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cc: Fish Division ✓
Educ.-Game
G. Alexander
D. S. Shetter
Hunt Creek Station
M. Hunt - 2
Inst. for Fish. Res.

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# SEASONAL MORTALITY AND GROWTH OF HATCHERY-REARED BROOK AND RAINBOW TROUT IN EAST FISH LAKE, MONTMORENCY COUNTY, MICHIGAN, 1958-1959

G. R. Alexander and D. S. Shetter

Institute for Fisheries Research

Michigan Department of Conservation

Lewiston, Michigan

## Introduction

More knowledge must be gained about trout populations if suitable stocks of trout are to be maintained for the angling public. Two characteristics of fish populations that are of primary importance are mortality and growth. Many studies have been made of the growth of trout but considerably fewer on mortality, or its complement, survival. Most published data on mortality (as well as growth) pertain to relatively long intervals, compiled on an annual basis. Seasonal mortality patterns and factors affecting this mortality for various types of trout populations and environments need to be determined. Similar information on trout growth is highly desirable.

The present study considers seasonal mortality and growth between October, 1958, and September, 1959, of hatchery-reared brook trout (Salvelinus

fontinalis) and rainbow trout (Salmo gairdneri) released in East Fish Lake, Montmorency County.

East Fish Lake has a surface area of 16 acres. More than half of the basin is deeper than 20 feet and the maximum depth is about 40 feet. It stratifies in midsummer but oxygen and temperature levels are suitable for trout throughout the year. The water is hard (about 175 p.p.m. of methyl-orange alkalinity). Aquatic vegetation is sparse except on the shoals, where Chara is common and scattered patches of Scirpus spp., Potamogeton spp., and Nuphar spp. occur. Brook sticklebacks (Eucalia inconstans) and mudminnows (Umbra limi) are the only species of fish other than trout which have been observed since the fall of 1956, when the lake was treated with rotenone.

East Fish Lake is an ideal body of water for the type of study discussed here. It has a reputation of being excellent brook trout water and is located on the Hunt Creek Trout Research Area, where a fishing-permit system insures a complete creel census. Also, the lake has a barrier weir at the outlet, which isolates the trout population.

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## Methods

Hatchery-reared brook and rainbow trout of identical length and age (I) were used so that survival and growth of the two species could be compared. On October 14, 1958, 300 brook and 300 rainbow trout ranging in total length from 8.5 to 9.5 inches (average, 8.9) were marked by removal of the left pelvic fin and planted in East Fish Lake.

Population estimates and growth data were obtained from these populations of trout during the following periods (which are discussed consecutively in the text): October 14-November 6; November 6-12; December 29-January 9; February 26-March 11; April 20-22; and the winter of 1959-1960. All population estimates were regarded as applying to the midpoint date of each of these periods. Estimates for rainbow trout were made only for January 2, March 4, and the winter of 1959-1960 because too few fish were marked in other periods to permit satisfactory estimates.

Four different estimates were obtained (based on different methods of recovery) of the number of brook trout present in East Fish Lake during the first period (October 14-November 6). All four estimates were based on recaptures from 150 different brook trout trap-netted and marked during this period. Trout were removed from the nets daily and returned to the lake after the lower portion of the caudal fin had been removed. All estimates for this first period, and for later periods, were based on the numbers of marked and unmarked trout among fish recovered, and it was assumed throughout the study that the mortality rates of the marked and unmarked members of the population were identical. The first population estimate was based on recapture by netting during the netting period; the second on recapture by experimental fishing on November 6-12; the third on recapture by direct-current electrofishing on April 20-22; and the fourth on recoveries by anglers during the 1959 fishing season (April 25-September 13). The first two population estimates were made by the method suggested by Schumacher and Eschmeyer (1943), and the latter two (and other estimates discussed below) were based on the Petersen Index.

During the second period (November 6-12), or the period of fall experimental angling, 95 different brook trout were caught by angling

with artificial flies or salmon eggs. These trout were marked by clipping the dorsal lobe of the caudal fin. Two estimates were obtained of the brook trout population for the second period--one from the number of upper-caudal-marked trout and unmarked fish in the sample taken by spring electrofishing and the other from the number of marked and unmarked trout in anglers' creels during the trout season.

