CHANGES IN STANDING CROP OF BROOK TROUT CONCURRENT WITH REMOVAL OF EXOTIC TROUT SPECIES, GREAT SMOKY MOUNTAINS NATIONAL PARK

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CHANGES IN STANDING CROP OF BROOK TROUT CONCURRENT WITH REMOVAL OF EXOTIC TROUT SPECIES, GREAT SMOKY MOUNTAINS NATIONAL PARK

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January, 1981

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ABSTRACT

Exotic rainbow trout (*Salmo gairdneri*) and brown trout (*Salmo trutta*) were removed by electrofishing from sympatric populations containing native brook trout (*Salvelinus fontinalis*) in remote headwater stream study areas in the Great Smoky Mountains National Park. Exotic trouts were removed each year and brook trout were marked and returned to the areas from which they were captured. As exotic species were removed from sympatric populations, brook trout populations responded markedly, showing increases in numbers and total weights as reflected by standing crops of each sympatric population. In 1978, the standing crop of only one sympatric population had increased to surpass the numerical value present at the beginning of this investigation in 1976. Although the standing crops of other streams did not recover to the 1976 values, the species composition changed markedly, with brook trout contributing the greatest weight per hectare in each sympatric population in 1978 and 1979. Standing crops of all sympatric populations decreased between 1978 and 1979, but brook trout still contributed the greatest weight per hectare. Exotic trouts were not eradicated from any study area, and it is improbable that they can be by a two-man electrofishing team.

INTRODUCTION

The brook trout (Salvelinus fontinalis) is the only salmonid native to the Great Smoky Mountains National Park (GRSM). Once though to occupy approximately 680 kilometers (km) of the park's 1173 km of fishable trout streams, this species is now relegated to the small headwater streams, usually 1000 m above Mean Sea Level (MSL) (Alan Kelly, personal communication). Presently, brook trout exclusively occupy approximately 197 km of streams, of which only 64 km lie upstream from natural barriers that are apparently impassable to upstream passage by salmonids (Alan Kelly, personal communication).

King (1937) attributed changes in brook trout distribution between the early 1900s and the 1930s to several factors, including extensive logging, fires, the use of explosives and nets to capture trout, and the introduction of rainbow trout (Salmo gairdneri). In the early 1900s, rainbow trout were introduced into every major watershed at easily accessible locations. Park officials assumed that brook trout would recover lost habitat after the cessation of logging in 1936 (King, personal communication). As reforestation progressed, recovery of brook trout failed to occur, however. During this period, rainbow trout began to move upstream from where they had been stocked and invaded previously unstocked waters (King 1937).

Studies by King (1937, 1939), Lennon (1967) 1/, and Jones (1975) 2/ have enabled monitoring of the changes in brook trout and rainbow trout distribution. Figure 1 shows the progressive decline in the number of

1/ U.S. Fish & Wildlife Service, Gatlinburg, TN

2/ U.S. Fish & Wildlife Service, Gatlinburg, TN

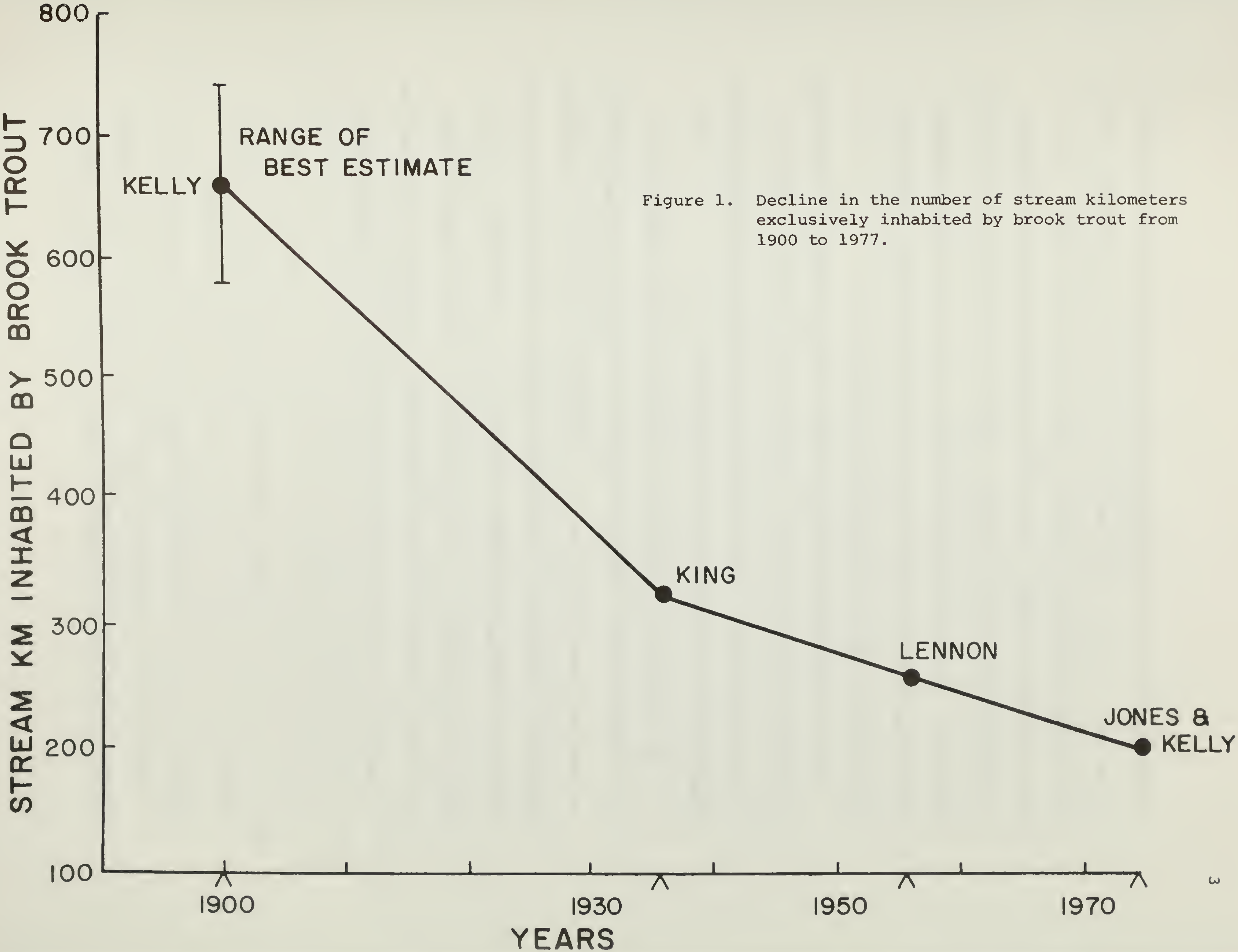

Figure 1. Decline in the number of stream kilometers exclusively inhabited by brook trout from 1900 to 1977.

kilometers of stream exclusively occupied by brook trout from the 1930s to the 1970s. Lennon (1967) stated that generally the distribution found in his investigation was similar to that found by King (1937). But in a more recent study Jones (1975) stated that brook trout had essentially disappeared from 45 percent of the stream miles they occupied in the 1950s (Figure 1). This loss of habitat by brook trout has been most apparent in the lower reaches of each watershed and has been mainly attributed to the invasion of exotic rainbow trout and brown trout.

The results of the recent brook trout surveys concerned National Park Service officials. This led to funding of this preliminary effort to attempt eradication of exotic trouts by backpack electrofishing techniques. Other eradication methods were not approved for use.

The objectives of the present investigation were to determine: (1) Whether a two-man crew (one operator and one assistant) equipped with one backpack electrofishing unit could eradicate exotic trouts from mixed populations upstream from natural obstructions; (2) the species composition, distribution, movements, numbers, sizes, and weights of trout species in sympatric populations; (3) the distribution, movements, numbers, sizes, and weights of brook trout and rainbow trout in allopatric populations and to compare these parameters with sympatric populations after attempting to eradicate the exotic trout.

DESCRIPTION OF STUDY AREAS

One sampling area was chosen from each of 6 streams of either Order 2 or Order 3. Five of the sampling areas began immediately above a natural obstruction (waterfall or cascade). The sixth stream was a tributary of another sampling area, and no obstruction separated the two. The streams were typical of montane creeks in the Appalachian highlands of the southeastern United States. Most of the obstructions in the study areas were classed as cascades, but two were designated as waterfalls. In this investigation, waterfall is defined as a vertical or undercut substrate face of at least 1.1 m, measured from the surface of the plunge pool to the upstream lip. The main water column passing over a falls either descends unimpeded or flows downward, adhering to the substrate face. A cascade is defined here as an obstruction having a minimum vertical rise of 1 m and a slope of not less than 14 percent.

Certain sections within the sampling areas contained only brook trout or only rainbow trout. Other sections contained both species interspersed throughout. Mayr, according to Cain (1960), introduced the word "sympatric" to indicate two forms or species of fishes occurring together. Mayr also introduced the word "allopatric" to indicate two forms or species not occurring together, implying geographic separation. These two words are used in this report to differentiate between sections containing one species of trout and sections containing more than one salmonid species within the same stream.

Watershed vegetation along the slopes of stream courses included second-growth yellow birch (*Betula allegheniensis*), sweet birch (*Betula lenta*), (*Acer* species), hemlock (*Tsuga canadensis*), yellow buckeye (*Aesculus octandra*), and tulip poplar (*Liriodendron tulipifera*) forming the major forest canopy. The dominant understory immediately overhanging all study streams contained Rhododendron species, Hydrangea arborescens, and doghobble (Leucothoe fontenosa).

Beetree Creek

This stream flows into Deep Creek at an altitude of approximately 853 m above MSL in Swain County, North Carolina (Fig. 2). The study area began about 15 m above its confluence with Deep Creek and extended 900 m upstream. This study area contained a sympatric population of brook and rainbow trouts and an allopatric population of rainbow trout. No trout were found above the cascade at 975 m above Mean Sea Level (MSL) in any year. Approximately 2.4 km of Beetree Creek continued above the study area. Beetree Creek is shown on the Clingman's Dome 7.5 minute quadrangle map (1964).

Discharge was taken in the summers of 1977 and 1978 and measurements fluctuated between 0.04 m^3/sec at low flow to 0.08 m^3/sec at moderate stages of discharge. Conductivity varied between 7 umhos/cm and 8 umhos/cm, and the pH was 6.7 in 1977 and in 1978. Stream gradient along the channel was approximately 17 percent.

Mouse Creek

This stream has an approximate total length of 2.74 km, lies in Haywood County, North Carolina, and empties into Big Creek at an approximate altitude of 701 m above MSL (Fig. 3). The study area began above a large cascade (Mouse Creek Falls) about 20 m upstream from the mouth of the creek and extended 900 m upstream. Only rainbow trout were present in this study area. Approximately 1.82 km of stream lies above the study area. Mouse Creek is shown on the Luftee Knob 7.5 minute quadrangle map (1964).

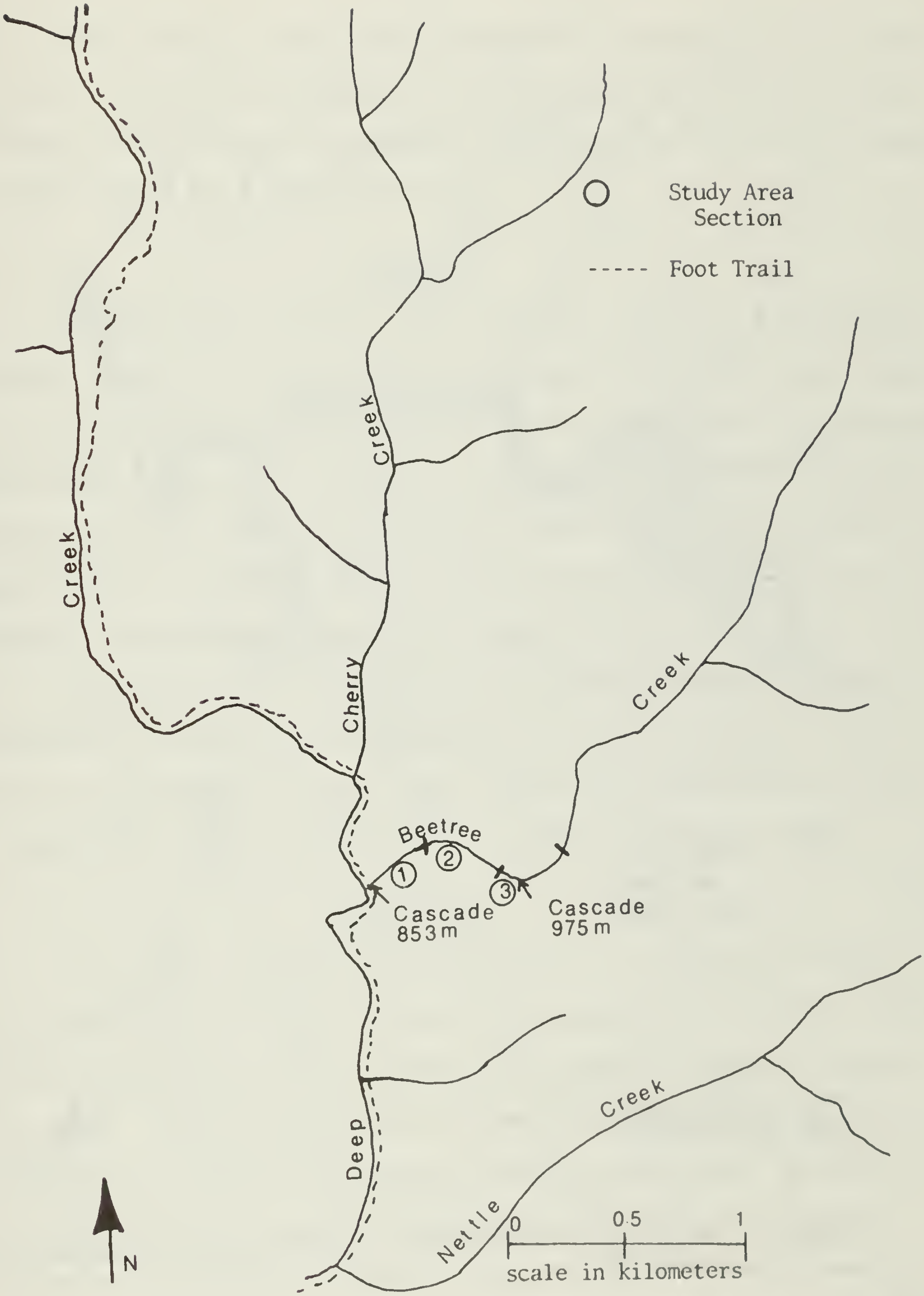

Figure 2. Beetree Creek, Swain County, North Carolina (elevations of cascades are above MSL)

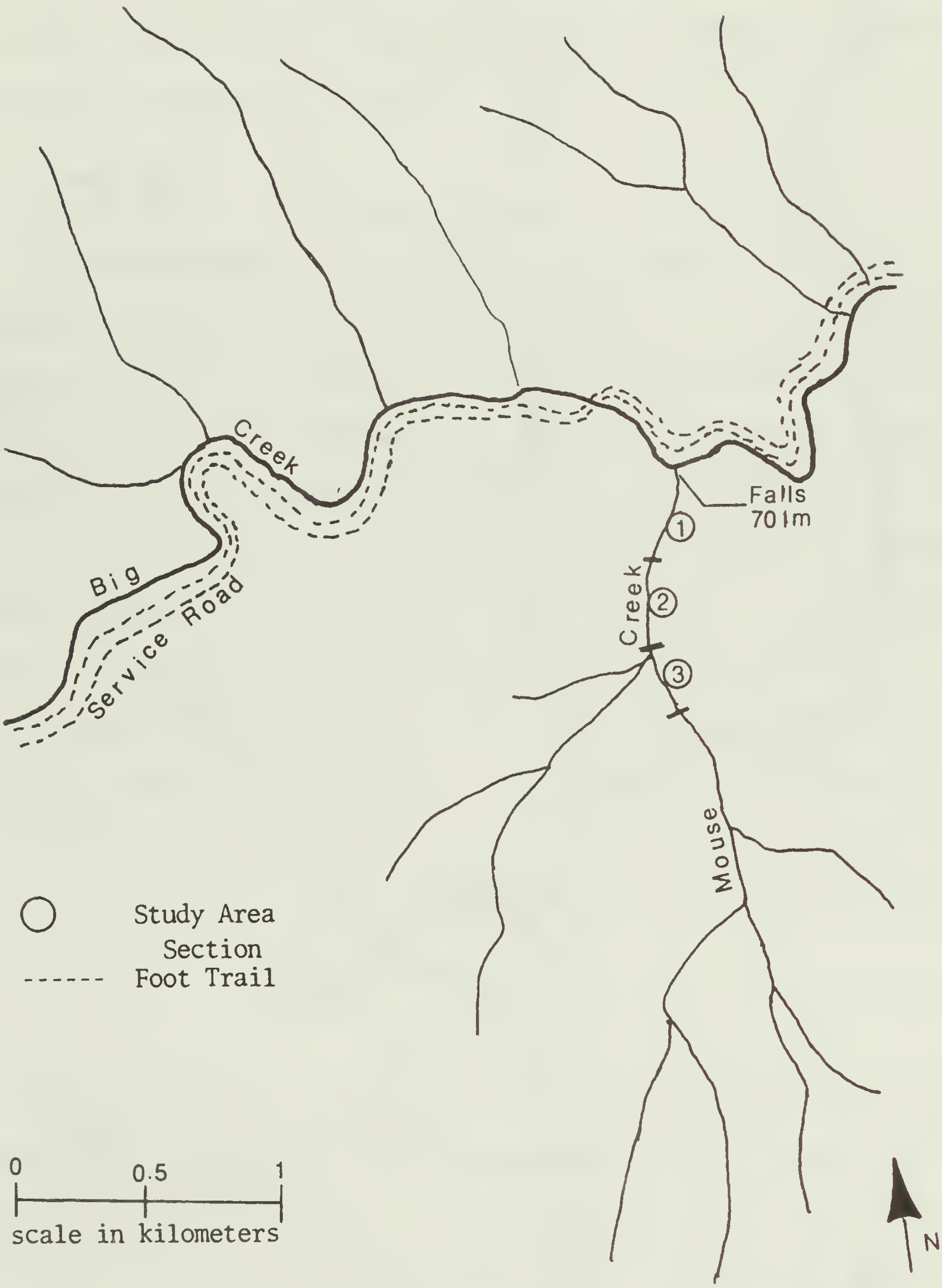

Figure 3. Mouse Creek, Haywood County, North Carolina (elevation of falls above MSL)

Mouse Creek has an approximate gradient of 18 percent along the stream channel. Discharge varied between 0.02 m^3/sec and 0.10 m^3/sec during the summers of 1977 and 1978. Conductivity was 20 umhos/cm in 1977 and 11 umhos/cm in 1978, with a pH of 7.0 in both years.

Sams Creek

In Sevier County, Tennessee, Sams Creek is a tributary of the Middle Prong of Little River (Fig. 4). The stream has an approximate total length of 6.9 km. The sampling area began at a falls at an altitude of approximately 889 m above MSL, some 3.5 km above the junction of Sams Creek with Middle Prong. The trout population of this study area was entirely sympatric. Approximately 2.2 km of stream lay above the study area. This creek is shown on the Thunderhead Mountain 7.5 minute quadrangle sheet (1964).

Stream gradient along the stream channel is approximately 8 percent. Discharge fluctuated from 0.03 m^3/sec at low flow to 6.18 m^3/sec at high flow in the summers of 1977 and 1978. Conductivity varied between 10 and 11 umhos/cm and pH varied from 6.8 to 6.9 in summers of 1977 and 1978.

Silers Creek

Silers Creek, in Sevier County, Tennessee, is a tributary of Fish Camp Prong (Fig. 5). This creek has a total length of approximately 3.05 km, and the study area began at a cascade 1036 m above MSL, about 200 m above its mouth. Twelve hundred meters of stream comprised the study area, and approximately 1.85 km of stream extend above the study area. The study area contained both a sympatric population and an allopatric brook trout population. Silers Creek is shown on the Silers Bald 7.5 minute quadrangle sheet (1964).

Figure 4. Sams Creek and Starkey Creek, Sevier County, Tennessee (elevations of falls above MSL)

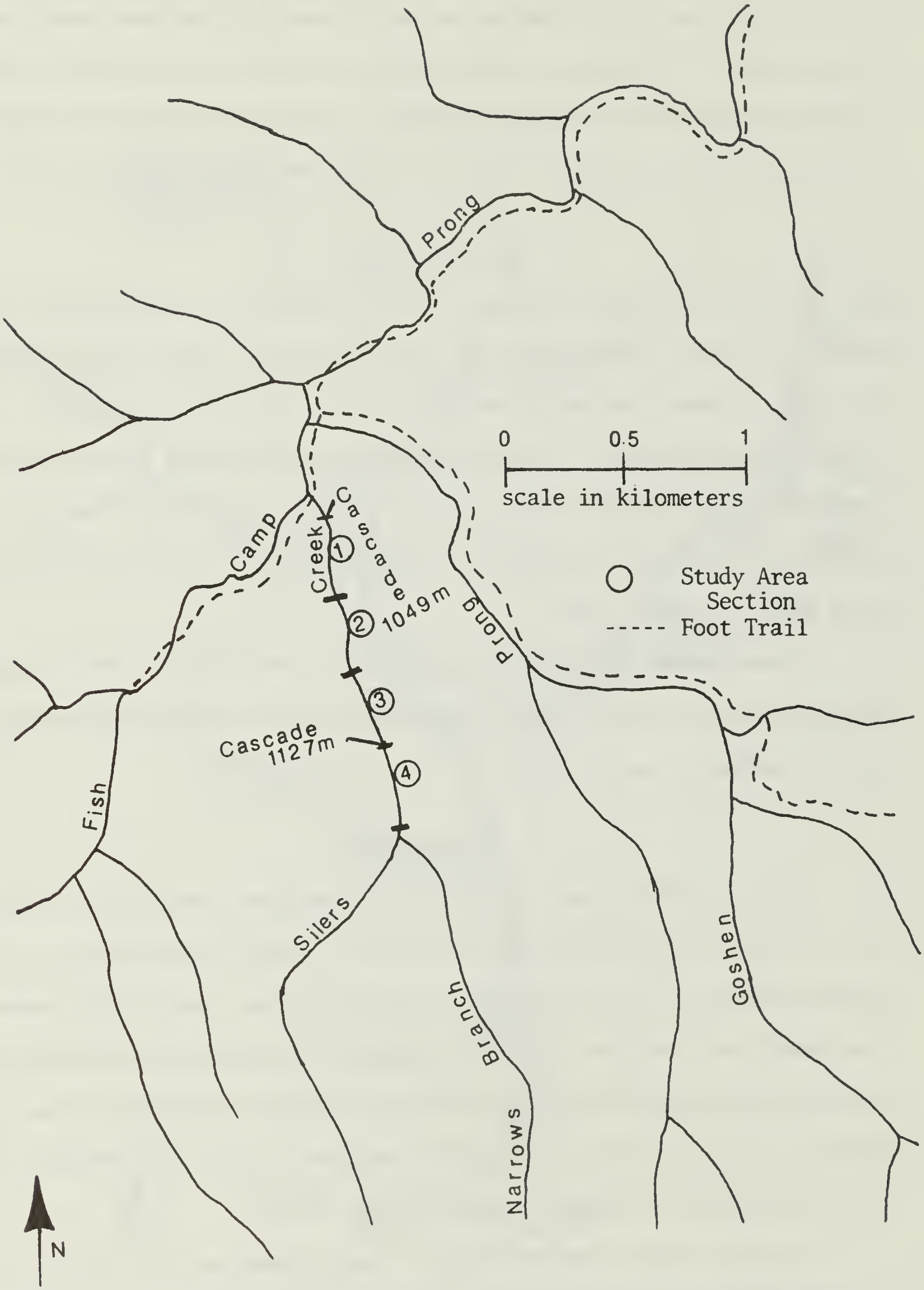

Figure 5. Silers Creek, Sevier County, Tennessee (elevations of cascades are above MSL)

Silers Creek has a gradient of approximately 10 percent along the stream channel. Discharge varied from 0.03 m^3/sec at low flow to 0.14 m^3/sec at high flow during the sampling periods. Conductivity was 10 umhos/cm in 1978, and pH varied from 6.8 to 6.9 in the summers of 1977 and 1978.

