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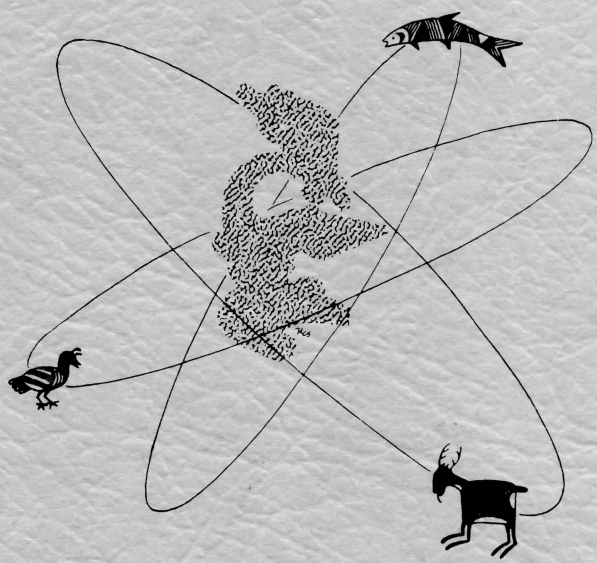
ECOLOGY AND MANAGEMENT OF BROWN TROUT IN LITTLE DESCHUTES RIVER



Fishery Research Report Number 8

Research Division

Oregon Wildlife Commission

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ECOLOGY AND MANAGEMENT OF BROWN TROUT IN LITTLE DESCHUTES RIVER

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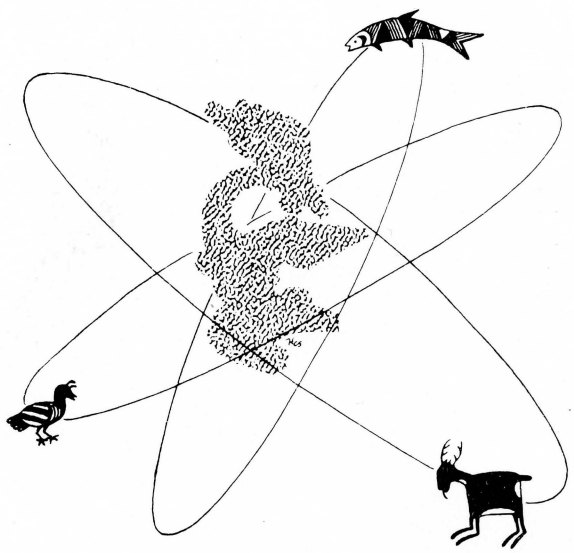

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ABSTRACT

A study of brown trout and some of the factors limiting their distribution and abundance was conducted during the years 1968 through 1971 in the Little Deschutes River. Data were collected on population statistics, age and growth, maturation, fecundity, food habits, and the relationship between brown trout numbers and physical and biological parameters of the environment.

Population estimates of 2,300 (one year and older) brown trout per surface acre occurred where good habitat was available. The growth rate was only 3-4 cm per year – a result of low nutrient water and high trout density. High survival from egg through adult has led to high densities of fish mostly under the "legal" length of six inches (15 cm).

Fish mature during their third summer of life, and though individuals are small and not very fecund (150 to 400 eggs per female), a large egg deposition occurs each year which contributes to the high fish density.

Study sites in the natural, free-flowing stream channel with adequately vegetated banks had greater trout populations than areas heavily grazed. An area with good streamside cover supported 1,853 more brown trout (1+ and older) or 146.9 pounds more per acre than did a badly overgrazed area.

Cover was found to be the most important physical parameter governing the number of brown trout.

Little movement of tagged fish older than one year occurred in the upper Little Deschutes River but no estimate of fry movement was made. There is however, a spring and summer movement of brown trout (ages 0-IV) into irrigation canals from the main Deschutes River and that portion of the Little Deschutes River subject to irrigation releases from Crescent Lake. Thus, a large number of brown trout are lost annually by entry into unscreened or improperly screened irrigation canals.

Low densities of brown trout were noted in areas of Crescent Creek, the main Deschutes River and the lower Little Deschutes River subjected to abnormally low winter flows that resulted from irrigational storage.

Angling pressure and harvest were extremely light and probably indicated a lack of interest in fishing for small fish.

Growth rate of brown trout from streams in three major river systems was comparable.

INTRODUCTION

Brown trout were introduced into Oregon early in the current century. Subsequent natural reproduction resulted in the development of a sport fishery in several streams including the Deschutes River in Central Oregon. The once successful Deschutes River fishery has been modified by superimposed irrigation regimes: abnormally high flows in summer and critically low flows in winter adversely affects spawning areas, stream productivity and ultimately, the fish population. In addition, irrecoverable loss of brown trout occurs through unscreened or improperly screened irrigation canals in the spring and summer months. Land development has also contributed to the decline of the trout population. Removal of streamside vegetation as a result of over-grazing or home development has reduced brown trout habitat and promoted soil erosion and siltation.

This study was initiated to gain an understanding of the ecological requirements of brown trout and to determine the effects of water development and land use on fish populations. To meet these objectives, several aspects of the life history and ecology of brown trout were studied, namely: abundance, distribution, survival, age, growth, fecundity, food, migrations and ecological relationships to other species.

GENERAL DESCRIPTION OF THE UPPER DESCHUTES RIVER WATERSHED

Location and Geology

The Deschutes River watershed is located in the central area of the state. Its headwaters are in the Cascade Mountains, a narrow line of peaks 7,000-11,000 feet high. They consist of Pleistocene cores of andesite with a Pliocene shield of volcanic basalt that overlie Miocene flows of the Columbia Lava plateau and Tertiary flows of the western Cascades (Hodge 1938). The soil in the Deschutes Basin is in part residual but most is an admixture of volcanic ash (Fenneman 1931).

The study was centered in the upper sub-basin, which includes all the watershed above Benham Falls and contains 1,710 square miles, about 16 percent of the total area of the Deschutes Basin (Figure 1). The drainage area of the Little Deschutes River, the main tributary of the Deschutes in the sub-basin, comprises about 60 percent of the total sub-basin area. Crescent Creek, another important tributary, drains about 11.5 percent of the sub-basin area. There are more than 750 miles of streams in the sub-basin of which only 310 are perennial in nature. The upper sub-basin includes 71 miles of the Deschutes main stem, 97 miles of the Little Deschutes River and 30 miles of Crescent Creek. Paulina Creek, which originates at Paulina Lake, is the only stream of significance that heads east of the Deschutes River.

The Deschutes River has an average drop of only 8.5 feet per mile in the 71 miles from Lava Lake to Benham Falls. The Little Deschutes River drops 350 feet in its upper three miles but averages only nine feet per mile in its lower 94 miles to the confluence with the main stem. Crescent Creek has an average gradient of about 15 feet per mile between Crescent Lake and its confluence with the Little Deschutes River (Oregon Water Resources 1961).

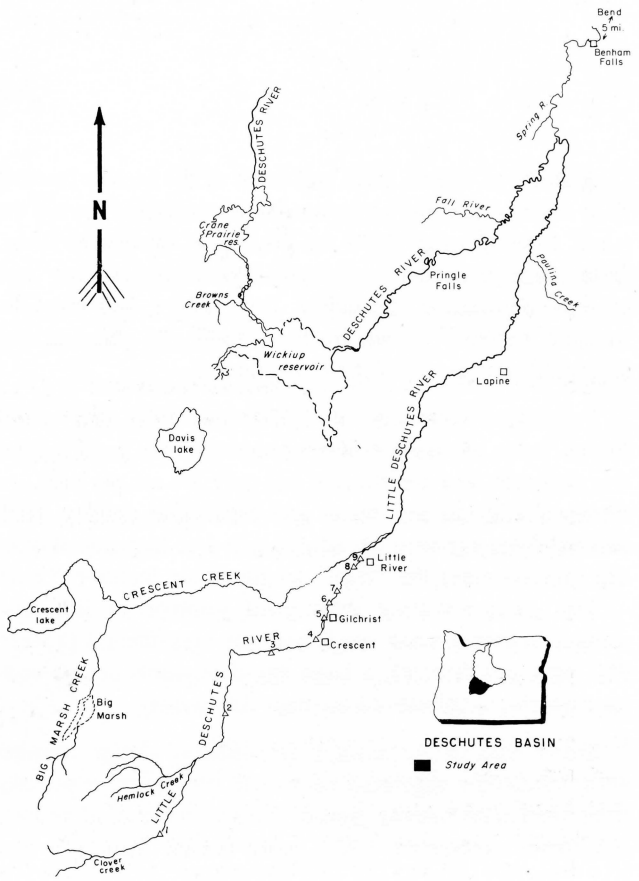


Figure 1. Map of the upper Deschutes River showing study sites (Δ).

LOCATION AND DESCRIPTION OF STUDY SITES

Physical and Chemical Characteristics

The study was restricted principally to the Little Deschutes River and its tributaries (Figure 1). Some portions of the Little Deschutes River are relatively pristine with no major developments except for a log pond at Gilchrist. Its low gradient, broad flood plain and meandering course indicate significant ageing. Discharge at Lapine ranges from 200-400 cfs during the summer with most of the flow coming from Crescent Lake, a storage basin for irrigation water. The unaltered flow in September-October at Lapine ranges from 50-100 cfs. At Crescent, the late summer and fall flows average 30 cfs (Appendix I).

Water temperature records were obtained during the summer of 1971 at six stations along the Little Deschutes River. These data are summarized as mean weekly maximal temperatures (Figure 2). Only three stations are shown for clarity, but other stations were contained between upper and lower values. Temperature differential between the upper and lower stations, a distance of 40 miles, is 7°C. The mean weekly minimum and maximum temperatures for two study sites are presented in Figure 3. The 5.5°C increase between these two sites reflects the warming influence of Gilchrist log pond and the removal of streamside vegetation. The average monthly temperatures

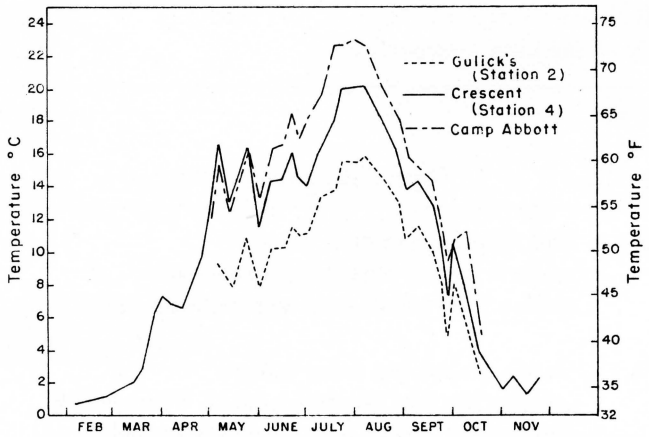


Figure 2. Mean weekly maximal temperatures at three stations on the Little Deschutes River from May-October 1971.

(Table 1) indicate severe conditions during the winter and it was only from May to September that temperatures at most stations were above 10°C.

Current speed, flow, pH and calcium carbonate content were monitored. The mean velocity, as measured with a Gurley flowmeter varied between pools, riffles, and "flat" reaches, as well as with flow. Generally as the flow decreased so did the mean velocity (Appendix II). A maximal acidic reading of 6.2 was recorded under flood conditions when water was draining marshes of the upper catchment area. Under normal conditions, when the river was low, the pH was 7.0 to 7.6 (Appendix III). The low ionic content of the Little Deschutes River is reflected in the conductivity of 36 micromhos (k_{25}) at normal water levels. The corresponding total dissolved solids were 25 mg/l. The calcium content (hardness) of 12 mg/l estimated as $CaCO_3$ is low (Appendix III).

Spawning gravel is intermittent and no sizable gravel concentrations exist. Most deposits are thin, overlying a pumice bed, and are marginal for spawning.

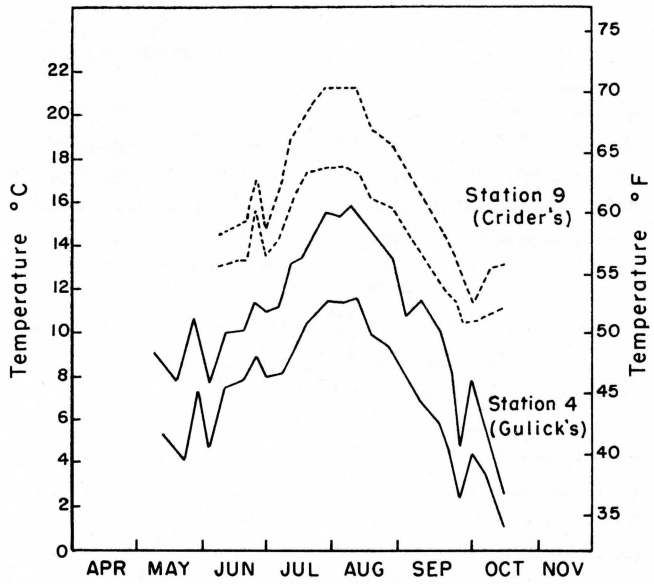


Figure 3. Mean weekly maximal and minimal temperatures at two study sites on the Little Deschutes River in 1971.

During the summers of 1969 and 1970, four study stations were established upstream of the town of Crescent. In 1971 five additional stations were established downstream of Gilchrist. Areas chosen for study were affected by man to various degrees and were compared as to species composition and abundance (Table 2).

Biological Characteristics

Fishes

The fish were collected by electrofishing and occasionally through the use of rotenone. All major and most minor streams of the upper Deschutes watershed were sampled. The following list represents all species found during this study in the sub-basin.

TABLE 1
Average monthly temperatures and ranges (°C) at four stations on the Little Deschutes River from March to November 1971

Month	Gulick's	Crescent	Gilchrist	Crider's
March		3.2 (2.4-4.0)		
April		6.5 (5.4-7.6)	7.0 (6.7-7.3)	
May	7.6 (5.8-9.3)	11.8 (8.8-14.7)	11.0 (9.8-12.2)	
June	8.9 (7.5-10.2)	13.3 (12.2-14.3)	13.3 (12.7-13.9)	14.7 (13.9-15.5)
July	11.6 (8.8-13.5)	16.1 (15.0-17.1)	17.0 (16.7-17.2)	17.8 (16.3-19.3)
August	12.7 (10.6-14.9)	17.3 (15.8-18.8)	19.0 (18.8-19.1)	18.5 (16.8-20.2)
September	7.4 (5.7-9.1)	10.8 (9.7-11.8)	12.9 (12.7-13.1)	12.4 (11.5-13.2)
October	4.3 (3.0-5.5)	6.6 (5.7-7.4)	8.1 (7.9-8.3)	
November		1.6 (1.2-1.9)	3.3 (3.1-3.5)	

TABLE 2
Description of sites selected for study on the Little Deschutes River

Location (Station No.)	Length of study sections (ft)	Surface area (acres)	Elevation above MSL (ft)	River mile above Deschutes R.	General stream characteristics
Cow Camp (1)	608	0.365	5,100	93	Limited grazing in most years; sparse lodgepole pine along stream bank; stable stream banks; good within-stream cover
Gulick's (2)	624	0.282		79	Heavily grazed, but dense willows covering much of the stream banks. Where willow cover absent, stream banks generally eroded.
Old Mill (3)	570	0.214		66	Heavily grazed; willow cover along most of one bank; other bank eroded.
Crescent (4)	325	0.229	4,500	65	Heavily grazed for many years; only a few clumps of willows; stream banks eroded.
Rocky Reach (5)	600	0.411		63	Conifers and deciduous trees line edge of stream; large rocks and boulders within the stream; steep gradient resulting in shallow, fast-water areas.
Willows (Deschutes Village) (6)	300	0.191		62	No grazing; dense willow cover along banks; considerable aquatic vegetation.
Larson's (7)	600	0.289		61	Heavily grazed with limited willow cover on portions of banks; banks devoid of cover show signs of erosion; considerable aquatic vegetation.
Conifers (8)	600	0.341		60	Conifers and deciduous trees line much of the bank; many deep slow pools; considerable aquatic vegetation.
Crider's (9)	600	0.279	4,350	58	Area grazed; evidence of bank erosion; willow cover along most of one bank.

Scientific Name	Common Name	Relative Abundance
Salmo trutta	Brown trout	Abundant
Salvelinus fontinalis	Brook trout	Common
Salmo gairdneri	Rainbow trout	Scarce
Prosopium williamsoni	Mountain whitefish	Abundant
Ictalurus nebulosus	Brown bullhead	Abundant
Gila bicolor	Tui chub (roach)	Abundant
Cottus perplexus	Sculpin	Common

Brown trout, brook trout, sculpins and tui chub are present in most small tributary streams. All of the larger tributaries supported trout, chubs, sculpins, bullheads and whitefish.

Major Foods

The benthos and drift were sampled occasionally in order to establish a reference collection of the major stream invertebrates. These data are presented in Appendix IV.

METHODS

Fish Collection, Marking and Population Estimates

Since the majority of streams in the upper Deschutes Basin are small, representative samples of brown trout were obtained through electrofishing. A 2,500-watt D.C. generator was utilized in readily accessible areas, and a 500-watt D.C. backpack unit was used in more remote sections (Figures 4 and 5).

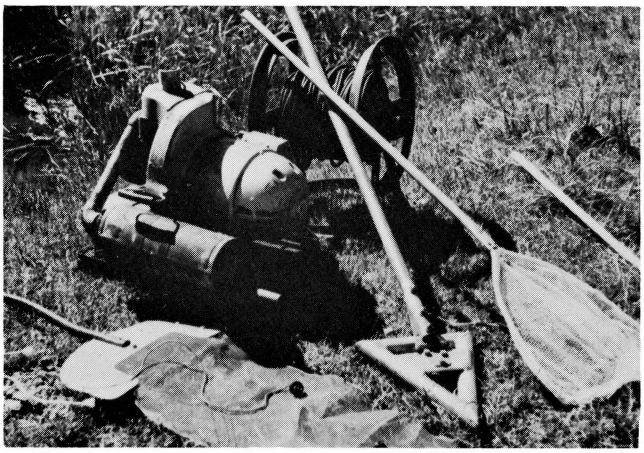


Figure 4. Direct current generator used in electrofishing accessible stream area.

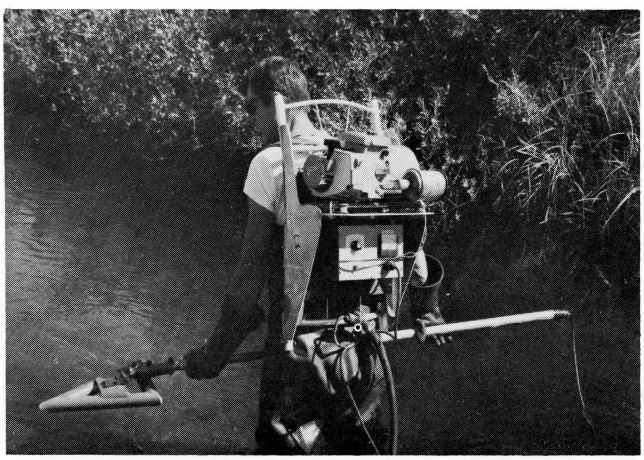


Figure 5. Backpack electrofishing unit for use in inaccessible stream areas.

