SUMMARY OF AQUATIC STUDIES ON BLUEWATER CREEK, MONTANA

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Special Publication
Montana Department of Fish and Game
February 1979

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ABSTRACT

Aquatic data collected on Bluewater Creek since 1959 was summarized. Bluewater Creek was a chemically fertile spring creek with optimum water temperatures for wild brown trout. Abundant aquatic plants and a diverse benthic fauna maintained standing crops of benthic organism of 95 to 310 pounds/acre. Drift organisms moved into brown trout feeding sites at a rate of 24 to 41 organisms/minute. Brown trout diets suggest they are opportunists utilizing seasonally available foods. Brown trout spawning season was from mid-October to end of November. No Age-I females were mature, but 82% of the Age-11 and 100% Age-III females were mature. The average egg complement was 325 eggs/female. Emergences took 60-70 days and February 1 best describes the birthday of brown trout. Egg mortality was low in clean headwaters and progressively increased as sediment concentrations increased. Browns were 0.6 inches at emergence.

The average seasonal biomass of brown trout was 261 pounds/acre in the spring compared to 264 pounds/acre in the fall. Brown trout larger than 6 inches averaged 159 and 187 pounds/acre in spring and fall respectively. Catchable sized brown trout number 16,629 and 3,167 pounds in Bluewater Creek. Densities of catchable sized fish fluctuated least in the area where the majority of trout were harvested.

Sex ratio of brown trout was 1:1.3 males to females. Males dominated the Age-V+ fish. Total annual harvest of fish 6 inches and larger was 2,500 taken by 500 persons averaging 5 fish per trip.

Of 4,292 known-age brown trout from 3 year classes, it was found that the 1973 Year Class lived 3 years, the 1972 Year Class lived 4 years and the 1969 Year Class lived to their 7th year. Aging by the scale technique was invalid in Bluewater Creek even though scales appeared typical of brown trout. Growth rates were poor. Fish averaged 8.5 inches at 30 months of age while Age-7 fish were only 2.3 inches longer. Age-0 fish could be separated by length frequencies. Lengths of known-age trout overlapped as many as five age groups.

Nine years of stream sediment studies showed reduced carrying capacities with increased sediment concentrations. Brown trout were most dramatically suppressed at concentrations over 50 ppm and loads over 40 tons/day. sediment reductions of 10 to 52% resulted from 3 stream improvement projects.

lnstream flow requests of 6,878, 18,823 and 14,479 acre-feet were made for 3 stream reaches having average annual flow yields of 8,328, 20,502 and 31,974 acre-feet, respectively.

INTRODUCTION

Bluewater Creek has been a focal point of aquatic study for years because of accessibility, climate, proximity to two colleges and a university, a self-sustaining trout fishery, land ownership and use patterns, a substantial spring source and chemical fertility. Earliest studies centered on the potential of Bluewater Springs as a water supply for the present Bluewater Springs Trout Hatchery. Specific stream studies began in 1959. This report summarizes aquatic studies of unpublished data and portions of research found in job progress reports, theses and publications.

BACKGROUND

An investigation of Bluewater Creek was initiated in 1959 to measure effects of sediment, discharge and water temperatures on trout populations, bottom fauna and trout egg incubation. Data from the stream sediment investigation was found in six Federal Aid Documents, D-J Job Progress Reports F-20-R-5 through F-20-R-15, Job III-a, Marcuson (1966-1970). Bianchi (1963) reported the effects of sedimentation on egg survival of rainbow and cutthroat trout. Peters (1967) described the influences of sediment on a trout stream from agricultural practices and later (1971) on the effects of sediment control on fish populations.

In 1969, Graham and Marcuson started a study of production of brown trout in Bluewater Creek. This study failed statistically but contributed considerable unpublished detail regarding composition of brown trout. Two additional studies, a quantitative examination of aquatic insects (Zillges,1971) and a fecundity study (Lockard, 1974) were conducted as supplements to the production study.

Recent investigations include data collected to assist in the selection of adequate instream discharges necessary for the maintenance of the fishery (Montana Fish and Game Commission, 1976).

STUDY AREA

Bluewater Creek is an 18-mile spring creek meandering through semi-rough prairie country in southcentral Montana. It is a tributary to the Clarks Fork of the Yellowstone River. Figure 1 shows the location of most of the intensive study sites. Physical descriptors are presented in Table 1.

Bluewater Creek valley had a semi-arid climate with an annual average precipitation of 10 inches. The average frost-free season was from May 19 to September 17. Air temperature extremes were common with temperatures as high as 108° F. and as low as -35° F.

Salix and *Betula occidentalis* were abundant woody vegetation types along stream banks in the upper half of stream. Downstream, considerable woody vegetation had been removed for intensive agricultural operations.

METHODS

This paper incorporates data collected as part of several specific studies on Bluewater Creek. Particular methodologies can be obtained by examining documents listed in the Literature Cited Section. Major emphasis involved seasonal collections of brown trout with a 230-volt D.C. powered electrofishing unit. Fish were measured for total lengths, weighed, marked by various combinations of fin clips and returned for subsequent recaptures. Permanent marks were applied to all young-of-the-year brown trout captured in the 1969, 1972 and 1973 Year Classes and for a portion of the 1974 Year Class. Egg densities, scales and otoliths were collected from sacrificed brown trout of known-age.

Scales were collected in the usual manner and their plastic impressions were magnified with a Baush and Lomb Projector for interpretation. Otolith interpretation was attempted by examination of fresh specimens and by cross sectioning, polishing and staining preserved otoliths.

