MICHIGAN DEPARTMENT OF NATURAL RESOURCES

FISHERIES DIVISION

Fisheries Research Report No. 1816

October 10, 1974

SURVIVAL, GROWTH, DIET, AND PRODUCTION OF HATCHERY TROUT STOCKED IN SIX POTHOLE LAKES IN MICHIGAN[1]

By Howard Gowing

ABSTRACT

In the fall of 1965, populations of age-0 and age-I brook trout were established at three different densities in six Pigeon River lakes, as follows: (1) low-density lakes, 194 fish per hectare; (2) intermediate-density lakes, 396 fish per hectare; and (3) high-density lakes, 1,335 fish per hectare. There was a direct relationship between total trout density at the outset and the natural mortality rate (q) of the 1965 year class during the first winter after stocking. For the 1964 year class, high densities (125 to 857 fish per hectare) at the outset of the first summer were associated with high natural mortality rates during the summer. Growth in length of the 1965 year class was highest in low-density lakes, intermediate in the lakes of intermediate density, and lowest in high-density lakes. Brook trout stocked at a mean length of 142 mm in November 1965 attained a length of 245 mm in September 1966 after one growing season in the low-density lakes, 218 mm in the intermediate-density lakes, and 173 mm in the high-density lakes. Highest growth rates (g) were achieved in the low-density lakes, and lowest in the high-density lakes. There was an inverse relationship between trout density at the outset of the study, and growth rates (g) of the 1965 and 1964 year classes during the first year. The 1965 and 1964 year classes showed negative growth rates (g) during the first winter in the high-density lakes.

Based on the total volume of food observed in the stomachs of trout sampled over a 2-year period, insects made the largest contribution to the diet of trout in all lakes except in West Lost. Crayfish were predominant in trout from West Lost Lake. In three of the lakes containing crayfish, this food type ranked second. Fish, other than trout, ranked second in two of three lakes containing fish. Cladocerans made the third largest contribution in four of the six lakes.

---

[1] A contribution under Dingell-Johnson Project F-30-R, Michigan.

The largest standing crop of the 1965 year class occurred in the fall, after the first summer. Maximum standing crop of the 1964 year class was established at the outset. Maximum production of trout flesh in the six lakes, grouped in three pairs, was achieved after the first summer. Production attained in the low-density and intermediate-density lakes during this period was similar (11.0 and 10.6 kg/ha), whereas it was about two times greater in the high-density lakes. The largest average production (46 kg/ha) was generated in the high-density lakes during the 23 months; the low-density lakes produced about 19 kg/ha; and the lakes of intermediate density produced 15 kg/ha. Greater production in the high-density lakes was achieved primarily by a large population of slow-growing fish. The 1965 year class contributed about 77% of total production in the low-density lakes, 83% in the intermediate-density lakes, and 93% in the high-density lakes.

The best ratio of standing crop at the outset, to total production, was observed in the low-density lakes. However, total production was less than two times the initial standing crop. As a guide for future management, satisfactory growth of individual fish will require low stocking rates, as determined here and in other studies.

Introduction

Stocking trout in inland lakes is an important management tool and this report is concerned with some of the consequences of varying the stocking density. This study is an assessment of survival, growth, diet, and production of hatchery brook trout in six lakes that were paired and stocked at three different densities. In 1964, Allison and Latta (1969) found no relationship between gill louse parasitism and condition and rate of natural mortality of brook trout in these lakes. In 1965, the stocking densities were manipulated to gain information on the growth and development of the trout and the gill lice populations. The report in preparation on gill louse population dynamics will complement the present report.

Description of the lakes

The six lakes, which lie within a 2-square-mile area, are located in the Pigeon River Area in north-central Michigan. These are small oligotrophic lakes, and on the basis of their geological origin are classified as limestone sinks. Five of the six lakes have surface areas between 1.4 and 2.4 ha; the sixth lake is 4.1 ha (Table 1). Except for Ford Lake, all tend to be subcircular in form and have steep cone-shaped basins that set about 10 meters below the surrounding terrain. Maximum depths range from 8.8 m (Ford Lake) to 18.0 m (Hemlock Lake). In Hemlock, West Lost, and Lost lakes, water hardness varied from 114 to 145 ppm $CaCO_3$; in North Twin, South Twin, and Ford lakes, it ranged between 29 and 71. All lakes show thermal stratification. In the late summer of 1966, dissolved oxygen in excess of 3 ppm was found to a depth of nearly 8 m in Ford Lake (the shallowest basin), and to almost 13 m in Hemlock Lake (the deepest basin). In 1967, a complete overturn did not occur in Hemlock and Lost lakes, which now are meromictic lakes.

The six lakes were closed to public fishing. Removal of trout was limited to sampling by Department personnel for this study.

Methods

In the fall of 1965, these lakes contained from one to four year classes of brook trout (Table 2). However, only the 1964 year class was of significant size; it comprised between 87% (West Lost) and 100% (Ford Lake) of the populations. Trout of the 1964 year class ranged in length from 196 to 246 mm. Only a few fish of the older year classes survived the early months of the present study.

In November 1965, brook trout of age-group 0 were stocked in the six lakes at three different densities: 125 fish per hectare in North Twin and Hemlock, 245 per hectare in South Twin and Lost, and 1,247 per hectare in West Lost and Ford lakes. These trout were 127 to 152 mm in length, and averaged about 29 g in weight. Counting fish present prior to the November 1965 plantings, the trout population densities were: (1) low-density lakes, North Twin 188 and Hemlock 201 trout per hectare; (2) intermediate-density lakes, South Twin 411 and Lost 380 trout per hectare; and (3) high-density lakes, West Lost 1,398 and Ford 1,272 trout per hectare.

Semiannual estimates of trout were made in the spring and fall, employing the Petersen mark-and-recapture method, and following the procedure of Waters (1962). For the low- and intermediate-density lakes, additional estimates were made by intensive netting at termination of the study. These estimates were used to calculate mortality rates.

Production of trout during a given period was computed as a product of the average weight of the standing crop and the instantaneous growth rate (g) of trout during this interval (Ricker, 1958). Production here means all flesh elaborated during the interval of time, including growth of trout that died during this period.

For studies of growth (length and weight), trout were sampled during both spring and fall, by angling, electrofishing, and netting; additional information was obtained from samples collected monthly for food studies.

The diet of trout was assessed from an analysis of stomach contents. In general, about 10 trout stomachs (5 from the 1965 year class, and 5 from the 1964) were collected monthly from the low-density lakes. For the intermediate- and high-density lakes, the 1965 and 1964 year classes were sampled at rates of about 10 and 5 trout per month, respectively. Organisms found in the stomachs were counted, and their volumes were determined by fluid displacement.

To point out major trends, to make comparisons, and to allow, in part, for the inherent differences in productivity of these lakes, means of various parameters for the two lakes in each density-pair were used. In this report, "the first winter" refers to the period from November 1965 to April 1966. For the 1965 year class, this is obviously the first winter in the lake, but for the 1964 year class, it is the second winter. Similarly, the first summer refers to the period from April 1966 to October 1966.

