FISHERIES FIELD TRIP 1983

We will observe examples illustrating quantification of trout habitat, the factors that determine habitat quality and habitat degradation. In Yellowstone Park, we will have opportunity to further observe the association of trout density with habitat parameters and learn about management techniques designed to preserve the world's largest concentration of native inland cutthroat trout.

To increase the depth of the learning experience and to have a basis for assigning grades, the following questions are to be answered and returned by Wednesday, June 15. The answers to the questions should be apparent from the trip experience. If not, ask questions.

1. How can habitat be quantified into a numerical index for comparison?

2. Why is it desirable to have a system or index of habitat quality for specific situations? Ex. construction of dam on a river, environmental impact assessment for livestock grazing, logging, mining, water depletion project, stream channelization, etc.

3. How can habitat be affected by: A. livestock grazing, B. change in flow regime, C. highway construction?

4. Do optimum habitat characteristics change during the life history of a fish--spawning habitat, juvenile habitat, adult habitat, overwintering habitat?

5. Why have the special regulations restricting angler catch worked so well on cutthroat trout in Yellowstone Park but have had little impact on the fisheries for non-native species of trout?

6. What is overexploitation?

United States Department of the Interior
NATIONAL PARK SERVICE
YELLOWSTONE NATIONAL PARK
WYOMING 82190

IN REPLY REFER TO:

YELL-362c
Rev. 6/82

April 12, 1983
Approximate arrival:
June 7, 1983

Dr. Bob Bahnke
Department of Fish, Wildlife & Biology
Colorado State University
Fort Collins, Colorado 80523

Dear Friend:

Thank you for your recent request concerning a planned group tour of Yellowstone National Park.

This letter should be presented to the park ranger at the entrance station when you arrive. Since your tour is being conducted for educational purposes and is sponsored by a bona fide school, college, or other educational institution, park regulations permit waiver of entrance fees. Your non-fee permit is printed below and should be carried in your vehicle.

We extend our best wishes to your group for a safe and pleasant trip.

Sincerely,

Thomas O. Hobbs

Thomas O. Hobbs
Chief Park Ranger

United States Department of the Interior
NATIONAL PARK SERVICE
Yellowstone National Park
NON-FEE PERMIT

Issued To: Dr. Bob Bahnke
Purpose: Educational
Route: General
Issuing Park Ranger:

PARK - ENTRANCE	DATE OF ISSUE	PERMIT NO.	NO FEE PAID	NUMBER OF DAYS
General	6/7/83			3

SURRENDER THIS PERMIT UPON LEAVING THE PARK

☆ U.S. GOVERNMENT PRINTING OFFICE 1976—678-018/553 REGION NO. 8

Special Rules and Regulations, in part from the Code of Federal Regulations, Title 36, Yellowstone National Park, Part 7, Section 7.13; and the Wyoming Statutes 1977, Title 31, Motor Vehicles, Section 31-5-1002.

(a) Weight and Size for Vehicles

(2) No vehicle and load shall have a gross weight in excess of 450 pounds per inch width of tire, or carry more than 18,000 pounds on any one axle, and no vehicle whatsoever having a total gross weight of vehicle and load or combination of vehicles and loads in excess of 76,800 pounds shall be operated or moved upon any park road.

(i) Provided, the Superintendent may prescribe reduced limits as to weight thereof, on designated highways as posted, whenever said highways may be damaged or destroyed by the above load limits because of deterioration, rain, snow, frost, and other climatic conditions.

(5) (i) Buses shall be no more than 102 inches (8½ feet) in width . . . 13 feet 6 inches in height . . . or 40 feet in length.

(b) Traffic Control

Speed limit: 45 miles per hour for passenger cars, buses and trucks of less than 17,000 pounds gross vehicular weight unless lesser limits are posted. 35 miles per hour for vehicles whose rated gross vehicle weight is in excess of 17,000 pounds.

United States Department of the Interior
NATIONAL PARK SERVICE
YELLOWSTONE NATIONAL PARK
WYOMING 82190

IN REPLY REFER TO:
Rev. 10/81

YELL-362b

Dr. Bob Bahnke
Department of Fish, Wildlife & Biology
Colorado State University
Fort Collins, Colorado 80523

April 12, 1983

Dear Friend:

We are pleased to learn of your plans to camp in Yellowstone National Park this season.

Reservations have been made for 12 persons at the Indian Pond Campground on the night(s) of June 7, 8, & 9. Please check at the Lake Ranger Station before going to the campground. The ranger there will assist your group in getting settled.

Indian Pond is located approximately three miles east of Fishing Bridge and has pit toilets and picnic tables. The only available water is from either Yellowstone Lake or Indian Pond. You should have containers for transporting drinking water or some means of purifying the water from the lakes.

The camping fee is $1.00 per person, per night. Payment should be made at the Lake Ranger Station upon arrival; preferably in cash or by Traveler's Checks payable in United States dollars. Certain educational, scientific, and therapeutic groups which qualify for exemption of the entrance fee will also be exempt from the camping fee.

Groups not utilizing their reserved campsite must cancel their reservation at least 24 hours in advance of scheduled use, in order that the space may be released to other groups. Groups will lose future reservation privileges should they fail to cancel reservations for campsites not used.

General rules and regulations governing campground use are listed on the reverse side of this letter. Noncompliance with park regulations may be cause to terminate the group's stay and possibly preclude their use of the campgrounds in the future.

We hope that you enjoy your visit. If we can be of further assistance please feel free to contact us.

Sincerely,

Thomas O. Hobbs

Thomas O. Hobbs
Chief Ranger

GENERAL RULES AND REGULATIONS GOVERNING CAMPGROUND USE

Camping and Sanitation

Groups shall keep their campsite clean. Burn all combustible rubbish in campfires. Dump all refuse in receptacles provided. Carry all waste water to the nearest restroom for disposal. The cleaning of fish or the washing of clothing at campground hydrants is prohibited.

Quiet is maintained between the hours of 10 p.m. and 6 a.m. The operation of motor-driver power generators or similar noise-producing motors or machinery is not permitted during quiet hours. Motor-driven power generators are permitted in Mammoth, Canyon, Fishing Bridge, Bridge Bay, Grant Village and Madison Campgrounds during daylight hours. Portable engines and motors are not permitted in any of the other campgrounds in Yellowstone National Park.

Groups shall not leave their camp unattended for more than 24 hours without special permission of a park ranger.

Food Storage Suggestions for Campers

Any food or food container that emits an odor, or is left on tables or in open boxes, or any garbage, is a definite invitation to bear damage. Generally, campers who keep a clean camp are bothered less by bears.

1. Food should not be stored on tables or in tents.
2. Seal surplus food in clean wrapping material or in airtight containers. Ice chests or portable coolers must be kept in the trunk of your vehicle or within solid-walled recreation vehicles.
3. Keep your food as cool as possible.
4. Your car trunk is one of the best food storage places.
5. Report all bear damage and injuries to a park ranger.

Pets

All pets must be on a leash, crated, or otherwise under physical restrictive control at all times. Pets are prohibited on boardwalks, nature trails, and backcountry trails.

Fires

Build fires only in the regular fireplaces. Fires shall be completely extinguished when the campsite is left unattended. Fire permits are required for fires in backcountry and wilderness locations.

The use or possession of fireworks and firecrackers is prohibited.

Lost Articles

Persons finding lost articles should deposit them at the nearest ranger station leaving their own names and addresses.

STREAM IMPROVEMENT IN WYOMING[1/]

By N. Allen Binns, Supv. Aquatic Habitat Crew, Wyoming Game and Fish Department

While stream improvement efforts in Wyoming date back many years, much work has been done in the last decade (Appendix I). Game and Fish, Forest Service and BLM personnel have actively sought to improve fishery habitat in recent years with a series of projects.

What is stream improvement? Basically, it is an attempt to improve a fishery by manipulating fluvial habitat. Stream improvement attempts to correct habitat deficiencies by installing various devices or by altering existing habitat conditions. When habitat is the factor that is limiting trout production, correction of habitat shortcomings can do much to help a trout population. Two common habitat deficiencies encountered in Wyoming are stream bank erosion and lack of shelter for trout.

Eroding stream banks are a common problem in many Wyoming streams. Silt from such erosion smothers fish food organisms and fish eggs, and also fills pools needed for shelter and plugs riffle interstices. Eroding stream banks can be stabilized by rock riprap or by tree retards (bushy trees cabled into the bank and backed with rock). Tree retards provide overhead cover for trout

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1/ A poster display prepared for the Colo-Wyo. Chapter AFS meeting at Ft. Collins, Colorado, March 3-4, 1982.

and also help build the bank back by trapping silt and debris. Stream bank damage by livestock can sometimes be remedied by controlling livestock access to stream edges. Fences work best, but are expensive and require periodic maintenance plus removal of trespass animals. Cattle access can sometimes be controlled by tree blocks (bushy, strong limbed conifers anchored along bank tops).

Some streams lack deep pools where trout can live, feed and hide from enemies. Deep water shelter is essential during low flow periods. A solution to this common problem is to install devices that force the stream to scour pools. Carefully installed log or rock plunges direct and concentrate water flow so that extra energy is available to scour pools below the structures.

In some Wyoming streams, swift currents make life difficult for trout. This problem is especially bad in large rivers with monotonous stream beds where there is little shelter from the current. Other waters suffer from boom/bust cycles where fish must alternately cope with floods and low flows. Lack of shelter is the basic problem in such streams and can be corrected by installing boulder clusters. Boulder placements create pocket pools around the rocks where trout can seek refuge from swift currents. Boulders placed in the Clarks Fork River sharply decreased current speed. At low discharge, water velocity behind the boulders ranged from 0.4 to 1.3 fps, as opposed to 2.8 to 4.0 fps in nearby unobstructed areas. Scuba and fisherman results around rock clusters placed in the Green River have verified that trout use the pocket pools created by boulder clusters.

Does stream improvement work? Present evidence is affirmative, provided the work is done properly. Installation of man-made devices in Lawrence Creek, Wisconsin, significantly increased the standing crop of brook trout (Hunt 1971). Seven years after stream improvement devices were placed in Beaver Creek, Wyoming, the brook trout population increased from 12 lb/ac to 272 lbs/ac (Binns 1981). In addition, the once sporadic, put-and-take fishery changed to a self-supported, wild trout fishery. In the Keogh River, British Columbia, boulder groupings were effective in increasing salmonied density and standing crop (Ward and Slaney 1979). They recommended triangular groupings of three to five boulders, using rocks no smaller than two feet in diameter. In the 1930's, the Civilian Conservation Corp installed many devices in Wyoming streams. The fact that some of these structures are still functional demonstrates the durability that can be expected from high quality stream improvement projects.

To be cost effective, stream improvement devices must function for many years. This means that durable materials must be used to build the devices. It also means that the right structure must be properly installed in the right location. Corner cutting with inferior materials or sloppy installation or poorly chosen locations usually translates into shortened structure life. Periodic maintenance of structures is also important in extending structure life.

Literature Cited

Binns, N.A. 1981. Beaver Creek revisited. Wyoming Wildlife. Vol. XLV, No. 5, May. pp. 22-23.

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

Ward, B.R. and P.A. Slaney. 1979. Evaluation of instream enhancement structures for the production of juvenile steelhead trout and coho salmon in the Keogh River: progress 1977 and 1978. Province of British Columbia, Ministry of Environment, Fisheries Tech. Circular No. 45. 47 pp.

APPENDIX I. Stream improvement projects in Wyoming.

Some Stream Improvement Work in Wyoming

Abbreviations: WGF - Wyoming Game & Fish Dept.; USFS - U.S. Forest Service; SCS - Soil Conservation Service; BLM - Bureau of Land Management; PFA - Public Fishing Area; CCC - Civilian Conservation Corps

Stream	Location	Work Done
Little Popo Agie River, Fremont County	WGF PFA, upstream from Hwy. 28 near Lander; Work accessible from both. Parking areas.	Bank stabilization with tree retards rock riprap; instream boulder placement to create trout holding area; riparian area fences (lower and PFA only) to protect banks from cattle. Installed 1975-79.
North Fork Popo Agie River, Fremont County	WGF PFA near Lander.	Bank stabilization with trees and cork. Installed 1977-80.
Beaver Creek, Crook County	North of Sundance on road from Cook Lake to upper Beaver Creek; structures located downstream from Togus Creek.	(1) Near Togus Creek inflow--USFS bank stabilization work with rock, stock fence and steel posts, installed about 1970. Non-recommended structure. Poor results from structures. Heavy flood damage and damage from rock fill collapsing fence and posts. (2) Between bridge and first cattleguard below Togus Creek, WGF installed various experimental structures 1973-77. Good results from structures. Structures allowed the establishment of a naturally maintained brook trout fishery.
Little Big Horn River, Sheridan County	Along forest road downstream from Half Ounce Creek confluence.	USFS overpour structures - some problems due to inadequate rock riprap at bank end of structures. Installed 1980.

