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POPULATION DYNAMICS OF WILD BROWN TROUT IN GAMBLE CREEK, SUBJECT FIRST TO ANGLING, THEN WITH NO ANGLING[1]

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ABSTRACT

During an 8-year period between 1966 and 1973, a 0.76-mile section of Gamble Creek containing brown trout was closed to fishing. Density, age structure and other parameters of the population were monitored annually in the spring and fall. Similar data were available for this stream section for five consecutive years (1961-1965) prior to its closure to fishing. A compulsory creel census was conducted on 1.5 miles of Gamble Creek during 1961-1965. Population dynamics of brown trout were compared for these two periods.

During 1961-1965 angling pressure was light, varying from 46 to 62 hours per acre; and the catch was small, ranging between 2.8 and 6.2 pounds per acre.

Growth rate of brown trout did not change during the period of study. Average back-calculated lengths (total) for age-groups 0 through IV were 3.3, 6.5, 9.1, 11.3, and 12.7 inches, respectively. This represents comparatively slow growth. Survivorship curves from egg through age V were similar for the two experimental periods. During the period open to fishing, average total production was about 60 pounds per acre, of which anglers harvested about 4 pounds per acre. Average production was about 96 pounds per acre during the period when the stream was closed to fishing; during those years there were greater densities of both fingerlings and legal-size trout.

Population data accumulated between 1947 and 1973 suggest that changes in fingerling and juvenile trout may be temporal and coincidental with closure to fishing. There is little evidence from the long history of fishing on Gamble Creek to indicate that closing the stream to fishing increased the density of legal-length trout. Trout movement into this stream section probably accounted for the increase. The population of brown trout is not generated completely within the study area, but rather is influenced by both internal and external factors.

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[1] Contribution from Dingell-Johnson Project F-35-R, Michigan.

Introduction

Success in management of trout streams rests largely upon an assessment of the trout population under the impact of angling. Comparatively little is known about natural populations of trout in streams unexploited by man. Management would be enhanced if we could assess the response of a trout population when fishing mortality is removed. An opportunity to examine this question was provided when a segment of Gamble Creek, one of several streams in the Rifle River Recreation Area under compulsory creel census, was closed to fishing after the 1965 fishing season. Five years prior to closure, 1961-1965, the brown trout population in this stream section was monitored. Thus, a body of information has been accumulated on the brown trout population and fishing in Gamble Creek.

Monitoring the population during an 8-year period of no fishing--which is sufficient time to cover the life span of most brown trout--provides a basis for comparing the dynamics of exploited and non-exploited populations of wild brown trout. The principal objectives of the study are to determine the number of trout, and the size structure, age, growth, and other parameters, in a stream population of brown trout; and to determine the effects, on these parameters, of closing the stream to public fishing.

Description of study site

Gamble Creek is a relatively small trout stream about 3 1/2 miles long, located in the east central Lower Peninsula of Michigan. It has a watershed of about 25 square miles; this area is the northeastern limit of the Rifle River drainage. The Rifle River is a major tributary of Saginaw Bay. The lowermost 1.5 miles of Gamble Creek (5.9 acres) lies within the boundary of the Rifle River Recreation Area, a 4,318-acre tract of land containing several lakes and five trout streams in northeastern Ogemaw County. Gamble Creek enters the Rifle River Recreation Area at the north boundary and flows southward about 0.76 mile before

entering Mallard Pond--a very shallow, 3.8-acre pond. Ridgeroad Bridge crosses the stream midway between the north boundary of the Area and Mallard Pond. Vaughn Creek, with a flow of 7 cfs, empties into Gamble Creek at this site. Just below this confluence, Gamble Creek has a flow of about 15 cfs. Oyster Creek, with a flow of 7 cfs, is the lowermost tributary of Gamble Creek. One small branch enters Gamble Creek immediately above and two just below Mallard Pond.

The outlet of Grousehaven Lake is connected to the upper end of Mallard Pond. Approximately one-half mile below Mallard Pond, Gamble Creek flows into Devoe Lake, a marl oligotrophic lake. Near its mouth Gamble Creek has a volume of 21 cfs (August 1951). The outfall of Devoe Lake is the origin of the Rifle River. About 1/4 mile above the mouth of Gamble Creek, a 2,300-foot diversion channel was cut in 1950 linking it with the Rifle River at Devoe Lake outlet.

All stream and lake fishing in the Rifle River Recreation Area between 1945 and 1965 was under a compulsory daily-permit system. Creel census records for upper and lower Gamble Creek were based on a division of the stream at Ridgeroad Bridge.

