent" rating, ANOVAs were completed on the BI scores and corrected EPT counts to test for subtle changes that might have occurred within the invertebrate samples. No significant differences were found between sections for any of these tests (BI: p-value = 0.46, EPT taxa: p-value = 0.11). We also show those values in Figs. 9 and 10. While there are some suggestions of differences among sites for some time periods (e.g., the BI score for the early period), we conclude that, overall, there was neither a shift to pollution-tolerant fauna nor a loss of EPT fauna that can be assigned to the impacts of the feeders.

Invertebrate taxa lists for all streams, arranged by sections and sampling periods, are found in Appendix A.

Fish Community Response

Our original intent was to use the fish data for Index of Biotic Integrity (IBI) ratings (Karr et al. 1986, and an unpublished NCDEM manuscript). However, due to the lack of a sufficient number of fish species present in these streams, the North Carolina Mountain IBI developed by the NCDEM (the NCDEM IBI) was not applicable to assigning a fish-based biotic index for the waters we sampled. Nonetheless, we include an account of each site's fish species composition for purposes of documentation. No statistical analysis was conducted on the fish data because it was agreed at the outset of the project that NCWRC would analyze and state conclusions regarding trout population responses to the feeders. Borawa et al. (1995) report conclusions regarding the trout species, and estimate trout abundances from depletion curves over the three consecutive passes with the electroshockers. We report only the total number of fish collected in those three passes, without use of any further model to estimate true density.

Appendix B lists all species found in each stream and their abundances for 300 m of stream sampled in each section. Rainbow trout (*Oncorhynchus mykiss*), the species of primary interest to the NCWRC feeder study (Borawa et al. 1995), was the only fish species present in all sections of all streams. Although the NCDEM IBI does not have any specific criteria to assign a quality rating for streams of this nature, it is generally accepted that streams with abundant trout populations are assumed to be of high water quality. At all collection sites, fish appeared to be in good health when visually examined upon capture; there were no obvious indications of infection in any of the species captured from study streams.

Table 5. Bioclass assignment of sections. Bioclass assignments are based on model biotic index scores and corrected EPT (Ephemeroptera, Plecoptera, Trichoptera) counts.

1. Curtis Creek and Catawba River. Early

Section	Biotic Index Score	Corrected EPT Count	Bioclass
Above Feeders	2.63	46	5 - Excellent
Fed Section	2.73	44	5 - Excellent
Below Feeders	3.09	39	4.5 - Excellent
Control Stream	2.73	40	4.5 - Excellent

2. Curtis Creek and Catawba River. Late

Section	Biotic Index Score	Corrected EPT Count	Bioclass
Above Feeders	2.58	36	4.5 - Excellent
Fed Section	2.20	37	4.5 - Excellent
Below Feeders	2.44	31	4.2 - Good
Control Stream	2.60	32	4.2 - Good

3. Kimsey Creek and Bearpen Creek. Early

Section	Biotic Index Score	Corrected EPT Count	Bioclass
Above Feeders	2.65	45	5 - Excellent
Fed Section	2.93	45	5 - Excellent
Below Feeders	2.91	45	5 - Excellent
Control Stream	2.72	47	5 - Excellent

4. Kimsey Creek and Bearpen Creek. Late

Section	Biotic Index Score	Corrected EPT Count	Bioclass
Above Feeders	2.50	37	4.5 - Excellent
Fed Section	2.60	40	4.5 - Excellent
Below Feeders	2.03	36	4.5 - Excellent
Control Stream	2.42	38	4.5 - Excellent

5. Looking Glass Creek and Davidson River. Early

Section	Biotic Index Score	Corrected EPT Count	Bioclass
Above Feeders	2.63	45	5 - Excellent
Fed Section	2.87	48	5 - Excellent
Below Feeders	3.24	42	4.7 - Excellent
Control Stream	2.50	49	5 - Excellent

Table 5 (continued)

6. Looking Glass Creek and Davidson River. Late

Section	Biotic Index Score	Corrected EPT Count	Bioclass
Above Feeders	2.55	46	5 - Excellent
Fed Section	2.81	40	4.7 - Excellent
Below Feeders	2.52	42	4.7 - Excellent
Control Stream	2.74	41	4.7 - Excellent

7. South Toe River and Upper Creek. Early

Section	Biotic Index Score	Corrected EPT Count	Bioclass
Above Feeders	2.49	44	5 - Excellent
Fed Section	2.97	43	5 - Excellent
Below Feeders	2.59	39	4.5 - Excellent
Control Stream	2.36	44	5 - Excellent

8. South Toe River and Upper Creek. Late

Section	Biotic Index Score	Corrected EPT Count	Bioclass
Above Feeders	2.31	50	5 - Excellent
Fed Section	2.87	36	4.5 - Excellent
Below Feeders	2.17	41	4.7 - Excellent
Control Stream	2.97	45	5 - Excellent

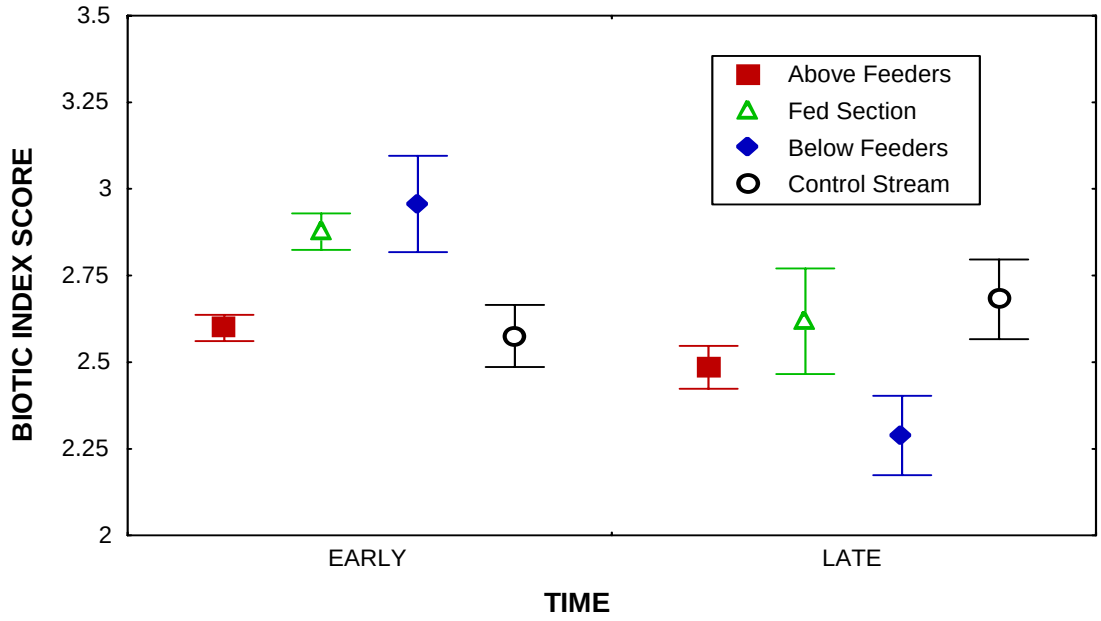

Figure 9. Biotic Index scores from NC Department of Environmental Management model (mean ± SE). In the Biotic Index model (not to be confused with Bioclass rating in Table 5), lower scores represent higher water quality. All of the scores are <4.0, and are regarded as indicating "excellent" water quality.

