— Mundie & Traber. 83
Carrying capacity of an enhanced side-channel for rearing salmonids.

at .42 m³/sec. flow (c. 15 cfs) – too high
all left overwinter — velocity too high.–

at .14 m³/s (ca 5 cfs) – w/ 2.6% of river flow
fish / unit area = 31 x no. of yearling steelhead. 10x biomass than main river channel.

— N. Fk. Poudre

indeco
Professional Engineers for Industrial Design and Engineering
TYROL WEST BLDG. • 1500 S. LILAC DRIVE • MINNEAPOLIS, MN 55416 • 612/545-6224

June 4, 1984

Dr. Robert Behnke
3429 E. Prospect Street
Fort Collins, CO 80525

Dear Dr. Behnke:

As we discussed by telephone, enclosed for your use is a copy of the information provided to me by the Bureau of Reclamation on the Gunnison River fishery.

Please give me a call if you have any questions. I look forward to receiving your report.

Very truly yours,

Blaine M. Johnson

Blaine M. Johnson, P.E.

BMJ:mn

Enclosure

United States Department of the Interior
BUREAU OF RECLAMATION
UPPER COLORADO REGION
GRAND JUNCTION PROJECTS OFFICE
764 HORIZON DRIVE
GRAND JUNCTION, COLORADO 81501

IN REPLY REFER TO: GJ-150
120.1
Uncompahgre Project

MAY 30 1984

Mr. Blaine Johnson
Indeco
351 Tyrol W. Building
1500 S. Lilac Drive
Minneapolis, Minnesota 55416

Dear Mr. Johnson:

In accordance with your telephone request of May 8 to Steve McCall of my staff, we have enclosed the following environmental information on the Gunnison River to assist you in evaluating impacts of hydropower development on the Uncompahgre Project's South Canal. The information includes:

1. Tables showing "weighted useable area" of adult rainbow trout habitat at various flows for winter and summer.

2. Graphs showing habitat, wetted perimeter, etc., at various flows.

3. Simulated historic flow table of the Gunnison River (assuming operation of Crystal Dam over 1952-1980 water year).

4. Draft description of existing fishery and chapter from Federal Aid Reports on the Gunnison River.

One significant finding of our studies is that substantial fishery habitat losses occur when flows drop from 300 to 200 cfs in the river downstream from the Gunnison Tunnel. In terms of hydropower development on the South Canal, bypasses of a minimum of 300 cfs past the tunnel in the non-irrigation season would be much more acceptable than 200 cfs.

We are enclosing a bill for collection of $17.00 for search time and copying fees. If you have any further questions, please contact this office.

Sincerely yours,

for Stephen K McCall
J. F. Rinckel
Projects Manager

Enclosures

cc: Regional Director, Salt Lake City, Utah
Attention: UC-150, UC-400, UC-600
(w/enclosures)

STREAM FISHERIES INVESTIGATIONS

Federal Aid Study F-51-R

Job 1. Fish Flow Investigations by R. B. Nehring and R. Anderson

Job 3. Special Regulations Evaluations by R. B. Nehring and R. Anderson

Job 4. Wild Trout Introduction by R. A. Anderson

Job 5. Arkansas River Aquatic Invertebrate Investigations by R. Anderson and D. Winters

Job 6. Colorado River Aquatic Invertebrate Investigations by R. B. Nehring

Jack R. Grieb, Director

Federal Aid in Fish and Wildlife Restoration

Job Progress Report

F-51-R

Colorado Division of Wildlife

Fish Research Section

Fort Collins, Colorado

July 1983

Gunnison River

Electroshocking studies on the Gunnison River began in the summer of 1981. Population estimates were completed on three sections of the river during 1982. The uppermost was a 3.2 km (2 miles) section located between the Duncan and Ute trails access points on the west rim of the Black Canyon. The mid-section that was surveyed is 6.4 km (4 miles) long and takes in that portion of the river 0.4 km upstream from the Smith Fork confluence downstream to the North Fork of the Gunnison confluence. The lowermost section runs from the North Fork confluence 13.4 km (8.3 miles) downstream near the village of Austin.

The Gunnison River in the upper two sections (Duncan-Ute and Smith Fork-North Fork) falls in a regular stairstep fashion (pool-riffle-pool-riffle) down the canyon. The lower section (North Fork-Austin) has a much lower gradient with some pools running from 0.4 to 0.8 km in length. These pool sections are broken up by riffles and deep runs that are up to 0.4 km in length. Heavy irrigation returns degrade the river with high silt loads and increased water temperatures from the North Fork of the Gunnison valley. This undoubtedly has a profound impact on the aquatic ecology of the Gunnison River.

Until October 1981, the standard statewide angling regulations (8 trout/day and no terminal tackle restrictions) were in effect on the Gunnison River. However, the Wildlife Commission was receiving numerous reports of many overlimit catches and other problems from concerned anglers. As a result of these reports and the results of our 1981 electroshocking studies, the Wildlife Commission implemented a complex regulation on 42 km of the Gunnison River in the Black Canyon in October 1981. The bag limit was reduced from 8 trout/day to 4, with all trout between 12 to 16 inches being returned to the water. Only one of four trout could be over 16 inches and terminal tackle was restricted to artificial flies and lures only. This regulation will remain in effect at least through 1984 while we evaluate angler impacts on the trout population.

We were most concerned about the impacts of overharvest on the trout population in the Smith Fork to North Fork sections of the Gunnison River. This was the area that was receiving the heaviest fishing pressure. A creel census conducted in 1977 by W. Wiltzius (1978) revealed more than 5,000 hours of angling effort on this 6.4 km section of river. Our survey of the same area in 1982 revealed more than 17,000 hours of angling effort, 3.25 times as much pressure as was observed in 1977. Details of the creel census for 1982 and the comparison with the 1977 creel census can be found in Appendix V, Tables V-1 through V-9.

Total angling effort on the 42 km section of river was estimated at more than 51,000 hours from May through September 1982. Total catch was estimated at 57,400 trout. We estimated a catch of 31,800 (55.4%) rainbow and 24,900 (43.3%) brown trout, with a harvest (trout kept) of 10,100 (58%) rainbow and 7,300 (42%) brown trout.

These statistics indicate that the regulations imposed in October 1981 are having the intended impact, i.e., recycling the trout. The creel survey in 1982 indicated 68% of all rainbow and 71% of all brown trout caught were released. We estimated the rainbow exploitation rate at 22.2% and the brown exploitation rate at 14.5%. Exploitation rate is defined as:

$$\text{Exploitation rate (\%)} = \frac{\text{Angler harvest}}{\text{Angler harvest + population estimate}} \times 100\%$$

The creel census used was the postcard method previously described by Nehring and Anderson (1981). Vehicle counts were made twice daily on two randomly selected weekdays and one weekend day each week. Thus, 40% of all weekdays, 50% of all weekend days, and 100% of all holidays were censused. Access to the river is by a paved road at the upper end (Crystal Dam Access Road), an improved gravel road at the lower end (North Fork Access Area) and four steep trails (Chukar, Bobcat, Duncan, and Ute) from the west side of the canyon across BLM land. Due to the difficulty of access and the time required to hike down and along trails in the canyon, we determined that two vehicle counts per day resulted in a near 100% count for each count day. A total of 1,060 postcard census forms were put out, 402 were returned, for a 37.9% return. This return rate was similar to return rates for the same method on the Arkansas, Fryingpan, and South Platte rivers in 1980 and 1981 (Nehring and Anderson 1981, 1982).

Angler catch-per-man-hour (CPMH) averaged 1.12 over the 1982 season with the rainbow CPMH averaging 0.62 and the brown CPMH averaged 0.49. Total catch in 1977 was estimated at 14,345 trout. Total catch in 1982 was estimated at 57,363 trout, four times the estimated catch in 1977.

The results of our population surveys in 1981 and 1982 indicate the regulations imposed appear to be having a positive impact on the trout population, especially on the Smith Fork-North Fork Section. While the total number of rainbows (≥ 15 cm) decreased from 7,092 in 1981 to 4,360 in 1982, rainbows ≥ 30 cm increased from 489 in 1981 to 1,189 in 1982. Numbers of rainbows ≥ 40 cm remained approximately the same. The large increase in the number of rainbow between 30 cm (12 inches) and 40 cm (16 inches) was undoubtedly due to the impact of the regulation on angler harvest in that size class.

Brown trout numbers increased from 2,297 to 3,857 between 1981 and 1982 in the Smith Fork-North Fork Section of the river. Browns ≥ 30 cm also increased from 323 to 563 between 1981 and 1982. Numbers of brown trout ≥ 40 cm remained about the same between years. We hope to see some improvement in the numbers of brown trout and rainbow trout ≥ 40 cm in 1983 and 1984. However, it is quite possible these fish will be continually cropped off by angler harvest.

On the Duncan-Ute Trail Section, we did not see any dramatic changes in either the brown or rainbow trout population between 1981 and 1982 except that brown trout ≥ 30 cm decreased from 1,903 to 736. Total rainbow numbers increased 11.8% and total brown numbers decreased by 32%.

The growth rate of both rainbow and brown trout in the Gunnison River is very fast. Rainbows average 35-39 cm and browns 41-44 cm in length at age 4. Proper management should maintain excellent numbers of both species in the 40 cm to 50 cm and larger size classes.

Over the long run the numbers of quality size trout that can be maintained in the Gunnison River will probably be controlled more by the stability of water flows out of Crystal Dam than any other single factor. These flows have been remarkably stable since 1977 when Crystal Dam went into operation. However, in the spring of 1982, severe short-term fluctuations occurred between April 15 and April 25. This was right during the rainbow spawning and incubation period. Flows were stable at about 1,200 ft^3/sec up until April 15. This flow completely fills the channel and high water velocities occur all across the channel forcing the rainbows to spawn close to the bank. Flows decreased rapidly commencing on April 16 and dropped to 105 ft^3/sec on April 20 (see Table 14 for details). On April 24, dozens of dry rainbow redds were observed in the section of the river between the Duncan and Ute trails. We hypothesized that the entire 1982 year class of rainbow trout was probably lost as well as many of the brown trout for the 1982 year class. Examination of the histograms for the Gunnison River in Appendix III reveal that these expectations were realized. Both rainbow and brown trout recruitment were negligible for 1982 compared to 1981. Table 15 presents actual numbers of young-of-the-year (YOY) rainbow and brown trout sampled in 1981 and 1982 during the electroshocking surveys. These numbers indicate a loss of about 88% of the 1982 brown year class and 95% of the 1982 rainbow year class, when using the 1981 year as a base level for recruitment.

An incremental analysis of the Gunnison River flows was completed on the Duncan-Ute Trail Section of the river in early November 1982. Based on these results, we will be making recommendations for a range of flows throughout the year to the Bureau of Reclamation and the Uncompahgre Valley Water Users Association. This subject is dealt with the detail under Job 1, within this report.

Table 14. Discharge patterns in the Gunnison River below the Gunnison Tunnel in April 1982.

Date	Maximum	Minimum
4/1 - 4/15	1,200	1,210
4/16	620	608
4/17	608	338
4/18	--	338
4/19	--	339
4/20	338	105
4/21	213	190
4/22	207	190
4/23	310	206
4/24	300	214
4/25	--	214

Table 15. Young-of-the-year (YOY) rainbow and brown trout sampled in the Gunnison River in 1981 and 1982.

	1981		1982	
	Brown	Rainbow	Brown	Rainbow
Duncan-Ute	179	125	29	11
North Fork-Smith Fork	239	138	24	2

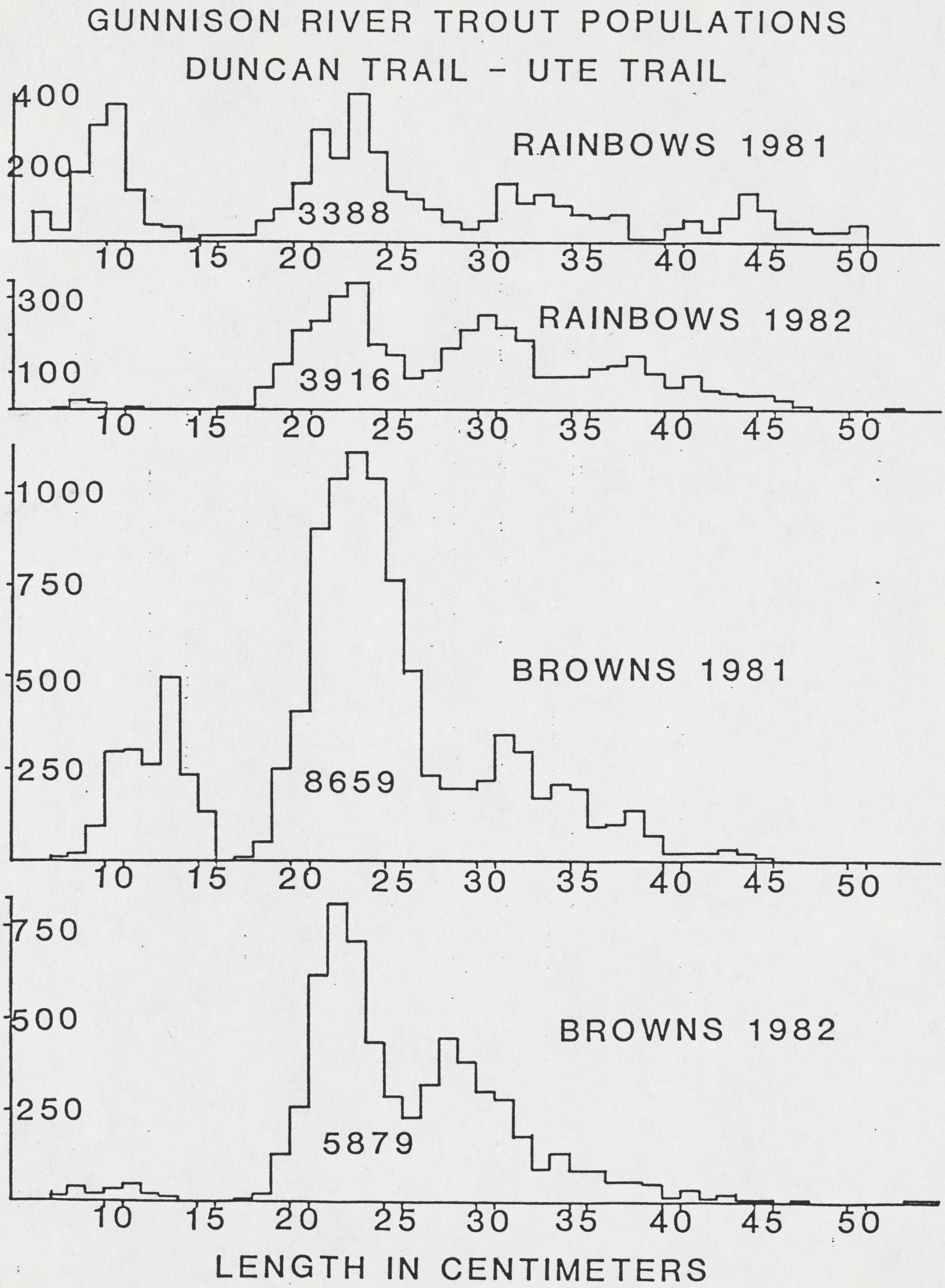
GUNNISON RIVER TROUT POPULATIONS
DUNCAN TRAIL - UTE TRAIL
400
200
RAINBOWS 1981
3388
10 15 20 25 30 35 40 45 50
300
100
RAINBOWS 1982
3916
10 15 20 25 30 35 40 45 50
1000
750
500
250
BROWNS 1981
8659
10 15 20 25 30 35 40 45 50
750
500
250
BROWNS 1982
5879
10 15 20 25 30 35 40 45 50
LENGTH IN CENTIMETERS

Figure II-15.

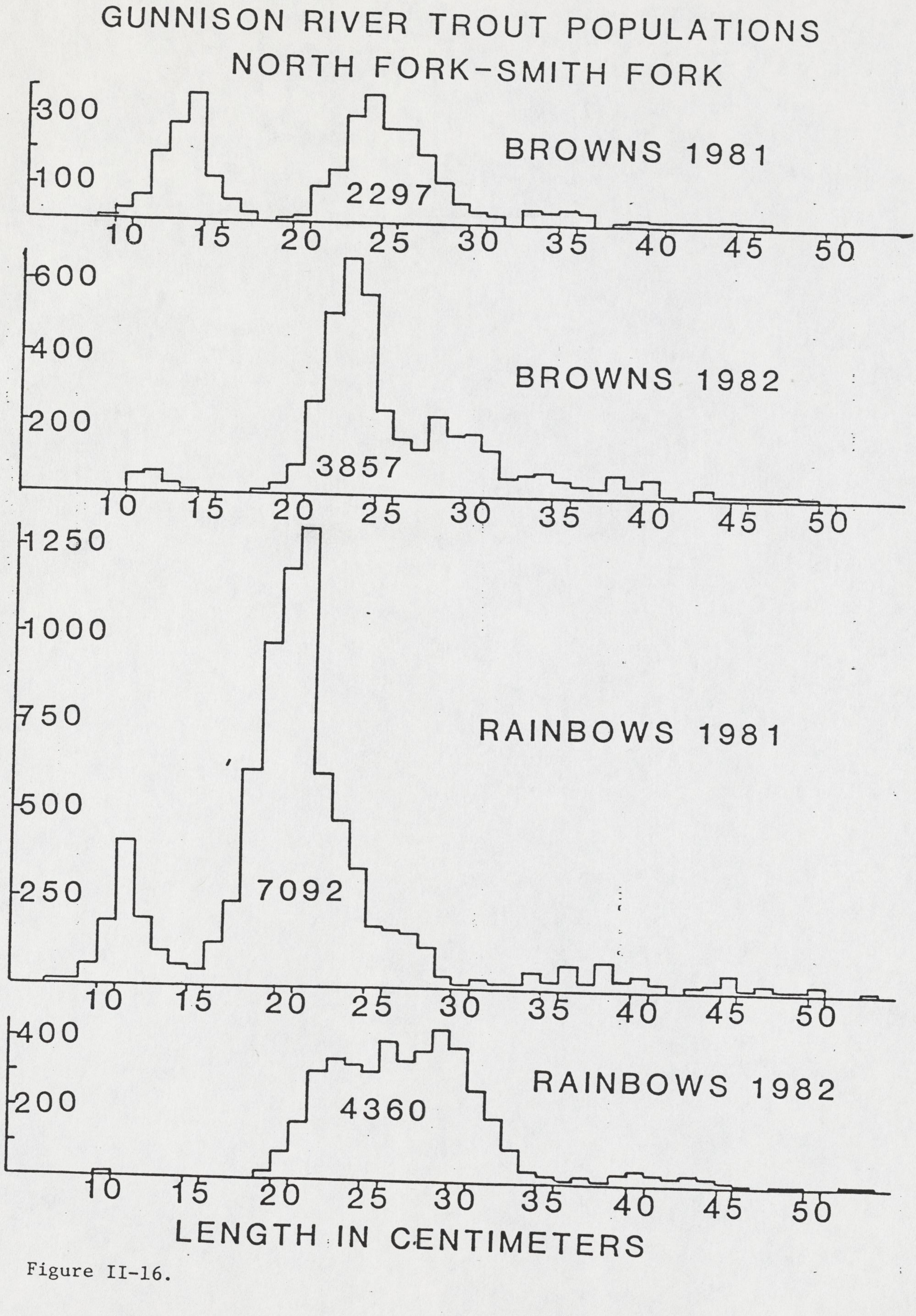
GUNNISON RIVER TROUT POPULATIONS
NORTH FORK-SMITH FORK
300
100
BROWNS 1981
2297
10 15 20 25 30 35 40 45 50
600
400
BROWNS 1982
200
3857
10 15 20 25 30 35 40 45 50
1250
1000
750
RAINBOWS 1981
500
250
7092
10 15 20 25 30 35 40 45 50
400
RAINBOWS 1982
200
4360
10 15 20 25 30 35 40 45 50
LENGTH IN CENTIMETERS

Figure II-16.

