To the Graduate Council:

I am submitting herewith a thesis written by James W. Habera entitled "Effects of Rainbow Trout Removal on Trout Populations and Food Habits in Great Smoky Mountains National Park." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Wildlife and Fisheries Science.

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EFFECTS OF RAINBOW TROUT REMOVAL ON TROUT POPULATIONS AND FOOD HABITS IN GREAT SMOKY MOUNTAINS NATIONAL PARK

A Thesis

Presented for the

Master of Science

Degree

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James W. Habera

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ABSTRACT

The range of the brook trout (Salvelinus fontinalis) in the Great Smoky Mountains National Park has continued to recede since the 1930's in the face of expanding rainbow trout (Salmo gairdneri) and, more recently, brown trout (Salmo trutta) populations. Exotic salmonid populations have been controlled with relatively intense electrofishing efforts in streams having barriers to prevent reinvasion by these fish.

Two years of moderately intense exotic salmonid removal efforts were evaluated for a group of nine Park streams, eight of which had no effective downstream barrier. Food habits of adult sympatric brook and rainbow trout collected from three of the streams both before and after the removal efforts were also examined.

Rainbow trout total catch decreased for seven of the removal streams over the study period while brook trout total catch increased. Mean density and standing crop of rainbow trout in these streams decreased significantly relative to three control streams. Mean density and standing crop of brook trout increased concurrently.

The total catch of rainbow trout for the other two removal streams increased 252% over the two years. Mean density and standing crop of rainbow trout in these two streams also increased markedly. These increases were attributed to excessive mean stream widths, deep pools, large numbers of pre-removal rainbow trout, and the lack of barriers.

Food habits of adult brook and rainbow trout were very similar both before and after removal efforts. No apparent shift in the diet of adult brook trout, due to an attenuation of competition, was noted.

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CHAPTER I

INTRODUCTION

The Great Smoky Mountains National Park (GSMNP) contains over 1173 kilometers of coldwater streams (Kelly et al. 1980). These streams are inhabited by 42 species of fish, according to surveys by the U.S. Fish and Wildlife Service in the 1970's and early 1980's (Steve Moore, pers. commun.). The only salmonid native to the GSMNP, as well as the entire southern Appalachian Mountain region, is the brook trout (*Salvelinus fontinalis*). Changes in brook trout distribution in the GSMNP during this century have been suggested by Jones (1975) as being indicative of trends that have occurred throughout the southern Appalachian Mountain region.

Brook trout once occurred in nearly every stream above the elevation of 600 m in what is now the GSMNP, but reproducing populations are now relegated mainly to headwater streams above 900 m in elevation (King 1937, 1942; Lennon 1967; Bivens 1984). These streams have an average gradient of more than 15%, although brook trout formerly occupied streams having gradients of 5% and less (Larson and Moore 1985). Since the early 1900's, brook trout have lost 70% of their range in the GSMNP (Kelly et al. 1980). According to Jones (1975), a 45% decrease in total stream length occupied by brook trout in the Park took place between the 1950's and 1970's. In the state of Tennessee, brook trout now inhabit only about 20-30% of their historic range (Bivens et al. 1985) and populations have declined similarly throughout the southern Appalachian Mountain region (Larson and Moore 1985).

Brook trout population declines and distribution changes in the GSMNP have been attributed to extensive logging, fires, exploitative fishing practices and the introduction of exotic rainbow trout (Salmo gairdneri) which occurred during the first three decades of this century (King 1937; Kelly et al. 1980). Although deforestation and other disturbances which caused reductions in brook trout distribution have been controlled and water quality has improved, brook trout have failed to reoccupy much of their former range, primarily because of the presence of rainbow trout (King 1937; Kelly et al. 1980).

After 1910, every major watershed in the GSMNP area was being frequently and heavily stocked with rainbow trout (Jones 1975). By 1942, the rainbow trout had become the dominant salmonid species in the GSMNP (King 1942) and since then, rainbow trout have continued to dominate trout habitat and encroach upon remaining brook trout populations. Larson and Moore (1985) indicated that the potential now exists for sympatry of brook and rainbow trout throughout the headwaters of the southern Appalachians.

Brown trout (Salmo trutta) have also become a threat to brook trout populations in recent years. This species, which had invaded the GSMNP from adjacent State waters by 1950, was established in over 80 stream km by 1977 (Kelly et al. 1980). Initially, brown trout displaced only rainbow trout at lower elevations (Jones 1975; Kelly et al. 1980). Now however, they have reached higher elevations (up to 1300 m in one watershed according to Jones 1975) and have become sympatric with brook and rainbow trout in several GSMNP streams. Brown trout will surely have a negative impact on brook trout populations in these areas.

Interspecific competition between brook and rainbow trout has been cited as being a significant factor in the ability of rainbow trout to expand their range within a stream (King 1937; Lennon 1967; Whitworth 1980; Larson and Moore 1985), but the actual mechanism through which this competition acts remains unclear. It has been shown that brook trout can compete successfully in agonistic encounters with rainbow trout of the same size (Newman 1956; Helfrich et al. 1982). However, under the conditions found in the GSMNP and elsewhere in the southern Appalachians, rainbow trout hold a potential competitive advantage over native brook trout since the latter species tends to be smaller (King 1937; Lennon 1967; Larson and Moore 1985). Whitworth and Strange (1983) observed that rainbow trout in a southern Appalachian stream outgrew sympatric brook trout at age I+ and then continued to maintain a size-at-age advantage. Few individuals of either species, however, tend to survive past age II+ in these headwater areas (Whitworth and Strange 1983; Durniak and England 1986). Stream infertility (Lennon 1967), inbreeding (Bivens 1984), and decades of selective angling pressure (Power 1980) have also been implicated as factors contributing to the small size of brook trout.

King (1937) suggested that competition for food organisms between brook and rainbow trout seemed to be more important than antagonistic interactions. Tebo and Hassler (1963) noted that brook and rainbow trout are opportunistic feeders having similar food habits in western North Carolina streams. Other studies (Lohr 1985; Rose 1986) have also demonstrated significant dietary overlap between these two species, particularly in the young-of-the-year (YOY) age class. The overlap of salmonid diets can be quite important in small streams where habitat segregation is limited (Nyman 1970). Under these conditions, food segregation is less likely, thus creating the potential for interspecific competition.

Brook trout have become increasingly susceptible to environmental extremes with their isolation into headwater refugia by the upstream advance of exotic salmonids. Floods (King 1942; Hanson and Waters 1974; Hoopes 1975), harsh winters (Lennon 1967; LaRoche and Pardue 1980), and pH depressions due to acid precipitation (Schofield 1980) are all potentially more devastating to brook trout inhabiting these areas.

Additionally, it is quite likely that restricted gene flow and severe inbreeding are occuring in these small, disjunct brook trout populations. Unless gene flow between populations can be enhanced, the danger exists that the genetic variability of GSMNP brook trout may be lost. According to Beardmore (1983), inbreeding and the loss of genetic variation often leads to the eventual extinction of a population. Moreover, electrophoretic research by Stoneking et al. (1981) supported Lennon's (1967) contention, based on morphological characteristics, that southern populations of brook trout (especially those from the GSMNP) may be deserving of subspecific taxonomic status. Certainly, southern Appalachian brook trout comprise a distinct and valuable gene pool (Bivens 1984), the loss of which would be most unfortunate.

If brook trout are to regain any of the habitat that has been lost to rainbow trout, then not only will the displacement of brook trout by these exotic salmonids have to be controlled, but the process will have to be reversed. The removal of rainbow trout by electrofishing is the management technique currently being used to expand brook trout range in the GSMNP. Efforts to eradicate rainbow trout from mixed zones in selected GSMNP brook trout streams using this method began in 1976 (Moore et al. 1985).

Moore et al. (1981, 1983) observed increases in brook trout abundance and standing crop concurrent with the removal of rainbow trout from mixed populations. Even though rainbow trout were not entirely eliminated in a given section of stream, a sharp reduction in their numbers seemed to allow brook trout standing crop in that area to increase (Moore et al. 1983). Therefore, at this time, the removal of rainbow trout from selected streams where they occur sympatrically with brook trout and the prevention or suppression of their return seems to be the key to controlling the loss of brook trout range in the GSMNP.

Riley (1986) evaluated rainbow trout removal efforts of one, two, and three electrofishing passes in nine GSMNP streams. The objective was to determine the most efficient removal effort necessary to achieve a reduction in rainbow trout density sufficient to enhance sympatric brook trout populations. Electrofishing efforts of one and three passes were found to cause significant decreases in rainbow trout numbers. Riley (1986) concluded that one-pass removal efforts were most efficient since three-pass efforts required 60% more time than one-pass efforts and may have led to the brook trout population decreases that occurred in 50% of the study sections in that group.

This study was undertaken, primarily, to determine the effects of two consecutive years of rainbow trout removal on populations of both rainbow and brook trout in these same nine streams. Eight of the streams had no effective downstream barrier to rainbow trout movement of the type described by Kelly et al. (1980) and two streams had physical characteristics capable of hindering electrofishing efficiency. It may, therefore, be possible to begin to evaluate the degree to which these conditions affect the recovery of rainbow trout populations in areas where removal efforts have been conducted.

If adult brook trout and rainbow trout are competing for a limited food supply, the removal of rainbow trout should serve to decrease this competition and possibly cause a shift in brook trout food habits. The secondary objective of this study was to determine if the food habits of adult brook trout changed concurrently with the removal of rainbow trout over the two-year period in three of the nine GSMNP study streams.

CHAPTER II

METHODS

Study Streams

For comparative purposes, the three control and nine treatment (removal) streams that were used by Riley (1986) were also utilized in this study. The names of these first, second, and third order streams and their locations within the GSMNP are given in Figure 1.

The lower (Section I) and upper (Section II) 100 m population estimate sections in each stream were located using the descriptions given in Riley (1986). Enhanced and revised descriptions of the stream and population estimate section locations are given in Appendix A.

During this study, three of the removal streams--Collins Creek, Indian Flats Prong, and Cosby Creek--were selected to receive the one-pass rainbow trout removals recommended by Riley (1986). These streams were chosen on the basis of their relative chemical and physical similarities.

Water Quality and Stream Channel Measurement

Selected water quality parameters were measured in each population estimate section. These included conductivity, pH, and water temperature. Dissolved oxygen was not measured because all streams were assumed to be at or near saturation based on data collected in other streams (Steve Moore, pers. commun.). Conductivity and pH measurements were obtained with a YSI-Model 33 SCT meter, a Lakewood portable

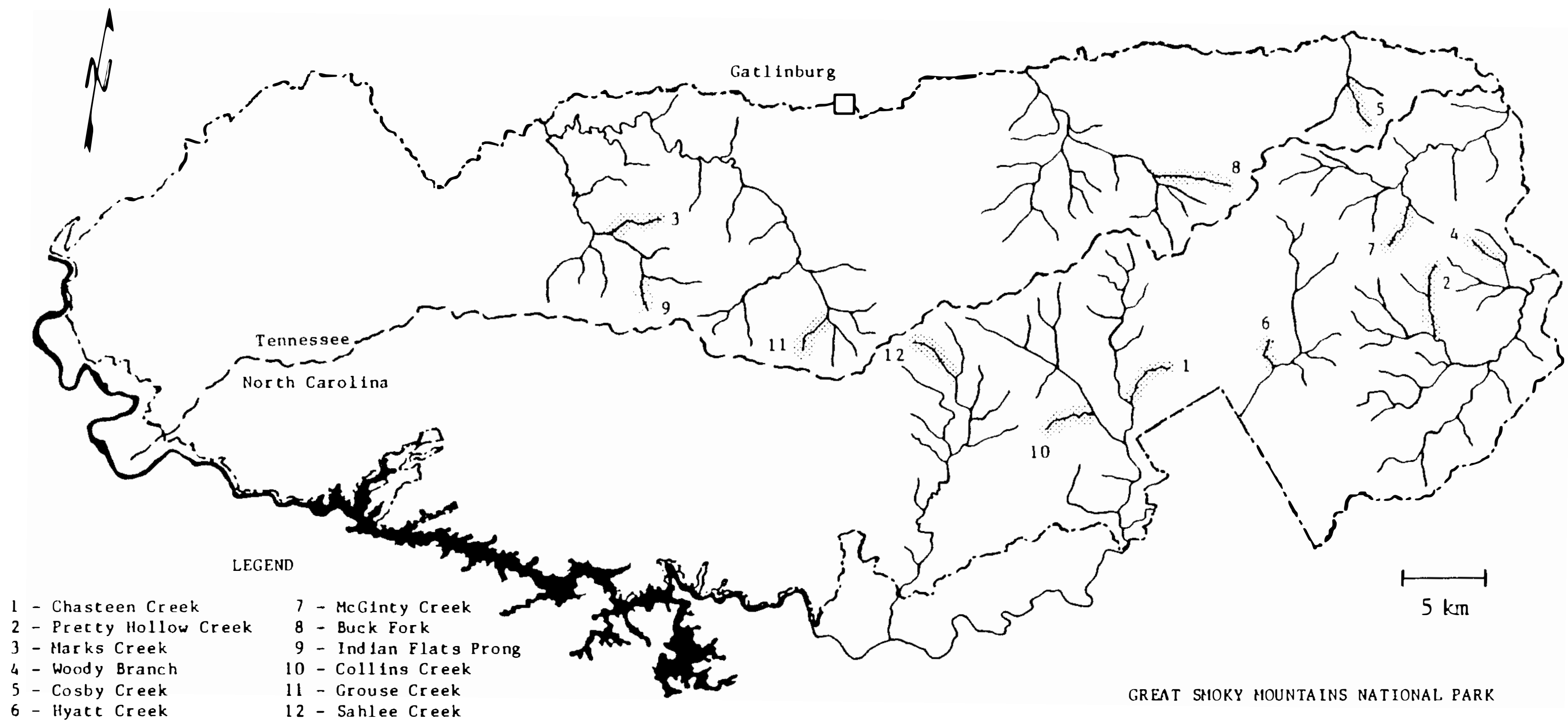

Figure 1. Locations and names of study streams in the Great Smoky Mountains National Park (1 - 3 = Controls; 4 - 12 = Removals).

conductivity/pH meter, or an Orion Model 211 digital pH meter. Water temperature was recorded prior to fish sampling. Equipment failure prevented the acquisition of conductivity and pH measurements on several occasions.

Stream channel characteristics measured for each population section included mean stream width (m), mean depth (cm) and gradient. Section lengths were also rechecked. Water quality and stream channel data for several study streams were obtained by workers collecting data for a concurrent GSMNP brook trout study.

Mean width in each section was determined by averaging stream widths measured at 10 m intervals or at 10 randomly chosen transects. Mean depth was determined by averaging depth measurements taken every 30 cm along each of the 10 randomly chosen transects in sections where these transects were used. Percent gradient was measured with a clinometer at 10 m intervals throughout each section, then an average was calculated. On several occasions, a clinometer was not available; therefore, gradients were later estimated from 7.5' quadrangle maps wherever possible.

Sampling and Rainbow Trout Removal

The sampling period extended from mid-June through early November 1986. Sampling in all streams except Cosby Creek was conducted during low or normal stream flow conditions. Rainfall on the day prior to sampling in Cosby Creek caused somewhat higher than normal flow conditions in this stream. Section I was sampled at this time, however, because it was decided that the flow conditions were not severe enough to adversely affect electrofishing success. In most cases, each stream was sampled during the same portion of the field season as in 1984 and 1985. Both sections of each stream were sampled on the same day or on consecutive days.

Fish population sampling equipment and technique consisted of one 700-volt AC backpack electroshocker of the design described by Moore et al. (1981) and a three-pass removal depletion (Bohlin 1982; Bohlin et al. 1982; Moore et al. 1983; Van Deventer and Platts 1983). After each electrofishing pass, all fish collected were anesthetized with tricaine methanesulfonate (MS-222). Salmonids were then individually weighed to the nearest gram (g) with hand-held spring scales and maximum total lengths to the nearest millimeter (mm) were recorded. Trout from the GSMNP with maximum total lengths greater than 90 mm are considered to be adults while those less than or equal to 90 mm are considered to be YOY (Moore et al. 1983).

Non-salmonids, consisting of longnose dace (Rhinichthys cataractae) from Section I of Pretty Hollow, Chasteen, and Cosby creeks, and mottled sculpins (Cottus bairdi) from Section I of Collins and Chasteen creeks, were not individually weighed and measured. Only total numbers, total weights, and maximum and minimum lengths were recorded for these species after each electrofishing pass.

After data collection, all fish were placed in holding nets outside of the population estimate section. Upon the completion of the third electrofishing pass, all fish were released into the section from which they were captured.

Following population estimation sampling in Section I of Collins Creek, Indian Flats Prong, and Cosby Creek, one-pass rainbow trout removals were conducted between the downstream boundary of the renovated area as described in Riley (1986) and the downstream end of Section II. Electrofishing was halted at some natural obstruction to fish movement at intervals of approximately 100 to 150 m so that weights and lengths could be recorded for all fish collected. Brook trout were returned to the stream and rainbow trout were either immediately taken downstream and released well below the lower end of the renovated area or they were placed in holding nets. Holding nets were collected after the completion of the day's removal effort and taken downstream out of the study area, whereupon the rainbow trout were released. After Section II was sampled, rainbow trout removal was completed for any of the renovation area remaining above the upstream end of this section.

Population Estimation

Salmonid population estimates used in calculating density and standing crop estimates were obtained using the MICROFISH 2.2 Software Package for Processing Electrofishing Data Obtained by the Removal Method (Van Deventer and Platts 1985). This software uses the Burnham maximum likelihood model (Platts et al. 1983; Van Deventer and Platts 1983) for population estimation and also provides capture probabilities. Annual population estimates and 95% confidence limits for each species in each stream are given in Table 1 in Appendix B.

