

## PRODUCTION AND FOOD OF CUTTHROAT TROUT IN THREE OREGON COASTAL STREAMS

GERALD R. LOWRY, Research Division, Oregon State Game Commission, Corvallis<sup>1</sup>

**Abstract:** Unfished populations of coastal cutthroat trout (*Salmo clarki clarki*) in three small coastal streams in Oregon were studied from April, 1962, until November, 1963. Population size, growth rate, and production were estimated for study areas in each stream. The mean annual biomass of cutthroat trout for all streams was 4.2 grams per square meter ( $\text{g}/\text{m}^2$ ). Growth in length was greatest in April and May and least in October and November. Production per year averaged  $4.1 \text{ g}/\text{m}^2$  for the three streams, but production levels were about 20 percent higher in one of the three. Food samples from trout stomachs taken during the period of emergence and early growth of coho salmon (*Oncorhynchus kisutch*) fry suggested that cutthroat trout were not important consumers of young coho. Aquatic arthropods were consistently an important part of the diet; earthworms decreased in importance and terrestrial arthropods increased in importance during the period February–June.

This study was undertaken to obtain data concerning the population dynamics of the coastal cutthroat trout in three small streams. The field work was carried on between April 15, 1962, and November 1, 1963. The specific objectives of the investigation were (1) to estimate the size of trout populations, (2) to estimate growth rates of trout, (3) to estimate the production of trout, and (4) to determine the food habits of trout in the late winter and spring.

A study of the effect of logging practices on the physical and biotic characteristics of the three study watersheds is under way (Chapman et al. 1961). An important use of the information obtained in this study will be to establish the pre-logging status of cutthroat trout populations. It is planned to conduct another study of the trout populations after logging is completed.

Although much has been written on the cutthroat trout (Cope 1958), relatively little is known about the coastal subspecies. Studies on cutthroat trout in Oregon have been made on movement and aging (Sumner 1962), food habits (Dimick and Mote 1934), life history and distribution (Dimick and Merryfield 1945), and spawning activities (Cramer 1940). The distribution, dis-

tinctive features, and life history of this trout in northern California are detailed by DeWitt (1954).

Several very thorough studies of population dynamics of fish were used in some respects as models for the present study. The production of bluegill in a eutrophic lake in Indiana was studied by Gerking (1962). The dynamics of fish populations are discussed by Ricker and Foerster (1948) and Ricker (1958).

I wish to thank D. W. Chapman, James Hall, Ray J. White, Homer J. Campbell, Robert W. Phillips, Norman Anderson, David L. Mays, Donald Jensen, Wes Harms, John Neilsen, and the many others who gave encouragement and assistance with this investigation.

Financial support was provided by a graduate research assistantship from the Research Division of the Oregon State Game Commission under the leadership of H. J. Rayner.

### DESCRIPTION OF AREA

The study was conducted on three coastal streams located about 8 miles south of Toledo, Oregon. Deer Creek, Flynn Creek, and Needle Branch are part of the Drift Creek stream system, which drains into Alsea Bay near Waldport, Oregon. The

area receives about 100 inches of rainfall per year, most of it from December to March. Water temperatures during 1959 and 1960 varied from about 40 to 60 F, the low temperatures during January and the high during July (Chapman et al. 1961). Air temperatures range annually from about 15 to 100 F. Both freezing weather and light snowfall occurred over short periods during the 1962–63 winter.

The topography is typical of the Coast Range, with steep-sided canyons and a dense cover of vegetation. The overstory is primarily merchantable Douglas fir (*Pseudotsuga menziesii*) and red alder (*Alnus rubra*), the latter most abundant near the streams.

The watersheds for Deer Creek, Flynn Creek, and Needle Branch are 759, 563, and 217 acres in area respectively. Stream-flow weirs, water temperature recorders, and rain gauges had been installed on the three streams. The mean discharges in cubic feet per second (cfs) were 6.48, 4.46, and 1.49 for Deer Creek, Flynn Creek, and Needle Branch respectively for the period from September, 1958, to October, 1962 (United States Geological Survey records, unpublished). The peak discharges in cfs were 114, 78, and 33 and minimum discharges were .3, .1, and near zero.

That portion of each stream used for population estimates was designated as the study area (Table 1) and extended upstream from the fish traps. Markers erected at 100-ft intervals for past studies were used to delineate the study area even though some changes in streambed had altered the distances slightly. Tributaries in Deer Creek were designated by the distance above the stream-gauging weir and the direction of entry. A more complete description of the study area is available in Chapman et al. (1961), Chapman (1962), and Chapman (1965).

Table 1. Physical dimensions of the three study areas in summer (adapted from Chapman 1961).

	DEER CREEK	FLYNN CREEK	NEEDLE BRANCH
Total length (m)	2,324	1,433	966
Mean width (m)	1.80	1.74	1.10
Mean depth (cm)	11	13	7
Total surface area* ( $\text{m}^2$ )	4,192	2,480	1,060
Pool area ( $\text{m}^2$ )	2,599	1,512	684
Riffle area ( $\text{m}^2$ )	1,593	968	376
Percentage pool	62.0	61.0	64.5

\* Winter (high water) surface area about double (Chapman et al. 1961).

Fishes present included coastal cutthroat trout, coho salmon, steelhead trout (*Salmo gairdneri*), and the reticulate sculpin (*Cottus perplexus*). No angling was allowed in the three study streams.

### METHODS

#### Population Estimates

Seven estimates of the size of trout populations were made in each of the three study streams between July 1, 1962, and June 30, 1963 (hereafter referred to as the production year). An additional estimate was made in September, 1963, in Deer Creek as a check on the procedure of estimation. In June, 1963, estimates were made of the population size of young-of-the-year trout in several Deer Creek tributaries.