Stream	Location	Work Done
Clarks Fork Yellowstone Park County	At WGF PFA upstream from bridge on Hwy. 120 north of Cody.	WGF boulder placements installed in spring 1981. Rocks survived 200 year flood in June 1981.
Snake River, Teton County	Upstream and downstream from Wildon Bridge west of Jackson.	Federal levees to confine flood flows. The river has been forced to meander between the levees. This has caused severe damage (erosion) to islands, and associated fish and wildlife habitat.
Salt River, Lincoln County	(1) Downstream from Hwy. 89 bridge south of Thayne.	(1) WGF - SCS bank stabilization project for entire lower river between Thayne and Etna. Most of the work is on private land, but some tree revetments can be seen below the bridge. Work started in 1970's.
	(2) WGF PFA near Afton (Burton Easement)	(2) WGF bank stabilization with rock riprap, plus fencing to control cattle trampling. Installed early 1970's.
Willow Creek, Lincoln County	At WGF PFA (Turn east from Hwy. 89 about 1/2 mile south of Silver Stream Motel complex south of Thayne.)	Digger logs (from old telephone poles) installed by WGF about 1969. Stream has cut around or under most structures. Non-recommended structures.
Salt Creek, Lincoln County	Downstream from USFS Allred Flat Campground south of Smoot.	WGF-USFS Coop project. Bank stabilization with tree retards and rock, plus instream structures at upper end. Installed 1981.

Stream	Location	Work Done
Huff Creek, Lincoln County	(R. 119 W., T. 28 N., Sec. 27) Tributary to Thomas Fork River. Access by fair to poor dirt road east from Hwy. 89.	WGF-BLM Coop project in 1981-82: instream structures and bank stabilization with rock riprap inside large exclosure. BLM experimental exclosures installed 1976 (small one near mouth of creek) and 1979 (Large one 1.25 mile long, upper valley) to control cattle use of riparian area.
Green River, Sweetwater County	Between Fontenelle Dam and the confluence of Big Sandy River. Easiest access to rock work is immediately above the old CCC bridge at Fontennelle and below the Weeping Rocks Campground near the dam.	WGF boulder placement project started in 1981. The granite boulders were hauled from South Pass.
Fool Creek, Sheridan Wyoming	Along forest road north from Burgess Junction.	USFS instream structures (mostly overpours and deflectors)--some problems due to inadequate rock riprap on bank and of structures. Installed in late 1970's.
Sand Creek, Crook County	State land downstream from county club land.	CCC drop structures installed about 1935. Devices have become calcified and appear as rock ledges.
Tosi Creek, Sublette County	USFS land upstream from Snook Moore Ranch to the cascades.	CCC log crib structures; several still functional. WGF-USFS coop project installed wedge dams and log plunges in 1981.
Big Sandy River, Sublette County	USFS land at Big Sandy Opening near the campground.	CCC log crib structures; several still functional.

06233000 LITTLE POPO AGIE RIVER NEAR LANDER, WYO.

LOCATION.--Lat 42°43'00", long 108°38'34", in NE¼SE¼ sec.27, T.32 N., R.99 W., Fremont County, on left bank 700 ft downstream from bridge on State Highway 28, 2.5 miles downstream from Red Canyon Creek, and 9.5 miles southeast of post office in Lander.

DRAINAGE AREA.--125 sq mi.

PERIOD OF RECORD.--March 1946 to current year.

GAGE.--Water-stage recorder. Datum of gage is 5,436.49 ft above mean sea level.

AVERAGE DISCHARGE.--25 years, 80.3 cfs (58,180 acre-ft per year).

EXTREMES.--Current year: Maximum discharge, 960 cfs June 18 (gage height, 5.33 ft); minimum daily, 17 cfs Jan. 5.
Period of record: Maximum discharge, 2,010 cfs June 16, 1963 (gage height, 6.64 ft); minimum daily, 12 cfs Jan. 20, 21, Feb. 26 to Mar. 2, 1960, Jan. 10, 11, 18, 19, 1963.

REMARKS.--Records good except those for winter period, which are poor. Diversions for irrigation of about 540 acres above station. Slight regulation by Christina Lake (capacity, about 3,860 acre-ft).

REVISIONS.--WSP 1709: Drainage area.

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1970 TO SEPTEMBER 1971

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	25	29	29	24	28	20	29	60	529	296	102	47
2	25	30	30	23	21	22	30	73	494	299	99	45
3	25	25	29	21	21	23	27	99	470	299	97	48
4	25	25	28	19	20	22	26	118	431	296	97	56
5	25	27	28	17	19	21	25	145	442	278	99	56
6	27	27	27	18	18	19	26	120	452	255	90	47
7	34	28	27	20	19	18	28	113	459	250	85	48
8	30	29	27	22	20	19	30	115	498	250	82	76
9	34	29	27	24	20	20	32	127	574	248	82	59
10	37	30	27	27	21	21	38	137	634	228	79	60
11	31	28	27	27	21	22	45	137	662	208	76	64
12	38	32	28	26	20	23	39	163	682	197	75	60
13	37	32	27	26	21	25	35	202	678	186	71	59
14	34	29	26	24	22	23	38	253	646	178	66	57
15	27	31	27	24	22	22	51	275	658	163	64	57
16	32	32	28	26	21	22	55	317	738	155	62	59
17	30	31	27	28	22	21	53	288	795	149	61	63
18	28	32	25	28	22	20	54	245	850	155	60	64
19	31	31	23	29	22	21	48	215	760	302	59	63
20	30	31	22	29	21	22	47	202	670	238	56	65
21	30	30	21	28	20	22	47	197	678	200	53	64
22	29	28	22	26	19	23	52	213	694	202	51	62
23	27	27	23	24	20	24	53	202	738	200	51	63
24	31	30	22	23	22	27	56	193	722	184	50	63
25	22	32	23	23	23	25	66	215	670	163	50	60
26	23	31	24	24	22	25	59	258	642	147	48	58
27	26	31	24	25	21	30	60	317	618	137	50	57
28	28	30	24	26	21	28	57	374	452	126	48	56
29	31	30	25	26	------	26	56	547	380	122	53	55
30	31	31	25	27	------	29	57	674	326	117	55	56
31	30	------	25	28	------	29	------	594	------	109	48	------
TOTAL	913	888	797	762	589	714	1,319	7,188	18,042	6,337	2,119	1,747
MEAN	29.5	29.6	25.7	24.6	21.0	23.0	44.0	232	601	204	68.4	58.2
MAX	38	32	30	29	28	30	66	674	850	302	102	76
MIN	22	25	21	17	18	18	25	60	326	109	48	45
AC-FT	1,810	1,760	1,580	1,510	1,170	1,420	2,620	14,260	35,790	12,570	4,200	3,470

CAL YR 1970 TOTAL 26,159 MEAN 71.7 MAX 395 MIN 18 AC-FT 51,890
WTR YR 1971 TOTAL 41,415 MEAN 113 MAX 850 MIN 17 AC-FT 82,150

PEAK DISCHARGE (BASE, 350 CFS)

DATE	TIME	G.HT.	DISCHARGE	DATE	TIME	G.HT.	DISCHARGE
5-30	1100	4.89	742	7-19	0530	3.87	380
6-18	0500	5.33	960				

06233000 LITTLE POPO AGIE RIVER NEAR LANDER, WY

LOCATION.--Lat 42°43'00", long 108°38'34", in NE¼SE¼ sec.27, T.32 N., R.99 W., Fremont County, Hydrologic Unit 10080003, on left bank 700 ft (213 m) downstream from bridge on State Highway 28, 2.5 mi (4.0 km) downstream from Red Canyon Creek, and 9.5 mi (15.3 km) southeast of post office in Lander.

DRAINAGE AREA.--125 mi^2 (324 km^2).

PERIOD OF RECORD.--March 1946 to current year (no winter records since 1971).

REVISED RECORDS.--WSP 1709: Drainage area.

GAGE.--Water-stage recorder. Datum of gage is 5,436.49 ft (1,657.042 m), National Geodetic Vertical Datum of 1929.

REMARKS.--Records good. Diversions for irrigation of about 540 acres (2.19 km^2) above station. Slight regulation by Christina Lake, capacity, about 3,860 acre-ft (4.76 hm^3).

COOPERATION.--Records collected and computed by Office of the Wyoming State Engineer and reviewed by Geological Survey.

AVERAGE DISCHARGE.--25 years (water years 1947-71), 80.3 ft^3/s (2.274 m^3/s), 58,180 acre-ft/yr (71.7 hm^3/yr).

EXTREMES FOR PERIOD OF RECORD.--Maximum discharge, 2,010 ft^3/s (56.9 m^3/s) June 16, 1963, gage height, 6.64 ft (2.024 m); minimum daily, 12 ft^3/s (0.34 m^3/s) Jan. 20, 21, Feb. 26 to Mar. 2, 1960, Jan. 10, 11, 18, 19, 1963.

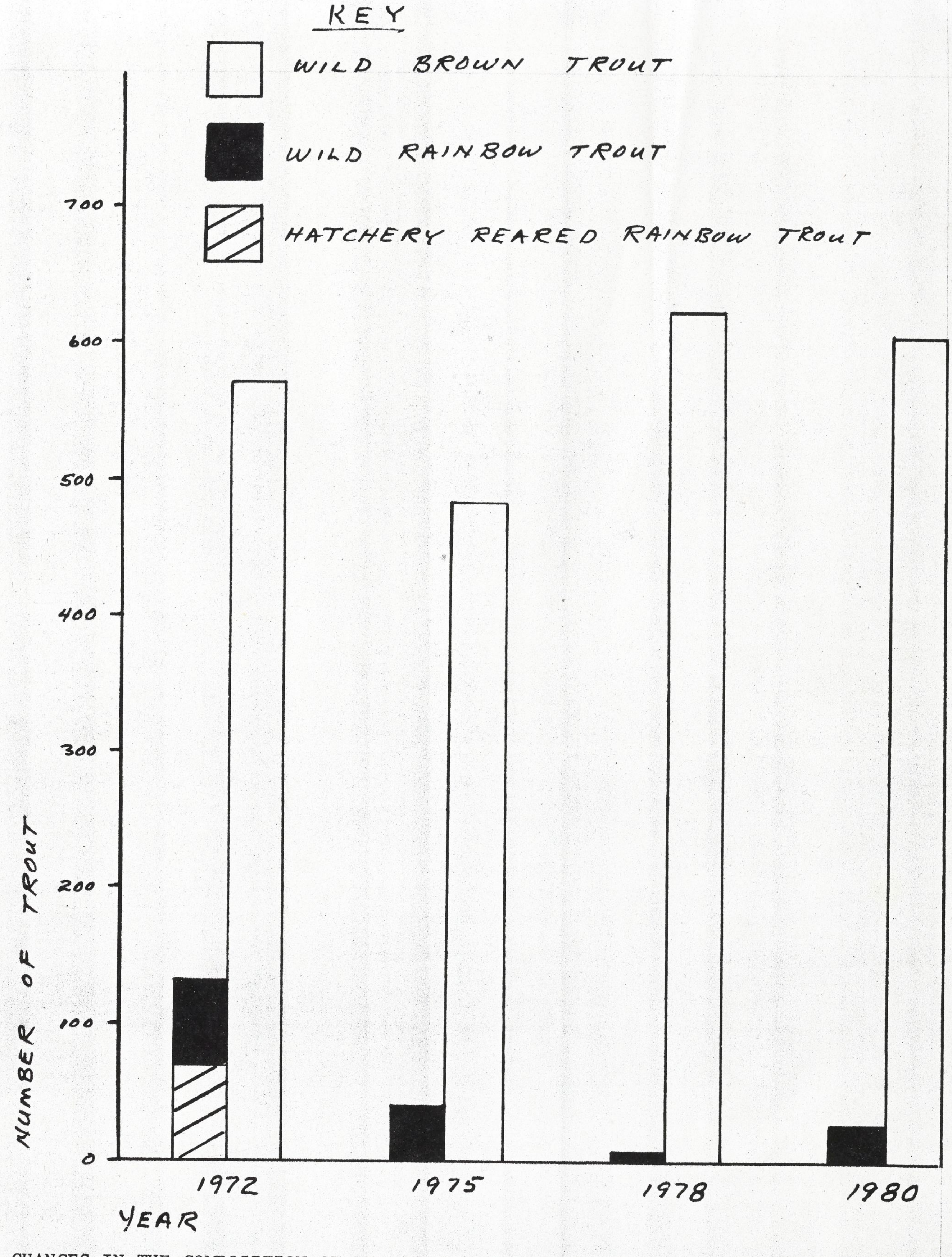
EXTREMES FOR CURRENT YEAR.--Peak discharges above base of 350 ft^3/s (9.91 m^3/s) and maximum (*):

Date	Time	Discharge (ft^3/s)	Discharge (m^3/s)	Gage height (ft)	Gage height (m)	Date	Time	Discharge (ft^3/s)	Discharge (m^3/s)	Gage height (ft)	Gage height (m)
May 29	0730	*660	18.7	4.83	1.472	June 14	0830	379	10.7	4.09	1.247
June 7	0230	394	11.2	4.13	1.259						