Investigations by Shetter (1948) on Gamble Creek in 1947-1950 involved population studies for a section of stream between the site of an old beaver dam above Mallard Pond and the north boundary of the Rifle River Recreation Area. Between 1953 and 1957, annual fall estimates of brown trout were obtained for this stream section. From 1958 to 1963, estimates were obtained for a new, larger section of stream which extended from Mallard Pond to the north boundary of the Area. During this period, however, estimates of trout in the smaller original site were also kept. In 1963, Gamble Creek from Mallard Pond to the north boundary of the Area was designated upper Gamble Creek, and the stream from Mallard Pond to Devoe Lake was termed lower Gamble Creek, for creel census purposes. After 1963, population data for the original study area were not retained. Estimates of brown trout in the new experimental section of Gamble Creek were obtained annually in the spring and fall from 1961 through 1973. The study section was open-ended, there being no barriers to fish movement.

Throughout the years of creel census on Gamble Creek the legal size limit was 7.0 inches (total length).

Methods

The study site on Gamble Creek from Mallard Pond to the north boundary of the Rifle River Recreation Area was closed to fishing from 1966 through 1973. The experimental water was fished annually in the spring and fall with dc electrofishing gear to obtain estimates of brown trout by the Petersen mark-and-recapture method. Estimates of trout were computed by the Bailey modification of the Petersen formula.

A series of scale samples were collected during the period of electrofishing. When possible about 20 fish of each inch group in the population were scale sampled, excluding 2- and 3-inch trout. An assessment of the age of these fish was the basis for determining the age structure of the trout population.

Growth in length, back-calculated from measurements of annuli on scales, was derived from the body-scale relationship:

$$\text{Log ASR (anterior scale radius)} = 1.20947 + 0.88766 \text{ Log L}$$

Production was computed according to the method of Ricker (1958). Production is the growth in weight of all trout in the population during a specific period and includes growth of trout that died during this period.

Results

Angling and catch records

Gamble Creek has had a history of remarkably stable but very light fishing pressure (Table 1). Since the inception of public angling in 1945 until 1965, fishing pressure has averaged 49 hours per acre. During the 5 years previous to closure (1961-1965), fishing pressure did not vary much from this average. For comparison, fishing pressure on 4.6 miles of the Rifle River in the Area averaged 185 hours per acre during 1945-1950 and nearly 300 hours per acre for the period 1956-1961 (Gowing, 1958).

Light fishing pressure resulted in small annual harvests of brown trout. Over a 21-year period the annual harvest of brown trout in Gamble Creek ranged between about 1 and 19 fish per acre, representing from less than 1 to 10 pounds per acre. The average annual catch was 6.5 fish or 3.1 pounds per acre.

Anglers exploited only a small fraction of the brown trout population in Gamble Creek. An indication of this can be seen when residual stocks of legal-length brown trout in the fall, after the close of the season, are compared to the anglers' catch for that season (Tables 1 and 2). For the 16 years in which population data are available, stocks of legal-length brown trout averaged 182.8 fish per acre in the 0.76-mile study section, and the average catch for the 1.5 miles of stream censused was 7.8 fish per acre, a ratio of about 23 to 1. A more precise measure of exploitation is the anglers' take of legal-length trout present at the beginning of the season. A representative example is shown for the years 1963-1965 in Table 3. Trout of catchable size for age-groups II through VI ranged from 3.2 to 11.0%, and averaged 8.1%. Values of such a range, varying from 6 to 28% but mostly above 13%, are reported in the literature (Allen, 1951; Schuck, 1945; and Hobbs, 1948) and are correlated generally with fishing intensity. In general, Gamble Creek prior to closure contained a nearly unexploited population of brown trout.

Trout populations

Figure 1 depicts the long-term trends in the numbers of fish of three size groups that comprised the brown trout population in the experimental section. Brown trout spawning occurs in this section of stream, but however, not enough to generate the density of trout present. An unknown number of fingerlings (2.0-3.9 inches) is recruited annually from outside the study section. Over the years the fingerling group showed the greatest annual fluctuation in density, varying from 114 (1950) to 1,075 (1958) trout per acre. The largest population of fingerlings occurred generally in 1947 and 1948 and between 1953 and 1958, intermediate levels during the period of closure (1966-1973), and lowest levels between 1961 and 1965.

During these years sublegal brown trout (4.0-6.9 inches tended to follow this same pattern of abundance. They fluctuated between 225 and 370 fish per acre, averaging slightly less than for the years 1947-1950. During the 5 years prior to closure, the number of sublegals was reduced but remained reasonably stable. Sublegals generally increased after closure, until 1969, and thereafter diminished to the level of 1961-1965. For the period of closure the average density was about 203 compared to 180 fish per acre for the years 1961-1965.