Table V-1. Creel census results from the Gunnison Canyon, May - September 1982.

Statistic	East Portal Est.	East Portal S.E.	Chukar Trail Est.	Chukar Trail S.E.	Bobcat Trail Est.	Bobcat Trail S.E.	Duncan Trail Est.	Duncan Trail S.E.	Ute Trail Est.	Ute Trail S.E.	North Fork to Smith Fork Est.	North Fork to Smith Fork S.E.
FM hours	16,979	1,245	7,429	842	1,570	355	4,172	728	3,391	482	17,087	1,386
Total catch	11,008	1,889	12,897	2,821	2,364	970	5,810	902	5,160	1,216	20,124	3,396
Creel catch	2,952	554	1,957	394	920	306	2,124	299	1,768	453	7,992	2,007
Rainbow catch	6,567	1,469	6,891	1,787	838	426	2,529	713	3,078	550	11,946	1,978
Rainbow creeled	1,754	359	1,030	298	249	82	710	189	1,106	354	5,276	1,706
Brown catch	4,324	900	5,972	1,317	1,501	593	3,034	432	2,083	776	8,020	2,073
Brown creeled	1,187	406	897	176	646	227	1,167	261	662	214	2,716	1,168
Total CPMH	0.65		1.63		1.51		1.39		1.52		1.18	
Rainbow CPMH	0.39		0.87		0.53		0.61		0.91		0.70	
Brown CPMH	0.26		0.75		0.96		0.73		0.61		0.47	

Table V-2. Comparison of creel census statistics from April 16 - October 11, 1977 vs May - September 1982 for the Black Canyon of the Gunnison.

	1977 est.	1982 est.
FM hours	22,079	51,128
Total catch	14,345	57,363
Creel catch		17,713
Rainbow catch	11,634	31,849
Rainbow creeled		10,125
Brown catch	2,529	24,934
Brown creeled		7,275
Total CPMH	0.65	1.12
Rainbow CPMH	0.53	0.62
Brown CPMH	0.12	0.49

Table V-4. Creel census of the Black Canyon of the Gunnison River, May - September 1982, Crystal and East Portal access area.

Statistic	May Mean	May S.E.	June Mean	June S.E.	July Mean	July S.E.	August Mean	August S.E.	September Mean	September S.E.	Totals Mean
FM - hours	5282	898	2516	332	4059	552	3465	413	1656	398	16978
Total catch	2490	1053	739	388	3211	786	2086	712	2493	1089	11009
Creel catch	802	281	241	170	1138	386	306	135	464	178	2951
Rainbow catch	2299	990	500	341	1000	181	1395	458	1374	905	6568
Rainbow creeled	622	220	241	170	362	110	253	115	277	163	1755
Brown catch	180	72	240	159	2115	701	680	294	1109	449	4325
Brown creeled	170	71	0	0	777	384	53	34	187	106	1187
Total CPMH	0.47		0.29		0.79		0.60		1.50		0.65
Rainbow CPMH	0.44		0.20		0.25		0.40		0.83		0.39
Brown CPMH	0.03		0.09		0.52		0.20		0.67		0.26

Table V-5. Creel census of the Black Canyon of the Gunnison River, May - September 1982, Chukar Trail access.

Statistic	May		June		July		August		September		Totals
	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean
FM hours	2067	424	1338	538	1356	268	2385	349	783	214	7929
Total catch	1558	547	409	199	4828	1182	4224	2022	1878	1460	12897
Creel catch	567	179	136	77	271	98	638	146	345	294	1957
Rainbow catch	969	480	176	105	2272	830	2577	1352	897	660	6891
Rainbow creeled	249	87	57	45	102	22	368	175	254	219	1030
Brown catch	555	151	233	121	2556	757	1647	680	981	814	5972
Brown creeled	288	118	79	39	169	77	270	66	91	74	897
Total CPMH	0.75		0.31		3.56		1.77		2.40		1.63
Rainbow CPMH	0.47		0.13		1.68		1.08		1.15		0.87
Brown CPMH	0.27		0.17		1.88		0.69		1.25		0.75

Table V-6. Creel census of the Black Canyon of the Gunnison River, May - September 1982, Bobcat Trail access.

Statistic	May		June		July		August		September		Totals
	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean
FM hours	600	212	415	182	337	166	88	62	130	130	1570
Total catch	311	201	389	135	446	446	455	319	763	763	2364
Creel catch	189	149	325	93	86	86	90	51	230	230	920
Rainbow catch	131	99	76	17	257	257	51	2	324	324	839
Rainbow creeled	65	50	76	17	34	34	22	4	52	52	249
Brown catch	181	109	288	105	189	189	405	317	439	439	1502
Brown creeled	124	99	225	68	51	51	68	55	178	178	646
Total CPMH	0.52		0.94		1.32		5.17		5.87		1.51
Rainbow CPMH	0.22		0.18		0.76		0.58		2.49		0.53
Brown CPMH	0.30		0.69		0.56		4.60		3.38		0.96

Table V-7. Creel census of the Black Canyon of the Gunnison River, May - September 1982, Duncan Trail access area.

Statistic	May		June		July		August		September		Totals
	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean
FM hours	1316	589	942	283	604	140	789	239	520	163	4171
Total catch	1005	226	601	80	1167	601	1079	135	1959	614	5811
Creel catch	435	203	497	48	228	34	348	55	616	204	2124
Rainbow catch	565	156	108	108	722	616	501	84	633	293	2529
Rainbow creeled	319	159	40	40	52	37	171	40	128	76	710
Brown catch	440	154	246	189	445	65	578	95	1326	338	3035
Brown creeled	116	50	211	178	176	19	177	30	488	181	1168
Total CPMH	0.76		0.64		1.93		1.37		3.77		1.39
Rainbow CPMH	0.43		0.11		1.20		0.63		1.22		0.61
Brown CPMH	0.33		0.26		0.73		0.73		2.55		0.73

Table V-8. Creel census of the Black Canyon of the Gunnison River, May - September 1982, Ute Trail access area.

Statistics	May		June		July		August		September		Totals
	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean
FM hours	1264	229	804	273	516	214	487	200	320	139	3391
Total catch	1151	670	977	489	2003	638	173	123	857	608	5160
Creel catch	451	291	342	246	695	215	115	97	166	62	1769
Rainbow catch	732	483	790	426	1010	51	42	26	503	381	3077
Rainbow creeled	232	117	300	209	499	259	15	15	61	32	1107
Brown catch	419	226	187	107	992	688	131	98	354	235	2083
Brown creeled	219	183	42	38	196	44	101	82	105	48	663
Total CPMH	0.91		1.22		3.88		0.36		2.68		1.52
Rainbow CPMH	0.58		0.98		1.96		0.09		1.57		0.91
Brown CPMH	0.33		0.23		1.92		0.27		1.11		0.61

Table V-9. Creel census of the Black Canyon of the Gunnison River, May - September 1982, North Fork area.

Statistic	May Mean	May S.E.	June Mean	June S.E.	July Mean	July S.E.	August Mean	August S.E.	September Mean	September S.E.	Totals Mean
FM hours	2044	488	2030	500	5219	689	5706	872	2088	445	17087
Total catch	2015	1106	0	0	9748	2247	6806	2263	1555	374	20124
Creel catch	1898	1087	0	0	3880	1485	1256	658	958	457	7992
Rainbow catch	288	170	0	0	6996	1562	3556	1130	1106	406	11946
Rainbow creeled	288	170	0	0	3325	1519	1059	629	603	423	5275
Brown catch	1728	1155	0	0	2751	1326	3092	1070	450	250	8021
Brown creeled	1611	1119	0	0	555	197	196	82	355	261	2717
Total CPMH	0.99		0		1.87		1.19		0.74		1.18
Rainbow CPMH	0.14		0		1.34		0.62		0.53		0.70
Brown CPMH	0.85		0		0.63		0.54		0.22		0.47

GUNNISON RIVER SPORT FISH POPULATION EVALUATION AND FISHERMAN USE AND CATCH STUDY FROM THE EAST PORTAL ACCESS AREA BELOW CRYSTAL DAM TO THE NORTH FORK CONFLUENCE

by
R. Barry Nehring
Wildlife Researcher C
2300 S. Townsend
Montrose, Colorado 81401

for
U.S. Department of the Interior
Bureau of Reclamation
764 Horizon Drive
Grand Junction, Colorado 81501

December 27, 1983

GUNNISON RIVER SPORT FISH POPULATION EVALUATION AND FISHERMAN USE AND CATCH STUDY FROM THE EAST PORTAL ACCESS AREA BELOW CRYSTAL DAM TO THE NORTH FORK CONFLUENCE.

INTRODUCTION

Historical Background

The Gunnison River has had a fabled and colorful history throughout the 20th century. In 1907 the Redlands Power and Diversion Dam first interrupted the free-flowing Gunnison just upstream from Grand Junction. In 1910 the Gunnison Tunnel was completed and it became possible to divert much of the summer flow from the Gunnison into the Uncompahgre Valley. For the first-half of the 20th century the Gunnison River in the Gunnison-Sapinero reach was considered the best trout stream in the entire United States according to a research committee of the National Geographic Society (Colorado Conservation Comments, 1946). However, that all ended when that area of the fabled Gunnison was inundated by Blue Mesa and Morrow Point Reservoirs in the late 1960s.

By the dawn of the 1970s it became clear that the ecology of middle section of the Gunnison River (from the Gunnison Tunnel to the North Fork of the Gunnison River) was changing rapidly due to the impacts of Blue Mesa and Morrow Point reservoirs. What was once the haven of rough fish from the catostomid and cyprinid families was becoming a budding trout fishery. (Wiltzius 1978). By the late 1970s this section of Gunnison had blossomed into a full blown trophy trout fishery with rainbow and brown trout in the 18" to 24" size range being caught on a daily basis. By the advent of the 1980's this locally renowned fishery was receiving regional and national recognition. Many articles acclaiming the rebirth of the Gunnison have appeared in both regional and national magazines and newspapers. Articles have appeared in Trout, Outdoor Life, and Fly Fisherman magazines as well as the Grand Junction Daily Sentinel, Denver Post, Rocky Mountain News, and the Colorado Springs Gazette Telegraph since 1981, just to name a few. The reborn Gunnison is clearly receiving national recognition once again.

DESCRIPTION OF THE STUDY AREA

The study area is bounded at the upstream end by Crystal Dam and the Gunnison Tunnel weir and the downstream end at the confluence of the North Fork and mainstem of the Gunnison rivers. The entire section is approximately 27 miles (43.5 km) long.

Two sections of river within this area have been the subject of electrofishing studies commencing in 1981 up to the present. Population estimates using a multiple-mark-recapture method have been completed on the Smith Fork-North Fork section (approximately 4 miles or 6.5 Km) and the Duncan-Ute trail section (approximately 2 miles or 3.2 Km) for 1981, 1982, and 1983.

Studies of fisherman use and harvest were conducted from May 1 through September 30 in 1982 and 1983. Data collection in 1983 was possible due to a cooperative agreement between the Bureau of Reclamation and the Colorado Division of Wildlife. Fisherman catch, harvest, and use patterns were studied at six main access points between the Gunnison Tunnel weir and the North Fork confluence area in 1982 and 1983. No attempt was made to evaluate fisherman catch, harvest, and use patterns from the trails originating within the Black Canyon of the Gunnison National Monument in 1982 or 1983. Wiltzius (1978) in his 1977 study determined that the number of anglers, angler days, and angling hours expended within the National Monument accounted for only 3.6% to 6.7% of the total use for the entire 27 miles reach. Logistically, it would not have been possible to include the National Monument access areas in the study and still complete the study using only one vehicle and one census clerk. Wiltzius (ibid) also found the 1977 data in the National Monument unusable from a statistical standpoint. For these reasons the National Monument anglers were not included in the study EXCEPT for those fishing within the National Monument from the Crystal Dam access area.

Thus the six areas censused in both 1982 and 1983 included the Crystal Dam access point, the North Fork access point, and the Bobcat, Chukar, Duncan, and Ute trail areas. Access from the north canyon rim downstream of the National Monument is an arduous process across private land and/or difficult four wheel drive roads and the use from these points was considered negligible by both Wiltzius and the author.

METHODS AND MATERIALS

Trout population estimates were carried out using boat electrofishing equipment. Two marking runs and a final recapture run were made in each of the two study areas. By using a different mark on each run it was possible to derive two separate Peterson estimates as well as a combined estimate for the three runs.

The formula for the Peterson population estimate (N) is given in equation 1 below:

$$(1) \quad N_i = (M_i)\,(C_{i+1})/R_{i+1})$$

Where M_i = number of marked trout at large in the population after the ith marking run

C_{i+1} = total number of trout captured on the $_i$th + 1 shocking run

$R_i + 1$ = number of recaptured marked trout taken on the i^{th} +1 shocking run

The formula for the 95% confidence interval is given by equation 2 below:

$$(2)\quad N_i \pm 1.96\sqrt{M_i^2(C_{i+1})(C_{i+1} - R_{i+1}) / (R_{i+1})^3}$$

The creel census procedure used to collect the angler catch, harvest, and use patterns was based on a modified fisherman count/interview system described by Powell (1975). Since actual fisherman contacts and interviews in the Gunnison gorge would be very difficult and expensive to acquire a voluntary mail-back post-card questionnaire was placed on angler vehicles at each of the access points on two randomly selected weekdays and one weekend day each week from May 1 through September 30, 1982 and 1983. The returned questionnaires together with vehicle count information collected twice each day at each of the six access points were used to formulate estimates of (1) total angling hours (2) total catch, (3) total harvest and (4) total catch-per-man-hour of angling (CPMH). These statistics were also compiled by species for rainbow and brown trout.

Total catch includes all trout caught, kept and released. Harvest includes only those trout kept by anglers. This differentiation allowed us to evaluate the numbers of trout kept as well as those released. A facsimile of the census form used in the study in 1982/83 is shown in Figure 1 below.

Area ______________________ Date ____________

The Division of Wildlife is conducting a survey to determine fisherman use and harvest in this area. Report information ONLY FOR THE AREA YOU JUST FINISHED FISHING. Please take a few minutes to fill out the questionnaire and return it as soon as possible, EVEN if you didn't catch fish. Thanks.

1. How many people in your vehicle actually fished? ____________
2. What was the TOTAL number of hours spent fishing by all members of your party combined in this area? ____________
3. How many and what sizes of fish did you all keep?

	0-6 in.	6-9 in.	9-12 in.	12-15 in.	15-18 in.	18-21 in.	21-24 in.	over 24 in.
Rainbow								
Brown								
Other								

4. How many and what sizes of fish did you all release?

Rainbow								
Brown								
Other								

Figure 1. Creel census card for Gunnison River.

The post-card questionnaire creel census method has been used successfully on the South Platte, Fryingpan, and Arkansas rivers in 1979, 1980, and 1981. The data collected by this census method compares well in accuracy and precision with the actual angler count/interview system of Powell (1975) which was used simultaneously on those three streams.

Breaking the harvest down into trout kept and trout released by species and size group allowed us to determine which groups of trout were being subjected to the heaviest angling pressure.

RESULTS AND DISCUSSION

Population estimates with 95% confidence limits, trout density and biomass estimates for the Black Canyon of the Gunnison study areas (1981-1983) are summarized in Table 1 in the Appendix. These studies were initiated in 1981 after concern was expressed by fishermen that the fishery in the Gunnison River was being over-exploited as a result of increasing use by anglers. This rapid increase in use seemed to be the result of regional and national publicity given to the Black Canyon of the Gunnison by the news media.

Our population estimates completed in August 1981 definitely indicated that the more heavily used-easy access sections of the Gunnison were indeed being over-exploited. Using Wiltzius' 1977 creel census data and our 1981 population estimates we were able to make an "educated guess" that angler harvest had probably increased about 40% to 50% between 1977 and 1981. The water release patterns below the Gunnison Tunnel weir from March through September in 1977 and 1981 were very similar. Bypass flows were in the 200-400 ft 3/sec range throughout that seven month period in both years, creating near ideal flows for anglers. Trout population densities in 1981 (on a unit area basis) were 71% lower in the easy access Smith Fork - North Fork section as compared to the difficult access Duncan-Ute trail section. Biomass estimates for the Smith Fork-North Fork area were 76% lower than the Duncan-Ute trail area in 1981. Numbers of quality size trout ($\geq$ 35 cm or 14 inches) were 5.6 times as abundant in the difficult access Duncan-Ute Trail area as in the Smith Fork-North Fork section. For detailed information on population density and biomass estimates between the areas refer to Table 1 in the Appendix.

As a result of these findings the Colorado Wildlife Commission enacted an emergency fishing regulation for the Gunnison Gorge from Crystal Dam to the North Fork confluence in October 1981. This regulation reduced the bag limit from

8 trout/day to 4 trout/day. In addition, terminal tackle was restricted to flies and lures only, and a size limit was imposed as well. Of the 4 trout/day only one could be over 16" in size and all trout between 12" and 16" in size were to be returned to the water immediately.

This regulation was designed to (1) reduce overall angler harvest, (2) enhance the survival of quality size trout, especially the rainbows which were suffering most heavily under excessive angling harvest, and (3) protect new spawning stock of rainbow and brown trout in the 12" to 16" size range to insure adequate reproduction and recruitment of new age classes of trout to the population.

Close scrutiny of the standing crop and biomass estimates for 1981, 1982, and 1983 in Table 1 in the Appendix reveals that the regulation is having the anticipated impacts, especially on the population in the Smith Fork-North Fork section. In this area total trout numbers have increased from 7851 in 1981 to 13,273 in 1983. Numbers of trout/ha have increased from 393 to 664 from 1981 to 1983. Total trout biomass/ha has increased from 76.3 kg/ha (1981) to 185.8 kg/ha. Numbers of quality size trout (≥35 cm)/ha has increased from 28 (1981) to 32 (1982) and 80 (1983).

Although the changes have not been as dramatic in the Duncan/Ute trail area; nonetheless, positive benefits are taking place. Rainbow biomass has increased from 110.7 kg/ha (1981) to 149.8 kg/ha (1983). Rainbow numbers have increased; 3,388 (1981) to 3,916 (1982) to 4,274 (1983). Numbers of quality size rainbow (≥35 cm)/ha have increased from 87 in 1981, to 94 in 1982, and 147 in 1983.

Brown trout numbers, biomass, and number of quality size trout in the Duncan/Ute trail area have been steadily decreasing from 1981 to 1983. This is usually the response in situations where sympatric populations of rainbow and brown trout occur and both species are protected from over-exploitation by anglers. We have seen this occur on the South Platte, Fryingpan, Colorado, and Roaring Fork rivers (Nehring and Anderson 1981, 1982, 1983).