Results

Mortality

During the 23-month period of this study, trout populations were reduced 93 to 97% in the low-density lakes, 98 to 99% in the intermediate-density lakes, and 88 to 89% in the high-density lakes. Of the total loss of trout, our monthly sampling removed 29% of the fish in North Twin, 42% in Hemlock, 37% in South Twin, 49% in Lost, 6% in Ford, and 16% in West Lost. The remaining loss was from natural mortality. It is believed that there was very little poaching.

During the study no consistent pattern appeared in the seasonal instantaneous natural mortality rates (q) among the 1965 year class in the paired lakes (Fig. 1 and Table 3). In the intermediate- and high-density lakes, natural mortality rates in summer exceeded values for winter (Latta, 1963). Unexpectedly, however, in the low-density lakes natural mortality rate increased during the second winter, conceivably a chance occurrence of predation, and possibly some poaching in Hemlock Lake.

The seasonal pattern of natural mortality rates for the 1964 year class differed among the three pairs of lakes. The principal difference was that in the low and intermediate lakes, natural mortality rates dropped during the first summer, whereas they increased in the high-density lakes.

There was a direct relationship between total trout density at the outset of the study and the natural mortality rate of the 1965 year class during the first winter ($r = 0.905$, d.f. 4, $P < 0.05$). Initial densities of fish for this period ranged between 188 and 1,398 trout per hectare. In the case of the 1964 year class, high trout densities at the outset of the first summer were associated with high natural mortality rates during the summer ($r = 0.868$, d.f. 4, $P < 0.05$). At the start of the summer, densities varied from 125 to 857 trout per hectare. In both the low- and intermediate-density lakes, highest natural mortality rates of the 1964 year class occurred during the second winter when densities ranged between 47 and 144 fish per hectare.

Growth

Growth in length of the trout in the 1965 year class was highest in low-density lakes, intermediate in the intermediate-density lakes, and lowest in the high-density lakes (Fig. 2). In general, growth rate increased during early spring, was most rapid during late spring and summer, decreased in the fall, and was minimal in winter. The 1965 year class at the outset averaged 142 mm, and after 10 months these fish were 245 mm in length in the low-density lakes, 218 mm in the intermediate-density lakes, and 178 mm in the high-density lakes.

In all lakes, growth in weight followed the same seasonal pattern as growth in length. A greater increment of growth occurred during the spring and summer than in fall and winter. Instantaneous growth rates (g) of the 1965 year class were higher in 1966 than in 1967 in the low- and intermediate-density lakes (Table 4). However, in the high-density lakes the growth rate was higher in 1967 than in 1966, reflecting mostly a high growth rate in Ford Lake in 1967. In general, highest growth rates were achieved in the low-density lakes; and poorest growth, in the high-density lakes. There was an inverse relationship between total trout density (number per hectare) at the outset and growth rates of the 1965 year class during the first year ($r = -0.81$, d.f. 4, $P < 0.05$). An indication of competition for food among the 1965 year class in the high-density lakes was shown by their negative growth rates during the first winter (Table 4).

For the 1964 year class, the seasonal pattern of instantaneous growth rate (g) was similar to that for the 1965 year class, but the growth rates (g) were lower. Growth rate of this year class during the first year was also inversely related to total trout density at the outset ($r = -0.93$ d.f. 4, $P < 0.05$). The 1964 year class, like the 1965 year class, showed a negative growth rate during the first winter, suggesting severe competition (Table 5). Relatively few of the 1964 year class survived to the end of the 23-month study period.

Diet

Number of brook trout which had to be sacrificed for the food habits study was as follows (total for the 2 years): 152 from each of the two low-density lakes, 246 and 261 from the intermediate-density lakes, and 255 and 275 from the high-density lakes. In all, 12 orders of organisms were found in these stomachs, of which not more than 9 orders, nor less than 7, were present in the stomachs of trout from any one lake (Table 6). The bluntnose minnow (Pimephales notatus), an inhabitant of Hemlock Lake, was the only cyprinid found in these lakes. The mudminnow (Umbra limi) occurs only in Ford Lake. A small population of the white sucker (Catostomus commersoni) resides in Lost Lake. The crayfish, Orconectes virilis, occurred in all lakes except Ford.

Of the total food volume, insects made up the largest part (37-64%) in all lakes except West Lost (Table 6). In this lake, crayfish were predominant, constituting 71% of the total volume of food. In three of the five lakes containing crayfish (South Twin, Lost, and North Twin) crayfish made the second largest contribution (13-32%). Fish, other than trout, ranked second (21-34%) in total volume of food consumed in Ford and Hemlock lakes. Cladocerans made the third largest contribution (4-20%) in four of the six lakes.

A seasonal assessment of the diet of brook trout was based on monthly samples taken during 1966. From the two low-density lakes, 109 and 128 stomachs were examined; from the intermediate-density lakes, 161 and 181 stomachs; and from the high-density lakes, 171 and 181 stomachs. The food organisms were mostly in four categories, namely: insects, crayfish, cladocerans, and fish. The contribution by crayfish is somewhat inflated in our figures because of a relatively slow rate of digestion. Nearly all of the crayfish consumed by trout were young of the year.

Seasonally, most prevalent in the diet were insects during the spring; and cladocerans in late summer, fall, and winter (Table 7). In West Lost, crayfish appeared in every monthly sample of trout stomachs during 1966, representing 75% of the total volume of food consumed. In

Lost Lake, crayfish were observed in 11 out of 12 monthly samples, and represented 33% of the total volume of food consumed. Some crayfish were eaten in North Twin and South Twin, and a few in Hemlock Lake. In Ford Lake the mudminnow appeared in the diet in all seasons. The bluntnose minnow appeared regularly in trout from Hemlock Lake, occurring in all monthly stomach samples during 1966. Of the total volume of food sampled, fish contributed 43% in Hemlock and 23% in Ford Lake.

Standing crop and production

The largest standing crop of trout, for the 1965 year class, occurred in the fall of 1966 after the first summer; and it exceeded the initial biomass, except in the lakes with high densities of trout (Fig. 3). In the high-density lakes the terminal standing crop was relatively high, primarily as a result of the relatively fast growth rate during the second summer, exceeding that of the first. For the 1964 year class, maximum standing crop was established at the outset of the study; and thereafter it declined, more rapidly in the high-density lakes.

Average maximum production of trout flesh was achieved in the three pairs of lakes after the first summer (Fig. 4). Production attained during the first summer was 11.0 kg/ha in the low-density lakes, 10.6 in the intermediate-density lakes, and 20.5 in the high-density lakes (Table 8). Production remained relatively high during the second summer in the high-density lakes as growth rates (g) improved. Overall, during the 23-month study, the high-density lakes generated the highest production, 46 kg/ha, while the low-density lakes on the average (19 kg/ha) exceeded the intermediate-density lakes (15 kg/ha) by more than 22%. The 1965 year class represented about 77% of total production in the low-density lakes, 83% in the intermediate-density lakes, and 93% in the high-density lakes.

