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THE EFFECTS OF CONTROLLED DEWATERING ON A TROUT STREAM

by

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VITA

The author, Melvin Earl Kraft, was born in Bozeman, Montana, September 15, 1942, to Earl and Melva Mae Kraft. He graduated from Bozeman Senior High School in 1961. In the fall of 1961, he entered Montana State College and in June, 1965, received a Bachelor of Science degree in Fish and Wildlife Management. He received the Captain T. Booth Holker Award in the spring of 1965. Immediately following graduation, he began graduate studies at Montana State University in Bozeman. He held a graduate assistantship in the Zoology and Entomology Department for the academic years 1965-1966 and 1966-1967. He married the former Carol Saviah Clothier in September, 1967.

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ABSTRACT

The effect of controlled flow reductions on the physical characteristics and fish populations of Blacktail Creek, Montana, were studied from June, 1965, through September, 1967. Three test sections (designated A, B, and C) were dewatered 75%, 50%, and 25% respectively for about 3 months during the summers of 1965 and 1966 and all three sections were dewatered 90% during 1967. Two additional sections were designated as controls. A pool and run in each section were mapped and their fish populations sampled. About 90% of the fish were eastern brook trout. During 1965 and 1966 catchable trout were jaw-tagged while in 1967 they were cold-branded. Average current velocity was the most effected physical parameter with over 70% reduction when flows were reduced 90%. Area and average depth were least effected. Fast water types which comprised over 60% of the area at normal flows were reduced to 15% or less while slow-shallow water types increased from about 35% at normal flows to about 85% when flows were reduced 90%. During 1965 and 1966 no substantial changes in numbers or weights of fish could be attributed to flow reductions. The standing crop of eastern brook trout in two runs were most effected during 1967. Number decreased about 75% and weight over 58%. Movement of marked fish was greatest from section B and C runs which was consistent with low standing crops in these areas. A multiple linear regression with physical parameters as independent variables and fish numbers as dependent variables accounted for 77% and 83% of the variation in the number of age I and older brook trout in runs and pools and was significant at the 0.01 level.

INTRODUCTION

The normal flows of many streams are altered when water is used or controlled for hydroelectric production, irrigation, flood control, or municipal water supplies. Pfitzer (1954), Irving and Cuplin (1956), Powell (1958), Abdurakhmanov (1958), Dyuzhikov (1961), and Sharonov (1963), reported that reduced and fluctuating flows below reservoirs adversely affected fish growth and reproduction and caused certain species to disappear. Work by Weber (1959) and Curtis (1959) showed the effects of reduced flows on the physical characteristics of rivers. Schieminz (1960) showed fish movement at changing flows and stated that the variation in the local living space depending on the level of the water appeared to be a substantial cause for fish movement. Clothier (1954) reported upstream movement of fish coincident with water reductions in irrigation canals. It is possible that decreased cover and increased competition brought about by reduced water levels caused the fish to move.

Of major importance in the western United States is the reduction of summer stream flows when water is used for irrigation. Spindler (1955) and Clothier (1953, 1954) discussed fish losses in irrigation diversions and methods of reducing such losses but little is known about how this dewatering affects the stream.

The Montana Fish and Game Department began a study in 1964 to determine if reduced stream flows affect a trout population, and if so, what flows are required to sustain a population sufficient for recreational fishing (Wipperman, 1966). In conjunction with the above study

I undertook an investigation to determine how different amounts of dewatering affected the physical characteristics of specific pools and runs and their fish populations. Field studies were made on Blacktail Creek, Montana, from June, 1965, through September, 1967.

DESCRIPTION OF AREA

Blacktail Creek drainage (312 sq. miles) lies in Beaverhead County in southwestern Montana. The major tributaries rise on the southwest slopes of the Snow Crest Mountains about 8,600 feet msl (mean sea level) and flow about 18 miles before joining to form Blacktail Creek at approximately 6,500 feet msl. At higher elevations they flow through coniferous forests which gradually give way to sagebrush or grassland hills. Blacktail Creek meanders about 28 miles to join the Beaverhead River at about 5,100 feet msl at Dillon, Montana. The upper half of Blacktail Creek flows through a broad valley with grass covered collescent alluvial fans bordering both sides of the 1.4 mile wide flood plain. The valley is cut in Tertiary deposits of glacial outwash, sand, and gravel (Alder, 1953). The major land use in this area consists of livestock grazing and haying of native grasses in meadows. The lower half of the creek cuts across the Beaverhead valley and is severely dewatered for irrigation during summer months. The study area was located in the upper half of Blacktail Creek, above irrigation diversions, where the stream gradient was 41 feet per mile.

Flows of Blacktail Creek are characterized by high spring runoffs and low flows the remainder of the year. Flow records from a United States Geological Survey gage station about 8 miles below the study area showed that from 1948 through 1965 a peak mean monthly discharge of 237 cfs (cubic feet per second) occurred in June, 1964, and the low monthly discharge of 16 cfs occurred in the winters of 1964 and 1959. Mean monthly discharges for 1965, 1966, and the 18 year average are shown in Figure 1.