An electric shocker was used to capture trout for marking and recapture. The shocker was of the backpack type with pulsating direct current rated at 440 volts and 80 milliamps (Lowry 1964). Recoveries of marked trout were also made at the fish traps from February to June, 1963.

A "point census" mark and recapture scheme of sampling was used (Ricker 1958: 82). Trout were marked at the first sampling date, marked and recovered at intervening dates, and recovered only at the last sampling date. Individual fish were marked

<sup>1</sup> Present address: U.S. Soil Conservation Service, Ladysmith, Wisconsin.

no more than once. Fish were marked by the removal of selected fins and by numbered plastic tags placed subcutaneously (Butler 1957). Excessive tag loss made the plastic tags unsuitable for population estimates.

In a study of tag loss among hatchery cutthroat trout at the Alsea Fish Hatchery, rates of tag loss varied directly with time and inversely with fish size, reaching 64 percent among 125-mm trout after 95 days.

Estimates of the trout populations were calculated by use of the expression given by Ricker (1958:84):

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

where

$\hat{N}$  = estimate of population size,

$M$  = number of fish marked,

$C$  = number of fish examined for marks, and

$R$  = number of marked fish recaptured.

Binomial graphs (Adams 1951:14) were used to attach 95 percent confidence limits to the point estimates where recovery ratios ( $R/C$ ) exceeded 0.10, and Poisson tables (Chapman 1948:76) were used with recovery ratios less than 0.10.

The principal difficulties encountered in obtaining reliable estimates of population size were size selectivity of the electric shocker, growth of trout during the period that marks were recovered, and recruitment from small tributaries.

The effect of the size selectivity of the electric shocker was minimized by making separate estimates for each age group (Ricker 1958:97). The 1959 year class and all older trout were combined into one category called 1959+ for all analyses. In some cases, estimates could not be made for 1962 and 1959+ year classes because of insufficient sample sizes.

The sample of marked and unmarked fish at each recovery period was separated into age groups by length-frequency analysis. Data on marked and unmarked fish in the sample were accumulated for several subsequent sampling periods and population estimates were made by age groups. This procedure solved the problem of growth during the period of mark recovery and restricted the problem of recruitment to age groups (Ricker 1958:86).

Recruitment from small tributaries of the study areas occurred during the production-year and an attempt was made to limit its effect on the population estimates. Recoveries of marked fish of the 1962 year class were accumulated only for the three sampling dates following marking instead of throughout the sampling period. Some upward bias was still expected from that procedure and estimates of age groups showing much recruitment could not be considered completely satisfactory. Fortunately, most of the recruitment was among the youngest age group. Other solutions to the growth and recruitment problems (Ricker 1958:87) probably would not provide superior results in view of the sampling problems.

Trout passing downstream through the fish traps were also examined for marks, and these data were added to those obtained with the electric shocker when calculating the point estimates of population size (except for the 1962 year class). The ratios of marked trout to total catch from trap-data were slightly lower on the average than the same ratios obtained by electrofishing. This indicated that a portion of the migrants came from sections of the stream above the regular study area or that the recovery ratios from electrofishing were higher than the proportion of marked fish in the population, or both. The latter possibility seemed most likely; thus the com-

binning of trap-data and electrofishing data had the advantage that their respective biases probably tended to cancel each other.

### Growth

Fork lengths were measured to the nearest millimeter on a portable measuring board. Trout were weighed on a triple beam balance to the nearest gram during July, August, and September of 1962 in the study areas and during January, February, and March of 1963 at the fish traps. A total of 519 weight measurements were taken, of which 99 were at the traps.

I obtained estimates of growth by calculating the mean length of a sample of each age group at each sampling date. Age groups of trout in the sample were separated by a visual inspection of peaks and troughs in a graph of length-frequency. Some overlap existed between nearly all age groups and the separations must be regarded as slightly arbitrary; thus no confidence limits were attached to estimates of mean length. Although such separations were somewhat artificial, I felt that they yielded valid estimates of mean length of age groups. The frequent sampling dates and 5-mm grouping intervals allowed a high level of continuity and discrimination in observing the relative position of the central group of trout in an age group on the length-frequency graphs.

Additional persuasive evidence of validity of the age groupings was provided by an analysis of scales of downstream migrants captured in the fish traps at the lower ends of the study sections (Lowry 1965). The mean lengths of fish of each age group determined by the scale analyses were very similar to those resulting from length-frequency analyses reported in this study. A part of the overlap in size range shown by the scale analyses was an artifact of combining samples taken over a 4-month period when growth was occurring, and of

using a larger size-interval for groupings. Nonetheless, the comparison did crudely substantiate the correctness of the length-frequency determination. Scale samples taken in the summer within the study area also confirmed the length-frequency determinations but were numerically inadequate to use to separate year classes and were not taken at most sampling times.

Estimates of mean lengths of each year class were undoubtedly biased upward from the size selectivity of the electrofishing gear. I assumed that the upward bias stayed relatively constant as the trout of an age group grew larger. Relative change in mean length between sampling dates was therefore assumed to be representative of the average growth for the period. Growth rates obtained this way may be either too low or too high if a selective mortality for faster or slower growing fish is operating (Ricker 1958:187). The additional assumption was made that emerging trout fry averaged 25 mm in length (Summer 1962: 82).

Growth in length was converted to weight units with weight prediction equations developed from length-weight data by means of the following relationship (Rounsefell and Everhart 1953:320):

$$\log W = \log c - n \log L,$$

where

$W$  = weight,

$L$  = length, and

$c$  and  $n$  = constants.

I calculated instantaneous rates of growth for each month by converting mean weights to natural logarithms and employing the formula (McFadden 1961:11):

$$g = \log_e W_t - \log_e W_0,$$

where

$g$  = instantaneous rate of growth,

$W_t$  = weight at the end of time  $t$ , and

$W_0$  = initial weight.

