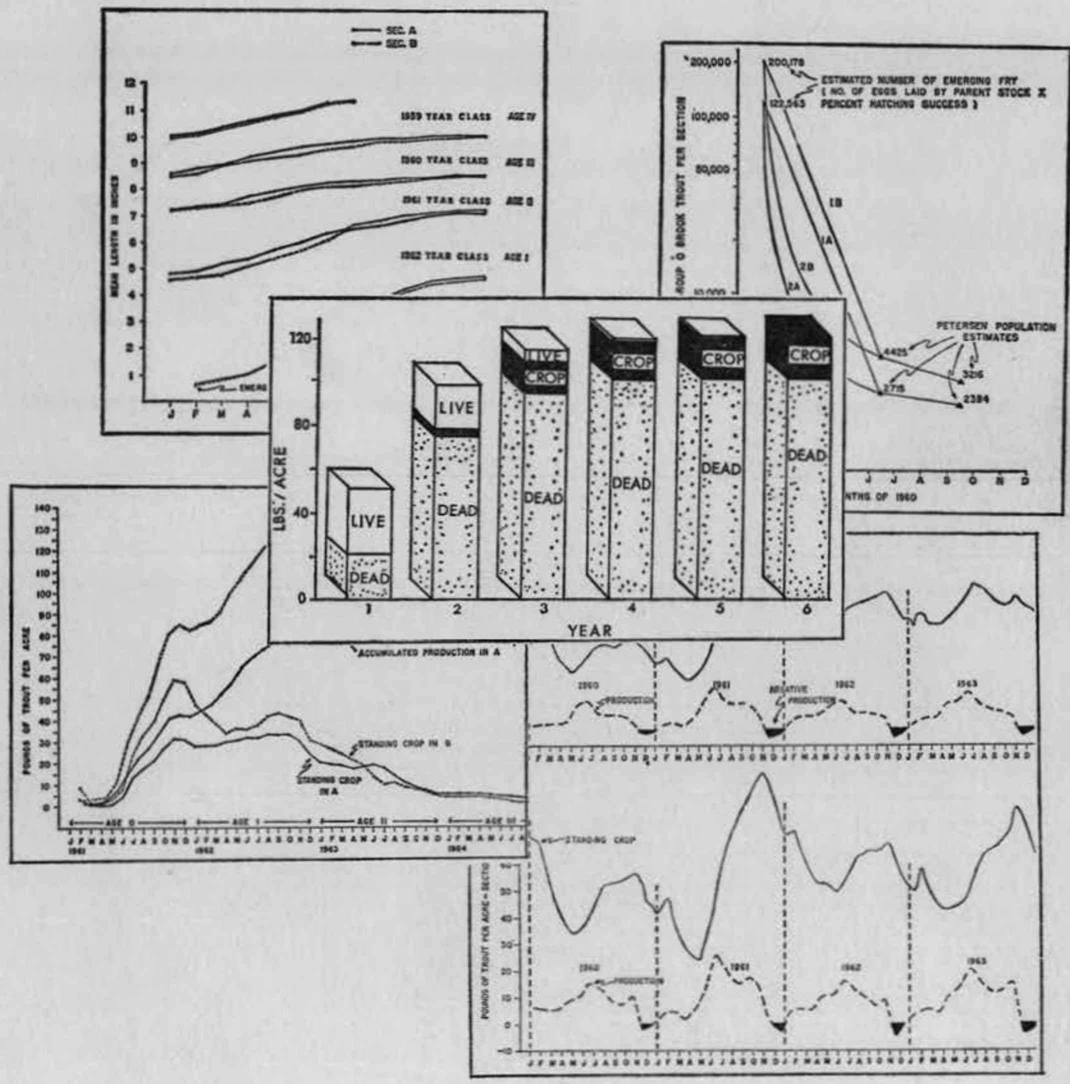
PRODUCTION AND ANGLER HARVEST OF WILD BROOK TROUT

IN LAWRENCE CREEK, WISCONSIN



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ERRATA

"Production and Angler Harvest of Wild Brook Trout in Lawrence Creek, Wisconsin"
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Because of the necessity for a last-minute change, printer, editor and author became involved in a misunderstanding! Tables 13 and 14 were dropped, but Table 13 should have remained. It appears below -- please insert it at page 31, and make the following changes in table references:

Pg. 31, second column, 13th line from bottom: Table 7 should be Table 13.

Pg. 31, second column, 4th line from bottom: Table 3 should be Table 7.

Pg. 32, first column, 9th line from top: Table 7 should be Table 13.

Pg. 39, Table 17, last line in parens should be (1 ÷ 2).

TABLE 13

April and September Standing Crops of Brook Trout, Annual Production, and Ratios of April and September Standing Crops to Annual Production in Lawrence Creek During 1960-64

YEAR	STANDING CROP (Lbs./Acre)		ANNUAL PRODUCTION (Lbs./Acre)
	April	September	
1960	37.0	51.6	93.0
1961	26.1	68.3	88.5
1962	61.1	62.6	83.6
1963	57.9	60.8	96.3
1964	68.9	70.8	91.3

YEAR	RATIOS OF MONTHLY STANDING CROPS TO ANNUAL PRODUCTION	
	April Standing Crop : Annual Prod.	September Standing Crop : Annual Prod.
1960	1:2.5	1:1.8
1961	1:3.4	1:1.3
1962	1:1.4	1:1.3
1963	1:1.7	1:1.6
1964	1:1.3	1:1.3
5-Year Means	1:2.1	1:1.5

Thank you for your cooperation.

WISCONSIN CONSERVATION DEPARTMENT
Research and Planning Division

PRODUCTION AND ANGLER HARVEST

OF WILD BROOK TROUT

IN LAWRENCE CREEK, WISCONSIN

By

Robert L. Hunt

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To the many other people who participated in the planning sessions, or assisted in electrofishing operations or creel census at Lawrence Creek, or offered their helpful suggestions during the many discussions of the study, or assisted in preparation of this report, the author sincerely acknowledges his appreciation for services rendered.

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Edited by Ruth L. Hine

ABSTRACT

Production (total growth in weight by all fish in the population during a given time period including growth by fish that died during the period) of wild brook trout *(Salvelinus fontinalis)* in Lawrence Creek was calculated monthly during 1960-64, for all age groups, and throughout the lifespan of the 1959-61 year classes. Contemporary statistics on the sport fishery were derived from a compulsory creel census. Three trout population estimates made annually with electrofishing gear provided the basic data for estimating monthly numerical densities. Growth data were collected monthly from known-age trout during 1963 and in April, June, and September during all other years.

Data summarizing growth, biomass, angler harvest and production for 60 consecutive months are presented separately for stream sections A and B and then for the entire stream by including less precise data for stream sections C and D.

Standing crops of brook trout were higher per unit area in section B than in section A during 58 of 60 consecutive months. Mean monthly biomass was 44 pounds per acre in A and 60 pounds per acre in B. Maximum monthly biomass in section A was accounted for by age group I trout in 4 of the 5 years and by age group 0 trout in 1 year. In section B peak biomass was attained by age 0 trout 2 of the 5 years and by age I trout in 3 years. Biomass normally declined from an October peak one year until May or June of the folllowing year. Biomass then increased steadily to another peak in October that was terminated by the onset of spawning.

Mean annual production was 48% greater in section B (104 pounds per acre) than in section A (70 pounds per acre) over the 5-year period. Maximum production per month occurred in June in both sections all 5 years. Monthly and annual production were usually higher in section B because it had greater densities of age group 0 trout, not because growth was better there. Production was negative during 10 of 60 months in section A and during 8 of 60 months in section B.

Annual production in the entire stream varied by only 15% during 1960-64, ranging from 84-96 pounds per acre. Production by age 0 and age I trout accounted for 81-95% of annual production.

Production by the 1959-61 year classes during their lifespans amounted to 157, 68, and 119 pounds per acre, respectively. Production was greatest during the first year of life for all three year classes.

During the 1961-64 trout fishing seasons 442-752 brook trout 8 inches (minimum legal size limit) or larger were creeled annually. Annual harvests amounted to 9-14 pounds per acre. The bulk of the catch consisted of age II trout. No age 0 trout were creeled and so few of age I were taken that standing crops and production were essentially unaltered by angler harvest during the first two years of life. Weights of annual angler harvests were equivalent to 10-15% of annual production.

Angler harvests from the 1959-61 year classes were equivalent to 6%, 16%, and 15% of lifetime production by the 3 year classes.

Annual production during 1960-64 averaged 2.1 times greater than standing crops present in April and 1.5 times greater than standing crops present in September.

Although production varied greatly within age groups from year to year, annual production by all age groups consistently approached 90 pounds per acre. The trout food supply did not appear to critically limit annual production.

Data concerning accumulated production at the end of successive years of life, and the amounts still present as the standing crop, or removed by anglers, or removed by natural mortality are presented and discussed for three-year classes of brook trout. These data constitute perhaps the most significant contribution of this study.

Reliable indices of two of the most important parameters of the population, i.e., annual production and the amount of this production removed annually by anglers, could have been obtained from a study lasting one or two years. However, a study covering the lifespan of several generations of trout was judged essential before biomass, production, and harvest could be reliably associated with age groups typical of the population.

During the lifespan of a year class of brook trout in Lawrence Creek production is equivalent to less than one-half of 1% of "potential production" (defined as the product of the number of emerging fry and the weight attained by the last survivor).

CONTENTS

INTRODUCTION

Production is the amount of tissue elaborated during a specified period of time regardless of whether or not all of it is still present at the end of that time (Ivlev, 1945; Gerking, 1962). In contrast to measures of standing crops, which only account for growth of fish still living, production accounts for growth by all fish in a population during a given time period including growth achieved by fish that died during the period.*

Production, so defined, was calculated for the wild brook trout (*Salvelinus fontinalis*) population in Lawrence Creek for the years 1960-64 and during the lifespan of the 1959-61 year classes. These production data, dependent upon the dynamic relationship of numerical density and growth rates of trout in Lawrence Creek plus contemporary data on angler harvest derived from a compulsory creel census, constitute the basis of this report. These production and harvest data are also part of a larger incompleted study concerning changes in a trout population and its food supply resulting from changes in stream morphometry due to intensive habitat alteration.

Published measures of standing crops of fish in lakes and streams are relatively common. Measures of standing crops and yield are much less common. Estimates of production are rare in fishery literature, and determination of production and yield even more so. This situation is unfortunate in view of the great value of production data in understanding fish population dynamics. Christenson and Smith (1965) have stated: "In an analysis of a fishery, the determination of the capability of a water to produce fish is of primary importance." Production data, such as those to be presented for the Lawrence Creek fishery, are, therefore, of primary importance because they attempt to account for all growth in a fish population.

The value of securing fish production data has also been stressed by Ricker and Foerster (1948) who concluded: ". . . if a computation of production differs from the true value even by 50 percent, it is still a much better piece of information than is yield for the purpose of estimating the utilization of fish food resources, or in connection with most other questions involving the 'trophic-dynamic' aspect of aquatic ecology." In his thorough investigation of production in three populations of juvenile coho salmon (*Oncorhynchus kisutch*), Chapman determined that production was 1.5 to 3.0 times greater than weight of the seaward migrants. This finding suggested to him "the importance of obtaining production data for any quantitative consideration of trophic relationships in these streams." Carlander (1955) emphasized the superiority of production information over measures of standing crops because: "Standing crops of fish do not necessarily bear a close relationship to fish production, but usually the standing crop is the only available estimate of fish production."

Basic data required to calculate fish production are: (1) the standing crop by number and weight present some time during the year, (2) rates of growth during sucessive short periods throughout the year, and (3) rates of mortality during these same periods. Use of such values to compute production and interpret its biological significance was pioneered by Ricker and Foerster (1948) in their investigation of young sockeye salmon (*Oncorhynchus nerka*) in Cultus Lake, British Columbia. One of the first important accounts of fish production in flowing waters was reported by Allen (1951) in his monograph on wild brown trout (*Salmo trutta*) in the Horokiwi Stream, New Zealand. Other accounts of fish production in lakes or ponds have been published by Johnson and Hasler (1954) concerning domestic rainbow trout (*Salmo gairdneri*) stocked in six small privately-controlled lakes in Michigan and Wisconsin, by Hatch and Webster (1961) concerning stocked domestic and wild brook trout in four small private lakes in New York, by Gerking (1962) concerning bluegill sunfish (*Lepomis macrochirus*) in Wyland Lake, Indiana, by Cooper, Hidu, and Anderson (1963) concerning large mouth bass (*Micropterus salmoides*) production in a small pond in Pennsylvania, and by Flick and Webster (1964) concerning production of domestic and "wild" brook trout stocked in several drainable ponds in New York.

Reports of production in streams include papers by Horton (1961) dealing with wild brown trout (*Salmo trutta*) in three short stretches of Walla Brook, England, by Warren, Wales, Davis, and Doudoroff (1964) dealing with wild and domestic cutthroat trout (*Salmo clarki*) stocked in four experimental sections of Berry Creek, Oregon, and by Chapman (1965) dealing with wild coho salmon in three small coastal streams in Oregon.

My investigation differs from those studies cited in two significant ways: (1) Only the Lawrence Creek data concern production and angler harvest of

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*Production, standing crop and other terms used in this bulletin are defined on page 5.

wild brook trout in a lotic environment. (2) The Lawrence Creek data include chronological summations of production by three year classes of stream-dwelling salmonids from emergence to extinction. Allen (1951) and Horton (1961) determined production by a "year class" by summing production within a single year by all age groups. However, my data suggest that such hypothetical calculations, dependent upon assumptions of initially similar density of several successive generations plus similar rates of growth and mortality, may be substantially different from actual production by a generation of trout during its lifetime.

The relevance of these and the other studies cited will be considered in more detail in the Discussion section of this bulletin.

TERMINOLOGY

The following terms and their definitions are used in this study:

PRODUCTION: Growth in weight by all fish in the population during a specified period of time including growth by fish that died during the period.

ACCUMULATED PRODUCTION: The sum of production from month to month for the time periods specified.

NEGATIVE PRODUCTION: A loss of body weight greater than the elaboration of new body material by the population during a specified period of time.

POTENTIAL PRODUCTION: The maximum quantity of organic matter that could have been elaborated during the life of a year class if all emerging fry attained the weight of the last survivor.

STANDING CROP: The number and/or weight of fish present at any one time.

STOCK: Used interchangeably with "standing crop".

BIOMASS: Weight of the standing crop of fish present at any one time.

ANGLER HARVEST: The number and/or weight of legal-sized fish removed by fishing.

YEAR CLASS: The fish hatched in a given year. In Lawrence Creek brook trout spawn in the autumn of one year and hatching occurs early in the following year. Year classes are identified by the year of hatching.

AGE GROUP or **AGE:** The year of life of a year class or generation indicated by a roman numeral. Although emergence of age group 0 brook trout is considered to occur on February 1, the age group becomes age group I eleven months later on January 1. Thus, the first "year of life" is only 11 months long.

(g), (i) and **(k):** Instantaneous rates of growth, mortality, and increase or decrease in biomass, respectively, during a specified period of time ($k=g-i$).

DESCRIPTION OF LAWRENCE CREEK

Although previous published accounts of research at Lawrence Creek contained descriptions of its physical and biotic characteristics, much new information has been assembled. In addition, resurveys of stream morphometry have revealed substantial differences in physical dimensions of stream sections used in this report and those previously published.

Lawrence Creek is located about 40 miles south-southeast of the geographical center of Wisconsin. Local annual rainfall averages 29 inches (Table 18, Appendix). The stream is 3.36 miles long from the junction of its two main tributaries in Adams County to its termination at Lawrence Millpond in Marquette County. All but 350 yards of the stream (in section D) is included within the 824-acre Lawrence Creek Public Hunting and Fishing Grounds. The stream has an approximate surface-water drainage area of 6.4 square miles, and an approximate ground-water drainage area of 16.8 square miles. Elevation at its source is 920 feet and total drop is 29 feet, or 8.5 feet per mile.

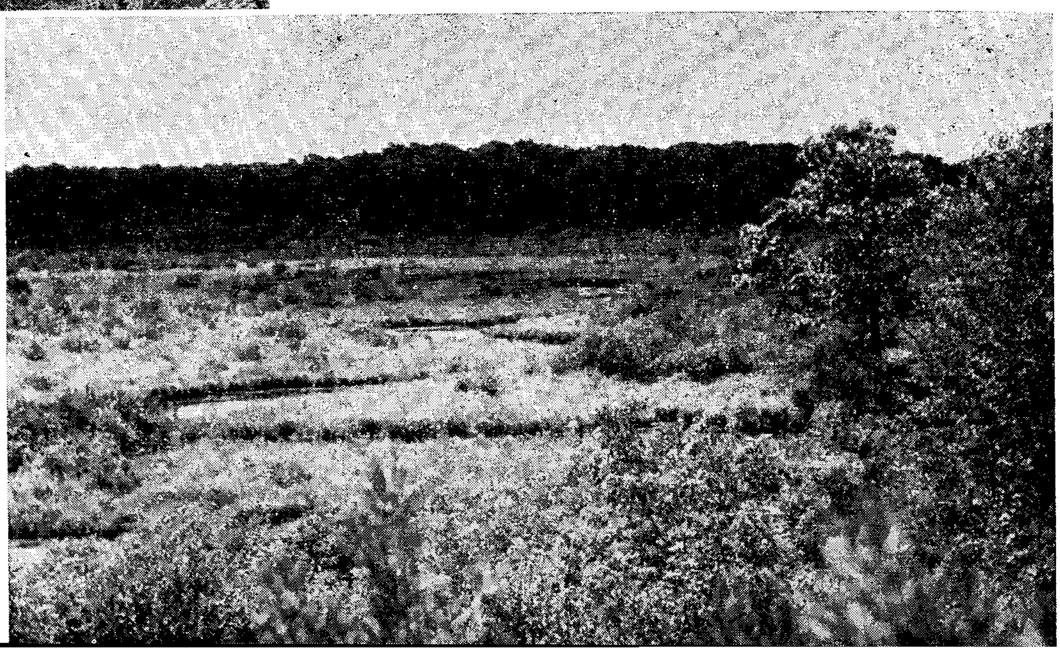
Poff and Threinen (1963) classified 15 of the 30 streams in Marquette County as trout streams, and 44% (109 miles) of the total stream mileage as trout waters. Lawrence Creek maintains the best population of wild brook trout in the county.

During 1963 detailed maps (scale of 1 inch = 25 feet) were prepared of stream sections A and B. Stream bottom was classified as sand, silt, or gravel; all pools were drawn to scale and their maximum depths were recorded; amounts and locations of permanent bank cover (defined as at least 12 inches of water depth beneath at least 6 inches of overhanging cover) were recorded; average cross-sectional

A major spawning area in section A of Lawrence Creek. A luxuriant growth of water cress provides excellent habitat for young trout.

The upper half of section B meanders through a marsh meadow. The riffle portion of section B, like A above, provides several hundred yards of clean gravel, moderate water depth, moderate velocity and numerous feeder springs.

Below section B, the stream meanders through a second marsh meadow area which includes most of stream sections C and D. Here the width increases, and long sandy flats are interspersed between deep holes on the bends.



depth of the stream channel was determined at 20-foot intervals. Bottom types, pools, cover, and depth were recorded in the spring before streamflow was confined by flourishing aquatic vegetation. Separate maps were prepared for each numbered electrofishing station of approximately 100 yards within each section. A reproduction of one of these maps is included as Figure 23, Appendix. Permanent bench marks, consisting of numbered metal fence posts were erected to provide fixed points for comparative resurveys during 1966-67.

Physical dimensions of the four stream sections based on the most recent data are summarized in Table 1. Data on bottom types, pools, and permanent bank cover are also included for sections A and B. Similar empirical data are not presently available for sections C and D. In general terms, C and D both contain more deep pools and probably more permanent bank cover than A and B. Gradient of C and D is lower. There are many long sandy flats and thicker accumulations of silt, but the amount of exposed gravel is much less. Dimensions of all sections were determined by taped measurements in 1955. Only the dimensions of A and B were revised following the precise mapping done in 1963. The planimetered acreage of section A based on the 1963 maps was 88% greater than the 1955 estimate (3.81 vs. 2.03 acres) and the surface area of section B was increased by 38% (from 2.28 to 3.15 acres) following the 1963 survey.

Stream temperature has been monitored continuously at two sites since 1956. One thermograph recorder is located at the A-B boundary. The other is two miles downstream in section D. Streamflow has been automatically recorded at a site near the C-D boundary since 1960, and weekly staff gauge readings have been made at the A-B boundary bridge and at the outlet since 1955.

Both the temperature regime and flow of Lawrence Creek appear to be quite stable from year to year. Undisturbed natural vegetation over most of the watershed reduces direct runoff to the stream and flood stages are of short duration in comparison to conditions on many other trout streams in central Wisconsin (Fig. 1). It is common knowledge among local anglers that Lawrence Creek is relatively clear-flowing when other nearby streams are too flooded and turbid to be fished. The large deep aquifer supplying Lawrence Creek through a series of scenic springs throughout its length undoubtedly contributes to its relatively high stability in flow and temperature from year to year (see Tables 19 and 20, Appendix).

Annual water temperature normally ranges from 32°F, recorded 5-10 days each winter, to about 75°F, recorded 1-3 days each summer. Maximum water temperature usually exceeds 60° about 25% of the days, exceeds 55° about 50% of the days and exceeds 45° about 75% of the days each year. Weekly means range from about 35° to 65° annually (Fig. 2). Comparisons of temperature data from the two recording sites indicate differences of about 2° in monthly means. The lower portion of the stream is slightly colder in the winter and slightly warmer in the summer.

At the junction of the two main tributaries, baseflow is approximately 3.5 c.f.s. Volume of flow increases to about 10 c.f.s. at the A-B boundary bridge, to 16 c.f.s. at the C-D water level recorder site, and to 20 c.f.s. at the mouth. A typical annual summary of monthly mean streamflows and monthly extremes based on continuous flow records at the C-D recorder site is illustrated in Figure 3. Streamflow ranged from 15 c.f.s. in July to 35 c.f.s. in May. Monthly mean flows covered a range of only 16.8 - 18.8 c.f.s. for December and June, respectively.

TABLE 1

Physical Characteristics of the Four Study Sections of Lawrence Creek Labeled A Through D Proceeding Downstream

Item		Section of Stream			
	A	B	C	D	Total
Length in feet	5631	4525	3881	3713	17750
Average width in feet	23	24	26	33	
Area in acres	3.81	3.15	2.29	2.80	12.05
Percent of stream bottom composed of:					
sand	48.8	50.8			
silt	46.7	37.1			
gravel	4.5	11.8			
Number of pools*	188	275			
Average pool depth in inches	17.3	17.6			
Percent of bottom in pools	4.4	7.8			
Permanent bank cover in feet	719	750			

* Pools were defined as depressions in the stream bottom wherever there was an abrupt change in bottom slope.

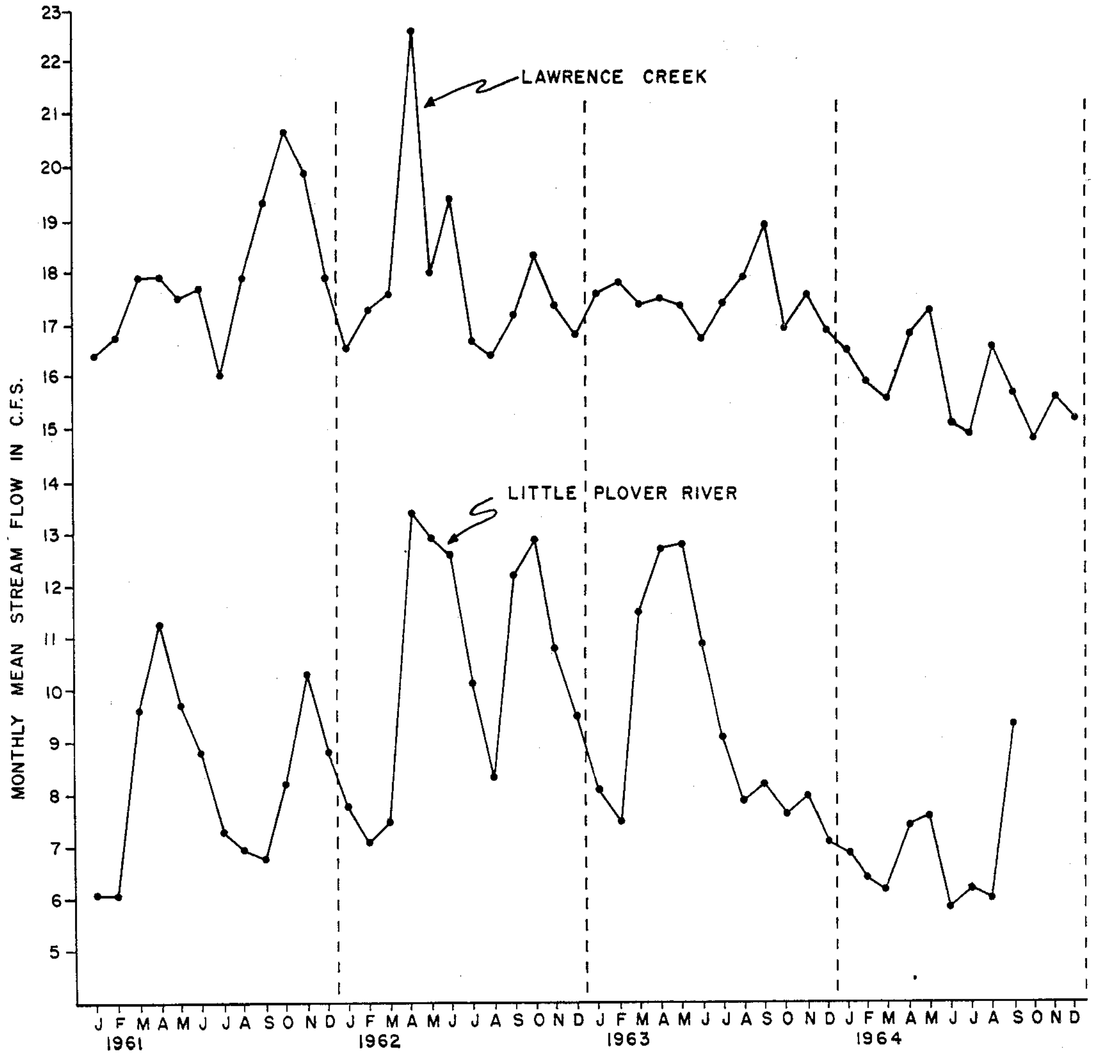


Figure 1. Comparisons of monthly mean streamflow of Lawrence Creek and Little Plover River, a brook trout stream of the same length located 50 miles north of Lawrence Creek.