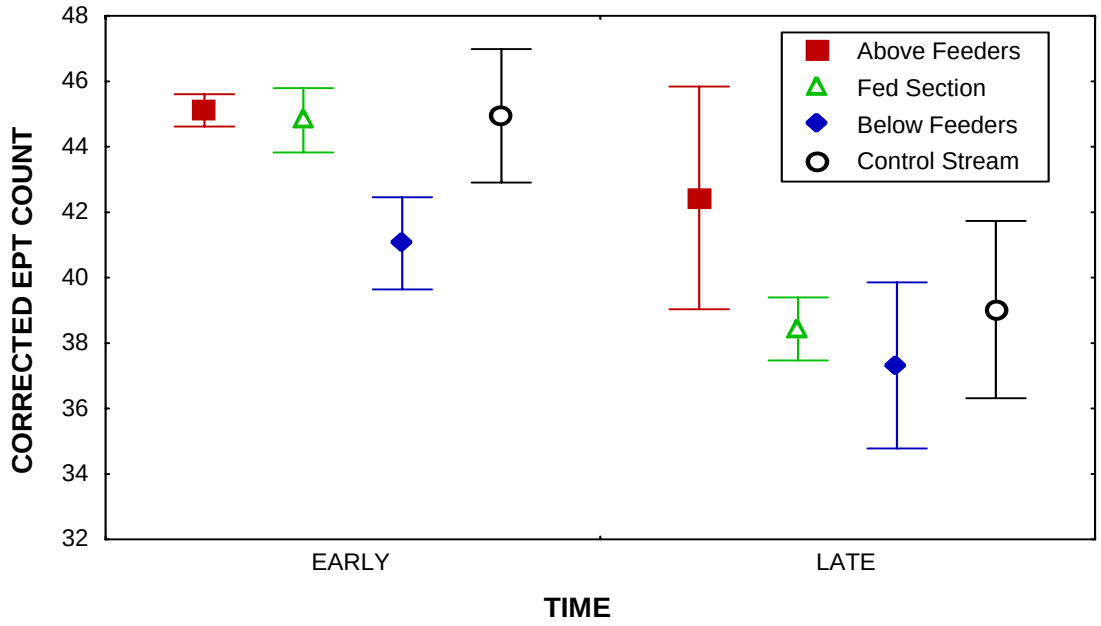

Figure 10. Total number of Ephemeroptera, Plecoptera, and Trichoptera (mean ± SE), corrected for stream size by the NCDEM model. Higher scores indicate higher water quality.

Figures 11 and 12 illustrate the average individual weights and average numbers found per 300 m of section sampled for rainbow trout, mottled sculpin, and longnose dace (we emphasize that the numbers we report here represent the sum of three electrofishing passes per sampling trip; the NCWRC estimates can differ because those estimates are based on depletion sampling). Averages for rainbow trout were taken from all four study streams; averages for mottled sculpin and longnose dace were taken from the two study streams where they were present. There appeared to be dramatic increases of average individual weight of rainbow trout within the FS section, i.e., a shift towards larger individuals, and this phenomenon has been analyzed more completely by Borawa et al. (1995). There also appeared to be substantial increases in total numbers of fish present within the FS section (Fig. 12), with rainbow trout numbers appearing to respond more strongly than mottled sculpin and longnose dace. These data do not address the question of the relative contributions of immigration, emigration, reproduction, mortality, and growth in producing these patterns, but we note that the data of Borawa et al. (1995) show increases of trout numbers and mean size in the fed section without evident depletion of adjacent populations.

Other Observations

In the course of the study, we also made visual inspections of the study areas. This lead to an observation regarding aesthetics which was not part of our planned analyses and was not quantified, but we report it for completeness. During the high temperatures and low flows of summer of 1993, stream channels decreased in size, and food pellets began to accumulate on the stream banks near some of the feeders; the rotting of these pellets produced an unpleasant odor, attracted terrestrial dipteran flies, and produced a sight that would usually be taken to be unpleasant to recreational users of the site. Under these conditions, pellets also accumulate in some shallow water areas, and fungal growth was evident on the pellets. The Principal Investigator on the NCWRC study, Mr. James Borawa, was aware of these conditions, but chose not to alter the feeders (correctly, in our view), in order to maintain the original experimental design.

We also inspected the streams for evidence of “nuisance” algal growth in the fed sections. None was evident (an attempt to measure periphyton growth yielded insufficient replication due to human removal of the sampling devices and loss of the devices in spates). Finally, we made an attempt to observe fish feeding on the pellets, to obtain some information on whether the food pellets were being directly consumed by the trout, or possibly enhancing trout growth indirectly through stream enrichment; we determined that the trout were directly consuming some of the food pellets, but did not make quantitative estimates of the proportion consumed.

Finally, we note that Cady (1994) also conducted an analysis of the invertebrate community of one of the four study sites, Kimsey Creek, in terms of “functional feeding groups” of the insects. Cady (1994) divided the juvenile insects into four feeding groups: shredders, which consume coarse particulate matter (particle size > 1 mm); collectors, which feed on fine particulate organic matter either by filtering the seston or foraging on detritus on the substratum (particle size < 1 mm); grazers, which crop stream algal stands, and predators, which consume live animal prey. Cady (1994) concluded that there were no shifts in the relative proportions of the functional feeding groups among the treatment sections in Kimsey Creek, whether the proportions were calculated from the number of species or the numbers of individuals in each group. However,

Cady (1994) did detect an increase in mean body size in three collector species in the Fed Section of Kimsey Creek, relative to Above Fed and Below Fed sections, and interpreted this change as probably reflecting increased input of food for those collectors, either as suspended particles from decomposed trout pellets or detritus derived from the pellets.

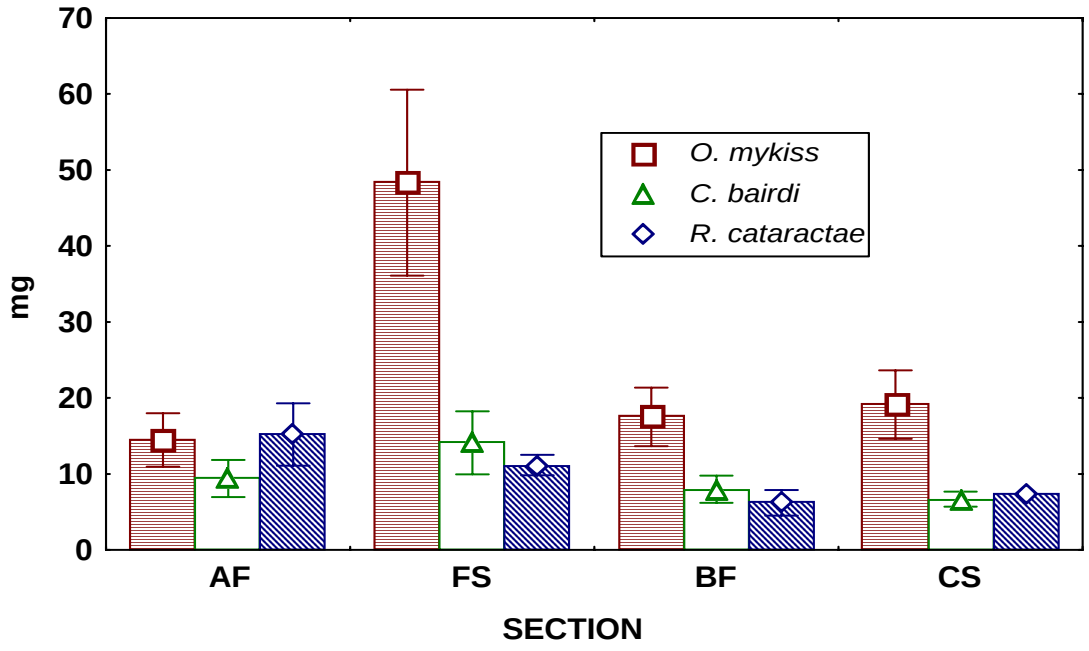

Figure 11. Mean individual masses of rainbow trout, mottled sculpin, and longnose dace (mean ± SE).

