

UNITED STATES DEPARTMENT OF THE INTERIOR

FISH AND WILDLIFE SERVICE

Fishery Resources



FISHERY AND AQUATIC MANAGEMENT PROGRAM

in

YELLOWSTONE NATIONAL PARK

Technical Report for Calendar Year 1980

MAY 1981

ANNUAL PROJECT TECHNICAL REPORT FOR 1980

Fishery and Aquatic Management Program

Yellowstone National Park

Ronald D. Jones, Project Leader

May, 1981

Authors (alphabetical):

Patricia E. Bigelow, Biological Aid: Nonconsumptive use of aquatic areas.

Daniel Carty, VIP (Volunteer in Park): History of the fishery of the Madison River.

Robert E. Gresswell, Fishery Biologist: Fishery management evaluations, Yellowstone Lake gillnetting, Clear Creek spawning run, Pelican Creek spawning run, Back-country lake surveys and Cascade and Slough Creeks projects.

Ronald D. Jones, Project Leader: General subjects.

Sandra M. Rubrecht, Biological Technician: LeHardy's Rapids, Back-country stream surveys and General subjects.

Cover photo: Commission of Fish and Fisheries - Yellowstone Expedition, 1901

TABLE OF CONTENTS

	<u>Page</u>
Title page.....	i
Table of Contents.....	ii
Introduction.....	1
Parkwide fishing in 1980.....	7
Yellowstone Lake.....	11
Yellowstone River.....	17
Soda Butte Creek.....	22
Hellroaring Creek.....	24
LeHardy's Rapids.....	25
Clear Creek spawning run.....	32
Pelican Creek spawning run.....	41
Largemouth gillnetting.....	53
Nonconsumptive use of the aquatic resources.....	68
History of the fishery of the Madison River, YNP.....	73
Cascade and Slough Creeks - Population estimates and habitat evaluations.....	90
Stream surveys	
Hellroaring Creek.....	95
Canyon Creek.....	97
Clear Creek.....	110
Lake Survey Program.....	116
Forest Lake.....	117
Ice Lake.....	128
Obsidian Lake.....	134
Scaup Lake.....	139
Native species restoration program.....	144
Other project activities.....	148
Acknowledgments.....	154
Literature cited.....	155

INTRODUCTION

In the Yellowstone National Park Establishment Act of 1872, the Park was "dedicated and set apart as a public park or pleasuring-ground for the benefit and enjoyment of the people and for the preservation, from injury or spoilation of all timber, mineral deposits, natural curiosities or wonders. . . , and their retention in their natural condition."

Since that time, legislation and policies have further defined the purpose of the Park to prohibit hunting of all birds and mammals and to regulate fishing. The Park is currently managed as a natural area to perpetuate as a natural ecosystem the native fauna, flora, geology and scenic landscape. Since fishing is often harvest oriented, it has the potential to cause significant disturbance to the ecosystem. Fishing in Yellowstone National Park has, however, historical precedence and has been a major visitor activity during the past century. After very liberal initial regulations, present restrictions have evolved (since the 1930's) to more closely reflect the Park's primary purpose. Specifically, the objectives of the fishing program are:

1. To manage fishing as an integral part of the Park's ecosystem.
2. To provide anglers with a high quality angling experience with wild trout under natural settings.
3. To preserve and restore native species and aquatic habitats.

High quality angling has been defined as having the opportunity to fish for rare native species or wild trout in pristine waters where angler harvests do not exceed natural replenishment rates, or reduce fish numbers, biomass, sizes and age groups from that which would occur in the absence of fishing. This management goal necessitates both a philosophical and literal distinction between catching fishes for recreation and removing fishes for consumption. This distinction is especially important since all maintenance stocking for harvest purposes ended in the early 1950's. Wild stocks, therefore, bear the pressure of increasing public interest. Management practices, consisting mainly of restrictive regulations, have had to be innovative to keep abreast of increasing trends of parkwide angler use, rapid increases in back-country visitation and growing interest in specialized fishing (such as fly fishing).

Regulations that attempt to restore or protect fishes and maintain high quality angling involve manipulating season dates, restricting baits, using creel and size limits and designating certain species or waters for catch-and-release fishing. Additionally, certain waters are closed to protect rare or endangered species, nesting birds or to provide vistas for viewing scenic landscapes and undisturbed wildlife (including fishes).

Yellowstone has one species of fish (the Montana grayling) and over a dozen waters restricted to catch-and-release fishing only. A number of other waters, including Yellowstone Lake, are partially catch-and-release as a result of maximum or minimum length limits. These highly restrictive regulations have, by most measures of angling quality, improved populations and provided fishing superior to that found before the restrictions.

In 1980, the National Park Service issued an estimated 184,200 free fishing permits to fish Park waters. Permit holders comprised a composite group from all 50 states, all Canadian Provinces and numerous foreign countries. The largest single group came from the local states of Montana, Wyoming and Idaho. Although Park anglers fish approximately 120 different lakes and streams, about 30 fisheries comprise most of the fishing pressure. Six fisheries are of such a quality to attract national attention. An average of 3-4 articles are published annually in national magazines concerning various Park waters and are generally complimentary.

The fact that twelve states have fewer total licensed anglers than Yellowstone illustrates the national importance of Park fisheries. The number of Park license-holders is greater than 80% of the total licenses issued by the state of Wyoming, over 70% of the total issued by Montana and 50% of the total by Idaho. Using values reported in the 1975 National Survey of Hunting, Fishing and Wildlife Associated Recreation (USDI, Fish and Wildlife Service 1977), Yellowstone hosts about 1.1% of the national cold water anglers. Park fishermen have a substantial economic impact; it is estimated that they spend about 4 million dollars annually in and around the Park.

These facts are presented not only to show the widespread importance of the Park's fisheries but also to pinpoint the difficulties faced in the management of those fisheries. Although fishing pressure declined in 1979, increases in 1980 equal some of the highest levels yet estimated. The overall trend in the past decade has been upward, similar to increases in total Park recreational visitation.

Although the format of this year's technical report is similar to that of previous years, the loss of two professional biologists from the project staff has necessitated a drastic reduction in content, especially the analysis of data from the Volunteer Fisherman Report System (VFR). For 1980, discussion of VFR is limited to Yellowstone Lake and River, Soda Butte Creek and Hellroaring Creek, but data for over 30 lakes and streams that make up over 96% of the total Park angling use and effort are given in tabular form (Tables 1 and 2).

Table 1. Fishery statistics from Yellowstone Park waters with over 10 angler-days in the sample and which comprise over 96% of the parkwide angler day use in 1980

Water	% of total parkwide angler days	Total reported angler days (yrs)	Estimates for the season					Average size fish landed (inches)	Average size fish creel (inches)	Percent anglers landing 1 or more fish	Average expertise	% Anglers satisfied with:	
			Anglers	Length angler days (hours)	Angler days (trips)	Angler hours (effort)	Landing rate	Creel rate	Total fish landed	Total fish creel		Overall experience	Fish sizes caught
Parkwide Fisheries	100.00	13,400	130,800	2.44	311,260	798,000	0.96	0.13	725,300	100,900	67	73	66
Yellowstone Lake	41.74	5,585	47,782	2.46	129,910	319,533	0.86	0.19	275,162	60,920	65	74	55
Yellowstone River	14.50	1,935	19,280	2.46	43,794	106,801	1.18	0.07	124,206	7,140	79	85	81
Madison River	6.72	899	8,699	2.44	20,904	51,065	0.62	0.05	31,853	2,519	52	54	44
Firehole River	5.17	692	8,046	2.46	16,089	39,607	0.81	0.03	32,186	1,127	62	68	61
Lewis Lake	3.78	506	1,888	3.16	11,962	37,108	0.48	0.17	17,679	6,220	44	65	55
Gibson River	3.65	489	6,532	1.82	11,367	20,689	0.81	0.08	16,581	1,639	55	57	52
Shoshone Lake	3.47	464	2,858	3.26	10,785	35,127	0.40	0.13	14,202	4,392	28	51	39
Slough Creek	2.92	390	4,270	2.88	9,064	26,108	1.50	0.02	39,197	458	80	87	82
Lamar River	1.74	233	2,788	2.20	5,412	11,902	1.94	0.09	23,061	1,026	86	82	81
Soda Butte Creek	1.55	207	1,906	2.09	4,807	10,645	1.44	0.21	14,443	2,053	72	78	74
Gardiner River	1.55	207	2,958	2.05	4,907	9,747	1.41	0.28	13,762	2,757	82	80	76
Bechler River	1.09	145	1,553	2.25	3,388	7,618	1.00	0.11	7,615	870	79	69	63
Lewis River	1.07	143	2,100	1.93	3,318	6,415	0.98	0.07	6,312	414	62	66	56
Rez Parce Creek	0.73	98	1,394	1.72	2,771	3,910	0.54	0.15	2,105	598	38	49	44
Indian Creek	0.65	87	1,100	1.74	2,000	3,500	2.10	0.23	7,300	800	74	50	57
Gallatin River	0.60	80	880	2.63	1,400	4,800	0.68	0.19	3,300	900	82	74	59
Lewis-Shoshone Ch.	0.54	72	799	2.81	1,667	4,683	1.42	0.09	6,668	417	76	71	71
Falls River	0.54	72	1,076	2.07	1,667	3,445	0.96	0.12	3,314	427	71	68	64
Grebe Lake	0.52	69	970	2.07	1,597	3,308	1.42	0.12	4,709	387	77	78	78
Heart Lake	0.43	74	406	2.47	1,341	3,129	1.20	0.23	1,611	342	100	64	44
Riddle Lake	0.39	52	500	2.12	1,200	2,500	0.59	0.23	1,500	600	90	85	70
Trout Lake	0.37	50	700	1.97	1,200	2,300	0.38	0.09	900	200	41	74	59
Sylvan Lake	0.35	47	700	1.90	1,100	2,100	1.26	0.06	2,600	100	68	71	74
Snake River	0.34	45	700	2.02	1,000	2,100	0.69	0.09	1,400	200	61	64	54

Table 2. Fishery statistics from Yellowstone Park waters with less than 40 angler days per year represented in the sample*

Water	% of total parkwide angler-days	Total reported angler days (VFR)	Estimates for the season					Percent of anglers landing one or more fish	Average experience	% anglers satisfied with:	
			Anglers	Angler days (trips)	Angler hours (effort)	Landing rate	Creel rate			Overall experience	fish sizes caught landed
			$\bar{x}$ length (hours)					$\bar{x}$ size fish landed (inches)	$\bar{x}$ length creel (inches)		
Pelican Creek	0.73	98	1,200	2,300	6,300	1.43	0.02	14.0	9.0	96	91
Lower Creek	0.43	58	640	1,340	2,410	1.36	0.62	9.4	9.7	96	69
Little Firehole River	0.27	36	350	830	1,550	0.77	0.13	9.3	10.9	67	79
Cache Creek	0.26	35	480	810	1,910	2.01	0.27	11.5	11.9	95	88
Obsidian Creek	0.19	26	370	600	920	1.50	0.37	9.2	9.2	61	41
Pebble Creek	0.18	24	300	550	840	1.21	0.23	9.5	11.3	82	67
Clear Creek*	--	52	280	370	790	3.03	0.21	14.3	11.7	96	67
Hellroaring Creek*	--	49	175	344	790	1.71	0.40	9.9	10.6	89	60
Cascade Creek*	--	18	90	130	240	0.77	0.16	10.9	13.0	50	30

* figures presented for these fisheries are an average value for 1978, 1979 and 1980 except for reported use which is the sum of those years.

Table 3. Fisherman use, effort, harvest, and success estimates for Lewis Lake combined boat and shore fishery for 1964, and 1971 through 1980

Year	Angler days	Average length angler day	Angler hours	Landing rate	Total trout landed	Creel rate	Total trout creeled	Weight harvest lbs/acre
1964	8,800	3.0	26,400	0.56	14,800	0.41	11,100	4.9
1971	6,700	3.6	23,900	0.50	11,950	0.33	7,950	-
1972	9,300	3.9	36,400	0.53	19,300	0.30	10,900	-
1973	9,800	3.3	32,300	0.40	12,900	0.21	6,800	-
1974	7,100	3.3	23,400	0.59	13,800	0.26	6,100	-
1975	5,300	3.0	15,900	0.66	10,500	0.28	4,450	-
1976	8,600	3.1	26,300	0.70	18,400	0.23	6,050	-
1977	8,900	3.0	26,600	0.53	14,100	0.23	6,100	3.1
1978	8,700	2.9	25,400	0.52	13,200	0.21	5,300	2.9
1979	9,303	3.2	29,600	0.56	16,600	0.17	5,100	3.2
1980	11,760	3.2	37,100	0.48	17,679	0.17	6,220	2.7
3 years of 5-fish creel limit	8,250	3.5	28,900	0.53	15,350	0.35	9,980	4.9
8 years of 2-fish creel limit	8,700	3.1	27,025	0.54	14,647	0.26	6,990	3.0

Percentage of trout landed measuring over:

Average size:

Year	12 in	14 in	16 in	18 in	20 in	landed (n)	creeled (n)
<u>Brown Trout</u>							
1973	70.4	32.0	15.2	0.8	0.8	13.9 (125)	-
1974	66.6	43.3	16.2	1.9	0.5	13.9 (210)	-
1975	80.6	48.3	10.6	2.0	1.1	14.6 (350)	-
1976	72.8	48.4	18.1	1.1	0.4	14.3 (684)	-
1977	71.1	47.0	15.7	4.0	0	14.2 (598)	15.5 (279)
1978	85.7	57.6	19.0	5.5	0.5	15.2 (559)	16.1 (218)
1979	81.4	58.7	27.1	2.9	0.2	15.1 (543)	16.3 (190)
1980	94.3	78.7	55.2	16.7	4.6	14.7 (681)	15.1 (225)
<u>Lake Trout</u>							
1973	100.0	100.0	30.8	30.8	0	17.3 (13)	-
1974	83.3	70.5	26.3	11.7	10.5	16.3 (86)	-
1975	94.8	79.0	57.9	34.2	6.6	17.6 (76)	-
1976	95.9	80.6	31.6	17.3	6.1	16.6 (98)	-
1977	95.2	87.7	62.6	23.4	3.1	17.6 (227)	17.9 (90)
1978	91.8	75.0	38.8	24.6	4.7	17.0 (232)	17.9 (113)
1979	96.0	90.6	56.0	15.2	2.9	17.3 (277)	18.6 (102)
1980	94.3	78.7	55.2	16.7	4.6	17.1 (174)	17.4 (91)

Despite the recommendation of several important regulation changes (Jones et al 1980), the statutes remained unchanged during 1980. Since we believe these changes are necessary to both protect native fishes and to maintain quality angling, we urge that these regulations be initiated as soon as possible.

PARKWIDE FISHING IN 1980

Recreational visitation in Yellowstone Park increased 5.4% over 1979, to slightly over 2 million visitors (Table 4). Due to problems with permit handling, an accurate count of the fishing permits could not be obtained in 1980. Consequently an estimate of the number issued was made utilizing the relationship between recreational visitation and annual permit issuance during the past seven years. Despite the increase in recreational visitation, the estimated number of permits (184,200) decreased the second year in a row (Table 4). After adjustments for permit holders that did not fish, the number of anglers was estimated to be 130,800 in 1980.

The exit gate survey indicated that anglers spent an average of 2.0 days fishing in the Park and fished approximately 1.12 different waters per day. Computations utilizing these data (Jones et al 1977) yielded estimates of total use (311,260 angler days) and effort (758,000 angler hours) (Table 4). Both figures represent substantial increases over 1979 and equal the second highest estimates since 1973 (Table 4).

An estimated 725,300 fish were landed and 101,000 creeled at a rate of 0.96 and 0.13 fish per hour, respectively (Table 5). Of the fish landed, 86% were released and 14% creeled.

The number of fish landed per average angler trip (2.44 hours) was 2.3, and the number creeled was 0.32 (Table 6). Anglers indicating satisfaction with their fishing trip landed 3.0 fish, whereas those that were unsatisfied landed only 1.3 fish. The average length of fish landed was also higher for satisfied anglers (345 mm or 13.6 inches) than unsatisfied fishermen (300 mm or 11.8 inches).

Species composition was indicated by anglers for 58,430 landed fish; 69.9% were reported as cutthroat trout, followed by rainbow trout (9.4%), brown trout (9.3%), brook trout (6.1%) and lake trout (1.5%). Small numbers of grayling, mountain whitefish, cutthroat x rainbow hybrid and non-game species were also caught.

The average size of landed fish (360 mm or 14.2 in) decreased slightly in 1980 but remained within the range reported since 1973. Of 58,225 fish, about 67% were greater than 305 mm (12 in) and 47% exceeded 355 mm (14 in). The average length of creeled fish was 341 mm (13.4 in). Lake trout were the largest fish landed (475 mm or 18.7 in) followed by cutthroat trout (400 mm or 15.7 in), brown trout (346 mm or 13.6 in), whitefish (345 mm or 13.6 in), cutthroat x rainbow hybrids (320 mm or 11.5 in) and brook trout (252 mm or 9.9 in).

Table 4. Estimates of park recreational visitation, fishing permits issued, total parkwide anglers, total parkwide angler-days, Yellowstone National Park, 1972 - 1980

	1972	1973	1974	1975	1976	1977	1978	1979	1980
Total Park Recreational Visitation:	2,246,827	2,061,537	1,928,915	2,239,483	2,519,224	2,481,933	2,618,380	1,892,908	2,000,273
Percent change from previous year:	---	-8.3%	-6.4%	+16.1%	+12.5%	-1.5%	+5.2%	-38.3%	+5.4%
Park Fishing Permits Issued:	---	169,103	164,600	191,550	213,200	217,000	218,000	195,100	184,200
Percent change from previous year:	---	---	-2.7%	+16.4%	+11.3%	+1.8%	+0.5%	-11.7%	-5.6%
Total Parkwide Anglers:	---	121,888	116,518	138,332	151,730	154,581	155,700	139,100	130,800
Percent change from previous year:	---	---	-4.4%	+17.0%	+11.3%	+1.9%	+0.7%	-11.9%	-6.0%
Total Parkwide Angler days:	---	230,100	220,000	257,300	284,200	311,300	333,800	291,300	311,300
Percent change from previous year:	---	---	-4.4%	+17.0%	+10.5%	+8.7%	+6.7%	-14.6%	+6.9%
95% Confidence Limits:	---	225,500-234,700	215,500-224,300	248,400-266,300	278,500-289,900	304,000-318,500	326,200-341,500	274,500-308,200	287,900-324,600

1) Actual number unknown, figure given is an estimate.

Table 5. Fisherman use, effort, success, and harvest for Yellowstone National Park, 1973 - 1980

Year	Angler days	x length angler day	Total hours fished	Landing rate	Total fish			Percentage anglers satisfied with:			Average total length of fish landed (in.)	Mean expertise level (95% C.I.) ²⁾
					landed	Creel rate	total fish creeled	overall experience	numbers caught	sizes caught		
1980	311,260	2.44	758,000	0.96	725,300	0.13	101,000	73	66	68	14.6	1.87 (1.86-1.88)
1979 ¹⁾	291,300	2.49	725,300	1.01	731,100	0.15	107,300	73	67	68	14.4	1.88 (1.87-1.90)
1978	333,800	2.23	744,400	0.99	736,900	0.17	126,500	73	66	68	14.2	1.86
1977	311,300	2.33	725,300	0.98	710,800	0.20	145,100	75	68	70	14.3	1.83
1976	284,200	2.36	670,700	1.02	684,100	0.20	134,100	74	69	69	14.1	1.90
1975	257,300	2.31	594,400	1.09	647,900	0.23	136,700	77	74	75	14.2	---
1974	220,000	2.42	531,300	0.86	456,900	0.19	101,000	---	---	---	---	---
1973	230,100	2.45	564,400	0.86	485,400	0.16	90,300	---	---	---	---	---

1) Revised from that reported in Jones et al 1980.

2) Based on: 1.0 = inexperienced angler, 2.0 = experienced, 3.0 = expert. 95% confidence interval in parenthesis.

Table 6. Characteristics of satisfied and unsatisfied anglers, and the influence of the relative expertise of anglers to sportfishing success in Yellowstone National Park, 1980

	Mean number days fishing	Mean number hours fished/day	Landing rate (fish/hour)	Creel rate (fish/hour)	Fish landed/ angler-day	Fish creeled/ angler-day	Average length fish landed (in.)	Average ¹⁾ expertise	Sample anglers (n)
Satisfied Anglers		2.55	1.16	0.16	3.0	0.41	13.6	1.01	4420
Unsatisfied Anglers		2.35	0.53	0.07	1.3	0.16	11.8	1.85	1978
sum or x	1.81	2.44	0.96	0.13	2.3	0.32	13.4	1.87	7412
Inexperienced Anglers	1.72	2.24	0.63	0.15	1.41	0.34	13.2	1.0	1415
Experienced Anglers	1.83	2.46	0.98	0.14	2.41	0.34	13.3	2.0	4250
Expert Anglers	1.85	2.69	1.62	0.13	4.36	0.35	13.6	3.0	733
sum or x	1.81	2.44	0.96	0.13	2.34	0.32	13.4	1.87	7412

Satisfaction Matrix

	Satisfied Anglers			Unsatisfied Anglers		
	Overall Satisfaction	Satisfaction with numbers landed	Satisfaction with sizes landed	Overall satisfaction	Satisfaction with numbers landed	Satisfaction with sizes landed
Landing Rate (fish/hr)						
Inexperienced anglers	0.7	0.8	0.7	0.3	0.3	0.4
Experienced anglers	1.2	1.2	1.1	0.4	0.4	0.8
Expert anglers	1.8	1.9	1.7	0.8	0.7	1.5
Creel Rate (fish/hr)						
Inexperienced anglers	0.17	0.18	0.16	0.07	0.08	0.10
Experienced anglers	0.16	0.17	0.16	0.05	0.07	0.08
Expert anglers	0.14	0.15	0.15	0.09	0.07	0.09
Fish Size (Inches)						
Inexperienced anglers	13.3	13.3	13.5	12.6	12.8	11.5
Experienced anglers	13.4	13.4	13.8	11.6	12.7	11.1
Expert anglers	13.8	13.6	14.2	12.1	13.6	11.6

1) Based on 1.0 = inexperienced angler; 2.0 experienced; 3.0 expert.

2) The averages are based on all anglers in the sample. Not all anglers marked satisfaction or expertise boxes therefore the sums of the columns do not add up to the total given.

The percentage of fishermen that reported satisfaction with their overall fishing experience were 73% in 1980. Satisfaction rates with numbers and sizes of fish landed were 66% and 68%, respectively (Table 5).

On the VFR card, fishermen are asked to judge their own technical expertise level, and expertise is then estimated for each water by an arbitrary value whereby 1.0 is an inexperienced angler, 2.0 is experienced and 3.0 is an expert. In 1980, the mean expertise for 7,334 Park anglers was 1.87, a value indicating that most fishermen fall into the inexperienced to experienced category (Table 5).

YELLOWSTONE LAKE

Through the past century Yellowstone Lake has remained the most popular sport fishery in the Park. Despite its great size (35,400 ha or 87,450 acres) and once seemingly inexhaustable trout population, man has had, and continues to have, a significant impact on the Yellowstone Lake cut-throat trout fishery. Large scale spawn taking operations, commercial fishing, efficient forest fire suppression and a 100 year history of almost unabated sport fishery harvests have, both singly and in combination, altered historical trout stocks radically from the original state. Managers attempted to enhance and protect this, the largest inland cut-throat population in the world, and regulations restricting anglers date back to the 1880's. Between that time and 1968, periodic reductions in the creel limit failed to have lasting positive effects, however, and angling success and the condition of the trout stocks declined (Gresswell in press).

A 356 mm (14 in) minimum size restriction imposed in 1970 helped to curb the intense overfishing which occurred during the 1950's and 1960's. Despite initial benefits, however, it soon became evident that rising effort and harvests and a rapid decrease of older and larger trout negated positive changes.

In 1975, a 330 mm (13 in) maximum size restriction was imposed in order to take advantage of compensatory survival in younger age groups and improve the population age structure. With an increase of older and larger trout, the stability and productivity of multiple age spawning stocks would theoretically resemble historic levels. Although the regulation has remained unchanged since its initiation, current regulations emphasize catch-and-release fishing except that two fish may be kept per day if they are under 330 mm (13 in) in length. This regulation was applied to lake tributaries in 1978.

During 1980, fisherman use on the lake comprised 42% of the total park-wide angling use. An estimated 47,800 anglers spent 129,000 angler days and 319,500 angler hours fishing the lake (Table 7). Fisherman use (angler days) decreased in 1980, but effort (angler hours) rose due to the increase in the length of the angler day.

Angler use continues to be most heavily concentrated in the accessible areas including the northwest portion of the lake, the West Thumb segment, western shoreline and eastern shore. The central and southern areas continue to sustain the lowest proportion of use (Table 7). From 1969 through 1974, areas of the lake with easy access accounted for 84 to 88% of the use. Since 1975, annual percentages have ranged from 89 to 94%. The effect of the current regulation on this apparent shift in

Table 7. Fishing statistics from Yellowstone Lake, 1980

Yellowstone lake area:	Predicted totals for season										% Anglers satisfied with:			
	% of lake total	Total VFR use reported	Anglers	X length angler day (hours)	Angler days (trips)	Angler hours	Landing rate	Creel rate	Total fish landed	Total fish creeled	Overall experience	Fish numbers	Fish sizes	Mean expertise
1 Shore Boat	4.18 1.42	234 80	2,764 494	1.85 2.33	5,435 1,853	10,078 4,308	0.63 1.10	0.17 0.37	6,353 4,740	1,732 1,584	71 89	70 85	79 89	1.71 1.64
2 Shore Boat	27.67 19.65	1,546 1,098	13,745 9,616	2.12 2.90	35,955 25,533	76,078 74,088	0.55 0.97	0.14 0.25	41,936 71,794	10,433 18,779	63 80	54 73	67 84	1.74 1.71
3 Shore Boat	7.28 1.32	407 74	3,405 706	2.31 2.66	9,459 1,713	21,826 4,549	0.72 1.40	0.18 0.26	15,662 6,394	3,947 1,163	74 88	64 82	74 85	1.77 1.62
4 Shore Boat	11.83 9.23	661 516	5,752 3,264	2.01 3.27	15,368 11,995	30,884 39,204	0.53 0.81	0.13 0.26	16,282 31,868	3,909 9,995	66 82	51 72	67 80	1.79 1.82
5 Shore Boat	0.03 3.18	2 178	35 1,606	2.83 3.14	38 4,132	108 12,966	1.01 2.06	0.01 0.29	109 26,759	1 3,756	100 98	100 95	100 85	2.00 1.74
6 Shore Boat	0.17 2.91	10 163	106 1,006	2.73 3.51	224 3,783	613 13,277	2.48 2.16	0.37 0.18	1,517 28,634	225 2,364	100 92	100 89	100 89	2.33 1.91
7 Shore Boat	0.42 1.66	24 93	212 371	1.57 2.85	550 2,155	864 6,147	2.52 2.03	0.26 0.20	2,176 12,454	223 1,254	90 100	90 95	80 75	1.91 1.95
Unknown	8.93	499	5,099	2.09	11,599	24,248	0.89	0.17	21,479	4,032	71	62	68	1.83
All boat	39.42	2,202	17,062	3.02	51,215	154,684	1.18	0.25	182,874	38,931	84	77	83	1.75
All shore	51.63	2,884	25,620	2.10	67,079	140,562	0.60	0.15	84,178	20,496	67	57	69	1.76
Entire lake	100.00	5,585	47,782	2.46	129,910	319,533	0.86	0.19	275,162	60,920	74	65	74	1.76

pressure is not clear. Although the accessible areas have smaller trout and thereby provide a greater chance of creeling a limit, rising energy prices may also contribute significantly to affect the apparent shift in use patterns. Regardless of the reason, it has been these more accessible areas which have been historically overfished.

