Population Dynamics and Net Production of Brown Trout (Salmo trutta) in Two Areas of a High Gradient Mountain Stream

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POPULATION DYNAMICS AND NET PRODUCTION OF BROWN TROUT (*SALMO TRUTTA*) IN TWO AREAS OF A HIGH GRADIENT MOUNTAIN STREAM

by

Jeffrey C. Gosse

A thesis submitted in partial fulfillment
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Jeffrey C. Gosse

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Trout (*Salmo trutta*) in Two Areas of a High
Gradient Mountain Stream

by

Jeffrey C. Gosse, Master of Science

Utah State University, 1978

Major Professor: William T. Helm
Department: Wildlife Science

Estimates of the brown trout (*Salmo trutta*) population were made in two areas of the Blacksmith Fork River, Cache County, Utah, from June 1972 to June 1973. Additional data were obtained on movement, growth, mortality, biomass, production, and yield.

Population density was highly variable in the area where habitat alterations had occurred, but was relatively uniform where the habitat was undisturbed. The brown trout exhibited little movement except during spawning season. Instantaneous growth and mortality rates are provided for each age group.

Mean annual biomass in the two areas was 12.0 and 10.2 grams per square meter and production was estimated at 9.2 and 7.7 grams per square meter per year in the two study areas. Gametes comprised approximately 5 percent of the annual production and angler harvest removed 39 percent of production.

(77 pages)

INTRODUCTION

In the past decade, estimates of fish production have become increasingly common. These studies are much more useful than the more commonly used estimates of standing crop, as has been pointed out by a number of authors (Ricker and Foerster 1948, Macfayden 1948, Hunt 1966, Hopkins 1971). But production estimates do not represent the total impact of a population upon a community, since only the population's energy output is evaluated. As Chapman (1968, p. 196) stated in regard to production estimates, "Energy consumption by fish . . . is a far more useful statistic in studies of total energy turnover." In evaluating the total impact of a population on an ecosystem, the relationship between consumption and production is probably the most useful bioenergetic measure.

The present study is part of a project designed to measure both consumption and production on the Blacksmith Fork River, Cache County, Utah. Studies were begun in 1969 to determine the energy uptake and production of the fish populations. Kimball (1972), Meyers (1972), and Salevurakis (1974) estimated the rate of food uptake and caloric value of invertebrates consumed by two species of fish: brown trout (*Salmo trutta*) and mountain whitefish (*Prosopium williamsoni*).

In the present study, dynamics of the brown trout population in two areas of the same river were described. The objectives were to

1. Determine the density, mean weights, and growth and mortality rates of the fish by age groups.
2. Provide standing crops, throughout the year, for use with energy uptake rates in estimating energy consumption.
3. Estimate total annual fish production and percent yield to anglers.

Data were collected for population estimates and production from June 1972 through June 1973. Preliminary studies were conducted during the summer of 1971.

SITE DESCRIPTION

Physical parameters

The Blacksmith Fork River drains an area of approximately 648 sq km, consisting primarily of limestone mountains. This and previous studies utilized a section of the river extending 19 km through a narrow canyon of the same name in Cache County, Utah. Elevation is 1,676 m at the head of the canyon and 1,433 m at the mouth. Numerous seepages, springs, and two tributaries, Rock Spring Creek and Lefthand Fork, supplement the river along this section. Two small reservoirs of 1 and 1.6 hectares are located on the river.

Two areas were chosen for population and production estimates (Figure 1). The first study area began at the second dam and continued downstream for 6.5 km to the upper reaches of the first reservoir. It averaged 11.5 m in width with a total surface area of 7.5 hectares. This area of the river had a wide variety of habitat types due to alterations from road construction, agriculture, and residential development. It was chosen for study because the two impoundments would serve as effective barriers against fish migration.

The second study area was located upstream from the first. It began approximately 200 m above the mouth of Rock Creek and extended upstream for 1.6 km with a mean width of 7.8 m and total area of 1.2 hectares. There was little physical disturbance here and the habitat was consistent throughout the area. Prior to, and independent of this study, the Utah State Division of Wildlife Resources had

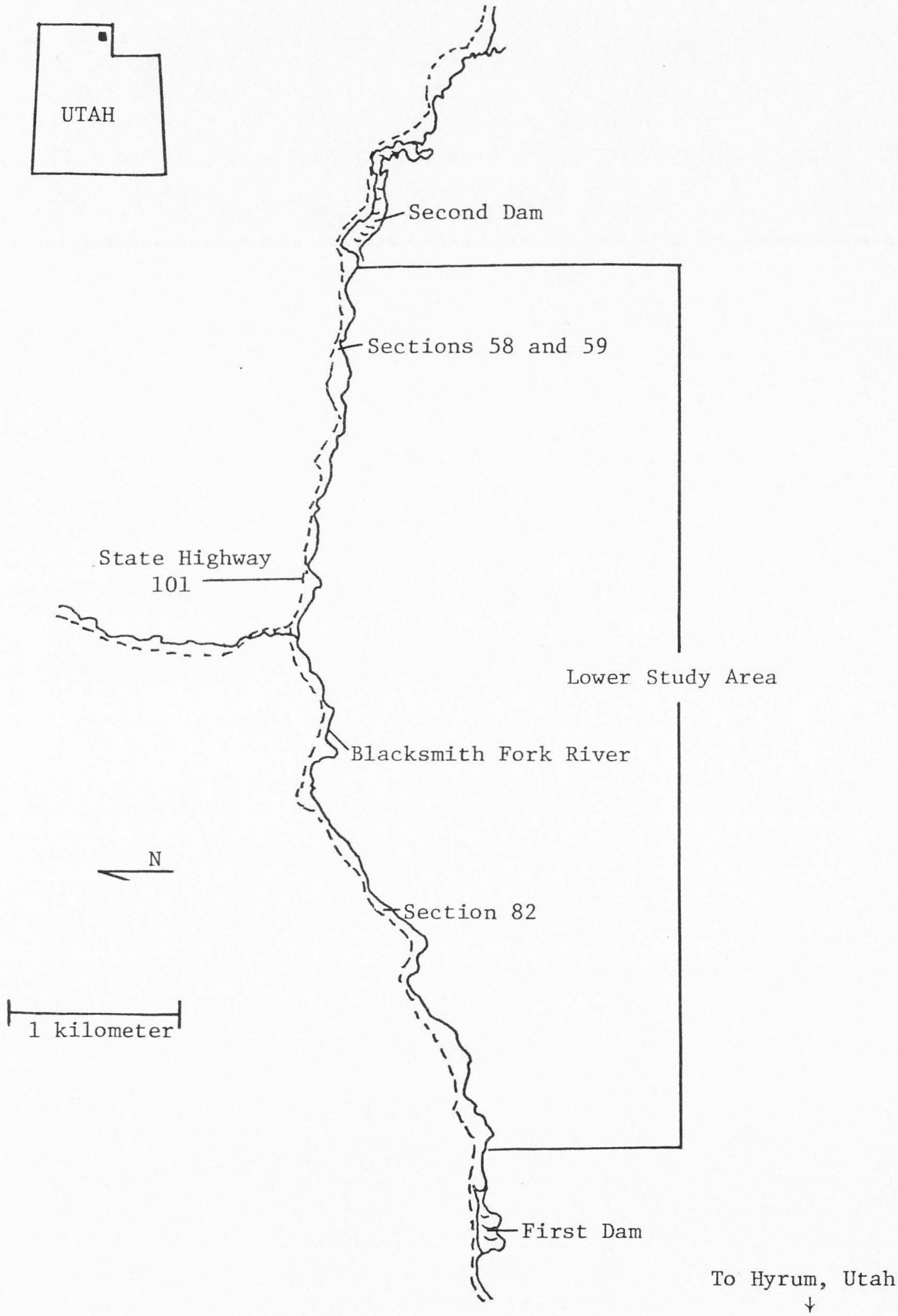

Figure 1. Lower and upper study areas, Blacksmith Fork River, Utah.

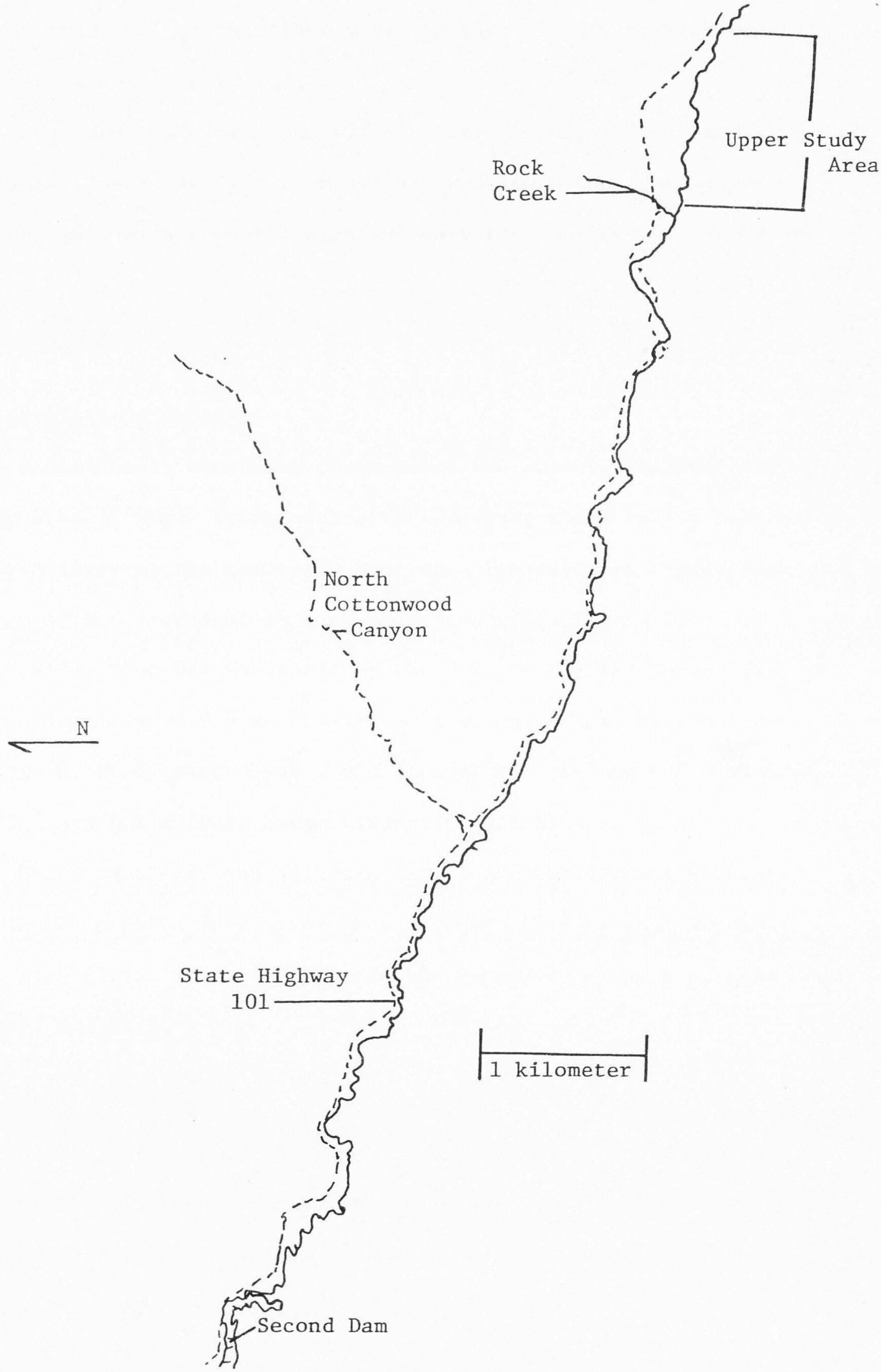

Figure 1. Continued.