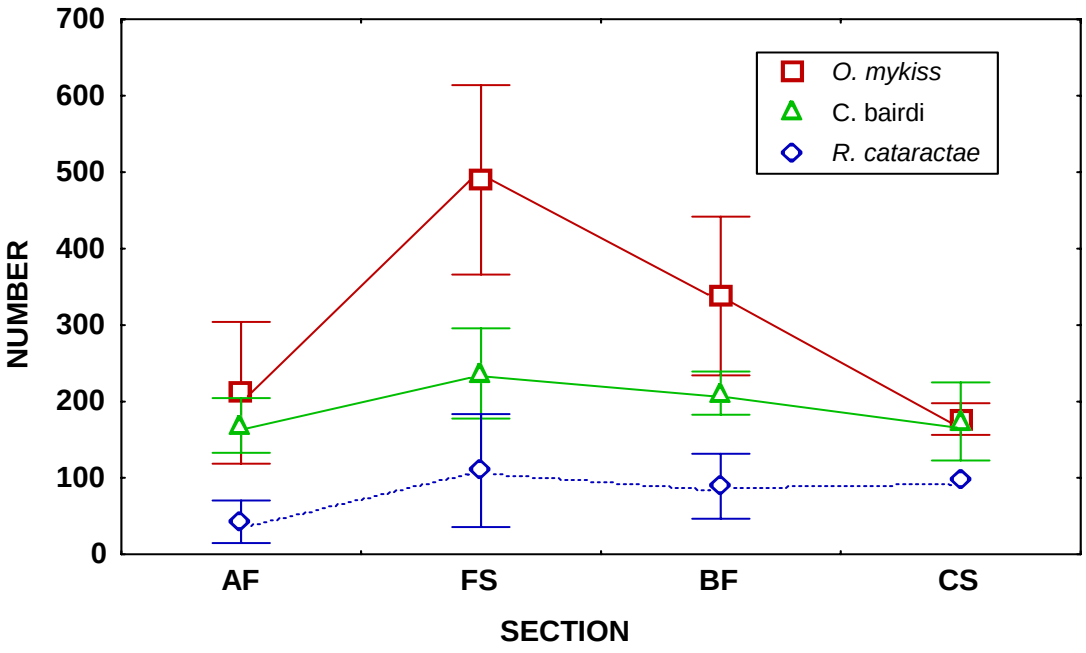

Figure 12. Number of rainbow trout, mottled sculpin and longnose dace in each 300 m stream section (mean ± SE).

DISCUSSION

Our replicated statistical analyses failed to detect any effects of the feeders on measures of water quality, i.e., the nutrient concentrations and invertebrate community composition. However, in view of the large response of the trout population to the feeders, as was the goal of the management (Borawa et al. 1995 and Figs. 11 and 12), one is confronted with an obvious question: Given that the food input was non-negligible from the viewpoint of the rainbow trout population, might common sense suggest that there should be some increase in nutrient concentrations attributable to the feeders, whether due to excretion by the trout and/or decomposition of uningested food pellets? Restated, was there potentially a nutrient increase which we missed due to a Type II statistical error, i.e., failure to detect an effect that was nonetheless present, due to inadequate statistical replication to detect the effect?

Figure 13 addresses that question, in which we focus on estimates of the increases in nutrient levels, if present, rather than on the statistical significance (p-values) of the treatment effects. For that analysis, we use our data in a way that is more traditional in studies of this type: we compare the nutrient concentrations above and below the purported impact, i.e., we calculate the percent increase in nutrient concentration in the fed section as

$$\%\ change = \frac{X_{FS} - X_{AF}}{\overline{X}_{AF}} \bullet 100\%,$$

where, for a given nutrient quantity, the value from the Fed Section is X_{FS}, the value at the Above Fed section is X_{AF}; and division is by the overall mean from all AF sections for that particular nutrient quantity ($\overline{X}_{AF}$) (division by the mean avoided a potential problem of division by zero for a few cases). Thus, for each of the five nutrient values in Fig. 13 (ammonia, nitrite, nitrate, total P, and DRP), each estimate represents the mean of twelve values (four streams, each with three dates; we also show the SE's based on those twelve values for informational value, but do not use those SE's for any statistical inference). Similarly, the Bioclass value represents the mean of eight values (four streams, each with two dates; SE's are also shown for informational purposes only).

The analysis in Fig 13 yields three conclusions that extend the analyses in the Results section that were our planned analyses in our original study design.

- First, our point estimates of relative nutrient levels are all positive, i.e., our best estimate of differences in nutrient levels, if present but statistically undetected, is that nutrients were higher in the fed sections than upstream of the fed sections. This makes sense.

- Second, we can conduct a post-hoc "meta-analysis" of the data which finds that there is evidence of some decreased water quality associated with the feeders, albeit it a subtle decrease, if present. While our planned statistical analysis found no significant impact treatment (AF, FS, BF, CS) on any individual nutrient or the invertebrate-based Bioclass rating, we note that 6 of 6 measures of water quality were in the direction of indicating a negative impact of the feeders on