Yellowstone Lake fishermen landed an estimated 275,200 trout and released 214,200. The total angler-caused mortality was estimated at 88,400 (60,900 creeled plus an estimated 27,500 which may have died of hooking wounds following release). Overall landing and creel rates were 0.86 and 0.19 trout/hour, respectively. Landing and creel rates from the boat segment (1.18 and 0.25 trout/hour, respectively) were substantially above those from the shoreline segment (0.60 and 0.15 trout/hour, respectively) (Table 7). Success by area continues to be inversely related to angling pressure, e.g. the more remote areas continue to sustain higher rates than the more heavily fished accessible areas. Sixty-five percent of the lake's one-day anglers landed one or more trout, whereas 35% creeled one or more.

In 1980, the lengths of 20,200 trout were reported from Yellowstone Lake; it is apparent that the illegal harvest of trout over 13 inches is a continuing problem. An estimated 20,400 trout over 13 inches and 3,600 over 14 inches were creeled. Although the number of illegal trout in the creel has declined since the first year of the maximum size limit, the violation rate remains a concern. Not only does the public voice its concern over the level of violations, but the 20,400 illegal trout creeled remains far above an acceptable level.

The age-size structure of the cutthroat population continues to improve since the implementation of the 330 mm size limit (Table 8). The average size of trout landed in 1980 was 371 mm (14.6 in). Length frequencies continue to show general improvement indicating survival of proportionately more fish to older and larger size groups (Table 8). The percentage of trout landed exceeding 406 mm (16 in) in total length (20.5%) continues substantially higher than before the regulation change. The percentages of landed trout measuring over 475 mm (18 in) and 508 mm (20 in) are the highest yet reported.

During 1980, the percentage of fishermen which reported satisfaction with their overall fishing experience was 74%; satisfaction with numbers and sizes landed was 65% and 74%, respectively (Table 7). The average expertise in 1980 was measured at 1.76 on the lake.

Table 8. Average length and length frequencies of cutthroat trout landed and creeled from Yellowstone Lake, 1973-1980

		Number and percentage of trout in length groups (inches):							N	
		<10	10-12	12-14	14-16	16-18	18-20	> 20		
Number of trout reported landed:										
13"	1980	295	1,500	5,418	8,855	3,268	699	212	20,217	
max.	1979	781	2,463	7,042	13,193	5,308	912	237	29,936	
size	1978	1,174	3,878	10,322	14,794	4,523	728	188	35,607	
	1977	645	3,029	10,068	11,778	3,619	613	228	29,980	
	1976	816	3,415	10,160	10,123	2,295	349	94	27,252	
	1975	686	2,634	8,654	8,366	1,571	155	44	22,110	
14"	1974	823	1,861	6,276	8,296	1,097	90	4	18,447	
min.	1973	131	364	1,204	1,521	268	9	0	3,497	
size										
Percentage of trout reported landed:										
13"	1980	1.5	7.4	26.8	43.8	16.2	3.3	1.0	20,217	
max.	1979	2.6	8.2	23.5	44.1	17.7	3.0	0.8	29,936	
size	1978	3.3	10.9	29.0	41.5	12.7	2.0	0.5	35,607	
	1977	2.2	10.1	33.6	39.3	12.1	2.0	0.8	29,980	
	1976	3.0	12.5	37.3	37.1	8.4	1.3	0.3	27,252	
	1975	3.1	11.9	39.1	37.8	7.1	0.7	0.2	22,133	
14"	1974	4.5	10.1	34.0	45.0	5.9	0.5	0.02	18,447	
min.	1973	3.7	10.4	34.4	43.5	7.7	0.3	0	3,497	
size										

Percentage of trout landed measuring over:										
		>12 in	>14 in	>16 in	>18 in	>20 in	Mean length landed		Mean length creeled	
							in	mm	in	mm
13"	1980	91.1	64.3	20.5	4.4	1.0	14.6	371	12.6	320
max.	1979	89.2	65.6	21.6	3.8	0.8	14.6	370	12.4	316
size	1978	85.8	56.8	15.3	2.6	0.5	14.2	360	12.4	314
	1977	87.8	54.2	14.9	2.8	0.8	14.2	360	12.6	319
	1976	84.8	47.5	14.1	2.0	0.3	13.8	350	12.4	314
	1975	84.9	45.8	8.0	0.9	0.2	13.7	349	12.4	316
14"	1974	85.5	51.4	6.5	0.5	0.02	13.8	350	--	--
min.	1973	85.8	51.4	7.9	0.3	0	13.8	350	--	--
size										

Discussion

Thus far, it would appear that the 330 mm maximum size limit is accomplishing the objective of increasing the proportion of older and larger cutthroat trout in Yellowstone Lake. Scattered historic size data and current estimates utilizing the Walford line (Ricker 1975) suggest a maximum of eleven age groups prior to modern angler exploitation. It is doubtful, however, that the cutthroat population could reach historic levels under the current regulation. Ricker (1963) warns that exploitation as low as 5% annually may significantly alter a pristine population.

It is apparent, however, that the 330 mm (13 in) maximum size limit has been more successful at mimicking historic levels than any regulations utilized thus far. Average age at Clear Creek is the highest it has been in the past three decades; the appearance of age VII+ trout is significant. Average lengths of trout landed in the fishery, spawners at Clear Creek and prespawners in fall-set gillnets are the greatest yet recorded.

What may be as important as the shift in population structure is that these changes are occurring while use (in the range of 150,000 angler days annually) and effort (over 350,000 angler hours) remain high. Despite these levels of pressure, the landing rate has been excellent, averaging 0.97 trout/hour since 1975. The continued decrease in creel rate during this period is indeed curious, but data indicate that it is not related to a depletion of legal size trout.

The biological mechanisms of the regulation are not completely understood at present, but harvesting trout prior to maturity shifts fishing mortality to life stages which may better be able to withstand high levels of exploitation. The relatively short period that trout are vulnerable to harvest in Yellowstone Lake may also influence results. Most trout do not enter the fishery until approximately 300 mm (11.8 in) and are beyond the legal limit within one growth season.

As angler use and effort steadily increased, creel limits as low as three trout per day failed to protect the structure of this cutthroat population. Fishing closure or "no kill" (catch-and-release only) fishing would undoubtedly provide maximum protection. The 330 mm (13 in) maximum size limit, however, not only provides substantial protection, but allows a daily creel limit which would satisfy all but the most greedy anglers. Currently five large trout (356-457 mm or 14-18 in) are captured and released for each trout under 330 mm (13 in) creeled. Over two-thirds of all anglers catch one or more trout, and over one-third creel one or more. Excellent landing rates, often associated with "no kill" regulations, have been sustained while anglers have retained the privilege

of harvesting trout for a campfire meal.

Results from Yellowstone Lake fishery during the first five years of the 330 mm (13 in) maximum size limit are indeed encouraging; however, it should be emphasized that these results do not describe an equilibrium condition. The number of years required to evaluate such regulations is unknown, but the decrease of larger fish after the first several years of the 356 mm (14 in) minimum size limit and the continuing changes associated with the 330 mm (13 in) maximum size limit underscore the necessity of long term research.

YELLOWSTONE RIVER

Approximately 114 km (71 miles) of the Yellowstone River flow through the Park. It is our second most popular fishery sustaining about 43,800 angler days in 1980 (Table 1). Riverwide, fishing is considered excellent by accepted western trout standards. In 1980, an estimated 18,300 fishermen spent 106,800 angler hours fishing the river. Anglers landed a total of 124,200 fish and creeled 7,100 for overall landing and creel rates of 1.2 and 0.07 fish/hour, respectively (Table 1). The average length for landed fish was 365 mm (14.4 in), and the average size of fish creeled was 325 mm (12.8 in). Eighty-five percent of the anglers responding by VFR card were satisfied with their overall fishing experience; this is over 10% above the parkwide average. Anglers satisfied with the numbers and sizes of fish landed (81% and 87%, respectively) were similarly above the parkwide averages (Table 1). Riverwide statistics are strongly influenced by the popular catch-and-release segment which accounts for 76% of the total angling activity.

Because of differences in the amount of use, accessibility, fish barriers and species composition, we consider the river to have at least six identifiable fishery segments. These segments have different regulations concerning creel limits and season lengths.

At the end of 1980, catch-and-release only fishing had been in force on a 14.5 km (9 mile) section of the river downstream from Yellowstone Lake for eight years. A 10.3 km (6.4 mile) reach in Hayden Valley was closed to all fishing in 1965 and divides the catch-and-release portion. The first 1.6 km (1 mile) downstream from Yellowstone Lake outlet is also closed. In 1980, the catch-and-release portion hosted 13,000 anglers who spent 33,100 angler days and 81,900 hours fishing for cutthroat trout (Table 9). An estimated 86,600 trout were landed and at a rate of 1.06 trout/hour, and over 1,900 trout were illegally creeled. The average length of cutthroat landed was 394 mm (15.4 in). Fishermen satisfied with overall fishing experience (85%), numbers of fish caught (88%) and sizes caught (91%) was significantly higher on this segment than most of the other fisheries in the Park. Fishermen were highly successful as 78% landed one or more trout.

In 1980, angler use increased and was the highest since the catch-and-release regulation was implemented in 1973. The landing rate was lower than any measured since the beginning of catch-and-release, although recent landing rates continue to be significantly above pre-catch-and-release rates.

Table 9. Creel survey summary, Yellowstone River between Fishing Bridge and Chittenden Bridge, 1951-55, 1967-68, 1970 and 72, and 1973 through 1980¹⁾

	4.2 fish creel limit ⁴⁾ No size limit Bait fishing permitted		3 fish creel limit No size limit Bait fishing permitted		3 fish creel limit 14" minimum size limit Bait fishing prohibited		Catch-and-release fishing only Lures and flies only Bait fishing prohibited		1973	1974	1975	1976	1977 ⁶⁾	1978	1979	1980
	1951 to 1955 $\bar{x}$	1957 to 1968 $\bar{x}$	1970 and 1972 $\bar{x}$	1973	1974	1975	1976	1977 ⁶⁾								
Angler days (trips) ¹⁾	45,430	44,300	45,120	25,000	23,900	27,900	30,900	26,900	26,300	28,900	33,100					
$\bar{x}$ Length angler trip (hrs)	1.97	2.00	1.87	2.35	2.31	2.48	2.45	2.44	2.50	2.60	2.48					
Total hours fished	89,500	88,625	84,400	58,750	55,200	69,200	75,700	65,600	65,700	75,300	81,900					
Landing rate (trout/hr)	2)	2)	0.74	1.74	2.25	2.04	1.43	1.43	1.23	1.10	1.06					
Total trout landed	2)	2)	62,550	102,200	124,200	141,100	108,200	93,500	80,800	82,800	86,600					
Creel rate (trout/hr)	0.41	0.43	0.18	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02					
Total trout creeled	36,700	38,100	14,825	590	550	690	980	1,300	1,100	1,500	1,900					
Angler days per mile ⁸⁾	2,800	4,600	4,700	2,900	2,700	3,200	3,600	3,100	3,000	3,300	8,800					
Angler days per acre ⁸⁾	63	105	107	63	60	70	78	68	66	72	82					
Angler hours per acre ⁸⁾	123	209	199	147	138	173	189	164	164	188	205					
Mean angler expertise ⁷⁾	-	-	-	-	-	-	2.00	1.98	1.99	2.02	2.05					
% Trout landed and released	2)	2)	76.2	99.4	99.9	99.5	99.8	99.6	99.6	99.3	99.1					
$\bar{x}$ Length trout creeled ⁵⁾	3)	13.5"	14.7"	3)	3)	3)	3)	14.3"	13.3"	13.2"	13.4"					
$\bar{x}$ Length trout landed	3)	3)	3)	14.3"	14.4"	14.5"	14.7"	14.7"	15.1"	15.3"	15.4"					

1) Statistics for 1951 through 1972 have been converted from summer to season-long estimates.

2) Trout landed and released were not measured during this period.

3) Not measured.

4) Three years of 5 fish creel limit plus two years of 3 fish creel limit.

5) Illegal beginning in 1973.

6) Revised upward 6% from that reported (Jones et al 1978).

7) Based on formula: 1.0 = inexperienced, 2.0 = experienced, 3.0 = expert.

8) Yellowstone River between Fishing Bridge and Chittenden Bridge is 16 mi long and averages 730 acres. Area open to fishing was 9.7 mi and 425 acres between 1965 and 1972. Beginning in 1973, the open area was 8.7 mi and 400 acres.

Data from fishermen indicated the size of the average trout landed increased from 363 mm (14.3 in) in 1973 to 389 mm (15.4 in) in 1980 (Table 9). Significant improvement in the size structure of the population has also occurred since the implementation of catch-and-release rules:

Percentage of Trout Landed Measuring Over:

Year	12 in	14 in	16 in	18 in	20 in
1980	93.8	77.8	37.6	9.2	1.2
1979	92.5	77.5	35.9	8.7	1.0
1978	91.1	71.6	33.2	9.0	1.8
1977	89.2	68.7	26.2	5.3	0.9
1976	90.0	67.7	24.3	4.4	0.7
1975	92.7	60.4	15.4	2.6	0.3
1974	89.5	63.3	26.6	6.6	1.2
1973	86.3	62.5	17.3	3.1	0.7

Although estimates for 1973 and 1974 suffer from poor sample sizes, beginning in 1975, a minimum of 10,000 trout are represented in the values presented. Results for 1980 show the highest values ever for trout over 356 mm and 406 mm (14 and 16 in, respectively).

The second most heavily fished segment of the Yellowstone River was in the Tower Junction area between Quartz and Little Buffalo Creeks. Regulations there allowed two fish of any size to be creel per day. Also, the season opened about 45 days earlier than the catch-and-release section and that portion of the river above Yellowstone Lake. In recent years, fisherman use has grown in this section to 13% of the river's total use. Estimates indicate angler days were approximately 4,000 in 1976, 6,900 in 1977, 7,300 in 1978, 6,300 in 1979 and 5,700 in 1980. In 1980, 14,200 angler hours resulted in landing and creel rates of 1.2 and 0.2 fish/hour, respectively. Cutthroat trout dominated the catch, but rainbows, hybrids, brooks, browns and mountain whitefish were also reported. The average size of fish landed and creel was 303 mm (11.9 in) and 316 mm (12.5 in), respectively. Satisfaction indices for overall satisfaction, numbers and sizes landed (81%, 76%, and 76%, respectively) were about average for the Yellowstone River and above average for the Park.

The section of the Yellowstone River in the Grand Canyon, which now sustains about 4.5% of the river's total use, has few access points, and the hike from the river is rigorous. Regulations in effect are the same as those described for the Tower Junction segment. In 1980, 2,000 angler days and 4,500 angler hours were expended landing 14,500 trout. This translated into a landing rate of 3.2 trout/hour, one of the highest in the

Park. About 1,700 trout were creeled in 1980, yielding a creel rate of 0.4 fish/hour.

The mean size of trout landed and creeled was 294 mm (11.6 in) and 310 mm (12.2 in), respectively. Overall satisfaction was rated 94%, while satisfaction with numbers and sizes landed was 93% and 70%, respectively.

The upper Black Canyon reach of the Yellowstone between Knowles Falls and Little Buffalo Creek sustained 900 angler days and 2,200 angler hours in 1980. An estimated 3,000 fish were landed and 400 creeled resulting in landing and creel rates of 1.4 and 0.19 fish/hour, respectively. In recent years, about two-thirds of the catch were cutthroat trout, followed by rainbows (and hybrids) and mountain whitefish. The average sizes of fish landed and creeled were 326 mm (12.9 in) and 378 mm (14.7 in), respectively. Satisfaction indices for overall satisfaction, numbers and sizes landed (96%, 92% and 96%, respectively) were excellent and well above the parkwide average.

There has been a slight decrease in angler use and effort in recent years on this reach of the river, but success values show no definite pattern of change.

In the lower Black Canyon section (between the north Park boundary and Knowles Falls), an estimated 300 angler days and 700 angler hours were spent fishing. Since this reach is popular with local anglers who do not return VFR cards as commonly as nonlocals, these values may be conservative. Although measurements from this segment vary widely from year to year (probably due to small sample sizes), estimated landing and creel rates of 1.1 and 0.2 fish/hour, respectively, are about average for the Yellowstone River. In recent years, cutthroat and rainbow (and hybrid) trout and mountain whitefish were caught in about equal numbers; a few brown and brook trout were also reported. The average size of fish landed and creeled (302 mm or 11.9 in and 339 mm or 13.3 in, respectively) has not varied significantly in the past five years. Satisfaction indices (overall 82%, sizes and numbers 73%) were average for the Yellowstone River and for Park fisheries. Considering the limitations of the sample sizes, it would appear that angler use and success measures for this segment have been relatively stable in recent years.

The Yellowstone River inlet to Yellowstone Lake is remote and is only accessible to fishermen in mid- to late summer and fall. The fishing season opens on July 15th, and the stream has the same restrictions as

Yellowstone Lake: catch-and-release only, except that two fish may be kept per day if under 330 mm (13 in) length. Although we estimate 1,200 angler days and 3,800 angler hours were expended in 1980, small sample sizes hamper analysis on this portion. Approximately 5,700 trout were landed and 170 creeled yielding landing creel rates of 1.5 and 0.04 trout/hour, respectively. Cutthroat trout were the only species caught and averaged 403 mm (15.9 in) landed and 377 mm (14.6 in) creeled. Satisfaction indices were all above average; overall satisfaction and satisfaction with sizes were 100% while satisfaction with numbers was 88%.

SODA BUTTE CREEK

Soda Butte Creek, a major tributary of the Lamar River in the northeast portion of the Park, flows 16 miles from the Park boundary to their confluence. A paved road provides easy access along its entire length making the stream especially vulnerable to excessive angler harvest. Although it has been a popular fishery for over 100 years, quality has decreased substantially since the late 1800's when it was known for fast fishing and large trout. Since 1974, angler use has doubled on Soda Butte Creek and is apparently coinciding with Park angler use patterns rather than angling quality or regulations.

Declines in the Soda Butte fishery have been compounded by pollution from mine tailings at an abandoned mine site in Cooke City, Montana. Additionally, nonnative species occur both higher in the drainage and below the stream confluence with the Lamar River. Although plans have been made to remove the mine tailings, the removal of this pollution source may initiate the downstream migration of nonnative trout. A truly healthy and productive native cutthroat trout population undoubtedly provides the best solution to recovering a quality fishery (even with continuing pollution) and to reduce the impact of nonnative immigration if it should occur.

The present trout population is thought to be over 90% cutthroats, 8% rainbows and hybrids and a small percentage of brook trout. Regulations on Soda Butte Creek allow two fish per day of any size to be creeled.

During 1980, about 1,900 anglers spent 4,800 angler days and 10,000 angler hours fishing the stream (Table 1). An estimated 14,400 trout were landed and 2,100 creeled, resulting in landing and creel rates of 1.4 and 0.2 trout/hour, respectively. The average sizes of trout landed and creeled were 267 mm (10.7 in) and 290 mm (11.7 in), respectively. Seventy-two percent of the anglers fishing the stream landed one or more trout.

Angler use on this stream was high in the early 1970's, fell in 1974-75 and has increased since that time. Measures of success continue to be above average for Park waters; however, these rates are believed to be artificially supported by population interaction with the Lamar River which has a documented increase in robustness since catch-and-release regulations were implemented in 1974.

It has been recommended that Soda Butte Creek be restricted to catch-and-release regulations beginning in 1981. These restrictions are expected to begin restoration of the historic potential of this population and significantly improve sport fishing as it has on other restricted streams in this drainage (Slough Creek and Lamar River). An intensive stream survey including population estimates is scheduled for 1981 in order to provide data needed for future monitoring and comparisons with past studies.

HELLROARING CREEK

Hellroaring Creek drains an extensive area north of the Park in the Gallatin National Forest (see Stream Surveys this report). The lowermost 14.5 km (9 mi), which is located in the Park, enters the Yellowstone River at the head of the Black Canyon of the Yellowstone and is popular with day use and overnight backpack fishermen. The stream is thought to contain cutthroat trout, although anglers consistently report catching small numbers of rainbow, hybrid, brook and brown trout. Regulations in the 1970's have allowed two fish of any size to be creel per day.

For 1977-1980, an annual average of 190 anglers spent 405 angler days and 930 angler hours fishing the stream (Table 2). An estimated 1,300 trout were landed and 270 creel at rates of 1.4 and 0.3 trout per hour, respectively. The average size of trout landed was 254 mm (10.0 in).

The number of VFR returns for Hellroaring Creek in 1980 was less than half the average for this creek and makes comparisons difficult (Table 2). The statistical reliability is questionable on waters with less than 40 angler days (Jones et al 1979), but since annual returns have been quite consistent, a drastic decrease in use is indicated. As expected with reduced effort, catch and creel rates rose.

There has been an increasing amount of feedback from anglers who are concerned about what they claim is a declining fishery in Hellroaring Creek. The VFR returns from 1980 may reflect this decline. A more complete stream survey, including population estimates, is planned for 1981 to gather additional information necessary to properly evaluate this essentially native trout fishery.

LEHARDY'S RAPIDS

Monitoring of the cutthroat trout spawning run at LeHardy's Rapids continued in 1980. Weekly sampling was conducted between May 13-July 16, 1980. Beginning May 29, all trout captured were tagged with numbered T-tags and checked for hooking scars and the copepod Salmincola sp. All other sampling procedures remained unchanged from previous years (Varley et al 1976 and Jones et al 1978).

Results and Discussion

A total of 485 cutthroat trout were captured including 2 subadults. The mean total lengths and weights for 293 adult males and 190 adult females were 391 mm and 488 g, and 372 mm and 418 g, respectively (Table 10). Differences between sexes in mean total length and weight were significant again in 1980. No other fish species were observed.

In 1980, the mean lengths of adult males and females, and all adults remained relatively the same as 1979 (Figure 1). From 1974-79, there had been an increasing trend in the mean lengths of trout sampled which coincided with a notable increase in the percentage of trout over 406 mm in length (Figure 2). Although in 1980 there were a slight decrease in mean length and the percent of trout captured over 406 mm, these changes were statistically insignificant. Biological significance is also doubtful since the capture of fewer large fish in 1980 is probably due to a shorter sampling period.

In 1980, the mean weights of both adult males and adult females decreased from 1979, but remained higher than those from 1974-78 (Table 10). This decrease parallels the decline in mean lengths found in 1980 for both sexes.

The sex ratio of adult males to adult females was 1.5:1 in 1980. This is a change in the ratio from 1979 and represents the greatest proportion of males yet recorded at LeHardy's Rapids. Male:female ratios greater than 1:1 have been common in the LeHardy's sample since 1974. This is quite different from other tributaries to Yellowstone Lake, such as Clear, Cub and Pelican Creeks, where ratios since 1945 have been comparatively lower (between 0.59-0.74:1) (Jones et al 1979, Jones et al 1978 and Ball and Cope 1961). On Yellowstone Lake, several different size and creel limits have been implemented and discarded since 1945, but none of these changes have notably affected the M:F ratio. It would appear then, that the change in sex ratio now observed at LeHardy's Rapids is linked to the cessation of harvest under the current restrictions.

Table 10 Total number and average length, weight, and condition factor of cutthroat trout for each year sampled at LeHardy's Rapids, Yellowstone River, 1974 - 1980

Year	Adult Males				Adult Females				All Adults				Immatures & Subadults			
	Number captured	Avg length (mm)	Avg weight (g)	Avg K factor	Number captured	Avg length (mm)	Avg weight (g)	Avg K factor	Number captured	Avg length (mm)	Avg weight (g)	Avg K factor	Number captured	Avg length (mm)	Avg weight (g)	Avg K factor
1974 ¹⁾	177	375	394	0.75	244	352	339	0.78	463	362	363	0.76	43	177	60	0.84
1975	338	385	451	0.78	426	359	363	0.78	775	370	401	0.78	40	205	116	1.04
1976 ¹⁾	531	384	431	0.75	423	362	360	0.75	964	375	399	0.75	29	173	71	1.04
1977 ¹⁾	133	382	429	0.77	111	362	370	0.78	245	373	402	0.77	2	250	139	0.87
1978	399	386	458	0.78	358	364	413	0.85	759	376	437	0.81	68	169	62	0.96
1979	334	394	514	0.83	237	371	431	0.84	571	385	480	0.83	5	225	122	0.91
1980	293	391	488	0.81	190	372	418	0.80	483	384	460	0.81	2	247	184	0.94

1) Due to erroneous measurements, fish were deleted from average weight and K factor calculations only, as follows: 6 males and 2 females from 1974, 1 male and 2 females from 1976, and 1 male and 1 female from 1977.

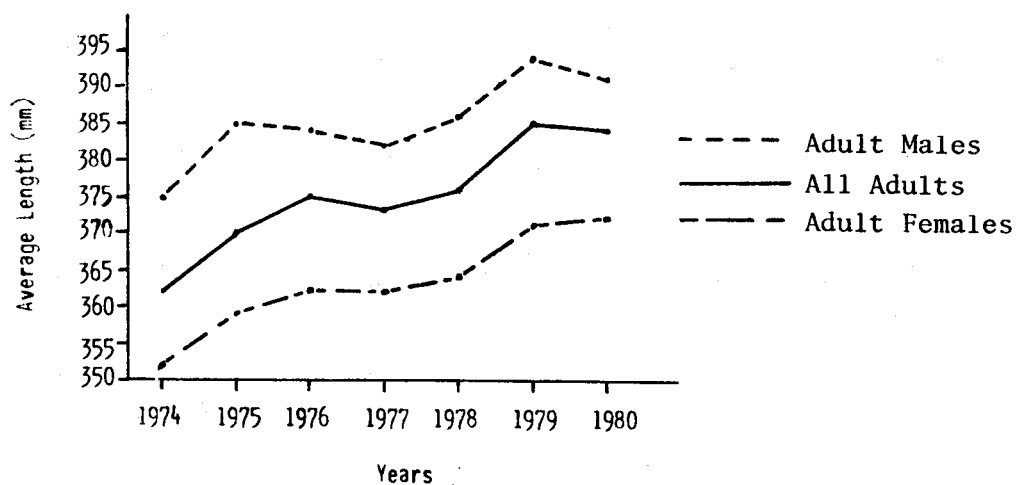


Figure 1. Average lengths for the entire season for adult males, adult females and all adults, LeHardy's Rapids, 1974-1980.

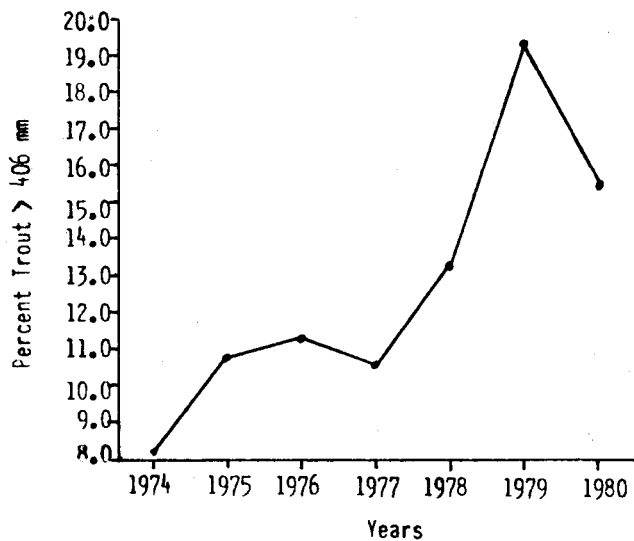


Figure 2. Percentage of adult trout greater than 406 mm captured at LeHardy's Rapids, 1974-1980.