I calculated daily instantaneous rates of growth by dividing the monthly values by the number of days in the month.

The growth of trout of the 1963 year class in tributary 6200 West of Deer Creek was estimated from shortly after emergence until November 1 by estimates of mean size of trout captured with the fish shocker. In all calculations, emergence of fry was assumed to occur on April 1, but it may have occurred over a broad period before and after that date.

Subcutaneously tagged trout were checked for growth at later recaptures, but as only small samples were available because of excessive tag loss, the results were inconclusive.

Table 2. Estimates of cutthroat trout population in Deer Creek, Flynn Creek, and Needle Branch, with 95 percent lower and upper confidence limits given in parentheses.

DATE	YEAR CLASS				
	1963	1962	1961	1960	1959+
<i>Deer Creek</i>					
July 1, 1962			271 (211-346)	200 (169-245)	39 (30-52)
Aug. 7, 1962		No estimate	363 (290-447)	250 (194-350)	62 (36-125)
Sept. 12, 1962		147 (37-260)	485 (350-630)	334 (222-571)	67 (33-200)
Nov. 9, 1962		428 (65-2,420)	683 (341-1,195)	164 (110-288)	No estimate
Feb. 10, 1963		348 (94-1,010)	281 (149-472)	149 (58-323)	No estimate
April 20, 1963		316 (71-1,180)	428 (94-1,570)	73 (23-185)	8 (2-50)
June 12, 1963	182 (27-984)	380 (304-475)	124 (100-178)	60 (41-100)	12 (6-57)
Sept. 3, 1963	404 (303-571)	300 (225-428)	83 (58-131)	34 (19-87)	No estimate
<i>Flynn Creek</i>					
July 10, 1962			384 (300-493)	108 (87-153)	45 (33-67)
Aug. 9, 1962		No estimate	323 (247-420)	157 (114-220)	67 (32-160)
Sept. 11, 1962		100 (22-374)	415 (346-519)	154 (95-250)	59 (30-200)
Nov. 3, 1962		444 (69-2,555)	322 (196-594)	136 (75-300)	No estimate
Jan. 25, 1963		212 (71-570)	293 (170-464)	42 (11-121)	No estimate
April 13, 1963		492 (230-925)	226 (95-415)	37 (5-204)	No estimate
June 11, 1963	57 (7-1,050)	355 (220-645)	121 (54-766)	21 (10-88)	No estimate
<i>Needle Branch</i>					
July 13, 1962		18 (6-200)	107 (73-160)	64 (49-91)	17 (11-29)
Aug. 8, 1962		No estimate	93 (64-140)	43 (29-71)	25 (4-141)
Sept. 10, 1962		No estimate	108 (72-186)	40 (24-73)	11 (2-62)
Oct. 27, 1962		125 (18-685)	92 (40-178)	35 (7-128)	9 (3-100)
Jan. 18, 1963		111 (24-407)	92 (38-187)	25 (14-60)	No estimate
April 6, 1963		333 (118-765)	No estimate	No estimate	No estimate
June 10, 1963	63 (36-173)	250 (171-406)	34 (18-150)	11 (7-35)	No estimate

**Production**

Production was calculated as the product of the average biomass of each age group and the instantaneous rate of growth for each month (Ricker 1958:32). This computing method estimates "the total quantity elaborated during a stated period of time, regardless of whether or not all of it survives to the end of that time" (Ricker and Foerster 1948:175).

Average biomass was calculated as the arithmetic mean of the estimated biomasses at the beginning and end of each month (Ricker 1958:209). The biomass at the first of each month was calculated as the product of the population size and the mean weight of each age group (from curves

drawn to the seven estimates). Conversions of length to weight to natural logarithm of weight were made with a computer.

**Food**

At each 2-week interval from February 9 to June 12, 1963, about 20 trout were collected by electrofishing in Deer Creek, and a sample of stomach contents was taken from each trout with alligator ear forceps (Wales 1962). This interval was selected to include the period of coho fry emergence. Typically, such sampling was started at about 2,000 ft upstream from the gauging weir and continued upstream until about 20 samples were obtained. The samples of stomach content were preserved in 95 percent ethyl alcohol.

In the laboratory, the food samples were separated into component groups of organisms and the unidentifiable material in the remaining liquid was filtered so that no food particles were lost. The samples were then air-dried to remove alcohol, placed in gelatin capsules and oven-dried for 24 hours at 90 C, and kept in a desiccator until weighed. Final tabulations were made on the basis of percentage occurrence by dry weight.

**RESULTS**

**Population Size**

The relative population size of the same age groups in all three streams varied in a nearly parallel fashion during the course of study (Table 2). Estimates of population size each month for production calculations were obtained from graphs of population size similar to Fig. 1. Increases in population size of certain age groups were apparently the result of immigration of fish from the small tributaries to the area under study. The extremes of the estimates of total population size for the three streams were:

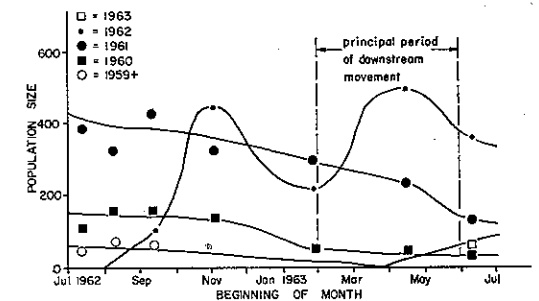


Fig. 1. Population size of trout in Flynn Creek by year class.