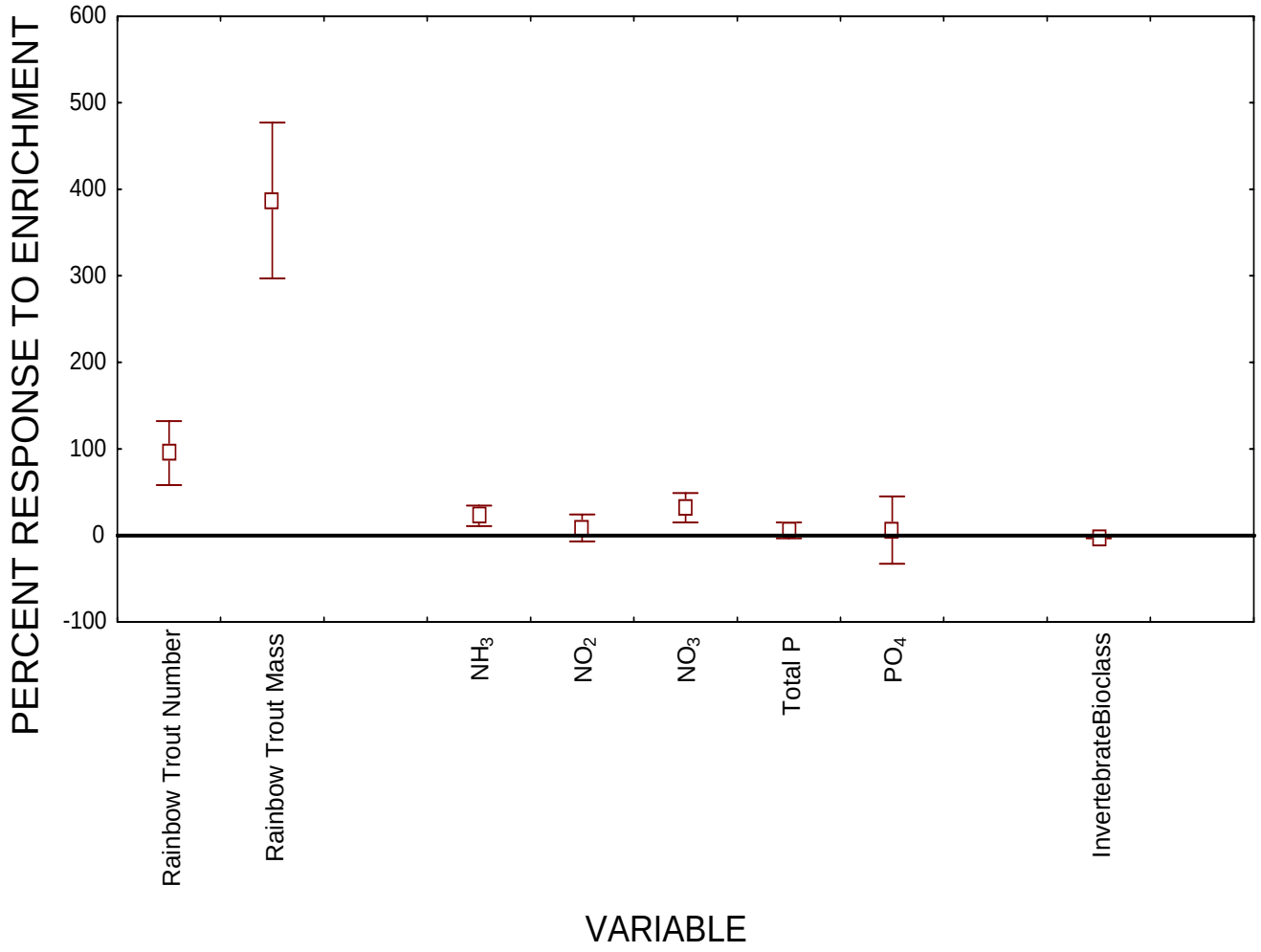

Figure 13. Percent change in numbers per hectare and mass per hectare of rainbow trout in the fed section relative to the section above the feeders, as abstracted from Borawa et al. (1995), and percent change in nutrient parameters and invertebrate Bioclass, as estimated in this report. Mean $\pm$ SE. While no nutrient or Bioclass variable showed statistically significant change when considered individually, 6 of 6 estimates of water quality yielded values point estimates falling on the side of water quality deterioration (sign test, $p = .033$, 2-tailed), if deterioration is defined as higher nutrient levels and lower Bioclass. However, the changes in nutrients and Bioclass, if actually present, were small relative to the response of the target species of the management experiment (rainbow trout).

water quality (5 of 5 nutrient variables yielded positive estimates, and the Bioclass value yielded a negative estimate). That is, while independent statistical analyses yielded no statistically significant differences among treatments, combining the data yields a consistent pattern to the direction of change: by a sign test, the probability of all 6 metrics falling in the same direction is p=.016 by a one-tailed test, and p=.033 by a two-tailed test (we did not state a hypothesis concerning the direction of change prior to the study, but inherent in the experiment is the expectation that the feeders would increase nutrients if the feeders do in fact affect nutrient levels; thus a one-tailed test is reasonable, but a two-tailed test is more conservative and also reasonable). Considering only the nutrient levels, 5 of 5 differences fall in the direction of elevated nutrients in the Fed Section, with probabilities p=.031 one-tailed or p=.063 two-tailed.

- Third, and perhaps most important from a management perspective in which costs and benefits are compared, the feeder-induced percent change in nutrient concentrations and invertebrate Bioclass values are, if present at all, small relative to the percent change in the management target (the trout). By the estimates we extracted from Borawa et al. (1995, their Figs. 2 and 4), the feeders increased rainbow trout numbers (number/area) by about 100%, and biomass standing crop (grams/area) by about 400%. These increases were "purchased" with much smaller estimated percent increases in nutrient levels.

Taken as a whole, we conclude from this meta-analysis that (a) although there was no statistically significant effect of the feeders detected for any nutrient parameter when analyzed separately, the effect of the feeders, if present but undetected, is to raise nutrient levels, (b) the full weight of the evidence is that the feeders did raise nutrient levels overall when the directions of change of each parameter are combined in the fuller picture of the meta-analysis, but (c) the relative magnitude of change in nutrient levels and the invertebrate community, if present, was small relative to the response of the trout. We note, especially, the invertebrate communities, on which we put primary confidence as a long-term integrator, indicate that water quality in the Fed Sections remained at the "Excellent" Bioclass rating we would normally expect for such sites in the absence of the feeders; deterioration, if present, was subtle.

Our overall conclusion is that accomplishment of the positive management impacts on trout fisheries stated in Borawa et al. (1995) were achieved without any marked decline in water quality, as measured by nutrient levels and invertebrate community composition at the feeding levels and the spatial extent of the experiment conducted. Because the water quality assessments were made in the third year of the feeders' input, and taken in a year with unusually low water flow, we feel that this conclusion is likely to be valid even if the feeding activity were extended to additional years with the same intensity, although we cannot strictly dismiss the possibility that deterioration of water quality would become apparent under some climatic circumstances, or over a longer time scale. We also note that evidence from the fish farming industry has established that effluents from fish farms can produce deterioration in water quality downstream of such operations (e.g. Liao 1970a,b; Hinshaw 1973, Alabaster 1982, Butz and Vens-Cappell 1982, Korzeniewski et al. 1982a,1982b, Mantle 1982, Kendra 1991, Pillay 1992, Eagleson 1994). Impacts are also reported in downstream impoundments rather than in the stream itself (Alabaster 1982, Eagleson 1994). While we feel that feeding programs of the intensity (food/area/time) and extent (ca. 1 km of stream, and one stream per local watershed) of the present experiment can be conducted without serious concern for deterioration of local water quality, increases in intensity

(more food/area/time) and/or extent (longer stream reaches, or multiple streams per watershed) could presumably deteriorate water quality at feeding levels which are presently unknown.

Borawa et al (1995) analyze the economics and other aspects of the study, and make recommendations on establishment of feeding programs. Among these recommendations are that stream sections of at least 1.6 km be used, that feeders with adjustable rates or hand feeding be used, and that feed be applied at a rate of 3-5% of trout standing crop per day (this level of feeding would be less than in the present experiment; James Borawa, personal communication). These recommendations by Borawa et al. (1995) are based on management goals regarding trout production and recreational fishing, and the recommendation to use adjustable feeders or hand feeding also address the aesthetic and wastage issue observed in the present experiment. Assuming that the feeding intensity (food per area per time) implemented in such a program is no higher than the present experiment, we feel that these recommendations are also reasonable recommendations regarding water quality, provided that the extent of the feeding program is not expanded substantially. We have no data to indicate levels of program expansion that would prove detrimental, nor any criteria for stating an acceptable level of deterioration; our sense of the system is that stream reaches $\leq$2 km and widely dispersed among watersheds may be safely included in feeding programs of the type envisioned by Borawa et al. (1995), where by "safely" we mean without deterioration of the Bioclass of the local stream area. However, we also would add that an assessment of water quality impacts should be a planned part of any future implementation of feeding programs exceeding the present experiment, given the absence of knowledge of cumulative impacts of longer stream reaches and/or more sites per watershed. Ideally, a future water quality assessment would include some mass-balance assessments of the contribution of the feeding to the nutrient and energy budgets of the stream ecosystems, with attention given to potential nutrient inputs to downstream impoundments. At a minimum, the monitoring should include some monitoring of benthic invertebrates in the vicinity of the fed sections; the most cost-effective and reliable monitoring would probably be periodic visits by experienced NCDEM personnel to determine Bioclass ratings for the sites.

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Appendix A. List of invertebrate species found in each section (AF = Above Feeders, FS = Fed Section, BF = Below Feeders, CS = Control Stream) for both collection periods in each of the four study drainages. Numbers indicate the number found in the standard samples.

Table A.1. Curtis Creek and Catawba River invertebrate taxa.