The density of legal-length brown trout during the years 1947-1950 and 1953-1959 fluctuated annually, the former averaging 163 and the latter 191 fish per acre. Legals during 1961-1965 remained at the same density as those during the years 1953-1959, or about 187 fish per acre. However, legals increased during the period of closure and maintained their highest recorded levels through 1971, varying between 296 and 317 fish per acre, before falling during the last 2 years to the level of 1961-1965. Part of the drop in density of legals and sublegals in 1972 is attributed to mortalities that resulted from lampricide (TFM) treatment of Gamble Creek in July 1972. Viewed over many years, these lightly exploited populations showed shifts in numerical strength and size structure.

Tables 4 and 5 give the average fall and spring populations per acre of stream, and the size and age structure of brown trout in the experimental waters of Gamble Creek during the 5-year period of fishing (1961-1965) and during the 8-year period of no fishing (1966-1973). Survivorship curves were derived from semi-annual population estimates, in sequence, by age class, beginning with the deposition of eggs and terminating with age-VI trout.

Survival rates

Survivorship curves for brown trout during 1961-1965 and 1966-1973 are shown in Figure 2. The numbers of eggs and fry cited in Figure 2 were derived from data on maturity and fecundity reported by Alexander (1974) for brown trout in the North Branch Au Sable River. Recruitment

occurred in both periods, particularly of age-II trout between spring and fall. The survivorship curves were smoothed to provide the best estimates of production. It is apparent from the curves that there is no difference between the survival rates of brown trout for the two periods.

Growth

Growth rates of brown trout in the experimental waters of Gamble Creek are shown in Figure 3. Average growth rates of trout during the period of stream closure remained unchanged from the previous 5 years under fishing. The growth rate of brown trout in these waters is generally slower than that reported for this species in the Pigeon River, Michigan (Cooper, 1953), Prickley Pear Creek, Montana (Bishop, 1955), and Logan River, Utah (Sigler, 1952) as shown below in calculated total lengths for ages I to IV:

Stream	Ages			
	I	II	III	IV
Gamble Creek	3.3	6.5	9.1	11.3
Pigeon River	3.7	8.0	11.0	14.1
Prickley Pear Creek	3.8	7.7	11.1	13.7
Logan River	4.0	6.9	9.7	12.1

Production

Average annual production during the period of 1961-1965 amounted to 60.6 pounds per acre (Table 6). Summer production (May-September) exceeded winter production (October-April) by about 28%. Production by age-0 trout accounted for 14% of annual production, while age-II and age-III trout together accounted about equally for 64%. During the period of closure, average annual production was 95.8 pounds per acre. Again, summer production exceeded winter production. Production by age-0 trout represented 24% of annual production; age-I and age-II trout accounted for about 24 and 30%, respectively. Production during the period

of closure was about 58% greater than during the period of 1961-1965. For the summer production periods, the principal difference was the greater production of young-of-the-year trout during the closure period and secondarily by the greater production by age-II and age-III trout. For the winter production periods, the greatest disparity occurred in age-II trout; their production in the period of closure exceeded that for the period of 1961-1965 by nearly 48%. Since growth and survival rates remained unchanged during the two periods, the difference in production was due to the greater number of trout present during the period of closure.

Average annual production of 95.8 pounds per acre during the period of closure in Gamble Creek fell within the upper range of 17.8 to 106.9 pounds per acre for brown trout in small streams in England (Le Cren, 1969), but was considerably less than the 352.7 pounds per acre reported for a formerly polluted zone in Black Earth Creek, Wisconsin (Brynildson and Mason, 1975), and even much less than the 481.4 pounds per acre reported for Horokiwi Stream in New Zealand (Allen, 1951). Reports of brook trout production have varied from 55.2 pounds per acre in Valley Creek, Minnesota (Elwood and Waters, 1969) to 267.4 pounds per acre in Big Spring Creek, Pennsylvania (Cooper and Scherer, 1967). Hunt (1966) reported brook trout production in Lawrence Creek, Wisconsin, ranging between 84 and 97 pounds per acre during a 4-year period; there, average harvest by anglers was 11.6 pounds per acre. In Gamble Creek the average annual production (60 pounds per acre) and harvest (4.1 pounds per acre) during 1961-1965 were not of the magnitude in Lawrence Creek. However, brown trout production in Gamble Creek (95.8 pounds per acre) during the period of closure was comparable to brook trout production in Lawrence Creek.