Chemical analyses of water samples taken from midstream in March, 1963, before the spring thaw, yielded these results:

Total Alkalinity ($CaCO_3$)	162	ppm
Phosphate as P	0.020	ppm
Nitrate Nitrogen	1.80	ppm
Calcium Ca^{++}	43.5	ppm
Magnesium Mg^{++}	16.0	ppm
Sodium Na^{+}	1.40	ppm
Potassium K^{+}	.74	ppm
Sulfate $SO_4 =$	1.0	ppm
Iron Fe^{++}	Trace >0.01	ppm
pH	8.0	ppm
Specific conductance at 25° C.	272.8	

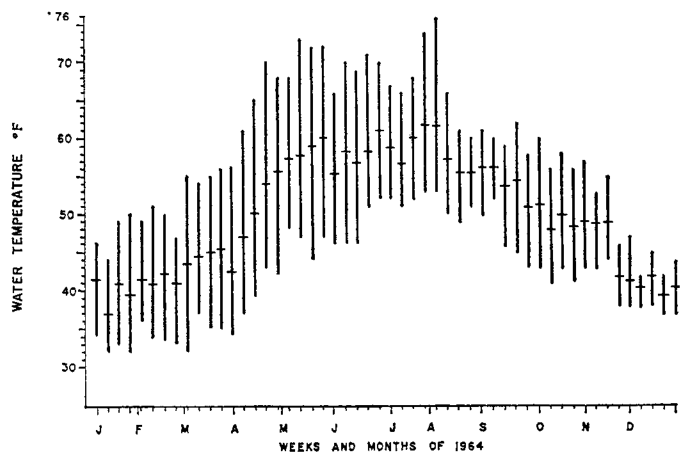


Figure 2. Weekly range and weekly mean water temperature of Lawrence Creek at the section A-B boundary during 1964. Weekly means indicated by the cross-bars are averages of 7 daily means.

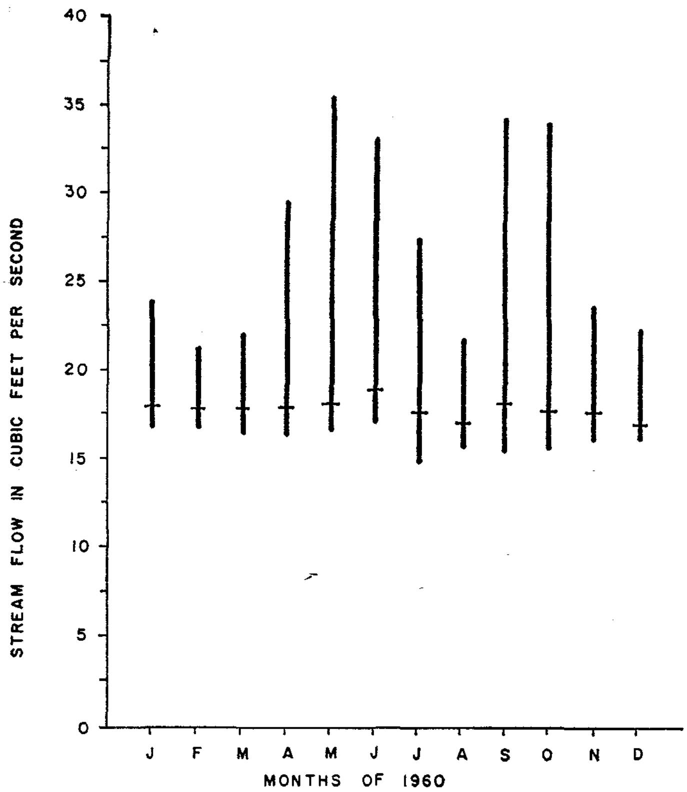


Figure 3. Monthly range and monthly mean streamflow of Lawrence Creek at the section C recorder site during 1960. Monthly means indicated by the cross-bars are averages of daily means for the month.

METHODS

Population Size, Growth and Production

Production of brook trout in Lawrence Creek was calculated as the product of the average biomass and the instantaneous rate of growth (g) for each age group each month. Average monthly biomass represented the arithmetic mean of biomass at the beginning and end of each month. Biomass at the beginning of the month represented the product of the number of trout of each age and the average weight of an individual fish of that age.

Population size at the beginning of each month (beyond the 6th month of life) was determined graphically by plotting straight line interpolations between three fixed point estimates within the year and one point from the year before and the year after. These point estimates represented standing crops of trout present at the time of the annual April, June, and September population estimates. Population estimate data, based on two electrofishing runs through the entire stream, were summarized by age group and inch-group within each of the four experimental sections (A-D). Since 1959, age structure calculations have been based on frequency distributions of marked, known-age trout within each inch group. During 1955-58, scale samples were collected to augment data on known-age trout during the time a predominantly known-age population was being established. As a part of each June population estimate beginning in 1959, permanent marks were applied to all unmarked young-of-the-year captured on both electrofishing runs. Markings designated the year of hatching and the section of capture. Unmarked young-of-the-year trout captured during September population estimates that had escaped capture in June were also marked. As a result of these biannual marking operations, at least 75% of the 1959-65 year classes consisted of marked individuals by the end of their tenth month of life. Electrofishing efficiencies on both marking and recapture runs were normally so high in Lawrence Creek that 95% confidence limits for population estimates usually differed by less than 5% from the point estimates for numbers of age I and age II trout present within each section, by less than 5% for the number of age 0 trout present in sections A and B, and by less than 10% for the number of age 0 trout present in sections C and D. As an example, Table 21 in the Appendix provides a summary of the number of trout of each age estimated to be present in each stream section in April and September, 1963 and the 95% confidence limits expressed as a percentage (plus or minus) of these point estimates. Additional descriptions of the routine population estimate procedures used at Lawrence Creek have been published by McFadden (1961) and Hunt, Brynildson and McFadden (1962).

Growth data were collected monthly during 1963. A 230-volt D.C. electrofishing unit was used to collect monthly samples of trout from the same 300-yard stretches of sections A and B. Length-weight data were taken in the field from marked, known-age trout only, sex was recorded when possible, and the trout were released. Point estimates of mean lengths and weights were plotted on calendar paper for each month. Lengths and weights as of the first day of each month were read from straight line plots connecting sampling points within the month and point estimates for the previous month. Since trout of age-group IV were not consistently present in the 300-yard sampling zones, monthly increments of growth were estimated from data gathered throughout each section during several April, June, and September population estimates.

Monthly increments of growth in other years were derived from free-hand curves anchored by the 3 point estimates of growth during the year. Throughout the study growth data were collected during each April, June, and September population estimate. The 1963 growth curves determined for each age group on the basis of 12-point estimates were used as guides to construct growth curves for other years of less intensive sampling.

Estimates of population size and growth of age-group 0 brook trout required additional calculations for the first 5 months of life since this age group was not included in population estimates until June. Year class density at emergence was based on an estimate of egg production by the parent spawning stock and annual sampling of trout redds to determine success of embryonic development. The product of potential egg deposition and percentage of viable eggs or sac-fry provided an estimate of the number of fry emerging. Although a few fry are known to emerge as early as January 1 in Lawrence Creek, peak emergence is normally closer to February 1. This date was used as a standard in all production calculations each year. Consequently annual production for age group 0 represents the sum of only 11 monthly increments. Numbers of age 0 brook trout for the months of March, April, May and June were estimated graphically by extending a curved line (using a French curve) backward from the fixed mid-September estimate, through the fixed mid-June estimate to the speculative estimate at emergence. Chapman (1965) relied upon approximately the same technique to estimate densities of coho salmon during their first few months of life.

Increments of growth in length and weight of age 0 brook trout during the February-June period were determined empirically from samples collected monthly during 1963. Fry were collected with a hand-net or electric shocker and returned to the laboratory. A triple-beam balance was used to determine the aggregate weight (to 0.1 grams) of the live sample of fry and an average weight was computed. Mean length (to 0.1 inches) was based on measurements of individual fry. Growth increments of age 0 brook trout for February, March and April, as determined in 1963, were used for these three months for all years. Between-year variations in monthly growth entered the calculations from May through December.

A computer program was employed to carry out final mathematical calculations of production. Basic data fed into the computer program included numbers of trout of each age present and their mean individual weights at the beginning of each month. Calculations followed the methods outlined by Ricker (1958). Final print-out sheets contained monthly tabulations of instantaneous growth rates (g), instantaneous mortality rates (r), instantaneous rates of increase or decrease (k), biomass in grams on the first of the month, average monthly biomass in grams and production in grams and pounds. Also included were the original entries of population size and mean individual weight at the beginning of each time interval.

Facsimiles of the program data form and finished print-out form are included as Figures 24 and 25, (Appendix).

Habitat alteration to improve the trout population of Lawrence Creek was carried out during 1964. Installation of overhanging bank-cover devices and current deflectors throughout section A, the upper mile of Lawrence Creek, was undertaken intensively to (1) narrow and deepen the stream channel, (2) provide increased year-round cover for trout, and (3) increase the trout food supply by exposing sand-covered gravel and by providing more surface area of logs and stones for attachment of aquatic organisms. The plan to evaluate the effectiveness of this development consists of comparing and interrelating changes in (1) the trout population and its food supply, (2) physical features of the stream, and (3) the angler harvest. The plan also provides for monitoring these factors in an adjacent undeveloped section of stream to provide a baseline reference throughout the study. Consequently, when the trout production program was designed it included measures of production only within section A, the development zone, and section B, the adjacent reference zone.

Therefore, within the following units of this bulletin dealing with results and a discussion of their implications, emphasis will be placed first upon angler harvest and production in sections A and B, and second upon harvest and production in the entire stream by including less precise estimates of production in sections C and D.

Estimates of production in sections C and D were obtained in the following manner:

1. A ratio of mean annual biomass of trout to annual production was calculated separately for each age group in section A and in section B each year. Mean biomass was based on standing crops determined by population estimates in April, June, and September. Annual production for A and B was derived from the computer program calculations.
2. Mean standing crops of trout of each age group in sections C and D were derived from April, June, and September population estimate data.
3. Comparisons of growth of trout within sections indicated that growth in section C was similar to growth in section B, and growth in section D was similar to growth in section A. Therefore, age group ratios of mean annual standing crops to annual production in section A were applied to mean annual standing crops of trout in section D to yield estimates of annual production by each age group in section D.
4. Similarly, standing crop — production ratios for section B were applied to standing crops of trout present in section C to derive estimates of annual production by each age group in section C.

Angler Harvest

Angler harvest data were obtained by the same procedure in all stream sections for all years. A compulsory creel census has been conducted at Lawrence Creek since establishment of a year-round trout research station there in 1955. Anglers were required to obtain a free permit at the checking station on the stream before each fishing trip. Permits were returned and catches were presented for examination before anglers left the area. Anglers could choose any stream section, but permits were issued for only one section per angling trip. Creel census data included the amount of angling effort and composition of the catch from each section each fishing season. Length, weight, sex, and age data were recorded for all trout in the catch.

Lawrence Creek is the only trout stream in Wisconsin where a compulsory creel census is operative. The system is used to more efficiently evaluate various experimental fishing regulations, a fundamental research objective at Lawrence Creek.

Effects of various size limits, bag limits, and lure restrictions on this brook trout fishery have been reported by McFadden (1956), McFadden (1961), Hunt et al. (1962), and Hunt (1964).

RESULTS

Data summarizing seasonal and annual trends of growth and density of brook trout in Lawrence Creek are presented in some detail in order to (1) characterize the quality of the data entering the production calculations, and (2) describe what is known about growth and density of a brook trout population for its intrinsic merit.

Standing Crops

Monthly standing crops of brook trout in section A ranged from 39.0 pounds per acre in January to 53.4 pounds per acre in July, 1963. In section B standing crops ranged from 42.5 pounds per acre in April to 76.0 pounds per acre in October. The average standing crop for the year was 45.7 pounds per acre in A and 57.5 pounds per acre in B.

Age structure of the average standing crop in sections A and B for 1963 is summarized in Table 2.

The data in Table 2 reveal that the 26% higher average standing crop in section B was largely due to its nearly 100% greater average density of age 0 trout. Densities of other age groups were nearly the same in the two sections.

Section A—1963

The standing crop of age group 0 brook trout in section A declined from about 4.5 pounds per acre at emergence to 0.7 pounds per acre in mid-March (Fig. 4). Thereafter its biomass increased each

TABLE 2

Average Standing Crop of Brook Trout Per Acre in Sections A and B During 1963 Summarized by Age Group Within Sections

Age Group	Avg. Pounds of Trout/Acre Section A	Section B
0	10.0	19.5
I	20.3	22.3
II	14.3	14.7
III	1.0	0.9
IV	0.1	0.1
Sum: 0-IV	45.7	57.5

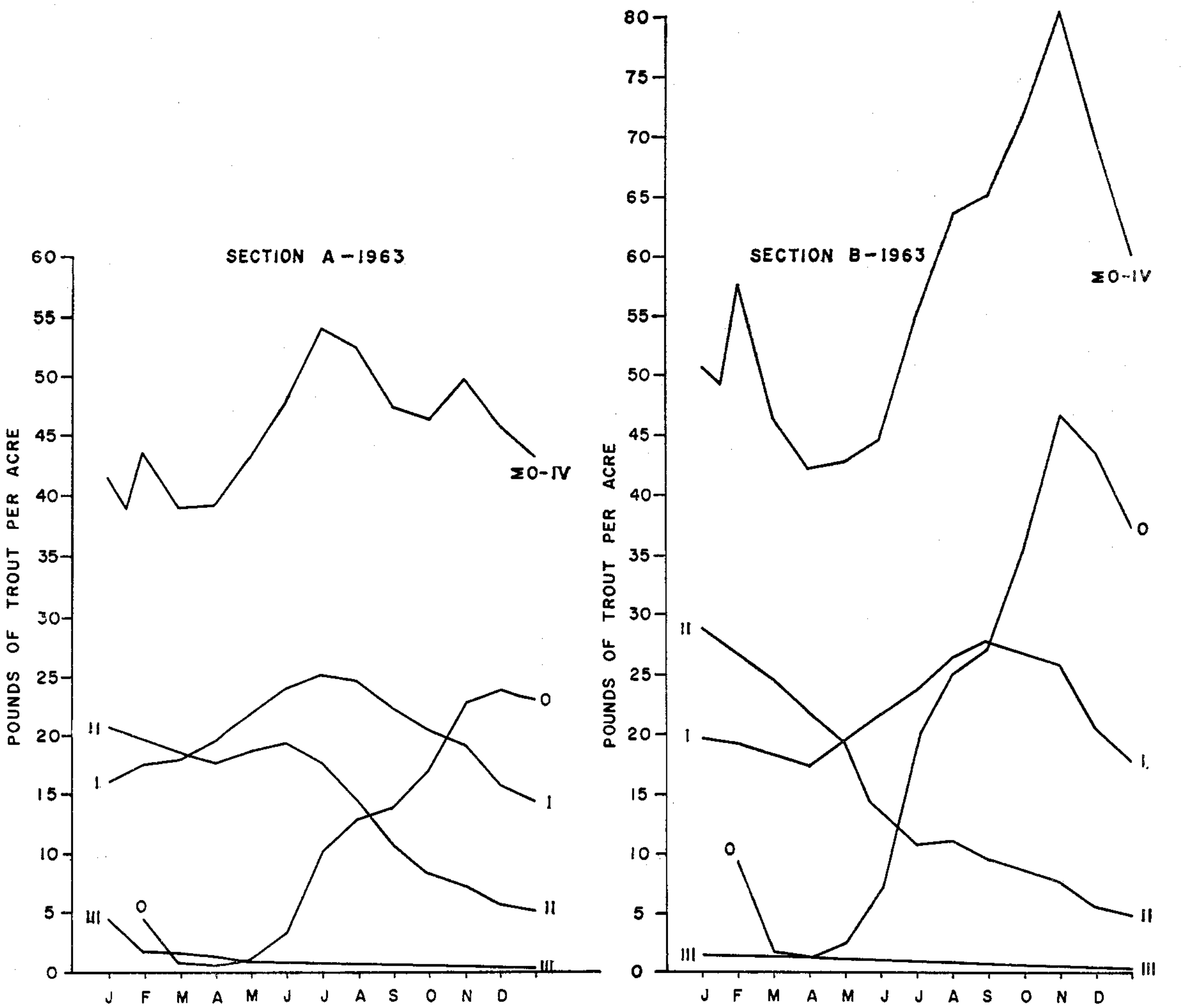


Figure 4. Standing crops of brook trout, expressed as pounds per acre, in sections A and B during 1963.

month to a peak of 23.4 pounds per acre on December 1. By the year's end biomass had declined somewhat to 23.1 pounds per acre. Weight of age group I trout in A increased from 16.1 pounds per acre in January to 24.8 pounds per acre in mid-July, the highest monthly density attained by any age-group in the section. Thereafter its biomass steadily declined to a level of 14.5 pounds per acre by the end of December. The age group II stock began the year at its maximum biomass of 20.7 pounds per acre, declined somewhat during February and March, increased slightly during April and May, and then declined steadily to only 5.3 pounds per acre in December. The age group III stock contributed little to total biomass. Its weight decreased each month from a January high of 4.5 pounds per acre to a December low of 0.3 pounds per acre. The sparse age IV stock in A was eliminated in July when the last survivor was creeled.

The biomass of all brook trout in A declined during January, was temporarily bolstered by recruitment of the emerging 1963 year class on February 1, but abruptly declined again to its lowest level of 39.0 pounds per acre by the end of February. The biomass increased steadily during the March-July period (largely as a result of growth within the age 0 and I stocks) to reach its peak biomass of 53.4 pounds per acre in mid-July. Biomass declined during August and September, rose slightly during October, then fell off again to a level of 43.2 pounds per acre by the end of the year. During the last half of 1963 the rapid increase in weight of the age 0 stock partially offset but could not surmount the declining biomass among the older age groups (Fig. 4).

Section B—1963

Within section B trends of age group density from month to month were similar to those occurring in section A, but densities of the various age groups in B relative to each other were quite dissimilar to the pattern noted in A. In section B it was the age 0 stock not the age I stock that accounted for the highest monthly standing crop, and maximum weight of the age II stock in B also exceeded the maximum weight of the age I stock. The biomass of brook trout in B also continued to increase during the July-September period in contrast to the declining biomass characteristic of section A during this period.

From an initial weight of 9.5 pounds per acre at emergence, weight of the age 0 stock in section B decreased during February and March to only 1.2 pounds per acre by April 1, but during the next six months its biomass increased dramatically. Peak biomass of 46.5 pounds per acre, a value greater than the average weight of all age groups in section A, was reached by November 1. Throughout 1963 biomass of age 0 trout was always greater in B than in A.

Biomass of age I trout in B peaked at 27.3 pounds per acre on September 1 and then declined to 18.0 pounds per acre by the end of the year. During 8 of the 12 months biomass of age II trout in B exceeded that in section A. Biomasses of age III and IV trout in section B were much like those in section A.

Standing crops of brook trout were greater in B than in A during all months except May and part of June, and the much greater accumulation of flesh within the age 0 stock in B during the last half of 1963 is reflected by the strongly skewed biomass curve for this section in comparison to the plot of monthly biomasses in section A during 1963 (Fig. 4).

Biomass data used to construct Figure 4 were extracted from Tables 21 and 22, Appendix. Numerical densities of the various age groups of brook trout in A and B during 1963 are also summarized in Tables 21 and 22, Appendix, and illustrated in Figure 5.

Sections A and B—1960-64

Standing crops of brook trout in pounds per acre were higher in section B than in section A during 58 of 60 consecutive months. Section A had slightly higher standing crops than section B only in May and June, 1963 (Fig. 6). Maximum monthly biomass per year in A was accounted for by age I trout in 4 of the 5 years, the exception being 1961 when weight of age 0 trout was greater. In section B the highest standing crop was attained by age 0 trout during 1961 and 1963 and by age I trout the other 3 years. Also, as noted earlier, maximum weight of age II trout also exceeded that of age I trout during 1963.

Except for the fact that monthly standing crops in B were consistently higher, seasonal trends were very similar in A and B for all years except 1963. Perhaps if data for other years had been as complete as those used to calculate monthly standing crops in 1963, more variation between sections might have been detected in other years, too. Or, 1963 may have been exceptional.

The average standing crop of trout in section A was equal to 68.3 pounds per acre during 1964. Monthly averages for other years amounted to 62.0, 54.1, 50.8 and 44.5 pounds per acre. In section B, standing crops calculated monthly were highest on the average during 1961, amounting to 94.1 pounds per acre. Monthly standing crops in other years averaged 90.7, 80.2 and 70.9 pounds per acre (Table 3).

In both sections biomass normally declined from October or November of one year to May or June of the following year, after which biomass again began to build throughout the summer and autumn months to a peak that was terminated by the onset of spawning (Fig. 6).

TABLE 3

Maximum Monthly Biomass of Brook Trout of Age Groups 0-IV in Sections A and B of Lawrence Creek Each Year During the 1960-64 Period

		Maximum Biomass in Pounds Per Acre					
Year	Section	0	I	II	III	IV	Sum 0-IV
1960	A*	20.4	34.3	5.3	4.4	0.9	44.5
	B**	30.3	58.8	7.1	4.7	0.4	70.9
1961	A	32.0	30.8	8.0	0.2	0.2	62.0
	B	59.3	36.6	17.4	0.3	0.1	94.1
1962	A	17.2	33.4	16.6	2.1	0.1	50.8
	B	23.8	47.9	21.1	2.0	0.0	70.9
1963	A	23.8	25.0	20.7	4.5	0.2	54.1
	B	46.5	27.8	28.9	1.6	0.3	80.2
1964	A	24.4	41.7	15.9	5.4	0.3	68.3
	B	42.5	50.4	18.6	4.8	0.3	90.7
Mean biomass per month for the 60-month period:							
	A	9.5	25.3	7.8	1.4	0.1	44.1
	B	16.5	33.0	9.2	1.2	0.1	60.0

*A — 3.81 surface acres
**B — 3.15 surface acres

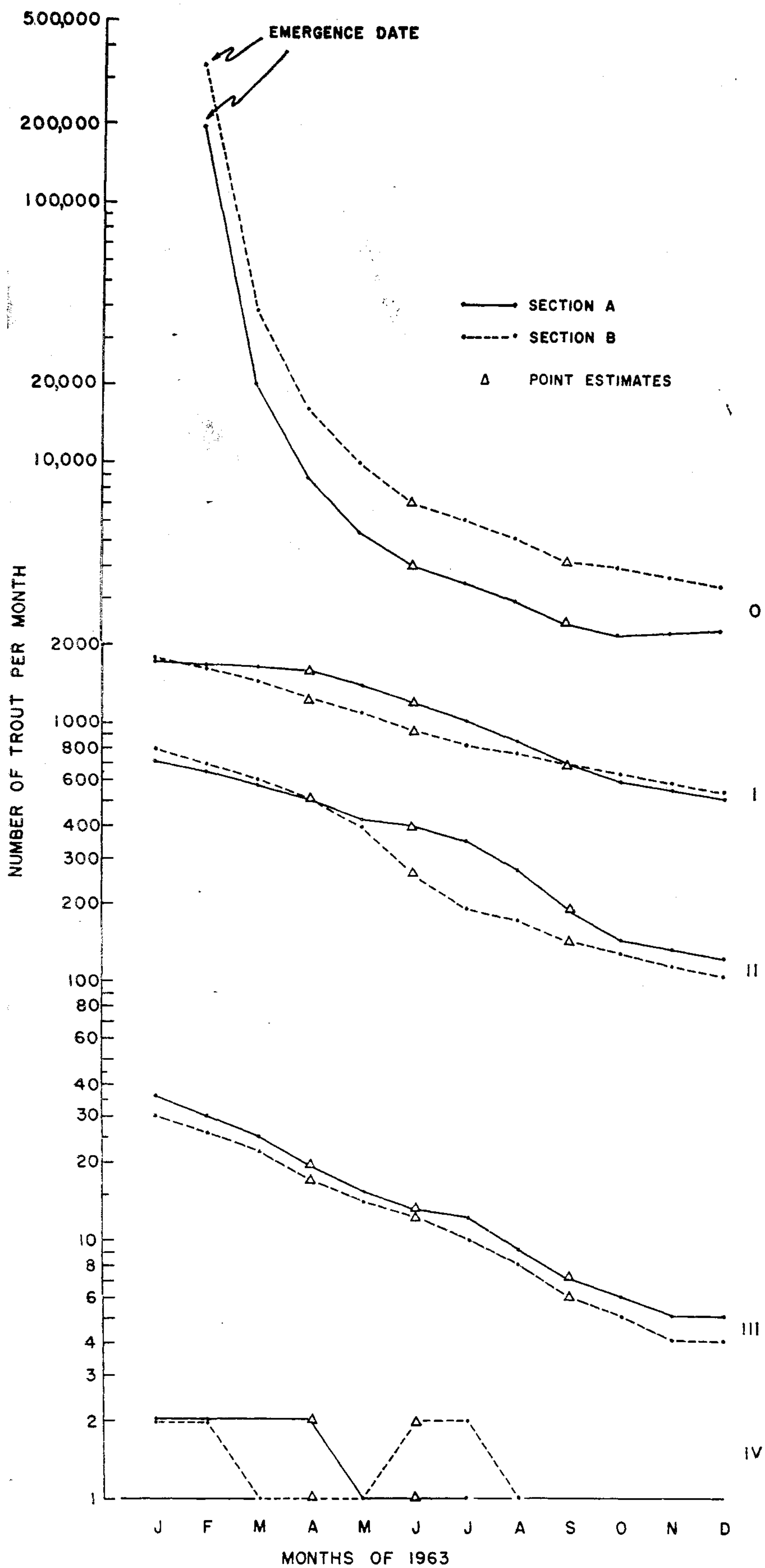


Figure 5. Numbers of age groups 0 through IV brook trout present on the first day of each month in sections A and B during 1963.