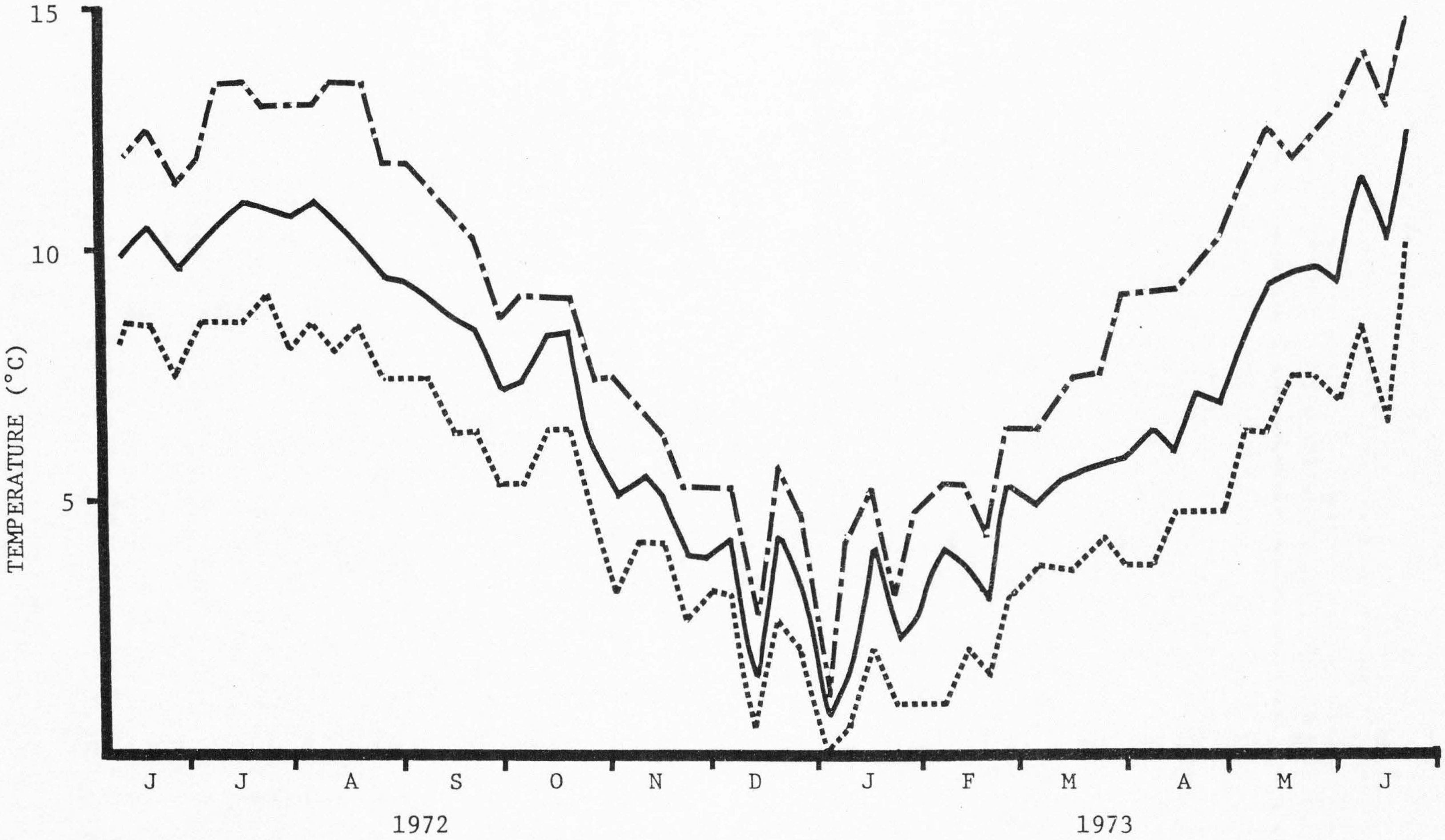

Figure 2. Weekly mean, minimum, and maximum water temperatures (°C) in the Blacksmith Fork River, Utah from June 1972 through June 1973.

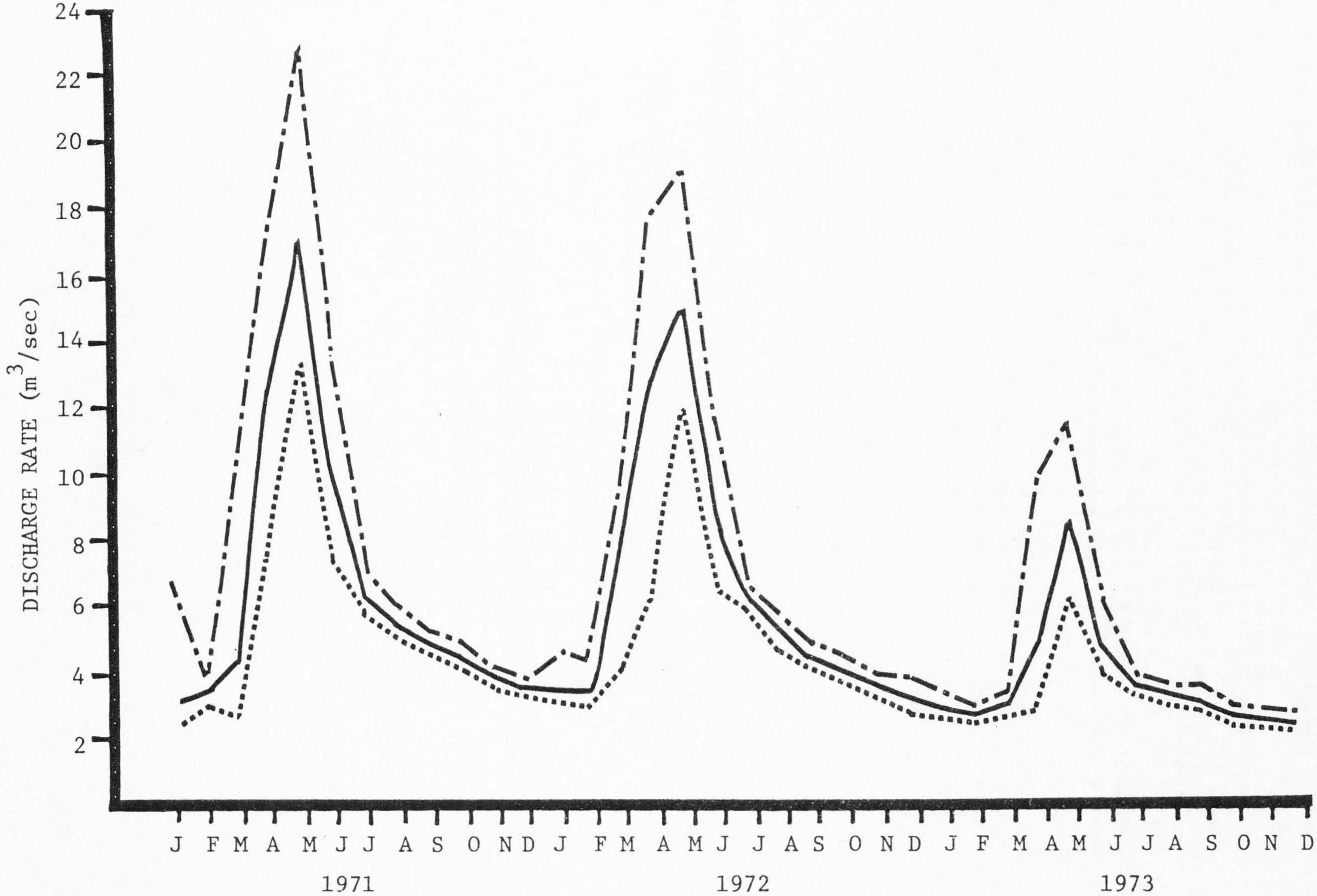

Figure 3. Monthly mean, minimum, and maximum discharge rates (m^3/sec) for the Blacksmith Fork River, Utah from January 1971 through December 1973.

Table 1. Mean concentrations[1] of selected chemical parameters in the Blacksmith Fork River, Utah from December 1969 to December 1971.

Chemical	Concentration
Sodium (Na)	3.7 ppm
Calcium (Ca)	44.5 ppm
Magnesium (Mg)	18.1 ppm
Potassium (K)	2.1 ppm
Phosphorus (P)	0.0 ppm
Nitrates (NO_3)	0.6 ppm
Bicarbonate (HCO_3)	3.1 me/l
Chlorine (Cl)	0.3 me/l
Sulphates (SO_4)	0.4 me/l
pH	6.5 - 8.2[2]
Conductivity	325 umhos[3]

1/ From Hart, Southard, and Williams, 1973.

2/ Range

3/ Measured at various times during this study and standardized to 25 C.

(*Catostomus platyrhynchus*), Utah sucker (*Catostomus ardens*), and Utah chub (*Gila atraria*) were also present. Rainbow trout (*Salmo gairdneri*) and brook trout (*Salvelinus fontinalis*) have been introduced through stocking but probably do not reproduce naturally.

Kimball (1972) and Meyers (1972) described the invertebrate fauna of the river.

METHODS

Collections

Fish were captured by electrofishing with a 0.5 kw, 400 cycle/sec, AC, backpack shocker. Each section of stream was electrofished separately. Captured fish were held in 100 l plastic buckets. In the wider areas, the river was divided longitudinally and each half electrofished separately. Both sides were always collected before processing.

Fork and total lengths were recorded for all fish collected. Fish weighing ≤ 12, ≤ 500, and over 500 g were weighed to the nearest 0.1, 1, and 10 g, respectively. Weights were taken only during marking collections. Young-of-the-year fish were weighed only for monthly growth estimates in order to minimize stress.

Numbered dart tags (Dell 1968) were used to mark fish over 50 g. Smaller fish were marked using a series of fin clips. The first three marks consisted of pelvic or adipose fin removals (Wales and German 1956). Further marks were made using a punch to mark the fin rather than removal. Scales, used for age determination, were removed from below the dorsal fin of fish representing each of the different length groups.

After processing, all fish were held until fully revived and released in the section of capture. Mortalities were examined for sex and, during spawning, gametic weight. Visual inspections of sections were made, at varying intervals after collections, to check for delayed mortalities. A group of tagged fish was also held in an instream live-box to monitor effects of processing.

Age determination

Scales were impressed on acetate and examined on a micro-projector. Distance from focus to each annulus and anterior radius was measured to the nearest millimeter. Scales were verified with an independent reading. Lengths of fish at annulus formation were calculated using Carlander's (Lagler 1956) third degree polynomial:

$$L = x + b_o r + b_1 r^2 + b_2 r^3$$

where: L = fork length,

r = radius at annulus formation,

and x, b_o, b_1, b_2 = empirical constants.

Most of the scales read were taken from 15 June to 24 June, 1972. These direct readings provided a baseline for age-group determinations. The calculated lengths of annulus formation and those made by Sigler[1/] (1951) were used as additional baseline information. From these, age-groups were determined using monthly length-frequency histograms from the study sections. At attempt was made to use length plotted on probability paper for separating age-groups (Cassie 1954). This method was discontinued because it proved no more useful than regular histograms and was more tedious.

Movement

It was possible to obtain movement data on tagged fish (some age I and older) since the section of capture was recorded each time

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[1/] Sigler's back calculations were converted from standard length to fork length using his factor of 1.127.

a fish was collected. Movement was analyzed primarily to correct population estimates for migration. Measurement of movement is discrete (160 m sections) and not necessarily realistic when considering adjacent sections, since this may represent travel of only a few meters across an imaginary boundary. It must be assumed that tagged fish behaved the same as untagged fish in order to apply the movement data to the entire population.

Population estimates

Population estimates were made in the lower study area in 1971 to determine the feasibility of the study. Population densities varied greatly among sections, necessitating studying the entire area, rather than attempting representative sampling.