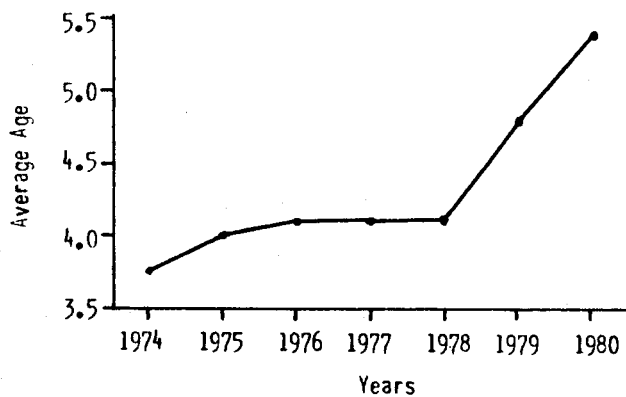


Figure 3. Average age of all adult trout captured at LeHardy's Rapids, 1974-1980.

Ages were determined on 74 of the cutthroats using the scale method (Laakso and Cope 1956) and were then fitted to an age-length key to expand ages for the entire sample (Kimura 1977). The average ages for adult males, adult females and all adults were 5.8, 5.1, and 5.4, respectively. These represent sharp increases in mean age over previous years (Figure 3). As in 1979, fish of age VII+ were once again recorded and appear to have definitely re-established themselves in the river population.

In 1980, hooking scars and the copepod Salmincola sp. were also checked on 451 of the trout captured. From those fish, 159 (35.2%) were found to have the copepod, 35 (7.8%) had hooking scars, 18 (4.0%) had Salmincola sp. and hooking scars and 239 (53.0%) were without either scars or the copepod (Table 11). Those fish having hooking scars only had a large mean length and high mean K factor. This would suggest that generally larger, healthier fish are being caught by anglers. Trout found with Salmincola sp. and both the copepod and hooking scars combined had lower mean K factors than the other two categories, suggesting a weakened, less healthy condition (Table 11).

Conclusions

The following results were found at LeHardy's Rapids:

1. As in 1979, mean lengths in 1980 continued to remain high displaying an increasing trend since sampling began in 1974.
2. The proportion of adult males to adult females (1.5:1) has increased at LeHardy's Rapids since 1974.
3. This year we observed the highest mean age yet determined as well as more definite evidence of the reappearance of age VII+ fish in the river population.
4. Salmincola sp. infested trout have a lower K factor suggesting a weakened, less healthy condition.
5. Sampled trout with hooking scars have large mean lengths and high condition factors.

Recommendations

We recommend that regular weekly sampling should be continued in 1981 to help verify the VFR average lengths and document continuing changes in the catch-and-release section. At this time, it is imperative to continue monitoring trends observed for mean length and age as well as growth patterns and rate of return as determined by the numbered T-tags used during the 1980 field season.

Table 11. Mean lengths, weights, condition factors, numbers and percentages of totals of trout checked for hooking scars and Salmincola, LeHardy's Rapids, 1980

	Mean length (mm)	Mean weight (g)	Mean K factor	Number	Percent of total sampled
Hooking scar (only)	392	493	0.81	35	7.8
<u>Salmincola</u> sp. (only)	382	444	0.79	159	35.2
Hooking scar and <u>Salmincola</u> sp.	393	486	0.78	18	4.0
Without either	382	459	0.81	239	53.0
TOTALS AND AVERAGES	383	457	0.80	451	100.0

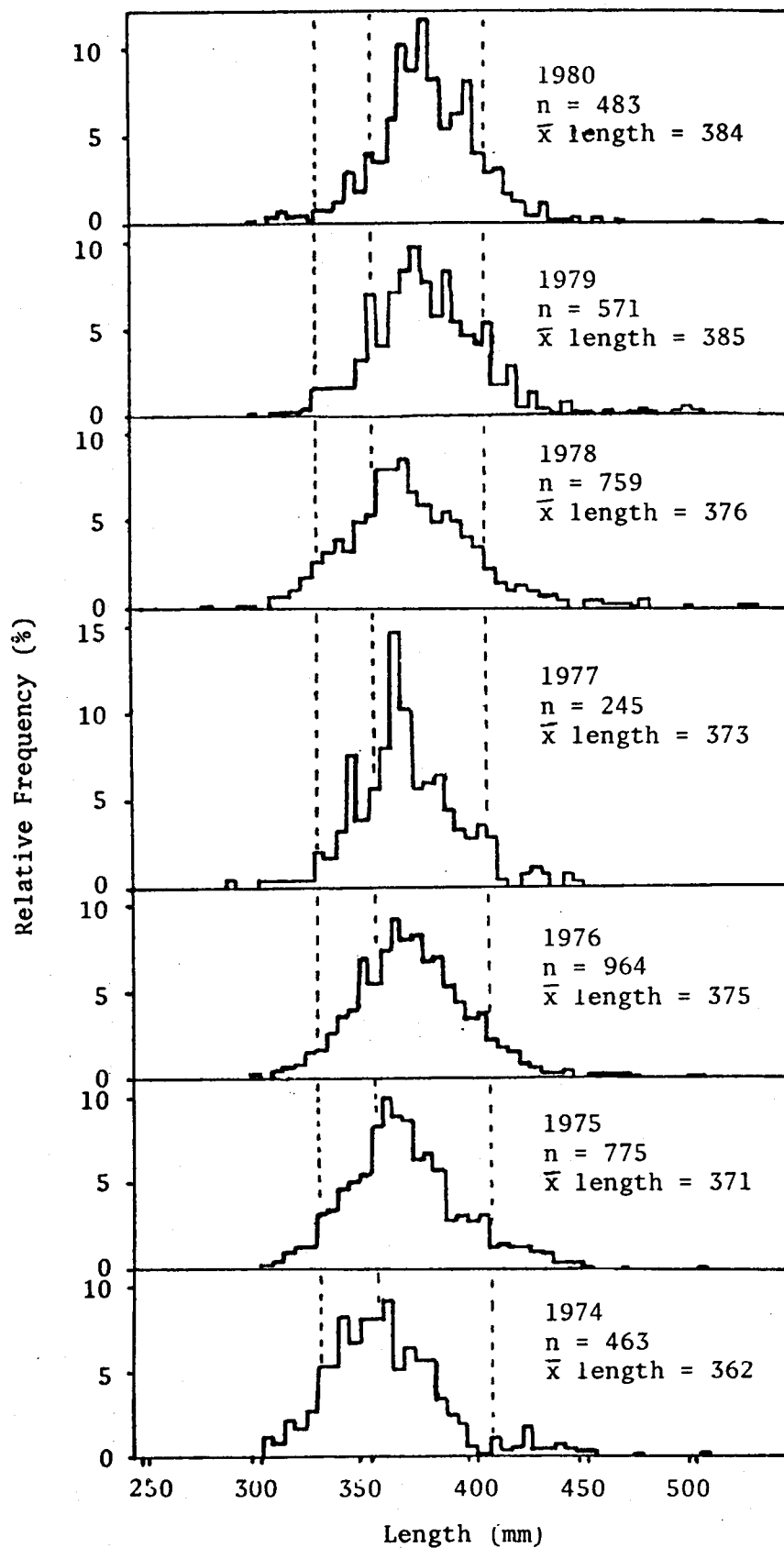


Figure 4. Length frequency of all adult cutthroat captured at LeHardy's Rapids, 1974 - 1980.

Table 12. Mean total lengths of cutthroat trout captured in the Yellowstone River, 1952-1979

Regulations	Year	Mean total length in mm (inches)			Sample size	Area	Source
		Dip net	Electrofishing	Hook and line			
5 fish bag limit, no size limit	1952 ¹⁾	368 (14.5)			382	LeHardy's Rapids	Cope 1953
	1952				107	Above Upper Falls	Cope 1953
3 fish bag limit, no size limit	1967		345 (13.6)		346	Excluding Hayden Valley	Unpublished data
	1967				127	Excluding Hayden Valley	Dean and Varley 1973
	1968		351 (13.8)		351	Excluding Hayden Valley	Unpublished data
	1968				487	Excluding Hayden Valley	Dean and Varley 1973
3 fish bag limit, 14 inch min. size limit	1970				43	Excluding Hayden Valley	Dean and Mills 1971
	1970			424 (16.7)	17	Hayden Valley	Dean 1972
	1971		447 (17.6)		309	Hayden Valley	Dean 1972
	1971		361 (14.2)		378	Fishing Bridge	Dean 1972
	1972				125	Excluding Hayden Valley	Dean and Varley 1973
	1973				2,798	Above falls, excluding Hayden Valley	Jones et al 1976
Catch-and-release	1974 ¹⁾	362 (14.3)			463	LeHardy's Rapids	Dean et al 1975
	1974				3,763	Excluding Hayden Valley	Jones et al 1976
	1975 ¹⁾	370 (14.6)			775	LeHardy's Rapids	Varley et al 1975
	1975				10,540	Above falls, excluding Hayden Valley	Jones et al 1976
	1976 ¹⁾	375 (14.8)			964	LeHardy's Rapids	Jones et al 1976
	1976				11,062	Above falls, excluding Hayden Valley	Jones et al 1976
	1977 ¹⁾	373 (14.7)			245	LeHardy's Rapids	Jones et al 1977
	1977				10,239	Above falls, excluding Hayden Valley	Jones et al 1977
	1978 ¹⁾	376 (14.8)			759	LeHardy's Rapids	Jones et al 1978
	1978				8,950	Above falls, excluding Hayden Valley	Jones et al 1978
	1979 ¹⁾	385 (15.2)			571	LeHardy's Rapids	Current report
	1979				8,495	Above falls, excluding Hayden Valley	Current report
	1980 ¹⁾	384 (15.1)			483	LeHardy's Rapids	Current Report
	1980				7,789	Above falls, excluding Hayden Valley	Current Report

1) All adults only.

CLEAR CREEK CUTTHROAT SPAWNING RUN

Clear Creek flows westward from the Absaroka Mountains and empties into Yellowstone Lake along the east shore. A fish trap above the mouth of this stream has been operated annually since 1977.

The information currently collected at the trap is diverse. Spawner counts and length measurements, some of which date back to 1945, provide an excellent data base for analyzing long-term changes in the cutthroat trout population. Additional information has been collected concerning run duration, instream mortality and age composition of the run. Investigation of the effects of density independent factors, such as water temperature and stream flow, also continues.

Methods

The upstream trap was installed at Clear Creek on May 15 and remained in operation until August 9. During peak runoff it was necessary to remove grates from the weir for one overnight period (May 21-22). The trap box was open daily from 0800-2000 hours. Ascending trout were tallied as they passed through a counting chute (Jones et al 1979) mounted on the upstream side of the trap box.

On May 14, two portable wooden traps were installed to capture downstream migrants. High water forced the removal of these traps from May 20 to June 7. During this period trout were captured from 1300-2400 hours daily as they congregated above the weir. On June 7, one of the wood traps was reinstalled and on June 11, a second permanent downstream trap was installed below the weir. Both traps were operated from 0800-2400 hours daily. Downstream traps were removed for the season on August 14.

Fish sampling procedures were identical for the upstream and downstream traps at Clear Creek. Weekly samples of 100 spawners were collected from each trap for length and weight measurements. Scales from a subsample of 20 trout from each of these collections were used for age determination. Additional scale samples were taken as needed to provide data for the population extremes. Length frequency data (5 mm intervals) were collected from 75 trout daily. All sampled trout were inspected for fin clips.

Daily water temperatures were obtained with a hand thermometer. A staff gauge located approximately 400 m above the weir was used to monitor the pattern of stream discharge. Fifty-nine flow measurements were taken at a transect near the gauge and these data were fitted to a level-flow prediction equation.

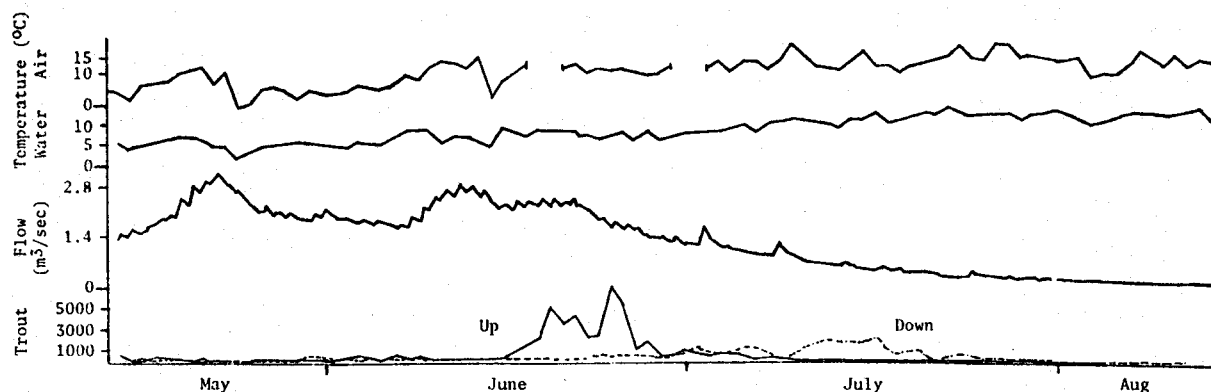


Figure 5. Pattern of daily temperature (air and water), flow, and cutthroat spawning migration, Clear Creek 1980.

Bear activities were monitored daily at the trap. Campsites near the stream were closed to minimize the chance of visitor encounters with bears. Cleanliness procedures were strictly followed (Jones et al 1978).

Results

Upstream migration. A total of 47,115 cutthroat trout were counted through the upstream trap at Clear Creek. The number of migrants fluctuated greatly during the first 33 days (May 15-June 16) varying from 696 (May 15) to 0 (May 23 and 25) (Figure 5). Over 75% of the run (35,467) ascended from June 17 to June 28. After July 9, the run gradually dwindled to an average of 2 fish per day during the final 9 days (August 1-9).

During the downstream migration in 1979, the adipose fin was removed from 42,229 cutthroat trout at Clear Creek (Jones et al 1980). In 1980, 4,516 trout in the upstream run were inspected for clips, and only 237 marks were reported. This suggests that 5.2% of the trout entering Clear Creek were clipped, yielding a 5.8% consecutive-year return of 1979 spawners. Additionally, 33 trout with adipose clips were found at Pelican Creek indicating a 1.3% straying rate for those trout recaptured in 1980.

Mean daily water temperature generally increased throughout the season and ranged from 1.4°C (May 25) to 15°C (July 23). Peak discharge (3.2 m³/sec) occurred on May 23, but levels dropped rapidly for the next 16 days because of cool weather. The flow generally declined after reaching a second peak (2.0 m³/sec) on June 12. Rapid increases in the number of upstream migrants coincided with increasing temperatures and decreasing flows (Figure 5).

Mean total length and weight of upstream cutthroat trout were 391 mm and 500 g, respectively, and the average condition factor (K) was 0.83. The male:female ratio was 0.52:1. Average total length and weight for males (399 mm and 509 g, respectively) were significantly greater than females (388 mm and 495 g, respectively). The weekly average of length, weight and K decreased significantly as the spawning migration progressed (Table 13).

Fingerling trout (presumed yearlings) were first observed near the weir on June 10. Young-of-the-year cutthroat were not seen until July 11. Occasionally somewhat larger trout (presumed age II) were also found after July 1. Despite the occurrence of spawning longnose suckers near the mouth of Clear Creek and directly below the weir, none were captured in the traps.

Downstream migration. A total of 33,841 cutthroat trout were passed downstream at Clear Creek; however, high water severely hampered downstream trap operation and counts were not complete in 1980. Very few migrants were captured prior to trap alterations on June 24. The pattern of the downstream run definitely reflects trap inefficiency during the early portions of the run (Figure 5).

Average total length and weight for the downstream migrants were 396 mm and 471 g, respectively (Table 14). The average K factor was 0.75, and the male:female ratio was 0.74:1. Males had a significantly greater mean total length (404 mm) and weight (509 g) than females (390 mm and 444 g, respectively).

Mean length of downstream migrants differed significantly from upstream migrants. Both males and females in the downstream run displayed significantly lower weights and K factors. As in the upstream migration, there were significant decreases in weekly averages of length, weight and K factors during the study (Table 14).

Bear tracks and partially eaten fish were observed along the stream on several occasions in late June and July; a black bear cub was seen at the weir on July 22. Other wildlife observed feeding in or near Clear Creek during the spawning season included family groups of mink, common loons, common mergansers, California gulls, as well as several ospreys, golden and bald eagles, great blue herons and white pelicans (as many as 24 at one time). An otter was seen in the lake near Elk Point.

Discussion

Although there has been variation in the numbers of spawners entering Clear Creek since 1977, the dynamics of the run appear to be quite

Table 1.3 Weekly mean length, weight, and condition factor of cutthroat trout spawners in the upstream trap in Clear Creek, May 13 - August 4, 1980¹⁾

Date	Males				Females				Totals				M:f ratio
	Number	Average length (mm)	Average weight (g)	Average K factor	Number	Average length (mm)	Average weight (g)	Average K factor	Number	Average length (mm)	Average weight (g)	Average K factor	
May 13 - May 19	29	421	663	0.88	71	400	598	0.93	100	406	617	0.91	0.41:1
May 20 - May 26	39	407	568	0.84	61	392	538	0.88	100	398	550	0.87	0.64:1
May 27 - June 2	32	406	549	0.82	68	390	526	0.88	100	395	533	0.86	0.47:1
June 3 - June 9 ²⁾	33	401	516	0.80	66	389	507	0.86	100	393	509	0.84	0.50:1
June 10 - June 16	30	392	470	0.78	70	387	493	0.84	100	389	486	0.82	0.43:1
June 17 - June 23	34	396	528	0.85	66	390	519	0.87	100	392	522	0.86	0.52:1
June 24 - June 30	39	391	481	0.80	61	383	496	0.88	100	387	490	0.85	0.64:1
July 1 - July 7	31	394	476	0.77	69	387	483	0.83	100	389	481	0.81	0.45:1
July 8 - July 14 ²⁾	20	397	492	0.78	79	384	463	0.81	100	387	468	0.80	0.25:1
July 15 - July 21 ²⁾	34	395	487	0.78	65	382	435	0.78	100	387	454	0.78	0.52:1
July 22 - July 28	45	396	463	0.74	55	380	407	0.74	100	387	432	0.74	0.82:1
July 29 - August 4	24	388	413	0.70	16	383	349	0.62	40	386	387	0.67	1.50:1
Composite	390	399	509	0.79	747	388	495	0.84	1140	391	500	0.83	0.52:1

1) Based on daily samples of cutthroat trout which were both measured and weighed.

2) One trout on June 3 - 9, one on July 8 - 14, and one on July 15 - 21 were not separated by sex but were used in weekly totals.

Table 14 weekly mean length, weight, and condition factor of cutthroat trout spawners in the downstream trap in Clear Creek, May 13 - August 12, 1980¹⁾

Date	Males			Females			Totals		
	Number	Average length (mm)	Average weight (g)	Average K factor	Number	Average length (mm)	Average weight (g)	Average K factor	M:F ratio
May 13 - May 19	5	424	678	0.88	95	401	522	0.80	0.05:1
May 20 - May 26	24	418	623	0.85	76	397	507	0.88	0.32:1
May 27 - June 2	47	410	578	0.82	53	395	489	0.78	0.89:1
June 3 - June 9	50	409	571	0.813	50	388	459	0.78	1.00:1
June 10 - June 16	66	427	633	0.81	34	395	467	0.75	1.94:1
June 17 - June 23	53	411	580	0.81	47	389	444	0.75	1.13:1
June 24 - June 30	37	399	510	0.79	63	389	465	0.78	0.59:1
July 1 - July 7	26	404	519	0.78	74	388	443	0.76	0.35:1
July 8 - July 14	31	391	456	0.77	69	390	427	0.72	0.45:1
July 15 - July 21	54	395	458	0.74	46	382	392	0.70	1.17:1
July 22 - July 28	49	393	423	0.69	51	384	380	0.67	0.96:1
July 29 - August 4 ²⁾	59	395	407	0.66	40	378	340	0.63	1.48:1
August 5 - August 11	45	391	389	0.64	55	384	354	0.62	0.82:1
August 12 - August 14	17	389	368	0.62	12	382	315	0.57	1.42:1
Composite	563	404	509	0.76	765	390	444	0.74	0.74:1

1) Based on daily samples of cutthroat trout which were both measured and weighed.

2) One trout on July 29 - August 4 was not separated by sex but was used in weekly totals.

stable. Larger trout enter the stream first; mean length, weight and K factor gradually decrease during the season. Most males are usually ripe when they enter the stream, but females apparently ripen during the upstream migration.

The seasonal pattern is strongly influenced by stream flows and water temperatures (Figure 5). Since these factors are interrelated, it is difficult to separate their effects; however, numbers increase in June as flow decreases from its peak and water temperature rises above 10° C.

The daily pattern of upstream migration at Clear Creek also appears to be related to flow and water temperature. The number of trout increases from 1300-1700 hours as water temperature rises and flow decreases. As flow rises and temperature drops (1700-2100 hours), the number of spawners declines. Relatively few upstream migrants are seen after dark. This pattern resembles observations at Cub Creek and Pelican Creek in recent years. Although Bulkley (Pers. Com. 1978) reported nocturnal upstream migrations in these streams during the 1950's, all upstream movement has been during daylight hours in the past decade.

Downstream migration during the early weeks of the spawning run is mostly nocturnal and appears to follow increases in stream flow between 1900-2400 hours. This observation suggests that many post-spawners move downstream during periods of heavy runoff. As stream discharge decreases later in the spawning run, the majority of downstream migration occurred between 1300-2000 hours.

Since all spawners leave Clear Creek after spawning and there are no residents other than a small number of yearlings and age II+ cutthroat, the difference between accurate upstream and downstream counts provide an unbiased estimate of instream spawning mortality. The incomplete count of downstream migrants in 1980 prevented a current estimate of mortality; however, from 1977-1979, instream mortality ranged from 6.7% in 1977 to 18.5% in 1978. The mean estimate of 11.5% is much lower than the instream mortality estimate of 48.1% for five tributaries from 1949 to 1953 (Ball and Cope 1961). Only one estimate of 41.2% was made for Clear Creek during that period. Figures were primarily calculated from tag return data, but in 1953, one estimate of 45.6% was based on total upstream and downstream counts in Arnica Creek. Although these earlier findings may be biased by tagging mortality and the use of artificially spawned trout in the estimates, significant changes in the population structure may have occurred due to intensive exploitation in the 1950's.

Analysis of clipped trout at Clear Creek in 1980, revealed a consecutive-year spawner return rate of 5.8%. Returns from Pelican Creek suggest a 1.3% straying rate for those trout marked in 1979. Since additional returns of clipped trout are expected in 1980, complete analysis and thorough discussion is not practical at present.

Comparison of ten years of length frequency data collected since 1961 (Figure) has provided a means of monitoring the influence of angling during this period (Jones et al 1978). The continued shift towards larger trout in recent years has been interpreted as a positive response to increasingly restrictive regulations since 1969.

The current spawning migration at Clear Creek underscores the disastrous effects of low spawner escapement, due both to egg-taking operations and overharvest, during the 1940's, 50's and 60's. Although the current structure of the cutthroat trout population may still be far removed from historic levels, spawning migrations at Clear Creek in recent years indicate the potential of a native cutthroat trout population under protective regulations. The large variety of piscivorous birds and mammals currently associated with the spawning migration illustrates the importance of the cutthroat trout to the Yellowstone Lake ecosystem.

Conclusions and Recommendations

Although the annual spawning run in Clear Creek varies in magnitude and timing, the seasonal pattern of the migration appears to be influenced by decreasing stream flow and increasing water temperature. Larger spawners enter earlier; average length, weight and K factor decrease throughout the season. Recent increases in average size of cutthroat spawners and shifts in length frequency curves appear to be positive effects of the 330 mm maximum size limit.

At Clear Creek, studies on the dynamics of the cutthroat spawning run have revealed that daily upstream migration increases from 1300-1700 hours with increasing water temperature and decreasing flow. The number of upstream migrants declines with decreased temperature and rising flows from 1900-2400 hours; very few fish move upstream after dark. Downstream migration is primarily nocturnal (1900-2400 hours) during peak runoff, but migrations occur between 1500-2000 hours as flow decreases.

Preliminary clip returns indicated a consecutive-year spawner return to Clear Creek of 5.8%. An additional 33 clipped trout at Pelican Creek suggest a 1.3% straying rate of the 52,763 trout spawning at Clear Creek in 1979. Further analysis and comparisons with previous work (Ball 1955; Ball and Cope 1961) will be possible as monitoring efforts continue.

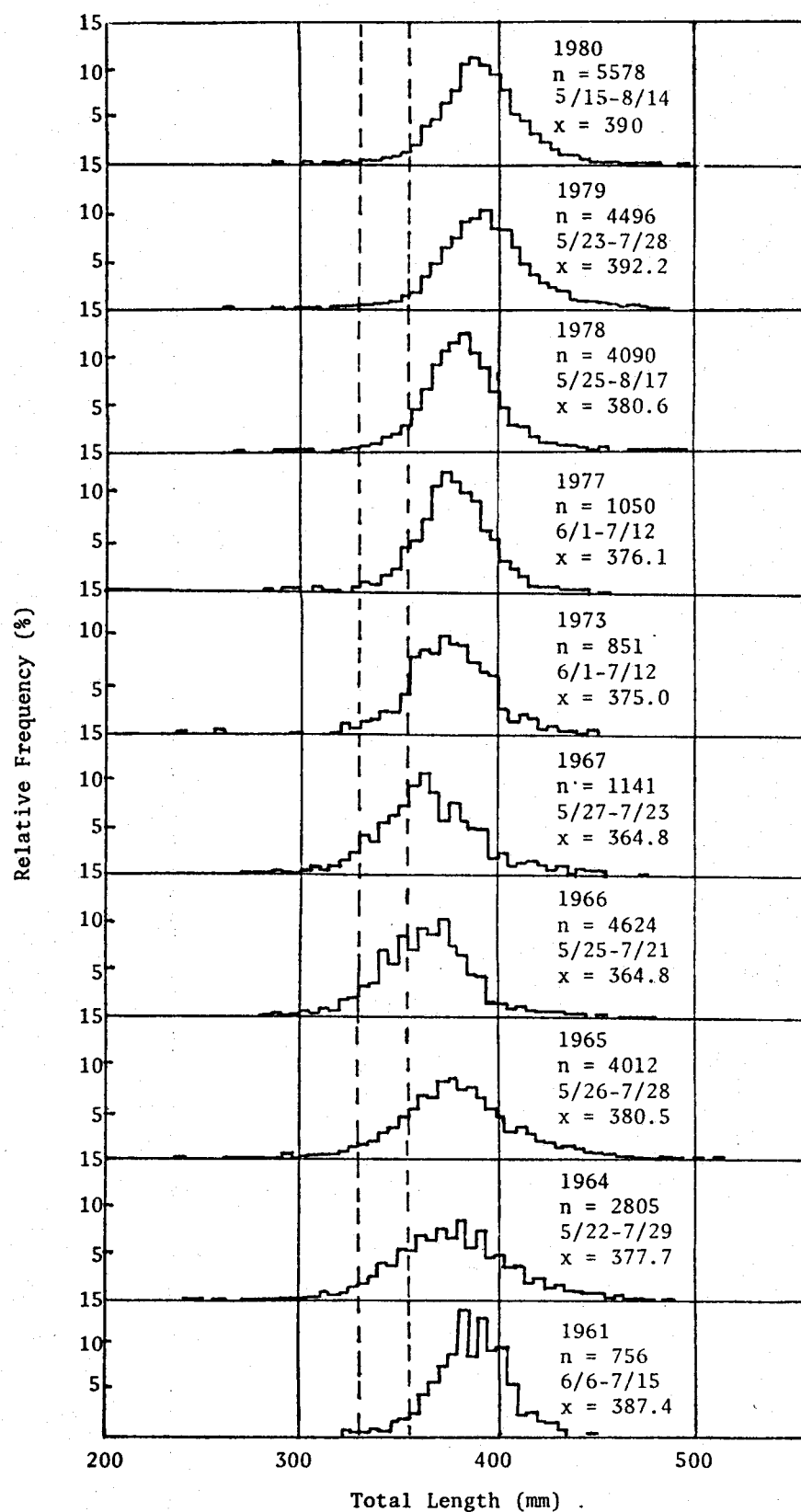


Figure 6. Length frequency of cutthroat trout in the upstream spawning migration in Clear Creek in recent years.