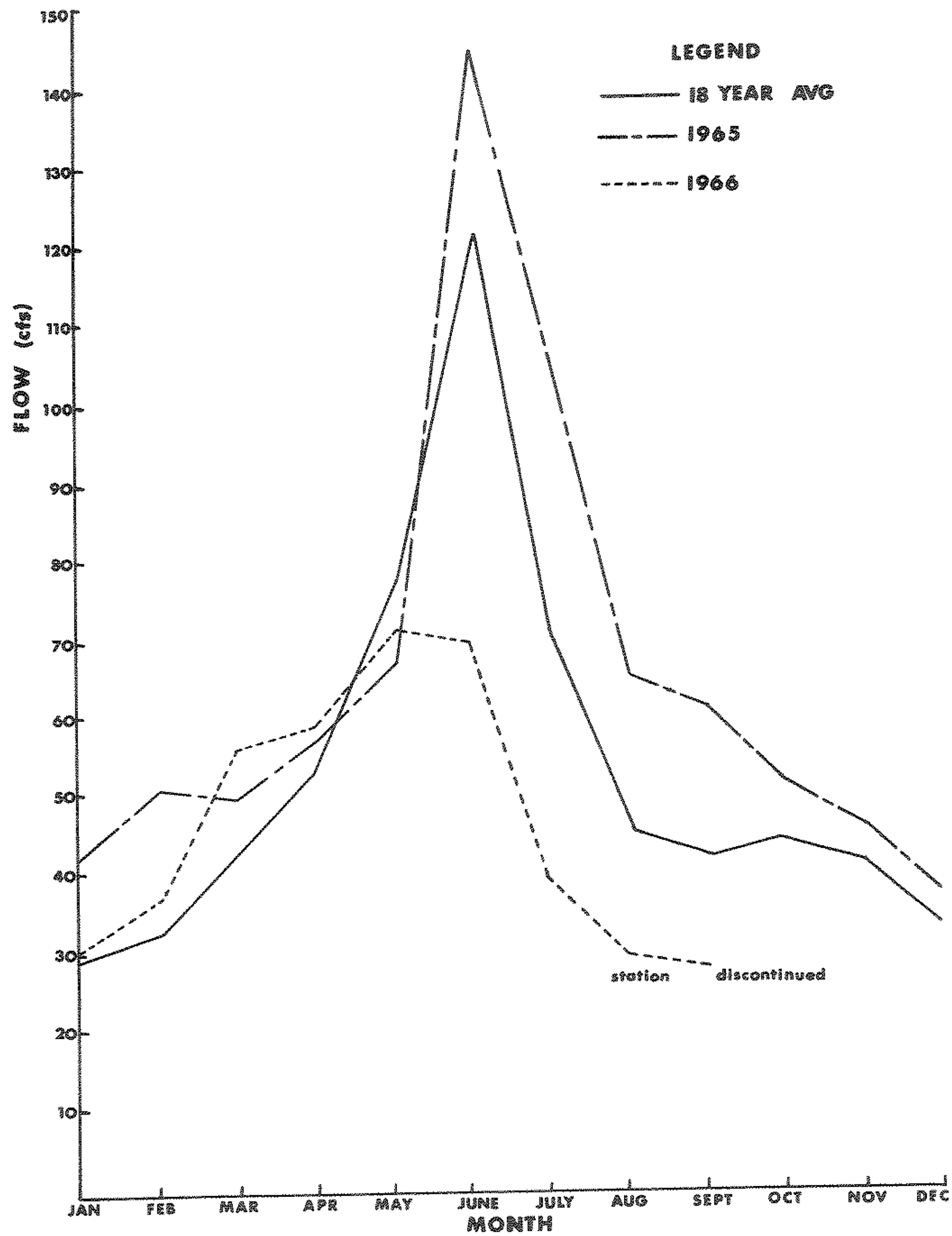

Figure 1: Mean monthly discharges for 1965, 1966, and the 18 year average.

No tributaries occurred between the study area and the gage station but flows increased progressively downstream due to accretions from springs and ground water. The gage station was discontinued in September, 1966, but a flow recorder at the study area showed 1967 flows to be near average.

Blacktail Creek flows in a well defined channel and bank erosion or flooding are uncommon. Shrubs comprised 57% of the stream bank vegetation and open meadows 43%. Willow (Salix sp.) was predominant in shrub areas being interspersed with water birch (Betula sp.), wild rose (Rosa sp.) and wild gooseberry (Ribes sp.) (Figure 4). Meadow vegetation was primarily sedges (Carex sp.), and grasses (Agrostis sp. and Phleum sp.). Slender pondweed (Potamogeton filiformis) and aquatic buttercup (Ranunculus aquatilis) were present in the stream.

Temperature ranges for July through September were: 30.5 - 63.5 F, 31.5 - 68.0 F, and 42.5 - 66.5 F for 1965, 1966, and 1967 respectively. Chemical analyses made in the study area during August, 1965, gave the following: total alkalinity 202 ppm, total hardness 237 ppm and specific conductance 284 microhms.

Species of fish taken in order of decreasing abundance were brook trout (Salvelinus fontinalis), rainbow trout (Salmo gairdneri), and mountain whitefish (Prosopium williamsoni). Mottled sculpins (Cottus bairdi) while abundant were not collected efficiently.

METHODS

A 1,700 foot portion of Blacktail Creek was divided into three sections of about equal length and designated section A, B, and C progressing downstream (Figure 2). A diversion canal was dug around the sections with short returns entering the upper end of section B and C. Steel structures for regulating flows were installed in May, 1965, at the head of section A, the head of the canal, and in the canal and at the head of each return to section B and C. Fish traps were installed at the lower end of section C and at the upper end of section A in April, 1966. Two control sections were established, one about one-half mile above and the other one-fourth mile below the dewatered sections. A "pool" and "run" in each of these five sections were selected for intensive study. A pool was defined as a deep-slow portion of the stream, usually in a bend and with associated cover. A run was generally a straight portion of stream with average depth, average velocity and some cover. The stream was closed to fishing from one mile above to one mile below the study sections.

The base flow for dewatering was determined by considering August flows for the six years preceding 1965 and the lowest three years (1959, 1961, and 1963) were averaged to give 32 cfs. Section A was dewatered to 8 cfs, section B to 16 cfs, and section C to 24 cfs during 1965 and 1966. All three sections were dewatered about 90% to a flow of 3 cfs in 1967 (Figures 3 - 6). Ground water accretions were not sufficient to alter flows in the dewatered sections. The dewatering period was selected to