Starkey Creek

This creek is approximately 2.18 km long and is a tributary of Sams Creek. It lacks an obstruction in the study area, and no obstruction separates this stream from Sams Creek (Fig. 4). The study area of this creek began at its junction with Sams Creek, approximately 968 m above MSL, and extended 600 m upstream from this point. This area contained only an allopatric brook trout population. Approximately 1.56 km of this stream lies above the study area.

Discharge was 0.06 m^3/sec in June 1978. Conductivity was 11 umhos/cm, and pH was 6.9 in 1978. This stream is located on Thunderhead Mountain 7.5 minute quadrangle map (1964).

Taywa Creek

This creek is in Swain County, North Carolina, and joins Bradley Fork at an altitude of 856 m above MSL (Fig. 6). Taywa Creek has a total length of approximately 2.68 km, and the study area began about 9.67 km above the confluence at a cascade 1006 m above MSL. Both a sympatric population and an allopatric brook trout population were found in this study area. Approximately 0.81 km of stream lies above the study area. This stream is located on the Smokemont 7.5 minute quadrangle map (1964).

On July 6, 1977, the discharge of Taywa Creek was 0.03 m^3/sec during a period of low flow. Conductivity and pH were measured in 1978 and were 9 umhos/cm and 6.4. Stream gradient along the channel was approximately 7.6 percent.

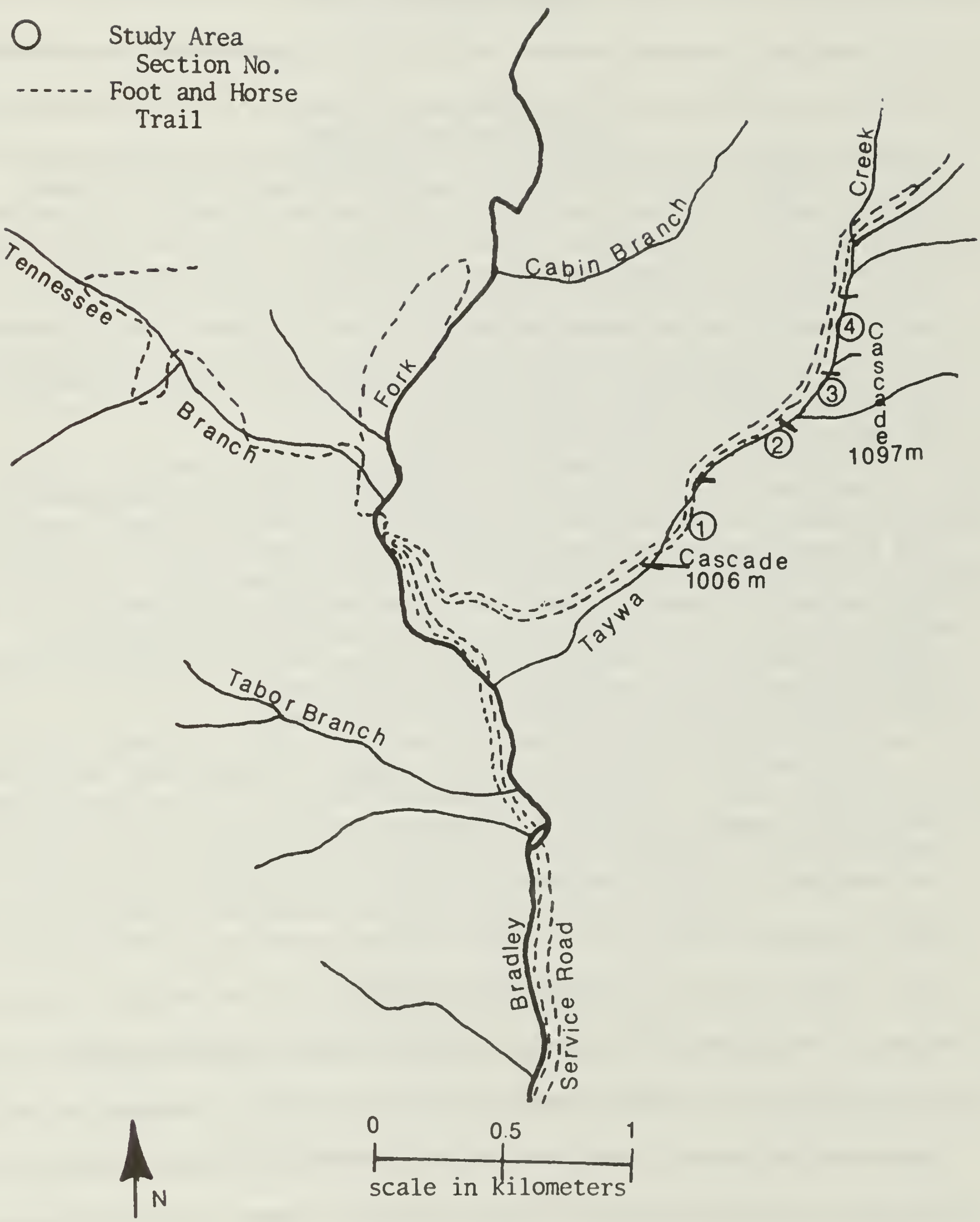

Figure 6. Taywa Creek, Swain County, North Carolina (elevations of cascades are above MSL)

METHODS AND MATERIALS

Electrofishing Units

Gasoline-operated backpack electrofishing devices weighing approximately 18 kg each were used to aid in capture of trout in all 6 study areas. The original device consisted of an O & R gasoline engine (Model 13B-337) turning a "Tiny Tiger" 110-VAC alternator; a transformer placed in the system which increased the voltage to approximately 700 VAC; and 2 electrodes (an automobile radio antenna and the metal rim of a dip net) equipped with an operator-controlled safety switch. The entire device was carried, controlled, and used by one person to collect fish unharmed.

Frequent failure of the O & R engine in 1976 and early summer of 1977 led to modifications of the electrofishing devices. The O & R engine was replaced with a Homelite chain saw engine during the latter part of the 1977 sampling season. An automotive fan belt was used to drive the alternator. The transformer and electrodes were left unaltered.

Problems with the Homelite engine, the alternator, and the transformers during the summer of 1977 led to further modifications of the device prior to sampling in 1978. The Homelite engine was replaced with an Echo "Weed Eater" engine (Model 200 D). This gasoline engine was quite similar to the type used by fishery biologists of the North Carolina Wildlife Commission. Also, an AC-DC Coffelt convertor permitting selection of voltages between 0 VAC and 700 VAC (with approximately one-half these voltages for DC) was added to the system. The "Tiny Tiger" 110-VAC alternator remained in the system. The auto antenna was replaced with a bamboo pole sheathed with 9 inches of copper in its terminal as an electrode. The metal-framed dip net continued to be used as the other electrode.

Voltages between 500 VAC and 700 VAC were tried with the new unit in 1978. The investigators found 650 VAC the most suitable voltage to use with the improved unit in the low conductivity streams encountered at high elevations in the GRSM.

Sample Area Designation

Each of the 6 creeks has 1 sampling area which was sampled in 1976, 1977, 1978, and 1979. The words or terms "sampling area," "study streams," and "study area" refer specifically to that contiguous section of each stream sampled by electrofishing. Each area was chosen to begin above an obstruction (Figs. 2 through 6) with the exception of Starkey Creek (a tributary of Sams Creek), which lacked an obstruction between Starkey Creek and Sams Creek. All areas with sympatric trout populations were designated for rainbow trout removal; thus, this study was conducted without a control.

Each sampling area, designated by the name of the creek, was divided into sections in 1977, 1978, and 1979. Sections, identified in each area by Arabic numerals (Figs. 2 through 6), were 300 m in length with the exception of one 60 m section in Sams Creek (Fig. 4). The number of sections within an area depended upon the length of the sympatric population zone or the length of the stream in which fish were found.

Sampling Techniques

During sampling in 1977, 1978, and 1979, block nets, 1.2 m in depth and 5 mm mesh, were placed across the stream at both ends of a section. These nets prevented trout escaping from the section being sampled, prevented invasion of trout from outside the section, and helped meet certain assumptions of the population estimators. Captured brook trout were placed in a temporary holding area in the upstream end of each section. Each holding area was approximately 50 m in length and was separated from the rest of the section by placing block nets across the stream. The holding area was electrofished three times, with captured trout being weighed and measured and kept in buckets until sampling was completed. Brook trout were then marked and released in the holding area. Native char captured during each of three passes in the remainder of the section were then placed in the holding area once data collection was completed. Brook trout were not redistributed in each section upon completion of the third pass; rather, the nets were removed and the fish allowed to naturally move about the stream. This procedure was followed because the senior author felt that additional handling might unduly stress the populations.

Data Collection Methods

Salmonids collected on each pass were measured, weighed, and counted. An Ohaus hand-held spring scale and Ziploc plastic bag were used to weigh all fish. This scale was accurate to ± 1 g and had a maximum capacity of 250 g. Total length (TL) was measured to an accuracy of ± 1 mm. In 1976, 5 to 30 Age 0 fish (less than 101 mm in length) were placed together in a plastic bag and weighed collectively, but fish greater than 101 mm in length (age 1+) were weighed individually. In 1977, 1978, and 1979, all fish collected were weighed individually, age 0 fish also being weighed in groups when appropriate.

From each sampling area, all rainbow and brown trouts captured were removed and discarded with the exception of 209 fish. The 209 fish were marked with a fin clip and released below natural obstructions at the beginning of certain study areas to test the effectiveness of the barriers at preventing upstream passage by trout. As few brown trout were captured, and only in Beetree Creek, rainbow trout hereafter will be the synonym for both species of exotic trouts. All brook trout captured were marked with various fin clips and returned to the section from which they were taken (Table 1; all tables appear in the Appendix).

Brook trout movements were determined from the recapture of fish marked and released in previous years.

Population estimates were made according to the method described by Zippin (1958). The method utilizes catch per effort and cumulative catch in a regression to estimate population size. Catch per effort was the Y value, and cumulative catch was the X value.

Stream width was measured at 30 m intervals in each section of all study streams. Water surface area, in m^2, was calculated and used to compute fish biomass (weight) per area, and area per fish for each study stream. These were computed for brook trout and rainbow trout in each study area.

The efficiency of electrofishing was analyzed by enumerating the number of fish captured on each pass. Total number of fish captured in a stream in a given year was obtained by summing the number of fish captured on each pass. The number of fish captured on each pass was divided by the total number of fish to obtain the percentage captured on each pass.

Portions of two study streams were devoid of fish. No fish were found in the last 180 m of Beetree Creek above a cascade, or in the last 150 m of Mouse Creek. Any portion of a study stream devoid of fish was not used in the calculations of surface area per fish and weight per unit area.

The mean gradient of each stream along its channel was determined using a portable aneroid altimeter, a 30-m tape, a Sunnto clinometer marked in percentage, and the appropriate 7.5 minute quadrangle sheet having a scale of 1:24000.

Conductivity and temperature were measured with a YSI salinity, conductivity, and temperature meter. A portable Digisense pH meter was used in 1977 and a portable Analytical Measurements (Model 107) pH meter was used in 1978 to determine pH. Stream velocity was taken at 0.6 the maximum depth from the surface with a Teledyne Gurly pigmy current meter upstream from the obstructions.

RESULTS AND DISCUSSION

Analyses of Time Spent in Field

Field time associated with electrofishing was divided into two components: (1) Walking to and from a sampling area while transporting equipment and camp gear; and (2) time spent electrofishing, including measuring, weighing, and transporting fish.

Park study streams were located in steep, rugged terrain. Because of this, access was limited to walking or hiking to transport gear to the study sites. The remote locations of these streams necessitated camping in these areas so that completion of the work could be expedited. An estimated walking rate of 4.0 km/hr while carrying 18 to 36 kg of equipment was judged reasonable for the terrain encountered at the study areas. The tabulation below gives close approximations of kilometers walked and time required:

Date	Kilometers	Hours @ 4.0 km/hr	8-hr days
1976	278	69.6	9.0
1977	230	57.6	7.0
1978	488	122.0	15.0
1979	238	59.6	7.5
TOTAL	1234	308.8	38.5

Schedules for sampling were selected in 1976, 1977, 1978, and 1979. The average time required to fully fish a 300 m section of one study area and record population data was approximately 8 hrs, excluding time required to walk into and return from a sample site. This 8-hr average is known to be conservative.

Close approximations of total hours of sampling accomplished and total hours of this activity lost, caused primarily by equipment failure, are tabulated below. If a scheduled trip to a sampling area was canceled because of faulty electrofishing equipment, the time was tabulated as lost, as was the remainder of a scheduled sampling period following failure of equipment in the field.

The time tabulations below, including percent of total time sampled or lost in parentheses, do not include other additional maintenance, field, or administrative duties associated with this project:

	Time Sampled		Time Lost		Totals	
Date	Hours	8-Hr Days	Hours	8-Hr Days	Hours	Days
1976	141 (46%)	18	167 (54%)	21.0	308	39.0
1977	156 (50%)	20	158 (50%)	20.0	314	40.0
1978	208 (78%)	26	60 (22%)	7.5	268	33.5
1979	136 (85%)	17	24 (15%)	3.0	160	20.0
TOTALS	641 (61%)	81	409 (39%)	51.5	1050	132.5

Approximately 54 percent of the total time available for electrofishing in 1976 and 50 percent of this time in 1977 were lost because of engine failure of the electrofishing unit. In these 2 years, only one (Beetree Creek) of the 6 study streams was completely sampled. Using the improved electrofishing unit in 1978 and 1979, all streams were completely sampled. After changing to the more dependable Echo engine in 1978, shortcomings of the electrical system in the electrofishing unit became apparent. Prior to 1978 field work, the average fishing time lost due to engine failure amounted to 52 percent. In 1978, 63 percent less fishing time was lost than was lost in 1976-1977; and of the 3.5 fishing days lost in 1978 because of failure of the electrofishing unit, only one-half day (7 percent) could be attributed to engine malfunction. In 1979, 85 percent less fishing time was lost than was lost in 1976 and 1977, and 60 percent less fishing time was lost than in 1978. No time loss could be attributed to engine malfunction in 1979.

Effectiveness of Electrofishing

Tables 2, 3, and 4 indicate that percentage of the total number of fish captured on the first sampling pass through a stream progressively increased in all 4 years. Apparently, as the investigator gained electrofishing experience and better equipment was obtained, study streams were sampled more effectively.

In all years, a higher percentage of rainbow trout were captured on the first pass than were brook trout in the sympatric populations (Table 2). Tables 3 and 4 indicate that a higher percentage of rainbow trout than brook trout was also captured on the first pass in the allopatric populations. Possible reasons for the higher percentage capture of rainbow trout on the first pass are (1) rainbow trout were usually larger than brook trout, making them easier to see while electrofishing; (2) rainbow trout are lighter in color than brook trout, again making them easier to see; and (3) when rainbow and brook trout were simultaneously shocked, the tendency was to net the larger rainbows first.

Microhabitat differences selected by rainbow and brook trout also influenced effectiveness of electrofishing. Rainbow trout were usually found in the main current flow and were easier to see when shocked. Brook trout were usually found in waters of less velocity close to overhanging cover and were not as readily seen when shocked.

Effectiveness of electrofishing varied from stream to stream (Tables 2, 3, and 4). Variables which may have influenced effectiveness were water conductivity, stream width, pool depth, amount of vegetation overhanging the stream, number of deadfalls in the stream, stream gradient, stream braiding, and fish size. Libosvarsky (1962) found that these variables affected electrofishing success in Czechoslovakia.

Results presented in Tables 2, 3, and 4 are indicative of what an experienced two-man crew (one shocker and one assistant) can accomplish in remote headwater streams of the GRSM. These data suggest a larger crew with more electrofishing units could capture more fish on each pass. The authors doubt that a two-man crew with one backpack shocker can remove all trout from even the smallest streams of the GRSM.

Trout Distribution Within The Study Area

General Observations

Field observations showed that in streams in which brook and rainbow trout were found, both species were found in the same pool. When this occurred, rainbow trout were generally found in turbulent water at the head of the pool. Brook trout were most often found at the sides or tails of pools in slower water where overhead cover was present. Alan Kelly and Willis King (personal communications) observed this same phenomenon in GRSM streams.

Brook Trout

Brook trout distribution is given for 1977, 1978, and 1979, as no study area was divided into sections in 1976. The number of brook trout captured in 1976 and mean surface area per fish are given in Tables 5 and 6.

Brook trout were not evenly dispersed in any of the sympatric populations, either between or within sections. In sympatric populations, those individual sections within a study stream containing the largest number of brook trout and having the smallest surface area per fish in 1977 also were found to have the highest number of brook trout in 1978 and 1979 (Table 5). This phenomenon was not noted in allopatric brook trout populations, due to the incomplete sampling of one or more of these populations in 1976 or 1977 (Table 6). The number of brook trout captured in each section of Starkey Creek was approximately the same in 1977, 1978, and 1979. Length frequency distributions for allopatric and sympatric brook trout populations were similar for each creek in each year (Figs. 7-13; Figs. 7-20 are in the Appendix).

Rainbow Trout

Distribution of rainbow trout within 5 of the 6 study areas has changed little during this investigation. Data in Tables 5 and 7 indicate the section in which the greatest number of rainbow trout captured in each stream during 1977 was the same section in which the greatest number of exotics was captured in 1978 and 1979. Rainbow trout length frequency distributions (Figs. 14-18) are similar for all streams and years. Data analyses indicate that length ranges in individual sections are similar and that large rainbow trout (180 mm or greater TL) were captured in all sections of each study area.

Applicability of Population Estimates

Based upon Zippin population estimates, on the average, 94.4 percent (range 65.1 to 100) of the brook trout and 95.4 percent (61.1 to 100) of the rainbow trout were removed from the study areas. Confidence intervals (90%) for the estimates were narrow, implying that a majority of the trout in each section prior to each pass were captured during subsequent sampling passes. This reduces the variability of the points from the regression line, resulting in the narrow confidence intervals (C. McHenry, Mathematics Department, Tennessee Technological University, personal communication).

It is doubtful, however, that the populations were estimated as well as suggested by the regression statistics. Data from July and August samples of Silers Creek in 1978 suggested that between about 52 and 60 percent of the total number of fish were collected and that about 75 percent of the total biomass was caught for brook trout in allopatric and sympatric stream sections in July (Table 8).

In the July 1978 sampling of both allopatric and sympatric populations of the Silers Creek area, 555 brook trout were marked (Age I+ = 333, Age 0 = 222). In August, 39 days after the July sampling, both populations were again completely sampled. Five hundred nine (509) brook trout were captured (Age I+ = 283, Age 0 = 226). Of this total catch, 316 fish or 62 percent had been marked in the July sample. In the August sample, 232 (83 percent) Age I+ trout and 84 (37 percent) Age 0 trout had been marked in July. In the August sample, 142 unmarked Age 0 trout were taken. Their mean total length (TL) was 8.1 mm greater than the mean TL of this group in the July sample. The larger size of these Age 0 char in the August sample increased their visibility and were, therefore, more likely to be captured during electrofishing.

Similar results were obtained for rainbow trout in Silers Creek, except no fish were marked and released for recapture in August. Nonetheless, 97 rainbow trout were removed in July; 56 were adults and 41 were age 0. In August, 65 trout were captured, 13 adults and 52 age 0. Thus, a total of 162 rainbow were captured in the two samples, with 59.9 percent being caught in July; 44.1 percent of the age 0 and 81.2 percent of the adults. These data indicate that age 0 rainbow trout were probably too small to be easily seen in July. They were probably easier to see in August due to a 15.5 mm increase in mean TL.

Other investigators have found that smaller trout are more difficult to capture than larger trout. Cooper and Lagler (1956) noted that larger fish were easier to capture by electrofishing than were smaller fish in trout stream populations. Boccardy and Cooper (1963), when comparing the efficiency of capture of different size classes of brook trout by electrofishing and by rotenone, found that the smaller sizes were more difficult to capture. In a Prince Edward Island stream, Saunders and Smith (1954) stated that it was more difficult to capture fingerling trout than older trout by electrofishing. Warner (1970) stated that young of the year brook trout were not uniformly vulnerable to electrofishing gear. Goodnight and Bjornn (1971) believed that trout and salmon fry were difficult to capture consistently because of their small size, and imply that the number of Age 0 fish appear to increase with time throughout the summer because as their size increased, they were more readily seen and harvested.

The percentage of the total number of brook and rainbow trout captured in the first sampling of Silers Creek is lower than values reported by other investigators. Regan (1966) found in Main Diamond Creek, New Mexico, that 100 percent of the trout population was captured in 3 electrofishing efforts in 2 sections of that stream. A Czechoslovakian investigator, J. Libosvarsky

(1962), frequently obtained estimated captures of over 90 percent of the total population in 3 electrofishing efforts. He found that often a considerable number of efforts may be required to catch all the fish present in a stream.

