AN ABSTRACT OF THE THESIS OF

CLAIR MILTON KUNKEL for the degree of MASTER OF SCIENCE

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Title: BIOLOGY AND PRODUCTION OF THE RED-BAND TROUT (*Salmo* sp.) IN FOUR SOUTHEASTERN OREGON STREAMS

Abstract approved: Dr. John McIntyre

The red-band trout is native to many small, isolated streams in southeastern Oregon. A study of the red-band population of Threemile Creek and Reservoir was conducted from August 1973 to June 1975. Data were collected concerning population size, age composition, growth, biomass, recruitment, fecundity, and habitat. During the spring of 1975 similar data were collected for red-band populations in Home, Rattlesnake, and Buck creeks. The average trout biomass in Threemile Creek was 24.2 g/m^2 and average production was 17.2 $g/m^2/yr$. The production rate of 17.2 $g/m^2/yr$ is among the highest reported for salmonids in small streams and is probably in part due to the stable environment afforded by the springs which feed Threemile Creek. Biomass in the other study streams ranged from 2.4 to more than 6.7 g/m^2 and production ranged from 1.2 to more than 4.2 $g/m^2/yr$, not including production of age 0-I fish. Trout biomass in Threemile Reservoir was 84 kg/ha in September 1974, and annual production was 80 kg/ha. The presence of the

reservoir has increased the total production of the Threemile system by at least 12 times. Most female trout in the streams and reservoir matured at age III. Egg production in the Threemile system was considerably greater than in the other study streams. Spawners from the reservoir contributed nearly five times as many eggs to Threemile Creek as did the stream-dwelling females during the spring of 1974. The egg contribution of reservoir fish was probably greater than that required to perpetuate the observed trout densities in the stream. However, the resulting high density of fry may insure adequate contribution of young trout to the reservoir. Reservoir trout could serve as an egg source for rehabilitation of native trout in southeastern Oregon streams, where desirable. During spring more than 250 reservoir trout averaging 39.8 cm in length migrated into Threemile Creek to spawn, and provided excellent opportunity for anglers. Terminal reservoirs might be considered as management tools for trout populations in small streams, providing larger trout than the stream would normally produce. Such reservoirs could serve as multiple purpose water storage facilities for irrigation, stock watering, and trout production. The status of the trout populations studied was relatively good in stream sections that had not been disturbed by man's activities.

Biology and Production of the Red-band Trout (*Salmo* sp.) in Four Southeastern Oregon Streams

by

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BIOLOGY AND PRODUCTION OF THE RED-BAND TROUT (Salmo sp.) IN FOUR SOUTHEASTERN OREGON STREAMS

INTRODUCTION

Native populations of an unnamed species of Salmo commonly known as red-band trout occur in several streams draining into ancient lake basins in southeastern Oregon. Some information regarding the genetics and distribution of the red-band is available (Wilmot 1974). Relatively little is known of the biology of red-band trout populations or of the physical and chemical characteristics of the streams in which they occur.

The study described in this thesis was initiated to provide information regarding the life history, population dynamics, and habitat of red-band trout populations in several streams, and in an irrigation reservoir terminal to one of the streams. The specific objectives of the study were to:

1. Estimate the population density of red-band trout in the streams and reservoir.
2. Estimate the age composition of the red-band trout populations.
3. Estimate the growth, biomass, and production of each year-class in the populations.
4. Describe certain physical and chemical characteristics of the streams and reservoir.

Streams chosen for the study were: Threemile and Home creeks located south of Frenchglen, Harney County; Rattlesnake Creek located northeast of Burns, Harney County; and Buck Creek located west of Silver Lake, Lake County (Fig. 1). The trout from these streams were shown to have a chromosome number of 2N=58 and identical karyotypes (Wilmot 1974).

The approach taken in this study was to obtain detailed information from Threemile Creek at two-month intervals from August 1973 to June 1975, and to obtain as much information as possible from the other streams during a single visit to each during the spring of 1975.

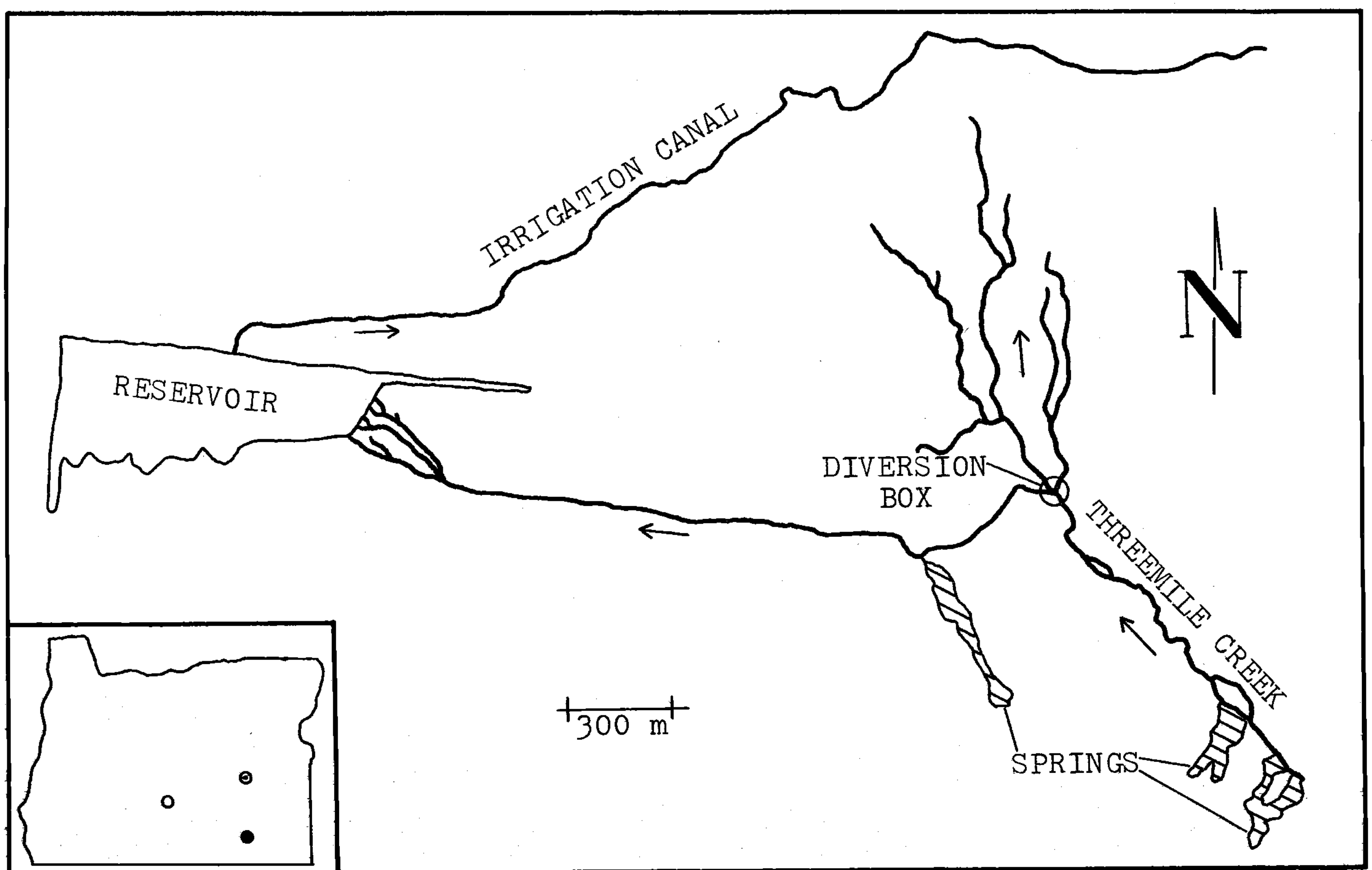

Figure 1. A map of Threemile Creek and Reservoir system; arrows show direction of stream flow. Inset shows location of: Threemile and Home creeks (●); Rattlesnake Creek (⊙); and Buck Creek (○).

DESCRIPTION OF STUDY AREAS

Threemile Creek and Reservoir

Threemile Creek arises from springs in a steep-walled canyon west of Steens Mountain and flows westward into a terminal irrigation reservoir (hereafter referred to as Threemile Reservoir) on the floor of Catlow Valley. The length of the stream from source to reservoir is approximately 3,300 m (Fig. 1). The main trout population exists in 1, 120 m of stream between the source and a concrete irrigation diversion box located in the canyon mouth. The stream above the box is publicly owned (Bureau of Land Management) and below the box flows over land owned by a private ranching company. Most of the main stream below the diversion box has been channelized and is lacking in streamside cover. Channelization, livestock grazing, and dewatering have rendered most of the lower stream unsuitable as trout habitat.

The section of stream above the diversion box affords excellent trout habitat. The stream banks support dense thickets of willow (Salix sp.) and other plants that overhang the water. Few beaver now use the creek, but past activity resulted in much downed wood in the stream and burrows in the banks. Mats of aquatic buttercup (Ranunculus sp.) and algae contribute to available cover in the stream. The stream substrate consists mainly of large boulders and rubble, with suitable spawning gravel evident in places. Caddisfly larvae (Trichoptera), mayfly (Ephemeroptera) and stonefly (Plecoptera) naiads, aquatic beetles (Coleoptera), and snails (Gastropoda), were abundant in the stream during all seasons. A cursory examination of trout stomachs indicated that these organisms were important components of the trout diet.

The spring-fed flow of Threemile Creek was relatively stable throughout the study period. Average flow estimates of 72. 2 l/sec in July 1974 and 75. 6 l/sec in December 1974 were typical except in late spring when melting snow contributed substantially to the volume of flow. Estimated flow in March 1975 during a period of light runoff was 109. 1 l/sec.

Water temperatures measured near the diversion box ranged from 5. 0 to 16. 5° C (Table 1). In the upper stream water temperature was generally as much as 3° C cooler during hot weather and 3° C warmer during cold weather due to the stabilizing influence of the springs. The relatively low levels of alkalinity and total dissolved solids (TDS) and the average pH value of 7. 5 are typical of many western trout streams (Table 1).