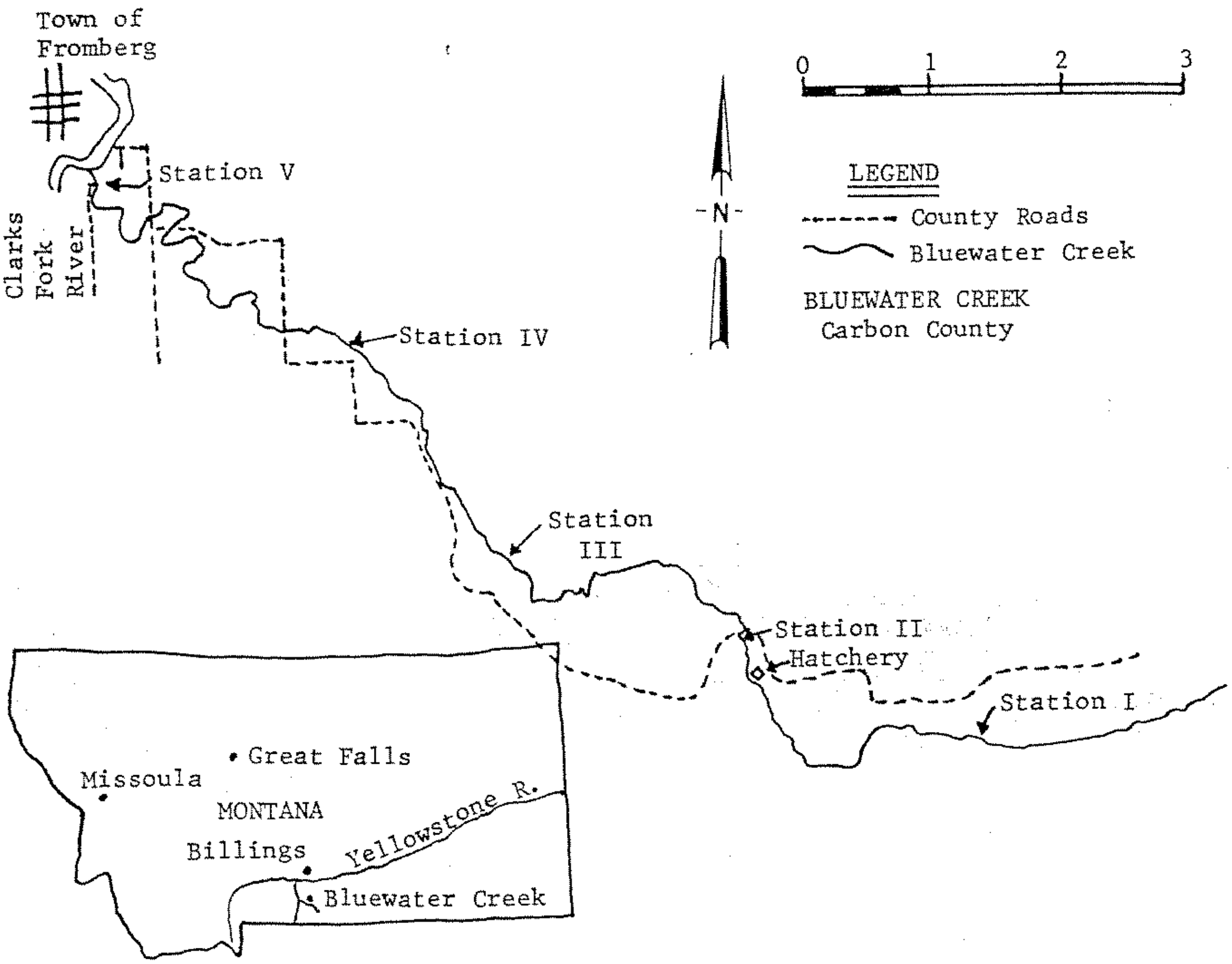

Figure 1. Map of Bluewater Creek showing locations of sampling stations.

Table 1. Descriptive parameters for five stations on Bluewater Creek

	Stations				
	1	2	3	4	5
Mean width (ft.)	11	12	13	14	15
Gradient (ft./mile)	11	11	30	26	10
Discharge (cfs)[1/]	10.5	27.8	23.7	21.4	41.6
Sediment discharge (ppm)[1/]	25	71	201	263	437
Sediment discharge (tons/day)[1/]	0.8	5.1	18.0	21.1	61.1
Drainage area (miles^2)	8.1	28.1	43.9	46.6	53.2

[1/] Average of 8 years of record.

FINDINGS

Chemical

Analysis of chemical constituents was performed by technicians at the water quality laboratory at Montana State University and by field techniques used in the various studies. Table 2 lists chemical parameters. As far as is known Bluewater Creek is more chemically fertile than any other stream in the State of Montana.

Thermal

Water temperatures for three stations are summarized for 12 years of continuous records in Table 3. With the exception of small amounts of surface run-off, Bluewater Creek derives its water from spring flows which hold a constant temperature of 56° F. Water temperatures change upward or downward depending upon atmospheric conditions and become more variable as the distance from the spring source increase. Ice formation does not occur, regardless of the severity and duration of freezing atmospheric conditions, until the water flows at least 10 miles from its spring source. Water near the mouth undergoes the greatest annual temperature fluctuation.

Fish composition

Brown trout (*Salmo trutta*) dominated the fish occupying the upper half of the creek. Browns have been sampled in low numbers in lower stream reaches; however, their distribution was such that they are significant in the stream from headwaters to one-half mile below Station 4.

An occasional rainbow trout (*Salmo gairdneri*) and on one sampling occasion a few kokanee (*Oncorhynchus nerka*) were sampled near Bluewater Spring Trout Hatchery. These fish were escapees from this rearing station and no reproduction was evident.

People who have lived along the stream 50 or more years remember when cutthroat trout (*Salmo clarki*) was the only trout species in Bluewater Creek. Hatchery personnel recall catching an occasional cutthroat during the 1930's. The majority of their catch was an equal number of brook trout (*Salvelinus fontinalis*) and brown trout. No brook trout have been observed since initiation of aquatic research on the creek.

The lower half of the stream contained large numbers of suckers and minnows. The following include an approximate ranking of abundance of fish other than trout in Bluewater Creek: longnose dace (*Rhinichthys cataractae*), flathead chub (*Hybopsis gracilis*), mountain sucker (*Catostomus platyrhynchus*), white sucker (*Catostomus catostomus*), carp (*Cyprinus carpio*), mountain whitefish (*Prospium williamsoni*) and shorthead redhorse (*Maxostoma macrolepidotum*).

Aquatic plants

The upper half of Bluewater Creek had abundant growths of water cress (*Rorippa nasturtium - aquaticum*), *Berula erecta* and horned pondweed (*Zannichellia*). Nearly all the undisturbed stream banks had some degree of rooted aquatics. Duckweed (*Spirodela* and *Limna*), *Chara*, *Vaucheria*, an unidentified moss and a leafy liverwort were common. Vegetation existed year-around in headwater reaches reaching maximum densities in early summer. Stream velocities, depths and excellent cover for small trout are provided by areas of this vegetation. Cladophora was the only common aquatic plant in the lower portion of stream.

Aquatic fauna

Seventy-four benthic samples were collected with a Surber Sampler along Bluewater Creek. The average number of organisms per square foot are presented in Table 4. Those forms typical of unpolluted waters were found in the upper stream reaches.