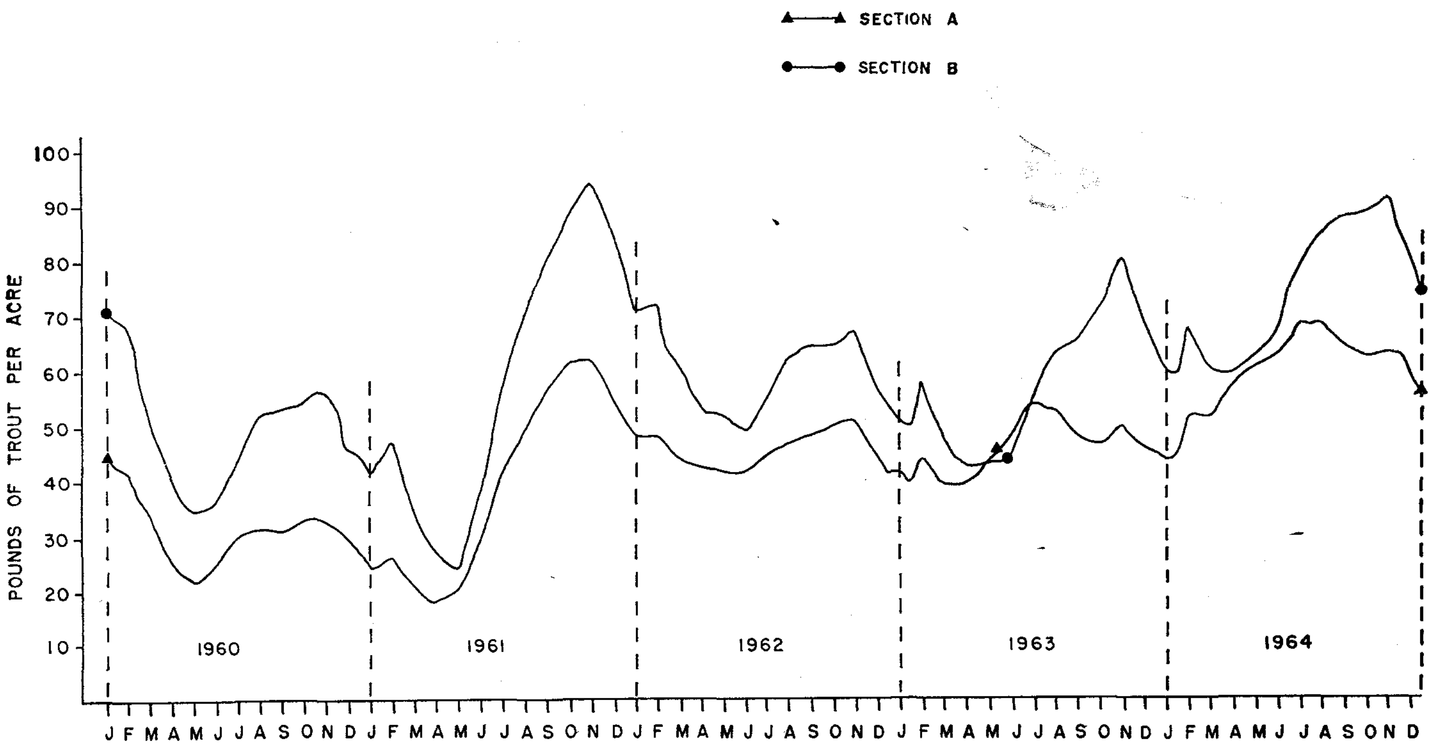


Figure 6. Monthly standing crops of brook trout in sections A and B during 1960-64, expressed as pounds of trout per acre.

GROWTH

Monthly growth in length and weight of age groups 0 through IV brook trout in sections A and B is illustrated in Figures 7 and 8. Calculated lengths and weights are positioned at the first day of each month except for final points in each series which represent lengths and weights on December 31. In section A monthly weights were based on samples averaging 95, 110, 52, and 10 for age groups 0 through III respectively. Numbers of trout of ages 0-III weighed monthly in B averaged 110, 113, 41, and 5.

Numbers of trout measured monthly for length-age data were sometimes higher but never lower than numbers weighed.

Growth in length was very similar in both sections for any one age group as was monthly growth in weight for age groups 0 and I. However during most months growth in length and weight did appear to be slightly better in A than in B. For age 0 stocks this divergence was noted in July and continued through October. Mean weight of age I trout in A tended to be higher than in B from February through July; from April onward mean weight of the age II stock was consistently higher in A than in B; during the first 4 months average weights of age III trout in A were 10-15 grams higher than in B.

Section A—1963

Age group 0 brook trout averaged 0.6 inches and 0.04 grams at emergence. An increase of at least 0.1 inch was detected in all monthly samples and weight increased each month except during December. Growth was most rapid during May when average length increased by 60 percent (from 1.5 to 2.4 inches) and average weight by 300 percent (from 0.4 to 1.6 grams). On December 31 mean length was 4.7 inches and mean weight was 18 grams.

Age group I brook trout (1962 year class) began the year at an average length of 4.8 inches and an average weight of 16 grams, or 2 grams less than the average weight the 1963 year class had attained by January 1 of its first year of life. At the end of 1963, mean length of age group I trout had increased to 7.1 inches and mean weight to 54 grams. Length increased each month except during December. Weight increased to a peak of 61 grams on November 1, then declined during November and December by 11%. Loss of weight was associated with spawning which normally reaches peak intensity during the first two weeks of November in Lawrence Creek.

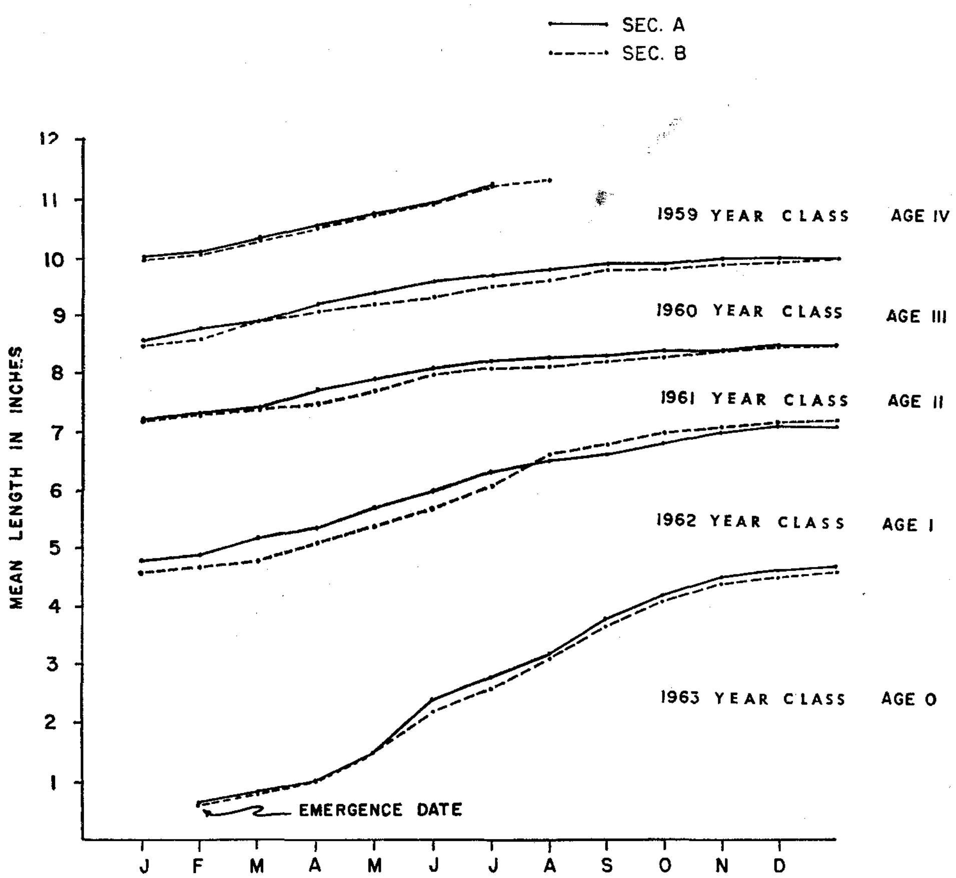


Figure 7. Mean lengths of 5 year classes of brook trout in sections A and B during 1963. Points on the curves are placed at the first day of the month.

Approximately 83% of the age I females spawn for the first time and most age I males are participating for a second time. Growth in length of age I trout during the year averaged 2.3 inches, an annual increment of 48%. Maximum weight of 45.0 grams was reached in late October. Growth during the year represented an increase of 281%.

Mean length of age group II trout increased from 7.2 inches to 8.5 inches during the year, a gain of 18%. Average weight increased by 50 grams to a peak in October of 102 grams, an increment of 102%. Average weight then decreased by 17% during November and December. No change in length was detectable during August, October, and December.

Age group III trout averaged 8.6 inches and 90 grams on January 1. No change in average length was detected after November 1 when it had reached 10.0 inches. By December 31 average weight had declined to 130 grams after reaching a peak of 159 grams on October 1.

Section B—1963

Age group 0 brook trout collected monthly were consistently 0.1-0.2 inch smaller on the average in section A than in section B from May through December. Average lengths of age I brook trout were a little lower in B than in A during the first 6 months but slightly higher during the last 6 months. Trout of age groups II and III tended to be slightly smaller in B than in A in all monthly samples. Weight-age trends in section B followed much the same pattern as the length-age trends with reference to section A, except that weights of age 0 trout were slightly heavier in B than in A. Maximum mean weights attained by age groups 0 through III were 18 grams in December, 64 grams in October, 99 grams in September, and 158 grams in September (Figs. 7 and 8). During the spawning period reductions in average weight amounted to 16% for age I trout, 25% for age II trout, and 11% for the sparse age III stock.

Sections A and B—1960-64

Patterns of growth in weight from month to month for age groups 0-III during 1960-64 are illustrated in Figure 9 for section A and Figure 10 for section B. Points on the growth curves were determined from field data. Such points are positioned at April, June, and September intercepts for all years and at all monthly intercepts for 1963, the year of intensive sampling. Growth of young-of-the-year was assumed to be similar until May each year.

Sectional differences in growth of age 0 trout were minor within years and from year to year during

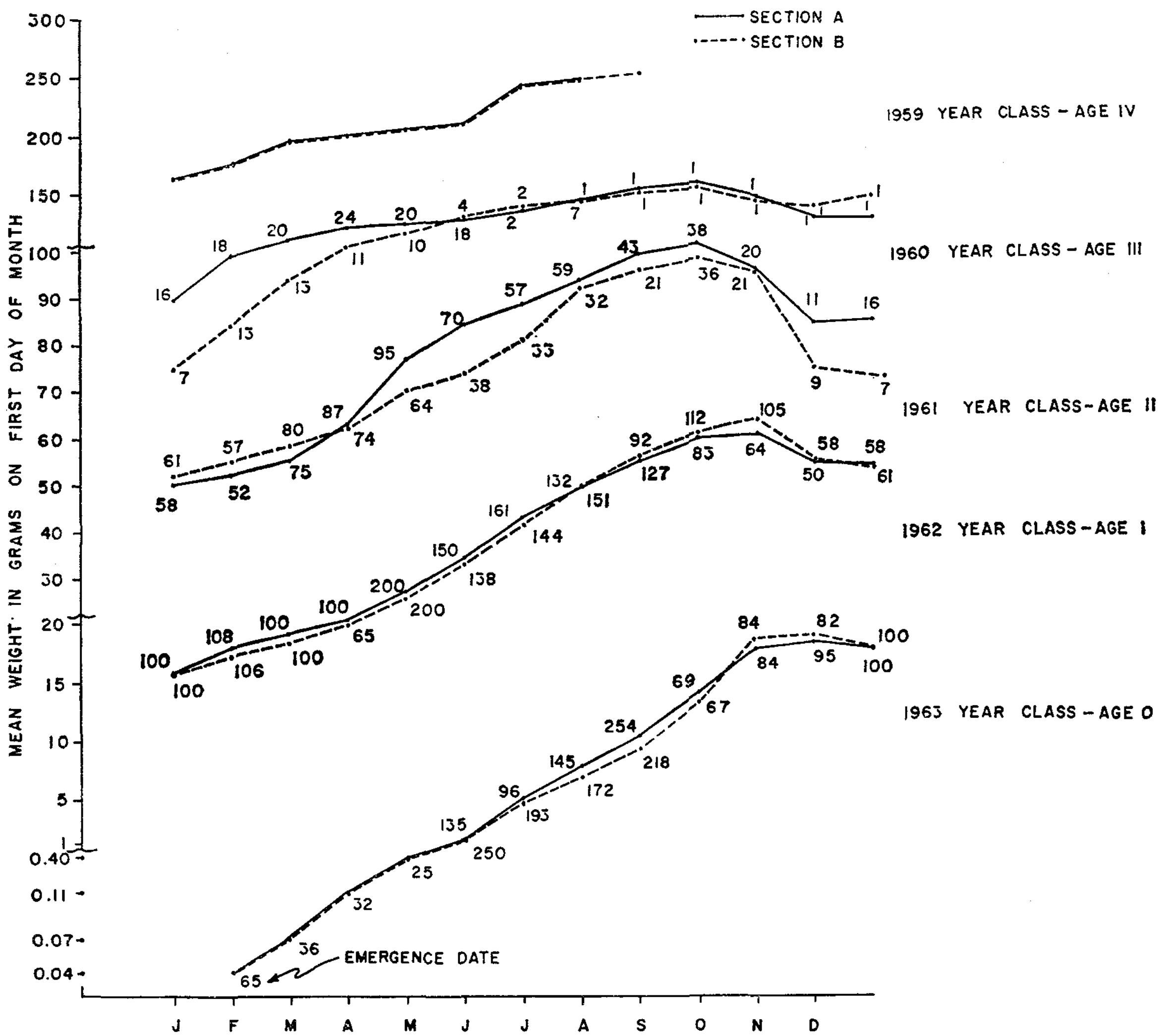


Figure 8. Mean weights of 5 year classes of brook trout in sections A and B during 1963. Monthly sample sizes are indicated along the curves on the first day of the month.

comparable months of life. Growth among older age groups was usually better in A than in B all 5 years. Also obvious is the exceptionally good growth of age groups I and II in both sections during 1961. Age 0 trout also grew well during 1961 but the departure is less apparent. The stock of age III brook trout was too sparse to obtain adequate growth data during 1961. During 1959 and 1964 growth appeared to be generally below average in both sections for all age groups.

PRODUCTION

Production, accumulated production, and standing crops of brook trout expressed in pounds per acre per month, in sections A and B during 1963 are diagrammed in Figure 11. Monthly production according to age group is diagrammed in Figure 12, and monthly instantaneous growth rates by age groups are illustrated in Figure 13.

Production of new body tissue by brook trout in section A averaged 6.0 pounds per acre per month as compared to 8.9 pounds per acre per month in section B. In 8 of 12 months production was higher in B than in A (Fig. 11). In both sections production increased from January through June. In section A production then declined but remained positive through October. During November and December production was negative. In section B production decreased during July and August, increased during September and October and was also negative during November and December. Negative production implies that loss of body weight is greater than elaboration of new tissue during the month. Apparently during the spawning period reduction in body weight

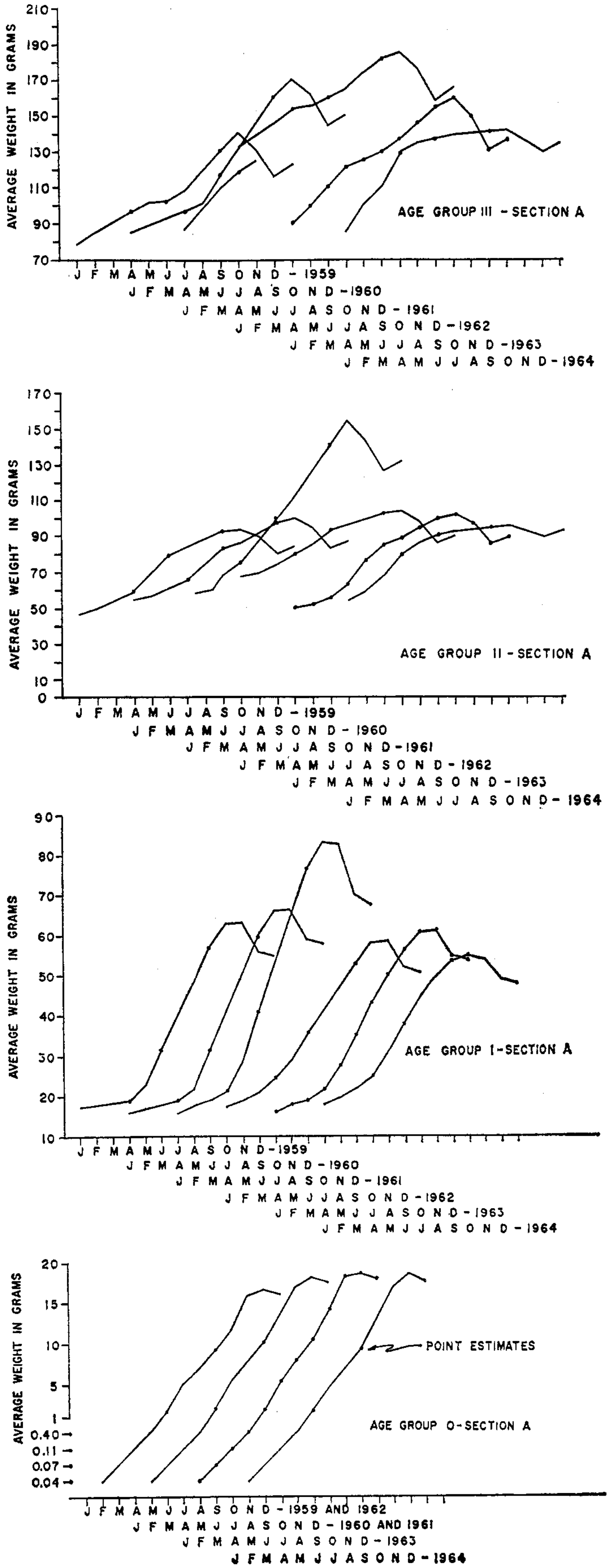


Figure 9. Monthly weights of age groups 0 through III brook trout in section A during 1959-64. Point estimates noted were derived from field data.

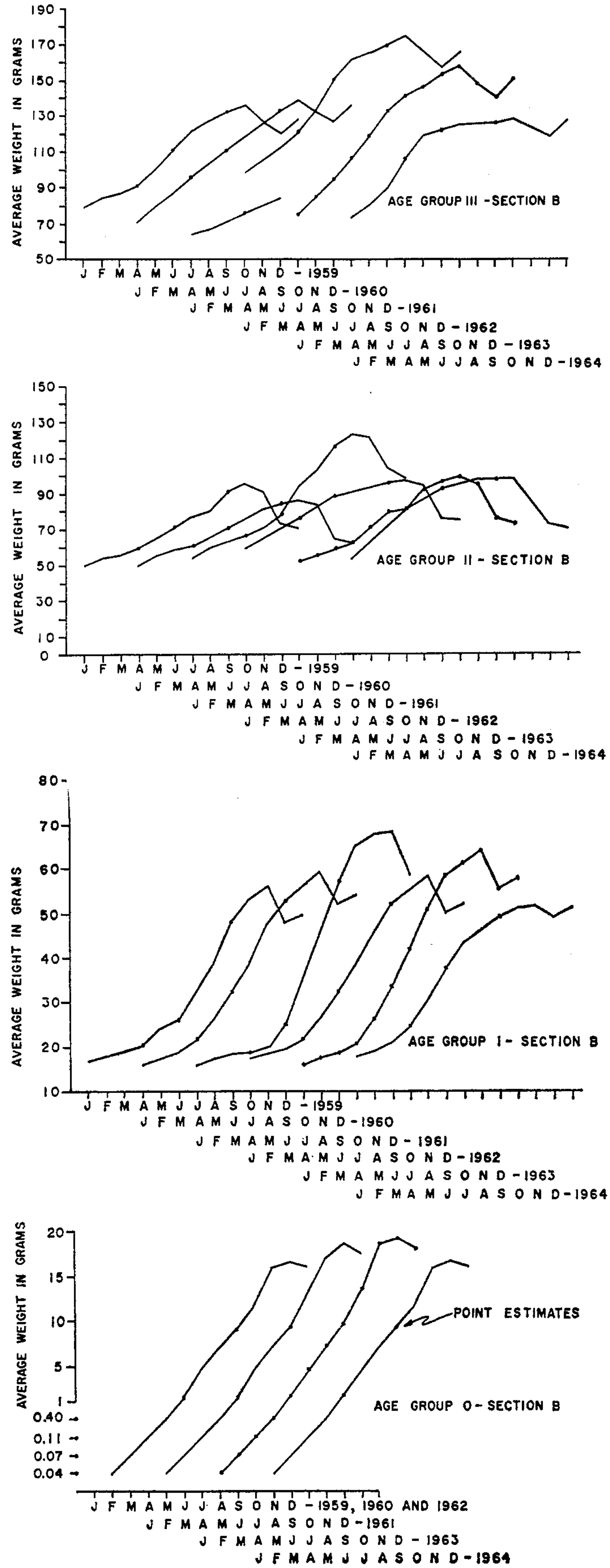


Figure 10. Monthly weights of age groups 0 through III brook trout in section B during 1959-64. Point estimates noted were derived from field data.

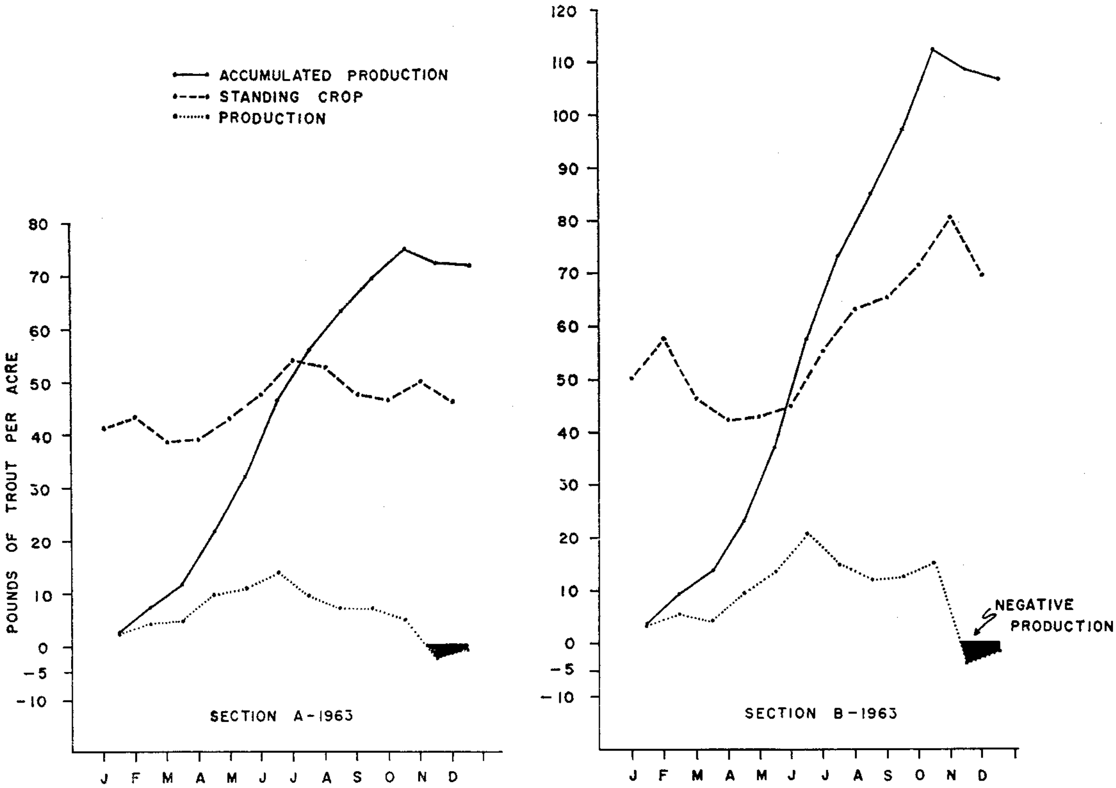


Figure 11. Standing crops of brook trout, expressed as pounds per acre at the beginning of each month, production in pounds per acre during the month, and accumulated production from month to month during 1963 in sections A and B of Lawrence Creek.

through expulsion of reproductive products was greater on the average than production of new fish flesh.