Electrofishing is a valid method for obtaining fish for population estimates as well as for stomach analyses. The apparatus can catch fish from all habitats of a stream and does not select them on the basis of feeding behavior or readiness to take food. Fish caught for feeding studies are thus more representative of the fish population than are those caught by methods such as angling or netting. Unfortunately, large trout and nongame species are more vulnerable to electrofishing than fish of the year. The recapture of 1+ and older fish ranged from 35 to 75 percent depending on flow and amount of streamside cover. The recapture of 0+ fish was more difficult, ranging from 4 to 45 percent of those initially marked.

Numbers of trout and other species were estimated by isolating study areas with stop-nets. The entire area within the nets was usually fished four times. Fish collected were held in holding pens until sampling was complete. The captured fish were anesthetized with tricaine methanesulfonate (MS 222), measured to the nearest millimeter (fork length) and occasionally weighed. Fish larger than 13.5 cm were tagged with a numbered plastic dangler tag (5.0 x 14 mm) attached with polyvinyl thread (0.25 mm) beneath the dorsal fin (Figure 6). Fins were also clipped for future identification in case of tag loss. Fish from 9.0-13.5 cm were fin clipped and some received a smaller numbered tag. The fish were allowed to revive and were then released into the study area. After the fish had settled down, stop nets were removed. In August and September when stream temperatures were elevated, the anesthetic solution and recovery water were oxygenated.

Figure 6. Brown trout showing position of plastic dangler tag.

In order to calculate a length-weight relationship, weights were obtained throughout the summer. The fish were weighed to the nearest 0.1 gram on a Mettler K-7 balance.

Population estimates were calculated from a marked to unmarked ratio using the formula given by Ricker (1958):

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

where
N = estimated size of the population;
M = number of fish marked;
C = catch or sample taken for census; and
R = number of recaptured marks in sample.

Sampling procedure for population estimates differed for each of the three years 1969, 1970 and 1971. During the summer of 1969, over 1,800 brown trout were captured, tagged and released in the Little Deschutes River. Subsequent electrofishing for population estimation was carried out from one week to five weeks following the initial capture. In 1970, 1,300 trout were tagged and released; subsequent sampling occurred two or three days

later. In 1971, fish were released following marking, but the stop nets were left in the stream overnight and the areas were again electrofished the following day.

Age Determinations

For many years annuli on the scales of brown trout have been used to calculate age and growth (length for age). The basic assumption implied or expressed in published work (e.g. Allen 1938; Went and Frost 1942), has been that growth is isometric, the scale and body grow in direct proportions, and the ratio of scale length to fish length remains constant, whatever the length of the fish. The method of back-calculation, which as established for sprats and herring by Lea (1910) and Hjort (1910) was first used for brown trout by Dahl (1910). Dahl stated that the scale growth is proportionate to the growth of the fish, but later added a proviso that there may be reasons to doubt this. Brown trout from different environments have been found to differ in body length/scale length relationship, in some growth was allometric, in some isometric (Kipling 1962).

Cooper (1953) and Nicholls (1957) have studied allometry in brown trout in Michigan and Tasmania, respectively. Cooper concludes that back-calculation by direct proportion cannot be justified, whereas Nicholls concludes that it is justified. Sigler (1952) found allometric growth in brown trout from Utah. Kipling (1962) notes that correction for allometry is required for all fish of age 1 when back-calculation is made by direct proportion.

Scale samples of brown trout were collected throughout the Little Deschutes River as well as from most streams in the Deschutes River Basin. Scales were taken from below the dorsal fin and above the lateral line. Scales from fish that had spawned previously were generally discarded. The scales were examined under a low-power binocular microscope and four to five, chosen as most suitable for back-calculation, were mounted in a glycerine and waterglass medium on a glass slide and examined on a microprojector (88X) screen. Annuli and scale radius were marked off on a cardboard strip for later measurement. Measurements to the nearest millimeter were made from the center of the focus along the median anterior radius of the scale. Generally three representative scales from each fish were measured and the mean value was used in the calculation of the body length-scale radius regression.

The length-frequency distribution has also served as an estimate of the age distribution of a fish population. It is thought that Peterson in 1891 made the original statement of the method. This method is based on the assumption that fish lengths for a single age class are normally distributed. When a uniform sample of a population is taken, which includes all size groups in proportion to abundance, fish lengths may be plotted in a length frequency histogram and a rough approximation of age groups made. If size frequency is a valid index of size groups, several modes should appear in the histogram. The distance between the peaks will be a rough approximation of the population's annual growth increment. The method is useful if employed within its limitations. Age groups can usually be differentiated for the first 2 to 4 years of a fish's life, but older age groups are difficult to segregate because of increasing overlap in lengths. In our study, length frequencies were used to complement scale readings and for a quick determination of age when only minor overlap of histograms occurred.

Mapping of Stream Areas

In order to quantitatively define the physical characteristics of the study areas as well as to estimate the number and kinds of fish utilizing the sites, all study areas were mapped in August 1971, at low stabilized flows of 35-50 cfs. Each study area was classified as to depth and current velocity (Table 3). Transects were established at 10-foot intervals and depths were taken every foot along each transect. Current velocities were measured with a Gurley current meter (Model F 625) at 0.4 feet of the observed depth at approximately 2-foot intervals along the transect.

TABLE 3
Criteria for water-type classification

Water Type	Depth (ft)	Current velocity (ft/sec.)
Shallow-Slow (SS)	0.1-1.5	<1.0
Deep-Slow (DS)	>1.5	<1.0
Shallow-Fast (SF)	0.1-1.5	⩾1.0
Deep-Fast (DF)	>1.5	⩾1.0

Types of cover mapped included brush, overhanging vegetation, undercut banks, aquatic vegetation, downed logs and miscellaneous materials on the stream bed. The term "brush" was used to describe dead submerged woody portions of bank vegetation which were often strengthened by living plants. Overhanging vegetation was categorized as living plants providing an overhead canopy less than one

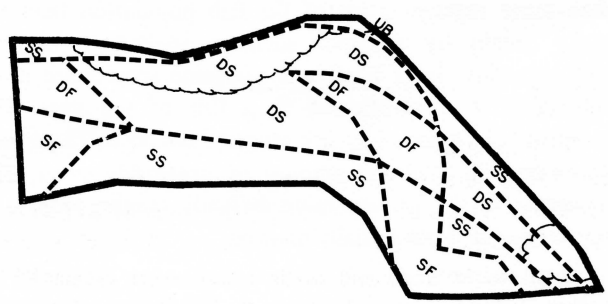


Figure 7. Sample representative map of stream section showing method of depicting water types, depth and cover (SS = shallow slow, DS = deep slow, SF = shallow fast, DF = deep fast, UB = undercut bank).

foot above the water's surface. Miscellaneous cover included underwater shelves made up of clay or rocks, tree roots, rubble and debris. Surface area, water type and extent of cover were determined from maps through the use of a polar planimeter; thalweg depth, and averages of depth, width and volume were calculated for each study area. Figure 7 is a sample representative map drawn to show water types, depth and cover. The data were analyzed by a multiple linear regression and analysis of variance techniques (Bailey 1959; Snedecor 1956) in order to determine the relationships between physical parameters and fish populations.

RESULTS AND DISCUSSION

Population Statistics

Population Size and Age Composition

Brown trout were found at all sites but in varying densities. In the late summer of 1971, as many as 2,300 brown trout (per acre) one year of age and older occupied sections of stream with good cover (Table 4, Figure 8a). The site at Crescent (Figure 8b) was almost devoid of cover and had a population less than half that estimated for other locations.

TABLE 4

Estimated numbers of brown trout per surface acre that were older than one year at four study sites on the Little Deschutes River, 1969-1971

	Year		
Location	1969	1970	1971
Cow Camp		1,246	1,542
Gulick's	1,317 1,652	1,261 1,502	2,342
Old Mill		1,320	1,714
Crescent	540 609	541	

The population estimates in 1969 and 1970 are considerably lower than in 1971, largely because the streamflow was lower; 31 cfs in 1969 and 1970 compared to 53 cfs in 1971 (Appendix I). Also, there was a different interval between marking and recapture, and some mortality of marked fish or movement from the study sites may have occurred.

In 1970 and 1971, population estimates were calculated for each age class at each site (Table 5, Figure 9). The number of older trout, ages three to five, was greatest upstream of Crescent where better habitat was available.

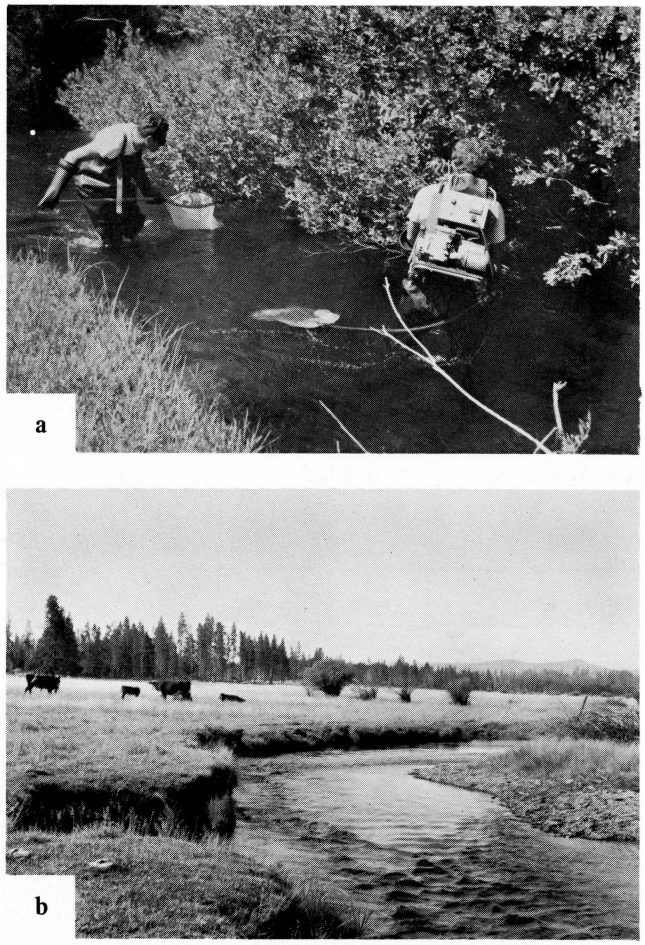


Figure 8. **Contrasting brown trout habitat (a) large brown trout populations found in areas having good streamside cover, Old Mill; (b) over-grazing and stream bank erosion reduce brown trout populations, Crescent.**

Downstream of Crescent the bulk of the population was composed of trout one year old and younger. Since fry (0-age) were not always captured in relation to their abundance, numbers given (for fry) in Table 5 may not be valid population estimates.

The average age of the population decreased downstream. At Cow Camp, all age groups were well represented whereas at the Conifer and Crider sites, zeros and one-year-old fish comprised 90 percent of the population (Figure 9). The population of trout older than one year that became legally catchable increased from 20 percent at Cow Camp to 57 percent at Crider's (Figure 9).

Biomass

Biomass or standing stock is the total weight of all living individuals of the species at any given time. It is the sum of the products of numbers of individuals and mean individual weight for all homogenous groups within the population. In the present study, biomass was calculated from population estimates and average weight for each one-centimeter

TABLE 5
Estimated number of brown trout per acre by age group at study sites, 1970-1971

Location	Age Group 0*	I	II	III	IV	V
1970						
Cow Camp	433	830	238	115	60	3
Gulick's (a)	1,287	670	454	110	39	0
(b)	1,124	833	489	128	50	0
Old Mill	1,374	888	299	87	47	5
Crescent	943	349	118	52	22	0
1971						
Cow Camp	677	994	321	151	52	25
Gulick's	702	1,379	745	163	50	14
Old Mill	1,145	1,159	276	210	56	19
Rocky Reach	1,623	355	32	17	2	1
Willows	2,864	796	115	21	8	3
Larson's	7,235	242	163	17	3	0
Conifers	1,551	414	47	21	6	2
Crider's	1,642	405	65	11	8	3

*Fish of zero age were not captured in relation to their abundance.

group. Since the surface area of each study site is known, the biomass was converted into pounds per surface acre (Table 6). The estimated standing stocks at Gulick's and the Old Mill were highest and probably reflect better habitat and cover. The biomass of brown trout older than one year at these locations was at least twice that estimated elsewhere (Table 7). Estimates of standing stock of brown trout 15 cm and larger at Gulick's and the Old Mill were more than 100 pounds per surface acre (Table 7) whereas estimates for other areas ranged from 30 to 60 pounds. Upstream of Crescent only 1 to 4 percent of the total biomass is composed of other species (brown bullhead, roach, whitefish and cottids) whereas downstream of Gilchrist log pond the other species comprise 16 to 24 percent (Table 7, Figure 10).

In New Hampshire, Hoover and Morrill (quoted by Needham, 1940) found the average biomass of brook trout in two small streams to be 35.7 pounds per acre, whereas other species of fish present brought the total to 41.4 pounds per acre. In Michigan, trout stocks weighed between 1.4 and 96.9 pounds per acre with total biomass of all species between 4.1 and 178.0 pounds per acre (Shetter and Hazzard 1939; Shetter and Leonard 1943). Schuck (1945) found the mean stock of brown trout of Crystal Creek in New York to be 13.8 pounds per acre. Higher standing crops were recorded by Needham, Moffett and Slater (1945) from Convict Creek in California, which contained only trout. The weight of trout appeared to be significantly affected by angling, since the standing crop in a closed angling section varied yearly between 214 and 434 pounds per acre, while in the same period the crop of another section open to angling was between 40 and 146 pounds per acre. Allen (1951) reported biomass estimates of trout in the Horokiwi (New Zealand) that are generally higher

TABLE 6
Biomass estimates (pounds per acre) of brown trout in August 1970 and September 1971 for each year class at various study sites

Location	Age Class 0[a]	1	2	3	4 and older	Total biomass
1970						
Cow Camp	1.4	20.8	15.0	15.0	16.8	69.0
Gulick's	5.0	24.5	42.3	17.7	17.2	106.7
Old Mill	9.2	42.3	32.5	20.0	18.5	122.5
Crescent	5.9	14.4	13.3	10.4	10.0	54.0
1971						
Cow Camp	1.9	22.7	19.8	20.2	19.3	83.9
Gulick's	4.3	50.0	71.9	31.3	41.7	199.2
Old Mill	7.2	59.6	32.4	53.9	27.6	180.7
Rocky Reach	13.1	28.3	5.6	6.3	3.0	56.3
Willows	18.8	53.4	16.7	8.6	8.4	105.9
Larson's	51.2	18.0	21.3	6.6	3.4	100.5
Conifers	11.5	35.1	10.6	9.1	10.2	76.5
Crider's	16.3	30.7	11.8	5.7	25.9	90.4

[a] Incomplete estimate for 0-aged fish.

TABLE 7
Biomass estimates (pounds per acre) of brown trout one year and older in age, and other species occupying study sites in September 1971

Location	Biomass brown trout 1+ and older	Biomass brown trout ⩾15 cm	Biomass other species	Other species as percent of total biomass
Cow Camp	82.0	45.1	3.1	3.6
Gulick's	194.9	135.3	1.9	1.0
Old Mill	173.5	116.5	0	0
Crescent (1970)	48.1	34.5	6.7	11.0
Rocky Reach	43.2	30.7	14.5	20.5
Willows	87.1	51.3	26.4	20.0
Larson's	49.3	38.8	31.8	24.0
Conifers	65.0	52.7	15.2	16.6
Crider's	74.2	61.2	25.8	22.2

than have been recorded for North American trout streams. In addition to supporting over 200 pounds per acre of trout, the Horokiwi also contained native fish.

The standing stock of native legal brown trout in the Little Deschutes River ranged from 30 to 135 pounds per acre (Table 7). Although the entire stream is open to angling, it is fished lightly in comparison to streams elsewhere in the United States. Only the areas at Crescent and Cow Camp receive much angling pressure. If the Little Deschutes River were fished as intensively as eastern and mid-western streams, the standing crop of legal brown trout would probably stabilize at 15-30 pounds per acre.

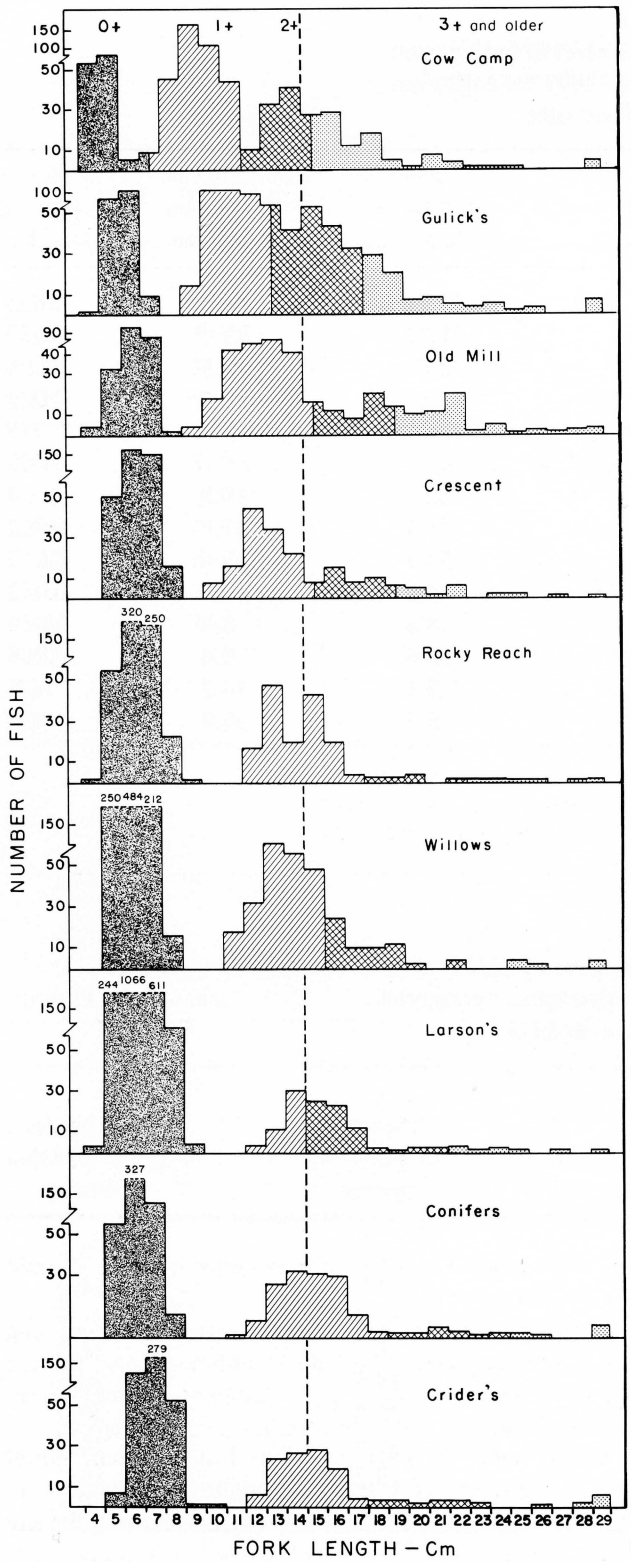


Figure 9. 1971 population estimates and age composition of brown trout at study sites (vertical line indicates legal length).