Discussion

Mortality

In general, trout populations established in landlocked lakes are relatively short-lived, and experience a high rate of natural mortality. In the low-density lakes, where sampling mortality accounted for 29 to 42% of the total loss, only small remnant populations remained after 23 months. In the intermediate-density lakes, where monthly sampling of trout was about 6% greater than in the low-density lakes, terminal populations represented losses of 98-99%. For the high-density lakes the total loss of trout, both sampling and natural, represented a smaller percentage (88-89%) of the initial stock than in the other lakes. Also, monthly sampling of trout represented a very small part of total mortality. As a result terminal densities in these lakes were larger than in the other lakes, amounting to 149-155 fish per hectare.

Brook trout, of age 0 and age I in fall 1958, and at a density of 277 fish per hectare, incurred a total mortality of 99% after 2 years (Latta, 1963). About 57% of this loss was attributed to fishing. During this same period a population of brook trout (age 0 and age I) in Ford Lake, at a density one-half as large as used in the present study, was reduced to a density of about 5 fish per hectare after 2 years (Latta, 1963). In this instance, anglers' catch accounted for about 35% of the total loss.

In a small rehabilitated lake subject to moderate fishing pressure, Johnson (1955) reported total mortalities of 88.3, 98.3 and 98% for rainbow trout after 1, 2, and 3 years, respectively. His spring-stocked trout ranged in length from 107 to 162 mm and were stocked at densities of 158 to 403 fish per hectare. For fingerling rainbow and brown trout stocked in a softwater lake in Wisconsin in June, Brynildson and Kempinger (1973) reported that fishing and natural mortality nearly depleted the former after three summers, while a remnant population of the latter persisted into the fifth summer. Tuunainen (1970) reported similar findings for the same species in Swedish lakes.

In general, natural mortality is greater in summer than in winter (Eipper, 1961; Latta, 1963). Alexander and Shetter (1969) observed a differential mortality of fall-stocked brook and rainbow trout yearlings during the first winter after planting. They reported further that, on the average, about 50% of the brook trout stocked in the fall (46 fish per hectare) survived until the fishing season in late April, and anglers subsequently caught 79% of these. On the other hand, nearly all of the rainbow trout stocked in the fall (46 per hectare) survived until spring, and anglers cropped 70% of these the first summer and an additional 10% during the next two seasons.

Several investigators have indicated that fish and/or avian predators can markedly reduce salmonid populations (Foerster and Ricker, 1941; Johnson and Hasler, 1954; Smith, 1956; Eipper, 1964; and Alexander and Shetter, 1969). Cause of trout mortality in the present study is unknown. From observations during the study, hooded mergansers were observed occasionally on North Twin, South Twin, and West Lost lakes, while the great blue heron was observed more commonly on Ford and Hemlock, and infrequently on West Lost.

For a time period from May to October, Johnson and Hasler (1954) reported that natural mortality of age-I and age-II rainbow trout in three dystrophic lakes was due to predators, and not to density per se.

Early in the present study, there were two instances which indicated that mortality rate (q) was density dependent. Mortality rates for the 1965 and 1964 year classes during the first winter were directly proportional to their total densities at the outset of the study. Again, in the summer of 1966, there was a positive correlation between density of all trout at the outset (April 1966) and the mortality rate of the 1964 year class.

Growth

Growth of brook trout in this study did not compare well with growth in East Fish Lake, a nearby oligotrophic lake of 6.5 ha (Alexander and Shetter, 1969). Yearling brook trout, stocked in East Fish Lake in the fall, gained an average of 124 mm during the first year after planting. In the low-density lakes, where growth was best, brook trout of the same age, the 1964 year class, showed an average gain in length of 54 mm after a comparable period of time, which in this instance represented their second year of growth in these lakes.

As there was an inverse relationship between density of trout at the outset and subsequent growth, both the 1965 and the 1964 year classes in the high-density lakes showed the lowest growth rates during the first year of the study. An indication of the impact of an early mean density of 1,335 fish per hectare on growth was shown by negative growth rates exhibited by both year classes in West Lost, and by the 1965 year class in Ford Lake during the first winter. Evidently competition for food was strong, even though maintenance requirements for trout are minimal during the colder months. The greatest numerical loss of the 1965 year class in West Lost occurred during the first winter and was reflected in the higher growth rate during 1966 than in Ford Lake. On the other hand, the largest numerical loss of the 1965 year class did not occur in Ford Lake until the summer of 1966, and its impact was indicated by a marked increase in growth rate (g) in the second year.

In six Wisconsin dystrophic lakes, Johnson and Hasler (1954) observed an inverse relationship between total standing crop of trout and growth in weight of age-I rainbow trout. Instantaneous growth rates were related to four levels of standing crop, the first three being very similar to those in the present study. In the Wisconsin dystrophic lakes, standing crops at the two lower levels (between 10 and 30 kg/ha) had no apparent effect on growth rate. Only those standing crops at the higher levels had an effect. In lakes at the Pigeon River area, the impact of standing crop on growth rates was observed at a biomass of 12-13 kg/ha, which reflected differences from the Wisconsin lakes in productivity and/or differences in species of trout used in these two groups of lakes. From experiences in New York farm ponds, Eipper (1961) indicated that for trout in the age-I to age-II range, there was evidence of an inverse relationship between growth rates and mean population densities above 247 trout per hectare.

Diet

Diet of trout in each of the lakes was somewhat unique during the 23-month study. In the low-density lakes three categories of food occurred in excess of 0.10 cc per fish stomach. In North Twin Lake these were crayfish (0.29 cc), hemipterans (0.22 cc), and dipterans (0.15 cc); while in Hemlock they were fish (0.41 cc), dipterans (0.36 cc), and odonates (0.10 cc). In the intermediate- and high-density lakes, there was only one source contributing more than 0.10 cc per fish; in South Twin and Lost lakes it was dipterans (0.19 cc) and crayfish (0.11 cc), respectively; in the case of West Lost it was crayfish (0.38 cc); and in Ford Lake, odonates (0.12 cc).

Assuming that at any one instant the fastest growing brook trout would have a higher volume of food per fish than the slower growing fish, a correlation (r) was derived to inspect this relationship. Data used were the logarithmic mean number of trout per hectare in 1966, and the mean volume of food per fish in each lake. The relationship was not significant. Nevertheless, the mean volume of food per stomach in the low-density lakes was two times larger than that for the intermediate- and high-density lakes.