The capture probability of larger salmonids (adults) has been reported to be higher than that of smaller ones (YOY) when collected from small streams by electrofishing (Bohlin and Sundstrom 1977; Armour et al. 1983). Fausch and White (1986), on the other hand, observed that electrofishing was largely unbiased when used to sample juvenile stream salmonids. In any case, a certain degree of unequal catchability may not seriously affect population estimates other than to cause slight underestimations with three-pass depletions (Bohlin and Sundstrom 1977). Separate population estimates for YOY trout were not obtained for this reason and because the number of YOY captured in each section was frequently quite small and removal patterns were often non-descending. Instead, the number of YOY captured during each pass was added to the number of adults captured of the same species, then one population estimate was generated.

No population estimates were calculated for Collins Creek Section II, since the rainbow trout removal pass was erroneously extended well into this section and the fish collected there could not be separated from those captured downstream. Since no population estimates were calculated for this section during this study, density and standing crop estimates were not possible.

Calculation of Salmonid Densities and Standing Crops

Fish population data were standardized on the basis of density and standing crop for comparisons between years, between removal and control streams, and between species. Before densities and standing crops could be derived, it was necessary to obtain data in addition to population estimates, such as area and salmonid biomasses, for each section in each year.

Areas for each population estimate section in 1986, with the exception of Collins Creek Section II, were calculated using mean section width and total section length. Area calculations were made for all sections in 1984 and 1985 using data from Riley (1986). Since specific mean widths were not given for 1985, areas were calculated using the mean widths for 1984.

Biomass for each salmonid species in each section (except Collins Creek Section II) was determined by multiplying the population estimate for a particular species by the mean weight per fish in that section (Armour et al. 1983). When the population estimate equalled the total catch for a given species in a particular section, as it did in many cases, biomass was set equal to the total weight of all fish of that species collected there.

No weights were recorded for YOY salmonids in 1984 or 1985. However, weight estimates for these fish were generated by calculating least squares regression equations based on the lengths and weights of all YOY brook trout (n=260), rainbow trout (n=271), and brown trout (n=25) collected in 1986. The regression equation for each species is given below:

Brook trout: $W = .137\ L - 6.187 \quad (r^2 = .84)$

Rainbow trout: $W = .097\ L - 3.694 \quad (r^2 = .76)$

Brown trout: $W = .073\ L - 2.818 \quad (r^2 = .74)$

where: W = weight (g)
L = maximum total length (mm)

Densities of brook and rainbow trout were calculated using the estimated area of each section and the corresponding population estimates. Densities were expressed as the number of fish per hectare (n/ha). Standing crops, in terms of kilograms per hectare (kg/ha), were calculated for each species using the salmonid biomasses and area estimates for each section in each year.

Statistical Analyses

All statistical analyses were performed using the Statistical Analysis System (SAS) on the mainframe Converstional Monitoring System (CMS) at the University of Tennessee. Analyses of variance (ANOVA's) employing a 2x3 unbalanced factorial design were used. SAS's REGWQ procedure (SAS User's Guide: Statistics 1985), which utilizes the Ryan-Einot-Gabriel-Welsch multiple-range test (Ryan 1960; Einot and Gabriel 1975; Welsch 1977) was applied to the main effects means when the overall F-test indicated significance at the 0.05 level. The Ryan-Einot-Gabriel-Welsch multiple-range test strictly controls the TYPE I experimental error rate (the possibility that two means will be declared significantly different when they are not) and is considered to be more powerful than Tukey's Honest Significant Difference test or Duncan's multiple-range test (Einot and Gabriel 1975; Ramsey 1978). A 0.05 level of significance was used for comparisons in all post-tests.

Riley (1986) suggested that streams with mean widths greater than 6.1 m (20 feet) might be unsuitable for renovation efforts employing only one electrofishing unit. Two of the removal streams--Buck Fork and Indian Flats Prong--had mean widths exceeding 6.1 m in 1984 (Riley 1986) and in 1986. Therefore, mean widths for the population estimate sections in Buck Fork and Indian Flats Prong were compared to mean section widths for the other streams collectively in both 1984 and 1986 using a 2x2 ANOVA.

Brook and rainbow trout mean densities and standing crops were compared between years and between control and removal streams for each year. Mean densities and standing crops were also compared between species for both control and removal stream populations in each year.

Mean adult lengths and weights were calculated for each species from each population estimate section in 1986 and for fish collected in 1984 and 1985 using data from Riley (1986). Length and weight data for adults of each species were compared between years and between populations from control and removal streams in each year. Comparisons were also made between species for both control and removal stream populations in each year.

It was hypothesized that different electrofishing crews and lower stream flow conditions might have influenced capture probabilities during this study. Therefore, overall mean capture probabilities for brook and rainbow trout during each year were compared in order to determine whether or not significant differences existed between years (i.e. electrofishing crews) or between species.

Food Habit Analyses

Fifteen adult brook trout and 15 adult rainbow trout were collected from the sympatric zones in Collins Creek, Indian Flats Prong, and Cosby Creek, ventrally incised, and preserved in 10% formalin for food habit analyses. Fifteen adult trout of each species were also collected and similarly preserved from their respective allopartic zones in each stream to serve as controls. In Cosby Creek, it was necessary to collect allopatric rainbow trout several hundred meters downstream of the lower end of the renovated area because of the absence of allopatric fish within this area. Upon return to the laboratory, all specimens were removed from the formalin and rinsed with tapwater for approximately 30 minutes. They were then stored in 50% isopropanol (Haedrich 1983).

Fifteen brook and rainbow trout (not all of which were adults) were collected and preserved from the same areas of the same three streams (with the exception of allopatric rainbow trout from Cosby Creek) by Riley in 1984, but were not analyzed. These fish were acquired from storage at GSMNP for food habit analysis and comparison with fish collected during this study. Collection of the 1986 samples coincided with the summer collection dates of the 1984 samples in each stream.

Stomachs were removed from all fish in the laboratory and individual food items were identified to the lowest practical taxon. Immature aquatic insects were keyed using Brigham et al. (1982). All food items were blotted dry on absorbent paper, then weights were obtained for individual items or groups of similar items with an American Scientific Products Z-6000DR electronic balance. Weights could not be obtained for many individual food items and groups of items, particularly larval and nymphal instars, because the balance was not sensitive below 0.01 g.

Food items were categorized into three major food groups: Terrestrial Invertebrates (terrestrial insects, arthropods, and adults insects of the aquatic orders); Aquatic Insects (aquatic nymphs and larvae of Ephemeroptera, Trichoptera, Plecoptera, Diptera, Odonata, Coleoptera, and Heteroptera); and Other (primarily crustaceans and salamanders, but also includes molluscs, fish, and unidentified items).

Data from corresponding populations in all three streams were combined for each year. Frequencies of occurrence, percentages by number, and percentages by weight were calculated for each of the three major food groups from the diets of allopatric (n=21, 1984; n=45, 1986) and sympatric (n=30, 1984; n=44, 1986) brook trout and allopatric (n=15, 1984; n=45, 1986) and sympatric (n=28, 1984; n=35, 1986) rainbow trout.

CHAPTER III

RESULTS

Water Quality and Stream Channel Characteristics

Study stream conductivities were relatively low, averaging 24.7 µmhos/cm with a range of from 12.5 to 36.2 µmhos/cm. Stream pH averaged 6.3 and varied from 5.6 to 6.7. Water temperature averaged 15.8 C and ranged from 12 to 18 C. Mean stream width for the population estimate sections was 5.0 m, with a range of from 2.1 to 7.5 m. Population estimate section widths in Buck Fork and Indian Flats Prong, however, averaged 6.8 m and were significantly wider ($P < .0006$) than those of the other streams as a group (Figure 2). In 1984, population estimate section widths in Buck Fork and Indian Flats Prong were also significantly wider ($P < .0001$) than those of the other streams (Figure 2). Mean depth in the poplation estimate sectons was 11.7 cm, ranging from 4.1 to 21.9 cm and gradient averaged 10% with a range of from 4 to 15 %. Water quality and stream channel data for all streams appear in Tables 2 and 3 in Appendix C.

Total Catch and Percent YOY

Controls and all Removal Streams

Actual total catch of brook and rainbow trout and the number of YOY of each species are compared for each year in control streams (Figure 3) and removal streams (Figure 4). Total estimated populations were not used for comparison because no separate estimates were obtained for YOY.

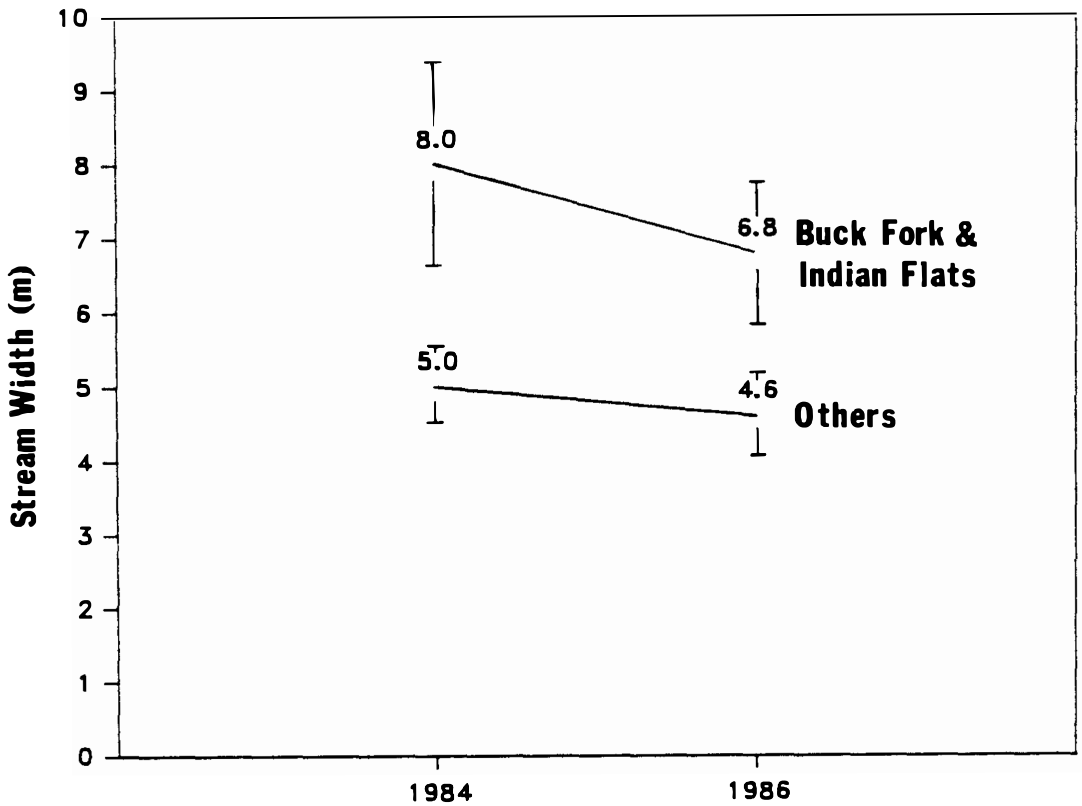

Figure 2. Mean stream width of population estimate sections in Buck Fork and Indian Flats Prong and all other streams as a group in 1984 and 1986. Bars indicate 95% confidence limits.

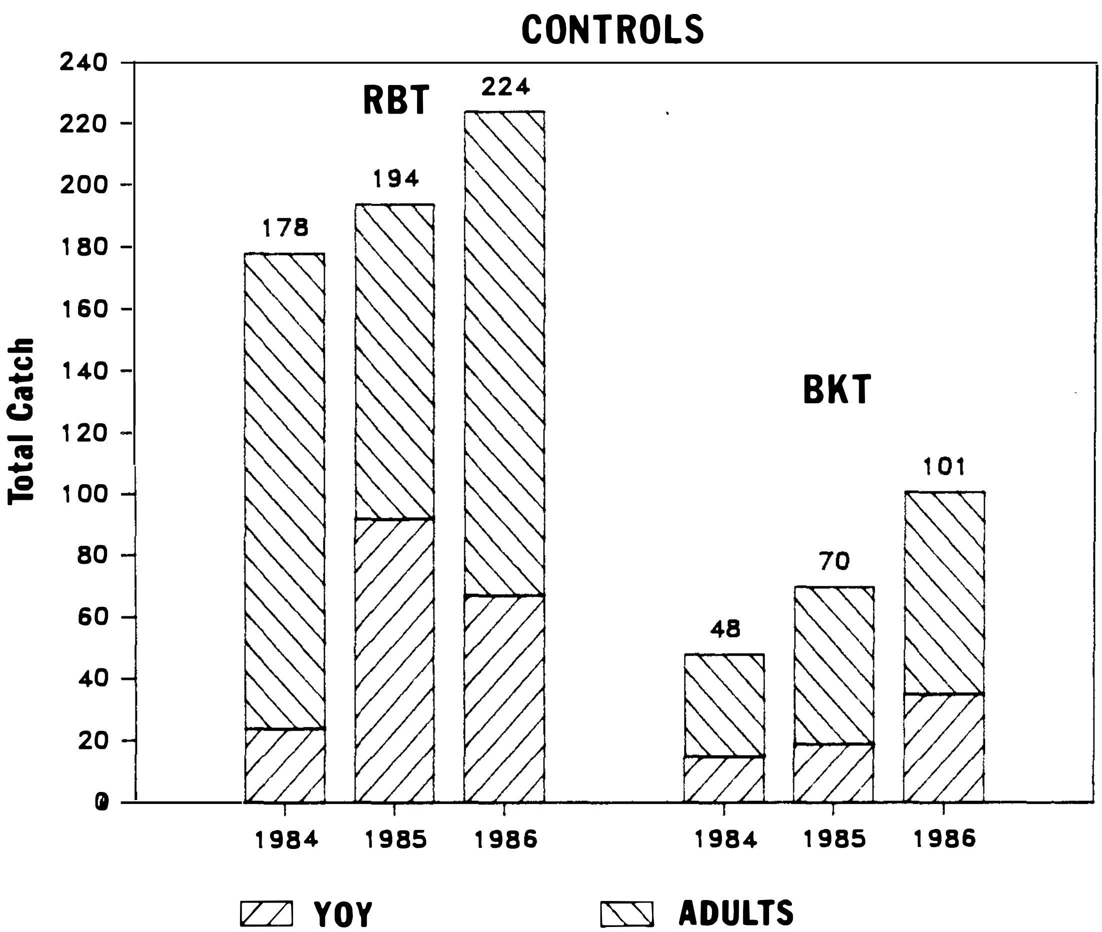

Figure 3. Annual total catch of rainbow trout (RBT) and brook trout (BKT) in control streams.

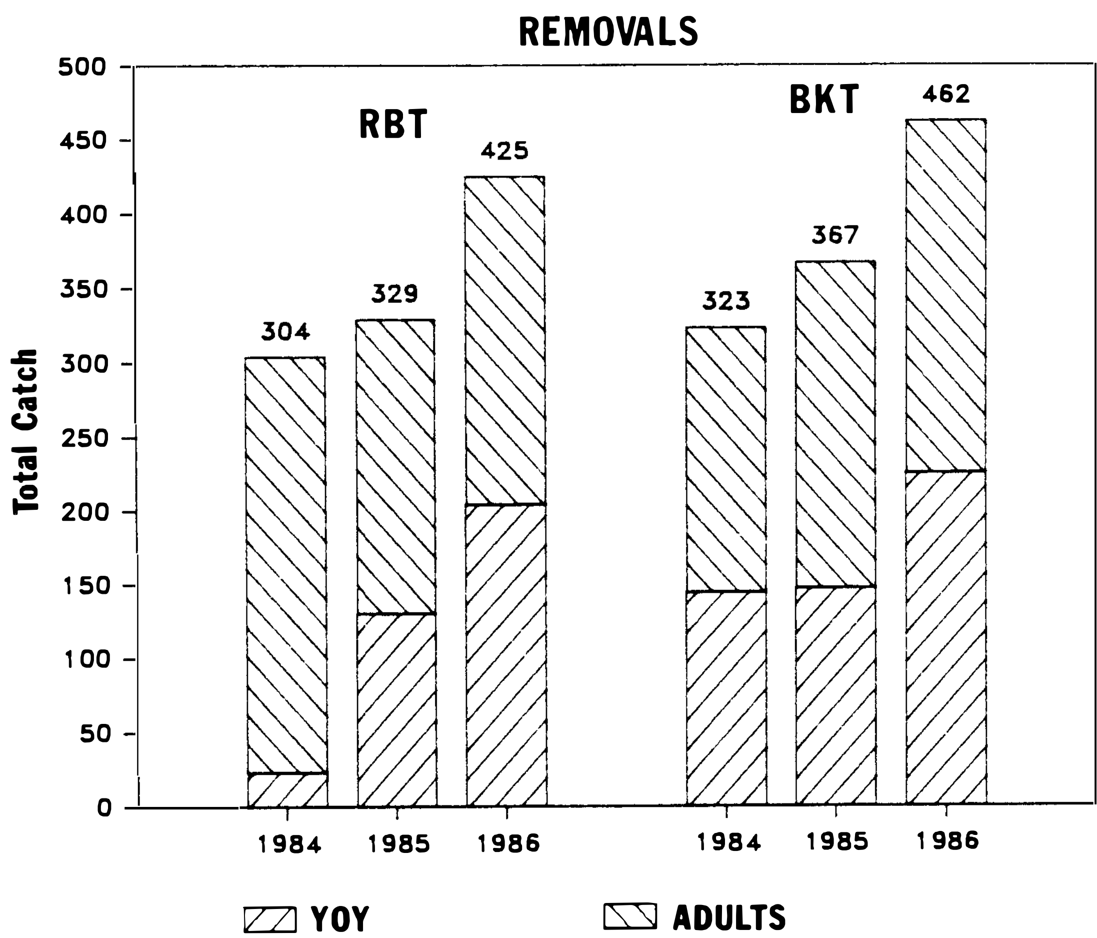

Figure 4. Annual total catch of rainbow trout (RBT) and brook trout (BKT) in removal streams.