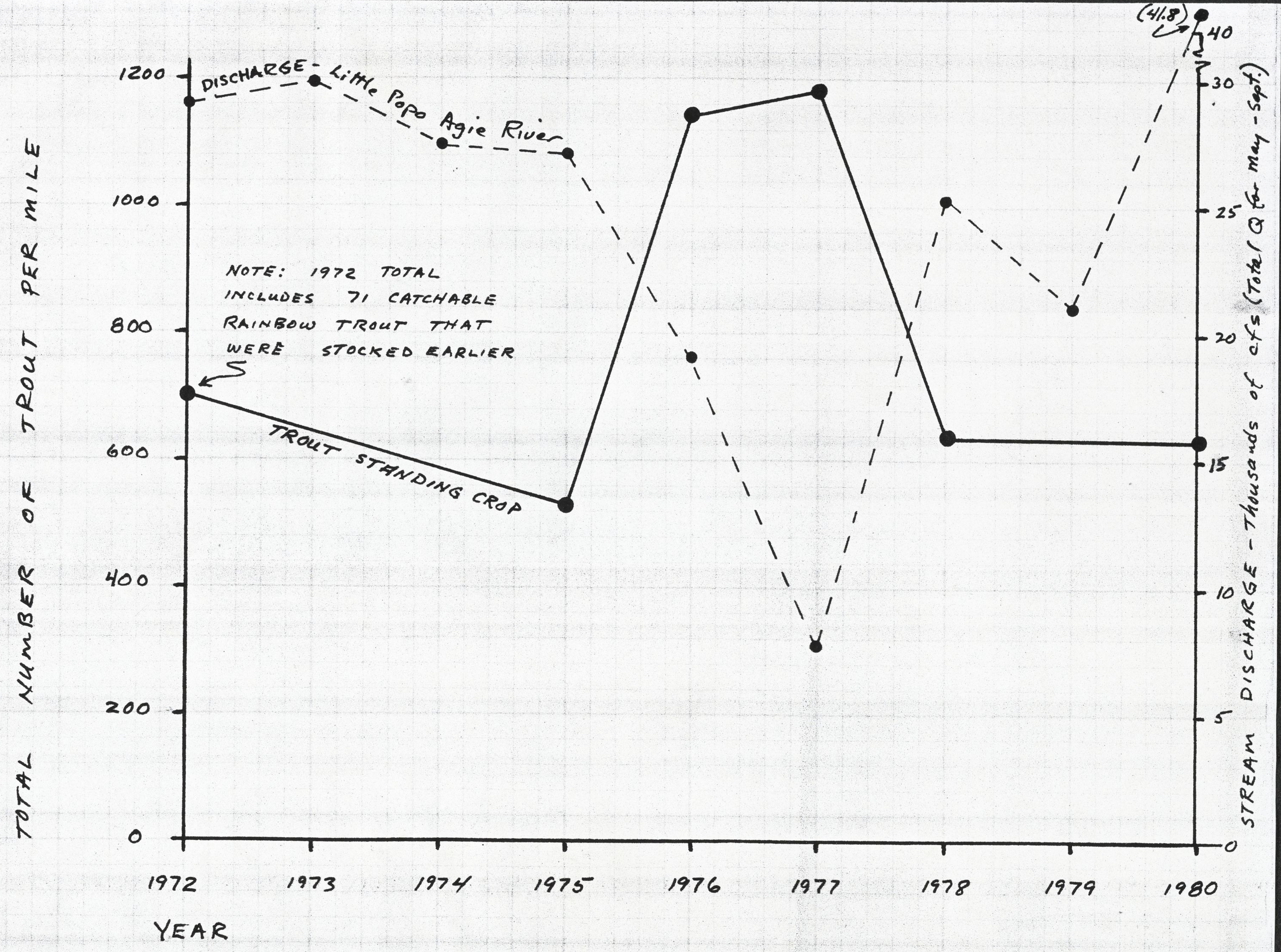
Minimum daily discharge during period of operation, 21 ft^3/s (0.60 m^3/s) Apr. 2-5.

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1978 TO SEPTEMBER 1979
MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1							22	88	277	170	54	50
2							21	120	250	158	50	46
3							21	112	259	150	46	45
4							21	106	295	140	45	43
5							21	140	337	132	43	43
6							24	145	373	128	41	43
7							32	115	352	138	39	41
8							29	115	289	120	41	41
9							34	108	250	112	45	39
10							43	106	235	108	52	43
11							32	97	235	99	46	43
12							32	97	256	92	43	45
13							30	106	310	90	54	45
14							30	122	349	88	78	46
15							34	118	331	84	84	46
16							43	150	280	84	72	48
17							59	182	262	82	76	45
18							70	202	247	82	97	46
19							64	228	225	82	82	45
20							57	253	202	84	135	45
21							55	274	190	82	145	45
22							68	313	190	80	110	45
23							78	358	190	84	92	45
24							78	367	188	92	86	43
25							64	412	185	82	76	43
26							66	421	182	76	72	41
27							70	460	180	72	68	43
28							78	510	178	70	64	43
29							72	609	172	66	59	41
30							76	424	170	63	54	39
31							---	328	---	57	52	---
TOTAL							1424	7186	7439	3047	2101	1316
MEAN							47.5	232	248	98.3	67.8	43.9
MAX							78	609	373	170	145	50
MIN							21	88	170	57	39	39
AC-FT							2820	14250	14760	6040	4170	2610



CHANGES IN THE COMPOSITION OF THE TROUT FISHERY AT THE LITTLE POPO AGIE RIVER PUBLIC FISHING AREA FROM 1972 TO 1980. ABOUT 1,000 CATCHABLE RAINBOW TROUT WERE STOCKED ANNUALLY PRIOR TO 1974. NO HATCHERY REARED TROUT WERE STOCKED AFTER 1974 AND THE TROUT FISHERY HAS BEEN SUPPORTED ENTIRELY BY WILD BROWN AND RAINBOW TROUT SINCE THAT TIME. THE RAINBOW TROUT POPULATION HAS BECOME SMALLER, WITH FEWER LARGE FISH. THE BROWN TROUT POPULATION HAS INCREASED ABOUT 50 FISH/MILE, POSSIBLY IN RESPONSE TO THE HABITAT IMPROVEMENT PROJECT, AND THE CESSATION OF STOCKING.



TROUT STANDING CROP AND STREAM DISCHARGE AT THE WILKES PUBLIC FISHING AREA ON THE LITTLE POPO AGIE RIVER FROM 1972 to 1980. ABOUT 1,000 CATCHABLE SIZE, HATCHERY REARED RAINBOW TROUT WERE STOCKED IN THE 1.45 MILE AREA IN 1972, AND ANNUALLY PRIOR TO THAT TIME. NO HATCHERY REARED TROUT WERE STOCKED AFTER 1973. HABITAT IMPROVEMENT STRUCTURES WERE INSTALLED IN THE PFA BETWEEN 1975 AND 1980.

①

Little Popo Agie R. 8/5/75
upper end public fishing area.
rated by Binns & Pistono

Point	Width		Thalweg
1	0	37 ft (bottom of sta.)	22 ft (from top down)
2	30'	40	75'
3	60'	27	22'
4	90'	27	31'
5	120'	34	79'
6	150'	35	38'
7	180'	31	31'
8	210'	26	55'
9	240'	35	
10	270'	35	
11	300'	34	
12	330'	26	
13	360'	27 (top of sta.	

$\Sigma = 353 ft$

$\bar{X} = 31.8 ft$

Time of Travel

~~[illegible]~~

1.8 min. = 108 sec.

353 ft / 108 sec = 3.27 fps

Area of sample station

31.8 ft × 360' = 11,448 ft²

②

Little Popo Agie R. at upper end of Public fishing area 8/5/75
rated By: Binns & Pistono

COVER

footage	Area	Type
22'×30'	660 ft²	Ⓐ pool-run by old diversion pipe
14'×30'	420 ft²	Ⓑ pool by brush (overhanging)
4'×10'	40 ft²	Ⓒ brush pile west bank
30'×5'	150 ft²	Ⓓ rocky bank
10'×5'	50 ft²	Ⓔ tree roots along bank
9'×2'	18 ft²	Ⓕ snag
10'×2'	20 ft²	Ⓖ brush pile east bank
20'×30'	600 ft²	Ⓗ pool
20'×30'	600 ft²	Ⓘ shallow pool & run
20'×60'	1200 ft²	Ⓙ rocky run
25'×60'	1500 ft²	Ⓚ rocky run

$\Sigma = 5,258 ft^2$

5258 ft² / 11,448 ft² = 46% cover

③

Little Popo Agie R. at upper end of public fishing area 8/5/75

Eroding stream banks (Unstable banks)

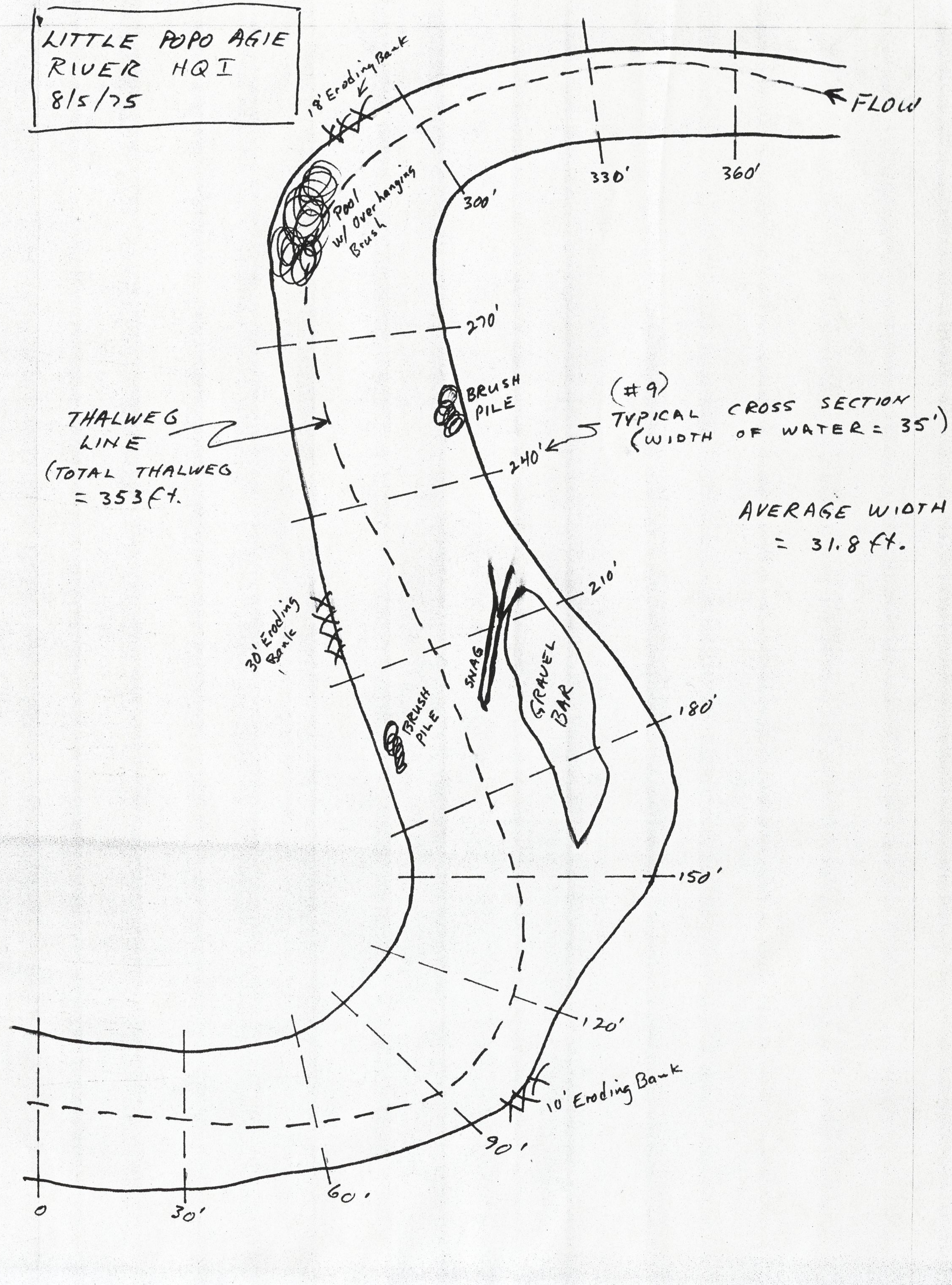
18 ft
30
10
Σ = 58 ft

58'/360' = 16%

water temp. at 3pm 62°F; water clear
bottom fauna - 6 ft² samples taken from riffle in middle of sta. scattered Cladophora on rocks; otherwise riffle clean