The goals of the wild trout and gold medal trout management program in effect on the Gunnison Gorge are to enhance angler success as measured by catch-per-man-hour (CPMH) and increase the number of quality (≥35 cm total length) size trout in the population.

Angler Harvest and Creel Census

As indicated earlier, creel census data was collected using the voluntary postcard method. Counts were made and postcards distributed on two randomly selected weekdays and one weekend day each week between May 1 and September 30, 1982 and 1983. Thus, 40% of all weekdays and 50% of all weekend days were censused during the study period. In 1982, 402 postcards were returned from a total of 1060 for a 37.9% return. In 1983, 1006 postcards were put out and 310 were returned for a sample of 30.8%.

For a detailed description of the results of the angler censuses from 1977, 1982, and 1983, the reader is directed to Tables 2 through 6 in the Appendix.

The hours of angling effort on the Gunnison Gorge for May-September 1983 are unusually low. The highest discharge measured at the Gunnison Tunnel weir in 1983 was 9840 ft^3/sec on June 29th, the highest reading since June 21, 1965! This is the first year since 1965 when the mean daily discharge (by month) past the Gunnison Tunnel weir exceeded 1000 ft^3/sec from May through September. In 1965 Blue Mesa, Morrow Point and Crystal Dams were not yet in operation. By using the 1977 census data of Wiltzius (1978) as a baseline for comparison we can get a good indication of the profound changes in angling effort in 1982 and 1983.

Total hours of angling effort were 22,079, 51,128 and 39,160 in 1977, 1982, and 1983, respectively. Total catch was 14,345, 57,363, and 33,723 in 1977, 1982, and 1983, respectively. Although discharge levels were lower and more stable in 1977 than 1982, the creel census statistics for those two years are more comparable than 1977 and 1983. Discharge levels (May-September) in 1977 past the Gunnison Tunnel weir were among the lowest since Blue Mesa and Morrow Point became operational while the 1983 releases are the highest in 20 years. Thus, 1977 and 1982 offer the best comparison for observations of change without the additional problem of the vast difference in discharge levels acting as a complicating factor. Total catch in 1982 was 4 times the 1977 catch and total pressure was 2.3 times higher in 1982.

Comparison of pressure (hours) and catch statistics for the Crystal Dam access area only, reveal the highest levels were in 1983. Fisherman hours and total catch statistics were 10,679, 16,978, 23,628, and 7,385, 11,009, 18,952, respectively, for 1977, 1982, and 1983. I feel the higher levels in 1983 (despite the extremely high water levels) were the result of anglers being shifted from the trail areas (Chukar, Duncan, Bobcat, and Ute) to the easy access East Portal, Crystal Dam area.

Indeed, although angling effort (hours) and total catch statistics for the trail areas in 1983 were 56.5% and 154% higher than in 1977, they were much lower than the observed levels of 1982. Hours of effort and total catch were 54.5% and 68.1% lower, respectively, in 1983 when compared with 1982. This supports my hypothesis that anglers switched from fishing the difficult access trails in 1982 to the easy access East Portal area in 1983 because of the high water levels.

Although the contract called for breakdown of the length, weight, and age classification of the catch, only a length classification of the catch is possible. Since all of the creel census information was returned on a voluntary postcard (rather than a personal contact) basis it was not possible to collect age and weight data. Anglers would not be able to take scales or weigh individual fish in the field with enough accuracy to make the effort worthwhile. However, the breakdown of the catch by species and three inch length groups was possible for both the 1982 and 1983 census periods. And a length breakdown of the catch in itself gives a general indication of the weight and age classification of the catch since both weight and age are positively correlated with length. This length breakdown of the catch (both kept and released) by species for both 1982 and 1983 is presented in Tables 7 and 8 in the Appendix. A general discussion of this breakdown follows.

From May through September 1982, many more trout (both rainbows and browns) were released than were kept at all access areas, without exception (Table 7). The converse was true for rainbows in 1983, i.e., more rainbows were kept than were released (Table 8). Two explanations for this change are possible. In 1982 much confusion existed in the mind of the fishing public as to what the "new" regulation was. Therefore, rather than be accidently caught with too many trout, the majority of the anglers chose to release their catch than get caught with an illegal size trout. By 1983, with better signs, clearer boundaries, and more public awareness of the regulation, more anglers took home their legal catch. This probably accounted for some of the "extra" harvest in 1983.

The second explanation is probably more plausible and accounted for a greater share of the increased harvest in 1983. This explanation has two components. The upper boundary of the special regulation area in 1983 was changed from the Crystal Dam outfall downstream to the upstream boundary of the Black Canyon of the Gunnison National Monument. Thus, a bag limit of 8 trout and no terminal tackle restrictions were in effect at most of the East Portal - Crystal Dam access area in 1983, undoubtedly resulting in the greater harvest this year. Concommitant with this was the fact that the extremely high water levels throughout the May-September 1983 time period prevented fishermen from crossing the Gunnison River at either the North Fork (downstream boundary) or the East Portal area (near upstream boundary). This prevented those anglers that prefer to release their catch from even gaining access to the better fish populations available within the inner canyon catch and release areas. Thus, rather than fight the crowds at the easy access areas, probably many catch and release advocates decided not to even fish the Gunnison Gorge in 1983.

Flow Impacts on Angler Use and Harvest

Variations in discharge levels between 1982 and 1983 had a significant impact on angler use. The number of vehicle trips/month into the Black Canyon from the south rim trails was compared to the mean daily discharge/month. These data are presented in Table 1 below.

Table 1. Comparison of Angler Use (Expressed as Total Vehicle Trips/Month) at the Bobcat, Chuckar, Duncan, Ute Trails and Mean Daily Discharge/Month (Expressed in ft^3/sec) for May-September 1982-1983.

	1982		1983	
Month	Vehicles	Discharge	Vehicles	Discharge
May	186	420	88	1093
June	137	759	26	3836
July	120	763	29	4443
August	127	754	109	2183
September	69	1048	139	1224

These data were subjected to statistical analyses to determine what sort of a relationship existed between angler trips/month and mean daily discharge/month. The data were fitted to a linear regression line, a logarithmic curve, a power curve, and an exponential curve. The logarithmic curve gave the best fit. The sets of data points X_i (vehicle trips/month) and Y_i (mean daily discharge/month) were fitted to the general formula for a logarithmic curve given in equation 3 below:

(3) $y = a + b \ln x$

where $a = \frac{1}{n} (\Sigma y_i - b\Sigma \ln x_i$

and $b = \frac{n\Sigma y_i \ln x_i - \Sigma \ln x_i \; \Sigma y_i}{n\Sigma (\ln x_i)^2 - (\Sigma \ln x_i)^2}$

The regression coefficients are a and b and the coefficient of determination (r^2) measures the goodness of fit. Equation 4 below gives the formula for determing r^2.

(4) $r^2 = \frac{\left[n \; \Sigma y_i \ln x_i - \Sigma \ln x_i \; \Sigma y_i\right]^2}{\left[n \; \Sigma(\ln x_i)^2 - (\Sigma \ln x_i)^2\right]\left[n\Sigma y_i{}^2 - (\Sigma y_i)^2\right]}$

The sign (+ or -) and magnitude of r gives a measure of the degree of association between the variable x and y.

For the data in Table 1, regression coefficient a = 10,132.52, regression cofficient b = -1895.44 and the coefficient of determination (r^2) = 0.8198. The correlation coefficient r = -0.9054. The highly negative correlation coefficient (r) indicates a strong inverse relationship between fisherman use as measured by vehicle trips/month and mean daily discharge/month.

Other comparisons of variables were examined for correlations and association as well. I tested fisherman hours/month versus mean daily discharge/month and total catch/month versus mean daily discharge/month. Neither comparison indicated near as strong a relationship as the comparison of vehicle trips/month versus mean daily discharge/month. I feel too many other factors influence total catch and hours of angling effort and these factors would mask or confuse the relationship with discharge. Weather, trout feeding periods and patterns, angler ability, and water clarity or turbidity will all have a much stronger impact on (1) the length of time an individual angler continues to fish and (2) his success while fishing than will the water level in the stream. But, the decision to fish or not to fish (as determined by vehicle trips or vehicle counts at the access points) are probably more directly related to the water level in the river and not influenced by these other extraneous factors.

Since mathematical relationships such as logarithmic equations can often be intimidating for biologists, a graphic analysis of the relationship between vehicles trips/month and mean daily discharge/month is presented in Figure 2. This clearly shows the strong inverse relationship between vehicle trips and stream discharge. The highest use occurred in May 1982 when the discharge was the lowest. The reader is reminded that these were actual counts on census days only. Total estimates of vehicle trips/month would be more than double this amount since only 40% of all weekdays and 50% of weekend days were counted.

In September 1982, 69 vehicles were counted when the flow was 1048 ft^3/sec while 186 vehicles were counted in May 1982 when the discharge was 420 ft^3/sec. Thus, vehicle trips increased almost 170% as the flow was reduced by 60%. In comparison, in 1983, for a 306% increase in flow (May to July) vehicle trips decreased 70%. This indicates that flow variation below 1000 ft^3/sec have a much more dramatic impact on angler use than flow increases above 1000 ft^3/sec. Once flows rise above 1000 ft^3/sec most of the fishermen will choose to stay off the river. The Gunnison River in the Black Canyon is most fishable in the 200 - 600 ft^3/sec range. It is still fishable at 600 - 1000 ft^3/sec but cannot be crossed safely even in chest waders at these levels. At flows over 1000 ft^3/sec the fishability of the river is very limited, except from a raft, boat or canoe.

CONCLUSIONS

Fisherman use and harvest on the Gunnison River from the Crystal Dam - East Portal access area downstream to the North Fork confluence has increased dramatically in the past five years. In the event of an unusually dry year and water levels in the Gunnison River are held at 200 - 300 ft^3/sec from April through September, fishing pressure would probably exceed 100,000 hours between the East Portal access and the North Fork confluence. The Gold Medal and Wild Trout management program implemented by the Colorado Division of Wildlife is having a beneficial impact on the trout population in the Gunnison River. National notoriety on this river is rapidly approaching the notoriety of the upper Gunnison (Sapinero to Gunnison) in the 1940s and 1950s.

Flows in the range of 300 - 1000 ft^3/sec are most beneficial for the trout population, for the anglers, and for the floaters in the Black Canyon of the Gunnison from the East Portal weir to the North Fork confluence. Flows in excess of 1000 ft^3/sec become increasingly less beneficial for the fish, the fishermen, and the floaters. Flows lower than 200 ft^3/sec are very detrimental for floaters, but especially for the trout populations during the spawning and egg incubation periods. For the rainbow trout this is from about April 1 to July 1 each year and for brown trout from about October 15 to March 15. It is most important to remember that flows below 200 ft^3/sec are much more detrimental to the trout population than are flows in excess of 1000 ft^3/sec. Hopefully these flow ranges can be considered in future operation plans for Crystal Dam and Power Plant.

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APPENDIX

Table 1. Gunnison River standing crop and biomass estimates, Fall 1981, 1982, and 1983.

Study section description	Study section size: length (m)	width (m)	area (ha)	Species	Population statistics: N	95% C.I.	fish/ha	Kg/ha	trout/ha >35 cm
				1981					
Duncan/Ute Trail Area	3220	31.0	10	Brown	8659	±3554	866	201.2	71
				Rainbow	3388	±2819	339	110.7	87
				Total Trout	13,607	±5893	1361	311.9	158
Smith Fork to N. Fork Area	6440	31.0	20	Brown	2297	±764	115	25.8	8
				Rainbow	6067	±2162	303	50.5	20
				Total Trout	7851	±1939	393	76.3	28
				1982					
Duncan/Ute Trail Area	3220	31.0	10	Brown	6031	±1730	603	143.8	42
				Rainbow	3916	±1121	392	110.3	94
				Total Trout	9847	±1997	985	254.1	136
Smith Fork to North Fork Section	6440	31.0	20	Brown	3734	±1197	186	48.0	16
				Rainbow	4554	±1572	228	51.3	16
				Total Trout	8233	±1935	411	99.3	32
North Fork Confluence to Austin Bridge	12,900	45.7	59	Brown	3565	±1467	60	25.6	14
				Rainbow	2195	±1525	37	12.0	7
				Total Trout	5875	±2131	100	37.6	21
				1983					
Duncan/Ute Trail Area	3220	31.0	10	Brown	5861	±1908	586	134.5	39
				Rainbow	4274	±1406	427	149.8	147
				Total Trout	10,200	±2360	1020	284.3	186
Smith Fork to North Fork Section	6440	31.0	20	Brown	8145	±2675	407	104.5	35
				Rainbow	4682	±1641	234	81.3	45
				Total Trout	[illegible]	[illegible]	[illegible]	[illegible]	

Table 2. Comparison of fisherman use and catch from April 16 - October 11, 1977 versus May 1-September 30, 1982 and 1983.

Statistic	1977	1982	1983
FM Hours	22,079	51,128	39,160
Total Catch	14,345	57,363	33,723
Total Harvest		17,713	13,151
Rainbow Catch	11,634	31,849	24,140
Rainbow Harvest		10,125	11,067
Brown Catch	2,529	24,934	9,562
Brown Harvest		7,275	2,085
Total CPMH	0.65	1.12	0.86
Rainbow CPMH	0.53	0.62	0.62
Brown CPMH	0.12	0.49	0.24

Table 3. Comparison of fisherman use and catch statistics for the Crystal Dam access point from 1977, 1982 and 1983.

Statistic	1977	1982	1983
FM Hours	10,679	16,978	23,628
Total Catch	7,385	11,009	18,952
Total Harvest	---	2,951	10,687
Rainbow catch	6,560	6,568	16,248
Rainbow Harvest	---	1,755	9,437
Brown Catch	790	4,325	2,683
Brown Harvest	---	1,187	1,249
Total CPMH	0.69	0.65	0.80
Rainbow CPMH	0.61	0.39	0.69
Brown CPMH	0.074	0.26	0.11

Table 4. Comparison of Fisherman use and catch statistics for the Chukar, Bobcat, Duncan, Ute, and North Fork access points from 1977, 1982, and 1983.

Statistics	1977	1982	1983
FM Hours	9919	34,148	15,532
Total Catch	5811	46,356	14,771
Total Harvest	---	14,762	2,466
Rainbow Catch	4249	25,282	7,893
Rainbow Harvest	---	8,371	1,631
Brown Catch	1495	20,613	6,878
Brown Harvest	---	6,091	836
Total CPMH	0.59	1.36	0.95
Rainbow CPMBH	0.43	0.74	0.51
Brown CPMH	0.15	0.60	0.44

TABLE 5. FISHERMAN USE AND CATCH STATISTICS FOR THE CRYSTAL DAM AND EAST PORTAL ACCESS AREAS: MAY-SEPTEMBER 1983

Statistic	May Est.	May S.E.	June Est.	June S.E.	July Est.	July S.E.	August Est.	August S.E.	September Est.	September S.E.	Tota
FM Hours	1488	445	2149	522	4258	632	12,777	1134	2956	510	23,62
Total Catch	442	225	782	423	4992	1496	11,001	1805	1735	582	18,95
Total Harvest	277	124	664	372	3182	1020	5,854	1174	710	233	10,68
Rainbow Catch	388	194	774	426	4238	1278	9,609	1708	1239	477	16,24
Rainbow Harvest	264	112	656	375	2800	896	5,179	1032	538	187	9,43
Brown Catch	55	44	8	8	755	289	1,383	286	483	176	2,68
Brown Harvest	13	13	8	8	382	168	675	199	171	70	1,24
Total CPMH	0.30	---	0.36	---	1.17	---	0.86	---	0.59	---	[illegible]
Rainbow CPMH	0.26	---	0.36	---	0.99	---	0.75	---	0.42	---	[illegible]
Brown CPMH	0.04	---	0.004	---	0.18	---	0.11	---	0.16	---	[illegible]

TABLE 6. FISHERMAN USE AND CATCH STATISTICS FOR THE CHUKAR, BOBCAT, DUNCAN, UTE, AND NORTH FORK ACCESS AREAS: MAY-SEPTEMBER 1983

Statistic	May Est.	May S.E.	June Est.	June S.E.	July Est.	July S.E.	August Est.	August S.E.	September Est.	September S.E.	Total
FM Hours	2199	428	1315	313	1597	202	4879	627	5542	631	15,532
Total Catch	519	350	681	486	891	458	2088	720	10,592	3312	14,771
Total Harvest	211	178	638	453	332	225	292	116	993	189	2,466
Rainbow Catch	339	180	681	486	813	459	1012	322	5,048	2193	7,893
Rainbow Harvest	121	89	638	453	254	169	161	67	457	185	1,631
Brown Catch	180	180	0	0	78	56	1076	452	5544	1631	6,878
Brown Harvest	90	90	0	0	78	56	131	63	537	215	836
Total CPMH	0.24	---	0.52	---	0.56	---	0.43	---	1.91	--	0
Rainbow CPMH	0.15	---	0.52	---	0.51	---	0.21	---	0.91	---	0
Brown CPMH	0.08	---	0	----	0.05		0.22	---	1.00	---	0

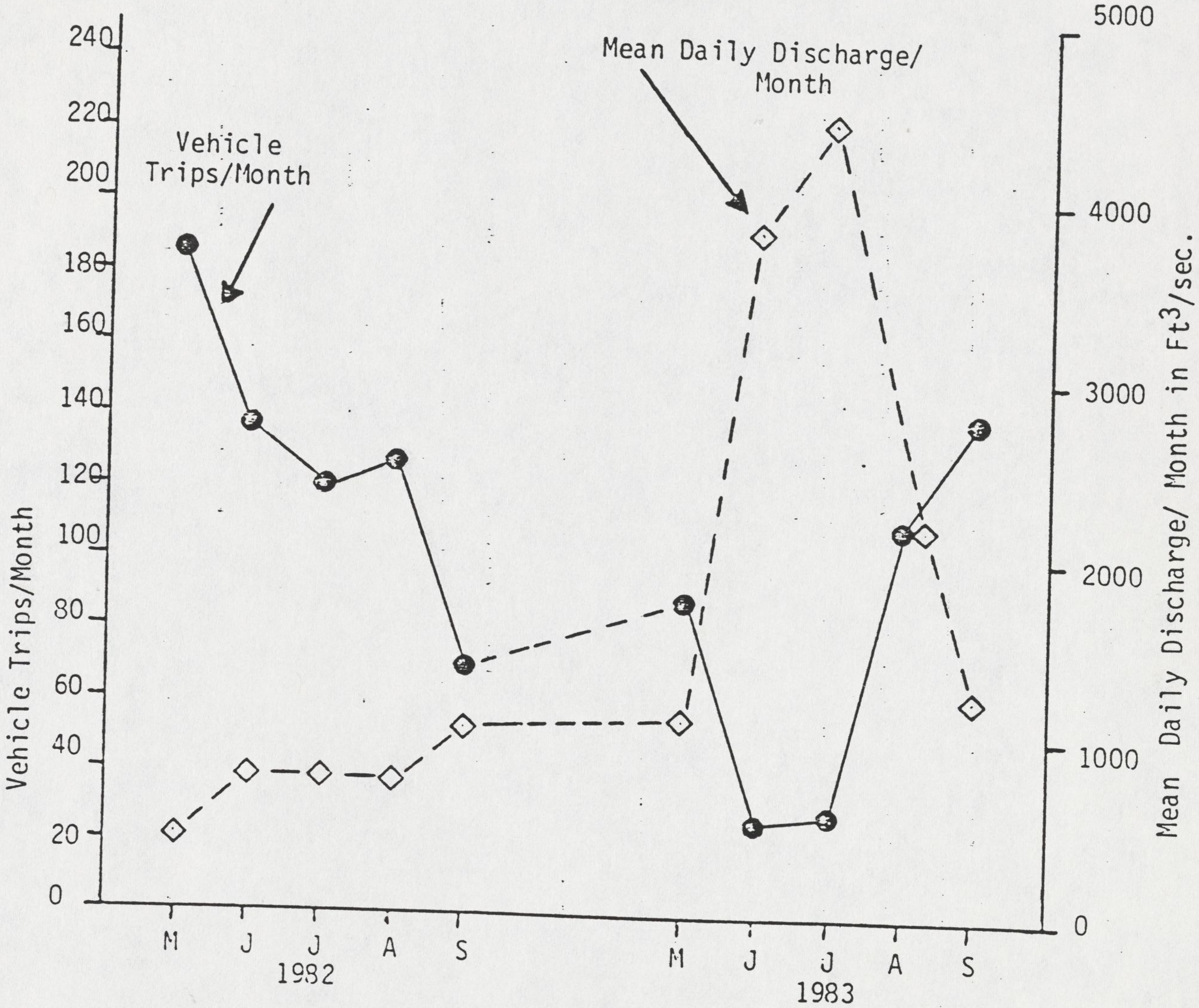
Table 7. Harvest distribution by species, numbers, size, and location on the Gunnison River, May - September 1982.