The total catch of rainbow trout in control streams increased 25.8% between 1984 and 1986. The total catch of control brook trout increased 110.4% over the same period; however, brook trout total catch as a percentage of the combined total catch for both species in control streams increased from 21.9% to only 31.1%. The percentage of YOY in the rainbow trout total catch from control streams increased a net 16.4% between 1984 and 1986 while the percentage of YOY in the brook trout total catch increase only 3.3% over the same period (Figure 5).

The total catch of rainbow trout in removal streams increased 39.8% between 1984 and 1986. Although brook trout total catch increased 43.0% over the same period in these streams, brook trout total catch as percentage of the combined total catch for both species increased from 51.5% to only 52.1%. The percentage of YOY in the rainbow trout total catch from removal streams increased by 40.4% between 1984 and 1986 while the percentage of YOY brook trout in the total catch increased only 4.1% during the same period (Figure 5).

Removal Streams Excluding Buck Fork and Indian Flats Prong

The total catch of rainbow trout in Buck Fork and Indian Flats Prong increased from 80 to 282 fish (252.5%) between 1984 and 1986 and the number of YOY captured in these two streams increased from 1 in 1984 to 125 in 1986 (Figure 6). No other streams exhibited such large increases in rainbow trout total catch (Table 1, Appendix B) or YOY (Table 4, Appendix D). Brook trout total catch increased from 13 to 57, but only increased from 14.0% to 16.8% of the combined total catch for both species (Figure 6).

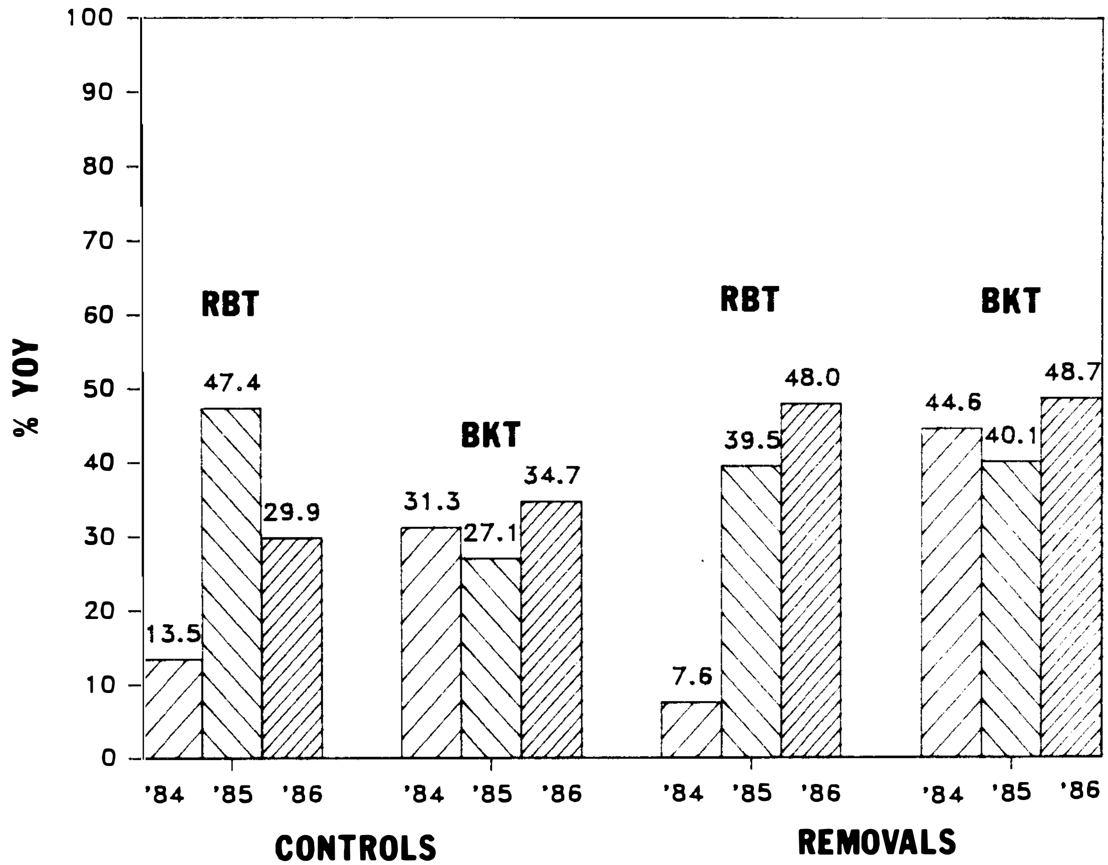

Figure 5. Percentage of YOY in the annual total catch of rainbow trout (RBT) and brook trout (BKT) in control and removal streams.

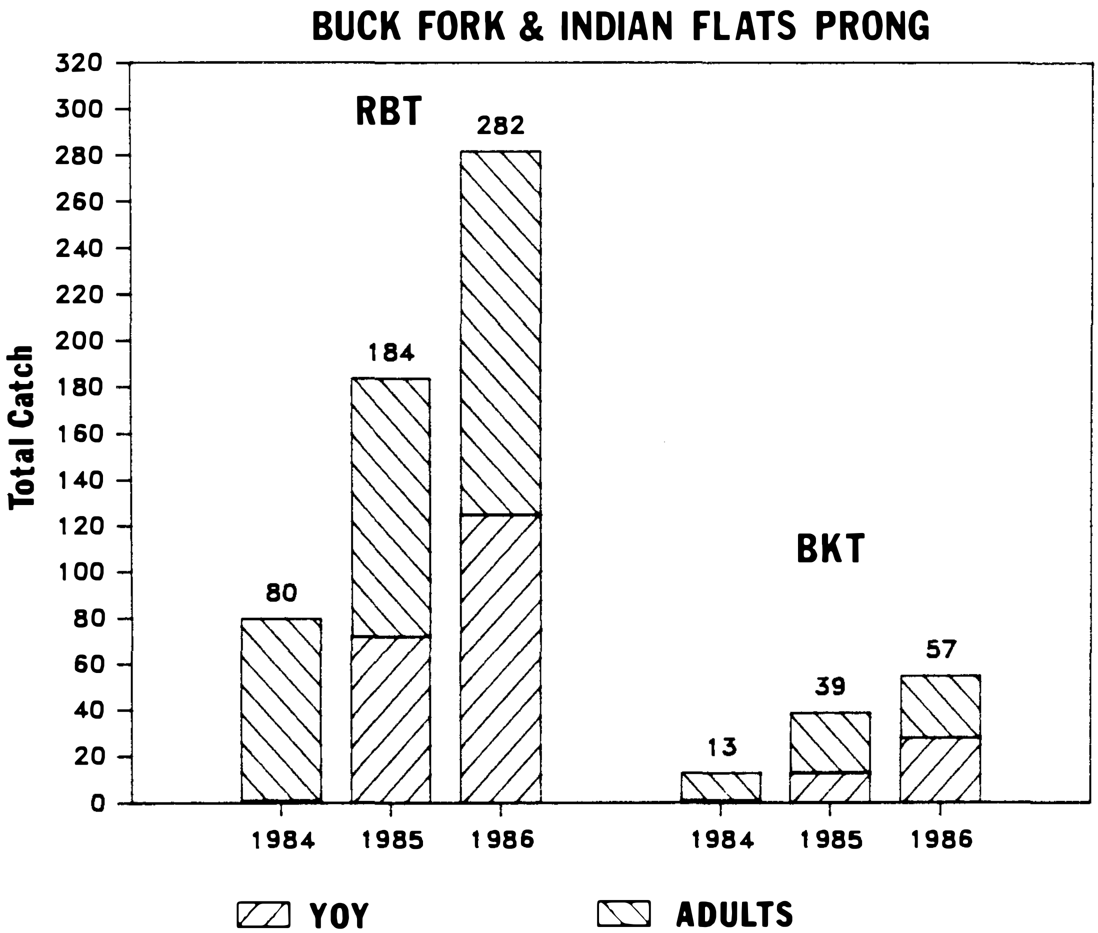

Figure 6. Annual total catch of rainbow trout (RBT) and brook trout (BKT) in Buck Fork and Indian Flats Prong.

In 1984, the rainbow trout total catch in Buck Fork and Indian Flats made up 26.3 % of the total rainbow trout catch in all removal streams. In 1986, the total catch of rainbow trout in these two streams represented 66.4% of the total rainbow trout catch in all removal streams.

When data from Buck Fork and Indian Flats were excluded from consideration because of their uncharacteristic nature, rainbow trout total catch in the remaining removal streams no longer tended to increase, but declined instead (Figure 7). Rainbow trout total catch decreased 36.2% between 1984 and 1986 while brook trout total catch increased 31.3% over the same period. Rainbow trout total catch as a percentage of the combined total catch for both species decreased from 41.9% in 1984 to 26.0% in 1986.

Mean Densities

Controls and all Removal Streams

Mean brook and rainbow trout densities in control and removal streams in each study year are compared in Figure 8. Mean densities did not differ significantly ($P > .05$) between years in any population or between control and removal populations of the same species in any given year. Brook and rainbow trout mean densities did not differ significantly in control streams in 1984 and 1985, but in 1986, mean rainbow trout density was significantly higher ($P < .0144$) than mean brook trout density. In removal streams, brook and rainbow trout mean

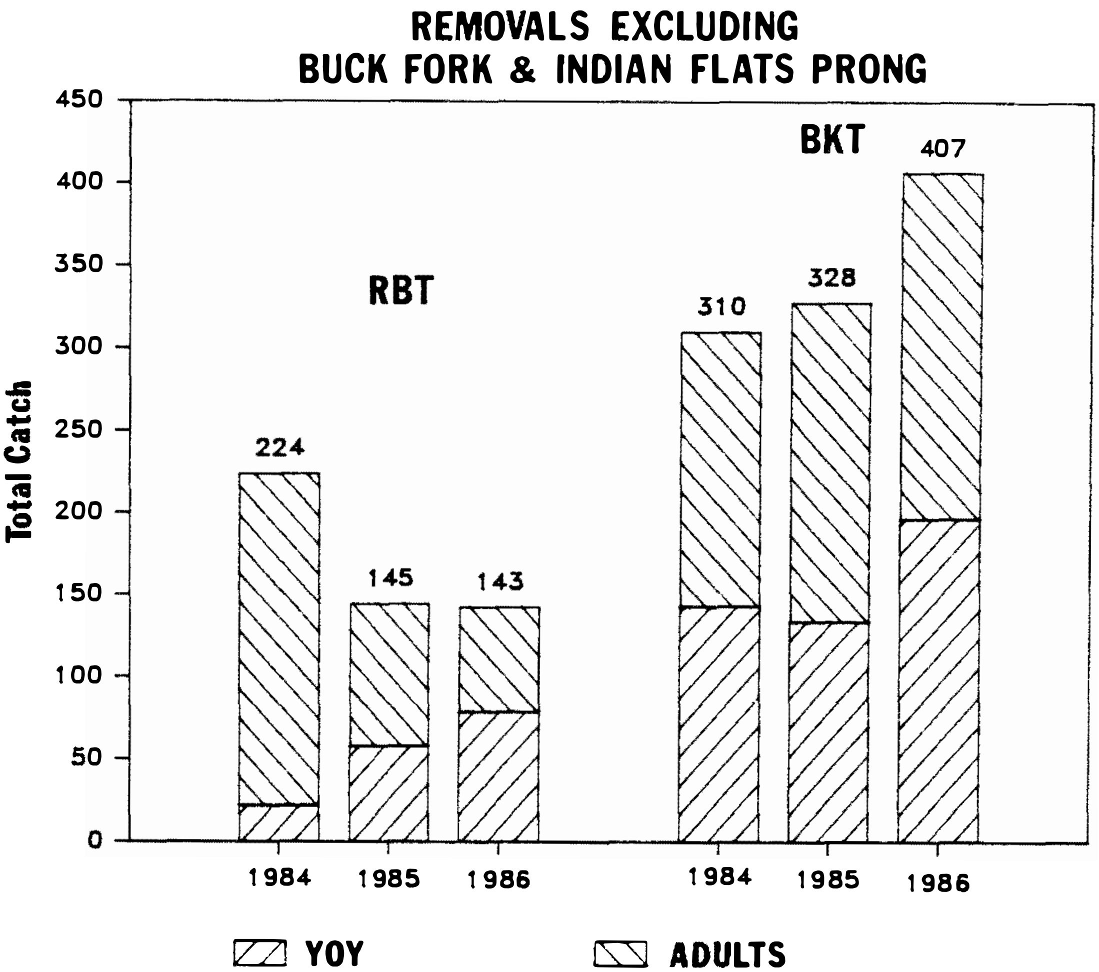

Figure 7. Annual total catch of rainbow trout (RBT) and brook trout (BKT) in removal streams exclusive of Buck Fork and Indian Flats Prong.

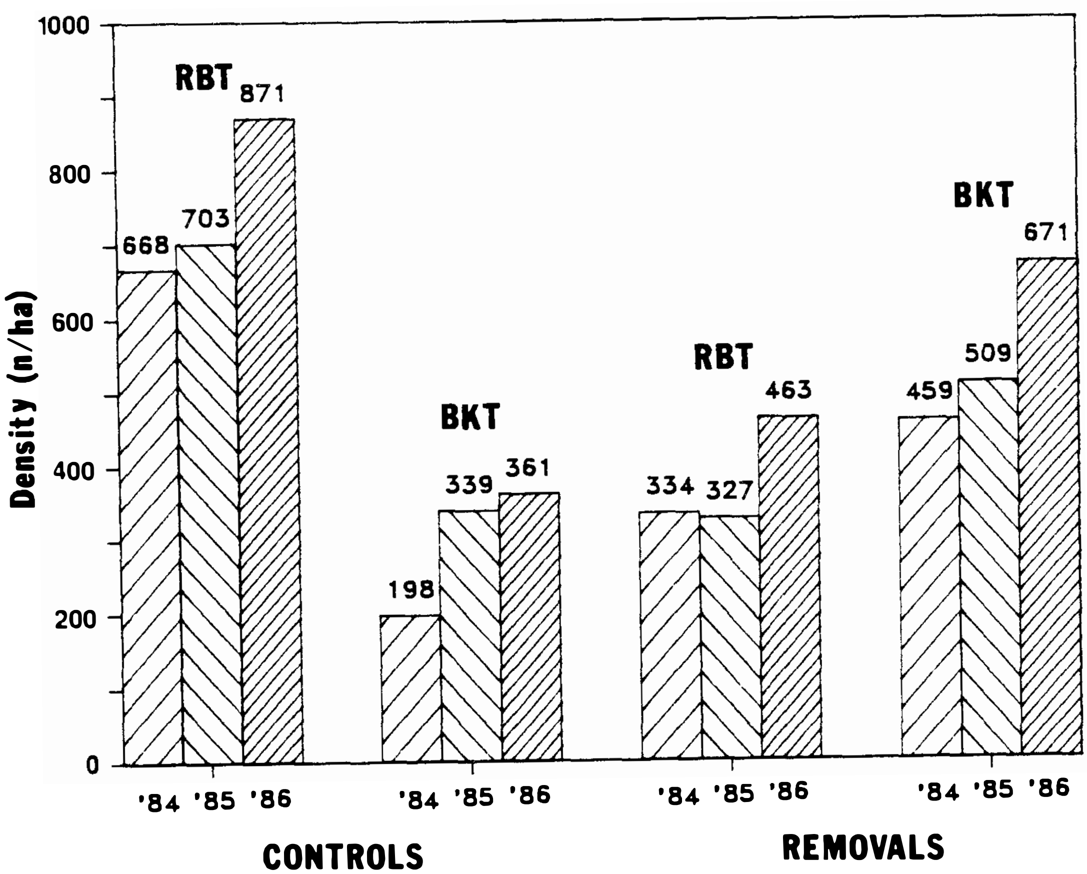

Figure 8. Annual mean density of rainbow trout (RBT) and brook trout (BKT) in control and removal streams.

densities did not differ significantly in any year when compared interspecifically.

Mean rainbow trout density as a percentage of total salmonid density in control streams decreased from 76.5% to 66.4% between 1984 and 1986 while the portion of total salmonid density represented by brook trout increased from 22.7% to 27.5% over the same period. In removal streams, mean rainbow trout density as a percentage of total salmonid density decreased from 42.0% in 1984 to 40.5% in 1986 while the percentage of total salmonid density made up by brook trout increased only 1.0%--from 57.7% to 58.7%--over the two years.

Removal Streams Excluding Buck Fork and Indian Flats Prong

Mean rainbow trout density in Buck Fork and Indian Flats Prong increased more than threefold between 1984 and 1986 (Figure 9). Increases in rainbow trout density of this magnitude were not documented in any of the other study streams (Table 5, Appendix E). Although mean brook trout density also increased steadily over the same period, it was low initially (Figure 9) and brook trout density as a percentage of the combined density for both species in these two streams increased from 13.5% to only 16.2% over the two years.