Table 2. Range and mean chemical values at two stations on Bluewater Creek

	Stations 1	Stations 2
Alkalinity (ppm $CaCO_3$)		
range	94. - 220	101 - 252
mean	210	212.
Dissolved oxygen (ppm)		
range	7.8 - 10.8	8.0 - 10.4
mean	8.7	8.6
pH		
range	7.6 - 8.6	6.6 - 8.7
Total hardness (ppm $CaCO_3$)		
range	280 - 750	480 - 1,050
mean	451	850
Conductivity (Umhos)		
range	721 - 938	812 - 2,650
mean	825	1,122
Silica (ppm)		
range	8.2 - 12.4	8.0 - 12.8
mean	11.2	12.4
Phosphate (P)	.01	.02
Sodium (Na^+)	5.52	12.87
Potassium (K^+)	1.96	2.42
Sulfate (SO_4=)	25.8	70.8
Nitrogen (NO_{3-N})	.312	.409
Chloride (ppm)	2.20	2.45
Fluoride (ppm)	1.12	1.19

Table 3. Monthly mean maximum, minimum and mean temperature (F.) in Bluewater Creek for 12 years of record at 3 stations

	Stations								
	1			2			4		
	min.	mean	max.	min.	mean	max.	min.	mean	max.
January	49	51	52	46	48	50	36	38	40
February	50	51	53	46	49	51	40	42	45
March	51	52	54	46	50	54	42	44	47
April	51	54	56	49	53	57	46	50	53
May	53	55	58	51	56	60	52	61	69
June	53	56	59	54	58	62	53	59	65
July	54	57	59	53	58	63	59	64	68
August	55	57	59	52	57	63	59	62	65
September	53	55	57	50	54	59	54	56	58
October	52	53	55	49	52	55	45	50	53
November	51	52	53	48	50	52	41	43	44
December	49	50	52	46	48	50	38	40	41

Table 4. Summary of benthic invertebrates collected at five stations on Bluewater Creek

Classification	No./Ft.^{2} Stations 1	2	3	4	5
Amphipoda	1	1	0	0	0
Oligochaeta	1	1	29	170	29
Ephemeroptera	54	52	116	41	17
Plecoptera	28	29	38	3	1
Coleoptera	28	21	1	1	1
Tricoptera	175	122	27	14	6
Diptera	44	18	12	12	136
Mollusca	6	44	2	2	0
Others	2	3	0	4	3
Total	339	291	225	247	193

As the collections proceeded downstream, the fauna became less diversified and was dominated by diptera and aquatic worms. A list of recognizable species is in the appendix.

Based on total wet weights of 19 of the 74 benthic samples, it was estimated that the standing crop of bottom fauna ranged from 95 to 310 pounds per acre. Benthic fauna was lowest during late October and November and highest during March and April.

Zillges (1971) collected 15 day and 15 night drift samples at Stations 2 and 5. Over four times more drift occurred at night. May flies, primarily Baetis parvus, were the major drifting form at Station 5. Station 2 also had large numbers of drifting May flies (Ephemerella inermis and Baetis). Stone flies (Isoperla spp.), Chironomids and Simulium also constituted major drifting forms in Bluewater Creek; however, stone flies were a minor item at Station 5.

Table 5 is an abbreviated presentation of Zillges findings on drift forms. My calculations of Zillges data revealed that the average number of aquatic insects drifting by Station 2 was 41 per minute compared to 24 per minute at Station 5. The orders in Table 5 are listed by magnitude for both stations combined; however, variability between sites was common. The only organism collected in larger numbers downstream was the caddis fly, Hydropsyche sp.

Certain aquatic organisms like dragonflies and scuds were readily observed in upper Bluewater Creek but rarely captured and quantified. These forms are typical of aquatic plant communities, undercut banks and debris habitats. In a similar stream in Minnesota, Waters (1965) found that the scud, Gammarus limnaeus, was a primary drift species. Gammarus was commonly observed in Bluewater and in brown trout stomachs but was never captured in 30 drift samples and only rarely captured in benthic collections.

Brown trout diets

Stomach contents were examined for numerous brown trout taken during different seasons. It appears that these fish were opportunists, taking a variety of food organisms. Their intake paralleled seasonal sources. Trout eggs were common food for brown trout during spawning season, juvenile trout were consumed during the emergence period, terrestial insects dominated during summer and early fall and aquatic forms were consumed on a regular basis. Food does not appear to be limited to fish in Bluewater except possibly for the months of October and November. These months revealed the lowest numbers of available aquatic forms, terrestrial items were rare and sexual agressiveness of brown trout precluded eating or searching out food. During the spawning season, stomachs often contain burrowing benthic organisms and trout eggs not commonly observed during other seasons. Those forms dislodged from the substrate during redd construction were typically small organisms of insignificant weight. Shrimp (Gammarus) were found in stomach contents but to a lesser degree than the more available May flies, stone flies and caddis flies.

Fecundity and spawning of brown trout

Spawning activity became evident by mid-October and most brown trout discharged sexual products by the end of November. The peak spawning activity occurred the second week of November. Samples of fish from December through January revealed an occasional yearling as small as 3.5 inches causing speculation that some spawning occurred later than the end of November. With mean water temperatures of 53^{o} F. in October, 52^{o} F. in November, 50^{o} F. in December and 51^{o} F. in January at Station 1, it seemed reasonable that the spawning period could be very lengthy. However, no normal adult females were found with sexual products during December through February collections. Temperature patterns of the upper two stations during the spawning season are presented in Figure 2.