**Highest population**

- Deer Creek—1300 (November, 1962)
- Flynn Creek—950 (November, 1962)
- Needle Branch—414 (April, 1963)

**Lowest population**

- Deer Creek—500 (July, 1962)
- Flynn Creek—600 (August, 1962)
- Needle Branch—205 (July, 1962)

Electrofishing in tributaries of the study area in Deer Creek disclosed that young-of-the-year trout were present in several of the tributaries, but that population densities differed greatly from one tributary to another. An estimated 245 (95 percent confidence limits of 124 and 750) trout of the 1963 year class were present in a 100-m section of tributary 6200 West on June 12, 1963. On June 27, 1963, an estimate of 173

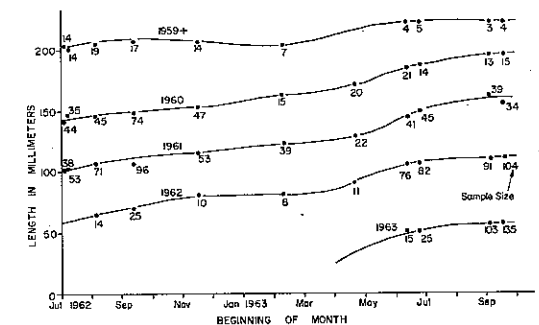


Fig. 2. Growth in length of each year class of trout in Deer Creek.

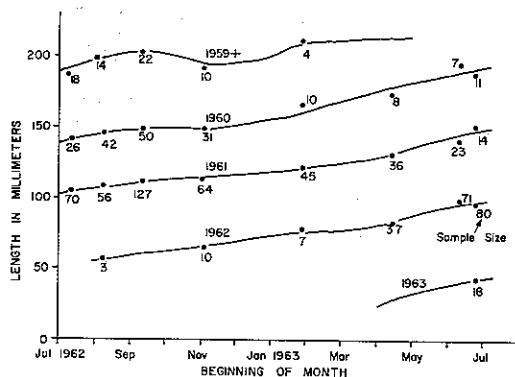


Fig. 3. Growth in length of each year class of trout in Flynn Creek.

(95 percent confidence limits of 82 and 400) young-of-the-year trout was obtained for sections of four small tributaries with a combined total length of about 400 m (tributaries 1500 East, 2300 West, 3500 West, and 6400 East). Three other tributaries had no trout present.

Tributary 6200 West was the largest of the tributaries listed and appeared to have the most dependable summer flow as well as large areas of small gravel. The mean discharge of this tributary was estimated as 0.65 cfs (peak discharge of 8.7 cfs and minimum discharge of near zero) for the period of September, 1958, to October, 1962. This was based on a multiplication of

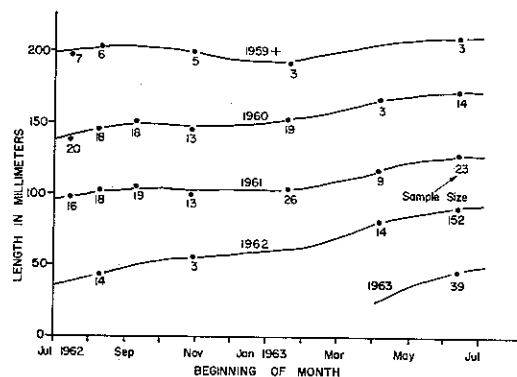


Fig. 4. Growth in length of each year class of trout in Needle Branch.

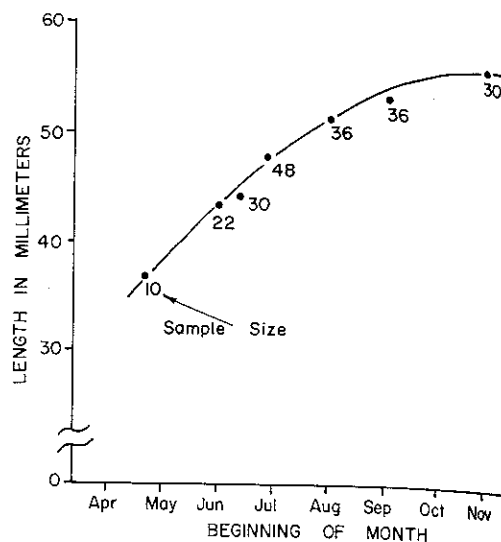


Fig. 5. Growth in length of trout in a Deer Creek tributary during the first 7 months of life.

the ratio of the area of the tributary watershed to the area of the total Deer Creek watershed by the discharge at the Deer Creek gauging weir.

### Growth

The data suggested a continuous growth in length throughout the study period for

Table 3. Production of cutthroat trout (all age groups combined) for the study areas of the three streams.

MONTH	PRODUCTION (g/m <sup>2</sup> )		
	Deer Creek	Flynn Creek	Needle Branch
July, 1962	0.24	0.61	0.45
August	0.27	0.46	0.22
September	0.35	0.25	0.05
October	0.35	0.18	0.07
November	0.25	0.24	0.03
December	0.29	0.30	0.09
January, 1963	0.23	0.39	0.15
February	0.20	0.33	0.38
March	0.19	0.42	0.78
April	0.50	0.62	0.60
May	0.63	0.66	0.39
June	0.49	0.46	0.27
Total for year (g/m <sup>2</sup> )	4.0	4.9	3.5

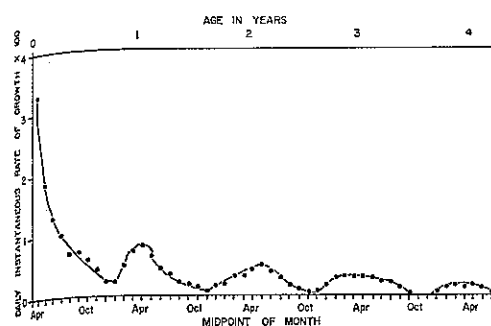


Fig. 6. Instantaneous rate of growth of a composite year class of trout (data from all three streams combined and smoothed for months).

some age groups of trout in all streams (Figs. 2, 3, and 4). However, the limited amount of data during November, December, and January prevented a conclusion that this actually did occur. Negative growth in length for the 1959+ year class was suggested on all three streams during November and December. This was thought to be the result of the selective emigration of larger members of this age group to spawning areas in the small tributaries outside of the study sections. The seasonal pattern of trout growth and the mean size of age groups during the production year were similar in the three study areas. Growth in length of young-of-the-year trout in tributary 6200 West of Deer Creek was similar to growth within the regular study areas during the period of observation (Fig. 5).