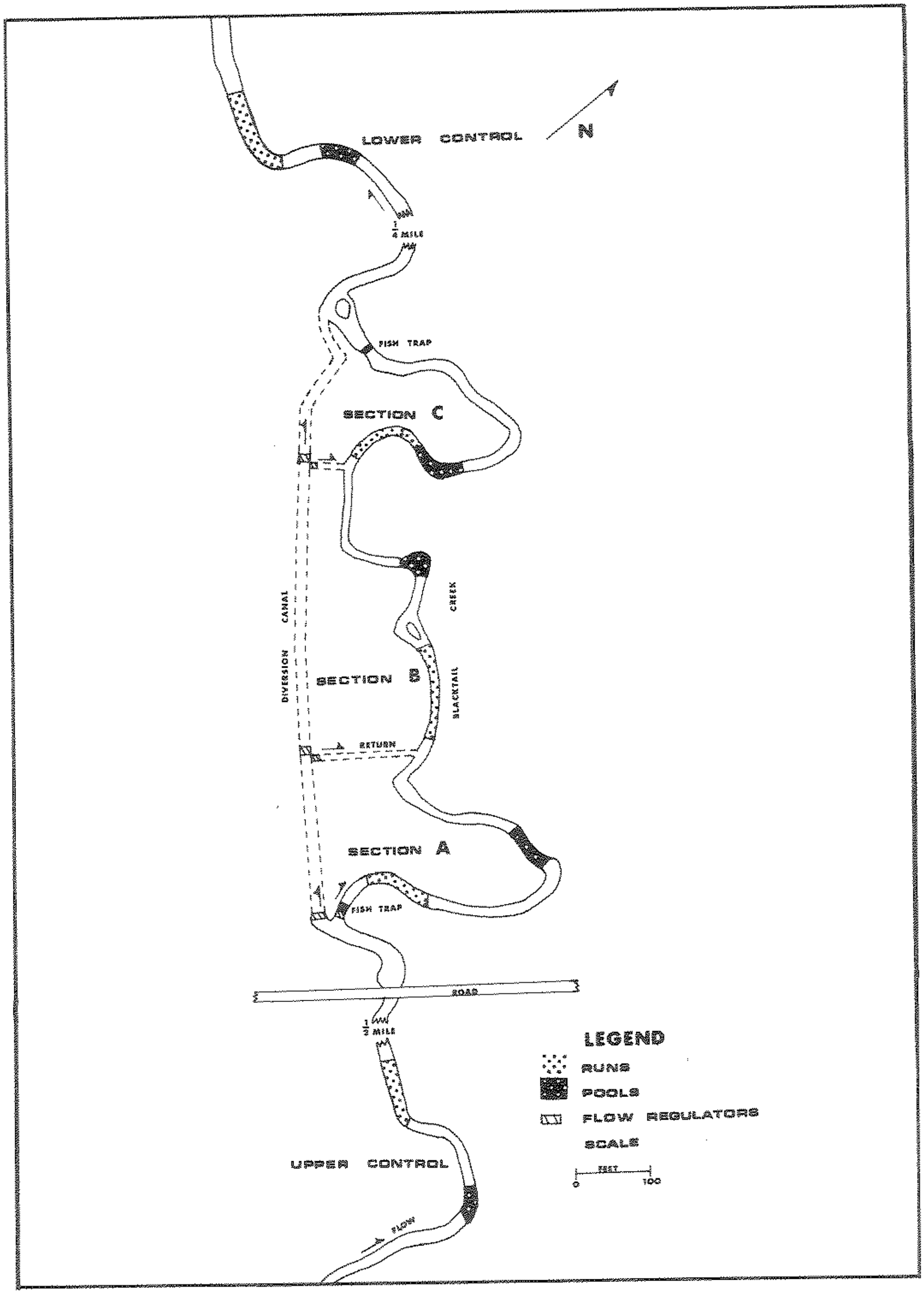

Figure 2: Map of study area showing location of study sections and diversion canal.

Figure 3: Section A pool (32 cfs).

Figure 4: Section A pool (3 cfs).

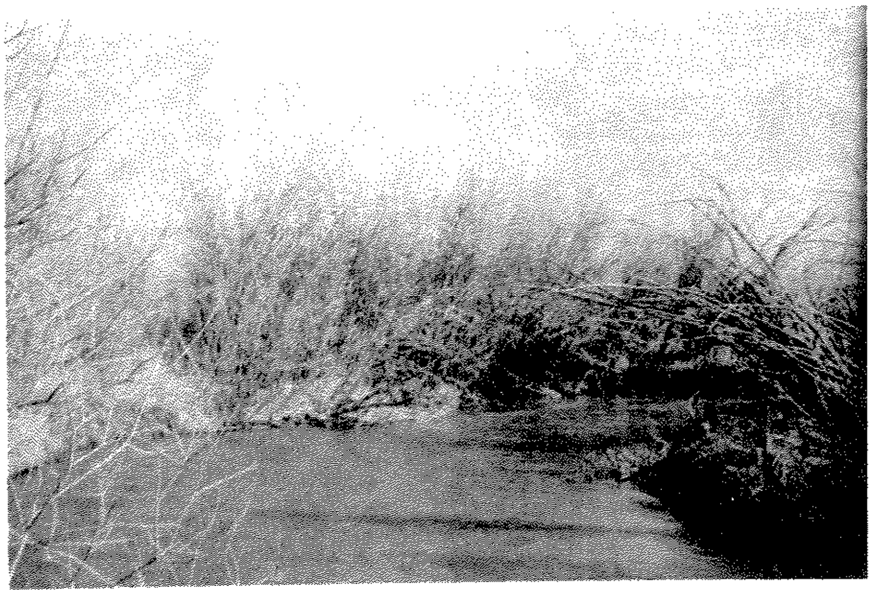

Figure 5: Section C run (32 cfs).

Figure 6: Section C run (3 cfs).

simulate the normal irrigation season of about 3 months.

Fish populations in all sections were sampled in the spring before dewatering and in the fall before normal flows were restored. Sampling was done by electrofishing using a 300 volt, 850 watt direct current unit. The entire sections were sampled but selected pools and runs were isolated with blocking nets. Three passes per sampling period were made through each area. Equal effort to capture fish in each section should give comparable population data without adjusting figures by recapture experiments (Wipperman, 1966) and would minimize the effects of shocking and handling fish. Captured fish were anesthetized with MS-222 (Tricaine Methanesulfonate) and measured (total length) to the nearest 0.1 inch and weighed to the nearest 0.01 pound. Trout over 6.9 inches in total length in the selected pools and runs of the dewatered sections and the lower control were marked with colored plastic jaw tags in 1965 and 1966. In 1967 trout in these areas were cold-branded as described by Everest and Edmondson, 1967 (personal correspondence). All symbols were distinguishable 4 months after branding. Trout over 6.9 inches long in the pool and run of the upper control were fin-clipped each year. In 1965 the Montana Fish and Game Department fin-clipped fish in all sections, using a different combination for each section.

All pools and runs were mapped each summer during the dewatering period and at least once when the flow was near 32 cfs. Transects were established at 5-foot intervals measured at the middle of the stream and depth and velocity were measured every two feet along each transect.

Velocities were measured with a Gurley current meter at 0.4 of the observed depth. The water comprising a pool or run was classified using a modified water-type key (Burkhark, 1964) based on depth and velocity (Table 1).