Instream spawning mortality calculations utilize counts of upstream and downstream spawners. Although estimates were not made in 1980, the three year (1977-1979) average instream spawning mortality (11.5%) is substantially lower than the average estimate of 48.1% for five tributaries from 1949-1953.

We recommend that studies on Clear Creek continue in order to gain further understanding of the dynamics of this important spawning population. Such studies should include emphasis on the frequency of repeat spawning and the occurrence of alternate and consecutive spawners in the Clear Creek stock. Efforts to describe the daily migration pattern (both upstream and downstream) should also continue in 1981.

PELICAN CREEK SPAWNING RUN

Entering Yellowstone Lake along the north shore about 2.4 km east of Fishing Bridge (Figure 7), Pelican Creek is the largest tributary to the northern portion of the lake. Total stream length is about 160 km, and the drainage area has been estimated at 15,540 ha. Although late summer flows are low ($1 \text{ m}^3/\text{sec}$), peak flow may exceed $28 \text{ m}^3/\text{sec}$ (Ball and Cope 1961).

A fish trap (approximately 1.6 km above the mouth) was utilized for spawntaking activities in Pelican Creek from the early 1900's until 1953. Because of its potential value for monitoring the spawning population, the trap was not removed when hatchery operations ceased. The current trap, built in 1963, is located several hundred meters upstream of the old trap. Continued erosion problems at the trap have resulted in frequent alterations including the addition of a 12 m wide bypass weir (1978), a total reconstruction of the main weir apron (1979) and modification of the bypass weir (1980).

Fishery information for the Pelican Creek spawning run, including spawner counts and length measurements date back to 1945. The trap was operated annually from 1976-1979 for the continued collection of population data and the experimental destruction of the longnose sucker run (an exotic to the lake drainage). With the deletion of the sucker removal program, emphasis of the trap operation in 1980 shifted to the description of the dynamics of the cutthroat trout spawning migration. In addition to spawner enumeration and trout size data, current investigations include determination of run duration, instream mortality, age composition and effects of density independent factors, such as water temperature and stream flow.

Methods

The upstream trap was installed on May 9 and remained in operation until August 8. Traps were manned daily until July 25 when operation was limited to weekdays. Normally the trap was opened about 0800 hours, but fish processing did not usually begin until 1100-1300 hours. During the early portion of the run, traps remained open until 2100-2200 hours, but beginning June 11, the trap was closed for the day between 1700-1800 hours.

All trout and suckers were removed from the trap with dipnets, and fins were clipped to provide future identification. Both left pelvic and adipose fins were removed from the trout; suckers received a caudal fin clip. After clipping, fish were counted and released upstream.

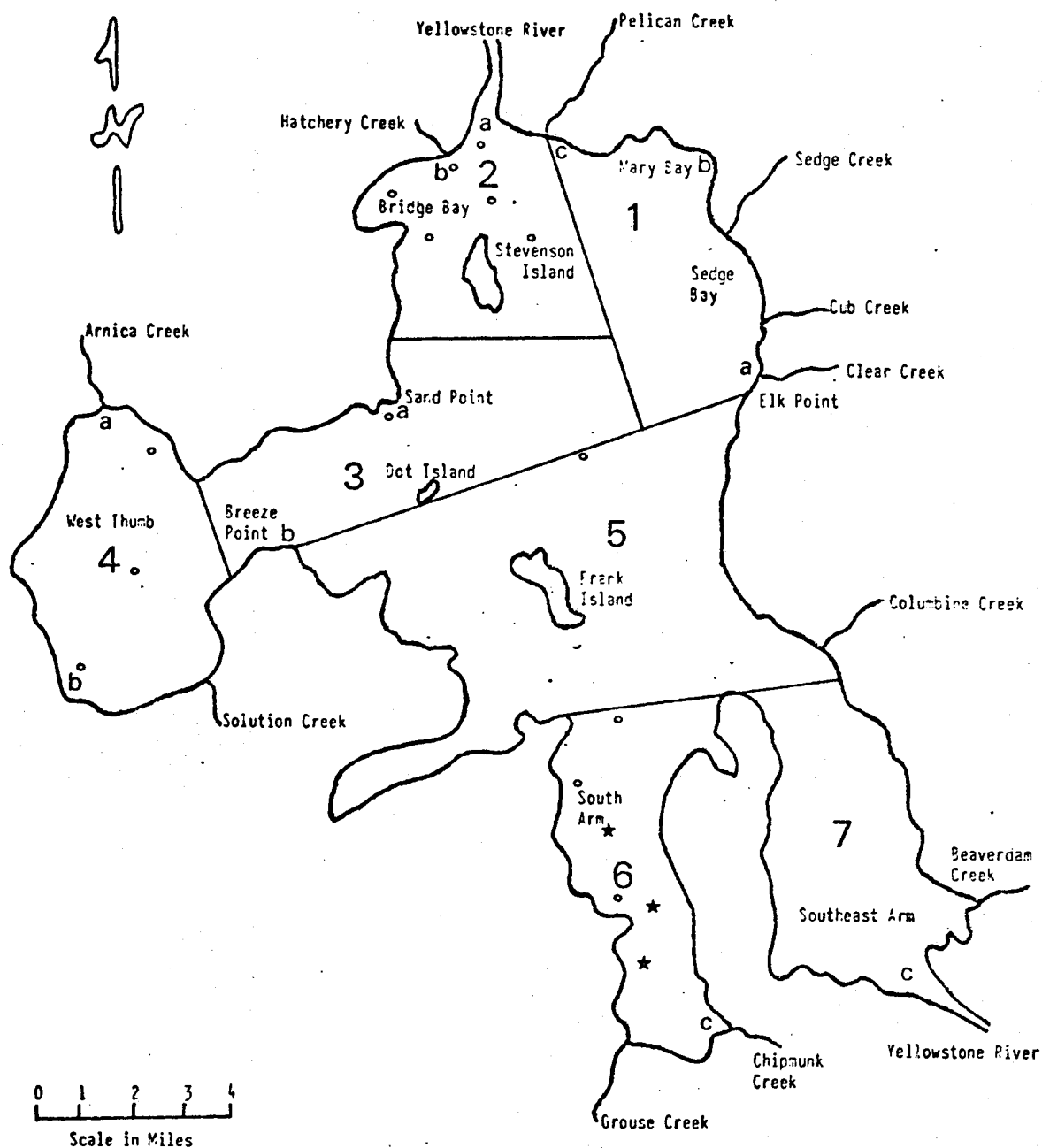


Figure 7. Creel survey, gillnetting, plankton sampling (★) and spawning trap sites, Yellowstone Lake, 1980.

Until June 3, downstream migrants were merely netted over the weir as they congregated upstream. On that date, a downstream trap was assembled on the east end of the weir, and this trap remained operational until August 22 (after August 8, the trap was run on August 11, 18 and 22 only).

During peak runoff, it was necessary to remove grates from the weir. Grates were out for several 24 hour periods (May 10-11, May 23-26) and 7 additional overnight periods (May 9, May 18-22 and May 28).

Fish sampling procedures were similar for upstream and downstream traps. Weekly samples of 100 cutthroat spawners were collected from each trap for length and weight measurements. Scales from a subsample of 20 trout were used for age determination. Additional scale samples were taken as needed to provide data population extremes. Length frequency (5 mm intervals) were collected from 75 trout daily; in the downstream run, 75 clipped trout and 75 unclipped were measured. Both length and weight data were collected from all previously tagged suckers and trout. Additionally, all tagged suckers were killed and opercles were removed for age determination.

A hand thermometer was used to take frequent water temperature observations, and from this data daily extremes were obtained. No attempts to measure water level were made in 1980. Bear activities were monitored daily, and cleanliness procedures were strictly followed (Jones et al 1978).

Results

Cutthroat Trout

Upstream migration. A total of 23,150 trout (including 729 trout which had already been clipped at Pelican Creek in 1980) were passed upstream at Pelican Creek. The number of migrants remained low for the first 19 days (May 9-May 27), varying from 7 (May 9) to 465 (May 17) (Figure 8). Approximately 81% of the run (18,656) ascended between May 28 and June 14. After June 14, the run gradually diminished to an average of 1.5 trout/day for the final 30 days (July 10-August 8).

Mean daily water temperature generally increased throughout the season and ranged from 5.4° C (May 9) to 24.4° C (July 24). Water flow appeared to peak on May 26. As with Clear Creek, rapid increases in the number of upstream migrants coincided with increasing temperatures and decreasing flows (Figure 8).

Mean total length and weight of upstream cutthroat trout were 381 mm and 444 g, respectively, and the average condition factor (K) was 0.79. The

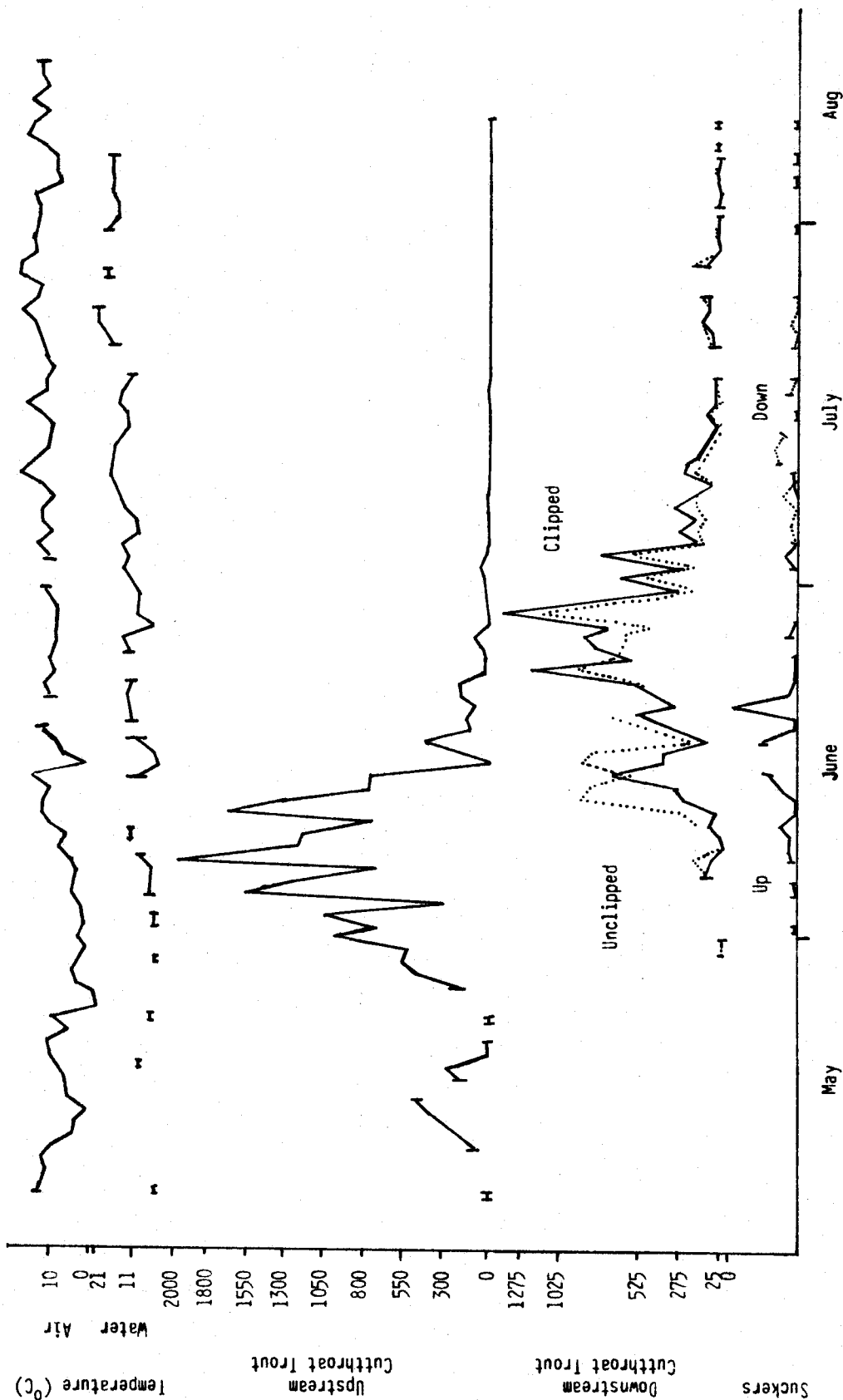


Figure 8. Pattern of daily temperature (air and water), and cutthroat trout and longnose sucker spawning migrations, Pelican Creek, 1980.

male:female ratio was 0.79:1. Average total length and weight for males (384 mm and 453 g, respectively) were significantly greater than females (377 mm and 432 g, respectively). The weekly average of length, weight and K decreased significantly as the spawning migration progressed (Table 15).

A total of 34 tagged cutthroat trout were recaptured in 1980, representing a 11.4% consecutive-year return of the 296 tagged trout released in 1979 (Jones et al 1980). There was a 5 mm increase in the mean length of the recaptures when compared to the original tagged sample (384 mm and 378 mm, respectively). All tagged trout were released upstream after processing.

Downstream migration. A total of 32,777 cutthroat trout (15,792 clipped; 16,734 unclipped) were passed downstream at Pelican Creek. During the first 34 days, lakeward migration was low and varied from 0 (May 9-29, June 5) to 319 (June 11) (Figure 8). Approximately 80% of the postspawners migrated between June 12 and July 3. An average of 63 trout/day were captured during the final 11 days of operation. A higher percentage of unclipped trout were observed during the early part of the run, but after June 20, clipped fish were more common.

The weekly length-weight samples of 100 lakeward migrants provided an overall composite of the downstream run (Table 16). Average total length and weight were 380 mm and 392 g, respectively. The average K factor was 0.71, and the male:female ratio was 0.51:1. Males had a significantly greater mean total length (392 mm) and weight (423 g) than females (379 mm and 386 g, respectively).

In order to further investigate the dynamics of the downstream migration, immatures were deleted from both clipped and unclipped trout, and these two groups were analyzed separately (Figure 9). Although average length of the combined unclipped sample dropped drastically during the middle portion of the season, deletion of the immatures dampened these changes almost completely. Apparently immatures had much less effect on the clipped sample. Regardless of the effect of the immatures, unclipped trout were larger during the initial and final weeks of the run, but were smaller than clipped trout during peak periods.

Comparisons of mean length between the upstream and downstream runs were also complex. When only clipped trout were considered, there were no significant differences between runs, but if unclipped trout are included the interpretation becomes confounded by immatures. As the previous analysis of clipped and unclipped trout indicated, if the immatures are included, the downstream run would have a lower mean length than the upstream run. Regardless of combination, weights and K factor were

Table 1.5 Weekly mean length, weight, and condition factor of cutthroat trout spawners in the upstream trap in Pelican Creek, May 13 - July 9, 1980

Date	Males			Females			Totals			M:f ratio
	Number	Average length (mm)	Average weight (g)	Average length (mm)	Average weight (g)	Average K factor	Number	Average length (mm)	Average weight (g)	Average K factor
May 13 - May 19	56	407	574	43	385	0.84	100	397	540	0.65
May 20 - May 26	28	391	550	35	375	0.91	63	382	502	0.89
May 27 - June 2	56	388	488	44	373	0.84	100	381	477	0.86
June 3 - June 9	32	387	440	68	384	0.75	100	385	446	0.78
June 10 - June 16	43	386	436	57	380	0.75	100	382	435	0.77
June 17 - June 23	34	372	395	66	375	0.75	100	374	397	0.75
June 24 - July 2	34	379	380	45	369	0.69	79	373	373	0.71
July 3 - July 9	26	361	358	62	375	0.74	88	371	380	0.74
Composite	309	384	453	420	377	0.78	730	381	444	0.79

Table 16 Weekly mean length, weight, and condition factor of cutthroat trout spawners in the downstream trap in Pelican Creek, June 10 - August 10

Date	Males				Females				Totals				
	Number	Average length (mm)	Average weight (g)	Average K factor	Number	Average length (mm)	Average weight (g)	Average K factor	Number	Average length (mm)	Average weight (g)	Average K factor	M:f ratio
June 10 - June 16	18	385	441	0.77	82	376	405	0.76	100	377	411	0.76	0.22:1
June 17 - June 23	29	398	460	0.74	71	368	358	0.72	100	377	387	0.72	0.41:1
June 24 - June 30	35	387	408	0.70	65	378	366	0.68	100	381	381	0.68	0.54:1
July 1 - July 7	38	388	393	0.66	57	380	352	0.64	100	379	361	0.65	0.67:1
July 22 - July 28	36	389	430	0.73	57	379	372	0.68	100	372	374	0.72	0.63:1
July 29 - August 3	31	399	413	0.65	65	387	414	0.71	100	383	408	0.70	0.48:1
August 4 - August 10	44	395	416	0.67	53	388	436	0.74	100	389	420	0.71	0.83:1
Composite	231	392	423	0.70	450	379	386	0.70	700	380	392	0.71	0.51:1

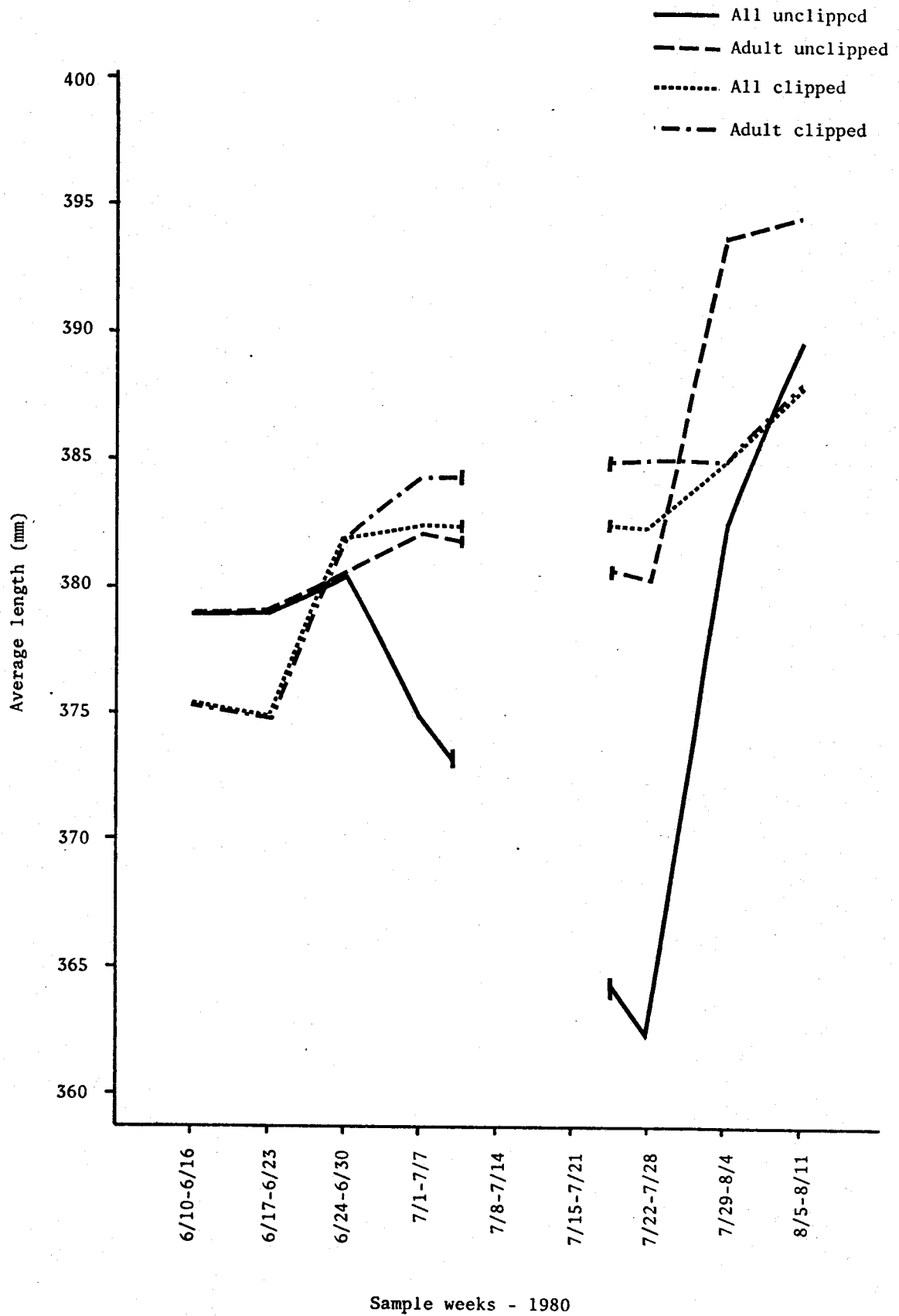


Figure 9. Average length of cutthroat trout (clipped and unclipped) in the downstream trap at Pelican Creek, 1980.

significantly lower for lakeward migrants. Unlike the upstream migration, however, mean length, weight and K factor did not display a decreasing trend through time (Table 16).

Although no bears or bear tracks were observed in the area, other wildlife forms were abundant. Piscivorous animals included otters, ospreys, belted kingfishers, bald eagles and great blue herons. Moose were abundant throughout the season in the large meadow area of the Pelican Creek floodplain, but bison were observed mainly in the earlier portion of the season. Other animals associated with the aquatic system included muskrats, widgeons, scaup and beaver.

Longnose suckers

A total of 1,494 longnose suckers were passed upstream. Numbers peaked in mid-June as the upstream trout run decreased and the downstream migration was increasing (Figure 8). The upstream sucker run began as water temperature rose above 14.4° C and flows decreased well below peak.

Mean length for 326 suckers was 374 mm. Females had a significantly greater mean length than males (397 mm and 362 mm, respectively). Male:female ratio was 1.8:1.

A total of 21 tagged suckers were recaptured. Mean length and weight for tagged suckers were 407 mm and 757 g, respectively; mean K factor was 1.11. Only one female was recovered, and total length for this individual (441 mm) was greater than any of the males captured (mean: 403 mm).

Only 684 longnose suckers were counted during the downstream migration. Average length for 645 suckers (583 clipped; 62 unclipped) was 388 mm. Again females were larger than males (401 mm and 375 mm, respectively). Male:female ratio was 0.97:1. Average length for downstream migrants was significantly greater than upstream, but differences were only found in males. When clipped suckers were compared to unclipped, the latter had a significantly greater mean total length (388 mm and 412 mm, respectively).

Discussion

The spawning migration at Pelican Creek began much earlier than Clear Creek again in 1980. Larger trout entered the stream first; mean length, weight and K factors decreased during the season. Most males were ripe when they entered the stream, but females apparently ripened during the

upstream migration. The number of spawners increased as water flow decreased from its peak and temperature began to rise toward 10° C. Reappearance of clipped trout in the upstream trap indicated that about 3.1% of the trout entered the trap more than once.

Daily migration patterns were similar to Clear Creek. Very few fish moved upstream in the morning, but by 1200-1300 hours, large numbers were entering the trap. Most upstream movement ceased at about 1700-1800 hours daily. It would appear that temperature was a significant factor for triggering daily upstream movement, and combined with increasing flows in the late afternoon, probably influences the daily decline in numbers. Although the majority of downstream movement also occurred in the afternoon, this pattern may have been influenced by trap operational procedures (hours of operation).

Because of the complex pattern of downstream movement in Pelican Creek, it is impossible to obtain an unbiased estimate of instream mortality. Downstream migrants outnumbered upstream migrants even when immatures (approximately 3.3% of the downstream run) were deleted from the totals. Although 31.8% of the clipped trout did not return, the high percentage of unclipped adult migrants suggests that some adfluvial trout remain in the stream overwinter.

Comparison of six years of length frequency data since 1960 (Figure 10) provides a means of monitoring the influence of angling during this period (Jones et al 1978). The shift towards larger size in recent years suggests a positive response to increasingly restrictive regulations since 1969.

The low number of suckers entering the upstream trap in 1980 reflects the intensive efforts to destroy the run from 1976-1979. During that period, 39,391 suckers were removed from Pelican Creek. Both males and females were significantly smaller in 1980, further illustrating the effects of the control program. Apparently a large proportion of the current run was comprised of younger, perhaps initial spawners; the remainder were probably "strays" from other spawning areas.

Conclusions and Recommendations

Although the spawning runs at Pelican Creek and Clear Creek differ distinctly in terms of species composition, magnitude, timing and spawner size, factors influencing the season migration, such as temperature and flow, appear to

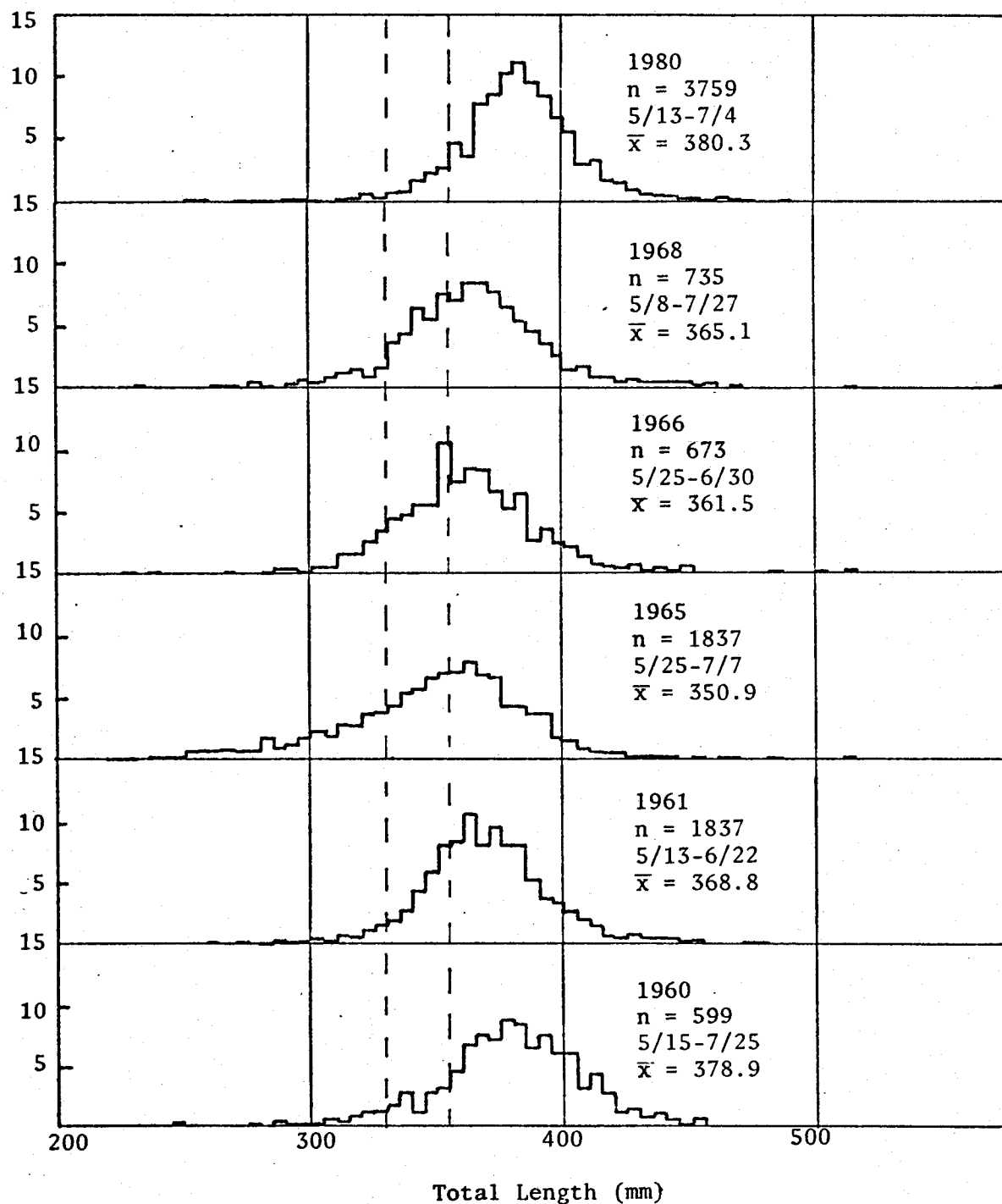


Figure 10. Length frequency of cutthroat trout in the upstream spawning migration in Pelican Creek in recent years.

operate in a similar manner in both streams. In each stream, larger spawners enter earlier; length, weight and condition factors decrease during the season. Males are usually ripe upon stream entry, but females apparently ripen while in the stream. Recent increases in average size and shifts in length frequency appear to be positive effects of the 330 maximum size limit.