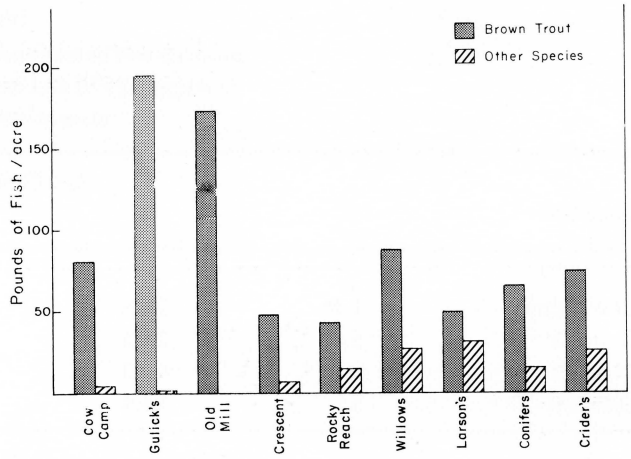


Figure 10. Biomass estimates of brown trout one plus and older and of other species occupying study sites.

Coefficient of Condition

The coefficient of condition or length-weight ratio of stream trout varies during the year and is related to growth (Went and Frost 1942; Cooper and Benson 1951; Cooper 1953; Ellis and Gowing 1957). Coefficient of condition is a useful measurement of seasonal growth changes and is a means of comparing relative well-being. On the upper Little Deschutes River fish from the Gulick's study site and Hemlock Creek showed lower coefficient of condition values than did fish from Big Marsh Creek, Crescent Creek, or the irrigation canal (Table 8). These lower condition factors probably result from the high trout densities and reduced food potential in the upper study sites. Similarly fish captured in the fall were generally in better condition than those captured in the spring (Table 8).

In 1971 the condition of brown trout was calculated for fish captured in August and September. They were combined into size groups representative of their age classes (Appendix V). Brown trout that fell into the 4 cm group at Cow Camp and Gulick's were in significantly (P=.01) better condition than other fish from these stations. Brown trout in the 10-20 cm groups downstream of Gilchrist pond had a higher condition than those above the pond (Appendix V). The greater coefficient of condition is probably related to the lower density of fish. No significance can be given to differences in coefficient of condition of fish in the 25 cm group since there were so few fish available.

Maturity

In the upper Little Deschutes River, some brown trout mature after their third summer of life (2+) although the majority mature at 3+ (Table 9). All were mature by the end of their fifth summer. Both sexes matured in similar proportions at age 2+ (Table 9). The smallest mature male and female were 14.5 cm and 14.8 cm, respectively. Only a

TABLE 8
Coefficient of condition of brown trout in Little Deschutes River and tributary streams, 1969-1970

Location	Date	Number of fish in sample	Average length (cm)	Coefficient of condition	S.E.
Big Marsh Creek	7/17/69	16	13.3	1.066	0.033
Big Marsh Creek	10/31/69	9	17.4	1.081	0.030
Crescent Creek	10/16/69	25	22.7	1.142	0.028
Hemlock Creek	7/14/69	27	13.6	0.980	0.022
Hemlock Creek	5/28/70	23	12.1	0.998	0.018
Gulick's	10/31/69	89	14.0	0.967	0.008
Gulick's	4/27/70	23	12.7	0.926	0.013
Gulick's	5/15/70	15	11.7	0.934	0.022
Old Mill	4/21/70	35	13.9	0.948	0.012
Old Mill	9/23/70	61	19.0	1.055	0.012
Irrigation Ditch - Crescent	6/18/70	28	12.3	1.135	0.016
Vandverts Ranch	9/15/70	47	23.7	1.011	0.008

TABLE 9
Age at maturity of brown trout from Little Deschutes River, 1969 and 1970 (combined)

Sex and state of maturity	Age and Length 2+ (14.5 - 19.5 cm) Number	Percent	3+ (20.0 - 26.0 cm) Number	Percent	4+ and older (≥26.5 cm) Number	Percent
Male immature	173	46.8	39	25.5	0	
Female immature	135	36.5	16	10.5	0	
Male mature	30	8.1	42	27.4	21	65.6
Female mature	32	8.6	56	36.6	11	34.4
n	370		153		32	

few of the fish scales collected from mature or maturing fish in the Little Deschutes River showed evidence that the fish had spawned previously. Apparently few survive the rigors of spawning, subsequent loss of body condition, and the harsh winter environment that follows. In contrast, scales from some of the large brown trout from Wickiup Reservoir, Suttle Lake and Gilchrist Pond often showed two or three spawning checks.

Brown trout spawn from September to January in various areas of Oregon but in the Little Deschutes River spawning usually commenced in mid-September and was completed by mid-November. Although several factors undoubtedly influence the actual date of spawning, the completion of maturation is obviously of prime importance in determining the earliest date within the period. Stuart (1953) noted that climatic conditions were correlated with the condition of the ovaries in the spring and that a very cold winter appeared to retard initial growth whereas a mild winter accelerated it.

There appears to be only limited movement of spawning fish in the Little Deschutes River, although some fish are known to move upstream approximately one mile from Gilchrist Pond into the Little Deschutes River to spawn.

Since there are only sparse and intermittent gravel deposits upstream of Crescent, a number of females were observed digging redds in coarse pumice. Generally the site chosen for the redd was situated at the tail of a pool or at its side where the water velocity did not exceed 1.5 fps and depth was at least 0.8 feet. The pumice redds were quite shallow and females that used the areas showed few of the exterior signs of spawning such as eroded caudal and anal fins. Judging from the number of fry observed during the summer, spawning appears to be successful at most sites except at Cow Camp (Appendix VI).

Fecundity

The relationship between size of fish and number of eggs produced is important in studying the reproductive potential of fish populations. The fecundity of brown trout has been examined by workers in New Zealand (Allen 1951; Hobbs 1937; and Hardy 1967); England (Bagenal 1969); Tasmania (Nicholls 1958); United States (Brown and Kamp 1942; McFadden et al. 1965); and Sweden (Alm 1949). Most workers noted a direct relationship between length or weight of females and number of eggs. Selected fish were measured and ovaries taken and preserved in formalin. Any female from which ova could be stripped was discarded from our study. The number of ova was determined by separating the eggs from connecting tissue and counting them individually.

There was a curvilinear relationship between egg number and fish length (Figure 11). In the Little Deschutes River, mature females ranged from 14.8 to 56.7 cm, although egg counts were made on some larger females from Gilchrist Pond and Browns Creek. Numbers varied from 128 to 3,148 for females from the Little Deschutes River. One female of 63 cm from Browns Creek contained over 5,000 eggs. The majority of females from the Little Deschutes River were from 17 to 26 cm and contained 150 to 400 eggs. The regression line which best fit the 1969 and 1970 data was $Y = 977 - 8.28 x + 0.022x^2$. Evidently any large female that spawns successfully could equal several smaller females in biotic potential.

Eggs were found to vary between fish in size and number, even from fish of the same length and stock, but eggs produced by an individual female tended to be uniform in size. The mean egg diameter for brown trout from Crescent (4.13 mm) was significantly larger ($P = .01$) than at Cow Camp (3.68 mm) whereas egg number and fish size at these locations were similar. Whether survival or growth of the resulting alevins is enhanced by the larger egg size is not known. However, Bagenal (1969) concluded from a series of experiments that under natural conditions in the Lake District, the survival of trout is significantly greater in fry derived from large eggs.

Survival Rates

Survival rates were calculated from the age composition data in Table 5 with the assumption that the populations remained stationary during the histories of age groups I through IV (Table 10). This is a valid assumption for most stream-dwelling trout populations (McFadden et al. 1964); successively older age groups are usually represented by

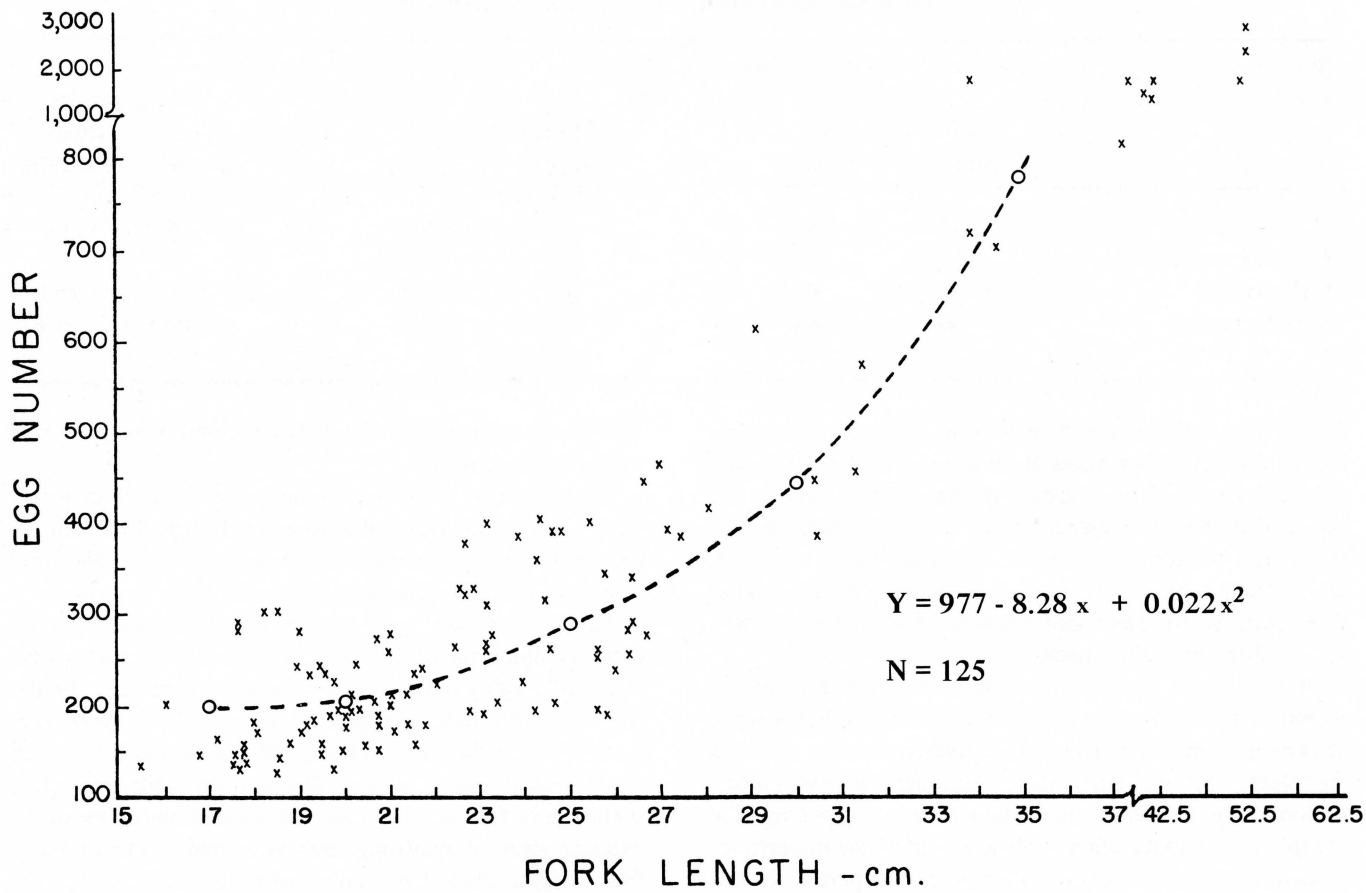


Figure 11. Relationship of egg number to fork length for brown trout collected from Little Deschutes River.

TABLE 10
Annual survival of brown trout as calculated from age composition of each population, 1970-1971

Location	Age Groups 0-1	1-2	2-3	3-4	4-5	Mean 1-4
1970						
Cow Camp	[a]	0.335	0.430	0.359	0.050	0.350
Gulick's (a)	0.497	0.474	0.247	0.262	0.0	0.474
(b)	0.572	0.444	0.266	0.280	0.0	0.444
Old Mill	0.492	0.332	0.232	0.379	0.106	0.329
Crescent	0.370	0.370	0.436	0.294	0.0	0.370
1971						
Cow Camp	[a]	0.321	0.435	0.378	0.481	0.316
Gulick's	[a]	0.416	0.237	0.300	0.280	0.419
Old Mill	[a]	0.330	0.526	0.281	0.339	0.330
Rocky Reach	0.201	0.132	0.429	0.250	0.500	0.126
Willows	0.248	0.156	0.222	0.400	0.375	0.152
Larson's	0.056	0.434	0.115	0.167	0.0	0.434
Conifers	0.240	0.157	0.400	0.333	0.333	0.152
Crider's	0.235	0.196	0.360	0.857	0.375	0.187

[a]Incomplete estimate for fish of 0-age.

progressively diminished numbers of fish. Seldom is the situation encountered where a very large year class numerically dominates the population over a period of years. Weighted mean annual survival rates were calculated from Formula 2.2 of Ricker (1958) as follows:

$$\hat{s} = \frac{N_2 + N_3 + N_4 + \ldots + N_r}{N_1 + N_2 + N_3 + \ldots + N_{r-1}}$$

Brown trout of zero age were less abundant than yearlings at Cow Camp in 1970 and 1971, and at Gulick's and the Old Mill site in 1971. These were the only situations which violate the above assumption, as a result the analysis was restricted to age groups I through IV. The exceptions all occurred in areas of good protective cover where zeros were probably not captured in relation to their abundance.

Under the assumption that the populations were stationary, average annual egg production is equal to the egg complements of the stocks of Table 5. The variables used in computing egg complements were (1) percentage of females in each age group (50:50); (2) percentage of mature females in each age group (Table 11); (3) average egg complement of fish (Figure 11); and (4) average size of fish at each age (Table 11). The number of yearling trout (Table 5) divided by average annual egg production provides an estimate of survival during the first 24 months of life (Table 12).

The survival data have been arranged in an ecological life table (Table 12). The general procedure and several examples from the literature are given by Andrewartha and Birch (1954). The age of the fish (x) is given in years, with the egg stage being taken as x=0. Therefore, a yearling trout is designated as age two in the table, and age group II fish as age three, etc. Frequently only females are included in calculations, but because the Deschutes area populations consisted of equal proportions of both sexes in all age

TABLE 11
Maturity and estimated egg production in brown trout of several ages from Little Deschutes River, 1969-71

Age group	Mean length (cm)	No. of fish	Percent mature	Estimated fecundity
II	17	134	14.9	205
III	23	48	70.8	237
IV	28	3	100.	384
V	31	1	100.	524

TABLE 12
Ecological life table and age-specific fecundity rates for stationary populations of brown trout in the Little Deschutes River, 1970-71

Year	Age in years (x)	l_x	m_x	$l_x m_x$	$\Sigma l_x m_x$
1970	2	0.0335	0	0	
	3	0.0125	15.58	0.1947	
	4	0.0047	84.02	0.3949	
	5	0.00176	192.0	0.3379	
	6	0.00066	262.0	0.1729	
					R_o = 1.100
1971	2	0.0336	0	0	
	3	0.0119	15.6	0.1856	
	4	0.0042	84.4	0.3545	
	5	0.0015	192.0	0.2880	
	6	0.0005	275.8	0.1379	
					R_o = 0.966

groups the data also apply to both sexes combined. The l_x column gives the probability at birth of being alive at age x, l_0 being taken as unity. The value of l_2 for each population is the ratio of the number of yearlings to average annual egg production. The values of l_3 were calculated by multiplying l_2's by the mean annual survival rates for age groups I to IV; l_3's multiplied by mean annual survival rates gave l_4's, etc. Mean annual survival rates were used rather than rates for the individual ages in order to decrease sampling errors which become large for the older age groups, and because most studies of brown trout populations suggest that survival is fairly uniform over the ages presented in these data.

The m_x column gives the number of female eggs produced per year by a female of age x. Each value is the number of eggs produced by the age group divided by the number of fish in the age group. Both dividend and divisor are double the actual number of females, of course, so that in these populations "female eggs per female is equivalent to total egg production per fish." Generally, survival during the first two years of life is lower than during the third, fourth and fifth years. Actually the period of heavy mortality is probably restricted to the first few months of life (Allen 1951; Shetter 1961; Latta 1962; LeCren 1965), and survival during the second year, at least, is similar to that presented in the life tables for the later years. Yearling females in the Little Deschutes did not reach maturity as was noted in streams studied by McFadden et al. (1964) and thus m_2 is 0. Maximal values of $l_x m_x$ are reached at x=4.

The net reproduction rate, R_o, calculated by summing the $l_x m_x$ products, is the ratio of total female births in two successive generations, or, since the sex ratio in this case is 1:1, the multiplication per generation of the entire population. When R_o is less than unity, the population is declining; when R_o is greater than unity, the population is increasing. The values in Table 12 must approximate unity because the brown trout population was assumed to have been stationary during the study period. The assumption is the basis for the estimate of average annual egg production. Thus, the l_2 value computed for the population is that value which produces a $l_x m_x$ of approximately unity. High or low survival of young fish, survival of adults and fecundity rates may act in almost any combination to keep a brown trout population stationary (Table 10). Each rate would probably be determined by environmental factors, and obviously it is through the survival and fecundity rates that environmental influences determine population density.