Three study sections each 183 m in length were established within the uppermost 1, 120 m of Threemile Creek (Table 2). The upper section extended from the stream source down, the lower section was at the lower extreme of the trout habitat, and the middle

Table 1. Temperature, total alkalinity, TDS, and pH of Threemile Creek.

Date	Temp. (^{o}C)	Total Alkalinity (mg/l $CaCO_3$)	TDS (mg/l)	pH
8/ 3/73	16.5			
8/23/73	11.5			
10/26/73	10.5			
12/15/73	8.0			
4/ 6/74	8.0			
4/26/74	6.0			
6/24/74	13.5			
7/31/74	16.5	39.0	70	--
8/24/74	14.5	38.2	--	7.2
11/ 7/74	8.0	38.8	86	7.4
2/ 6/75	5.0	36.8	89	7.7
3/30/75	7.5	34.0	92	7.5
5/19/75	8.0	33.7	72	7.5

Table 2. Physical characteristics of the study sections on Threemile, Home, Rattlesnake, and Buck creeks. (Slight discrepancies between dimensions and surface area are due to rounding error).

Stream (Section)	Length (m)	Avg. Width (m)	Avg. Max. Depth (cm)	Pool Surf. Area (m^2)	Riffle Surf. Area (m^2)	Total Surf. Area (m^2)
Threemile						
(Upper)	183	2.4	36	206	233	439
(Middle)	183	2.1	38	188	196	384
(Lower)	183	2.5	32	169	288	457
Home	100	5.8	57	205	370	575
Rattlesnake	119	4.2	47	177	317	494
Buck						
(Upper)	38	3.3	48	46	81	127
(Lower)	130	4.6	44	201	398	600

section was approximately midway between. Each study section was stratified into four subsections each approximately 46 m in length. Sampling was conducted in one subsection (or partial subsection) in each main section at bi-monthly intervals from August 1973 to June 1975 (except for April and June, 1974, and May and June, 1975, when the lower, lower and middle, lower and upper, and lower sections only were sampled, respectively).

The only fish species captured in the stream was the red-band trout. The chub Gila bicolor (subspecies) was collected from the stream in 1954 and 1971 (Bond 1975) but in this study the chub was found only in the reservoir.

An earthen dike impounds water from Threemile Creek to form Threemile Reservoir (Fig. 2). Flow from the reservoir to the irrigation system is controlled by means of a large valve located in the dike.

Surface area and depth of the reservoir vary considerably depending upon the relative amount of impoundment at different times of the year. Most of the reservoir averages approximately 0. 5 m deep but a narrow 0. 9-2. 1 m deep trough, formed by the removal of material for the dike, exists along the north and west reservoir perimeter. During summer, 1974, trout were confined to the deeper water because of excessive water temperatures in the shallower areas. Surface area over the deeper water (the area of suitable trout

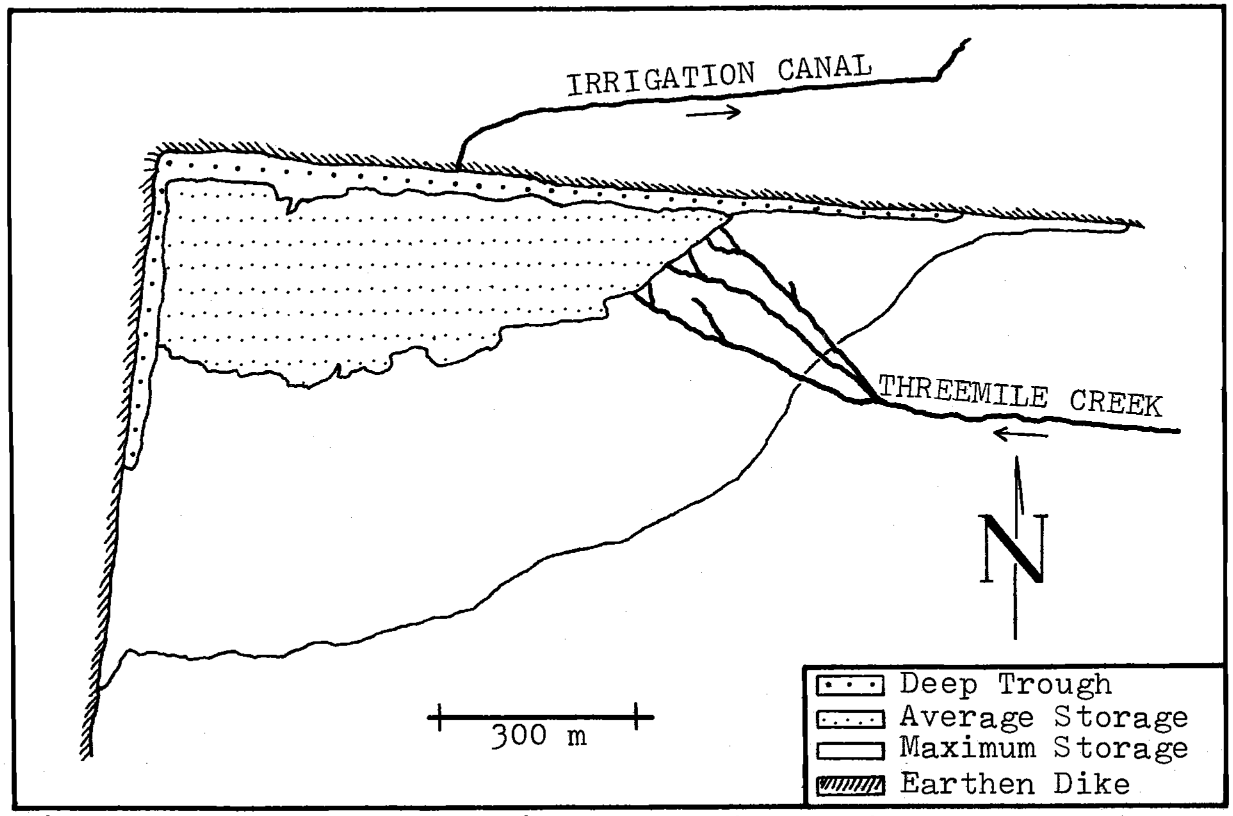

Figure 2. A map of Threemile Reservoir showing the location of the deep trough, and the relative size of the reservoir at average and maximum water storage levels. Arrows show direction of stream flow.

habitat during summer) was estimated from an aerial photograph to be 6. 3 ha.

The reservoir bottom consists of very fine sediment. During the winter of 1974-75 ranch employees reinforced the face of the dike with large boulders, many of which now form part of the substrate near the dike.

Owing to high turbidity, aquatic vegetation was sparse. Clumps of Potamogeton sp. and Ranunculus sp. were observed in the shallow areas only. Depth of visibility was measured at 23 cm with a Secchi disk.

Alkalinity and TDS tended to be somewhat higher in the reservoir than in the stream (Table 3). The average pH value of 7. 5 was similar to that of the stream. During the study period temperature and dissolved oxygen (D. O.) levels (Table 4) remained within the tolerance limits of trout. During the summer, flow from Threemile Creek formed a protective layer of cooler water near the bottom along the dike. It is conceivable however, that during a summer of low water level and little inflow from the creek, temperature and D. O. levels might become unsuitable for trout.

A large population of the chub (Gila bicolor) inhabited the reservoir and provided an important source of food for trout. Aquatic insects, planktonic crustaceans, and leeches were also abundant.

Table 3. Total alkalinity, TDS, and pH in the reservoir.

Date	Total Alkalinity (mg/l $CaCO_3$)	TDS (mg/l)	pH
7/74	64.5	110	7.7
8/74	58.2	--	7.4
9/74	--	160	--
11/74	63.1	190	7.5
12/74	57.6	150	7.8
4/75	54.8	149	7.3

Table 4. Average dissolved oxygen and temperature in Threemile Reservoir. (Range in parentheses).

Date	n	Dissolved oxygen (mg/l)		Temperature (°C)		Time
		Bottom	Surface	Bottom	Surface	
7/74	3	5.3(4.8-5.9)	6.8(6.4-7.3)	18.2(17.5-18.5)	20.3(19.8-21.0)	Evening
8/74	1	6.9	7.2	16.5	--	Morning
11/74	7	10.8(10.1-11.2)	11.1(10.7-11.3)	4.9(4.2-5.7)	5.1(4.4-6.0)	Noon
12/74	5	13.2(12.6-13.6)	13.5(13.4-13.6)	0.3(0.1-0.4)	0.2(0.0-0.4)	Noon
4/75	6	9.8(9.4-10.2)	10.1(9.8-10.5)	8.7(7.5-10.3)	13.0(11.5-14.2)	Afternoon

Home Creek

Home Creek also flows in a canyon from Steens Mountain and terminates in Catlow Valley. The upper reaches of the stream afford excellent trout habitat similar to that of Threemile Creek. Below the canyon mouth the stream has been channelized and the streambanks have been subjected to heavy livestock grazing. Cover is sparse and the area is virtually devoid of trout. There is an irrigation diversion box at the lower end of the creek.

The study was conducted in June 1975 on a section of stream (Table 2) located about two miles upstream from the canyon mouth at Catlow Rim. No fish species other than red-band trout were captured in Home Creek.

Flow, temperature, and chemical characteristics are presented in Table 5. It is notable that the temperature of 21.0° C was 4.5° C higher than any temperature measured in Threemile Creek.

Table 5. Temperature, chemical characteristics, and flow of Home, Rattlesnake, and Buck creeks.

Stream	Month	Temp. (°C)	TDS (mg/l)	Total Alkalinity (mg/l $CaCO_3$)	pH	Flow (l/sec)
Home	June	21.0	94	38.8	6.9	792.1
Rattlesnake	April	6.5	100	38.4	7.4	1,185.4
Buck (Upper)	March	0.0	60	23.2	6.8	307.6
Buck (Lower)	March	0.0	60	23.2	6.8	511.9

Rattlesnake Creek

Rattlesnake Creek flows southward through a shallow canyon from Malheur National Forest to a marsh north of Malheur Lake. In much of the canyon the stream is heavily shaded by coniferous and deciduous trees. Undercut banks, deep pools, and dense streamside vegetation provide abundant trout habitat. The stream channel has been altered in many places by the placement of culverts and fill for a road. The stream bottom consists largely of boulders and rubble, with much silt present in areas of relatively low current velocity. The lower reach of the stream flows through flat agricultural land where streamside cover is relatively sparse.