Accumulated production reached a peak value of 74.9 pounds per acre in October in section A after which it declined to 71.8 pounds per acre because of negative production in November and December. In section B accumulated production reached 112.5 pounds per acre in October, a 50.2% higher accumulation than in section A, and then it too declined during November and December to a value of 106.8 pounds per acre by the end of the year. Maximum production per month was 14.1 pounds per acre in A in June and 20.6 pounds per acre in B in June.

Ratios of mean monthly biomass to annual production were 1:1.56 for section A and 1:1.86 for section B. Efficiency of output per producing unit was higher in B than in A.

Section A—1963

Age group 0 trout (1963 year class) accounted for 45.5% of the annual production in A during 1963, or more than any other age group. During February, its first month of life, age group 0 produced 1.5 pounds per acre, but only 0.3 pounds per acre in March. During the next three months, production by age 0 trout increased to 1.1, 3.4 and 8.2 pounds per acre. Production decreased again during July and August to values of 4.7 and 3.8 pounds per acre, then increased to 4.8 and 5.3 pounds per acre in September and October. Production was almost zero during November and negative (-0.9 pounds per acre) during December (Fig. 12). Average monthly production by age 0 trout was 3.0 pounds per acre based on 11 months of life during 1963, or 2.7 pounds per acre on a 12-month basis.

Average production by age group I was 2.3 pounds per acre per month and ranged from -2.0 in December to 5.5 in May. Age group I trout accounted for 37.5% of the annual production by all trout in the section.

Maximum production by age II trout amounted to 3.7 pounds per acre in April. Production was negative during November and December. Production for the year averaged 1.0 pounds per acre per month and this age group accounted for 15.9% of annual production in the section.

Production by age groups III and IV was insignificant, accounting for only 1.1% of annual production in section A.

Average monthly biomass of the various age groups in section A, total production by each age group during the year, and ratios of production to average biomass are summarized in Table 4. These

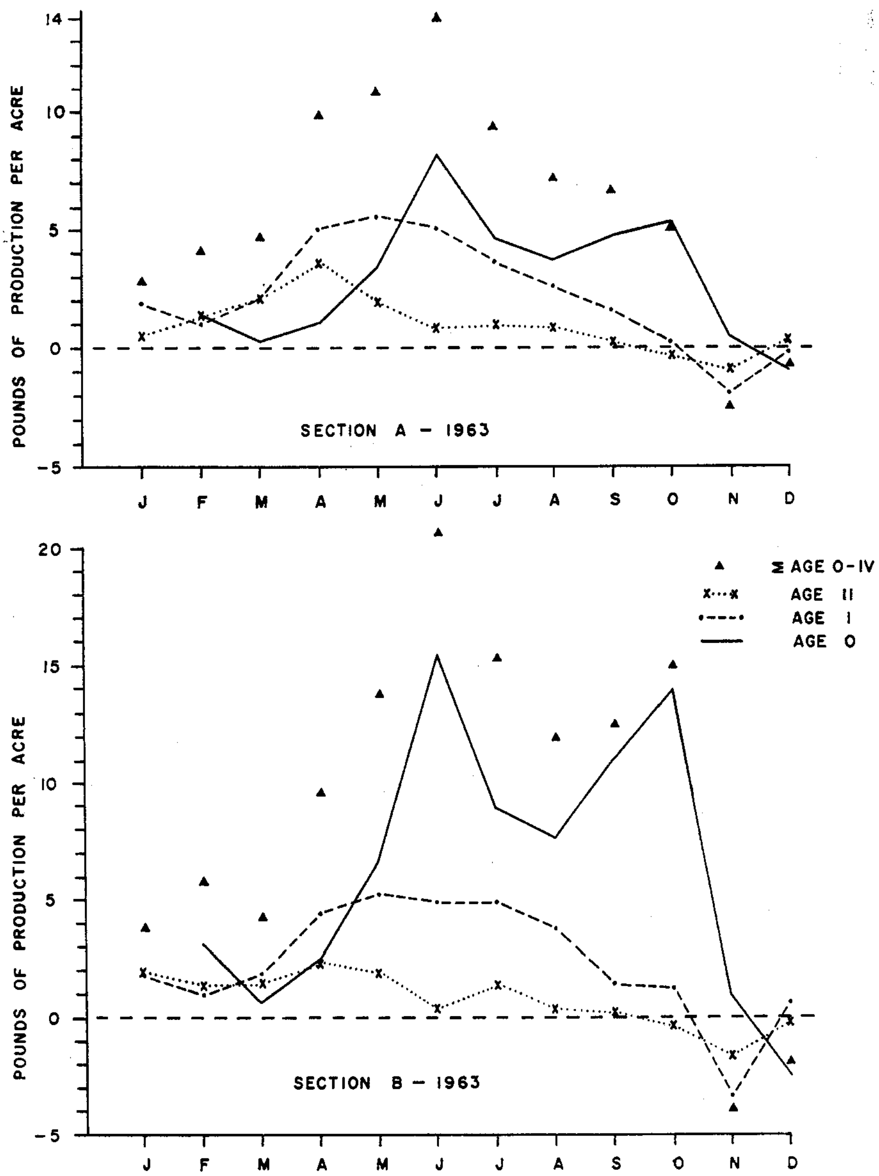


Figure 12. Production by brook trout in sections A and B of Lawrence Creek during 1963, expressed as pounds per acre according to age groups. Monthly production by age groups III and IV was too small to plot but their contributions to total monthly production are included.

data indicate a definite decreasing efficiency in production of new body tissue with increasing age.

Section B—1963

Age-production trends from month to month in section B were very similar to those in section A during 1963, although as noted earlier production was usually greater in B than in A (Fig. 12). For example production by age group 0 trout in B was 109% greater than in A even though monthly trends in production were exactly similar. However, the large quantitative difference in production by the two age group 0 stocks was reflected in the upward surge in standing crops noted in B but not in A during the August-October period (Fig. 11) when production by age I+ trout was declining similarly in both sections (Fig. 12). Declining production of age I+ trout was more than offset in B by the abundant, fast-growing young-of-the-year, but in A there were not enough trout of the youngest age group to maintain the standing crop even though they were growing as well as those in B (Fig. 13). Section B contained 76% more age 0 trout than A on September 1 (4,120 vs. 2,340) and 83% more on October 1 (3,850 vs. 2,100) whereas the numbers of age I+ trout were nearly the same in both sections (Tables 22 and 23, Appendix).

Production per month by age group 0 was greater in B than in A during the first 10 months of life but negative production, or loss of body weight on the average, was also greater in B during December. During June production by age 0 trout in B (15.4 pounds per acre) was 9% greater than the combined production of all age groups in A. Production per

TABLE 4

Average Monthly Biomass, Annual Production, and Ratios of Average Biomass to Annual Production for Each Age Group of Brook Trout in Section A During 1963

Age Group	Average Standing Crop in Pounds Per Acre	Annual Production in Pounds Per Acre	Ratio of Standing Crop to Production
0	10.1	32.7	1:3.2
I	20.3	27.0	1:1.3
II	15.0	11.4	1:0.8
III	1.2	0.7	1:0.6
IV	0.2	0.1	1:0.5

month by age I trout in B exceeded that in A only 4 of 12 months. Negative production was characteristic of the age I stock during November and December in A, but only during November in B. Production by age II trout was greater in B than in A only 3 months, and negative production occurred 2 months in A and 3 months in B. Nevertheless, average production per month was greater in B than in A for all age groups except age II during 1963.

Sections A and B—1960-64

Production by all brook trout in sections A and B during each of 60 consecutive months is shown in Figure 14 as the lower curve for each section. The second curve for each section represents the standing crop present on the first day of each month.

During the March-June period each year, increasing production was clearly reflected in the rapid build-up of standing crops. Declining standing crops and declining production also paralleled each other each year during November and December. During other periods, however, standing crop and production trends were often opposite, and especially in section B where the standing crop during the first few months each year tended to decrease despite an increasing production rate.

In section A production was negative during 10 of the 60 months (in November and December all 5 years). In section B production was negative 8 of 60 months.

Production was greater during October than during September in 4 of 5 years in section B but not in section A where production in October was always less than during September. The greater density of age 0 trout in B was again the chief cause for the difference in these monthly production trends.

Maximum production per month occurred in June in both sections all 5 years, and was always greater in B than in A by 23-57% as the selected data summarized in Table 5 indicate.

Annual production in section A ranged from 58.0 pounds per acre in 1960 to 86.2 pounds per acre in 1964. The 5-year average was 70.3 pounds per acre of production per year. In section B, annual produc-

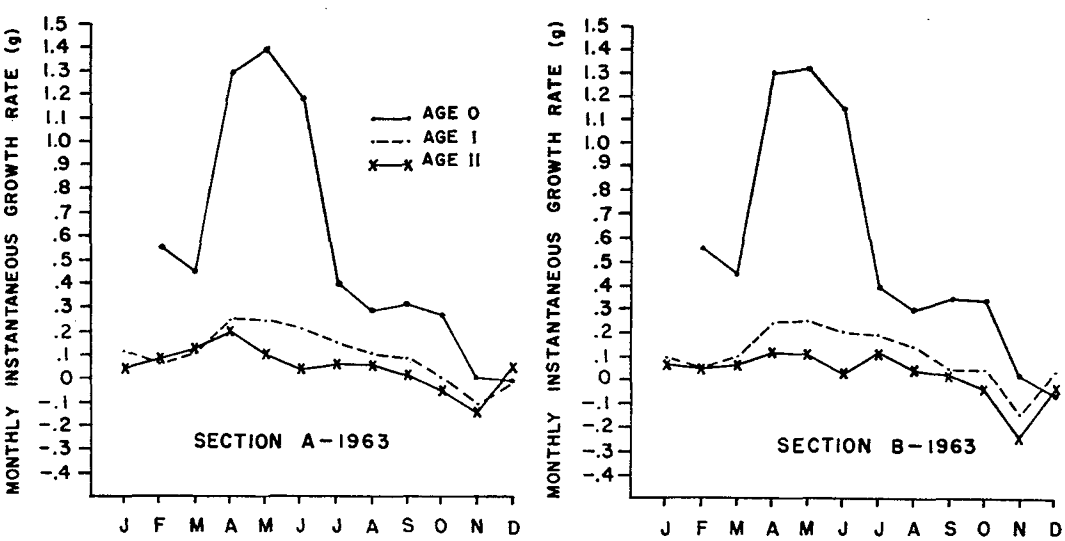


Figure 13. Monthly instantaneous growth rates of age groups 0, I and II brook trout in sections A and B of Lawrence Creek during 1963. Growth rates of age groups III and IV resembled age group II.

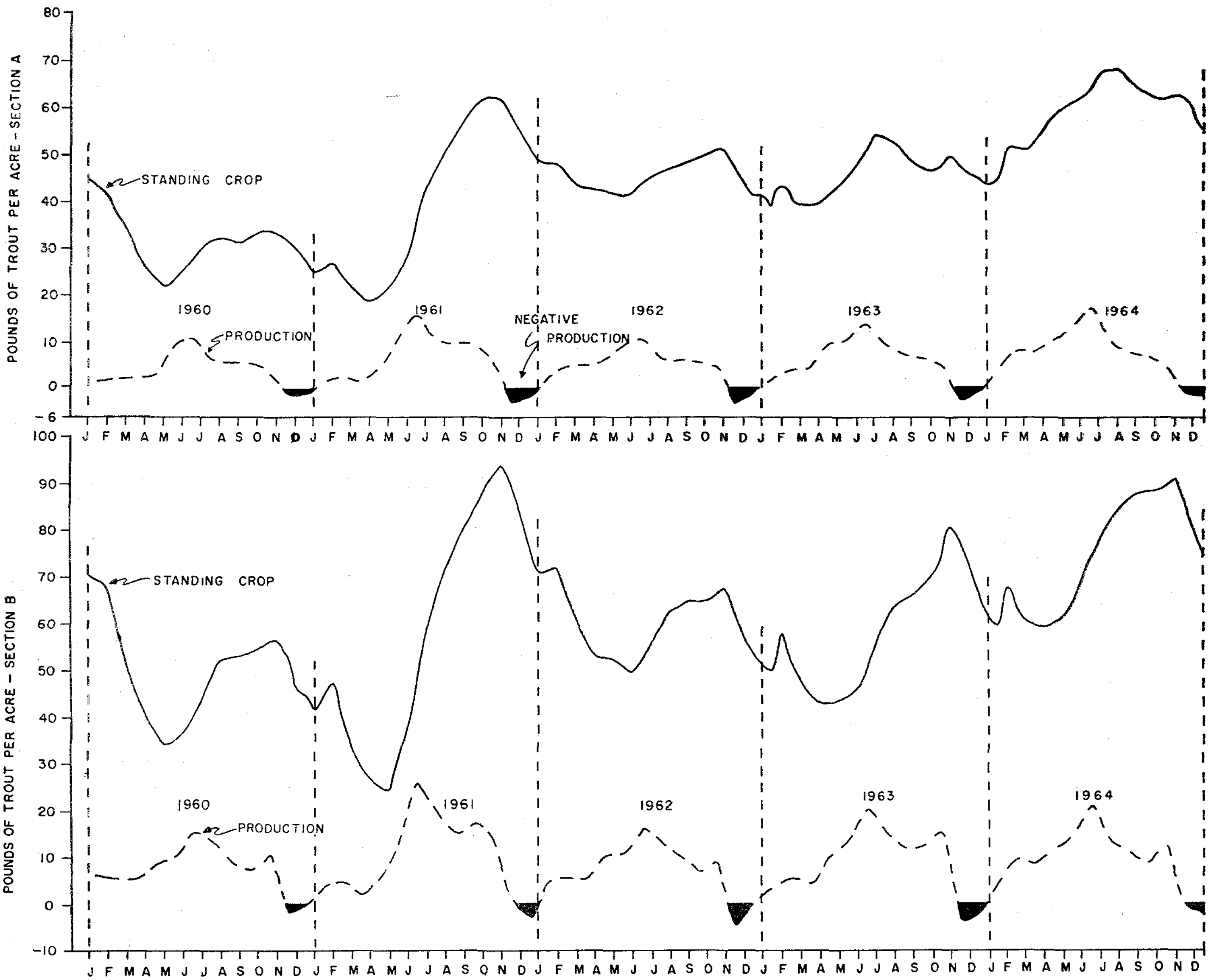


Figure 14. Standing crops of brook trout on the first day of the month and production during the month for 60 consecutive months (1960-64) in sections A and B of Lawrence Creek.

tion ranged from 88.9 to 119.5 pounds per acre, and the 5-year average of 103.8 pounds per acre was 47.7% greater than that for section A (Table 6).

Entire Stream—1960-64

As explained earlier in the section on Methodology, ratios of average standing crops to production in sections A and B were applied to measures of average standing crops in sections C and D to derive yearly estimates of production for the remaining two stream sections. Results of these production calculations plus those for A and B are summarized in Figure 15 and Table 7 in which annual production for the stream as a whole and for each section is expressed in pounds and in pounds per acre. In Table 7 annual production is further categorized according to age structure of stocks in each section and in the entire stream for the years 1960-64.

Annual production in the entire stream varied by only 15% during the 5-year period. Production per year ranged from 1,007.9 to 1,160.5 pounds, or 83.6 to 96.3 pounds per acre. Annual production per mile

TABLE 5

Production by Brook Trout in Sections A and B During June of 1960-64

	Production in Pounds Per Acre				
	1960	1961	1962	1963	1964
Section A	11.8	16.4	11.1	14.1	17.2
Section B	15.7	25.8	16.9	20.6	21.2
Percent difference (B ÷ A)	33.1	57.3	52.2	46.1	23.2

TABLE 6

Annual Production in Sections A and B During 1960-64, Expressed in Pounds Per Acre

	Production Per Year in Pounds Per Acre					Avg.
	1960	1961	1962	1963	1964	1960-65
Section A	58.0	74.6	60.9	71.8	86.2	70.3
Section B	90.1	119.5	88.9	106.8	113.4	103.8
Percent difference (B ÷ A)	55.3	60.2	46.4	48.7	31.6	47.7

of stream, ranged from 300.0 to 345.4 pounds. Mean annual production for the 5-year period amounted to 1,091.2 pounds, or 90.5 pounds per acre, or 324.8 pounds per mile of stream.

Production in pounds per acre was greatest in D in 1960, in B in 1961, in C in 1962 and 1963 and in B in 1964. Average annual production in each section for the 5-year period 1960-64 is summarized in Table 8.

Estimates of production in pounds are perhaps more meaningful than estimates in pounds per acre in comparing relative production within sections, because of possible underestimates of surface area in C and D as previously discussed. Estimates of

TABLE 7

Production of Brook Trout in Lawrence Creek During 1960-64, Summarized by Year, Section and Age Group

		Production in Pounds							Production in Pounds Per Acre					
		Age Group							Age Group					
Year	Section	0	I	II	III	IV	Sum 0-IV	Section	0	I	II	III	IV	Sum 0-IV
1960	A	104.5	103.7	3.8	2.8	0.7	215.5	A	28.8	27.2	1.0	0.8	0.2	58.0
	B	141.3	133.1	4.9	4.3	0.2	283.8	B	44.9	42.2	1.5	1.4	0.1	90.1
	C	83.7	175.4	4.3	9.6	0.9	273.9	C	36.6	76.6	1.9	4.2	0.4	119.7
	D	37.2	282.8	10.8	16.8	0.0	347.6	D	13.3	101.0	3.9	6.0	0.0	124.2
Entire Stream:		366.7	695.0	23.8	33.5	1.8	**1120.8**	Entire Stream:	30.4	57.7	2.0	2.8	0.1	**93.0**
1961	A	161.1	109.8	13.2	0.2	0.1	284.4	A	42.3	28.8	3.4	0.1	<0.1	74.6
	B	257.4	99.5	16.1	0.2	0.1	373.3	B	81.7	31.6	6.1	0.1	<0.1	119.5
	C	122.9	63.4	23.2	0.1	0.0	209.6	C	53.7	27.7	10.1	<0.1	0.0	91.5
	D	70.7	78.8	48.4	0.1	1.1	199.1	D	25.3	28.1	17.3	<0.1	0.4	71.1
Entire Stream:		612.1	351.5	100.9	0.6	1.3	**1066.4**	Entire Stream:	50.8	29.2	8.4	<0.1	0.1	**88.5**
1962	A	88.1	129.0	13.6	1.0	<0.1	231.7	A	23.1	33.9	3.6	0.3	<0.1	60.9
	B	124.2	133.4	20.8	1.9	0.0	280.3	B	39.4	42.3	6.6	0.6	0.0	88.9
	C	70.4	128.2	22.5	5.4	0.0	226.5	C	30.7	56.0	9.8	2.4	0.0	98.9
	D	63.0	172.3	25.1	9.0	0.0	269.4	D	22.5	61.5	9.0	3.2	0.0	96.2
Entire Stream:		345.7	562.9	82.0	17.3	<0.1	**1007.9**	Entire Stream:	28.7	46.7	6.8	1.4	<0.1	**83.6**
1963	A	124.4	102.7	43.6	2.5	0.3	273.5	A	32.6	27.0	11.4	0.7	0.1	71.8
	B	215.3	88.0	30.0	2.8	0.3	336.4	B	68.4	27.9	9.5	0.9	0.1	106.8
	C	135.8	71.4	50.6	5.0	0.7	263.5	C	59.3	31.2	22.1	2.2	0.3	115.1
	D	102.4	99.0	73.5	7.7	4.3	286.9	D	36.6	35.4	26.2	2.8	1.5	102.5
Entire Stream:		577.9	361.1	197.7	18.0	5.6	**1160.3**	Entire Stream:	48.0	30.0	16.4	1.5	0.5	**96.3**
1964	A	152.0	138.5	27.9	9.6	0.5	328.5	A	39.9	36.4	7.3	2.5	0.1	86.2
	B	196.2	127.9	25.8	7.5	0.2	357.6	B	62.3	40.6	8.2	2.3	<0.1	113.4
	C	65.8	91.9	25.1	16.2	0.8	199.8	C	28.7	40.1	11.0	7.1	0.3	87.2
	D	53.5	109.6	34.1	16.8	0.6	214.6	D	19.1	39.1	12.2	6.0	0.2	76.6
Entire Stream:		467.5	467.9	112.9	50.1	2.1	**1100.5**	Entire Stream:	38.8	38.8	9.4	4.2	0.2	**91.3**
5-Year Average: Annual Production in Pounds							**1091.2**	Annual Production in Pounds per Acre						**90.5**

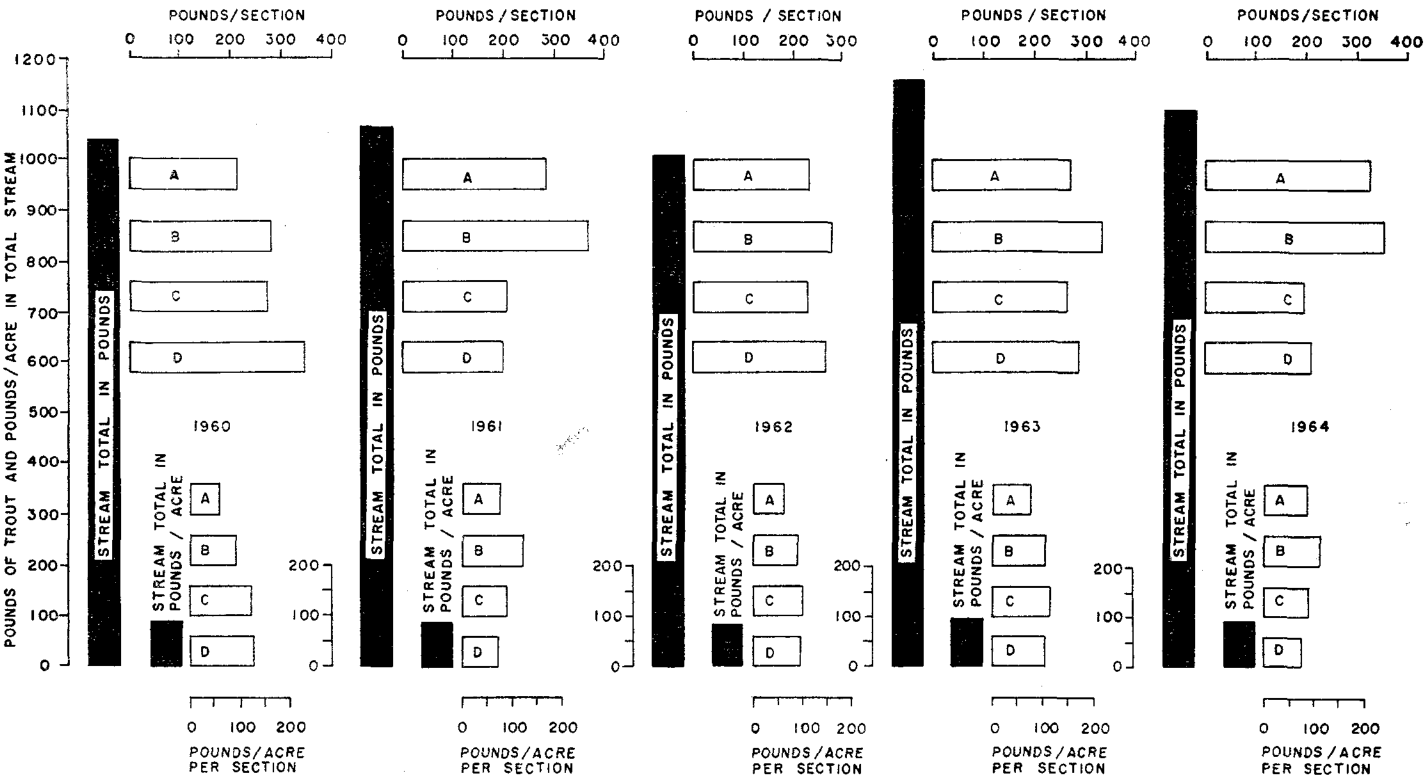


Figure 15. Production of brook trout during 1960-64, expressed in both pounds and pounds per acre for each stream section and for all sections combined.

production in pounds are unaffected by possible errors in sectional dimensions because these calculations are based on standing crops of trout derived from population estimates within fixed section boundaries.

Using annual production in pounds as the comparative criterion, then, section A accounted for 24.4%, section B for 29.9%, section C for 21.5% and section D for 24.2% of annual production in Lawrence Creek during 1960-64.