The survival of adult trout in the Little Deschutes River is fairly high, probably indicating light cropping of the population. The survival of young is high also, but the stream is infertile and the fecundity rate is consequently low, offsetting high survival to produce a stationary population. Allen (1951) found that for the Horokiwi the survival rate for several brown trout populations varied between 0.21 and 0.07. He noted that a more relevant comparison is provided by the data of Schuck (1945) who studied a stream-living brown trout population, in which the survival from year to year over the first five years varied irregularly between 0.22 and 0.50. Other data on mortality rates in trout populations in streams are provided by Shetter and Hazzard (1939). In two Michigan trout streams they found that the survival from year to year over the first four years varied irregularly between 0.14 and 0.35, with a mean of 0.20. In the Hinds River, New Zealand, Lane

(1964) noted that survival from Age II onwards ranged from 0.09 to 0.18. Needham, et al. (1945) found that in Convict Creek the average survival of brown trout for one year after the first autumn averaged 0.15, although it varied from year to year between 0.09 and 0.41 and was largely dependent on severity of the winter. Older trout apparently had higher mortality rates. In the Little Deschutes River (above Crescent) the survival rate for the brown trout population varied between 0.25 and 0.57. Downstream of Crescent the survival of the younger age groups (0-II) was lower than that calculated for ages III to V (Table 10).

Age and Growth

Anterior scale radii were measured for 1,336 fish captured in the Little Deschutes River from 1965 to 1971. The relationship between anterior scale radius and fork length can be represented by a straight line although two straight lines would be more accurate because fish from 5 to 12 cm appear to grow faster than their scales (Figure 12).

A regression line was calculated from the scale-body relationship shown in Figure 12. Attempts to utilize a body-scale regression to back-calculate previous growth always led to underestimation. When a nomogram was used and the focus set at 3.5 cm a more realistic estimate of growth at prior ages was attained. Consequently, back-calculations of growth were made with the aid of a computer program using a correction factor of 3.5 in the Rounsefell-Everhart (1953) formula:

$$L^1 = C + \frac{S^1}{S}(L - C)$$

where L^1 = length of fish when annulus formed:
L = length of fish at time scale sample obtained;
S^1 = length of scale radius to annulus;
S = length of total scale radius; and
C = correction factor representing body length at scale formation.

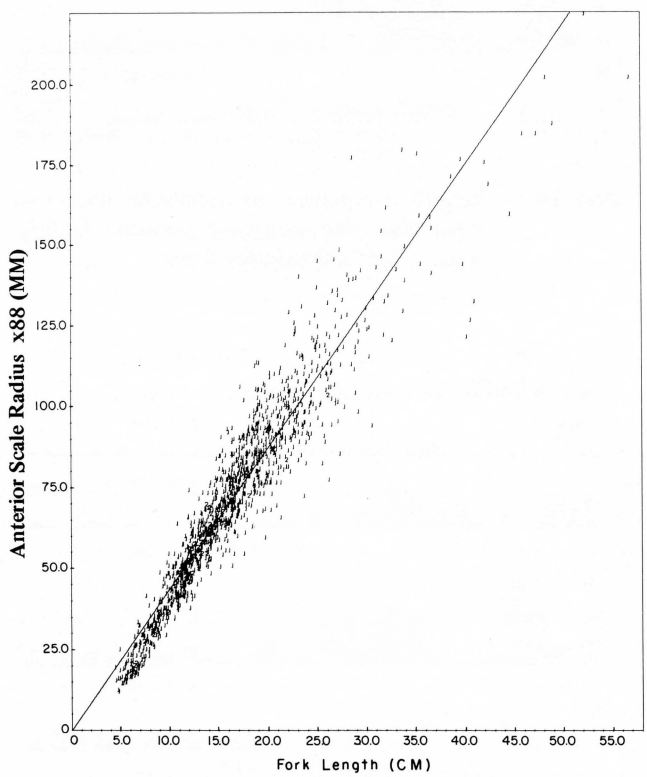


Figure 12. Body-scale relationship of 1,336 brown trout from Little Deschutes River.

Growth of brown trout from the Little Deschutes River is slow and fish average 7 cm by the end of their first summer. The average back-calculated lengths for brown trout (from the Little Deschutes River) at annulus formation for years 1-5 were: 7.6, 12.4, 17.2, 21.9 and 28.7 centimeters (Appendix VII). The "legal" length of 15 cm (6 inches) was reached in the third summer of life. Growth was relatively uniform during the first three years and increased slightly from ages IV to VI, possibly because larger fish were more piscivorous. Age groups I and II were the most plentiful and 86 percent of the fish sampled were in age groups I-III.

In comparison to fish 40 miles downstream, those in the headwater region are smaller throughout their lives (Figure 13, Appendix VII). Trout from the upper three stations showed similar growth, but when compared to those at Crescent and other downstream areas, their growth was considerably slower after the first year of life. The changes in growth rate within the 40 miles of stream can be accounted for by temperature differences between the headwaters and downstream areas, and a lower density of fish in downstream areas.

Growth of brown trout in the Little Deschutes River system is neither as fast as that reported by Schuck (1945) for Crystal Creek, New York, nor as fast as that reported by Bishop (1955), Purkett (1951), or Kathrein (1951) for streams in Montana (Table 13). Brown trout growth rates observed in 28 other Oregon streams (Appendix VIII) were similar to that found in the Little Deschutes River. The slow growth in the Little Deschutes River is also indicated by the length-frequency distributions (Figures 14 and 15). Growth of fish of zero age appears to be moderate from emergence through the fall months, with virtually no growth in winter. Trout older than one year grow slowly during the summer and fall and achieve most of their growth in the spring. The growing season is further defined by growth observed for recaptured marked fish (Appendix IX). Brown trout marked in May and recaptured in September showed the greatest daily average increment of growth whereas those marked in October and recaptured the following March, showed the least. Beyerle and Cooper (1960) found that half of the yearly growth occurred in a

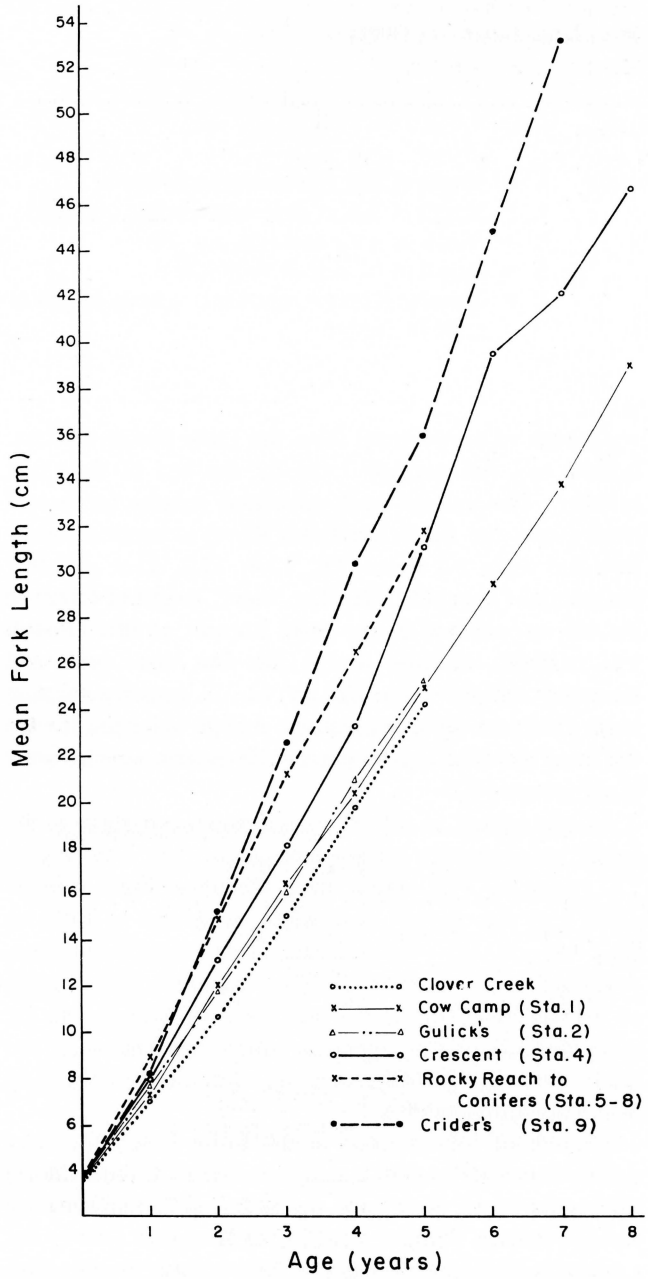


Figure 13. Average growth rates of brown trout from study sites on the Little Deschutes River.

two-month period, mid-April to mid-June in Pennsylvania streams with almost no growth for the months of December through March. In England, Egglishaw (1970) and Mann (1971) both noted that the most rapid trout growth occurred during the months of April through June with decreased growth from July to November and no growth from November to March.

Migration and Movement

There is little migration of brown trout in the Little Deschutes River south of Gilchrist. In the summer of 1969 and 1970, over 3,000 "dangler tags" were placed on "legal" native brown trout captured in the upper Little Deschutes River. One hundred and three tags from angler-caught brown trout were returned during the 1969-1971 fishing seasons; six additional tags were returned in the summer of 1972. Of the 109 tags returned by anglers, all but three were taken in the vicinity of the tagging site. The exceptions had moved one mile downstream and taken up residence in Gilchrist Pond. A total of 438 brown trout tagged 1-15 months earlier (Appendix IX) were recaptured in the immediate vicinity or had moved a maximum of 300 yards from their release point. Electrofishing in areas between tagging sites in 1969, 1970 and 1971 produced only 2 tagged fish that had strayed up to 5 miles downstream. During the spawning season a few large brown trout (40-55 cm) which had migrated upstream from the log pond to find a suitable spawning area were captured south of Crescent. Having taken up residence, brown trout remain in specific areas in the Little Deschutes River.

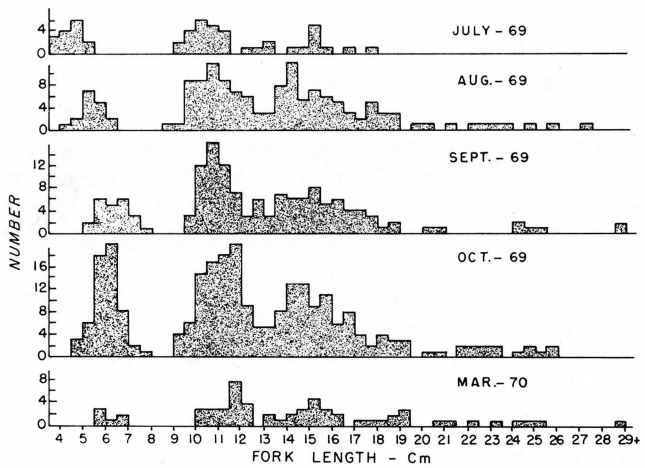


Figure 14. Length frequency distributions of brown trout for five sampling periods, Gulick's station, Little Deschutes River.

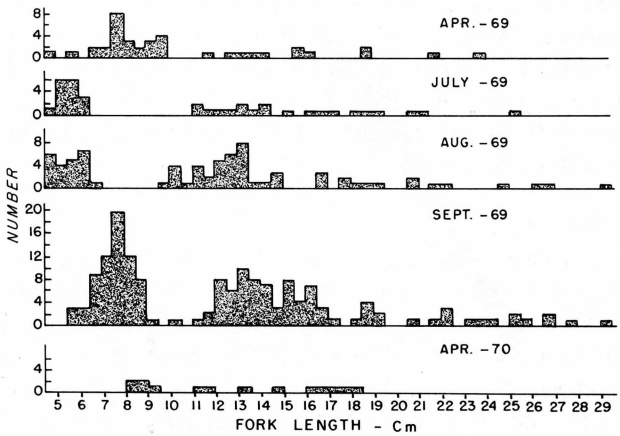


Figure 15. Length frequency distribution of brown trout for five sampling periods, Crescent station, Little Deschutes River.

TABLE 13
Comparison of growth of brown trout from Little Deschutes River with that in streams in Montana and New York

Age	Mean length (cm) L. Deschutes River	Crystal Creek[1]	Prickley Pear Creek[2]	Missouri River[3]	West Gallatin River[4]
1	7.6	15.2	9.7	10.0	9.4
2	12.4	19.5	19.7	20.7	22.5
3	17.2	26.0	28.2	30.5	33.6
4	21.9	29.3	35.0	38.8	40.6
5	28.7	35.3	42.0	46.1	48.3

[1] Schuck, 1945
[2] Bishop, 1955
[3] Kathrein, 1951
[4] Purkett, 1951

Since good spawning gravel is intermittent and sparse in much of the Little Deschutes River and density of brown trout high at most stations, some downstream movement of fry must occur. No measurement of such movement was obtained.

In the main Deschutes River a substantial movement of ages 0+ - II+ brown trout occurs during the spring and summer into the irrigation canals (Appendix X). Whether this movement is influenced by the sudden increase in streamflow (reservoir releases) or due to increased population density (fry emergence) and subsequent aggressive territorial action is not known. In Montana, Clothier (1953) found no correlation between size of irrigation canal or volume of flow and the number of fish lost. He did note, however, that canals that had creeks entering them had a greater abundance of fish. A downstream movement of juvenile trout (0+, I+ and II+ fish) from nursery streams into loughs prior to the winter was noted by Stuart (1957) and Vickers (1969). Similarly, Jones (1970) noted a downstream movement of 0+ and I+ trout from streams in Wales for most months from September through November, whereas, Allen (1951) concluded that relatively little movement occurred in the Horokiwi. Allen regarded the trout population as being not only isolated and self-contained but also composed of a succession of distinct local populations.

Food Habits

Stomachs were excised from fish collected by electrofishing in areas adjacent to study sections.The "occurrence" method was used for analysis (the percentage that one invertebrate form comprised of the stomach contents). Stomachs were divided into three groups based on fish size, 0-age fish (fry 3.6-9.0 cm), one and two-year-olds (10.0-19.9 cm), and older fish (≥ 20.0 cm).

Ephemeropteran nymphs and simuliid and trichopteran larvae and pupae were the most important foods of fry (Table 14, Figure 16). Aquatic insects were important in the diet of one and two-year-old fish but terrestrial insects were also present (Table 15,* Figure 16).Terrestrial insects were most important in the diets of older fish except at Cow Camp where other aquatic insects belonging to the orders of Coleoptera, Diptera and Plecoptera were predom-

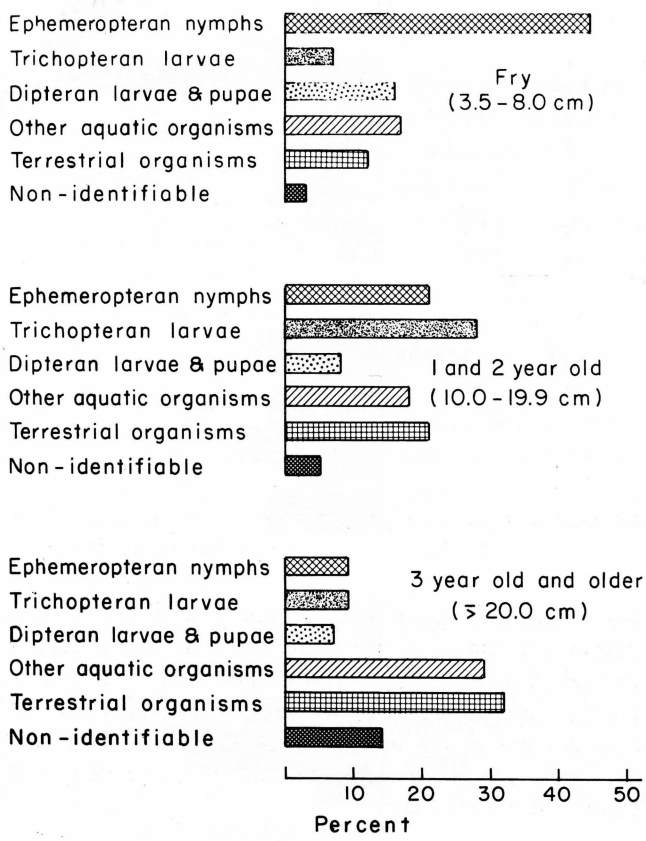


Figure 16. Percent of total food organisms from brown trout stomachs, Gulick's station, Little Deschutes River.

*See Appendix XI

TABLE 14
Food of brown trout fry taken at Gulick's on the Little Deschutes River. Food items expressed as percent of total volume of organisms eaten.

	Sampling period						
	7/25/69	10/2/69	4/27/70	5/15/70	7/13/70	8/4/70	10/22/70
Number of stomachs	9	5	8	5	6	10	5
Average volume (cc)	0.15	0.02	0.01	0.1	0.1	0.1	0.1
Ephemeropteran nymphs	35	10	60	45	50	45	70
Trichopteran larvae		10	10	10	15	10	
Dipteran larvae & pupae	60	15	15	15	5	15	15
Aquatic Coleopteran larvae	3	30	10	20	15	20	10
Plecoptera				5			
Terrestrial organisms	1	30[a]				3	
Unidentified & miscellaneous organisms	1	5	5	5	15	7	5

[a]Annelids following heavy rains

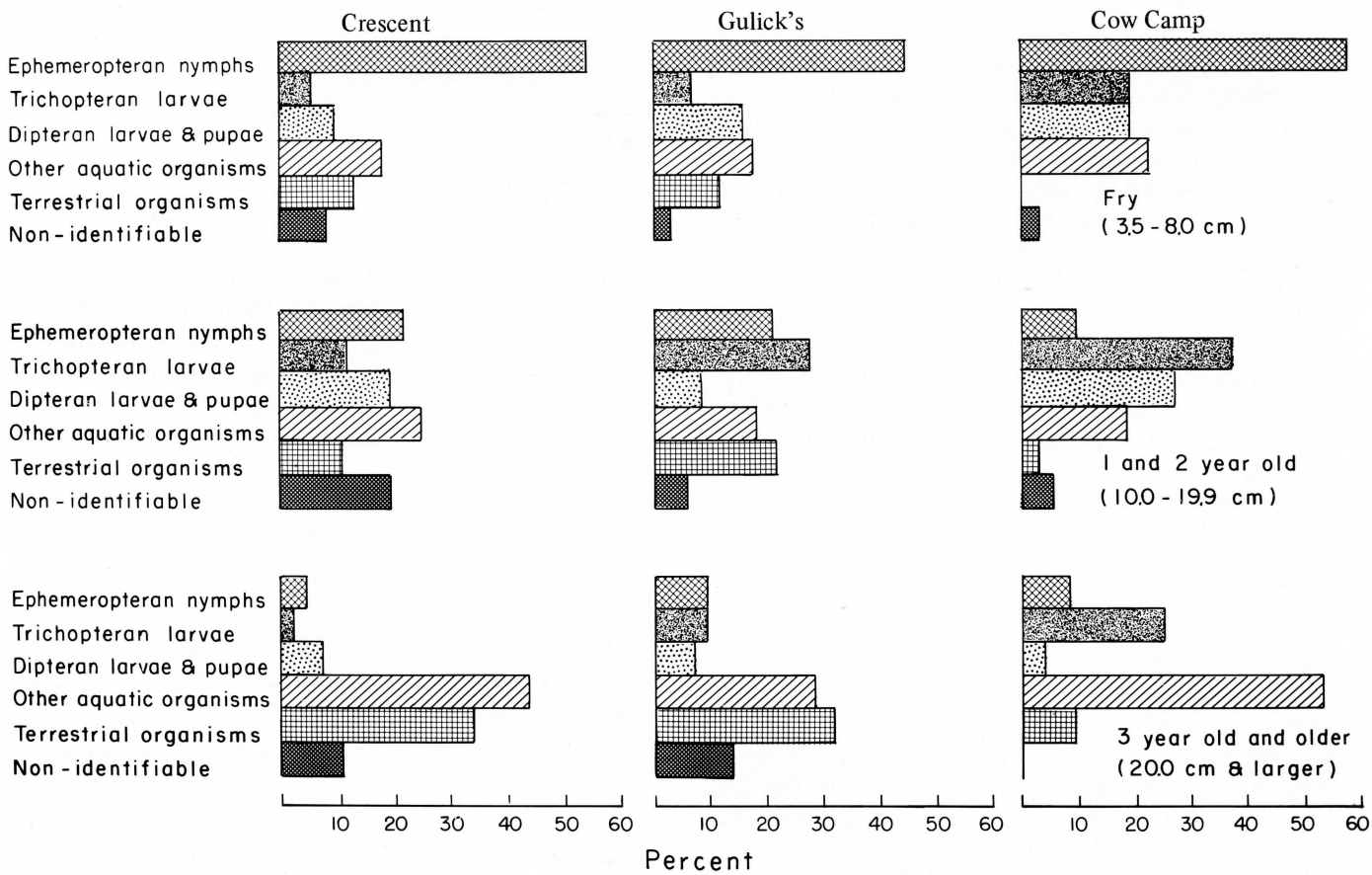


Figure 17. Percent of total food organisms from brown trout stomachs at three study sites, Little Deschutes River.

inant (Figure 17). Fish were also important in the diets of larger brown trout but were not represented in each sample period.