Changes in Standing Crop in Trout Populations

Standing crop has been defined differently by various researchers (Bagenal 1978; Everhart, Eipper, and Young 1975; Watt 1968). In this investigation, as no species of fishes other than trout were taken in any sample, the terms "total" or "collective" standing crop refer to total weight per hectare of both brook and exotic trout taken in all sympatric study areas in each year, or to either all brook trout or all exotic trout taken in all sympatric and allopatric areas in each year of study.

Sympatric Populations

All areas collectively by year. In Figure 7 , standing crops of trout from the four sympatric populations collectively are shown for each year. Rainbow trout weight per hectare dominated these four areas (78.6 percent) in 1976 at the initiation of removal of these species. In 1977 brook trout collective weight per hectare surpassed that of rainbow trout, attaining 55 percent of the total standing crop (Fig. 7). Total standing crop for both species decreased from 116.3 kg/ha in 1976 to 58.8 kg/ha in 1977 (Fig. 7), a decrease of 49.4 percent. In 1978, brook trout weight per hectare in all areas collectively was more than double that of rainbow trout, increasing to 71.8 percent of the total standing crop for that year (Fig. 7). The total standing crop for both species in 1978 increased to 80.7 kg/ha (Fig. 7), 37.8 percent greater than in 1977 but 30.6 percent less than in 1976. In 1979, brook trout standing crop in all areas collectively was more than four times that of rainbow, increasing to 80.7 percent of the total standing crop for that year (Fig. 7). The total standing crop for both species in 1979 was 60.6 kg/ha, 24.9 percent less than 1978, 3.1 percent greater than 1977, and 47.9 percent less than in 1976.

Data in Figure 7 illustrate an increase in brook trout standing crop in all areas as rainbow trout were removed. Variations in population strength affect the brook trout standing crop each year.

Individual streams by year. Beetree Creek contained 3 more brook trout than rainbow trout in 1976. Sams Creek in the same year contained 191 more brook trout than rainbow trout (Table 9). But rainbow trout dominated total standing crop in both creeks in 1976 (Table 9 and Fig. 8a). In 1977, 1978 and 1979, brook trout standing crops in both streams surpassed those of rainbow trout; dramatically so in 1977, 1978, and 1979 in Sams Creek. Of all sympatric areas in 1976, Sams Creek contained the smallest standing crop of rainbow trout and the greatest standing crop of brook trout. This pattern was repeated in 1978 and 1979, and this was the only sampling area where the 1978 total standing crop (dominated by brook trout, 88.4 percent) exceeded the total standing crop of 1976 (Fig. 8a).

Silers Creek contained the second smallest percentage of brook trout (18.4 percent) and the greatest standing crop of rainbow trout (28.1 kg/ha) of any study stream in 1976 (Fig. 8b). In the same year, Taywa Creek supported the smallest percentage (10.2 percent) and standing crop (2.3 kg/ha) of brook trout of any study stream in 1976 (Fig. 8b). The sampling area of Taywa Creek alone failed to produce an increase in brook trout standing crop in each successive year, as this parameter decreased in 1977 but increased in 1978 (Fig. 8b). The decrease in the 1977 value is most likely due to incomplete sampling rather than a decrease in the number of brook trout.

The brook trout standing crop in each of the 4 sympatric populations in 1979 was greater than in 1976, when removal of rainbow trout began. Concomitantly, the standing crop of rainbow and brook trout in each stream decreased. When comparing percentage gain in brook trout segments of the total sympatric standing crops among the 4 areas between 1976 and 1979, data indicate that those areas where brook trout contributed a relatively high percentage to the total standing crop in 1976 showed the greater percentage increase in 1978 (Beetree Creek and Sams Creek)(Figs. 8a, b). The phenomenon was observed in Sams Creek but not in Beetree Creek in 1979.

Summarizing changes in composition of total standing crops of sympatric populations between 1976 and 1979 within each sampling area, percentages calculated from Figs. 8 a,b show the brook trout standing crop in Beetree Creek decreased 2 percent and the rainbow trout standing crop decreased 83 percent. The brook trout standing crop in Sams Creek increased 89 percent and rainbow trout standing crop decreased 94 percent. In Silers Creek the standing crop of brook trout increased 20.8 percent and rainbow standing crop decreased 88 percent. The brook trout standing crop of Taywa Creek increased 81 percent and standing crop of rainbow trout decreased 85 percent.

Species composition in sympatric populations may be expected to vary annually due to normal variations caused by natural fluctuations within population parameters. Some sampling areas were incompletely sampled in some years (Figs. 8a and 8b), and the electrofishing fishing techniques are believed to have failed to capture all trout in 3 passes. Despite the several unmeasured variables, the investigators believe removal of rainbow trout appeared to be the major factor leading to the substantial increase of brook trout weight per hectare in portions of the study streams containing sympatric trout populations.

Allopatric Brook Trout Populations and Comparisons With Sympatric Populations

Silers Creek

A brook trout population classed as allopatric existed in 3 of the 6 sampling areas. None of these were completely sampled in the first 3 years. The allopatric brook trout population in Silers Creek occupied the last 300 m (Section 4) of this study area, above a cascade (Fig. 5) which is considered by the investigators as being impassable to upstream passage by park salmonids. This population was not sampled in 1976. Calculations made from information presented in Table 10 indicated a standing crop of 15.8 kg/ha for allopatric brook trout in 1977. In this year, the standing crop of this allopatric population was 63.9 percent greater than the standing crop of the sampling area's sympatric brook trout population (9.6 kg/ha). In 1978 the allopatric standing crop was 31.7 kg/ha, an increase of slightly more than 100 percent over 1977. This 1978 allopatric population exceeded the brook trout segment (17.8 kg/ha) in the sympatric population of Silers Creek by 78.1 percent. In 1979, the allopatric standing crop was 30.5 kg/ha, a decrease of 3.8 percent from 1978. The 1979 allopatric brook trout standing crop exceeded the brook trout segment (19.5 kg/ha) in the sympatric population in Silers Creek by 56.4 percent. Standing crops of both allopatric and sympatric brook trout in the Silers Creek area increased between 1977 and 1978, but standing crop in the allopatric population increased at an approximate rate of 16 kg/ha/yr. The same parameter increased at an approximate rate of 8 kg/ha/yr for brook trout in the sympatric population. Brook trout standing crop of Silers Creek increased between 1978 and 1979 but at a slower rate (1.7 kg/ha/yr) than between 1977 and 1978.

Taywa Creek

In Taywa Creek's sampling area, the allopatric brook trout population was confined to the last 270 m of Section 4, above a cascade. This cascade appeared to be impassable to upstream passage by park salmonids. The allopatric population was sampled in 1976 and 1978 but not in 1977. Calculations from information in Tables 9 and 10 show a 1976 standing crop of 17.4 kg/ha for allopatric brook trout, 656.5 percent greater than the standing crop of brook trout from the sympatric brook trout population of this stream in the same year. The allopatric population increased by 30.5 percent in 1978 to 22.7 kg/ha. Brook trout from the sympatric population in 1978 also increased to 6.4 kg/ha. This was 177.4 percent greater than in 1976, but the 1978 sympatric population was 71.9 percent less than the allopatric population in the same year. A decrease in standing crop occurred in allopatric and sympatric brook trout populations between 1978 and 1979. The allopatric population decreased by 43.6 percent in 1979 to 12.8 kg/ha. The sympatric population standing crop decreased by 34.4 percent in 1979 to 4.2 kg/ha. The sympatric char standing crop was 67.2 percent less than the allopatric char standing crop in 1979, but was 826 percent greater than in 1976. Standing crops of brook trout from both allopatric and sympatric populations increased between 1976 and 1978. Standing crop in the allopatric population increased 5.3 kg/ha/yr; and brook trout from the sympatric population increased about 4.1 kg/ha/yr, 23 percent less than in the allopatric population.

Between 1978 and 1979, standing crop in the allopatric brook trout population decreased 9.9 kg/ha/yr; and brook trout in the sympatric population decreased 2.2 kg/ha/yr, 78 percent less than the allopatric population.

Starkey Creek

Starkey Creek's sampling area, containing only an allopatric population of brook trout, began at its confluence with the Sams Creek sympatric area. No natural obstruction prevented the invasion of Starkey Creek by rainbow trout from the sympatric population of Sams Creek, nor were any obstructions within Starkey Creek. Two adult rainbow trout were captured and removed from this area, one fish in 1976 and one in 1977. No rainbow trout were seen in the area in 1978 or 1979. In 1976, only 875 m^2 of the 2631 m^2 area (33 percent) were sampled. In 1977, 1978, and 1979, the entire study area was sampled. Compared with the allopatric brook trout populations discussed previously, Starkey Creek's population had the lowest standing crop sampled in each year except 1979, when Taywa Creek's allopatric population was the lowest. Starkey Creek's allopatric population had a standing crop of 12.2 kg/ha in 1976, 42.6 percent below that of Taywa Creek in the same year. In 1977 this parameter increased 4.9 percent to 12.8 kg/ha, 19 percent less than present in Silers Creek in 1977. Starkey Creek's allopatric brook trout population increased to 18.1 kg/ha in 1978, a gain of 11.4 percent over 1977 and 48.4 percent greater than 1976.

In 1979 the allopatric char population increased to 19.6 kg/ha, a gain of 6.5 percent over 1978, a 53.2 percent increase over 1977, and a 60 percent increase from 1976. Starkey Creek's standing crop in 1978 remained lowest of the 3 allopatric brook trout areas, 20.2 percent below that of Taywa and 42.8 percent less than Silers Creek. In 1979, Starkey Creek's standing crop was 27.7 percent greater than Taywa Creek but 35.7 percent less than the allopatric brook trout standing crop of Silers Creek.

Allopatric Rainbow Trout Populations and Comparisons With Sympatric Populations

Beetree Creek

Two study streams, Beetree Creek and Mouse Creek, contained an allopatric rainbow trout population. The allopatric rainbow trout population of Beetree Creek was found in the last 90 m of Section 2 and the first 120 m of Section 3. No fish of any species were taken above the cascade shown at 975 m above MSL in Figure 2. Calculations from Table 11 indicate a standing crop of 21.2 kg/ha in the allopatric rainbow population of 1976 when removal of this species began. Twenty-five Age I+ and no Age 0 fish were in this sample. Standing crop of rainbow trout from the sympatric population in the same year was calculated as 20.78 kg/ha, some 2 percent less (Table 11). The standing crop of the allopatric population in 1977 was 2.91 kg/ha, based upon capture of one adult and one age 0 fish. The standing crop of rainbow trout from the sympatric population was 3.75 kg/ha in 1977, about 29 percent greater than that of the allopatric standing crop. Twelve adult fish composed the entire sample. (Table 9).

The 1978 Beetree Creek allopatric population standing crop, containing only 4 adults, was 4.11 kg/ha. Standing crop of rainbow trout from the sympatric population of this creek in 1978 was 3.93 kg/ha, contributed by 9 adults. No fish were captured in the allopatric population of this creek in 1979, a 100 percent reduction in standing crop, based upon capture results. Standing crop of exotic trouts in the sympatric population in 1979 was 3.51 kg/ha, contributed by 6 fish. In 1976, both allopatric and sympatric rainbow trout populations in Beetree Creek had approximately the same standing crops, the allopatric group being about 2 percent greater. In 1977 the allopatric standing crop had decreased approximately 86 percent as the same parameter from the sympatric segment decreased about 82 percent (Tables 9 and 11).

Between sampling in 1977 and 1978, standing crops of both populations increased: the allopatric value by 1.2 kg/ha and the sympatric value by 0.2 kg/ha.

The standing crops of both allopatric and sympatric populations decreased between 1978 and 1979, the allopatric value by 4.11 kg/ha and the sympatric value by 0.42 kg/ha. In the allopatric population between 1976 and 1979, standing crop had decreased 100 percent. Rainbow trout standing crop from the sympatric segment between 1976 and 1979 had decreased by approximately 83 percent.

Mouse Creek

Mouse Creek sampling area extended 900 m upstream from a cascade (Fig. 3) listed on the appropriate 7.5 minute quadrangle sheet as Mouse Creek Falls. This barrier is impassable to upstream passage by fish. The sampling area was 900 m in length, contained only rainbow trout in the lower 750 m (4451 m^2), and had no fish in the last 150 m in any year. Calculations from Table 11 indicate that the standing crop in 1976 was 14.12 kg/ha, contributed by 130 fish, 7 percent of which were Age 0 (Table 11). Standing crop in 1977 had decreased to 6.81 kg/ha (52 percent less) conduced by 33 fish, 3 percent of which were Age 0. In 1978, standing crop increased slightly (2 percent) to 6.97 kg/ha, contributed by 83 fish, of which 54 percent were Age 0. In 1979, the standing crop decreased (65.7 percent) to 2.39 kg/ha, contributed by 20 trout, of which none were Age 0.

Between 1976 and 1979, an approximate decrease of 83.1 percent occurred in the standing crop, one of the smallest decreases in all rainbow trout standing crops between first and final samplings during this investigation. This phenomenon was not unexpected, as GRSM park personnel received information that some local fishermen admitted they had stocked rainbow trout in Mouse Creek after sampling was completed in 1977. This information cannot be validated, however, and relative minimal decreases in rainbow trout standing crops in Mouse Creek following annual fish removal possibly may be attributed to less efficient sampling caused by the braided channel of this stream.

The investigators feel that standing crops determined for all study streams by sampling with backpack electrofishing gear were undoubtedly influenced by unmeasured variables, the most obvious being incomplete sampling, reproduction, fish movements and dates of sampling.

Changes in Mean Length, Mean Weight, and Mean k Factor

Brook Trout

Data presented in Figures 9 through 15 indicate that brook trout length frequency distribution in both allopatric and sympatric populations was similar. Mean lengths for Age 0 brook trout in the above distributions occur at different lengths in different years in the distribution. This appears to be due to sampling time, as the earlier the stream was sampled, the smaller the size of the Age 0 trout and the fewer captured (refer to pp. 23-24). Mean lengths ($\bar{l}$) of Age I+ and older fish are similar for allopatric and sympatric populations within the same year and between years in the length frequency distributions (Figs. 9-15).

Data presented in Table 12 indicate that in all sympatric brook trout populations (except Taywa Creek) which were sampled in all 4 summers of this investigation, the mean weight ($\bar{w}$) of Age I+ and older brook trout decreased between 1976 and 1977. Mean weights of Age I+ brook trout in all sympatric populations increased from 1977 to 1978, but this parameter decreased from 1978 to 1979 (Table 12). Starkey Creek contained the only allopatric brook trout population to be sampled in all four summers of this investigation, and the above phenomenon was noted between 1976 and 1978; however, brook trout mean weight increased slightly between 1978 and 1979 (Table 12). Reasons for variation of native char mean weight in allopatric and sympatric populations between years are not clear but appear to be the result of natural fluctuations in population structure. Natural fluctuations in brook trout population structure need further study in GRSM.

Mean length and mean weight of brook trout in sympatric populations after the removal of exotic trouts were usually greater than in allopatric populations from 1976 to 1978 (Tables 12 and 13). Silers Creek, 1977; Taywa Creek, 1979; and Sams Creek, compared with Starky Creek, 1978, were the exceptions to this observation. This does not seem unusual, as under the influence of decreased competition from rainbow trout, one should expect the brook trout to grow more rapidly, provided there is no ingress of brook trout or exotic trout species from outside the area. Once brook trout numbers have increased sufficiently, their growth rate should decrease, and the values of $\overline{l}$, $\overline{w}$ and mean condition factor ($\overline{k}$) in the sympatric populations should become similar to those of allopatric populations.

Tests for significant differences between the allopatric and sympatric brook trout populations were not calculated. Dr. C.E. McHenry (Department of Mathematics, Tennessee Technological University, personal communication) stated that "t" tests could be calculated, but the level at which significant differences would occur would be quite low. He stated that for all practical purposes, the population size was known and the values in Tables 12 and 13 show parameters of those populations and not estimators of the populations in the study areas. Dr. McHenry also stated that most likely the populations were not normally distributed because the small difference in mean values, large variability, and high coefficient of variation indicated a skewed distribution. Dr. McHenry concluded that, as the population size was essentially known, it was not necessary to use inferential statistics, as they are used to look at small samples and then make generalizations about the population. The above statements also apply to the rainbow trout population.

The trebd of the findings in this investigation has indicated that, as exotic trout species were removed, sympatric brook trout populations are becoming more like the allopatric populations. This is most obvious in the parameters of area per fish and weight per area (Tables 9 and 11). The length of time required for brook trout in sympatric populations to become similar to those in allopatric populations will depend upon (1) continued declines in exotic trout biomass; (2) productivity of the streams; (3) reproductive success; (4) survival of brook trout; and (5) natural catastrophes, such as floods and severe winters.

Rainbow Trout

Data presented in Tables 9, 11, and 14 indicate generally that in both the sympatric and allopatric rainbow trout populations, the number of fish and weight per area has decreased and that the area per fish has increased. The decrease in both weight per area and number of rainbow trout captured was expected because this species was removed each year. Length frequency distributions are similar for all years (Figs. 16-20), even though a portion of the population was removed each year.

In three of the five streams containing rainbow trout, $\bar{l}$, $\bar{w}$, and $\bar{k}$ were lower in 1977 than in 1976 (Tables 14 and 15). These parameters increased in all five streams containing rainbow trout between 1977 and 1978, but decreased between 1978 and 1979 (Tables 14 and 15). Decreases in $\bar{l}$ and $\bar{w}$ were desired, as this would indicate the larger exotics were being removed each year.

Increases in $\bar{l}$, $\bar{w}$, and $\bar{k}$ between 1977 and 1978 were probably due to increased growth rates of remaining rainbow trout as intraspecific competition was reduced.

The number of rainbow trout in each study area would probably decrease with subsequent, additional electrofishing in these areas. How soon exotic trouts can be fully eradicated from the study areas will depend on (1) how effectively these streams can be electrofished; (2) immigration of rainbow trout into these areas from downstream, if possible; and (3) reproductive success of exotic trouts remaining in the streams.

Movements of Displaced Brook Trout

Movements were determined from recaptured marked brook trout in sections other than where originally marked and released. The approximate distance a marked fish had traveled was calculated as being the distance from its release site to the center of the different section to which the fish had moved. Migrations were so calculated because during sampling the exact location a marked fish was captured could not be determined.

From 1976 to 1978, 1855 Age I+ brook trout were marked and released in the study areas. Of this number, 422 (22.7%) were recaptured one or more times. Two hundred thirty (54.5%) of these individuals were recaptured only in the same 300 m sections where originally marked and released. One hundred ninety-two (45.5%) of the 442 individuals contributed information concerning the movements of displaced brook trout. Movement data came mainly from single channel situations, but one tributary situation also provided movement data (Table 16). In single channels, three types of situations occurred from which movement took place. These were: (1) sections from which fish could only move upstream; (2) sections from which brook trout could only move downstream; and (3) sections from which brook trout could move in both directions.

In sections from which native char could have moved in either direction, there was no significant difference in the number that moved upstream versus downstream (X^2, P=0.05). Additionally, there was no significant difference in the number of brook trout that moved out of these sections and those which remained in the sections (X^2, P=0.05). There was no significant difference in the number of brook trout moving out of those sections where they could only move upstream or downstream (X^2, P = 0.05).

The mean distance an individual brook trout moved downstream was significantly greater than the mean distance moved upstream (X^2, P=0.05). This was also true for brook trout in the tributary situation, in which the fish moved downstream, then upstream. Brook trout which could only move downstream moved significantly greater distances than those which could only move upstream.

McFadden (1961) in Wisconsin found that brook trout moved upstream and downstream in Lawrence Creek but stated that population movements were not extensive. Hunt (1974) noted that adult brook trout in Lawrence Creek, Wisconsin, migrated upstream to spawn in the fall and moved downstream into deeper pools in the winter. Shetter (1961) found that brook trout movements in Michigan fluctuated upstream and downstream in a transitory manner. In Massachusetts, according to Bridges (1972), tag return data indicated that the bulk of the brook trout population occupied the same general area as the previous year. Stefanich (1951) found in Prickley Pear Creek, Montana, that brook trout were recaptured in the sections where they were tagged. A study by Flick and Webster (1975) suggested localized movements of brook trout indicative of resident and migratory segments of the population.

Brown trout showed little population movement in New Zealand (Allen 1951) and in Oregon (Lorz 1974). Phinney (1975) in Montana and Hunt (1965, 1974) in Wisconsin stated that movement of Age 0 brook trout was predominately downstream. In his 1965 paper, Hunt also stated that Age 0 brook trout moved both upstream and downstream but that more downstream movement occurred.

The movements of brook trout populations observed in this study appeared to be similar to movements found by other investigators. The amount of migration probably varies with the time of year, water levels, and water temperature. When the size of the migrating fish was compared to that of nonmigrating fish in this investigation (by a Student "t" test), no differences in mean length were observed ($p > 0.05$).

Relationship Between Age and Total Length

Brook Trout

Table 17 gives the length ranges, mean lengths, and standard deviations for brook trout age groups found in this and other studies in GRSM. Char were aged by various methods in these studies, but length ranges and mean lengths of brook trout are similar for each age class. Length ranges are similar for each age group between years; this does not seem unusual as all collections were probably made at approximately the same time of year.

Table 17 indicates that from Age 0 to Age I+ brook trout have essentially the same mean length increase between years. Between 1977 and 1978, the mean length increase from Age 0 to Age I+ was approximately 58 mm, $s = 11.0$; and from 1978 to 1979, the mean increase was 44 mm, $s = 13.0$. This pattern of nearly identical mean length increase for the same age group between years was also observed for Age II+ and Age III+ brook trout (Table 17). McFadden et al. (1967) found that the mean length increase for age groups I and II did not vary much from year to year for those age groups in Hunt Creek, An attempt was made to determine the age classes of brook trout in the study areas from length frequency distributions (Figs. 7 through 13). The overlap of size ranges between age classes (Table 20) renders this difficult, at best. The length frequency distributions shown in Figures 7 through 13 indicate that the population structure in all streams was similar. These data also show that the growth in each study stream was similar.

Rainbow Trout

Methods are available for determining the age of salmonids; however, rainbow trout were not aged in this study. Rainbow trout were removed from the streams as they were captured. No rainbow were marked and returned to the streams from which they came; thus no known-age fish were available for the determination of the relationship of age to total length. Rainbow trout length frequency distributions are shown in Figures 14 through 18. Information presented in these figures indicates that Age 0 exotics ranged from 31 mm to 90 mm TL. The length range varied with the time of collection, as was seen when Silers Creek was sampled twice in 1978. The investigators believe that the ages of rainbow trout greater than 101 mm TL would be difficult to determine from the length frequency distributions in Figures 14 through 18. Distinctive peaks occurring in these distributions may or may not be the center of an age class. The age class distribution apparently does not change much after a portion of the exotic population has been removed. Information in Figures 14 through 18 indicate the number of rainbow trout is greatly reduced but that the length range is about the same.