A two-catch mark and recapture method was used to determine 1972 population estimates. Capture efficiency in most areas of the river was below that required by the two-catch multinomial method (Zippin 1958). Multiple catch estimates would have been prohibitive because of the effort involved.

The population was estimated by age-groups to facilitate calculation of production and to adjust for gear selectivity. Estimates were made using a modified Petersen formula (Regier and Robson 1967):

$$\hat{N} = \frac{(M + 1)\ (C + 1)}{(R + 1)} - 1$$

where: $\hat{N}$ = estimated number of fish in the population,

M = number of fish marked,

C = number of fish in the sample,

and R = number of marked fish in the sample.

The population of each section was first estimated independently. Sections were then combined, whenever possible, in making final population estimates. This reduces the variance of the estimate by increasing the sample size. Two conditions had to be met before sections could be combined. First, they had to be geographically and temporally associated (physically adjacent to the stream with both mark and capture collections having occurred on nearly the same dates). The second collection of the section usually occurred 5 to 15 days after marking.

The second condition, constant gear efficiency among sections, is briefly mentioned by Allen (1951), but has been largely ignored since. As in the case of size selectivity, adjustments must be made when a difference in gear efficiency (due to changing physical conditions) occurs. Combining estimates of sections having different gear efficiencies results in a biased estimate unless there is random distribution of fish among sections. Such distribution is seldom the case in smaller streams (Miller 1957, Shetter 1968, Chapman 1968). Combining estimates of sections was somewhat subjective. Since gear efficiency among sections varied among age-groups, it was possible for some age-groups to be recruited similarly while others were not. Sections were not combined whenever doing so resulted in any large biases.

Population estimates of sections within the study areas were made over a period of time during the summer of 1972. The separate estimates were back calculated to the beginning of the production year, 15 June, and combined to give an instantaneous estimate of the total population. Back calculations were made using the formula for instantaneous mortality (Chapman 1958):

$$Z = \frac{\ln N_1 - \ln N_2}{\Delta t}$$

revised to:

$$\ln N_1 = \ln N_2 + Z\Delta t$$

where: Z = instantaneous rate of mortality,

and N_1, N_2 = estimates of the number of fish at times, t_1 and t_2.

The binomial distribution (Davis 1964) was used to calculate 95 percent confidence intervals for the individual estimates. Crow (1956) lists tables to calculate intervals for estimates involving 30 or fewer captures. For more than 30 captures, approximations were made using graphs (Clopper and Pearson 1934). These confidence intervals were back calculated as were the point estimators. In order to get confidence intervals on the total population, the variance of each estimator was calculated using the approximation (Sisson[1/]):

$$s^2_{N_i} = \left[\frac{L_u - L_l}{4} \right]^2$$

where: N_i = estimated population size for an age-group in section(s) i,

and L_u, L_l = upper and lower confidence limits, respectively.

These were then combined to give a variance of the total population (s^2_T) with the formula:

$$s^2_T = \Sigma(s^2_{N_i})$$

1/ Personal communication from Donald V. Sisson, fall, 1973, College of Science, Utah State University, Logan, Utah.

where: T = total population of an age-group,

and N_i = estimated population for an age-group in section(s) i.

This formula assumes the N_i's are independent resulting in the covariance portion of the equation equaling zero. The final confidence intervals are then calculated using the formula

$$T + t \sqrt{\frac{s_T^2}{n}}$$

where: T = total population of an age-group,

t = the appropriate value from student's t-distribution,

and n = number of separate estimates comparising the total estimate.

Growth and mortality rates

Rates of growth and mortality were estimated from selected sections within the lower study area, since it was impossible to sample the entire study area each sampling period. These sections were arbitrarily chosen because of the high numbers of fish available and the ease with which they could be electrofished. It was assumed that rates of growth and mortality in the study sections were representative of the rest of the study area.

Mean weights and population estimates were obtained monthly from June through November 1972 and in January, March, and June 1973 for sections 59 and 58 (Figure 1). Mean weights of fish in section 60 were also used for the first five collections. A second estimate of mortality for age-group 0 was determined in section 82 from July through October 1972.

Each successive collection in these sections served as the recapture for the previous month and the marking for the present month in making population estimates. In March and June 1973, special collections were made for the second segment of the population estimate. Adjustment was made for movement of fish into the sections between collections.

Growth rates, by age-groups, were determined using the actual mean weights. This approach minimizes the error introduced by other methods; conversion of weight from length, or the assumption that length-weight relationships remain constant throughout the year. Growth was calculated using the formula (Chapman 1968):

$$G = \frac{\ln \bar{w}_2 - \ln \bar{w}_1}{\Delta t}$$

where: G = instantaneous rate of increase in weight,

and $\bar{w}_1$, $\bar{w}_2$ = mean weights of an age-group at times t_1 and t_2, respectively.

This formula assumes that growth is exponential over the period Δt, when Δt is relatively short.

Ideally, mortality rates should be calculated for the same periods. However, the large variability of successive population estimates would not have yielded realistic mortality rates. Therefore, a single mortality rate was calculated for each age-group for the entire production year by fitting a line through successive estimates ($\ln \hat{N}_t$) by the least squares method. With the slope of the line equal to b, then:

$$Z = \frac{-b}{\Delta t}$$

where: Z = instantaneous mortality rate.

Angler harvest

In conjunction with a new management policy, the Utah State Division of Wildlife Resources conducted a creel census on the Blacksmith Fork River from June through September 1972. Data gathered from angler counts and interviews were extrapolated to give estimates of monthly fish catches. The river was divided into seven areas. Area four coincided with the lower study area of this project. The upper study area was only a part of area seven, hence, it was not included in yield analysis.

Since lengths and weights of harvested fish were not taken, the mean weights of the fish caught were estimated from the data of this study, adjusting for the six inch size limit in effect. Catchable fish included age II+ fish for the first three months, and age I+ fish for September.

Production

Biomass at the time of each collection was estimated using the formula:

$$B_o = \bar{w}_i \hat{N}_i$$

where: $\bar{w}_i$ = mean weight of the age-group,

and $\hat{N}_i$ = estimated size of the age-group.

Mean biomass ($\bar{B}_i$) between collections was then obtained by the formula (Chapman 1958):

$$\bar{B}_1 = \frac{B_o \ (e^{(G-Z)}-1)}{G-Z}$$

where: G, Z = instantaneous growth and mortality rates, respectively, for the periods between collections.

Production for a cohort (i) for one time interval (t) was found by the formula:

$$P_{it} = G_{it}\bar{B}_{it}$$

Total annual production is the sum of production of all cohorts over time.

The weight of sexual products (sperm and eggs) was estimated and included in the final production estimates. Special collections were made in November 1972 to determine the percentage of gametic weight in ripe fish. Sex ratios were determined from these collections and from those made by Salevurakis (1973). Age of maturation was determined from lengths of the smallest fish which were predominantly mature.

Data analysis

All data were recorded on computer data sheets to be keypunched directly onto cards. A series of programs, for use on a digital computer, was written to check for any fundamental errors in the data. Fork and total lengths were compared with each other, as were weight to fork length. Tagged fish were then compared each time they were recaptured for length and weight discrepancies.

Another series of programs was then used to examine movement and to compute mean weights and lengths, instantaneous growth and mortality rates, standing crops, population and production estimates.

RESULTS

Age determination

Regenerated scales and distorted annuli became increasingly common with age for the brown trout examined. Only a few fish of age-group IV and older had scales that could be confidently used to age individuals. Since the back calculation of lengths from annuli required relatively large and equal numbers of fish for each age-group, no fish of age-group IV or older were used. A mean length was not calculated for age-group IV because those fish that could be confidently used had lengths skewed toward the smaller sizes. Age-group IV was separated by length on the basis of Sigler's (1951) findings and inspection of the length frequency histograms. All older age-groups were considered as one. An age-group V occurred during January and March because 1 January was used as the arbitrary emergence date for the fry. This age-group was indistinguishable from older fish by June.

The age determinations appeared valid for three reasons: (a) there was complete agreement between age determination from scales and length frequency data for age 0 and for age I whenever the length frequency was distinct from age II; (b) there was no significant difference ($\alpha = 0.05$) in back calculated lengths for the different age-groups (Table 2); (c) the mean back calculated lengths agreed relatively well with those determined by Sigler (1951) (Table 3).

The basic problem in attempting to separate the various age-groups was the increasing overlap of size groups with age. Such

Table 2. Mean back calculated lengths (mm) at the time of annulus formation for three age-groups of brown trout from the Blacksmith Fork River, Utah. Student's t values are given for comparison between means.

	Age at Annulus Formation				
Age-group	I	t		II	t
I+	110.4				
		0.13			
II+	107.2		0.08	192.3	
		0.05			0.03
III+	108.6			188.3	

*Significant at 0.05 level.

Table 3. Comparison of mean lengths (mm) at time of annulus formation back calculated from scale readings for brown trout collected during this study from the Blacksmith Fork River, Utah and those collected by Sigler (1951) in the Logan River, Utah.

Age at Annulus Formation	Back Calculated Length (mm)	
	This study	Sigler[1/]
I	110	98
II	192	167
III	238	238

[1/] Converted from standard length to fork length using Sigler's factor of 1.127.

continuity in size ranges made it probable that some fish were placed in the wrong age-group regardless of where the divisions were made. This introduced some error into estimates of growth and mortality rates.

Movement

Directional movement of brown trout was analyzed using the chi-square test (Table 4). Movement, not associated with spawning, into adjacent sections was not significantly directional ($\alpha = 0.05$). This supports the hypothesis that movement into adjacent sections was more indicative of section boundaries bisecting normal territories, rather than actual relocation by the fish. Fish traveling two or more sections moved significantly ($\alpha = 0.05$) more often upstream.

Table 4. Directional movement of brown trout in the Blacksmith Fork River, Utah during spawning and nonspawning seasons. Number of fish in each category and chi-square values comparing direction of travel are given.

	Adjacent Section			Two or More Sections		
Period	Down	Up	Chi-square	Down	Up	Chi-square
Spawning	56	86	5.92*	11	72	43.37*
Nonspawning	90	104	3.84	20	42	7.11*

*Significant at the 0.05 level.

Spawning movement includes all movement that either began or ended in October or November. Upstream movement was significant

($\alpha = 0.05$) both for adjacent sections and for fish traveling two or more sections (Table 4). Since only the study sections were sampled during these months, this movement indicated that fish left the sections they were found in during the summer and traveled upstream to spawn.

Population estimates, except for study sections, consisted of two collections usually made less than 16 days apart. A total of 8.7 percent of the fish recaptured during this time interval had moved, but only 1.9 percent moved two or more sections (Table 5). Population estimates were not thought to be affected by fish traveling into adjacent sections since this movement was considered random, localized travel across an imaginary boundary. Fish marked in 1972 that moved beyond adjacent sections were considered as recaptures, regardless of the section of origin, because of the low numbers involved.

Table 5. Number and percent of brown trout moving and remaining stationary in the Blacksmith Fork River, Utah within 16 days after being marked.

Type of movement	Number of Fish			Percent of total
	Lower study area	Upper study area	Total	
Stationary	629	132	761	91.2
Adjacent sections	54	3	57	6.8
Two or more sections	16	0	16	1.9

Fish moving out of the growth and mortality study sections between collections did not affect the population estimates (Ricker 1958) as long as movement of marked and unmarked fish was proportional. Adjustments were made for immigration since most fish in these sections were tagged and only those captured on the previous collection were considered marked. Immigration accounted for 8.5 and 2.0 percent of the fish collected during spawning and nonspawning periods, respectively (Table 6). Adjustments were made by increasing the number of recaptures by the appropriate percentage.

Table 6. Number and percent of brown trout moving into the growth and mortality study sections in the Blacksmith Fork River, Utah during spawning and nonspawning periods.