Using 519 observations of length and weight (420 from within the study section in summer and 99 at the traps in winter), analysis of variance (Williams 1959) indicated that at the 0.01 level, no significant differences existed in the length-weight relationships of trout between streams within seasons. Significant differences were present, however, between seasons within streams.

Separate weight-prediction equations de-

veloped for trout in summer and winter were:

$$\text{Summer—log}_{10} \text{ weight (g)} = -4.85940 + 2.94833 [\text{log}_{10} \text{ length (mm)}]$$

$$\text{Winter—log}_{10} \text{ weight (g)} = -4.63032 + 2.82703 [\text{log}_{10} \text{ length (mm)}]$$

The prediction equation for summer weight was used for all calculations of production because I did not know whether the difference in winter was due to seasonal loss of condition or was associated with seaward migration.

Assuming that the growth of each age group during the year of study was representative of growth during other years, I constructed a composite graph of daily instantaneous rates of growth for the trout in all three streams combined (Fig. 6). This graph was constructed by drawing smooth curves to the estimates of mean size and interpolating growth rates for each month. Growth rates were highest near early April and lowest near early December for all streams. Caution should be used in the interpretation of the graph since seasonal loss of weight was not taken into account (that is, the summer weight-prediction equation was used in all calculations of monthly instantaneous rates of growth). As a result, growth rates for winter periods were probably underestimated. The growth rates probably fell to zero the first winter and below in succeeding winters.

### Production

Total annual production was estimated as 16.7, 12.2, and 3.69 kg, or 4.0, 4.9, and 3.5 g/m<sup>2</sup> in the study areas of Deer Creek, Flynn Creek, and Needle Branch respectively. Production per month was lowest in late fall in Flynn Creek and Needle Branch, but lowest in March for Deer Creek (Table 3). The difference for Deer Creek was a mathematical result of the estimated heavy recruitment of trout from the tributaries

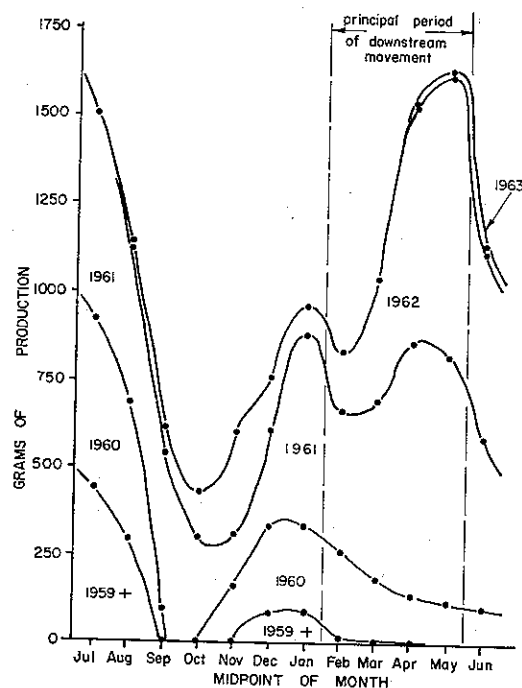


Fig. 7. Monthly production in Flynn Creek by year class from July, 1962, through June, 1963.

during August, September, and October and the estimated low growth rates until the populations reached lower levels in April. Some of the variation may have been the result of sampling errors in the basic statistics used to calculate production. The mean annual biomass of trout in  $\text{g}/\text{m}^2$  was 4.6, 4.8, and 3.3 for Deer Creek, Flynn Creek, and Needle Branch, respectively.

Production in the Flynn Creek study area decreased until October and then increased to the seasonal peak in April and May (Fig. 7). A minor trough in the production curve occurred in January and February. This may have been the result of little growth by the 1961 year class and decreases in the population size of the 1959+ year class. Little production was achieved in the study area by trout of the 1963 year class because

they were present in such low numbers. Flynn Creek was selected for this example since it seemed most representative of the changes occurring in all three streams and also because data for Flynn Creek were used for the example of obtaining monthly population data.

The mathematical result of production calculations for the 1959+ group was negative for some months. While negative values of production are possible (that is, trout may utilize their own tissue to meet maintenance requirements), the negative production values I obtained were probably a consequence of the method of estimating rates of growth. Therefore, zero was used as a best estimate of production during those months.

#### Food

Aquatic arthropods were the most important food of trout from mid-February to mid-June (Table 4). Earthworms diminished in importance and terrestrial arthropods increased in importance during this period. In a further classification of the food samples, Diptera, Trichoptera, and Plecoptera were the three most important insect orders.

Juvenile salmonids were found in stomachs of trout. The importance of juvenile salmonids and other large food animals may have been exaggerated because their estimated utilization was based on only a few occurrences. During the time coho fry were emerging, as well as later, we captured large (150–250 mm) trout near and even right among these fry. Even when the belly of a trout was distended with food, we rarely found juvenile salmonids in the stomach. However, in the unnatural situation in the downstream trap, 92 percent by weight of the stomach contents of 12 cutthroat trout consisted of coho fry. A total of 18 coho fry were removed from one

Table 4. Percentage occurrence by dry weight of food items removed from the stomachs of trout from Deer Creek in 1963.