SUMMARY

A higher percentage of rainbow trout was captured on the first of 3 passes through an area that had brook trout from sympatric populations. Rainbow trout were usually larger than brook trout and were lighter in color than the native char. This made them easier to see and capture while electrofishing.

Rainbow trout and brook trout from sympatric populations were unevenly dispersed in all study areas. Sampling sections which contained the greatest number of trout in 1977 also had the greatest number of fish in 1978.

Two complete samplings of Silers Creek in 1978 provided support to the observation that the Zippin method of population estimation underestimated the population size. Apparently, the cause of underestimation was the difference in the catchability of Age 0 and Age 1+ fish. The Zippin estimator assumes an equal catchability of fish, but size of fish and time of year affect the number of Age 0 fish that can be captured.

Sample data indicated that increases in brook trout standing crop occurred in both allopatric and sympatric brook trout populations. Increases in the standing crop of allopatric brook trout populations are probably due to the complete sampling of these areas only in 1978. Not to be overlooked is the fact that much more standing crop data is available from the sympatric populations. Rates of increase in sympatric brook trout populations may have been somewhat suppressed due to continued competition from rainbow trout remaining in the stream. Brook trout standing crops in sympatric populations have shown a pronounced progressive cumulative increase as rainbow trout were removed from the study areas each year. The rates of increase in brook trout standing crops, as well as decreases in rainbow trout standing crops, should not be expected to continue in the manner described in this report. The rates should be expected to vary annually due to normal variations within population parameters. Removal of rainbow trout is apparently the major factor leading to substantial increases in brook trout standing crops in sympatric populations.

Movement data were obtained from the recapture of marked brook trout. Of the 442 marked individuals recaptured in 1977, 1978, and 1979, 230 were recaptured in the same sections where they were previously marked. One hundred seventy-eight of the recaptured fish exhibited either upstream or downstream movements. Fourteen char in a tributary situation moved in both directions. Total known movement from the 442 brook trout was 79,850 m. Of this total movement, 62 percent was downstream.

Initially, brook trout were separated by total length into 2 age groups: Age 0 $\leq$ 91 mm and Age I+ $\geq$ 91 mm. Further age estimates were made from the recapture of marked fish. Results from this study and other studies of brook trout from the GRSM indicate overlap in the length ranges of successive age groups. Data indicate that length frequency distributions can be used only to roughly estimate age of brook trout from GRSM.

The findings in this investigation indicated that sympatric brook trout populations, after removal of exotic trout species, are becoming more like allopatric brook trout populations. This was most obvious in the increase in area per brook trout and weight per area for brook trout.

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APPENDIX

Table 1. Fin clips used as identifying marks for brook trout in each study area, by section for 1976, 1977, and 1978 (Key: Lo = left pectoral clip, RO = right pectoral clip, LP = left pelvic clip, V = ventral clip, A = adipose clip; all brook trout young of the year less than 91 mm were marked with an adipose clip).

Stream	Year	Section	Clip Given	Number Marked
Beetree	1976	1-3	LO 32	A-34
	1977	1	LO 24	A-5
		2	RO 35	A-7
		3	LP 1	A-0
	1978	1	RO 15	A-7
		2	LO 28	A-15
		3	RP 1	A-0
	1979	1	RP 11	A-6
		2	LP 25	A-19
		3	No brook trout collected	
Sams	1976	1	LO 15	A-27
		5	LO 27	A-33
	1977	1	LO 36	A-3
		2	RO 85	A-23
		3	RP 97	A-8
		4	V 21	A-1
		5	RO 74	A-14
	1978	1	LP 32	A-4
		2	LO 87	A-52
		3	RP 102	A-57
		4	V 41	A-3
		5	LP 128	A-35
	1979	1	RP 44	A-2
		2	LP 104	A-8
		3	RO 114	A-11
		4	V 18	A-1
		5	LO 105	A-12
Starkey	1976	1	RO 26	A-44
	1977	1	LP 69	A-19
		2	LO 68	A-4
	1978	1	RO 64	A-15
		2	RP 75	A-9

Table 1. Continued.

Stream	Year	Section	Clip Given		Number Marked
Starkey (continued)	1979	1	LP	59	A-1
		2	LO	83	A-7
Silers	1976	1 and 1/2 of 2	LO	35	A-26
	1977	1	RO	53	A-35
		2	LP	44	A-5
		3	RP	38	A-13
		4	LO	61	A-30
	1978	1	RP	65	A-63
		2	RO	59	A-38
			LP	48	
		3	RP	30	A-31
		4	LO	131	A-90
	1979	1	LP	64	A-19
		2	LO	72	A-67
		3	RP	120	A-31
		4	RO	142	A-35
Taywa	1976	1-3	LO	19	A-8
		4	LO	15	A-16
	1977	1	No brook trout collected		
		2	RO	2	A-0
	1978	1	LP	1	A-0
		2	RO	11	A-5
		3	LO	21	A-56
		4	LP	54	A-55
	1979	1	LO	1	A-3
		2	RP	4	A-6
		3	RO	34	A-6
		4	LP	42	A-23

Table 2. Percentage of the total number of brook trout and rainbow trout captured on each electrofishing pass through sympatric populations of study areas in 1976, 1977, and 1978 ($\overline{x}$ = mean, s = standard deviation).

Stream	Year	Brook Trout Electrofishing Pass No. 1 (%)	2 (%)	3 (%)	Rainbow Trout Electrofishing Pass No. 1 (%)	2 (%)	3 (%)
Beetree	1976	61	19.5	19.5	78	11	11
	1977	63	29	8	92	8	0
	1978	76	12	12	78	0	12
	1979	77	16	7	83	17	0
	$\overline{x}$	69	19	11.6	83.7	9	5.8
	s	7.3	6.3	4.9	5.9	6.1	5.8
Sams	1976	No data					
	1977	67.7	20.5	11.8	89	11	0
	1978	62	27	11	82	18	0
	1979	58	31	11	55	30	15
	$\overline{x}$	62.6	26.2	11.3	75.3	19.7	5
	s	4	4.3		14.7	7.8	7.1
Silers	1976	No data					
	1977	61	31	8	72	18	10
	1978	71	20	9	76.3	13.4	10.3
	1979	69	22	9	76	17	7
	$\overline{x}$	67	24.3	8.7	74.8	16.1	9.1
	s	4.3	4.8	0.5	2	2	1.5
Taywa	1976	56	7	37	66.7	22.8	10.5
	1977	No data					
	1978	65	23	12	69	25	6
	1979	71	21	8	73	23	4
	$\overline{x}$	64	17	19	69.6	23.6	6.8
	s	6.2	7.1	12.8	2.6	1.0	2.7
All creeks by pass	$\overline{x}$	66	21.5	12.6	76.2	16.5	6.6
	s	6.3	6.8	7.7	9.3	7.6	5.1

Table 3. Percentage of the total number of brook trout captured on each electrofishing pass through allopatric populations in the study areas, by stream and year (Mean $\overline{x}$) and standard deviation (s) for each pass are presented at the bottom of each column).

		Brook Trout		
		Electrofishing Pass No.		
Stream	Year	1	2	6
Silers	1976	No data	--	--
	1977	No data	--	--
	1978	72%	20%	8%
	1979	76%	20%	4%
Starkey	1976	No data	--	--
	1977	63%	26%	11%
	1978	71.7%	16.6%	11.7%
	1979	60%	33%	7%
Taywa	1976	No data	--	--
	1977	No data	--	--
	1978	70%	22%	8%
	1979	82%	16%	2%
Buckeye Gap*	1978	69%	23%	8%
Meig's Post*	1978	74%	19%	7%
	$\overline{x}$	70.9%	21.7%	7.4%
	s	6.2%	4.9%	2.9%

*Sweeney, unpublished data, GRSM, 1978.

Table 4. Percentage of the total number of rainbow trout captured on each electrofishing pass through allopatric populations in the study areas, by stream and year (mean ($\overline{x}$) and standard deviation (s) for each pass are presented at the bottom of each column)

		Rainbow Trout		
		Electrofishing Pass No.		
Stream	Year	1	2	6
Beetree	1976	68%	32%	0%
	1977	60%	50%	0%
	1978	100%	0%	0%
	1979	No fish collected		
Mouse	1976	No data		
	1977	82%	12%	6%
	1978	76%	24%	0%
	1979	60%	20%	20%
	$\overline{x}$	74.3%	2%	4.3%
	s	14.0%	15.7%	7.3%

Table 5. Number of m^2 per fish for brook and rainbow trout in each section of each study area containing a sympatric population captured in 1976, 1977, and 1978.

Stream	Year	Section Number	Section* Area (m^2)	Brook No. Fish	Brook m^2/Fish	Rainbow No. Fish	Rainbow m^2Fish
Beetree	1976	No sect.**	1791	66	27	63	28
	1977	1	984	29	34	10	98
		2	807	42	19	2	404
	1978	1	984	22	45	6	164
		2	807	43	18	3	269
	1979	1	984	17	58	5	197
		2	807	44	18	1	807
Sams	1976	No sect.	6058	304	20	113	54
		1	1401	39	36	5	280
		2	1413	108	13	2	707
		3	1815	105	17	11	165
		4	249	22	11	0	--
		5	1476	88	17	1	1476
	1978	1	1401	36	39	5	280
		2	1413	141	10	2	707
		3	1815	159	11	12	151
		4	249	44	6	1	249
		5	1476	163	9	2	738
	1979	1	1401	46	30	4	350
		2	1413	111	13	2	707
		3	1815	125	15	5	363
		4	249	19	13	1	249
		5	1476	114	13	8	185
Silers	1976	No. sect.	1584	61	26	96	17
	1977	1	1002	88	11	15	67
		2	1137	49	23	51	22
		3	1467	51	29	75	20
	1978	1	1002	128	8	6	167
		2	1137	97	12	36	32
		3	1467	109	13	55	27
	1979	1	1002	83	12	6	167
		2	1137	139	8	16	71
		3	1467	151	10	19	78
Taywa	1976	No. sect.	3045	27	113	228	13
	1977	1	1008	0	0	3	336
		2	1050	2	525	2	525
	1978	1	1008	1	1008	30	34
		2	1050	16	66	47	22
		3	987	90	11	24	41

Table 5. Continued.

Stream	Year	Section Number	Section* Area (m^2)	Brook		Rainbow	
				No. Fish	m^2/Fish	No. Fish	m^2/Fish
Taywa	1979	1	1008	4	252	6	168
		2	1050	10	105	15	70
		3	987	40	25	5	197

*Areas may not agree in all years due to sampling variations caused by equipment failure.

**Study area not subdivided into sections.

Table 6. Number of m^2 per fish in allopatric brook trout populations of Silers Creek, Starkey Creek, and Taywa Creek, giving area of each section and number of fish captured in 1976, 1977, and 1978.

Stream	Year	Section Number	Section* Area (m^2)	Brook Trout No. Fish	Brook Trout m^2/Fish
Silers	1976	Not sampled	--	--	--
	1977	4	1230	91	14
	1978	4	1230	221	6
	1979	4	1230	177	7
Starkey	1976	1	875	70	13
	1977	1	1224	88	14
		2	1407	72	20
	1978	1	1224	79	16
		2	1407	84	17
	1979	1	1224	60	20
		2	1407	90	16
Taywa	1976	4	395	31	13
	1977	Not sampled	--	--	--
	1978	4	702	96	7
	1979	4	702	65	11
Buckeye Gap**	1978	--	300	62	5
Meigs Post**	1978	--	403	85	5

*Areas may not agree in all years due to sampling variations caused by equipment failures.

**Unpublished data from Sweeney 1978, GRSM.

Table 7. Number of m^2 per fish in allopatric rainbow trout populations of Beetree Creek and Mouse Creek, giving the area of each section and number of fish captured in 1976, 1977,1978, and 1979.

Stream	Year	Section Number	Section* Area (m^2)	Rainbow Trout No. Fish	Rainbow Trout m^2 Fish
Beetree	1976	2 & 3	735	25	29
	1977	2 & 3	735	2	368
	1978	2 & 3	735	4	184
	1979	2 & 3	735	--	
Mouse	1976	No section	4353	130	33
	1977	1	2214	10	221
		2	1463	19	77
		3	676	4	169
	1978	1	2214	25	89
		2	1463	57	26
		3	676	1	676
	1979	1	2214	2	1107
		2	1463	18	81
		3	670	--	--

*Areas may not agree in all years due to sampling variations caused by equipment failures.

Table 8. Percentage of the numbers and standing crop of Ages 0 and adult brook trout captured from allopatric and sympatric sections of Silers Creek in July, based upon the estimates from the mark recapture experiment in 1978

		Percent captured of estimated present by age class	Percent captured of total estimated present	Percent estimated present
Standing Crop *				
Age 0	Sympatric	33.9	4.25	12.53
	Allopatric	44.4	4.67	10.53
Adult	Sympatric	79.2	69.29	87.47
	Allopatric	79.9	71.47	89.47
Numbers				
Age 0	Sympatric	33.9	20.50	60.4
	Allopatric	44.4	24.52	55.3
Adult	Sympatric	79.2	31.37	39.6
	Allopatric	79.9	35.70	44.7

* Mean weight (gm) per fish for Age 0 and adults were 2.75 and 3.84, and 29.5 and 29.1 in July and August, respectively.

Table 9. Numbers and weights of brook and rainbow trouts from sympatric populations of study areas, by year and by stream. (Parentheses indicate percentage of total numbers and total weights contributed by fish less than 91 mm total length brook trout marked and released, rainbow trout removed each year.)

			Brook Trout				Rainbow Trout			
Stream	Year	Sample Area (m^2)	Total No. Fish	Total Wt. (g)	Area, m^2 per Fish	Wt, mg per m^2	Total No. Fish	Total Wt. (g)	Area, m^2 per Fish	Wt, mg per m^2
Beetree	1976	1791	66 (52)	1100 (18)	27	614	63 (13)	3722 (1)	28	2078
	1977	1791	72 (17)	1724 (3)	25	963	12 (0)	671 (0)	149	375
	1978	1791	66 (33)	1828 (3)	27	1021	19 (0)	704 (0)	199	393
	1979	1791	61 (41)	1081 (10)	29	603	6 (0)	628 (0)	299	351
% Change, 1976 & 1979			-8%	-2%	+7%	-2%	-90%	-83%	+968%	-83%
Sams	1976	6058	304 (55)	6100 (17)	20	1007	113 (15)	9868 (1)	54	1629
	1977	6354	362 (14)	8296 (3)	18	1306	20 (35)	1080 (6)	318	170
	1978	6354	543 (28)	14981 (2)	12	2358	22 (0)	1972 (0)	289	310
	1979	6354	415 (8)	12117 (1)	15	1907	20 (40)	608 (10)	318	96
% Change, 1976 & 1979			+37%	+99%	-25%	+89%	-82%	-94%	+489%	-94%
Silers	1976	1584	61 (43)	1004 (14)	26	634	96 (21)	4451 (3)	17	2810
	1977	3606	188 (28)	3476 (8)	19	964	141 (13)	7044 (1)	26	1953
	1978	3606	334 (40)	6416 (10)	11	1779	97 (42)	3444 (1)	37	955
	1978	3606	373 (30)	7045 (5)	10	1954	41 (29)	1224 (1)	88	339
% Change, 1976 & 1979			+320%	+602%	-46%	+208%	-57%	-72%	+418%	-88%
Taywa	1976	3045	27 (30)	701 (7)	113	230	228 (25)	8009 (3)	13	2630
	1977	2058	2 (0)	76 (0)	1029	37	5 (0)	226 (0)	412	110
	1978	3045	107 (62)	1943 (17)	32	638	101 (79)	1882 (12)	30	618
	1979	3045	62 (24)	1268 (4)	49	416	26 (0)	1170 (0)	117	384
% Change, 1976 & 1979			+130%	+81%	-57%	+81%	-89%	-85%	+800%	-85%

Table 10. Numbers and weights of brook trout from allopatric populations of study areas, by stream and by year. (Parentheses indicate percentage of total numbers and total weights contributed by fish less than 91 mm total length; brook trout marked and returned.)

Stream	Alt. (m) + MSL	Year	Area (m^2)	Total No. Fish	Total Wt. (g)	Area (m^2) per Fish	Wt. (mg) per m^2
Silers	Between	1976	Not sampled	--	--	--	--
	1128 &	1977	1230	91 (33)	1945 (12)	14	1581
	1158	1978	1230	221 (41)	3897 (6)	6	3168
		1979	1230	177 (20)	3755 (5)	7	3052
Starkey	Between	1976	875	70 (63)	1067 (13)	13	1219
	975 &	1977	2631	160 (14)	3366 (3)	16	1279
	1036	1978	2631	163 (15)	4772 (1)	16	1814
		1979	2631	150 (5)	5160 (1)	18	1961
Taywa	Between	1976	395	31 (52)	689 (14)	13	1744
	1097 &	1977	Not sampled	--	--	--	--
	1128	1978	710	96 (52)	1613 (12)	7	2272
		1979	710	65 (35)	1006 (8)	11	1417
Meigs Post*	1143	1978	403	85 (32)	1900 (7)	5	4715
Buckeye Gap*	1173	1978	300	62 (44)	1073 (8)	5	3577

*Information from Sweeney 1978; not part of study areas (unpublished electrofishing data from GRSM).

Table 11. Numbers and weights of rainbow trout from allopatric populations of study areas, by stream and by year. (Parentheses indicate percentage of total numbers and total weights contributed by fish less than 9 1 mm total length; rainbow trout removed each year.)

Stream	Alt. (m) +MSL	Year	Area (m^2)	Total No. Fish	Total Wt. (g)	Area (m^2) per Fish	Wt. (mg) per m^2
Beetree	Between	1976	735	25 (0)	1560 (0)	29	2122
	930 &	1977	735	2 (50)	214 (2)	368	291
	975	1978	735	4 (0)	302 (0)	184	411
		1979	735	No fish collected			
Mouse	Between	1976	4451	130 (7)	6287 (1)	34	1412
	734 &	1977	4451	33 (3)	3033 (1)	135	681
	914	1978	4451	83 (54)	3102 (3)	54	697
		1979	4451	20 (0)	1202 (0)	223	270

Table 12. Mean length ($\bar{l}$), mean weight ($\bar{w}$), mean k ($\bar{k}$), and standard deviations for each mean for brook trout 91 mm - 280 mm total length from study areas with sympatric brook and rainbow trout populations.

Stream	Year	n	$\bar{l}$	s	$\bar{w}$	s	$\bar{k}$	s
Beetree	1976	32	134.25	24.52	28.22	17.46	1.03	0.20
	1977	60	139.36	21.49	27.41	15.10	0.94	0.18
	1978	44	150.17	26.41	39.00	21.77	1.06	0.26
	1979	36	132.86	31.72	27.24	18.07	1.05	0.14
Sams	1976	136	150.64	22.71	39.06	15.78	1.10	0.18
	1977	313	123.48	20.91	25.20	13.42	1.01	0.17
	1978	392	146.37	21.50	36.81	17.22	1.10	0.17
	1979	383	139.73	26.08	30.73	16.88	1.05	0.17
Silers	1976	35	133.20	22.16	24.77	9.82	1.03	0.23
	1977	135	129.11	19.32	23.68	11.95	1.02	0.17
	1978	202	138.76	20.57	29.54	14.25	1.03	0.13
	1979	256	131.18	26.16	25.60	16.32	1.02	0.14
Taywa	1976	19	145.50	21.59	34.61	15.89	1.08	0.17
	1977	2	146.00	53.74	38.00	35.56	1.02	0.02
	1978	33	147.97	22.60	40.38	20.13	1.17	0.11
	1979	47	126.38	19.62	24.79	12.03	1.18	0.17

Table 13. Mean length ($\bar{l}$), mean weight ($\bar{w}$), mean k ($\bar{k}$), and standard deviations for each mean for brook trout 91 mm - 280 mm total length from study areas with allopatric brook trout populations.

Stream	Year	n	$\bar{l}$	s	$\bar{w}$	s	$\bar{k}$	s
Silers	1976	Not sampled 1976						
	1977	61	135.13	26.83	28.08	17.01	1.03	0.20
	1978	131	136.09	18.51	28.31	12.78	1.05	0.13
	1979	142	126.72	24.65	24.08	14.64	1.06	0.14
Starkey	1976	26	141.23	18.60	33.50	11.76	1.16	0.18
	1977	137	130.59	25.42	23.65	14.10	1.00	0.16
	1978	139	145.97	20.70	34.15	14.67	1.04	0.11
	1979	142	144.80	26.99	35.65	20.85	1.07	0.14
Taywa	1976	15	146.25	21.81	38.75	26.21	1.12	0.16
	1977	--	No data					
	1978	54	139.34	19.88	31.85	17.57	1.11	0.12
	1979	34	132.71	22.17	28.17	15.10	1.12	0.17
Meigs Post	Late August 1978	58	141.29	23.51	30.52	16.51	1.00	0.10
Buckeye Gap	Late July 1978	35	135.68	20.83	28.26	12.06	1.05	0.10

*Data from Sweeney 1978 (unpublished electrofishing data, GRSM)

Table 14. Mean length ($\bar{l}$), mean weight ($\bar{w}$), mean k ($\bar{k}$), and standard deviations (s) for each mean for rainbow trout 9 1 mm - 280 mm total length captured in the sympatric populations of the study areas

Stream	Year	n	$\bar{l}$	s	$\bar{w}$	s	$\bar{k}$	s
Beetree	1976	76	166.16	29.18	51.83	29.11	1.04	0.14
	1977	8	156.00	36.86	39.57	31.05	0.87	0.08
	1978	9	183.56	27.46	71.89	31.85	1.10	0.09
	1979	2	166.50	51.62	65.50	50.20	1.29	0.10
Sams	1976	96	208.00	16.18	101.91	23.98	1.12	0.14
	1977	13	174.50	44.20	62.75	41.43	1.03	0.13
	1978	22	188.32	34.82	89.18	46.86	1.22	0.20
	1979	12	155.67	24.60	42.17	16.57	1.06	0.14
Silers	1976	76	171.86	34.04	56.72	32.12	1.05	0.17
	1977	122	175.15	29.21	56.56	28.85	0.98	0.20
	1978	56	183.85	38.91	69.57	42.76	1.03	0.33
	1979	29	152.55	21.24	41.62	20.24	1.13	0.14
Taywa	1976	170	152.58	27.96	45.62	26.34	1.20	0.17
	1977	3	173.67	19.23	70.67	26.85	1.29	0.11
	1978	21	188.78	30.56	85.89	51.92	1.18	0.13
	1979	26	152.35	25.50	45.00	25.07	1.20	0.20

Table 15. Mean length ($\bar{l}$), mean weight ($\bar{w}$), mean k ($\bar{k}$), and standard deviations (s) for each mean for rainbow trout 91 mm - 280 mm total length captured in the allopatric population of Mouse Creek

Stream	Year	n	$\bar{l}$	s	$\bar{w}$	s	$\bar{k}$	s
Mouse	1976	121	168.39	27.48	51.46	28.75	0.98	0.22
	1977	32	179.88	35.86	75.72	34.05	1.21	0.20
	1978	38	181.32	28.19	78.87	44.13	1.22	0.11
	1979	20	172.75	24.60	60.10	32.55	1.08	0.14

Table 16. Known Movements of Displaced Brook Trout In The Study Streams, 1976 to 1979

	Number Moving	Percent of Total Recapture	Direction of Movement	Distance Moved	Mean
	36	18.8	up only[1]	10,980	305
	36	18.8	down only[2]	20,400	567
	59	30.7	up only[3]	16,050	272
	47	24.5	down only[3]	24,530	522
	14	7.2	down then up[4]	4,590 down 3,300 up	328 236
Total	192	45.5		79,850	416

1. Char recaptured from sections where they could only move up.

2. Char recaptured from sections where they could only move down.

3. Brook trout recaptured from sections where they could move in either direction.

4. Brook trout recaptured from a tributary situation.

Table 17. Comparison of age to length ranges and mean lengths of brook trout in the GRSM from the present and other studies (sample sizes in parentheses).