Study of Rattlesnake Creek was conducted during April 1975. No trout were captured in the uppermost reaches of the stream, which are isolated by waterfalls. Trout were most abundant in the middle area of the canyon. In addition to red-band trout, the speckled dace (*Rhinichthys osculus*) was abundant.

The study section (Table 2) was located above the first crossing of the road that follows the stream. The flow of Rattlesnake Creek was influenced considerably by runoff from melting snow (Table 5).

Buck Creek

Buck Creek flows northeast from Fremont National Forest through a series of canyons and meadows and terminates in Paulina

Marsh north of Silver Lake. Streamside cover of willow is dense, with shading from coniferous and deciduous trees. Beaver are abundant in many areas, providing excellent cover in the form of downed wood and burrows in the stream banks. Much of the stream bottom in the upper area consists of bare bedrock with boulder, rubble, and sand substrate common in the middle area.

In March 1975 two stream sections (Table 2) of Buck Creek were studied. The upper study section was at the head of a shallow canyon directly below Cashow Flat, and the lower section was in a deep canyon about one and one-quarter miles upstream from the Pitcher Ranch. In addition to red-band trout, speckled dace and brook trout (Salvelinus fontinalis) were captured in both study sections of Buck Creek.

METHODS

Selection of Study Sections

Preliminary sampling by electroshocking was conducted to determine the relative population densities of trout at various locations in all study streams. Study sections were established in areas with relatively high trout densities. Thus the results of this study are reflective of the better trout habitat of the study streams.

Capture and Handling of Fishes

A battery powered backpack electroshocker was used to capture fish. Stream sections to be sampled were blocked at upper and lower ends with small mesh seines. The stunned fish were netted and placed in buckets until two or three electroshocking passes through the section had been completed. The fish captured during each pass were counted and held separately.

In Home Creek electrofishing resulted in relatively low capture success so that the multiple pass removal method of population estimation could not be used. As an alternative, all trout that were captured in two passes were marked with an adipose fin clip and released. The stop nets were left in overnight and fish were captured from the section the following day.

Most fish were weighed to the nearest 0.1 g on a triple beam balance (fish of up to six months old were weighed in groups) and fork-length was measured to the nearest millimeter. Because of weather conditions and mechanical problems, no fish from Threemile Creek were weighed in October and December, 1973, and May 1975. The least squares regressions of log weight on log length (Appendix I) for August 1973, February 1974, and June 1975, respectively, were used to estimate mean weights for the above dates. In June 1975, 51 trout from Threemile Creek were weighed and measured, but data were not suitable for estimation of population size.

A scale sample was taken from between the dorsal fin and lateral line of each fish (except young of the year during the summer months in Threemile Creek) for the purpose of age determination. During the spawning period the sex of trout was determined by external examination.

A study of Threemile Reservoir was conducted at monthly intervals from July through September 1974, and in December 1974 and April 1975. During warm weather, trout were confined to relatively deep water adjacent to a dike which forms the northern and western perimeter of the reservoir.

Fish were captured with a 1/4 inch mesh, 125 x 8 foot seine except in July when a 90 foot seine was used. One end of the seine was held stationary on the dike while the remainder of the net was paid out behind a boat that was rowed in a semi-circle and brought back to the dike. The seine was then hauled onto shore to collect the fish. Seining was begun at the extreme northeast corner of the reservoir then continued at 45 m to 135 m intervals along the dike.

Lengths and weights were measured and a scale sample was collected from each fish. Since all individuals were not weighed, a least squares regression of log weight on log length (Appendix I) was used to estimate mean weight when necessary. Before release, trout were marked with an adipose or ventral fin clip.

A sample of approximately 420 chubs was collected from the reservoir during September 1974, and preserved in a solution of one part formaldehyde to nine parts water. Length, weight, and age data were compiled by the Fish Biology class (fall quarter 1974) at Oregon State University.

Population Estimation and Age Determination

Population estimates for stream fish were calculated with the formula for a two-pass removal method described by Seber and Whale (1970). In a few cases it was necessary to make three passes to obtain suitable sample sizes and the formula for a three-pass removal method was used (Seber and Whale 1970). Separate estimates were made for each age-group. Young of the year fish were generally too small to capture in numbers representative of their abundance until the fall season. In several instances, a low number (one to six) of fish of a particular age-group was captured during the first pass and none were captured during the second or third passes. When this occurred the number of fish captured was used as the estimate for that age-group. Population size in Home Creek was estimated using the mark-recapture equation discussed by Robson and Regier (1968, page 133). Estimates were possible for age III and older fish in Home Creek.

Original plans were to use a mark-recapture method to estimate population size of trout in the reservoir. However, due to the low percentage of recapture, suitable estimates using this method were possible only for age II+ and III+ fish in August based on recapture data obtained in September, and age II+ fish in September based on December data. Calculations were based on the formula presented by Robson and Regier (1968, page 133). In addition a rough estimate of trout density was made by dividing the average number of trout caught per haul of the seine by the estimated area covered by one haul. Age composition was estimated from the proportion of each age-group represented in the catch, assuming that use of the 1/4 inch mesh seine resulted in little size selectivity for age II and older fish. Population density of chubs in the reservoir was estimated using catch per unit area data from September 1974.

During the spring seasons of 1974 and 1975 numbers of reservoir trout spawning in Threemile Creek were estimated with the two-pass removal method and the formula described by Seber and Whale (1970).

Length frequency distributions and enumeration of scale annuli were used to determine the age of stream and reservoir fish. The age designation of each year-class was updated at the end of March in each year.

Production

Production may be defined as the total elaboration of fish tissue during any time interval, including that formed by individuals that do not survive to the end of the interval (Ivlev 1966, Chapman 1971). The graphical method described by Allen (1951) was used to estimate trout production in Threemile Creek. The estimated population density of a particular age-group was plotted against the mean weight of the age-group for each sampling date. Production during any time interval was represented by the area under the curve corresponding to that interval. Production for each two-month interval during the study period was determined for each year-class. Because sampling dates did not always correspond exactly to two-month intervals, interpolation was used where necessary.

A modification of Allen's graphical method (Power 1973) was utilized to estimate annual production of fish in Threemile Reservoir and Home, Rattlesnake, and Buck creeks. This method was also used to obtain a second estimate of production in Threemile Creek, to make comparison with the other streams possible. The estimated population density of each age-group was plotted against the mean weights of the age-groups. The area under such a curve estimates annual production, assuming that age composition and growth of each year-class at each age remain relatively stable through time.

The mature fish in Home Creek had spawned prior to the date of sampling causing the length-weight relationship (Appendix I) to be considerably different from that of the other populations studied. To facilitate comparison of biomass and production of Home Creek trout with the other populations, the length-weight relationship of Threemile Creek fish in March 1975 was used to estimate the weight of Home Creek fish.

Fecundity

Eggs were collected from 11 females in Threemile Creek and four females in Buck Creek during March 1975, and two females in Rattlesnake Creek during April 1975. Egg samples were obtained from a relatively wide length range of fish. Numbers of eggs in the samples were determined by direct count. The relationship between fork length and egg number was estimated by the least squares regression of log egg number on log length. During May 1975, eggs were collected from four reservoir females that showed no evidence of having spawned. Data from these samples were combined with the data for Threemile Creek fish to estimate the fork length-egg number relationship for reservoir trout.

RESULTS

The Fish Populations of Threemile Creek and Reservoir

Population Density and Age Composition of Trout

Population estimates and standard errors for the individual study sections of Threemile Creek and the area (m^2) of the sections are presented in Appendix II. The data for the separate sections were combined for each month to estimate the average (weighted by area) population characteristics for the stream above the irrigation diversion box.

The highest estimated density of trout in Threemile Creek was 2 fish/m^2 for the 1974 year-class in November 1974 (Fig. 3). The 1970 and 1969 year-classes were nearly depleted by the end of their fifth year. Individuals of the 1968 year-class were rare. Population estimates of young trout in the 1973 and 1974 year-classes were not obtained until October 1973 and November 1974, respectively. The estimated density of the 1974 year-class in November 1974 was nearly twice that of the 1973 year-class in October 1973. However, by May 1975 the density of the 1974 year-class had declined to approximately the same level as had the 1973 year-class in May 1974. This suggested that spawning in 1974 resulted in the emergence of