In order to compare "competition" for food between trout and other species, gill nets and trap nets were set in Gilchrist Pond during 1969 and 1970. Even though it is atypical of the natural stream, Gilchrist Pond was used for the comparison of diets, since many species of fish were present and were readily caught. Diptera (all stages), especially members of the family Chironomidae, were important to brown trout (Table 16*). Odonata, Ephemeroptera and Coleoptera were also eaten. Snails and fish were common during most months. Brown bullheads fed extensively on larvae and pupae of Ephemeroptera and Diptera and to some extent on snails and freshwater shrimp. Although many of the roach examined had empty stomachs, others had fed on larvae and pupae of Diptera, snails, amphipods and aquatic vegetation (Table 16).

The three species for which significant numbers of stomachs were obtained had overlapping food habits. Trout fed on all stages of aquatic insects whereas the roach and brown bullhead ate almost no adult insects. Thus, the trout fed at the surface as well as on the bottom in comparison to roach and brown bullhead which obtained all their food below the water's surface.

In 1970 a one-mile section of the main Little Deschutes River at the Vandevert Ranch was treated with 2 ppm of rotenone. Fish affected by the toxicant were collected in stop nets. All trout were measured and weighed as was a representative sample of roach, whitefish and brown bullhead. Stomachs were collected from each species (Table 17*). Most of the fish fed on Ephemeroptera, Diptera and Trichoptera. The brown trout was the most diverse in its food habits. Fish collected from the Little Deschutes River below Gilchrist Pond had similar food habits (Table 17).

Hopkins (1965) noted that there was overlap in food requirements of four species of fish in a New Zealand stream. Three species fed extensively on mayflies (*Deleatidium*) although each favored a different size range. McCormack (1962) concluded that competition for food between trout fry, bullheads (*Cottus gobio* Linnaeus), and young Atlantic eels (*Anguilla anguilla* Linneaus) might be serious in some situations. Similarly, Maitland (1965) found common food requirements of salmon fry, trout, minnows, stone loach and three spined sticklebacks and suggests that under certain conditions that there is competition for food among them. Whereas, Thomas (1962) concluded that no serious interspecific competition takes place between salmon, trout and eels in the River Teify. He noted that when species coexisted they lived on different foods for several reasons including territorial segregation. Similarly, Straskraba et al. (1966) concluded that there is little evidence of competition for food among brown trout, minnow (*Phoximus phoxinum* L.), carpathian sculpin (*Cottus poecilopus* Heckel) and stone-loach (*Nemacheilus barbatulus* L.), in a Czechoslovakian stream. Their fish were collected in a short period in July and thus their observations are limited. Nevertheless, they found a differentiation of the niches from which the three most common species of fish obtained their food. The authors stress that too often data in the literature which has led to opposite results is too limited to be conclusive.

*See Appendix XI.

Factors Influencing Fish Populations

Physical Parameters of Study Sites

Individual sites ranged in surface area from 8,300 to about 18,000 square feet, with volumes from 14,000 to 35,000 cubic feet (Table 18). Average depths varied from 1.2 to 2.3 feet and average widths from 19 to 27 feet. The average current velocity ranged from 0.8 to 1.7 feet per second. There was no predominant water type at all sites. Deep slow waters were dominant at four of the sites and accounted for 50 percent or more of the water mapped. Water that was deep and fast dominated at three sites and at the remaining two it was shallow and fast.

Total cover ranged from 3,700 square feet at Cow Camp to 500 at Crescent (Appendix XII). The relationship of total cover to surface area ranged from 27 percent at Gulick's to 5 at Crescent. Willows (*Salix* sp.) were the most important species of plant, constituting cover at six of the sites. Aquatic vegetation (*Potamogeton* sp., *Ranunculus* sp., and *Anacharis* sp.) and semi-aquatic vegetation (grasses and sedges) were common and dominated at two areas. Downed trees and logs provided the dominant cover at the remaining location.

Fish Populations of Study Area

Trout less than 8 cm (3-3½ inches) were primarily fish of the year. They constituted from 8 to 81 percent of the total number of fish sampled but less than 25 percent of the weight, except at Larson's where they constituted about 51 percent. Because young of the year were not collected in proportion to their abundance, they were excluded from most analyses.

Standing crops of all species of fish larger than 8 cm were estimated (Table 19, Figure 18). Brown trout constituted over 98 percent of the trout in the Little Deschutes River system. Only at the Cow Camp was the number of brown trout lower (92 percent). Other species constituted an average of 19.2 percent of the fish populations. Roach (*Gila bicolor*) were the most plentiful, followed by whitefish and brown bullheads. Fish communities at study stations varied from a pure culture of brown trout (Old Mill) to one dominated by rough fish (Larson's; 35.5 percent brown trout and 57.7 percent roach, Figure 18).

Relationship of Trout Populations to Physical Environment

Attempts to use a multiple linear regression with surface area, volume, water type, total cover, average depth, width,

TABLE 18
Physical parameters of study sites at low flows of 35-50 cfs in the summer of 1971

Location	Surface area (ft^2)	(acres)	Volume (ft^3)	Average depth (ft)	Average width (ft)	Average current velocity (fps)	Water types (%)[a]	Total cover (ft^2)	(%)[b]
Cow Camp	15,909	(0.365)	34,841	2.19	24.4	0.96	DS 62 DF 18	3,765	(24)
Gulick's	12,288	(0.282)	18,801	1.53	20.4	1.51	DF 35 SS 29	3,277	(27)
Old Mill	9,354	(0.214)	15,902	1.70	19.6	1.51	DF 48 SS 25	1,368	(15)
Crescent	9,999	(0.229)	13,999	1.40	26.8	1.57	SF 36 DF 28	516	(5)
Rocky Reach	17,907	(0.411)	21,667	1.21	27.6	1.75	SF 41 SS 28	1,478	(8)
Willows	8,311	(0.191)	16,373	1.97	23.2	0.99	DS 45 DF 33	1,668	(20)
Larson's	12,576	(0.289)	28.799	2.29	21.2	1.37	DF 55 DS 27	2,628	(21)
Conifers	14,863	(0.341)	29,577	1.99	24.4	0.85	DS 52 SS 27	3,326	(22)
Crider's	12,167	(0.279)	26,887	2.21	20.8	1.0	DS 59 SS 20	3,073	(25)

[a] See Table 3 for classification (SS = shallow slow; SF = shallow fast; DS = deep slow and DF = deep fast

[b] Percent of total surface area

current velocity and mean thalweg depth as independent variables (Appendix XII) and biomass (pounds per acre), numbers of trout per acre, or number of trout per 1000 feet of stream as the dependent variables (Appendix VI) met with little success as the number of stations sampled (9) was small compared to the 15 variables measured. The regression showed significance when all the variables were used (the model was overloaded) but failed to show significance when only a few of the independent variables were chosen.

A strong relationship exists between trout density in the Little Deschutes River and the corresponding cover and flow. The station at Gulick's, for example, with its extensive willow cover provides more habitable living space with increased flow than do the stations at Cow Camp and Old Mill. An increase of 9 cfs at Gulick's (1971 flow compared to 1970) increased the brown trout population by 36 percent whereas the same increase in discharge at Cow Camp and Old Mill showed increases of 17 and 22 percent respectively. The additional wetted perimeter in 1971 at Gulick's with its greater cover available was characterized by an increased trout population.

The density of trout in the Little Deschutes River therefore appears to be largely determined by the physical environment, especially cover (Figure 18). The value of cover is probably related to security and the photonegative response of trout, causing them to seek overhead cover (Gibson and Keenleyside 1966; Lewis 1969; McCrimmon and Kwain 1969) which may be a rheotactic response, but more probably is related to feeding and territoriality. Chapman (1966) refers to the phenomenon as the "space-food convention". Muller (1953) and Nilsson (1957) found

TABLE 19
Estimated number of fish per acre (excluding fry) in study areas, 1971

Location	Acres	Total trout	Brown trout	Whitefish	Brown Bullhead	Roach	Standing crop (lb/acre)
Cow Camp	.365	1,600	1,477				84.8
Gulick's	.282	2,316	2,316	11			196.9
Old Mill	.214	1,738	1,738				173.0
Crescent (1970)	.229	463	463	244	6	18	54.8
Rocky Reach	.411	430	423	10	58	58	57.7
Willows	.191	932	932	63	102	10	113.5
Larson's	.289	415	415	45	35	675	81.1
Conifers	.341	490	487	12	18	282	80.2
Crider's	.279	487	480	76	108	140	100.0

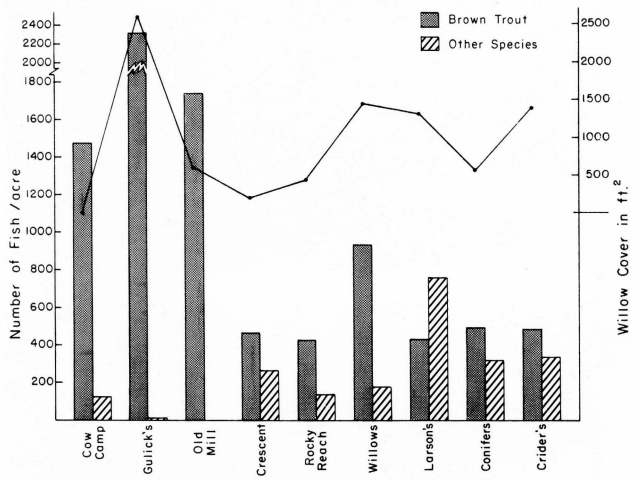


Figure 18. Estimated number of brown trout one plus and older and of other species occupying study sites.

that benthic drift is the major food source in streams and in areas of faster current velocity the supply of drift would be greater. Thus in swifter areas of the stream, fish require less space to obtain needed food, and consequently, territory size is reduced and population densities can be greater (Chapman 1966). Kalleberg (1958) found smaller territories for juvenile Atlantic salmon and brown trout in higher current velocities and related this to visual isolation. Hartman (1963) noted seasonal changes in behavior of brown trout in response to cover and current. In winter, trout associated strongly with cover and low water velocity whereas in summer there was a movement away from cover and from the stream bottom. Hartman hypothesized that winter behavior affords protection against predation and displacement in the stream, whereas the summer distribution allows the fish to feed more when food is abundant and when higher metabolism requires more food. These concepts may explain the greater densities of trout per unit area of cover.

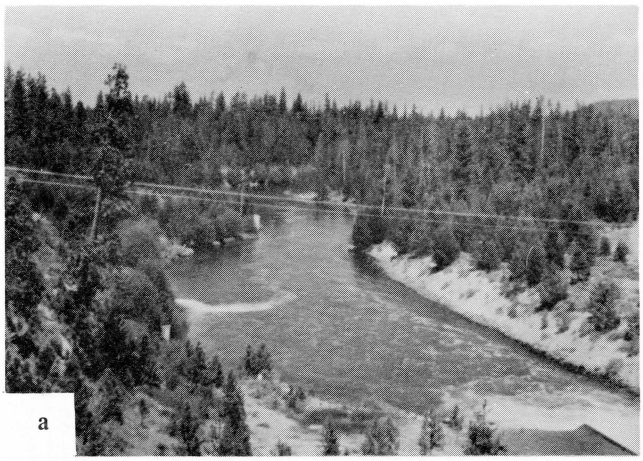
There were other factors not studied that could account for some of the unexplained variation in trout numbers. Foremost among these is food and since it is partially dependent upon the substrate could be more abundant in one area than another. Light intensity under the cover could also be important because denser cover that allows less light penetration may be more attractive to trout owing to the photonegative response. The interspecific relationships of trout to other fish have not been considered nor have their specific microhabitat requirements.

Effect of Man on the Watershed

By using poor land practices or careless road construction, man can turn back the evolutionary clock. Gebhards (1970) noted that "man has gained the knowledge and technical skill that makes him capable of completely altering, or nullifying natures handiwork – but he rarely ponders his inability to duplicate it! Changes brought about in the watershed by logging, road construction, over-grazing by livestock, or other disturbances of the land, can greatly alter the pattern of water movement and even water quality within the watershed."

Changes in the watershed are often reflected in the stream's productivity. Dams and reservoirs for power, flood control and irrigation have flooded many miles of streams in Oregon and additional dam construction will probably eliminate even more in the future. Water diversions for irrigation partially or completely dewater numerous streams and present trends point to additional diversions.

The Deschutes Basin is confronted with all of these disturbances of the natural stream. The main river and some of its tributaries have been dammed for irrigation water and flood control, resulting in superimposed irrigation regimes



a

b

Figure 19. Deschutes River below Wickiup Reservoir: a) June 1969 approximately 1,500 cfs; b) November 1969 approximately 20 cfs.

with flows abnormally high in summer and critically low in winter (Figure 19a and b). Irrecoverable losses of brown trout occur through unscreened, or improperly screened irrigation canals (Figure 20, Appendix X). Siltation of much of the potential spawning gravels has also occurred.

Figure 20. Canal at end of irrigation season (improperly screened or unscreened canals lead to considerable losses of brown trout).

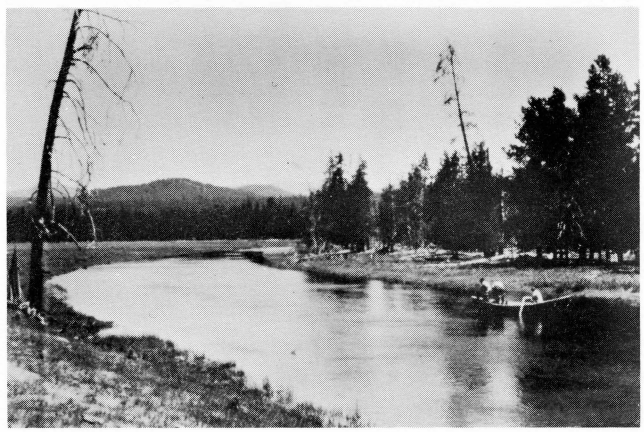


Figure 21. Little Deschutes River: showing lack of streamside cover, sloughing banks and stream bank erosion caused by overgrazing, lack of stream bank protection and fluctuating water levels.

Added to the losses and degradation of the stream environment has been man's physical alteration of the channel and bank vegetation (Figures 21 and 22). Boussu (1954) found that when undercut banks and overhanging brush of streams were removed, trout populations, especially the larger fish, were adversely affected. Gunderson

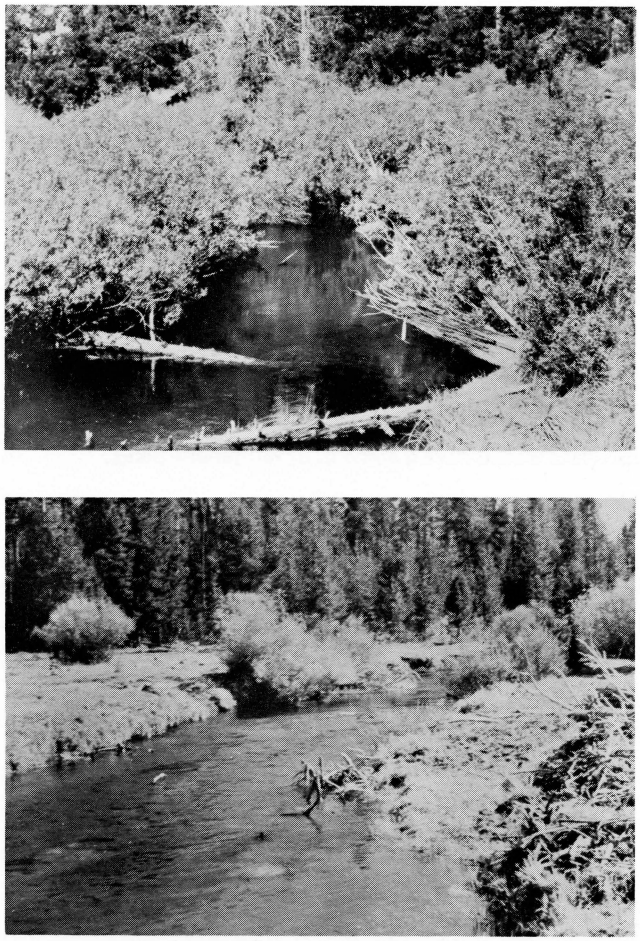


Figure 22. **Little Deschutes River downstream of Gilchrist, Oregon. Two adjacent stream sections separated by a fence. Note unstable conditions of severely grazed area compared to ungrazed area.**

(1968) found major differences in the stream morphology and fish populations between two adjacent segments of Rock Creek (Montana), one of which had been disturbed through overgrazing of the flood plain vegetation. The weight of trout per acre was 31 percent greater in the ungrazed section than in the section heavily used by cattle. Marcuson (1971), following up Gunderson's work, recorded that there were 149.7 pounds or 1,056 brown trout per acre more in the natural area than in the grazed section of stream. Elser (1968) noted that trout were 78 percent more abundant and there was 80 percent more brush cover in the unaltered mountain sections of Little Prickly Pear Creek than in sections that had undergone channel alteration. Lewis (1969) showed the aggregate amount of brush, overhanging vegetation, undercut banks and miscellaneous cover to be the most important physical factor governing brown trout numbers in study pools of the same stream.