Table 1. Water-type classification.

Water type	Depth (feet)	Current velocity (feet per second)
Deep Fast	+1.5	+1.00
Fast Shallow	0.1-1.5	+1.00
Slow Shallow	0.1-1.5	-1.00
Deep Slow	+1.5	-1.00

Cover was mapped and included overhanging vegetation (dead or alive) and undercut banks. Overhanging vegetation had to be submerged or within one foot of the water's surface to be classified as cover. Surface area, water-type composition, and extent of cover were determined with a planimeter from the maps. Average width, depth and current velocity were calculated for each area. The thalweg, and the maximum velocity were also determined.

The data were analyzed in a multiple linear regression by the computing center at Montana State University to determine the relationships between physical characteristics and fish populations of pools and runs.

RESULTS

Physical Parameters of Runs and Pools

A total of 22 maps were constructed at flows ranging from 3 to 35 cfs. Mapping results are summarized in Table 2. Area losses of pools and runs ranged from 6% when flows were reduced by 25% to 24% when reduced 75%. At 90% flow reduction, area loss ranged from 17-36%. There were no measurable decreases in average depth when flows were reduced by 25%. Decreases in average depth at 75% and 90% flow reductions did not exceed 30% and 42% respectively. Thalweg reductions approximately paralleled those of average depths but were of slightly greater magnitude. Decreases in average water velocity in pools and runs ranged from 18% when flows were reduced by 25% to 56% with the 75% flow reduction. At 90% reduced flows, average current velocity losses ranged from 71-85%. Maximum velocity usually decreased less than average velocity. At flow reductions from 25% to 75%, cover losses exceeded 36% in only one instance (54%). At reduced flows of 90%, cover losses ranged from 39-56%. Average velocity was most seriously effected by flow reductions and area and depth were least effected (Fig. 4, 6). Area, average depth, and total cover were more effected in runs than in pools when 90% dewatered. Reduction in velocity was greatest in pools. Wipperman (personal correspondence) measured the entire dewatered portion of stream at 90% flow reductions and found results similar to those above.

Flow reductions resulted in pronounced changes in the extent of water types (Fig. 7, 8). With 90% flow reductions the following conditions prevailed: deep-fast which comprised 20% or more of the area at normal flows

Table 2. Physical parameters of runs and pools.

	Flow cfs	Surface Area ft^2	Avg Depth ft	Thal-weg ft	Avg vel fps	Max vel fps	Total Cover ft^2
Upper control run	29	1418	1.1	1.5	1.57	2.20	203
Lower control run	33	2504	1.3	1.9	1.39	1.95	428
Upper control pool	29	756	0.9	1.8	1.91	2.70	140
Lower control pool	33	1086	1.2	2.2	1.62	2.39	438
Section A run	35	1503	1.0	1.7	2.13	3.29	405
	8	1139	0.7	1.1	1.03	1.38	280
	3	1055	0.6	1.0	0.58	0.97	190
Section A pool	35	1168	1.2	2.2	1.47	2.07	263
	8	918	1.0	1.6	0.64	0.98	115
	3	882	0.8	1.4	0.34	0.62	120
Section B run	35	2345	0.9	1.8	1.80	2.93	411
	14	1964	0.8	1.5	1.31	2.01	338
	3	1493	0.6	1.0	0.53	0.87	178
Section B pool	35	1868	1.1	2.4	1.52	2.25	405
	14	1635	1.1	2.0	0.91	1.64	258
	3	1553	0.9	1.7	0.31	0.71	233
Section C run	35	1750	1.2	2.1	1.91	2.78	463
	27	1571	1.2	1.8	1.57	2.51	323
	3	1230	0.7	1.2	0.47	0.90	283
Section C pool	35	1530	1.2	2.1	1.55	2.24	298
	27	1436	1.2	2.1	1.12	1.67	250
	3	1158	0.9	1.5	0.23	0.46	163