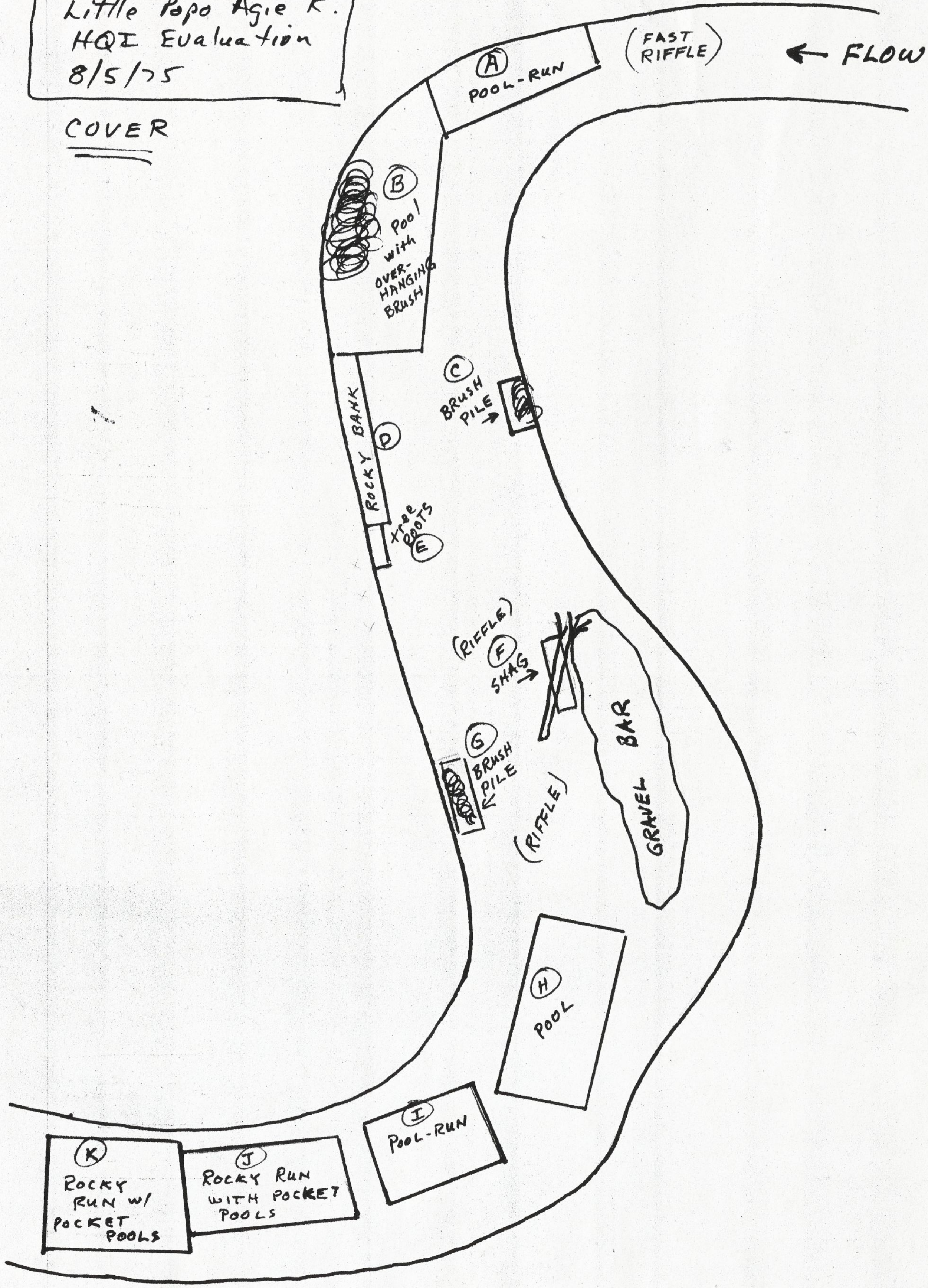
CPSF	4	74%
ASFV	2	
Temp	3	(68°F) (U.SGS records)
nitrate N	1	(0.012 mg/l)
food abundance	2	(131 org./ft²)
food diversity	2	(1.68)
cover	3	(46%)
eroding banks	3	(16%)
substrate	2	
velocity	2	(3.27 fps)
width	3	(31.8 ft)

LITTLE POPO AGIE
RIVER HQI
8/5/75



Little Popo Agie R.
HQI Evaluation
8/5/75

COVER



Flow: 78 cfs at gage

(S. 4, R. 99 W., T. 31 N.)

HABITAT QUALITY INDEX ATTRIBUTE RATING SUMMARY SHEET

STREAM: Little Popo Agie River LOCATION: Upper End of Public Fishing Area

DATE DATA COLLECTED: 5 August 1975 HQI SCORE = 60 lbs/acre

TROUT STANDING CROP: 38 lbs/ac 1975 lbs/acre = 65 trout habitat units
(if available) 55 lbs/ac 1976

ATTRIBUTE (Symbol)	(Name)	DATA	RATING
(X_1)	Late Summer Stream Flow (Critical Period Stream Flow - CPSF)	Aug. Daily Flow = 80.3 cfs Aug. CPSF = 55.4 cfs (8 yrs. of record) .55.4/80.3 = 69%	4
(X_2)	Annual Stream Flow Variation		2
(X_3)	Maximum Summer Stream Temperature	68 °F ____ °C	3
(X_4)	Nitrate Nitrogen	0.012 mg/l	1
(X_5)	Fish Food Abundance	131 organisms/square foot	2
(X_6)	Fish Food Diversity	D_s = 1.68	2
(X_7)	Cover	46 % of total area	3
(X_8)	Eroding Stream Banks (Bank Stability)	16 %	3
(X_9)	Substrate		2
(X_{10})	Water Velocity	Time of Travel Velocity = 3.27 ft/sec. = ____ cm/sec.	2
(X_{11})	.Stream Width	31.8 feet (avg.)	3

$F = X_3(X_4)(X_9)(X_{10})$ = (3)(1)(2)(2) = 12

F+1 = 13

$S = X_7(X_8)(X_{11})$ = (3)(3)(3) = 27

S+1 = 28

(put HQI calculations on back of sheet)

8/5/85

STREAM Little Popo Agie River at PFA

$X_1 + 1$	=	5
$X_2 + 1$	=	3
$X_3 + 1$	=	4
$F + 1$	=	13
$S + 1$	=	28

HQI SCORE

60.38 lbs/acre

65.21 trout Habitat Units (English) (60.38 X 1.08)

67.68 kg/hectare

73.09 trout Habitat Units (metric) (67.68 X 1.08)

Trout Riverine Field Sampling Procedures

1. Select a representative reach sampling site.
   A. The reach length should be 10 to 14 times the average stream width, but at least 100m in length. This length will usually include a fairly complete mix of stream features, e.g., pools, riffles, runs and meander bends.

2. Sample measurements
   A. Variables that are measured once at each end of the total river area being studied.

Variable	Measurement Description
V_1 Average maximum daily water temperature	Measure during the warmest period of the day (2-4 p.m.), and year (late summer low flow period). Three or more measurements are preferred in order to obtain an average value.
V_2 Average maximum daily water temperature (embryo development)	Measure during the warmest period of the day (2-4 p.m.) during the mid to late embryo development period. Three or more measurements are preferred in order to obtain an average value.
V_3 Average minimum daily dissolved oxygen	Measure (preferably in early morning before full daylight) during mid to late embryo development and the late summer flow period. One measurement at each designated time period will usually suffice unless local conditions indicate that dissolved oxygen content may vary widely from day to day.
V_{13} Annual maximum or minimum pH	Measure twice daily in early morning and late evening during average summer flow conditions. If a pH problem exists measure again during the late summer low flow period.

   B. Variables that are measured at each potential spawning site preferably during average flow conditions during the embryo development period.
   A potential spawning site is an area $\geq 0.5m^2$ in size where the dominate substrate is comprised of gravels ranging from 0.3 to 8.0 cm in diameter and the water is $\geq$ 15 cm deep. Measure each potential spawning site within the representative reach and record the m^2 of area for each site. If the sum of the potential spawning site areas is <5% of the total representative reach area, then continue sampling potential spawning sites outside of the representative reach section boundaries until an area equal to 5% of the total habitat area has been sampled, or until all potential spawning sites have been sampled, whichever comes first.

Variable	Measurement Description
V_5 Average velocities over spawning areas	Measure the average water column velocity at 0.6 tenths of the depth above the bottom over each area of spawning gravel. For large spawning areas, measure the velocity at three points 1/4th, 1/2, and 3/4ths of the distance across each area of spawning gravel.
V_7 Average size of spawning gravel	Visually estimate the average size of gravel 0.3-8.0cm in longest axis at each potential spawning site.
(See V_{16} below)	Measure or estimate the % imbeddedness and the % fines mixed with the spawning gravel at each potential spawning site.

C. Variables that are measured at each transect during average summer flow periods unless some other time period is specified.

Variable	Measurement Description
V_4 Average thalweg depth	Measure the deepest point along each transect.
V_6 Percent cover	Measure the linear distance bisected by the transect line of each area of potential cover. Cover is defined as an area where the stream bottom is visually obscure due to overhanging banks or vegetation, water depth, surface turbulence, or instream objects such as logs, debris piles, or large rocks, in water $\geq$15cm deep and at minimal water column velocities of $\leq$15cm/sec.
V_8 Percent substrate size class used for escape and winter cover by fry and small juveniles.	Measure the linear distance bisected by the transect line for all substrate between 10 and 40cm in largest diameter. Estimate the % imbeddedness and % fines mixed with this substrate class. (See V_{16} below).
V_9 Dominate substrate type for insect production	Measure or estimate the amount of substrate $\geq$ 3cm in size (longest axis along each transect in riffle-run areas and assign it to one of the following three classes: A. The dominate substrate class is rubble or small boulders, (or aquatic vegetation in spring areas) with limited amounts of gravel or large boulders present.

Variable	Measurement Description
	B. Rubble, gravel and boulders occur in about equal amounts. C. Fines, bedrock or large boulders are dominant. Rubble or gravel are $\leq$ 10%. Measure or estimate the % imbeddedness and % fines at each transect. (See V_{16} below)
V_{10} Percent pools	Measure the linear distance of each pool bisected by the transect line.
V_{11} Average percent vegetation along the streambank for allochthanous inputs	Estimate the percentage of each of four classes of streambank cover. 1. (% shrubs), 2. (% grasses and and forbes), 3. (% trees), and 4. (% bare ground). Estimate over an area 10m wide and 30m deep at each end of each transect. Visualize the area as if you were looking straight down on it from above. There will often be overlap, hence % shrubs + % grasses and forbes + % trees + % bare ground can be $\geq$ 100%.
V_{12} Average percent rooted vegetational ground cover along the stream banks for erosion control (optional)	Measure or estimate the average percent of the streambank area covered by rooted vegetation as viewed from above. Consider a strip of riparian area 10m wide and 30m deep along each end of the transects. (% covered + % bare = 100%)
V_{14} Average annual base flow regime	Measure, estimate, or obtain figures from waterflow records on the average annual daily flow and average 30 day low flow for the stream section being evaluated.
V_{15} Pool class rating	Determine the pool class rating for each pool bisected by the transect line. Classify into three classes: A. first class, B. second class, and C. third class as described on pages 24 and 25 of the species summary. Measure or estimate the area in m^2 of each pool classified.
V_{16} Percent fines	Measure or estimate the percent fines (particles < 0.3cm in size) and % imbeddedness at, 1) each potential spawning site, 2) each area of escape or winter cover substrate class, and 3) each riffle-run transect area. $\% \text{ fines} = \left(\frac{\text{area of fines}}{\text{total area of interest}} \times 100\right)$

% imbeddedness = the average % depth that substrate particles of interest are buried in fines.

V_{17} Percent of stream area shaded. (optional)

At each transect measure or estimate the percentage of the stream shaded from the sun between 10 a.m. and 4 p.m. during the summer growing season.

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Please note typo corrections

Transactions of the American Fisheries Society 108:215–228, 1979

Quantification of Fluvial Trout Habitat in Wyoming

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Abstract

A Habitat Quality Index (HQI) was developed to predict trout standing crop in Wyoming streams. Measurements of trout habitat were collected from 36 streams that ranged in elevation from 1,146 to 3,042 m. Average late summer stream width varied from 1.4 to 44 m, while average daily flow was between 0.6 and 1.46 m^3/second. Stream gradient ranged from 0.1% to 10%. A multiple regression analysis indicated those habitat measurements best related to trout standing crop in the study streams. Predictive models were built from these measurements. The best HQI model explained 96% of the variation in trout standing crop (multiple regression correlation coefficient $R = 0.983$), suggesting a close relationship between HQI predictions and measured trout stocks. The nine habitat attributes used in this model were late summer stream flows, annual stream flow variation, water velocity, trout cover, stream width, eroding stream banks, stream substrate, nitrate nitrogen concentration, and maximum summer stream temperature.

Fishery managers have long grappled with the problem of placing a value on fishery resources, especially in conjunction with cost-benefit analysis for proposed water development projects. Most of these efforts have attempted to assign a monetary value to the fishery resource, but the results of such endeavors have not always been realistic or successful. However, in recent years, the federal Congress has drastically changed the planning of water resource projects in the United States.

In response to the Water Resources Planning Act (Public Law 89-80), the Water Resources Council (1973) established principles and standards for planning water and related land resource projects. These rules required both economic and environmental evaluations before a water development project could be approved. Thus, for the first time, nonmonetary evaluations of fishery resources became an accepted procedure. This new approach contrasted with past practices where project feasibility was often decided solely by monetary considerations.

Procedures for nonmonetary measurement of aquatic habitats were primitive when the new rules were issued and a methodology gap soon became evident. Early attempts to develop a suitable methodology (Anonymous 1974) were too subjective and not realistic when applied to trout streams in the Rocky Mountain area.