The preference of trout for areas with protective cover has been recognized for many years. In England, for example, establishment of artificial "lies" which act as shelter for trout has long been practiced. Efforts to clarify the relationship of cover and trout numbers in North America include the habitat improvement studies by Tarzwell (1937, 1938), Shetter et al. (1946) and Saunders and Smith (1962). White and Brynildson's (1967) "Guidelines for management of trout stream habitat in Wisconsin" has done much to improve trout habitat in Wisconsin and other states, through restoration of abused river channels and streambanks. Significant increases in standing crops of wild brook trout followed man-made modifications of trout habitat in the upper mile of Lawrence Creek (Hunt 1971). Similarly, Lowry (1971) showed increases in numbers of brown trout following habitat alteration such as installation of current deflectors and cover devices.

RECOMMENDATIONS

Discontinue all stocking of the Little Deschutes River except Gilchrist Pond and possibly those areas downstream of its confluence with Crescent Creek where potential for native trout is small and angling pressure is intense enough to warrant stocking catchable trout.

An educational program is needed to elucidate environmental needs of trout so that further degradation of the stream will not occur as a result of over-grazing, land development and alteration of normal stream flows.

On Forest Service land, grazing leases should be reviewed periodically and discussions held with lessees concerning preservation of trout habitat.

The benefits of stream bank protection should be publicized so that the landowner can take corrective and preventive measure in order to avoid further land loss from sloughing banks and soil erosion.

On streams subject to irrigation withdrawals higher winter flows are desirable if true multiple use of the water resource is to be realized.

In areas where degradation of the stream has occurred, bank stabilization or other stream improvements should be initiated by federal and state agencies and service clubs. If trout habitat can be restored by improving cover and increasing present winter flows a return to high population densities would probably be observed over most of the Little Deschutes River.

The Water Resources Board should require a reduction of present transmission and lateral-line water losses occurring in the various irrigation districts. Lining main canals and changing to sprinkler systems would do much to reduce present water losses and thus make additional water available in the natural stream for fish and wildlife propagation and enhancement of recreational opportunities.

It would be beneficial to the area if local planning and zoning committees were established so that land development would proceed in an orderly fashion and all user interests would have a voice in development plans.

Losses of trout into irrigation canals should be checked by proper installation and operation of louvers and rotary fish screens (see Appendix X).

An extensive educational program is needed to steer anglers away from the expensive, artificial "put-and-take" fishing and into utilization of the high standing crop of small native fish. Since the Little Deschutes River water is extremely low in nutrients it is unreasonable to expect it to produce "trophy" fish, but the area is capable of producing high quality recreational opportunity (large populations of small wild trout and minimal inter-angler contact in an aesthetically pleasing area).

Remove the present 6-inch size limit in an effort to increase the harvest of small trout since most die before reaching legal size.

Periodically sample trout populations in order to check the effects of man's activity on their abundance and distribution.

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LITERATURE CITED

Allen, K. Radway. 1938. Some observations on the biology of the trout in Windermere. J. Anim. Ecol. 7:333-349.

————. 1951. The Horokiwi stream. A study of a trout population. New Zealand Marine Dept. Fish Bull. No. 10. 231 p.

Alm, G. 1949. Influence of heredity and environment on various forms of trout. Rept. Inst. Freshwater Res. Drottningholm. 29:29-34.

Andrewartha, H. G. and L. C. Birch. 1954. The distribution and abundance of animals. The University of Chicago Press, Chicago, Illinois. 782 p.

Bagenal, T. B. 1969. The relationship between food supply and fecundity in brown trout (*Salmo trutta* L.). J. Fish Biol. 1:167-182.

————. 1969. Relationship between egg size and fry survival in brown trout (*Salmo trutta* L.). J. Fish Biol. 1:349-353.

Bailey, Norman T. J. 1959. Statistical methods in biology. John Wiley & Sons Inc., New York. 200 p.

Beyerle, G. B. and E. L. Cooper. 1960. Growth of brown trout in selected Pennsylvania streams. Trans. Amer. Fish. Soc. 89(3):255-262.

Bishop, C. G. 1955. Age, growth and condition of trout in Prickley Pear Creek, Montana. Trans. Amer. Microscopical Soc. 74(2): 134-145.

Boussu, M. F. 1954. Relationship between trout populations and cover on a small stream. J. Wildl. Mange. 18(2):229-239.

Brown, C. J. D. and Gertrude C. Kamp. 1942. Gonad measurements and egg counts of brown trout, *Salmo trutta* from the Madison River, Montana. Trans. Amer. Fish. Soc. 71:195-200.

Chapman, D. W. 1966. Food and space as regulators of salmonid populations in streams. The Amer. Naturalist 100:345-357.

Clothier, William D. 1953. Fish loss and movement in irrigation diversions from the West Gallatin River, Montana. J. Wildl. Mange. 17(2):144-158.

Cooper, E. L. 1953. Periodicity of growth and change of condition of brook trout (*Salvelinus fontinalis*) in three Michigan trout streams. Copeia:1953(2):145-155.

———— and N. G. Benson. 1951. The coefficient of condition of brook, brown and rainbow trout in the Pigeon River, Otsego County, Michigan. Prog. Fish Cult. 13(4):181-192.

Dahl, K. 1910. The age and growth of salmon and trout in Norway as shown by their scales. London. The Salmon & Trout Association.

Egglishaw, Henry J. 1970. Production of salmon and trout in a stream in Scotland. J. Fish. Biol. 2:117-136.

Ellis, Robert J. and H. Gowing. 1957. Relationship between food supply and condition of wild brown trout, *Salmo trutta* Linnaeus, in a Michigan stream. Limnol. and Oceanogr. 2(4):299-308.

Elser, Allen A. 1968. Fish populations of a trout stream in relation to major habitat zones and channel alterations. Trans. Amer. Fish. Soc. 97(4):389-397.

Fenneman, N. M. 1931. Physiography of western United States. McGraw-Hill Co. New York. 534 P.

Frost, W. E. and M. E. Brown. 1967. The trout. Collins, St. James's Place, London. 286 p.

Gebhards, Stacy. 1970. The vanishing stream. Idaho Wildl. Review. Mar./Apr. 4 p.

Gibson, R. J. and M. H. A. Keenleyside. 1966. Responses to light of young Atlantic salmon (*Salmo salar*) and brook trout (*Salvelinus fontinalis*). J. Fish. Res. Bd. Can. 23:1007-1024.

Gunderson, Donald H. 1968. Floodplain use related to stream morphology and fish populations. J. Wildl. Mange. 32(3):507-514.

Hardy, C. J. 1967. The fecundity of brown trout from six Canterbury streams. New Zealand Marine Dept. Fish Tech. Rept. No. 22. 14p.

Hartman, G. F. 1963. Observations on behavior of juvenile brown trout in a stream aquarium during winter and spring. J. Fish. Res. Bd. Can. 20(3):769-787.

Hjort, J. 1910. Report on herring investigations until January 1910. Publ. Circ. Cons. Explor. Mer. No. 53.

Hobbs, D. F. 1937. Natural reproduction of Quinnat salmon, brown and rainbow trout in certain New Zealand waters. New Zealand Marine Dept. Fish Bull. No. 6. 104 .

Hodge, E. T. 1938. The Cascade Plateau province (Oregon). Geolog. Soc. Oregon Country News Letter 4(1):3-11 and 4(2):16-26.

Hoover, Earl E. and G. W. Morril, Jr. 1939. Autecology of Brook Trout, *Salvelinus fontinalis,* in two primitive streams of Northern New Hampshire. Tech. Circ. No.2, N.H. Fish and Game Dept., 22 p.

Hopkins, C. L. 1965. Feeding relationships in a mixed population of freshwater fish. New Zealand J. of Sci. 8(2):149-157.

Hunt, Robert L. 1971. Responses of brook trout population to habitat development in Lawrence Creek. Wisconsin Dept. of Natural Resources, Tech. Bull. No. 48. 35 p.

Jones, A. Neville. 1970. A study of salmonid populations of the River Teify and tributaries near Tregaron. J. Fish Biol. 2:183-197.

Kalleberg, H. 1958. Observations in a stream tank of territoriality and competition in juvenile salmon and trout (*Salmo salar* L. and *S. trutta* L.). Rept. Inst. Freshwater Res. Drottningholm. 39:55-98.

Kathrein, Joseph W. 1951. Growth rate of four species of fish in a section of the Missouri River between Holter Dam and Cascade, Montana. Trans. Amer. Fish. Soc. 80:93-98.

Kipling, C. 1962. The use of the scales of the brown trout (*Salmo trutta* L.) for the back-calculation of growth. J. Cons. Int. Explor. Mer. 27:304-15.

Lane, E. David. 1964. Brown trout (*Salmo trutta*) in the Hinds River. Proc. New Zealand Ecol. Soc. 11:10-16.

Latta, William C. 1962. Periodicity of mortality of brook trout during first summer of life. Trans. Amer. Fish. Soc. 91(4):408-411.

Lea, E. 1910. On the methods used in the herring investigations. Publ. Circ. Cons. Explor. Mer. No. 53:7-174.

LeCren, E. D. 1965. Some factors regulating the size of populations of freshwater fish. Mitt. Internat. Verein. Limnol. 13:88-105.

Lewis, Stephen L. 1969. Physical factors influencing fish populations in pools of a trout stream. Trans. Amer. Fish. Soc. 98(1):14-19.

Lowry, Gerald R. 1971. Effect of habitat alteration on brown trout in McKenzie Creek, Wisconsin. Dept. of Natural Resources Res. Rept. No. 70. 27 p.

Maitland, P. S. 1965. The feeding relationships of salmon, trout, minnows, stone loach and three-spined sticklebacks in the River Endrick, Scotland. J. Anim. Ecol. 34:109-133.

Marcuson, P. 1971. Rock Creek floodplain study. Montana Fish & Game. D-J Prog. Rept. F-20-R-14. 4 p.

Mann, R. H. K. 1971. The populations, growth and production of fish in four small streams in southern England. J. Anim. Ecol. 40(1):155-190.

McCormack, J. C. 1962. The food of young trout (*Salmo trutta*) in two different becks. J. Anim. Ecol. 31(2):305-316.

McCrimmon, H. and Wen-Hwa Kwain. 1966. Use of overhead cover by rainbow trout exposed to a series of light intensities. J. Fish. Res. Bd. Can. 23:983-990.

McFadden, James T. and Edwin L. Cooper. 1964. Population dynamics of brown trout in different environments. Physiol. Zool. 37(4):355-363.

_____, _____ and John K. Anderson. 1965. Some effects of environment on egg production in brown trout (*Salmo trutta*). Limnol. and Oceanogr. 10(1):88-95.

Müller, Karl. 1953. Investigations on the organic drift in North Swedish streams. Rept. Inst. Freshwater Res. Drottningholm. 35:133-148.

Needham, P. R. 1940. Production in inland water. Proc. Sixth Pac. Sci. Congress 1939. 3:353-358.

_____ J. F. Moffet and D. W. Slater. 1945. Fluctuation in wild brown trout populations in Convict Creek, California. J. Wildl. Mange. 9(1):9-25.

Nicholls, A. G. 1957. The Tasmanian trout fishery. Aust. J. Mar. Freshwater Res. 8:451-475.

_____ 1958. The egg yield from brown and rainbow trout in Tasmania. Aust. J. Mar. Freshwater Res. 9(4):526-536.

Nilsson, Nils-Arvid. 1957. On the feeding habits of trout in a stream of northern Sweden. Rept. Inst. Freshwater Res. Drottningholm. 38:155-166.

Oregon, State Water Resources Board. 1961. Deschutes River Basin. Oregon State Printer, Salem, 188 p.

Purkett, C. A., Jr. 1951. Growth rate of trout in relation to elevation and temperature. Trans. Amer. Fish. Soc. 80:251-259.

Ricker, William E. 1958. Handbook of computations for biological statistics of fish populations. Fish. Res. Bd. Can. Bull. 119. 300 p.

Rounsefell, George A. and W. Harry Everhart. 1953. Fishery science - Its methods and application. John Wiley and Sons Inc., New York. 444 p.

Saunders, J. W. and M. W. Smith. 1962. Physical alteration of stream habitat to improve brook trout production. Trans. Amer. Fish. Soc. 91(2):185-188.

Schuck, Howard A. 1945. Survival, population density, growth and movement of the wild brown trout in Crystal Creek. Trans. Amer. Fish. Soc. 73:209-230.

Shetter, David S. 1961. Survival of brook trout from egg to fingerling stage in two Michigan trout streams. Trans. Amer. Fish. Soc. 90(3):252-258.

_____ and A. S. Hazzard. 1939. Species composition by age groups and stability of fish populations in sections of three Michigan trout streams during the summer of 1937. Trans. Amer. Fish. Soc. 68:280-302.

_____ and J. W. Leonard. 1943. A population study of a limited area in a Michigan trout stream, Sept. 1940. Trans. Amer. Fish. Soc. 72:35-51.

_____, O. H. Clark and Albert S. Hazzard. 1946. The effects of deflectors in a section of a Michigan trout stream. Trans. Amer. Fish. Soc. 76:248-278.

Sigler, William F. 1952. Age and growth of the brown trout, *Salmo trutta fario* Linnaeus, in Logan River, Utah. Trans. Amer. Fish. Soc. 81:171-178.

Snedecor, George W. 1956. Statistical methods. The Iowa State College Press, Ames, Iowa. 534 p.

Straskraba, Milan, Jiri Chiar, Stanislav Frank and V. Hruska. 1966. Contribution to the problem of food competition among the sculpin, minnow and brown trout. J. Anim. Ecol. 35(2):303-311.

Stuart, T. A. 1953. Spawning migration, reproduction and young stages of loch trout. Scottish Home Dept. Fresh. and Salmon Fish Res. No. 5. 39 p.

_____ 1957. The migrations and homing behavior of brown trout, *Salmo trutta*. Scottish Home Dept. Fresh. and Salmon Fish Res. No. 18. 26 p.

Tarzwell, C. M. 1937. Experimental evidence on the value of trout stream improvement in Michigan. Trans. Amer. Fish. Soc. 66:177-187.

_____ 1938. Factors influencing fish food and fish production in southwestern streams. Trans. Amer. Fish. Soc. 67:246-255.

Thomas, J. D. 1962. The food and growth of brown trout, *Salmo trutta* L. and its feeding relationships with the salmon parr *Salmo salar* L. and the eel *Anguilla anguilla* (L.) in the River Teify, West Wales. J. Anim. Ecol. 31:175-205.

Vickers, K. U. 1969. Observations on the salmonid populations of the Lough Erne tributaries in northern Ireland. J. Fish. Biol. 1:297-309.

Went, A. E. J. and W. E. Front. 1942. River Liffey Survey V. Growth of brown trout, *Salmo trutta* L. in alkaline and acid waters. Proc. Roy. Irish Acad. 68(Sec. B. No. 7):67-84.

White, Ray J. and Oscar M. Brynildson. 1967. Guidelines for management of trout stream habitat in Wisconsin. Dept. Nat. Resources., Div. of Conserv. Tech. Bull. No. 39, 65 p.

APPENDICES

Appendix I. Streamflows at various stations on the Little Deschutes River (L.D.R.) as collected by OSGC Environmental Division, 1969-1971. (mean monthly flows recorded at gauging stations of U.S. Geological Survey)

Date recorded	L.D.R. Cow Camp	Hemlock Creek	L.D.R. Mowich	L.D.R. Crescent	L.D.R. gauge at Lapine $\bar{x}$	Crescent Cr. at lake	Gauge at lake $\bar{x}$	Crescent Cr. at Gilchrist	Big Marsh Cr.
5/13/69	320	80	400	150	(434)		(1.4)		
6/18/69		40				2		107	105
6/27/69				95	(251)	2	(1.4)	108	106
7/ 2/69			85	69		2		135	133
7/11/69			81	74		56		150	60
7/23/69			48	48		129			
7/29/69	39	18	57	47	(177)	128	(96.1)		
8/15/69			45	39		163			
8/25/69	24	12	36	31	(216)	162	(177.0)		
9/11/69			46	32		147			
9/30/69	21	12	33	30	(127)	59	(83.5)	103	44
10/22/69	32	10	41	28	(109)	40	(38.8)	84	44
11/24/69	24	8	32	28	(69)	3	(2.9)	37	34
12/ /69					(101)		(2.9)		
1/ /70					(260)		(3.2)		
2/ /70					(226)		(3.5)		
3/24/70					(192)	4	(3.5)	124	121
4/21/70				87	(200)	4	(3.8)	110	106
5/ 5/70				82		4		108	104
5/28/70				111	(197)	4	(4.0)		
6/ 2/70						4		110	106
6/23/70					(186)	98	(31.4)	181	83
7/29/70					(219)	250	(182.0)		
8/26/70			34	31	(248)	260	(236.0)	320	60
9/ /70					(134)		(82.9)		
10/ /70					(89)		(29.8)		
11/ /70					(163)		(1.9)		
12/ /70					(132)		(2.2)		
1/ /71					(299)		(3.3)		
2/ /71					(307)		(4.2)		
3/ /71					(209)		(5.3)		
4/ /71					(377)		(6.0)		
5/ /71					(641)		(6.3)		
6/ /71					(445)		(7.2)		
6/ /71					(445)		(7.2)		
7/14/71	73		98	98					
7/26/71	55		80	80	(297)		(129.)		
8/16/71	37		53	53	(308)		(222.)		
9/20/71	32		39	39	(307)				

Appendix II. Flows at study stations on Little Deschutes River in the summer of 1971.

Station	Date	Total width (ft)	Mean depth (ft)	Mean velocity (ft/sec)	Flow (cfs)
Crescent	7/14/71	22.4	2.5	1.8	98
	7/26/71	22.8	2.3	1.4	80
	8/16/71	21.4	2.2	1.1	53
	9/20/71	23.0	2.1	0.9	39
Old Mill	7/14/71	26.0	2.1	1.6	98
	7/26/71	26.0	1.7	1.7	80
	8/16/71	23.7	1.2	1.3	53
	9/20/71	22.0	1.1	1.0	39
Gulick's	7/14/71	35.1	2.5	1.1	98
	7/26/71	35.1	2.2	1.1	80
	8/16/71	32.6	1.4	0.8	53
	9/20/71	26.0	1.4	0.8	39
Cow Camp	7/14/71	21.3	3.0	1.2	73
	7/26/71	21.3	2.7	1.0	55
	8/16/71	21.2	2.3	.8	37
	9/20/71	21.2	2.2	.7	32

Appendix III. Chemical characteristics of Little Deschutes River, 1969-1971.