	Stationary Fish		Moving Fish		
Period	Number	Percent	Number	Percent	Total
Spawning	1100	91.5	102	8.5	1202
Nonspawning	2021	98.0	42	2.0	2063

Population estimates

The uniform physical characteristics of the upper study area permitted combining all ten sections in making a population estimate (Appendix Table 17). The lower half of section 61 (lower study area) couldn't be effectively electrofished until water levels receded in August, resulting in a two part estimate. Accessibility to the river was denied for the second (capturing) collection in section 65 and parts of sections 73 and 74. Estimates were made by adding the number of fish marked in these areas to the number marked in the remainder of the section (or to section 66 for the former). Data from the previous year indicates that the sections are similar.

Population estimates for the various sections were back calculated to 15 June 1972, allowing for a direct comparison of densities among sections (Table 7). The variability of these densities demonstrates the necessity, in this case, to sample a large area of the river in order to obtain representative estimates. The range of densities is an order of magnitude. This difference is even more dramatic when individual age-groups are compared.

Total estimates for age-groups II and III have the lowest coefficients of variation in the two study areas (Table 8). Estimates for the younger and older age-groups became increasingly less precise. In both areas, the densities of the first two age-groups were inversely related to the third. Whether this is real or an artifact will be considered later.

Estimates from the study sections demonstrate changes in the various age-groups throughout the year (Table 9 and Figure 4). Estimates for the 1972 year-class, from both sections 58-59 and 82 were low for the June 1972 sampling period, probably because of high stream flow causing inefficient collecting. A similar, but subtle, increase occurred only once again, for the 1971 year-class during the last collection. Part of this increase probably resulted from the difficulty in separating age-groups II and III because of overlapping length frequencies at this time.

If the inverted age structure, mentioned earlier, was due solely to error resulting from low vulnerability, a large increase in the

Table 7. Population estimates back calculated to 15 June 1972 by sections and age-groups for brown trout in the Blacksmith Fork River, Utah.

Section	Age Group 0	I	II	III	IV	V+	Total	Total/ section
5-14	542	236	567	342	69	4	1760	176
52-57	6	694	1078	406	55	6	2245	374
58-60	323	405	795	468	180	8	2179	726
61-upper	3	44	36	28	12	0	123	-
61-lower	0	21	13	36	10	0	80	203
62	2	54	87	56	9	2	210	210
63-64	0	56	147	74	15	1	293	146
65-66	52	154	117	174	131	3	631	316
67-71	195	94	256	206	86	6	843	169
72	115	26	52	54	15	0	262	262
73-74	65	193	57	21	34	0	370	185
75	47	84	70	30	22	0	253	253
76	122	10	16	14	7	0	169	169
77-80	89	91	223	159	57	4	623	156
81	1	14	45	37	27	3	127	127
82	59	4	22	8	8	0	101	101
83	36	17	43	8	5	0	109	109
84	233	24	42	42	3	0	334	334
85-86	5	59	34	26	19	1	144	72
87	5	73	45	93	6	4	226	226
88-92	1099	333	197	258	99	30	2016	403

Table 8. Population estimates ($\hat{N}$) by area and age-group on 15 June 1972 with 95% confidence intervals, coefficients of variation (CV), and densities per hectare ($\hat{N}$/hectare) for brown trout in the Blacksmith Fork River, Utah.

Age group	$\hat{N}$	Confidence interval	CV (%)	$\hat{N}$/hectare
		Upper Area		
0	542	300 - 1238	43	437
I	236	167 - 389	23	190
II	567	465 - 731	12	457
III	342	288 - 385	7	276
IV	69	42 - 174	48	56
V+	4	1 - 115	712	3
Total	1760			1419
		Lower Area		
0	2457	1778 - 3136	27	328
I	2450	1837 - 3063	25	327
II	3375	3279 - 3471	3	450
III	2198	2091 - 2305	5	293
IV	800	664 - 936	17	107
V+	58	28 - 108	59	9
Total	11348			1513

Table 9. Population estimates for study sections 58 and 59 with 95% confidence intervals for brown trout in the Blacksmith Fork River, Utah.

Date		Year Class						
Marked	Collected	1973	1972	1971	1970	1969	1968	1967+
6/15/72	7/15/72		269	332	675	401	133	8
			53-11256	259-449	604-773	342-499	101-210	5-43
7/15/72	8/23/72		1892	373	709	316	63	2
			381-84000	287-535	625-890	266-418	53-83	2-59
8/23/72	9/12/72		1124	353	627	203	50	1
			242-22499	253-521	537-766	178-256	42-75	0-39
9/12/72	10/21/72		279	495	616	297	70	9
			114-766	365-731	552-742	244-396	54-102	2-199
10/21/72	11/18/72		447	304	603	335	98	7
			194-1689	267-431	556-816	286-484	78-166	4-26
11/18/72	1/23/72		666	349	581	329	67	9
			145-14499	274-523	518-787	279-484	55-123	4-199
1/23/73	3/3/73		165	283	465	193	31	2
			78-549	231-388	413-561	166-254	26-47	1-14
3/3/73	3/23/73		121	242	417	149	28	2
			77-226	204-299	360-526	128-199	21-50	2-7
6/19/73	6/28/73	1469	97	381	332	68		3
		300-24499	68-165	323-485	277-462	44-139	-	0-76

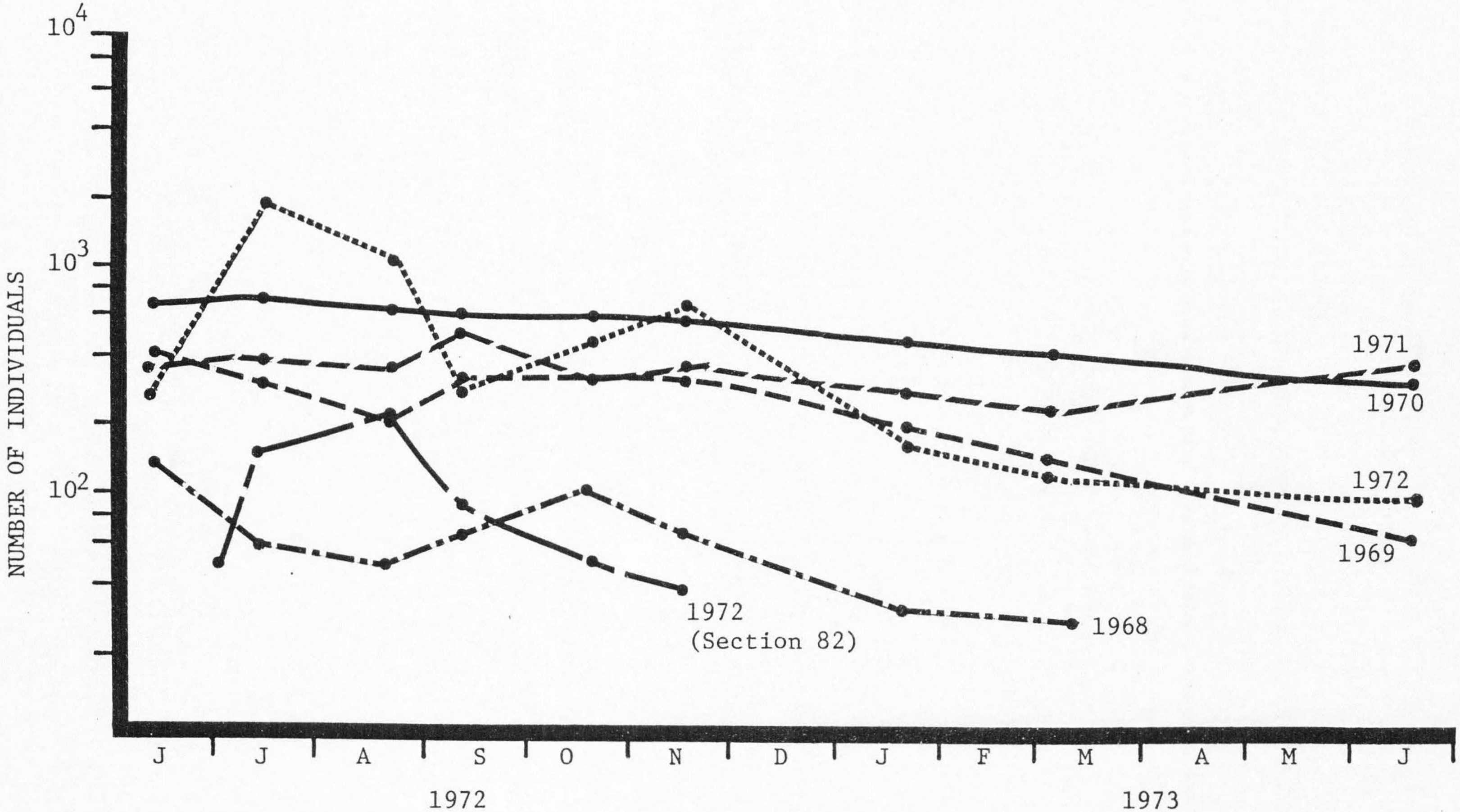

Figure 4. Population estimates by year-class from study sections 58-59 and for the 1972 year-class from section 82 from June 1972 to June 1973 for brown trout in the Blacksmith Fork River, Utah.

younger age-groups would be expected as they increased in size. Since this did not occur, and since the 1973 year-class was also large in comparison, it is probable that 1972 and 1971 year-classes were, in fact, weak. Spring floods were very high in 1971 and 1972 (Figure 3) and may have affected survival of young fry.

The precision of most of the population estimates was below the 10 percent level suggested by Robson and Regier (1964). Estimates of ages II and III for the entire study areas attained this level (Table 8), but become less precise with the smaller samples from the study sections (Table 9). Estimates of the younger age-groups fell short of the desired precision due to their low gear vulnerability, while estimates of older ages were less precise because of the low numbers present.

Growth

Mean weights, used to calculate growth rates, were obtained in collections from study sections (Figure 5). Several adjustments were necessary in calculating mean weights and growth rates due to small sample sizes. For collections where only a few of the age-group 0 fish collected were weighed, the mean weight was determined from the length-weight relationship of all fish collected. Only lengths were recorded during the second collection in March. Weights were calculated from lengths using length-weight relationships from the first collection in March.

Realistic growth rates couldn't be obtained for age-group V+ fish because of their low numbers. Growth rates from age-group IV fish were applied to the mean weights of age-group V+ fish obtained in June (Table 10). Age-group 0 fish consistantly exhibited the