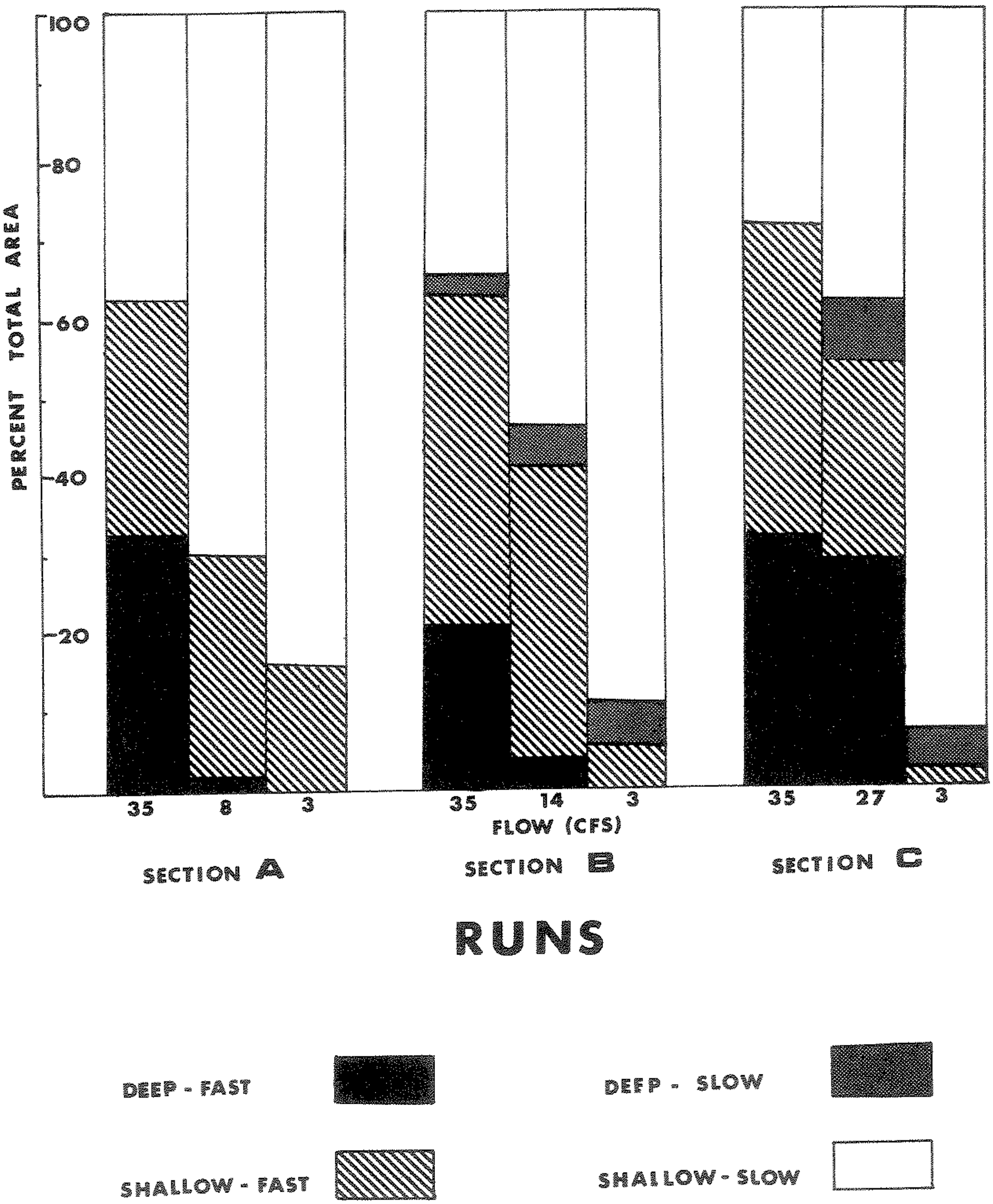

Figure 7: Percent of water-types in runs at various flows.

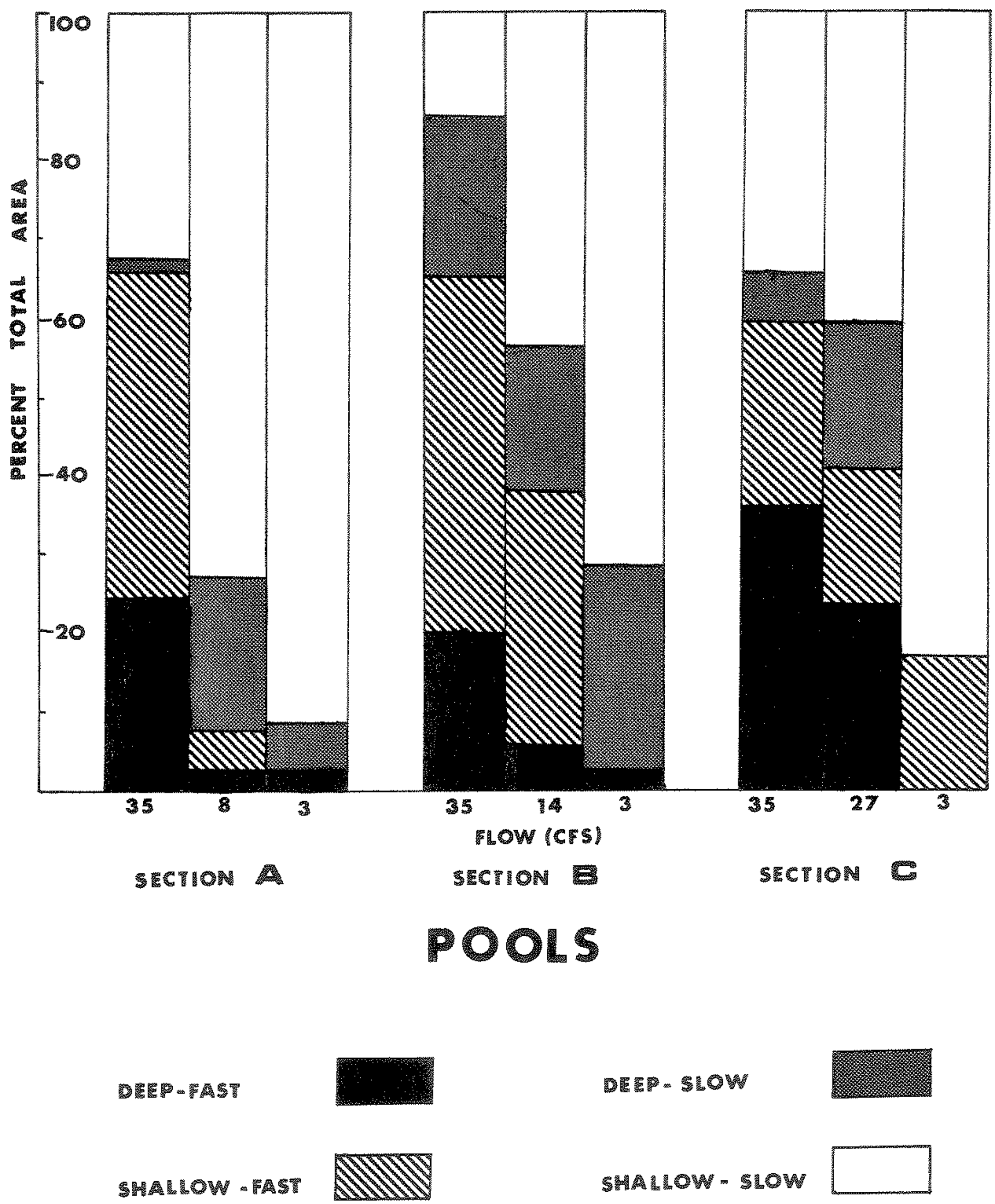

Figure 8: Percent of water-types in pools at various flows.

was eliminated; slow-shallow increased from about 35% at normal flows to 85%; fast-shallow was reduced or eliminated; and deep-slow remained about the same.

Fish Populations of Runs and Pools

A total of 3,514 fish were collected during the study. Eastern brook trout comprised 87%, rainbow trout 8%, and mountain whitefish 5% of the total fish collected during the first sampling period. Control and dewatered sections had comparable species compositions but there were about 50% less in the controls. Data on fish of age group 0 were separated from older age groups since age group 0 fish were too small to be collected during spring sampling. Standing crops of larger fish (age I and older) before and after flow reductions are presented in Table 3.

Fish population data for the fall of 1965 are not suitable for determining the effects of dewatering since sampling occurred during the eastern brook trout spawning period. The flow control structure at the head of section A acted as a barrier so that migrating fish concentrated in the most dewatered area. The number and weight of brook trout in section A nearly doubled during the period of reduced flows. The number and total weight of brook trout in section B and C pools increased over 10% more than those in control pools.