Accordingly, a project was initiated by the Wyoming Game and Fish Department to develop, and field-test, a standard method to quantify habitat for trout streams in Wyoming. Initial results of this investigation were encouraging and a preliminary Habitat Quality Index (HQI) was developed (Binns 1978a, 1978b). Since the initial report on the HQI, additional streams have been measured and the method has been improved. In the present paper, we report on the improved HQI methodology, which was developed from habitat evaluations made at 36 study sites in Wyoming.

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TABLE 1.—*Pertinent characteristics of the Habitat Quality Index (HQI) study sites.*

HQI study site	Length of site (m)	Elevation (m)[a]	Gradient %	Average width (m)[b]	ADF (m^3/second)[c]	Trout species present[d]
1. Sand Creek	101	1,146	0.8	6.2	0.8	Bn, Rb
2. Duck Creek, upper	61	2,201	0.2	4.0		Bn, Rb
3. North French Creek, upper	85	2,954	0.9	3.6		Bk
4. Duck Creek, lower	91	2,188	0.2	4.0		Bn, Rb
5. North French Creek, lower	30	2,926	4.7	4.0		Bk
6. Hog Park Creek	189	2,533	0.6	6.1	0.8	Bn, Bk, Rb
7. Nash Fork Creek	34	3,042	4.6	4.6		Bk
8. Green River, Pape Ranch	91	2,225	0.3	21.6	14.6	Bn, Rb
9. North Brush Creek	30	2,448	2.9	10.2	1.5	Bk, Bn, Rb
10. Douglas Creek	207	2,835	0.6	7.2	0.9	Bn, Rb
11. East Fork Wind River	61	2,301	4.8	7.0		Ct
12. Green River, Blackmon Ranch	213	2,245	0.3	28.6	14.6	Bn, Rb
13. New Fork River	244	2,130	0.1	23.2	11.0	Bn, Rb
14. Little Popo Agie River (1975)	110	1,686	0.5	9.7	2.3	Bn, Rb
15. South Brush Creek	30	2,463	4.2	7.3	0.9	Bk, Bn, Rb
16. Beaver Creek, upper	183	1,524	0.4	3.1		Bk
17. Sweetwater River, Number 1	229	2,271	0.2	14.8	1.8	Bn, Rb
18. Gros Ventre River	91	2,018	0.6	27.4	13.5	Ct, Rb
19. Muddy Creek	82	1,457	0.4	6.4	0.6	None
20. Beaver Creek, lower	82	1,311	1.0	4.0		None
21. Hams Fork River	168	2,170	0.1	13.7		Rb, Bn
22. Raymond Creek	73	2,012	6.4	2.3		Ct, Bk
23. Tongue River	122	2,079	1.3	14.6	6.5	Rb, Bk, Ct
24. South Tongue River	137	2,371	1.0	13.0	2.2	Rb, Bk, Bn
25. South Fork Hog Park Creek	61	2,617	1.2	4.9		Bn, Bk, Rb
26. Little Popo Agie River (1976)	110	1,686	0.5	9.7	2.3	Bn, Rb
27. North Platte River	335	2,353	0.3	44.5	12.3	Bn, Rb
28. Rose Creek	52	2,341	5.7	2.4		Ct
29. West Branch Creek, upper	61	2,563	7.7	5.6		Ct
30. West Branch Creek, lower	91	2,347	2.9	4.8		Ct, Bk, Rb
31. Solomon Creek	34	2,618	6.0	2.3		Ct
32. Harrison Creek	30	2,508	3.6	2.4		Ct
33. Green Timber Creek	37	2,536	4.0	2.0		Ct
34. Deadman Creek	30	2,597	8.0	3.3		Ct
35. Green River, Whiskey Grove	305	2,344	0.6	36.3		Rb, Bk
36. Rabbit Creek	84	2,612	10.0	2.7		Ct
37. Encampment River	91	2,204	0.6	18.0	3.1	Bn, Rb, Bk
38. Coal Creek	75	2,006	1.1	2.1		Ct, Bn
39. Sweetwater River, Number 2	93	2.268	0.2	10.1	1.8	Bn, Rb
40. Giraffe Creek, lower	100	2,066	4.0	3.4		Ct
41. Giraffe Creek, upper	108	2,140	2.0	3.4		Ct
42. Sweetwater River, Number 3	91	2,265	0.2	8.5	1.8	Bn, Rb
43. Huff Creek, upper	91	2,024	1.6	2.6		Ct
44. Little Muddy Creek	61	2,009	0.5	1.4		None

[a] Meters above mean sea level.
[b] Average width of water surface during late summer.
[c] Average daily flow (ADF) as recorded at United States Geological Survey gauging stations (Anonymous 1976).
[d] Listed in order of abundance: Bk = brook trout (*Salvelinus fontinalis*); Bn = brown trout (*Salmo trutta*); Ct = cutthroat trout (*Salmo clarki*); Rb = rainbow trout (*Salmo gairdneri*).

Methods

Study Sites

Trout habitat was measured in a wide variety of Wyoming streams. Study site elevations ranged from 1,146 to 3,042 m above mean sea level, with stream gradients between 0.1% and 10% (Table 1). Average stream width, in late summer, varied from 1.4 to 44 m. Average daily stream flow (ADF) was between 0.6 and 14.6 m^3/second. Riparian vegetation differed from dense coniferous forest to sagebrush desert to hay fields.

Study station length varied from 30 to 335 m, depending on the amount of stream needed to adequately sample available habitat. Large streams were usually best represented by a long station.

TABLE 2.—*Fluvial habitat attributes selected for field-testing during development of the Habitat Quality Index.*

Physical	Chemical	Biological
Late summer stream flow	Nitrate nitrogen	Stream bank vegetation
Annual stream flow variation	Total alkalinity	Fish food abundance
Maximum summer stream temperature	Total phosphorus	Fish food diversity
Water velocity	Total dissolved solids	Fish food type
Turbidity	Hydrogen ion	
Cover		
Stream width		
Stream depth		
Stream morphology		
Eroding banks		
Substrate		
Bed material		
Silt deposition		

Selection and Measurement of Habitat Attributes

We assumed that the best habitat for trout would be associated with a high standing crop of trout, and that standing crop is a consistent index of existing habitat quality.

The concept of multivariate control for fluvial environments has been documented (Platts 1974) and numerous physical, chemical, and biological factors interact to provide a given fish population size (Reid 1961; Macan 1963: Nikolsky 1963). The most important abiotic factors for fluvial fish habitats are temperature, rate of water flow, fluctuation in discharge, and cover availability (Hynes 1972).

In reality, any investigation of the limiting factors acting on a trout stream is controlled more by man's ability to measure than by theoretical considerations as to the true dominant limiting factors. Consequently, data availability and ability to measure were among the criteria used to select, for field-testing, 22 attributes characterizing fluvial habitat for trout (Table 2).

Although past measurements were available for some of these attributes, most had to be measured in the field. We standardized our period of attribute measurement to August and the first half of September, when flows are low, trout are often stressed, and sampling is facilitated in Rocky Mountain streams.

Stream discharge and temperature records were available for some streams at federal-state gauging stations (Lowham et al. 1975; Anonymous 1976). The maximum summer water temperature, late summer stream flow, and annual stream flow variation attributes were evaluated from these records. Wyoming Game and Fish Department records of past surveys were also consulted. When no records were available, the late summer stream flow, annual stream flow variation, bed material, silt deposition, stream morphology, substrate, and bank vegetation attributes were judged from close observation of existing conditions, and from physical evidence, such as high water marks and silt deposits.

Water velocity was measured by dividing the thalweg length for the study section by the time required for a fluorescent dye to travel through that section.

Samples of benthic macro-invertebrates, most of which are used as food by trout, were taken with a Surber square foot sampler, preserved with an alcohol-formalin mixture, and later identified. The food abundance, food diversity, and food type attributes were judged after these samples were processed.

Cover for trout has been defined as sheltered areas in a stream channel where a trout can rest and hide from predacious enemies (Arnette 1976). In Rocky Mountain streams, cover has been identified as water depth, surface turbulence, loose substrate, large rocks and other submerged obstructions, undercut banks, aquatic and overhanging terrestrial vegetation, dead snags and other debris lodged in the channel, and anything else that allows trout to avoid the impact of the elements or enemies (Gunderson 1968; Wesche 1973; Banks et al. 1974; Mullan 1975).

Using the above criteria, we identified and measured each patch of cover, summed the measurements, and calculated the percentage

TABLE 3.—*Stream habitat attributes used in the Habitat Quality Index, the characteristics used to rate them, and their multiple regression correlation coefficients* (R) *from a multiple regression analysis of their relationship to trout standing crop.* R *values followed by an asterisk (*) are significantly different from zero at the* $\alpha = 0.95$ *level (*R *= 0.378 from Table A-30a, Dixon and Massey 1969). ADF = average daily flow for the water year, obtained from gauging station records, if available; CPF = average daily flow during August and the first half of September only, from gauging station records, if available; SAV = submerged aquatic vegetation, includes algae and moss growing on rocks.*

Attribute	Symbol	R	Rating characteristics	
			0 (worst)	1
Late summer stream flow	X_1	0.36	Inadequate to support trout (CPF < 10% ADF)	Very limited: potential for trout support is sporadic (CPF 10–15% ADF)
Annual stream flow variation	X_2	0.80*	Intermittent stream	Extreme fluctuation, but seldom dry; base flow very limited
Maximum summer stream temperature (C)	X_3	0.28	<6 or >26.4	6–8 or 24.2–26.3
Nitrate nitrogen (mg/liter)	X_4	0.69*	<0.01 or >2.0	0.01–0.04 or 0.91–2.0
Fish food abundance (number/0.1 m^2)	X_5	0.57*	<25	26–99
Fish food diversity (D_s)[a]	X_6	0.57*	<0.80	0.80–1.19
Cover (%)[b]	X_7	0.55*	<10	10–25
Eroding banks (%)[c]	X_8	0.45*	75–100	50–74
Substrate	X_9	0.44*	SAV lacking	Little SAV
Water velocity (m^3/second)[d]	X_{10}	0.38*	<8 or >122	8–15.4 or 106.6–122
Stream width (m)	X_{11}	0.38*	<0.6 or >46	0.6–2.0 or 23–46

of cover present in each study section. When identifying cover, there was no substitute for experienced personnel, especially local biologists familiar with the stream. We often used a consensus of opinion from the biologists making the HQI measurements. When considering potential cover, the trout species present in each stream were considered, but young-of-the-year fish were ignored. In large rivers, deep water was not considered fully functional as cover for trout unless there was also shelter from the current.

All eroding or unstable stream banks were measured and the sum divided by the total length of the section to give the proportion of eroding banks.

Each site was subdivided into at least ten equally spaced cross sections, where width of the water surface and water depth were measured.

Water samples were collected at each site when habitat measurements were taken. Alkalinity and pH were analyzed in the field, by the methyl orange indicator method for the former and a colorimetric comparator for the latter. Phosphorus, nitrate nitrogen, total dissolved solids (TDS), and turbidity samples were processed at the Wyoming Game and Fish Depart-

TABLE 3.—*Continued.*

Attribute	Rating characteristics		
	2	3	4 (best)
Late summer stream flow	Limited; CPF may severely limit trout stock every few years (CPF 16–25% ADF)	Moderate; CPF may occasionally limit trout numbers (CPF 26–55% ADF)	Completely adequate; CPF very seldom limiting to trout (CPF > 55% ADF)
Annual stream flow variation	Moderate fluctuation, but never dry; base flow occupies up to two-thirds of channel	Small fluctuation; base flow stable, occupies most of channel	Little or no fluctuation
Maximum summer stream temperature (C)	8.1–10.3 or 21.5–24.1	10.4–12.5 or 18.7–21.4	12.6–18.6
Nitrate nitrogen (mg/liter)	0.05–0.09 or 0.51–0.90	0.10–0.14 or 0.26–0.50	0.15–0.25
Fish food abundance (number/0.1 m^2)	100–249	250–500	>500
Fish food diversity (D_s)[a]	1.20–1.89	1.90–3.99	>4.0
Cover (%)[b]	26–40	41–55	>55
Eroding banks (%)[c]	25–49	10–24	0–9
Substrate	Occasional patches of SAV	Frequent patches of SAV	Well developed and abundant SAV
Water velocity (cm/~~m^3/~~second)[d]	15.5–30.3 or 91.4–106.5	30.4–45.5 or 76.1–91.3	45.6–76
Stream width (m)	2.1–3.5 or 15.1–22.9	3.6–5.3 or 6.7–15	5.4–6.6

[a] For the purpose of the Habitat Quality Index, Diversity Score (D_s) is defined as follows: $D_s = \text{antilog}_{10}\bar{D}$, where D is calculated for each taxon from the formula: $D = P_i \log_{10} P_i$. When P_i is defined as $1/N$, and N is the number of organisms, then the formula reduces to $D = \log_{10} N$, as discussed in Watt (1968). $\bar{D}$ is the mean of all the D values for the sample.

[b] % cover = total amount of cover (m^2)/total area in study section (m^2).

[c] % eroding banks = total length (m) of eroding stream banks (both sides) in section/total length (m) (one side) of study section.

[d] Time-of-travel water velocity, determined with fluorescent dye. Velocity = thalweg length/time required for dye to traverse section.

$$D = -\sum_{i=1}^{n} P_i \log_{10} P_i$$

ment Water Quality Laboratory in Lander, Wyoming, by standard methods (American Public Health Association et al. 1971).