Between December 29 and January 9, 38 brook and 49 rainbow trout were caught by angling through the ice. These trout were marked by removing the right pectoral fin before returning them to the water. Petersen-type population estimates for this period were based on the ratio of these marked trout observed among fish collected in the spring electrofishing and in the anglers' catch during the season.

Ice fishing was again employed to capture trout between February 26 and March 11. A total of 52 brook and 46 rainbow trout were caught and marked by removing the right pelvic fin. Population estimates for this fourth period were calculated from the ratios of marked to unmarked trout in the spring electrofishing and in the anglers' catch.

On April 20-22, just prior to the trout season, 42 brook trout were captured by direct-current electrofishing. These fish were marked by removing the dorsal fin. Population estimates for the period were based on the ratio of dorsal-marked to unmarked trout in the anglers' catch.

No direct population estimates utilizing the mark-and-recapture method were attempted during the 1959 trout season. However, the numbers of trout caught by fishermen were shown by the creel census. The total catch subtracted from the preseason population estimate gave a hypothetical fall population remaining after the season. Also, the anglers' catch for various two-week intervals during the angling season gave us some indication of the mortality pattern during the trout season.

Population estimates were not conducted in the fall of 1959. However, a fair knowledge of the population of trout remaining after the fishing season was gained by experimental ice fishing in the winter of 1959-1960.

## Results

The population estimates for different dates from October 26 to April 21 are shown in Table 1. As mentioned above, four estimates were made, all based on trap-netted fish but on different methods of recovery, for October 26 (midpoint of the October 14-November 6 period). The four estimates were 329, 285, 300, and 314.[1] The first two estimates were determined by the Schumacher-Eschmeyer method; one was based on trout recovered by netting and the other on recoveries by experimental angling. The third was a Petersen estimate based on marked and unmarked trout recovered during spring electrofishing; and the fourth was based on fish creeled by anglers during the season.

The estimates of the number of brook trout in East Fish Lake on November 9 (the midpoint of the November 6-12 marking period) were 285 (based on 14 fin-clipped trout out of 42 brook trout captured by spring electrofishing) and 288 (on the basis of the ratio of marked to unmarked trout creeled during the fishing season). A comparison of these estimates with estimates for October 26 suggests that about 13 brook trout died between the two dates.

Recaptures by electrofishing of trout marked on December 29-January 9 yielded a population estimate of 123 brook trout for January 2; recoveries by anglers gave an estimate of 124. Thirty-two marked rainbow trout among 197 creeled during the fishing season gave an estimated population of 302 for January 2. (Too few rainbow trout were captured by spring electrofishing to make a second estimate.) These data suggest that the rainbow trout

[1] These early estimates of the population soon after the planting date demonstrated that the methods used in determining population numbers were reliable because the estimates were close to the actual numbers known to have been planted.

Table 1.--Estimates of the population of brook and rainbow trout in East Fish Lake, October 26, 1958-April 21, 1959

| Species and date[1] of estimate | Type of estimate[2] | Method of original capture[3] | Method of recapture[3] | Number of fish marked | Number of marked fish recovered | Number of unmarked fish recovered | Population estimate[4] |
|---|---|---|---|---|---|---|---|
| Brook trout | | | | | | | |
| Oct. 26, 1958 | S | N | N | 150 | ... | ... | 329 (243-415) |
| | S | N | A | | ... | ... | 285 (239-331) |
| | P | N | E | | 21 | 21 | 300 (224-469) |
| | P | N | C | | 42 | 46 | 314 (246-405) |
| Nov. 9, 1958 | P | A | E | 95 | 14 | 28 | 285 (183-475) |
| | P | A | C | | 29 | 59 | 288 (302-396) |
| Jan. 2, 1959 | P | A | E | 38 | 13 | 29 | 123 (81-224) |
| | P | A | C | | 27 | 61 | 124 (90-181) |
| Mar. 4, 1959 | P | A | E | 52 | 22 | 20 | 99 (83-123) |
| | P | A | C | | 43 | 45 | 106 (85-137) |
| Apr. 21, 1959 | P | E | C | 42 | 36 | 52 | 103 (79-145) |
| Rainbow trout | | | | | | | |
| Jan. 2, 1959 | P | A | C | 49 | 32 | 165 | 302 (213-445) |
| Mar. 4, 1959 | P | A | C | 46 | 31 | 166 | 292 (200-418) |

[1] Midpoint of period during which trout were captured for marking.