Mean densities for all populations were recompared after the exclusion of data from Buck Fork and Indian Flats Prong (Figure 10). Differences between years for both species in control and removal streams remained non-significant. Mean brook trout density in removal stream populations was not significantly higher than in control stream populations in any year; however, mean rainbow trout densities in

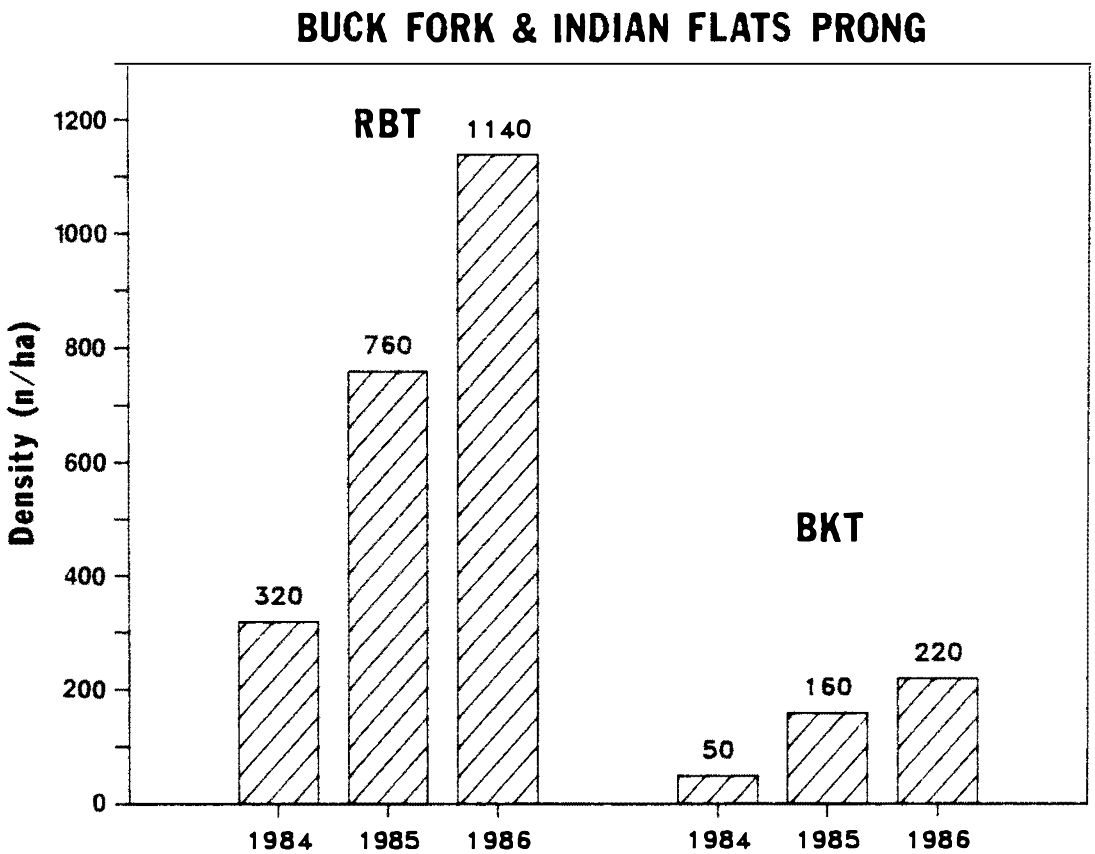

Figure 9. Annual mean density of rainbow trout (RBT) and brook trout (BKT) in Buck Fork and Indian Flats Prong.

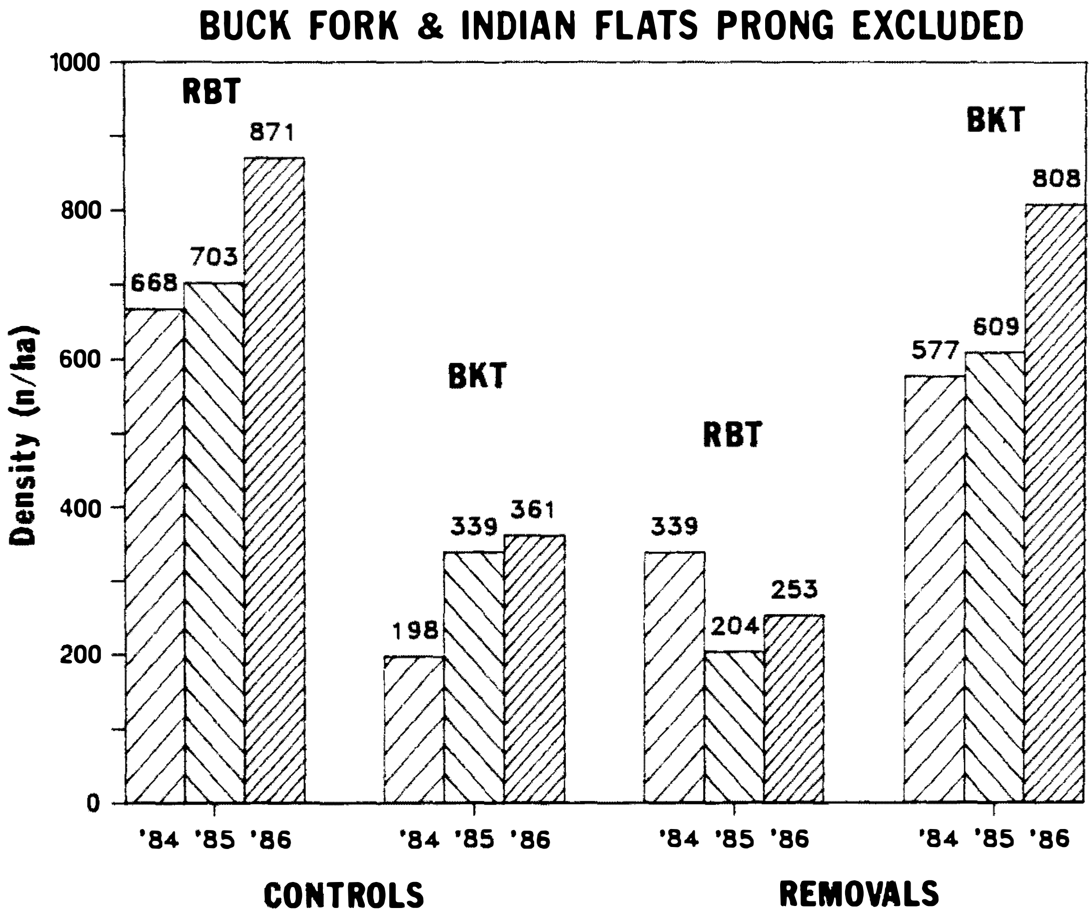

Figure 10. Annual mean density of rainbow trout (RBT) and brook trout (BKT) in control and removal streams exclusive of Buck Fork and Indian Flats Prong.

removal stream populations were significantly lower than in control stream populations in 1985 ($P < .0012$) and in 1986 ($P < .0001$). When brook and rainbow trout mean densities were again compared interspecifically, brook trout mean density was found to be significantly greater than that of rainbow trout in 1985 ($P < .0072$) and in 1986 ($P < .0005$).

Mean Standing Crops

Controls and all Removal Streams

Annual mean standing crops of brook and rainbow trout from control and removal streams are compared in Figure 11. Mean standing crops of both brook and rainbow trout did not differ significantly between years in either control or removal streams. Additionally, mean standing crops did not differ significantly between control and removal populations in any year for brook trout and did not significantly differ in 1984 or 1985 for rainbow trout. The mean standing crop of removal populations of rainbow trout was significantly lower ($P < .009$) than that of control populations in 1986. Rainbow trout mean standing crop was significantly greater than brook trout mean standing crop in control streams in 1984 ($P < .0001$), in 1985 ($P < .0061$), and in 1986 ($P < .0005$). Rainbow trout and brook trout mean standing crops did not differ significantly in removal streams in any year.

Mean rainbow trout standing crop in control streams decreased 6.6% between 1984 and 1986. Mean rainbow trout standing crop as a percentage of total salmonid standing crop (including brown trout) decreased from 84.4% to 78.4%. In removal streams, mean rainbow trout standing crop

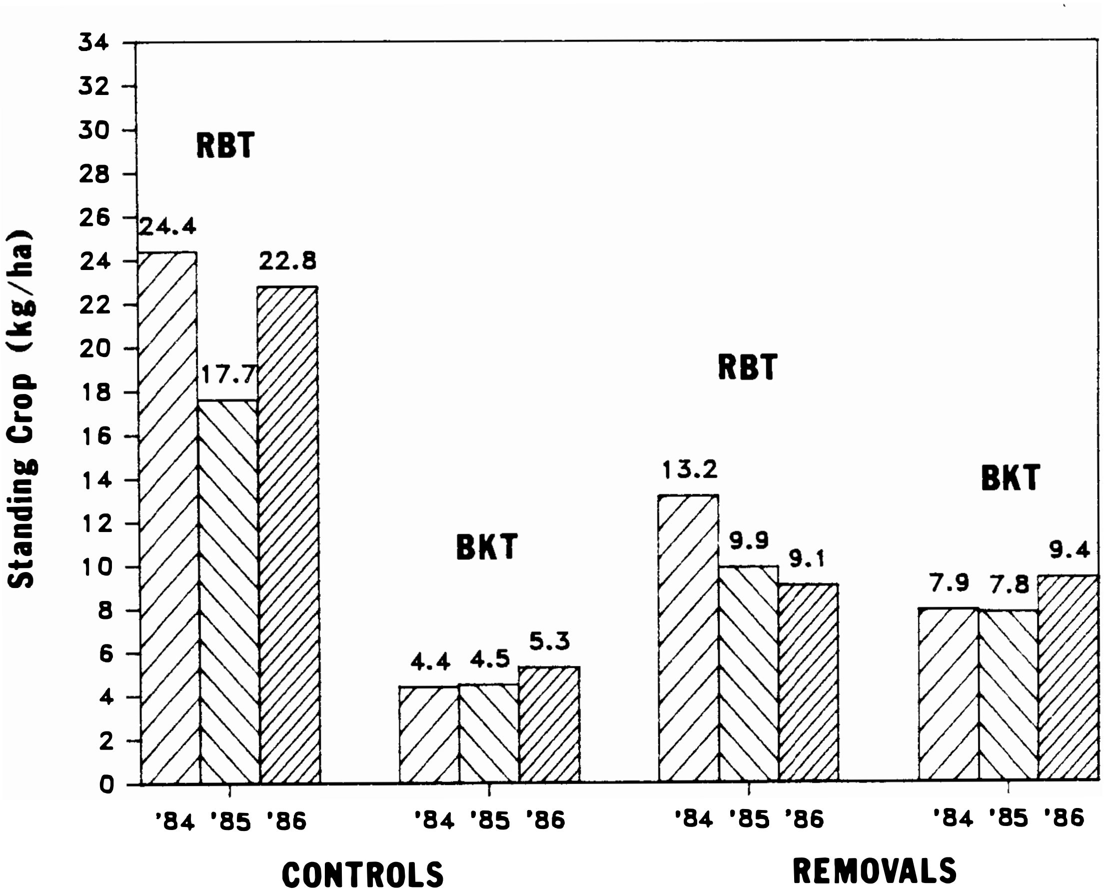

Figure 11. Annual mean standing crop of rainbow trout (RBT) and brook trout (BKT) in control and removal streams.

decreased 31.1% by 1986 and represented 48.1% of the total salmonid standing crop--a decrease of 11.6% from 1984.

Mean brook trout standing crop as a percentage of total salmonid standing crop increased from 15.2% to 18.2% in control streams between 1984 and 1986; however, in removal streams, brook trout made up 49.7% of the total salmonid standing crop in 1986, an increase of 14.0% over 1984.

Removal Streams Excluding Buck Fork and Indian Flats Prong

Mean rainbow trout standing crop in Buck Fork and Indian Flats Prong increased 54.5% between 1984 and 1986 (Figure 12). No other streams, control or removal, had rainbow trout standing crop increases of this degree over the two years (Table 6, Appendix F). Although brook trout mean standing crop also increased between 1984 and 1986, it comprised 10.5% of the total salmonid standing crop in these two streams in 1984 and only 16.2% in 1986.

Buck Fork and Indian Flats were excluded from the removal stream group and the data recompared (Figure 13). Mean standing crops still did not differ significantly between years in control or removal stream populations of either species. Differences in mean standing crop between control and removal stream populations of brook trout remained non-significant in each year; however, rainbow trout mean standing crop in removal streams was significantly lower than that in control streams in 1985 ($P < .0129$) and in 1986 ($P < .0002$). When compared interspecifically, differences between brook and rainbow trout mean standing crops remained non-significant in all years.

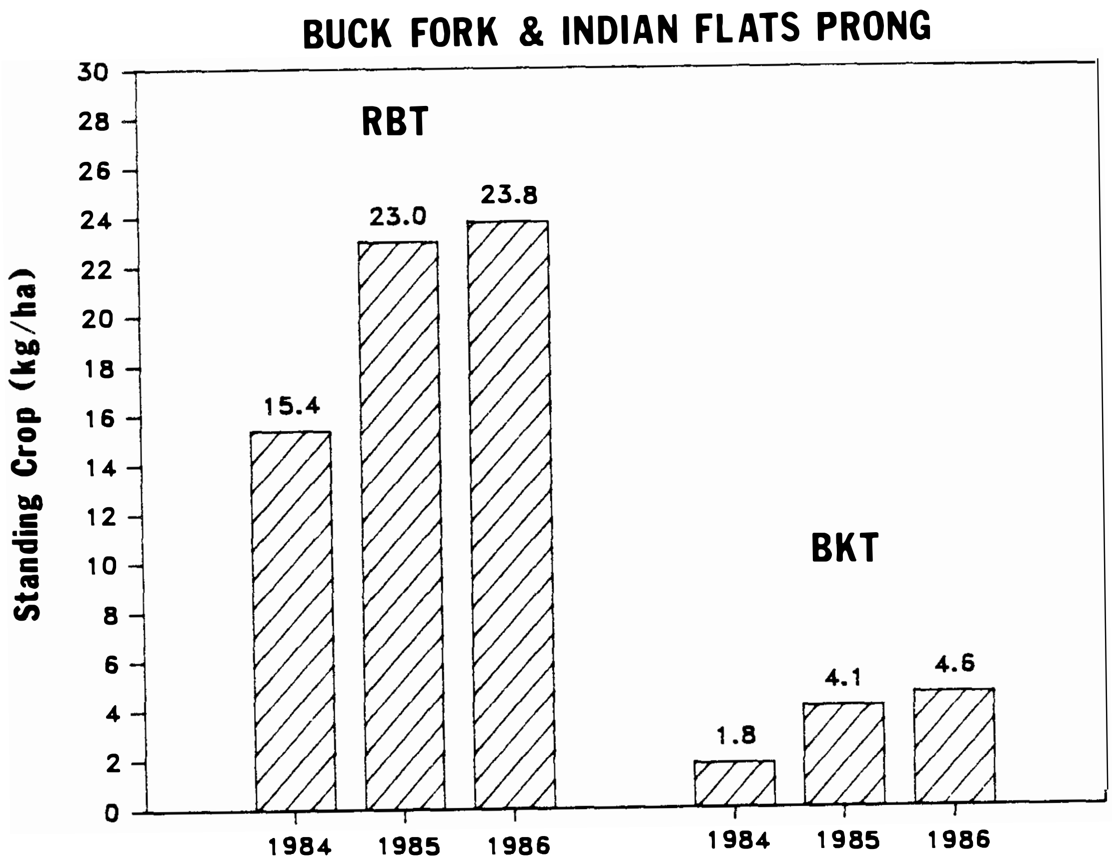

Figure 12. Annual mean standing crop of rainbow trout (RBT) and brook trout (BKT) in Buck Fork and Indian Flats Prong.

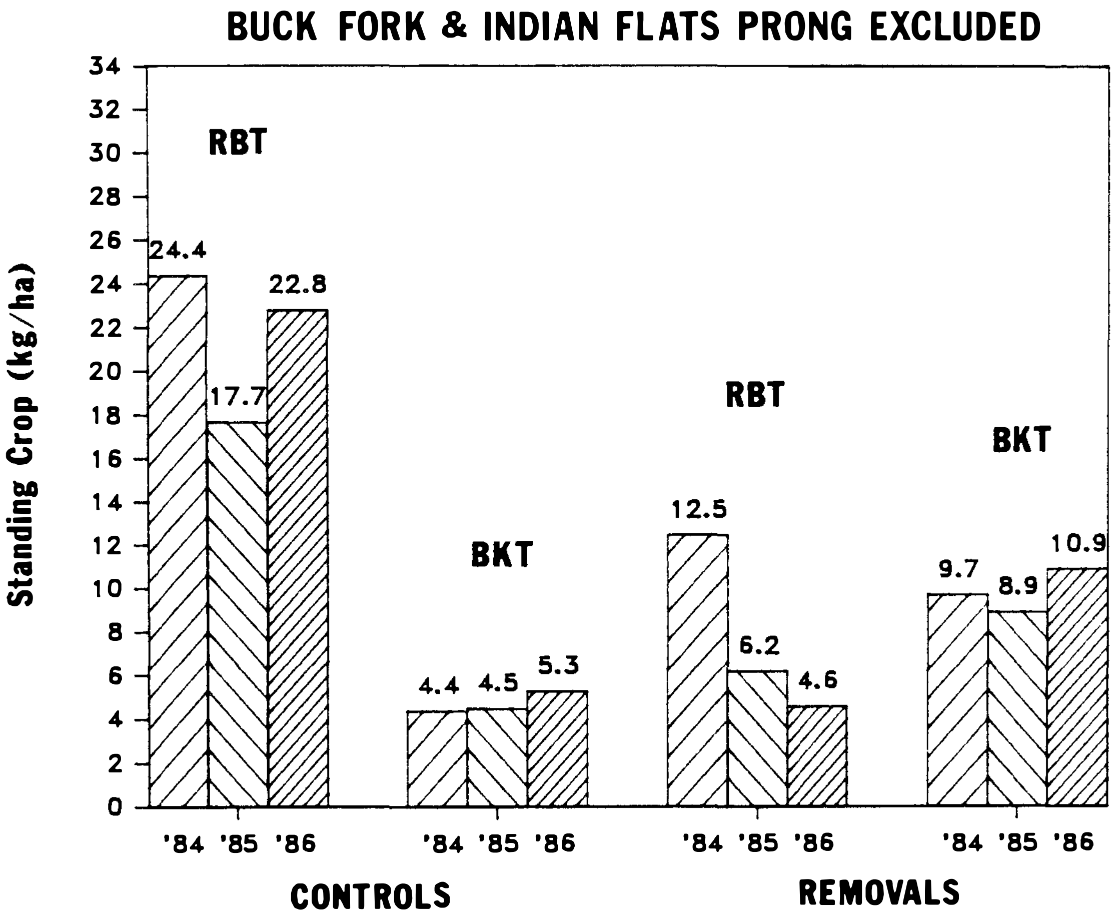

Figure 13. Annual mean standing crop of rainbow trout (RBT) (RBT) and brook trout (BKT) in control and removal streams exclusive of Buck Fork and Indian Flats Prong.