	AF	**AF**	**FS**	**FS**	**BF**	**BF**	**CS**	**CS**
EPHEMEROPTERA	Early	Late	Early	Late	Early	Late	Early	Late
Acentrella ampla							1	1
Baetis flavistriga					2		1	1
Baetis pluto								1
Baetis tricaudatus	17	18	4	4	11	9	10	3
Dannella lita	2				2		1	
Drunella cornutella	30	30	26	16	36	6	13	3
Drunella longicornis					2			
Drunella tuberculata	15	7	3	1		10	3	1
Epeorus dispar	20	30	20	30	26	17	17	27
Epeorus pleuralis	3		2				1	
Epeorus rubidus					1		10	3
Ephemera blanda	1		19	4	3	15		
Ephemera guttalata							2	6
Ephemerella catawba	10	3	10		28	4	30	19
Ephemerella dorothea							2	
Ephemerella invaria (gr.)	30	30	20		26			
Heptagenia julia				3				
Isonychia sp.	9	11	4	15	1	6	6	
Leucrocuta aphrodite		1		1	1	10		1
Paraleptophlebia sp.	1		3	1		2	9	3
Pseudocloeon spp.	17	19	30	13	10	8	30	5
Rhithrogena exilis	12	7	30	2	7	4		
Serratella carolina				2		1		
Stenacron carolina		1						
Stenonema modestum	12	7	18	26	17	19	12	4
PLECOPTERA								
Acroneuria abnormis	5	4	7	6	14	15	4	2
Allocapnia sp.	26	9	23	18	10	10	30	30
Amphinemura sp.	2	1	4		2		1	
Eccoptura xanthenes			1				1	
Isoperla holochlora	9	1	21	1	20		19	1
Isoperla nr. *holochlora*	3		1		1			
Isoperla nr. *slossonae*							2	
Paragnetina sp.								1
Perlesta sp.	11	1	4	8	11	3		
Pteronarcys spp.	3	2	11	10	29	5	10	3
Remenus bilobatus			2					
Sweltsa sp.	2	1	1	2	11			
Tallaperla sp.	17	8	30	30	29	14	28	12
Yugus arinus					1			

Table A.1. (continued)

	AF Early	AF Late	FS Early	FS Late	BF Early	BF Late	CS Early	CS Late
PLECOPTERA								
Yugus bulbosus		5	8	13		7	2	2
TRICHOPTERA								
Ceratopsyche macleodi		12	1	30		8		
Ceratopsyche slossonae			1		1			1
Ceratopsyche sparna			1					
Ceratopsyche ventura	1							
Diplectrona modesta	20	8	20	11	15	12	17	23
Dolophilodes sp.	2	23	15	25	2	5	2	
Glossosomatidae							2	
Lepidostoma sp.	4		4		3		1	
Lype diversa			2					
Neophylax oligius							10	10
Neophylax ornatus				1				
Neophylax sp.	1							
Parapsyche cardis						2		
Polycentropus sp.	3			1	3	1	2	4
Pycnopsyche guttifer			5	1	3	5	3	5
Rhyacophila carolina		2		2	1	1	1	
Rhyacophila fuscula	5		6	10	5	1	2	3
Rhyacophila nigrita	11				1		1	3
COLEOPTERA								
Anchytarsus bicolor							1	1
Ectopria nervosa	1	1		1	1			
Elmidae								4
Helophorus sp.					3			
Oulimnius latiusculus	18	7	4	2	5	4	9	2
Promoresia tardella	11	8	8	2	11	16	9	23
Psephenus herricki		1	1		1		16	14
ODONATA								
Lanthus vernalis	4	4	3	3	1	1	2	1
MEGALOPTERA								
Nigronia serricornis				1				
DIPTERA: CHIRONOMIDAE								
Ablabesmyia sp.			3		3			
Brundiniella eumorpha		10	5	5	10	7	3	3
Cardiocladius sp.								1
Cladotanytarsus sp.	3	7		10	10	10		
Conchapelopia (gr.)	33	3	5	3	10	1	3	3
Corynoneura sp.						1		
Cryptochironomus fulvus			4		4	5		4
Demicryptochironomus sp.		1		1	4	3	2	2
Diamesa sp.	1						2	1
Epoicocladius sp.				1				1

Table A.1. (continued)

CHIRONOMIDAE	**AF** Early	**AF** Late	**FS** Early	**FS** Late	**BF** Early	**BF** Late	**CS** Early	**CS** Late
Eukiefferiella brehmi (gr.)						2		
Heleniella spp.	5	2	1	10	3	10		3
Heterotrissocladius sp.		1						
Limnophyes sp.					1			
Lopescladius sp.	2				7			
Micropsectra sp. 1					10			
Micropsectra sp.	4		10	4				
Microtendipes sp. 1		1			3		1	
Odontomesa fulva			2		2			
Paracladopelma sp. 1		1			1			
Parametriocnemus lundbecki	2	2		1	4		10	3
Phaenopsectra sp.		1		1		4		
Polypedilum aviceps		1			1	5	1	
Polypedilum fallax			10		3			
Polypedilum laetum			10		1			
Polypedilum scalaenum					1		10	
Polypedilum tritum						5		
Potthastia sp.					4			
Prodiamesa olivacea	10	10	10	3	10	1		
Synorthocladius sp.						1		
Tribelos sp.				1				
Zavrelimyia sp.	1							
MISC. DIPTERA								
Antocha sp.							2	
Atherix lantha	1		1	1			3	1
Bezzia sp.	6	2	6	6	16	14	3	1
Blepharicera spp.	4					2	4	3
Chrysops sp.			1					
Dicranota sp.	26	16	18	17	32	10	11	5
Dixa sp.	4		5	1	1	1		
Hexatoma sp.	28	13	13	21	29	25	4	1
Odontomyia sp.					2			
Pedicia sp.				1				
Simulium parnassum			1		4	7	8	
Simulium pictipes	3		2	1				
Simulium vittatum	6	2	9				3	3
Tipula spp.			7	1	20	2	2	1
OLIGOCHAETA								
Lumbriculidae	5	5	8		10	10	10	10
CRUSTACEA								
Cambarus bartoni	10	10	10	10			10	10
GASTROPODA								
Elimia sp.	10	10	10	10	21	15	10	10

Table A.2. Looking Glass Creek and Davidson River invertebrate taxa.

	AF	**AF**	**FS**	**FS**	**BF**	**BF**	**CS**	**CS**
EPHEMEROPTERA	Early	Late	Early	Late	Early	Late	Early	Late
Baetis flavistriga		3	1	4	1	2	31	1
Baetis tricaudatus	2	3	8		2	1	31	11
Cinygmula subaequalis							3	
Dannella lita			1				7	
Drunella cornutella	13		15	1	8		31	20
Drunella longicornis							1	2
Drunella tuberculata	19	23	15	15	6	31		11
Drunella wayah	4		1		2		31	5
Epeorus dispar		3	16		16	10	5	7
Epeorus rubidus	3	5		1	4	4	15	8
Ephemera blanda	6	10	4	1	2	4	1	1
Ephemerella catawba	11	2	2	1	9	1	12	10
Ephemerella invaria (gr.)			1				12	1
Ephemerella rossi (gr.)							2	
Ephemerella subvaria				4				
Eurylophella temporalis	1		1			1		
Heptagenia julia			12	7	9	11		
Heterocloeon sp.							3	
Hexagenia sp.		1						
Isonychia sp.	2	3	2	4	3	1	3	1
Leucrocuta aphrodite				1	2	10	1	1
Nixe sp.			1	1			11	2
Paraleptophlebia sp.	7	1	13	2	8	12	8	4
Pseudocloeon spp.	6	8	2	1	1	2	11	11
Rhithrogena amica							1	
Rhithrogena exilis	1	1		1			1	
Serratella carolina	1	10				14		4
Stenacron pallidum	13	14					1	4
Stenonema modestum	7	10	9	13	10	22	6	3
PLECOPTERA								
Acroneuria abnormis	11	22	4	11	14	11	5	11
Acroneuria carolinensis							1	
Allocapnia sp.	30	20	30	21	31	31	31	31
Amphinemura sp.	5	1	5		1	2	3	1
Isoperla holochlora	22	1	6	1	6		15	4
Isoperla nr. *slossonae*							1	
Paragnetina immarginata	2	5	1	8			1	8
Perlesta sp.	10	4	10	1	2		4	8
Pteronarcys spp.	20	10	8	10	5	3	17	12
Remenus bilobatus	2				3		3	
Sweltsa sp.	2	6		4	6	2	4	5
Tallaperla sp.	30	30	30	11	5	21	11	33
Yugus bulbosus	4	10	1	1		4		4
TRICHOPTERA								
Agapetus sp.							1	
Apatania sp.							1	
Arctopsyche irrorata	6	6	4	14	2		3	2