During 1966, there was a 23% loss of brook trout number in the control sections and a 2% decrease in the dewatered sections. The greatest numerical decrease of brook trout (20%) occurred in section A run (75% flow reduction) while decreases of other sections did not exceed 6%. The

Table 3. Number and total weight (in parentheses) of fish age I and older before and after flow reduction.

EASTERN BROOK TROUT

	1965		1966		1967	
	June	Oct	May	Aug	May	Sept
Upper Control						
run	25 (4.59)	25 (7.18)	46 (3.86)	23 (2.37)	24 (3.79)	11 (2.07)
pool	12 (2.24)	10 (1.64)	14 (1.48)	18 (5.15)	8 (1.57)	6 (0.97)
Lower Control						
run	45 (7.57)	65 (14.59)	78 (10.37)	66 (9.35)	52 (7.65)	48 (9.74)
pool	32 (5.12)	38 (8.51)	39 (4.89)	30 (6.17)	36 (5.18)	24 (4.43)
Run total	70 (12.16)	90 (21.77)	124 (14.23)	89 (11.72)	76 (11.44)	59 (11.81)
Pool total	44 (7.36)	48 (10.15)	53 (6.37)	48 (11.32)	44 (6.75)	30 (5.40)
Total	114 (19.52)	138 (31.92)	177 (20.60)	137 (23.04)	120 (18.19)	89 (17.21)
Section A						
run	30 (6.74)	63 (18.32)	60 (7.36)	48 (4.61)	35 (5.06)	28 (4.16)
pool	52 (9.74)	81 (17.66)	46 (6.11)	48 (8.48)	38 (7.12)	43 (8.02)
Section B						
run	66 (11.32)	43 (7.18)	72 (7.81)	68 (7.24)	54 (5.04)	13 (1.32)
pool	41 (7.67)	73 (15.20)	57 (10.04)	55 (12.32)	63 (9.93)	58 (11.61)
Section C						
run	65 (10.84)	40 (7.85)	64 (8.21)	73 (12.20)	79 (12.68)	23 (5.20)
pool	39 (6.31)	36 (6.04)	60 (9.56)	59 (8.35)	32 (5.03)	40 (7.76)
Run total	161 (28.90)	146 (33.35)	196 (23.38)	189 (24.05)	168 (22.78)	64 (10.68)
Pool total	132 (23.72)	190 (38.90)	163 (25.71)	162 (29.15)	133 (22.08)	141 (27.39)
Total	293 (52.62)	336 (72.25)	359 (49.09)	351 (53.20)	301 (44.86)	205 (38.07)

Table 3. Continued.

RAINBOW TROUT

	1965		1966		1967	
	June	Oct	May	Aug	May	Sept
Upper Control						
run	1 (0.03)	0 (0.00)	3 (1.18)	0 (0.00)	7 (2.34)	0 (0.00)
pool	2 (1.05)	4 (1.40)	1 (0.09)	4 (1.43)	1 (0.30)	3 (0.38)
Lower Control						
run	3 (1.16)	3 (1.68)	3 (1.09)	7 (1.62)	5 (1.85)	6 (2.78)
pool	4 (1.13)	6 (2.47)	3 (1.06)	7 (4.19)	3 (1.65)	8 (2.19)
Run total	4 (1.19)	3 (1.68)	6 (2.27)	7 (1.62)	12 (4.19)	6 (2.78)
Pool total	6 (2.18)	10 (3.87)	4 (1.15)	11 (5.62)	4 (1.95)	11 (2.57)
Total	10 (3.37)	13 (5.55)	10 (3.42)	18 (7.24)	16 (6.14)	17 (5.35)
Section A						
run	0 (0.00)	2 (0.90)	1 (0.66)	0 (0.00)	0 (0.00)	0 (0.00)
pool	3 (2.31)	2 (1.50)	3 (1.18)	3 (1.48)	2 (1.10)	4 (1.61)
Section B						
run	5 (1.65)	3 (1.01)	3 (1.45)	0 (0.00)	3 (0.81)	0 (0.00)
pool	13 (7.69)	9 (4.59)	7 (2.97)	13 (7.70)	13 (7.43)	7 (3.37)
Section C						
run	6 (3.32)	3 (1.33)	5 (2.10)	4 (1.96)	5 (0.72)	5 (1.10)
pool	1 (0.24)	3 (1.94)	2 (1.38)	4 (2.47)	5 (3.42)	5 (2.64)
Run total	11 (4.97)	8 (3.24)	9 (4.21)	4 (1.96)	8 (1.53)	5 (1.10)
Pool total	17 (10.34)	14 (8.03)	12 (5.53)	20 (11.65)	20 (11.95)	16 (7.62)
Total	28 (15.21)	22 (11.27)	21 (9.74)	24 (13.61)	28 (13.48)	21 (8.72)

Table 3. Continued.

WHITEFISH

	1965 June	1965 Oct	1966 May	1966 Aug	1967 May	1967 Sept
Upper Control						
run	1 (0.30)	0 (0.00)	1 (0.54)	0 (0.00)	1 (0.44)	0 (0.00)
pool	1 (1.37)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)
Lower Control						
run	7 (5.45)	7 (1.60)	9 (4.03)	7 (2.18)	5 (3.02)	8 (3.99)
pool	3 (2.40)	3 (1.99)	4 (2.88)	1 (0.15)	1 (0.78)	3 (2.36)
Run total	8 (5.75)	7 (1.60)	10 (4.57)	7 (2.18)	6 (3.46)	8 (3.99)
Pool total	4 (3.77)	3 (1.99)	4 (2.88)	1 (0.15)	1 (0.78)	3 (2.36)
Total	12 (9.52)	10 (3.59)	14 (7.45)	8 (2.33)	7 (4.24)	11 (6.35)
Section A						
run	0 (0.00)	0 (0.00)	6 (4.94)	0 (0.00)	3 (1.31)	0 (0.00)
pool	2 (0.76)	0 (0.00)	5 (4.71)	0 (0.00)	2 (0.22)	0 (0.00)
Section B						
run	4 (2.27)	1 (0.47)	4 (1.97)	0 (0.00)	0 (0.00)	0 (0.00)
pool	2 (1.40)	5 (2.15)	4 (3.31)	3 (1.90)	1 (1.71)	5 (4.67)
Section C						
run	0 (0.00)	3 (0.57)	3 (1.09)	4 (3.77)	3 (2.61)	0 (0.00)
pool	5 (2.70)	11 (2.21)	6 (5.61)	6 (5.90)	2 (1.40)	0 (0.00)
Run total	4 (2.27)	4 (1.04)	13 (8.00)	4 (3.77)	6 (3.92)	0 (0.00)
Pool total	9 (4.86)	16 (4.36)	15 (13.63)	9 (7.80)	5 (3.33)	5 (4.67)
Total	13 (7.13)	20 (5.40)	28 (21.63)	13 (11.57)	11 (7.25)	5 (4.67)