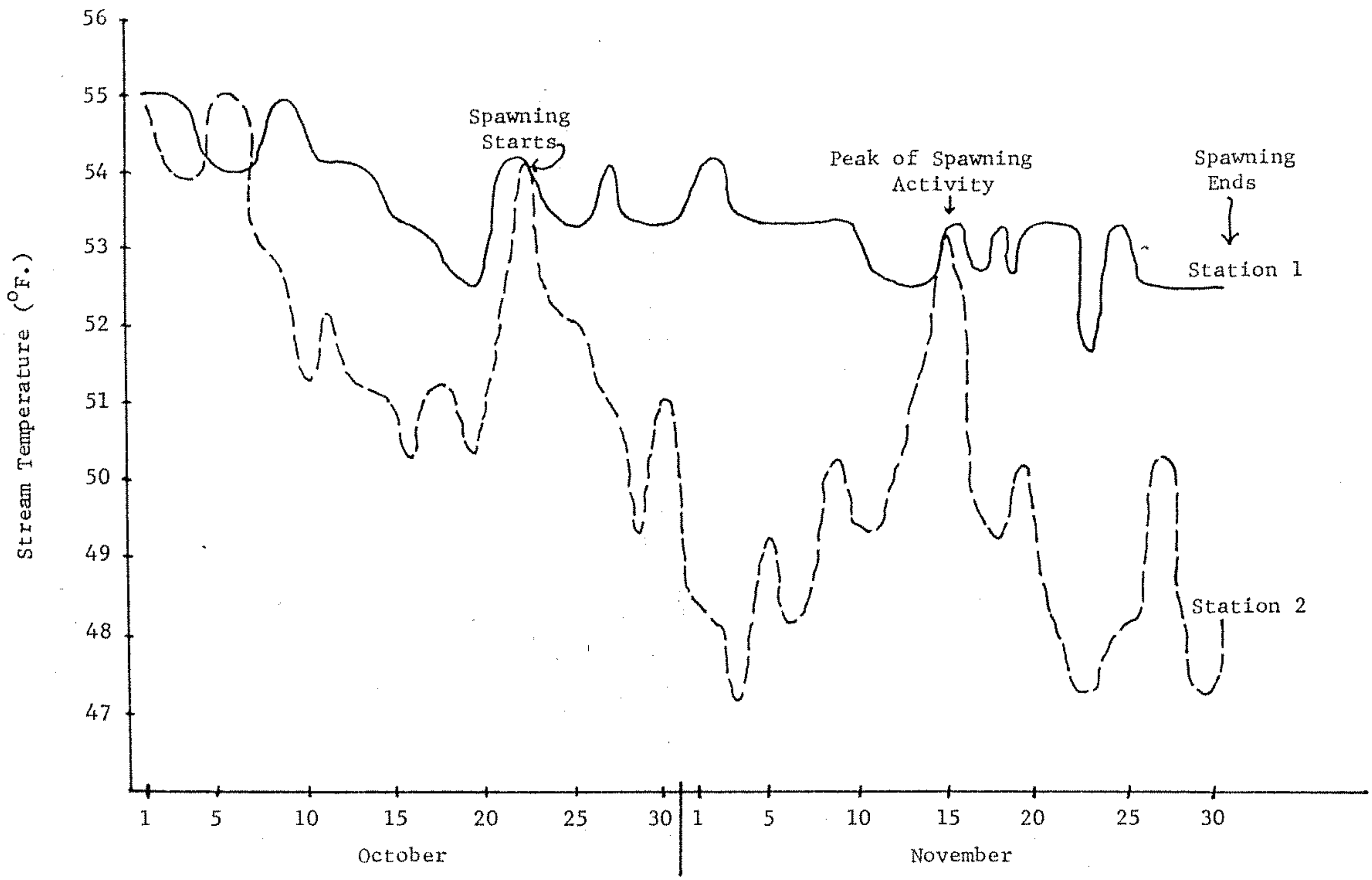

Figure 2. Mean daily temperatures averaged over 5 years of record for the months of October and November at 2 stations on Bluewater Creek.

Table 5. Numbers and volumes (cc) of insects from drift samples on Bluewater Creek

Classification	Day-Drift[1/] 2	Day-Drift[1/] 5	Night-Drift[1/] 2	Night-Drift[1/] 5	Dominate Species
Ephemeroptera	45.1 (t)	51.5 (t)	595.9 (2.7)	384.8 (0.6)	*Baetis parvus* *Ephemerella inermis*
Unid. Pupae	121.8	40.3	117.9	44.0	
Diptera	34.8 (t)	56.6 (t)	47.9 (t)	63.4 (t)	Chironomidae *Simulium arcticum*
Plecoptera	11.0 (t)	1.0 (t)	156.6 (1.0)	4.5 (t)	*Isoperla spp.*
Trichoptera	12.2 (t)	9.8 (t)	34.9 (0.2)	54.1 (0.3)	*Hydropsyche sp.*
Coleoptera	16.7 (t)	1.9 (t)	44.3 (t)	5.1 (t)	*Optioservus ovalis* *Helichus striatus*
Odonata	-- --	-- --	-- --	1.5 (0.2)	*Ophiogomphus*
Total	241.6 (t)	161.1 (t)	997.5 (3.9)	555.4 (1.2)	

[1/] Volumes in parenthesis - t=trace.

In 1974, Lockard compared fecundity of female brown trout with stream fertility in 17 Montana streams. Fish from Bluewater Creek, the most chemically fertile of the waters studied were least fecund. Lockard resolved that chemical fertility of streams is generally related to age at sexual maturity and fecundity of brown trout except in fish from Bluewater Creek. His findings were similar to McFadden, Cooper and Anderson (1965) where in Pennsylvania, brown trout from infertile waters had a smaller proportion of mature fish per age class and a smaller weight of eggs than comparable fish from fertile waters. Lockard concluded that "Bluewater Creek fish attained sexual maturity much earlier than fish from less fertile streams; however, these fish from the chemically most fertile stream had the poorest growth rates of all the fish studied."

Since aging fish in Bluewater Creek by the scale technique was not reliable, I felt that Lockard may have underestimated the age of some of the small females in the creek. To test Lockard's findings, I sacrificed 200 known-age females of the 1974 Year Class as I's in 1975, II's in 1976 and III's in 1977. I found no Age I females mature but did note a small number of mature males. Females of Age II were 82% mature and all Age III females were found to be mature.

Table 6 presents egg complements of Age II and III females from known-age brown trout at two stations. The 18% immature Age II females were typically smaller fish.

<u>Emergence and survival</u>

February 1 was considered the birthdate for brown trout in Bluewater Creek. Based on electrofishing, redd excavation and egg development in plastic vials, it was found that the earliest emergers escaped the gravels in early January and most were out by early February at Station 1 and by mid-February at Station 2. The average water temperature at Station 1 was 52° F. during incubation period; however, water temperatures were 5° F. cooler 6 inches within the substrate. It took an average of 60 days to emergence. At Station 2, the average water temperature during incubation was 48° F. and 43° F. around the eggs. Average time to emergence was 72 days.

Bianchi (1963) experimented with survival of eggs of rainbow and cutthroat trout placed in artificial redds at five stations along Bluewater Creek. Egg mortalities for rainbow trout were 67, 92, 97, 99 and 99% for Stations 1-5 respectively and 43, 94, 98, 100 and 87% for cutthroat trout eggs from Stations 1-5. In 1969, sediment control measures had reduced sediment loads by 32% at Station 2 and 52% at Station 3. Juvenile brown trout were noted farther downstream than previously observed; however, egg survival experiments were not repeated. It was assumed that egg survival was considerably improved at Stations 2 and 3.

Juvenile browns averaged .6 inches at emergence. By mid-March the average length of both early and late emergers was 2.1 inches.

<u>Population abundance of brown trout</u>

To best describe the population of brown trout in Bluewater Creek, I averaged 28 population estimates, collected at 3 stations, over all seasons for 6 years, 1969 to 1975. These average standing crops were further grouped to include fish above and below six inches (Table 7).

Figures for fish less than six inches do not include the most prolific size group of newly emerged juveniles during spring sampling periods. These juveniles are represented seven months later in fall samples (Table 7). An accumulation of 2,000 juvenile brown trout are required to increase the biomass by one pound. An average acre of brown trout water in Bluewater Creek contains 76,781 juveniles or 38 pounds. The above estimate was based on 929 reproducing size fish per acre, 1.3:1 ratio of females to males, an average egg complement of 325 eggs per female and an egg to emergence survival rate of 45%.