In Lawrence Creek the annual production of brook trout was about 2.1 times greater than the average standing crop present in spring, and 1.5 times greater than the average crop present in fall. Production of brown trout in Gamble Creek was derived from larger standing crops than in Lawrence Creek. In Gamble Creek the ratio of annual production

to spring standing crop averaged 0.92, and the ratio of annual production to fall standing crop was 0.89.

Discussion

Growth and survival rates for these populations did not change during the fishing and closure periods. However, there was an increase in the density of fingerling and of legal-length trout during the period of closure, and this was reflected in the greater production of trout for this period. The history of angling for brown trout in Gamble Creek provides little evidence that the increase in fingerlings and legal-length trout during the period of closure are attributable to the condition of no fishing. On the other hand, the long-term trend in the population density of legal-length trout offers little indication that the increase during the period of closure was temporal, unless it was masked by recruitment. There is evidence from population trends to suggest that shifts in the density of fingerlings and juvenile trout represented temporal changes, an increase in the former and a decrease in the latter coinciding with stream closure. Greater density of trout in the period of closure probably occurred through increased recruitment and for which there is no apparent explanation. As the population is not generated entirely within the study area, intrinsic as well as extrinsic factors influence population density.

Acknowledgments

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Table 1.--A summary of angling for brown trout in 1.5 miles (5.9 acres) of Gamble Creek in the Rifle River Recreation Area

Year	Hours fished per acre	Catch of brown trout		Catch per acre	
		Number	Pounds	Number	Pounds
1945	40.8	24	8.4	4.1	1.4
1946	11.4	15	4.9	2.5	0.8
1947	16.9	6	1.8	1.0	0.3
1948	19.4	5	1.4	0.8	0.2
1949	36.4	46	17.2	7.8	2.9
1950	56.1	24	7.7	4.1	1.3
1951	43.6	18	5.6	3.1	0.9
1952	18.2	11	4.4	1.9	0.7
1953	46.9	30	10.0	4.9	1.7
1954	56.3	62	28.3	10.5	4.8
1955	55.1	58	20.1	1.0	3.4
1956	77.1	43	18.5	7.3	3.1
1957	68.0	57	20.9	9.7	3.5
1958	91.4	112	59.8	19.0	10.1
1959	57.4	29	15.1	4.9	2.6
1960	62.7	61	33.4	10.3	5.7
1961	62.4	67	23.1	11.4	3.9
1962	45.8	55	20.3	9.3	3.4
1963	52.4	48	16.3	8.1	2.8
1964	57.9	68	26.3	11.5	4.4
1965	59.5	76	36.7	12.9	6.2

Table 2.--Fall estimates of fingerling, sublegal, and legal-length brown trout in the experimental waters of Gamble Creek (1.75 acres) expressed as number per acre

Year	Brown trout		
	Fingerling 2.0-3.9	Sublegal 4.0-6.9	Legal 7.0+
1947 [a]	961	393	170
1948	501	198	105
1949	303	373	186
1950	114	195	193
1953	466	226	166
1954	345	305	243
1955	507	223	158
1956	944	277	197
1957	609	370	234
1958	1,075	235	182
1959	162	272	156
1961	137	118	178
1962	265	190	132
1963	245	196	221
1964	240	190	171
1965	158	205	233
1966	382	167	319
1967	237	183	301
1968	309	215	317
1969	446	263	363
1970	318	232	296
1971	386	238	302
1972	401	166	151
1973	177	156	193

[a] Estimates of fish in the original site for 1947 to 1957 were adjusted to conform with estimates derived for the larger revised study site used in 1958 to 1973. Estimates obtained for both sites in 1958 to 1963 provided a basis for this adjustment.

Table 3.--Anglers' exploitation of the pre-season crop of legal-length brown trout, by age group, in the experimental waters of Gamble Creek in 1963-1964

Age group	1963			1964			1965		
	Spring estimate	Angler catch	% exploitation	Spring estimate	Angler catch	% exploitation	Spring estimate	Angler catch	% exploitation
II	94	11	11.7	77	7	9.1	38	2	5.3
III	150	17	11.3	175	15	8.6	92	3	3.2
IV	34	2	5.8	49	4	8.2	44	1	2.3
V	4	1	25.0	11	1	9.1	9	..	...
VI	...	...	....	...	..	...	1	..	...
Total	282	31	11.0	312	27	8.6	184	6	3.2

Table 4.--Average number of brown trout per acre each fall and spring in the experimental waters of Gamble Creek during the period 1961-1965