Production

Trout production (Table 8) tended to increase with increase in stocking density ($r = 0.920$, 4 d.f., $P < 0.05$). Brook trout populations (1965 and 1964 year classes), established at 41 to 54 kg/ha at the outset in the high-density lakes, showed the largest trout production over the 23-month period of study. These populations were comprised of small slow-growing fish. Production consisted of a relatively large number of fish each gaining a small annual increment in growth. Brynildson and Kempinger (1973) stocked age-0 brown trout and rainbow trout in a 38-ha lake in June, each species at the rate of 119 fish per hectare. After an 11-month period of no fishing, brown and rainbow trout had achieved average total lengths of 267 and 295 mm, respectively. Kilograms of brown trout produced were eight times the kilograms stocked, and rainbow trout did much better, with a production which was 25 times the kilograms stocked. According to Alexander and Shetter (1969), yearling brook and rainbow trout (226 mm) stocked in the fall, each at a density of 46 fish per hectare, grew in 1 year to averages of 350 and 402 mm, respectively. The ratio of kilograms produced, to kilograms stocked, was 0.7 for brook trout, and 3 for rainbow trout. Annually, anglers harvested about 3.5 kg of rainbow trout for every kilogram stocked, and for brook trout the ratio was 0.7. At the lowest initial densities, in North Twin and Hemlock lakes--averaging 194 fish per hectare for all trout--growth was best for the 1965 year class, which during the first year was from 142 to 244 mm. The ratio of kilograms stocked to total production of all trout in the low-density lakes was less than 2, which was poor compared to that reported by Brynildson and Kempinger (1973), and by Alexander and Shetter (1969).

In terms of trout lake management, this study shows that to obtain maximum growth of individual fish, stocking rates will need to be kept low. Satisfactory growth rates reported here, and by others, included (1) June stocking of age-0 trout at the rate of 238 fish per hectare, (2) fall stocking of age-I trout at the rate of 92 trout per hectare, and (3) fall stocking of age-0 trout at the rate of 194 fish per hectare.

Tables 9, 10 and 11 give additional data to supplement Tables 1-8.

Acknowledgments

I am grateful to the Pigeon River Station personnel, Harold H. Brado, Doyle E. Edson, William H. Karnes, and Gerald F. Myers, for their assistance in the field and laboratory. Dell H. Siler, a graduate student, analyzed the contents of some of the trout stomachs. Several people from the Grayling Research Station participated in the monthly sampling for trout. Alan D. Sutton drafted the figures. Gerald P. Cooper edited the manuscript.

Table 1.--Limnological characteristics of six Pigeon River Area lakes

Lake	Surface area (ha)	Maximum depth (m)	Alkalinity ppm $CaCO_3$	Conductivity [1] ohms/ cm^2	pH
N. Twin	1.9	12.5	29	20,900	6.7-8.4
Hemlock	2.4	18.0	145	4,070	6.8-8.7
S. Twin	1.6	10.1	65	8,400	7.1-8.4
Lost	1.5	15.2	114	3,500	6.6-8.4
W. Lost	1.4	13.1	134	4,160	7.4-8.2
Ford	4.1	8.8	71	5,320	

[1] Measurements corrected to 25 C.

Table 2.--Estimates of brook trout populations in six Pigeon River Area lakes in the fall of 1965

Lake	Year class					Total
	1964	1963	1962	1961	Unknown	
N. Twin	114	4	...	...	...	118
Hemlock	176	8	3	...	1	188
S. Twin	243	20	4	1	...	268
Lost	187	12	1	...	...	200
W. Lost	181	20	5	1	1	208
Ford	117	...	...	...	...	117

Table 3.--Seasonal mean instantaneous natural mortality rates (q) for the 1965 and 1964 brook trout year classes in the low-density lakes (N. Twin and Hemlock), the intermediate-density lakes (S. Twin and Lost) and the high-density lakes (W. Lost and Ford)

Lake, and period	Year class	
	1965	1964
N. Twin and Hemlock		
Nov 1965-Apr 1966	0.158	0.384
Apr 1966-Oct 1966	0.382	0.241
Oct 1966-Apr 1967	0.547	1.549
Apr 1967-Oct 1967	0.464	...
S. Twin and Lost		
Nov 1965-Apr 1966	0.106	0.742
Apr 1966-Oct 1966	0.399	0.190
Oct 1966-Apr 1967	0.162	1.443
Apr 1967-Oct 1967	1.436	...
W. Lost and Ford		
Nov 1965-Apr 1966	0.364	0.380
Apr 1966-Oct 1966	0.564	1.026
Oct 1966-Apr 1967	0.362	...
Apr 1967-Oct 1967	0.601	...

Table 4.--Seasonal mean instantaneous growth rates (g) for the brook trout of the 1965 year class in lakes of low, intermediate, and high densities, in the Pigeon River Area, from fish stocked in the fall of 1965

Trout density	1966		1967	
	Winter	Summer	Winter	Summer
Low	0.236	1.496	0.294	0.932
Intermediate	0.274	0.963	0.015	0.768
High	-0.150	0.576	0.322	0.827

Table 5.--Season of mean instantaneous growth rates (g) for the brook trout of the 1964 year class in lakes of low, intermediate, and high densities, in the Pigeon River Area during 1966

Trout density	Winter	Summer
Low	0.035	0.731
Intermediate	0.025	0.364
High	-0.195	0.118

Table 6.--The percentage of total volume of stomach contents, for orders of organisms in brook trout sampled in six Pigeon River Area lakes between November 1965 and October 1967

Order	North Twin	Hem-lock	South Twin	Lost	West Lost	Ford
Insecta	55	49	64	37	11	60
Cladocera	4	2	9	20	12	5
Decapoda	30	2	13	32	71	..
Annelida	4	1	2	2	2	2
Arachnida	<1	..	<1	<1	<1	<1
Caudata	<1	4	..	<1	..	3
Salientia	..	1	<1	..	..	<1
Ostracoda	<1	..	<1	..	1	..
Amphipoda	<1	..	1	..	<1	..
Copepoda	<1	..	<1	..	<1	..
Pelecypoda	..	<1	..	<1	..	<1
Teleostei	..	34	..	..	1	21
Fish eggs	<1	4	2	..	1	..
Unidentified	5	2	8	8	1	8

Table 7.--Percentage of total volume of stomach contents made up by four principal food types in brook trout, based on monthly samples from six Pigeon River Area lakes during 1966 (tr = trace)

Month	Food types				Food types			
	Insects	Cray-fish	Clad-ocera	Fish	Insects	Cray-fish	Clad-ocera	Fish
	North Twin				Hemlock			
Jan	54	..	46	..	98	..	tr	1
Feb	60	tr	39	..	99	..	..	tr
Mar	6	57	..	..	16	..	tr	73
Apr	100	..	..	..	10	..	..	82
May	79	..	..	..	66	..	3	30
June	39	59	2	..	84	..	2	14
July	56	19	..	..	50	..	24	26
Aug	49	11	40	..	53	..	14	7
Sep	94	..	..	..	75	..	25	..
Oct	62	38	..	..	31	20	..	..
Nov	23	44	6	..	60	9	..	..
Dec	71	14	6	..	39	..	..	60
	South Twin				Lost			
Jan	67	..	27	..	24	47	29	..
Feb	14	43	43	..	50	tr	49	..
Mar	3	..	97	..	12	41	47	..
Apr	77	..	tr	..	19	38	4	..
May	65	..	33	..	63	15	8	..
June	77	..	..	..	47	3	18	..
July	44	34	5	..	tr	58	41	..
Aug	100	..	..	..	37	..	49	..
Sep	80	17	1	..	78	17	3	..
Oct	35	..	26	..	23	52	3	..
Nov	16	2	11	..	10	75	14	..
Dec	90	8	1	..	37	31	31	..
	West Lost				Ford			
Jan	11	59	30	..	100	..	..	..
Feb	2	98	..	..	99	..	..	tr
Mar	3	96	tr	..	68	..	..	32
Apr	40	59	..	..	97	..	..	..
May	81	17	2	..	78	..	..	..
June	37	24	..	..	88	..	5	..
July	8	80	11	..	12	..	24	..
Aug	10	47	tr	..	21	..	21	58
Sep	11	88	tr	..	70	..	..	30
Oct	6	67	24	..	56	..	..	..
Nov	..	19	27	..	50	..	tr	38
Dec	3	80	17	..	21	..	10	37