[2] S = Schumacher and Eschmeyer; P = Petersen.

[3] N = trap netting; A = experimental angling; E = electrofishing; C = public fishing during the trout season.

[4] 95-percent confidence limits in parentheses.

suffered little mortality between planting and early January, whereas the brook trout population estimate of 124 suggests a mortality of about 163 between November 9 and January 2 (or a total of 176 out of 300 since the date of planting).

The occurrence of 22 fish which had been marked on February 26-March 11 among 42 brook trout captured in the spring electrofishing gave a population estimate of 99 brook trout as of March 4, 1959; the ratio of 43 marked trout out of 88 in the anglers' catch yielded an estimate of 106 (average of the two estimates, 103). This indicated a mortality of about 21 brook trout (17 percent of the number remaining in early January) between January 2 and March 4. The rainbow trout population of 292 on March 4 was calculated from 31 right-pelvic-marked trout among 197 caught by anglers.

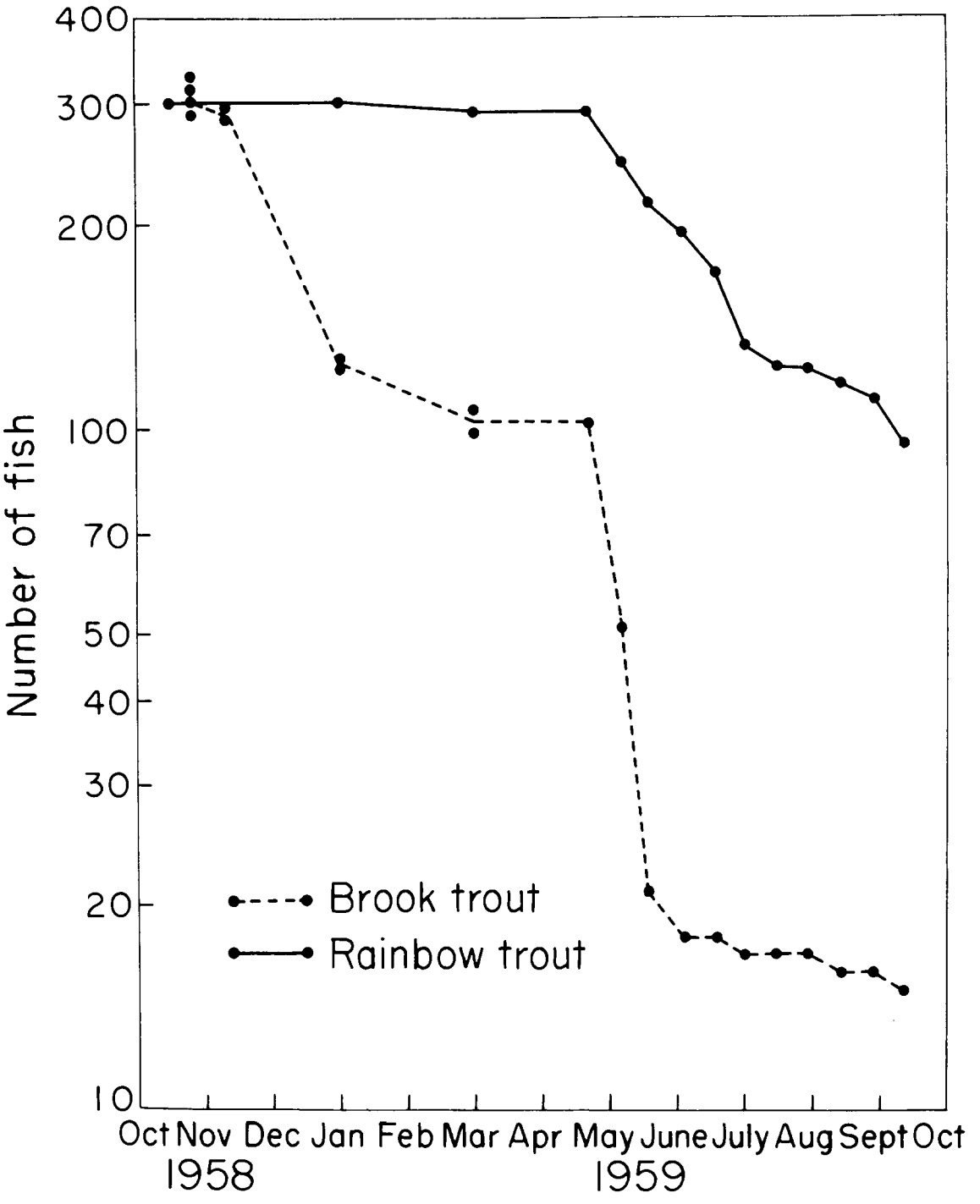
The brook-trout population estimate for April 21 was based on recoveries from 42 brook trout captured by electrofishing and marked by clipping the dorsal fin. The 36 marked fish recorded among 88 brook trout creeled during the fishing season gave an estimate of 103. Assuming that little or no mortality occurred among the rainbow trout between March 4 and April 21, about 292 rainbow and 103 brook trout were present at the opening of the trout season.