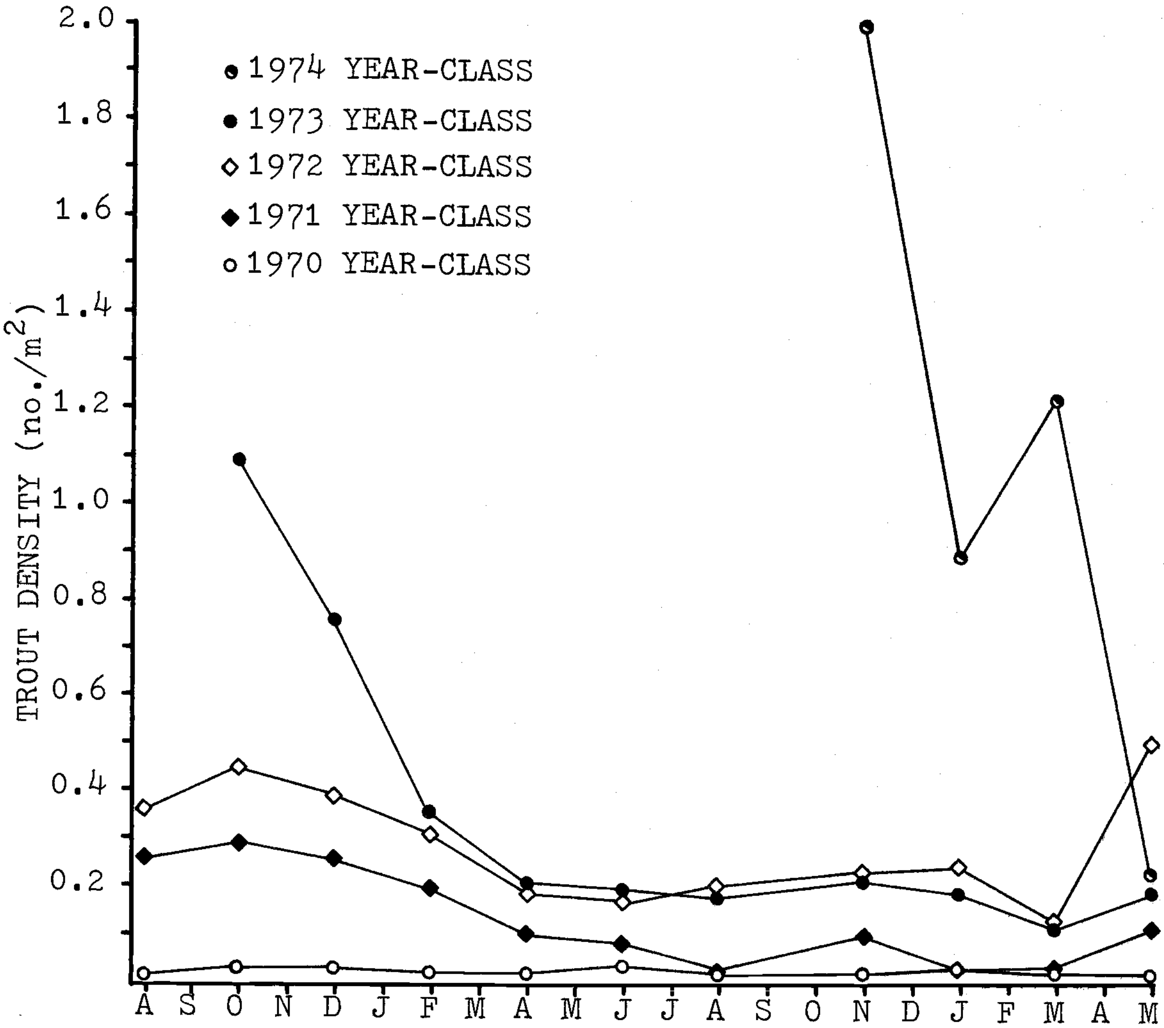

Figure 3. Density of the 1970-1974 year-classes of red-band trout in Threemile Creek from August 1973 to May 1975.

at least twice as many fry as in 1973, but that the stream was unable to support the higher density of the 1974 year-class.

The apparent increase in density of the older year-classes between March and May 1975 was probably the result of natural relocation of the stream bed in the middle study section. Increased flow from melting snow runoff removed natural debris that was diverting the stream, causing the flow to follow a different channel. Initially, food for trout was probably lacking in the new stream bed and displaced trout were forced to move into other areas of the stream, thus increasing trout density in the other study sections.

In December 1974 and April 1975 several trout of the 1974 year-class were captured in the reservoir. These fish exhibited color characteristics of stream fish, unlike older reservoir fish, which were bright silver. Scales collected from most reservoir trout showed a marked growth increase after the first annulus. Thus it was concluded that most fish that entered the reservoir left the stream during the first winter of life, although a small percentage ($< 10\%$) entered the reservoir during their second winter. A portion of the apparent mortality of ages 0+ and I+ trout in the stream can be attributed to young fish moving from the stream into the reservoir, although no estimate of their numbers was made.

Estimates of the numbers of trout in the 1972 and 1971 year-classes in the reservoir during August 1974 were 340 and 35, respectively. The size of the 1972 year-class during September 1974 was estimated to be 234. These estimates were based on mark-recapture data. Population estimates based on capture per unit area data from August and September, 1974 (Table 6) are similar to the estimates based on mark-recapture data. Capture data (Appendix III) from other sampling dates were not sufficient to estimate population numbers.

Table 6. Numbers of trout in Threemile Reservoir based on catch per unit area data.

	Age-group				
Date	I+	II+	III+	IV+	Total
8/74	300	246	27	--	573
9/74	208	456	90	35	889

The numbers of reservoir fish spawning in April 1974 and May 1975 (Table 7) were estimated by multiplying the average density (no/m) in the study sections by the length of stream from the diversion box to the stream source (1,120 m).

Table 7. Numbers of reservoir trout spawning above the diversion box in Threemile Creek in April 1974 and May 1975.

	Age-group				
Date	II	III	IV	VII	Total
4/74	22	202	11	--	235
5/75	22	146	79	1	248

Although the total numbers of spawners were approximately the same in both years, age IV trout represented a large proportion and age III a smaller proportion in 1975 as compared to 1974. No age V or VI fish were captured in the stream in either year. In 1975, one age VII female spawner from the reservoir was captured in the stream. This was the oldest trout from the reservoir examined during the study. An additional 20 to 50 reservoir trout were estimated to have spawned in approximately 675 m of stream below the diversion box, based on data from electroshocking and observations in that area.

Mortality of reservoir fish was relatively high after spawning due to removal by anglers and difficulty of returning to the reservoir because of low flows and stream diversion for irrigation purposes. The few reservoir trout which remained in the stream after spawning became emaciated and did not ripen during the following year.

Growth, Biomass, and Production of Trout

The average sizes attained by trout at each age in the stream and reservoir (Appendix II) were quite different. In August 1974 age III+ trout in the stream averaged 94 g while reservoir trout of the same age averaged 1,701 g in September 1974. Trout growth in Threemile Creek was similar to that of salmonids in other eastern Oregon streams (Osborn 1967, Lorz 1974). Growth of red-band trout in the reservoir was much greater than the growth of chinook

(*Oncorhynchus tshawytscha*) and coho (*O. kisutch*) salmon in a 7.5 ha eutrophic reservoir in central Oregon (Higley 1963).

The most significant contribution to the total biomass by any one age-group in Threemile Creek was that of age II+ trout (the 1971 year-class in 1973 and the 1972 year-class in 1974), which represented 33-56% of the total trout biomass during the study (Table 8). Numbers of age 0 fish captured in August 1973 and 1974 were low relative to their true abundance, thus the total biomass estimates for these dates are low. The estimates for May 1975 are thought to be biased upwards due to the previously mentioned natural relocation of the stream channel in the middle study section which led to increased trout density in the other study sections. The mean total biomass in the stream for all comparable 12-month periods in Table 8 was 24.2 g/m^2 not including the May 1975 estimate.

Total production of trout in Threemile Creek was highest during the months of April-July in 1974, and considerably lower for other periods during the study (Table 9). Production estimates for June-July 1974 and August-September 1973 and 1974 are low due to the lack of estimates for age 0+ fish. The mean total production for all comparable 12-month periods in Table 9 was 17.2 g/m^2.

Total production of age-groups 0+-IV+ in Threemile Creek during the period from August to March in 1973-74 and 1974-75 was 8.6 and 5.4 g/m^2, respectively. These are the dates during the study

Table 8. Biomass (g/m^2) of red-band trout in Threemile Creek.

Date	Year-class 1974	1973	1972	1971	1970	1969	1968	Total
8/73		1.4*	5.8	14.0	1.5	2.0	1.6	26.3
10/73		4.3	9.6	15.9	3.2	2.4	1.9	37.3
12/73		3.3	8.8	14.6	3.2	2.3	--	32.2
2/74		1.7	6.7	13.1	1.8	--	--	23.3
4/74		1.4	5.2	7.3	2.6	2.0	--	18.5
6/74		2.6	6.0	5.8	3.8	--	--	18.2
8/74	1.8*	3.0	11.2	2.2	1.8	--	--	20.0
11/74	6.2	4.4	13.3	4.7	2.8	--	--	31.4
1/75	3.1	4.2	13.2	2.6	3.5	1.5	--	28.1
3/75	4.4	2.6	7.8	3.5	2.1	0.5	--	20.9
5/75	1.2	5.0	31.5	5.0	0.5	--	--	43.2

*Estimates low due to under-representation of age 0+ fish.

Table 9. Production (g/m^2/2-months) of red-band trout in Threemile Creek.

Date	Year-class 1974	1973	1972	1971	1970	1969	Total
AS/73		**	1.7	0.3	0.1	0.1	2.2
ON/73		0.3	0.2	0.2	0.2	0.1	1.0
DJ/73		0.2	0.2	1.5	0.2	0.2	2.3
FM/74		0.5	1.4	0.9	0.3	0.1	3.2
AM/74		1.3	1.8	0.8	0.3	0.1	4.3
JJ/74		0.7	3.9	0.8	0.1	0.0	5.5
AS/74	**	0.5	0.5	0.2	0.1	0.0	1.3
ON/74	1.2	0.3	0.2	0.0	0.0	0.0	1.7
DJ/74	0.2	0.1	0.2	0.0	0.0	0.0	0.5
FM/75	0.6	0.3	0.8	0.2	0.0	0.0	1.9
A*/75	0.4*	0.4*	0.6*	0.1*	0.1*	--	1.6*

*Production estimate is for one month (April 1975) only.

**No estimate possible due to under-representation of age 0+ fish.

for which direct comparison of different year-classes at the same age is possible. With the exception of age 0+, production was higher for every age-group during the August to March period in 1973-74 than in the same period in 1974-75. While growth was similar both years (Appendix IV), biomass was somewhat lower in 1974-75, due mainly to a lower density of age I+ (1973 year-class) trout during that period (Fig. 3).

The estimated biomass of age I+-IV+ trout in the reservoir in September 1974 was 84 kg/ha and the estimated annual production was 80 kg/ha. These estimates are based on the 6. 3 ha area over the relatively deep water of the reservoir (Fig. 2). Total annual production in the stream above the diversion box was approximately 47 kg and when added to the total annual production of the reservoir (504 kg) provides a total annual trout production estimate of 551 kg for the entire Threemile system. The presence of the reservoir has apparently increased the total trout production potential of the Threemile system by at least 12 times.