FOOD MATERIAL	SAMPLING DATES										ALL SAMPLES COMBINED
	9 Feb	23 Feb	9 Mar	23 Mar	6 Apr	20 Apr	4 May	18 May	1 Jun	12 Jun	
Aquatic arthropods (except crayfish)	11.4	44.0	34.8	4.4	31.1	69.9	19.0	24.4	17.3	14.1	19.6
Frogs	—	—	—	58.8	—	—	—	—	—	—	16.6
Earthworms	20.4	42.5	37.6	—	28.9	0.3	40.2	—	—	—	15.6
Juvenile salmonids	—	—	—	33.1	—	—	2.8	—	0.1	—	9.7
Fish remains	—	0.9	—	—	25.1	9.0	—	17.3	—	58.3	7.6
Sculpins	—	—	—	—	—	—	27.1	—	28.7	—	7.5
Unidentifiable material	11.8	10.3	6.4	2.5	10.7	16.5	8.8	6.4	5.3	7.8	6.8
Crayfish	—	—	—	—	—	—	—	19.6	46.2	—	6.6
Terrestrial arthropods	0.2	trace	1.0	0.3	4.3	4.4	1.6	32.2	2.1	19.9	3.7
Salmonid eggs	56.2	2.3	—	—	—	—	—	—	—	—	3.7
Salamanders	—	—	20.3	—	—	—	—	—	—	—	2.3
Sculpin eggs	—	—	—	1.0	—	—	—	—	0.4	—	0.3
Total sample weight (mg)	601	429	1,093	2,673	793	303	1,321	281	1,226	759	9,477
Number of fish in the sample	7	20	20	21	19	19	20	6	19	20	171
Mean size of fish in the sample (mm)	147	148	157	152	129	146	146	136	164	156	149

gorged 140-mm smolt in the Deer Creek trap.

#### DISCUSSION

Good agreement was found among annual biomass levels in the three streams (46, 48, and 33 kilograms per hectare ( $\text{kg}/\text{ha}$ ) for Deer Creek, Flynn Creek, and Needle Branch, respectively). Deer and Flynn Creeks had the higher biomass levels and the greater mean depths. The pools in Needle Branch were relatively shallow and lacked the deeply undercut banks common in Deer and Flynn Creeks. From observations made while electrofishing the three streams, I concluded that the trout were more dependent on cover and pools for living space than were the juvenile coho. The largest trout were nearly always found in pools with greater than average depth and deeply undercut banks. This suggests that stream improvement consisting of the creation of deep pools and suitable cover might increase the carrying capacity of comparable streams for larger trout.

The data of my study can be usefully compared in some ways with two other studies, despite some important environmental differences. McFadden (1961:15) reported biomass levels of brook trout in Wisconsin that varied from 37 to 106  $\text{kg}/\text{ha}$  during a 4-year period. In New Zealand, Allen (1951:166–167) estimated the mean annual biomass of brown trout to be 265  $\text{kg}/\text{ha}$  over a 1-year period.

By combining my data on trout with those of Chapman (1965:48) on coho, it can be seen that about 78  $\text{kg}/\text{ha}$  of salmonid biomass were probably present in the three streams during the study period. Some steelhead trout were present in Deer Creek and are not included in that figure. Cottids and lampreys were also present. Viewed from the standpoint of biomass levels of cutthroat trout, the study streams appeared to be "sparsely populated," but from the standpoint of total salmonid biomass or total fish biomass, this was not the case.

The rate of growth of successive year classes of fish can probably be modified by

differences in their biomass level (Ricker 1958:186) and both entities seem susceptible to modification in response to changes in the environment of the population (Allen 1951:214). Only minor differences were evident in the growth of similar age groups of trout in the three streams. Differences in the maximal length reached by trout before leaving the streams were obvious. Deer Creek and Flynn Creek had "resident" trout up to 275 mm in length, while no resident trout in Needle Branch exceeded 225 mm.

The periodicity and rate of growth estimated for trout in the three streams agree well with that reported for brook trout in Wisconsin (McFadden 1961:23). The seasonal distribution of growth was nearly identical despite the climatic differences between the two regions. The growth rates for brook trout were higher than those I found for cutthroat trout during the growing season. Allen (1951:119) found growth rates for brown trout in New Zealand that were higher than growth rates during the first 9 months in my three study streams. Thereafter, Allen's data showed no seasonal fluctuations, indicating growth at the same rate in winter and summer.

In the study areas, immigration and emigration caused differences in biomass levels among age groups that would not be characteristic of a complete population. The number of trout in a year class ordinarily decreases after fry emergence, whereas immigration caused my populations to increase in some cases. The estimate of production generated from this trout population must be interpreted with that in mind. Also, since mortality and recruitment of trout occurred simultaneously throughout much of the study period, the magnitude of mortality and recruitment rates could not be assessed separately.

Production of trout per unit area was greatest in Flynn Creek and next greatest in

Deer Creek. Since biomass levels and growth rates of trout in the two streams were crudely similar, I thought that differences in the age distributions of trout caused most of the differences in production. The Flynn Creek study area had a greater proportion of younger trout and their greater rate of growth caused more production for a given level of biomass. The age distribution of trout in Needle Branch was similar to that in Flynn Creek, so production differences were primarily the direct result of differences in biomass.

The estimated 35-50 kg/ha production of trout in the three streams is much lower than the 544 kg/ha reported by Allen (1951:174) for a fished population of brown trout and lower than the 198 kg/ha I calculated from data reported by McFadden (1961:38) for a hypothetical unfished population of brook trout. The latter two studies were concerned with nonmigratory salmonid stocks in temperate streams. Chapman (1965:47) reported about 90 kg/ha of coho salmon production and some steelhead trout production in Deer Creek over a 4-year period. The reticulate sculpin was present in all three streams and also constituted

Table 5. A comparison of the production of composite year classes of trout expressed as percentage per growth year for five different streams.