greatest decrease of total weight (37%) also occurred in section A run while decreases in other sections did not exceed 13%. Wipperman (1967), found a slightly greater increase in the number of brook trout for sections A, B, and C during the dewatered period than in the controls.

During the 1967 dewatering period, control sections and dewatered areas showed a decrease in the number and weight of brook trout. Number decreased 6% and total weight 10% more in dewatered areas than in controls. Brook trout in section B run and C run were most seriously effected. Number decreased 76% and 71% and weight 74% and 59% respectively. The total weight and number of brook trout in section A run and pool decreased about 20%. The number of brook trout in runs of the control sections decreased 8% and 54% while weight decreased 45% in one run and increased 27% in the other. All dewatered pools showed an increase in brook trout weight ranging from 13-54%. Numbers in two pools increased over 13% while in the other (section B pool) they decreased 8%. Brook trout in pools of the control sections showed a consistant decrease in number (22% and 25%) and weight (14% and 38%). This indicates movement of fish from runs to pools in dewatered areas.

The number of rainbow trout and whitefish collected in individual pools and runs was too few to make good comparisons. Rainbow trout number and weight generally increased in control sections during the summer with greater increases occurring in the pools. Rainbow trout in runs of the dewatered areas usually decreased while those in pools showed no consistant increase or decrease. During 1967, whitefish in control sections showed a slight increase in number and weight, but in the dewatered sections showed a net decline. They disappeared from all runs and were found in only one of three pools.

Data on age 0 (fingerling) fish collected after the dewatering period were separated from older fish by length frequency analyses and by aging from scales (Wipperman, 1966). The number of fingerlings collected after each dewatering period are presented in Table 4. More brook trout were taken in run areas than in pools. The number of fingerling brook trout decreased in both the controls and study sections during the study period. Dewatering did not appear to cause the decline since decreases in controls exceeded those of the dewatered area.

Table 4. The number of age group 0 brook trout, rainbow trout, and whitefish collected in fall samples.

		1965			1966			1967		
Section		brook trout	rainbow trout	white fish	brook trout	rainbow trout	white fish	brook trout	rainbow trout	white fish
A	run	23	0	4	42	5	0	17	0	0
	pool	27	0	5	10	0	0	5	0	0
B	run	77	1	7	46	2	4	44	0	1
	pool	21	1	5	8	1	1	5	1	0
C	run	7	0	2	22	1	2	11	0	0
	pool	11	0	10	7	0	4	2	0	0
A, B, & C	runs	107	1	13	110	8	6	72	0	1
	pools	59	1	20	25	1	5	12	1	0
Controls	runs	60	4	7	38	3	0	19	3	5
	pools	26	0	1	6	2	0	8	1	6

Relationship of Physical Parameters to Fish Populations

A multiple linear regression was set up for 1966 and 1967 data with flow, surface area, average depth, average current velocity, thalweg, maximum velocity, and total cover as the independent variables and number of eastern brook trout per run or pool as the dependent variable. Regressions were computed separately for age 0 and older fish.

The seven parameters accounted for 77% and 83% of the variation in the number of age I and older brook trout in runs and pools respectively, and were significant at the 0.01 level. Area and average velocity were the most important parameters in pools while flow, average depth, area and total cover were important in runs. The seven parameters accounted for 82% and 68% of the variation in the number of age 0 brook trout in runs and pools and were significant at the 0.01 and 0.05 levels respectively. Flow, area, average current velocity and total cover were the most important parameters in runs while flow and average depth were most important in pools.

Regressions were computed for age 0 brook trout with age I and older brook trout included with the above independent variables. There was a strong indication that age I and older brook trout influenced the number of age 0 fish in pools but not in runs.

Because of the low number of observations it was not possible to compare statistically information from the control runs or pools to the dewatered runs or pools.

Recaptures of Marked Fish

A total of 485 trout were jaw tagged, 221 branded and 17 fin-clipped during the study (Table 5). About 90% of the fish tagged and recaptured were eastern brook trout. Fish in the upper control were fin-clipped in 1966 and 1967 but not tagged or branded to determine if a difference occurred in the percentage of returns between clipped fish and tagged or branded fish. The number clipped and recaptured was too small to give a reliable comparison.

During 1965 and 1966 fish recaptured in the place where marked were fewest from section A (75% flow reduction) and did not exceed 15%. Fish from the lower control recaptured in the place where marked was about 31% for both years. Only 15% of the tagged fish were recaptured in the place where marked from runs of section B and C during 1965 while 38% and 26% respectively were recaptured in the pools. During 1966, fish recaptured in the place where marked from the run and pool in section B were similar to those for the lower control but higher in section C run (38%) and lower in the pool (23%).

During 1967, fish recaptured in the place where marked in section A were considerably higher than in 1965 and 1966 and were similar to recaptures in the place where marked from the lower control (about 30%). Returns from section B and C pools were comparable to the two previous years and to the lower control. Recaptures in the place where marked were lowest in section B and C runs which was consistent with the low standing crops in these areas at the close of the dewatering period in 1967.

Table 5. The number and percent (in parentheses) of marked trout recaptured after each dewatering period for 1965, 1966 and 1967.