Inch group	Age group						
	0	I	II	III	IV	V	VI
Fall							
2	33.0	....	....	....	....	....	....
3	176.0	....	....	....	....	....	....
4	5.6	16.2	....	....	....	....	....
5	0.7	80.1	....	....	....	....	....
6	....	56.8	15.4	0.7	....	....	....
7	....	19.2	41.2	0.8	....	....	....
8	....	2.6	33.9	11.1	....	....	....
9	....	0.4	12.1	13.4	0.6	....	....
10	....	0.2	4.6	10.3	1.5	....	....
11	....	....	2.5	7.2	0.6	0.2	....
12	....	....	0.2	2.3	2.2	0.2	0.2
13	....	....	....	0.7	0.7	....	....
14	....	....	0.1	0.3	0.8	0.3	....
15	....	....	....	....	0.3	0.1	....
16	....	....	....	....	0.3	0.1	....
17	....	....	....	....	....	0.1	....
18	....	....	....	....	0.1	....	....
19	....	....	....	....	....	0.1	....
Total	215.3	175.5	110.0	46.8	7.1	1.1	0.2
Spring							
2	....	1.7	....	....	....	....	....
3	....	125.0	....	....	....	....	....
4	....	59.3	5.2	....	....	....	....
5	....	7.4	37.9	....	....	....	....
6	....	1.0	52.2	4.0	....	....	....
7	....	....	24.9	21.5	0.1	....	....
8	....	....	7.3	29.3	1.6	....	....
9	....	....	2.1	15.2	5.8	....	....
10	....	....	0.4	5.2	5.8	0.6	....
11	....	....	....	3.8	3.7	0.8	....
12	....	....	....	0.9	2.4	0.4	....
13	....	....	....	0.1	0.3	0.6	....
14	....	....	....	....	0.3	....	....
15	....	....	....	....	....	0.1	....
16	....	....	....	....	....	0.3	....
17	....	....	....	....	....	....	....
18	....	....	....	....	....	....	0.1
Total	....	194.4	130.0	80.0	20.0	2.8	0.1

Table 5.--Average number of brown trout per acre each fall and spring in the experimental waters of Gamble Creek during the period 1966-1973

Inch group	Age group 0	I	II	III	IV	V	VI
Fall							
2	80.4	....	....	....	....	....	....
3	251.3	....	....	....	....	....	....
4	16.1	16.6	....	....	....	....	....
5	2.7	83.6	1.4	....	....	....	....
6	....	65.7	14.7	....	....	....	....
7	....	23.3	50.0	1.5	....	....	....
8	....	8.8	48.5	8.1	....	....	....
9	....	0.6	30.0	16.6	0.3	....	....
10	....	0.4	10.2	20.8	1.5	....	....
11	....	....	4.8	13.4	3.1	....	....
12	....	....	0.3	8.5	1.4	....	....
13	....	....	....	3.0	1.2	0.5	....
14	....	....	0.1	1.8	0.3	0.1	....
15	....	....	....	0.4	1.2	0.2	....
16	....	....	....	....	0.1	0.1	0.1
17	....	....	....	0.2	0.2	0.2	....
18	....	....	....	....	0.1	0.1	....
Total	350.5	199.0	160.0	74.3	15.4	1.2	0.1
Spring							
2	....	2.6	....	....	....	....	....
3	....	116.0	....	....	....	....	....
4	....	106.9	5.3	....	....	....	....
5	....	11.8	43.5	0.3	....	....	....
6	....	0.6	67.4	12.1	....	....	....
7	....	....	32.5	26.7	0.4	....	....
8	....	....	16.8	36.6	2.1	....	....
9	....	....	4.2	31.5	6.6	0.3	....
10	....	....	0.3	15.0	11.1	0.7	....
11	....	....	....	7.9	5.2	1.5	....
12	....	....	....	0.7	3.8	1.2	0.1
13	....	....	....	0.3	2.2	1.4	....
14	....	....	....	....	1.1	0.3	....
15	....	....	....	....	0.2	0.3	....
16	....	....	....	....	....	0.1	....
17	....	....	....	....	....	....	....
18	....	....	....	....	....	0.1	....
Total	....	237.9	170.0	131.1	32.7	5.9	0.1

Table 6.--Average summer (May-September) and winter (October-April) production of brown trout in the experimental waters of Gamble Creek during the periods 1962-1965 and 1966-1973