Location	Date	pH	Conductivity K_{25} (micromhos)	Total dissolved solids (mg/l)	Total hardness (mg/l $CaCO_3$)	Total alkalinity (mg/l $CaCO_3$)
Clover Cr.	7/29/69	7.1	52	34	14	20
Cow Camp	7/25/69	6.8	49	26	12	20
	9/12/69	7.2	45	30	12	23
	5/28/70	7.8	33	21	10	40
	6/17/71	6.2	33	23	12	18
Gulick's	7/14/69	7.4	39	24	10	20
	7/25/69	6.8	39	25	12	20
	9/12/69	7.3	37	26	13	23
	10/31/69	7.7	42	28	10	20
	4/16/70	7.4	35	23	12	
	6/17/71	7.0	44	33	18	25
Crescent	7/24/69	7.1	39	26	12	15
	9/12/69	7.7	37	26	13	23
	4/16/70	7.7	35	24	12	
	6/17/71	6.7	30	22	12	15
Little River	7/25/69	7.0	41	26	12	20
Vandevert's	8/20/70	7.2	32	22	12	20
Reeve's	8/20/70	6.6	32	22	9	—

Appendix IV. The major orders and families of food organisms found in the Little Deschutes River.

Order	Family	Genera
Ephemeroptera		
	Heptageniidae	*Cinygmula, Heptagenia*
	Baetidae	
	Siphlonurinae	*Ameletus*
	Leptophlebiinae	*Leptophlebia, Paraleptophlebia*
	Ephemerellinae	*Ephemerella*
	Baetinae	*Baetis*
Odonata		
Anisoptera		
	Aeshnidae	
Zygoptera		
	Agrionidae	
	Coenagrionidae	
Plecoptera		
Filipalpia	Peltoperlidae	
Setipalpia	Perlodidae	
	Chloroperlidae	*Paraperla*
	Perlidae	
Hemiptera	Corixidae	
	Notonectidae	
	Belostomatidae	*Lethocerus americanus*
	Gerridae	
Megaloptera		
	Sialidae	
Trichoptera		
	Limnephilidae	
	Rhyacophilidae	
	Hydropsychidae	
	Brachycentridae	
Lepidoptera		
Hymenoptera		
Coleoptera	Hydrophilidae	
	Haliplidae	
	Dytiscidae	
	Hydroscaphidae	
	Staphylinidae	
	Elmidae	
Diptera	Tipulidae	*Hexatoma*
	Simuliidae	
	Rhagionidae	
	Dixidae	
	Tendipedidae	
	Empididae	
	Culicidae	

Appendix IV continued

Appendix IV continued

In addition to the aquatic insects or their adult forms listed, the following miscellaneous invertebrates were found:

Phylum Crustacea
- Class Crustacea
  - subclass Malacostraca
    - Order Amphipoda
    - Order Decapoda
- Class Arachnoidea
  - Order Hydracarina

Phylum Mollusca
- Class Gastropoda
- Class Pelecypoda

Phylum Annelida
- Order Oligochaeta
- Order Hirudinea

Appendix V. Coefficient of condition of brown trout from study areas sampled in August and September 1971.

	Size group (range)				
Location	4 cm (4.0-9.9)	10 cm (10.0-14.9)	15 cm (15.0-19.9)	20 cm (20.0-24.9)	25 cm (25.0-33.0)
Cow Camp	1.139	1.034	1.050	0.995	1.009
n	90	96	31	9	2
Gulick's	1.109	1.016	1.031	1.026	1.047
n	15	166	83	17	4
Old Mill	1.045	1.069	1.037	1.029	1.176
n	17	161	48	20	2
Rocky Reach	1.078	1.092	1.078	1.051	0.963
n	31	28	35	7	3
Willows	1.053	1.053	1.060	1.115	1.056
n	8	67	37	1	3
Larson's	1.106	1.097	1.097	1.044	1.147
n	6	24	39	6	2
Conifers	1.125	1.073	1.086	1.053	1.036
n	18	38	63	11	3
Crider's	1.060	1.062	1.064	1.031	1.125
n	36	49	38	8	3

Appendix VI. Estimated fish populations of study areas in summer of 1971.

	Cow Camp	Gulick's	Old Mill	Crescent[a]	Rocky Reach	Willows	Larson's	Conifers	Crider's
Biomass total fish (lbs/acre)	86.8	201.2	180.6	60.7	70.9	132.3	132.3	91.7	116.3
Biomass total trout (lbs/acre)	86.8	199.3	180.6	54.0	58.0	105.9	100.5	77.0	91.3
Biomass total brown trout (lbs/acre)	82.7	199.3	180.6	54.0	56.4	105.9	100.5	76.5	90.5
Biomass brown trout 1+ older (lbs/acre)	80.7	195.0	173.0	48.1	43.2	87.1	49.3	65.0	74.2
Biomass brown trout 15+ cm (lbs/acre)	45.1	135.3	116.5	34.5	30.7	51.3	38.8	52.7	61.2
Biomass brown trout fry (lbs/acre)	2.0	4.3	7.6	5.9	13.2	18.8	51.2	11.5	16.3
Biomass total trout-brown trout fry (lbs/acre)	84.8	195.0	173.0	48.1	44.8	87.1	49.3	65.5	75.0
Biomass total fish-brown trout fry (lbs/acre)	84.8	196.9	173.0	54.0	57.7	113.5	81.1	80.2	100.0
Number total fish/acre	2,036	3,050	2,822	1,563	2,178	3,885	8,284	2,384	2,556
Number total trout/acre	2,036	3,039	2,822	1,301	2,051	3,712	7,530	2,073	2,233
Number total brown trout/acre	1,912	3,039	2,822	1,301	2,044	3,712	7,530	2,070	2,226
Number brown trout 1+ older/acre	1,477	2,316	1,738	463	423	932	415	487	480
Number brown trout 15+ cm/acre	299	812	593	192	217	319	263	290	272
Number brown trout fry/acre	436	723	1,084	838	1,620	2,780	7,114	1,584	1,746
Number total fish-brown trout fry/acre	1,600	2,326	1,738	725	557	1,105	1,170	801	810
Number total fish/1,000 ft.	1,222	1,376	1,060	1,102	1,492	2,473	3,990	1,355	1,188
Number total trout/1,000 ft.	1,222	1,371	1,060	917	1,405	2,363	3,627	1,178	1,038
Number total brown trout/1,000 ft.	1,148	1,371	1,060	917	1,400	2,363	3,627	1,177	1,035
Number brown trout 1+ older/1,000 ft.	886	1,045	653	326	290	593	200	277	223
Number brown trout 15+ cm/1,000 ft.	179	366	223	135	148	203	127	165	127
Number brown trout fry/1,000 ft.	262	326	407	591	1,110	1,770	3,427	900	812
Number total fish-brown trout fry/1,000 ft.	961	1,050	653	511	382	703	563	455	377

[a]Estimated on basis of 1970 data

Appendix VII. Growth of brown trout from Little Deschutes River system as back-calculated from scales (in centimeters).

Age of fish	I	II	III	IV	V	VI	VII	VIII	Average growth rate	No. of fish
A. Clover Creek										
No. of fish	13	9	6	6	2					
Length after										
1 year	6.4	6.8	7.5	7.3	8.8				7.0	36
2 years		10.1	11.0	10.6	12.3				10.7	23
3 years			14.1	15.2	16.7				15.0	14
4 years				19.2	21.1				19.7	8
5 years					24.2				24.2	2
B. Cow Camp										
No. of fish	91	76	91	26	8	1	1	1		
Length after										
1 year	7.0	7.0	7.4	7.5	8.1	6.8	7.8	7.6	7.2	295
2 years		11.4	12.2	12.4	13.3	10.6	11.1	11.8	12.0	204
3 years			16.2	16.7	17.7	17.3	17.3	16.1	16.4	128
4 years				19.6	21.8	23.0	21.9	20.7	20.3	37
5 years					24.5	25.8	25.1	26.5	24.9	11
6 years						27.8	29.7	30.9	29.4	3
7 years							31.9	35.5	33.7	2
8 years								38.9	38.9	1
C. Gulick's										
No. of fish	67	89	51	19	2					
Length after										
1 year	7.5	7.4	7.6	8.2	7.8				7.6	228
2 years		11.7	11.9	12.7	12.8				11.9	161
3 years			15.6	17.3	17.3				16.1	72
4 years				20.9	21.2				20.9	21
5 years					25.2				25.2	2
D. Crescent										
No. of fish	73	78	88	42	8	3	1	1		
Length after										
1 year	7.6	8.0	8.2	8.1	8.7	9.7	9.0	8.6	8.0	294
2 years		13.0	13.2	13.1	13.9	16.6	15.4	14.7	13.2	221
3 years			17.6	18.2	19.9	26.6	21.5	19.6	18.1	143
4 years				22.2	24.7	32.6	27.3	25.8	23.3	55
5 years					28.4	36.5	32.0	33.8	31.0	13
6 years						40.5	36.9	38.6	39.4	5
7 years							40.3	43.6	42.0	2
8 years								46.5	46.5	1

Appendix VII Continued

Appendix VII Continued

Age of fish	I	II	III	IV	V	VI	VII	VIII	Average growth rate	No. of fish
E. Rocky Reach to Conifers										
No. of fish	46	27	15	6	2					
Length after										
1 year	8.5	7.9	8.9	9.0	10.1				8.9	96
2 years		13.6	15.2	14.1	17.0				15.0	50
3 years			21.4	19.1	22.7				21.1	23
4 years				24.6	28.1				26.4	8
5 years					31.7				31.7	2
F. Crider's										
No. of fish	32	12	5	1	2	1	1			
Length after										
1 year	7.8	7.8	9.2	7.8	9.1	9.5	10.4		8.1	54
2 years		14.3	15.4	16.9	15.3	16.5	18.8		15.1	22
3 years			20.6	22.7	20.6	22.8	35.1		22.5	10
4 years				28.1	27.4	28.4	40.3		30.3	5
5 years					31.7	34.4	46.0		35.9	4
6 years						38.6	50.6		44.6	2
7 years							53.7		53.7	1
G. Little Deschutes R. upstream of Crescent										
No. of fish	244	252	236	93	20	4	2	2		
Length after										
1 year	7.3	7.5	7.7	7.9	8.4	9.0	8.4	8.1	7.6	853
2 years		11.9	12.5	12.7	13.4	15.1	13.2	13.2	12.4	609
3 years			16.5	17.4	18.4	23.9	19.4	17.4	17.0	357
4 years				21.0	22.8	30.2	24.6	23.3	21.7	121
5 years					26.1	33.8	28.6	30.1	27.7	28
6 years						37.3	33.3	34.8	35.7	8
7 years							36.1	39.5	37.8	4
8 years								42.7	42.7	2
H. Little Deschutes R.										
No. of fish	358	372	313	127	30	6	3	3		
Length after										
1 year	7.4	7.4	7.8	7.8	8.5	8.8	9.1	8.2	7.6	1212
2 years		12.0	12.6	12.5	13.6	15.6	15.1	12.9	12.4	854
3 years			16.8	17.1	18.9	24.0	24.6	18.9	17.2	482
4 years				20.8	23.5	29.9	29.9	24.8	21.9	169
5 years					26.9	33.7	34.4	30.8	28.7	42
6 years						37.1	39.1	36.1	37.4	12
7 years							42.0	41.1	41.5	6
8 years								43.8	43.8	3

Appendix VIII. Growth Rates of Brown Trout From Oregon Waters.

One segment of the project was a comparison of growth rates of brown trout from various Oregon waters. To accomplish this goal brown trout were collected from the Deschutes, Klamath and Umpqua River Basins. Streams, reservoirs and lakes known to have reproducing populations of brown trout were electrofished and gill netted for fish samples. Length, weight and a scale sample was taken from a representative number of the fish collected. A water sample was also collected from each stream and analyzed for conductivity, pH, total dissolved solids and total hardness.

The streams all had relatively low conductivity and hardness (Table A) which has been related elsewhere to slow growth and low fish production. The streams studied ranged in conductivity from 21 to 108 micromhos and in hardness from 6 to 34 mg/l calcium carbonate (Table A). Frost and Brown (1967), noted that in the British Isles there is a threshold of hardness at about 150 ppm of calcium carbonate, above which the trout may grow at maximal rates, but below which they are limited in their early growth. Values for total hardness were highest from streams of the Klamath Basin but were only a fifth of the value Frost and Brown gave for minimal growth. The growth rates calculated for the various waters are given in Table B.

The most rapid growth was noted in fish that had generally spent time in a lake, pond or reservoir (Browns Creek, Link Creek, Wickiup Reservoir). Similarly, brown trout obtained from waters with a low density of fish or higher water conductivity showed rapid growth (Crescent Creek, Deschutes River, irrigation canals, Five Mile Creek). In the majority of streams the growth of brown trout was slow and legal size (15.0 cm) was not attained until after the third summer of life. The slow growth rates are probably a combination of the low productivity of the water, the short season of favorable water temperature, and the high density of fish in most areas.

Table A. Water chemistry of streams from Deschutes, Klamath, Rogue and Umpqua River Basins.

	Date	pH	Conductivity K_{25} micromhos	TDS (mg/l)	Hardness (mg/l $CaCo_3$)
			Umpqua Basin		
Lake Creek	10/ 6/71	6.5	29	20	8
N. F. Umpqua River (Above Bradley Cr.)	8/ 5/70	7.2	36	23	12
N. F. Umpqua River (½ mi. downstream U.S.F.S. Rd 2500)	8/ 5/70	7.0	36	25	14
N. F. Umpqua River (below Lemolo Reservoir)	10/ 6/71	6.9	42	32	12
Spring River	10/ 6/71	6.8	52	39	14
Thielson Creek	10/ 6/71	6.5	21	16	6
			Rogue Basin		
Crater Creek	10/29/71	6.6	44	30	14
Mill Creek	10/29/71	6.9	70	48	26
N. F. Rogue (Prospect)	10/29/71	6.8	52	36	20

Table A Continued

	Date	pH	Conductivity K_{25} micromhos	TDS (mg/l)	Hardness (mg/l $CaCo_3$)
			Klamath Basin		
Five Mile Creek	10/21/71	7.1	82	55	24
Meryl Creek	10/21/71	7.0	70	46	23
Miller Creek	8/ 5/70	6.8	26	16	7
N. F. Sprague (Sand Hill crossing)	10/21/71	6.6	40	28	15
(Obenchain Ranch)	7/31/70	8.6	55	33	18
S. F. Sprague (Sprague R. Camp)	7/31/70	8.6	90	56	30
Sprague River (at Beatty)	7/31/70	8.4	97	61	33
Sprague River (Chiloquin)	10/ /69		108		
Seven Mile Cr.	7/30/70	7.4	65	40	20
Wood River	7/30/70	7.3	84	56	20
Williamson	10/ /69		76		
			Deschutes Basin		
Big Marsh Cr.	7/30/69	7.1	35	21	10
	9/12/69	6.9	35	20	10
	10/31/69	7.7	36	23	12
	5/28/70	7.7	25	16	8
	8/ 5/70	6.9	40	27	12
Browns Creek	7/18/69	7.5	48	33	16
	9/12/69	7.3	47	32	18
Crescent Cr. (Quarry)	7/24/69	6.8	30	19	10
	9/12/69	7.2	26	18	10
	4/16/70	7.3	24	19	13
Deschutes River (Sheep Springs)	9/12/69	8.0	55	39	13
(Lava Lagoon)	7/31/69	7.1	36	21	10
Fall River	7/18/69	7.8	62	38	18
	4/16/70	7.1	48	36	19

Table A Continued

	Date	pH	Conductivity K_{25} micromhos	TDS (mg/l)	Hardness (mg/l $CaCo_3$)
			Deschutes Basin continued		
Hemlock Creek	7/14/69	7.3	35	20	10
	9/12/69	7.1	30	21	11
	10/31/69	7.7	32	21	10
	4/16/70	7.3	27	17	12
	5/28/70	7.6	26	18	8
	6/17/71	6.2	25	17	10
Little Deschutes River*					
Spruce Creek	7/29/69	7.1	35	22	12
Spring Creek (Metolius R.)	10/26/71	6.7	52	37	18
Jack Creek (Metolius R.)	10/26/71	6.5	37	28	12
Lake Creek (Metolius R.)	6/17/71	7.1	48	31	18

*See Appendix III for water chemistry of individual study sites.

Table B. Growth rates of brown trout back-calculated from scales of fish from the Deschutes, Klamath, Umpqua, and coast drainages (in centimeters).