When Buck Fork and Indian Flats Prong data were excluded, rainbow trout mean standing crop in the remaining streams decreased 63.2% between 1984 and 1986. In 1986, rainbow trout represented only 28.9% of the total salmonid standing crop--a decrease of 25.0% over the two years. Brook trout standing crop as a percentage of total salmonid standing crop increased from 41.8% in 1984 to 68.6% in 1986 in these streams.

Mean Lengths and Weights

Mean adult lengths and weights are compared in Figures 14 and 15 respectively for each species from control and removal stream populations in each year. Mean adult lengths and weights did not differ significantly between years or between control and removal stream populations in any given year for either species. When compared interspecifically, adult rainbow trout were significantly longer than adult brook trout in control streams in 1984 ($P < .0023$) and in 1985 ($P < .0001$), but there was no significant difference in mean adult length between the two species in 1986. In removal streams, adult rainbow trout were significantly longer than adult brook trout in 1984 ($P < .0003$) and in 1985 ($P < .0001$). Again, there was no significant difference in mean length between the two species in 1986. Adult rainbow trout were significantly heavier than adult brook trout in control streams in 1985 ($P < .0004$), while mean weights for the two species did not differ significantly in 1984 or 1986. Adult rainbow trout were significantly heavier than adult brook trout in removal

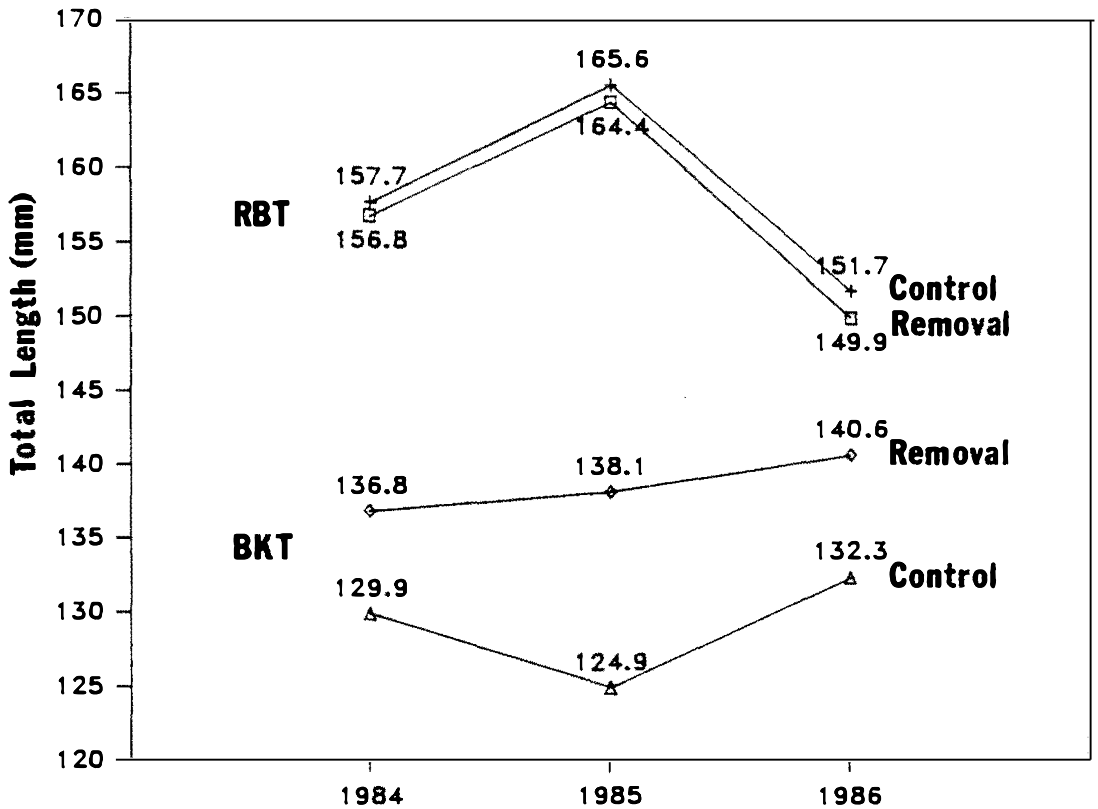

Figure 14. Annual mean length of adult rainbow trout (RBT) and adult brook trout (BKT) in control and removal streams.

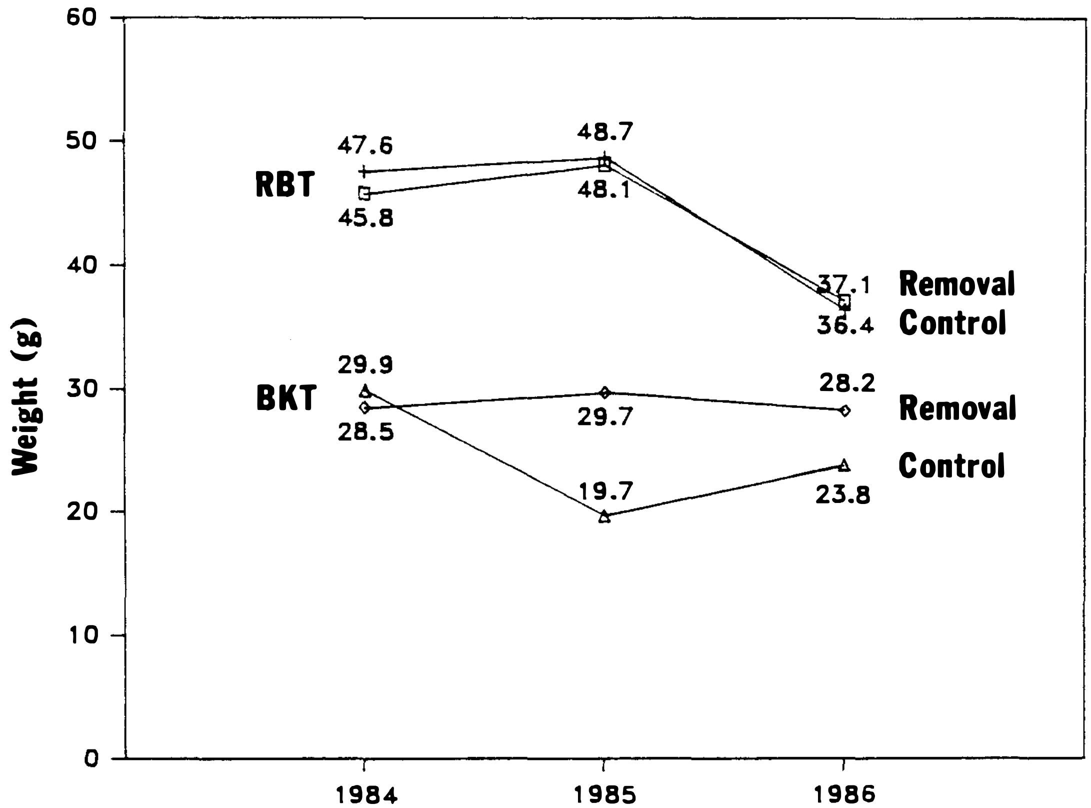

Figure 15. Annual mean weight of adult rainbow trout (RBT) and adult brook trout (BKT) in control and removal streams.

streams in 1984 ($P < .0001$) and in 1985 ($P < .0001$). Mean weights for the two species were not significantly different in 1986.

Capture Probabilities

The mean capture probability of each species for all study streams collectively was within the expected 0.5 to 0.7 range reported by Bohlin (1982) in each year. When capture probabilities were tested statistically, no significant differences were found between years for either species or between species in any given year (Figure 16). Capture probabilities for brook and rainbow trout from Buck Fork and Indian Flats Prong were compared respectively to capture probabilities for each species from the remaining streams and again, the differences were non-significant.

Other Species

Numbers of longnose dace and mottled sculpin in streams in which they occurred did not change appreciably over the two year study period. However, brown trout populations, found in the lower reaches of Chasteen, Sahlee, and Collins creeks, seemed to be on the increase, particularly in Chasteen and Collins creeks. Brown trout population estimates for these streams are given for each year in Table 1 in Appendix B.

The total catch of brown trout in Section I of Chasteen Creek in 1984 and 1985 was two and one fish respectively, but in 1986, 13 brown trout were captured in this section and 22 were estimated to be present.

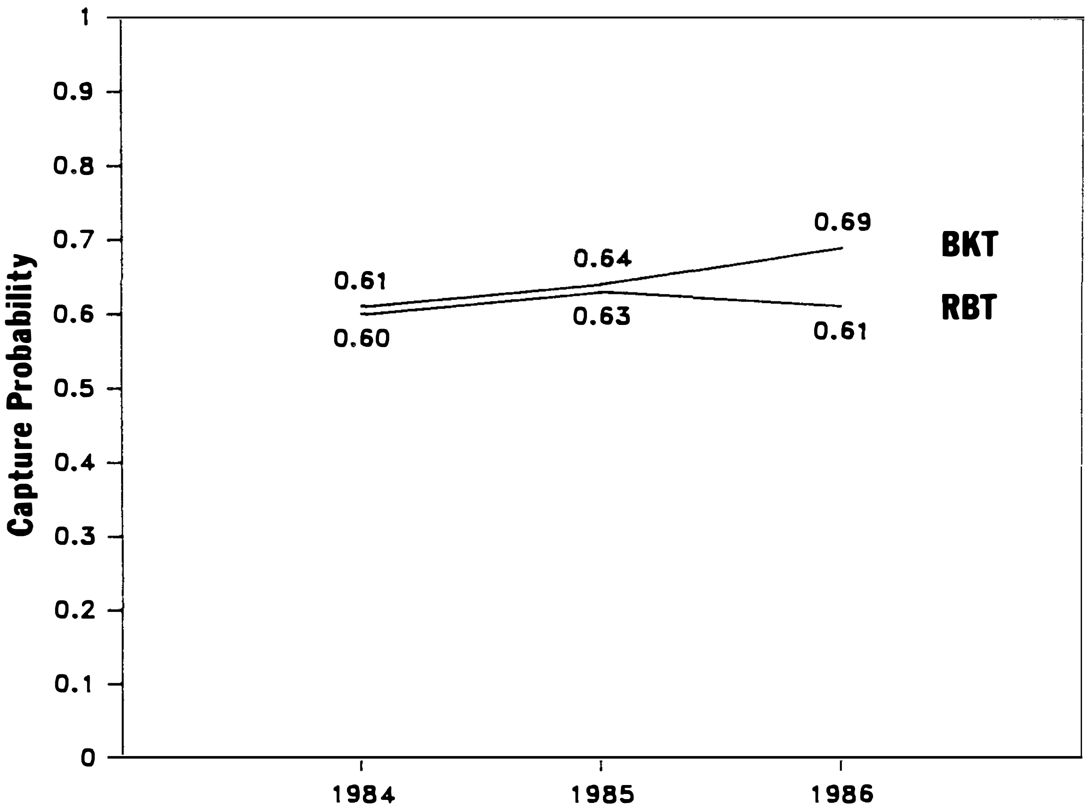

Figure 16. Mean capture probabilities of rainbow trout (RBT) and brook trout (BKT) for all study streams as a group in each year.

One YOY was captured in both 1984 and 1985, but in 1986, eight of the total catch of 13 brown trout were YOY.

Since exotic salmonid removals were conducted in Collins Creek again during this study, it was possible to compare the total catch of brown trout from throughout this stream in 1986 to data obtained by Riley. The total catch of brown trout in Collins Creek increased from 14 in 1984 to 17 in 1985 (J. Riley, pers. commun.), then to 48 in 1986. The percentage of the total catch made up of YOY increased from 0% in 1984 to 35.3% in 1985, then to 64.6% in 1986. In addition, one large brown trout (~460 mm) was stunned but ultimately evaded capture just downstream of the trail crossing on Collins Creek. Another brown trout (~220 mm) was captured but escaped during net transfer just beyond the upper end of Section II at an elevation of approximately 850 m. Both fish were upstream of any previously documented occurrence of brown trout in this creek.

Mean brown trout standing crop in control streams increased from 0.1 kg/ha in 1984 to 1.0 kg/ha in 1986 while it decreased from 1.0 kg/ha to 0.4 kg/ha in removal streams over the same period. Between 1984 and 1986, brown trout increased from 0.4% to 3.4% of the total salmonid standing crop in control streams while this species decreased from 4.6% to 2.2% of the total salmonid standing crop in removal streams over the same period. Mean brown trout density in control streams increased from 0.8% to 6.1% of total salmonid density between 1984 and 1986. In removal streams, mean brown trout density as a percentage of total salmonid density increased from 0.3% to 0.8% over the two years.

Food Habits

Frequencies of occurrence, percentages by number, and percentages by weight of the three major food groups in the diets of allopatric and sympatric populations of each species are compared for 1984 (Figure 17) and 1986 (Figure 18). All food items identified from trout stomachs are listed in Table 7 in Appendix G along with the streams in which they were found and the number of each item that occurred in each population.

Brook Trout

Terrestrial invertebrates occurred most frequently and were most numerous in the diets of both sympatric and allopatric brook trout in 1984. These terrestrial food items made up the largest percentage of the diet of allopatric brook trout by weight (99.3%), but salamanders and crustaceans constituted the majority of the diet of sympatric brook trout in terms of weight. Aquatic insects occurred least frequently and represented the smallest percentage of the diet of allopatric brook trout by number and weight in 1984. In sympatric brook trout populations in 1984, the Other food category (mostly crustaceans and salamanders) occurred less frequently and in fewer numbers than the other two major groups; however, by weight, this group represented the largest percentage of the diet of sympatric brook trout in the three streams.

By 1986, aquatic insects, found in 93.2% of the stomachs examined, had replaced terrestrial invertebrates as the most frequently occurring food items in the diet of sympatric brook trout. While terrestrial invertebrates still occurred most frequently in the diet of allopatric

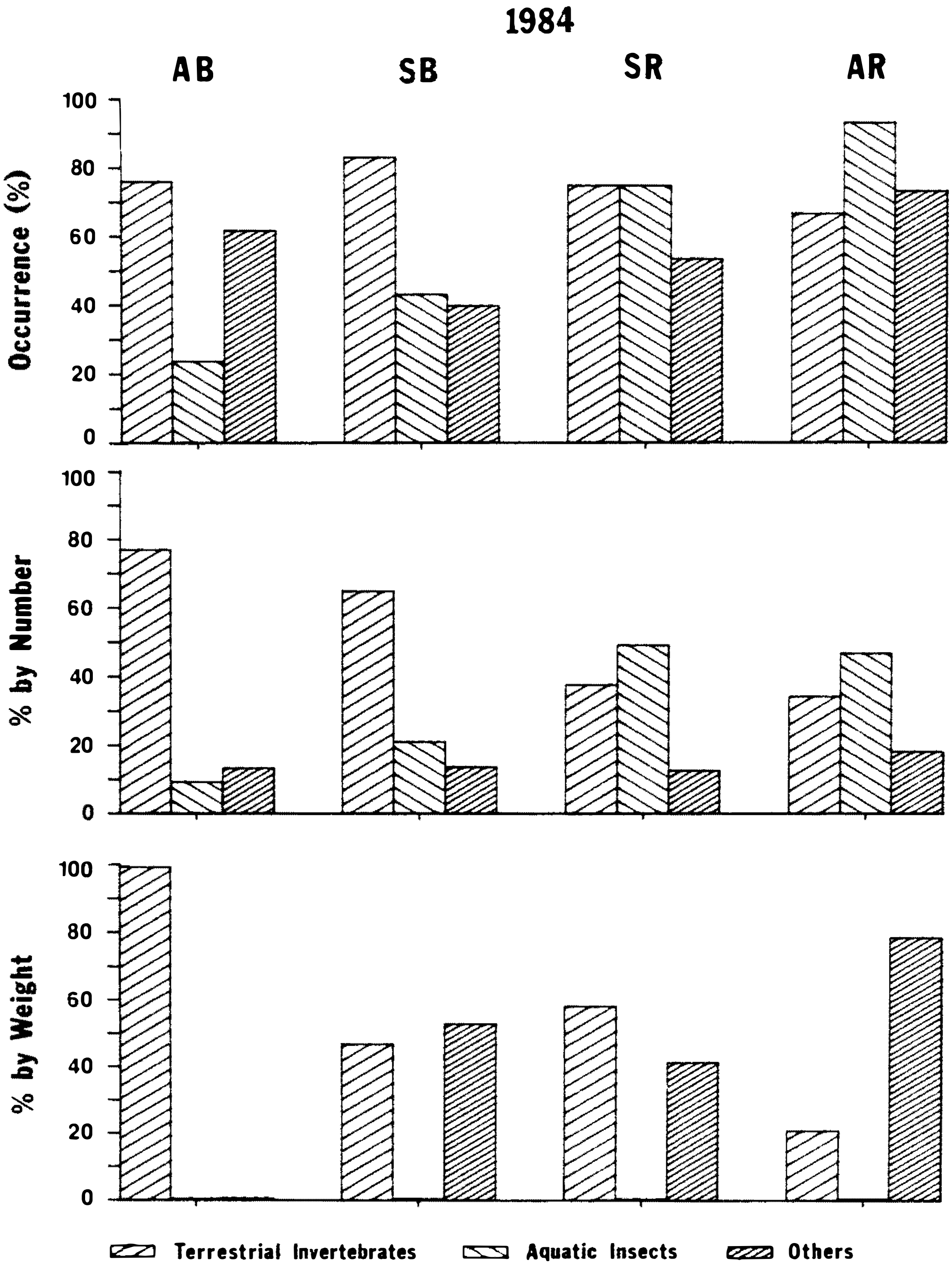

Figure 17. Percentage of each major food group by occurrence, number, and weight in the diets of allopatric and sympatric brook (AB, SB) and rainbow (AR, SR) trout in 1984.