Table A.2. (continued)

TRICHOPTERA	**AF** Early	**AF** Late	**FS** Early	**FS** Late	**BF** Early	**BF** Late	**CS** Early	**CS** Late
Brachycentrus spinae							1	
Ceratopsyche macleodi	12	30	12	31	14	31		1
Ceratopsyche slossonae						31	10	5
Ceratopsyche sparna		5	3	21	6	7	4	27
Diplectrona modesta	10	1	2				8	
Dolophilodes sp.	12	14	2	14	3	17	1	14
Fattigia pele	2					2		
Goera fuscula	1	3		1				
Lepidostoma sp.	20	5	20	3	3	11	5	11
Lype diversa						11		
Neophylax mitchelli		3	3					
Neophylax oligius		1						
Polycentropus sp.	1	1	2		3	2	6	1
Pseudostenophylax uniformis			1					1
Psilotreta sp.			7	1	1	1		
Pycnopsyche guttifer	1	1	6	8	8	3	1	1
Rhyacophila carolina	4	9	3	2	3	2	3	5
Rhyacophila fuscula	7	5	2	1	9	16	1	1
Rhyacophila nigrita	5	4	1		1	1	1	1
COLEOPTERA								
Anchytarsus bicolor		1					1	
Ectopria nervosa		1					1	
Oulimnius latiusculus	1	22	15	4	4	6	2	1
Promoresia tardella	4	11	8	7	7	7	15	4
ODONATA								
Cordulegaster maculata			1	1	1	1		
Lanthus vernalis	3	9	8	4	4	6	2	3
MEGALOPTERA								
Nigronia serricornis				1	1	3	4	2
DIPTERA: CHIRONOMIDAE								
Brundiniella eumorpha	6	5	6	10	3	10	11	5
Cladotanytarsus sp.	7		1		1			
Conchapelopia (gr.)	10	2	10	3	10	10	11	10
Cryptochironomus fulvus	10	5	5	5	3	4	4	6
Demicryptochironomus spp.	8	1	1				1	
Diamesa sp.	1	2	1	1	8	3		
Epoicocladius sp.						1		
Eukiefferiella brehmi (gr.)							1	
Eukiefferiella brevicalcar (gr.)				1				
Eukiefferiella claripennis (gr.)							1	
Heleniella sp.								1
Heterotrissocladius sp.								1
Micropsectra sp. 3						10		
Micropsectra sp. 9							1	
Micropsectra sp.	5	1		2	1		2	10

Table A.2. (continued)

CHIRONOMIDAE	**AF** Early	**AF** Late	**FS** Early	**FS** Late	**BF** Early	**BF** Late	**CS** Early	**CS** Late
Microtendipes sp. 1		1		1			1	2
Microtendipes sp. 2		1				1		
Odontomesa fulva	2						1	
Orthocladius clarkei (gr.)			1			5	1	
Pagastia sp.	1	1			2	2	7	6
Paracladopelma sp.		1						
Parakiefferiella sp.								1
Paralauterborniella nigrohalteralis				2				
Parametriocnemus lundbecki						1	8	
Phaenopsectra sp.	5		10	11	10	5	1	10
Polypedilum aviceps	1		3	11	2	3	1	1
Polypedilum fallax					3	1	1	
Polypedilum illinoense					1			
Polypedilum laetum	5	3	6		3	5	3	
Polypedilum scalaenum						8	10	
Potthastia sp.				2		1		
Prodiamesa olivacea	3	5	4	1	3	2		1
Rheocricotopus tuberculatus	1		1		1		1	
Rheotanytarsus sp.		1					1	1
Sublettea coffmani						1	1	3
Tanytarsus sp.				1			2	1
Thienemaniella sp.			1					
Tvetenia bavarica (gr.)							1	1
MISC. DIPTERA								
Antocha sp.							6	
Atherix sp.							6	7
Bezzia sp.	1	2	3	3	1	10	1	4
Blepharicera sp.					1			
Dicranota sp.	26	17	15	6	3	8	10	3
Dixa sp.	4	2	1				1	
Empididae	1							
Hexatoma sp.	3	3	5	6	8	7	2	10
Simulium parnassum					2		1	3
Simulium pictipes		1			1		1	3
Simulium vittatum	1	10	3	1	3	1	7	13
Tipula spp.	5	2	10					1
OLIGOCHAETA								
Lumbriculidae	3	10	10	10	10	10	3	3
CRUSTACEA								
Cambarus bartoni	10	10	10	10	5	5	2	2
PELYCEPODA	**AF** Early	**AF** Late	**FS** Early	**FS** Late	**BF** Early	**BF** Late	**CS** Early	**CS** Late
Pisidium sp.	10	10	10	10				

Table A.3. South Toe River and Upper Creek invertebrate taxa.

EPHEMEROPTERA	**AF** Early	**AF** Late	**FS** Early	**FS** Late	**BF** Early	**BF** Late	**CS** Early	**CS** Late
Ameletus lineatus			2		1			
Baetis flavistriga			12	7	8	15	2	4
Baetis intercalaris			2					5
Baetis pluto	1							
Baetis tricaudatus	15	30	3	2	10	6	12	15
Centroptilum sp.						2		
Cinygmula subaequalis	6		4	1				
Dannella lita		1			2			
Drunella cornutella		2		6	4	6		
Drunella longicornis		1	1					
Drunella tuberculata		30		7		30	30	
Drunella wayah	6	12	5	13	17	30	3	
Epeorus dispar		8		2	3	6	3	7
Epeorus pleuralis	17	20	7	1	6		1	12
Epeorus rubidus				3	6	2	1	
Ephemerella catawba	10	3	11		10	6		13
Ephemerella invaria (gr.)	30	30	20	4	15			15
Ephemerella rossi (gr.)	3	1	3		1			4
Eurylophella temporalis			1				2	
Heptagenia julia		5		5		21	2	
Heterocloeon sp.							10	
Leucrocuta aphrodite		8		2		3	20	3
Nixe sp.		1		1	3	4		
Paraleptophlebia sp.	15	5	16	7	16	4		13
Pseudocloeon spp.	5	1	13	5	25	30	2	3
Rhithrogena exilis	8		1		10	16	1	
Serratella carolina						10	1	
Stenacron carolina		2		2				1
Stenonema modestum	5	10	6	6	3	7	17	6
Stenonema pudicum								10
PLECOPTERA								
Acroneuria abnormis	3	13	3	6	3	10	6	7
Acroneuria carolinensis					2	10		
Allocapnia sp.	15	22	7	30	12	30	30	30
Amphinemura sp.	9	3	7		9			18
Beloneuria sp.				1				
Eccoptura xanthenes								1
Isoperla holochlora	1	5	2		9	9	1	12
Isoperla nr. *holochlora*	4	2	2					2
Isoperla nr *slossonae*	1	1						
Perlesta sp.	8	9	1	1	11	9	13	2
Pteronarcys spp.	1		1		2	10		2
Remenus bilobatus	5	1	4		4			2
Sweltsa sp.	10	25	12	7	15	30	18	12
Tallaperla sp.	10	18	11		5	30	12	20
Yugus bulbosus	4					8	2	