Table 6. Egg complement of Age II and III females from 119 known-age brown trout at Station 1 and 2, Bluewater Creek

	STATION 1 Age Group		STATION 2 Age Group	
	II	III	II	III
Mean egg count	218	319	329	436
Range of eggs counted	52-412	72-713	162-534	82-839
Number of females	38	44	17	20
Mean length of females	7.9	8.2	9.3	9.3
Length range of females	6.3-9.3	5.8-10.5	7.8-11.4	6.6-12.2
Mean weight of females	.17	.22	.31	.32
Weight range of females	.09-.30	.06-.54	.16-.52	.10-.68

Table 7. Brown trout abundance of Bluewater Creek averaged over 6 years, 1969-1975

	Less Than 6 Inches[1]	6 Inches and Larger
Number/acre (spring)[2]	2,298	917
Number/acre (fall)	2,398	937
Pounds/acre (spring)[2]	64	159
Pounds/acre (fall)	77	187
Number/1,000 feet	603	253
Pounds/1,000 feet	19	48
Yearly number/acre	2,219	929
Yearly pounds/acre	69	175
Number/mile	3,184	1,336
Pounds/mile	100	253
Number/stream[3]	39,791	16,629
Pounds/stream	1,254	3,167

[1] Standard deviations were considerably higher than for 6 inch and larger fish.

[2] Spring numbers do not include juveniles - only yearling and older fish under 6 inches.

[3] Based on 65,988 feet of brown trout waters.

Not counting the juvenile population each spring, the average spring standing crop of all brown trout was 223 pounds/acre compared to 264 pounds/acre average for fall. If 38 pounds/acre was a realistic estimate of juveniles then the spring and fall biomasses were about equal. The catchable sized fish over 6 inches contributed 159 pounds/acre in the spring and 187 pounds/acre average in the fall.

The condition factor ($CF = W/L^3 \times 10^5$) of yearling and older brown trout progressively increased downstream from 34.6 to 37.1. The condition of these fish was slightly higher in the fall (35.7) compared to 35.4 in the spring. Vincent (1977) reported condition factors in the mid-40's for brown trout in the Madison River.

The number and weight of catchable 6-inch and larger brown trout in Bluewater Creek was calculated at 16,629 fish and 3,167 pounds (Table 7). Examination of numbers of 6-inch and larger fish occurring each season at each station divulged a range of 548 to 1,521 fish per acre.

A comparison of catchable size fish/acre at Station 1 disclosed a low population density of 373 in the spring and 549 in the fall of 1973. Other than this density change of 176 fish/acre, the population of 6-inch and larger fish remained close to 480 fish/acre.

An electrofishing section between Stations 1 and 2 had a low of 1,020 catchable fish/acre to a high of 1,521 fish/acre. This 501 density fluctuation was separated by 4 years and reflected a low spring density and a high fall density. The mean density of catchable size brown trout in this area was 1,176 fish/acre. This sampling area was on private land where no fishing was allowed.

The 6-year mean number of 6-inch and larger fish at Station 2 was 1,129 fish/acre. The density of these fish ranged from 584 to 1,285 fish. The low 584 fish/acre occurred in the fall of 1970. The next lowest population estimate of 6-inch plus fish per acre was 788 in the spring of 1975. The typical fluctuation of catchable sized fish, disregarding the two extremes above, was within 150 fish of the 1,129 fish/acre mean. This portion of the brown trout fishery received the majority of the angling pressure on Bluewater Creek.

Sex ratio

Yearling and older brown trout are easily sexed by the curvature of the anal fin method described by Gruchy and Vladykov (1968). The method was found valid in Bluewater Creek. Sexes of 8,600 fish collected at Stations 1 and 2 kindled a ratio of 1.3 females per male. Sex ratio of 819 known-age brown trout was dominated by females through Age Group IV. Among fish V and older, males surpassed females 3 to 1.

Fish harvest

An organized creel census was never conducted on Bluewater Creek. Total harvest of fish was estimated by combining results of random creel checks, observations of fishermen by hatchery and management personnel and discussions with landowners. The vast majority of the fishing pressure occurred on state owned land near the hatchery. No fishermen were ever observed or reported by landowners along lower reaches of Bluewater. Several areas under private ownership were essentially closed to fishing.

Bluewater Creek was open year-long and received fishermen mostly from the Bridger-Fromberg area. Most fishing occurred during the spring and fall. The area had a reputation for abundant rattlesnakes which discouraged fishing during the hottest season. The majority of the fishermen were retired persons.

The Bluewater area averaged one car per day with a 1.5 fisherman per car average. They caught an average 5 fish per trip over 6 inches in length. Considerably more fish less than 6 inches were captured but were returned voluntarily for larger fish. Total annual harvest was estimated at 2,500 fish over 6 inches in length. With the exception of a few hatchery reared rainbow trout, the anglers harvested wild brown trout.

Age and growth

Aging brown trout by the scale method was performed by Peters (1971) for Bluewater fish. He found no significant differences of growth rates between stations which were subjected to increased degrees of sediment loads. Peters assigned overall lengths to the last annulus as follows: Age I - 3.9 inches, II - 6.6, III - 9.7; older fish scales were not readable.

Graham and I also reviewed scales from brown trout in Bluewater Creek and arrived at growth interpretations (unpublished) but both of us agreed that we were influenced by length frequency and that scale interpretation was not self-evident. As a part of an attempted production study, we permanently marked juveniles of the 1969, 1972 and 1973 Year Classes and recorded progress of these fish at each recapture until none remained in the population. Data collected from three mark and recapture sections has been combined with three year classes (Figures 3 and 4).

A total of 4,292 juveniles of the 1969, 1972 and 1973 Year Classes were marked in early September. Emerging fish were not marked until 7 months of age to lessen chances of mortality, ease of handling and better recruitment to electrofishing gear for population estimates. An unexplained decline in both length and weight occurred between Age II fish captured in the fall and Age III fish captured the following spring. A similar decline occurred between Age IV and Age V fish. It was obvious that such declines were impossible for specific individuals, but the possibility of sampling smaller individuals within a population could be real. This exemplifies the disadvantage of using marks other than those identifying individuals.

The last individuals of the 1969 Year Class were captured in mid-September 1975 as VI's. Only 3 marked fish of the 1972 Year Class were captured in October of 1976 as Age Group IV and of 1,294 juveniles of the 1973 Year Class only 22 were recaptured beyond age II; the last 3 were captured at 44 months of age. No explainable reasons were evident to account for the loss of the 1972 or 1973 Year Classes.

Examination of Figures 3 and 4 show not only poor growth of fish but a large degree of overlap of sizes among age groups. For example, the smallest Age VI fish falls within the size ranges of every age group to Age I. Only Age 0 fish separated from the others in a length-frequency distribution.

Growth of known-age fish as it was in the fall was: Age 0 - 3.6 inches, I - 7.0, II - 8.5, III - 8.5, IV - 9.3, V - no fall fish and VI - 10.8 inches and Age 0 - .03 pounds, I - .14, II - .22, III - .24, IV - .32, V - no fall fish and VI - .52 pounds. Except for the first 30 months of age the brown trout living 6 years only grew 2.3 inches and .30 pounds. Fall to spring sampling revealed little overwinter growth despite water temperatures in the low 50's for most of the trout producing water. Following spawning season, fish in Bluewater Creek tend to become snakey in appearance and remain so until early spring. I'm sure a production study would reveal negative values during a portion of this period.