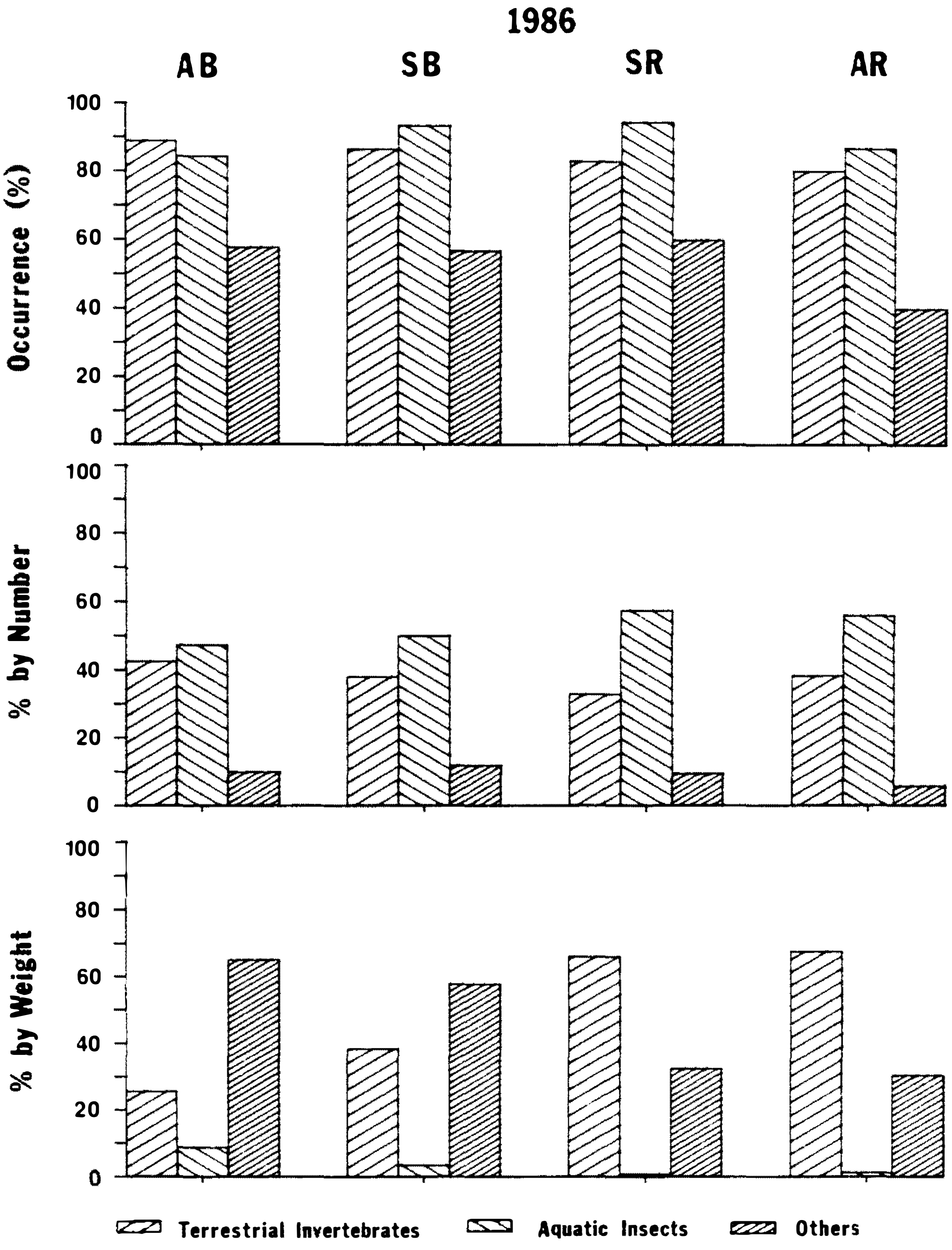

Figure 18. Percentage of each major food group by occurrence, number, and weight in the diets of allopatric and sympatric brook (AB, SB) and rainbow (AR, SR) trout in 1986.

brook trout in 1986, the frequency of occurrence of aquatic insects had increased from 23.8% to 84.4%. The Aquatic Insect group represented the largest portion (50%) of the diet of sympatric brook trout by number in 1986. However, aquatic insects were also the most numerous food items in the diet of allopatric brook trout in this year, having increased from 9.4% to 47.4%. Crustaceans and salamanders made up the largest percentage of the diets of both populations by weight in 1986, although this group occurred least frequently and in the fewest numbers. By weight, aquatic insects contributed the least to the diets of allopatric (8.8%) and sympatric (3.4%) brook trout in 1986. This was also true in 1984, when aquatic insects represented only trace amounts (<1%) of the diets of each population by weight.

Rainbow Trout

Aquatic insects occurred most frequently (93.3%) in the diet of allopatric rainbow trout and were also most prevalent in terms of number in 1984. Terrestrial invertebrates occurred least frequently (66.7%) in this population. Aquatic insects and terrestrial invertebrates occurred equally often (75.0%) in the diet of sympatric rainbow trout in 1984, but aquatic insects made up the largest percentage by number. Crustaceans were least numerous in the diets of both populations in 1984, but represented the largest portion of the diet of allopatric rainbow trout by weight. Salamanders were not found in any rainbow trout stomachs examined from 1984. Terrestrial invertebrates made up the greatest percentage of sympatric rainbow trout diets by weight in this year.

In the 1986 sample, aquatic insects occurred most frequently in the diets of both populations of rainbow trout and also remained most numerous. The percentage by number of food items in the Other category (primarily crustaceans in this case) decreased somewhat relative to 1984 levels in both populations. Only one salamander was recovered from a rainbow trout stomach in 1986. Terrestrial invertebrates made up the largest portion of the diet of sympatric rainbow trout by weight again in 1986, but also represented the largest percentage of the diet of allopatric rainbow trout by weight in this year--increasing from 21.0% in 1984 to 68.0% in 1986.

CHAPTER IV

DISCUSSION

Evaluation of Rainbow Trout Removals

The total catch of rainbow trout unexpectedly increased during the two years of removal efforts in the nine treatment streams. The structure of the rainbow trout populations in these streams shifted strongly toward YOY. Brook trout population structures remained quite stable, although total catch for both populations of this species increased during the study. Total catch and percent YOY of rainbow trout in control streams also increased, but not to the same degree as in the removal streams.

The relatively low percentage of YOY rainbow trout in both control (13.5%) and removal (7.6%) streams in 1984 (Figure 5, page 23) may have been the result of severe flooding that occurred in March and April of that year. Rainbow trout fry would have just begun to emerge from the substrate during this period (Steve Moore, pers. commun.). Trout fry and unhatched eggs are known to be highly susceptible to flooding (Elwood and Waters 1969; Seegrist and Gard 1972). Young brook trout, having emerged earlier, would have been larger and thus better able to find shelter from the high waters. This seems to be substantiated by the higher percentages of YOY brook trout present in control (31.3%) and removal (44.6%) streams in 1984.

Mean rainbow trout density in both control and removal populations remained relatively constant between 1984 and 1985, but increased substantially in 1986 (Figure 8, page 27). This sudden increase in rainbow trout mean densities in 1986 was almost certainly due to the reduced stream areas caused by severe drought conditions in the spring and summer of that year. This same trend can also be seen for brook trout from removal streams and, to a lesser extent, for control brook trout.

Although mean rainbow trout standing crop in the removal streams decreased during the study and was significantly lower than that in the control streams in 1986, this decrease was not due to a reduction in rainbow trout numbers. It can, however, be directly attributed to the increasingly greater proportion of YOY rainbow trout in removal stream populations in each study year. This effect was also apparent in the control streams in 1985. A large increase in the percentage of YOY rainbow trout was accompanied by a decrease in mean standing crop relative to the previous year. Brook trout mean standing crop increased nominally over the study period in control and removal streams. Since the percentage of YOY brook trout remained relatively constant, the increase was likely due to the increase in numbers of brook trout.

The increasing total catch, relatively stable mean density, and small reduction in mean standing crop would seem to suggest that the two years of removal efforts had little effect on rainbow trout populations other than to alter their structure in favor of YOY. This evaluation is further supported by the lack of any distinct increases in brook trout mean density or standing crop. Moore et al. (1983) achieved much sharper decreases in mean rainbow trout standing crop (from 22.9 to 5.7 kg/ha) and much greater increases in mean brook trout standing crop (from 6.2 to 14.5 kg/ha) after the first two years of removal efforts in a group of four GSMNP streams. However, Moore et al. (1983) used an effort of three removal passes per stream per year. Additionally, all four streams apparently had effective downstream barriers, since no finclipped rainbow trout released below the barriers were recaptured above them.

Only three of the treatment streams in this study were given three removal passes in 1984; the other six were given either one or two passes. In 1985, each treatment stream received only one removal pass, since Riley (1986) determined that this effort was the most efficient, all things considered. Also, rainbow trout marked in 1984 were recaptured in Grouse Creek in 1985 (Riley 1986) and rainbow trout marked by Riley in 1985 were recaptured in Grouse Creek in 1986. It is certainly possible that reinvasion occurred in other streams as well.

In light of the present data and the observations of Moore et al. (1983) and Moore et al. (1986), one removal pass, on all but the smallest streams, would not be a sufficient amount of effort to effectively reduce rainbow trout populations initially. The streams given one pass removals by Riley in 1984 were first or second order streams with very small pre-removal rainbow trout populations. If larger streams or streams with larger pre-removal populations of rainbow trout had been included in this group, one removal pass may have been deemed inadequate.

It would appear that insufficient effort and a lack of downstream barriers led to the overall ineffectiveness of the two years of rainbow trout removal, but other factors were also involved. Since rainbow trout capture probabilities were nearly identical in each study year, the increasing total catch of this species could not be the result of greater efficiency by electrofishing crews in 1985 and 1986. However, the excessive mean widths of Buck Fork and Indian Flats Prong and the abundance of deep pools ($\geq$1 m) in these streams have undoubtedly had a negative effect on the efficiency of rainbow trout removals during this study. Riley (1986) suggested that streams with mean widths exceeding 6.1 m (20 ft) would not be suitable for renovation with one electrofishing unit. Moore et al. (1986) reported that the physical features of Silers Creek, including its numerous deep pools ($\geq$1 m), decreased electrofishing efficiency by making it easier for rainbow trout to evade capture and more difficult to recover all stunned fish.

It is possible that, in streams with channel characteristics such as those in Buck Fork and Indian Flats Prong, a segment of the rainbow trout population would likely have a very low or no catchability. Bohlin (1977) routinely captured brown trout, introduced into a section of natural stream, after 15 or more electrofishings and was never able to recapture the entire population. The presence of "non-catchable" fish, however, does not lower the overall capture probability for the entire population. This seems to have been the case for Buck Fork and Indian Flats Prong. Rainbow trout in these streams had a mean capture probability for the study period (0.61) nearly identical to that of the other study streams as a group (0.62), even though a number of fish obviously remained uncaught.

The large increases in total catch, percentage of YOY, mean density, and mean standing crop, seemingly suggest a stimulation of the rainbow trout populations in Buck Fork and Indian Flats Prong. According to Everhart and Youngs (1981), increased mortality in a fish population will cause the population to attempt to compensate by increasing biomass through higher growth, reproduction, and survival rates. The large increase in the number of YOY rainbow trout in Buck Fork and Indian Flats Prong (Figure 6, page 24) was most likely due to an increase in their survival in 1985 and 1986, not necessarily to a general increase in the reproductive rate of rainbow trout. The simultaneous increases in mean rainbow trout standing crop and the number of adults captured, however, are more difficult to explain. For example, assuming that the one YOY and 79 adult rainbow trout collected in these two streams in 1984 fairly represented the actual population structures, it seems unlikely that recruitment of uncaptured YOY could have accounted for more than a small portion of the 112 adult rainbows that were removed in 1985.

Although Whitworth and Strange (1983) determined that rainbow trout generally exhibited little net movement in a southern Appalachian stream, they also noted that a few individuals moved more than 300 m upstream over the course of a year. These fish, however, had not been displaced. In this study, large numbers of rainbow trout from Buck Fork and Indian Flats Prong were "dumped" on top of dense, established populations downstream. This would have almost certainly heightened any propensity for movement, particularly by the displaced fish. Many of these fish would likely move back upstream, since net movement by rainbow trout seems to be in this direction (Whitworth and Strange 1983). Numerous marked rainbow trout from Grouse Creek were released into dense downstream populations in 1984 and 1985 and some of these fish are known to have returned in both 1985 and 1986.

It is quite likely that reinvasion also occurred in Buck Fork and Indian Flats Prong, perhaps on a larger scale. Reinvading trout, in addition to adults that had escaped capture, might explain the lack of reductions in mean rainbow trout standing crop and the number of adults between 1984 and 1985. Recriutment of YOY was potentially of greater importance in these streams in 1985 and 1986, since many more were present.

Streams with physical characteristics like those of Buck Fork and Indian Flats Prong are undoubtedly ill-suited to reclamation for brook trout by means of one electrofishing unit. This unsuitability is apparently compounded by the presence of large rainbow trout populations and the absence of downstream barriers to salmonid migration. Although Grouse Creek had substantial numbers of rainbow trout and lacked a barrier, no adverse stream channel features were present. Rainbow trout total catch, density, and standing crop were reduced somewhat over the study period. It is unlikely, however, that brook trout populations in this stream could ever be meaningfully bolstered by the continued use of the present techniques.

When the seven remaining treatment streams were considered separately, rainbow trout total catch decreased over the study period. The decline in mean standing crop was much more similar to that noted by Moore et al. (1983) and, for these streams, was due not only to the increasing percentage of YOY rainbow trout but also to the decreasing numbers of rainbow trout present in each year. Four of these seven streams had obstructions that would have hindered (but not prevented) rainbow trout immigration. In addition, most had smaller rainbow trout populations and none had physical features that would have negatively affected electrofishing efficiency.

The enhancement of brook trout populations in the removal streams when Buck Fork and Indian Flats Prong were excluded was much more evident. Mean density of brook trout in these streams became significantly higher than that of rainbow trout in 1985 and 1986. Although mean brook trout standing crop did not significantly exceed that of rainbow trout in any year, the difference was nearly significant in 1986. Significance would probably be achieved with another year of rainbow trout removals. Furthermore, allopatric populations of brook trout appear to have been re-established in Section II of Sahlee Creek and Section I of Hyatt Creek, as no rainbow trout were collected in those areas in 1985 or 1986. No rainbow trout were captured or seen in Section II of Cosby Creek in 1986, suggesting a return to allopatry there also.

The difference between the mean lengths and weights of adult brook and rainbow trout in removal streams was apparently reduced during the study. Adult rainbow trout, which were significantly longer and heavier than adult brook trout in removal streams in 1984 and 1985, had lost this advantage by 1986. The mean lengths and weights of removal stream rainbow trout closely paralleled those of control fish; therefore, the decreases in mean lengths and weights of removal stream rainbows could have been due to natural variation.

The small non-salmonid populations that occurred in two of the removal streams did not appear to have any effect upon co-occurring brook trout populations. Flick and Webster (1975) removed non-salmonids from a small Adirondak stream over a 13-year period and observed no concurrent increases in brook trout density or standing crop. The presence of dace and sculpins in conjunction with populations of brook trout in southern Appalachian streams was deemed inconsequential by Gray and Pardue (1978). Wilson and Harned (1983), however, found that blacknose dace (*Rhinichthys atratulus*) and brook trout had similar diets in a GSMNP stream and suggested that interspecific competition was possible. In any case, as Kelly et al. (1980) noted, range overlap of brook trout and dace (and sculpins) occurs on a very limited basis in the GSMNP and any impacts on overall brook trout growth or survival would be negligible.