The complex downstream migration pattern in Pelican Creek precludes instream spawning mortality estimates. The appearance of immature trout (mean length: 160 mm) indicates that a substantial number of trout use the stream as a nursery area before entering the lake. Although some of the unclipped adults were undoubtedly trout which entered the stream prior to trap installation, there was a substantial lakeward migration of adult trout which may have overwintered in the stream.

We recommend that trapping operations on Pelican Creek continue in order to gain further insight into the complex dynamics of this important tributary system. Studies should include continued monitoring of marked trout in attempts to determine the occurrence of alternate and consecutive spawners in the trout population. The extent of stream utilization by cutthroat and sucker spawners should also be determined. This information will be extremely useful for future comparison as the spawning population of long-nose suckers increases.

LARGEMESH GILLNETTING

The objective of the largemesh gillnetting program has been to monitor relative abundance and population structure of cutthroat trout and longnose suckers in Yellowstone Lake. In order to reduce variability and enhance the interpretation of data, the experimental design has been altered since the program was initiated in 1969. Despite changes, data has remained comparable for the ten years in which studies have been conducted. Jones et al (1977, 1978, 1979 and 1980) provide summaries of previous results.

In 1980, gillnets were set September 15-19 (Figure 7). All sampling procedures, including terms used to describe stage of maturity (Jones et al 1979), remained the same as 1978. Additionally, gonad weights were recorded for 84 of the trout sampled.

Results

Cutthroat Trout - 1980

A total of 715 cutthroat trout (13.0 trout per net) were captured. Average length and weight were 309 mm and 329 g, respectively (Table 17). Average condition factor (K) was 0.88.

Comparison of length and stage of maturity indicated that most trout less than 300 mm were nonspawners (Table 17). The percentage of nonspawners was greater than 40% up to 356 mm. Male prespawners were larger than female prespawners and dominated all size-groups above 381 mm.

The number of trout captured differed significantly among the 11 netting sites. Sites 1b, 4b, and 1c had the greatest catch per net (20.6, 18.0 and 17.0, respectively) and sites 2a, 1a and 7c had the lowest (5.8, 6.8 and 8.8, respectively) (Table 18).

When net catches were combined into four lake zones (North: 1a, 1b, 1c, 2a, 2b; Central: 3a, 3b; West Thumb: 4a, 4b; and South: 6c, 7c), differences between zones were not statistically significant. West Thumb had the greatest mean number per net while Central had the lowest (15.3 and 11.9, respectively) (Table 18).

Average total length of trout differed significantly among the 11 netting sites. Trout from site 7c were significantly larger than all other sites. The smallest trout were captured at sites 4a, 1a and 4b (Table 18).

Table 17 Length frequency distribution, average lengths and weights, and condition factors of prespawning and nonspawning cutthroat trout and longnose suckers captured in large-mesh gillnets, 1.5 - 4.6 m depth interval, Yellowstone Lake, 1980

Interval, Yellowstone Lake, 1980																							
Species	Maturity ₁ category	Size-group (total length - mm)															Total number	Average total length (mm)	Average weight (g)	Average condition factor (K)			
		101	127	152	178	204	229	254	279	305	330	356	381	406	432	457					483	508	533
Cutthroat trout	Nonspawners	1		20	63	60	81	69	23	33	49	59	45	10	3			516	281	248	0.87		
	Prespawning males					1		1		3	7	24	41	13	10	2		102	389	552	0.91		
	Prespawning females									1	13	43	32	8				97	376	487	0.91		
	TOTALS and AVERAGES	1		20	63	61	81	70	23	37	69	126	118	31	13	2		715	309	329	0.88		
Longnose suckers	Nonspawners			19	8	22	26	16	13	12	4							120	241	176	1.08		
	Prespawning males						1	3	26	28	31	21	50	49	16	1		226	370	667	1.25		
	Prespawning females								1	2	11	20	24	23	56	47	15	2	1	202	432	939	1.38
	TOTALS and AVERAGES			19	8	22	27	20	39	42	46	41	74	72	72	48	15	2	1	548	365	660	1.17

1) Prespawning fish defined as those judged to have sufficient gonadal development to spawn in 1980; nonspawners include immature, and mature fish which were judged to lack sufficient gonadal development to spawn in 1980.

2) Weights were not obtained from 44 cutthroat nonspawners.

Table 18 Gillnet catches of cutthroat trout by areas, Yellowstone Lake, 1969, 1970, 1971, 1972, 1974, 1976, 1977, 1978, 1979, and 1980¹⁾

Area	Number per net ²⁾										Average total length (mm)										Average weight (g)									
	1969	1970	1971	1972	1974	1976	1977	1978	1979	1980	1969	1970	1971	1972	1974	1976	1977	1978	1979	1980	1969	1970	1971	1972	1974	1976	1977	1978	1979	1980
1A	3	10	15	15	11	19	10	14	12	7	277	290	291	297	249	315	301	286	276	279	213	311	249	269	167	322	273	254	222	357
1B	19	18	5	13	12	9	23	9	18	21	293	308	363	253	330	322	261	327	281	302	272	279	363	276	341	337	214	360	245	392
1C	5	10	23	21	25	22	15	15	12	17	322	327	306	262	304	306	305	281	312	310	317	348	267	231	267	280	292	235	316	316
2A	17	11	21	16	21	11	16	10	10	6	328	365	326	329	300	337	290	313	322	344	359	450	318	350	269	363	268	336	335	418
2B	5	15	8	12	26	21	21	17	9	14	378	279	379	321	266	291	286	298	306	309	527	223	452	352	200	267	258	242	303	314
3A	3)	20	3)	17	6	19	19	16	19	12	3)	352	3)	296	284	302	265	293	280	308	3)	362	3)	262	253	255	219	283	239	369
3B	3)	9	3)	3	12	15	12	14	12	12	3)	352	3)	368	311	324	341	319	306	341	3)	390	3)	410	290	322	399	337	304	410
4A	3	2	3)	9	19	13	7	15	16	13	360	352	3)	358	290	331	283	286	288	268	411	320	3)	405	265	331	256	260	255	217
4B	28	32	3)	19	12	10	15	18	18	18	290	280	3)	334	301	324	269	302	294	286	261	249	3)	358	285	306	215	290	280	255
6C	14	7	3)	8	6	12	12	13	12	15	341	364	3)	349	348	330	344	342	374	339	403	438	3)	459	361	353	430	416	517	430
7C	16	1	3)	17	20	14	22	13	10	9	300	224	3)	329	324	337	292	365	335	345	249	108	3)	349	309	358	270	479	400	414
Totals	110	135	72	150	170	165	682	766	748	715																				
Averages											311	315	321	313	298	317	290	308	303	309	312	320	305	320	266	314	271	316	301	329

1) Experimental gillnets (38.1 m long) set overnight (7.6 m graduated mesh panels 19, 25, 32, 38, and 51 mm) in the 1.5 - 4.6 m depth interval.
 2) From 1969 - 1976, only 1 set was made in each area at the specified depth interval; for 1977, the number represents an average of 4 sets and for 1978, 1979, and 1980, represents an average of 5 sets.
 3) Areas not sampled.

Differences between sites in the length of prespawners were also significant. The relationships between site and the average length of prespawners and the average length of all trout captured differed; however, site 7c had the largest trout in both cases.

When length comparisons of all trout were made by zone, cutthroat in the South were significantly larger than those from other zones. Prespawners were also compared by zone, and significantly larger trout were again found in the South. The effect of smaller trout on average length is illustrated by the length-frequency histogram (Figure 11).

A gonadal-somatic index (GSI) (LeCren 1951) was calculated for 84 cutthroat trout. Nonspawning cutthroat greater than 304 mm (TL) had significantly lower GSI values (0.09 and 0.45 for males and females, respectively). As expected, females had greater GSI in both maturity categories.

Longnose Suckers - 1980

The average length and weight were 365 mm and 660 g, respectively, for the 458 longnose suckers captured (Table 19). The average K factor was 1.17.

Approximately 99% of suckers over 305 mm were categorized as prespawners (Table 20). Males were judged prespawners at a smaller size, and females dominated size classes over 432 mm. These results are consistent with previous studies (Jones et al 1978, 1979 and 1980).

Discussion

Cutthroat Trout 1969-1980

Average number per net. Although a trend of an increased number of cutthroat trout per net was reported through most of the 1970's (Jones et al 1978), decreases have occurred since 1978 (Table 21). Differences in the number captured between years, however, were not statistically significant. This lack of significance is related to the high degree of variability inherent with the gillnetting results (Jones et al 1978) and make the interpretation of results particularly difficult.

Although these results could be symptomatic of overharvest, current effort and creel figures have remained much below those of the known overharvest period during the late 1950's and early 1960's. Length

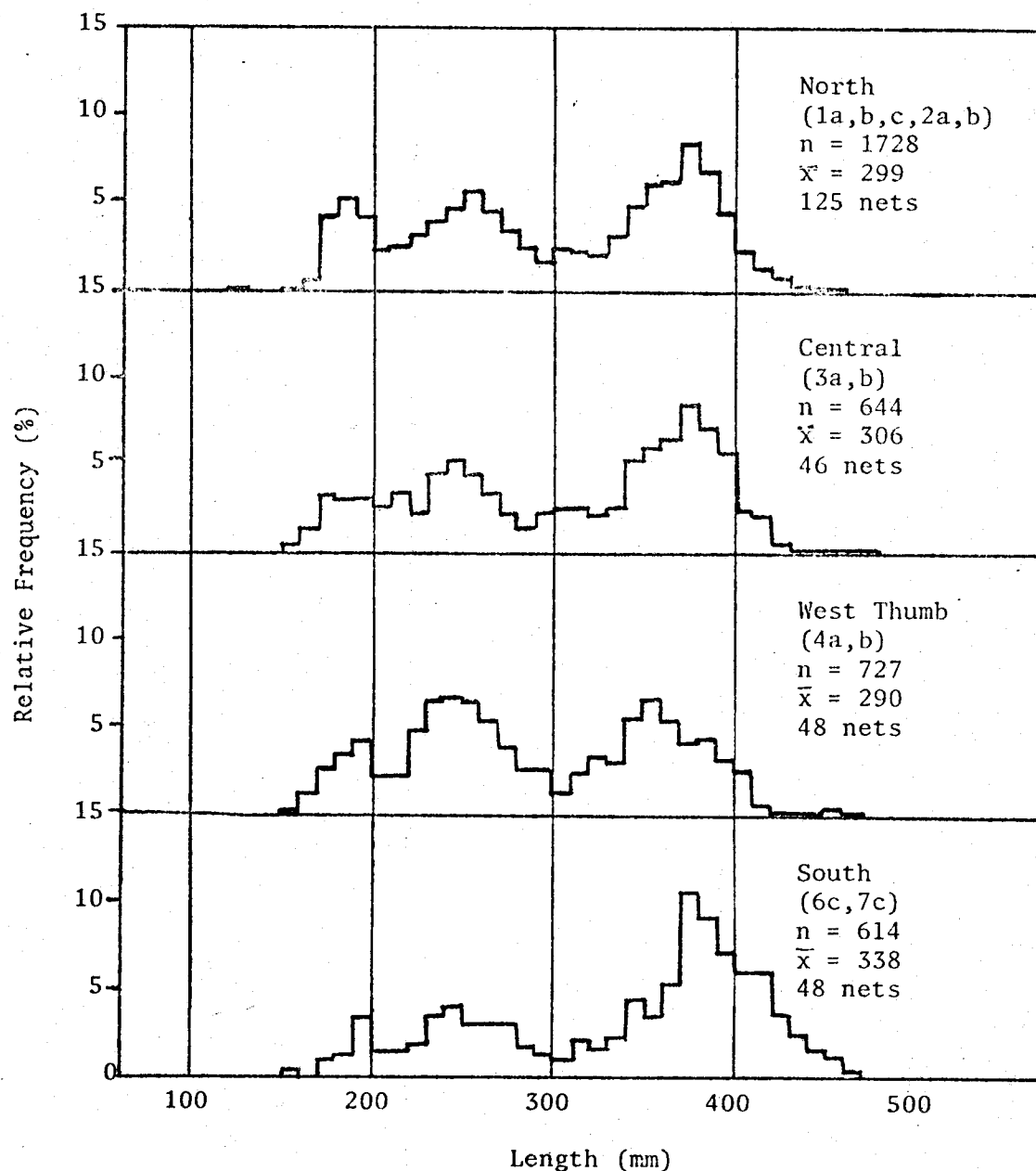


Figure 11. Length frequencies of cutthroat trout captured in largemesh gillnets at the 1.5 - 4.6 m depth interval in Yellowstone Lake, 1969 - 1980.

Table 1. Gillnet catches of longnose sucker by areas, Yellowstone Lake, 1969, 1970, 1971, 1972, 1974, 1976, 1977, 1978, 1979, and 1980¹⁾

Area	Number per net ²⁾										Average total length (mm)										Average weight (g)									
	1969	1970	1971	1972	1974	1976	1977	1978	1979	1980	1969	1970	1971	1972	1974	1976	1977	1978	1979	1980	1969	1970	1971	1972	1974	1976	1977	1978	1979	1980
1A	7	13	17	4	27	13	9	4	18	5	431	444	432	446	401	427	440	437	435	422	938	1076	963	1012	804	930	595	902	566	979
1B	28	3	75	4	26	30	3	18	21	12	319	392	267	291	340	334	408	353	342	330	415	791	273	260	561	527	847	594	567	502
1C	39	4	7	0	15	13	8	7	11	9	411	427	433	—	428	414	434	424	429	428	855	970	935	—	952	951	1047	913	964	957
2A	13	23	13	3	9	26	14	11	18	15	394	380	410	242	401	408	407	412	413	410	825	773	869	167	774	834	840	859	864	848
2B	31	16	73	2	26	13	13	13	23	13	323	415	312	318	345	394	413	307	334	360	434	883	413	575	574	560	898	423	563	657
3A	3)	3	3)	0	6	8	4	6	5	2	3)	425	3)	—	392	396	380	354	396	402	3)	1003	3)	—	775	765	716	593	791	777
3B	3)	1	3)	0	18	14	8	3	13	15	3)	306	3)	—	355	373	361	329	325	322	3)	366	3)	—	546	651	656	478	484	468
4A	5	4	3)	3	5	13	4	5	6	5	368	376	3)	422	385	411	400	409	397	416	621	692	3)	961	790	876	810	859	810	855
4B	1	3	3)	2	17	14	8	9	12	17	425	317	3)	358	358	395	431	321	345	312	860	367	3)	600	637	720	529	467	552	429
6C	1	0	3)	5	4	0	0	1	5	6	360	—	3)	330	369	—	—	285	285	300	614	—	3)	457	646	—	—	304	339	346
7C	22	1	3)	5	22	16	10	2	7	11	358	214	3)	290	356	398	409	338	362	414	592	112	3)	286	577	806	889	595	589	895
Totals	147	71	185	28	175	160	319	398	695	458	365	398	316	335	370	389	401	363	371	365	635	838	459	519	668	759	833	654	699	660
Averages																														

1) Experimental gillnets (38.1 m long) set overnight (7.6 graduated mesh panels 19, 25, 32, 38, and 51 mm) in the 1.5 - 4.6 m depth interval.

2) From 1969 - 1976, only 1 set was made in each area at the specified depth interval; for 1977, the number represents an average of 4 sets and for 1978, 1979, and 1980, represents an average of 5 sets.

3) Areas not sampled.

Table 20 Comparative largemouth gillnetting results, longnose suckers, 1.5 - 4.6 m depth interval, Yellowstone Lake, 1969, 1970, 1971, 1972, 1974, 1976, 1977, 1978, 1979, and 1980

Category	1969	1970	1971	1972	1974	1976	1977	1978	1979	1980
Number of gillnets set ¹⁾	9	11	5	11	11	11	44	55	55	55
Average number of suckers caught per net	16.33	6.45	37.0	2.54	15.91	14.55	7.25	7.25	12.64	9.98
95% confidence interval of number of suckers caught per net	±10.65	±5.01	±42.17	±1.29	±5.92	±5.36	±1.83	±1.99	±2.07	±1.82
Percentage of suckers over 356 mm (TL)	66.0	83.1	34.0	42.9	69.7	80.6	80.9	58.3	62.6	59.3
Percentage of suckers over 406 mm (TL)	29.2	59.2	17.8	28.6	29.1	44.4	55.5	38.9	45.2	39.4
Percentage of suckers over 457 mm (TL)	6.1	12.7	2.7	7.1	5.7	7.5	14.7	11.1	13.0	12.6
Percentage of prespawning suckers ²⁾	92.1	100	100	88.2	100	95.2	100	92.5	87.8	78.1
Ratio of prespawning males to females	1.28	0.80	2.00	2.00	1.28	1.07	1.48	1.13	0.99	1.12
Average length (mm) of prespawning males	382	386	357	378	372	387	390	385	399	370
Average length (mm) of prespawning females	419	440	417	428	415	425	441	435	440	432
Condition factor K	1.207	1.235	1.207	1.205	1.215	1.227	1.229	1.187	1.197	1.171

1) Number of sets has been limited to the 1.5 - 4.6 m depth interval to ensure comparability.

2) Percentage of longnose suckers over 310 mm (TL) which were judged to have sufficient gonadal development to spawn the following spring.

Table 21. Comparative largemouth gillnetting results, cutthroat trout, 1.52-4.57 m depth interval, Yellowstone Lake, 1969, 1970, 1971, 1972, 1974, 1976, 1977, 1978, 1979, and 1980

Category	1969	1970	1971	1972	1974	1976	1977	1978	1979	1980
Number of gillnets set ¹⁾	9	11	5	11	11	11	44	55	55	55
Average number of trout caught per net	12.22	12.27	14.4	13.63	15.45	15.0	15.55	13.93	13.60	13.0
95% confidence interval of number of trout caught per net	±6.71	±5.90	±9.76	±3.57	±4.75	±3.06	±1.98	±1.06	±1.27	±1.53
Percentage of trout over 356 mm (TL)	29.1	26.7	37.5	32.7	34.7	37.6	33.0	37.5	32.3	40.6
Percentage of trout over 406 mm (TL)	1.8	3.0	1.4	3.3	0.6	2.4	4.7	5.4	7.4	7.1
Percentage of trout over 457 mm (TL)	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.3	0.1	0.3
Percentage of prespawning trout ²⁾	53.6	46.6	54.3	39.8	56.4	48.6	75.6	65.7	59.0	50.1
Ratio of prespawning males to females	1.06	1.73	1.50	0.52	1.00	1.43	0.98	1.06	0.91	1.05
Average length (mm) of prespawning males	353	359	360	358	349	370	376	383	387	389
Average length (mm) of prespawning females	346	351	368	369	359	365	362	372	374	376
Condition factor K	0.924	0.917	0.853	0.937	0.859	0.877	0.892	0.923	0.915	0.884

1) Number of sets has been limited to the 1.52-4.57 m depth interval to ensure comparability.

2) Percentage of cutthroat trout over 304 mm (TL) which were judged to have sufficient gonadal development to spawn the following spring.

frequency analysis indicated a very low abundance of trout less than 120 mm in 1978 and 1976 (the 1976 and 1974 year-classes, respectively). Despite a strong 1975 year-class, it appears that current declines may indeed be a reflection of natural fluctuations in year-class strength rather than signs of overharvest.

When data from the ten years of gillnetting were combined, differences in the number of trout between sites were significant. The relationship between site and number of trout captured has changed since 1977. Sites 4a, 6c, 3b and 1a, however, continued to be among the lowest, and site 4b has remained the highest.

Although the relationships between lake zone and the number of trout has varied annually, there was little difference between zones when data from ten years were combined (Table 22). Biological interpretation of these results is confounded by the high degree of variation and absence of observable trends.

It has been suggested that differences in the length of trout captured since 1969 are due mostly to fluctuations in the proportion of smaller fish in the sample (Jones et al 1978). The yearly fluctuations in the proportion of smaller trout, and thus the mean length of the entire sample, may be caused by differences in population distribution or may reflect year-class fluctuations of the smaller trout prior to entry into the fishery. Since the mean length of prespawners is not affected by changes in the proportion of smaller trout, comparisons of prespawners may provide an effective means of detecting changes in mature trout.

Differences in the length of prespawning trout between sample years were significant. The previously reported annual trend of increasing length (Jones et al 1980) continued in 1980, and the length of prespawners (380 mm) was the largest reported since the survey began in 1969. This increase is interpreted as a positive response of the cutthroat population to the 330 mm maximum size limit imposed in 1975.

When prespawners were separated by sex, both males and females displayed significant differences in mean length between years. The response of prespawners to harvest changes has been most pronounced in prespawning males (Figure 12). Since most large cutthroat are males, such a response could be expected.

During the years (1970-1974) when a minimum size limit restricted harvest, mean lengths of male prespawners declined rapidly. Although female prespawners followed a similar pattern, reaction was slower. When larger trout became protected by the 330 mm maximum size limit (1975), the males responded rapidly; females again followed a similar

Table 22. Gillnet catches of cutthroat trout by general area, Yellowstone Lake, 1969, 1970, 1971, 1972, 1974, 1976, 1977, 1978, 1979, and 1980.¹⁾

Year	Number/net				Average total length (mm)				Percentage under 210 mm				
	North	Central	W. Thumb	South	North	Central	W. Thumb	South	North	Central	W. Thumb	South	Total
1969	10	--	16	15	316	--	296	319	12.2	--	9.7	10.0	10.9
1970	13	14	17	4	311	352	285	346	7.8	0.0	17.6	0.0	8.1
1971	14	--	--	--	321	--	--	--	1.4	--	--	--	1.4
1972	15	10	14	12	297	307	342	336	11.7	0.0	0.0	4.0	6.7
1974	19	9	16	13	289	302	294	329	14.7	16.7	25.8	0.0	14.7
1976	16	17	13	13	310	311	328	333	11.0	5.9	4.3	7.7	8.5
1977	17	15	11	17	284	293	273	309	28.2	23.1	30.3	13.3	24.6
1978	13	15	17	13	298	305	294	353	13.2	8.6	5.4	0.8	8.5
1979	12	15	17	11	297	290	291	356	18.1	21.0	14.5	6.1	16.0
1980	13	12	15	12	307	325	278	341	14.0	11.0	16.0	11.0	13.4
Totals	1728	644	727	614					16.4	14.1	14.2	7.3	14.1
Averages	14	14	15	14	299	306	290	338					

1) Net locations combined as follows: North - 1A, 1B, 1C, 2A, 2B; Central - 3A, 3B; W. Thumb - 4A, 4B; South - 6C, 7C.

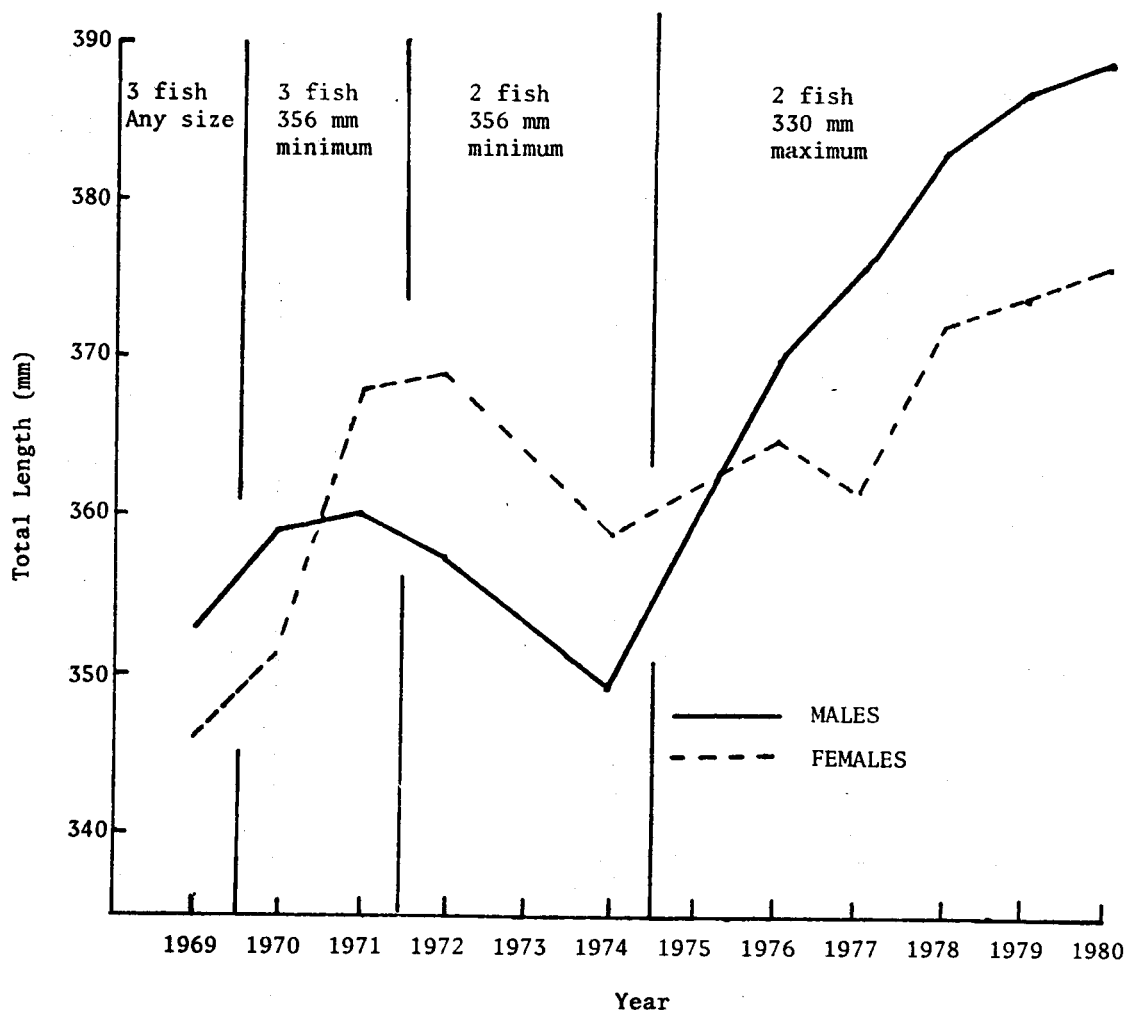


Figure 12. Mean total length of prespawning cutthroat trout captured in largemouth gillnets, Yellowstone Lake, 1969 - 1980.

pattern but at a slower rate.