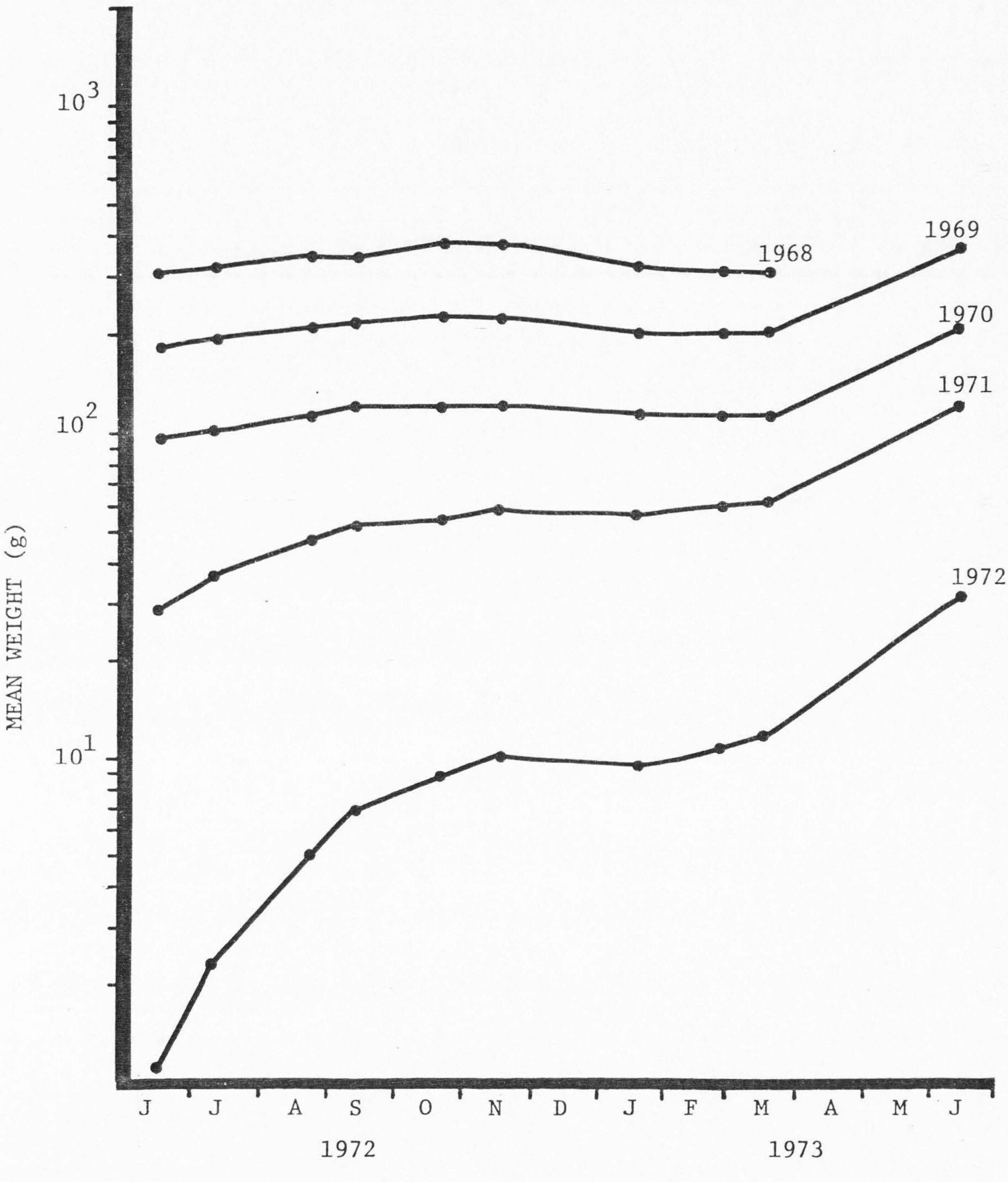

Figure 5. Mean weights by year-classes of brown trout collected in study sections of the Blacksmith Fork River, Utah from June 1972 to June 1973.

Table 10. Daily instantaneous growth rates for each year-class during each of the periods for which production was estimated for brown trout in the Blacksmith Fork River, Utah.

Starting Date	No. of Days	Year-Class 1972	1971	1970	1969	1968	1967+ 1/
6-15-72	30	.0242	.0085	.0016	.0021	.0012	.0012
7-15-72	39	.0194	.0061	.0033	.0019	.0022	.0022
8-23-72	20	.0178	.0052	.0023	.0017	-.0005	-.0005
9-12-72	39	.0062	.0013	.0001	.0008	.0022	.0022
10-21-72	28	.0049	.0019	-.0005	.0000	.0001	.0001
11-18-72	66	-.0008	-.0002	-.0009	-.0015	-.0022	-.0022
1-23-72	39	.0037	.0015	-.0003	-.0001	-.0010	-.0010
3-03-73	20	.0039	.0015	-.0003	-.0001	-.0010	-.0010
3-23-73	88	.0111	.0076	.0071	.0066	2/	.0066

1/ Rates taken from 1968 year-class and for 3-23-73, from 1969 year-class.

2/ Year-class 1968 combined with older fish for this period.

highest rate of growth while succeeding age-groups tended to grow slower than previous ones. Differences in growth rates became less pronounced with age.

The similarity in growth patterns of age-groups II, III, and IV appears to justify the use of rates from age-group IV fish for age V+. All ages exhibit retarded growth rates in the summer, little or no growth in the fall, loss of weight in early winter, and major growth in the spring. Loss of weight is the only manner in which negative production occurs (Chapman 1967). This loss of weight is most likely real, since it occurs in all age-groups and was also observed in individual tagged fish. This loss of weight does not seem unusual, considering the cold temperatures encountered in early winter (Figure 2) and the physiological stress of spawning. Mean weights of brown trout of various ages from the Blacksmith and from other waters are presented in Table 11 for comparison.

Table 11. Estimated mean weights (g) for brown trout at the end of each year of life from selected writers.

Source	Location	Age During the Past Year				
		0	I	II	III	IV
This study	Utah	12.0	63.8	116.2	209.8	323.9
Sigler 1951	Utah	11.3	59.8	172.3	304.3	501.9
Beyerle and Cooper 1960	Penn.	11.4	92.7			
Allen 1951	N.Z.	165	400			
Allen 1951	N.Z.	70	165			

Mortality

Daily instantaneous mortality rates and correlation coefficients (r) values for these rates were calculated for each age-group (Table 12). The rates for age-group I probably contain a large degree of error. Exponentially constant mortality was assumed throughout the year and all rates are in error to whatever extent mortality was not constant.

Table 12. Daily instantaneous mortality rates with correlation coefficients (r) and annual percent mortality for brown trout in the Blacksmith Fork River, Utah.

Age-group	Instantaneous mortality rate	r	Annual percent mortality
0	0.008861	0.88[1/]	96
I	0.000506	0.30	16
II	0.002070	0.98	53
III	0.004088	0.88	78
IV	0.004531	0.77	81

1/ The r values for the two rates were 0.88 and 0.89.

Two rates of mortality were calculated for age-group 0 fish (one from sections 58-59 and one from section 82) in order to obtain a more accurate estimate of mortality. In each case, initial population estimates were not included because of low recruitment (Figure 4). The rates were significantly different ($\alpha = 0.05$) and were combined to give one rate (Snedecor and Cochran 1967).

Age-group IV mortality rates were applied to age-group V+ because of the low number of the latter.

No mortality or signs of stress were observed with tagged fish held for 10 days in a live-box. Visual inspection of the river indicated some delayed mortality among whitefish but rarely among brown trout.

Angler harvest

The large angler catch in September (Table 13) resulted primarily from the estimated number (731) of fish caught on Labor Day. This estimate was determined with catch rates obtained from five fishermen interviews. While this may be an overestimate, estimates of catches from the three preceeding months may be low because of the difficulty involved in interviewing private landowners along the river (Summers[1/]). The decrease in mean weight observed in September (Table 13) resulted from the inclusion of age-group I fish in the catchable population. Estimates of mean weights were subject to error since angling is generally biased in regard to size. An estimated total of 271.9 kg of brown trout were harvested, or 3.6 g/m^2.

Standing crop and production

Maximum biomass was observed at the beginning of the production year (Figure 6). Biomass declined steadily until the end of March when it rose sharply. The similar trends in standing crop between the two study areas is partially because the same growth and mortality

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[1/] Personal communication from Ken Summers, Utah State Division of Wildlife Resources, Ogden, Utah.

Table 13. Estimated number, mean weight (g), and total biomass (kg) of brown trout harvested by anglers in the Blacksmith Fork River, Utah from June through September 1972.

	June	July	August	September	Total
Estimated number caught [1/]	380	302	87	952	1721
Estimated mean size (g)	168	174	188	146	
Total biomass (kg)	63.8	52.5	16.3	139.3	271.9

[1/] Unpublished data from Kent Summers, Utah State Division of Wildlife Resources, Northern Region, Ogden.

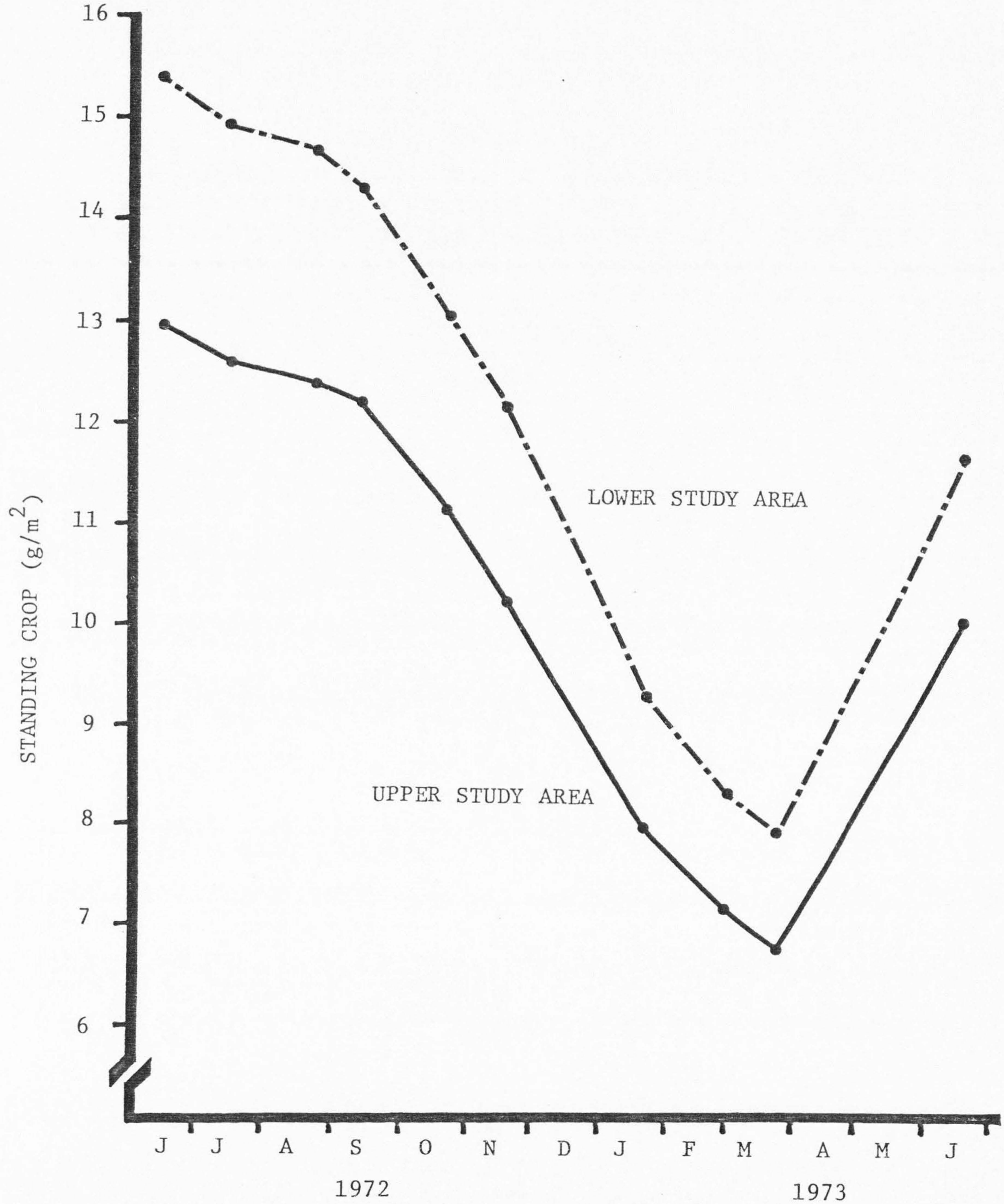

Figure 6. Standing crop (g/m^2) of brown trout for the two study areas in the Blacksmith Fork River, Utah from 15 June 1972 through 14 June 1973.

rates were used for both. However, differences would be expected since the two areas contained different age structures.

The last observed standing crops in June were smaller than the previous year. The 1972 year-class was not included in these estimates and may account for part of this decline. The available data were too incomplete to attempt even a crude estimate of their biomass. This year-class was also not included in production estimates.

A more probable reason for the difference in June biomass was the low standing crop of the 1973 year-class (Figure 7). Growth for this age group was apparently normal, since the final mean weight in June approximated that of the previous age-group (Figure 5). However, a high mortality rate (Table 12) and low initial population (Table 8) resulted in a continued low standing crop.