Table A.3. (continued)

TRICHOPTERA	**AF** Early	**AF** Late	**FS** Early	**FS** Late	**BF** Early	**BF** Late	**CS** Early	**CS** Late
Apatania sp.		2				2	1	
Arctopsyche irrorata		5				10	2	
Ceratopsyche macleodi	2	30		3		30	30	2
Ceratopsyche morosa						30		
Ceratopsyche slossonae		1	5	1	13			
Ceratopsyche sparna				1				
Cernotina spicata	1							
Diplectrona modesta	3	4	1	1	1		1	4
Dolophilodes sp.	8	7	3		10	24	4	23
Glossosoma sp.						2		
Glossosomatidae	1	3	1					
Lepidostoma sp.	2	3	30	15	30	5	3	10
Lype diversa								1
Micrasema burksi						1		
Molanna blenda								1
Neophylax mitchelli			10		5	5		
Neophylax oligius					5	5		
Neophylax ornatus	10	10						
Parapsyche cardis		4					1	
Polycentropus sp.	1		3		2		8	
Psilotreta frontalis	2							
Psilotreta sp.				1				
Pycnopsyche guttifer	1	4	5	6	10	3		
Rhyacophila amicus			1					
Rhyacophila carolina	3	3	1	1	3	10	3	8
Rhyacophila fuscula	10	4	1	1	4	3	1	2
Rhyacophila melita					2	2		
Rhyacophila nigrita	3	2	1	6	8	3	6	4
Rhyacophila torva								1
Rhyacophila vuphipes							1	
COLEOPTERA								
Helophorus sp.		1	1				1	1
Optioservus sp.						2		
Oulimnius latiusculus	2			1	3	8		
Promoresia tardella	3	8	3	1	3	11	7	11
ODONATA								
Lanthus vernalis	4	5	2	5	3	3		4
MEGALOPTERA								
Nigronia serricornis	1							
Sialis sp.							3	
DIPTERA: CHIRONOMIDAE								
Ablabesmyia parajanta/janta	10							
Brillia sp.					11			1
Brundiniella eumorpha		3				2		

Table A.3. (continued)

CHIRONOMIDAE (cont.)	**AF** Early	**AF** Late	**FS** Early	**FS** Late	**BF** Early	**BF** Late	**CS** Early	**CS** Late
Cardiocladius sp.			3					
Chaetocladius sp.								1
Conchapelopia (gr.)	10	10	10	10	10	10	10	10
Corynoneura sp.	2				1			
Cricotopus nr *flavocinctus*			1			1		
Cricotopus varipes (gr.)					2			
Cricotopus/Orthocladius sp. 2	1		10					
Cryptochironomus fulvus	1	3				3	10	
Cryptochironomus sp.								1
Demicryptochironomus sp.						1		22
Eukiefferiella brehmi (gr.)			3	2		10	3	
Eukiefferiella brevicalcar (gr.)	1					2		
Heleniella sp.	2							
Heterotrissocladius marcidus		10						
Limnophyes sp.		2						
Micropsectra sp.	1	1				3	4	
Microtendipes sp. 1						3	10	
Microtendipes sp. 2	1				1	3		
Odontomesa fulva							1	
Orthocladius obumbratus (gr.)					1			
Paracladopelma sp.		1			5			
Paramerina sp.							1	
Parametriocnemus lundbecki	2	5		2	5	3		1
Phaenopsectra sp.		10	10	10			1	
Polypedilum aviceps	3	1	1		10	3	10	10
Polypedilum fallax					3			1
Polypedilum illinoense				1				
Polypedilum laetum								1
Prodiamesa olivacea				3				
Rheocricotopus tuberculatus					4			1
Rheotanytarsus sp.	1	5			1			2
Stilocladius clinopecten	2							
Synorthocladius sp.						10	1	
Tanytarsus sp.	1	1		1	10	10	1	
Thienemaniella sp.							1	
Tribelos sp.							1	
Tvetenia bavarica (gr.)		1			1			
MISC. DIPTERA								
Antocha sp.	4		7					3
Bezzia sp.	1	5		10	2	14	8	4
Dicranota sp.	30	30	5	30	8	17	13	10
Dixa sp.		2	2			2	1	8
Dolichopodidae								1
Empididae								1
Hexatoma sp.	11	1	3	1	7	5	3	1
Pericoma sp.	2							
Simulium pictipes					3	10		
Simulium vittatum	4	1	4	3	8	20	3	1

Table A.3. (continued)

OLIGOCHAETA

Lumbriculidae	2	5	5	5	2	2	4	2
CRUSTACEA								
Cambarus bartoni	10	10	10	10	10	10	5	5

Table A.4. Kimsey Creek and Bearpen Creek invertebrate taxa.

EPHEMEROPTERA	**AF** Early	**AF** Late	**FS** Early	**FS** Late	**BF** Early	**BF** Late	**CS** Early	**CS** Late
Baetis intercalaris	1						4	
Baetis tricaudatus	20	25	9	35	1	35	3	7
Cinygmula subaequalis	7		14		20	3	40	
Dannella lita	8		3					
Drunella cornutella	38	7	7	4	5	3	7	11
Drunella tuberculata		88		77		385		58
Drunella wayah							1	
Epeorus dispar	19	61	6	47	3	55	3	7
Epeorus pleuralis	35		38	1	8		4	
Epeorus rubidus					2	6		
Ephemerella catawba	16		14	3	10	1	26	5
Ephemerella invaria (gr.)	32		212		49		123	
Ephemerella rossi (gr.)	42		18				9	
Eurylophella temporalis			1		3			
Habrophlebia vibrans							1	
Heptagenia julia	1	64		141		169		50
Isonychia sp.	10	13	9	25	12	39	1	42
Nixe sp.	2							
Paraleptophlebia sp.		1	10		14		34	5
Pseudocloeon spp.	128	36	216	42	30	48	25	31
Rhithrogena exilis	1		6		8	2		
Serratella carolina						3		
Stenacron pallidum		4						
Stenonema modestum	6	14	10	16	17	2	2	2

PLECOPTERA									
Acroneuria abnormis	P				3	1	2		3
Allocapnia sp.	Sh	28	49	73	103	30	164	66	212
Amphinemura sp.	CG (Sh)	18	2	18	4	15		9	11
Isoperla holochlora	P	10	1	41	4	29	2	2	8
Isoperla nr. *holochlora*	P	10		15		1		16	
Perlesta sp.	P				1	1		1	21
Pteronarcys spp.	Sh	48	45	75	218	25	89	8	45
Remenus bilobatus	P			9		13		12	
Sweltsa sp.	P	1	8	8	10	3	47	7	12
Tallaperla sp.	Sh	80	317	47	797	67	495	25	582
Yugus bulbosus	P	53	115	50	89	26	140	8	46

TRICHOPTERA									
Apatania sp.	Sc							1	
Arctopsyche irrorata	CF	2	9		8		11	7	4
Ceratopsyche macleodi	CF		80		100		41		22

Table A.4. (continued)