STREAM	GROWTH YEAR*					TOTAL PRODUCTION OF COMPOSITE YEAR CLASS (g/m <sup>2</sup> )
	1	2	3	4	5	
Deer Creek	5.4	34.6	37.3	20.7	1.9	4.0
Flynn Creek	4.5	38.3	38.9	16.6	1.7	4.9
Needle Branch	5.1	50.6	29.4	13.2	1.7	3.5
Lawrence Creek†	45.6	40.1	14.3	-	-	19.8
Horokiwi Stream‡	54.6	34.7	7.9	2.8	-	54.4

\* June 1 to June 1 for Horokiwi Stream and December 1 to December 1 for the other four streams.

† Calculated from biomass and instantaneous rates of growth reported by McFadden (1961:38).

‡ Calculated from the data of Allen (1951:174).

an unmeasured source of fish production. Therefore, total production of salmonids in Deer and Flynn Creeks and Needle Branch was about 130 kg/ha and total fish production slightly greater.

To facilitate reasonable comparisons of my production data with data from New Zealand and Wisconsin, I separated total production into production occurring during each growth year (Table 5). A growth year was defined as that part of the life of an age group between successive troughs of the curve of instantaneous growth rate. Data of the single production year for the several year classes were assumed to be representative of production during the life of a typical year class for this purpose.

Since 85 to 90 percent of the total production of both Horokiwi Stream and Lawrence Creek occurred in growth periods one and two, and since only about 50 percent of the production in my three study areas occurred in the same periods, I concluded that I missed a substantial amount of production of young trout in the small tributaries above the study sections. The comparison depends on an assumption that the distribution of mortality throughout life was similar in the compared populations. The value of the estimate is diminished because trout in Horokiwi Stream and Lawrence Creek were not migratory.

Production can be compared to initial biomass and the resulting statistic has some value as an index of the efficiency of production. Since emigration and immigration obscure the usefulness of any such comparisons in Deer Creek, Flynn Creek, and Needle Branch, a comparison was made on the basis of the mean annual biomass of all age groups. The result of these calculations may also be thought of as the annual instantaneous rate of growth of all age groups combined. Much higher efficiencies were achieved by the trout in Horokiwi Stream

Table 6. Ratios of trout production to mean annual biomass.\*

FISH	STREAM	RATIO
Cutthroat trout	Deer Creek	0.87
Cutthroat trout	Flynn Creek	1.02
Cutthroat trout	Needle Branch	1.04
Brook trout†	Lawrence Creek	1.66
Brown trout‡	Horokiwi Stream	2.08

\* Data for all year classes combined.

† Calculated from biomass and instantaneous rates of growth reported by McFadden (1961:38).

‡ From the data of Allen (1951:165, 174).

and Lawrence Creek than in the study streams (Table 6). This was partly so because most of the production (85 to 90 percent) occurred during the first 2 years of life in the former two situations and in my data portions of this period were missed. It also seems possible that the crudely similar communities and species of trout might have had inherently different efficiencies of production. Also, Davis and Warren (1965:859) found that efficiencies of production for sculpins in laboratory streams were partly a function of the biomass of sculpins.

Production at any trophic level is limited by the flow of energy through the food web, and information on food habits is especially interesting in relation to estimates of production. Terrestrial arthropods appeared to be relatively unimportant to trout during the February to June period that food habits were examined. The pool-dwelling and cover-seeking behavior of cutthroat trout may mean that they have fewer opportunities to obtain food from the surface than do juvenile coho.

In the same study stream, Demory (1961) found that food having an aquatic origin made up 56 percent (by dry weight) of the coho diet during a 1-year period. Diptera comprised 24 percent, Ephemeroptera 14 percent, Coleoptera 10 percent, and Trichoptera 6 percent of the coho diet. Al-

though the same categories of food were utilized by cutthroat trout less frequently, aquatic arthropods were still the most important food. Diptera was the most important order of insects and both Coleoptera and Ephemeroptera were prominent in the trout diet. Since trout and coho fed on the same orders of insects, some competition for food may have existed.

The array of food items I found in trout stomachs is similar to that reported by Dimick and Mote (1934) for cutthroat trout from throughout Oregon. They found about 74 percent aquatic insects (numerically), 17 percent terrestrial insects, and 3 percent crustaceans in the stomachs of 326 cutthroat trout from various lakes and streams in Oregon. They found 81 juvenile coho, only two of which were from stomachs of trout less than 255 mm in length.

The results of the food study suggest that the cutthroat trout was not an important consumer of coho in Deer Creek. However, there are several reasons why this conclusion may be faulty. Systematic food samples taken every 2 weeks may have missed periods when trout ate fry. Sampling was not concentrated near coho redds at the time fry emerged. Consumption might have been greatest there. Diel variations in food utilization were not examined.