Table 8.--Mean standing crop and production of brook trout in lakes of low, intermediate, and high densities, in the Pigeon River Area, between November 1965 and October 1967

Trout density, and date	Standing crop kg	Standing crop kg/ha	Production kg	Production kg/ha
Low-density				
November 1965	26.30	12.60	.....	.....
April 1966	17.02	7.86	3.07	1.40
October 1966	29.78	13.54	23.51	11.00
April 1967	12.11	5.35	6.32	2.75
October 1967	9.94	4.45	8.05	3.69
Total	.....	.....	40.95	18.84
Intermediate-density				
November 1965	36.06	23.06	.....	.....
April 1966	19.70	12.65	3.56	2.28
October 1966	22.12	14.16	16.60	10.55
April 1967	8.00	5.37	0.27	0.18
October 1967	2.82	1.80	3.78	2.41
Total	.....	.....	24.21	15.42
High-density				
November 1965	122.41	48.25	.....	.....
April 1966	67.90	25.50	17.93	6.80
October 1966	62.22	30.14	44.23	20.51
April 1967	43.40	20.02	5.81	2.22
October 1967	56.56	21.21	41.14	16.57
Total	.....	.....	109.11	46.10

Table 9.--Semiannual estimates of the 1965 year class of brook trout, following November stockings in six Pigeon River Area lakes

95% confidence limits in parentheses [1]

Lake	Number stocked Nov 1965	Estimated number of fish 1966 April	1966 October	1967 April	1967 October
North Twin	240	183 (144-280)	68 (55-116)	28 (4-52)	10[a]
Hemlock	295	221 (156-442)	180 (133-315)	66 (50-108)	27[a]
South Twin	390	296 (232-407)	131 (105-181)	52 (32-138)	9[a]
Lost	370	293 (211-480)	171 (138-232)	114 (80-229)	11[a]
West Lost	1750	1193 (967-1458)	952 (818-1176)	581 (436-872)	209 (172-280)
Ford	5100	3430 (2429-5830)	1270 (1071-1707)	860 (632-1344)	634 (544-793)

[1] Data determined from charts in Clopper and Pearson (1934).

[a] Minimum estimate based on number of fish handled.

Table 10.--Semiannual estimates of the 1964 year class of brook trout in six Pigeon River Area lakes, starting with fall of 1965

95% confidence limits in parentheses[1]

Lake	Residual stock fall, 1965	Estimated number of fish			
		1966		1967	
		April	October	April	October
North Twin	114 (100-153)	54 (33-145)	21 (18-42)	2[a]	...
Hemlock	176 (146-241)	105 (61-368)	72 (52-134)	18 (14-72)	8[a]
South Twin	243 (195-336)	94 (78-141)	46 (34-101)	3[a]	...
Lost	187 (162-230)	75 (53-150)	43 (32-95)	5[a]	2[a]
West Lost	181 (161-219)	67 (33-166)	18 (11-70)	...	...
Ford	117 (104-147)	84 (51-253)	14 (12-36)	3[a]	...

[1] Data determined from charts in Clopper and Pearson (1934).

[a] Minimum estimate based on number of fish handled.

Table 11.--Periodic sampling of the 1965 year class of brook trout which were stocked in six Pigeon River Area lakes in November 1965 at an average length of 142 mm and an average weight of 29 g

Lake, year, and month	Number of fish	Length (mm) Mean	Length (mm) Standard error	Weight (g) Mean	Weight (g) Standard error
NORTH TWIN					
1965					
December	5	145	1.6	29	1.1
1966					
January	6	160	5.5	42	4.3
February	5	155	3.0	42	3.0
March	5	165	4.7	38	2.6
April	10	168	2.4	40	1.7
May	5	162	4.1	40	2.5
June	6	188	3.1	74	3.8
July	5	213	5.9	129	7.3
August	6	234	6.9	176	10.4
September	5	254	6.5	208	19.3
October	5	256	7.2	221	13.5
November	3	269	16.1	188	33.0
December	6	262	9.7	199	16.8
1967					
January	3	277	11.1	214	24.5
February	5	272	7.8	202	18.9
March	4	279	6.8	201	10.8
April	5	256	11.5	158	24.1
June	...	...	...	...	...
August	5	328	14.9	522	84.9
October	16	333	6.2	572	25.7
HEMLOCK					
1965					
December	5	145	2.9	30	3.0
1966					
January	5	157	4.6	37	2.5
February	5	145	4.9	32	2.8
March	5	162	2.5	37	1.9
April	5	162	5.3	37	4.0

(continued, next page)

Table 11.--continued

Lake, year, and month	Number of fish	Length (mm) Mean	Length (mm) Standard error	Weight (g) Mean	Weight (g) Standard error
HEMLOCK (cont.)					
1966					
May	5	177	5.4	46	6.1
June	5	193	7.8	76	8.4
July	5	206	3.0	105	4.7
August	6	218	3.4	122	1.9
September	5	241	6.5	142	5.8
October	5	239	3.8	137	8.9
November	5	241	8.2	136	6.4
December	5	251	7.9	158	12.5
1967					
January	5	264	10.9	186	19.6
February	5	264	8.6	182	16.8
April	5	264	16.4	198	34.3
June	5	312	7.8	308	21.2
August	5	335	5.4	452	20.7
October	33	330	12.5	395	17.4
SOUTH TWIN					
1965					
December	10	150	2.9	29	1.9
1966					
January	10	150	4.8	34	1.9
February	10	160	2.2	36	1.6
March	10	155	3.5	31	7.8
April	10	165	3.3	38	3.4
May	10	165	4.1	44	3.9
June	4	198	8.1	99	14.2
July	11	208	4.3	119	7.0
August	7	211	8.9	114	17.1
September	9	236	3.7	164	7.1
October	10	216	6.1	121	8.9
November	10	231	5.3	124	8.3
December	10	241	5.4	132	10.0

(continued, next page)