When scales were examined from fish of known-age, I was able to achieve the following interpretation of readable scales: 100% - Age 0, 63% - I, 59% - II, 36% - III, 10% - IV and 0% on all older fish. Otoliths from numerous known-age fish were examined as fresh, stained, cut and polished specimens without meaningful results. The only reliable aging technique for brown trout in Bluewater Creek appears to be known-age measurements of individually identifiable fish.

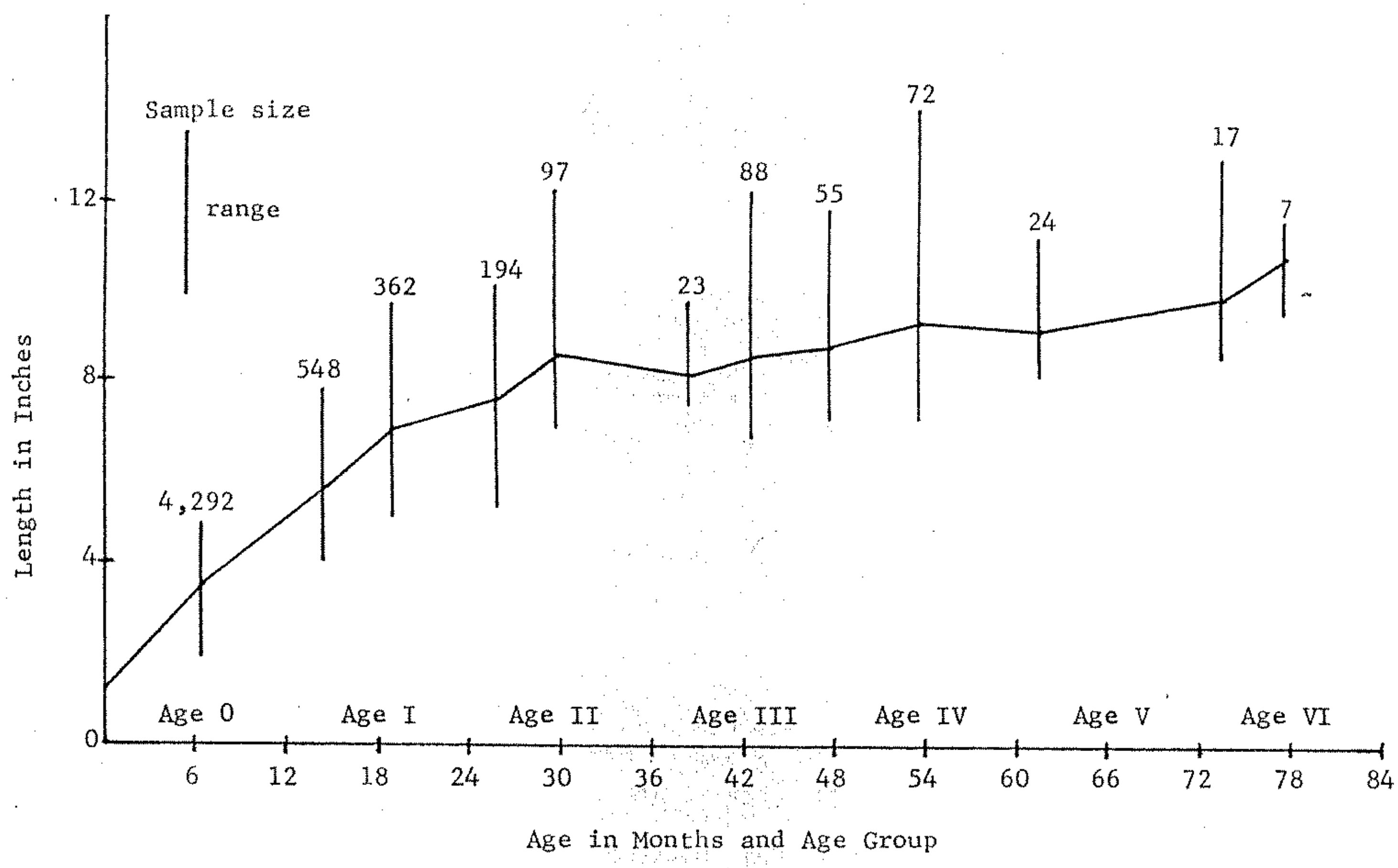

Figure 3. Age and growth in length of known-age brown trout of three year classes averaged for three sections, Bluewater Creek.