Species kept/ released	0-6 in.	6-9 in.	9-12 in.	12-15 in.	15-18 in.	18-21 in.	21-24 in.	Total in.
East Portal Access Area								
Rainbow kept	20	139	658	159	219	359	199	1753
Rainbow released	103	535	2017	948	843	185	182	4813
Brown kept		204	575	204	167	18	19	1187
Brown released	301	403	1349	359	704	14	7	3137
Chukar Trail Area								
Rainbow kept	82	107	348	13	240	240		1030
Rainbow released	506	695	948	1627	1469	616		5861
Brown kept	87	99	560	26	99	26		897
Brown released	186	571	1780	1754	731	53		5075
Bobcat Trail Area								
Rainbow kept	32	76	108	--	11	22		249
Rainbow released		111	103	144	151	80		589
Brown kept	89	177	342	38				646
Brown released		315	282	116	108	34		855
Duncan Trail Area								
Rainbow kept	8	62	386	69	123	54	8	710
Rainbow released		561	368	735	116	39	0	1819
Brown kept	50	367	648	60	43			1168
Brown released	15	504	904	337	107			1867
Ute Trail Area								
Rainbow kept	9	179	383	153	332	34	17	1107
Rainbow released	29	114	743	714	286	86		1972
Brown kept	12	121	386	96	48			663
Brown released		711	437	109	164			1421
North Fork Access Area								
Rainbow kept		879	2970	879	273	273		5274
Rainbow released	260	2153	3007	840	336	76		6672
Brown kept	75	175	1745	424	199	75	25	2718
Brown released	257	1189	2427	1125	225	81		5304

Table 8. Harvest distribution by species, numbers, size, and location on the Gunnison River from the East Portal to the North Fork Confluence, May-September 1983.

Species Kept/Released	0-6 in.	6-9 in.	9-12 in.	12-15 in.	15-18 in.	18-21 in.	21-24 in.	Total
East Portal Access Area								
Rainbow kept	125	561	1511	3285	2757	1059	141	9437
Rainbow released	639	951	1184	2260	919	749	109	6811
Brown kept	0	170	586	385	93	0	15	1249
Brown released	85	709	461	111	68	0	0	1435
Chukar Trail to North Fork Access Area								
Rainbow kept	15	44	1234	15	176	147	0	1631
Rainbow released	69	47	89	115	36	8	0	364
Brown kept	33	213	229	262	49	49	0	836
Brown released	549	1173	2702	1128	475	15	0	6042

Figure Two. Comparison of Vehicle Trips/ Month at the Bobcat, Chukar, Duncan, and Ute Trails into the Black Canyon of the Gunnison versus Mean Daily Discharge/ Month from May - September 1982-1983.



PRELIMINARY DRAFT

Table A-1
Pre-Project, Simulated Historic Flows (cfs)
below the Gunnison Tunnel

Year	Oct.	Nov.	Dec.	Jan.	Feb.	March	Apr.	May	Jun.	Jul.	Aug.	Sept.
1952	553.	1360.	1452.	2023.	2108.	2230.	2431.	2634.	3015.	2022.	754.	885.
1953	1279.	1712.	1526.	1321.	1247.	1170.	240.	1114.	946.	200.	200.	330.
1954	1182.	1220.	1470.	851.	568.	200.	200.	200.	200.	200.	200.	200.
1955	200.	200.	200.	927.	682.	365.	200.	483.	200.	200.	200.	200.
1956	200.	495.	1329.	1232.	1084.	928.	200.	1073.	669.	200.	200.	200.
1957	443.	1164.	1427.	2134.	2291.	2498.	2399.	2752.	3787.	4674.	2052.	995.
1958	1302.	1738.	1779.	1952.	2092.	2035.	1920.	2742.	2406.	1006.	200.	719.
1959	1066.	1198.	1535.	1087.	864.	599.	200.	587.	244.	200.	200.	200.
1960	200.	1104.	1491.	1316.	1229.	1152.	497.	1248.	921.	200.	200.	205.
1961	1133.	1165.	1394.	1050.	803.	515.	200.	607.	267.	200.	200.	200.
1962	200.	1101.	1626.	1835.	1987.	2084.	2186.	2198.	1944.	848.	730.	794.
1963	1129.	1036.	1407.	1041.	821.	571.	200.	524.	200.	200.	200.	200.
1964	200.	200.	1298.	1198.	1037.	836.	200.	1296.	725.	200.	200.	200.
1965	729.	1237.	1472.	1993.	2096.	2229.	2094.	2344.	2443.	2201.	1378.	980.
1966	1312.	1731.	1796.	1415.	1313.	1218.	221.	1312.	520.	200.	200.	200.
1967	200.	821.	1733.	1074.	894.	641.	200.	501.	208.	200.	200.	200.
1968	200.	465.	1753.	1428.	1368.	1311.	375.	1318.	1243.	200.	390.	893.
1969	1272.	1711.	1760.	1479.	1462.	1493.	1152.	1420.	933.	200.	200.	460.
1970	1138.	1738.	1785.	2006.	2184.	2189.	1848.	2435.	2252.	1225.	771.	1209.
1971	1311.	1741.	1790.	1955.	2045.	2010.	1650.	1540.	1300.	322.	730.	913.
1972	1250.	1625.	1764.	1225.	1110.	1022.	200.	785.	320.	200.	200.	200.
1973	592.	1735.	1525.	1541.	1547.	1631.	1184.	1692.	1377.	303.	762.	634.
1974	772.	1722.	1761.	1297.	1218.	1184.	347.	1584.	754.	200.	200.	200.
1975	200.	1171.	1757.	1626.	1668.	1791.	1297.	1567.	1465.	923.	828.	891.
1976	652.	1521.	1762.	1197.	1055.	874.	200.	761.	307.	200.	200.	200.
1977	243.	1077.	1428.	744.	430.	200.	200.	200.	200.	200.	200.	200.
1978	200.	200.	200.	890.	929.	1027.	875.	1493.	1611.	299.	655.	226.
1979	656.	1396.	1547.	1716.	1802.	2017.	1622.	2213.	1991.	647.	762.	443.
1980	820.	1346.	1722.	1769.	1899.	2113.	1732.	2026.	1763.	781.	654.	404.
Ave.	712.	1204.	1500.	1425.	1373.	1315.	906.	1402.	1180.	643.	478.	468.
Max	1312.	1741.	1796.	2134.	2291.	2498.	2431.	2752.	3787.	4674.	2052.	1209.
Min	200.	200.	200.	744.	430.	200.	200.	200.	200.	200.	200.	200.

Available [redacted] Habitat[1] (Weighted Useable Area)
For Rainbow Trout[2] Over a Range of
Flows for Two Sites on the Gunnison River

Flows (cfs)	Above The North Fork		At Duncan Trail	
	Summer	Winter	Summer	Winter
200	1,030	1,281	781	23
300	1,760	1,602	1,398	55
400	2,696	1,652	1,811	59
500	3,325	1,765	2,045	42
600	3,487	1,845	2,135	34
700	3,673	1,645	2,279	86
800	3,642	1,531	2,357	150
900	3,220	1,293	2,455	228
1000	3,161	1,130	2,581	286
1200	2,834	882	2,509	365
1400	2,520	725	2,467	366
1600	2,404	513	2,480	325
1800	2,303	433	2,384	297
2000	1,991	373	2,185	232
2200	1,852	317	1,819	177
2400	1,566	249	1,570	151
2600	1,200	238	1,440	150
2800	1,061	228	1,500	164
3000	994	223	1,653	180

1/ Instream Flow Group, Incremental Methologly, IFG4. Western Energy and Land Use Team. U.S. Fish and Wildlife Service, Fort Collins, Colorado

2/ Based on reference curves developed on the Green River below Flaming Gorge Dam.

- hatchery stocked + leave area overwinter -

PRELIMINARY DRAFT

~~CHAPTER II~~

~~EXISTING ENVIRONMENT AND ENVIRONMENTAL CONSEQUENCES~~

General Description of the Project Area

The Wayne N. Aspinall Unit is composed of three dams--Blue Mesa, Morrow Point, and Crystal--with powerplants and reservoirs along a 40 mile stretch of the Gunnison River from the town of Gunnison to a short distance above the Black Canyon of the Gunnison National Monument.

Crystal Dam, Reservoir, and Powerplant are situated in Montrose County in west-central Colorado on the Gunnison River about 12 miles east of the city of Montrose and about 53 miles west of the town of Gunnison. Crystal Reservoir is the lowest in the series of three impoundments on the Gunnison River built by the Bureau of Reclamation to provide storage and hydroelectric power generation. Crystal was finished in 1977 and filling was completed by 1978. The two upper dams, Blue Mesa and Morrow Point, were completed in 1965 and 1968, respectively. The three reservoirs are entirely within the Curecanti National Recreation Area, which is bordered on the north by the Gunnison National Forest and on the west by the Black Canyon of the Gunnison National Monument.

The Gunnison River, a major tributary of the Colorado River, is formed by the confluence of the East and Taylor Rivers northeast of the town of Gunnison. The Gunnison River is about 190 miles long and has a total drainage area of about 8,000 square miles. The elevation ranges from about 14,000 feet above sea level at the headwaters of the Taylor River to 4,555 feet at the confluence with the Colorado River.

The Gunnison River has carved a steep walled, narrow gorge about 47 miles long known as the Black Canyon. The deepest and most spectacular reach of this gorge, about 2 miles downstream from Crystal Dam, has been designated as the Black Canyon of the Gunnison National Monument. Within the Monument, the gorge depth ranges from 1,730 to 2,725 feet, while the width narrows to 1,100 feet at the rim and as little as 40 feet at the bottom.

The Gunnison River has a highly variable gradient. The stretch from Crystal Dam to the North Fork of the Gunnison has an average rate of fall of about 43 feet per mile, with the steepest area in the Black Canyon ranging from 75 to 260 feet per mile (Wiltzius, 1978). Thus, historically the Black Canyon acted as a barrier to fish migration due to its numerous falls and high water velocity making a natural separation between the upper and lower reaches of the Gunnison River. The average annual flow through the Monument is approximately 1,050 cfs.

In 1910, the Gunnison Tunnel was completed near the present upstream boundary of the Monument. In dry years, it was capable of diverting the entire summer flow of the river for irrigation in the Uncompahgre Valley. Historically, the fish found below this tunnel were nongame species such as suckers, minnows and chubs. However, the 60 mile section of river above the Gunnison Tunnel where the Aspinall Unit impoundments are located was a world-famous trout fishery.

The cold water now being released from the Aspinall Unit has greatly influenced the downstream distribution of some fishes. An excellent trout fishery has developed in the Black Canyon reach where trout were once rare. Figure 2 shows this section of the river.

The semiarid climate of the project area is characterized by short, cool summers and long, often harsh winters. Precipitation averages about 11 inches annually. Vegetation in the project area generally varies from Douglas fir and aspen found on high mesas, to sagebrush on hillsides and stands of pinon-juniper in canyons. Immediately adjacent to the river grasses and willows grow and scattered cottonwood trees are found.

General Impacts

The decision to build any of the alternatives considered would result in two types of impacts--short-term impacts related to construction and long-term impacts related to operation changes.

Final construction techniques are not known at this time but would be similar for either the 5- or 6-MW additions. In a "worst case" scenario the addition could require placing of a cofferdam (probably prefabricated concrete wall) in the construction area and dewatering behind it. Water quality would be protected during dewatering activities by treatment of discharges as required under Section 402 of the Clean Water Act. Placing of the barrier or cofferdam would unavoidably increase turbidity in the river for a short period but would be limited as much as possible. Overall short-term impacts would be minor.

Flows would be maintained in the river as the existing powerplant and the right bypass would remain functional and therefore irrigation, environmental, and other water needs would be met downstream.

In the long-term, impacts of alternatives would be related to changes in release patterns from Crystal Dam. The alternatives would increase the volume of water that could be directed through Crystal's powerplants. Overall, there would be a trend towards increased spring and early summer releases compensated by decreases in other periods. While this trend would be toward a more "natural" hydrograph, it could affect resources that have developed under existing conditions.

Environmental parameters that would not be affected include geology, vegetation, land ownership, climate, and air quality.

PRELIMINARY DRAFT

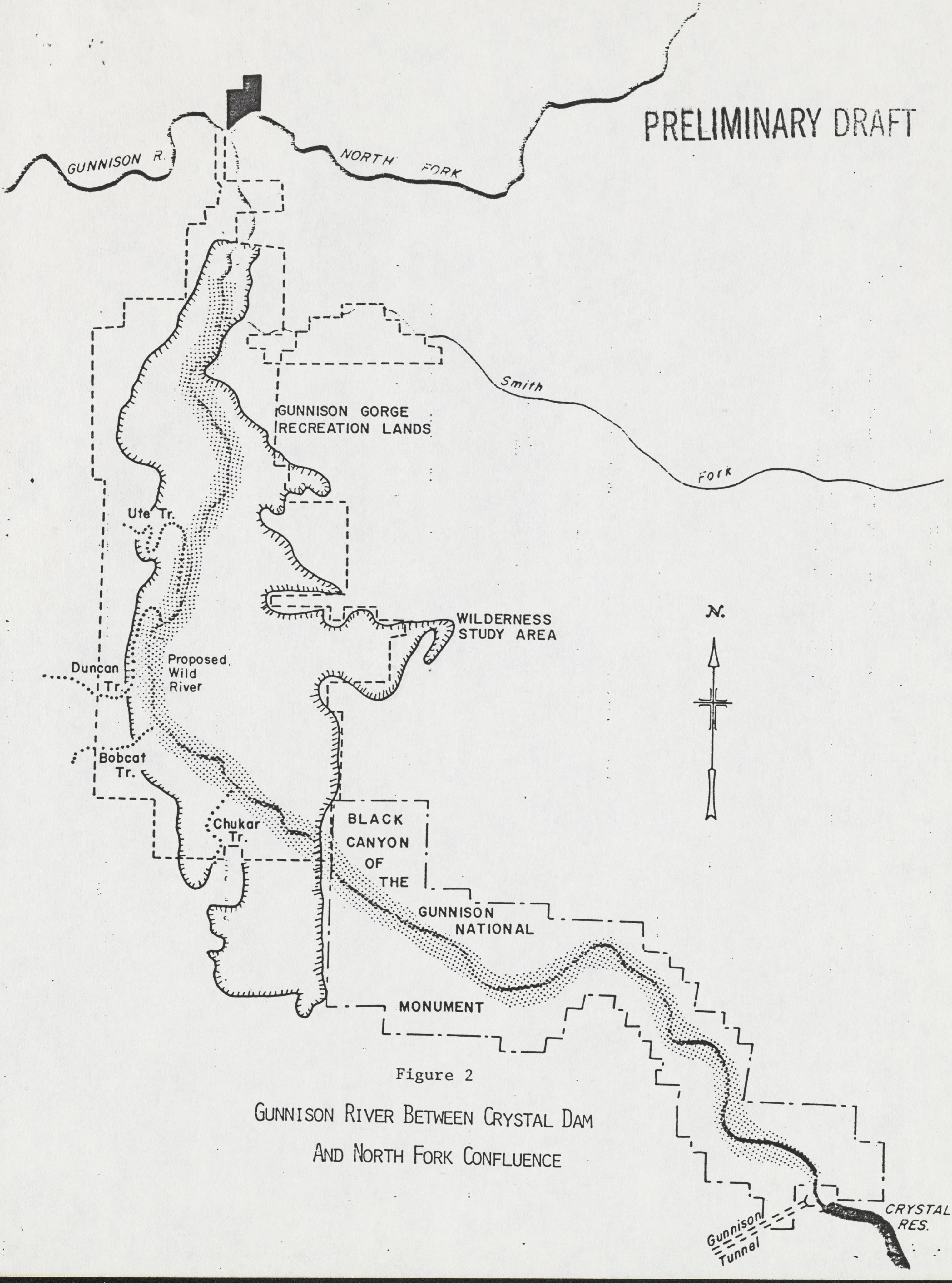


Figure 2

GUNNISON RIVER BETWEEN CRYSTAL DAM
AND NORTH FORK CONFLUENCE

Fishery

Existing conditions

Although the Curecanti National Recreation Area encompasses all three reservoirs of the Aspinall Unit, little recreation occurs in Crystal Reservoir because of limited access. Crystal Reservoir does however support a rainbow and brown trout population. Blue Mesa and Morrow Point Reservoirs support good trout and kokanee salmon fisheries.

A nationally significant and high quality fishery, composed primarily of rainbow and brown trout, exists on the 28-mile Black Canyon reach of the Gunnison River from Crystal Reservoir to its confluence with the North Fork of the Gunnison River. This stretch has been designated a Gold Medal water. Below the North Fork, the trout habitat gradually declines as the water becomes warmer and more turbid. Suckers and minnow species dominate this lower reach to its confluence with the Colorado River near Grand Junction.

Table 2 is a species list of the most common fish collected in the Gunnison River between Crystal Dam and the confluence with the North Fork.