Table 11.--continued

Lake, year, and month	Number of fish	Length (mm) Mean	Length (mm) Standard error	Weight (g) Mean	Weight (g) Standard error
SOUTH TWIN (cont.)					
1967					
January	10	244	4.7	139	10.7
February	10	239	6.4	124	12.3
March	5	231	8.8	140	27.8
April	10	236	6.6	112	11.0
June	1	277	...	254	...
August	5	292	12.6	286	38.0
October	16	300	6.5	329	27.6
LOST					
1965					
December	10	147	1.6	32	1.1
1966					
January	10	142	2.4	27	1.0
February	10	147	3.0	31	1.6
March	10	162	2.1	35	1.6
April	10	162	2.2	34	1.4
May	10	170	1.5	44	0.9
June	10	173	2.5	47	1.9
July	10	180	2.2	64	2.8
August	10	188	2.9	68	3.7
September	9	201	2.6	91	4.5
October	10	198	3.9	74	2.8
November	10	196	4.0	65	4.9
December	10	208	4.1	88	4.5
1967					
January	10	216	3.6	90	3.0
February	10	216	1.7	78	2.6
April	11	203	4.4	64	3.7
June	10	213	2.8	97	3.7
August	4	226	3.8	117	7.1
October	13	236	7.2	157	16.7

(continued, next page)

Table 11.--continued

Lake, year, and month	Number of fish	Length (mm) Mean	Length (mm) Standard error	Weight (g) Mean	Weight (g) Standard error
WEST LOST					
1965					
December	12	145	2.3	30	1.5
1966					
January	10	152	2.2	34	1.4
February	10	152	2.4	29	1.7
March	10	145	3.2	24	2.4
April	11	147	1.8	24	1.5
May	10	155	3.4	35	3.1
June	11	160	3.6	42	3.5
July	10	173	4.4	56	4.2
August	9	180	4.2	61	4.4
September	16	178	2.8	61	3.7
October	12	180	4.0	58	3.6
November	10	191	4.6	64	4.9
December	10	198	5.4	70	7.8
1967					
January	10	208	7.4	84	9.2
February	10	208	3.7	89	1.3
March	10	198	5.8	63	4.3
April	12	201	5.5	71	6.0
June	10	213	5.5	98	5.5
August	9	224	3.8	120	6.2
October	10	239	7.8	159	12.2
FORD					
1965					
December	10	150	1.4	29	1.1
1966					
January	10	142	2.2	26	1.3
February	10	142	3.0	28	1.8
March	10	147	1.6	25	0.9
April	19	142	4.1	24	2.3
May	10	155	5.4	39	4.9
June	10	160	2.1	40	1.6

(concluded, next page)

Table 11.--concluded

Lake, year, and month	Number of fish	Length (mm)		Weight (g)	
		Mean	Standard error	Mean	Standard error
FORD (cont.)					
1966					
July	10	155	2.2	40	1.8
August	11	165	2.6	42	2.8
September	10	168	2.9	43	3.4
October	10	175	2.0	53	4.6
November	10	190	4.2	60	4.3
December	10	185	3.0	54	3.2
1967					
January	10	193	4.3	61	4.6
February	10	185	2.4	54	1.5
April	10	193	6.1	61	7.1
June	10	203	4.8	84	6.0
August	10	203	7.5	96	6.0
October	11	229	4.7	126	7.6

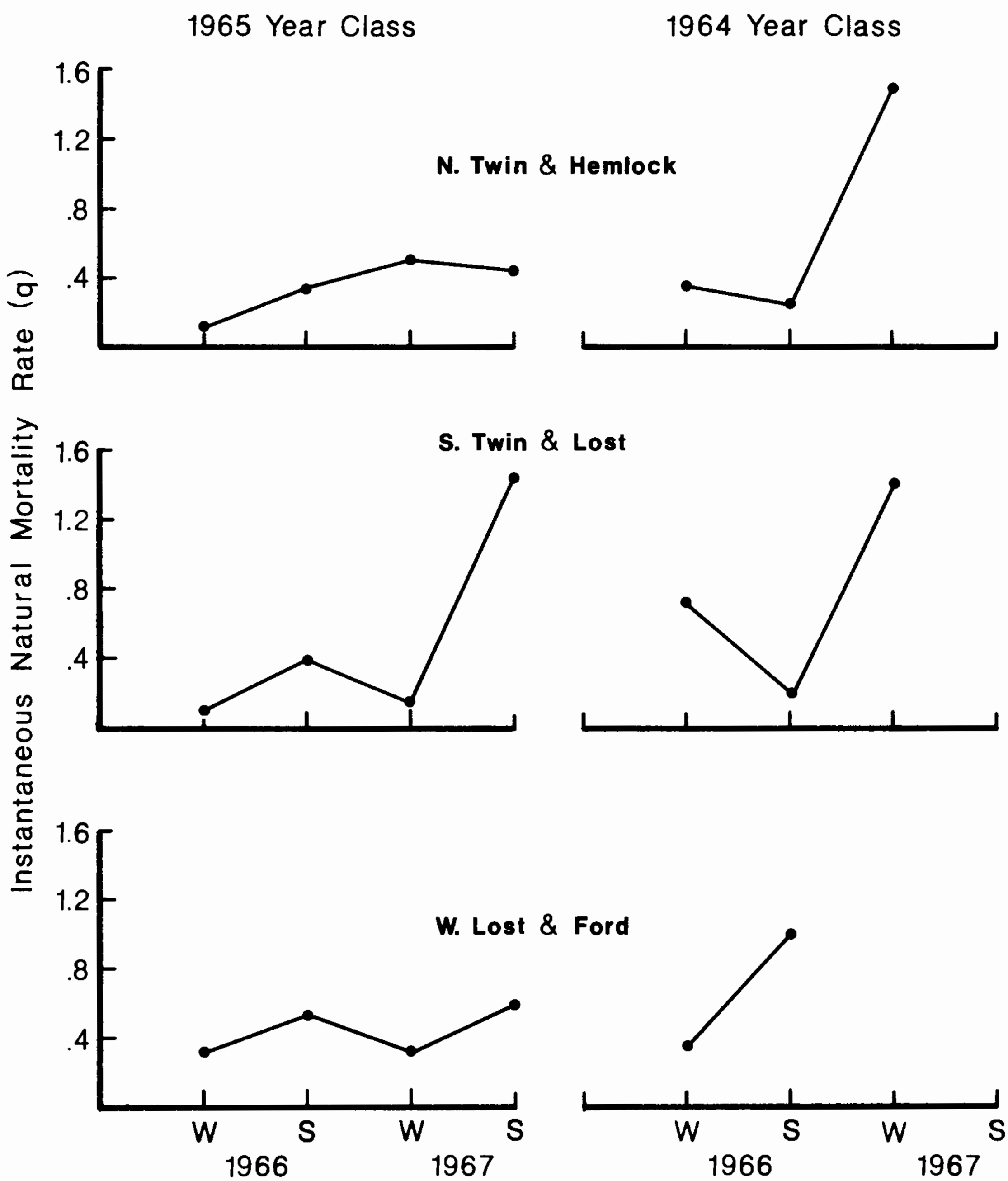

Figure 1.--Seasonal (winter and summer) mean instantaneous natural mortality rates for the 1965 and 1964 brook trout year classes in the low-density lakes (North Twin and Hemlock), intermediate-density lakes (South Twin and Lost), and high-density lakes (West Lost and Ford).