Age	1962-1965			1966-1973		
	Per acre			Per acre		
	Number	Standing crop (pounds)	Production (pounds)	Number	Standing crop (pounds)	Production (pounds)
May to September						
Fry	8854.0	1.95		1624.0	3.59	
0	215.3	2.84	4.25	350.5	4.63	16.76
I*	194.4	6.85		237.9	8.38	
I	175.5	16.24	10.49	199.0	18.41	12.31
II*	130.0	19.47		170.0	25.46	
II	110.0	25.68	9.94	160.0	37.36	13.84
III*	80.0	26.78		131.1	43.89	
III	46.8	21.51	7.64	74.3	34.37	12.52
IV*	20.0	11.01		32.7	18.01	
IV	7.1	4.85	1.61	15.4	10.52	2.99
V*	2.8	2.27		5.9	4.78	
V	1.1	0.97	0.12	1.2	1.06	0.21
October to April						
0	215.3	2.84		350.5	4.63	
I*	194.4	6.85	4.47	237.9	8.38	6.20
I	175.5	16.17		199.0	18.41	
II*	130.0	19.47	8.72	170.0	25.46	10.51
II	110.0	25.68		160.0	37.36	
III*	80.0	26.78	9.90	131.1	43.89	14.62
III	46.8	21.51		74.3	34.37	
IV*	20.0	11.01	2.85	32.7	18.01	4.43
IV	7.1	4.85		15.4	10.52	
V*	2.8	2.27	0.58	5.9	4.78	1.26
V	1.1	0.97		1.2	1.06	
VI*	0.1	0.10	0.05	0.1	0.10	0.11