Rating of Attributes

When field measurements were completed, we rated the habitat attributes with a rating chart. This chart had five categories of value, from zero (worst) to four (best) (Table 3). For example, a stream temperature of 15 C was assigned a value of four, while a temperature of 28 C had a value of zero. As a further example of the rating procedure, measurements and ratings have been compiled for Muddy Creek, the Little Popo Agie River, and Sand Creek (Table 4).

Trout Standing Crop

Estimates of trout standing crop were obtained from Wyoming Game and Fish Department records, Binns (1972), Wesche (1974), Burton and Wesche (1974), Baxter and Loar (1975), and Wesche et al. (1977). At most sites, trout were sampled with electrofishing gear and standing crops were estimated by either the Peterson mark-and-recapture technique (Ricker

TABLE 4.—*Habitat Quality Index attribute measurement data, ratings and calculations for Muddy Creek (a poor trout stream), the Little Popo Agie River (a middle-grade trout stream), and Sand Creek (an excellent trout stream).*

Attribute	Model symbol	Muddy Creek Data	Muddy Creek Rating[a]	Little Popo Agie River Data	Little Popo Agie River Rating	Sand Creek Data	Sand Creek Rating
Late summer stream flow[b]	X_1	CPF = 212% ADF[c]	4	CPF = 74% ADF	4	CPF = 100% ADF	4
Annual stream flow variation	X_2		1		2		4
Maximum summer water temperature (C)	X_3	30	0	20	3	20	3
Nitrate nitrogen (mg/liter)	X_4	0.096	2	0.012	1	0.19	4
Fish food abundance (number/0.1 m²)	X_5	8	0	131	2	935	4
Fish food diversity	X_6	0.70	0	1.68	2	4.24	4
Cover (%)	X_7	7	0	46	3	69	4
Eroding banks (%)	X_8	49	0	16	3	<5	4
Substrate	X_9		0		2		4
Water velocity (m/sec)	X_{10}	1.12	1	1.00	2	0.55	4
Stream width (m)	X_{11}	6.4	4	9.7	3	6.2	4
Calculation of trout standing crop[d]							
$X_1 + 1$		5		5		5	
$X_2 + 1$		2		3		5	
$X_3 + 1$		1		4		4	
$P + 1$		1		217		16,385	
$F + 1$		1		13		193	
$S + 1$		1		28		65	
Model I-predicted standing crop (kg/hectare)		0		84		748	
Model II-predicted standing crop (kg/hectare)		0		68		688	
Measured standing crop (kg/hectare)							
1975		0		43		634	
1976				62			

[a] See Table 3 for criteria.

[b] CPF—average daily flow during August and the first half of September; ADF—average daily flow during the water year (October 1 to September 30).

[c] Late summer flows in Muddy Creek are augmented by abundant irrigation return flows.

[d] $P = X_4 \cdot X_5 \cdot X_6 \cdot X_7 \cdot X_8 \cdot X_{10} \cdot X_{11}$; $F = X_3 \cdot X_4 \cdot X_9 \cdot X_{10}$; $S = X_7 \cdot X_8 \cdot X_{11}$.

1975) or by the removal method (DeLury 1947, 1951). The exceptions to this procedure were (1) Sand Creek, where the abundant trout population was sampled with a single electrofishing pass through the study station, and (2) the Tongue, South Tongue, and Encampment rivers where sodium cyanide was used to collect the trout in mark-and-recapture samples.

Potential HQI sample sites were carefully screened to eliminate those heavily stocked or subjected to unusual habitat disturbances, such as channelization. Most of the streams sampled for trout also contained whitefish, suckers, minnows, and (or) sculpins.

Results

Development of Model I

When all attributes had been rated on streams 1–20, the relationships between habitat attributes and trout standing crop were explored with multiple regression analysis. This analysis indicated that eight attributes were significantly correlated with trout standing crop at the 95% confidence level (Table 3). Four attributes—late summer stream flow ($R = 0.36$), turbidity ($R = 0.29$), maximum summer stream temperature ($R = 0.28$), and bank vegetation ($R = 0.28$)—were almost significant at that level (R is the multiple regression correlation coefficient).

Model-building trials included all attributes with correlation coefficients near or greater than 0.30. The late summer stream flow, annual stream flow variation, and maximum summer stream temperature attributes were designated as primary limiting factors before the trials began and were included as separate factors in all models tested. Various combinations of the remaining attributes in Table 3, except substrate (X_9), were tried in the search for the best model.

As noted above, four of the 12 attributes tested in models had marginal relationships with trout standing crop and their inclusion in the trials was questionable. However, when the various combinations were tried in the model-building trials, the temperature and late summer stream flow attributes improved model performance. Their exclusion reduced model precision. Bank vegetation and turbidity did not contribute to model performance and they were dropped from the trials. The important point about the attributes selected for the model is not so much which ones were used, but rather that those attributes selected work together in the model to produce a reasonable prediction of trout standing crop.

The first predictive model (Model I) related ten habitat attributes to trout standing crops in streams 1–20. Model I is given by the following expression:

$$\log_{10}(\hat{Y} + 1) = [(-1.18257) + (0.97329)\log_{10}(X_1 + 1) + (1.65824)\log_{10}(X_2 + 1) + (1.44821)\log_{10}(X_3 + 1) + (0.30762)\log_{10}(P + 1)] \cdot [1.12085];$$

where

$\hat{Y}$ = Predicted trout standing crop;
X_1 = Late summer stream flow;
X_2 = Annual stream flow variation;
X_3 = Maximum summer stream temperature;
$P = X_4(X_5)(X_6)(X_7)(X_8)(X_{10})(X_{11})$;
X_4 = Nitrate nitrogen;
X_5 = Fish food abundance;
X_6 = Fish food diversity;
X_7 = Cover;
X_8 = Eroding stream banks;
X_{10} = Water velocity;
X_{11} = Stream width.

From the data in Table 4, the predicted trout standing crop for the Little Popo Agie River study station is calculated thus:

$$(\hat{Y} + 1) = [(-1.18257) + (0.97329)\log_{10}(5) + (1.65824)\log_{10}(3) + (1.44821)\log_{10}(4) + (0.30762)\log_{10}(217)][1.12085];$$

$$\hat{Y} = \text{antilog}_{10} 1.88(1.12085) - 1.0 = 84 \text{ kg/hectare}.$$

For our purposes, the standing crop of trout predicted by the model and the HQI score were considered equivalent. When HQI scores ($\hat{Y}$) were plotted against measured trout standing crop (Y), the scatter of data points was best fitted by the linear equation $Y = 11.983 + 0.846(\hat{Y})$ (Fig. 1). Model I explained 95% of the variation in trout standing crop at test sites 1–20 and a high correlation coefficient ($R = 0.977$) suggested a strong relationship between HQI score and trout standing crop.

Testing Model I

The predictive performance of Model I varied from stream to stream at sites 1–20, but the residual errors (Table 5) indicated that overall model performance was good. Although these results demonstrated credibility, there was need for measurements from additional test streams before the HQI could be used with confidence. Accordingly, habitat attributes and trout standing crop measurements were gathered from study sites 21–36 in 1976–1977.

Model I performed satisfactorily when used

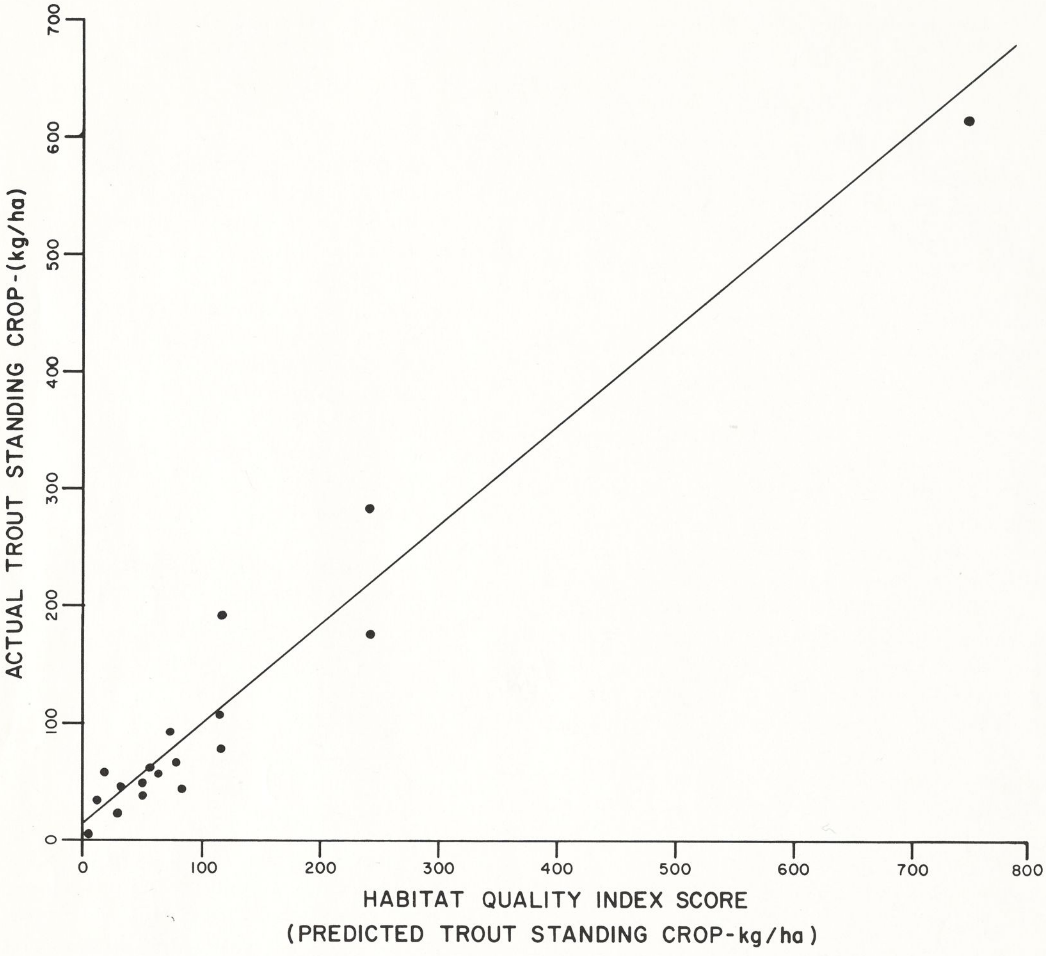

FIGURE 1.—*Relationship between HQI score* ($\hat{Y}$) *and trout standing crop* (Y) *at 20 Wyoming streams evaluated with HQI Model I in 1975. The multiple correlation coefficient,* $R = 0.977$ *for the linear relationship:* $Y = 11.983 + 0.846(\hat{Y})$.

to predict trout standing crop at these 16 new sites (Table 5). The multiple correlation coefficient dropped from 0.977 to 0.771, but this apparent deterioration of model performance was offset by a reduction in the mean of the sum of squares of residual errors (SSRE) from 1,550 to 783. Thus, we were encouraged to proceed with further refinement of the HQI method.

Development of Model II

In addition to the need for further refinement, the fish food abundance and diversity attributes used in Model I posed problems. While benthic macro-invertebrates were easily collected from most streams, sorting and identifying them was often tedious, difficult, and time consuming. Calculation of HQI scores was often delayed while samples were processed. Also, most fishery managers do not have the time, or the expertise, to process the fish food samples required by Model I.

Consequently, we replaced the fish food abundance and diversity attributes with a new substrate attribute. Because benthic macro-invertebrate occurrence is a function of available food and cover, which can be furnished by submerged aquatic vegetation, we assumed that benthic macro-invertebrate occurrence could be estimated by careful observation of vegetation abundance on the stream substrate.

When streams 1–20 were evaluated with the

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THE STATE OF WYOMING

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EARL M. THOMAS
DIRECTOR

May 31, 1983
Lander Office
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Dr. Robert Behnke
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Dear Bob:

Regarding your planned field trip on June 6th, Dick Baldes said today that he would be unable to help with the tour due to other commitments. However, I will be able to show your students the stream improvement work and HQI station at the Little Popo Agie River, as was done in 1981. We could also look at the overgrazing problems on Squaw Creek. Due to the large snowpack, the stream improvement work at Pass Creek will be inaccessible. Flood flows may cause us some viewing problems at the other sites.

Regarding points of emphasis for my part of the tour, the primary subjects covered will be: (1) streamflow records, (2) stream improvement techniques and benefits, (3) wild trout vs hatchery trout on the Little Popo Agie River, (4) HQI methodology, and (5) the influence of land use practices on a trout fishery.

I will plan to pass out handouts on streamflow records and the wild/hatchery trout situation on the Little Popo Agie River, as in 1981. If you still have your copies of the 1981 handouts, perhaps you can develop some questions for your students. Information for the HQI will come from my report "HQI Procedures Manual," especially the section dealing with the case study example on the Little Popo Agie River. Hopefully, you have a copy so you can develop some questions.

If I do not hear otherwise from you, I will plan to meet you at the Wyoming Game & Fish Office (260 Buena Vista) sometime the morning of June 6th.