A total of 51 percent of the 607 fish examined were found to be males. Sexual products for males and females constituted 2 and 13 percent, respectively, of total wet weight. Males generally were mature by age-group II and females by age-group III. Numbers and mean weights of fish present on 19 November 1972 were used in the calculation. The total weight of sexual products is estimated at 0.5 and 0.4 g/m^2 for the lower and upper study areas, respectively (Table 14).

Total production was negative in both study areas during the period from November to January (spawning season) and in the upper area from January to March (Table 15). The 1970 and older year classes exhibited negative production in both study areas during much of the fall and winter (Appendix Tables 22 and 23).

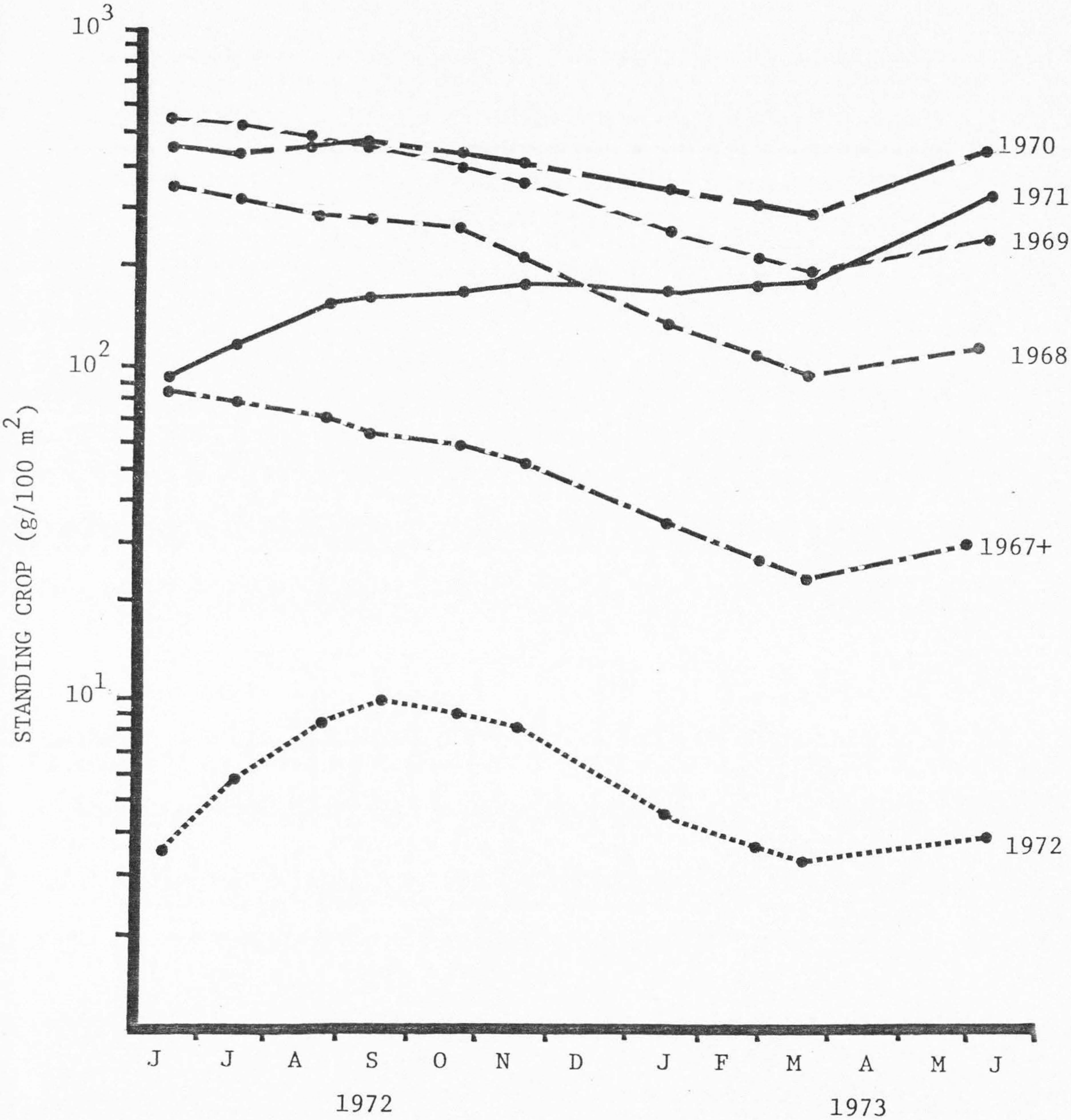

Figure 7. Standing crop (g/100 m^2) for each age-group of brown trout in the lower study area of the Blacksmith Fork River, Utah from 15 June 1972 through 14 June 1973.

Table 14. Mean wet weights (g), numbers, and total gametic weights (kg) by age-groups of the reproductive population of brown trout in the two study areas of the Blacksmith Fork River, Utah.

Age	Mean weight (g)	Total number fish	Number of mature males	Total male gametic weight (kg)	Number of mature females	Total female gametic weight (kg)	Total gametic weight (kg)
				Lower Area			
II	125	2445	1247	3.1	-	-	3.1
III	234	1161	592	2.8	369	17.3	20.1
IV	396	395	201	1.6	194	10.0	11.6
V+	1166	34	17	0.4	17	2.6	3.0
Total				7.9		29.9	37.8
				Upper Area			
II	125	411	210	0.5	0	0.0	0.5
III	234	181	92	0.4	89	2.7	3.1
IV	396	34	17	0.1	17	0.9	1.0
V+	1166	2	1	0.0	1	0.2	0.2
Total				1.0		3.8	4.8

Table 15. Mean biomass (g/m^2) and net production ($g/100\ m^2$) of brown trout in the upper and lower study areas of the Blacksmith Fork River, Utah from 15 June 1972 through 14 June 1973.

Period	Mean Biomass g/m^2)		Net Production ($g/100\ m^2$)	
	Upper area	Lower area	Upper area	Lower area
6/15/72 - 7/15/72	12.8	15.1	84.4	100.4
7/15/72 - 8/23/72	12.5	14.8	141.0	165.5
8/23/72 - 9/12/72	12.3	14.5	50.6	53.5
9/12/72 - 10/21/72	11.6	14.3	37.5	53.6
10/21/72 - 11/18/72	10.7	12.6	7.1	10.5
11/18/72 - 1/23/73	9.0	10.6	-28.1[1/]	-33.5[1/]
1/23/73 - 3/3/73	7.5	8.8	- 0.6	0.7
3/3/73 - 3/23/73	6.9	8.1	0.2	1.1
3/23/73 - 6/14/73	8.1	9.6	478.9	567.9
	Yearly mean biomass (g/m^2)		Total net production ($g/m^2/yr$)	
	10.1	12.0	7.7	9.2

[1/] Includes weight of sexual products for this period.

Total annual production for the lower and upper study areas was 8.7 and 7.3 g/m^2, respectively. When the weights of gametes were included in the production which occurred during spawning, respective rates for annual production were 9.2 and 7.7 g/m^2. Gametes thus represented roughly 5 percent of total production. Angler harvest (yield) removed 39 percent of production in the lower study area.

Total accumulated production (including gametes) is shown in Figure 8. While there is production during the summer and early fall, the major amount occurs during the spring when growth rates are the highest. The relationship of standing crop, accumulated production and production per interval of time is shown in Figure 9, and mean biomass per unit area, production per unit area and production:biomass ratios from this and other studies are presented in Table 16.

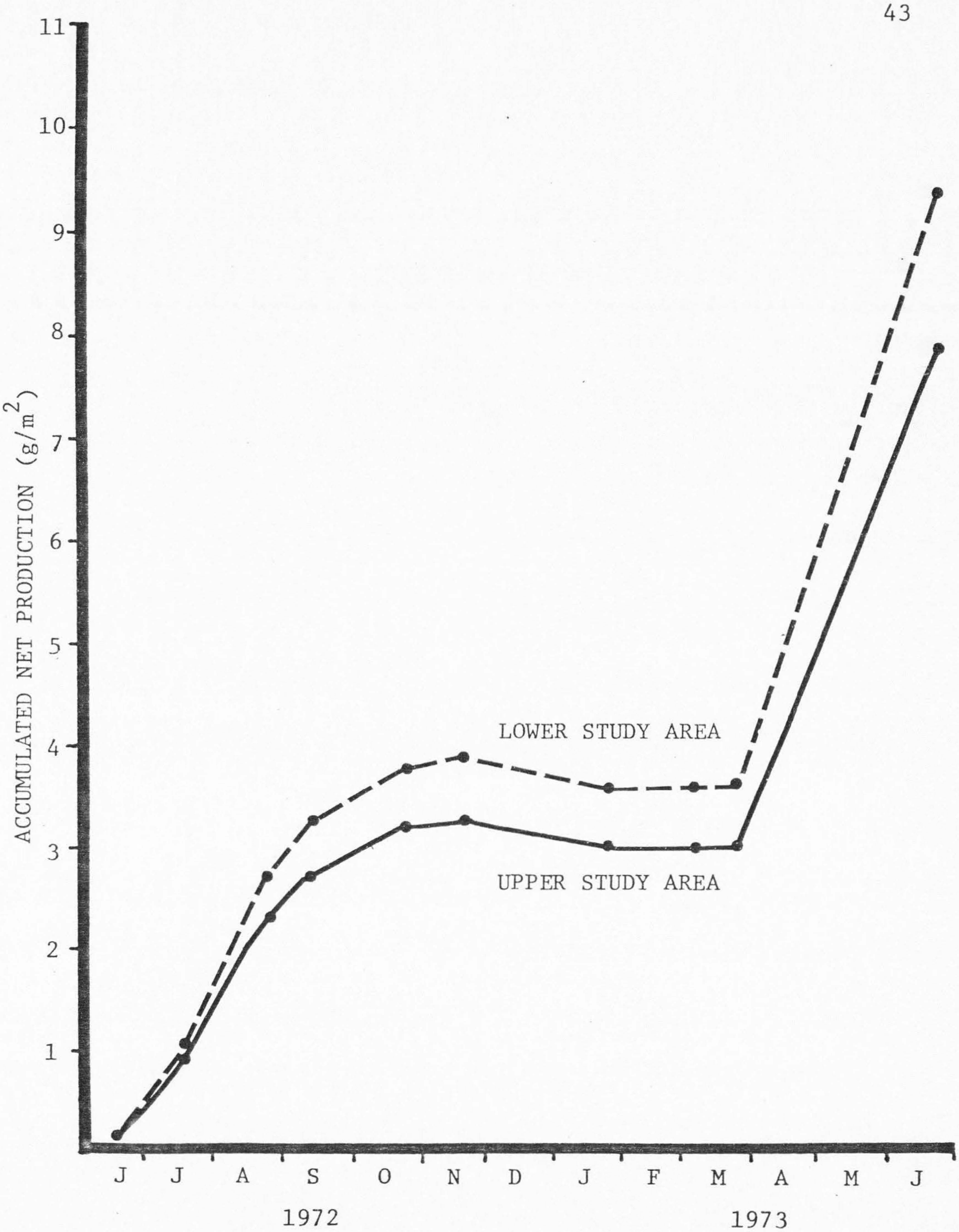

Figure 8. Accumulated net production (g/m^2), including sexual products, for brown trout in the Blacksmith Fork River, Utah.