Brown trout, which seem to be continuously increasing in abundance and extending their range throughout the GSMNP, can and do negatively impact brook trout populations. In streams where they occur together, brown trout compete with brook trout for food (Nyman 1970; Johnson 1981), resting cover (Fausch and White 1981), and spawning areas (Kaeding 1980). Additionally, Faush and White (1981) suggested that the predation of brown trout on young brook trout is partially responsible for brook trout population declines where the two species occur sympatrically. Brown trout can live longer and attain greater sizes than brook or rainbow trout in the GSMNP and may present the greatest future threat to brook trout populations in streams open to invasion by this species.

Brook and Rainbow Trout Food Habits

The food habits of trout in this study were comparable to those of wild adult brook and rainbow trout collected during the summer as reported by Lord (1933), Johnson (1981), and Lohr (1985). The definite similarity between the diets of adult brook and rainbow trout in southern Appalachian streams described by Tebo and Hassler (1963) and Lohr (1985) was also evident.

Sympatric brook and rainbow trout diets closely resembled each other in 1984. Essentially, the only difference was that rainbow trout seemed to feed more extensively on aquatic insects. The occurrence and quantity of these food items was noticeably greater in the diet of rainbow trout than in the diet of brook trout. The diets of allopatric brook and rainbow trout exhibited the same trait in 1984. Nearly all of the aquatic insect nymphs and larvae that had been consumed by the trout were early instars; therefore, they contributed only trace amounts to the diets of both species in terms of weight.

Lohr (1985) observed that terrestrial invertebrates contributed the most to the summer diets of adult sympatric brook and rainbow trout in a GSMNP stream. Terrestrial invertebrates were also the mainstay of the diets of both species during the first year of this study, as they constituted the largest percentage by weight. This measure is usually considered to be of greater importance than either occurrence or percentage by number (Wallace 1981; Bowen 1983). Although crustaceans and salamanders actually represented the largest percentage by weight of the diets of sympatric brook trout and allopatric rainbow trout in 1984, this is misleading. Only three of these food items were found in a sample of 30 sympatric brook trout and only two were found in a sample of 15 allopatric rainbow trout. As Wallace (1981) pointed out, the primary shortcoming of the percentage by weight analysis is that it can overemphasize the stomach contents of a few individuals.

In 1986, the diets of sympatric brook and rainbow trout were once again very similar. The occurrence and percentage by number of aquatic insects in the diet of sympatric brook trout increased substantially relative to 1984, surpassing terrestrial invertebrates in both areas. Lohr (1985) also reported that the number of aquatic insects in the diet of adult brook trout from a mixed population increased dramatically (>40%) after rainbow trout density was decreased by electrofishing. It would appear that the sympatric brook trout in this study had begun to exploit a food resource that they were previously not able to fully utilize because of the presence of rainbow trout. However, the occurrence and percentage by number of aquatic insects also increased substantially in the diets of allopatric brook trout and, to a lesser extent, allopatric and sympatric rainbow trout. Therefore, the increased use of aquatic insects by sympatric brook trout, as well as by the other populations, was probably little more than a response to an increase in the abundance of aquatic insects in the three study streams in 1986. Even with the greater utilization of aquatic insects by all trout populations in the summer of 1986, this group still contributed very little to trout diets in terms percentage by weight.

Crustaceans and salamanders were the most important food group in terms of weight in the diets of both populations of brook trout in 1986. Terrestrial invertebrates continued to contribute the largest percentage by weight to the diets of both populations of rainbow trout. Griffith (1974) reported that brook trout showed an affinity for benthic food items and Lohr (1985) found that brook trout fed much more extensively on decapods and vertebrates than did rainbow trout. The greater utilization of crustaceans and salamanders by brook trout was the only noticeable difference between the diets of the two species in 1986.

Under sympatric conditions, brook and rainbow trout show a certain degree of habitat segregation in GSMNP streams (Kelly et al. 1980; Larson and Moore 1985). Cunjak and Green (1983) reported similar findings for sympatric brook and rainbow trout in Newfoundland streams. Spatial separation of two salmonid species can serve to lessen direct competition for food (Nilsson 1955; Glova 1984). Chapman (1966) stated, however, that competition by stream salmonids for food is not eliminated merely by spatial differentiation. In any case, the ability of sympatric salmonid species to partition food supplies through habitat segregation and thus limit competition seems to be possible chiefly for species which have coevolved. In this study, it did not appear that two years of rainbow trout removals led to any noteworthy shifts in the food habits of sympatric brook trout.

Hynes (1970) indicated that there is no unequivocal evidence that food supply limits any species of stream fish. It is not known whether or not food was a limited resource during this study. If food was a limiting factor in either year, it should have served to heighten any direct competition between the two species for this resource. Also, since rainbow trout density was not reduced at all in Indian Flats Prong, the food habits of sympatric brook trout from this stream would not be expected to change. These conditions could have decreased the likelihood of detecting any overall dietary shifts by sympatric brook trout.

The most detrimental competition between brook and rainbow trout in the GSMNP probably does not occur after the fish reach adulthood. Rather, it most likely occurs between YOY brook and rainbow trout just after the emergence of the latter. Rose (1986) observed that no spatial segregation existed between young brook and rainbow trout for two months following the emergence of rainbow trout in a tributary of Lake Superior. He showed that both the quantity of food in brook trout stomachs as a percentage of body weight and their growth rate declined significantly during this period, then increased after the dispersal of YOY rainbow trout. Rose (1986) also analyzed the data of Whitworth and Strange (1983) from a southern Appalachian stream and was able to find the same sort of brook trout growth decline. Poor first year growth in brook trout has been correlated with higher winter mortality (Hunt 1969) and can lead to lower numbers of yearling brook trout.

CHAPTER V

SUMMARY

Two consecutive years of rainbow trout removals of moderate effort resulted in significant reductions in mean rainbow trout density and standing crop relative to control populations in seven of nine treatment streams. Brook trout populations in these seven streams responded with concurrent (non-significant) increases in both mean density and standing crop. Brook trout even replaced rainbow trout as the major component of total salmonid standing crop in 1986.

If removal efforts had been more intense and downstream barriers had been present on all streams, the reduction of rainbow trout populations might have been even greater and potentially longer lasting. When study areas in Silers and Taywa Creeks--two of the streams used by Moore et al. (1983)--were resampled in 1986, brook trout populations in both had evidently returned to allopatry (unpublished data). No rainbow trout were captured above the barriers in either stream, although they were still present when the streams were last sampled in 1979.

The absence of barriers did not seem to markedly enhance the recovery of rainbow trout populations in these seven treatment streams while annual removals were being conducted. However, now that rainbow trout removals have ceased, it would be of interest to observe how the absence of barriers affects the length of time required by rainbow trout populations in these streams to return to pre-removal levels.

This study was not designed to test the effects of physical stream characteristics on the effectiveness of rainbow trout removals with one electrofishing unit. It became apparent, however, that excessive mean stream width (>6 m) and deep pools ($\geq$1 m) can have a substantial influence. These physical conditions, in combination with large pre-removal rainbow trout populations, the absence of barriers, and the practice of releasing large numbers of rainbow trout into dense populations downstream undoubtedly prevented the reduction of rainbow trout populations in Buck Fork and Indian Flats Prong. All of these factors should be given careful consideration before renovation efforts are attempted in other GSMNP brook trout streams. If barriers are present, though, streams with the other features might still be reclaimed by alternate methods.

The food habits of adult sympatric brook and rainbow trout were quite similar both before and after two years of rainbow trout removal efforts in three streams. The use of aquatic insects by sympatric brook trout increased substantially after rainbow trout removals, but similar increases in the use of these food items occurred in allopatric brook trout populations. This suggests that no competition-based dietary shift actually took place. It was not known if food was limiting in either 1984 or 1986 and rainbow trout numbers actually increased in one of the streams (Indian Flats Prong). These conditions could have made the detection of a shift in the food habits of sympatric brook trout more difficult. Competition for food between adult brook and rainbow trout has certainly not been disproven here, but it would not seem to be of major importance. As Rose (1986) demonstrated, competition for food is most intense between YOY brook and rainbow trout and apparently has the most serious consequences for brook trout at this age.

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APPENDIXES

APPENDIX A

STREAM AND POPULATION ESTIMATE SECTION LOCATIONS

CONTROL STREAMS

Chasteen Creek

Watershed:	Oconoluftee River
County:	Swain
State:	NC
Quadrangle:	Smokemont

Section I

Downstream Tag #:	318
Upstream Tag #:	319
Elevation:	731.5 m (2400 ft)
Landmarks:	This section begins about 60 m upstream of the first bridge on the Chasteen Creek jeep trail. Tag # 318 is on a hemlock on the right upstream side. Tag # 319 is on the right upstream side.

Section II

Downstream Tag #:	2D
Upstream Tag #:	1U
Elevation:	914.4 m (3000 ft)
Landmarks:	Tag # 1U is located on the right upstream side, about 350 m below the confluence of the left and right forks of Chasteen Creek. A tag on the right side of the jeep trail (#147U) also marks the upper end of this section. Tag # 2D is on a large dead tree that has fallen across the creek from the right upstream side.

Pretty Hollow Creek

Watershed:	Cataloochee Creek
County:	Haywood
State:	NC
Quadrangle:	Luftee Knob

Section I

Downstream Tag #:	110D
Upstream Tag #:	109U
Elevation:	921.2 m (3040 ft)
Landmarks:	This section begins about 30 m upstream of the horse corral at Campsite 39 on the Pretty Hollow Gap Trail. Tag # 110D is on a maple on the left upstream side and tag # 109U is on the right upstream side.

Pretty Hollow Creek (Continued)
Section II

Downstream Tag #:	122D
Upstream Tag #:	121U
Elevation:	1121.7 m (3680 ft)
Landmarks:	This section begins about 25 m upstream of the first foot bridge trail crossing. Tag # 122D is on a maple on the right upstream side and tag # 121U is on a birch on the left upstream side.

<u>Marks Creek</u>

Watershed:	Middle Prong Little River
County:	Sevier
State:	TN
Quadrangle:	Thunderhead Mtn.

Section I

Downstream Tag #:	120D
Upstream Tag #:	119U
Elevation:	688.9 m (2260 ft)
Landmarks:	This section is located about 200 m upstream of the confluence with Lynn Camp Prong. Tag # 120D is on a birch on the right upstream side and tag # 119U is on a birch on the left upstream side.

Section II

Downstream Tag #:	114D
Upstream Tag #:	113U
Elevation:	780.3 m (2560 ft)
Landmarks:	This section begins where the first large tributary (not in a culvert) flows across the trail from the left and enters Marks Creek. Tag # 114D is on a birch on the left upstream side and tag # 113U is on the left upstream side.

REMOVAL STREAMS

<u>Woody Branch</u>

Watershed:	Cataloochee Creek
County:	Haywood
State:	NC
Quadrangle:	Cove Creek Gap

Woody Branch (Continued)

Section I

Downstream Tag #:	182D
Upstream Tag #:	183U
Elevation:	938.8 m (3080 ft)
Landmarks:	This section begins about 50 m above the confluence with Andy Branch. Tag # 182D is on a birch on the right upstream side and tag # 183U is on a rhododendron on the right upstream side.

Section II

Downstream Tag #:	186D
Upstream Tag #:	185U
Elevation:	1006.1 m (3320 ft)
Landmarks:	This section is located at the base of a very large island, near the first old home-place on the right side of the trail. Tag # 186D is on a birch on the right upstream side and tag # 185U is on a birch on the left upstream side.

<u>Cosby Creek</u>

Watershed:	Pigeon River
County:	Cocke
State:	TN
Quadrangle:	Hartford

Section I

Downstream Tag #:	112D
Upstream Tag #:	105U
Elevation:	707.1 m (2320 ft)
Landmarks:	This section begins about 75 m upstream of the road crossing to Bryants Horse Barns at Cosby Campground. Tag # 112D is on a poplar on the right upstream side and tag # 105U is on a buckeye on the left upstream side.

Section II

Downstream Tag #:	124D
Upstream Tag #:	123U
Elevation:	780.3 m (2560 ft)
Landmarks:	This section is located about 75 m upstream of the first foot bridge. Tag # 124D is on a hemlock on the right upstream side and tag # 123U is on a hemlock on the right upstream side.

Cosby Creek (Continued)
Renovated Area

Downstream Tag #:	106
Elevation:	707.1 m (2320 ft)
Upstream Tag #:	123U
Elevation:	792.5 m (2600 ft)
Landmarks:	Tag # 106 is on a poplar on the right upstream side at the road crossing and tag # 123U is at the upper end of Section II.

Hyatt Creek

Watershed:	Straight Fork
County:	Swain
State:	NC
Quadrangle:	Bunches Bald

Section I

Downstream Tag #:	134D
Upstream Tag #:	139U
Elevation:	848.5 m (2800 ft)
Landmarks:	This section begins about 100 m upstream of the Big Cove (Round Bottom) Road bridge crossing. Tag # 134D is on a maple on the left upstream side and tag # 139U is on a poplar on the right upstream side.

Section II

Downstream Tag #:	108D
Upstream Tag #:	111U
Elevation:	1109.5 m (3640 ft)
Landmarks:	This section begins at the first Low Gap Trail crossing. Tag # 108D is on a maple on the left upstream side at the crossing (on the back or upstream side of the tree). Tag # 111U is also on a maple on the left upstream side.

McGinty Creek

Watershed:	Big Creek
County:	Haywood
State:	NC
Quadrangle:	Luftee Knob

Section I

Downstream Tag #:	4D
Upstream Tag #:	3U
Elevation:	1036.3 m (3400 ft)

McGinty Creek (Continued)

Landmarks:	This section begins about 20 m upstream of the Swallow Fork Trail crossing. Tag # 4D is on a birch on the right upstream side and tag # 3U is on a birch on the right upstream side.

Section II

Downstream Tag #:	8D
Upstream Tag #:	7U
Elevation:	1097.3 m (3600 ft)
Landmarks:	This section is located about 300 m above the upper end of Section I. Tag # 8D is on a birch on the left upstream side and tag # 7U is on a birch on the right upstream side.

Indian Flats Prong

Watershed:	Middle Prong Little River
County:	Sevier
State:	TN
Quadrangle:	Thunderhead Mtn.

Section I

Downstream Tag #:	102D
Upstream Tag #:	117
Elevation:	865.6 m (2840 ft)
Landmarks:	This section begins at the confluence with Lynn Camp Prong. Tag # 102D is on a birch on the right upstream side and tag # 117 is on a birch on the left upstream side.

Section II

Downstream Tag #:	104D
Upstream Tag #:	15U
Elevation:	877.8 m (2880 ft)
Landmarks:	This section begins about 70 m below Double Trestle Branch. Tag # 104D is on a birch on the right upstream side and tag # 15U is on a birch on the right upstream side. This section ends about 100 m below the first bridge crossing.

Renovated Area

Downstream Tag #:	102D
Elevation:	865.6 m (2840 ft)
Upstream Tag #:	No tag - marked by flagging
Elevation:	963.2 m (3160 ft)

Indian Flats Prong (Continued)

Landmarks:	The renovated area begins at Section I and ends at the pool at the base of the first of a series of large waterfalls.

Buck Fork

Watershed:	Middle Prong Little Pigeon River
County:	Sevier
State:	TN
Quadrangle:	Mt. Guyot

Section I

Downstream Tag #:	12D*
Upstream Tag #:	17U
Elevation:	883.9 m (2920 ft)
Landmarks:	This section begins about 100 m upstream of the confluence with Chapman Prong. Tag # 12D is on a birch on the right upstream side of the creek. Tag # 17U could not be located in 1986; the section ends about 20 m below a small island and about 30 m below a small waterfall.

Section II

Downstream Tag #:	14D
Upstream Tag #:	13U
Elevation:	1036.3 m (3400 ft)
Landmarks:	This section begins about 700 m upstream of the end of Section I and about 25 m upstream of the base of an island. Tag # 14D is on a hemlock on the right upstream side and tag # 13U is on a poplar on the right upstream side.

Collins Creek

Watershed:	Oconoluftee River
County:	Swain
State:	NC
Quadrangle:	Smokemont

Section I

Downstream Tag #:	316D
Upstream Tag #:	317U
Elevation:	743.7 m (2440 ft)
Landmarks:	This section begins about 30 m above the pump station on the Collins Creek Trail. Tag # 316D is on a poplar on the right

Collins Creek (Continued)

upstream side and tag # 317U is on a hemlock on the right upstream side.

Section II

Downstream Tag #:	268
Upstream Tag #:	143U
Elevation:	853.4 m (2800 ft)
Landmarks:	This section begins about 300 m upstream of the first trail crossing. Tag # 268 is on a poplar on the right upstream side. Tag # 143U is located on the right about 10 m below where the renovated tributary enters from the right upstream side. The location of this section is incorrectly described in Riley (1986).

Renovated Area

Downstream Tag #:	399
Elevation:	731.5 m (2400 ft)
Upstream Tag #:	102
Elevation:	853.4 m (2800 ft)
Landmarks:	The renovated area begins at the Collins Creek bridge on Hwy. 441. Tag # 399 is on the left upstream side. The area ends 170 m above where the renovated tributary enters. Tag # 102 is on a buckeye on the left.

Renovated Tributary

Landmarks:	Renovation ended at the large cascade about 100 m above the confluence with Collins Creek in 1986.

<u>Sahlee Creek</u>

Watershed:	Deep Creek
County:	Swain
State:	NC
Quadrangle:	Climgmans Dome

Section I

Downstream Tag #:	128D
Upstream Tag #:	127U
Elevation:	1109.5 m (3640 ft)
Landmarks:	This section begins about 30 m above the confluence with Deep Creek. Tag # 128D is on a hemlock on the right upstream side and tag # 127U is on a birch on the left.