During this same period an average of 43.3% of annual production in the stream was contributed by age 0 stocks, 44.9% by age I stocks, 9.4% by age II stocks, 2.2% by age III stocks and 0.2% by age IV stocks. Production within years was greatest by age I trout in 1960 and 1962, and by age 0 trout in 1961 and 1963. During 1964 age 0 and age I trout both accounted for 42.5% of total production. Cumulative production by age 0 and age I trout comprised 80.9-94.8% of annual production and 88.2% of total production for the 5-year period.

Production by the strong 1961 year class was well above average throughout its life. It accounted for 57.4% of annual production during 1961 as age 0, for 55.8% in 1962 as age I, for 17.0% in 1963 as age II, and 4.6% of annual production in 1964 as age III. Percentage contributions of each age group to annual production are listed in Table 9. These data indicate that production by the 1961 year class was greater during the first, third, and fourth years of life than that of any other year class. During the second year of life (age I) production by the 1959 year class was highest.

Growth achieved by all age groups of brook trout in Lawrence Creek during 1959 is not known, but production has been calculated for age 0 trout, the 1959 year class itself. This year class was the strongest on record for Lawrence Creek over a 13-year period (1953-65). It numbered 22,646 in September of its first year of life, which made it 112% stronger than the 13-year average of 10,708 young-

TABLE 8

Average Annual Production in Sections A Through D During 1960-64, Expressed in Both Pounds and Pounds Per Acre

Stream Section	Average Annual Production During 1960-64	
	Pounds	Pounds Per Acre
A	266.7	70.0
B	326.3	103.6
C	234.7	102.5
D	263.5	94.1
Total	1,091.2	——
Average	——	90.5

TABLE 9

Percentage Contribution of Age Groups 0-IV Brook Trout to Annual Production in Lawrence Creek During 1960-64

Year	Age Group 0	I	II	III	IV
1960	32.7	62.1	2.1	3.0	0.1
1961	57.4	33.0	9.5	<0.1	0.1
1962	34.3	55.8	8.1	1.7	0.1
1963	49.8	31.1	17.0	1.6	0.5
1964	42.5	42.5	10.3	4.6	0.1
5-yr. avg.	43.3	44.9	9.4	2.2	0.2
Cumulative sum	43.3	88.2	97.6	99.8	100.0

of-the-year in September. The 1961 year class was also a strong one, numbering 14,313 in September, or 33.7% above average. During their first year of life, growth by the 1959 and 1961 year classes amounted to 1,079.2 pounds and 612.1 pounds, respectively. It is, therefore, not surprising that highest known production by an age I stock occurred in 1960, the second year of life of the very strong 1959 year class.

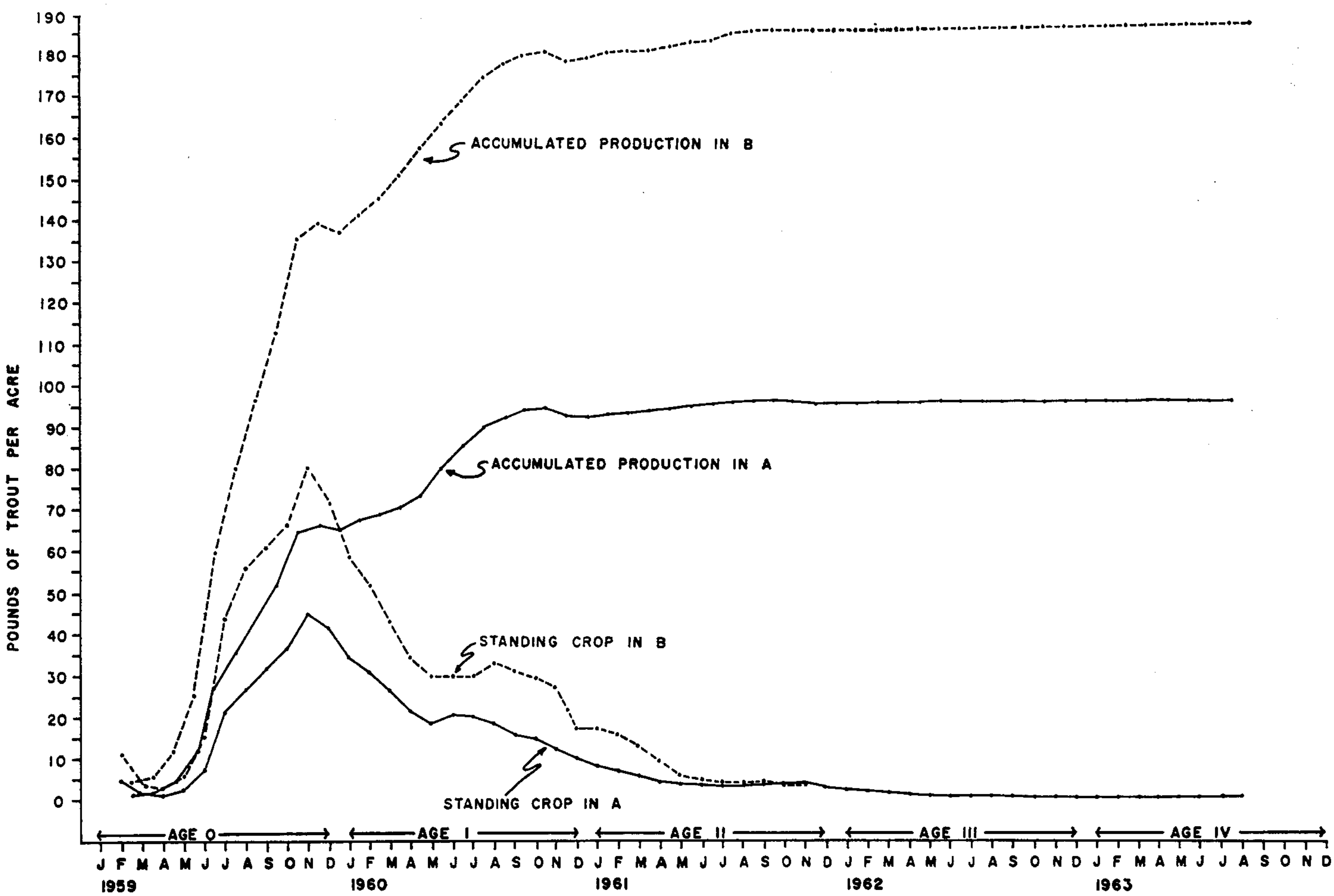
Production in terms of year classes, or generations of brook trout, rather than by age groups within years will be considered next.

Year Classes in Sections A and B

Data representing monthly standing crops and monthly production within sections A and B have been assembled for 3 year classes of brook trout from emergence to extinction. Estimates of production by the 1959-61 year classes have also been calculated for yearly periods in sections C and D. Following consideration of monthly standing crop and production trends by each year class in sections A and B these latter estimates of annual production in C and D will then be incorporated in the analyses so that approximate production trends can be examined within the stream as a whole.

1959 Year Class

Two pairs of curves, one for section A, and one for section B, are illustrated in Figure 16. The lower



Figue 16. Monthly biomass of the 1959 year class of brook trout in sections A and B of Lawrence Creek and accumulated production attained by the year class from emergence to extinction in each section.

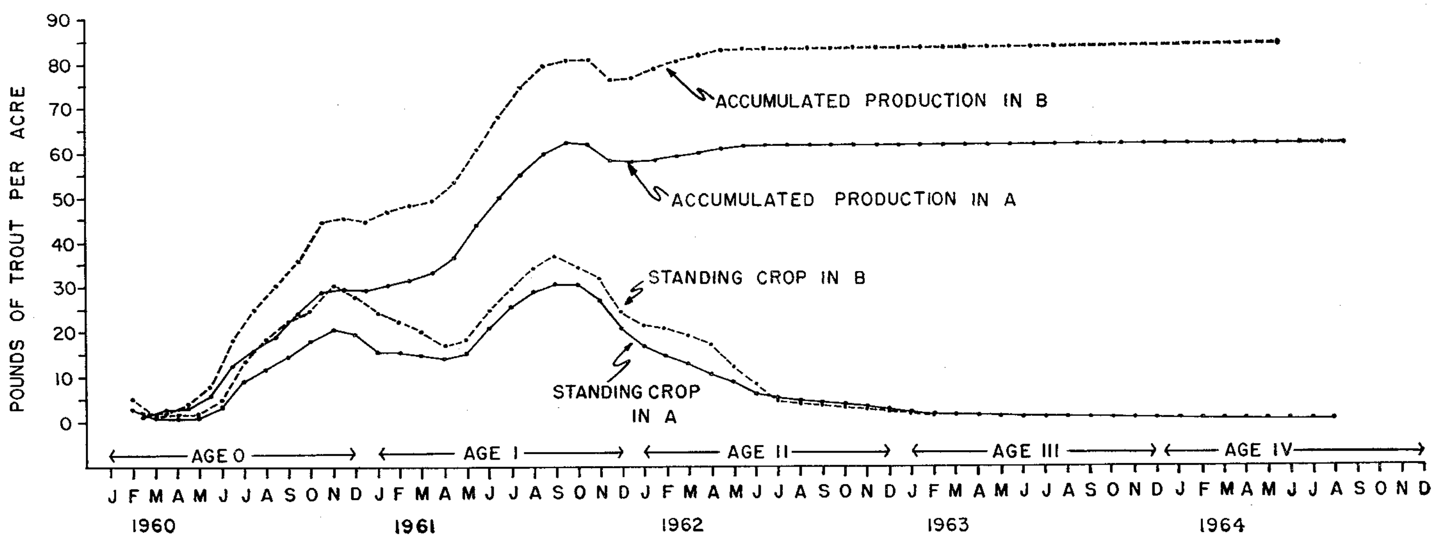


Figure 17. Monthly biomass of the 1960 year class of brook trout in sections A and B of Lawrence Creek and accumulated production attained by the year class from emergence to extinction in each section.

curve for each section represents the biomass on the first day of each month of life of the 1959 year class; the upper curve for each section represents accumulated production attributed to the year class from month to month. The space between the lower standing crop curve and the upper accumulated production curve is equivalent to the amount of production that has been removed by natural and angling mortality.

Initial weight of that portion of the 1959 year class hatching in section A was approximately 5.0 pounds per acre. In section B weight at emergence was 11.6 pounds per acre. This initial biomass advantage in B was maintained throughout most of its existence, but biomass trends from month to month in B were very similar to those in A. In both sections the biomass built rapidly to a peak about November 1 of the first year of life. Following a decline of several months, biomass again increased during late summer of the second year of life but the second peak was well below that reached the first year. Throughout the remainder of life biomass steadily decreased. Maximum monthly biomass, in the tenth month, was 44.4 pounds per acre in A and 80.2 pounds per acre in B.

Production by the 1959 year class in section A amounted to 96.2 pounds per acre compared to a lifetime production of 186.1 pounds per acre in section B. By the end of the first year of life 67.7% of lifetime production had been attained in A compared to 74.0% in B. After the second year of life accumulated production amounted to 96.0% and 96.8% of total production to be accrued. In A, lifetime production by the year class was 117% greater than its maximum biomass. In B, lifetime production by the year class was 126% greater than its maximum biomass.

1960 Year Class

Temporal production and biomass trends in sections A and B were again similar from month to month for the 1960 year class even though biomass and production were normally greater in B (Fig. 17). Notable differences in production and biomass are apparent, however, when year classes are compared. The 1959 year class was exceptionally strong; the 1960 year class was not. As a result, biomass in both sections reached their peak during the first year of life of the 1959 year class, but not until late in the second year of life of the 1960 year class when the standing crop in September, 1961 reached 30.8 pounds per acre in A and 36.6 pounds per acre in B. During its first year of life maximum biomass of the 1960 year class was 20.4 pounds per acre in A and 30.3 pounds per acre in B about November 1.

Accumulated production by the 1960 year class during its lifespan amounted to 62.0 and 84.0 pounds per acre in A and B respectively. After one year 45.3% and 53.4% of these totals had been accumulated. After two years 92.8% and 91.0% of lifetime production by the year class in A and B were accounted for. In both sections production on an annual basis was greatest during the first year of life even though biomasses reached their peak in September of the second year of life.

1961 Year Class

Initial biomass of the 1961 year class was intermediate to that of the 1959 and 1960 year classes.

Estimated egg production by parent stocks numbered 1,029,202 for the 1959 year class, 471,889 for the 1960 year class, and 606,780 for the 1961 year class. At 6 months of age, when the first population estimates were made, the three year classes numbered 30,967 and 10,017 and 16,468.

Monthly standing crops and accumulated production by stocks of the 1961 year class in A and B are shown in Figure 18. The curves reflect a relatively greater biomass level and greater quantities of new flesh being produced in B than in A from month to month. This situation was therefore typical for all 3 year classes discussed. Also, the intermediate density of the 1961 year class is nicely reflected in intrasectional comparisons of standing crops from month to month and accumulated production by the 3 year classes at various stages in their existence. For example, maximum densities of age 0 stocks in A were 44.4 pounds per acre in 1959, 20.4 pounds per acre in 1960, and 32.0 pounds per acre in 1961. In B age 0 densities reached 80.2 and 30.3 and 59.3 pounds per acre in 1959-61 respectively. At age I, peak biomasses in B were 58.8, and 36.6 and 47.9 pounds per acre for the 1959-61 year classes. Similarly, accumulated production attributed to stocks of the 1961 year class in A and B were also intermediate, amounting to 92.0 pounds per acre in A as compared to 96.2 and 62.0 pounds per acre by the 1959 and 1960 year classes, and 138.2 pounds per acre in B as compared to 186.1 and 84.0 pounds per acre by the 1959 and 1960 year classes in that section.

One interesting divergence in standing crops within the two sections distinguished the 1961 year class from the lifelong pattern described for the 1959-60 year classes. In section A biomass of the 1961 year class was highest during the second year of life, but in section B highest biomass occurred during the first year of life. The history of the other two year classes showed standing crops reaching peak weight in both sections during the same year of life—during the first year for the strong 1959 year and during the second year for the weak 1960 year class.

Age 0 brook trout were approximately 81% more numerous per month in B than in A during 1961, but the number of age I brook trout was only 18% higher on the average in B than in A during 1962. As a consequence, production by the 1961 year class in A appeared to be similar to that typical of a weak year class (like the 1960 year class), while production by individuals of the 1961 year class in B was more like that for a strong year class (like the 1959 year class). Of the total production to be made by the 1961 year class in section A, only 46.8% had been accounted for after one year of life and 84.3% after two years of life. In section B produc-

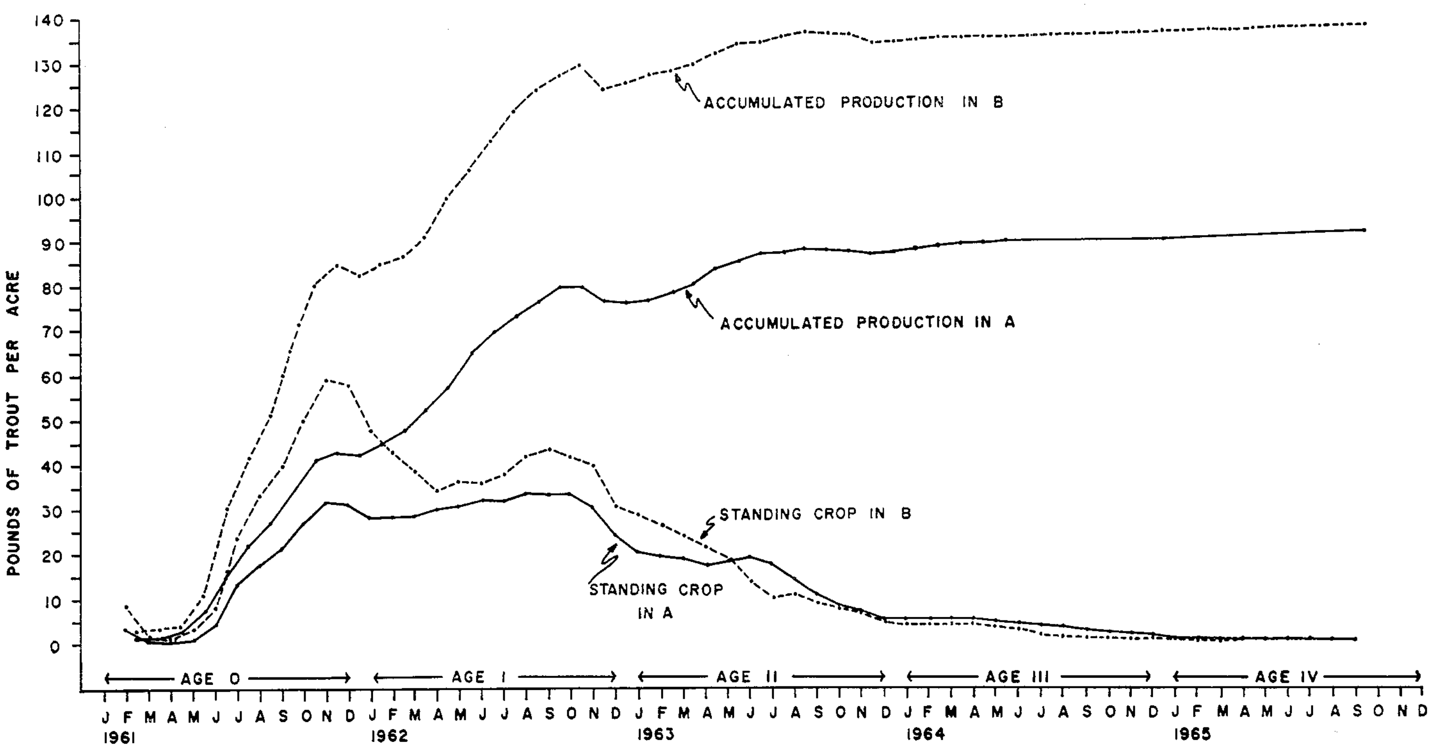


Figure 18. Monthly biomass of the 1961 year class of brook trout in sections A and B of Lawrence Creek and accumulated production attained by the year class from emergence to extinction in each section.

tion at the end of the first year represented 60.5% and after the second year 91.2% of lifetime production by the 1961 year class in that section.

Year Classes Throughout the Stream

Production from month to month by stocks of the 1959-61 year classes in sections C and D was not determined, but calculations were made to derive estimates of annual production in C and D by each year class. These results and the comparable values for sections A and B are listed in Table 10 and illustrated in Figure 19 for each year class during each year of its life. Production estimates are expressed in both pounds and pounds per acre.

1959 Year Class

Production by the strong 1959 year class during its lifespan amounted to 1,896.7 pounds or 157.4 pounds per acre for the entire stream. Production by the 1959 year class in section B accounted for 30.6% of total production by the year class throughout the stream, to rank first in sectional contributions. Annual production by the year class was highest during its first year of life. Age group 0 accounted for 56.9%, age group I for 36.6%, age group II for 5.3%, age group III for 0.8%, and age group IV for 0.3% of lifetime production by the year class. By the end of the second year of life 93.5% of lifetime production had been realized.

1960 Year Class

Production by the weak 1960 year class totaled 820.3 pounds, or 68.1 pounds per acre during its lifetime. Lifetime production was only 43.2% of that achieved by the 1959 year class. Production per section by stocks of the 1960 year class was highest in section B where 32.2% of lifetime production occurred. Age group 0 accounted for 44.7%, age group I for 42.8%, age group II for 10.0%, age group III for 2.2%, and age group IV for 0.3% of lifetime production. These percentages represent annual production rates of 30.4, 29.2, 6.8, 1.5, and 0.2 pounds per acre for age groups 0-IV, respectively. During the first two years of life, 87.5% of lifetime production by the year class was accomplished.

TABLE 10

Production by the 1959-61 Year Classes of Brook Trout in Lawrence Creek During Their Lifespan, Summarized by Age Group Within Year Classes

(Expressed in both pounds and pounds per acre for each stream section and for the entire stream)

		Production in Pounds						Production in Pounds/Acre					Percent of Total Production by Age Groups Within Year Class
Year	Age	Stream Section				Sum		Stream Section				Avg.	
Class	Group	A	B	C	D	A-D		A	B	C	D	A-D	
1959	0	248.3	430.7	325.8	74.4	1079.2		65.2	136.7	142.3	26.6	89.6	56.9
	I	103.7	133.1	175.4	282.8	695.0		27.2	42.2	76.6	101.0	57.7	36.6
	II	13.2	16.1	23.2	48.5	101.0		3.5	5.1	10.1	17.3	8.4	5.3
	III	1.0	1.9	5.4	6.8	15.1		0.3	0.6	2.4	2.4	1.2	0.8
	IV	0.3	0.3	0.7	4.3	5.6		<0.1	0.1	0.3	1.5	0.5	0.3
	V	—	—	0.3	0.5	0.8		—	—	0.1	0.2	<0.1	0.1
Year Class Totals Within Sections		366.5	582.1	530.8	417.3	**1896.7**	Year Class Avg. By Section	96.2	184.7	231.8	149.0	**157.4**	100.0
1960	0	104.5	141.3	83.7	37.2	366.7		27.4	44.8	36.6	13.3	30.4	44.7
	I	109.8	99.5	63.4	78.8	351.5		28.8	31.6	27.7	28.1	29.2	42.8
	II	13.6	20.8	22.5	25.1	82.0		3.6	6.6	9.8	9.0	6.8	10.0
	III	2.5	2.8	5.0	7.7	18.0		0.7	0.9	2.2	2.8	1.5	2.2
	IV	0.5	0.2	0.8	0.6	2.1		0.1	<0.1	0.3	0.2	0.2	0.3
Year Class Totals Within Sections		230.9	264.6	175.4	149.4	**820.3**	Year Class Avg. By Section	60.6	84.0	76.6	53.4	**68.1**	100.0
1961	0	161.1	262.6	122.9	70.7	617.3		42.3	83.4	53.7	25.2	51.2	43.1
	I	129.0	133.4	128.2	172.3	562.9		33.9	42.3	56.0	61.5	46.7	39.3
	II	43.6	30.0	50.6	73.5	197.7		11.4	9.5	22.1	26.3	16.4	13.8
	III	9.6	7.5	16.2	16.8	50.1		2.5	2.4	7.1	6.0	4.3	3.5
	IV	0.9	0.7	1.5	2.3	5.4		0.2	0.2	0.6	0.8	0.4	0.3
Year Class Totals Within Sections		344.2	434.2	319.4	335.6	**1433.4**	Year Class Avg. By Section	90.3	137.8	139.5	119.8	**119.0**	100.0
Avg. for 3 Year Classes: Lifetime production in pounds						**1383.4**	Lifetime production in pounds/acre					**114.8**	

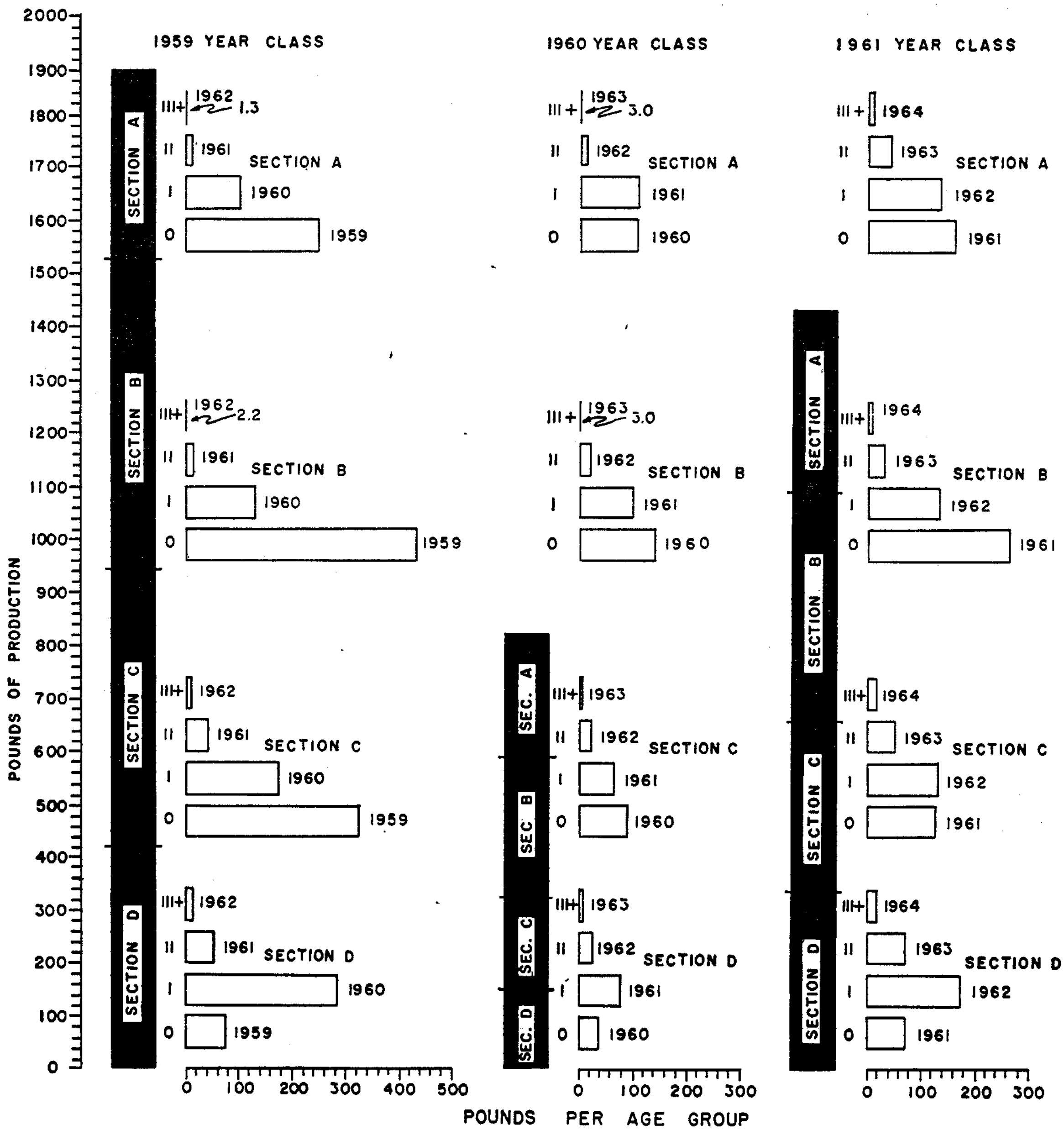


Figure 19. Production by the 1959-61 year classes of brook trout in Lawrence Creek summarized according to pounds produced by each year class and by age groups within year classes within sections.