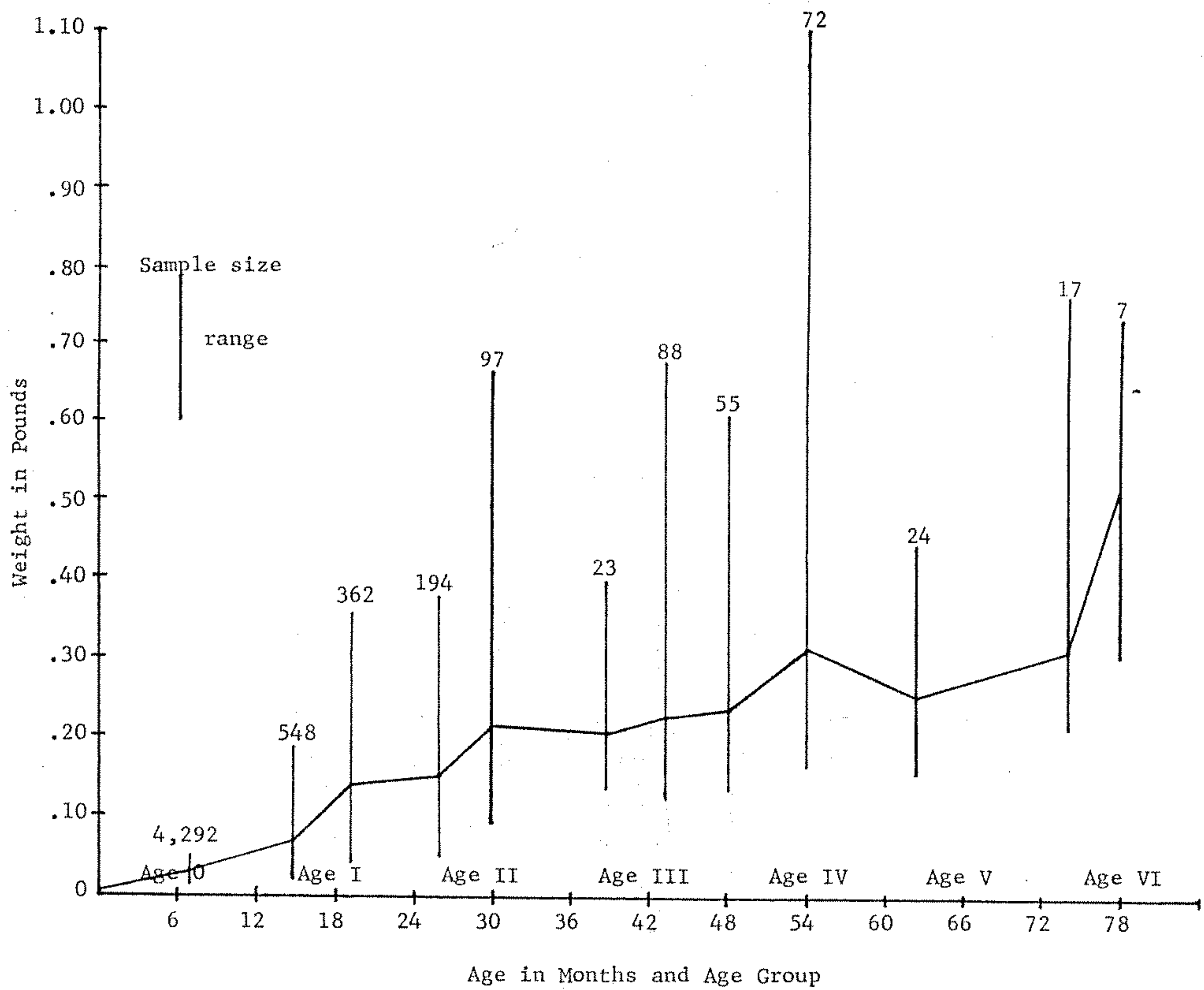

Figure 4. Age and growth in weight of known-age brown trout of three year classes for three sections, Bluewater Creek.

Sediment Study Summary
The first 6 years (1961-1966 of the stream sediment investigation involved comparisons of fish species abundance and distribution with suspended sediment concentrations, discharge and water temperature. Sediment loads which are a measure of sediment concentrations and discharge averaged 0.7 tons per day in the headwaters and progressively increased to a mean of 75.8 tons per day near the mouth. As a result of irrigation withdrawals and warmed return flows, lower reaches of Bluewater Creek underwent wide ranges of temperature fluctuations. Brown trout numbers decreased progressively downstream as the aquatic environment deteriorated. The first six years of study documented the detrimental effects of sediment on trout.

The nature of the study was then altered to evaluate major factors causing sedimentation in Bluewater Creek and take corrective steps to reduce this silt load. Three improvement projects were undertaken in the spring of 1966. A pipeline was installed to control erosion from a waste water ditch. Several hundred feet of eroded stream bank were lined with rock and as a part of the fishing access program, approximately 100 acres involving ½ mile of stream were fenced to restrict access by cattle.

Continued evaluation of the silt content in Bluewater Creek suggested that the improvements were effective in reducing silt loads. The average sediment load figured on 48 months of data collected prior to improvements was 6 tons/day at the sampling station immediately downstream from the improvements (Station 2). The average load at this station was reduced to 4.1 tons/day based on 28 months of record after improvements. This represents a 32% reduction of sediment load. At Station 3, a 52% reduction occurred and at Station 4, suspended sediments were reduced 44% calculated over the 28 months of record.

Response of the fishery to the improved water quality was obvious to the investigator but did not statistically show a significant response. Lack of statistical response might be explainable when one considers natural fluctuations of various year classes. Apparently many years and many year classes are needed to accurately assess responses of a population to subtle changes in the environment (see discussion, also Hunt, 1966 and Chapman, 1965). This investigator noted that following reductions of sediment loads there were juvenile brown trout farther downstream than previously observed and that large brown trout were more abundant at Station 4 than previously noted (Marcuson, 1967).

A positive response of brown trout to sediment reductions was with the percentage ratio of total weight of trout to rough fish of 39:61 before (1963) compared to 78:22 after (1968) stream improvements. Six miles further downstream (Station 4) the trout:rough fish ratio was 12:88 before compared to 51:49 after improvements.

The stream sediment investigation was completed in 1970. Observations and subsequent measurements indicated additional discharge of approximately 6 cfs after 1970. This additional flow was due to additional flows collected for hatchery operation. Sediment loads responded upward with these flow increases and from intensified agricultural operations upstream. Increased loads however do not appear to be anywhere near the magnitude common prior to the improvement projects.

Stream sediment problems can be effectively reduced, however land use changes often diminish or negate the results over time. Earlier discussion on sediment findings alluded to the percent reduction based on 28 months after stream improvements. Suspended sediment monitoring was discontinued in 1970, 52 months after improvements. By this time, Station 2 had a 20% suspended sediment reduction, Station 3 had a 10% reduction and Station 4 had a 14% reduction compared to reductions of 32, 52 and 44% after 28 months at Stations 2, 3 and 4 respectively.

Instream Flow Recommendations

Due to irrigation practices and type of agriculture along Bluewater Creek, three reaches were picked to best characterize flow regimes. These three reaches, upper, middle and lower Bluewater are described in unpublished form (Marcuson, 1976) on file at State of Montana Department of Fish and Game office in Billings.

The 9-year mean monthly discharge was 11 cfs, 28 cfs and 44 cfs for the upper, middle and lower sections respectively. Discharge at the middle section averaged 34 cfs at the time this report was compiled due to additional discharge from Bluewater Springs Trout Hatchery. Historic flow measurements were measured over the 9-year period at the 5 sediment stations and reflected existing agricultural use.

Bluewater Creek has special need for flow maintenance in that it is one of few rich prairie spring creeks. It is also a focal point of activity for wildlife, livestock, recreation and human occupation in this semiarid area. The recommended flows presented in Table 8 are considered necessary for maintenance of the fishery and allows for additional water for future agricultural expansion.

Major consideration was for adequate flows in the upper and middle trout producing sections. The upper section has little opportunities for intensifying agricultural operations. The request of 9.5 cfs is 1.5 cfs less than mean flows. The middle section requires 26 cfs to minimize sediment deposition and is 8 cfs less than the new (since 1970) mean discharge. The mean monthly flow in lower Bluewater for 9 years of record was 44 cfs, thus 24 cfs or 55% of the annual discharge is available for future agricultural expansion in the area where enlarging the agricultural base is most feasible.

DISCUSSION

A good trout fishery combines many ecological features. Adequate water precedes all needs, thus instream flow requests are essential to Bluewater's fishery. Secondly, trout need water of good quality. The chemical fertility of Bluewater Creek was well established, its major deterent to quality water was silt pollution from agricultural practices. The sediment study fortified knowledge of the detrimental effects of sediment to trout and also established that suspended sediments could be effectively reduced even in highly erodable country. It was also learned that an improved stream will need continued surveillance to retain a new improved status. With Bluewater Creek, improved water quality opened the door for new agricultural developments and subsequently new sediment sources. The possibility of new contamination is always a threat and will have to be contended with on a case by case basis. Besides treating sources of sediment, I feel the most effective means of maintaining quality water is through good land management techniques, efficient water use and maintaining good stream bank vegetative cover. Stream bank cover provides an effective sediment filter, trapping rich silts where vegetative matter quickly establishes.