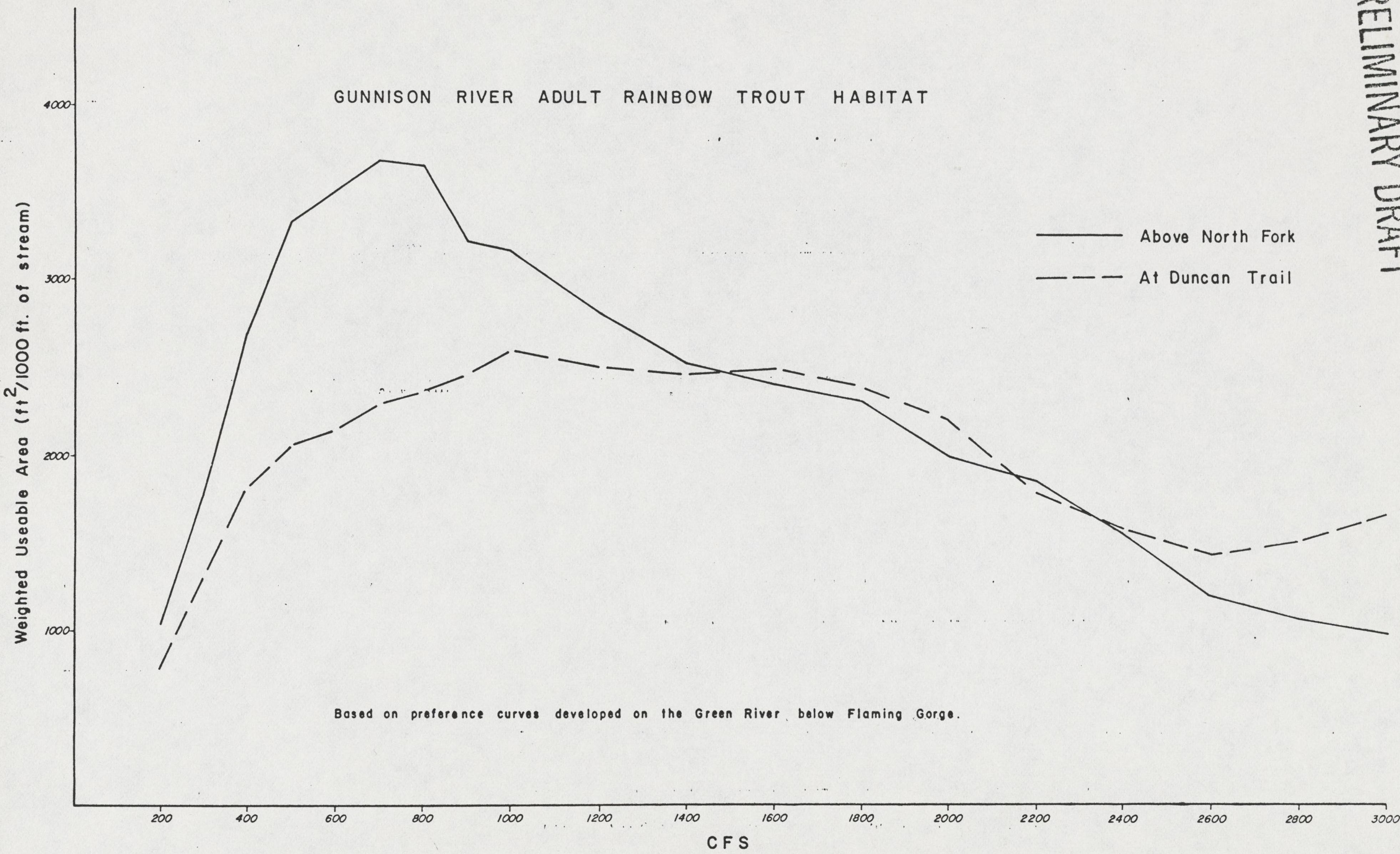
Table 2
Common fish species in the Gunnison River downstream from Crystal Dam

Rainbow Trout
Brown Trout
Flannelmouth Sucker
Bluehead Sucker
Western White Sucker
Longnose Dace
Mottled Sculpin
Longnose Sucker
Fathead Minnow
Carp
Roundtail Chub

Historically, two of Colorado's rare fishes, the Colorado squawfish and the razorback sucker, occurred in the Lower Gunnison River in substantial numbers. The Colorado squawfish is a Federally listed endangered species. These fish are still found although in greatly reduced numbers.

With the final filling of Crystal Dam in 1978, flows in the Gunnison River stabilized and the trout fishery began to rapidly improve. Figure 3 illustrates the amount of available adult rainbow trout habitat (weighted useable area) that presently exists in the Gunnison River as measured in two

Figure 3



PRELIMINARY DRAFT

river reaches utilizing the Instream Flow Group's (Fish and Wildlife Service) Incremental Methodology. Adult habitat conditions appear to be optimum at a flow of 500-1,000 cfs.

Studies have also shown that various flow-related factors greatly influence the fishery:

1. Stable or increasing flows during spawning are needed to protect eggs.

2. Medium to low flows provide best survival conditions for fry emerging from gravel.

3. A flow of 200 cfs is an adequate minimum but substantial habitat gains occur between 200 and 300 cfs as indicated in Figures 3, 4, 5, and 6.

As a result of the regional and national publicity given to the river, a rapid increase in fisherman use has occurred. Angler harvest increased by 40 to 50 percent between 1977 and 1981. Trout population densities began to fall, especially in the more accessible and easily fished reaches such as the North Fork access where trout populations dropped by approximately 70 percent in comparison to the lesser fished reaches upstream in the gorge. The number of "quality-sized fish" (greater than 14 inches) also dropped dramatically by 1981. As a result of these findings, the Colorado Wildlife Commission established regulations designed to: reduce overall angler take, enhance the survival of quality size trout, and protect new spawning stock of rainbow and brown trout in the 12 to 16 inch range to ensure adequate reproduction and recruitment of new age classes to the population.

Standing crop and biomass estimates for 1981-1983 indicate that the regulations are having the anticipated impacts (Table 3). Although brown trout populations have been decreasing, total trout numbers, density, biomass, and the number of quality size trout have all increased, particularly in the more heavily fished North Fork reach. The estimated standing crop of total trout is 408 fish per acre in the less accessible Black Canyon reaches and 266 fish per acre in the more accessible North Fork reach. Figures 7 and 8 illustrate the 1981 and 1982 length frequency distribution of the trout populations in the Gunnison River below Crystal Dam.

Impacts of flow changes--adult fish

Project impacts on fish habitat would result from changes in flows resulting from more operational flexibility. Annual average flows would not change because there would be no depletions associated with the project.

Figure 4

WETTED PERIMETER VS FLOW
GUNNISON RIVER AT DUNCAN TRAIL

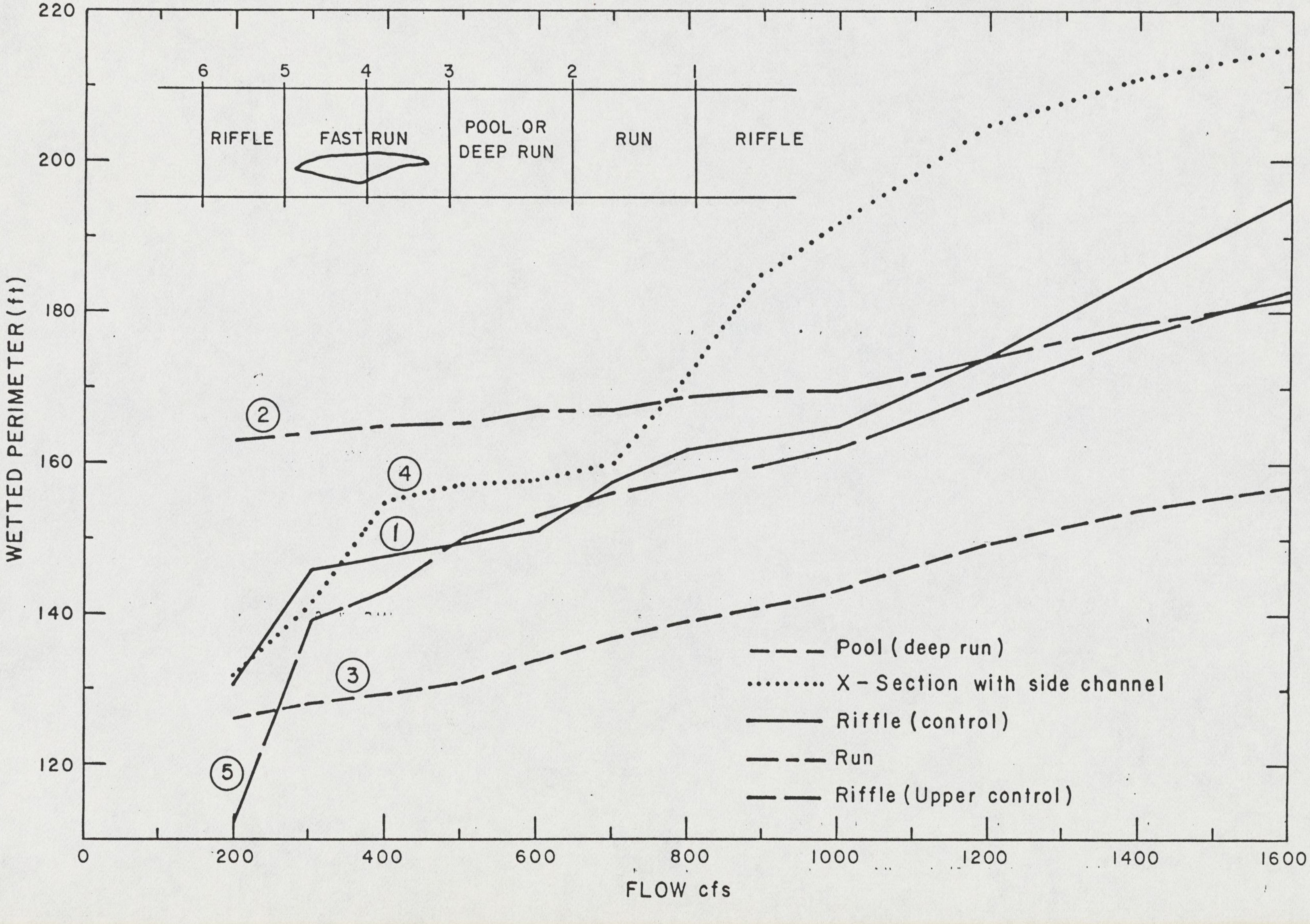


Figure 5

OVERWINTER HABITAT VS FLOW
TRANSECT 3 – DEEP RUN
DUNCAN TRAIL

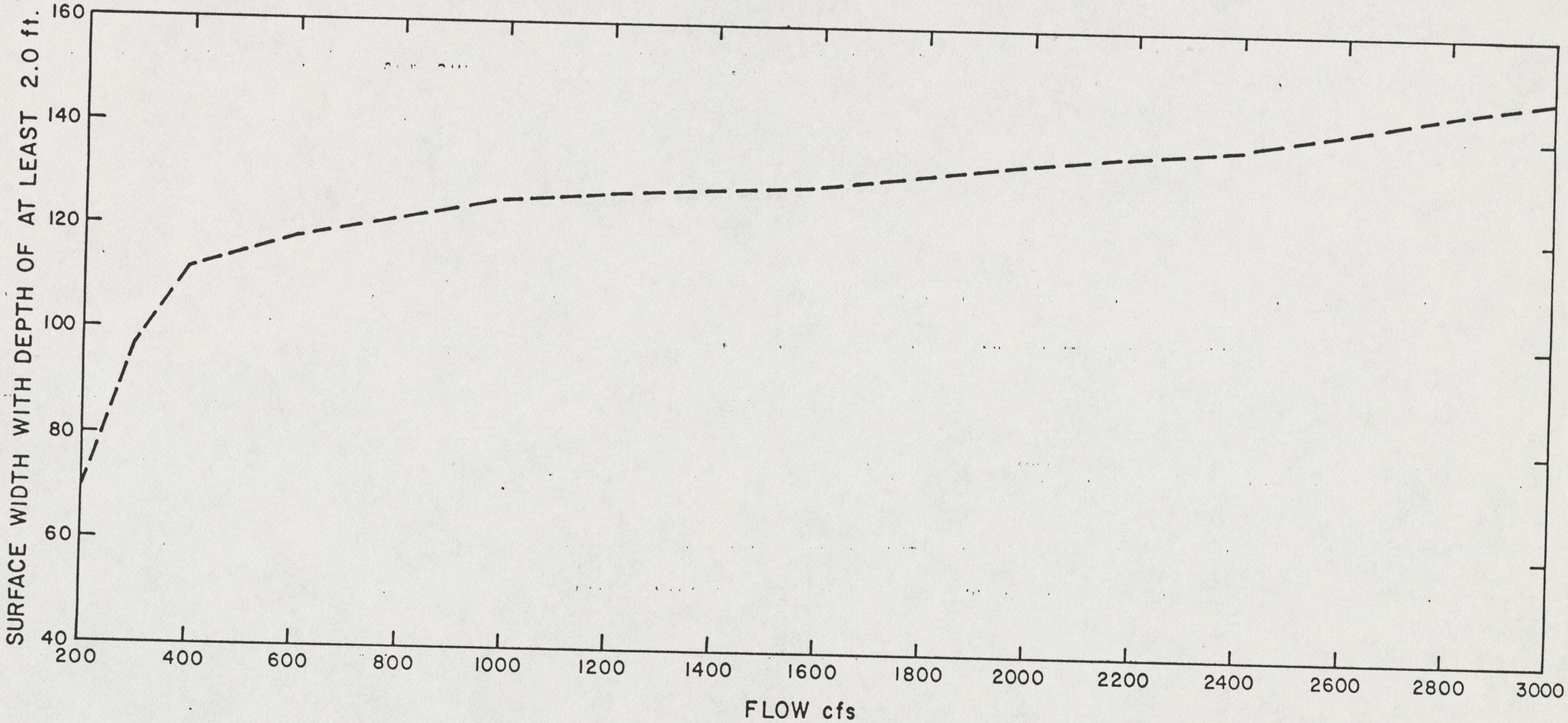


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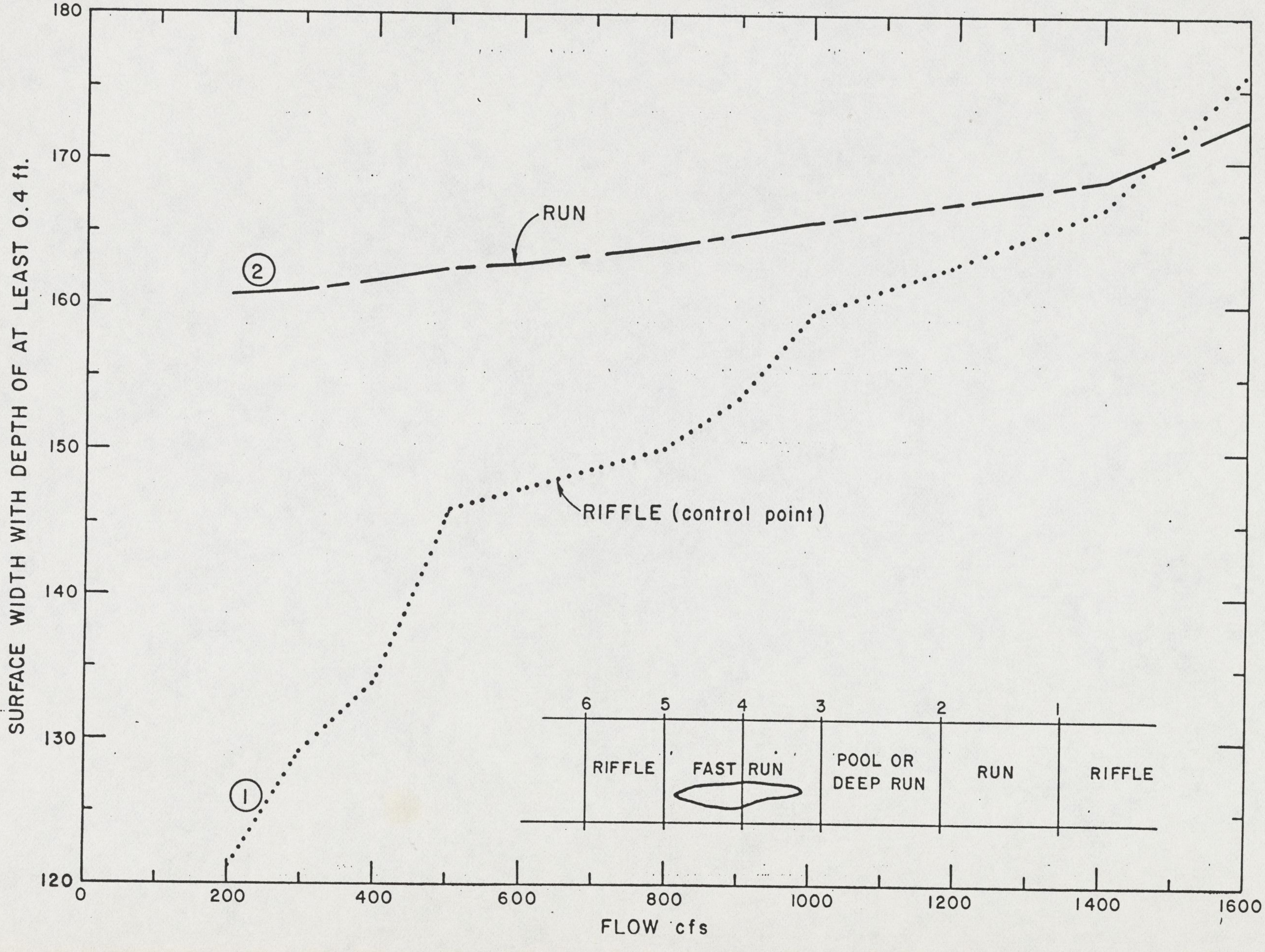
Figure 6

SPAWNING & MACROINVERTEBRATES VS FLOW AT DUCAN TRAIL



PRELIMINARY DRAFT

Table 3

Gunnison river standing crop and biomass estimates, Fall 1981, 1982, and 1983

Study section description	Length meters	Width meters	Area acres	Species	Number of fish	95% C.I.	Fish per acre	Pounds per acre	Trout per acre greater than 14 inches
Study section area					*Population statistics*				
				1981					
Duncan/Ute Trail Area	3220	31.0	25	Brown	8659	+3554	346	30.0	28
				Rainbow	3388	+2819	136	16.5	35
				Total Trout	13607	+5893	544	46.5	63
Smith Fork to N. Fork	6440	31.0	50	Brown	2297	+764	46	3.8	3
				Rainbow	6067	+2162	121	7.5	8
				Total Trout	7851	+1939	157	11.4	11
				1982					
Duncan/Ute Trail Area	3220	31.0	25	Brown	6031	+1730	241	21.5	17
				Rainbow	3916	+1121	157	16.5	38
				Total Trout	9847	+1997	394	37.9	54
Smith Fork to North Fork Section	6440	31.0	50	Brown	3734	+1197	74	7.2	6
				Rainbow	4554	+1572	91	7.7	6
				Total Trout	8233	+1935	164	14.8	12
North Fork Conflence to Austin Bridge	12900	47.5	147.5	Brown	3565	+1467	24	3.8	6
				Rainbow	2195	+1525	15	1.8	3
				Total Trout	5875	+2131	40	5.6	9
				1983					
Duncan/Ute Trail Area	3220	31.0	25	Brown	5861	+1908	234	20.1	16
				Rainbow	4274	+1406	171	22.4	59
				Total Trout	10200	+2360	408	42.4	74
Smith Fork to North Fork Section	6440	31.0	50	Brown	8145	+2675	199	15.6	14
				Rainbow	4682	+1641	94	12.1	18
				Total Trout	13273	+3216	266	27.7	32

1/ Adapted from: Nehring, B.R. 1983. Gunnison River Fish Population Evaluation and Fisherman Use and Catch Study From the East Portal Access Area Below Crystal Dam to the North Fork Confluence. 11 pp.