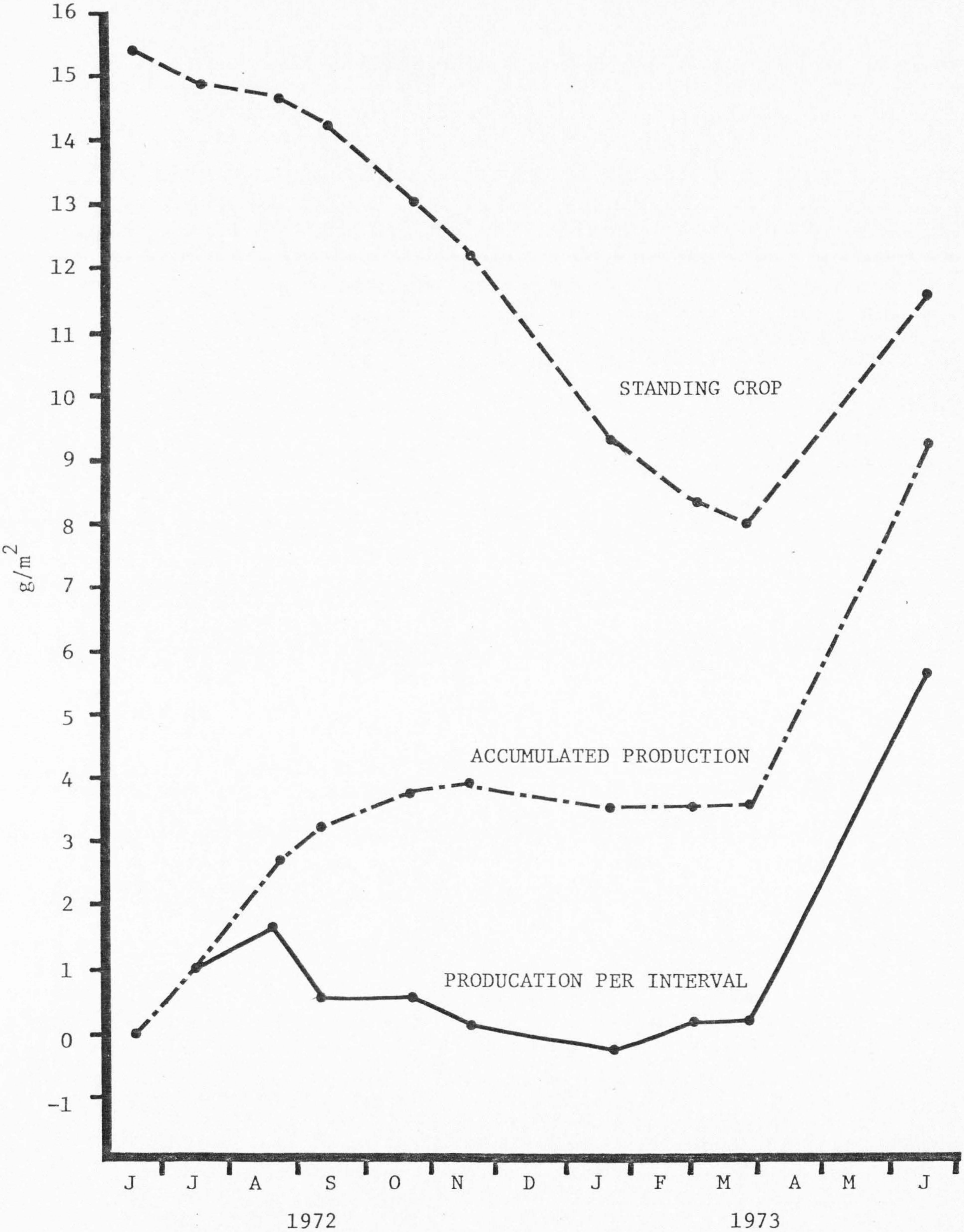

Figure 9. Standing crop, accumulated production, and production per interval (all in g/m^2) for brown trout in the lower study area of the Blacksmith Fork River, Utah.

Table 16. Mean biomass (g/m^2), production ($g/m^2/yr$), and production:biomass ratios (p:b) from selected studies.

Authors	Species	Location	Mean Biomass	Annual Production	p:b
Allen, 1951	Brown trout	New Zealand	26.6	54.7	2.06
Hunt, 1966	Brook trout	Wisconsin	5.8	10.1	1.74
Hopkins, 1971 1/	Brown trout	New Zealand	1.8	8.7	4.94
Lowry, 1966	Cutthroat trout	Oregon	4.2	4.1	0.98
This study	Brown trout	Utah	11.8	9.0	0.76

1/ Calculated from his data.

DISCUSSION

Movement

Stressed and slow growing trout have been observed to move downstream (Gresswell 1973, Miller 1957). Chapman (1962) found small salmon emigrating from areas of a stream while larger ones remained in their territories. Logan (1963) and Stefanich (1951) found more trout moving downstream than up, while Shetter (1968) observed a slight tendency for brown trout to move upstream. Fish were apparently not stressed by handling and marking in this study since in no case was there more downstream movement than up.

Although cutthroat trout in streams did not leave their home pools to spawn (Miller 1957), Stuart (1957) found brown trout moving upstream into tributaries of their resident lakes to spawn. In the present study, upstream movement appeared to be definitely associated with spawning. These fish apparently return to their original homes later, since many of the fish tagged in 1971 were found in the same sections in 1972. Schuck (1945), Allen (1951), and Stefanich (1951) all observed brown trout occupying the same areas of stream over time.

Gerking (1959) hypothesized that species exhibiting strong agonistic tendencies are stable with respect to movement. He also warned against the use of population estimates that do not take this stability into account. The movements of brown trout observed in the Blacksmith support this hypothesis, and justify estimating the population by sections.

Population estimates

Population estimates among sections of the upper study area did not exhibit the large variation in density observed among sections in the lower study area. This low variation can probably be attributed to the more uniform physical characteristics of the upper area. Allen (1951) found similar results with brown trout where certain "zones" of the river had relatively constant densities while others varied greatly, with maximum densities about six times greater than minimum. McFadden (1961) found that maximum densities of brook trout were four to ten times greater than minimum estimates among four sections, over a four year period. Thus great care should be taken whenever assuming that densities in sampling sections are representative of larger areas.

McFadden (1961), and Horton, Bailey, and Wildsdon (1968) reported pyramidal age structures with young-of-the-year comprising as much as 90 percent of the population. Thus, either size of year-classes did not fluctuate or such fluctuations were small compared to mortality rates. Hunt (1966) found that the 1959 year-class was 112 percent stronger than a 13 year average, but does not report whether this resulted in an inverted age structure. Lowry (1966) did find some inversion of age-groups, which he felt may have been due to movement. McFadden and Cooper (1962) also found cases of age inversion and estimated that weak year-classes, causing such inversions, occurred about 17 percent of the time. These reductions in recruitment and those found by Allen (1951) were associated with severe flooding. This is a probable explanation for the inversion in size of age-groups found in this study.

Population estimates of the individual age-groups were not always as precise as would be desirable, but the most precise estimates were of those age-groups which made the greatest contribution to production. Thus, unless the errors in estimates of the younger and older age-groups were greater than that indicated by the confidence intervals, production estimates were not greatly affected.

Growth

The seasonal pattern of growth found in the Blacksmith appears to be common for many populations. Numerous workers have found that growth of brown trout was most rapid in the spring, declined through the summer, and was negligible in late fall and winter (Allen 1951, Beyerle and Cooper 1960, Hopkins 1971, Egglishaw 1970). Negative growth (loss of weight) of stream salmonids was reported during the winter, by Hunt (1966), while Lowry (1966) and Goodnight and Bjorn (1971) suspected that it occurred but did not report it. Coche (1967) observed a loss in weight of trout in an impoundment during part of the fall and winter.

The seasonal growth patterns approximate production during the year (Figure 8) since mortality is assumed constant. Beyerle and Cooper (1960) also assumed constant mortality and found a similar relationship between growth and rate of change in biomass.

Other workers have found a pattern of growth, among different age-groups, similar to that found in the Blacksmith. Allen (1951) and Beyerle and Cooper (1960) observed a higher rate for age-group 0 fish than for age-group I fish. The former also found progressively lower growth rates with age. This pattern of growth is not approximated (as are seasonal growth patterns) by production of age-groups since mortality rates do change with age.

Growth, of brown trout in the Blacksmith, during the first year is similar to that observed in other streams in the United States, but much less than that found by Allen (1951) in New Zealand (Table 11). Growth appears to be slower during later years than in other streams. Carlander (1969) reports additional studies listing weights at annulus formation. Most exhibit more rapid growth than that found in the Blacksmith, although one was much slower.

Angler harvest

Most production studies do not estimate yield, except in cases where the entire population is removed (Coche 1967) or emigrates from the area (Chapman 1965). Hunt (1966) accurately determined angler harvest in Lawrence Creek by using a mandatory creel census. He found that anglers harvested an average of 13 percent of the total annual production. This figure is lower than the 39 percent observed in the Blacksmith, probably because most production in Lawrence Creek occurred before fish were large enough to be harvested by angling. Other sources of mortality reduced the stock before it could be harvested.

Standing crop

Seasonal patterns in standing crop appear to vary more from one stream system to another than do seasonal patterns in growth. While maximum biomass in the Blacksmith was observed in late spring, Hunt (1966) reported maximum biomass of brook trout in late fall and early winter over a four year period. Standing crop of juvenile coho salmon in three Oregon streams was consistently highest in early spring over a four year period (Chapman 1965). In New Zealand (Hopkins 1971) and Scotland (Egglishaw 1970), brown trout reached maximum biomass during late summer and early fall.

Unlike growth rates, little relationship was observed between patterns in biomass and cummulative net production or in production during sampling intervals (Figure 9). Allen (1971) discusses the relationship between production and biomass integral. Using the assumptions of exponential growth and mortality made in this study, this relationship is equal to the instantaneous growth rate for each production interval.

A wide range in mean biomass has been reported by various workers (Table 16). There is also a large degree of variation between annual production and mean biomass. Part of the difference between these ratios is caused by the age structure of the populations studied. Hopkins (1971) dealt only with young trout while Allen (1951) and Hunt (1966) dealt with five or more age-groups, although production occurred primarily in the first few age-groups. Lowry (1966) found that most production occurred in older age-groups, as was observed in the Blacksmith. Thus, the ratio between production and biomass appears to decrease as the age-group of the major producers increases. Hunt (1966) demonstrated this principle by comparing production: biomass ratios for successive cohorts.

Production

As mentioned earlier, the 1973 year-class was not included in production estimates because they could not be effectively recruited before the study ended in June. Allen (1951) found that age 0 fish contributed approximately 37 percent of total annual production during the same period of life while Hunt (1966) found that 20 percent of annual production occurred during this period. Thus, production estimates could be seriously underestimated from lack of these data.

The importance of including gametic weights as part of production estimates was discussed by Bagenal (1967), but this is very seldom done (Chapman 1966). Mathews (1971) did include gametes as part of production estimates for four warmwater species. He found a range of 0.4 to 6.1 g/m^2/year for gametic production, which was a small part of total production. These findings are similar to those of the Blacksmith, both in absolute values and percent of total production. Although gametes were a relatively small part of production in these studies, they can play a major part for certain populations (Bagenal 1967).

The seasonal pattern of production was compared earlier to growth and standing crop. As with growth, several workers have found production for salmonids greatest in the spring and early summer (Allen 1952, Chapman 1965, Hunt 1966). Hopkins (1971) found the greatest production for brown trout in New Zealand from summer through fall. Seasonal production patterns (other than maximum peaks) vary greatly between studies, although they may be quite similar for individual streams over a period of years (Hunt 1966).

It was mentioned earlier that many workers report the greatest proportion of total annual production is contributed by the youngest age-classes (Allen 1951, Hunt 1966, Egglishaw 1970, Mathews 1971).

Lowry (1966) found that about half of the total annual production could be attributed to age-classes 0 and I. He concluded that major segments of production for these age-groups occurred in unsampled tributaries. Reasons for the low population estimates, and hence, low production, for the youngest age-groups in the Blacksmith have already been discussed. It is probable that production among these age-groups either is, or normally is, greater than production among the older age-groups.

Chapman (1965, 1967) listed the results of most production studies that have been made. Estimates obtained for the Blacksmith approximate the mode of the range (2-18 g/m^2/year) of most studies. The major deviations from these values are those found by Mann (1965) and by Allen (1951): 42.6 and 54.7 g/m^2/year, respectively.