Sincerely,

Al

N. Allen Binns, Supv.
Aquatic Habitat Crew

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TABLE 5.—*Trout standing crops (SC) (kg/hectare) measured in Wyoming streams and predicted by Habitat Quality Index Models I and II. Model I was developed from streams 1–20, while streams 21–36 were used to test Model I performance. Model II was developed from streams 1–36 and its performance was tested with streams 37–44. SSRE = sum of squares of residual error;* R = *multiple correlation coefficient.*

Stream	Measured SC	SC predicted by Model I	Residual error Model I	SC predicted by Model II	Residual error Model II
1. Sand Creek	634	748	−114	688	−54
2. Duck Creek, upper	284	242	42	231	53
3. North French Creek, upper	192	116	76	162	30
4. Duck Creek, lower	176	242	−66	231	−55
5. North French Creek, lower	106	116	−10	93	13
6. Hog Park Creek	91	74	17	55	36
7. Nash Fork Creek	78	116	−38	88	−10
8. Green River, Pape Ranch	66	74	−8	70	−4
9. North Brush Creek	60	57	3	49	11
10. Douglas Creek	58	63	−5	81	−23
11. East Fork Wind River	57	17	40	77	−20
12. Green River, Blackmon Ranch	48	48	0	67	−19
13. New Fork River	45	31	14	45	0
14. Little Popo Agie River (1975)	43	84	−41	68	−25
15. South Brush Creek	38	49	−11	49	−11
16. Beaver Creek, upper	34	11	23	17	17
17. Sweetwater River, Number 1	22	27	−5	27	−5
18. Gros Ventre River	0	4	−4	2	−2
19. Muddy Creek	0	0	0	0	0
20. Beaver Creek, lower	0	0	0	0	0
Streams 1–20					
SSRE			30,991		13,706
Mean SSRE			1,550		685
R			0.977		0.985
21. Hams Fork River	125	136	−11	104	21
22. Raymond Creek	110	66	44	115	−5
23. Tongue River	88	178	−90	112	−24
24. South Tongue River	86	94	−8	69	17
25. South Fork Hog Park Creek	78	67	11	62	16
26. Little Popo Agie River (1976)	62	84	−22	68	−6
27. North Platte River	58	80	−22	68	10
28. Rose Creek	56	48	8	38	18
29. West Branch, upper	55	48	7	42	13
30. West Branch, lower	54	44	10	26	28
31. Solomon Creek	42	55	−13	42	0
32. Harrison Creek	28	29	−1	23	5
33. Green Timber Creek	25	12	13	25	0
34. Deadman Creek	20	25	−5	13	7
35. Green River, Whiskey Grove	19	15	4	10	9
36. Rabbit Creek	14	39	−25	36	−22
Streams 21–36					
SSRE			12,528		3,639
Mean SSRE			783		227
R			0.771		0.901
Streams 1–36					
SSRE			43,494		17,345
Mean SSRE			1,208		481
R			0.967		0.983
37. Encampment River	87			90	−3
38. Coal Creek	50			58	−8
39. Sweetwater River, Number 2	45			30	15
40. Giraffe Creek, lower	43			55	−12
41. Giraffe Creek, upper	27			24	3
42. Sweetwater River, Number 3	16			14	2
43. Huff Creek, upper	11			11	0
44. Little Muddy Creek	0			0	0

TABLE 5.—*Continued.*

Stream	Measured SC	SC predicted by Model I	Residual error Model I	SC predicted by Model II	Residual error Model II
Streams 37–44					
SSRE					455
Mean SSRE					57
R					0.965
Streams 1–44					
SSRE					17,800
Mean SSRE					405
R					0.983

new substrate attribute, a good linear relationship occurred between substrate ratings and trout standing crop ($r = 0.66$; significantly different from zero at the 99% level), as well as between substrate ratings and measured benthic macro-invertebrate standing crop ($r = 0.82$; significant at the 99% level).

To further refine the HQI, the *P* factor used in Model I was replaced by shelter index and food index factors. The shelter index was obtained by multiplying the ratings for the stream width, eroding stream banks, and cover attributes. Ratings for the maximum summer stream temperatures, water velocity, nitrate nitrogen, and substrate attributes were multiplied to give the food index.

With these changes, nine habitat attributes and the trout standing crop measurements from test sites 1–36 were subjected to a multiple regression analysis and a new HQI model (Model II) was prepared. Model II is given by the expression:

$$\begin{aligned}\log_{10}(\hat{Y} + 1) = [&(-0.903) + (0.807)\log_{10}(X_1 + 1)\\ &+ (0.877)\log_{10}(X_2 + 1)\\ &+ (1.233)\log_{10}(X_3 + 1)\\ &+ (0.631)\log_{10}(F + 1)\\ &+ (0.182)\log_{10}(S + 1)][1.12085];\end{aligned}$$

where

$\hat{Y}$ = Predicted trout standing crop;
X_1 = Late summer stream flow;
X_2 = Annual stream flow variation;
X_3 = Maximum summer stream temperature;
F = Food index = $X_3(X_4)(X_9)(X_{10})$;
S = Shelter index = $X_7(X_8)(X_{11})$;
X_4 = Nitrate nitrogen;
X_7 = Cover;
X_8 = Eroding stream banks;
X_9 = Substrate;
X_{10} = Water velocity;
X_{11} = Stream width.

Again, from the data in Table 4, the predicted trout standing crop for the Little Popo Agie River station is calculated with Model II:

$$\begin{aligned}(\hat{Y} + 1) &= [(-0.903) + (0.807)\log_{10}(5)\\ &\quad + (0.877)\log_{10}(3) + (1.233)\log_{10}(4)\\ &\quad + (0.631)\log_{10}(13)\\ &\quad + (0.182)\log_{10}(28)][1.12085];\\ \hat{Y} &= \text{antilog}_{10}1.79(1.12085) - 1.0\\ &= 68 \text{ kg/hectare.}\end{aligned}$$

Model II explained 97% of the variation in trout standing crop at study sites 1–36. Improved correlation ($R = 0.983$) and a drop in SSRE from 43,494 to 17,346 (Table 5) indicated increased model precision. Model II performed better than its precursor, since mean SSRE dropped from 1,550 (Model I, $N = 20$) to 481 (Model II, $N = 36$). For sites 1–36, the plot of HQI score ($\hat{Y}$) against measured trout standing crop (Y) was best described by the linear relationship $Y = 5.978 + 0.926(\hat{Y})$ (Fig. 2).

Testing Model II

As with Model I, additional measurements were needed before the new model could be used with confidence. Suitable measurements were available from ongoing studies of cutthroat trout habitat and instream flows in Wyoming and were used to test Model II. At sites 37–44, Model II predicted trout standing crop with satisfactory precision and a low degree of error (Table 5).

When trout standing crop was estimated at

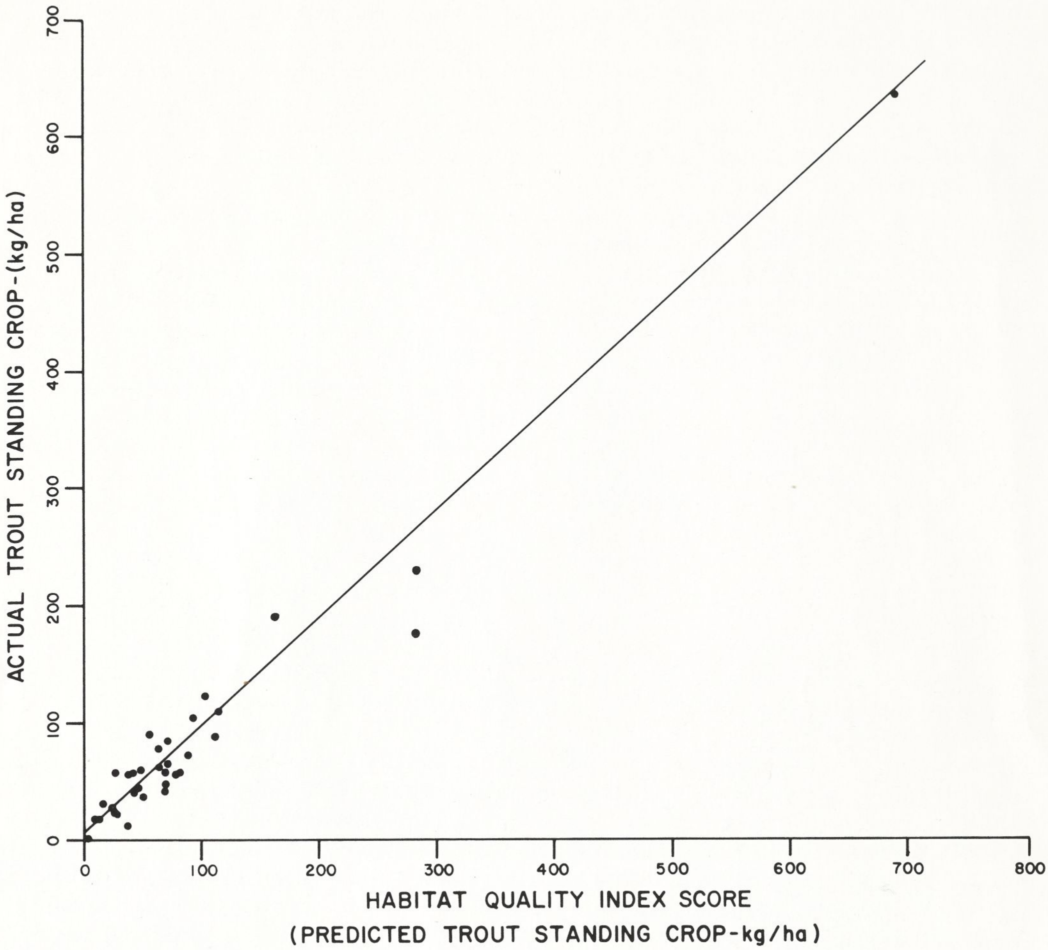

FIGURE 2.—*Relationship between HQI score* (Ŷ) *and trout standing crop* (Y) *at 36 Wyoming streams evaluated with HQI Model II in 1975–1977. The multiple correlation coefficient* $R = 0.983$ *for the linear relationship:* $Y = 5.978 + 0.926(\hat{Y})$.

sites 1–20 with Model I, the prediction errors ranged as high as 114 kg/hectare. However, when Model II predicted trout standing crop at sites 1–36, no prediction was in error by more than 55 kg/hectare and at only three sites did the error exceed 50 kg/hectare. Because all three streams contained numerous trout, a prediction error of ±50–60 kg/hectare was less serious than if trout were sparse. Thus, a prediction error of 54 kg/hectare at Sand Creek seemed large, but the predicted standing crop was actually within 9% of the measured value.

Thus, we have concluded that Model II is the better model and is a valid predictor of trout standing crop in Wyoming streams. Model II is the model we are currently using for habitat evaluation work on Wyoming trout streams.

Discussion

We have used the HQI method with satisfactory precision on a wide variety of Wyoming streams and the method has produced reliable estimates of habitat quality and trout standing crop. The HQI estimates of trout standing crop on large streams have often proven quicker, easier, and cheaper to obtain than estimates made by conventional fish sampling techniques. In streams where electrofishing is ineffective due to water purity or a large volume of water, HQI predictions have often provided the only available estimates of trout stocks.

For example, streams in the Big Sandy River drainage contain few electrolytes and trout standing crop estimates made with electrofishing gear were of questionable accuracy, even when salt blocks were added to the water to improve conductivity. To solve this problem, the HQI was used to obtain these estimates.

As a further example of HQI use, we used Model I to gain an understanding of potential changes in habitat and standing crop for Colorado River cutthroat trout (*Salmo clarki pleuriticus* Cope) that would result from a proposed transbasin water diversion project in the North Fork Little Snake River drainage (Binns 1977, 1978b). In Green Timber Creek, the HQI predicted a trout standing crop that was 74% less than the average for nearby Deadman, Harrison, and Solomon creeks. This difference was attributed to the long-term impact of a transbasin water diversion installed in 1964 on upper Green Timber Creek. Thus, we were able to document the habitat and standing crop deterioration that could be expected from an expanded transbasin diversion in the North Fork drainage. This information proved valuable in project feasibility debates and in obtaining an assurance of adequate instream flows for trout.

We have also assessed habitat improvement potential and documented habitat degradation with the HQI. Fishery managers were then able to quantify trout habitat evaluations in discussions with the other resource agencies. For example, an HQI evaluation of Huff Creek, which contains one of the few remaining stocks of the rare Bonneville cutthroat trout (*Salmo clarki utah* Suckley), identified eroding stream banks, trout cover, and water temperature as distressed habitat features. The HQI predicted that habitat improvement could raise the trout standing crop in Huff Creek from the present 1.5 kg/hectare to 67 kg/hectare. An increase of this magnitude would contribute much to the continued survival of this trout and was a prime selling point in discussions with land managers.

Depending on the needs of HQI users, several options are possible for use of the HQI. First, users can choose between Model I and Model II. While Model II is the more accurate predictor, some users with access to the required fish food data may prefer to use Model I. Second, the HQI can be used to predict trout standing crop in kg/hectare. This is the most common use. A third option is available when the HQI is modified to give a habitat evaluation in habitat units (Binns 1977, 1978a, 1978b). Thus, the user also has the option of presenting the evaluation in kg/hectare, in habitat units, or, when a control stream is available, as a percentage, comparing an impacted habitat against a normal one.