PRELIMINARY DRAFT

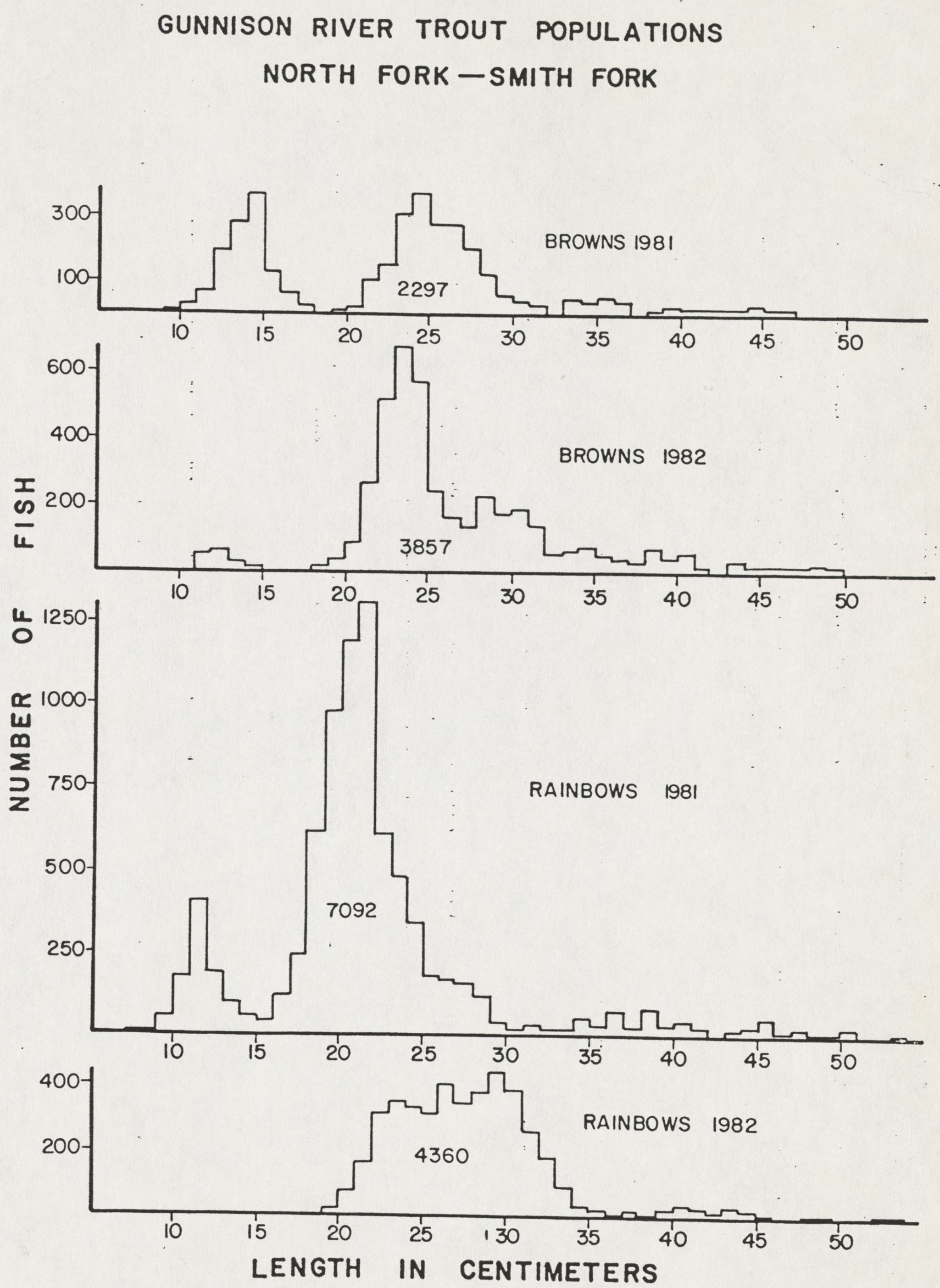


Figure 7

LENGTH FREQUENCY DISTRIBUTION

(NEHRING, R.B. AND R. ANDERSON. 1983. <u>STREAM FISHERIES INVESTIGATIONS</u>. COLORADO DIVISION OF WILDLIFE. JOB PROGRESS REPORT, FEDERAL AID PROJECT. F-51-R-8. 188 PG.)

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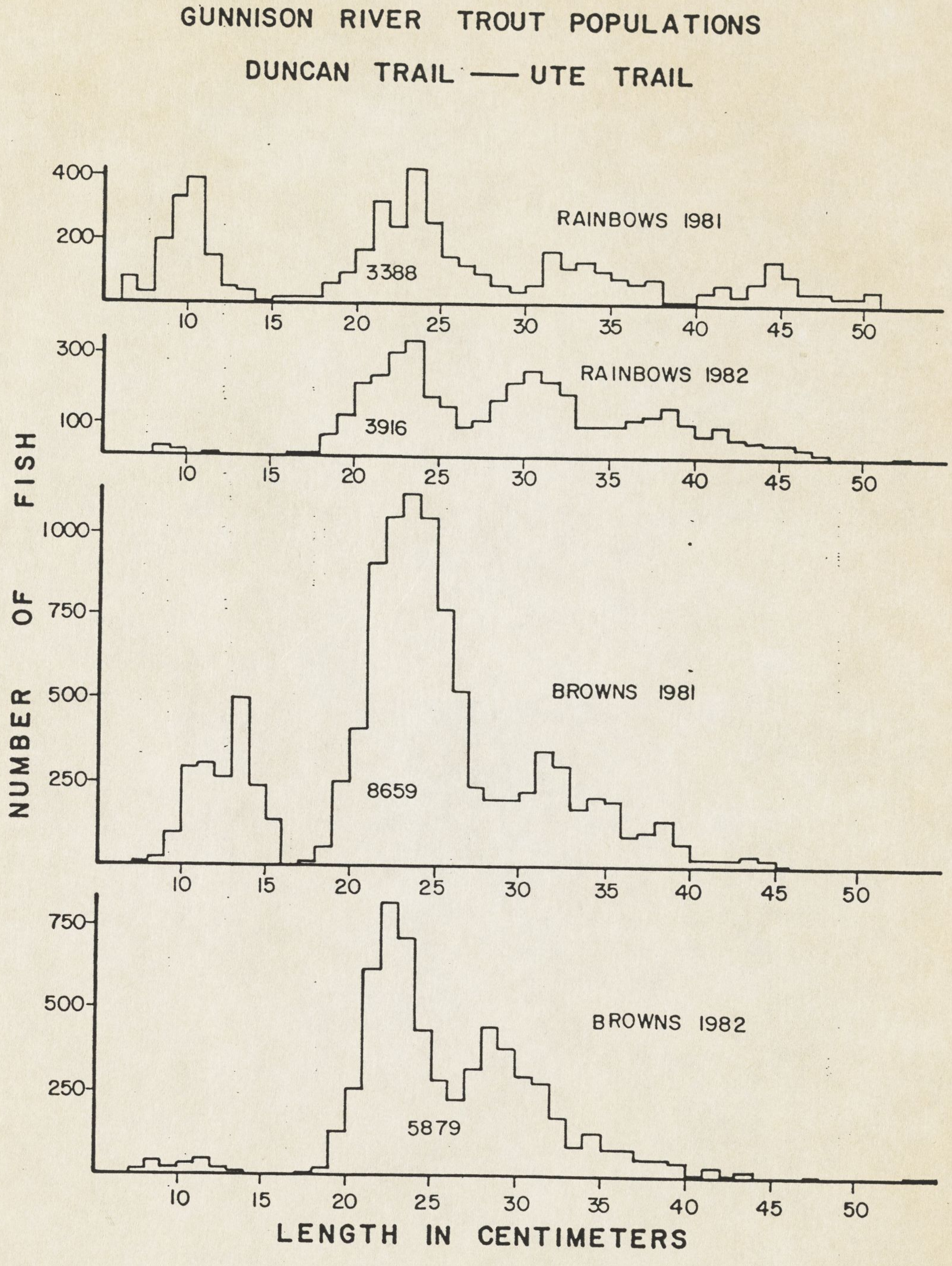

Figure 8

LENGTH FREQUENCY DISTRIBUTION

(NEHRING, R.B. AND R. ANDERSON. 1983. STREAM FISHERIES INVESTIGATIONS. COLORADO DIVISION OF WILDLIFE JOB PROGRESS REPORT, FEDERAL AID PROJECT F-51-R-8. 188 PG.)

POTENTIAL IMPACTS OF REDUCED WINTER FLOWS IN GUNNISON RIVER ON TROUT REPRODUCTION AND GROWTH IN RELATION TO LOWER WATER TEMPERATURES AND ICE FORMATION

Robert J. Behnke
Department of Fishery and Wildlife Biology
Colorado State University

ABSTRACT

Personal experience, personal communications, empirical evidence, and a survey of the literature leads to the conclusions that lower winter flows and lower water temperatures will not negatively impact reproductive success nor growth rates if incubation flows are stable. These conclusions are based on the facts that innate spawning site selection by trout place their eggs in areas protected from ice formation, and trout experience zero winter growth when temperatures descend into the 37-40° F range. Unless some section of the Gunnison River that now exhibits temperatures of 40° F or more would have the temperature reduced below 40° by reduced flow, no reduction in growth is expected -- i.e., winter growth is presently zero when temperatures are less than 40° F.

INTRODUCTION

Since writing my analysis of potential fishery impacts in the Gunnison River from flow depletions (Fisheries impact analysis for year-round flow depletion of 1000 cfs from Gunnison River in Black Canyon area) for INDECO, an expression of concern was made by FERC regarding the impact on incubating brown trout eggs due to possible ice formation in the river. Another concern has been expressed by the Colorado Division of Wildlife regarding the affects of lower winter water temperatures on growth of trout.

The following discussion, based on personal experience, personal communication, and a synthesis of the literature reveals why there is not likely to be a detectable change in survival of incubating eggs nor in trout growth as a result of lower water temperatures due to reduced winter flows.

AREA OF CONCERN AND PROBLEM

About 25 miles of the gold medal section of the Gunnison River (from diversion tunnel to confluence with North Fork) will be subjected to year-round flow depletions up to 1050 cfs if a proposed hydro electric project is constructed. My previous report discussed the reasons why the proposed depletions with a 200 cfs minimum flow would not negatively impact the present trout fishery, and could, in fact, improve the fishery especially if flows were not significantly lowered after spawning (during egg incubation period). The present concerns to be addressed regard the fact that a lesser volume of reservoir water (due to flow diversion through the Gunnison Tunnel) as it travels downstream exposed to ambient air temperature, will cool down more rapidly during winter months than under the present winter flow regime. This more rapid cooling may stimulate ice formation in the river which could possibly destroy or freeze redds, and the lower temperatures could possibly negatively impact growth. Neither of these possibilities is likely to occur because of site selection by spawning trout and the assumption that trout growth during winter (December through February) is essentially zero (or negative) under the present winter flow-temperature regime.

The winter water temperature from Crystal Dam is assumed not to exceed about 39-40^{o}F and with gradual cooling downstream, the water temperature in the river at the confluence with the North Fork should reach 32-33^{o} F during the coldest days of winter under present conditions. This longitudinal river temperature profile can be expected to change with lower flow volume; the cooling effect toward the 32-33° F minimum will occur in a shorter distance than under the present flow regime. For example, in a section of the river that now experiences minimum winter temperatures of about 35-36° F, the minimum temperatures of a reduced flow regime may be 33-34° F. I would point out that a predictive flow-temperature model has been developed that could provide a refined analysis of downstream temperature change due to flow change given known data on flow, temperature, solar radiation, wind, channel morphology, and gradient. This model description is to be published by USFWS as Instream Flow Information Paper 16. The authors are: Theurer, F., K. Voos, and W. J. Miller. Such refinement, however, would be only of academic interest, and not truly relevant to predicting growth changes. This is due to the fact that trout exhibit zero (or negative) winter growth when water temperatures drop below about 40° F and I cannot conceive of a situation where the present flow regime maintains a temperature of 40°+ F during any season which would be significantly lowered below 40° by a flow reduction.

ICE FORMATION

Two types of ice are common in rivers exposed to harsh winter climates. Anchor ice typically forms on the upstream face of boulders protruding above the surface on extremely cold nights (> 0° F). A sheet of ice extends below the water surface and may cover the substrate (Hynes 1970). Typically anchor ice melts during the next day before significant build-up occurs, but in many rivers, an annual accumulation of ice can be expected, such as the North Fork of the White River and Saguache Creek in Colorado, and the West Gallatin River, Montana (Brown 1953). Such accumulations may create ice jams and local flooding.

Frazil ice formation occurs when the water in a river is supercooled, typically by passing through a long, shallow riffle exposing much surface area (in relation to volume) to extremely low air temperatures. When supercooled water is seeded with ice crystals, such as from snow or anchor ice, a slush-like frazil ice is created which is carried downstream in the current until mixed with warmer water such as in a deep pool. Thus, winter temperatures in rivers in harsh winter climates remain at or near 32° F until the spring thaw. Trout species have evolved adaptations to cope with winter conditions such as moving into deep pools to overwinter and proper site selection of fall spawning species to place their eggs in areas of upwelling or downwelling where ice formation cannot destroy their redds.

The University of California, Berkeley, maintains a trout research station at Sagehen Creek in the Sierra Mountains. Ten years of basic, year-round research was conducted on the trouts of Segehen Creek (brook, brown, and rainbow) to elucidate environmental factors determining trout abundance. While a graduate student at Berkeley, I participated in these studies. Sagehen Creek is exposed to extremely harsh winter conditions and is characterized by great amounts of anchor ice and frazil ice every winter (Needham and Jones 1959). Dr. Robert Butler, Penn. St. Univ., used Sagehen Creek to produce a film on ice formation in streams. Despite the extreme winter conditions and annual problems with ice formation, the overriding environmental factor determining reproductive success and year-class strength of the trout species in Sagehen Creek proved to be floods (peak discharge), not winter temperature or ice conditions (Seegrist and Gard 1972; Gard and Seegrist 1972).

POTENTIAL IMPACTS ON REPRODUCTION

The key to avoiding overwinter loss of incubating eggs in rivers exposed to harsh climates is for the female trout to select a redd site with proper upwelling or downwelling where ice will not form and where intragravel water temperature may be slightly warmer than the water in the river channel. There is some confusion in the literature concerning the influence of ground water in redd site selection and preferences of brook trout and brown trout (Latta 1969; Hansen 1975). The explanation of this somewhat contradictory data probably can be found in the fact that groundwater influence varies greatly in quantity and quality from one stream to another and in different sections of the same stream -- presence, absence, temperatures, O_2 and CO_2 content. In any event, eons of natural selection has precisely adapted fall spawning species to "know" where to construct a redd to maximize overwinter survival of incubating eggs. This point was nicely demonstrated by Reiser and Wesche (1977) who studied the hydraulic preferences of brook and brown trout spawning in Wyoming streams exposed to severe winter conditions. These authors attempted to duplicate the trout's selection criteria by constructing artificial redds in the Laramie River at sites with "ideal" hydraulic parameters. All of the eggs froze solid in the artificial redds. Survival to hatching was found only when eggs were planted in natural redds previously constructed by female trout.

There may be situations where an unusual combination of circumstances create environments unsuitable for overwinter egg survival. The Wolf River in northern Wisconsin is known to have poor reproduction of brown trout (Andrews 1981). The Wolf River drains a region characteried by severe winters. The stream channel is underlain by bedrock and ground water influence appears to be nil. Brown trout eggs from a hatchery were planted in the Wolf River and experienced 95 to 100% mortality. Temperature recordings showed 122 consecutive days with water temperature at or near (32-33° F) the freezing point. Ice formation is a common phenomenon in the Wolf River but the eggs did not freeze nor were the redds damaged. The major cause of mortality may have been the prolonged near-freezing temperatures and/or the developmental stage of the hatchery eggs when placed into the Wolf River and their sudden exposure to low temperatures. The Wolf River study suggests that some rivers may have conditions unsuitable for overwinter egg survival but such rivers must be extremely rare -- fall spawning salmonid fishes successfully reproduce in rivers within the Arctic Circle where eggs incubate through an extremely long winter. Brook and brown trout successfully reproduce in the headwaters of the Gunnison River and uncountable other streams in Colorado at considerably higher elevation in regions with much colder and longer winters than in the Black Canyon of the Gunnison. Such empirical evidence and the known biology of trout reproduction should allay concern that a reduced winter flow in the Black Canyon of the Gunnison will increase the mortality of incubating eggs from ice or associated effects of lower temperatures resulting from the lower flows. What can be predicted is that lower incubation temperatures will prolong the incubation period and hatching time would occur at a later date (about 550-600 degree day temperature units are accumulated by hatching -- decreasing the temperature by 1-2° F for 90-100 days can be expected to delay hatching by about 7-10 days).

The major factor favoring successful egg incubation, as discussed in my previous report, is stable flows after spawning and during the incubation and hatching period. Thompson (1972) gave a "rule-of-thumb" desired requirement for regulated rivers that incubation flows should not drop below 67% of the spawning flows.

GROWTH CONSIDERATIONS

The concern that lower winter water temperatures will reduce growth rate of trout (both rainbow and brown) appears to be groundless unless there is a segment of the river that maintains temperatures of 40° F or more at some time of the year under the current flow regime that will experience temperature reductions below 40° due to reduced flows. Considering annual seasonal air temperatures and the temperature regime of the water released from Crystal Dam, I cannot conceive that such a situation would occur. As previously discussed, what can be expected is that reduced flow volume will cool the river more rapidly as the water travels downstream during the winter. This cooling effect would be expected to lower the present longitudinal temperature gradient in the 25 mile Black Canyon section characterized by winter lows of $35\text{-}39^{\circ}$ F by $1\text{-}3^{\circ}$ F, depending on the distance downstream from Crystal Dam. This slight decline in temperature is not expected to produce a detectable impact on growth because, except for physiological adaptations to extreme cold in lake trout and Arctic char, species of *Salmo* experience zero growth at temperatures between $37\text{-}40^{\circ}$ F (synthesis from several references listed pertaining to feeding, growth, and temperature), and this seems to be particularly true in winter when the trout's annual physiological rhythm is programmed for reduced, zero, or negative growth. In laboratory feeding experiments, the regression line predicting zero growth in brook trout is 38.6° F (Haskell 1959), and approximate zero growth for brown trout would occur at about 3.8° C (39° F) according to the data of Elliott (1976). The laboratory feeding experiments are also supported by empirical evidence in nature. I know of no natural trout population (genus *Salmo*) where any growth has been documented to occur when water temperature is less than 40° F. Although trout will continue to feed in water as cold as 32° F, their digestion rate and food assimilation efficiency are greatly reduced (Elliott 1976).

Thus, I assume that trout growth in the Gunnison River ceases when water temperature drops below 39° F under the present flow regime. The duration of the "no growth" winter period when water temperatures are less than 39° F is not expected to change due to reduced flow because this period should essentially coincide with the period when 39° water is released from Crystal Dam.