Differences in length of prespawning trout from the four lake zones were also significant. Prespawners from the South (388 mm) were the largest and West Thumb prespawners (361 mm) were the smallest. Although prespawners from the North and Central zones (371 mm and 372 mm, respectively) differed from the other two zones, there was little difference between them.

Length frequency. A comparison of length frequency data from ten survey years illustrates several interesting trends (Figure 13). Since the 330 mm maximum size limit was imposed in 1975, there has been a shift towards larger fish in both the 330-400 mm and 400-500 mm groups. In 1980, the proportion of large cutthroat trout (406 mm) was among the highest sampled to date (Table 21). An increase in the total range of lengths sampled was also apparent (Figure 14).

In 1977, a large pulse of trout less than 210 mm suggested that the 1975 year-class was very strong (Jones et al 1978). In 1978, the increased frequency of trout in the 200-270 mm group was interpreted as growth of this year-class (Figure 13). When the majority of this year-class entered the fishery during 1979, the previously reported depression between 270-340 mm (Jones et al 1979) was dampened considerably. During the current year, the 1975 year-class has progressed to the right, making a substantial addition to the proportion of trout over 330 mm.

The extreme paucity of trout less than 210 mm in 1978 (the 1976 year-class) may partially explain the observed decrease in numbers in 1980. The weak 1976 year-class may be apparent during the 1981 spawning season, but catch rates are expected to improve next year. Average or slightly above average year-classes are indicated by the length frequency for 1977 and 1978, which should halt the trend of decreasing numbers in the next several years.

GSI values were compared to those collected in April, 1978 (Jones et al 1979) and those from the 1979 fall gillnetting. Values for nonspawners over 304 mm appear almost identical in all samples. Although there were differences between the fall samples, females had higher values than males for both years, and spring values were at least 3 times greater for females. Fall GSI values for males were similar in both 1979 and 1980 (3.05 and 2.59, respectively), but both were greater than estimates for spring males (1.90). Further replication of spring samples is needed to aid interpretation; however, these results suggest the existence of either early spring or late fall spawners in the cutthroat population.

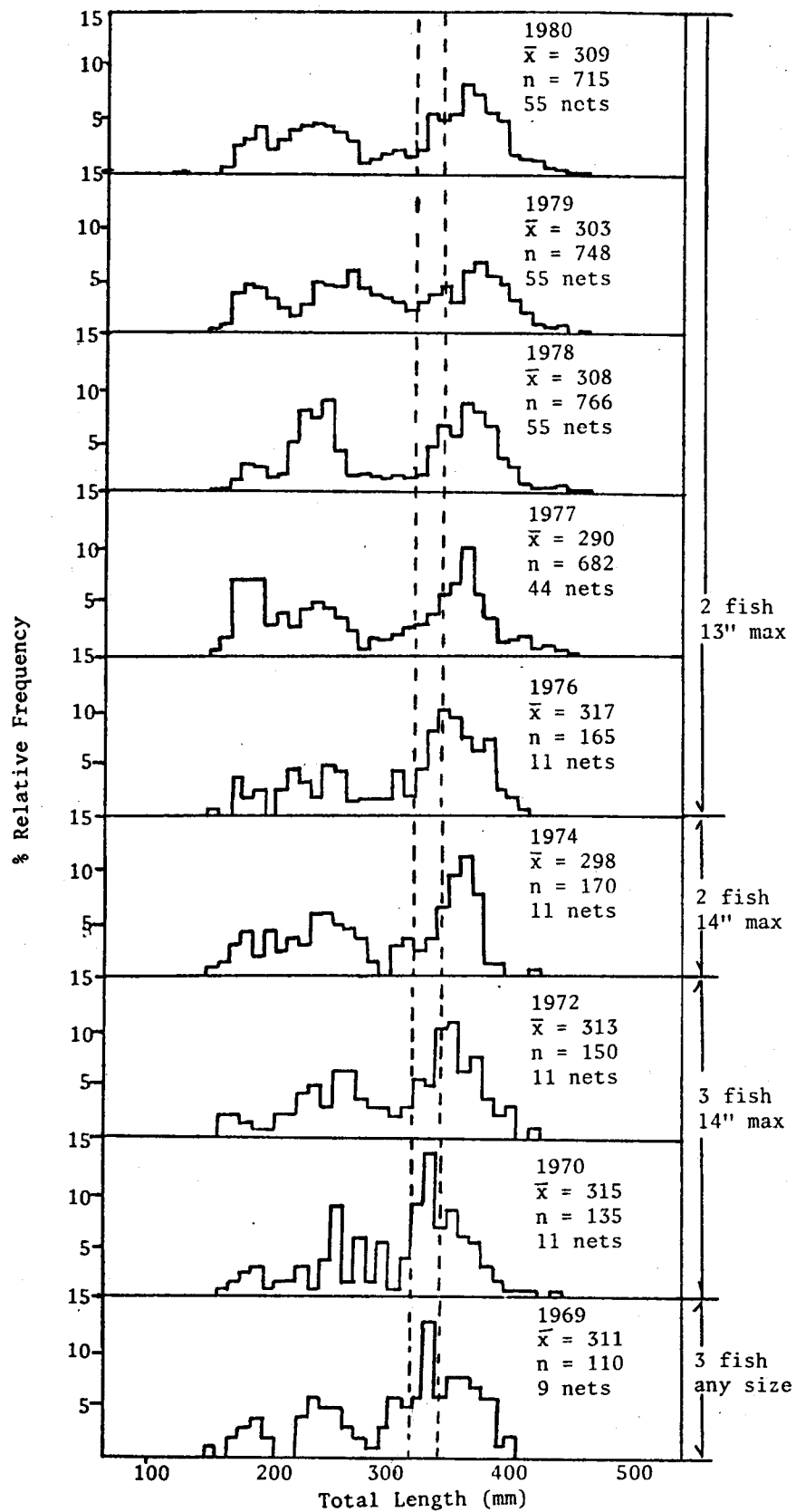


Figure 13. Length frequencies of cutthroat trout captured in largemesh gillnets at the 1.5 - 4.6 m depth interval, Yellowstone Lake, 1969 - 1980.

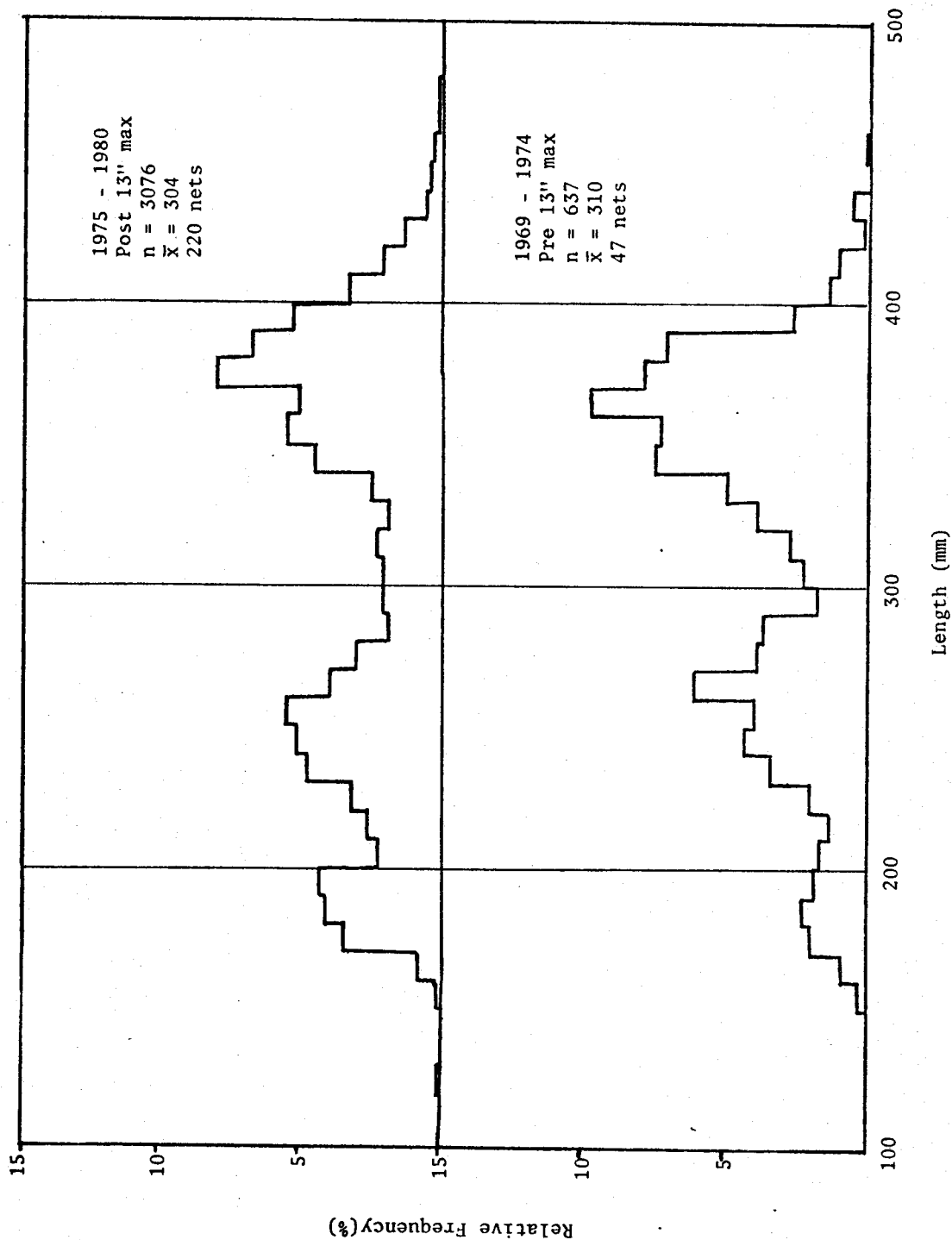


Figure 14 Length frequencies of cutthroat trout captured in largemouth gillnets at the 1.5 - 4.6 m depth interval in Yellowstone Lake, 1969 - 1980.

Longnose Suckers 1969-1980

Average number per net. Although differences between years in the number of suckers captured are significant, reasons for these changes remain unidentified. It is doubtful these differences are due to population fluctuations since the longnose sucker is believed to be longlived in Yellowstone Lake (Jones et al 1977). These fluctuations may be partially due to schooling behavior; such behavior would intensify variation in gillnet catch. Although it was speculated that the sucker eradication project at Pelican Creek had contributed to the lower sucker catches in 1977 and 1978, the sharp increase in the number per net in 1979 suggests that variability continues to confound comparisons (Table 20).

Average size. Comparisons between years (Table 19) yields significant differences in mean length. Mean length of suckers was inversely correlated to the male:female ratio ($r = 0.78$) and directly correlated to the percentage of suckers over 310 mm (TL) ($r = 0.94$). Since the latter two factors are probably related to distribution, annual variations affecting numbers captured may also affect variation in mean length.

The largemesh gillnetting program has provided only minimal information concerning the longnose sucker. If methods of ageing this species can be verified, they may provide a means of evaluating yearly fluctuations.

Conclusions and Recommendations

Analysis of data from ten years of largemesh gillnetting on Yellowstone Lake has provided insight into both the dynamics of the trout population and the limitations of this sampling method. Yearly variation in the number captured and mean length of longnose suckers continues to confound logical interpretation. Annual fluctuations in the mean length of cutthroat, however, appear to be related to the proportion of smaller trout (prior to entry into the fishery) in the sample. Significant increases in the mean length of prespawning male and female cutthroat trout and significant shifts toward larger trout in length frequency data since 1974 are believed to be positive effects of the 330 mm maximum size limit. High GSI values of fall captured prespawning male cutthroat trout suggest a high proportion of late fall or early spring spawning males in the fall sample.

We recommend that the largemesh gillnetting program be continued in order to provide an annual monitoring of the cutthroat population in Yellowstone Lake. Experimental expansion of this program is urgently needed to provide additional information concerning seasonal distribution and the annual sexual cycle of the cutthroat trout.

NONCONSUMPTIVE USE OF THE AQUATIC RESOURCE

In an era of diminishing natural areas and wildlife, nonconsumptive use (resource is unaffected by use) is an important utilization of the aquatic resource because it provides an opportunity for the nonangling Park visitor to observe and appreciate the beauty and value of a fish population in its natural setting. Fishing Bridge at the outlet of Yellowstone Lake and LeHardy's Rapids on Yellowstone River are two excellent examples of sites where the visitor can "fish-watch".

Fishing Bridge, once a popular place for angling, has been closed to fishing since 1973. Since that time, Park visitors have been using Fishing Bridge for observing various aspects of the aquatic ecosystem. Not only can the visitor watch spawning activities of the cutthroat trout and longnose sucker, but numerous fish eating birds and several aquatic-oriented mammals are also attracted to the area. Pelicans, mergansers, trumpeter swans and other waterfowl are often seen feeding in the river. Additional animals frequenting the area include kingfishers, ospreys, eagles, moose, muskrat beaver and otter. After spawning season is over (mid-July), trout can still be observed feeding in the area due to the large amounts of planktonic drift from Yellowstone Lake.

LeHardy's Rapids is located approximately 5.7 km downstream from the lake on Yellowstone River. During high-water (May through July) fish ascending the river in their upstream spawning migration accumulate near the west bank in pools immediately below the rapids. From here the fish jump the rapids, often having to make several attempts, providing an extraordinary sight for the visitor. The river is closed to fishing in 100 yards upstream and downstream from the rapids.

Methods

For the past three years (1978, 1979 and 1980), estimates of visitor use, including total time spent and total number of visitors, have been made at both Fishing Bridge and LeHardy's Rapids. In 1978 and 1980, mean length of stay was also determined for each site.

A "time available" method (Matheson 1949, Bulkley 1966, Geiger 1972 and Brown 1978) of data collection was employed; such methods have been used when effort available for counts was limited. Instantaneous counts of visitors at the site were taken as often as possible.

Each day was divided into intervals with a length slightly less than the mean length of stay (separate estimates were made for each area). The daily use curve was determined by averaging all counts for each interval.

Total visitor hours for each interval were then calculated using the standard trapezoidal formula:

$$\text{Effort (visitor hours)} = 1/2 I(t_i + t_{i+1}), \text{ where}$$

$I = \text{interval}$
 $t_i = \text{mean number counted at interval } i$

To obtain daily total for visitor hours, instantaneous counts were expanded by the proportion of daily use represented by each time interval. On days when more than one count was made, the mean visitor hours was used for that day, but days when no counts were made, an average of visitor hours from the last count day before and the next count day after was used. The total number of visitors for each day was obtained by dividing visitor hours by the mean length of stay, and season totals were calculated by summing daily totals.

The critical aspects of this type of estimate are the accurate determination of the daily use pattern and average time spent per person. Although use estimates for 1978 and 1979 have been previously reported (Jones et al 1979 and Jones et al 1980), current methods have been refined since that time; therefore, data from those years have been reevaluated in order to make all three years comparable.

Results

In 1980, mean length of stay at Fishing Bridge for 2,407 visitors from July 17 to September 12 was 10.7 minutes. (In 1978, mean length of stay at this site for 2,342 visitors was 10.8 minutes). For the 1979 calculations, mean length of stay was considered to be 10.7 minutes. The expanded number of visitors and visitor hours spent observing fish at the bridge in 1980 was 123,438 and 22,009 hours, respectively. Estimated use for 1979 was recalculated to be 161,108 visitors and 28,726 visitor hours, and recalculated figures for 1978 were 111,167 visitors and 19,821 visitor hours (Table 23).

At LeHardy's Rapids, mean length of stay in 1980 for 77 visitors from July 14 to July 23 was 5.3 minutes; however, in 1978, mean length of stay for 598 visitors from June 21 to July 21 was 8.4 minutes. Due to the larger sample size covering a longer sampling period in 1978 and given the insignificant change in length of stay at Fishing Bridge over the three year period, 8.4 minutes was assumed to be the most accurate estimate of mean length of stay at LeHardy's Rapids for all three years. Total number of visitors at the rapids and visitor hours spent there for 1980 were estimated to be 7,808 and 1,392 hours, respectively. Reevaluation of

Table 23. Nonconsumptive use of the aquatic resource, 1978-1980

	Year	Total Visitor Hours	Number Counts	Total Number of Visitor
Fishing Bridge	1978	19,821	582	111,167
	1979	28,726	670	161,108
	1980	22,009	551	123,428
LeHardy's Rapids	1978	543	222	3,044
	1979	1,665	206	9,338
	1980	1,392	94	7,808

the 1979 and 1980 data yielded estimates of 9,338 and 3,044 visitors and 1,665 and 543 visitor hours, respectively (Table 23).

Discussion

Weather is apparently one of the most significant factors in determining level of use (Jones et al 1980). Results over the three year period have shown an increase from 1978 to 1979 and a decrease from 1979 to 1980 at both sites. This corresponds to a warmer, sunnier summer in 1979 and a cooler, wetter summer in 1980. While the 45% increase in use at Fishing Bridge during 1979 may represent a true increase primarily due to better weather conditions, it probably also is, in part, due to intensified sampling (Jones et al 1980). The decrease of use in 1980 was the expected result of poorer weather conditions.

Time of season is another important factor which effects level of use at LeHardy's Rapids but apparently is not as important at Fishing Bridge (Jones et al 1979). Fish can easily be seen ascending the rapids during the major portion of the spawning run (late May to early June); however, once the spawning wanes and water levels decrease (mid July to September), trout numbers decline and additional portions of the river farther from shore become available for fish movement. At Fishing Bridge not only can the fish be observed all season, but individual fish can be watched for a much greater time span. Because of the more difficult access and observation and the shorter viewing season, visitor use at LeHardy's Rapids remains much lower than at Fishing Bridge. However, the level of use over the three year period followed the weather pattern in the same manner as at Fishing Bridge (an increase in 1979 at 306% and a decrease in 1980 at 16%).

Conclusions and Recommendations

The prohibition of angling from Fishing Bridge has not only provided the much needed protection for spawning trout but also developed a unique viewing platform for the Park visitor. Observing the interactions of a fish population within its natural habitat, including natural reproduction, feeding and as prey, is truly an educational experience for both the angling and nonangling public.

LeHardy's Rapids provides another unique opportunity for the public since visitors are able to get much closer to the fish and to observe their incredible jumping abilities.

Visitor use at both areas is not only enjoyable but also has educational value and should therefore be encouraged to help make the visitor's "Yellowstone experience" complete. With continuing high numbers of Park visitors, nonconsumptive use affords an exceptional experience, which can be enjoyed repeatedly by many without depleting the resource.

Estimation of visitor use should be continued in order to document the value of designating areas such as Fishing Bridge and LeHardy's Rapids for nonconsumptive use only and to monitor trends and possible causes in differences in level of use.

A HISTORY OF THE FISHERY OF THE MADISON RIVER, YNP

Introduction

Natural and human influences have combined to affect major changes in the game fish populations of the Madison River, YNP. Historic populations of "westslope" or upper Missouri cutthroat trout (Salmo clarki lewisi) and fluvial grayling (Thymallus arcticus) have been replaced by wild, self-sustaining populations of brown trout (Salmo trutta) and rainbow trout (Salmo gairdneri). Native populations of whitefish (Prosopium williamsoni) have survived and continue to flourish. Scientific investigations, begun in 1953 and continuing through 1980, reveal subtle, yet important shifts in the interrelationships of brown trout, rainbow trout and whitefish. The purpose of this investigation is to describe specific changes in the fishery and to examine the factors which have contributed to those changes.

Description of the River

The Madison River, formed by the union of the Firehole and Gibbon Rivers, flows in a westerly direction for 42.8 km before entering the Madison Arm of Hebgen Lake (Figure 15) (Jones et al 1978). The upper 9.7 km passes through a deep canyon faced on the north by cliffs and hills of welded tuff, and on the south by more rugged cliffs composed of rhyolite of the Madison Plateau. Once leaving the canyon, the river passes through an area of decomposed rhyolite and tuff (Wright and Mills 1967).

The river meanders at an average gradient of 1.4 m/km. Wide, shallow riffle areas predominate while other parts of the river contain deep holes. Large aquatic plant beds are present, and bottom fauna production is high (Benson et al 1959). River width ranges from 25.9 m-67.1 m with an average width of 44.5 m. River depth varies with season and location, the shallowest point during dry weather measuring about 0.2 m and the deepest point at the time of greatest runoff measuring about 3.1 m. Average depth is 0.8 m. Boulders, large to small cobble, coarse to fine gravel, sand and silt make up the substrate. These may be cemented together or may rest loosely on the bedrock (Todd 1967).

The rate of discharge from the river is lowest from January through March, averaging $11.6 \text{ m}^3/\text{sec}$ for the period 1948-73. Discharge reaches its maximum from mid-May through mid-June as a result of runoff from melting snow and seasonally heavy rainfall (averaging $25.1 \text{ m}^3/\text{sec}$ for the period 1948-73) (USGS 1949-73).

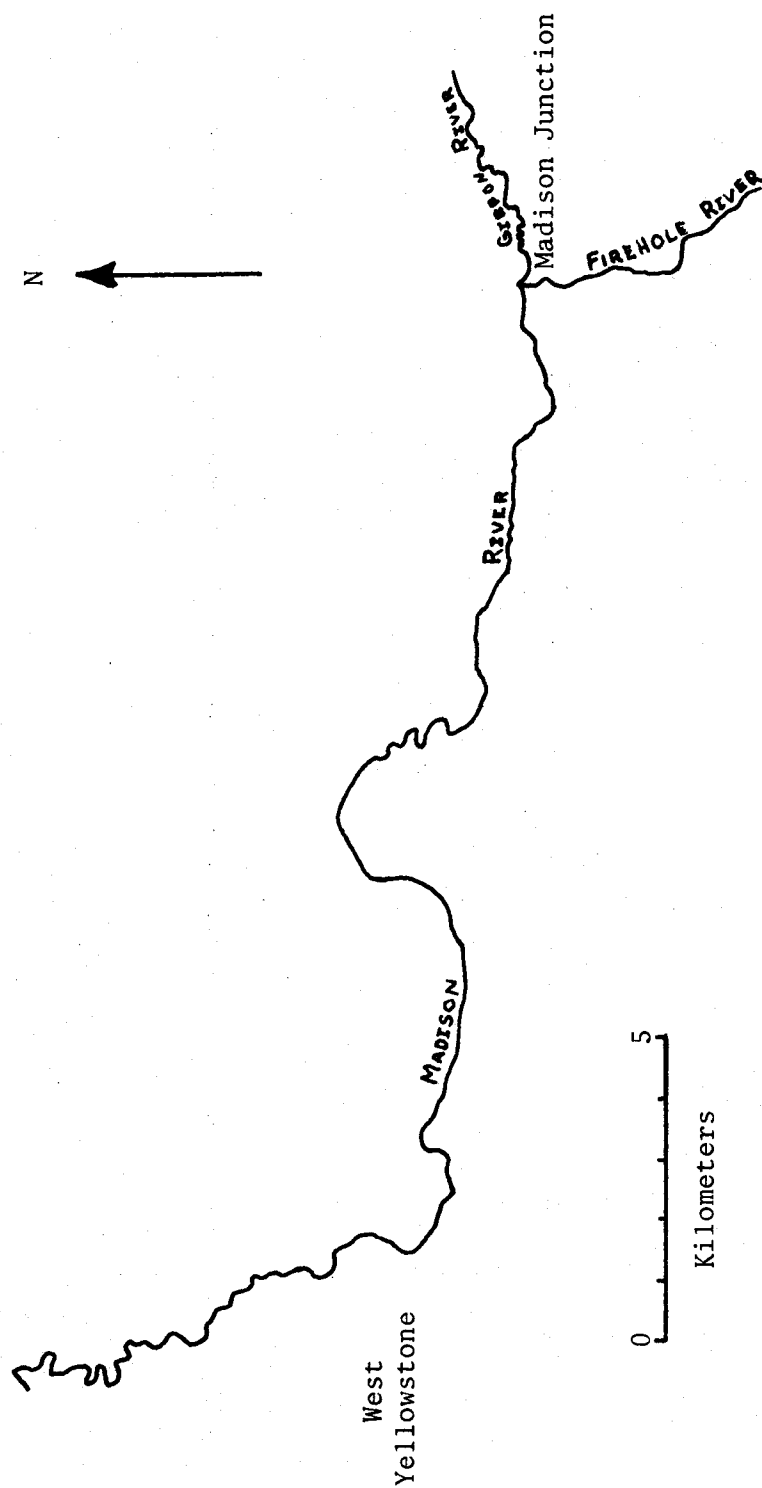


Figure 15. Madison River, Yellowstone National Park.

Water temperature is higher than most rivers and streams of the region due to the thermal discharge of hot springs and geysers into its tributaries (Allen and Day 1935). Water temperature remains relatively constant at minimum levels (1° to 4° C) from November through February. Temperatures then increase to maximum levels (20° to 25° C) in July and early August. Temperatures decrease again from late August through October (Agaard 1969). Yearly maximums and minimums are affected primarily by water level and air temperature.

Chemically, the river has been characterized as a sodium-bicarbonate-chloride type. Calcium and magnesium are present in small amounts. Silica concentrations are close to the saturation point of the water (Roeder 1966). Phosphate levels are much higher than those found in highly eutrophic waters (Wright and Mills 1967) while concentrations of inorganic nitrogen are very low and may be a limiting factor to plant growth (Wright et al, no date).

Methods

The history of stocking practices, fishing regulations, results from creel surveys, VFR returns and electrofishing were considered in order to describe and document changes in the fishery. Information from independent investigations on the aquatic invertebrate community, water flow, temperature and chemistry were combined with the above when discussing those factors which have contributed to the changes. Water flow and temperature data were divided in order to investigate possible effects of the Hebgen Lake earthquake of August 17, 1959.

Results

Water Flow

Monthly mean rates of discharge for the post-quake period (September 1959-September 1969) were slightly greater than for the pre-quake period (January 1948-July 1959) during all months except January, April and May (Figure 16). Peak discharge in the pre-quake period occurred in mid-May at $25.3 \text{ m}^3/\text{sec}$ while peak discharge in the post-quake period occurred in mid-June at $25.1 \text{ m}^3/\text{sec}$ (USGS 1948-70).

Water Temperature

Monthly mean temperatures for the post-quake period (August 18, 1959-December 1965) were slightly higher than for the pre-quake period (Janu-

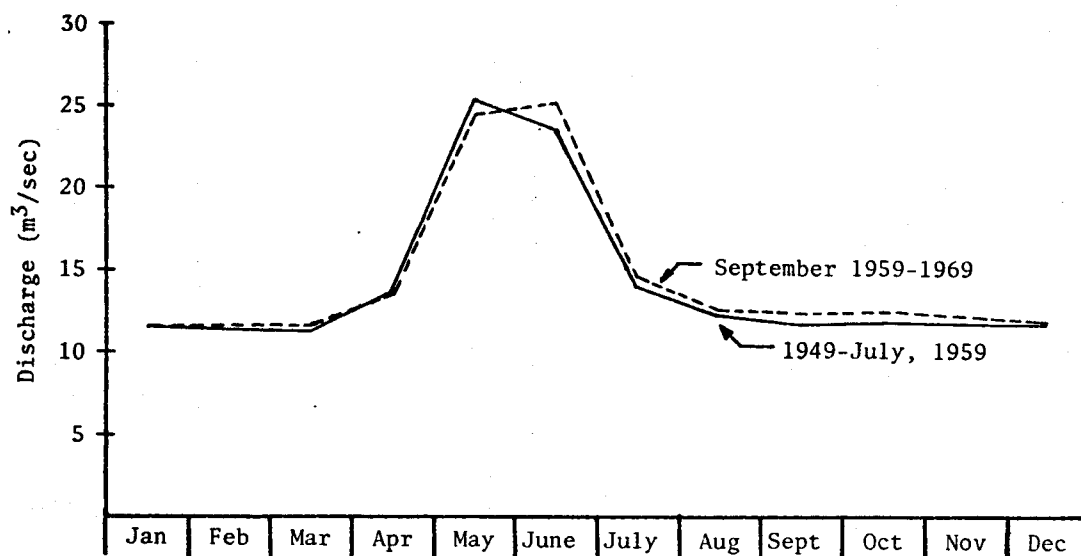


Figure 16 Monthly mean rates of discharge for the Madison River near Riverside Ranger Station, Yellowstone National Park: Ten years before and ten years after the August 17, 1959 Hebgen Lake earthquake.