#### LITERATURE CITED

- ADAMS, L. 1951. Confidence limits for the Petersen or Lincoln Index used in animal population studies. *J. Wildl. Mgmt.* 15(1):13-19.
- ALLEN, K. R. 1951. The Horokiwi stream: a study of a trout population. New Zealand Marine Dept. Fisheries Bull. 10. 238pp.
- BUTLER, R. L. 1957. The development of a vinyl plastic subcutaneous tag for trout. *California Fish and Game* 43(3):201-212.
- CHAPMAN, D. G. 1948. A mathematical study of confidence limits of salmon populations calculated from sample tag ratios. *Internatl. Pacific Salmon Fisheries Comm. Bull.* 2:67-85.
- CHAPMAN, D. W. 1961. Factors determining production of coho salmon, *Oncorhynchus kisutch*, in three Oregon streams. Ph.D. Thesis. Oregon State Univ., Corvallis. 214pp.
- . 1962. Aggressive behavior in juvenile coho salmon as a cause of emigration. *J. Fisheries Research Board Canada* 19(6):1047-1080.
- . 1965. Net production of juvenile coho salmon in three Oregon streams. *Trans. Am. Fisheries Soc.* 94(1):40-52.
- , J. F. CORLISS, R. W. PHILLIPS, AND R. L. DEMORY. 1961. Summary report. Alsea watershed study. Oregon Agr. Expt. Sta. Misc. Paper 110. 52pp.
- COPE, O. B. 1958. Annotated bibliography on the cutthroat trout. *Fishery Bull. Fish and Wildl. Serv.* 58(140):417-442.
- CRAMER, F. K. 1940. Notes on the natural spawning of cutthroat trout (*Salmo clarkii clarkii*) in Oregon. Vol. 3 (Oceanography and marine biology). *Proc. Pacific Sci. Congr.* 6:335-339.
- DAVIS, C. E., AND C. E. WARREN. 1965. Trophic relations of a sculpin in laboratory stream communities. *J. Wildl. Mgmt.* 29(4):846-871.
- DEMORY, R. L. 1961. Foods of juvenile coho salmon and two insect groups important in the coho diet in three tributaries of the Alsea River, Oregon. M.S. Thesis. Oregon State Univ., Corvallis. 68pp.
- DEWITT, J. W., JR. 1954. A survey of the coast cutthroat trout, *Salmo clarki clarki* Richardson, in California. *California Fish and Game* 40(3):329-335.
- DIMICK, R. E., AND D. C. MOTE. 1934. A preliminary survey of the food of Oregon trout. Oregon State Coll. Agr. Expt. Sta. Bull. 323. 23pp.
- , AND F. MERRYFIELD. 1945. The fishes of the Willamette River system in relation to pollution. Oregon State Coll. Eng. Expt. Sta. Bull. 20. 58pp.
- GERKING, S. D. 1962. Production and food utilization in a population of bluegill sunfish. *Ecol. Monogr.* 32(1):31-78.
- LOWRY, G. R. 1964. Some ways of increasing the utility of a backpack fish shocker. *Progr. Fish-Culturist* 26(3):127-130.
- . 1965. Movement of cutthroat trout, *Salmo clarki clarki* (Richardson) in three Oregon coastal streams. *Trans. Am. Fisheries Soc.* 94(4):334-338.
- MCFADDEN, J. T. 1961. A population study of the brook trout, *Salvelinus fontinalis*. *Wildl. Monogr.* 7. 73pp.
- RICKER, W. E. 1958. Handbook of computations for biological statistics of fish populations. Fisheries Research Board Canada Bull. 119. 300pp.

- , AND R. E. FOERSTER. 1948. Computation of fish production. *Bull. Bingham Oceanogr. Collection* 11(4):173-211.
- ROUNSEFELL, G. A., AND W. H. EVERHART. 1953. *Fishery science, its methods and applications.* John Wiley & Sons, Inc., New York. 444pp.
- SUMNER, F. H. 1962. Migration and growth of the coastal cutthroat trout in Tillamook

- County, Oregon. *Trans. Am. Fisheries Soc.* 91(1):77-83.
- WALES, J. H. 1962. Forceps for the removal of trout stomach content. *Progr. Fish-Culturist* 24(4):171.
- WILLIAMS, E. J. 1959. *Regression analysis.* John Wiley & Sons, Inc., New York. 214pp.
- Received for publication April 26, 1965.

#### AERIAL CENSUS OF MOOSE BY QUADRAT SAMPLING UNITS

CHARLES D. EVANS, Branch of River Basin Studies, U. S. Bureau of Commercial Fisheries, Anchorage, Alaska  
 WILLARD A. TROYER, Branch of Wildlife Refuges, U. S. Bureau of Sport Fisheries and Wildlife, Kenai, Alaska  
 CALVIN J. LENSINK, Branch of Wildlife Refuges, U. S. Bureau of Sport Fisheries and Wildlife, Bethel, Alaska

**Abstract:** A quadrat sampling method for conducting aerial census of moose (*Alces americana*) that is adapted to extensive units of habitat was developed and applied in two areas of Alaska. This report describes briefly the steps that were used in developing and applying the quadrat method. The areas were stratified into units of high, medium, and low moose density based on current observations. A sample of quadrats 1 square mile in area was drawn from each unit and a detailed census from the air was made on each sample quadrat. Both applications of this method provided usable data at reasonable cost. Results of these censuses were compared with results obtained by other methods in the same localities. With the quadrat method as a standard, results indicated that about half the animals were seen in an attempt at total area census and about one-fourth were seen when a continuous linear strip transect ½ mile in width was covered.

Techniques for taking wildlife censuses by aerial survey have included attempts to attain complete coverage by spotting all game in a unit of habitat (Buechner et al. 1951, Grzimek and Grzimek 1960) as well as various methods of sampling, usually based on linear strip transects. Sampling methods often were designed so that sampling errors could be evaluated. Watson and Scott (1956) and Bergerud (1963) described the use of such methods for estimating numbers of caribou (*Rangifer tarandus*). Crissey (1957) described similar methods applied to the entire breeding waterfowl population of North America. These methods all require that visibility bias, or errors affecting the percentage of the animals seen by observers, either be ignored or be evaluated separately. C. J. Lensink was able to evaluate visibility bias with considerable accuracy in aerial counts

of breeding waterfowl (1962. Waterfowl populations and production within the impoundment area of the proposed dam at Rampart on the Yukon River, Alaska. Unpubl. prog. rept., U. S. Bur. Sport Fisheries and Wildlife, Laurel, Maryland. 65 pp.). His air crew made repeated counts on randomly distributed sample plots and results from these runs were compared later with careful ground counts in order to derive correction factors that were applied to the aerial data.

Siniff and Skoog (1964) applied a new approach to aerial census of big game in a count of caribou conducted on 22,000 square miles of the Nelchina area in Alaska. Their method was based on sample plots 4 square miles in area on which observers attempted to count all animals. This method has several advantages: the small sample plots reduced error resulting from observers' in-