CONCLUSIONS

If "reduced winter flows" below dams with subsequent lower winter water temperatures have resulted in an obvious fishery problem (such as ice formation impacting reproduction or reduced growth rate due to lower winter temperature) I would expect that such a phenomenon has been documented and the information made known. In this regard I checked bibliographic or compilation sources such as Alderdice et al. (1977), Osborn and Allman (1976), and Walburg et al. (1981) for documentation. I found none. I then personally communicated with Pat Graham, Montana Fish and Game, and Tom Wesche, Wyoming Water Resource Inst., and asked them if they knew of an example where winter conditions in a regulated river caused egg incubation mortality from ice formation or reduced growth from lower water temperatures. They could not cite any example.

It should be recognized that if trout reproduction becomes more successful in the Gunnison River due to more stable incubation flows, growth rates can be expected to decline because growth is density dependent, especially during the first and second years of life.

The point to be recognized is that, based on empirical evidence, field and laboratory studies on trout physiology and life history, obvious fishery problems that may result from reduced winter flows are not apparent as interpreted from any direct cause-and-effect relationships, especially if incubation flows remain stable after spawning. All kinds of interacting factors are responsible for determining reproductive success, year-class strength, and growth. It is very difficult to isolate a single factor as the valid cause-and-effect action. Dennis Chitty, the reknowned British ecologist, once commented on mortality factors, but the essence of his remarks are applicable to any life history aspect under consideration. Chitty (1967) wrote:

> "The trouble is that animals die for all sorts of reasons (including starvation) and that anyone who works at it hard enough can find a correlation of some sort to support his views, whatever they happen to be."

The moral that can be drawn in relation to environmental assessment and mitigation concerns where priorities are to be placed. In regards to the Gunnison River trout fishery, would a study of winter growth rates under a reduced flow regime (in view that no baseline data exists for comparison) have a more positive influence on the trout fishery than a study of factors determining survival in the first year of life (nursery areas), that may lead to techniques to greatly enhance early life history survival? For example, Mundie and Traber (1983) found that by simply reducing the flow in a regulated side channel nursery area from 15 cfs to 5 cfs, 31 times more steelhead trout smolts were produced.

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FISHERIES IMPACT ANALYSIS FOR YEAR-ROUND FLOW DEPLETION OF 1000 cfs FROM GUNNISON RIVER IN BLACK CANYON AREA

Robert J. Behnke
Dept. Fishery and Wildlife Biology
Colorado State University
Fort Collins, CO 80523

ABSTRACT

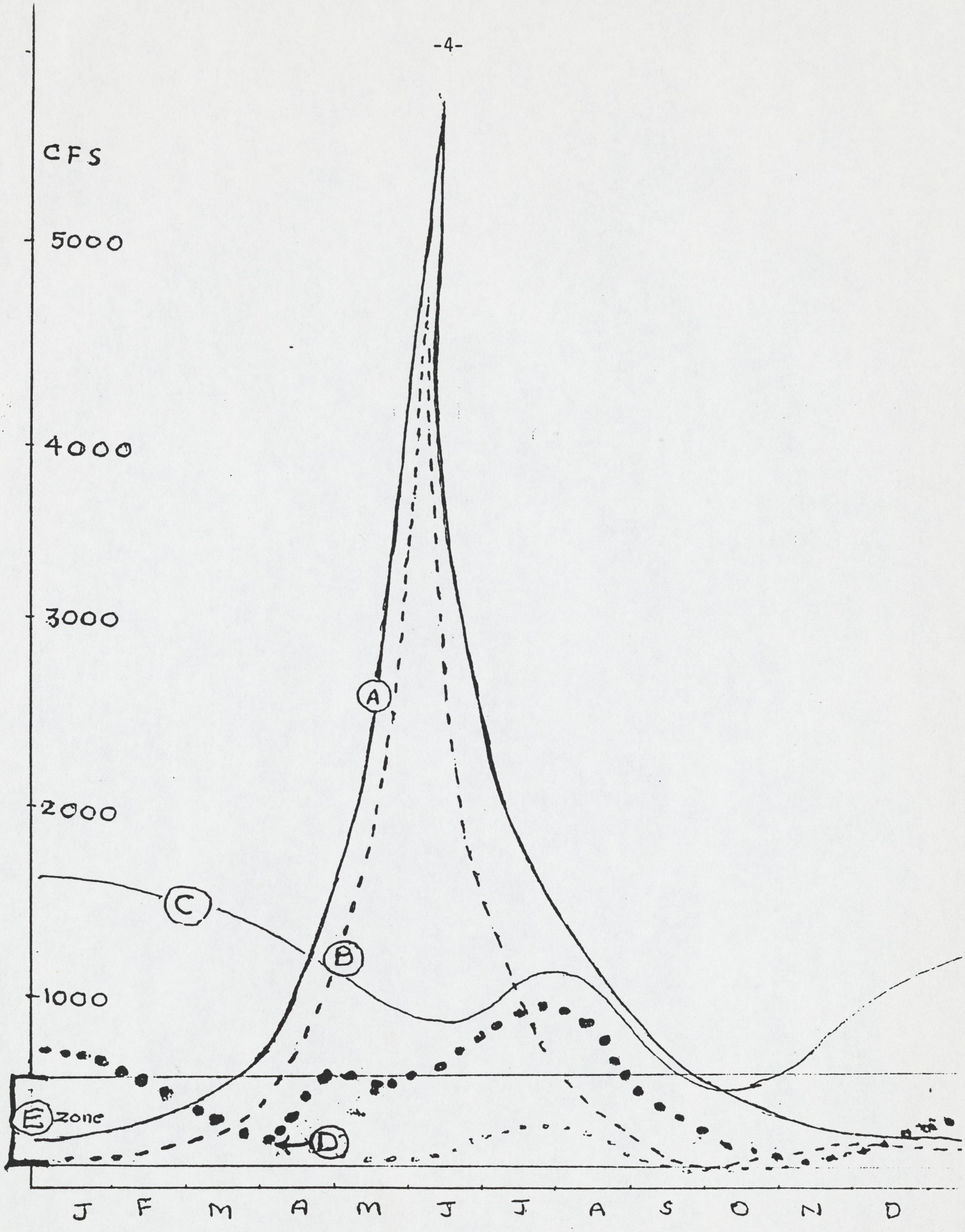
Analysis is made of potential fisheries impact of a year-round diversion of 1000 cfs. The major fishery of concern occurs in the Black Canyon area, extending 26.5 miles from Crystal Dam to the confluence with the North Fork. This fishery is designated as both a wild trout fishery and a gold medal fishery by the Colorado Division of Wildlife. Most emphasis is given to factors influencing spawning, egg incubation, hatching, and emergence of free-swimming fry. Empirical evidence correlating year-class strength to USGS flow records and instream flow analysis performed by the Colorado Division of Wildlife lead to the conclusion that a year-round reduction up to 1000 cfs, with maintenance of a 200 cfs minimum flow, would have a net positive benefit to the trout population because the lower flows would favor optimum habitat conditions for all life history stages for a greater part of the year than does the present flow regime.

INTRODUCTION

West Slope Hydro Partners has made a license application to the Federal Energy Regulatory Commission for construction and operation of hydroelectric generating facilities on an existing irrigation system. The existing irrigation system diverts water through a tunnel from the Gunnison River in the Black Canyon (diversion point approximately 1.5 miles below Crystal Dam) and has been in operation since 1910. Historically, water has been diverted only during the irrigation season, mainly from April through October, with peak diversions occurring in July and August, averaging more than 900 cfs. The proposed hydropower plans call for year-round diversion (except for annual canal maintenance shutdown) up to 1050 cfs. The resulting effect on the Gunnison River below the diversion tunnel to the junction with the Uncompahgre River, the return flow site (approximately 47 miles) would be an average increase in flow depletion of about 100 to 400 cfs from April through September, about 600 cfs during October and about 1000 cfs (theoretical potential to 1050 cfs) from November through March. A minimum flow of at least 200 cfs would be maintained at all times below the diversion point.

The regulation of Gunnison River flows by the Curecanti reservoirs has created one of the most outstanding wild trout fisheries in Colorado by greatly depressing or eliminating the annual peak flood flows releasing a more even flow distribution throughout the year, and reducing summer water temperatures, optimum for trout growth in the Black Canyon area, in comparison to historical conditions (Figures 1 and 2). The quality of the Gunnison River fishery in the Black Canyon, based on catch-per-man-hour of angling, and proportion of large trout in the population (percent of trout more than 14 inches and more than 16 inches) makes this section of the Gunnison River perhaps the finest public trout fishery in Colorado. The section of the Gunnison River from Crystal

Figure 1. Historical flow regimes in Gunnison River of Black Canyon. A. Virgin flow conditions when peak scouring flows of May to early July severely limited trout habitat. Natural reproduction during this period was probably an exceedingly rare event. B. Flow trend after completion of Taylor Reservoir (1937) and diversion through Gunnison tunnel during irrigation season. Peak flows somewhat reduced but summer flows greatly reduced. Sometimes no flow below tunnel during dry years. Trout habitat severely impacted. C. General trend of flow after Curecanti regulation (since October, 1965). More stable year-round flow and cooler summer water temperatures result in dramatic improvement in trout habitat and reproductive success. Brown trout and rainbow trout greatly increase in abundance and growth rate. Gold medal fishery established but in some years a drastic decline in flow after spawning (1982) or a high scouring flow (1983) greatly reduces year-class strength. D. General flow regime projected for year-round diversion of 1000 cfs. Note that in "normal" flow years the year round diversion with 200 cfs minimum flow would maintain flows for optimum habitat in the "E" zone. E. Zone of 200-600 cfs flows for optimum habitat conditions for all life history stages of both brown trout and rainbow trout as quantified in Figures 2, 3, and 4.


CFS
5000
4000
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2000
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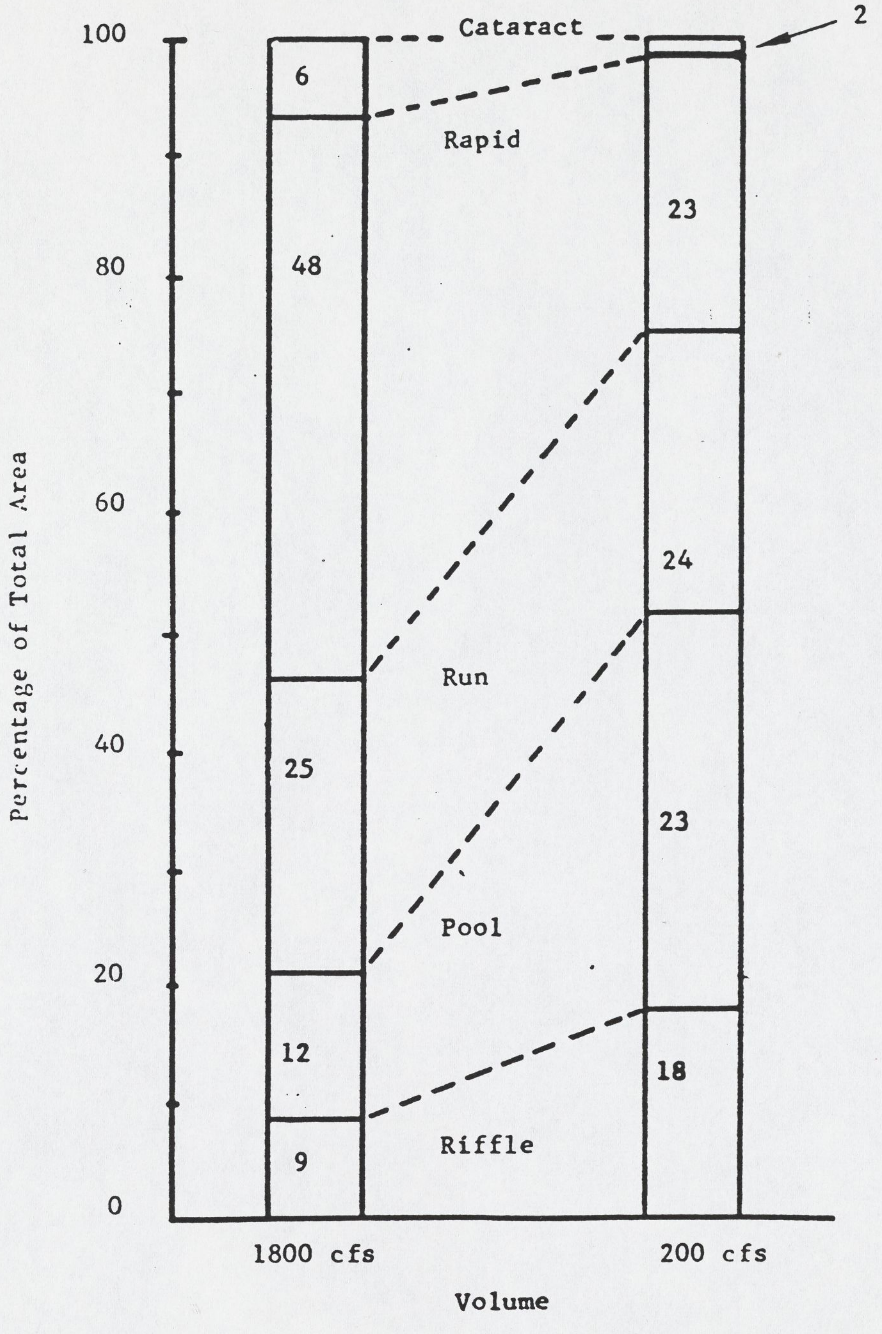
Figure 2. Illustration from Kinnear and Vincent (1967) comparing habitat changes from high flow (1800 cfs) to low flow (200 cfs). Note the increase in optimum trout habitat (pools and riffles) from 21% to 41% and decrease in areas with velocities too great for use by trout (cataracts and rapids) from 54% to 25% when the flow in the Gunnison River in the Black Canyon is reduced from 1800 cfs to 200 cfs. These habitat changes in relation to influence on the brown and rainbow trout populations are quantified in Figures 3 and 4 which present the results of instream flow analysis.


Percentage of Total Area
100
80
60
40
20
0
Cataract
2
6
Rapid
48
23
Run
25
24
Pool
23
12
18
Riffle
9
1800 cfs
200 cfs
Volume

Dam to the confluence with the North Fork (26.5 miles) has been designated as both a gold medal and a wild trout fishery (Nehring and Anderson 1982, 1983).

Thus, there is need to make a critical analysis of the potential impact of increased flow reduction on this fishery to ensure that thorough consideration is given to relate flow changes to potential positive and negative changes in trout habitat for different life history stages -- spawning and egg incubation, hatching and emergence, juvenile, and adult segments of life history.

HISTORICAL REVIEW

The total area of flow depletion impact concerns about 47 miles of the Gunnison River from the diversion tunnel intake to the confluence with the Uncompahgre River, but the area of main concern is the 26.5 mile "gold medal" trout fishery in the Black Canyon from Crystal Dam to the North Fork confluence. Although there is a fair population of large trout in the 9 mile section of the Gunnison River from the North Fork downstream to Austin Bridge (Nehring and Anderson 1982), this section is influenced by flows from the North Fork (long-term average daily flow of 445 cfs, typically ranging between 100 to 2000 cfs), and receives only a fraction of the use that is expended on the gold medal section.

The Black Canyon area was historically a transition zone between the cold, trout waters above the canyon and the warmer waters favoring species of minnows and suckers below the canyon. Environmental changes began in the late nineteenth century. The introduction of non-native species of fish and increased warming and turbidity from return irrigation flows caused the native cutthroat trout to be replaced by the introduced rainbow trout by about 1900 (Wiltzius 1978).

Based on what is known about the indigenous fish fauna of the upper Colorado River basin (Behnke and Benson 1983), the following fish species can be assumed to have existed in the Black Canyon area of the Gunnison River prior to Caucasian man's influence: Colorado River cutthroat trout (Salmo clarki pleuriticus), bluehead sucker (Catostomus discobolus), flannelmouth sucker (C. latipinnis), speckled dace (Rhinichthys osculus), roundtail chub (Gila robusta), and mottled sculpin (Cottus bairdi). During the past 100 years, the following species were introduced and established (occurring in the Gunnison River at some sites between Crystal Dam and the confluence with the Uncompahgre River): Rainbow trout (Salmo gairdneri), brown trout (S. trutta), fathead minnow (Pimephales promelas), red shiner (Notropis lutrensis) sand shiner (N. stramineus), carp (Cyprinus carpio), white sucker (Catostomus commersoni), longnose sucker (C. catostomus), and northern pike (Esox lucius). Historically, the Colorado squawfish (Ptychocheilus lucius), a federal and state listed endangered species occurred in the Gunnison River upstream to the town of Delta (vicinity of Uncompahgre confluence). The state listed endangered razorback sucker (Xyrauchen texanus) also had a similar historic distribution in the Gunnison River. These species are presently rare in the Gunnison River. Valdez et al. (1982) discussed a U.S. Fish and Wildlife Service study in the Gunnison River. Adult squawfish were collected to about 40 miles upstream from the confluence with the Colorado River (about 20 miles downstream of Uncompahgre confluence). One razorback sucker was found in the Gunnison River near Delta in 1981 (Valdez et al. 1982). Wiltzius (1978) described a razorback sucker collected above the Fifth Street bridge in Delta in 1975. There is no evidence (finding of young fish) that the squawfish or razorback sucker reproduce in the Gunnison River.

The federal and state listed endangered bonytail chub (Gila elegans) once shared a similar distribution pattern with the squawfish but the bonytail is now considered extinct in the entire upper Colorado River basin (Behnke and Benson 1983). The federal and state listed endangered humpback chub (Gila cypha) was never known to occur in the Gunnison River.

As previously mentioned, the first environmental impacts in the upper Gunnison River drainage concerned irrigation which returned warmer and more turbid waters to the river and the introductions of non-native fishes. These impacts caused the disappearance of the native cutthroat trout and its replacement by the non-native rainbow trout. The Gunnison diversion tunnel began operation in 1910 and could divert up to 1000 cfs of the Gunnison River in the Black Canyon. During low water years, essentially the entire flow of the Gunnison River was diverted in late summer and when Gunnison River flows fell below 1000 cfs, irrigation needs could not be met (Wiltzius 1978). The lack of assured irrigation water led to the construction of Taylor Park Reservoir (operational 1937) in the headwaters of the drainage to store water in the winter and spring months for release downstream to the diversion tunnel during the irrigation season. During the 1910-1965 period, the populations of rainbow and brown trout would have been severely limited in the Black

Canyon of the Gunnison by low flows and warm water during late summer and reproduction would have been limited by peak flood flows scouring the canyon. During this period, the Gunnison River above the Black Canyon was a world famous trout fishery. Because of this and the difficulty of access into the Black Canyon, few anglers fished in the canyon (Wiltzius 1978).

The most dramatic environmental change in the Black Canyon section of the Gunnison River occurred from the construction of the Curecanti impoundments (Blue Mesa Reservoir began filling in October, 1965) which regulated the Gunnison River flow by eliminating or greatly reducing the annual peak scouring flow. Also, cold water has been discharged during the summer months, which extends the zone of optimum water temperature for trout through the Black Canyon to the confluence with the North Fork. These environmental changes resulted in greatly increasing the reproductive success of trout, their abundance and growth rate (Kinnear and Vincent 1967, Wiltzius 1978, Nehring and Anderson 1982, 1983). The cooler waters and more uniform flow also affected the non-game fishes. Collections made in the Black Canyon in 1965 were predominated by three species of suckers (white, bluehead, and flannelmouth) which made up 75% of all fishes collected. The longnose sucker, a more coldwater adapted species, was not found at all. In collections made during 1975-1977, the longnose sucker was the most common fish species in the National Monument section of the Black Canyon, making up 43% by numbers of all fishes collected. The other three species of suckers comprised 25% of all fishes in the collections.