Population Density, Growth, Biomass, and Production of Chubs

Chubs were present in great numbers in the reservoir and grew to a mean weight of 79. 5 g in their third year of life (Table 10). The estimated chub biomass in September 1974 was 183 kg/ha, and the estimated annual production was 294 kg/ha. Age 0 chubs were captured in low numbers relative to their actual abundance, thus the biomass and production estimates are somewhat low. Many observations of trout predation on chubs in the reservoir were made during the study. Chubs probably contribute significantly to the rapid growth of reservoir trout and may form the basis for trout production in the reservoir.

Table 10. Population density and mean weight of chubs in the reservoir.

	Age-group				Total
	0+	I+	II+	III+	
Density (no./ha)	499*	7,788	1,098	100	9,485*
Mean Weight (g)	1.9	16.1	44.3	79.5	

*Estimate low due to under-representation by age 0+ fish.

Maturity and Fecundity of Trout

Relatively more males matured at age II than females in both 1974 and 1975 in Threemile Creek (Table 11). The sex ratio was approximately 1:1 at age III, with fewer females than males at older ages. Perhaps loss of condition from spawning resulted in a somewhat higher mortality of females after maturation.

The sex ratio of mature reservoir fish appears to have been about 1:1, although more males probably matured at age II than females (Table 12). No estimate of the percentage of immature

Table 11. Percentages of mature and immature Threemile Creek trout at each age, and mean lengths of mature females (1974 and 1975 data combined).

	Age-group									
	II		III		IV		V		VI	
Sex	n	%	n	%	n	%	n	%	n	%
Immature	113	86.3	23	15.1	0	--	0	--	0	--
Male	16	12.2	69	45.4	24	70.6	12	80.0	1	100.0
Female	2	1.5	60	39.5	10	29.4	3	20.0	0	--
Mean Length (mm)	147.5		175.4		215.8		231.3		--	

Table 12. Percentages of mature reservoir trout at each age, and mean lengths of mature females (1974 and 1975 data combined).

	Age-group							
	II		III		IV		VII	
Sex	n	%	n	%	n	%	n	%
Male	5	71.4	25	42.4	3	42.9	0	--
Female	2*	28.6	34	57.6	4*	57.1	1*	100.0
Mean Length (mm)	336.0*		433.6		533.0*		711.0*	

*1975 only.

trout at each age was made. No reservoir fish of age V or VI were captured in the stream.

The relationship between egg number and fork length (mm) using combined data from Threemile, Buck, and Rattlesnake creeks (n=16; r=0.967) was:

$$\log \text{egg no.} = -3.361 + 2.546 \log \text{length}.$$

This was very similar to the relationship using Threemile Creek data only, and was used to estimate egg numbers in all study sections. The estimated relationship using combined data for Threemile Creek and reservoir (n=14; r=0.800) was:

$$\log \text{egg no.} = -3.989 + 2.819 \log \text{length}.$$

While the numbers of stream and reservoir females spawning in the stream were similar in 1974 and 1975, the reservoir fish were estimated to have produced more than ten times as many eggs (Table 13). The numbers of eggs actually spawned were considerably lower than the numbers produced because many mature reservoir females were removed by anglers before most spawning had occurred. A creel census conducted during the opening weekend (April 24-25) of the 1974 angling season indicated that about 120 reservoir trout were harvested, thus lowering the potential number of eggs to be spawned by reservoir females to about 197,300. Since intensive spawning did not occur for another one to two weeks it may be assumed that additional reservoir females with eggs were removed. Even though relatively small numbers of resident stream spawners were taken by anglers the number of eggs actually spawned by reservoir fish was about five times greater than the number of eggs spawned by resident stream females. No creel census was conducted in 1975.

Table 13. Numbers of mature stream and reservoir females above the diversion box in Threemile Creek and the numbers of eggs they produced in 1974 and 1975.

	Age-group					
	II	III	IV	V	VII	Total
Stream						
1974						
no. Females	8	107	16	5	0	136
no. Eggs (100's)	12	241	61	23	--	337
1975						
no. Females	5	140	24	11	0	180
no. Eggs (100's)	7	315	92	50	--	464
Reservoir						
1974						
no. Females	6	116	6	0	0	128
no. Eggs (100's)	81	3,232	299	--	--	3,612
1975						
no. Females	6	84	45	0	1	136
no. Eggs (100's)	81	2,340	2,243	--	112	4,776

Recruitment of Trout

Resident stream trout in Threemile Creek attained the minimum legal size available to anglers (15.2 cm) during their third summer (age II+). The numbers of legal size trout above the diversion box in August 1973 and 1974 were approximately 817 and 654, respectively. Age II+ fish represented approximately 87% of the total.

No estimates were made of the numbers of stream trout taken by anglers. Discussion with local anglers led to the conclusion that some angling for stream-dwelling trout occurs during summer and fall. However, the most intense angling on Threemile Creek apparently occurs during spring, with most of the catch consisting of mature fish that migrate into the stream from the reservoir.

Recruitment of reservoir trout to the sport fishery occurred mainly when mature fish entered the stream to spawn. All trout that entered the stream were available to the fishery. Reservoir trout captured from the stream during the opening weekend of the 1974 angling season averaged 39.8 cm in length. About 16 anglers used the stream each day. Most anglers who had fished in the reservoir reported very poor results, probably due to the turbidity of the water.

Comparison of the Fish Populations of Home, Rattlesnake, Buck, and Threemile Creeks

Population Density and Age Composition of Trout

The highest total trout densities other than in Threemile Creek were in Buck Creek, and the lowest in Rattlesnake Creek (Table 14).

The densities for ages III-VI in Home Creek were similar to densities for ages III-VI in Buck Creek, thus the total density of all ages may have been similar in both streams. Because trout of age I were captured in low numbers relative to their abundance in Rattlesnake and Buck creeks, estimates for that age-group are low and total densities in Table 14 are for age II and older trout. Estimates could not be made for ages I and II in Home Creek. Capture data and population estimates for Home, Rattlesnake, and Buck creeks are presented in Appendix V.

Table 14. Population density (no./1000 m^2) of red-band trout in Home, Rattlesnake, Buck, and Threemile creeks. Totals are for age II and older fish.

Stream	Age-group							Total
	I	II	III	IV	V	VI	VII	
Home	--	--	29	22	15	3	--	69*
Rattlesnake	18	12	6	8	2	--	2	30
Buck (upper)	32	110	39	8	--	--	--	157
Buck (lower)	68	163	20	21	7	2	--	213
Threemile (4/74)	210	190	100	20	10	--	--	320
Threemile (3/75)	1,220	120	130	30	20	4	--	304

*Total is for age III and older.

Growth, Biomass, and Production of Trout

Mean length instead of mean weight was used to illustrate growth (Fig. 4), due to differences in condition between the various populations at the times of sampling. Differences in condition were due

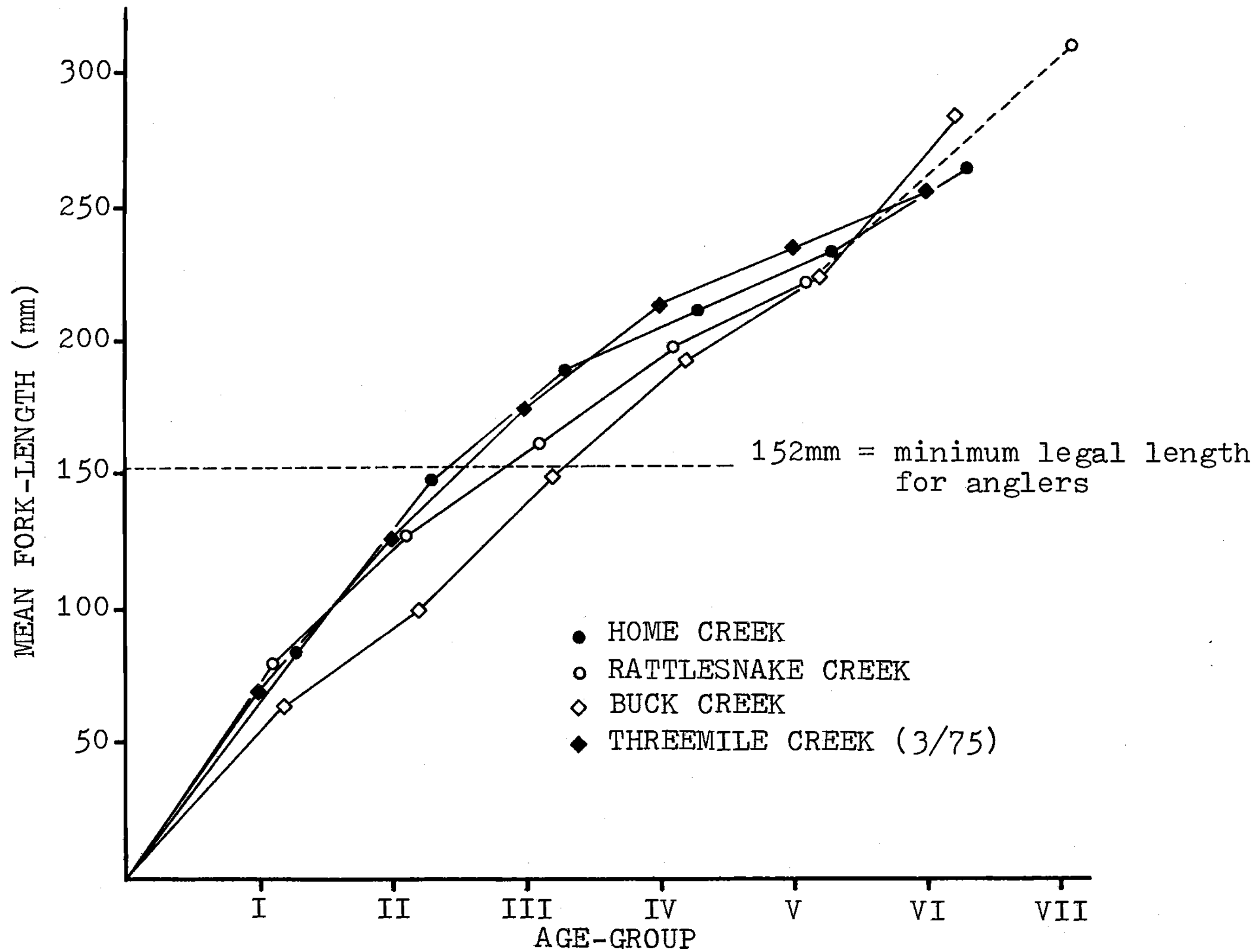

Figure 4. Mean length at each age of red-band trout in Home, Rattlesnake, Buck, and Threemile creeks during Spring 1975.

almost entirely to the state of maturity of fish from the older age-groups. Red-band trout in Threemile Creek appear to have grown relatively fast during their early years, slowing somewhat after age III. Trout in Rattlesnake and Buck creeks appear to have maintained a linear pattern of growth after age III while characteristics of growth in Home Creek were somewhat intermediate. Mean weight estimates are presented in Appendix IV.