Age Class	Study: Lennon* 1967	Konopacky* 1978	Robinette* 1978	Hoff* 1976	Present Study* 1977-1978	1979
Age 0						
Range (mm)	--	--	60-75	41-75	30-97**	49-90
$\bar{l}$	--	--	68.8 (13)	64.1 (21)	62.6 (750)	68.4 (228
			s=4.4	s=9.1	s=10.6	s=9.2
Age I						
Range (mm)	101-226	83-131	93-119	110-140	99-148	90-160
$\bar{l}$	--(107)	101.9 (81)	105.6 (33)	128.2 (14)	120.6 (90)	112.5 (17
			s=6.5	s=9.9	s=10.96	s=13.0
Age II	127-251	108-169	118-173	129-182	139-209	134-202
Range (mm)	--(88)	133.5 (91)	140-8 (45)	156.8 (21)	157.0 (33)	155.8 (42
$\bar{l}$			s=13.3	s=15.0	s=15.0	s=14.8
Age III						
Range	127-126	120-204	162-224	165-192	142-204***	146-208***
$\bar{l}$	--(20)	161.5 (24)	180.6 (22)	179.2 (6)	180.6 (5)	175.8 (17
			s=16.5	s=9.8	s=21.5	s=19.7
Age IV						
Range	203-226	132-207	--	--	--	
$\bar{l}$	-- (2)	175.5 (8)				

*Aging methods: Lennon - scales; Konopacky - otoliths and scales, total lengths in this table calculated from standard lengths; Robinette - vertebrae and scales; Hoff - vertebrae; present study - recapture of known age fish (brook trout recapture from allopatric and sympatric populations).

** Age 0 brook trout from 1976 are included in this group; other age classes could not be determined in 1976.

***This group is considered as Age III plus fish, as their age when initially marked as Age I plus fish in 1976 was not known.

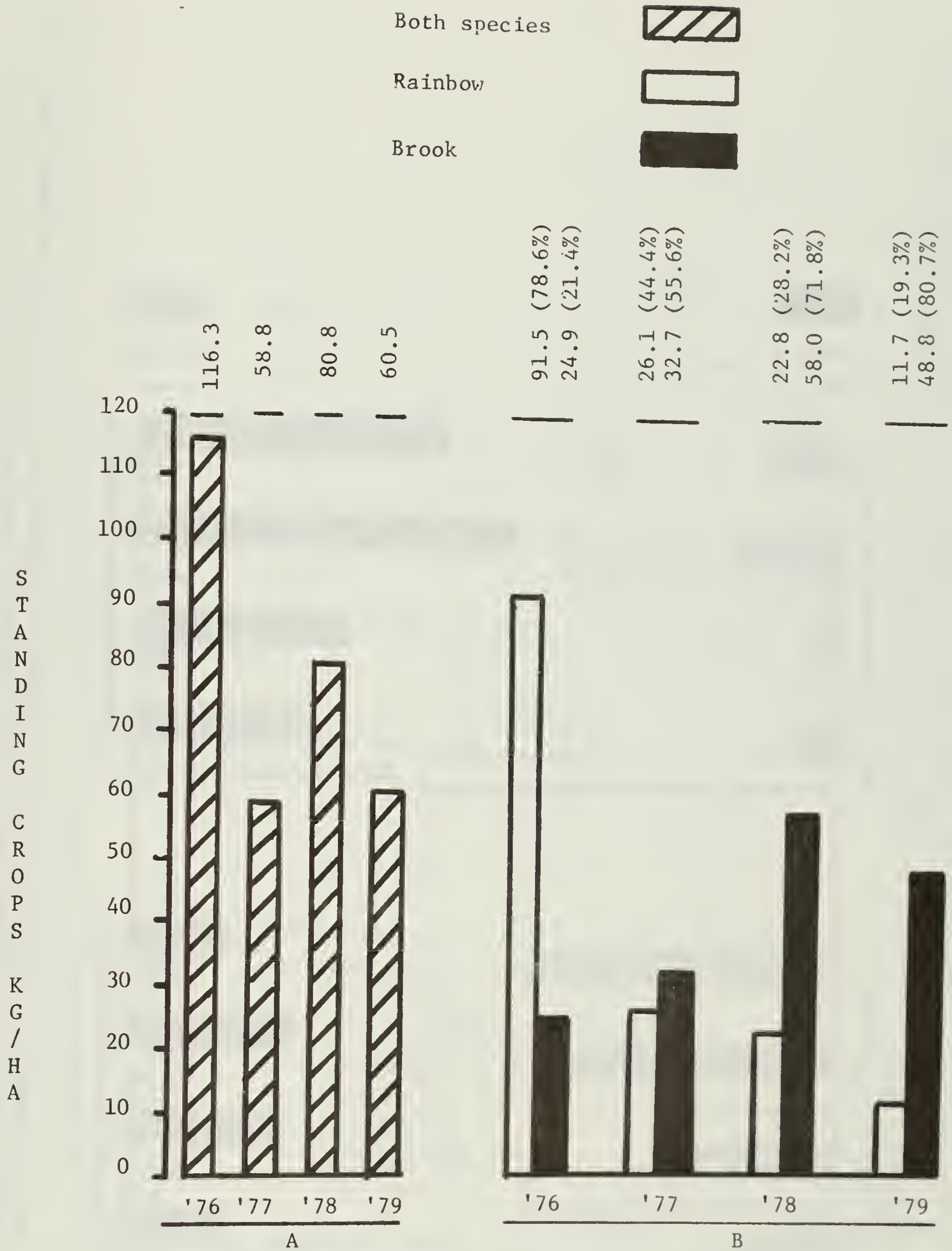

Figure 7. A--Changes in cumulative standing crop from four rainbow-brook trout sympatric populations after reduction of rainbow trout each year by removal; B--Cumulative standing crop by species.

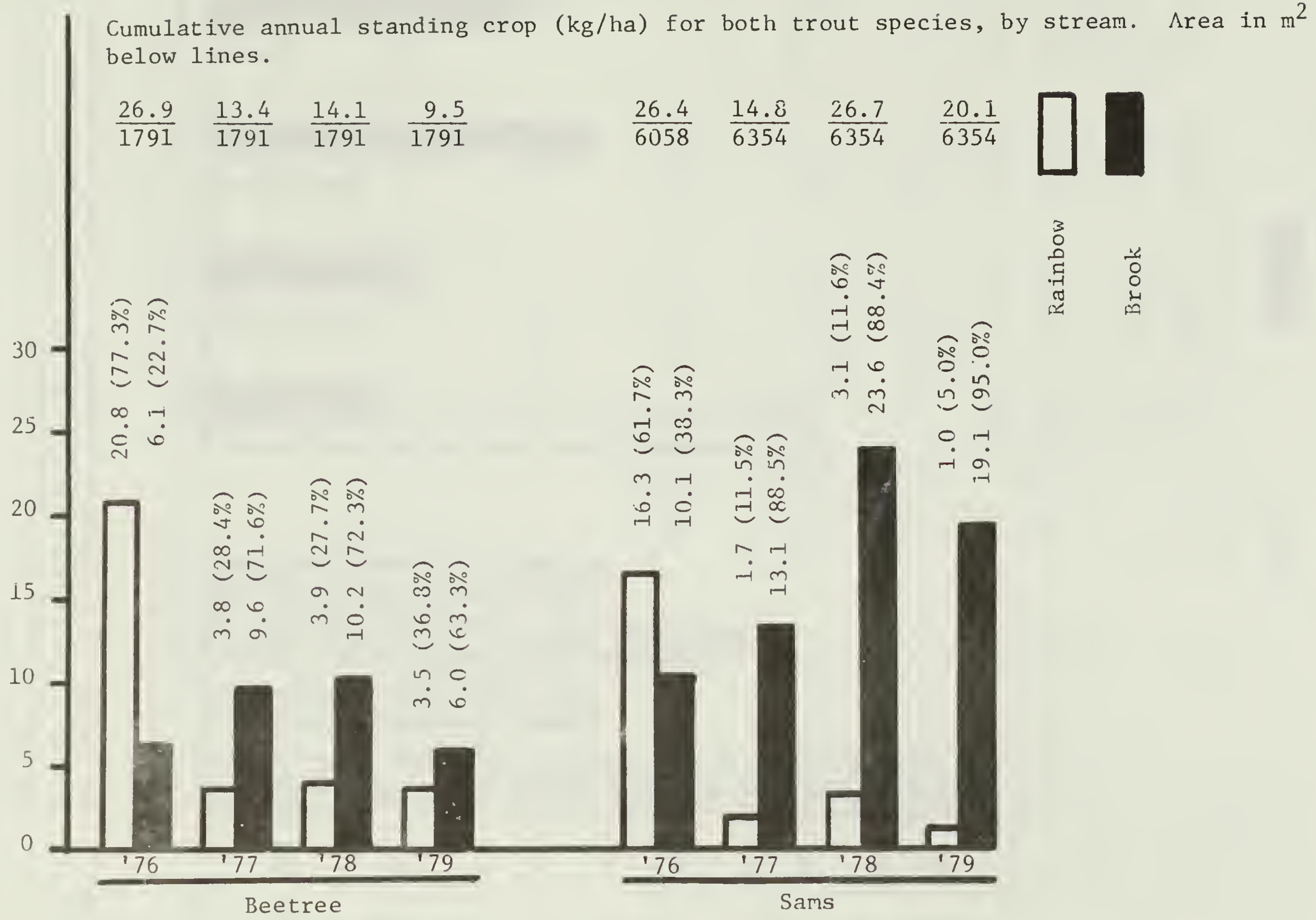

Figure 8a. Annual changes in standing crops from sympatric populations of brook and rainbow trouts for Beetree and Sams Creeks by species (captured brook trout marked and returned to stream; rainbow trout removed each year).

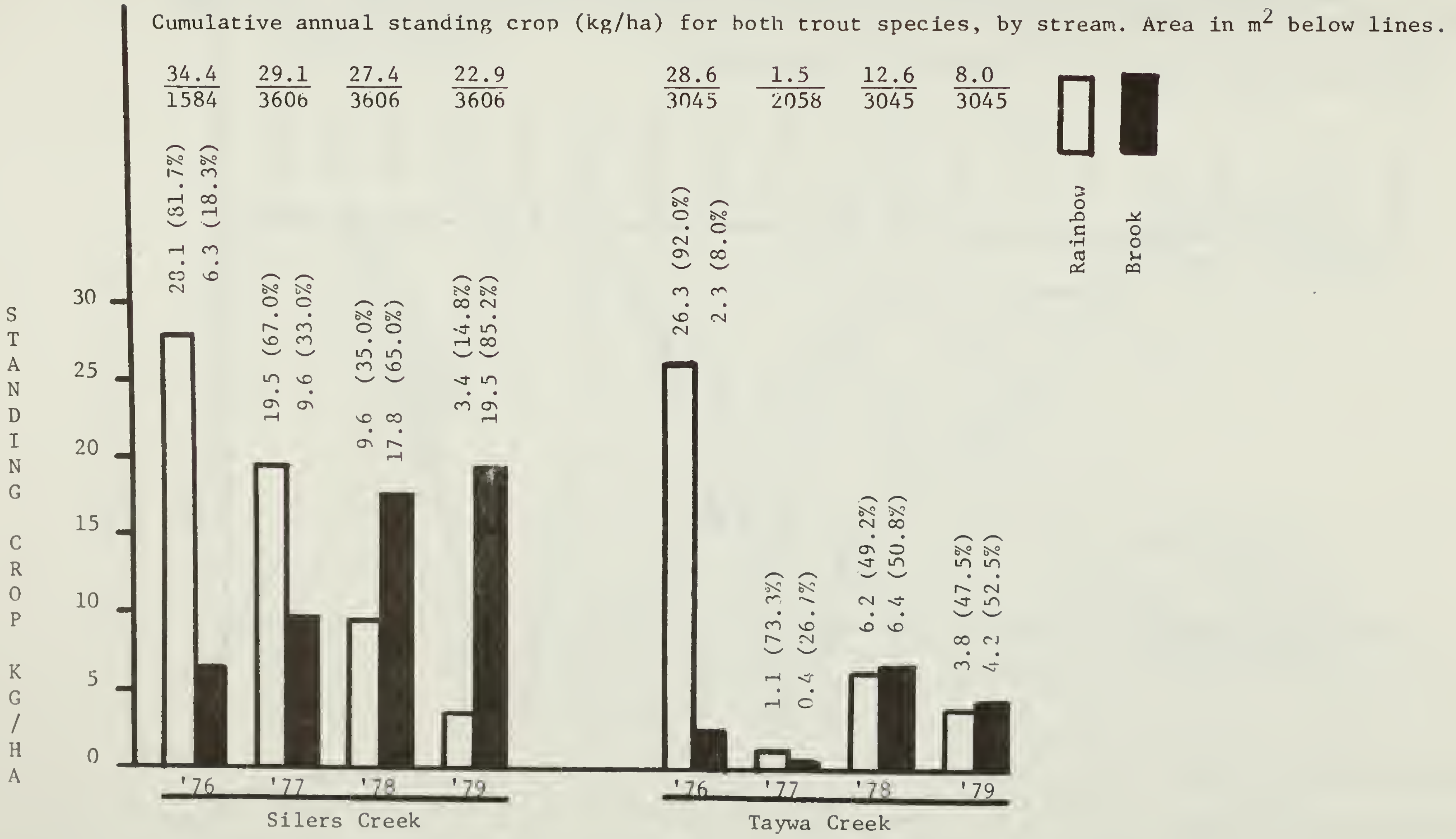

Figure 8b. Annual changes in standing crops from sympatric populations of brook and rainbow trouts for Silers Creek and Taywa Creek by species (captured brook trout marked and returned to stream; rainbow trout removed each year.)

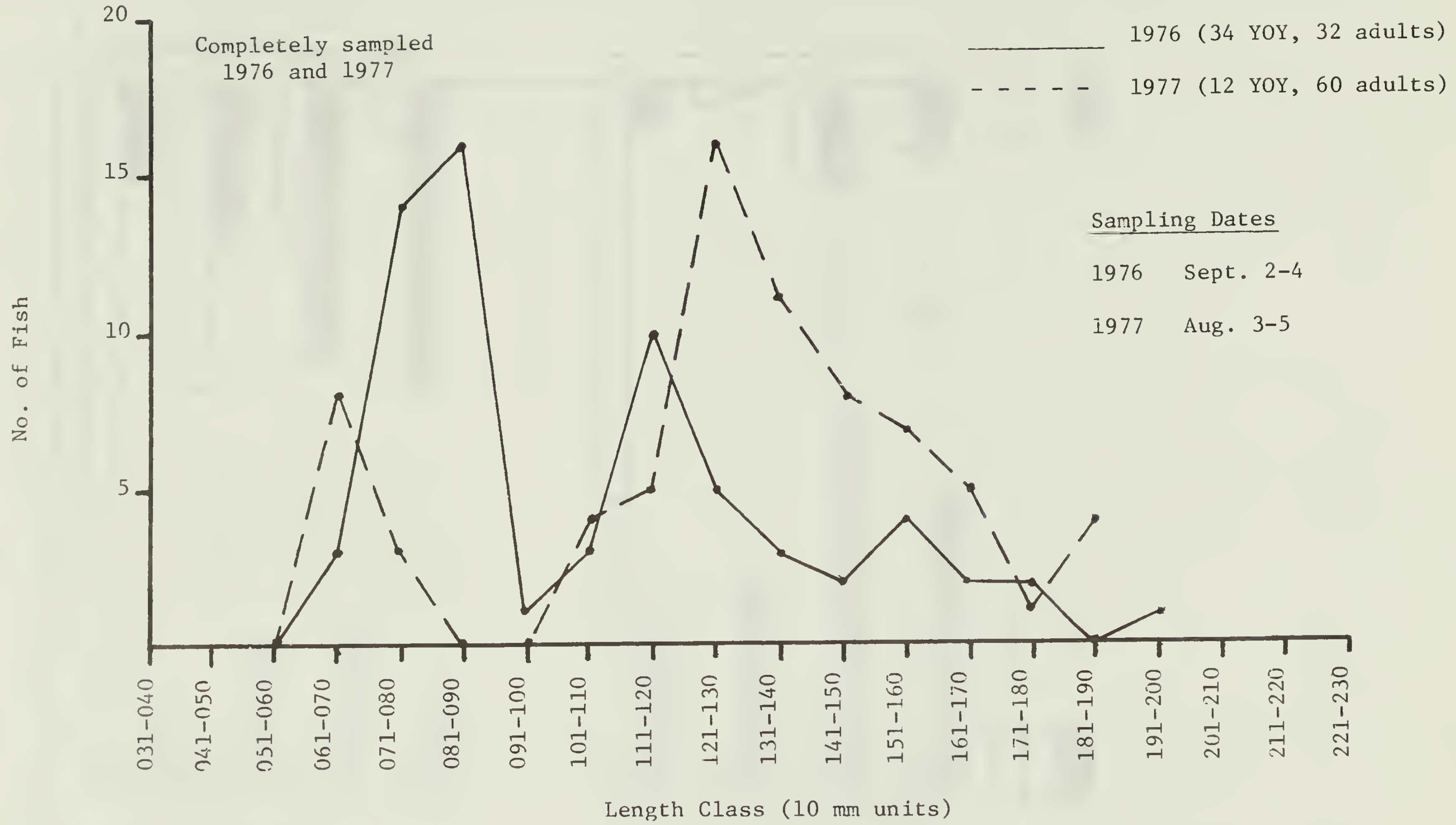

Figure 9a. Brook trout length frequency distribution in the sympatric population of Beetree Creek, 1976 and 1977 (brook trout were marked and returned to the stream each year; numbers in parentheses equal the sample size).

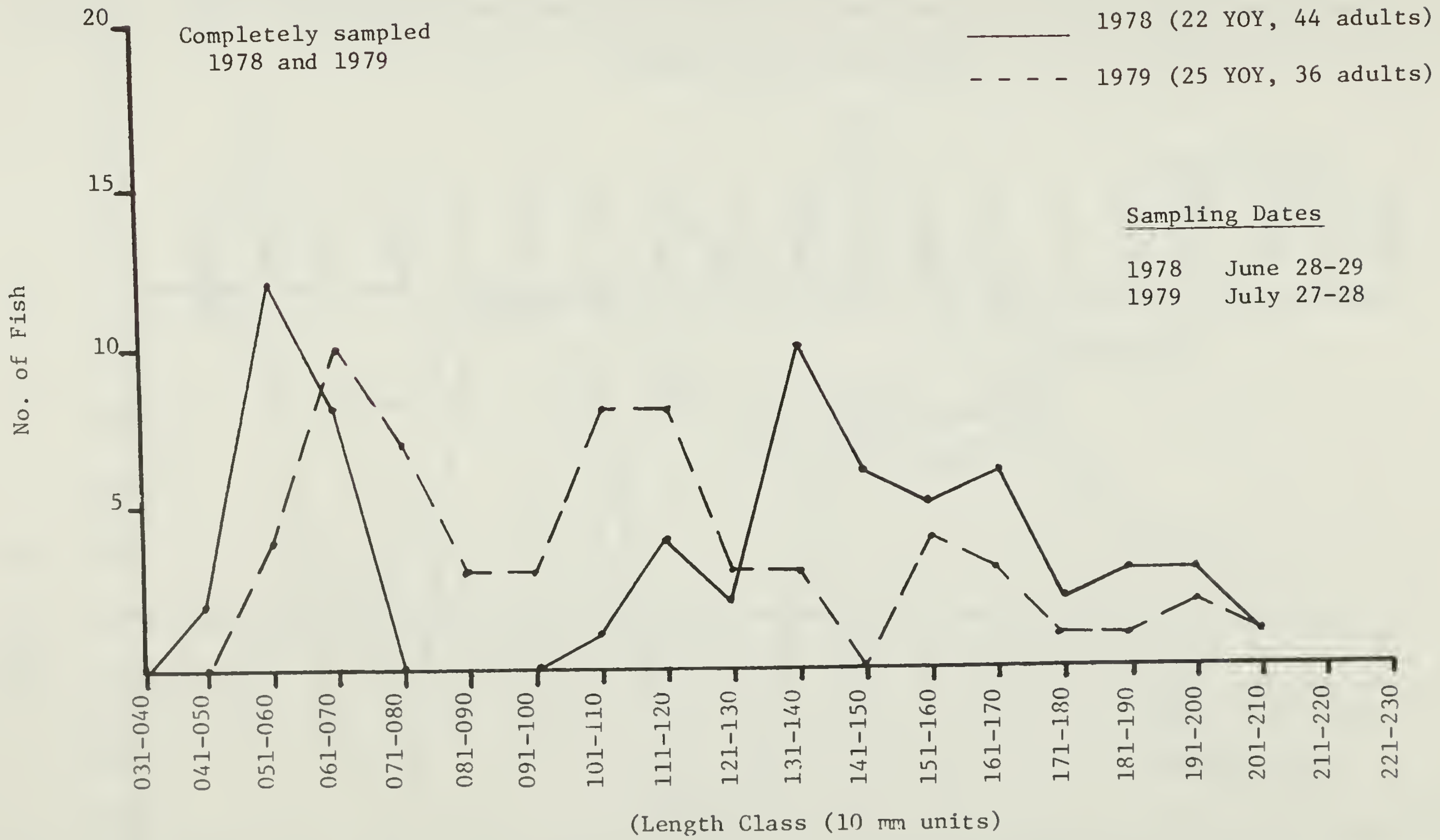

Figure 9b. Brook trout length frequency distribution in the sympatric brook trout population of Beetree Creek, 1978 and 1979 (brook trout were marked and returned to the stream each year; numbers in parentheses equal the sample size).