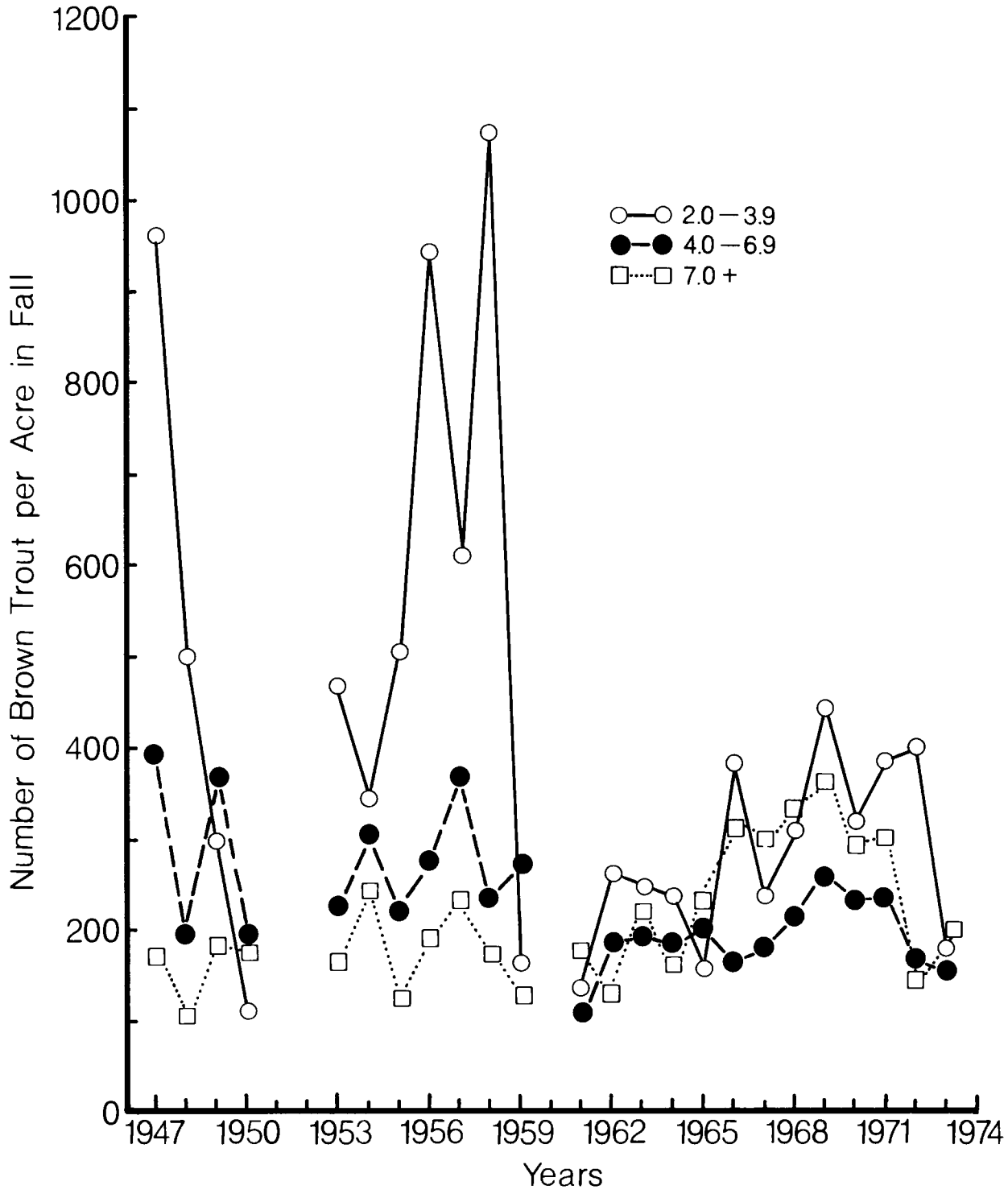

Figure 1.--Fall density of fingerling, sublegal, and legal-length brown trout during 1947 to 1973.

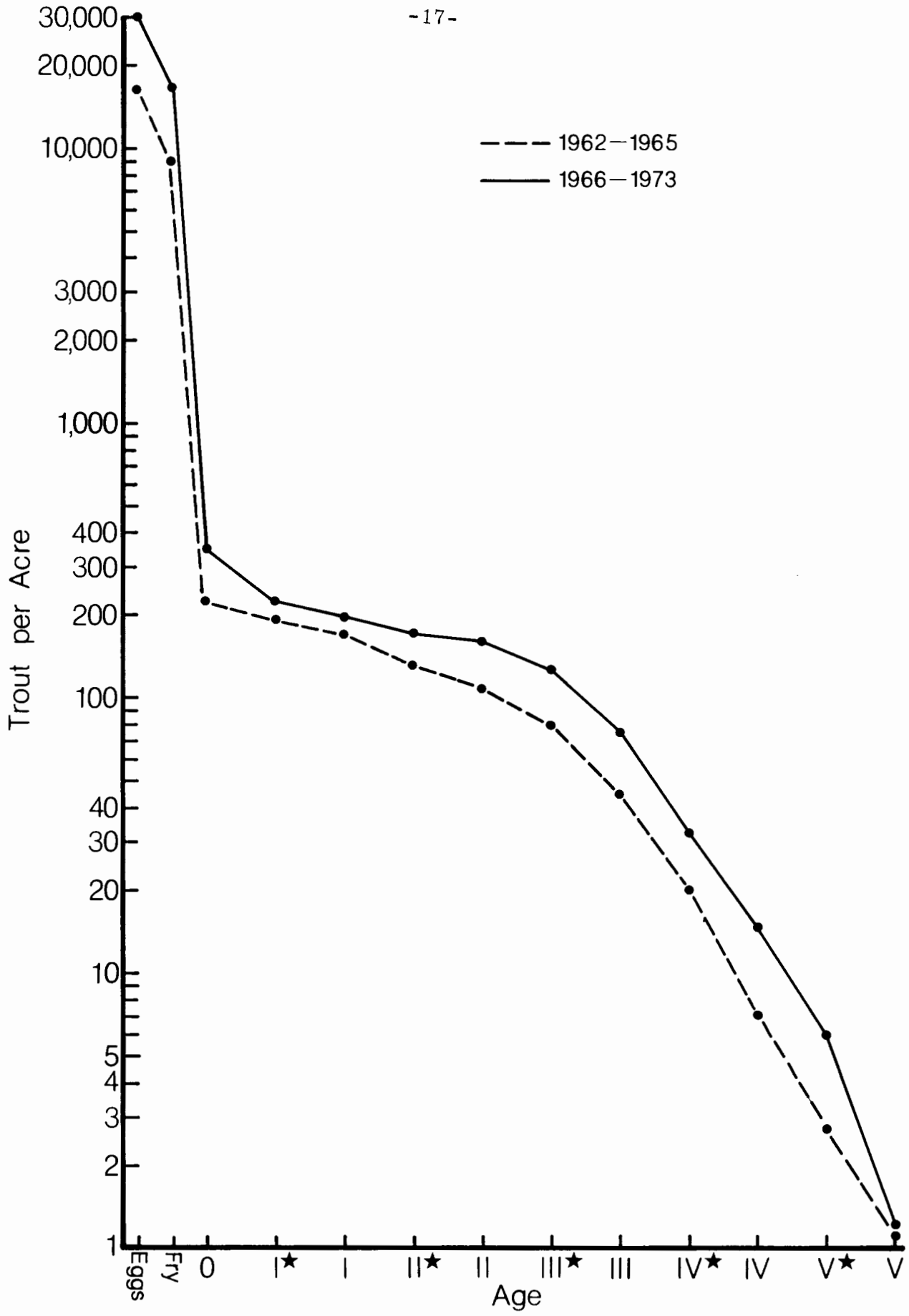

Figure 2.--Survivorship curves for brown trout in experimental water of Gamble Creek for the periods 1962-1965 and 1966-1973.