The trout biomass in Threemile Creek in April 1974 and March 1975 was from three to nine times greater than the trout biomass estimated for the other study areas (Table 15). Total biomass estimates for Rattlesnake and Buck creeks are low because of under-estimation of the numbers of age I fish. No estimates were made for age I and II trout in Home Creek.

Table 15. Biomass and annual production (g/m^2) of red-band trout in Home, Rattlesnake, Buck, and Threemile creeks.

Stream	Biomass	Production
Home	6.7*	1.3*
Rattlesnake	2.3	1.2
Buck (upper)	2.4	2.8
Buck (lower)	5.9	4.2
Threemile (4/74)	18.5	13.9
Threemile (3/75)	20.9	20.4

*Age III and older only.

The average of the annual production estimates for Threemile Creek (17.2 g/m^2) was about four to fourteen times greater than the annual production estimates for the other study areas (Table 15). Production estimates could not be made for the period from egg to age I, thus the estimates are for age I and older trout only. Only age III and older fish are represented in the production estimates for Home Creek.

The production values in Table 15 are based on minimal data, and therefore cannot be considered to be as accurate as estimates previously presented for Threemile Creek (Table 9). However, the values are useful for general comparison of trout production in the different study areas. The average production estimates for Threemile Creek from Table 9 and from Table 15 were equal (17.2 $g/m^2/yr$) although Table 9 was based on data obtained at intervals of two months and Table 15 was based on the age composition of single samples only. The estimate from Table 9 includes production during most of the first year of life while the estimate from Table 15 does not include production during the first year. The equality of the estimates, then, is fortuitous but does indicate that both methods of estimating production provided comparable results.

Threemile Creek apparently has a greater potential for trout production than the other areas, resulting mainly in a higher density of fish in Threemile. While Threemile trout may grow slightly faster during their early years, the maximum size attained is comparable to that of the other streams studied. Thus as suggested by McFadden and Cooper (1964), numerical adjustments to density and food supply apparently precede adjustments in growth rate and are so effective that growth rate varies but little, in many stream-dwelling salmonid populations.

Density, Growth, Biomass, and Production of Other Species

Speckled dace of age-groups 0+ -II+ were present in Rattlesnake Creek at an estimated density of 0.2/m^2. Biomass and annual production of dace were estimated as 0.5 g/m^2 and 0.3 g/m^2/yr, respectively. Data for brook trout and speckled dace in Buck Creek were insufficient to estimate density, growth, and production of those species. The biomass of brook trout (age 0+ -II+) captured in the upper and lower study sections was 0.8 g/m^2 and 0.2 g/m^2, respectively. The biomass of dace (age I) captured in each of the two sections was 0.1 g/m^2.

Some studies of salmonid populations (Hopkins 1965, LeCren 1969, Mann 1971) indicate that the presence of other fish species has little impact on the production of salmonids, while a laboratory stream study by Brocksen, Davis and Warren (1968) showed that the competition for food supply with sculpins and predaceous stoneflies reduced the production of cutthroat trout. It is likely that the diet of brook trout in Buck Creek and dace in Buck and Rattlesnake creeks is similar to that of young red-band trout, thus reducing the potential production of the latter.

Maturity and Fecundity of Trout

The number of eggs per 1000 m^2 estimated to have been produced by females in Home Creek was similar to the average of the numbers produced in Threemile Creek in 1974 and 1975 (Table 16). The numbers of eggs produced in the other study areas were one-fourth to one-third the average number produced in Threemile Creek. The estimates for Threemile Creek do not include the egg production of reservoir females. The estimates for Buck Creek may be low because the relative state of maturity at the time of sampling was not far advanced, making females difficult to identify by external characteristics. Similarly, the lack of data for age III females in the lower section of Buck Creek was probably due to the difficulty in identifying females. No mature females of age II were identified in streams other than Threemile.

Recruitment of Trout

Trout attained a length of 15. 2 cm (6 inches) early in the third year of life in Home Creek, late in the third year in Rattlesnake Creek, and early in the fourth year in Buck Creek (Fig. 4). The numbers of trout nearly 15 cm long or longer (age III and older)

Table 16. Numbers of females and eggs per 1000 m^2 in Home, Rattlesnake, Buck, and Threemile creeks.

Stream	Age-group II	III	IV	V	VI	VII	Total
Home							
no. females	--	18	11	15	--	--	44
no. eggs (100's)	--	51	40	70	--	--	161
Rattlesnake							
no. females	--	4	5	2	--	2	13
no. eggs (100's)	--	6	16	8	--	19	49
Buck (upper)							
no. females	--	10	8	--	--	--	18
no. eggs (100's)	--	13	22	--	--	--	35
Buck (lower)							
no. females	--	--	8	2	2	--	12
no. eggs (100's)	--	--	22	9	16	--	47
Threemile (1974)							
no. females	3	39	6	2	--	--	50
no. eggs (100's)	4	88	23	9	--	--	124
Threemile (1975)							
no. females	2	51	9	4	--	--	66
no. eggs (100's)	3	115	34	18	--	--	170

estimated to be present per 1000 m^2 of stream in the study areas during the spring season are presented in Table 17. Age II+ trout in Home Creek were near recruitment size in June 1975 but are excluded from Table 17 because they were sampled about three months later than the other populations. Age III trout in Buck Creek averaged 14.8 cm in March 1975 and were included in Table 17.

Table 17. Numbers of catchable-size red-band trout present per 1000 m^2 during early spring, their mean length, and the percentage of the total represented by age III fish in Home, Rattlesnake, Buck, and Threemile creeks.

	Number of Catchable Trout per 1000 m^2	Percentage of Age III	Mean Length of Catchable Trout (mm)
Home	60	48	210
Rattlesnake	20	33	198
Buck (upper)	10	0	189
Buck (lower)	50	70	184
Threemile (4/74)	130	71	194
Threemile (3/75)	180	77	189

It was apparent that large numbers of age II+ fish reached legal size during summer in Threemile and Home creeks, while trout of the same age-group in Rattlesnake and Buck creeks did not reach legal size until near the end of their third year (Fig. 4). Thus the relative numbers of recruits annually in Threemile and Home creeks were considerably higher than shown in Table 17. By August, an additional 240 trout per 1000 m^2 would be expected to reach legal size in Threemile Creek and an undetermined number in Home Creek.

The study section on Home Creek was about two miles from the nearest road, and the lower section on Buck Creek was approximately one mile from a private road with limited access. Thus both sections received relatively little use by anglers. The upper section on Buck Creek is within two hundred yards of a road and according to local people receives light angling pressure during the spring and fall seasons. The study area on Rattlesnake Creek is readily accessible by road and may receive relatively more angling pressure than the other study areas.

DISCUSSION

It is difficult to assess the influence that the reservoir has had on the red-band trout population of Threemile Creek. An obvious consideration is whether or not the egg contribution of reservoir females is necessary to maintain the observed high densities of trout in the stream.

It would be difficult to determine the relationship between the egg production and the number of fry that emerge from the gravel. Causes of egg mortality include egg retention by the female, incomplete fertilization, failure of eggs to lodge in the redd, disease, predation, and other factors (Allen 1951, Bagenal and Braum 1968). The effects of these factors can differ greatly between different species, streams, and even different locations in the same stream. The high density of spawners in Threemile Creek is another factor that may contribute to egg mortality. No measurement of the area of suitable spawning gravel was made, but because of the bedrock character of the stream bottom, availability of such gravel was limited. During the spawning season several spawning pairs were often observed over a relatively small area of substrate. Thus it is likely that trout spawning late in the season disturbed the redds of previous spawners. Under these conditions, an increase in spawner density past a certain level probably simply leads to higher egg mortality.

The number of age 0+ fish in the fall of 1974 was about twice the number in 1973, yet the numbers of age I fish present during April-May of 1974 and 1975 were about equal. Thus at least half of the spawning that occurred during 1974 was apparently in excess of that needed to produce the same number of age I trout as the 1973 year-class.

Reduced spawning in 1973 may have resulted from diversion of the stream away from the reservoir during the period in which the reservoir fish would have migrated to the upper stream area (personal communication, unknown angler). Thus most of the 1973 spawning may have been attributable to the resident stream spawners.

Although the high contribution of eggs from reservoir fish may not be necessary to perpetuate the present density of fish in Threemile Creek, the high density of age 0+ fish resulting from the "extra" spawning may be necessary to provide large numbers of young fish to the reservoir. Whether young fish emigrate into the reservoir because of competition in the stream, migrate due to genetically controlled responses, or simply end up in the reservoir by chance, high density in the stream probably results in larger numbers of young fish entering the reservoir. Therefore the large egg contribution of reservoir fish may serve to insure adequate replacement of trout to the reservoir, and thus perpetuate the spawning return of reservoir fish that contributes to the sport fishery on Threemile Creek.