Figure 10a. Brook trout length frequency distribution in the sympatric population of Sams Creek, 1976 and 1977 (brook trout were marked and returned to the stream each year; numbers in parentheses equal the sample size).

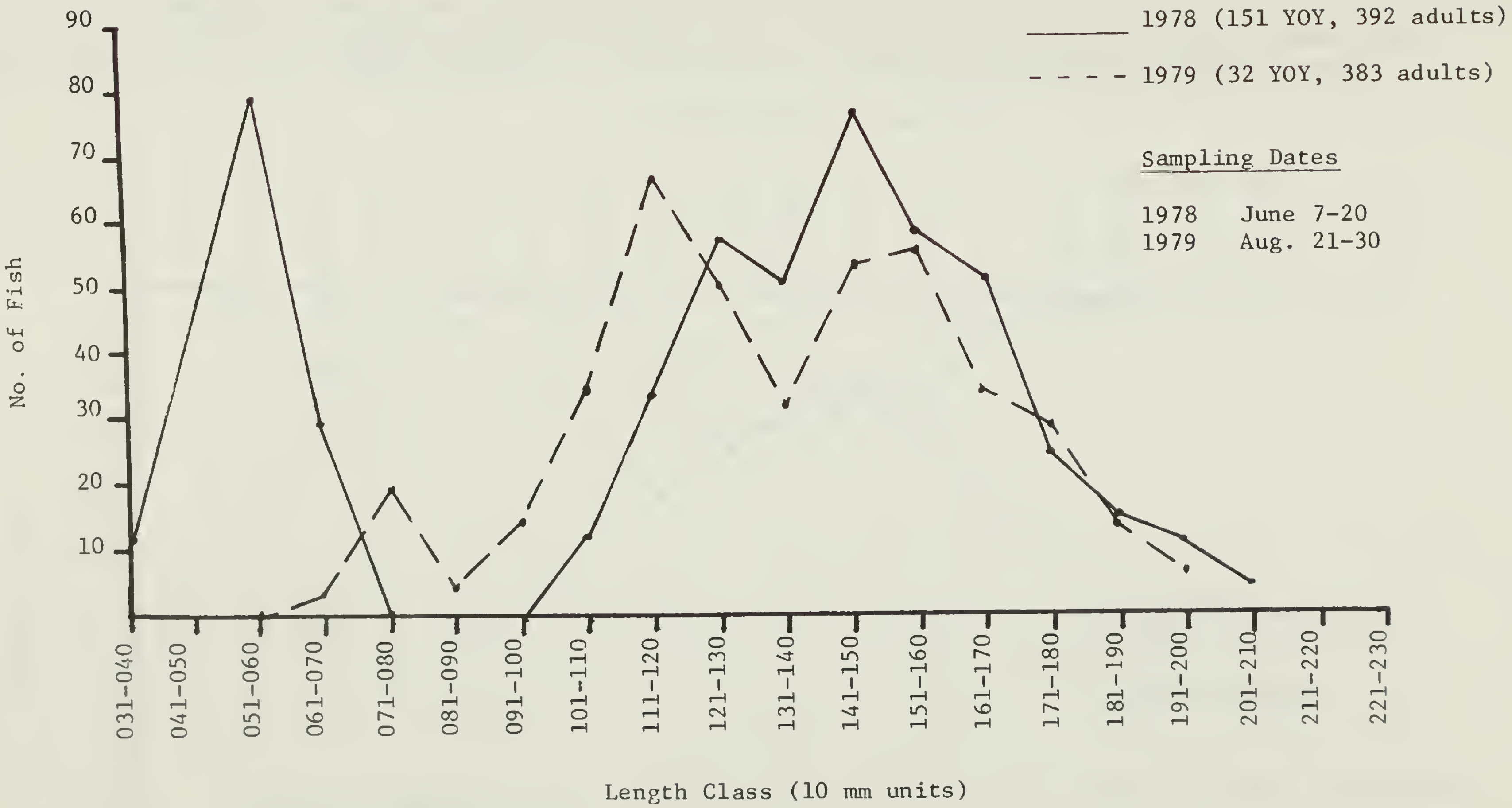

Figure 10b. Brook trout length frequency distribution in the sympatric population of Sams Creek, 1978 and 1979 (brook trout were marked and returned to the stream each year; numbers in parentheses equal the sample size).

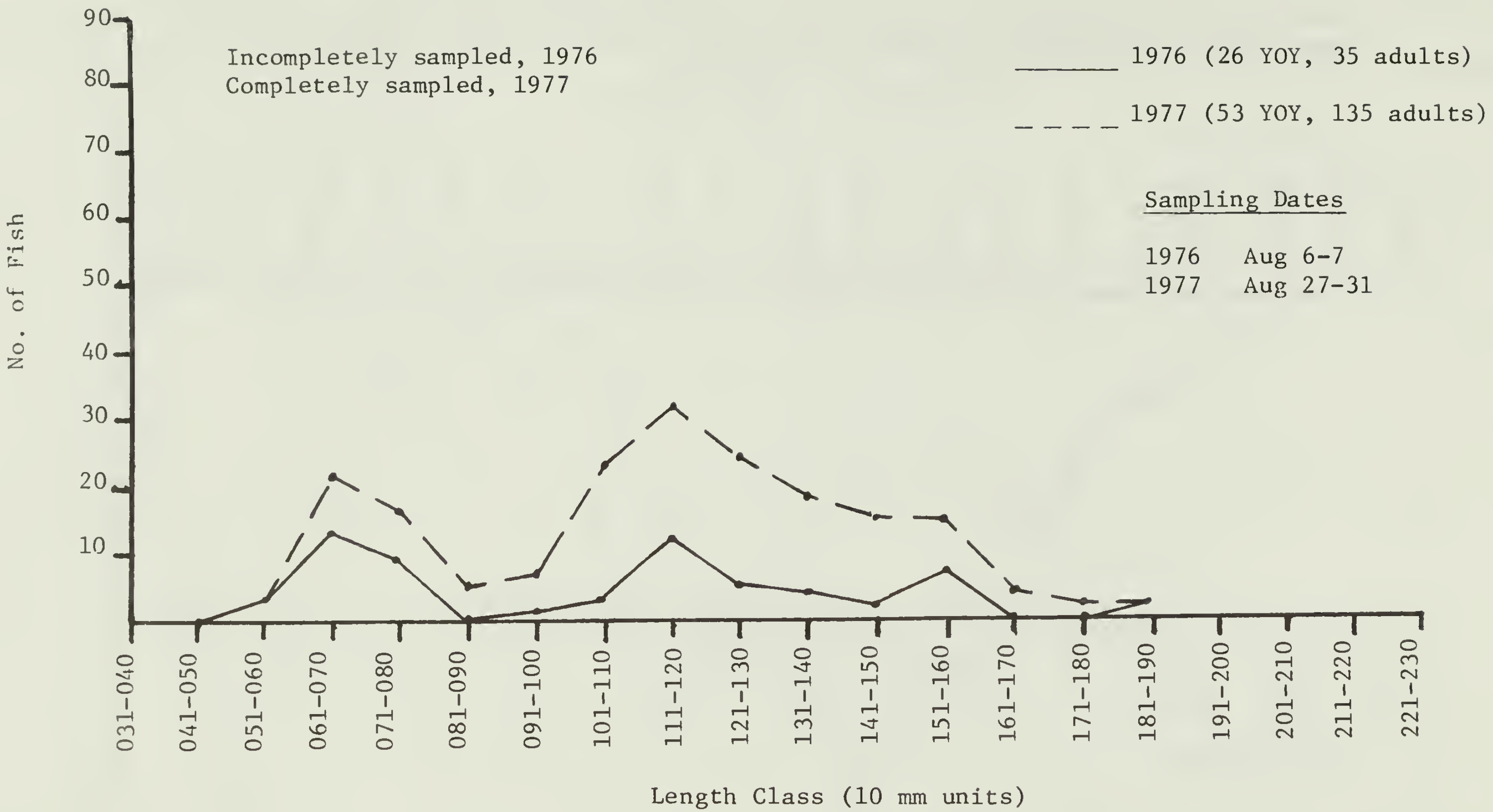

Figure 11a. Brook trout length frequency distribution in the sympatric population of Silers Creek, 1976 and 1977 (brook trout were marked and returned to the stream each year; numbers in parentheses equal the sample size).

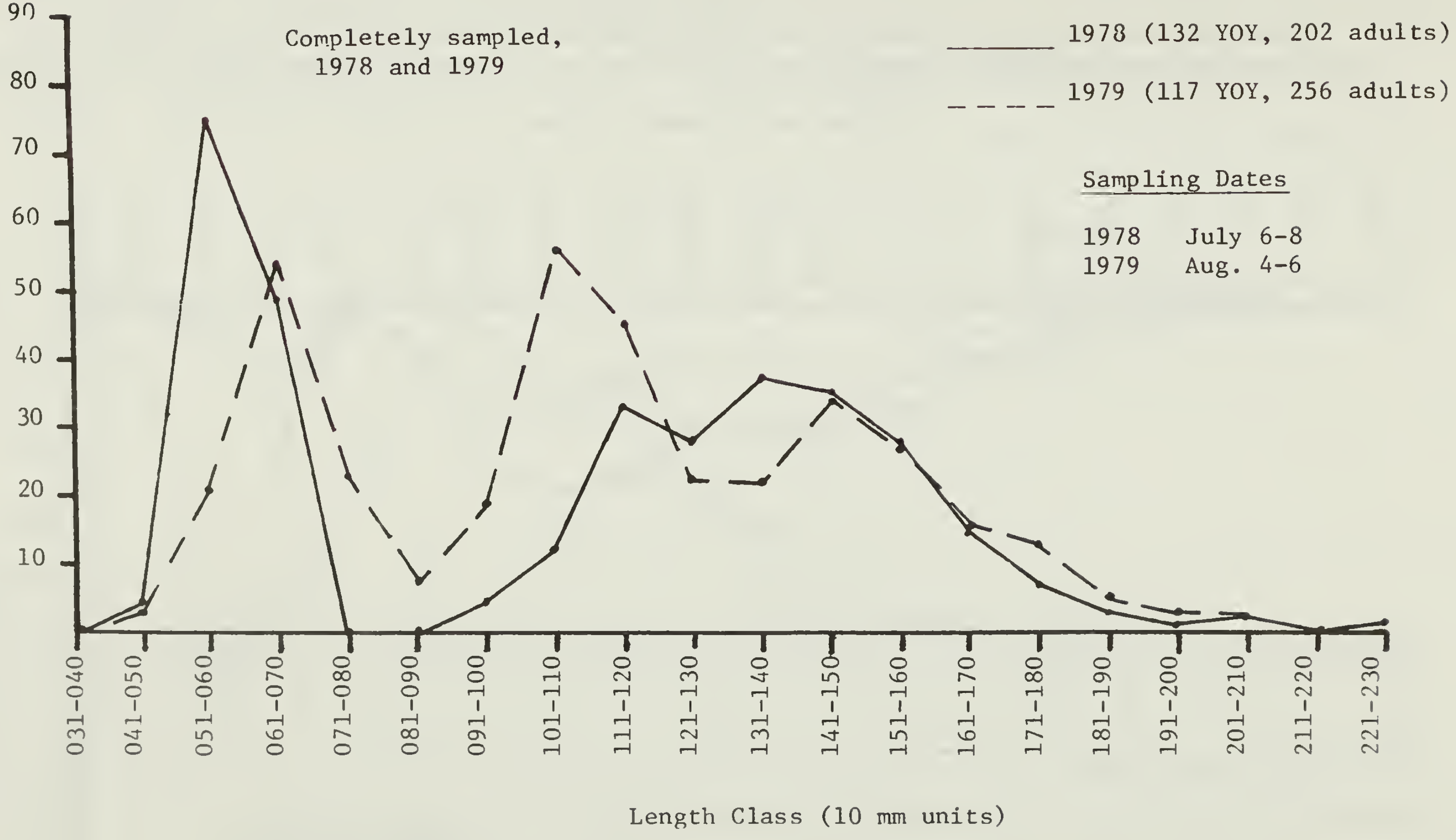

Figure 11b. Brook trout length frequency distribution in the sympatric population of Silers Creek, 1978 and 1979 (brook trout were marked and returned to the stream each year; numbers in parentheses equal the sample size).

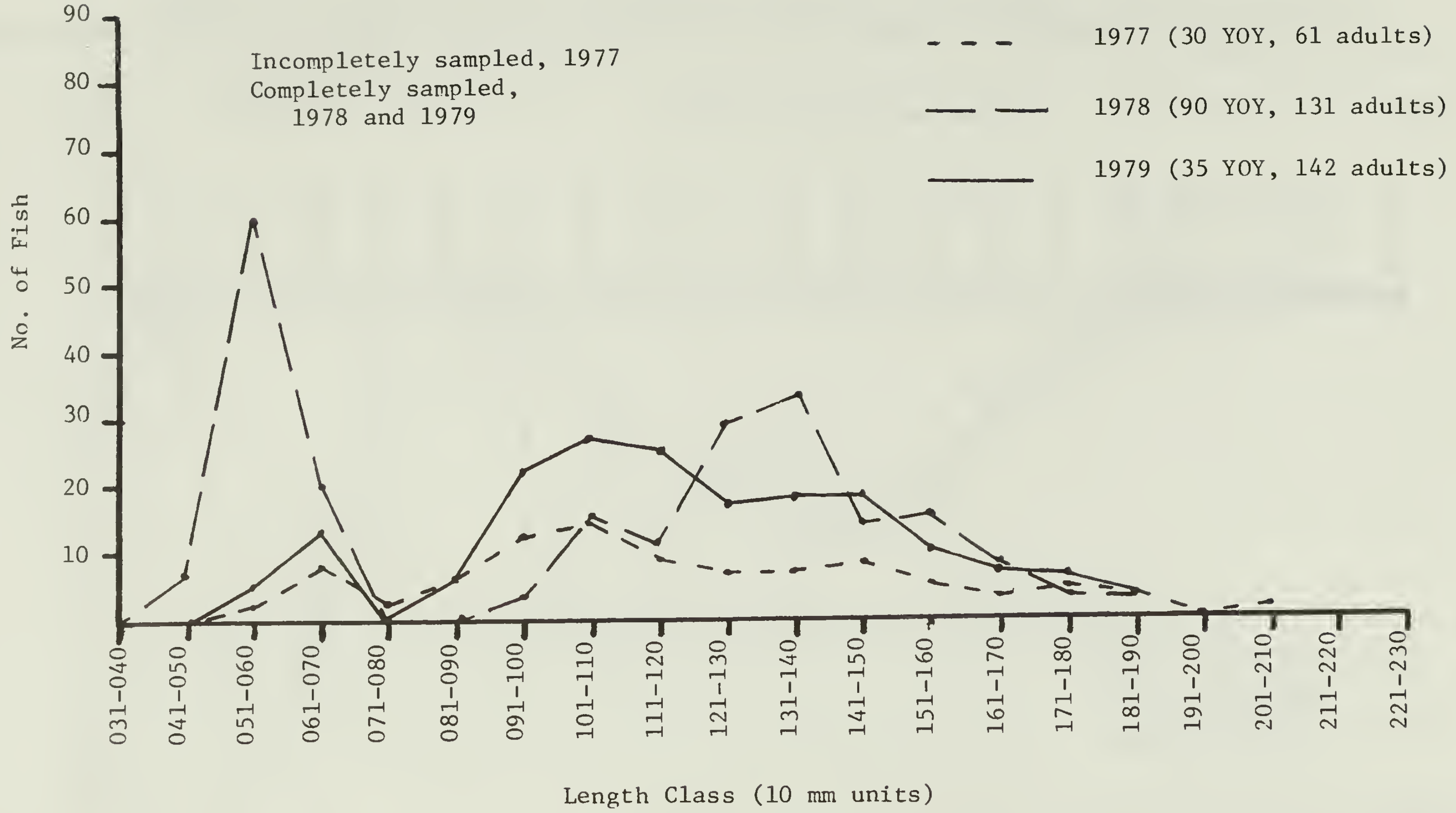

Figure 12. Brook trout length frequency distribution in the allopatric population of Silers Creek, 1977, 1978, and 1979 (brook trout were marked and returned to the stream each year; numbers in parentheses equal the sample size).

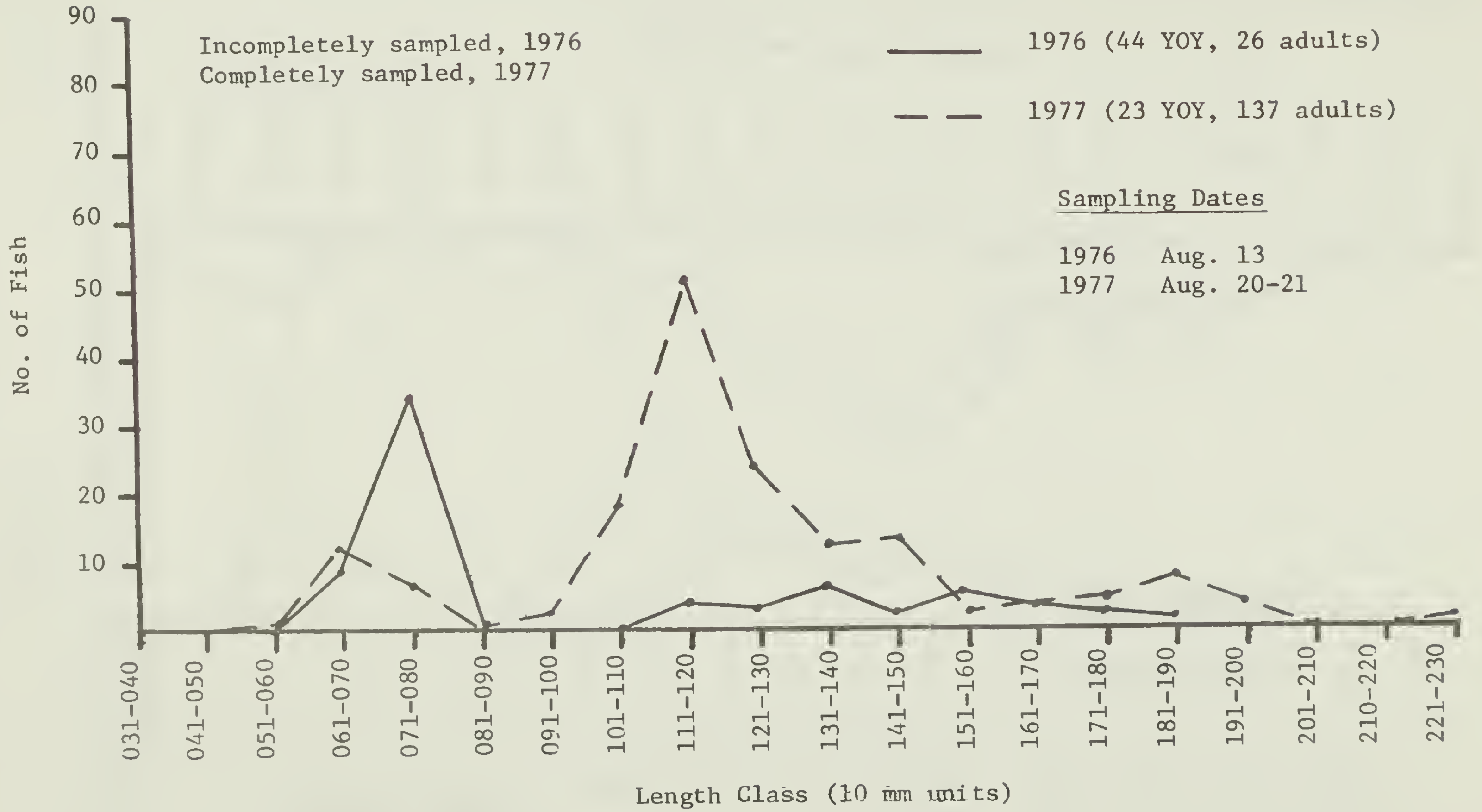

Figure 13a. Brook trout length frequency distribution in the allopatric population of Starkey Creek, 1976 and 1977 (brook trout were marked and returned to the stream each year; numbers in parentheses equal the sample size).

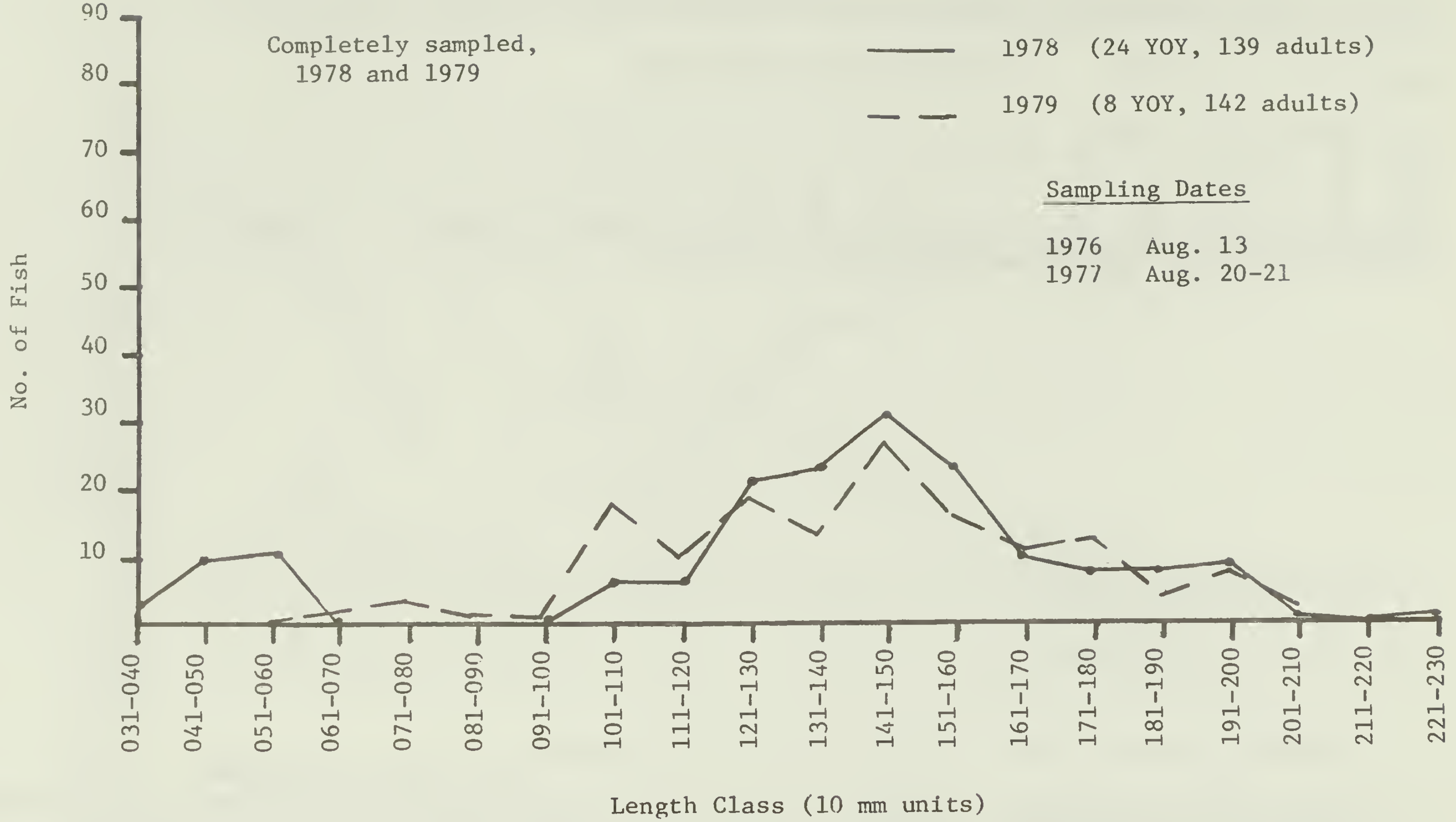

Figure 13b. Brook trout length frequency distribution in the allopatric population of Starkey Creek, 1978 and 1979 (brook trout were marked and returned to the stream each year; numbers in parentheses equal the sample size).