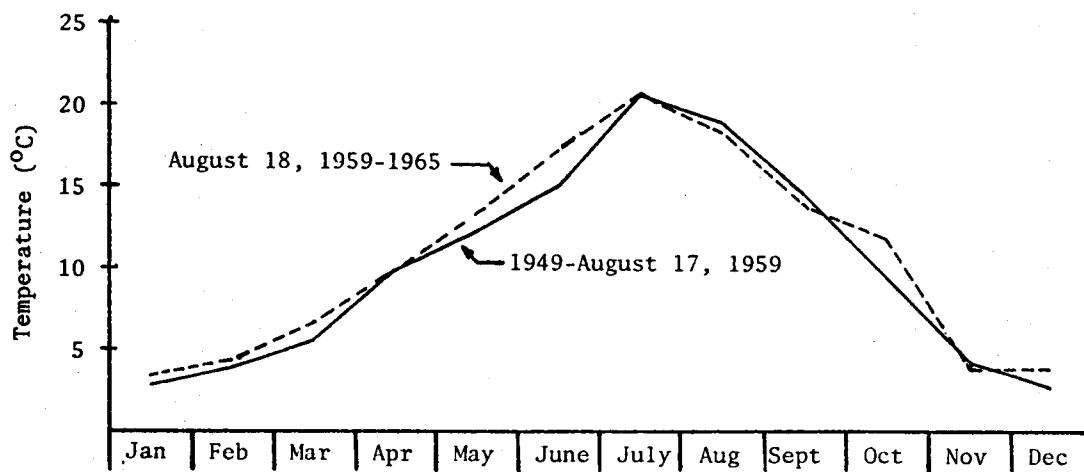


Figure 17 Monthly mean water temperatures for the Madison River near Riverside Ranger Station, Yellowstone National Park: 1949 - August 17, 1959 and August 18, 1959 - 1965.

ary 1949-August 17, 1959) but only during the months of constant and increasing water temperatures (Figure 17). Maximum temperatures for both periods occurred in July at a mean of 20.6° C (Agaard 1969).

Water Chemistry

Although long term data was not available, Roeder (1966) recorded maximum and minimum concentrations of various ions and silica during spring, summer and fall of 1963-1964. In order to obtain an indication of the consistency of water chemistry, spot observations from six other studies were compared to ranges observed by Roeder (Tables 24 and 25). Although there was some variation, no increasing or decreasing trends were recognizable.

Benthos and Drift Fauna

Heaton (1966), in the only comprehensive investigation of the benthos and drift fauna, examined a riffle in the river between June, 1963 and January, 1965. Numbers and volume of benthos were highest in early April and lowest in September, increasing from October through March as organisms increased in size. Numbers and volume of drift were greatest in June and least in November. Lowest total drift occurred when benthos was low, and highest total drift occurred when benthos was high. The numbers and volume of drift over a unit area of bottom during a 24 hour period were always greater than the benthos standing crop.

Electrofishing

Electroshocking operations in the spring and fall of 1978 were conducted at two stations. The upper station extended from the confluence of the Firehole and Gibbon Rivers to 5.2 km downstream. The lower station began at the cable car near the "Barns" and extended 11.6 km downstream to U.S. highway 191 (Jones et al 1978). Although electroshocking conducted in September 1957 (Benson et al 1959) occurred at seven stations along the river, only the upper two, J and K, fell within the limits of the upper station sampled in 1978. The lower two, O and P, fell within the limits of the lower station sampled in 1978. In order to minimize bias, comparisons were restricted to respective stations utilizing fall 1978 samples.

Upper Station. The number of fish collected by electrofishing in the fall of 1978 (55 fish/km) was significantly lower than the number collected in 1957 (116/km) (Figure 18). The biomass, however, significantly increased from 10.5 kg/km in 1957 to 25.9 kg/km in 1978 (Figure 19).

Table 24. Concentrations of selected ions and silica for the Madison River (upper station) determined between Aug 1 and Nov 30, 1966, 1967, 1970 and 1974 - compared to ranges of concentrations determined in the spring, summer and fall of 1963-64

Ion	1963-64	Sept 1966	Oct 1966	Aug-Sept 1967	May-Aug 1970	Sept 1974
Na ⁺ (meq/l)	2.10-5.00	4.00	4.11	4.5	2.81	2.89
HCO ₃ ⁻ (meq/l)	1.25-2.40	2.29	2.26	2.25	1.98*	1.79
Cl ⁻ (meq/l)	1.64-2.20	1.74	1.74	2.08	1.27	1.24
PO ₄ ⁺³ (meq/l)	.004-.019	--	--	0.013	0.004	--
Inorganic N	Too low to measure	--	--	.001 mg/l	.017 mg/l	--
SiO ₂	2.00-2.63 meq/l	92 mg/l	92 mg/l	--	92 mg/l	92 mg/l
References	Roeder (1966)	Thompson et al (1975)	Thompson et al (1975)	Wright and Mills (1967)	Anonymous (1972)	Stauffer et al (1980)

* Converted from mg/l CaCO₃

Table 25. Concentrations of selected ions and silica for the Madison River (lower station) determined Aug 1 and Nov 30, 1964, 1967, 1970, 1974 and 1975 - compared to ranges of concentrations determined in the spring, summer and fall of 1963-64

Ion	1963-64	Nov 1964	Aug-Sept 1967	May-Aug 1970	Sept 1974	Oct 1975
Na ⁺ (meq/l)	2.10-4.40	4.00	4.00	2.69	2.89	3.57
HCO ₃ ⁻ (meq/l)	1.25-2.30	2.36	2.40	1.85*	1.79	2.13
Cl ⁻ (meq/l)	0.94-1.75	2.08	2.08	1.24	1.24	1.41
PO ₄ ⁺³ (meq/l)	.005-.022	.005-.020	.009	.004	--	--
Inorganic N	Too low to measure	Too low to measure	.001mg/l	.005 mg/l	--	--
SiO ₂	2.02-2.50 meq/l	--	--	92 mg/l	87 mg/l	93 mg/l
References	Roeder (1966)	Heaton (1966)	Wright and Mills (1967)	Anonymous (1972)	Stauffer et al (1980)	Thompson (1979)

*Converted from mg/l CaCO₃

The species composition of the total number of fish captured/km revealed that brown trout declined from 74% of the number and 87% of the biomass in 1957 to 51% of the number and 46% of the biomass in 1978. Rainbow trout rose from 26% of the number and 10% of the biomass to 28% of the number and 30% of the biomass during the same period. Whitefish increased from 0.5% of the number and 3% of the biomass in 1957 to 22% of the number and 24% of the biomass in 1978.

An examination of length frequency histograms for each species highlights the increase in the relative abundance of fish ≥ 254 mm for brown trout and rainbow trout from 1957 to 1978. Length frequencies for whitefish are not comparable due to the small sample size collected in 1957 (Figure 20).

Lower Station. The number of fish collected in the fall of 1978 (45 fish/km) was significantly lower than the number collected in 1957 (171 fish/km) (Figure 21). The biomass, however, increased significantly from 9.4 kg/km in 1957 to 22.5 kg/km in 1978 (Figure 22).

The species composition of the total number of fish collected/km revealed that brown trout dropped from 44% of the number and 45% of the biomass in 1957 to 34% of the number and 36% of the biomass in 1978. Rainbow trout declined from 44% of the number to 14%, but rainbow biomass remained constant at 16% during the same period. Whitefish rose from 12% of the number in 1957 to 52% in 1978, while whitefish biomass increased from 39% to 48%.

An examination of length frequency histograms for brown trout points out the increase in the relative abundance of fish ≥ 178 mm from 1957 to 1978. During this same period, rainbow trout show an increase in the relative abundance of fish ≥ 254 mm. For whitefish there is an increase in the relative abundance of fish ≥ 305 mm (Figure 23).

Age and Growth of Wild Trout

Age and growth determinations were made for 80 brown and 87 rainbow trout collected by electrofishing in the spring and fall of 1978.

Spring and fall samples were combined to form a sufficient sample size and to provide a group of data comparable to previous studies. Age and growth determinations made by Benson et al (1959) were primarily based on scale samples obtained during creel census, but a few scale samples were obtained from electrofishing samples. Age and growth determinations made by Dean and Mills (1970) are entirely based on scale samples obtained during creel census.

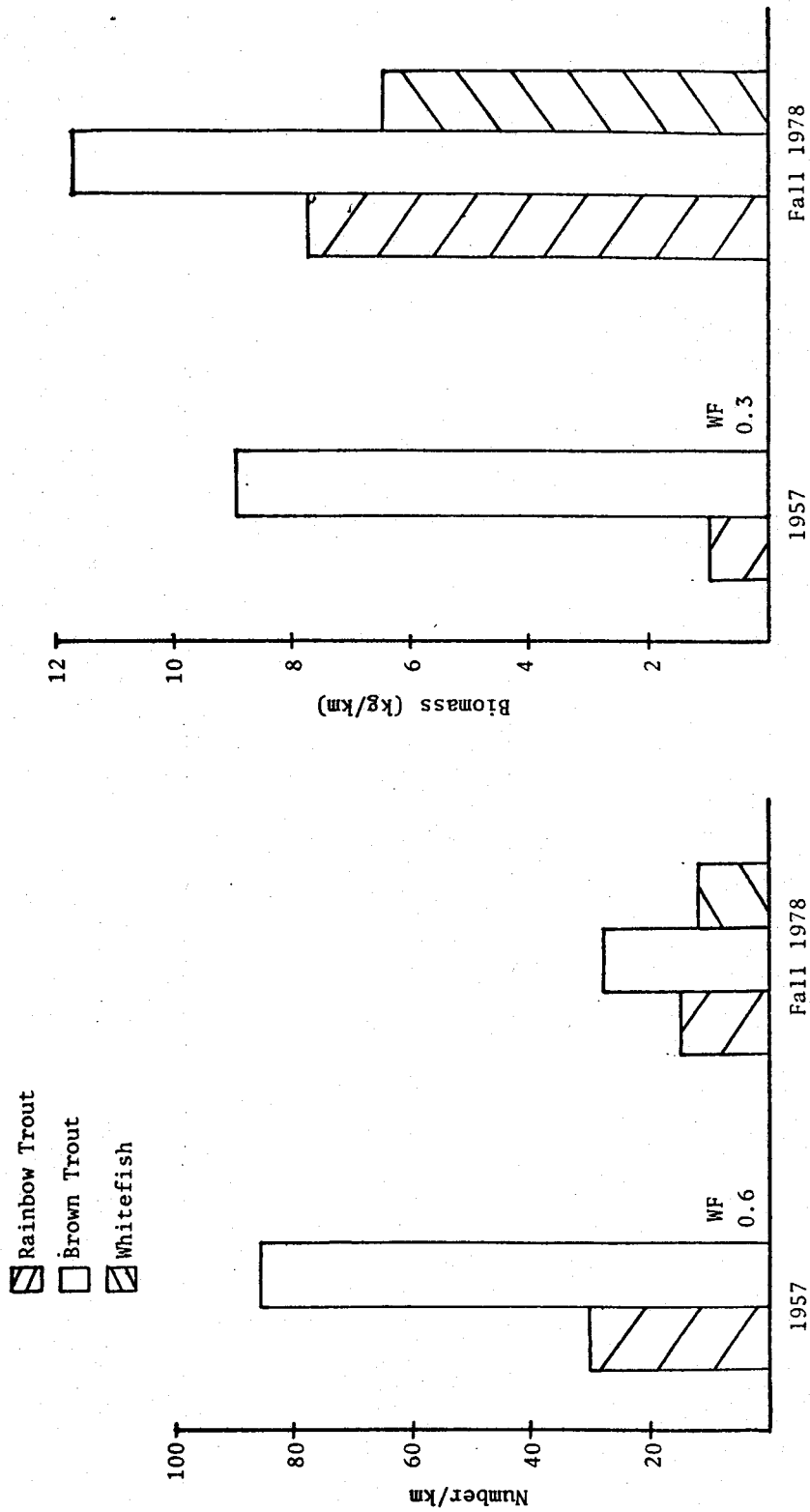


Figure 19. Biomass collected per kilometer by electrofishing at the upper station: 1957 and fall 1978, Madison River, YNP.

Figure 18. Number of fish collected per kilometer by electrofishing at the upper station: 1957 and fall 1978, Madison River, YNP.

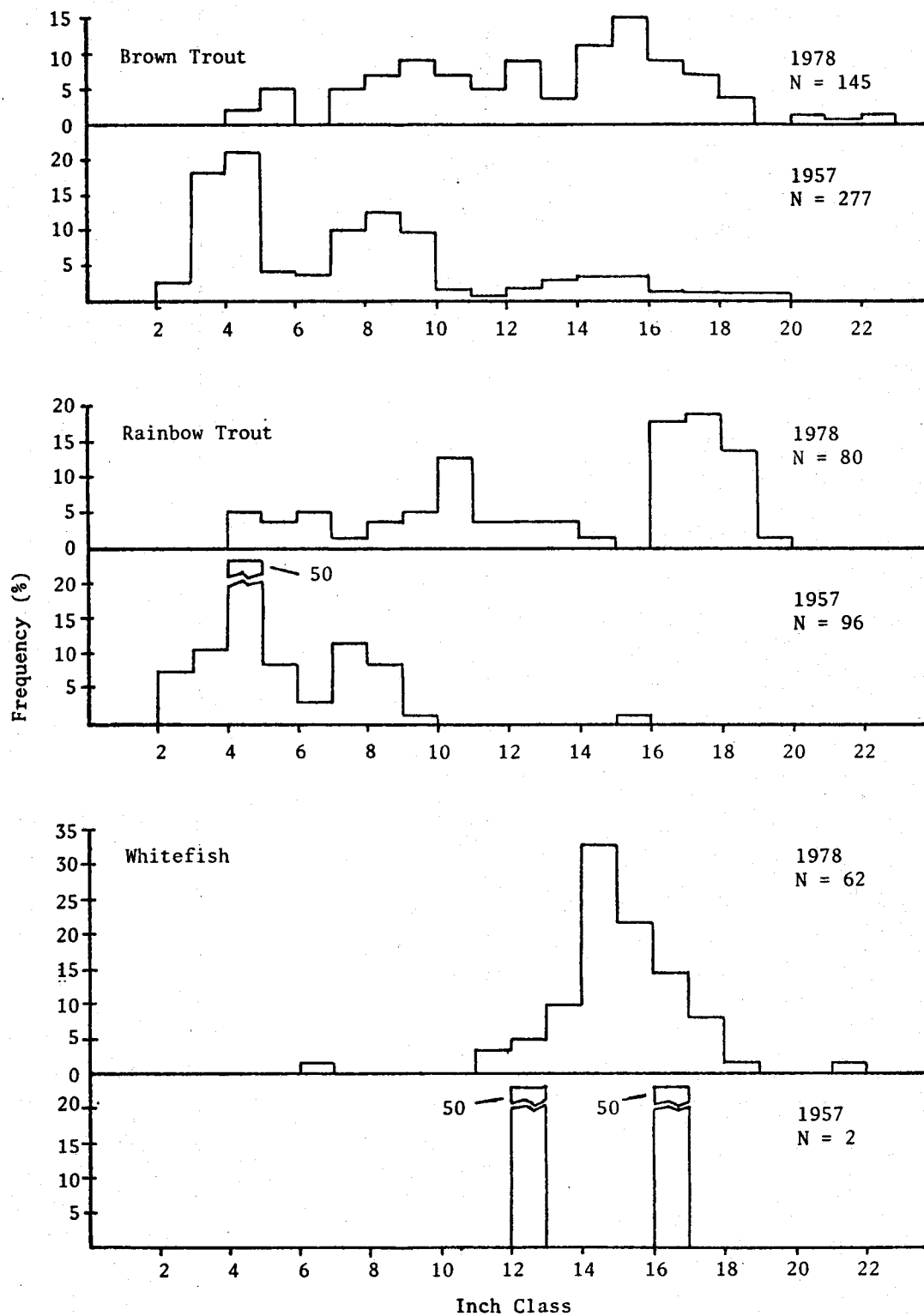


Figure 20 Length frequencies of brown trout, rainbow trout and whitefish captured by electrofishing at the upper station: 1957 and fall 1978, Madison River, YNP.

[Hatched Box] Rainbow Trout
 [White Box] Brown Trout
 [Diagonal Line Box] Whitefish

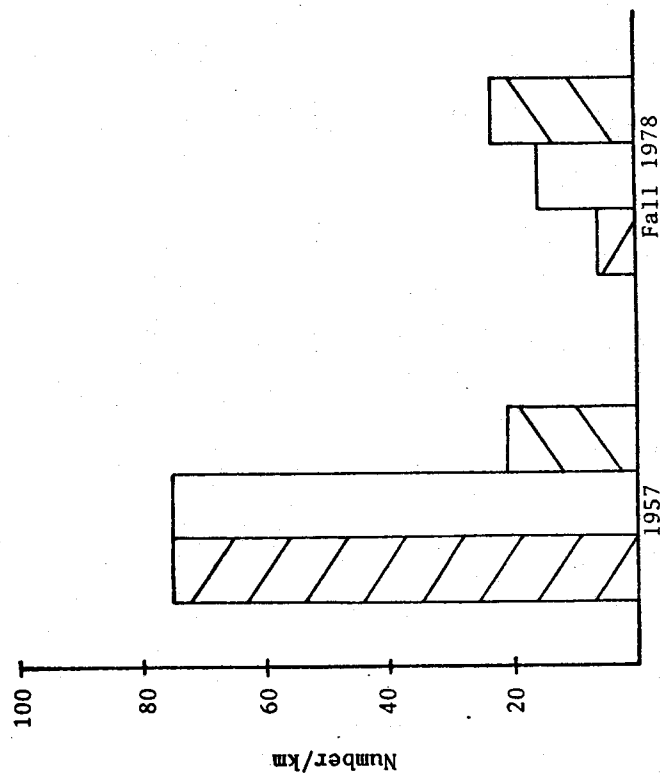


Figure 21 Number of fish collected per kilometer by electrofishing at the lower station: 1957 and fall 1978, Madison River, YNP.

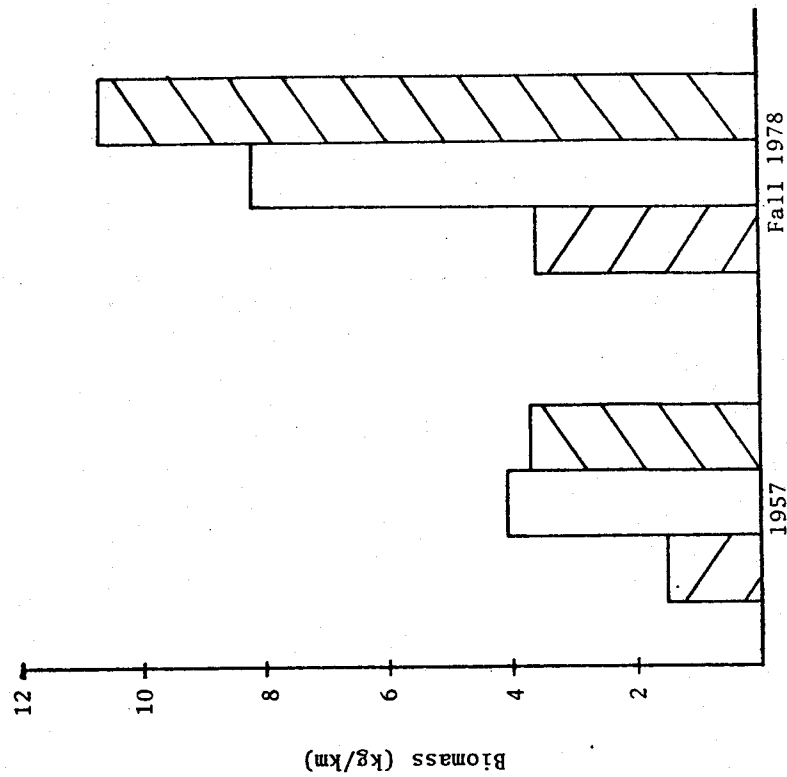


Figure 22 Biomass collected per kilometer by electrofishing at the lower station: 1957 and fall 1978, Madison River, YNP.

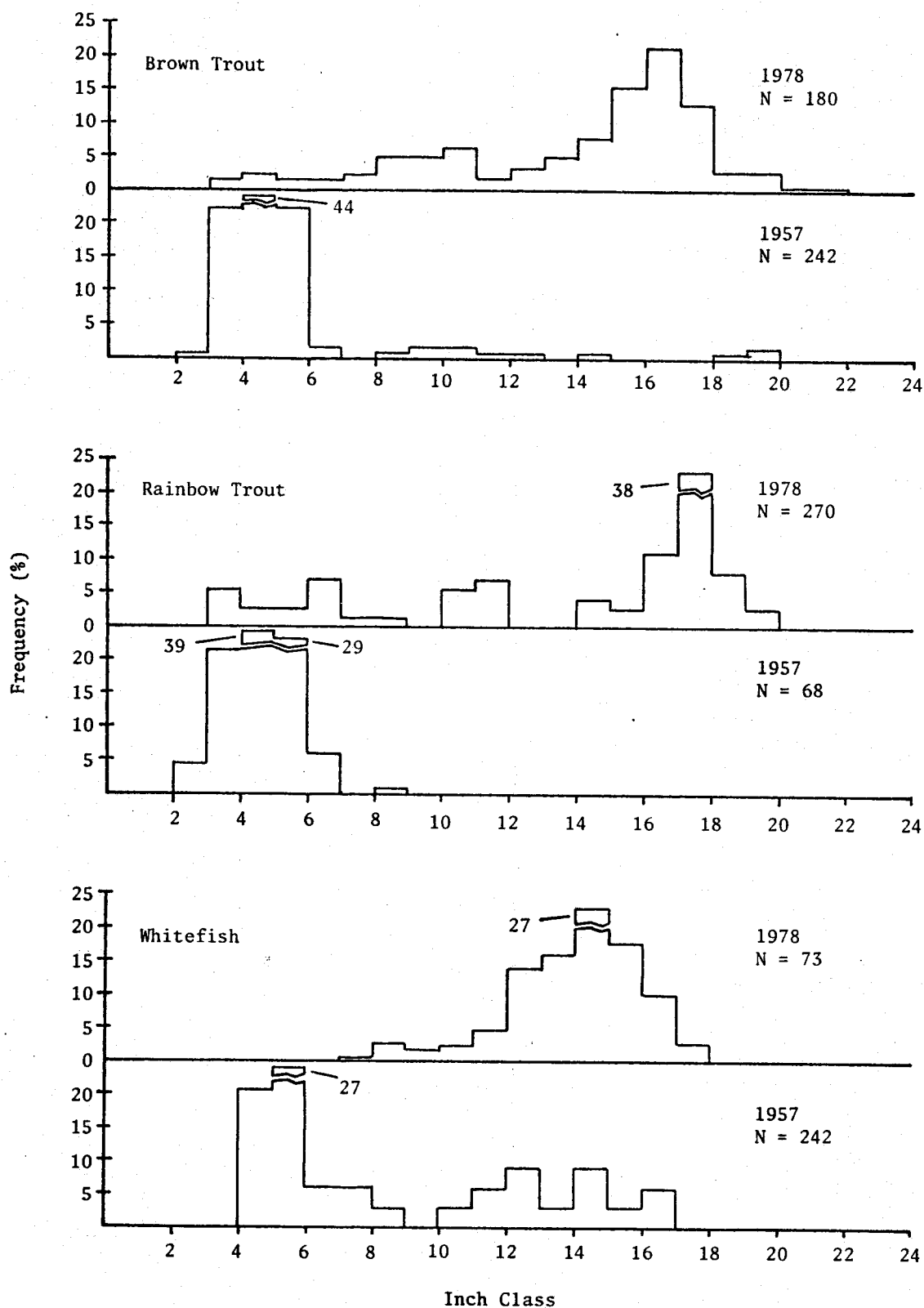


Figure 23 Length frequencies of brown trout, rainbow trout and whitefish captured by electrofishing at the lower station: 1957 and fall 1978, Madison River, YNP.

Brown trout in 1978 were found to be 104, 195, 287 and 381 mm in length at ages I, II, III and IV, respectively. Length at age I is similar to that determined in the two previous studies. Back calculated lengths reveal a substantial decrease in length at ages II, III and IV (Table 26).

Rainbow trout in 1978 were found to be 139, 243, 357 and 433 mm in length at ages I, II, III and IV, respectively. This is similar to growth observed in 1954-1957 (Table 27). Age and growth determinations were not made in 1969 due to an insufficient sample size.

Age and growth determinations for whitefish were limited to 1957 and 1969 (Table 28).

Creel Survey Comparisons

Angling records, existing between 1954-1957 and 1969-1980, were difficult to compare due to differences in stocking practices, fishing regulations and survey methods (Table 29). Between 1954-1980, the percent of brown trout in the catch declined. Highs of 69% and 70% observed in 1954 and 1969, respectively, dropped to a low of 43% in 1977-1979. During the same period, the catch of rainbow trout remained relatively stable, ranging from 15% to 31%. The catch of whitefish generally increased from 8% in 1954 to 28% in 1980 (Figure 24).

The mean length of landed brown trout has risen 23% (275 mm to 338 mm) since 1955, while the mean length of landed rainbow trout has risen 39% (232 mm to 323 mm). Mean length of landed whitefish, comparable only between 1969-1980, has remained relatively stable at 357 mm.

Angler effort and catch rate have increased from 1969 to 1980, but there has been a great deal of yearly variation (Figure 25).

Discussion

Physical, biological and chemical factors as well as fishery management practices and angler use affect the species composition and general condition of a fishery. The relative importance of each parameter varies over the years as well as varying during a particular year. Long term changes in the Madison River fishery and the relative importance of each factor in contributing to those changes are the primary considerations of the current study.

Table 26. Calculated mean total length (mm) at the end of each year of life for brown trout from the Madison River, YNP, 1978, 1969, and 1954-57

Year	N	Calculated length at spring annulus				
		I	II	III	IV	V
1978	80	104	195	287	381	482
1969 ¹⁾	62	104	229	315	396	--
1954-57 ²⁾	432	109	251	343	409	--

Table 27. Calculated mean total length (mm) at the end of each year of life for rainbow trout from the Madison River, YNP, 1978, and 1954-57

Year	N	Calculated length at spring annulus			
		I	II	III	IV
1978	87	139	243	357	433
1954-57 ²⁾	125	127	244	356	417

Table 28. Calculated mean total length (mm) at the end of each year of life for whitefish from the Madison River, YNP, 1969 and 1954-57

Year	N	Calculated length at spring annulus					
		I	II	III	IV	V	VI
1969 ¹⁾	17	109	221	287	328	353	361
1954-57 ²⁾	36	129	226	304	348	388	429

1) Dean and Mills 1970.

2) Benson et al 1959.

Table 29. Management practices and fisherman survey methods on the Madison River, YNP, 1954-57 and 1969-80

Year	Management			Survey methods		
	Stocking	Fly fishing only	5 fish; no size limit	2 fish; 16" min.	Creel census	"Catch" based on fish creeled
1954-55 ¹⁾	X	X	X		X	X
1956-57 ¹⁾		X	X		X	
1969 ²⁾		X	X		X	X
1970-72 ³⁾		X		X	X	X
1973-80 ⁴⁾		X		X		X

1) Benson et al 1959.