1961 Year Class

The 1961 year class, whose initial biomass was intermediate to that of the 1959 and 1960 year classes, produced 1,433.4 pounds of flesh during its existence. This quantity is 32.3% less than lifetime production by the 1959 year class, but 74.7% greater than lifetime production by the 1960 year class. Production per section was again highest in section B, where 434.2 pounds, or 30.3% of lifetime production by the year class occurred. Greatest production per year occurred during the first year of life, so this characteristic was also typical of all 3 year classes. Annual production during successive years of life amounted to 51.2, 46.7, 16.4, 4.3, and 0.4 pounds per acre for age groups 0 through IV, respectively. Age groups 0 and I accounted for 82.4% of lifetime production by the year class.

Average production by the 3 year classes was 1,383.4 pounds, or 114.8 pounds per acre during their lifespan. Average length of life was 55 months. Therefore a single year class representing a composite of the 1959-61 year classes would produce an average of 2.1 pounds of new flesh per month of life.

These averages of monthly and lifelong rates of production are probably higher than those typical of the Lawrence Creek population because they include production by the 1959 year class, the strongest of 13 year classes censused during their first year of life. From data included in Table 4, which excludes production by the 1959 year class during its first year of life and production by the 1961 year class during its last year of life, annual production over a 5-year period averaged 1,091 pounds for the entire stream. This value is 21.1% lower than the figure of 1,383 pounds derived from averaging lifetime production by the 1959-61 year classes. A year class producing 1,091 pounds of flesh over a span of 55 months would have an average monthly production rate of 1.6 pounds per acre.

ANGLER HARVEST

Opening and closing dates of trout fishing seasons at Lawrence Creek coincided with statewide dates. During 1960-64 all opening days were on Saturday, but the dates varied from April 28 to May 9. All five trout fishing seasons ended on September 7. Season length varied from 122 to 133 days. Because of the compulsory creel census system used at Lawrence Creek, angling was limited to a period from 6 a.m. to 10 p.m. In practice this restriction did not appear to produce a serious bias in the pattern of angling activity. Of the total hours of fishing recorded in 1964, for example, less than 4% occurred during the 6-7 a.m. period, and less than 2% during the 9-10 p.m. period.

In addition to the restriction on fishing hours, two sets of experimental fishing regulations were tested during the 1960-64 seasons. Both sets were more restrictive than the statewide regulations which consisted of a 6-inch minimum legal size limit and a daily bag limit of 10 for stream trout. The first set, a 9-inch minimum size limit and daily bag limit of 5, applied only to the 1960 season (to the 1958-59 seasons also, but harvests during these two seasons are not immediately relevant). Also, section A was closed to fishing as part of a 5-year experiment to evaluate the management potential of a headwaters trout refuge (Hunt and Brynildson, 1964).

The catch of brook trout in 1960 was the lowest recorded from Lawrence Creek since initiation of the creel census in 1955. Only 85 brook trout weighing 27.3 pounds were cropped. The catch included 7 age I, 23 age II, and 55 age III trout weighing 1.9 pounds, 6.5 pounds, and 18.9 pounds respectively. Fishing pressure was also the lowest on record amounting to 424 angling trips representing 1,007 hours of effort.

During the 1961-64 fishing seasons all sections were open to fishing but only fly-fishing was permitted in sections C and D. The bag limit remained at 5 but the size limit was reduced to 8 inches. Angling pressure and catch statistics during these 4 fishing seasons are listed in Table 11.

TABLE 11

Angling Pressure and Catch Statistics for the 1961-64 Trout Fishing Seasons at Lawrence Creek

Year	Angling Trips	Catch Number	Catch Pounds	Pounds Per Acre	Catch Per Hour
1961	592	442	107.3	8.9	0.35
1962	896	540	131.2	10.9	0.25
1963	874	752	169.0	14.0	0.33
1964	881	626	149.0	12.4	0.30

Within the context of this paper, any regulatory influence of the fly-fishing-only restriction on the catch is unimportant. Hunt (1964) concluded that harvests under this second set of fishing regulations were determined primarily by the amount of fishing pressure and number of legal-sized trout available. The restriction on fishing methods and the bag limit of 5 had only indirect effects upon the catch by influencing the amount of fishing pressure.

Numbers and pounds of brook trout of various ages harvested during the 1961-64 seasons are summarized in Table 12. The bulk of the catch each season (in both number and weight) was composed of age group II trout. No age group 0 trout were harvested and catches of age group I trout represented only 0.6-3.0% of the number of such trout present in the population prior to the fishing season. Catches of age group II brook trout represented 28-40% of the number comprising pre-season stocks. Catches of age group III brook trout represented exploitation

TABLE 12

Number and Pounds of Brook Trout of Various Ages Harvested By Anglers During the 1961-64 Trout Fishing Seasons

Year	Number of Brook Trout Creeled				Pounds of Brook Trout Creeled			
	I	II	III	IV+	I	II	III	IV+
1961	107	329	3	3	21.1	83.4	1.3	1.5
1962	80	404	56	0	17.1	93.2	21.0	0.0
1963	26	649	66	11	4.9	144.2	15.7	4.2
1964	47	414	155	10	8.0	92.6	42.5	5.1

rates of 30-58% of pre-season stocks, and 41-100% of the age IV trout were caught annually. However, total catches each season were equivalent to only 6-11% of the numbers of trout of age I and older trout present when fishing began.

Maximum angling effort and catch invariably occurred during the first week of the season and normally half of the total trips and total catch were recorded during the first one-third of the season. The combination of skewed angling effort and an 8-inch size limit reduced the harvest of age group I brook trout to a level well below that which would have occurred if the statewide size limit of 6 inches had been operative. Usually no age I trout had grown to 8 inches by opening day and only about 2% were legal-sized at mid-season. By the end of the fishing season, 10-25% were legal and a substantial portion of the catch the last few weeks was composed of age I trout, but the numbers creeled remained low because fishing pressure was low. Consequently the standing crop and production data used in this report have been derived from a population composed of year classes essentially unaltered by angling during their first two years of life — the period in which most production occurred and standing crops reached their peak density.

DISCUSSION

Standing crops, growth, production and harvest of brook trout in Lawrence Creek have each been considered largely in isolation. Now some interrelationships of these factors will be discussed and some of the results and implications of this investigation will be compared with those from other production studies.

Mechanisms of Production Differences

In Lawrence Creek variation in numbers of trout present was clearly of greater significance than variation in growth rates in determining differences in production from year to year and from section to section. For example, during 1963, the year for which the best data were available, annual production per acre was 49% greater in section B than in section A despite similar rates of growth in both sections throughout the year as judged by the monthly sampling that was done. However, the average number of trout was 70% greater in B than in A. This numerical superiority was due solely to the number of age group 0 trout which was 76% higher in B than in A. The number of age I+ trout was 7% lower on the average in B than in A.

The influence of numerical density on production is also evident when year classes are compared. The year class with the highest initial density had the greatest lifetime production while the year class with the lowest initial density had the least lifetime production. Although differences in instantaneous growth rates from month to month influenced production within each year class (growth rates being very high early in life, tending to diminish toward zero with time, and causing negative production some months), differences in growth rates between year classes were inconsequential during corresponding months of life (Fig. 20).

This conclusion regarding the influence of standing crops, or numerical density, on production in Lawrence Creek is supported by Chapman's (1965) conclusion that: "Variations in survivorship among streams and years appears to have strong impact on net production". The more fundamental question of why biomass levels are different, of why one stretch of Lawrence Creek consistently supports more trout than another stretch, remains largely unanswered. Its solution would resolve much of the mystery concerning observed differences in production from year to year and section to section.

In Lawrence Creek as a whole, standing crops in April ranged from 26-69 pounds per acre, standing crops in September ranged from 52-71 pounds per acre, and annual production ranged from 84-97 pounds per acre during the 1960-64 period. Spring standing crops varied by 165%, autumn standing crops varied by 37%, but annual production varied by only 15%. Annual production was approximately 2.1 times greater than the average standing crop present in the spring and approximately 1.5 times greater than the average standing crop present in the autumn (Table 7).

The rather narrow range of annual production calculations for the entire stream during the 1960-64 period constitutes an intriguing situation to speculate about. Even though annual production varied by 76% among age group 0 trout, by 98% among age group I trout, and by more than 700% among the older age groups, summations of annual production by all groups combined varied only 15% (Table 3). Such consistency suggests that some factor or combination of factors effectively limits production in the population as a whole to about 90 pounds per acre per year. If production by one

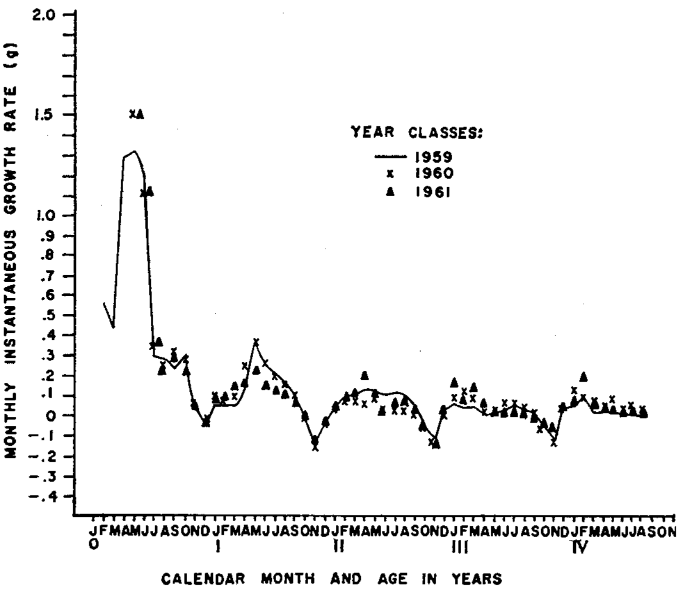


Figure 20. Monthly instantaneous rates of growth of the 1959-61 year classes of brook trout in Lawrence Creek during their lifespans.

age group is above average, compensatory adjustment in production among other age groups seems to occur. Moreover, if carrying capacity of the stream for brook trout is thought of in terms of potential growth by the trout population, the observed consistency in the level of annual production suggests that this carrying capacity is being approached every year under existing environmental conditions.

The data in Table 7, especially the ratios of April standing crops to annual production, indicate an inverse relationship exists between standing crops and efficiency of production. As April standing crops increase, the ratio of April standing crops to production decreases consistently. Efficiency of production appears to be a function of the biomass level.

Davis and Warren (1965) found a somewhat similar relationship of production to biomass during their laboratory stream experiments with sculpins (*Cottus perplexus*). Intraspecific competition for food and interspecific competition with stonefly naiads (*Acroneuria pacifica*) for food were the major influences altering the relation of sculpin production to sculpin biomass.

Relations of the brook trout population to its food supply are largely unknown in Lawrence Creek, as are the interspecific relations of trout to other competitors. Primary emphasis in this bulletin has been placed on simply presenting the results of production calculations and relating them to a known angler harvest. However, studies concerning the trout population in relation to its food supply are in progress. Their completion will provide some of the clues for establishing the biological basis of the production that has been measured.

Certainly the available food supply is one component of the environment that could be portioned among the various age groups in different amounts each year and still exert a limiting influence upon total growth. Available living space is another component to consider. It is relatively constant from year to year and of variable quality. Perhaps excess high-quality living space not utilized by an age group whose density is low is thereby made available to other age groups. Or, as noted by Chapman (1965) in his study of production in coho salmon populations, food availability and spatial requirements may be interrelated in their potential effect upon population growth. In three adjacent streams, annual production of juvenile coho was greatly different but annual production per unit area was very similar averaging about 36 pounds per acre. Chapman concluded that the same combination of environmental factors was probably operating similarly in all three streams to limit production.

Although annual production throughout Lawrence Creek was quite uniform during a 5-year period, it should also be recognized that production per unit area was not uniform throughout the stream. Production data that have been presented for sections A and B provide a good illustration of this fact. Annual production per acre in B averaged 48% higher than in A for the 5-year period. In A, annual production ranged from 58-86 pounds per acre, but in B annual production ranged from 89-120 pounds per acre. Obviously the environmental factors influencing production in section A operate at a more restrictive level than those in section B even if the modes of suppression are identical. The challenge to attempt to determine why production per unit area is consistently better in section B than in section A is apparent.

The Trout Food Resource

Unpublished data concerning standing crops of trout food in sections A and B of Lawrence Creek have been supplied to me by David A. White. These data imply that the food resource (as constituted by standing crops of only 4 principal food organisms) is not in nearly so short supply in Lawrence Creek as it appeared to be in the Horokiwi Stream studied by Allen (1951). Data presented by Allen indicated average standing crops of 110-320 pounds per acre of brown trout in the 4 study zones. In the same zones average standing crops of bottom fauna weighed only 23-40 pounds per acre. In other words, weight of the average stock of trout was several times greater than average weight of the food supply supporting it. Allen concluded that annual production in the trout population was largely limited by the food supply because competition for it was severe. In Lawrence Creek quite a different relation appears to exist between the trout population and its food supply. For example, in section A during 1963, average weight of the trout stock was about 46 pounds per acre, whereas average weight of the bottom fauna was 1,196 pounds per acre. Thus the average stock of trout was associated with an invertebrate food base 26 times as great. In section B during 1963 the average standing crop of trout weighed 58 pounds per acre and the average standing crop of bottom fauna weighed 1,413 pounds per acre. Approximately 24 pounds of food (4 organisms only) was present for each pound of trout. These two estimates of the magnitude of the food base in the two sections agree remarkably well considering the large expansion factors employed in the calculations. Of course food may still be an important component limiting production in Lawrence Creek but certainly not to the degree suggested for the Horokiwi Stream.

Unfortunately in both streams availability of the measured food resources to the trout is not known. Since trout feed mainly on drifting food rather than grazing on the stream bottom, measures of standing crops of attached bottom fauna may be misleading. Relationships of a trout population to its food supply are further complicated by the fact that the amount of drifting food does not necessarily increase as standing crops of attached bottom fauna increase (Warren et al., 1964 and Waters, 1965).

The estimated standing crops of bottom fauna in Lawrence Creek were based on collections of 25 random samples in section A and 25 in section B each month during 1963. Monthly standing crops were calculated to range from 263 to 2,326 pounds per acre in section A and 326 to 2,245 pounds per acre in section B.

Harvest in Relation to Production During 1961-64

In discussing relations of angler harvests to production, only data for the 1961-64 period will be considered for the moment because fishing regulations remained constant during those 4 years. When harvest and production of the 1959-61 year classes are considered, trout creeled during 1959, 1960 and 1965 will also be considered in order to cover all years of life of these year classes.

During the 1961-64 fishing seasons, angler harvests per season ranged from 8.9 to 14.0 pounds per acre and averaged 11.6 pounds per acre. During the same period production ranged from 83.6 to 96.3 pounds per acre and averaged 89.9 pounds per acre. Weight of seasonal catches were equivalent to 10% of annual production in 1961, 13% in 1962, 15% in 1963, and 14% in 1964. The average of these four values is 13%. These percentages do not literally represent the amount of annual production removed by anglers because most of the trout creeled during 1961-64 were 2 or more years old. Consequently weight of the catch one season is also related to annual production during the previous two or three years. However, a useful approximation of the amount of annual production being cropped should be represented by the 4-year mean percentage even if age composition of catches and production are not considered, because the average lifespan of a generation of brook trout in Lawrence Creek is between 4 and 5 years.

The most logically satisfying approach to relating catch and production statistics is, of course, to consider such data assembled throughout the lifespan of a generation of trout. However, none of the important papers dealing with production and harvest that have been cited contain such data for a single generation of wild trout during its entire lifetime. Therefore, the opportunity to relate precise measures of angler harvest to lifetime production for not just one but three classes of brook trout in Lawrence Creek constitutes one of the chief assets of this report. In the following discussion, harvest and production relationships will first be considered separately for each year class in sections A and B, for which the most reliable measures of surface acreages are available, and then for each year class throughout the entire stream.

Harvest in Relation to Production by 1959-61 Year Classes in Sections A and B

In section A accumulated production by the 1959 year class amounted to 96.2 pounds per acre. During the first 16 months of life, the period during which none of the individuals of the year class reached legal size, accumulated production totaled 73.0 pounds per acre of which 76% was removed by natural mortality some time during the period leaving a residual standing crop of 18.8 pounds per acre. During the remaining months of life the year class produced an additional 23.2 pounds of flesh per acre. This amount, plus the 18.8 pounds per acre existing as the standing crop when anglers began to harvest trout from this year class, constituted the portion of lifetime production (42.0 pounds per acre) from which an angler harvest of 2.1 pounds per acre was taken. Between the time harvest began and the year class disappeared another 39.9 pounds per acre of production was ultimately lost to natural mortality. The angler harvest represented only 2% of lifetime production and only 5% of the weight of trout available as the standing crop plus that production occurring after cropping began.

In section B accumulated production by the 1959 year class amounted to 184.8 pounds per acre. During the first 16 months of life growth was equivalent to 157.0 pounds per acre of which only 19% was still incorporated in the standing crop of 29.6 pounds per acre. Anglers removed 9.0 pounds per acre from this standing crop plus the additional 57.4 pounds per acre of production that occurred during the remaining months of life. The angler harvest in section B represented 5% of lifetime production and 10% of the production during the harvesting period plus the initial weight of the stock when harvesting began.

These relations between angler harvest from and production by a year class and the amount of production eventually creeled or removed by natural deaths are summarized in Table 15 for the stocks of all 3 year classes in sections A and B.

Harvest as a percentage of lifetime production was much lower in both sections for the 1959 year class than for either the 1960 or 1961 year class for at least three reasons: (1) the minimum legal size limit was 9 inches during 1959 and 1960 and 8 inches during 1961-65; (2) angling pressure per season was lower during 1959-60 than 1961-65; and (3) natural mortality removed a greater percentage of the production by the strong 1959 year class during the period prior to angler harvest. Harvest of all three year classes was consistently greater in section B than in section A for at least two reasons: (1) standing crops of trout were higher in B every year; and (2) angling pressure was higher in B every year.

Angler Harvest in Relation to Production By the 1959-61 Year Classes Throughout the Stream

The amount of production that had occurred at the end of successive years of life and the amount of this accumulated production still present in the standing crop, or removed by angling, or removed by natural mortality are illustrated as block diagrams in Figure 21 for the 1959-61 year classes in the entire stream. Data to construct this figure, which is modeled after one presented by Allen (1952) for a brown trout population, were extracted from Table 16.

1959 Year Class

The angler harvest of brook trout of the 1959 year class amounted to 9.3 pounds per acre. This harvest was equivalent to 6% of the accumulated production of 157.4 pounds per acre by the year class during its existence. Production during the first year of life was 89.6 pounds per acre of which 55% was removed by natural death and none by anglers. By the end of the second year of life 147.3 pounds per acre of production had occurred of which 86% was lost to natural mortality, less than 1% was represented by the harvest, and the remaining 14% was incorporated in the standing crop. Approximately 74% of the angler harvest from this year class was taken during its third year of life (age group II). By the end of that year accumu-

TABLE 15

Relations of Angler Harvest to Production Within Stocks of the 1959-61 Year Classes in Sections A and B

Item	1959 Year Class		1960 Year Class		1961 Year Class	
	Section A	Section B	Section A	Section B	Section A	Section B
Production during first 16 months of life (pounds per acre)	73.0	157.0	36.9	53.3	57.2	99.1
Percent of this production removed by natural mortality	75.6	81.0	59.1	67.2	44.9	63.0
Standing crop at 16th month of life when harvesting began (pounds per acre)	18.8	29.6	15.1	17.8	31.5	36.7
Production after angling began (pounds per acre)	23.2	57.4	23.7	30.7	34.8	39.1
Total production during lifetime (pounds per acre)	96.2	184.8	60.6	84.0	92.0	138.2
Total angler harvest during lifetime (pounds per acre)	2.1	9.0	8.6	13.5	9.4	19.7
Angler harvest as percent of lifetime production	2.2	4.9	14.2	16.1	10.2	14.2
Angler harvest as percent of production after 16th month of life plus weight of stock when angling began	5.0	10.3	22.2	27.8	14.2	26.0
Percent of lifetime production eventually lost to natural mortality	97.8	95.1	85.8	83.9	89.8	85.8

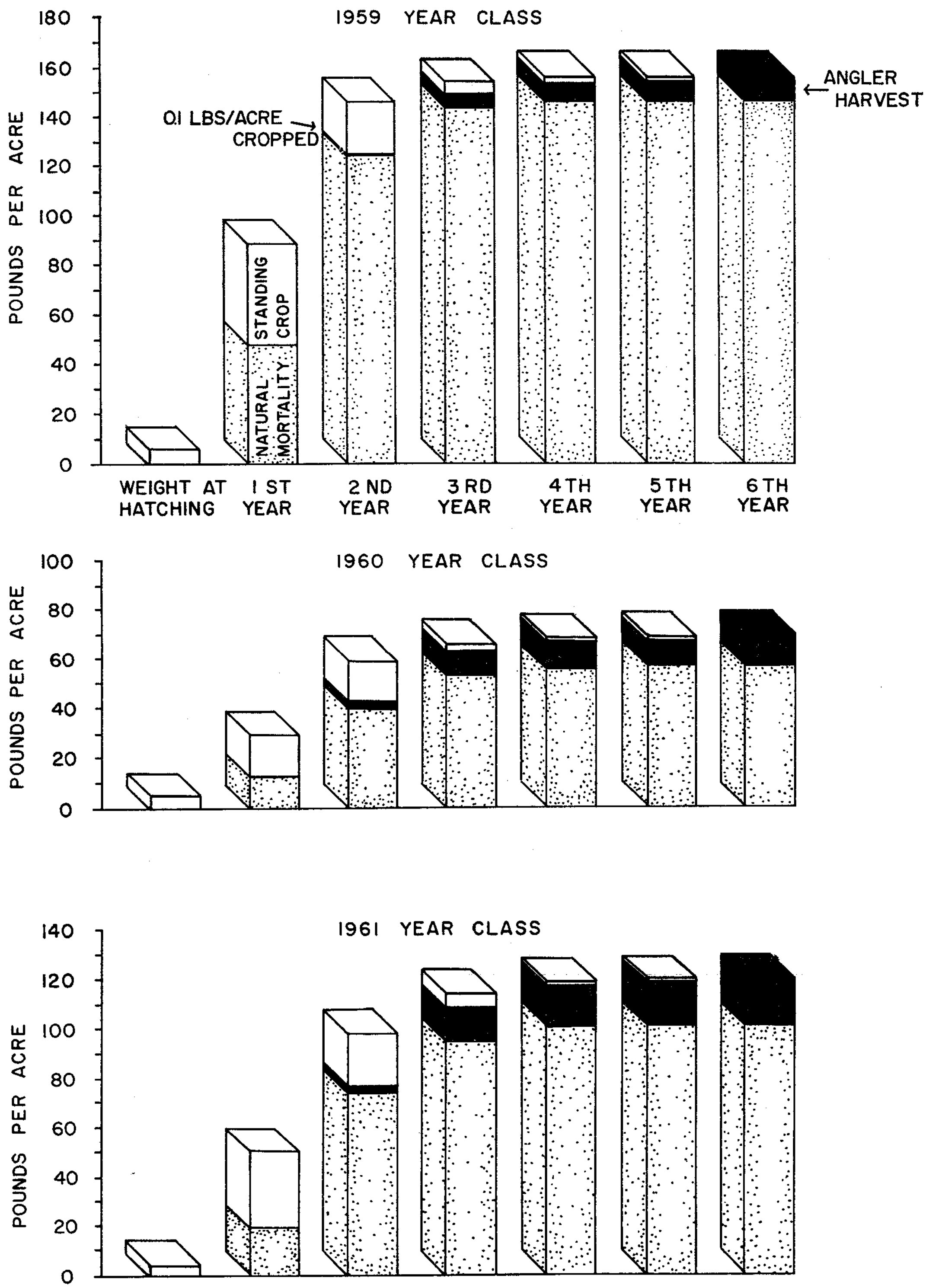


Figure 21. Accumulated production by the 1959-61 year classes of brook trout in Lawrence Creek and the amount of such production still present as the standing crop, or removed by natural mortality or cropped by anglers during successive years of life.