Production estimates of the Blacksmith are most probably low, resulting from the small size of the 1971 and 1972 year-classes and from the lack of an estimate for the 1973 year-class. If the production of these younger age-groups is normally (or really) as proportionally large as that found in most other studies, brown trout production in the Blacksmith would be significantly increased. Production of the other two major species in the Blacksmith, mountain whitefish and mottled sculpin, may equal or exceed that of the brown trout (Goodnight and Bjorn 1971).

SUMMARY AND CONCLUSIONS

Estimates of the brown trout population were made in two areas of the Blacksmith Fork River. Additional special collections were made throughout the year to provide data from which mean weights and mortality and growth rates of the fish could be calculated. This information was used to estimate standing crop throughout the year and annual production.

Movement of fish was low except during spawning, when there was a definite upstream migration. The behavioral ecology of brown trout is such that an assumption of random movement is often invalid, as Gerking (1957) hypothesized. This stability with respect to movement must be considered when subsampling or estimating populations of brown trout in similar streams.

Fish density was highly variable in the lower study area, but uniform in the upper area. This correlates to the variable stream habitat, resulting from human alterations, in the lower area and the uniform natural habitat in the upper area. Variability in population density, such as was found in the lower study area, must be considered before population estimates of a small section of stream can be expanded to the entire stream or before attempting a representative subsampling of the stream population. Variability of stream habitat or of fish densities may result in variable gear efficiency along the stream course. This must be accounted for in estimating populations, particularly when the population is relatively nonmobile as was found in this study.

The age composition of the population differed from that often found in other studies. There was evidence that two of the year-classes were weaker than normal, resulting in older age-groups being larger than younger age-groups. Such phenomena have been reported by other workers, usually resulting from severe flooding, as was probably the case in the present study. Even during normal years, the older age-groups probably comprise a larger proportion of the population than they do in smaller or lower gradient streams. This type of age composition was reflected in other parameters measured. Mean biomass was increased and the production:biomass ratio was decreased in comparison to other studies. The older age-groups contributed the major proportion of production resulting in a greater proportion available as yield to anglers.

Yearly mean biomass was estimated at 12.0 and 10.2 g/m^2 for the lower and upper study areas, respectively. The standing crop exhibited large fluctuations over the year as has been reported by other workers. These fluctuations do not follow predictable patterns and demonstrate the danger in attempting comparison of single or seasonal biomass estimates.

Annual production was estimated at 9.2 and 7.7 $g/m^2/yr$ for the lower and upper study areas, respectively. Gametes accounted for approximately 5 percent of production. Anglers removed an estimated 39 percent of production in the lower study area. Production was negative during part of the winter (resulting from weight loss) demonstrating the necessity of sampling throughout the production year. Possible errors in the production estimate and two years of reduced recruitment most likely caused these estimates to be low.

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APPENDIX

Table 17. Population estimates with 95% confidence intervals on original marking dates by sections and age groups for brown trout in the Blacksmith Fork River, Utah.

Section	Date Marked	Date Collected	Age 0	Age I	Age II	Age III	Age IV	Age V+
5-14	249	258	262	227	479	245	48	3
			145-599	160-373	392-617	206-275	29-120	1-79
52-57	179	189	5	690	1051	386	52	6
			1-117	478-992	877-1263	318-499	39-78	1-142
58-60	167	197	323	405	795	468	180	8
			58-7499	324-564	715-941	414-602	135-266	5-43
61 upper	182	196	3	44	35	26	11	0
			0-76	24-199	22-80	17-59	8-28	
61 lower	239	246	0	20	11	27	7	0
				9-70	7-30	8-538	3-159	
62	182	189	2	53	85	52	8	2
			2-59	30-132	49-204	28-128	3-47	0-58
63-64	239	246	0	54	127	55	11	1
				29-147	55-452	24-193	5-239	1-39
65-66	186	243	44	153	113	161	120	3
			10-832	39-3142	75-199	107-305	43-666	3-79
67-71	208	216	136	92	235	174	71	5
			46-764	58-176	202-393	147-224	45-127	2-119
72	204	215	83	26	48	46	12	0
			39-236	13-72	31-98	30-114	8-66	
73-74	203	215	47	189	53	18	29	0
			24-112	47-3799	35-118	15-39	11-587	

Table 17. Continued.

Section	Date		Age					
	Marked	Collected	0	1	II	III	IV	V+
75	203	215	3 8-713	83 30-466	65 28-233	26 13-89	19 6-384	0
76	203	215	89 22-1666	10 7-31	15 13-27	12 8-66	6 6-18	0
77-80	202	214	65 23-363	89 46-210	208 128-321	138 99-223	49 35-93	3 2-11
81	193	213	1 1-39	14 6-50	43 31-70	34 23-56	24 12-66	3 1-79
82	187	201	50 39-94	4 4-9	21 12-71	7 4-26	7 4-26	0
83	183	193	31 11-173	16 8-46	42 22-143	7 4-25	5 5-15	0
84	173	193	221 59-999	24 16-55	42 26-80	41 20-113	3 1-19	0
85-86	223	234	3 0-76	58 30-158	30 17-65	21 14-47	15 8-51	1 1-39
87	223	231	3 0-76	71 16-1499	40 19-112	74 32-263	5 1-117	3 3-79
88-92	222	230	675 228-2999	324 213-512	176 141-229	206 173-262	78 51-119	23 8-129
92-1	174	188	20 20-419	216 145-368	48 28-109	64 33-176	45 31-95	11 4-234

Table 18. Number per hectare of brown trout by year-class in the lower study area of the Blacksmith Fork River, Utah at the beginning of each period for which production was calculated.

Date	Year-Class 1972	1971	1970	1969	1968	1967+	Total
6/15/72	328	327	450	293	107	9	1513
7/15/72	251	322	423	259	93	8	1356
8/23/72	178	316	390	221	78	7	1189
9/12/72	149	312	374	201	71	6	1117
10/21/72	105	306	345	174	60	5	996
11/18/72	82	302	326	155	53	5	922
1/23/73	46	292	284	118	39	3	783
3/ 3/73	32	286	262	101	33	3	717
3/23/73	27	283	252	93	30	3	688

Table 19. Number per hectare of brown trout by year-class in the upper study area of the Blacksmith Fork River, Utah at the beginning of each period for which production was calculated.

Date	Year-Class						
	1972	1971	1970	1969	1968	1967+	Total
6/15/72	493	215	516	311	63	4	1601
7/15/72	378	212	485	275	53	3	1408
8/23/72	268	208	447	234	46	3	1205
9/12/72	224	205	429	216	42	3	1119
10/21/72	159	201	396	184	35	2	997
11/18/72	124	199	373	164	31	2	893
1/23/73	69	192	326	125	23	1	737
3/ 3/73	49	188	300	107	19	1	665
3/23/73	41	186	288	98	17	1	633

Table 20. Mean biomass (g/10 m^2) by year-class of brown trout in the lower study area of the Blacksmith Fork River, Utah from 15 June 1972 to 14 June 1973, inclusive.

Period	Year-Class						
	1972	1971	1970	1969	1968	1967+	Total
6/15/72-7/14/72	0.4	10.8	44.6	54.2	33.0	8.3	151.3
7/15/72-8/22/72	0.7	13.6	45.3	50.4	29.9	7.6	147.5
8/23/72-9/11/72	0.9	15.8	46.5	47.2	27.2	6.9	144.6
9/12/72-10/20/72	1.0	16.9	44.9	43.2	24.7	6.2	136.9
10/21/72-11/17/72	0.9	17.4	42.0	38.3	22.2	5.6	126.4
11/18/72-1/22/73	0.6	17.4	37.0	30.2	16.8	4.3	106.4
1/23/73-3/2/73	0.4	17.4	32.1	23.1	12.0	3.0	88.0
3/3/73-3/22/73	0.3	17.9	29.9	20.3	10.2	2.6	81.3
3/23/73-6/14/73	0.4	24.6	36.3	21.8	10.6	2.7	96.3
Mean	0.6	16.9	39.8	36.5	20.7	5.2	119.7

Table 21. Mean biomass ($g/10\ m^2$) by year-class of brown trout in the upper study area of the Blacksmith Fork River, Utah from 15 June 1972 to 14 June 1973, inclusive.

Period	Year-Class						Total
	1972	1971	1970	1969	1968	1967+	
6/15/72-6/14/72	0.6	6.0	46.8	52.8	17.8	3.2	127.7
7/15/72-8/22/72	1.0	8.2	47.6	49.1	16.2	3.0	124.9
8/23/72-9/11/72	1.3	9.6	48.8	45.9	14.7	2.7	123.0
9/12/72-10/20/72	1.3	10.2	47.1	42.1	13.3	2.4	116.5
10/21/72-11/17/72	1.2	10.5	44.1	37.2	12.0	2.2	107.2
11/18/72-1/22/73	0.8	10.5	38.9	29.4	9.1	1.7	90.4
1/23/73-3/2/73	0.6	10.5	33.7	22.4	6.5	1.2	74.8
3/3/73-3/22/73	0.5	10.8	31.4	19.8	5.5	1.0	69.0
3/23/73-6/14/73	0.5	14.8	38.2	21.2	5.8	1.1	81.4
Mean	0.9	10.1	41.8	35.5	11.2	2.1	101.7

Table 22. Production (g/100 m^2) of year-class of brown trout in the lower study area of the Blacksmith Fork River, Utah from 15 June 1972 to 14 June 1973, inclusive.

Period	Year-Class						Total
	1972	1971	1970	1969	1968	1967+	
6/15/72-7/14/72	3.3	27.6	21.8	34.4	10.5	2.7	100.4
7/15/72-8/22/72	5.4	32.5	58.1	37.8	25.4	6.4	165.5
8/23/72-9/11/72	3.4	16.3	21.0	16.1	-2.7	-0.7	53.5
9/12/72-10/20/72	2.4	8.7	2.5	13.0	21.6	5.4	53.6
10/21/72-11/17/72	1.2	9.1	-0.6	0.3	0.3	0.1	10.5
11/18/72-1/22/73	-0.3	-1.8	-21.0	-29.8	-24.4	-6.2	-83.5
1/23/73-3/2/73	0.6	10.4	-3.3	-1.3	-4.5	-1.1	0.7
3/3/73-3/22/73	0.3	5.4	-1.6	-0.6	-2.0	-0.5	1.1
3/23/73-6/14/73	3.3	155.0	214.9	120.9	58.9	14.9	567.9
Total	19.6	263.2	291.8	190.8	83.1	21.0	869.7

Table 23. Production (g/100 m^2) by year-class of brown trout in the upper study area of the Blacksmith Fork River, Utah from 15 June 1972 to 14 June 1973, inclusive.

Period	Year-Class						Total
	1972	1971	1970	1969	1968	1967+	
6/15/72-7/14/72	4.6	16.6	22.9	33.5	5.7	1.0	84.4
7/15/72-8/22-72	7.4	19.6	61.0	36.8	13.7	2.5	141.0
8/23/72-9/11/72	4.6	9.9	22.1	15.7	-1.4	-0.3	50.6
9/12/72-10/20/72	3.2	5.2	2.6	12.6	11.6	2.1	37.5
10/21/72-11/17/72	1.7	5.5	-0.6	0.3	0.2	0.0	7.1
11/18/72-1/22/73	-0.4	-1.1	-22.0	-29.0	-13.2	-2.4	-68.1
1/23/73-3/2/73	0.8	6.3	-3.5	-1.3	-2.4	-0.4	-0.6
3/3/73-3/22/73	0.4	3.3	-1.6	-0.6	-1.1	-0.2	0.2
3/23/73-6/14/73	4.6	93.5	225.6	117.6	31.7	5.8	478.9
Total	26.9	158.8	306.5	185.6	44.8	8.1	731.0