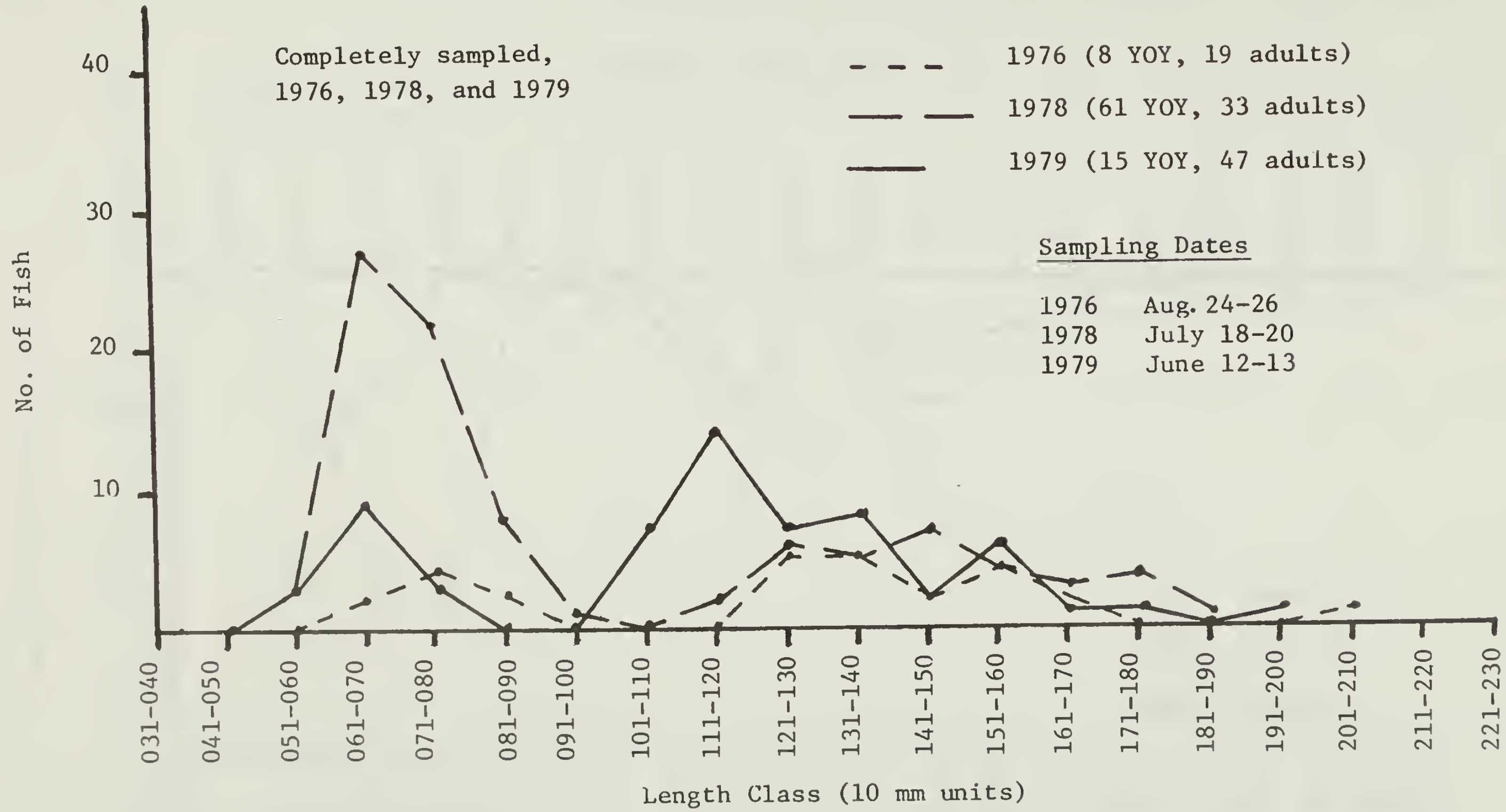

Figure 14. Brook trout length frequency distribution in the sympatric population of Taywa Creek, 1976, 1978, and 1979 (brook trout were marked and returned each year; numbers in parentheses equal the sample size).

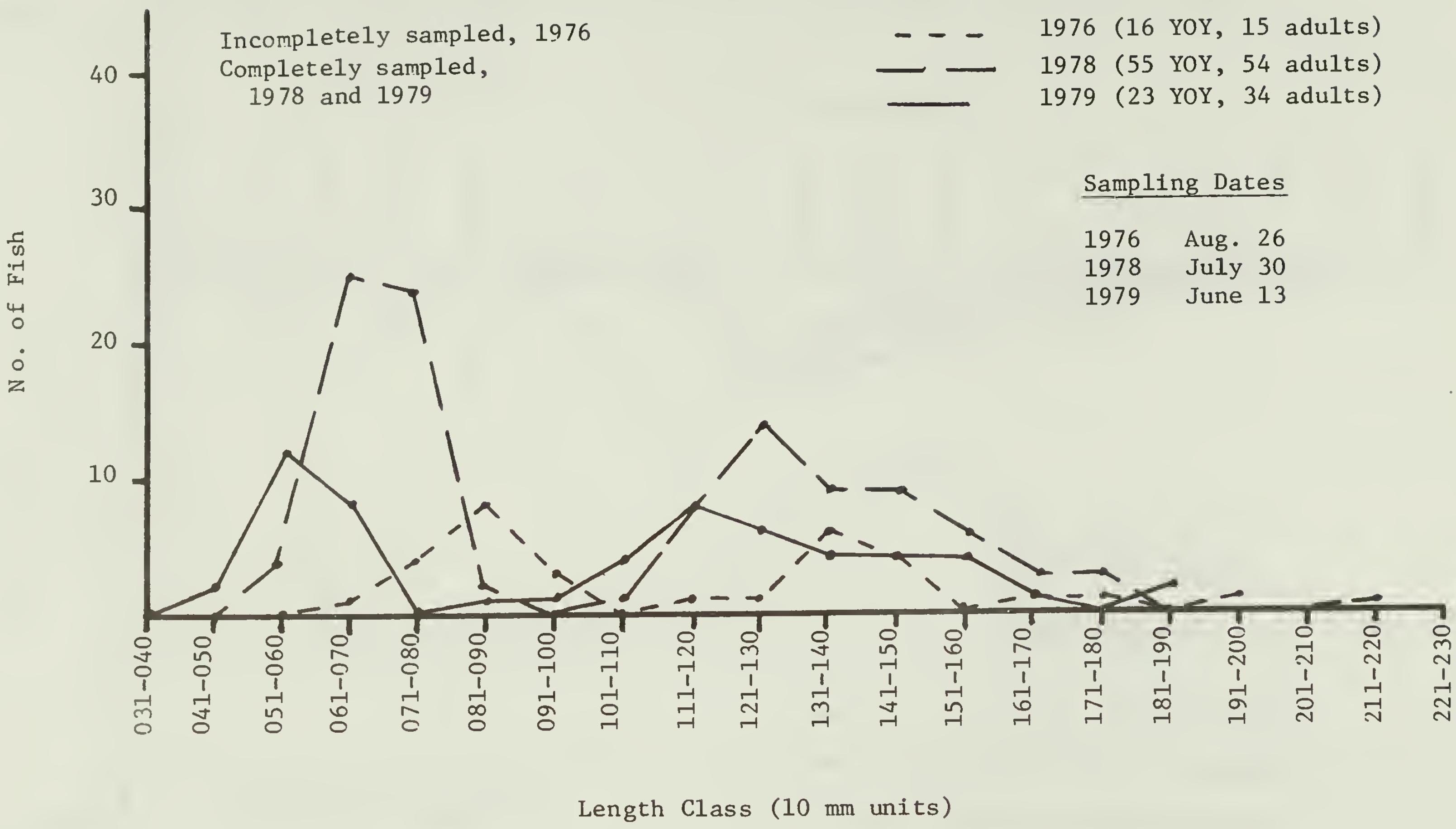

Figure 15 . Brook trout length frequency distribution in the allopatric population of Taywa Creek, 1976, 1978, and 1979 (brook trout were marked and returned each year; numbers in parentheses equal the sample size).

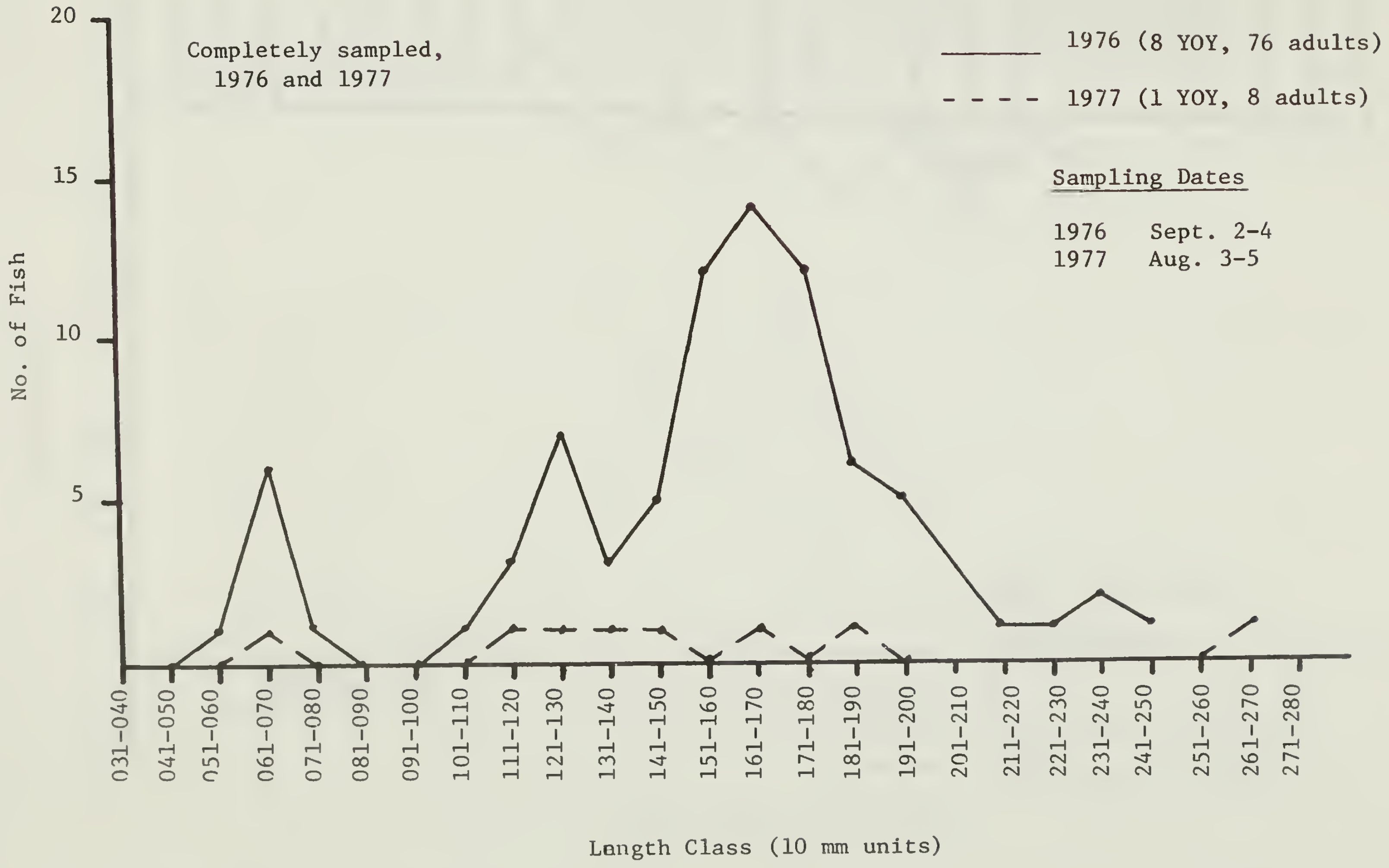

Figure 16a. Length frequency distribution for rainbow trout in Beetree Creek, 1976 and 1977. (Rainbow trout were removed each year; numbers in parentheses equal the sample size.)

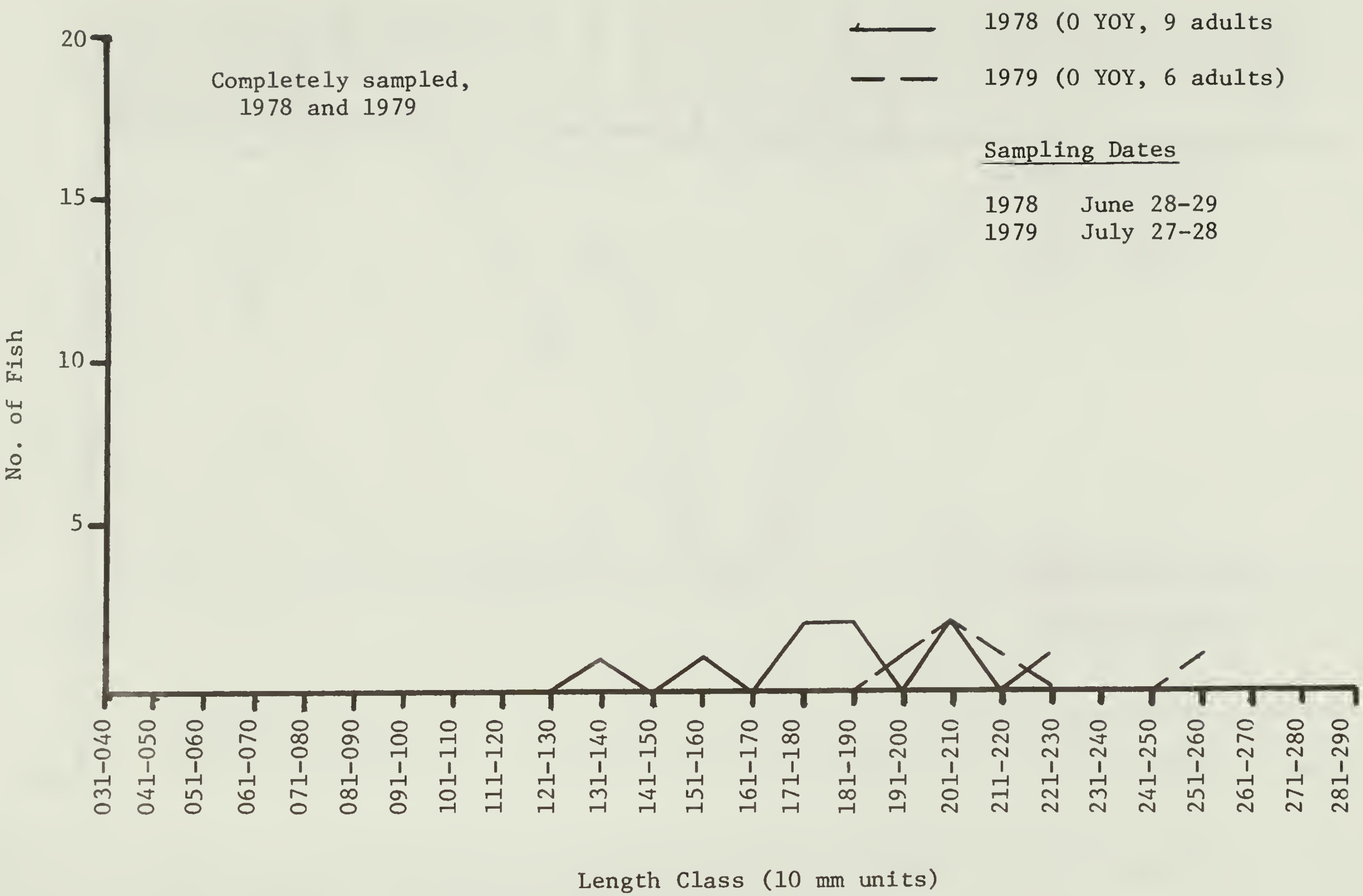

Figure 16b. Length frequency distribution for rainbow trout in Beetree Creek, 1978 and 1979. (Rainbow trout were removed each year; numbers in parentheses equal the sample size.)

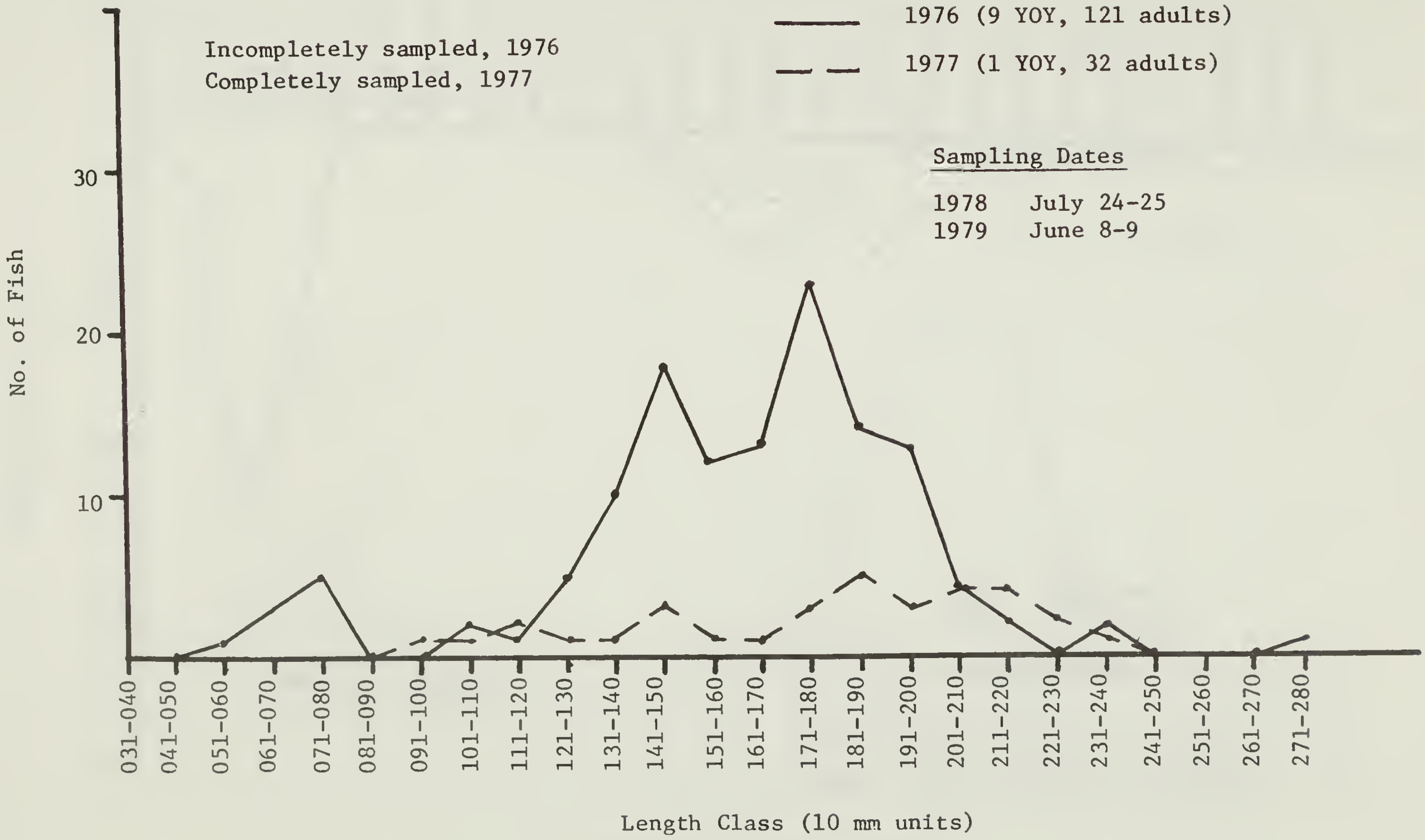

Figure 17a. Length frequency distribution of rainbow trout captured in Mouse Creek, 1976 and 1977. (Rainbow trout were removed each year; numbers in parentheses equal the sample size.)