TABLE 16

Accumulated Production by the 1959-61 Year Classes of Brook Trout in Lawrence Creek and the Amount Still Present as the Standing Crop or Removed by Natural Mortality or Harvested by Anglers During Successive Years of Life

		Pounds of Brook Trout Per Acre			
Year Class	Year of Life	Accumulated Production	Weight of Standing Crop	Angler Harvest	Accumulated Production Removed by Natural Mortality
1959	1	89.6	41.1	0.0	48.5
	2	147.3	21.2	0.1	126.1
	3	155.7	3.5	6.9	145.3
	4	156.9	0.4	1.8	147.7
	5	157.4	0.2	0.3	148.2
	6	157.4	0.0	0.2	148.1
	Cumulative Total	157.4		9.3	
1960	1	30.4	16.6	0.0	13.8
	2	59.6	17.8	1.8	40.0
	3	66.4	3.1	7.7	53.8
	4	67.9	0.6	1.3	56.5
	5	68.1	0.1	0.2	57.0
	6	68.1	0.0	0.0	57.1
	Cumulative Total	68.1		11.0	
1961	1	51.2	31.8	0.0	19.4
	2	97.9	22.1	1.4	74.4
	3	114.3	6.2	12.0	94.7
	4	118.6	0.7	3.5	101.0
	5	119.0	0.1	1.1	100.9
	6	119.0	0.0	0.0	101.0
	Cumulative Total	119.0		18.0	

lated production had reached 155.7 pounds per acre. The standing crop represented only 2% of this production, 4% had been harvested, and 94% had been removed by natural mortality.

1960 Year Class

During the lifespan of the 1960 year class 68.1 pounds per acre of flesh were produced of which 11.0 pounds per acre, or 16%, was removed by anglers. Production during the first year of life amounted to 30.4 pounds per acre. Weight of surviving trout at the end of the year accounted for 55% and weight of the trout that died during the year accounted for the remaining 45% of first-year production. At the end of the second year of life, accumulated production had reached 59.6 pounds per acre. It was distributed among the standing crop, angler harvest, and natural mortality components in percentages of 30, 3, and 67. After three years, accumulated production had increased another 11% to 66.4 pounds per acre. Only 5% of accumulated production was still incorporated in the standing crop and 12% in the catch. Angler harvest during the third year of life amounted to 7.7 pounds per acre. During the third, fourth, and fifth years of life, weight of the catch each year was greater than production during the year. The harvest efficiency of 16% of total production by the 1960 year class is the highest rate among the three year classes considered.

1961 Year Class

Total production by this year class was equivalent to 119.0 pounds per acre. Anglers removed 18.0 pounds per acre, or 15% of lifetime production. During the first year of life 51.2 pounds per acre of production resulted. Of this, 62% remained incorporated in the standing crop and 38% had been lost to natural mortality, which represents the lowest percentage loss of production during the first year of life among the three year classes. By the end of the second year, accumulated production amounted to 97.9 pounds per acre and 23% of this was still present in the standing crop, about 1% had been harvested, and 76% had died. At the end of the third year of life only 5% of the accumulated production of 114.3 pounds per acre since emergence was still accounted for by the standing crop, 11% had been removed by angling, and 84% had been lost to natural mortality. Approximately 67% of the total harvest from this year class consisted of age group II trout and 19% of age group III trout.

Although lifetime production by the 1961 year class was about 25% greater than that by the 1960 year class, percentages of lifetime production represented by the angling harvest were nearly the same (16% of the 1960 year class and 15% of the 1961 year class). Angling regulations applying to these two year classes were constant. Both cropping efficiencies were similar to the 13% efficiency level derived earlier by averaging seasonal catches in proportion to annual production during 1961-64.

Angler Harvest and Production by Year Classes vs. Harvest and Production by Age Groups

Both Allen (1951) and Horton (1961) reconstructed events occurring in a "typical year class" of brown trout in such terms as the amounts of flesh produced during each year of life, the proportion still surviving as the standing crops, the proportion removed by anglers, and the proportion removed by natural mortality. Both investigators used data gathered for several age groups in the population for one or two years. These data were synthesized to represent year classes. Justification for the necessary synthesis is as good or bad as the assumption that growth, mortality, and harvest of all age groups during a single year is equivalent to growth, mortality, and harvest during the whole life of a single typical year class. Inherent in the stated assumption are also the unstated assumptions that one of the years of observation was typical and that the configuration of a typical year class can be recognized.

The data that have been presented for the brook trout population in Lawrence Creek offer an opportunity to investigate such assumptions, especially as they pertain to the 1960 and 1961 year classes and also to the 1959 year class to a lesser degree:

(1) During the life of the 1960 year class, 820.3 pounds of flesh were elaborated. This quantity is 27% less than production by all age groups during 1960.

(2) During the life of the 1961 year class, 1,433.4 pounds of flesh were produced. This quantity is 34% greater than production by all age groups during 1961.

(3) The angler harvest of all ages of trout during 1961 was equal to 8.9 pounds per acre. The harvest from the 1961 year class during 1962-65 was equal to 18.0 pounds per acre, or 102% more than the harvest during 1961. (Fair comparisons of harvest from the 1959 and 1960 year classes to harvests during 1960-65 are not possible because changes in fishing regulations are involved.)

(4) Among the 3 year classes, standing crops after 1 year of life ranged from 16.6 to 41.1 pounds per acre and represented 46 to 62% of the production occurring during the first year. After two years of life, standing crops ranged from 18 to 22 pounds per acre and represented 14 to 30% of accumulated production. At the end of the third year of life, standing crops weighed 3.1 to 6.2 pounds per acre and represented 2 to 5% of accumulated production.

(5) Lifetime production by the 1959 year class was 131% greater than lifetime production by the 1960 year class. Production by the 1959 and 1961 year classes varied by 32%. Production by the 1960 and 1961 year classes varied by 75%.

(6) Annual production by all age groups combined varied by only 15% during a 5-year period. However, production per year varied by 76% among age group 0 stocks, by 98% among age group I stocks, and by more than 700% among older age groups during the same period.

(7) Weight of seasonal catches by anglers during 4 successive seasons having constant fishing regulations varied by 57%.

Although a few of these variables differed by less than 25% from year to year, most differed by much more than this. Consequently it would appear to be highly improbable that events concerning production, harvest, standing crops, and natural mortality of a normal year class in Lawrence Creek could be authentically assembled from a synthesis of data for all age groups derived from a year or two of sampling. Perhaps the basic difficulty to surmount in dealing with the Lawrence Creek population is deciding what constitutes a typical year class. This problem, like that of synthesizing data from age groups, is not likely to be resolved by a short-term study. However, the Lawrence Creek data also indicate that a useful approximation of two variables of great practical value probably can be obtained from a production study lasting only one or two years. Annual production for the population as a unit varied by only 15%, and seasonal catches in relation to annual production were about the same as catches from the 1960 and 1961 year classes in relation to lifetime production (13% average during 1961-64 versus 15% average for 1960-61 year classes).

The production and angler harvest data contained in this bulletin suggest that similar studies of short duration can provide useful approximations of annual production by a fish population and the efficiency of its harvest by anglers, but long-term studies are required to break down production and harvest into reliable components associated with age groups typical of that population, or to formulate theories of sequential events in the life of a normal generation of fish.

Production in Relation to Standing Crops

Lifetime production by the 1959 year class of brook trout in Lawrence Creek was 25 times greater than the weight of the emerging fry. Production during the first year of life was 14 times the initial weight of fry. Comparable values for the 1960 year class are 15 and 7 times its initial biomass and for the 1961 year class the values are 28 and 12 times its initial biomass. Ricker and Foerster (1948) calculated that annual production during the first year of life of sockeye salmon was 4 times the initial weight of fry for one year class and 13 times greater for another year class. From data included in Chapman's (1965) study of juvenile coho salmon, production prior to imigration to the sea was about 1.3-3.8 times greater than weight of emerging fry (based on my calculations using Chapman's data).

After the first year of life, production by the 1959 year class in Lawrence Creek was 1.6 times greater than the standing crop at the end of the first year of life. Production by the 1960 and 1961 year classes after their first year of life was 2.3 and 2.1 times greater than their standing crops when their second year of life began. These values could be thought of as growth following stocking of wild age group I brook trout in Lawrence Creek at densities of 41, 17, and 32 pounds per acre in January. Production of domestic age group I rainbow trout was about 1.5-2.0 times greater than weight of the trout stocked in the dystrophic lakes studied by Johnson and Hasler (1954). Production was approximately 1.4 times greater than initial weight of bluegills stocked in ponds studied by Hayne and Ball (1958). Production was only 0.5 times initial standing crops of bluegills in Gordy Lake and Wyland Lake as reported by Gerking (1962), and Hatch and Webster (1961) indicated that production by adult domestic rainbow trout was 0.7 to 1.7 times the weight at stocking in Panther Lake.

Allen (1951) concluded that the proportion of the production surviving as the standing crop in a population of wild brown trout was never higher than 30-35% during the first year of life of a normal year class and only 12-20% of accumulated production was accounted for by the standing crop after the second year of life. In Lawrence Creek standing crops at the end of the first year of life represented 46, 55 and 62% of first-year production by the 1959-61 year classes of brook trout and standing crops at the end of the second year of life represented 14, 30 and 23% of accumulated production. Allen pointed out that the most doubtful portion of his

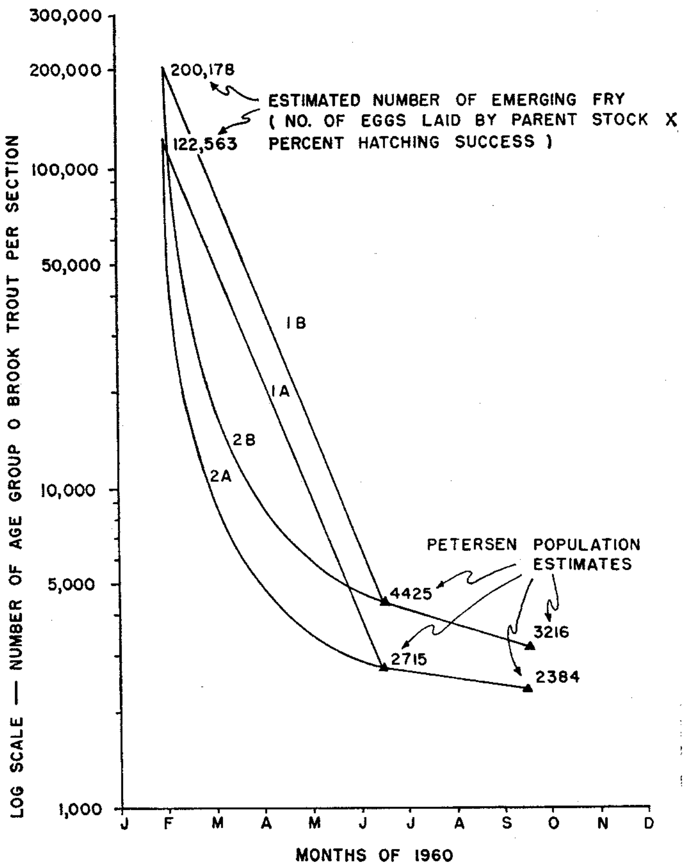


Figure 22. An illustration of the two methods employed to estimate numbers of age group 0 brook trout present in sections A and B on the first day of February through June each year during the 1959-64 period.

production estimates was the part dealing with the first few months of life of a year class when natural mortality was probably changing rapidly but the changes were unknown because population estimate data for this period were lacking.

Production estimates during the first 5 months of life of the 1959-61 year classes of brook trout in Lawrence Creek are also largely speculative. Growth data were collected monthly during this period but mortality rates were not determined. However, two methods of calculating production, using different hypothetical mortality trends, were tried. Both methods are illustrated in Figure 22 as they apply to the 1960 year class in sections A and B. The first method, indicated by lines labeled 1A and 1B, consisted of simply plotting a straight line from the June point estimate of numerical density of age 0 trout to the speculative estimate of numerical density at emergence. (Density at emergence was derived from the product of the number of eggs laid by the parent spawning stock and percentage of viable eggs or fry recovered from redds excavated prior to emergence of the year class.) Numbers of young-of-the-year in each section on the first day of March, April, May, and June were read from the

TABLE 17

Comparisons of Two Methods of Estimating Production During the First Five Months of Life for Stocks of the 1959-61 Year Classes in Sections A and B

	Pounds of Production Per Acre During February-June Periods					
	1959 Year Class		1960 Year Class		1961 Year Class	
	Section A	Section B	Section A	Section B	Section A	Section B
Method No. 1 (straight-line extrapolation)	38.4	81.5	16.7	25.9	25.5	48.1
Method No. 2 (curved-line extrapolation)	27.8	59.6	12.3	18.0	16.9	30.0
Percent difference (1 ÷ 2)	38	37	36	44	51	60

straight-line plot and combined with the appropriate growth statistics for that month. The second method, represented by the lines labeled 2A and 2B, is based on a curved line between the same two estimates of numerical density in each section. The curve becomes progressively steep as the emergence point is approached. The second method rests on the assumption that natural mortality is greatest just after emergence and then gradually diminishes. Numerical densities derived from the curved-line intercepts were combined with the same growth data used with the straight-line densities.

In Table 17 the paired estimates of production that resulted using these two methods are listed and compared for stocks of the 1959-61 year classes in sections A and B.

Production estimates derived by Method 2 were 36-60% lower. These were the values incorporated into all production calculations used in this bulletin because they were considered to be based on a more realistic approximation of temporal trends in mortality during the first few months of life.

Although the two methods resulted in rather large differences in production calculated for the February-June period, the larger of each pair of values could have been incorporated into summations of production on an annual or lifelong basis without drastically altering the results. Addition of the monthly increments of production derived by the straight-line method would have increased production calculated for the first year of life by only 5-7% for the three year classes involved. Apparently rather large errors in estimating numerical density early in the life of a year class can be tolerated without seriously biasing estimates of total production during the first year of life because the bulk of first-year production occurs during the June-December period.

Actual Production vs. Potential Production

In a paper dealing with computations of production by aquatic midge larvae, Neess and Dugdale (1959) derived an interesting statistic called "potential net production", which they defined as "the maximum quantity of material that could have been elaborated during the life of the cohort, and thus the total pupal crop, had there been no mortality". Actual production, or the amount of material actually elaborated during the life of the same cohort, was also computed and a ratio was established between potential and actual production. In this instance, the cohort (i.e., year class in fishery terminology) elaborated 8.7% of the amount of organic matter that might have been produced if all midge larvae had grown to full size.

I have calculated "potential net production" as the term applies to the 1959-61 year classes of brook trout in Lawrence Creek by multiplying the weight of the last survivor of each year class by the number of emerging fry. These potential production values were then compared to actual production values representing growth achieved during the life of each year class. In all three instances actual production was considerably lower in relation to potential production than in the example cited by Neess and Dugdale. Actual production as a percentage of potential production amounted to only 0.39% for the 1959 year class, 0.24% for the 1960 year class and 0.45% for the 1961 year class. Although it may seem to be only a matter of theoretical interest that production achieved by a year class of wild brook trout is less than one-half of one percent of potential production, even in a good trout stream such as Lawrence Creek, there is certainly an equally practical interest to consider: Present-day management of wild trout populations appears to have an almost unlimited opportunity for increasing trout production if the factors presently limiting growth and survival can be identified and remedial measures developed and applied to the benefit of trout and the fisheries they support.

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APPENDIX

Supplementary Tables and Figures

TABLE 18

Monthly Mean Air Temperature and Monthly Mean Precipitation Data at Montello in Marquette County

Month	Air Temperature (°F)	Inches of Precipitation
January	19	1.2
February	21	1.1
March	31	1.6
April	46	2.8
May	57	3.1
June	67	4.4
July	71	3.1
August	69	3.2
September	61	3.4
October	51	2.0
November	36	2.0
December	23	1.2

From: Poff, R. J. and C. W. Threinen (1963). Surface water resources of Marquette County. Wis. Conserv. Dept., Madison.

TABLE 19

Monthly Mean Stream Flows of Lawrence Creek at the Section C Recorder Site During 1960-65

	Mean Monthly Streamflow (c.f.s.)					
Month	1960	1961	1962	1963	1964	1965
January	17.8	16.4	16.5	17.6	16.5	15.1
February	17.6	16.8	17.3	17.8	15.9	15.2
March	17.7	17.9	17.6	17.4	15.6	15.5
April	17.8	17.9	22.6	17.5	16.8	16.7
May	18.0	17.5	18.0	17.4	17.3	16.4
June	18.8	17.7	19.4	16.7	15.1	15.0
July	17.6	16.0	16.7	17.4	14.9	15.0
August	17.0	17.9	16.4	17.9	16.6	15.8
September	18.1	19.3	17.2	18.9	15.7	20.0
October	17.6	20.7	18.3	16.9	14.8	16.9
November	17.6	19.9	17.4	17.6	15.6	16.8
December	16.8	17.9	16.8	16.9	15.2	17.8
Average of Monthly Means	17.8	18.0	17.6	17.5	15.6	16.3

TABLE 20

Monthly Mean Water Temperatures of Lawrence Creek During 1960-65

	Mean Monthly Water Temperature (°F)					
Month	1960	1961	1962	1963	1964	1965
January	38.7	37.6	39.1	40.3	40.0	36.6
February	40.3	42.5	39.1	40.4	41.5	38.1
March	42.2	45.0	45.3	45.6	44.5	41.1
April	51.5	49.6	51.3	52.8	51.7	48.1
May	55.3	56.1	57.5	55.6	58.6	57.6
June	56.4	59.0	58.3	59.4	58.4	59.6
July	57.1	59.1	57.6	59.1	59.5	60.0
August	57.5	59.0	57.8	56.9	57.2	58.5
September	53.9	55.4	53.7	54.0	53.8	53.8
October	47.6	51.6	51.4	52.9	49.2	49.7
November	41.7	45.0	45.4	46.4	46.0	43.3
December	37.3	40.0	41.9	37.9	40.7	40.3
Average of Monthly Means	48.3	50.0	49.9	50.1	50.1	48.8

TABLE 21

Point Estimates and 95 Percent Confidence Limits Expressed as a Percentage (plus or minus) of the Point Estimates of the Number of Brook Trout of Each Age Present in Lawrence Creek in April and September, 1963.

Month	Stream Section	Age Group 0	I	II	III+*
April	A		1520 (−1.3 +1.4)	444 (−4.7 +4.7)	18 (0.0 + 6.2)
	B		1137 (−1.6 +2.8)	449 (−2.0 +1.3)	16 (0.0 + 7.1)
	C		645 (−2.7 +3.4)	591 (−2.2 +3.0)	25 (−16.7 +25.0)
	D		1342 (−3.2 +2.1)	925 (−1.8 +2.2)	72 (− 2.8 + 4.1)
September	A	2077 (−2.4 +2.4)	606 (−1.0 +1.4)	149 (−1.4 +3.3)	6 (−50.0)
	B	3676 (−2.5 +2.3)	650 (−2.8 +0.8)	129 (−2.4 +1.5)	5 (− 0.0 +20.0)
	C	2601 (−4.2 +3.4)	589 (−1.1 +2.0)	249 (−2.4 +0.8)	6 (−20.0)
	D	2013 (−4.5 +5.8)	543 (−3.2 +2.8)	223 (−8.2 +8.1)	25 (−25.0 + 4.0)

* Confidence intervals sometimes represent differences of only one trout (plus or minus) from the point estimate for this age group.

TABLE 22

Number (N) of brook trout in Section A on the first day of the month, biomass (B) in pounds per acre, instantaneous growth rate (g) for the month, and production (P) in pounds per acre during the month for each age group present during 1960-64, plus (N), (B), (g) and (P) for age group 0 in 1959 and age group IV in 1965

Year	Age Group	Item	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1959	0	N	—	215,964	32,000	15,600	10,500	8,050	7,400	6,750	6,075	5,450	4,860	4,280
		B	—	4.99	1.29	0.99	2.42	6.98	21.40	26.55	31.63	36.26	44.43	40.86
		g	—	0.560	0.452	1,291	1.322	1.204	0.307	0.280	0.245	0.318	0.043	–0.031
		P	—	1.76	0.52	2.21	6.22	17.09	7.38	8.16	8.32	12.82	1.85	–1.15
1960	0	N	—	122,563	9,000	4,800	3,700	2,770	2,660	2,550	2,435	2,280	2,075	1,870
		B	—	2,83	0.36	0.30	0.85	2.88	8.46	11.50	14.08	17.80	20.40	19.47
		g	—	0.560	0.452	1.291	1.504	1.117	0.350	0.250	0.300	0.231	0.057	–0.028
		P	—	0.90	1.52	0.75	2.81	6.34	3.49	3.18	4.79	4.41	1.14	–0.51
1960	I	N	3,700	3,110	2,550	1,950	1,480	1,115	845	640	438	388	320	290
		B	34.25	30.59	26.55	21.43	18.83	20.32	20.04	18.70	15.20	14.81	12.31	9.90
		g	0.061	0.057	0.054	0.147	0.359	0.264	0.210	0.172	0.100	0.008	–0.120	–0.020
		P	1.97	1.63	1.30	2.95	7.03	5.32	4.04	2.92	1.43	0.10	–1.33	–0.15
1960	II	N	156	118	84	48	28	23	19	15	11	8	7	6
		B	4.96	3.88	2.98	1.85	1.19	1.10	0.95	0.80	0.62	0.46	0.38	0.29
		g	0.036	0.076	0.078	0.107	0.115	0.047	0.061	0.058	0.025	–0.056	–0.123	0.041
		P	0.16	0.26	0.19	0.16	0.13	0.05	0.06	0.04	0.01	–0.02	–0.04	0.01
1960	III	N	89	66	44	20	10	12	11	8	5	3	2	2
		B	4.37	3.39	2.36	1.12	0.58	0.81	0.83	0.67	0.46	0.29	0.18	0.16
		g	.046	0.044	0.042	0.050	0.137	0.113	0.108	0.092	0.066	–0.054	–0.111	0.041
		P	0.18	0.13	0.07	0.04	0.10	0.09	0.08	0.05	0.03	–0.01	–0.02	0.01
1960	IV	N	12	9	6	3	1	—	—	—	—	—	—	—
		B	0.92	0.74	0.56	0.29	0.10	—	—	—	—	—	—	—
		g	0.072	0.131	0.060	0.028	0.028	—	—	—	—	—	—	—
		P	0.06	0.08	0.03	0.01	—	—	—	—	—	—	—	—
1961	0	N	—	169,219	13,800	7,400	5,450	4,380	4,160	3,915	3,700	3,480	3,255	3,015
		B	—	3.91	0.55	0.46	1.25	4.56	13.23	17.66	21.40	27.18	32.01	31.40
		g	—	0.560	0.452	1.291	1.504	1.117	0.350	0.248	0.300	0.231	0.057	–0.028
		P	—	1.25	0.23	1.12	4.38	9.94	5.40	4.86	7.29	6.82	1.81	–0.84
1961	I	N	1,670	1,465	1,270	1,060	930	875	815	755	695	630	560	495
		B	15.45	15.25	14.10	13.18	15.06	20.75	25.22	28.39	30.76	30.25	26.73	20.04
		g	0.118	0.065	0.113	0.264	0.381	0.266	0.195	0.163	0.082	–0.006	–0.164	–0.036
		P	1.81	0.95	1.54	3.73	6.83	6.12	5.22	4.82	2.49	–0.17	–3.84	–0.66
1961	II	N	238	190	140	90	72	54	45	46	47	45	39	34
		B	7.98	6.70	5.50	3.93	3.60	3.10	2.90	3.35	3.80	3.89	3.22	2.49
		g	0.050	0.109	0.105	0.136	0.140	0.114	0.122	0.105	0.066	–0.044	–0.119	0.039
		P	0.37	0.66	0.49	0.51	0.47	0.34	0.38	0.38	0.25	–0.16	–0.34	0.09
1961	III	N	4	3	2	1	—	—	—	—	—	—	—	—
		B	0.20	0.17	0.12	0.06	—	—	—	—	—	—	—	—
		g	0.123	0.105	0.079	0.049	—	—	—	—	—	—	—	—
		P	0.02	0.02	0.01	—	—	—	—	—	—	—	—	—
1961	IV	N	2	1	1	1	1	—	—	—	—	—	—	—
		B	0.17	0.09	0.10	0.11	0.11	—	—	—	—	—	—	—
		g	0.058	0.118	0.054	0.026	0.025	—	—	—	—	—	—	—
		P	0.01	0.01	0.01	—	—	—	—	—	—	—	—	—

TABLE 22 (cont.)