Numerous researchers documented reduced carrying capacity of trout in lotic waters because of high sediment concentrations (Sanders and Smith, 1965; Herbert, et. al., 1961; Condone and Kelly, 1961; Doudoroff, 1957; Hynes, 1960 and Wallen, 1957). Unfortunately the quantity of sediment capable of harming an environment has never been firmly established for various fish species. The contention of this author is that sediment acted as the agent responsible for the demise of cutthroat trout and indirectly for the brook trout in Bluewater Creek.

Brown trout numbers in Bluewater Creek were found in far fewer numbers where sediment sustained high concentration levels. Like most fisheries, these brown trout tolerated

Table 8. Recommended flows for three sections of Bluewater Creek

Section		MONTHS												Total[2/]
		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	
Upper	cfs	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	
	AF	584	528	584	565	584	565	584	584	565	584	565	584	6,878 (8,328)
Middle[1/]	cfs	26	26	26	26	26	26	26	26	26	26	26	26	
	AF	1,599	1,444	1,599	1,547	1,599	1,547	1,599	1,599	1,547	1,599	1,547	1,599	18,823 (20,502)
Lower	cfs	20	20	20	20	20	20	20	20	20	20	20	20	
	AF	1,230	1,111	1,230	1,190	1,230	1,190	1,230	1,230	1,190	1,230	1,190	1,230	14,479 (31,974)

1/ Does not include additional 6 cfs since 1970.

2/ Number in parentheses is the 9-year average annual yield.

extremely high sediment discharge for short periods of time without noticeable harm. Populations of brown trout in Bluewater Creek were greatly diminished at concentrations over 50 ppm and loads over 40 tons/day.

It was the feeling of researchers on Bluewater Creek that the amount of sediment settling on the streambed over time was more closely related to numbers, age structure, species composition and biomass of fish populations. For sediment standards, it would be beneficial to quantify sediment loads with deposition rates. Meaningful standards would consider silt deposition during incubation period of trout eggs.

Fishermen using Bluewater Creek seem satisfied with fishing. Brown trout have been harvested at a rate of 2,500 fish by 500 anglers since 1970. Most of this harvest was from a stretch of accessible stream less than 1 mile in length (Station 2) out of 12.5 miles of brown trout water. This particular site maintained the highest number of catchable sized fish, the largest mean sized fish and the most stable density of fish 6 inches and longer among the sampling sites. Densities of 6-inch and larger brown trout fluctuated more from the 6 year mean density in areas where little or no angling occurred. Regulations of 10 fish daily and a season open 365 days per year were generous and with low fishing pressure appeared to be grossly under utilizing this resource.

It is my opinion that a spring stream as rich as Bluewater Creek and with optimum water temperatures for trout growth, should yield considerably more large fish. An acre of trout water produced an average 929 fish over 6 inches in length (175 pounds) per acre, but the mean length of brown trout only reached 10.8 inches, .52 pounds as 6 year old fish, 9.2 inches, .30 pounds as 5 year olds and smaller. The creek produced some large individuals (largest trout was 22.1 inches, 3.75 pounds), but some year classes died before they reached 9 inches and .25 pounds. The loss of 2 year classes[1/] eliminated 4 and 5 year old brown trout from Bluewater Creek in 1975. This loss occurred in areas of no fishing as well as areas with fishing.

I do not know whether losses of year classes are common phenomenons in wild fisheries or an unusual event; however, fluctuations in population density are commonly reported. McFadden (1961, 1967) and Hunt (1966) reported numerical variations and differing biomass contributions of numerous year classes in the same stream sections. It seems reasonable that these fluctuations in density are expected and that management interpretations based on short term population changes should be carefully scrutinized.

Aquatic organisms in Bluewater Creek were more diversified than that found in brown trout diets. Besides diversity of food organisms, large numbers of aquatic organisms commonly utilized as brown trout food were readily available. Drifting foods also appeared readily available. Waters (1965) noted that quantitative relationships between drift rates and population density on the stream bottom have not been determined. He noted that drift forms may originate 50-60 meters upstream and that physical nature of the stream, upstream from the drift site, influenced drift composition and density.

In Bluewater Creek the major aquatic foods consumed by brown trout were organisms typical of the drift community. For the most productive trout water, there were 40 organisms per minute entering the feeding stations downstream from riffles. It appeared that aquatic food was more than adequate to feed fish in Bluewater Creek not counting allochthonous foods available from spring to fall.

[1/] All permanently marked members of the 1972 and 1973 Year Classes from three sampling sections were no longer sampled nor were their unmarked cohorts recognized.

If everything in the environment appeared ideal for trout production (i.e. chemistry, temperature, habitat, food, etc.), the trout population was high, fish harvest was low yet growth was poor, then it appears that a spatial problem might well exist. Chapman (1962) suggested that spatial limitations act as density regulators in coho forcing less agressive fish to emigrate. He also found that feeding of coho in excess did not alter holding capacity of stream aquaria. Since it appeared that food was not limiting, I felt that crowding of fish in Bluewater Creek had lessened growth potential.

Manipulating seasons and catches at low fishing intensities will not allow adequate population reductions to see if there would be a positive growth response. Assuming that the harvest rate remained nearly constant, then additional population reductions by more controllable means would best test the growth/density hypothesis. In the event more research be undertaken on Bluewater Creek, I would urge manipulating population size of brown trout and if positive responses are not realized then I would attempt manipulation of the genetic pool by introducing new stocks of brown trout.

APPENDIX

List of Recognizable Insects Collected from Benthic and Drift Samples Collected in Bluewater Creek

Coleoptera

Agabus sp.
Bidessus affinis
Deronectes griseostriatus
Dineutus sp.
Elmidae
Enochrus sp.
Gyrinus bifarius
H. strigatus
Haliplus borealis
Helichus striatus
Hydroporus sp.
Laceophilus maculosus
Optioservus ovalis
Peltodytes callosus
Tropisternus sp.

Diptera

Cecidomyiidae
Chironomidae
Dicranota sp.
Dixa sp.
Empididae
Euparyphus sp.
Fannia sp.
Hemerodromiinae
Hexatoma sp.
Lispoides aequifrons
Pericoma sp.
Phaenicia sericata
Simulium arcticum
Sphaerophoria sp.
Tetanocera sp.
Tipula sp.

Ephemeroptera

Bertis parvus
Choroterpes albiannulata
Ephemerella inermis
Heptagenia elegantula
Tricorythodes minutus

Odonata

Ophiogomphus sp.

Plecoptera

Acroneuria sp.
Isogenus sp.
Isoperla spp.
Kathroperla sp.
Nemoura sp.

Trichoptera

Brachycentrus sp.
Hydropsyche sp.
Ochrotrichia sp.
Rhyacophila acropedes

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