The harvest of some mature fish before spawning had occurred did not appear to be detrimental to the trout population, at present levels of angling intensity. It is conceivable however, that during a season with a low return of spawners from the reservoir, or with future increases in angling pressure, angling could deplete the spawning population below a critical level. The average of the numbers of mature stream and reservoir males and females above the diversion box in 1974 and 1975 was approximately 580, or 116 five-fish bag limits. Considering the reservoir spawners only, the average was about 50 five-fish bag limits. Thus it may be desirable to monitor the future angling pressure on Threemile Creek, adjusting the bag limit and applying a special angling season to the stream, if necessary, to insure adequate escapement. Because of the high mortality experienced after spawning, the harvest of reservoir fish at that time may be desirable to prevent fish waste.

Other factors have the potential of being more detrimental to an adequate amount of spawning by reservoir fish than angling. If the stream is not diverted toward the reservoir during early spring, reservoir fish cannot reach the spawning area and the spawners are not available to sport anglers. If the stream is diverted after spawning occurs and before fry emergence, redds in the section of stream below the diversion box are dried up. This situation occurred during the spring of 1975. If the reservoir were allowed to dry up, or reach a critical low level during the summer, all fish in the reservoir probably would be lost. The outlet to the reservoir draws a large volume from the deep water in which trout reside during summer. The outlet is not screened, and many trout must be drawn off with the irrigation water. Channelization, dewatering, and lack of screens on irrigation outlets are serious problems on many salmonid-producing streams in eastern Oregon (Lorz 1974).

The small, terminal reservoir on Threemile Creek obviously provides unique sport angling opportunities for a stream of that size. While the stream annually produces approximately 700 legal size fish, the reservoir has the potential of contributing at least 240 more fish averaging 43 cm in length. Construction of small terminal reservoirs on isolated streams might be considered as a trout management tool, to provide high quality sport fisheries and serve a multiple purpose as water storage facilities for irrigation and stock watering. Such reservoirs might be especially productive if a forage fish such as the chub were available for trout.

Establishment of hatchery facilities to culture red-band trout for stocking and "rehabilitation" purposes in eastern Oregon streams has been considered (Southeastern Regional Meeting, Oregon Department of Fish and Wildlife, 1974). Utilizing the red-band population of Threemile Creek as a "natural" egg source for stocking and rehabilitation might provide a viable alternative to the expense and effort of establishing and maintaining a brood stock of red-band trout. The reservoir fish could provide large numbers of eggs to be planted in the gravel of other streams, or to be hatched artificially and the fry planted.

The average annual production of 17.2 g/m^2 in Threemile Creek is quite high compared to estimates of salmonid production in other areas. When comparing the annual production estimate for Threemile Creek with estimates for other areas, it must be borne in mind that production of young of the year prior to October was not estimated. LeCren (1969) reported annual production values that ranged from 2 to 12 g/m^2, for brown trout (Salmo trutta) in ten small streams in England. LeCren noted that these levels were similar to estimates for three salmonid species (Salvelinus fontinalis, Salmo clarki, and Oncorhynchus kisutch) in the United States, and proposed the existence of a production maximum of about 12 $g/m^2/yr$ for salmonids in natural small streams. Egglishaw (1970) reported average production values of 9 $g/m^2/yr$ for Atlantic salmon (Salmo salar) and 10 $g/m^2/yr$ for brown trout residing in the same stream in Scotland, but these production rates are probably not additive because of the ecological segregation of the species involved. Power (1973) reported an average value of 1.5 $g/m^2/yr$ for 39 estimates of production of Atlantic salmon, brown trout, and char (Salvelinus alpinus) in north Norway streams. In a detailed study by Hunt (1974) production of brook trout in Lawrence Creek, Wisconsin, averaged 12 $g/m^2/yr$ over an 11 year period. Average annual production in one section of Lawrence Creek was 18.8 g/m^2, and peaked at 25.8 g/m^2 in 1969. Increased production in that particular stream section was largely attributable to artificial improvement of the habitat. The highest value reported for a natural stream is 54 $g/m^2/yr$ (Allen 1951) for brown trout in the Horokiwi stream of New Zealand. The average trout biomass of 24 g/m^2 in Threemile Creek is similar to Allen's biomass estimate of 27 g/m^2.

In Oregon, Chapman (1965) reported an average annual production estimate of 9 g/m^2 for coho salmon in three coastal streams, and total production of coho, cutthroat, steelhead (Salmo gairdneri), and cottids in one stream was 16 g/m^2. Nickelson (1974) estimated the annual production of cutthroat trout in Berry Creek as 0.5 g/m^2, with negative production occurring from June to November. Osborn (1967) estimated production of age I+ rainbow trout only, for a two-month period as 0.6 g/m^2 in a southeastern Oregon stream. Production of age I+ red-band trout in Threemile Creek during a similar period (August + September) in 1973 and 1974 averaged 1.1 g/m^2, or two times greater than Osborn's estimate. In the present study, the 17.2 $g/m^2/yr$ estimate in Threemile Creek was compared with estimates for red-band trout ranging from 1.2 to 4.2 $g/m^2/yr$ in three other southeastern Oregon streams.

Coche (1967) summarized production values for salmonids in a variety of impoundments. Production of salmonids in oligotrophic lakes ranged from 0.6 to 65 kg/ha/yr, and in dystrophic lakes from 19 to 84 kg/ha/yr. A production estimate as high as 206 kg/ha/yr was reported for juvenile chinook salmon in a eutrophic reservoir in central Oregon (Higley 1967). However, that impoundment was not recommended as being a suitable rearing site for chinook salmon because of high mortality during severe summer conditions. The annual redband trout production of 80 kg/ha estimated for Threemile Reservoir is apparently rather high for salmonids in an impoundment, and the reservoir provided suitable trout habitat throughout the year.

The high trout production in Threemile Creek is probably largely attributable to the greater environmental stability of that stream, relative to the other streams studied. The watershed is quite limited in size, so that the relatively small amount of runoff that occurs results in minimal effects due to increased flows (such as scouring). The main water source for Threemile Creek is the springs, which provide a relatively stable water temperature. Such environmental stability may result in a greater and more constantly available supply of food organisms for trout. The dense and expansive growth of annual and perennial plants supported by the springs provides a large amount of dead vegetable material which may be an important source of nutrients for production in the stream and reservoir.

Among the most apparent threats to the well-being of red-band trout populations are various activities of man, including stream channel alterations, dewatering, livestock grazing, road construction, logging, and insecticide spraying. All of the streams studied had large areas which had been or are being affected by one or more of these activities. Much of the lower stream areas of Threemile and Home creeks have been channelized, are heavily grazed, and are dewatered partially or completely at times. As a result, these areas are virtually devoid of trout, or at best support a very limited biomass. In 1971 Wilmot and Bond (Bond 1975) collected chubs below the bridge on the road which crosses Threemile Creek, and Wilmot (1973) mentioned that trout were plentiful "in the pool below the bridge." At that time road improvement was being conducted in the form of widening and filling the existing road, and a culvert was placed in the stream. During the present study, no chubs were captured in that area, and of the few trout observed, most were migrants from the reservoir. The same road crosses Home Creek.

Buck Creek has several areas which are heavily grazed, resulting in trampled stream banks, lack of streamside cover, and smooth channels. Such areas support very few trout, if any.

Construction of the road that parallels Rattlesnake Creek has resulted in much alteration of that stream. Fill from the road forms the stream bank in some places, and several culverts have been placed in the stream at road crossings. During the study of Rattlesnake Creek in April 1975, road improvement in the form of widening, filling, and relocation of portions of the road bed was being conducted. Grazing, logging, and insecticide spraying are other activities that have occurred or are occurring in the Rattlesnake Creek drainage. The combined effect of these activities of man has probably contributed to some extent to the relatively lower levels of trout production measured in Rattlesnake Creek.

The status of the red-band trout populations that were studied appeared to be relatively good in areas of the study streams that had not been severely disturbed by man's activities. The virtual lack of trout populations in the severely disturbed areas provides an example of the dismal future of native trout populations if existing habitat is not protected.

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APPENDICES

APPENDIX I

LEAST SQUARES REGRESSIONS OF LOG WEIGHT (W) ON LOG LENGTH (L)

Table A. L (mm) - W(g) relationship of trout in Threemile Creek.

Date	n	r	Regression Equation
8/73	145	0.996	log W = -5.155 + 3.080 log L
2/74	61	0.993	log W = -5.218 + 3.114 log L
4/74	91	0.984	log W = -4.719 + 2.859 log L
6/74	50	0.997	log W = -5.257 + 3.136 log L
8/74	57	0.991	log W = -5.340 + 3.171 log L
11/74	179	0.996	log W = -4.833 + 2.942 log L
1/75	55	0.994	log W = -5.109 + 3.050 log L
3/75	131	0.997	log W = -5.029 + 3.030 log L
6/75	51	0.998	log W = -4.946 + 3.004 log L

Table B. L(mm)-W(g) relationship of trout in Threemile Reservoir.

Date	n		Regression Equation
7/74	20	0.965	log W = -5.801 + 3.344 log L
8/74	10	0.898	log W = -3.635 + 2.500 log L
9/74	31	0.892	log W = -4.900 + 3.000 log L
4/75	9	0.943	log W = -4.190 + 2.690 log L

Table C. L(mm)-W(g) relationship of trout in Home, Rattlesnake, and Buck creeks.