No direct population estimates were made during the 1959 angling season, but the complete creel census provided data on fish caught as the season progressed. These data, divided according to successive 2-week intervals of the trout season (Table 2), were combined with data from the earlier population studies to provide the logarithmic curve of mortality in Figure 1. Of the estimated 103 brook trout present at the opening of the fishing season, anglers caught 52 during the first two weeks of the season, 30

Table 2.--Mortality estimates for brook and rainbow trout in East Fish Lake, October 14, 1958 to September 13, 1959

| Period | Days in period | Brook trout | | | Rainbow trout | | |
|---|---|---|---|---|---|---|---|
| | | Mortality during period[1] | Estimated number of fish surviving | Instantaneous mortality rate per day | Mortality during period[1] | Estimated number of fish surviving | Instantaneous mortality rate per day |
| Oct. 14-Oct. 26 | 12 | 0 | 300 | 0 | 0 | 300 | 0 |
| Oct. 27-Nov. 9 | 14 | 13 | 287 | 0.00314 | 0 | 300 | 0 |
| Nov. 10-Jan. 2 | 54 | 163 | 124 | 0.01554 | 0 | 300 | 0 |
| Jan. 3-Mar. 4 | 61 | 21 | 103 | 0.00303 | 8 | 292 | 0.00045 |
| Mar. 5-Apr. 21 | 48 | 0 | 103 | 0 | 0 | 292 | 0 |
| Apr. 22-May 8 | 17 | 52 | 51 | 0.04136 | 44 | 248 | 0.00963 |
| May 9-May 22 | 14 | 30 | 21 | 0.06334 | 33 | 215 | 0.01019 |
| May 23-June 5 | 14 | 3 | 18 | 0.01102 | 16 | 199 | 0.00549 |
| June 6-June 19 | 14 | 0 | 18 | 0 | 30 | 169 | 0.01169 |
| June 20-July 3 | 14 | 1 | 17 | 0.00412 | 38 | 131 | 0.01821 |
| July 4-July 17 | 14 | 0 | 17 | 0 | 7 | 124 | 0.00389 |
| July 18-July 31 | 14 | 0 | 17 | 0 | 1 | 123 | 0.00057 |
| Aug. 1-Aug. 14 | 14 | 1 | 16 | 0.00434 | 7 | 116 | 0.00419 |
| Aug. 15-Aug. 28 | 14 | 0 | 16 | 0 | 4 | 112 | 0.00247 |
| Aug. 29-Sept. 13 | 16 | 1 | 15 | 0.00400 | 17 | 95 | 0.01178 |

[1] Mortality during periods prior to April 22 is based on population studies, and for subsequent periods on observed fishing mortality.




ESTIMATED POPULATIONS OF BROOK AND RAINBOW TROUT PLOTTED ON LOGARITHMIC SCALE, SHOWING SEASONAL INSTANTANEOUS MORTALITY RATES

Figure 1

during the second two weeks, and 6 during the remaining 16 weeks. Subtracting the total catch of 88 from the population estimate of April 21 leaves only 15 brook trout whose fate was unknown. Thus we believe that the brook trout mortality curve of Figure 1 is closely representative of mortality during the year.