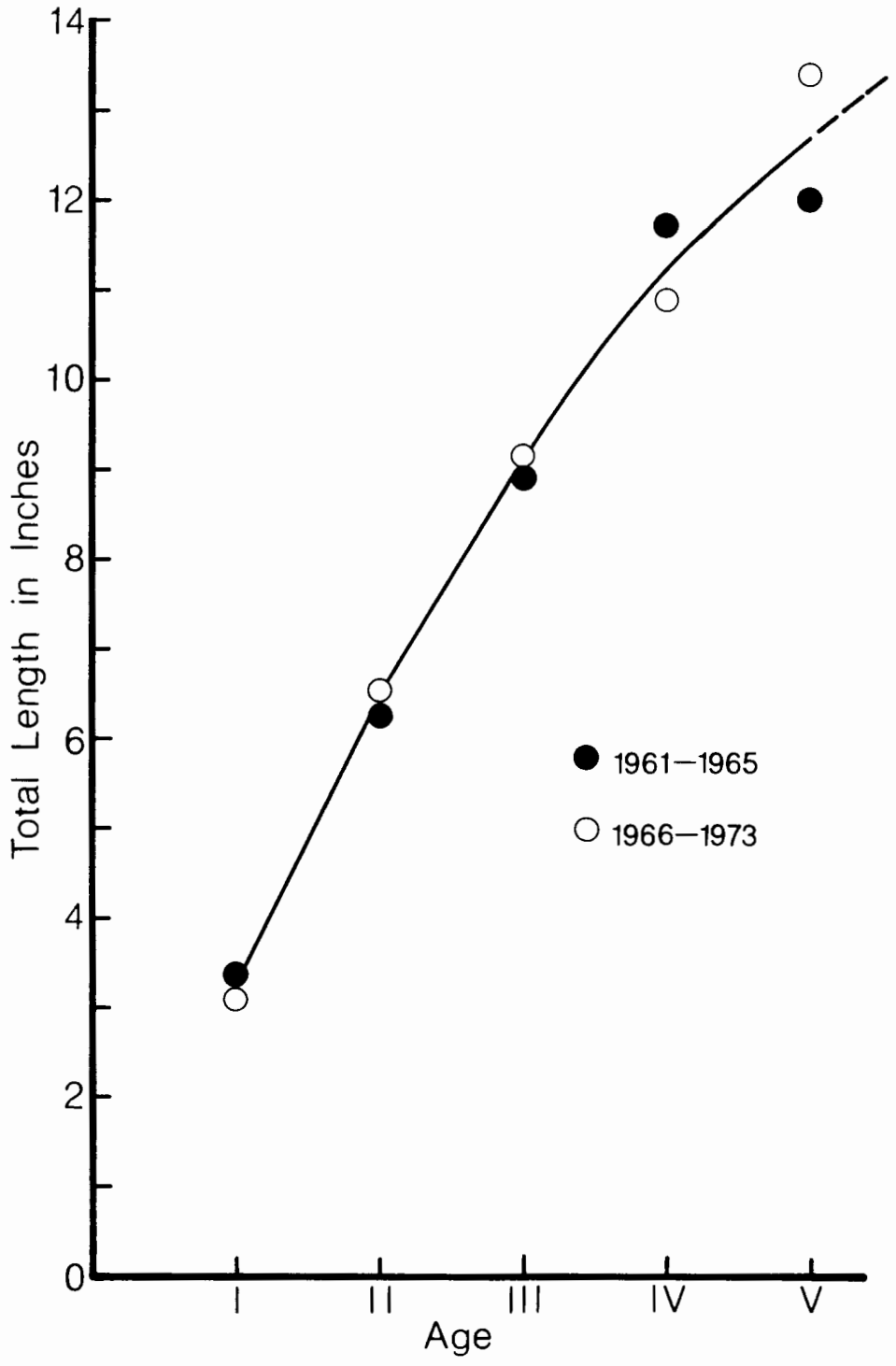

Figure 3.--Average growth of brown trout in the experimental waters of Gamble Creek during the spring and fall of 1961-1965 and 1966-1973.

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