By way of background, the concept of a habitat unit for expressing habitat evaluations was used, but not defined, by Anonymous (1974). A trout habitat unit subsequently was defined as the amount of habitat quality needed to produce an increase, in the trout standing crop, of 1 kg/hectare (Binns 1978a). Its value was equal to the reciprocal of the slope of the HQI regression equation (1/0.84 = 1.19 for Model I). Multiplying HQI score by 1.19 gave trout habitat units.

To calculate trout habitat loss or gain at proposed reservoir sites in trout habitat units, we used the HQI and Ryder's Morphoedaphic Index (MEI = total dissolved solids/mean depth) (Ryder 1965; Ryder et al. 1974). A study of MEI and trout stock relationship in Wyoming (Facciani 1977) provided additional data for a comparison with an HQI evaluation of the river to be impounded. When the controversial Kendall and Grayrocks reservoir proposals were evaluated, the HQI-MEI comparison predicted a 42% loss of trout habitat units at Kendall Reservoir and a 176% gain at Grayrocks Reservoir (Binns 1978a).

Various methods have been devised to evaluate fluvial environments, but not all have been objective, quantifiable, or divorced from monetary terms. However, recently developed methods have improved habitat evaluation procedures. A study of the influence of geomorphic processes in the Salmon River, Idaho, concluded that certain aquatic structural features controlled the density and composition of fish populations (Platts 1974). In Oregon, the influence of stream discharge on carrying capacity of salmonids was estimated with a habitat index (Nickelson 1976). Other recent methods have dealt with stream habitat surveys (Duff and Cooper 1978), inventory of aquatic habitat (Collotzi and Dunham 1978), and the classification of streams (Pennak 1978).

We feel that the most important feature of the HQI is that it provides objective and quantitative evaluations of the trout fishery resource in nonmonetary terms. Also, the HQI is based on trout standing crop and is derived from measurements of biologically pertinent attributes. The HQI has performed satisfactorily in Wyoming waters and we believe additional testing should prove the method usable in other areas.

With an understanding of the life history requirements of a specific fish species, the HQI could be modified to provide an evaluation of fluvial habitat conditions, and standing crop predictions, on a species-by-species basis for fish species other than trout.

Our experiences with the HQI suggest that anomalies in trout population density, such as those caused by extremes in climatic conditions, or by unnatural, human-controlled flows below reservoirs, could cause variability in HQI predictions. The HQI should be used with caution in such situations.

Acknowledgments

We thank Robert Wiley, Mike Stone, and Robert Pistono, Wyoming Game and Fish Department, and George T. Baxter, University of Wyoming, for their very helpful comments, technical assistance and manuscript review. Lyman McDonald contributed much statistical assistance and kindly reviewed the manuscript. Tom Wesche, Wyoming Water Resources Research Institute, generously provided trout standing crop data from his studies. We also express our sincere appreciation to the Wyoming Game and Fish Department for the use of their resources, and for the exceptional assistance and cooperation we received from the fishery management personnel of that agency. Funds for this study were provided by the Wyoming Game and Fish Department.

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ANNOTATED LIST OF REPTILES AND BATRACHIANS COLLECTED.

[By Frederick C. Test, Aid, Department of Reptiles, U. S. National Museum.]

The collecting of Reptiles and Batrachians was merely an incidental feature of the work of the party. No time was devoted to searching for specimens of these groups, and those found in the collection are such as the members of the party chanced to see while carrying on the main work of the expedition. Only a short time was spent at each locality and only the most common forms were found. The Batrachians greatly predominate, and the series of *Rana pretiosa* is an especially good one.

I wish here to express my thanks to Dr. Leonhard Stejneger for aid and suggestions in preparing these notes.

1. Eutænia sirtalis parietalis Cope.

Two typical adult specimens of this species were collected.

Museum No.	Collector's No.	Locality.	Date.
17566	8	Swan River, near Swan Lake, Montana	Aug. 3
17567	9	......do	Do.

2. Eutænia vagrans B. and G.

Of this species there are five specimens of varying ages and sizes.

Museum No.	Collector's No.	Locality.	Date.
17565	7	Swan River, near Swan Lake, Montana	Aug. 3
17568	10	......do	Do.
17569	74	McClellan Creek, near Helena, Montana	July 20
17570	75	......do	Do.
17571	76	......do	Do.

3. Ambystoma tigrinum Green.

Of this widely spread and usually abundant species, only four specimens were found, all larvæ.

Museum No.	Collector's No.	Locality.	Date.
17583	6	Jocko River, Ravalli, Montana	July 31

4. Bufo halophilus Baird.

Three typical specimens.

Museum No.	Collector's No.	Locality.	Date.
17634	15	Lewis Falls, Wyoming	Aug. 12
17635	16	......do	Do.
17636	66	President Camp, Wyoming	Aug. 13

5. Rana pipiens brachycephala Cope.

The two specimens collected have some of the proportions of *R. pipiens pipiens*, the head being considerably less than 3 in the length instead of $3\frac{1}{2}$, as it is said to be in *brachycephala*, but they have been referred to the latter on account of the absence of a well-defined dark bar on the front of the femur, a color feature more or less characteristic of Western specimens.

Museum No.	Collector's No.	Locality.	Date.
17572	80	Beaverhead River, Dillon, Montana	July 27
17573	....	Swan River, near Swan Lake, Montana	Aug. 3

6. Rana pretiosa B. & G.

Of the fifty-six specimens all but five are from streams that empty into the Pacific. These five, Nos. 17574 to 17578, are from the junction of Firehole and Gibbon rivers, the headwaters of the Madison Fork of the Missouri. This fact is particularly interesting, inasmuch as I have been able to find but three other records of this species occurring in streams flowing to the east. One of these is noted by Prof. E. D. Cope, who found it in Prickly Pear Cañon, just north of Helena, Montana. (Am. Nat., 1879, p. 435.) Another is a single specimen, U. S. National Museum, No. 11503, collected at Fort Ellis, Montana, by W. B. Pratt; and the third record consists of two specimens, U. S. National Museum, Nos. 11937 and 11939, collected by C. Hart Merriam at "Upper Firehole Basin, Yellowstone Park." In the list of specimens of *Rana pretiosa* belonging to the U. S. National Museum (see Cope's Batrachia of North America, p. 434) there are apparently two more records of this species occurring east of the Rocky Mountains, but both are due to misidentification, No. 3437, from the Red River of the North, R. Kennicott, being *R. septentrionalis*, and No. 4824, St. Catharine, Canada, D. W. Beadle, *R. sylvatica*. It may possibly be owing in part to insufficient exploration that there are so few instances of this frog being found east of the Great Divide.

In looking over this series, a very noticeable point is the lightening in color as the frog increases in age and size. The young is very dusky, the moss-agate-like dark dorsal spots being barely apparent, but as it grows the ground color pales, and while some of the black markings thus become more prominent, others fade entirely away. The largest specimen collected, No. 17603, a female from Deer Lodge River, Montana, is also the lightest colored. The ground color is very pale, rendering more conspicuous the few black dorsal blotches. The inferior dark markings are absent, and the usual bars on the legs are broken up into several small spots. There is indication of a light median line on the back posteriorly. No. 17604, a smaller female from the same locality, is much darker, with all the usual markings, and the dorsal blotches more numerous.

Four or five small specimens from Cottonwood Creek, Deer Lodge, Montana, show the darkest phase of the young very well, particularly No. 17593, a female, which has the black marbling of the throat finely marked, and all the spots on the sides and lower surface unusually distinct, while the upper ground color is so dark that the blotches on the back are hard to distinguish. No. 17591, a very slightly larger male, is almost as well marked. These differences in color are plainly not due to local causes, since dark and light come from the same locality; nor to sex, for dissection shows that the sexes are irregularly distributed among the varying shades of color.

There are a few exceptions to the general rule, notably No. 17572, a small male, which should be dark, but is quite light, and No. 17606, a rather large female, which is considerably darker than it ought to be.

Museum No.	Collector's No.	Locality.	Date.
17574	71	Junction of Firehole and Gibbon rivers, Montana	Aug. 9
17575	72	......do	Do.
17576	73	......do	Do.
17577-8	....	......do	Do.
17579	68	Lolo Creek, Missoula, Montana	July 30
17580	69	Big Blackfoot River, above Bonner, Montana	July 29
17581	70	......do	Do.
17582	67	Ravalli, Montana	July 31
17587-8	....	Little Blackfoot River, near Elliston, Montana	July 21
17589-602	....	Cottonwood Creek, Deer Lodge, Montana	July 22
17603-4	....	Deer Lodge River, Montana	Do.
17605-16	....	Browns Gulch, Silver Bow, Montana	July 27
17617-24	....	Cañon Creek, National Park, Wyoming	Aug. 8
17625	14	Foot of Shoshone Lake, Wyoming	Aug. 12
17626-7	....	Crawfish Creek, at Moose Falls, National Park, Wyoming	Aug. 13
17628	26	Jackson Lake, Wyoming	Aug. 14
17629	44	Two-Ocean Pass, Wyoming	Aug. 17
17630	45	......do	Do.
17631	46	......do	Do.
17632	48	......do	Do.
17633	49	......do	Do.

PRESERVATION OF FORESTS IN AND ABOUT YELLOWSTONE PARK.

According to Dr. Hayden, the Yellowstone Park region has a climate differing in many respects from that of other parts of the Rocky Mountain region. It has a very moist atmosphere, the rainfall is greater, its mean annual temperature is lower, and it is better clothed with vegetation. This region and the adjacent portions of Idaho and Wyoming constitute the most heavily timbered area in the West, excepting parts of Oregon and Washington west of the Cascade Range. The climate is, as regards temperature, subarctic. The winter begins with September and ends only in June, and frosts occur every month in the year.

On the morning of August 8, at our camp on Beaver Lake, the thermometer stood at 29° at 8 o'clock. At Two-Ocean Pass the temperature was 33° at 6:30 a. m., August 18, and nearly every night, during the time of our stay in and about the Park, the temperature was down to freezing.

According to Mr. Hague, "few regions in the Rocky Mountains are so highly favored as regards snow and rain fall. Snow falls early in October and rarely disappears before June, and throughout the winter is said to lie 6 feet in depth over the plateau and higher regions of the Park. On the evening of October 9 a storm began and continued without abatement for thirty-six hours, the snowfall measuring 36 inches. The Park is peculiarly well adapted for holding broad sheets of water. In consequence, we find here such bodies of water as the Yellowstone, Shoshone, Heart, and Lewis lakes, besides innumerable smaller ones. These lakes are the natural reservoirs for storing up the water supply. The Yellowstone Lake alone has an area of 150 [139] square miles," and the others no doubt double this area. From these numerous lakes the water is gradually fed out to the upper tributaries of the Missouri and the Columbia during the season of little rain.

Mr. Hague further says:

Forests cover the hills to the water's edge. The timber retains the snow late in the season, while it slowly melts away and fills the springs and lakes. If the forests are removed the snow will rapidly disappear under the direct rays of the sun by evaporation, and it will be largely carried off by the dry west winds which prevail. There would be enormous freshets in the spring, followed by a long parched season, the lakes and springs diminishing rapidly.

In another place Mr. Hague, who has given much attention to this important question, says:

I know of no tract in the Rocky Mountains where the necessity for the conservation of the forests appears so urgent, or the direct advantage to be gained so immediate, as right here on the Park Plateau at the headwaters of the Yellowstone and the Snake rivers. If the broad valley of the Yellowstone is ever to support any considerable population the forests and streams from these elevated regions must be protected. The Yellowstone Valley can stand no diminution in the water supply which it now receives.

The importance of this matter cannot be overestimated, and it is very gratifying to know that, under authority of an act of Congress of March 3, 1891, the President has already, by proclamation, set apart and reserved from settlement a wide strip of land lying south and east of the Yellowstone Park. This important addition to the Park comprises the greater part of the densely timbered region already mentioned.

RECOMMENDATIONS.

Among the many falls in and about the Yellowstone National Park, there are several in which the placing of fishways should receive consideration. Virginia Cascade and Gibbon Falls in Gibbon River, Keppler Cascade in Firehole River, and the upper and lower falls of Lewis River are of this number. All of these rivers, both above and below the falls which they contain, are ideal trout streams. Below each of the lower falls there is an abundance of excellent food-fishes—trout in the Lewis, and trout, grayling, and whitefish in the Gibbon—while above these falls there are no fish whatever, except those planted by the Commission in 1889 and 1890.

It would be comparatively an easy matter to construct a fishway at each of these falls which would enable the valuable native species to ascend to the upper courses of these streams and to the cold lakes in which most of them rise.

When sufficient time has elapsed to enable the various species of trout planted by the Commission in these waters to become thoroughly established, the desirability of placing fishways in these streams should receive careful consideration.

In the country about Cooke City, east of the National Park, are several lakes similar to those in the Park, but smaller. Clarke Fork of the Yellowstone, about the headwaters of which these lakes lie, has in it considerable falls which fish can not pass. As a result, these lakes and upper tributaries are barren of fish, and their stocking with species of *Salmonidæ* might be very properly undertaken by the Commission.