Rainbow trout were caught by anglers at a much slower rate than brook trout. Of the 292 available to anglers at the opening of trout season, 44 were creeled during the first 2-week period of the fishing season and 33 during the second (Table 2). Subsequent catches were smaller, but as many as 17 were caught during the last two weeks of the season. The total catch was 197, which left 95 rainbow trout unaccounted for at the close of the season. Experimental fishing in December 1959 and January and March 1960 yielded 13 rainbow trout (no brook trout) from the October, 1958, planting. Our only estimate of the number of rainbow trout remaining in the lake was based on the recovery of 1 marked trout among the 13 taken. We had marked 3 rainbow trout in October 1959 by electrofishing, so the estimate of rainbow trout surviving the trout season (based on these limited data) was 39. Thus a maximum of 82 (as few as 56, if the population estimate is accepted) rainbow trout died of natural causes during the fishing season.

## Discussion of Mortality

The instantaneous rate of mortality (Ricker, 1958) of brook trout was greatest during the first four weeks of the trout season (Figure 1) but nearly all of this was fishing mortality (82 trout caught). From November 9 to January 2 the rate was somewhat less, but the numerical loss or total mortality (163) was far greater, and it is assumed that all these trout fell

prey to natural causes. Thus two-thirds of the brook trout planted had died before the fishing season opened. Anglers caught 88 of 103 (85 percent) of the brook trout available at the opening of the trout season, but this was only 29 percent of the number planted at the beginning of the study.[2]

Both the natural and fishing mortality rates of rainbow trout were very different from those of brook trout. It was estimated that only 8 rainbow trout died between planting and the opening of the trout season. Anglers caught 197 of 292 (67 percent) of the rainbow trout available at the opening of the season, or 65 percent of the number planted. The catch of rainbow trout was distributed throughout the entire season, whereas 93 percent of the total brook trout catch was made during the first four weeks of the fishing season (Table 2).

## Growth

The total length of all trout handled during each phase of this study, and both lengths and weights of all trout caught by anglers during the fishing season, were recorded. A summary of the average lengths and weights, with the standard errors, are presented in Table 3.

The average length of both species of trout at planting in October was 8.9 inches. By January brook trout had gained an average of 1.0 inches, whereas rainbow trout had gained 1.7 inches. The "t" test showed that by this date rainbow trout were significantly longer than brook trout; they maintained this advantage throughout the study. Brook trout caught during the first two weeks of the trout season averaged 10.9 inches in length, whereas rainbow trout were 11.5 inches long. The length of one brook trout creeled during the last two weeks of the season was 14.1 inches, whereas

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[2] Anglers caught 82 percent of 350 hatchery-reared brook trout planted in East Fish Lake immediately before the trout season in 1957 (92 percent of the catch was made during the first 4 weeks of the season). The similarity in the known exploitation rate of 1957 and the estimated exploitation rate in the present study supports the reliability of the population estimate of 103 brook trout prior to the 1959 trout season.

Table 3.--Average length and weight of brook and rainbow trout on various dates, East Fish Lake, October 14, 1958-September 5, 1959