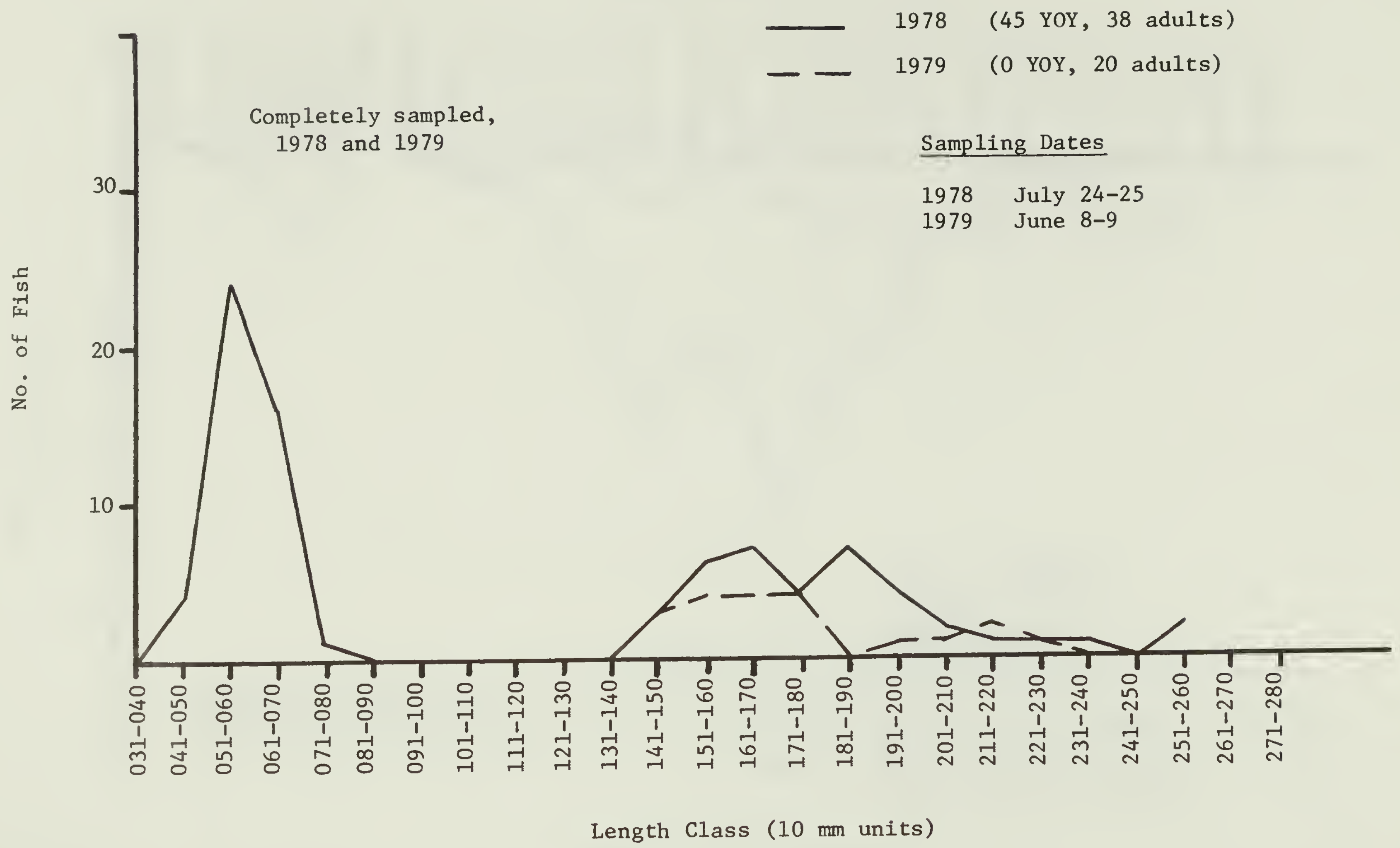

Figure 17b. Length frequency distribution of rainbow trout captured in Mouse Creek, 1978 and 1979. (Rainbow trout were removed each year; numbers in parentheses equal the sample size.)

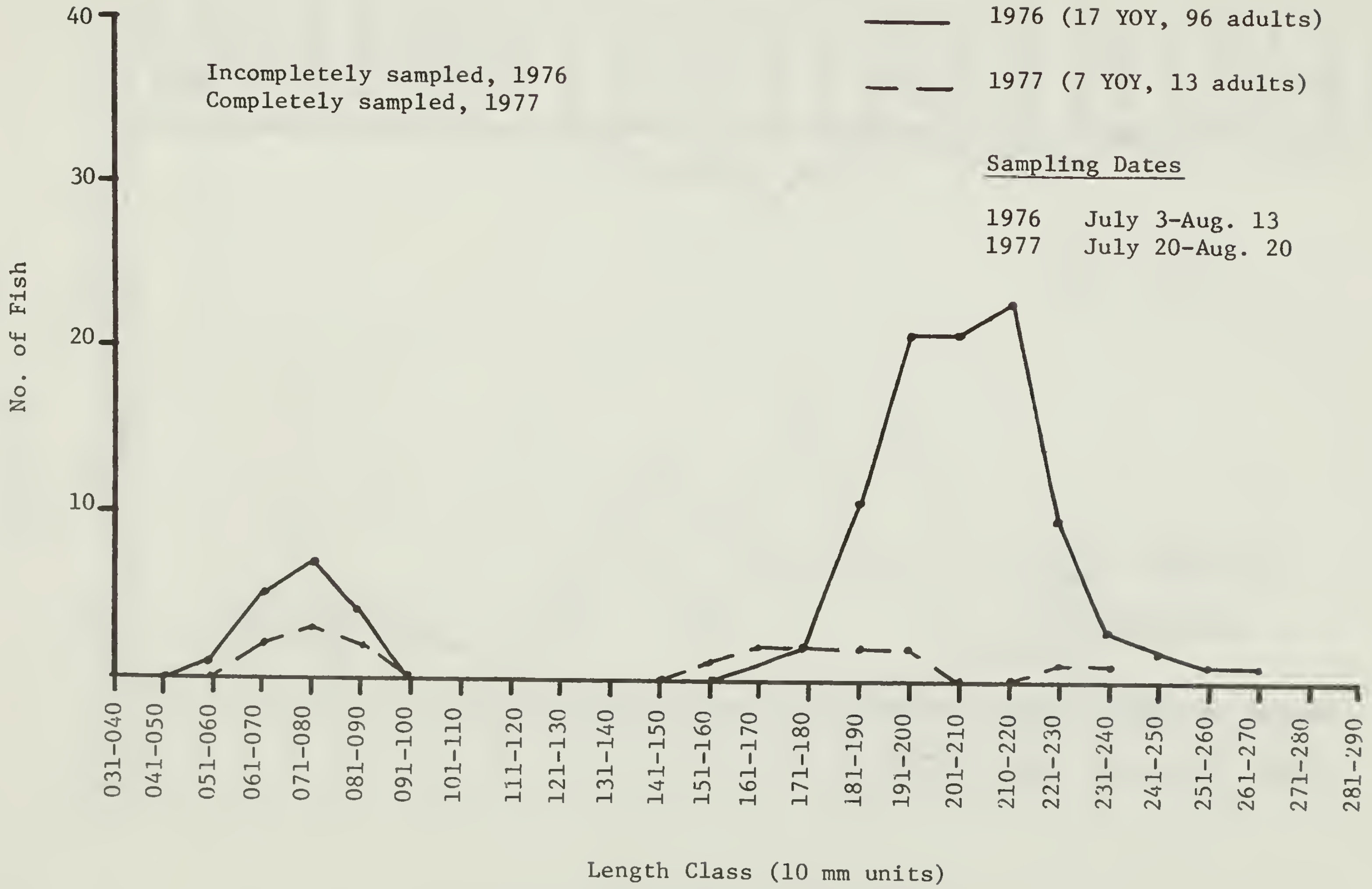

Figure 18a. Length frequency distribution of rainbow trout in Sams and Starkey Creeks, 1976 and 1977. (Fish from both streams comprise one sample; rainbow trout were removed each year; numbers in parentheses equal the sample size.)

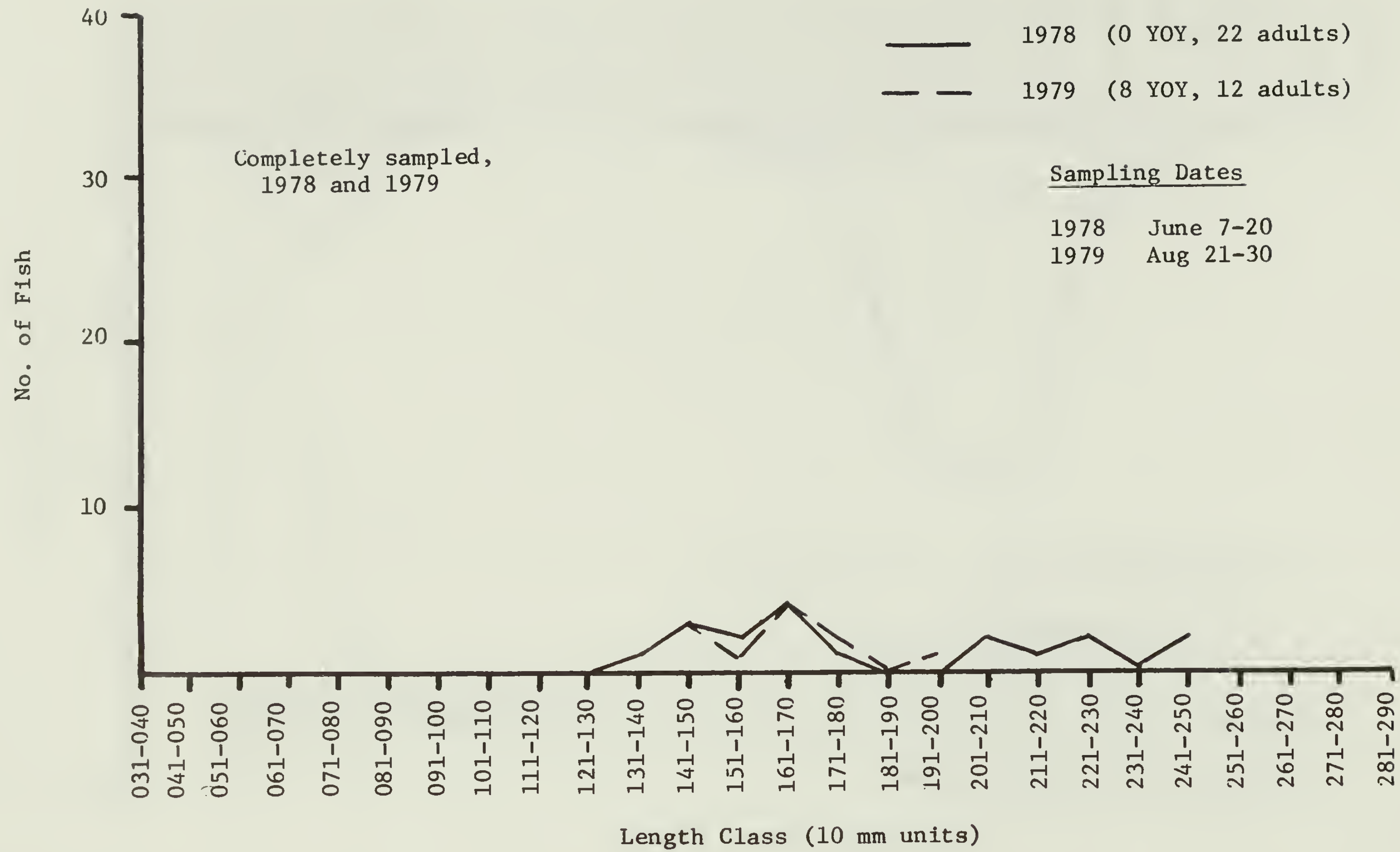

Figure 18b. Length frequency distribution of rainbow trout in Sams and Starkey Creeks, 1978 and 1979. (Fish from both streams comprise one sample; rainbow trout were removed each year; numbers in parentheses equal the sample size.)

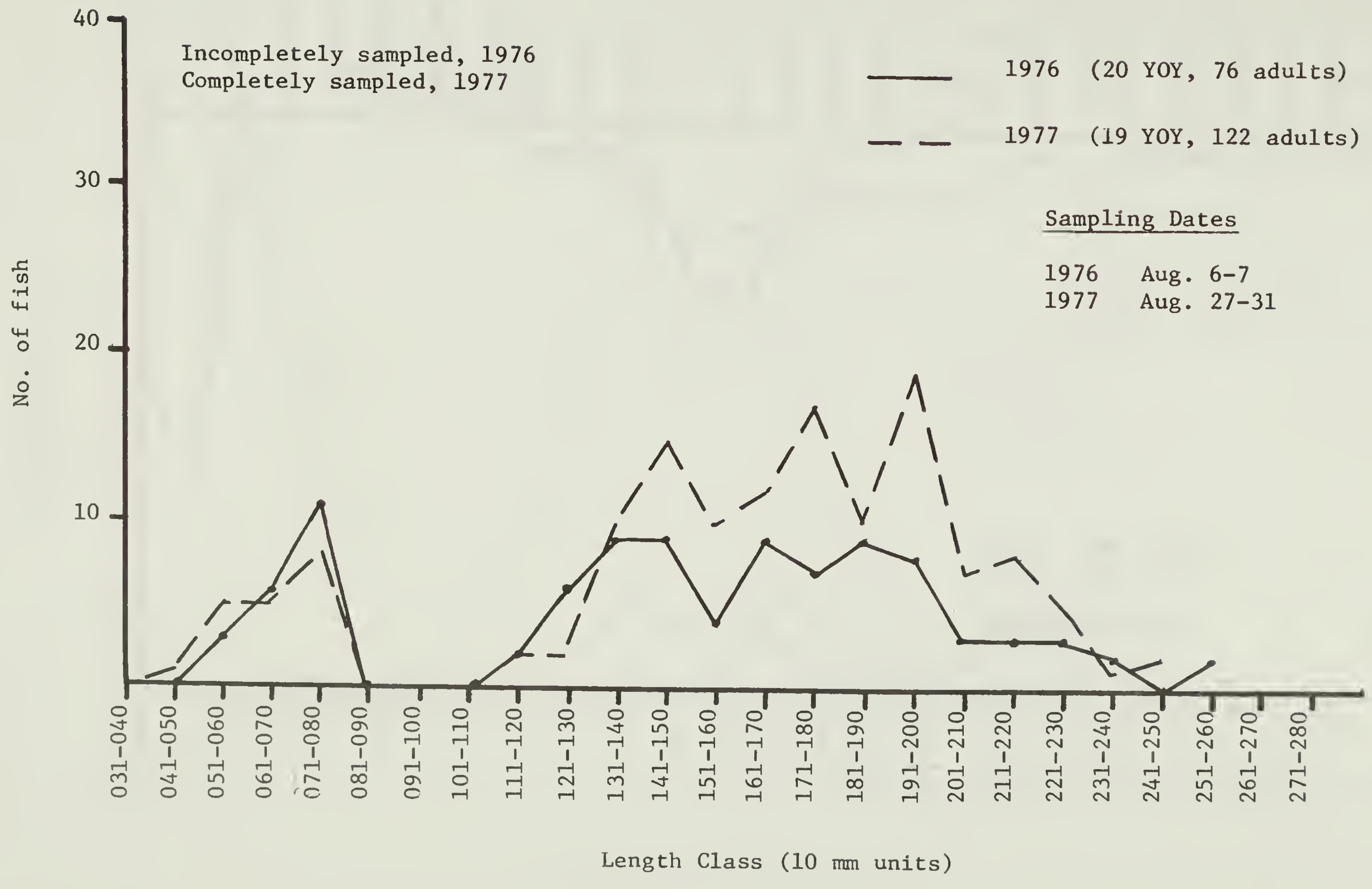

Figure 19a. Length frequency distribution of rainbow trout captured in Silers Creek, 1976 and 1977. (Rainbow trout removed each year; numbers in parentheses equal the sample size.)

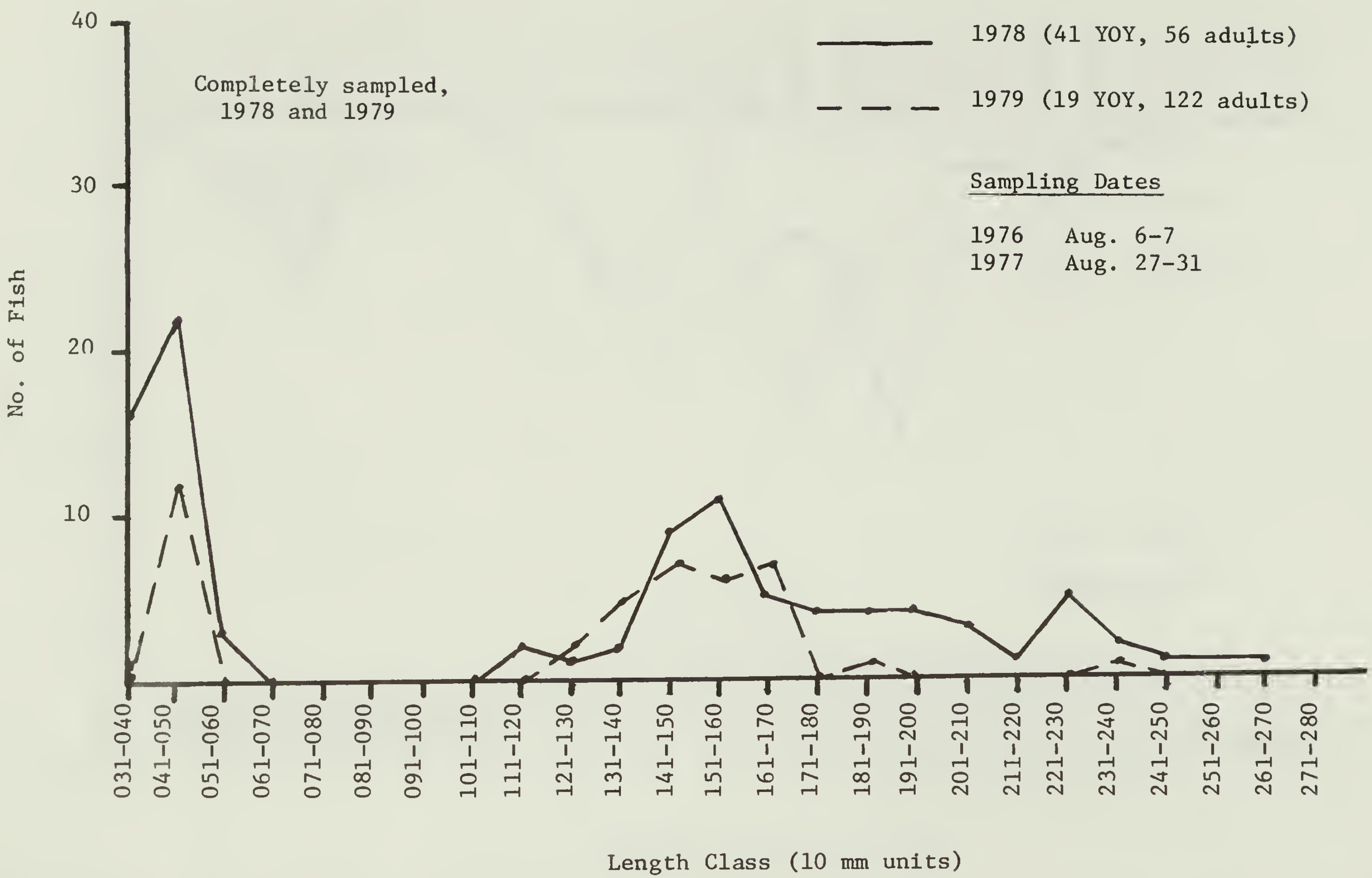

Figure 19b. Length frequency distribution of rainbow trout captured in Silers Creek, 1978 and 1979. (Rainbow trout removed each year; numbers in parentheses equal the sample size.)

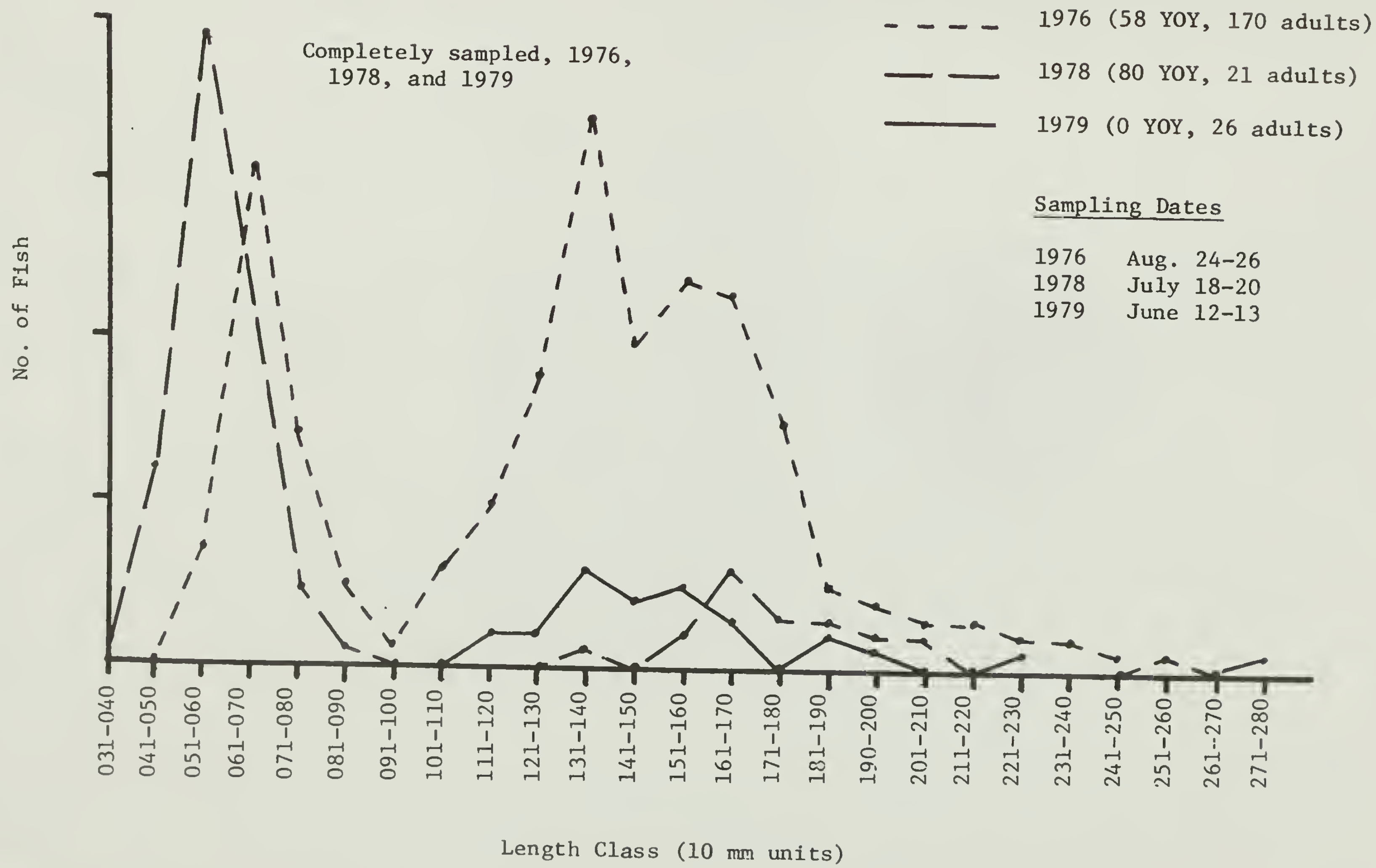

Figure 20. Length frequency distribution for rainbow trout captured in Taywa Creek, 1976, 1978, and 1979. (Rainbow trout were removed each year; numbers in parentheses equal the sample size.)

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