Stream	n	r	Regression Equation
Home Creek	25	0.978	log W = -4.177 + 2.640 log L
Rattlesnake Creek	40	0.997	log W = -4.904 + 2.984 log L
Buck Creek	68	0.996	log W = -5.202 + 3.111 log L

APPENDIX II

AREAS OF STUDY SECTIONS, POPULATION ESTIMATES AND STANDARD ERRORS FOR THREEMILE CREEK

Date	Section	Area (m^2)		Year-class 1973	1972	1971	1970	1969	1968
8/73	Lower	151	Pop. Est.	103	45	26	4	1	
			Std. Error	1.3	1.3	0.3	*	*	
	Middle	54	Pop. Est.	85	24	12		1	1
			Std. Error	175.1	30.3	6.0		*	*
	Upper	54	Pop. Est.	18	22	29		2	1
			Std. Error	1.4	0.2	1.3		*	*
10/73	Lower	94	Pop. Est.	100	24	17	3	2	
			Std. Error	20.6	5.9	3.5	*	*	
	Middle	54	Pop. Est.	65	39	18	2	1	1
			Std. Error	**	**	**	**	**	**
	Upper	102	Pop. Est.	108	49	37	3	1	1
			Std. Error	33.7	6.6	1.3	*	*	*
12/73	Lower	76	Pop. Est.	79	29	12	2	1	
			Std. Error	9.2	14.6	10.6	*	*	
	Middle	48	Pop. Est.	36	20	12	1	1	
			Std. Error	8.0	7.8	0.4	*	*	
	Upper	110	Pop. Est.	62	43	36	4	2	
			Std. Error	6.1	5.7	10.4	*	*	
2/74	Lower	84	Pop. Est.	27	16	12			
			Std. Error		6.9	10.6			
	Middle	70	Pop. Est.	20	30	22	2		
			Std. Error	2.4	20.4	3.4	*		
	Upper	55	Pop. Est.	29	18	7	1		
			Std. Error	14.6	1.4	0.6	*		
4/74	Lower	88	Pop. Est.	19	16	9	2	1	
			Std. Error	2.6	10.3	*	*	*	
6/74	Lower	63	Pop. Est.	7	9	7	3		
			Std. Error	0.6	*	0.6	*		
	Middle	49	Pop. Est.	15	10	2			
			Std. Error	**	**	**			

APPENDIX II (Continued)

Date	Section	Area (m^2)		Year-class 1974	1973	1972	1971	1970	1969	1968
8/74	Lower	64	Pop. Est.	69	4	6	2	2		
			Std. Error	3.0	3.5	*	*	*		
	Middle	41	Pop. Est.	74	4	2				
			Std. Error	52.5	1.5	*				
	Upper	63	Pop. Est.	90	21	27	2			
			Std. Error	10.9	16.0	3.7	*			
11/74	Lower	114	Pop. Est.	356	16	13	2			
			Std. Error	15.4	5.2	1.0	*			
	Middle	96	Pop. Est.	170	32	33	9	4		
			Std. Error	30.0	2.4	6.5	13.4	*		
	Upper	110	Pop. Est.	114	22	29	4	2		
			Std. Error	8.4	3.4	1.3	*	*		
1/75	Lower	57	Pop. Est.	40	8	9		1		
			Std. Error	9.7	*	2.1		*		
	Middle	96	Pop. Est.	88	20	17	3	1	2	
			Std. Error	19.8	2.2	1.6	*	*	*	
	Upper	110	Pop. Est.	107	21	36	4	5		
			Std. Error	61.3	2.0	8.0	1.5	*		
3/75	Lower	114	Pop. Est.	120	15	14	4			
			Std. Error	16.7	1.9	2.6	*			
	Middle	67	Pop. Est.	163	8	7				
			Std. Error	64.7	4.9	0.6				
	Upper	110	Pop. Est.	71	12	17	5	4	1	
			Std. Error	26.4	1.1	0.7	1.0	3.5	*	
5/75	Lower	114	Pop. Est.	36	11	9	2			
			Std. Error	99.5	1.4	2.1	*			
	Upper	110	Pop. Est.	14	33	102	12		1	
			Std. Error	**	**	**	**		**	

*All fish in sample were captured during the first pass; no standard error calculated.

**Population estimate based on three passes; no standard error calculated.

APPENDIX III

NUMBERS OF TROUT CAPTURED, MARKED, AND RECAPTURED IN THREEMILE RESERVOIR

Date		Year-class				
		1974	1973	1972	1971	1970
7/74	No. Capt.		7	17	5	
	Total Marked		0	0	0	
	No. Recapt.		0	0	0	
8/74	No. Capt.		11	9	1	
	Total Marked		4	12	4	
	No. Recapt.		0	0	0	
9/74	No. Capt.		17	25	5	2
	Total Marked		9	22	5	0
	No. Recapt.		0	1	1	0
12/74	No. Capt.	1	3	6	2	0
	Total Marked	0	26	45	8	2
	No. Recapt.	0	0	1	0	0
4/75	No. Capt.	9	9	4	0	0
	Total Marked	0	29	51	10	2
	No. Recapt.	0	0	1	0	0

APPENDIX IV

MEAN LENGTH (mm), MEAN WEIGHT (g), AND SAMPLE SIZE OF TROUT IN THREEMILE CREEK AND RESERVOIR, AND HOME, RATTLESNAKE, AND BUCK CREEKS

Table A. Threemile Creek.

Date		Year-class					
		1973	1972	1971	1970	1969	1968
8/73	$\bar{L}$	56	118	169	207	232	281
	$\bar{W}$	1.9	17.8	54.4	97.2	128.0	208.0
	n	142	77	63	4	4	2
10/73	$\bar{L}$	70	124	172	209	241	280
	$\bar{W}$	4.0	21.5	55.3	98.9	149.2	233.8
	n	200	89	67	8	4	2
12/73	$\bar{L}$	74	129	173	215	234	
	$\bar{W}$	4.3	22.6	56.2	106.2	136.5	
	n	149	71	47	7	4	
2/74	$\bar{L}$	78	126	180	220		
	$\bar{W}$	4.8	21.3	64.4	122.2		
	n	64	47	35	3		
4/74	$\bar{L}$	84	137	182	220	251	
	$\bar{W}$	6.7	27.8	71.0	113.8	175.4	
	n	17	11	9	2	1	
6/74	$\bar{L}$	106	146	185	229		
	$\bar{W}$	13.1	35.5	70.3	144.0		
		21	18	9	3		

APPENDIX IV (Continued)

Date		Year-class 1974	1973	1972	1971	1970	1969	1968
8/74	$\bar{L}$	49	115	168	203	230		
	$\bar{W}$	1.3	17.0	53.5	93.6	148.3		
	n	175	20	32	4	2		
11/74	$\bar{L}$	65	120	173	208	237		
	$\bar{W}$	3.1	20.2	56.7	98.5	152.0		
	n	528	63	68	11	6		
1/75	$\bar{L}$	72	130	175	206	232	266	
	$\bar{W}$	3.6	21.8	55.2	91.4	130.3	191.6	
	n	147	47	53	7	7	2	
3/75	$\bar{L}$	69	127	174	215	236	251	
	$\bar{W}$	3.7	21.9	60.0	108.6	152.6	156.5	
	n	224	32	36	9	3	1	
5/75	$\bar{L}$	78	132	176	213	240		
	$\bar{W}$	5.5	26.2	63.1	111.3	158.7		
	n	20	21	36	10	1		
6/75	$\bar{L}$	88	137	182	216			
	$\bar{W}$	7.7	29.6	69.5	116.5			
	n	29	16	4	2			

APPENDIX IV (Continued)

Table B. Threemile Reservoir

Date		Year-class				
		1974	1973	1972	1971	1970
7/74	$\bar{L}$		157	404	515	
	$\bar{W}$		38.2	825.4	1753.2	
	n		7	17	5	
8/74	$\bar{L}$		196	415	432	
	$\bar{W}$		75.6	898.2	1016.1	
	n		11	9	1	
9/74	$\bar{L}$		215	443	510	523
	$\bar{W}$		100.8	1095.2	1701.2	1834.3
	n		17	25	5	2
12/74	$\bar{L}$	65	258	439	504	
	$\bar{W}$	2.4	179	975	1550	
	n	1	3	6	2	
4/75	$\bar{L}$	87	268	456		
	$\bar{W}$	6.9	202.0	1129.5		
	n	9	9	4		

APPENDIX IV (Continued)

Table C. Home, Rattlesnake, and Buck Creeks.

Stream		Year-class						
		1974	1973	1972	1971	1970	1969	1968
Home Creek	$\bar{L}$	83	148	190	212	234	272	
	$\bar{W}$	7.2	40.1	76.5	98.2	121.0	146.4	
	n	4	2	8	6	4	1	
Rattlesnake Creek	$\bar{L}$	80	127	154	198	222	--	311
	$\bar{W}$	6.5	25.4	43.3	82.2	116.3	--	330.0
	n	20	9	7	3	3	0	1
Buck Creek								
Upper	$\bar{L}$	60	87	131	189			
	$\bar{W}$	2.2	6.7	25.2	73.6			
	n	4	14	5	1			
Lower	$\bar{L}$	65	100	148	192	238	286	
	$\bar{W}$	3.2	11.1	35.6	81.3	156.8	283.5	
	n	16	26	9	8	4	1	

APPENDIX V

NUMBERS OF TROUT CAPTURED, POPULATION ESTIMATES AND STANDARD ERRORS FOR HOME, RATTLESNAKE AND BUCK CREEKS

Table A. Home Creek

	Year-class					
	1974	1973	1972	1971	1970	1969
No. Capt. * Pass 1	3	0	6	2	1	1
No. Capt. Pass 2	1	2	3	5	3	1
No. Recapt.	0	0	1	1	0	1
Pop. Est.	--	--	18	10	4**	1**
Std. Error	--	--	13.8	6.7	**	**

*All fish captured during Pass 1 were marked.

**Population estimate assumed; no standard error.

Table B. Rattlesnake Creek.

	Year-class						
	1974	1973	1972	1971	1970	1969	1968
No. Capt. Pass 1	3	6	3	2	1	0	1
No. Capt. Pass 2	2	0	0	1	0	0	0
Pop. Est.	9	6*	3*	4	1*	0	1*
Std. Error	13.4	*	*	3.5	*	--	*

*Population estimate assumed; no standard error.

APPENDIX V (Continued)

Table C. Buck Creek.

		Year-class					
		1974	1973	1972	1971	1970	1969
Upper Section	No. Capt. *	4	14	5	1		
Lower Section	No. Capt. Pass 1	9	14	6	5	4	0
	No. Capt. Pass 2	7	12	3	3	0	1
	Pop. Est.	40	98	12	12	4**	1**
	Std. Error	63.0	214.2	6.0	10.6	**	**

*Total catch for 5 passes; virtually all fish of 1971-1973 year-classes in section were captured.

**Population estimate assumed; no standard error.