| Date | Brook trout | | | Rainbow trout | | |
|---|---|---|---|---|---|---|
| | Number of fish | Average total length (inches)[1] | Average weight (pounds)[1,2] | Number of fish | Average total length (inches)[1] | Average weight (pounds)[1,2] |
| October 14 | 300 | 8.90 (0.018) | 0.25 | 300 | 8.90 (0.018) | 0.23 |
| January 2 | 38 | 9.88 (0.095) | 0.38 | 49 | 10.57 (0.066) | 0.42 |
| March 4 | 54 | 10.21 (0.062) | 0.41 | 46 | 10.72 (0.072) | 0.44 |
| April 21 | 42 | 10.53 (0.077) | 0.45 | 9 | 11.02 (0.316) | 0.48 |
| May 1 | 52 | 10.85 (0.059) | 0.48 (0.010) | 44 | 11.53 (0.069) | 0.56 (0.010) |
| May 15 | 30 | 10.97 (0.098) | 0.53 (0.018) | 33 | 11.85 (0.101) | 0.64 (0.015) |
| May 29 | 3 | 10.90 (0.485) | 0.53 (0.015) | 16 | 12.43 (0.110) | 0.76 (0.023) |
| June 12 | ... | ... | ... | 30 | 13.48 (0.125) | 1.00 (0.025) |
| June 26 | 1 | 11.50 | 0.70 | 38 | 13.79 (0.101) | 1.09 (0.028) |
| July 10 | ... | ... | ... | 7 | 14.17 (0.286) | 1.16 (0.063) |
| July 24 | ... | ... | ... | 1 | 15.00 | 1.25 |
| August 7 | 1 | 13.50 | 1.22 | 7 | 15.94 (0.193) | 1.64 (0.064) |
| August 21 | ... | ... | ... | 4 | 16.38 (0.144) | 1.79 (0.032) |
| September 5 | 1 | 14.10 | 1.31 | 17 | 16.34 (0.129) | 1.78 (0.033) |

[1] Standard errors in parentheses.

[2] Weights for both species for January 2, March 4, and April 21 determined from length-weight-relationship table.

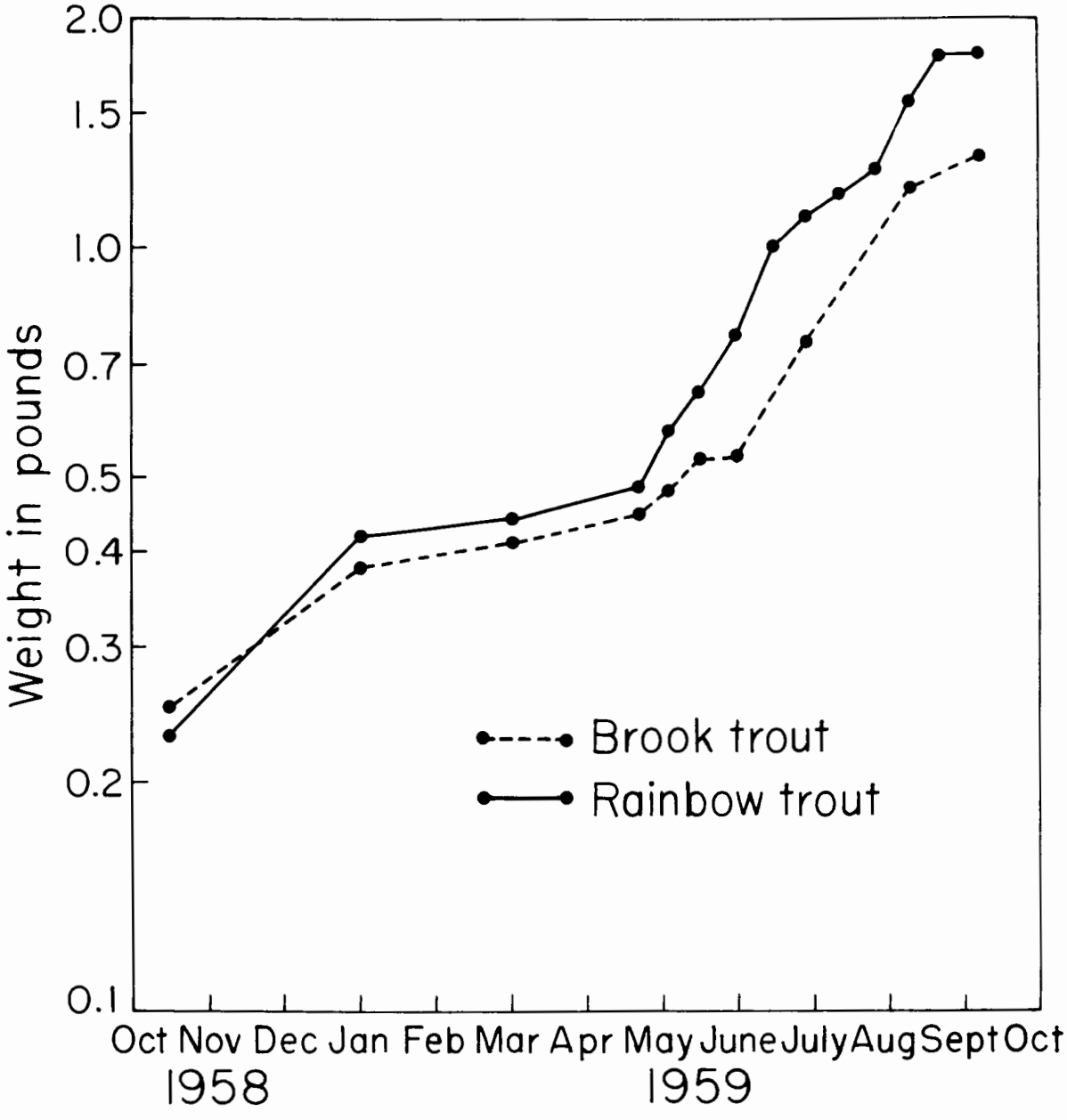
17 rainbow trout averaged 16.3 inches; thus the average increment between October 14, 1958 and the end of the 1959 trout season was 5.2 inches for brook trout and 7.4 inches for rainbow trout.