Sahlee Creek (Continued)
Section II

Downstream Tag #:	132D
Upstream Tag #:	131U
Elevation:	1156.2 m (3850 ft)
Landmarks:	This section is located where two ridges slope down to the creek near a natural opening on the left. Tag # 132D is on the left upstream side and tag # 131U is on a birch on the left upstream side.

Grouse Creek

Watershed:	Little River
County:	Sevier
State:	TN
Quadrangle:	Silers Bald

Section I

Downstream Tag #:	136D
Upstream Tag #:	135U
Elevation:	1048.5 m (3440 ft)
Landmarks:	This section begins at the confluence of Spud Town Branch and Grouse Creek. The confluence can be located by following the trail about 200 m past Campsite 30, and then descending down to the creek on the right. Tag # 136D is on a birch on the right upstream side at the confluence. Tag # 135U is on a large hemlock on the left upstream side.

Section II

Downstream Tag #:	154D
Upstream Tag #:	323U
Elevation:	1097.3 m (3600 ft)
Landmarks:	This section begins about 400 to 500 m upstream of the upper end of Section I or about 100 m above where a dry tributary enters from the right. Tag # 154D is on a birch on the left upstream side about 6 m back from the edge of the creek and tag # 323U is on a birch on the right upstream side.

APPENDIX B

SALMONID POPULATION ESTIMATES

Table 1. Annual population estimates and 95% confidence limits for rainbow trout (RBT), brook trout (BKT), and brown trout (BNT) in each section of each study stream.[a]

Stream	Species	1984 I	1984 II	1985 I	1985 II	1986 I	1986 II
Control Streams							
Chasteen	RBT	14(13-19)	13(13-15)	31(31-33)	27(26-31)	38(18-114)	21(20-25)
	BKT	*	14(10-32)	*	33(29-42)	*	44(42-49)
	BNT	2	*	1	*	22(13-56)	*
Pretty Hollow	RBT	54(49-63)	30(30-32)	47(45-52)	29(25-39)	71(69-75)	21(19-27)
	BKT	4(4-5)	26(25-30)	5(5-7)	44(27-87)	14(13-18)	42(41-46)
Marks	RBT	41(38-47)	41(35-53)	39(37-44)	30(30-32)	51(51-53)	50(47-56)
	BKT	*	9	*	9(9-10)	*	5(5-5)
Removal Streams							
Woody Branch	RBT	13(13-15)	6(6-9)	15(15-16)	*	22(20-28)	5(5-7)
	BKT	17	25(22-33)	36(29-51)	44(42-49)	22(22-24)	34(34-35)
Cosby	RBT	20(20-22)	6(6-6)	4(4-6)	3(3-6)	16(12-30)	*
	BKT	12(12-12)	82(67-102)	8(8-10)	79(77-84)	8(7-14)	69(67-73)
Hyatt	RBT	14(10-32)	*	*	*	*	*
	BKT	34(29-45)	17(17-18)	23(23-24)	16(16-16)	39(37-44)	21(21-21)
McGinty	RBT	6(6-9)	24(22-30)	5	9(9-10)	1	6(6-7)
	BKT	4(4-7)	16(16-18)	33(33-35)	20(20-21)	41(40-44)	47(47-49)
Buck Fork	RBT	30(29-34)	4(4-5)	72(45-123)	36(24-67)	94(91-99)	37(37-39)
	BKT	6(5-15)	3(3-6)	5(5-5)	12(10-21)	17(16-21)	16(16-18)
Indian Flats	RBT	21(20-25)	37(27-60)	68(66-72)	49(49-51)	89(88-92)	66(66-68)
	BKT	1	4(4-5)	10(10-11)	17(14-28)	7(7-8)	16(16-17)
Collins	RBT	17(14-28)	24(24-26)	18(16-25)	9(9-10)	14(10-30)	--
	BKT	7	31(27-41)	16(15-21)	60(43-90)	20(20-21)	--
	BNT	1	*	*	*	3(3-4)	--
Grouse	RBT	66(65-69)	55(52-61)	52(51-56)	33(32-37)	41(41-42)	41(37-49)
	BKT	29(29-30)	15(15-16)	7(7-9)	16(15-21)	14(14-16)	15(15-17)
Sahlee	RBT	6(6-7)	4	8(8-8)	*	11(11-11)	*
	BKT	33(24-55)	54(51-60)	14(14-15)	29(29-31)	51(49-56)	34(34-56)
	BNT	*	1	2	*	4	*

[a]In all cases, the lower limit was set equal to the total catch. When no fish were captured on the second and/or third runs, no confidence limits could be calculated.

*None captured.

APPENDIX C

WATER QUALITY AND STREAM CHANNEL CHARACTERISTICS

Table 2. Selected water quality parameters of each population estimate section in each study stream.

Stream	pH		Conductivity (μmhos/cm)		Temperature C	
	I	II	I	II	I	II
<u>Control Streams</u>						
Chasteen Creek	6.3	6.2	20.0	22.0	17	16
Pretty Hollow Creek	5.8	6.6	26.1	27.5	16	16
Marks Creek	6.1	6.3	17.3	25.3	18	17
<u>Removal Streams</u>						
Woody Branch	6.7	6.6	36.2	33.8	16	17
Cosby Creek	5.7	6.2	30.8	24.9	16	15
Hyatt Creek	6.7	6.7	*	*	13	12
McGinty Creek	6.6	6.4	31.1	24.8	16	15
Buck Fork	6.4	5.9	26.5	28.0	13	13
Indian Flats Prong	6.2	*	24.9	*	*	*
Collins Creek	*	*	15.0	*	16	*
Grouse Creek	6.1	5.6	16.3	16.8	18	17
Sahlee Creek	6.1	6.5	34.9	12.5	16	18

*Measurement not obtained.

Table 3. Selected channel characteristics of each population estimate section in each study stream.

Stream	Mean Width (m) I	Mean Width (m) II	Mean Depth (cm) I	Mean Depth (cm) II	Gradient (%) I	Gradient (%) II	Stream Order I	Stream Order II
Control Streams								
Chasteen Creek	5.0	4.9	*	21.9	4	9	3	2
Pretty Hollow Creek	5.7	5.1	11.7	9.2	7	9	2	2
Marks Creek	4.6	4.6	*	8.9	6	8	2	2
Removal Streams								
Woody Branch	4.9	3.5	4.3	4.1	10	11	2	2
Cosby Creek	7.3[a]	6.4[a]	*	*	8	15	3	2
Hyatt Creek	4.5	2.1	11.5	8.5	11	14	2	1
McGinty Creek	4.2	3.4	12.9	8.8	10	15	2	2
Buck Fork	7.2	7.5	19.5	16.8	11	13	2	2
Indian Flats Prong	6.5	6.0	*	*	6	*	2	2
Collins Creek	5.5	*	*	*	*	*	3	3
Grouse Creek	5.1	4.6	12.4	12.7	10	8	2	2
Sahlee Creek	2.8	2.5	12.4	12.0	11	11	1	1

[a]Measured during somewhat higher than normal flow conditions.

*Measurement not obtained.

APPENDIX D

YOUNG-OF-THE-YEAR SALMONIDS

Table 4. Annual catch of YOY rainbow trout (RBT), brook trout (BKT), and brown trout (BNT) in each section of each study stream.

Stream	Species	1984 I	1984 II	1985 I	1985 II	1986 I	1986 II
Control Streams							
Chasteen	RBT	6	1	27	11	6	0
	BKT	*	1	*	7	*	13
	BNT	1	*	1	*	8	*
Pretty Hollow	RBT	6	2	22	3	22	8
	BKT	0	6	1	11	7	15
Marks	RBT	4	5	18	11	14	17
	BKT	*	8	*	0	*	0
Removal Streams							
Woody Branch	RBT	2	0	5	0	13	5
	BKT	11	11	10	10	4	24
Cosby	RBT	5	2	0	0	9	*
	BKT	2	24	3	41	3	19
Hyatt	RBT	2	*	*	*	*	*
	BKT	12	9	15	5	10	1
McGinty	RBT	0	1	2	2	0	3
	BKT	0	1	16	10	33	29
Buck Fork	RBT	1	0	25	17	52	10
	BKT	0	1	2	4	10	12
Indian Flats	RBT	0	0	14	16	39	24
	BKT	0	0	2	5	2	4
Collins	RBT	2	0	5	0	6	--
	BKT	7	8	4	23	8	--
	BNT	0	*	*	*	0	--
Grouse	RBT	2	4	25	16	19	24
	BKT	14	8	0	7	8	3
Sahlee	RBT	1	1	4	*	0	*
	BKT	17	28	3	10	37	14
	BNT	*	0	1	*	0	*

*No YOY or adults captured.

APPENDIX E

SALMONID DENSITIES

Table 5. Annual densities (n/ha) of rainbow trout (RBT), brook trout (BKT), and brown trout (BNT) in each section of each study stream.

Stream	Species	1984 I	1984 II	1985 I	1985 II	1986 I	1986 II
Control Streams							
Chasteen	RBT	296	250	655	518	835	461
	BKT	0	269	0	634	0	966
	BNT	42	0	21	0	484	0
Pretty Hollow	RBT	982	769	850	744	1246	420
	BKT	73	667	91	1128	246	840
Marks	RBT	893	820	850	600	1181	1109
	BKT	0	180	0	180	0	111
Removal Streams							
Woody Branch	RBT	260	132	300	22	449	139
	BKT	340	552	720	971	449	943
Cosby	RBT	305	130	61	65	224	0
	BKT	183	1783	122	1717	112	1172
Hyatt	RBT	230	0	0	0	0	0
	BKT	558	895	377	842	682	1000
McGinty	RBT	109	444	91	167	24	176
	BKT	73	296	600	370	976	1382
Buck Fork	RBT	323	55	774	494	1306	548
	BKT	65	41	54	165	236	237
Indian Flats	RBT	299	598	967	791	1441	1279
	BKT	14	65	142	275	113	310
Collins	RBT	309	444	327	167	255	--
	BKT	127	574	291	111	364	--
	BNT	18	0	0	0	55	--
Grouse	RBT	1015	1146	800	688	820	891
	BKT	446	313	108	333	280	326
Sahlee	RBT	130	91	174	0	314	0
	BKT	717	1227	304	659	1457	1360
	BNT	0	23	43	0	114	0

APPENDIX F

SALMONID STANDING CROPS

Table 6. Annual standing crops (kg/ha) of rainbow trout (RBT), brook trout (BKT), and brown trout (BNT) in each section of each study stream.

Stream	Species	1984		1985		1986	
		I	II	I	II	I	II
<u>Control Streams</u>							
	RBT	9.4	16.6	6.5	14.1	21.9	12.4
Chasteen	BKT	0.0	11.3	0.0	10.0	0.0	13.2
	BNT	0.6	0.0	0.0	0.0	5.9	0.0
	RBT	28.7	21.3	18.5	21.3	26.2	9.2
Pretty Hollow	BKT	2.2	12.4	1.7	12.2	4.9	12.0
	RBT	35.6	35.0	22.8	22.7	35.3	32.1
Marks	BKT	0.0	0.8	0.0	3.2	0.0	1.8
<u>Removal Streams</u>							
	RBT	7.1	6.4	9.9	1.2	5.0	0.3
Woody Branch	BKT	3.4	5.6	10.1	14.9	9.6	7.7
	RBT	13.4	7.8	2.1	3.4	5.3	0.0
Cosby	BKT	5.6	42.3	4.0	21.9	2.4	20.5
	RBT	9.7	0.0	0.0	0.0	0.0	0.0
Hyatt	BKT	7.2	11.8	4.4	16.5	9.9	18.1
	RBT	2.7	13.2	2.4	7.6	0.4	3.5
McGinty	BKT	1.2	10.4	8.0	6.5	7.5	19.7
	RBT	14.3	2.2	19.6	8.5	17.5	12.3
Buck Fork	BKT	2.3	0.9	2.0	2.7	3.6	3.1
	RBT	15.8	29.4	33.9	29.8	34.8	30.6
Indian Flats	BKT	0.3	3.5	4.2	7.5	2.5	9.0
	RBT	9.5	17.2	6.8	7.9	4.6	--
Collins	BKT	0.1	9.7	4.7	8.0	3.7	--
	BNT	9.5	0.0	0.0	0.0	2.8	--
	RBT	37.8	41.4	21.3	20.9	20.0	14.4
Grouse	BKT	6.3	3.8	4.1	5.7	4.5	7.3
	RBT	6.0	2.8	3.5	0.0	5.7	0.0
Sahlee	BKT	9.2	19.1	6.7	9.0	12.8	17.8
	BNT	0.0	8.8	1.0	0.0	3.7	0.0

APPENDIX G

FOOD ITEMS

Table 7. Food items recovered from trout stomachs from each of the three sample streams and the number of each item that occurred in each population of brook trout (BKT) and rainbow trout (RBT).

Food Item	Stream			Occurrence			
				Allopatric		Sympatric	
	Cosby	Collins	Indian Flats	BKT	RBT	BKT	RBT
TERRESTRIAL INVERTEBRATES							
Arachnida	X	X	X	11	9	14	16
Coleoptera	X	X	X	21	33	16	23
Diptera	X	X	X	56	10	25	13
Hemiptera	X	X	X	21	12	31	24
Hymenoptera	X	X	X	12	19	26	28
Lepidoptera	X	X	X	47	35	41	29
Orthoptera	X	X	X	4	5	2	5
Millipedes	X	X			20		
Adult Ephemeroptera	X	X	X	7	1	9	6
Adult Odonata (Zygoptera)	X		X			3	3
Adult Plecoptera	X	X	X	4	4	9	3
Adult Trichoptera	X	X	X	19	11	17	19
AQUATIC INSECTS							
Ephemeroptera							
Baetidae	X	X	X	3	11	6	16
Ephemerellidae	X	X	X	5	5	2	14
Dannella sp.		X			1	1	3
Drunella sp.	X	X	X	4	4	1	4
Heptageniidae	X	X	X	13	10	10	20
Epeorus sp	X	X	X	2	5	3	4

Table 7. (Continued)

Food Item	Stream			Occurrence			
				Allopatric		Sympatric	
	Cosby	Collins	Indian Flats	BKT	RBT	BKT	RBT
Peltoperlidae	X	X	X	2	3	2	
Peltoperla sp.	X	X	X	2	3	2	
Perlidae	X		X	2	1		2
Acroneuria sp.	X		X		1		1
Paragnetina sp.	X			1			
Perlodidae	X	X	X	3	4	2	7
Pteronarcyidae		X	X		3	1	2
Pteronarcys sp.		X	X		3	1	2
Diptera							
Ceratopogonidae		X	X	2		1	1
Chironomidae	X	X	X	10	17	9	11
Dixidae	X	X	X	3			5
Dixa sp.	X	X	X	3			5
Simulidae	X	X	X	1	2	3	5
Tipulidae	X	X	X	6		6	7
Odonata							
Gomphidae	X	X		1		1	1
Lanthus sp.	X	X		1		1	1
Coleoptera		X	X	2	1	1	2
Eubriidae		X					1
Ectopria sp.		X					1
Heteroptera	X		X	3		3	1

Table 7. (Continued)

Food Item	Stream			Occurrence			
				Allopatric		Sympatric	
	Cosby	Collins	Indian Flats	BKT	RBT	BKT	RBT
Leptophlebiidae	X		X	2		8	3
Siphloneuridae	X		X		8		1
Trichoptera							
Glossosomatidae	X	X	X		38	1	12
Glossosoma sp.	X	X	X		38	1	12
Hydropsychidae	X	X	X	11	29	7	14
Diplectrona modesta		X		2	13	5	
Parapsyche cardis	X	X	X	5	3		14
Symphitopsyche sp.	X	X	X		8	1	
Limnephilidae	X		X	1			3
Pycnopsyche sp.			X	1			2
Odontoceridae			X	18	10	27	13
Psilotreta sp.			X	18	10	27	13
Philopotamidae	X	X	X	14	14	24	24
Dolophilodes sp.	X	X	X	14	14	24	24
Polycentropodidae	X	X		1	1		
Polycentropus sp.	X				1		
Rhyacophilidae	X	X	X	1	3		2
Rhyacophila fuscula	X	X			1		1
Sericostomatidae	X		X	1			1
Fattigia pele	X		X	1			1
Plecoptera							
Chloroperlidae	X		X			1	1

Table 7. (Continued)

Food Item	Stream			Occurrence			
				Allopatric		Sympatric	
	Cosby	Collins	Indian Flats	BKT	RBT	BKT	RBT
OTHER							
Crustacea							
Decapoda	X	X	X	13	7	23	13
Isopoda	X		X				3
Mollusca	X	X			2		
Vertebrata							
Salamanders	X			1		5	1
Fish (Salmonidae)		X		1			

VITA

James Wesley Habera was born in Mount Pleasant, Pennsylvania on January 16, 1962. He and his family moved to Bluff City, Tennessee in 1973. After graduating from Sullivan East High School in June 1980, he attended East Tennessee State University in Johnson City for two years. In the fall of 1982, he transferred to the University of Tennessee, Knoxville, where he received a Bachelor of Science degree in Wildlife and Fisheries Science in December 1984.

In September 1985, he entered Graduate School at the University of Tennessee, Knoxville, and was awarded a Hilton A. Smith Fellowship. He accepted a Graduate Research Assistantship and was also the recipient of a Carlos C. Campbell Memorial Research Fund Fellowship in 1986. In June 1987, he received a Master of Science degree in Wildlife and Fisheries Science, with specialization in fisheries.

Mr. Habera is an active member of the Tennessee Chapter of the American Fisheries Society and is also a member of the Gamma Sigma Delta Agricultural Honor Society.