Figure 1 illustrates the changing flow regimes during historical periods in the Black Canyon section of the Gunnison River. Figure 2 illustrates why low, stable flows (10% to 20% of average daily virgin flow), increases the amount of optimum trout habitat in the Black Canyon because of the increased area of low velocity habitat.

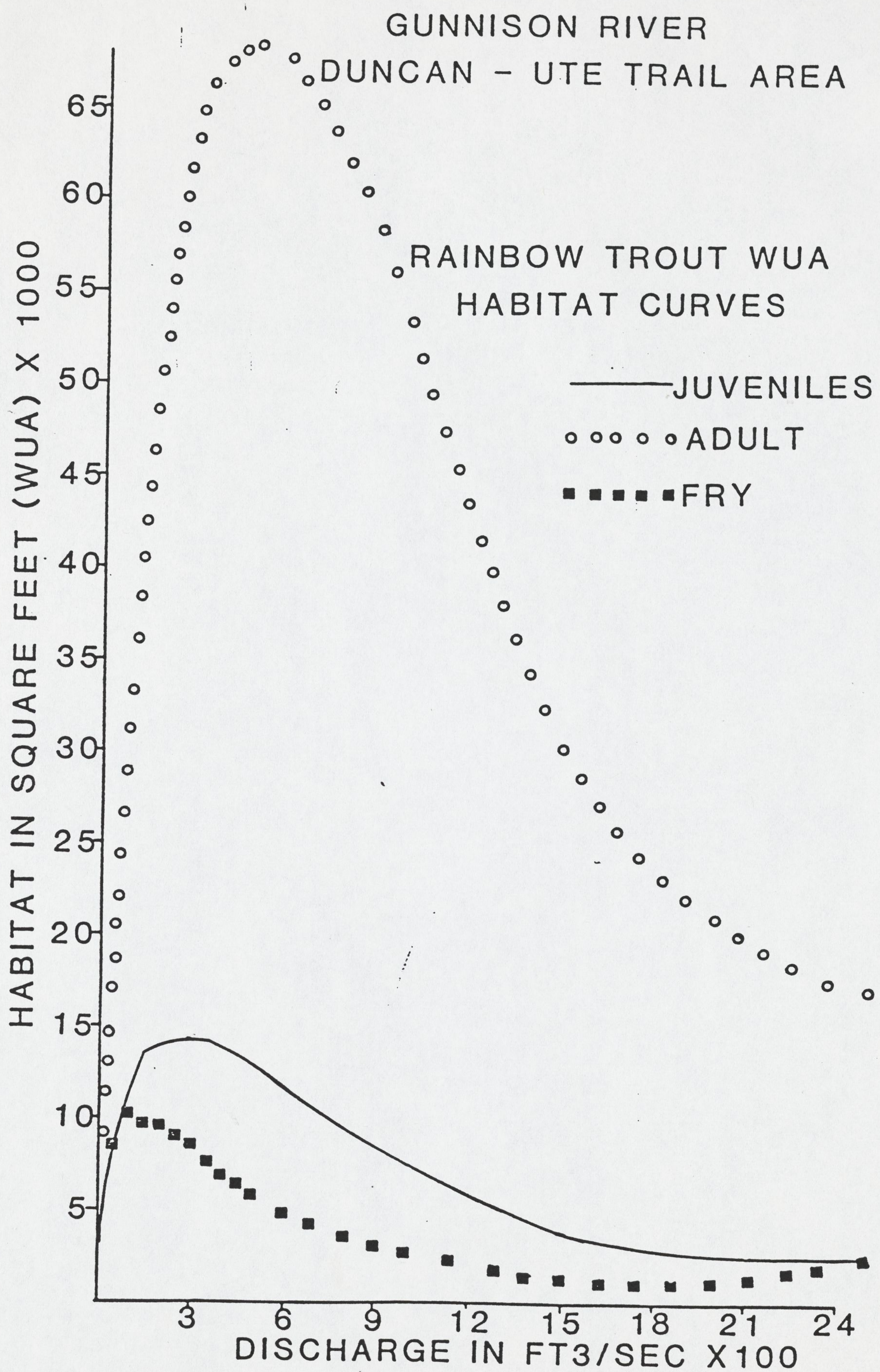
Sufficient information is now available on the biology and life history of the brown trout and rainbow trout, their preferred habitats, and environmental needs of different life history stages in relation to flows in the Black Canyon to make a critical assessment of a potentially optimal flow regime and examine how year-round diversion of 1000 cfs through the Gunnison tunnel might contribute to achieving a more optimal flow regime. The key element for a more optimal flow regime is the avoidance of short-term flow fluctuations (50-100% change in flow volume in one to a few days time, especially during egg incubation).

IMPACT ASSESSMENT

Impoundments regulating stream flow by a more constant year-round discharge with cold summer releases create some of the most famed trout fishing in the West. For example, the Colorado River below Glen Canyon Dam, the South Platte River below Cheeseman Dam, the Frying Pan River below Ruedi Dam, the "Miracle Mile" of the North Platte River below Seminole Dam, the San Juan River below Navajo Dam, and the Black Canyon of the Gunnison below Crystal Dam. Most "tailwater" fisheries, although providing an excellent environment for adult trout (mainly stocked hatchery trout), have little or no natural reproduction due to erratic flow fluctuations and/or an unsuitable temperature regime (Mullan et al. 1976, Walburg et al. 1981). The Gunnison River in the Black Canyon has had successful natural reproduction by brown and rainbow trout in most years since flow regulation by the Curecanti Project. The designation of the Gunnison River in the Black Canyon as "wild trout" waters by the Colorado Division of Wildlife, means that this fishery must depend on natural reproduction. The most vulnerable period of a trout's life cycle is the embryonic development stage (egg incubation), hatching and emergence of free-swimming young (when they must find protected areas of little or no current velocity), and the first few weeks after emergence. Older, larger trout are highly mobile and can readily retreat to deep pool areas during periods of torrential flow or extremely low flow. Thus, the greatest emphasis for impact analysis is given to a critical evaluation of flows in relation to spawning, egg incubation, and emergence of brown and rainbow trout.

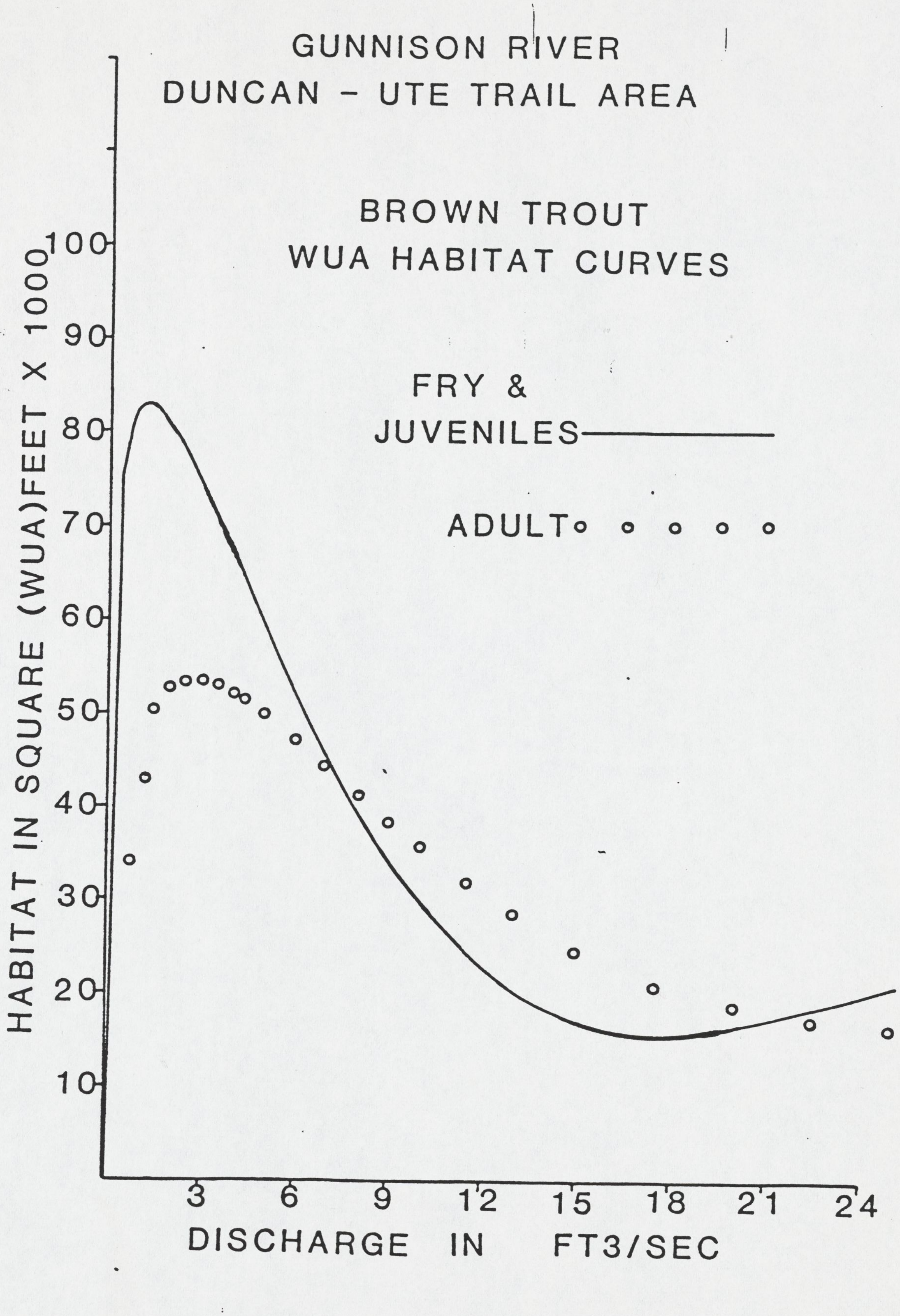
In 1982, the Colorado Division of Wildlife, in cooperation with the Bureau of Reclamation, made a detailed instream flow analysis of the Gunnison River in the Duncan-Ute trail area of the Black Canyon (Nehring and Anderson 1983). The PHABSIM model developed by the Instream Flow Group of the U.S. Fish and Wildlife Service was used which quantified the quantity and quality of habitat available to fry, juvenile, and adult brown and rainbow trout at various flows up to 2500 cfs. For all life history stages for both species, the amount of optimum habitat (weighted useable area: WUA) peaked between flows from about 150 to 600 cfs and rapidly declined at flows exceeding 1000 cfs. Approximately four times more habitat (WUA) was available for all life

Figure 3. From Nehring and Anderson (1983) graphically depicting the changes in trout habitat (weighted useable area = WUA) with changes in flow for various life history stages of rainbow trout. Note optimum habitat conditions for all life history stages occurs at flows from about 150 cfs to 600 cfs. This is due to the increase in amount of low velocity habitat. Figure 3 translates and quantifies the information of Figure 2 into units of useable trout habitat. Year-round diversion of 1000 cfs would maintain flows in the optimum range for a much greater part of the year than under past and present flow regimes.



GUNNISON RIVER
DUNCAN - UTE TRAIL AREA
RAINBOW TROUT WUA
HABITAT CURVES
JUVENILES
ADULT
FRY
HABITAT IN SQUARE FEET (WUA) X 1000
65
60
55
50
45
40
35
30
25
20
15
10
5
3
6
9
12
15
18
21
24
DISCHARGE IN FT3/SEC X100

Figure 4. Same as Figure 3 but for brown trout. Note approximate identical favorable response to 150 cfs - 600 cfs flows.


GUNNISON RIVER
DUNCAN - UTE TRAIL AREA
BROWN TROUT
WUA HABITAT CURVES
FRY &
JUVENILES
ADULT
HABITAT IN SQUARE (WUA)FEET X 1000
100
90
80
70
60
50
40
30
20
10
3
6
9
12
15
18
21
24
DISCHARGE IN FT3/SEC

history stages at 200 cfs in comparison to 2000 cfs according to the analysis (Figures 3 and 4).

There are many techniques in use to predict changes in habitat quality or fish abundance with changes in flow (Wesche and Rechard 1980), and investigators should understand that they are dealing with a great abstraction and simplification of nature in attempting to quantify a multi-dimensional niche of a species by a few components such as depth and velocity. I believe, however, that the instream flow analysis of the Gunnison River by Nehring and Anderson (1983) is accurate. This is due to the unique environment of river channels incised in deep canyons (in contrast to "normal" river channels where low flows of about 20% of the average daily flow recedes the wetted perimeter away from the undercut bank areas and causes the loss of prime habitat).

The greatly increased habitat values illustrated in Figures 3 and 4 at flows from about 150 to 600 cfs is also corroborated in Figure 2 which illustrates a change in types of habitat in the Gunnison River in the Black Canyon when flows change from 1800 cfs to 200 cfs. In changing from 1800 cfs to 200 cfs the amount of river with velocity too high to be used as trout habitat (cataracts and rapids) declines from 54% to 25%, and the amount of prime trout habitat (pools and riffles) increases from 21% to 41%.

Further corroboration was obtained by comparing size-age structure of the trout population in the Black Canyon (Nehring and Anderson 1982, 1983) to note trends in year-class strength (= success of natural reproduction for any single year) and correlate these data with U.S.G.S. flow records for the gaging station below the diversion tunnel. What becomes apparent is that lower than normal flow regimes benefit reproduction, and all life history stages (as can be interpreted from Figrues 1-4), but irregardless of the annual discharge regime, the greatest negative impact on reproduction is rapid fluctuation in flow between spawning and emergence of young. Nehring and Anderson (1983) pointed out the drastic decline in young-of-year brown and rainbow trout in 1982 compared with 1981 (88% and 95% reduction of the two species, respectively), and related the decline in spawning success to highly fluctuating flows during the March through June, 1982, period.

It is instructive to examine the 1981 flows (1981 water year) which produced strong year-classes of both trout species and the 1982 flows which produced extremely weak year-classes in order to better assess potential impacts of future increased diversion with empirical evidence.

Brown trout spawn on declining temperatures. Spawning is typically initiated when maximum daily water temperatures drop below about 48^{o}F. In most years, brown trout spawning will peak during October in the Gunnison River. The eggs incubate overwinter and hatch in late winter (late February, early March) with emergence of free-swimming fry from about late March to early or mid-April. Rainbow trout spawn on rising temperatures with spawning typically initiated when daily maximum water temperatures exceed about 42^{o}F. In most years, peak spawning will occur in April with hatching in mid-May - early June and emergence of free-swimming fry in the early to late June period.

The incubating eggs (buried about six inches in a gravel nest) must have sufficient circulation to maintain high oxygen levels (>5 ppm) and if the nest becomes filled with sediment, water circulation is cut off and the eggs perish. The sediment-free waters discharged from Crystal Dam essentially eliminate the problem of sediment and allow for adequate water circulation in nests at low flows. Trout construct their nests in gravel substrate at stream depths typically between one and two feet. Stage-flow relationships (change in river surface level correlated with change in flow) vary in different sections of a river in relation to gradient and channel configuration. Generally, a change in flow of about 100 cfs would be expected to change the river surface elevation by about one to two inches in a river the size of the Gunnison. Thus, if trout spawned at a high flow of 2000 cfs, at depths of one to two feet, and the flow decreased to 200 cfs during egg incubation, most of the nests would be stranded above the waterline.

Trout and salmon eggs can incubate in a moist environment if temperature and oxygen conditions are suitable (Reiser and White 1981). That is, developing eggs may survive dewatering for some time under certain conditions, but these conditions are improbable in the Gunnison River. For example, consider the development of the 1981 brown trout year-class (brown trout hatched in 1981) in comparison with the 1982 year-class. The 1981 year-class was initiated by spawning in the fall of 1980. Assuming most spawning occurred in October, nests were constructed and eggs began incubation at flows ranging from 556 cfs to 946 cfs. Flows ranged between 1000 to 1270 cfs from November through February. The hatching and emergence period was characterized by gradually declining flows, 1250 cfs on March 1 to 222 cfs by March 31. April, May, and June (and rest of summer months) had low flows between 148 to 624 cfs -- ideal for trout habitat, especially for the fry and juvenile stages (Figures 3, 4). Newly hatched fry cannot cope with high velocity flows (Barry Nehring informed me that the 1983 year-classes of brown and rainbow trout were essentailly lost due to the 1983 flood flows). Thus, the 1981 flow produced strong year-classes for both brown and rainbow trout.

Brown trout spawning during October, 1981, spawned at stable flows from 412 - 695 cfs. On November 3, flow suddenly dropped to 65 cfs (U.S.G.S. records are averaged for a 24-hour period and it is likely that no flow occurred at some time on November 3.). This rapid drop in flows would have stranded and dewatered the eggs in the nests. Although, as mentioned, eggs can withstand dewatering, cold temperatures likely froze the eggs causing high mortality. Flows from 104 to 130 cfs occurred on four other days in November, which probably sealed the fate of the 1982 brown trout year-class. From April 1-15, 1982, rainbow trout initiated spawning at flows between 588 and 714 cfs. Flows dropped to 187 cfs on April 20 and 197 cfs on April 27. Nehring and Anderson (1983) reported personal observation of nests stranded above the waterline and the demise of the 1982 year-class of both rainbow and brown trout.

Thus, it is possible to postulate an ideal flow regime for brown and rainbow trout natural reproduction in the Gunnison. The relationships between spawning, incubation, and hatching-emergence and flows demonstrate that after October (brown trout spawning), flows should not fluctuate drastically. A minimum instantaneous flow of 200 cfs should maintain a water surface level over virtually all spawning sites where spawning occurred at about 400 - 800 cfs flows. A low flow (ca. 200 cfs) is ideal for emergent fry with their inability to cope with high velocity flows.

The Gunnison drainage captured by the Curecanti impoundments is characterized by high variation in annual runoff. Despite the stabilizing effect of regulation, the annual flow regime expressed in total annual volume (acre feet), average monthly, and average daily flow, has exhibited considerable variation since regulation began in October, 1965. The empirical evidence demonstrate that most years of flow regulation have produced adequate to good spawning success for brown and rainbow trout, but rapid declines in flow during incubation or high flood flows during hatching and emergence can obliterate year-classes.

The year-round diversion of 1000 cfs through the diversion tunnel is predicted to have a beneficial impact on the brown and rainbow trout because it will maintain flows in the optimum range for trout habitat (200-600 cfs) for a greater part of the year and will not deplete flows below 200 cfs. The increased diversion would also reduce the rate or proportion of flow change. For example, a present change from 1500 cfs to 200 cfs during a brief period in the November - March period would be only a 500 to 200 cfs reduction with year-round diversion.

The benefits to trout spawning success by utilizing the Gunnison tunnel to divert water beyond the irrigation season was previously recognized by Wiltzius (1978) who suggested that water could be diverted through the tunnel during the normally high flow months from November through March to benefit brown trout spawning and diversion could be increased (above present diversion rate) from April through June to benefit rainbow trout spawning. Further optimization is possible if the timing of the annual "shutdown time" for canal maintenance is scheduled to a period recommended by the Division of Wildlife, and if the Bureau of Reclamation avoids rapid short-term fluctuations in release from Crystal Dam, with special attention given to stable flows during egg incubation-emergence periods.

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