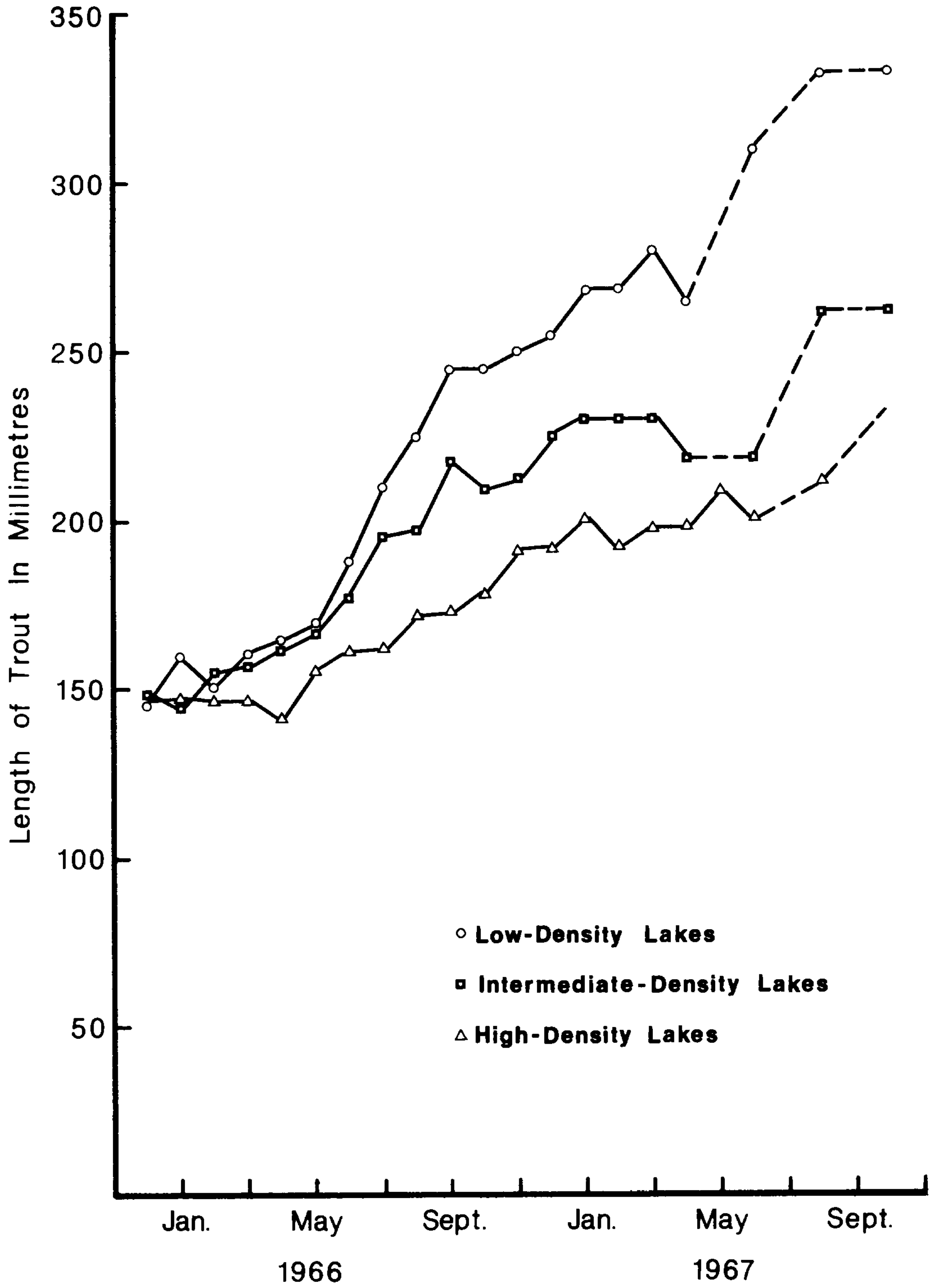

Figure 2.--Seasonal pattern of brook trout growth in low-, intermediate-, and high-density lakes in the Pigeon River area between December 1965 and October 1967.

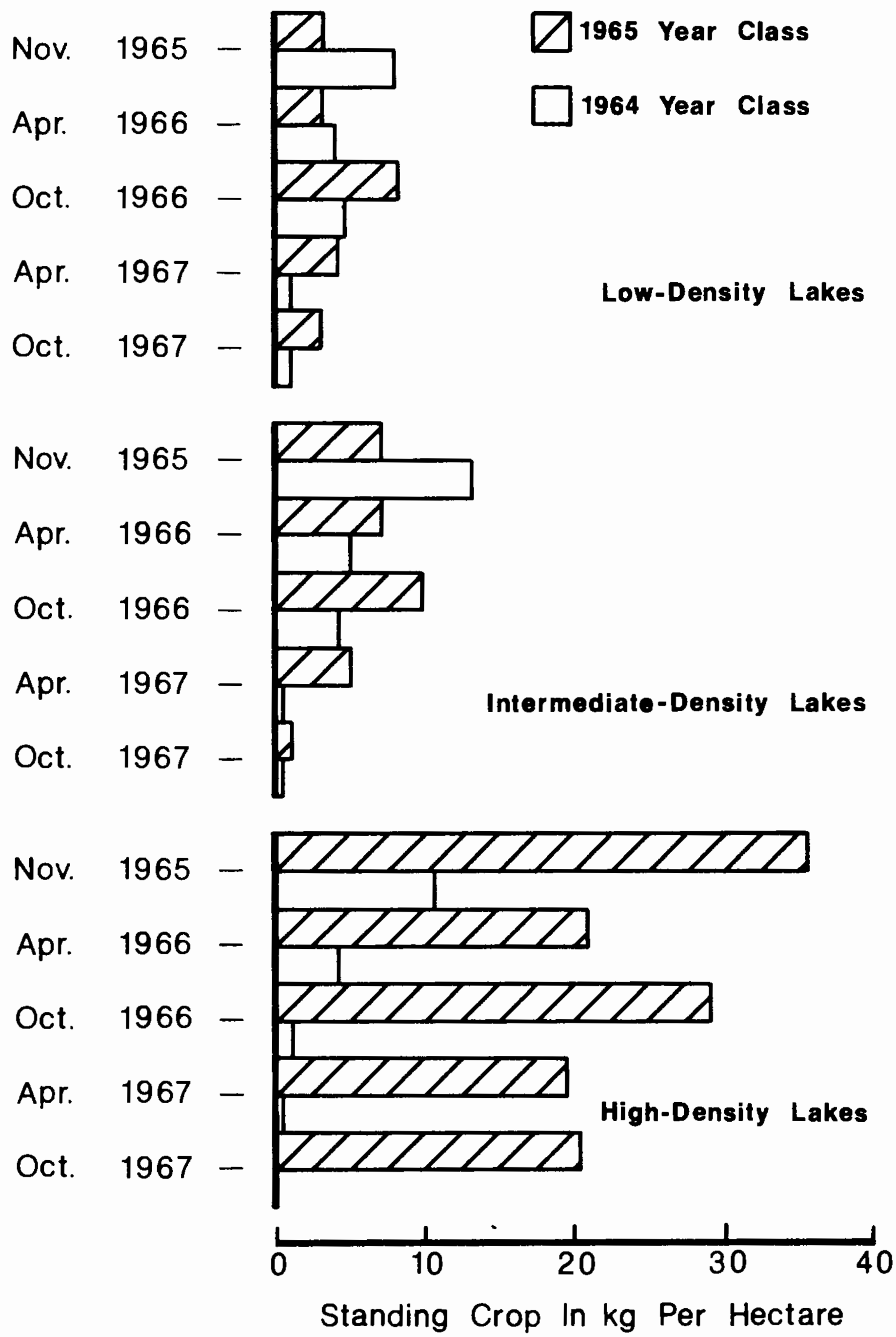

Figure 3.--Mean standing crop of the 1965 and 1964 year classes at 6-month intervals in low-, intermediate-, and high-density lakes in Pigeon River area lakes during 1966 and 1967.