Year	Age Group	Item	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1962	0	N	—	140,388	10,100	5,100	3,600	2,770	2,545	2,310	2,075	1,915	1,870	1,805
		B	—	3.24	0.40	0.32	0.83	2.40	7.36	9.08	10.80	12.74	17.09	17.23
		g	—	0.560	0.452	1.291	1.322	1.204	0.307	0.280	0.245	0.318	0.043	−0.031
		P	—	1.02	0.17	0.75	2.14	5.88	2.53	2.79	2.89	4.74	0.75	−0.51
1962	I	N	2,805	2,580	2,370	2,140	1,875	1,550	1,315	1,215	1,090	995	910	815
		B	28.40	28.36	28.79	30.33	31.46	32.28	31.95	33.39	33.42	33.39	30.80	24.52
		g	0.082	0.100	0.154	0.169	0.216	0.154	0.123	0.110	0.090	0.009	−0.118	−0.029
		P	2.33	2.86	4.56	5.21	6.89	4.95	4.02	3.66	3.01	0.28	−3.26	−0.66
1962	II	N	424	358	292	224	166	113	91	70	60	54	43	42
		B	16.55	14.39	12.58	10.36	8.25	6.11	5.10	4.02	3.54	3.21	2.72	2.08
		g	0.029	0.069	0.071	0.072	0.084	0.037	0.025	0.025	0.010	−0.050	−0.131	0.044
		P	0.45	0.94	0.82	0.67	0.60	0.21	0.12	0.09	0.03	−0.15	−0.31	0.09
1962	III	N	28	22	16	11	7	4	3	2	2	2	2	2
		B	2.13	1.76	1.34	0.97	0.62	0.36	0.28	0.20	0.21	0.21	0.20	0.18
		g	0.052	0.049	0.047	0.013	0.025	0.037	0.053	0.045	0.016	−0.044	−0.114	0.049
		P	0.10	0.08	0.06	0.01	0.01	0.01	0.01	0.01	—	−0.01	−0.02	0.01
1962	IV	N	1	1	—	—	—	—	—	—	—	—	—	—
		B	0.07	0.08	—	—	—	—	—	—	—	—	—	—
		g	0.073	0.132	—	—	—	—	—	—	—	—	—	—
		P	0.01	0.01	—	—	—	—	—	—	—	—	—	—
1963	0	N	—	192,728	20,000	8,600	5,300	3,940	3,410	2,880	2,340	2,100	2,150	2,195
		B	—	4.46	0.81	0.54	1.23	3.44	10.26	12.99	13.94	17.01	22.77	23.75
		g	—	0.560	0.452	1.291	1.386	1.179	0.405	0.278	0.307	0.268	0.022	−0.038
		P	—	1.48	0.31	1.14	3.38	8.20	4.72	3.75	4.75	5.33	0.50	−0.90
1963	I	N	1,740	1,680	1,620	1,560	1,375	1,180	1,006	846	685	584	545	505
		B	16.11	17.50	17.99	19.41	21.88	23.90	25.03	24.48	22.20	20.44	19.24	15.92
		g	0.118	0.065	0.113	0.246	0.241	0.206	0.151	0.113	0.077	0.008	−0.113	0.009
		P	1.98	1.14	2.12	5.08	5.52	5.04	3.73	2.65	1.65	0.16	−1.98	−0.14
1963	II	N	710	655	570	490	424	393	347	265	186	143	131	120
		B	20.74	19.71	18.47	17.86	18.89	19.33	17.77	14.41	10.76	8.44	7.35	5.90
		g	0.029	0.074	0.118	0.201	0.099	0.040	0.060	0.062	0.020	−0.050	−0.132	0.052
		P	0.59	1.41	2.14	3.69	1.89	0.75	0.97	0.78	0.19	−0.40	−0.87	0.29
1963	III	N	36	30	25	19	15	13	12	9	7	6	5	5
		B	4.49	1.72	1.61	1.34	1.08	0.97	0.86	0.76	0.62	0.55	0.42	0.38
		g	0.096	0.114	0.094	0.024	0.031	0.060	0.064	0.053	0.032	−0.065	−0.136	0.052
		P	0.17	0.19	0.14	0.03	0.03	0.06	0.06	0.04	0.02	−0.03	−0.06	0.02
1963	IV	N	2	2	2	2	1	1	1	—	—	—	—	—
		B	0.19	0.20	0.23	0.23	0.11	0.12	0.14	—	—	—	—	—
		g	0.058	0.108	0.025	0.025	0.024	0.149	0.020	—	—	—	—	—
		P	0.01	0.02	0.01	0.01	—	0.02	—	—	—	—	—	—
1964	0	N	—	270,155	30,000	12,200	7,500	5,420	4,580	3,715	2,870	2,420	2,350	2,280
		B	—	6.25	1.21	0.77	1.73	4.70	12.45	15.05	15.28	18.20	23.12	24.40
		g	—	0.560	0.452	1.291	1,322	1.142	0.398	0.273	0.346	0.268	0.085	−0.056
		P	—	2.09	0.45	1.62	4.26	9.80	5.48	4.14	5.79	5.54	2.01	−1.30
1964	I	N	2,220	2,280	2,315	2,375	2,215	1,880	1,620	1,440	1,260	1,140	1,060	982
		g	23.12	25.72	29.47	34.35	39.09	40.79	41.71	41.24	39.00	35.95	32.81	27.84
		P	0.080	0.121	0.128	0.199	0.207	0.171	0.106	0.078	0.019	−0.019	−0.088	−0.021
		B	1.96	3.33	4.08	7.30	8.25	7.06	4.42	3.12	0.69	−0.64	−2.66	−0.55

TABLE 22 (cont.)

Year	Age Group	Item	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1964	II	N	464	412	385	344	291	237	185	158	130	112	102	93
		B	5.32	5.55	5.39	5.33	4.90	4.36	3.85	3.32	2.62	2.31	1.96	1.57
		g	0.161	0.094	0.143	0.050	0.018	0.011	0.011	0.011	0.007	−0.050	−0.049	0.053
		P	0.87	0.52	0.76	0.25	0.08	0.04	0.04	0.03	0.02	−0.11	−0.09	0.08
1964	III	N	107	95	84	72	63	55	48	41	32	28	25	21
		B	5.32	5.55	5.39	5.33	4.90	4.36	3.85	3.32	2.62	2.31	1.96	1.57
		g	0.096	0.081	0.081	0.037	0.042	0.044	0.047	0.040	0.024	−0.043	−0.082	0.039
		P	0.87	0.52	0.76	0.25	0.08	0.04	0.04	0.03	0.02	−0.11	−0.09	0.08
1964	IV	N	4	3	3	2	2	2	2	1	—	—	—	—
		B	0.30	0.26	0.29	0.21	0.22	0.24	0.25	0.13	—	—	—	—
		g	0.143	0.107	0.081	0.054	0.090	0.028	0.041	0.026	—	—	—	—
		P	0.04	0.03	0.02	0.01	0.02	0.01	0.01	—	—	—	—	—
1965	IV	N	21	16	12	8	6	6	5	3	1	—	—	—
		B	0.94	0.68	0.52	0.39	0.39	0.47	0.47	0.34	0.16	—	—	—
		g	0.072	0.131	0.060	0.028	0.028	0.020	0.020	0.020	0.020	—	—	—
		P	0.07	0.09	0.03	0.01	0.01	0.01	0.01	0.01	<0.01	—	—	—

TABLE 23

Number (N) of brook trout in Section B on the first day of the month, biomass (B) in pounds per acre, instantaneous growth rate (g) for the month, and production (P) in pounds per acre during the month for each age group present during 1960-64, plus (N), (B), (g) and (P) for age group 0 in 1959 and age group IV in 1965

Year	Age Group	Item	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1959	0	N	—	414,288	84,000	37,000	22,000	15,770	13,750	11,775	9,700	8,250	7,250	6,290
		B	—	11.59	4.11	2.84	6.15	15.45	43.30	56.03	61.09	66.40	80.16	72.63
		g	—	0.560	0.452	1.291	1.253	1.168	0.413	0.280	0.245	0.318	0.043	−0.031
		P	—	4.40	1.57	5.81	13.54	34.30	20.15	16.42	15.63	23.28	3.31	−2.02
1960	0	N	—	200,178	18,000	8,900	5,900	4,620	4,230	3,820	3,410	3,060	2,740	2,420
		B	—	5.60	0.87	0.68	1.65	4.52	13.32	18.17	21.47	24.62	30.29	27.94
		g	—	0.560	0.452	1.291	1.253	1.168	0.413	0.280	0.245	0.318	0.043	−0.031
		P	—	1.82	0.36	1.51	3.87	10.42	6.50	5.56	5.65	8.72	1.26	−0.80
1960	I	N	5,250	4,230	3,260	2,240	1,595	1,310	1,112	984	845	746	652	564
		B	58.78	51.80	42.89	34.17	29.58	29.70	29.96	32.71	31.04	28.97	26.92	16.96
		g	0.090	0.072	0.148	0.195	0.201	0.172	0.210	0.100	0.056	0.061	−0.126	0.038
		P	4.96	3.39	5.70	6.22	5.96	5.15	6.58	3.19	1.67	1.71	−3.00	0.71
1960	II	N	204	160	119	74	46	32	23	19	16	13	11	10
		B	7.06	6.21	4.82	3.13	2.09	1.57	1.22	1.07	0.93	0.77	0.64	0.44
		g	0.114	0.044	0.042	0.072	0.081	0.075	0.064	0.030	0.024	−0.024	−0.266	−0.024
		P	0.76	0.24	0.17	0.19	0.15	0.10	0.07	0.03	0.02	−0.02	−0.15	−0.01
1960	III	N	94	74	54	33	18	8	4	3	3	3	2	2
		B	4.66	4.08	3.28	2.20	1.30	0.61	0.33	0.26	0.27	0.28	0.18	0.17
		g	0.107	0.096	0.093	0.080	0.070	0.061	0.058	0.058	0.041	−0.044	−0.035	0.065
		P	0.47	0.36	0.26	0.14	0.07	0.03	0.02	0.02	0.01	−0.01	−0.01	0.01
1960	IV	N	5	3	2	1	—	—	—	—	—	—	—	—
		B	0.44	0.28	0.22	0.11	—	—	—	—	—	—	—	—
		g	0.075	0.135	0.061	0.029	—	—	—	—	—	—	—	—
		P	0.03	0.03	0.01	0.003	—	—	—	—	—	—	—	—
1961	0	N	—	305,900	28,000	14,500	10,000	8,050	7,205	6,750	6,095	5,510	4,980	4,470
		B	—	8.56	1.37	1.11	2.79	8.45	23.69	33.06	39.24	50.13	59.25	57.87
		g	—	0.560	0.452	1.291	1.322	1.142	0.398	0.273	0.346	0.268	0.085	−0.056
		P	—	2.78	0.56	0.90	7.43	18.36	11.31	9.88	15.45	14.67	4.95	−2.94
1961	I	N	2,130	1,820	1,520	1,210	1,015	960	905	855	805	735	665	595
		B	23.85	22.28	19.67	16.51	17.75	23.85	29.13	34.10	36.61	34.72	31.64	24.35
		g	0.090	0.056	0.053	0.248	0.351	0.259	0.214	0.131	0.038	0.007	−0.150	0.009
		P	2.07	1.16	0.95	4.26	7.30	6.86	6.78	4.64	1.35	0.24	04.21	0.19
1961	II	N	460	380	290	200	120	87	58	53	48	43	38	34
		B	17.38	15.95	12.78	9.16	5.92	4.71	3.57	3.78	3.91	3.68	3.21	2.45
		g	0.105	0.049	0.039	0.074	0.095	0.127	0.148	0.133	0.050	−0.012	−0.161	−0.055
		P	1.76	0.70	0.43	0.56	0.50	0.53	1.59	0.51	0.19	−0.04	−0.45	−0.12
1961	III	N	8	6	5	4	2	—	—	—	—	—	—	—
		B	0.34	0.27	0.24	0.20	0.10	—	—	—	—	—	—	—
		g	0.054	0.073	0.055	0.052	0.049	—	—	—	—	—	—	—
		P	0.02	0.02	0.01	0.01	0.003	—	—	—	—	—	—	—
1961	IV	N	1	1	1	—	—	—	—	—	—	—	—	—
		B	0.09	0.10	0.11	—	—	—	—	—	—	—	—	—
		g	0.071	0.128	0.058	—	—	—	—	—	—	—	—	—
		P	—	—	—	—	—	—	—	—	—	—	—	—

TABLE 23 (cont.)

Year	Age Group	Item	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1962	0	N	—	220,822	20,250	9,750	6,050	4,470	3,900	3,300	2,720	2,340	2,150	1,960
		B	—	6.18	0.99	0.74	1.69	4.37	12.28	15.70	17.13	18.83	23.77	22.63
		g	—	0.560	0.452	1.291	1.253	1.168	0.413	0.280	0.245	0.318	0.043	−0.031
		P	—	2.01	0.39	1.58	3.80	9.73	5.78	4.60	4.41	6.77	1.01	−0.65
1962	I	N	3,910	3,370	2,860	2,310	1,980	1,615	1,410	1,305	1,200	1,095	995	900
		B	47.88	43.31	39.02	34.75	36.72	36.16	37.99	42.01	43.66	42.14	40.38	41.49
		g	0.056	0.053	0.098	0.209	0.189	0.185	0.178	0.123	0.056	0.053	−0.148	0.039
		P	2.54	2.17	3.60	7.47	6.87	6.86	7.12	5.25	2.41	2.19	05.33	1.18
1962	II	N	510	499	382	308	216	129	75	61	48	44	39	35
		B	21.05	20.58	18.84	16.24	12.39	7.89	4.77	3.96	3.19	2.98	2.56	1.84
		g	0.105	0.074	0.075	0.076	0.065	0.039	0.028	0.021	−0.021	−0.031	−0.219	−0.007
		P	2.18	1.45	1.32	1.09	0.66	0.25	0.10	0.08	0.06	−0.09	−0.48	−0.01
1962	III	N	29	25	21	16	11	5	2	3	4	4	3	2
		B	1.97	1.83	1.64	1.34	1.01	0.52	0.22	0.34	0.47	0.48	0.34	0.32
		g	0.074	0.065	0.069	0.095	0.128	0.071	0.025	0.027	0.023	−0.044	−0.056	0.056
		P	0.14	0.11	0.10	0.11	0.10	0.02	0.01	0.01	0.01	−0.02	−0.02	0.02
1962	IV	N	—	—	—	—	—	—	—	—	—	—	—	—
		B	—	—	—	—	—	—	—	—	—	—	—	—
		g	—	—	—	—	—	—	—	—	—	—	—	—
		P	—	—	—	—	—	—	—	—	—	—	—	—
1963	0	N	—	336,600	38,000	16,000	9,680	6,880	5,980	5,080	4,120	3,850	3,550	3,260
		B	—	9.42	1.86	1.23	2.71	7.22	19.66	24.89	27.10	35.84	46.46	43.58
		g	—	0.560	0.452	1.291	1.322	1.142	0.398	0.295	0.347	0.341	0.021	−0.059
		P	—	3.16	0.70	2.54	6.57	15.36	8.88	7.66	10.92	14.02	0.95	−2.40
1963	I	N	1,780	1,600	1,420	1,230	1,080	924	818	750	684	628	575	525
		B	19.93	19.60	18.38	17.65	19.65	21.66	23.76	26.51	27.77	26.81	25.76	20.39
		g	0.090	0.056	0.103	0.238	0.253	0.214	0.196	0.138	0.050	0.048	−0.143	0.035
		P	1.77	1.05	1.85	4.43	5.23	4.86	4.93	3.76	1.37	1.26	−3.29	0.70
1963	II	N	795	690	600	500	388	260	188	170	141	124	113	104
		B	28.93	26.80	24.56	21.87	19.14	14.37	10.66	11.01	9.52	8.55	7.55	5.46
		g	0.065	0.053	0.066	0.120	0.114	0.025	0.133	0.042	0.021	−0.031	−0.242	−0.020
		P	1.82	1.35	1.54	2.47	1.91	0.31	1.44	0.43	0.18	−0.25	−1.57	−0.10
1963	III	N	30	26	22	17	14	12	10	8	6	5	4	4
		B	1.57	1.54	1.45	1.26	1.16	1.11	0.99	0.82	0.64	0.55	0.41	0.39
		g	0.119	0.107	0.120	0.110	0.110	0.069	0.032	0.047	0.029	−0.064	0.054	0.069
		P	0.18	0.16	0.16	0.13	0.12	0.07	0.03	0.03	0.02	−0.03	−0.02	0.03
1963	IV	N	2	2	1	1	1	2	2	1	—	—	—	—
		B	0.23	0.25	0.13	0.14	0.15	0.30	0.34	0.17	—	—	—	—
		g	0.58	0.108	0.050	0.024	0.023	0.130	0.020	0.016	—	—	—	—
		P	0.01	0.02	0.01	0.00	0.01	0.04	0.01	—	—	—	—	—
1964	0	N	—	320,864	25,500	12,100	8,100	6,160	5,700	5,230	4,760	4,300	3,840	3,400
		B	—	8.98	1.24	0.93	2.26	6.46	18.74	25.61	30.64	34.60	42.46	39.26
		g	—	0.560	0.452	1.291	1.322	1.142	0.398	0.273	0.346	0.268	0.085	−0.056
		P	—	2.86	0.49	2.06	5.77	14.40	8.84	7.69	7.28	12.24	1.77	−1.11
1964	I	N	2,960	2,660	2,380	2,080	1,875	1,760	1,650	1,550	1,445	1,330	1,198	1,070
		B	4.83	4.64	4.66	4.71	4.16	2.73	1.99	1.57	1.15	1.07	0.94	0.82
		g	0.085	0.118	0.173	0.106	0.025	0.016	0.008	0.016	0.008	−0.040	−0.041	0.058
		P	0.40	0.55	0.81	0.46	0.09	0.04	0.02	0.02	0.01	−0.04	−0.04	−0.05

TABLE 23 (cont.)

Year	Age Group	Item	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1964	II	N	472	419	370	315	250	174	130	110	90	77	70	63
		B	17.70	18.32	18.64	17.74	15.04	10.77	8.23	7.08	5.82	5.00	4.11	3.17
		g	0.089	0.142	0.163	0.084	0.034	0.022	0.016	0.011	0.016	−0.087	−0.108	0.037
		P	2.77	2.62	2.03	1.08	0.37	0.21	0.13	0.03	0.03	−0.46	−0.56	−0.04
1964	III	N	94	83	74	63	50	32	23	18	13	12	11	10
		B	4.83	4.64	4.66	4.71	4.16	2.73	1.99	1.57	1.15	1.07	0.94	0.82
		g	0.085	0.118	0.173	0.106	0.025	0.016	0.008	0.016	0.008	−0.040	−0.041	0.058
		P	0.40	0.55	0.81	0.46	0.09	0.04	0.02	0.02	0.01	−0.04	−0.04	−0.05
1964	IV	N	3	2	2	1	1	—	—	—	—	—	—	—
		B	0.31	0.22	0.25	0.13	0.13	—	—	—	—	—	—	—
		g	0.065	0.118	0.043	0.026	0.026	—	—	—	—	—	—	—
		P	0.02	0.03	0.01	—	—	—	—	—	—	—	—	—
1965	IV	N	10	9	8	7	6	4	2	2	1	—	—	—
		B	0.70	0.67	0.63	0.57	0.51	0.44	0.35	0.25	0.13	—	—	—
		g	0.072	0.131	0.060	0.028	0.028	0.020	0.020	0.020	0.020	—	—	—
		P	0.05	0.95	0.03	0.02	0.01	0.01	0.01	<0.01	<0.01	—	—	—

Figure 23. Reproduction of one of the maps drawn to determine morphometric features of sections A and B of Lawrence Creek. Maps were drawn to a scale of 1 inch = 25 feet.

STREAM Lawrence Cr. (1 2: 0 1)

YEAR (3 4): 6 4 SECTION (5 6): 0 2

SPECIES (7): 1 ORIGIN (8): 1

SECTION	SPECIES	ORIGIN
00 = Z	1 = Brook (circled)	0 = Unknown
01 = A	2 = Brown	1 = Wild (circled)
02 = B (circled)	3 = Rainbow	2 = Hatchery
03 = C		
04 = D		
05 = E		

	AGE GROUP	TIME INTERVAL		MEAN INDIVIDUAL WEIGHT (TENTH GRAMS) ON FIRST DAY OF TIME INTERVAL						ESTIMATE OF POPULATION SIZE ON FIRST DAY OF TIME INTERVAL							REMARKS: INCLUSIVE DATES OF TIME INTERVAL	REMARKS: OTHER
	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24		
1	I	0	1				1	8	0				2	9	6	0		
2			2				1	9	0				2	6	6	0		
3			3				2	1	0				2	3	8	0		
4			4				2	4	5				2	0	8	0		
5			5				3	0	5				1	8	7	5		
6			6				3	7	5				1	7	6	0		
7			7				4	3	0				1	6	5	0		
8			8				4	6	5				1	5	5	0		
9			9				4	9	5				1	4	4	5		
10			10				5	1	0				1	3	3	0		
11			11				5	1	5				1	1	9	8		
12			12				4	9	0				1	0	7	0		
13			13				4	7	5					9	3	8		
14	II	0	1				5	3	6					4	7	2		
15			2				6	2	5					4	1	9		
16			3				7	2	0					3	7	0		
17			4				8	0	5					3	1	5		
18			5				8	6	0					2	5	0		
19			6				8	8	5					1	7	4		
20			7				9	0	5					1	3	0		
21			8				9	2	0					1	1	0		
22			9				9	2	5						9	0		
23			10				9	3	0						7	7		
24			11				8	4	0						7	0		
25			12				7	2	0						6	3		
26			13				7	1	0						5	6		
27																		

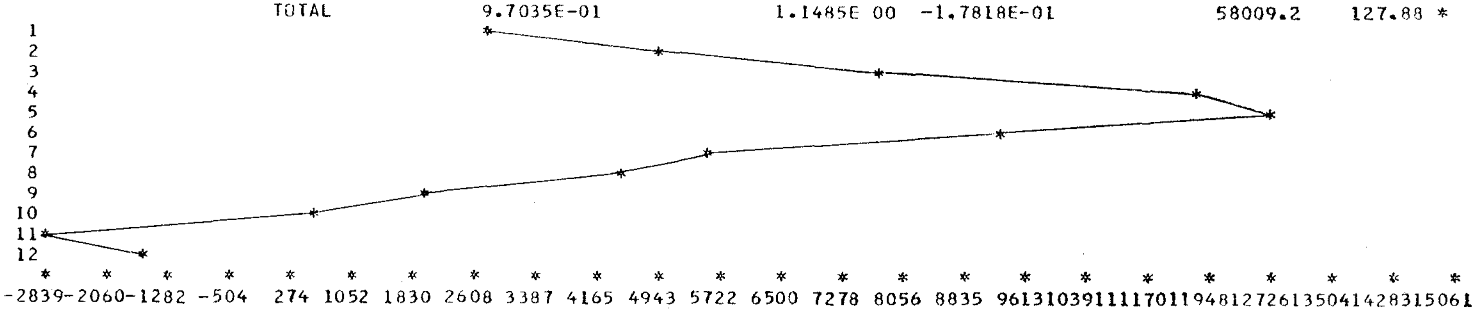
Figure 24. Sample input form used to record data necessary for IBM programming of production calculations.

PRODUCTION AND INSTANTANEOUS GROWTH RATE OF FISH FOR LAWRENCE CREEK

YEAR 1964

SEC B SPECIES BROOK TROUT ORIGIN 1 AGE GROUP 1

TIME INTERVAL	MEAN INDIVIDUAL WEIGHT	POPULATION ESTIMATE	BIOMASS	INSTANTANEOUS GROWTH RATE	PER CENT MORTALITY RATE	INSTANTANEOUS MORTALITY RATE	INSTANTANEOUS RATE OF INCREASE	AVERAGE BIOMASS	PRODUCTION OF FISH FLESH GRAMS	POUNDS
1	18.0	2960	53280.	5.4067E-02	10.1351	1.0680E-01	-5.2740E-02	51910.0	2806.6	6.1875
2	19.0	2660	50540.	1.0008E-01	10.5263	1.1117E-01	-1.1086E-02	50260.0	5030.1	11.0896
3	21.0	2380	49980.	1.5415E-01	12.6050	1.3467E-01	1.9474E-02	50470.0	7779.9	17.1519
4	24.5	2080	50960.	2.1905E-01	9.8558	1.0370E-01	1.1534E-01	54073.7	11845.0	26.1138
5	30.5	1875	57187.	2.0661E-01	6.1333	6.3242E-02	1.4337E-01	61593.7	12726.1	28.0563
6	37.5	1760	66000.	1.3685E-01	6.2500	6.4485E-02	7.2373E-02	68475.0	9371.4	20.6604
7	43.0	1650	70950.	7.8252E-02	6.0606	6.2467E-02	1.5784E-02	71512.5	5596.0	12.3370
8	46.5	1550	72075.	6.2520E-02	6.7742	7.0092E-02	-7.5721E-03	71801.2	4489.0	9.8966
9	49.5	1445	71527.	2.9852E-02	7.9585	8.2876E-02	-5.3023E-02	69678.7	2080.1	4.5858
10	51.0	1330	67830.	9.7561E-03	9.9248	1.0447E-01	-9.4714E-02	64763.5	631.8	1.3929
11	51.5	1198	61697.	-4.9761E-02	10.6845	1.1293E-01	-1.6270E-01	57063.5	-2839.5	-6.2601
12	49.0	1070	52430.	-3.1090E-02	12.3364	1.3160E-01	-1.6269E-01	48492.5	-1507.6	-3.3238
		TOTAL		9.7035E-01		1.1485E 00	-1.7818E-01		58009.2	127.88 *



Y-AXIS TIME INTERVAL VS X-AXIS NET PROD OF FLESH / TIME INTERVAL

TOTAL 9.7035E-01 1.1485E 00 -1.7818E-01 58009.2 127.88 **

Figure 25. Sample print-out sheet from IBM program of production calculations.

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