TRICHOPTERA	**AF** Early	**AF** Late	**FS** Early	**FS** Late	**BF** Early	**BF** Late	**CS** Early	**CS** Late
Ceratopsyche slossonae	CF				1		1	
Diplectrona modesta	CF	7	1	18	6		2	13
Dolophilodes sp.	CF	11	19	13	14	51	8	5	52
Glossosoma sp.	Sc				1				2
Goera fuscula	Sc	1		1	3				
Lepidostoma sp.	Sh	2	7	15	58	15	13	2	9
Lype diversa	Sc	2	1	1					3
Micrasema sp.	Sh				1		8		
Neophylax mitchelli	Sc	1		4	1	3			
Neophylax ornatus	Sc		2			1		1	
Polycentropus sp.	P		1	1		6		2	3
Pycnopsyche guttifer	Sh			1	2	1		1	
Rhyacophila carolina	P	12	4	8	2	7	1	8	24
Rhyacophila fuscula	P	17	33	21	10	11	5	10	4
Rhyacophila melita	P	2	2						
Rhyacophila nigrita (gr.)	P	2	2	1	2		1	1	3
COLEOPTERA									
Ectopria nervosa	Sc		7		5		2	3	3
Oulimnius latiusculus	Sc	26	9	10	1	7	10	2	23
Promoresia tardella	Sc	18	6	7	1		1	1	
ODONATA									
Lanthus vernalis	P	4	11	5	2	4	19	1	6
DIPTERA: CHIRONOMIDAE									
Brillia sp.	Sh			13	16	3	1	2	
Brundiniella eumorpha	P	5	4	3	16	2	9	7	1
Chaetocladius sp.	CG		3						
Chironomus sp.	CG			2					
Cladotanytarsus sp.	CG	4		4	1	1			
Conchapelopia (gr.)	P	13	9	22	5	56	8	17	14
Cricotopus/Orthocladius sp. 40	CG					1			
Cricotopus/Orthocladius sp. 51	CG					2			
Cryptochironomus fulvus	P						3		2
Demicryptochironomus sp.	CG	6	3	4		2		3	4
Diamesa sp.	CG	24	6	10	12	11	6		
Dicrotendipes sp.	CG							2	
Eukiefferiella brehmi (gr.)	CG					1			
Eukiefferiella gracei (gr.)	CG	1		1				1	
Heleniella sp.	CG		11	1					
Heterotrissocladius sp.	CG		23		9	5	8	2	45
Lopescladius sp.	CG	40		7	1	1	1	1	
Micropsectra sp.	CG	2	1	18	1	1	3	1	
Microtendipes sp. 2	CF		4	10	4	3	3	7	14
Odontomesa fulva	CG								3
Orthocladius clarkei (gr.)	CG	1		1		4	1	1	
Orthocladius obumbratus (gr.)	CG	1		3		2			
Pagastia sp.	CG	2	2						

Table A.4. (continued)

CHIRONOMIDAE	**AF** Early	**AF** Late	**FS** Early	**FS** Late		**BF** Early	**BF** Late	**CS** Early	**CS** Late
Parachironomus sp.	P		4						
Parametriocnemus lundbecki	CG		19	1	7	1	3	5	18
Paratendipes sp.	CG					2	1		
Phaenopsectra sp.	Sc			4	3				
Polypedilum aviceps	CG	10		33	1	7		3	4
Polypedilum fallax	CG	3	1	26		2	1		
Polypedilum illinoense	CG		1	3					
Polypedilum laetum	CG	13	21	38	1	2	2		2
Polypedilum scalaenum	CG		5	5			1		
Polypedilum tritum	CG		3	12	2	2	1		4
Prodiamesa olivacea	CG			7	7		8		9
Rheocricotopus sp.	CG			2					
Rheopelopia sp.	P						2		
Rheosmittia sp.	CG				1				
Rheotanytarsus sp.	CF		2	3		1		1	
Stempellinella sp.	CG	5		16					
Symposiocladius lignicola	Sh		2		1				4
Synorthocladius sp.	CG	1							
Tanytarsus sp.	CG	3	1	6					
Thienemaniella sp.	CG			1		4		1	
Tvetenia bavarica (gr.)	CG					1		2	
Tvetenia discoloripes (gr.)	CG	1							
MISC. DIPTERA									
Antocha sp.	CG	30		13		4		26	
Atherix sp.	P		8	1	4	2	6		2
Bezzia sp.	P	4	5	3	2	3	1		6
Dicranota sp.	P	9	8	16	8	16	19	19	10
Dixa sp.	CG								2
Empididae	P		3						
Hexatoma sp.	P			1	8	1	4	4	3
Simulium parnassum	CF	19		2		11		5	
Simulium vittatum	CF	15	3	4	1	9		23	
Tipula spp.	Sh	1		1					1
OLIGOCHAETA									
Lumbriculidae	CD	96	83	66	95	57	48	55	45
CRUSTACEA									
Cambarus bartoni	C/O	5	5	5	7	5	5	3	5
PELYCEPODA									
Pisidium sp.	CF	5		3	3	1			
GASTROPODA									
Elimia sp.	Sc			2	3	7	33		

***** CG = Collector-gatherer, CF = Collector-filterer, CD = Collector-deposit feeder, C/O = Collector-omnivore, P = Predator, Sc = Scraper, Sh = Shredder

** Functional feeding group designations from Merritt and Cummins (1984).

Appendix B. List of fish species found in each section of each of the four study creeks and the number collected in each 300-m section.

*Numbers in parentheses are three times the number found in 100 m to estimate number of each species for 300 m of the particular control stream.

Table B.1. Curtis Creek and Catawba River fish taxa.

Species	Above Feeders	Fed Section	Below Feeders	Control Stream*
Rainbow trout (*Oncorhynchus mykiss*)	120	625	413	76 (228)
Blacknose dace (*Rhinichthys atratulus*)	-	-	-	14 (42)
Bluehead chub (*Hybopsis leptocephala*)	-	-	-	12 (36)
Striped jumprock (*Moxostoma rupiscartes*)	-	-	2	-
White Sucker (*Catostomus commersoni*)	-	-	1	-
Fantail darter (*Etheostoma flabellare*)	-	-	69	-

Table B.2. Kimsey Creek and Bearpen Creek fish taxa

Species	Above Feeders	Fed Section	Below Feeders	Control Stream*
Rainbow trout (*Oncorhynchus mykiss*)	135	245	218	51 (153)
Brown trout (*Salmo trutta*)	115	177	166	14 (42)
Creek chub (*Semotilus atromaculatus*)	-	-	-	3 (9)
Mottled sculpin (*Cottus bairdi*)	118	153	171	97 (291)

Table B.3. Looking Glass Creek and Davidson River fish taxa.

Species	Above Feeders	Fed Section	Below Feeders	Control Stream*
Rainbow trout (*Oncorhynchus mykiss*)	490	768	593	64 (192)
Brown trout (*Salmo trutta*)	-	-	-	4 (12)
Brook trout (*Salvelinus fontinalis*)	2	-	1	-
Blacknose dace (*Rhinichthys atratulus*)	-	-	-	22 (66)
Longnose dace (*Rhinichthys cataractae*)	82	214	149	32 (96)
Mottled sculpin (*Cottus bairdi*)	-	-	-	43 (126)

Table B.4. South Toe River and Upper Creek fish taxa.

Species	Above Feeders	Fed Section	Below Feeders	Control Stream*
Rainbow trout (*Oncorhynchus mykiss*)	100	322	128	45 (135)
Brown trout (*Salmo trutta*)	10	26	73	1 (3)
Brook trout (*Salvelinus fontinalis*)	10	2	1	10 (30)
Longnose dace (*Rhinichthys cataractae*)	3	5	29	-
Mottled sculpin (*Cottus bairdi*)	219	320	251	34 (102)