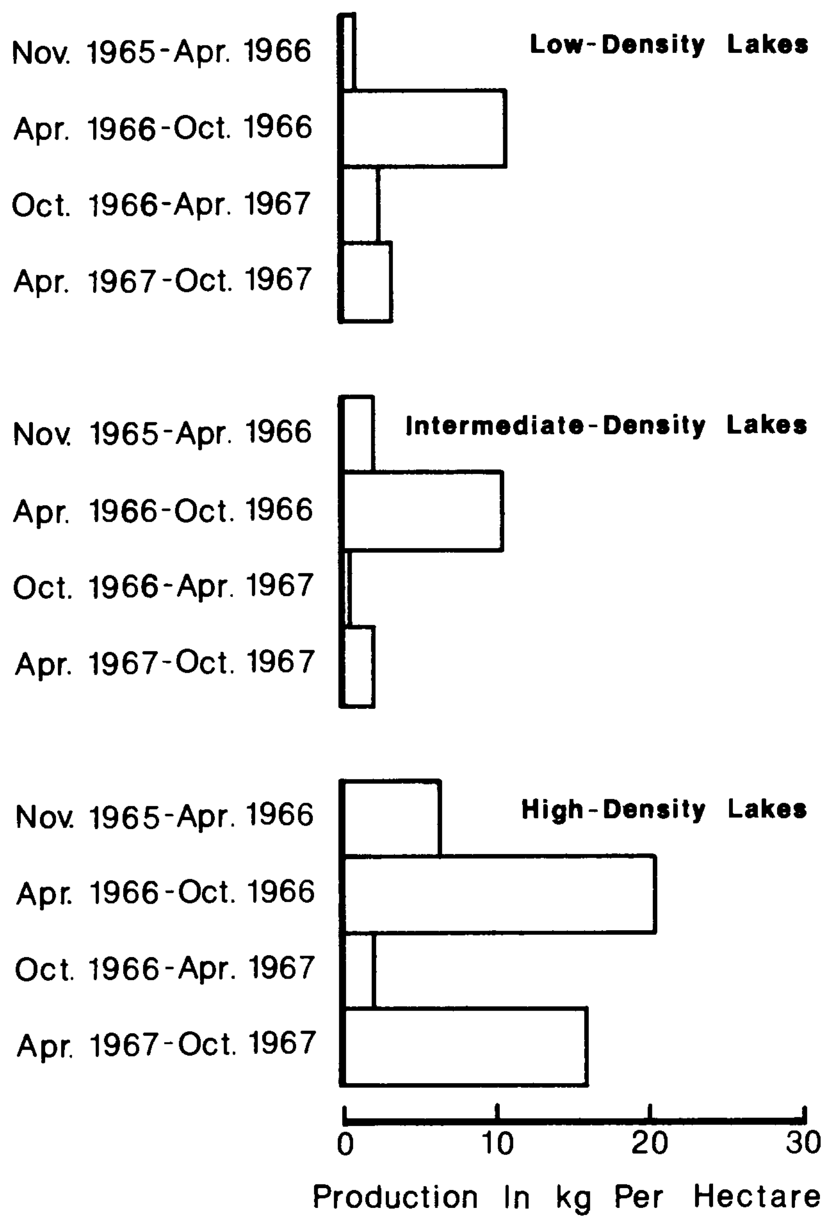

Figure 4.--Mean seasonal production of brook trout in low-, intermediate-, and high-density lakes in the Pigeon River area between November 1965 and October 1967.

Literature cited

Alexander, Gaylord R., and David S. Shetter. 1969. Trout production and angling success from matched plantings of brook trout and rainbow trout in East Fish Lake, Michigan. J. Wildl. Mgt., 33(3): 682-692.

Allison, L. N., and W. C. Latta. 1969. Effects of gill lice (Salmincola edwardsii) on brook trout (Salvelinus fontinalis) in lakes. Mich. Dept. Nat. Res., Research and Development Rep. No. 189, 32 pp.

Brynildson, Oscar M., and James J. Kempinger. 1973. Production, food and harvest of trout in Nebish Lake, Wisconsin. Wisc. Dept. Nat. Res., Tech. Bull. No. 65, 20 pp.

Clopper, C. J., and E. S. Pearson. 1934. The use of confidence or fiducial limits applied to the case of the binomial. Biometrika, 26: 404-413.

Eipper, Alfred W. 1961. Vital statistics of trout populations in New York farm ponds. Canad. Fish Cult., 29: 13-14.

Eipper, Alfred W. 1964. Growth, mortality rates, and standing crops of trout in New York farm ponds. N.Y. State Coll. Agr., Cornell Univ. Agr. Ext. Sta., Memoir 388, 68 pp.

Foerster, R. E., and W. E. Ricker. 1941. The effect of reduction of predaceous fish on survival of young sockeye salmon at Cultus Lake. J. Fish Res. Bd. Canad., 5(4): 315-336.

Johnson, Fritz H. 1955. Rainbow trout mortality and carrying capacity of rehabilitated trout lake in Minnesota. Prog. Fish-Cult., 17: 129-131.

Johnson, Waldo E., and Arthur D. Hasler. 1954. Rainbow trout production in dystrophic lakes. J. Wildl. Mgt., 18(1): 113-134.

Latta, William C. 1963. Semiannual estimates of natural mortality of hatchery brook trout in lakes. Trans. Amer. Fish. Soc., 92(1): 53-59.

Ricker, W. E. 1958. Handbook of computations for biological statistics of fish populations. Fish. Res. Bd. Canada, Bull. 119, 300 pp.

Smith, M. W. 1956. Further improvement in trout angling at Crecy Lake, New Brunswick, with predator control extended to large trout. Canad. Fish Cult., 19: 13-16

Tuunainen, Perka. 1970. Relations between the benthic fauna and two species of trout in some small Finnish lakes treated with rotenone. Ann. Fennici, 7: 67-120.

Waters, Thomas F. 1960. The development of population estimate procedures in small trout lakes. Trans. Amer. Fish. Soc., 89(3): 287-294.

Report approved by G. P. Cooper
Typed by M. S. McClure