	Mean length at age (standard deviation)								
Stream	1	2	3	4	5	6	7	8	No. of fish
				Umpqua Basin					
Lake Creek	8.7(1.5)	13.8(3.3)	36.1[a]						24
N. F. Umpqua (Bradley Creek)	5.8(0.8)	8.6(0.9)	12.1(1.2)	15.9(2.0)	19.7(1.3)	21.7(1.9)	25.1		37
N. F. Umpqua R.(above Lemolo Reservoir)	7.1(0.9)	10.1(0.9)	13.7(1.8)	19.0(4.1)	34.4				33
N. F. Umpqua R.(below Lemolo Reservoir)	9.5(1.1)	17.4(1.9)	22.9(0.1)						19
Spring River	6.3(0.8)								7
Thielson Creek	8.4(1.1)	14.2(1.6)	16.9(2.2)						4
Lemolo Reservoir	7.8(1.5)	12.7(2.5)	21.1(5.0)	28.0(5.8)	32.0(5.6)				45
[a]Only one fish - possibly from Lemolo Reservoir.				*Rogue Basin*					
N. F. Rogue River	9.2(0.9)	19.2(1.4)	30.3						4

Table B Continued

Stream	Mean length at age (standard deviation) 1	2	3	4	5	6	7	8	No. of fish
				Klamath Basin					
Five Mile Creek	11.5(1.9)	18.2(3.1)	25.3(2.7)	30.8(2.4)	36.4(2.5)	40.9(1.4)			25
Meryl Creek	8.1(1.1)	13.4(2.3)	18.2(2.8)	24.7(2.2)	28.5(2.0)	34.0(1.4)			43
Miller Creek	7.8(0.9)	13.4(1.8)	21.0(3.2)						70
N. F. Sprague	9.5(1.8)	16.3(2.8)	22.8(3.1)	31.0(4.1)	38.4(0.4)				66
Seven Mile Cr.	6.8(0.8)	11.5(1.1)	16.9(1.4)						59
Wood River	6.9(0.8)	16.3(1.4)	24.3	33.1	36.5				31
				Deschutes Basin					
Big Marsh Creek	8.2(1.3)	12.8(3.1)	14.7(1.4)						32
Browns Creek	10.2(2.0)	19.0(4.5)	29.6(6.2)	39.7(7.7)	46.9(6.2)	51.7(7.8)	59.1(3.0)		57
Crescent Creek	9.3(1.0)	15.8(2.4)	22.3(3.5)	33.4(2.4)	37.4(1.4)	40.3(1.4)			54
Deschutes River	11.1(2.6)	18.2(6.4)	24.7(7.9)	28.3(3.5)	37.3(2.8)				64
Fall River	9.2(1.1)	15.2(1.9)	20.7(1.9)						38
Hemlock Creek	6.7(0.5)	10.5(0.9)	14.3(1.1)	17.5(1.4)	20.0(2.1)				110
Lake Creek (Metolius River)	8.9(2.0)	21.3(3.9)	32.5(4.3)	35.6(1.4)					29
Link Creek (Suttle Lake)	10.4(1.2)	21.6(4.0)	31.8(5.9)	40.6(7.4)	46.7(8.2)				6
Little Deschutes R. (S. of Crescent)	7.6(0.9)	12.4(1.6)	17.0(2.2)	21.7(3.0)	27.7(4.6)	35.7(5.9)	37.8(5.2)	42.7(5.4)	853
Little Deschutes R. (N. of Crescent)	8.5(1.3)	14.6(2.4)	21.0(3.6)	33.5(4.7)	40.7(6.8)	48.9(6.8)			199
Spruce Creek	6.6(0.6)	10.2(0.7)	13.8(0.7)	17.1(1.0)					50
Irrigation canals	10.5(2.2)	17.1(2.5)	22.7(3.1)						68
Gilchrist Pond	8.2(1.1)	13.5(2.1)	19.3(3.4)	28.0(5.6)	41.5(7.1)				49
Wickiup Reservoir	10.9(2.5)	19.5(4.5)	31.4(6.5)	45.2(5.9)	49.1(5.3)	62.0	65.00		17
				North Coast Basin					
Beaver Creek (Siletz Lake)	8.5(1.1)	12.8(1.6)	25.3(5.3)	30.1	40.3	47.0			5
Valsetz Lake (Siletz R.)	11.6(1.5)	25.0(3.4)	31.8(3.0)	35.2(0.9)	40.1				16
Nestucca R.	12.2(1.4)	23.2(4.0)	28.5(2.7)	35.1(3.8)					4

Appendix IX. Average growth of brown trout tagged and recaptured from 1969-1971.

No. of fish	No. of days since first capture	Average growth (mm)	Mean daily growth(mm)	Area	Time of marking
58	50	10.6	0.212	Crescent	Aug. 1969
12	109	7.5	0.069*	Crescent	Aug. 1969
9	315	28.0	0.089	Crescent	Aug. & Sept. 1969
2	369	28.0	0.076	Crescent	Aug. 1969
17	50	8.3	0.166	Old Mill	June 1970
28	69	4.3	0.061	Old Mill	Aug. 1970
2	210	11.0	0.052	Old Mill	Sept. 1969
9	288	13.1	0.045	Old Mill	July 1969
9	390	54.9	0.141	Old Mill	Aug. 1970
7	403	69.1	0.171	Old Mill	Aug. 1970
1	424	56.0	0.132	Old Mill	July 1970
30	33	3.1	0.094	Gulick's	Aug. 1969
28	40	7.32	0.183	Gulick's	Aug. 1969
16	70	7.6	0.108	Gulick's	Aug. 1969
2	181	1.0	0.006	Gulick's	Oct. 1969
10	221	10.0	0.045	Gulick's	Aug. 1969
33	37	3.2	0.086	Gulick's	July 1970
5	88	20.6	0.234	Gulick's	May 1970
1	282	10.0	0.035	Gulick's	Oct. 1969
8	308	15.7	0.051	Gulick's	Sept. 1969
5	318	21.4	0.067	Gulick's	Aug. 1969
5	330	23.6	0.072	Gulick's	Aug. & Sept. 1969
24	405	54.4	0.134	Gulick's	Aug. 1970
4	442	60.0	0.136	Gulick's	July 1970
6	55	4.8	0.087	Cow Camp	Sept. 1969
40	27	4.6	0.170	Cow Camp	July 1970
15	54	8.7	0.161	Cow Camp	Aug. 1970
2	85	7.0	0.082	Cow Camp	July 1970
2	112	18.0	0.160	Cow Camp	July 1970
3	288	14.7	0.051	Cow Camp	Sept. 1969
2	315	33.0	0.105	Cow Camp	Sept. 1969
14	342	27.6	0.081	Cow Camp	Sept. 1969
19	398	32.6	0.082	Cow Camp	Aug. 1970
8	425	32.7	0.077	Cow Camp	July 1970
2	452	47.0	0.104	Cow Camp	July 1970

*All fish greater than 140 mm

Appendix X. Loss of Brown Trout From Deschutes River Basin Through Irrigation Canals.

A substantial loss of brown trout occurs each year as fish enter irrigation diversions. There are six canals diverting water from the Deschutes River in the vicinity of Bend. The major water users are Pilot Butte, North Unit and Central Oregon (Figure 23). Each major canal diverts about 200,000 acre feet per year. No functional screening devices existed on the Arnold, Central Oregon, Tumalo or Swalley Canals in 1965 and 1966. The North Unit Canal contains two large rotary screens at the point of water diversion. Periodic malfunction and lack of good seals allows for some fish loss. The Pilot Butte Canal (Central Oregon Irrigation District) was screened by louvers during the fall of 1965. Inadequate passage of water through the louvers led to the removal of the middle sections in 1965 and 1966. Prior to the 1967 irrigation season, the louver spacings were modified and the Central Region Fishery Staff trapped fish in the bypass to evaluate the efficiency of the new arrangement. In 201 days of continuous operation the louvers bypassed 4,891 fish. Kokanee accounted for 91.5 percent, brown trout 5.1 percent and rainbow trout 1 percent. Brown trout movement occurred mostly from mid-May to mid-June and essentially subsided by early August. In October 1967, fishery personnel of the Central Region rotenoned two small pools below the louvers (collected 37 brown trout, 1 kokanee and 47 whitefish) and concluded that small brown trout were not being bypassed by the present louver arrangement.

In 1968 the bypass of the Pilot Butte Canal was again trapped and 1,512 fish (837 kokanee and 487 brown trout) were salvaged. At the end of the irrigation season 45 brown trout, 3 rainbow and 18 whitefish were electrofished from two pools. The bypass was not trapped during 1969 through 1971 but inventory of one pool (30 ft. x 20 ft. x 4 ft.) approximately 1.5 miles downstream of the louver at the close of the irrigation season indicated little significant decrease in loss of game fishes (Table C). Thus a significant loss of brown trout does occur in this canal over the

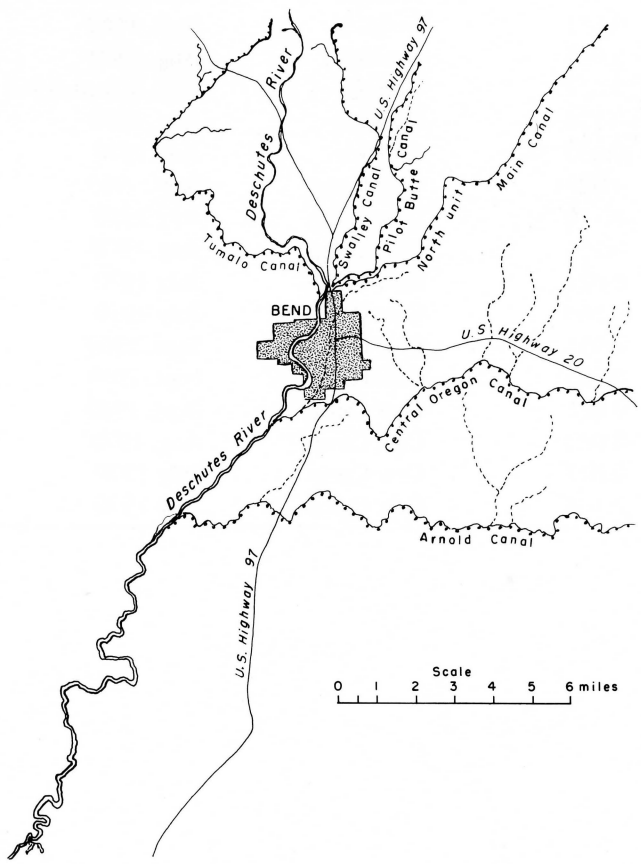

Figure 23. Major irrigation canals withdrawing water from Deschutes River in vicinity of Bend, Oregon.

Table C. Fishes collected from a pool of the Pilot Butte Canal at close of irrigation season, 1969-1971.

Species	Year inventoried 1969	1970	1971
Brown Trout	36	21	30
Rainbow trout	1	2	3
Whitefish	2	0	2
Coho	0	1	0
Kokanee	0	0	2

Table D. Fishes collected from two pools of the Central Oregon Irrigation Canal at close of irrigation season, 1968-1971.

Species	1968	1969	1970[a]
Brown trout	246	158	21
Rainbow	9	3	1
Whitefish	7	42	11
Roach	1	0	2
Kokanee	1	0	0
Brown bullhead	0	4	14

[a]Only lower pool sampled.

irrigation season since the pool(s) sampled are a fraction of those present at the curtailment of flow.

The intake of the Central Oregon Canal is south of Bend and is screened only by a trash rack. Two pools (300 ft. x 20 ft. x 1 ft. and 225 ft. x 25 ft x 1 ft.) near the intake were inventoried during 1968 and 1969, and one pool was surveyed in 1970 at the end of the season (Table D). In 1971 rebuilding of the headgate of the Central Oregon Canal called for installation of a louver and fish bypass facility.

Only one of three canals diverting water from the Little Deschutes River is presently used. No functional screen exists at any of the intakes. Areas of the canals were electrofished in the summers of 1969 and 1970 and brown trout and other species were captured. As the flow in the Little Deschutes River declines over the summer, two of the canals cease functioning and only isolated pools with their doomed fish remain.

Each year a substantial loss of brown trout occurs into the various irrigational canals because of the lack of adequate fish bypass facilities. Only at the Arnold and the Central Oregon Canal, under the present water conditions, would the cost of bypass facilities be justified, although, if an increase in Deschutes River flow of 100-200 cfs for fish enhancement or aesthestic value could be acquired immediately downstream of the other canal intakes, the cost of fish bypass facilities might be justified. Under the present summer water flows of 10-20 cfs, very few of the fish bypassed can find suitable habitat in which to take up residence until more optimal winter flows begin.

Appendix XI. Food habits of brown trout and other species.

Table 15. Food of brown trout ⩾ 10 cm in the Little Deschutes River near Gulick's, 1969-70 (percent of total volume of organisms eaten).

	Sampling period																			
	July 69		Sept. 69		Oct. 69		Mar. 70		Apr. 70		May 70		July 70		Aug. 70		Sept. 70		Oct. 70	
Size of fish (cm)[a]	10.0-19.9	⩾20.0	10.0-19.9	⩾20.0	10.0-19.9	⩾20.0	10.0-19.9	⩾20.0	10.0-19.9	⩾20.0	10.0-19.9	⩾20.0	10.0-19.9	⩾20.0	10.0-19.9	⩾20.0	10.0-19.9	⩾20.0	10.0-19.9	⩾20.0
No. stomachs	7	5	14	6	5	8	14	33	8	7	1	2	7	0	17	5	19	4	16	2
Average volume (cc)	0.3	2.3	0.09	0.18	0.14	0.3	0.15	0.8	0.15	0.21	0.2	3.0	0.2	–	0.2	1.7	0.25	0.6	0.2	0.3
Ephemeroptera (nymphs)			20	20		5	40	10	10	20	25		25		10	2	14	9	20	
Ephemeroptera (adults)																	1	1		
Trichoptera (larvae)	40	20	25	25	35	25	20	5	25	35			30		25	2	30	13	40	
Trichoptera (adults)											50									
Diptera (larvae & pupae)	5		5				25	5	23	6			5		10	3	10	2	16	
Diptera (adults)	20	10	15	40	20	10				10			10		15	12	15	3	4	
Aquatic Coleoptera (larvae)		10	5	5			3	25				10			8	3	8			10
Aquatic Coleoptera (adult)		40	5		30	25		10	15		10		3		2		2	5	3	
Odonata	10[b]											15			2	15[b]				
Plecoptera			10			20	10	35	25				3		3	6	2			10
Other aquatic organisms															5	15			5	
Other terrestrial organisms	10		5	5	10	10		10		15		70	13		16	11	12	15		35
Fish		15													3	20		50		
Miscellaneous & unidentified	15	5	10	5	5	5	2		2	14	15	5	11		1	11	6	2	12	45

[a] One and two year old (10.0 - 19.9 cm), three and older (⩾20.0 cm)

[b] Adult

Table 16. Stomach contents of brown trout, brown bullhead, and roach obtained from Gilchrist Pond 1969-70.[a]

	July 69				Aug. 69				October 69				April 70				May 70				June 70			July 70		
	Brown Trout		Brown Bullhead	Roach	Brown Trout		Brown Bullhead	Roach	Brown Trout		Brown Bullhead	Roach	Brown Trout		Brown Bullhead	Roach	Brown Trout		Brown Bullhead	Roach	Brown Trout	Brown Bullhead	Roach	Brown Trout	Brown Bullhead	Roach
Size of fish (cm)	10.0-20.0	>20.0			10.0-20.0	>20.0			10.0-20.0	>20.0			10.0-20.0	>20.0			10.0-20.0	>20.0			10.0-20.0			>20.0		
No. stomachs	13	3	7	9	4	2	5	6	5	6	6	12	4	3	3	13	4	4	14	10	3	5	9	3	9	9
Average volume (cc)	0.9	0.9	0.3	0.1	0.2	0.3	0	0	0.1	0.2	0	0	0.3	0.5	0	0.1	0.7	1.0	0.5	0.2	0.2	0.3	0.2	0.6	1.0	0
Ephemeroptera (larvae & pupae)		5	15		11	10			10	5				20			25		65		50	30			35	
Trichoptera (larvae)																									5	
Trichoptera (adult)					2																					
Diptera(larvae & pupae)	20	10	65	25	35	10			20	20			35	15			15		10	30		5	5		10	
Diptera (adult)	30	15			30	25			45	30			60	10												
Coleoptera		15			2				10	15[c]								13[c]								
Odonata (larvae)	10	10		5		15							5	55					10		35	5		10	10	
Odonata (adult)	30	20								15																
Mollusca					2	5				5									10	40		15	30	5	15	
Fish		25	10		15	35											25	50						80		
Crustacea	10		10	70					15	5									5			10			25	
Miscellaneous					3					5							35	37		30	15	35	65[b]	5		

[a]Values expressed as percent of total volume of organisms eaten

[b]Vegetation

[c]Adult form

TABLE 17
Food of brown trout, roach, brown bullhead and whitefish collected by electrofishing and rotenoning in areas below Gilchrist Pond, 1970-71

	Rotenoning 9/15/70					Electrofishing 7/24/70			Electrofishing 9/15/71			
	Brown Trout <20 cm	Brown Trout >20cm	Roach	Whitefish	Brown Bullhead	Brown Trout	Roach	Brown Bullhead	Brown Trout	Roach	Whitefish	Brown Bullhead
No. of stomachs	13	28	10	20	4	10	2	5	10	8	3	4
Average volume (cc)	0.46	0.98	.1	0.2	0.6	0.25	<.1	0.6	<.1	<.1	0.1	<.1
Ephemeroptera (larvae & pupae)	4	3		13		15		1	5		15	
Ephemeroptera (adult)	7	3		2		5						
Trichoptera (larvae & pupae)	6	5		4		6		2	85	80	60	40
Trichoptera (adult)		1		1								
Diptera (larvae & pupae)	2	5	15	55	15	6	10	10	5	18	10	
Diptera (adult)	6	9				15		5				
Aquatic Coleoptera	2	4				1					5	
Pleocoptera				1		3[a]						
Terrestrial organism	15[b]	25[b]				15						
Fish	10	15				10						
Odonata (larvae)	1	3				10			3			
Odonata (adult)		4										
Mollusca	1	1		7	50	6		70			5	30
Miscellaneous & debris	45	22	85	17	35	8	90	12	2	2	5	30

[a] adult form
[b] ⩾50 percent Fomicidae

Appendix XII. Physical parameters measured at selected study sites, 1971.

	Cow Camp	Gulick's	Old Mill	Crescent	Rocky Reach	Willows	Larson's	Conifers	Crider's
Total surface area (ft^2)	15,909	12,288	9,354	9,999	17,907	8,311	12,576	14,863	12,167
Surface area (acres)	.365	.282	.214	.229	.411	.191	.289	.341	.279
Volume (ft^3)	34,841	18,801	15,902	13,999	21,667	16,373	28,799	29,577	26,889
Shallow slow area (ft^2)	2,925	3,581	2,331	2,428	4,949	1,368	1,730	4,079	2,475
Shallow fast area (ft^2)	205	1,623	740	3,604	7,263	451	418	567	108
Deep slow area (ft^2)	9,906	2,788	1,810	1,174	1,386	3,763	3,454	7,770	7,180
Deep fast area (ft^2)	2,873	4,296	4,473	2,796	4,309	2,729	6,974	2,447	2,404
Total Cover (ft^2)	3,765	3,277	1,368	516	1,478	1,668	2,628	3,326	3,073
(% of total surface area)	(24)	(27)	(15)	(5)	(8)	(20)	(21)	(22)	(25)
Willow cover (ft^2)	0	2,622	635	114	447	722	1,346	577	1,399
(% total cover)	(0)	(80)	(46)	(22)	(30)	(43)	(51)	(17)	(46)
Log cover (ft^2)	722	34	0	0	735	301	96	512	79
Aquatic vegetation (ft^2)	2,683	557	587	237	159	583	672	2,104	1,303
Undercut bank (ft^2)	360	64	146	165	137	62	514	133	292
Mean depth (ft)	2.19	1.53	1.70	1.40	1.21	1.97	2.29	1.99	2.21
Mean thalweg depth (ft)	3.10	2.47	2.39	2.66	2.14	2.78	3.11	2.84	3.24
Thalweg length (ft)	748	658	532	482	722	396	712	698	648
Mean width (ft)	24.4	20.4	19.6	26.8	27.6	23.2	21.2	24.4	20.8
Mean velocity (ft/sec)	.96	1.51	1.51	1.57	1.75	.99	1.37	.85	1.00