Growth in weight of brook and rainbow trout, in general, followed a similar seasonal pattern (Figure 2). Between October 14 and January 2, increase in weight (calculated from a length-weight curve) was rapid; brook trout gained 52 percent of their weight at planting and rainbow trout gained 83 percent. The instantaneous rate of growth (Ricker, 1958) of rainbow trout was 44 percent faster than brook trout. It was during this period in late fall and early winter that rainbow trout gained the advantage which they held throughout the remainder of the study. Growth was negligible from January 2 to April 21, but increased markedly after this date (Figure 2). Both species grew at a fairly constant instantaneous rate from late April to September, with brook trout growing at a somewhat slower rate. There apparently was a slight slowdown during midsummer in the rate of growth of rainbow trout, but the samples were not large enough to be certain.

Rainbow trout gained an average of 0.25 pound from October 14 to April 21 and an additional 1.30 pounds by September 13. The increment in weight of rainbow trout for the study period was 1.55 pounds (520 percent). Brook trout gained an average of 0.20 pound from October 14 to April 21 and the two brook trout creeled late in the trout season (one in August, one in September) had gained an additional 0.82 pound (average); the weight increment since planting was 1.02 pounds, or 408 percent.

## Discussion

Because of the higher survival and faster rate of growth, the return of rainbow trout to anglers was much better than brook trout (a few additional recaptures of rainbow trout are expected during the 1960 fishing




WEIGHT OF BROOK AND RAINBOW TROUT PLOTTED ON LOGARITHMIC SCALE, SHOWING SEASONAL INSTANTANEOUS GROWTH RATES

Figure 2

season). This was the first introduction of rainbow trout into East Fish Lake, however, whereas brook trout have been planted annually for many years. It is widely acknowledged that initial introductions of trout in suitable lakes usually fare better than later plantings. We expect to obtain additional information on this point from similar future plantings in East Fish Lake and other waters.

The poor return of brook trout was due primarily to low survival between November 9 and January 2. The causes of this mortality are unknown. Since we know when the mortality occurred, however, certain possibilities (e.g., planting mortality) may logically be eliminated. It was observed during the fall netting and fishing that brook trout were in shallow water, whereas rainbow trout stayed in the deeper water. Brook trout could be seen and approached easily by rowboat during late October and early November, a period which coincides with the brook trout spawning season and the period of heavy mortality. Around November 9, 1958, most of the female brook trout captured were ripe, but had not yet spawned. The concentration of brook trout on the inlet delta and vicinity during this period may have encouraged predation by kingfishers, herons, mink and otter, all of which are known to frequent the area and presumably can capture trout in shallow water. Another possibility is furunculosis, a disease which may cause death at this time of year because the physical resistance of the brook trout is lowered due to spawning. Still another possibility might be that the trout died from a physiological change associated with spawning. (Hatchery brook trout of this age and size that are held in hatchery ponds are known to suffer mortality at the same time of year.) Although the heavy brook trout mortality of November 9-January 2 remains unexplained, these and other possibilities suggest potentially productive avenues for future research on the problem.