	1965				1966				1967			
		recaptures				recaptures				recaptures		
	tagged	same place	same sec.	another sec.	* tagged	same place	same sec.	another sec.	** tagged	same place	same sec.	another sec.
Section A												
run	21	3(14%)	7(33%)	0	29	2(7%)	2(7%)	1	17	5(29%)	7(14%)	0
pool	33	4(12%)	10(30%)	2	21	3(14%)	5(24%)	0	26	7(27%)	11(42%)	0
Section B												
run	40	6(15%)	9(23%)	6	26	7(27%)	10(38%)	3	19	2(11%)	3(16%)	6
pool	40	15(38%)	20(50%)	4	42	17(40%)	20(48%)	2	45	17(38%)	17(38%)	8
Section C												
run	37	6(16%)	7(19%)	7	32	12(38%)	15(47%)	3	38	7(18%)	14(37%)	4
pool	27	7(26%)	10(37%)	2	35	8(23%)	10(29%)	2	24	5(21%)	8(33%)	0
Lower Control												
run	24	6(25%)	7(29%)	0	42	12(29%)	12(29%)	0	30	10(33%)	12(40%)	0
pool	18	7(39%)	7(39%)	0	18	7(39%)	7(39%)	0	22	6(27%)	8(36%)	0
Upper Control												
run	--	------	-----	-	4	0(0)	-----	0	7	2(29%)	-----	0
pool	--	------	-----	-	3	3(100%)	-----	0	3	0(0)	-----	0
Section A	54	7(13%)	17(31%)	2	50	5(10%)	7(14%)	1	43	12(28%)	18(42%)	0
Section B	80	21(26%)	29(36%)	10	68	24(35%)	30(44%)	5	64	19(30%)	20(31%)	14
Section C	64	13(20%)	17(27%)	9	67	20(30%)	25(37%)	5	62	12(19%)	22(35%)	4
Controls												
Lower	42	13(31%)	14(33%)	0	60	19(32%)	19(32%)	0	52	16(31%)	20(38%)	0
Upper	--	------	-----	-	7	3(43%)	-----	0	10	2(20%)	-----	0

* Includes 1965 tagged fish still remaining

** Includes 1965 and 1966 tagged fish still remaining

During 1965, recoveries of fish tagged in specific runs and pools and recaptured in the same section where tagged (including recaptures in the place where marked) were all 30% or greater except from runs of section B and C which were 23% and 19% respectively. During 1966, recaptures in the same section where tagged were 29% or greater except those from section A run and pool which were 7% and 24% respectively. The percent of tagged fish from selected areas that were recaptured somewhere in their respective sections during 1967 were 33% or greater except from section B run which was 16%.

The low percentage of recaptures from runs in dewatered sections and section A pool in 1965 and section A run and pool in 1966 would indicate that fish populations were effected more by reduced flows during these years than was indicated by changes in the standing crop. However, recoveries of fish in the same section as tagged would indicate that the effect was more of movement than mortality. In general, a higher percentage of fish was recaptured in the pool than in the run of the same section all three years.

The number of fish moving from the selected area where tagged but staying in the same section was about equal to the number moving to another section. Movements from sections A, B, and C during the 3 years were 36%, 58%, and 6% respectively. The high percentage of fish movement from section B may be partially explained as they could move either upstream or downstream while those in section A or C could not. During 1965, 18 of 21 fish recaptured moved upstream from the section where tagged and this was probably due to the spawning migration of brook trout. During 1966, 9 of 11 fish moved upstream from their respective sections while in 1967, 9 moved up and 9 moved downstream.

During 1965, the percentage of tagged fish moving from runs was about equal to the percentage moving from pools. In 1966, a greater percentage of fish moved from runs than from pools, particularly from section B where 23% tagged in the run and only 12% tagged in the pool had moved. In 1967, movement of tagged fish from sections B and C runs were 37% and 29% respectively while movement from other selected areas did not exceed 18%. It was not determined if tagged fish moved to runs or pools since most recoveries were made in areas of the sections that were not classified. From limited tag recoveries, it appeared that fish usually move from one run to another or into pools and not from pools to runs.

Fish movement in and out of the dewatered portion of stream was monitored after the installation of fish traps in the spring of 1966. No fish moved through either trap during flow reductions in 1966. During 1967 over 100 trout entered the upstream trap but none entered the downstream trap. The movement reached a peak about 10 days after dewatering was complete. The first time a fish entered the trap the anal fin was clipped and the fish returned to the pool below the trap. If the fish re-entered, it was placed in the stream above the trap. About 50% entered the trap a second time. About 80% of the re-entries were over seven inches long and all were eastern brook trout except for 2 rainbow trout. One marked brook trout entered the trap but did not re-enter.

During the 1966 flow reduction period 28 dead brook trout (14 tagged), one tagged rainbow trout and 5 whitefish were recovered on the grates of the lower trap. Five of the fish were tagged in section C, 6 in section B and 4 in section A. About an equal number came from runs and pools. Over half of the tagged fish were picked up the first month of dewatering while over half of the untagged fish were picked up the second month. Four whitefish and 7 brook trout were found at the lower trap (one tagged in section C) during 1967. Jaw tagging in 1966 may have caused more mortality than the branding in 1967, however, the greater stream velocities in 1966 may have carried more weak or dead fish against the trap.

DISCUSSION

The changes occurring in the physical parameters measured at various levels of dewatering were not great. Even at 90% flow reductions the amount of area, depth and cover were still considerable, particularly in pools. Average current velocity showed a greater reduction than any other physical parameter which is consistent with findings of Curtis (1959).

Runs as defined, which may be considered as marginal habitat for catchable size trout with respect to depth and cover, showed a greater percentage reduction in these factors than pools. When 90% dewatered, brook trout in runs decreased 62% by number and 53% by weight while in pools they showed an increase in both weight and number. The number of trout recaptured in the run where marked were less than in pools and movements from runs were also greater.

A source of error in determining standing crops and recovering tagged fish was that all sections were sampled at comparable flows in the spring while dewatered areas were sampled at lower flows than controls at the end of dewatering. Sampling efficiency was probably higher at lower flows. It appears, however, that the total standing crop of fish in the runs and pools was not seriously effected when normal flows were reduced 90%. The overall effect on the fish population of a large section of stream with respect to reproduction and production may be more serious.

Sediment deposition and increased temperature resulting from dewatering could effect trout populations. Sediment deposition was extensive, especially in section A, due to the reduced current velocity in dewatered areas. Saunders and Smith (1956), stated that low standing crops of brook trout were closely associated with silting and appeared to result from the destruction of hiding places. During 1967, maximum-minimum thermometers at each end of the dewatered area did not show a measurable temperature difference. This was probably due to the short distance between stations and to ground water accretions.

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