2) Dean and Mills 1970, Erman 1972.

3) Dean and Mills 1971, Dean 1972, Dean and Varley 1973.

4) Dean and Varley 1974, Dean et al 1975, Varley et al 1976, Jones et al 1977-80.

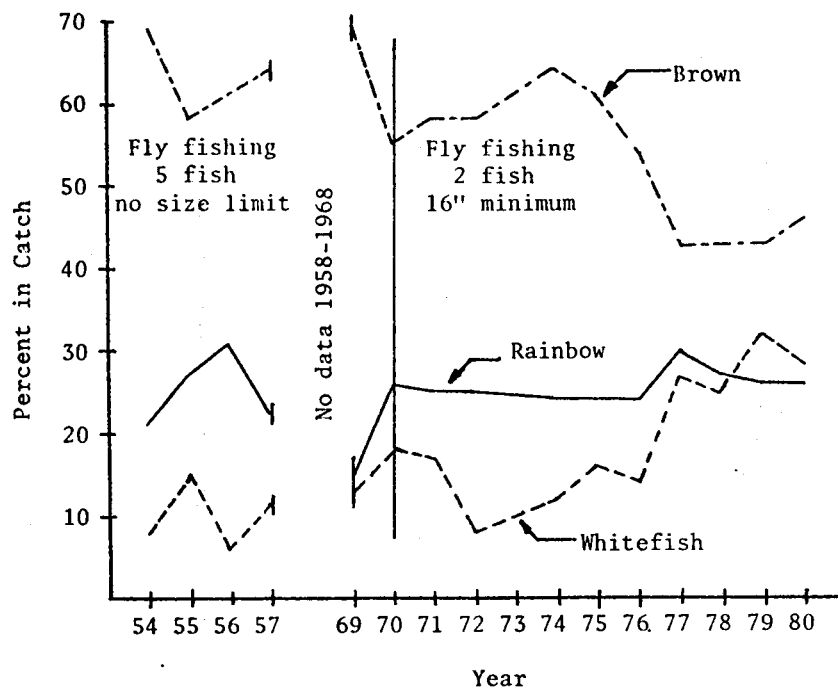


Figure 24. Species composition of the wild trout catch from the Madison River, Yellowstone National Park: 1954 - 1957 and 1969 - 1980.

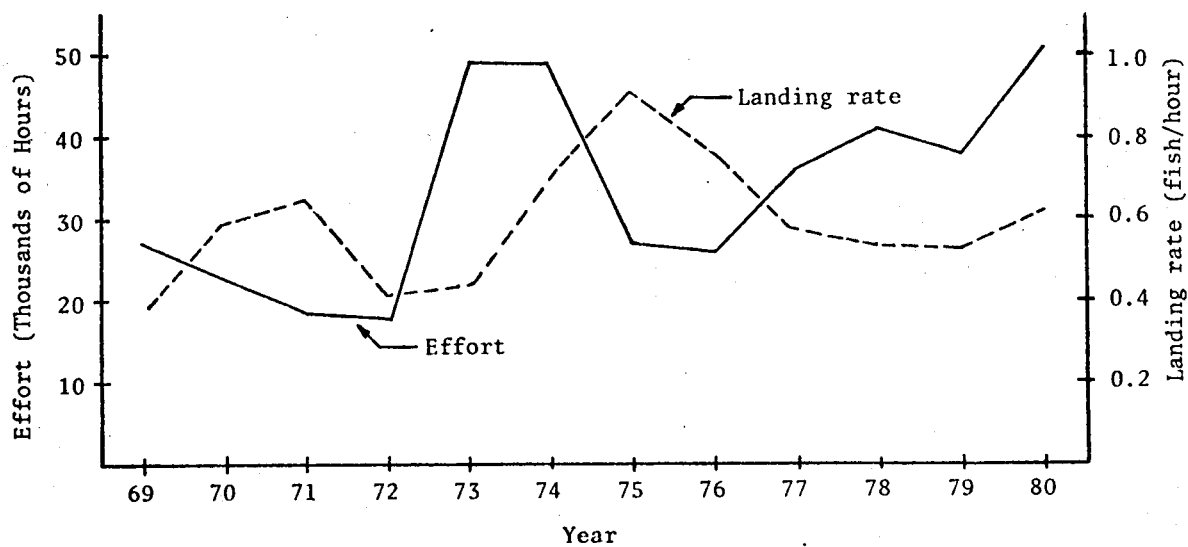


Figure 25. Angler effort and landing rate (species combined) from the Madison River, Yellowstone National Park: 1969 - 1980.

The Hebgen Lake earthquake apparently had no appreciable effects on abiotic conditions in the river as average water flow, water temperature and water chemistry have remained fairly constant over the years. It is also possible to speculate that the long term production of benthos and drift fauna has remained relatively stable. Because of this consistency, the above factors are not considered to have had a major impact on the disappearance of cutthroat and grayling or on the establishment of brown and rainbow trout; neither are they considered to have been a major influence on changes observed between brown trout, rainbow trout and whitefish within the last 25 years.

The disappearance of cutthroat and grayling was probably a combined result of a high level of harvest under liberal angling regulations in existence prior to 1930 and the introduction and establishment of brown and rainbow trout between 1889 and 1955. Reasons for the survival of whitefish are poorly understood. Apparently they compete successfully with brown and rainbow trout; however, lack of niche overlap may also contribute to their continued survival.

On the basis of electrofishing, brown and rainbow trout populations at the upper and lower stations have increased in biomass and declined in numbers. The rise in biomass appears due to an increase in the mean length of individual fish and to a greater relative abundance of larger fish within each population. It is assumed that the decline in numbers is associated with the inverse relationship of numbers and size under conditions of equilibrium (Nikloskii 1969). Whitefish populations at both stations appear to have remained stable, and increases in numbers and biomass, as well as an increase in the relative abundance of larger fish, are most likely due to differences in electroshocking methods.

Higher average landing and creel rates for brown trout seem to reflect their dominant position in the fish/faunal association of the river. Since 1974, however, the percentage of brown trout in the catch and the creel has declined. During this same period, the percentage of rainbow trout in the catch and the creel has increased, the percentage of whitefish in the catch has risen and the percentage of whitefish in the creel has fluctuated greatly. These trends seem to reflect the reduced vulnerability of brown trout to being recaptured, the susceptibility of rainbow trout and whitefish to increased angler effort and the selective creeling of rainbow trout over whitefish.

Growth rates for brown trout and whitefish have altered slightly, but significantly, while growth rates for rainbow trout have remained about the same. Progressive decreases in back calculated lengths at ages II, III and IV for brown trout and at all ages for whitefish seem to indicate

that under present conditions, these two species may be reaching the carrying capacity of the river. Also, growth rates would be expected to slow as the ratio of mature to immature fish increases. The greater length of rainbow trout at age I appears related to the fall spawning habits of Madison River rainbow (Jones et al 1979) and to a relatively shorter incubation period (Carlander 1969). Maintenance of high growth rates by rainbow at ages II, III and IV may indicate that a significant portion of the population is still being removed annually by a combination of natural and angling mortality.

Observed intraspecific and interspecific changes and trends in the species composition of the catch and the creel apparently have resulted from the two fish 406 mm (16 inch) minimum size restriction instituted in 1970. The regulation has substantially reduced harvest and allowed the establishment of more stable population structures for brown and rainbow trout. As whitefish populations appear to have remained unchanged, they seem little affected by the regulation.

From available information, the future of brown trout and whitefish in the fishery seem secure. It may be wise, however, in light of increasing angler effort, to place these two species under a maximum size limitation. By directing harvest on the immature portion of the population, growth rates and production should remain high while allowing greater harvest of smaller fish. It is believed that such regulations would increase the catch rate for brown trout and thereby increase the quality of the fishery, while providing increased protection for valuable spawning stocks. Although rainbow trout have benefited greatly from the two fish, 406 mm (16 inch) minimum size restriction, angling still appears to be a significant factor in total mortality. It may be best to reduce the number of rainbow trout harvested through further restrictive regulations such as catch-and-release only on this species.

Other important questions remain unanswered. The influence of the Hebgen Lake populations on resident populations, the quantitative and qualitative use of the food supply and the fall spawning habits of rainbow trout all require further investigation. Also, the niche requirements for each species should be studied in order to gain a more complete understanding of the Madison River fishery.

CASCADE AND SLOUGH CREEKS - POPULATION ESTIMATES AND HABITAT EVALUATION

Since extensive stream surveys were initiated in 1978, survey methods have been examined and revised repeatedly in hopes of attaining procedures best suited for Yellowstone waters. Coincidentally, several research entities have expressed a desire to utilize Park streams to test various stream habitat evaluation procedures. In August, 1980, project personnel joined with the Wyoming Game and Fish (WGF) Aquatic Habitat Crew, the U.S. Fish and Wildlife Service (FWS) Habitat Evaluation Procedures Group (HEPG) and the USFWS Instream Flow Group (IFG) to examine their respective procedures and compare them to previous evaluations completed by the project crew. Cascade and Slough Creeks were chosen because both contain wild populations of cutthroat trout and each stream had a prior survey using our current procedures (Jones et al 1979 and Jones et al 1980). These areas were also quite desirable because of their easy accessibility and reduced logistic demands.

Methods

Stations which represented various habitat types were selected on both streams. Cascade Creek had three stations each 91 m long (#1 = meadow area; #2 = head of canyon; #3 = canyon area). Four stations of various lengths were chosen at Slough Creek. Station 1 was a riffle area (82.3 m long) in McBride Canyon. Station 2, also in the canyon, represented a 1:1 pool:riffle section approximately 97.5 m long. The shortest section (62.2 m long) was station 3 located in a riffle area at the mouth of the canyon. Station 4 was long (365.8 m) and represented an open meadow, dominated by deep pools.

Combined FWS teams electrofished the four stations on Slough Creek (August 25-28) and the three stations on Cascade Creek (August 20-21) to obtain population estimates by the catch-removal method (Zippin 1958). Additionally, personnel from Idaho State University and Idaho Fish and Game obtained estimates at Slough Creek stations 1, 2 and 4 utilizing snorkel gear for direct total counts (Griffin 1981). Total length and weight measurements were taken from subsamples in each section and corresponding averages were used by HEPG personnel to estimate trout biomass. Net mesh size greatly biased fry estimates, so they were ignored in all biomass calculations.

Habitat evaluations were conducted by WGF and FWS biologists. The Habitat Quality Index (HQI) (Binns and Eiserman 1979) was utilized by

WGF at stations 1, 2 and 4 on Slough Creek and station 2 on Cascade Creek. Respective FWS crews used the Habitat Suitability Index (HSI) at all stations on both streams and the IFG method on all sections except station 1 at Slough Creek. Data collected by HEPG crew were utilized to further calibrate the HSI model and will not be discussed in the current report. Stream surveys utilizing a modified percent optimum method (Jones et al 1979) were conducted at all of these stations in 1978 and 1979 (Jones et al 1979 and Jones et al 1980).

Results

Cascade Creek

Because of its small size, Cascade Creek was well suited for capture-removal population estimates, but snorkel counts could not be utilized. Narrow confidence limits for estimates suggest a high degree of reliability and biomass calculations are also assumed to be accurate for all stations (21.2, 103.2 and 24.6 kg/ha for stations 1-3, respectively).

Age was determined for 18 trout captured at stations 2 and 3 and expanded for 83 measured fish using an age-length key (Kimura 1977). Ages varied from I+ to III+ with an average of 1.4 years.

Although IFG measurements of wetted usable area (WUA) were largest for station 2, there does not appear to be a direct linear relationship between WUA and electrofishing biomass estimates (Table 30). The HSI standing crop estimate (143 kg/ha) was much greater than the electrofishing estimate, but comparisons are limited because only station 2 was sampled in this manner. Optimum habitat ratings for these stations agree with slight differences between station 1 and 3, however, despite the highest biomass estimate, station 2 had an extremely low percent optimum value.

Slough Creek

The large size and flow of Slough Creek made electrofishing extremely difficult and population estimates consequently suffered. Expanded biomass estimates were 34.5, 43.9, 22.4 and 45.1 kg/ha for stations 1-4, respectively. Swift water hampered snorkel counts at station 1 (expanded biomass: 14.6 kg/ha), but since this method works well in deeper water, estimates for station 2 and 4 (72.6 and 52.3 kg/ha, respectively) are probably more representative of the true standing crop.

Table 30. Sampling results using four methods on Slough and Cascade Creeks, 1980

SCUBA counts		Electroshocking ¹⁾ expanded estimates/ section shocked			WY- HQI kg/ha	IFG-WUA m ² /ha	Optimum habitat ²⁾ rating
No.	kg/ha	No.	Biomass (g)	kg/ha			
Cascade Creek:							
Meadow							
≥127 mm	--	--	6	170	--	1,211	42.2
<127 mm	--	--	70	594			
fry	--	--	337	506			
Head of canyon							
≥127 mm	--	--	37	2,304	143	1,298	15
<127 mm	--	--	5	82			
Canyon							
≥127 mm	--	--	17	765	--	288	36.3
Slough Creek:							
Station 1							
≥127 mm	16	11.9	41	5,383	86	--	47.1 ³⁾
<127 mm	71	2.7	103	681			
fry	--	--	187	280			
Station 2							
≥127 mm	112	63.7	63	7,636	148	3,275	--
<127 mm	253	8.9	229	1,706			
Station 3							
≥127 mm	--	--	27	1,832	--	592	--
<127 mm	--	--	167	1,175			
Station 4							
≥127 mm	78	52.2	67	31,257	38	4,482	34.2
<127 mm	6	0.1	18	158			

1) Electroshocking estimates made by USFWS-HEPG personnel.

2) As reported in Jones et al 1980.

3) Stations 1, 2 and 3 were located within station 2 of the 1979 stream survey (Jones et al 1980).

IGF measurement of WUA appeared to be related to electrofishing estimates as they were at Cascade Creek, but again a direct linear relationship was not evident. The relationship between snorkle estimates and WUA (stations 2 and 4) appeared to be inverse, as biomass increased with decreasing WUA. Results from HQI failed to agree with either of the actual biomass estimates (Table 30). Although percent optimum ratings were only available for stations 1-3 combined and for station 4, those ratings show agreement with snorkle estimates and HQI predictions which indicated that station 4 was poorer habitat.

To further investigate the relationship of the two population estimates and the HQI, weighted means were computed for the entire stream from the Park boundary to the canyon using the data from stations 1, 2 and 4. The mean biomass estimates for electrofishing and snorkle counts were 42.7 and 50.3 kg/ha, respectively, and the predicted standing crop was 60 kg/ha using the HQI.

Age was determined for 51 trout from stations 1, 2 and 4 and expanded to 330 measured fish using an age-length key (Kimura 1977). Ages varied from I+ to VI+, and the average age was 1.6 years.

Discussion

Because of varying degrees of difficulty in the use of these methods and associated shortcomings of each, direct comparisons were somewhat confounded. Although snorkel counts could not be made in Cascade Creek because of insufficient depth and HQI sampling was limited to station 2, it is evident that station 2 is excellent habitat capable of sustaining a relatively large standing crop for a stream of this size. These results are much different from previous optimum rating (15%) and suggest necessary revision of our stream survey methods.

Difficulties with the various methods increased on Slough Creek; however, the optimum rating correlated better with biomass estimates there than it did at Cascade Creek. Snorkle counts were difficult at station 1 because of swift water and shallow depth; total population at this station is probably underestimated. Swift water also hampered electrofishing at station 1, and at station 2 excessive water depth greatly reduced efficiency. It is apparent that Slough Creek is too large for capture-removal estimates; however, simple mark-recapture estimates should work well in a stream of this size.

Although problems were also encountered with the HQI according to Binns (1981), it did reflect differences between trout habitat at the stations on Slough Creek. The deep pool area of station 2 was the best habitat because of water temperature, velocity and bank stability. Habitat value in the meadow station was lowered because of bank erosion, low velocity, consistent coarse gravel substrate in riffles and siltation in pools. Habitat deficiencies at all stations included poor cover, low nitrate concentrations and inadequate benthic food production.

Despite these encouraging results, the HQI method was also limited. Binns (1981) stated that lack of sufficient temperature and flow data may have biased habitat ratings upward. If the true temperature were only 1.1°C higher, standing crop predictions would decline by over 30%.

This combined study was extremely successful in uncovering deficiencies and difficulties in all the methods utilized. In most deep water sections, snorkel counts appeared to be more accurate; however, the use of mark-recapture type estimates with electrofishing gear would undoubtedly improve efficiency in larger streams. Temperature and flow data should be checked prior to the use of the HQI so that recorders could be installed if additional data is needed. Although IFG methods may provide excellent information concerning instream flow, such procedures are probably excessively labor intensive for the current level of stream survey work in the Park but undoubtedly have application in instances where a more detailed survey is necessary (i.e. potential disturbance by habitat alteration). Discrepancies between the optimum rating system and other methods strongly suggest that problems exist with current procedures and intensive study and possible revision of methods is necessary.

STREAM SURVEYS

Investigations into the Park's extensive aquatic stream resource were continued in 1980. A reconnaissance survey was conducted on Hellroaring Creek utilizing those methods described by Jones et al (1978). Canyon and Clear Creeks were surveyed using much the same methods described by Jones et al (1979), with the following changes: 1. three stations were sampled on each stream, 2. station length was increased to 305 m, and 3. the number of transects per station was increased to 5 (numbered from downstream to upstream) at 76 m intervals.

Hellroaring Creek

Hellroaring Creek originates outside the northern Park boundary in Gallatin National Forest and only the lower third is situated in the Park. The reconnaissance survey was conducted on the Park portion of the stream on July 24-25, 1980 (Figure 26). During the survey, wildlife was scarce along the stream course; however, elk droppings and game trails were abundant throughout.

Access to Hellroaring Creek can be accomplished by several trails both inside and outside the Park boundary. The shortest route is within the Park on a trail starting off the Grand Loop Road approximately 5.6 km east of Tower Junction. From this road, it is a short 3.6 km hike to the creek down a well-marked and maintained trail. Another short trail (7.2 km) starts from Tower Junction and crosses Yancey's Hole. Hellroaring Creek is also accessible while hiking along the extensive Yellowstone River pack trail. Several trails reach Hellroaring Creek outside the Park within Gallatin National Forest.

Historic and Fish Stocking Records

Historically, Hellroaring Creek was a cutthroat trout fishery. The stream was initially stocked in 1920 with cutthroats and received repeated stockings in 1922-24, 1938 and 1940-41. Although no other fish species were planted in the creek within the Park, species composition remains unknown. In 1944, Chapman reported the landing of rainbow, cutthroat and brook trout. Hanzel (1960), however, reported that the only game fish present in Hellroaring Creek during the 1955 creel census was cutthroat trout. Since there are no physical barriers to fish movement between the Yellowstone River, where anglers repeatedly report landing rainbows, brooks and browns, and Hellroaring Creek, it is possible that other fish species now inhabit the creek. It is also possible that other trouts have been stocked into the stream outside the Park boundary.

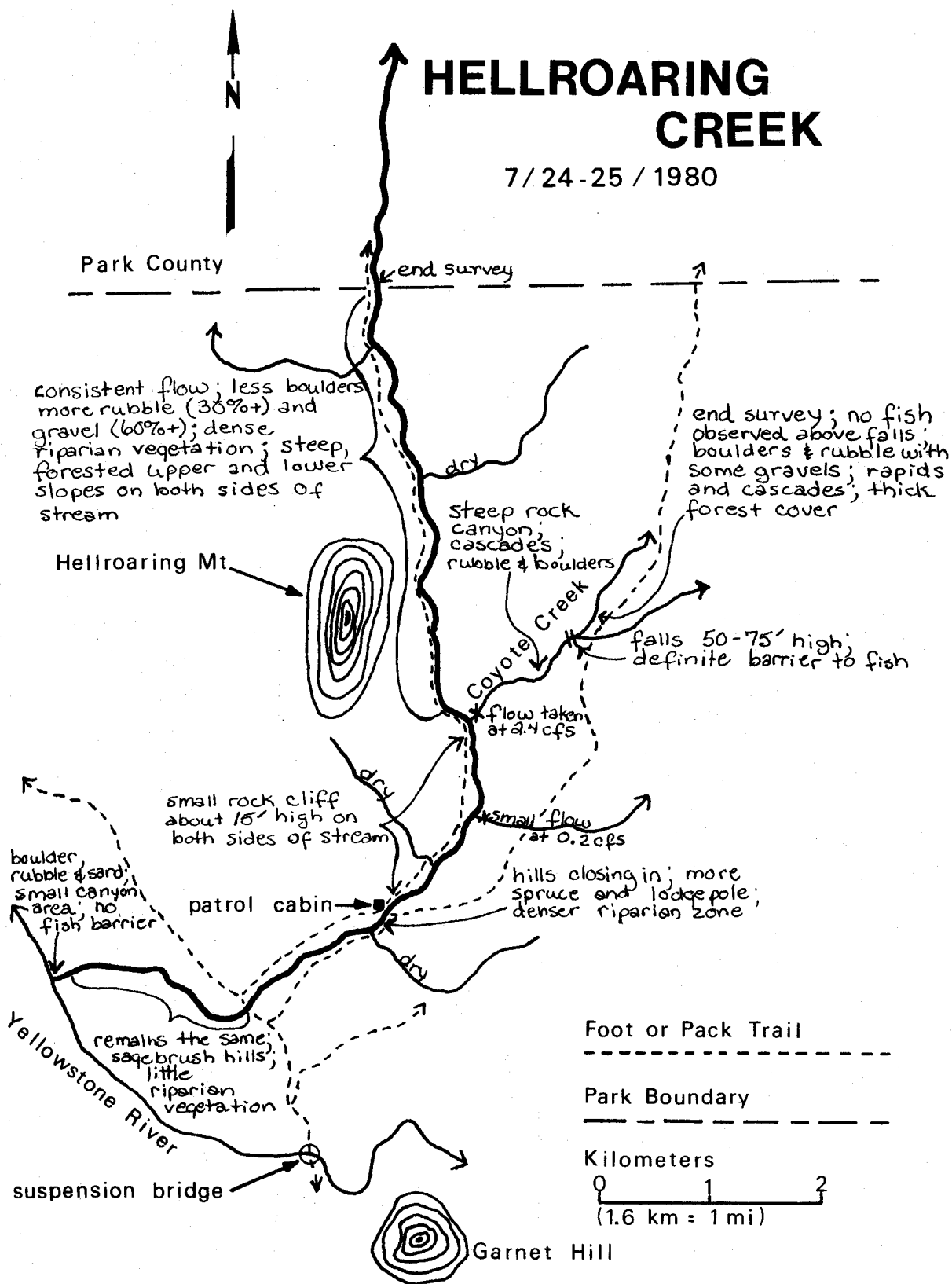


Figure 26. Hellroaring Creek, Yellowstone National Park, 1980.

Description of Area

From the Park boundary to the Montana-Wyoming state lines, Hellroaring Creek travels south for 6 km through a dense Douglas fir/pinegrass forest interspersed with large open areas of big sagebrush with Idaho fescue (Table 31). From here the creek continues 8.5 km to its mouth through generally open hills of big sagebrush and Idaho fescue influenced by infrequent stands of Douglas fir and lodgepole pine.

Geologically, Hellroaring Creek is influenced by Precambrian glacial till of gneiss and schist. Most of Hellroaring Mountain and part of the area around Coyote Creek is bedrock of andesitic breccias, conglomerates, sandstones and lavas of the Eocene era. Near the mouth, the stream pH was 7.7, conductivity was 81 μ mhos and temperature was 14.4°C at 1125 hours.

Hellroaring Creek enters the Park at an elevation of 1920 m. The total drainage area within the Park is 4,571 ha. The creek derives its main water supply from cold springs and snowmelt. From the Park boundary to the mouth, the stream descends at a moderately high gradient (29.4 m/km) over a generally rubble and gravel substrate. Aquatic vegetation is uncommon with only scattered mosses and algae. The riparian zone in the upper 6 km is forested with a dense pinegrass understory; the lower 8.5 km to the mouth has less conifers and more grasses and willows.

Angler Use and Pressure

Due to the many well-maintained trails, a patrol cabin and several back-country campsites along Hellroaring Creek, human visitation is heavy. VFR data for 1977 through 1980 show an average of 190 anglers spent 405 angler days fishing on the stream. Average landing and creel rates were 1.37 and 0.29 trout/hour/year, respectively, which is slightly above average by Yellowstone standards.

Canyon Creek

Canyon Creek originates on the western edge of the Central Plateau as a tributary to the Gibbon River below Gibbon Falls. A habitat survey was conducted on July 30-31, 1980 on three separate stations. Only the portion of stream below the barrier falls was included in the survey (Figure 27). No wildlife was observed during the survey and very little evidence of human or wildlife visitation was apparent.

Although no maintained trails or roadways lead to Canyon Creek, easy access can be obtained via an overland route from Gibbon Falls picnic area (downstream from Gibbon Falls). After fording the Gibbon River, it is a short (0.3 km) walk to the mouth of Canyon Creek.

Table 3 Station Parameters for stations on Canyon, Clear and Hellroaring Creeks, YNP, 1960

Parameters	CANYON CREEK				CLEAR CREEK				HELLROARING CREEK			
	Station 1	Station 2	Station 3	Station 1	Station 2	Station 3	Station 1	Station 2	Station 3	Near mouth	Small tributary off Buffalo Plateau	Coyote Creek near its mouth
Stream order at station	2	2	2	3	3	3	3	3	3	3	2	2
Gradient (entire stream in park)		2.0%						0.9%			1.1%	
Average velocity (m/sec)	0.34	0.16	0.30	0.18	0.24	0.27	0.11	0.14	0.27		0.03	0.10
Average flow (m ³ /sec)	0.11	0.15	0.21	0.11	0.14	0.30	0.11	0.14	0.30		0.005	0.68
Average depth (m)	2.44	5.30	3.93	4.15	5.61	7.83	4.15	5.61	7.83		0.81	3.89
Average width (m)	0.18	0.21	0.21	0.27	0.15	0.18	0.27	0.15	0.18		0.15	0.21
Maximum depth (m)	0.30	0.46	0.38	0.91	0.29	0.49	0.91	0.29	0.49		0.06	0.26
Air temperature (°C)	25.0	20.6	27.2	20.0	14.4	12.2	20.0	14.4	12.2			
Water temperature (°C)	17.8	15.0	20.0	9.4	10.6	10.6	9.4	10.6	10.6	14.4	13.9	15.0
Time of day (hrs)	1530	1040	1340	1000	1300	1200	1000	1300	1200	1125	1420	1500
Land use:												
Immediate area												
drainage												
Ownership												
Access												
Aquatic vegetation												
Fish species:												
historical												
present (observed)												

continued on next page

Table 3] continued

Parameters	CANYON CREEK			CLEAR CREEK			HELLGARING CREEK		
	Station 1	Station 2	Station 3	Station 1	Station 2	Station 3	Near mouth	tributary off Buffalo Plateau	Coyote Creek near its mouth
Main habitat types: upper slopes	sub-alpine fir, englemann spruce grasses, whitebark pine	sub-alpine fir, englemann spruce grasses, whitebark pine	sub-alpine fir, englemann spruce grasses, whitebark pine	sub-alpine fir, englemann spruce grasses, whitebark pine	sub-alpine fir, englemann spruce grasses, whitebark pine	sub-alpine fir, englemann spruce grasses, whitebark pine	sub-alpine fir, englemann spruce grasses, whitebark pine	sub-alpine fir, englemann spruce grasses, whitebark pine	sub-alpine fir, englemann spruce grasses, whitebark pine
lower slopes	lodgepole pine, some juniper	lodgepole pine, some juniper	lodgepole pine, some juniper	lodgepole pine, some juniper	lodgepole pine, some juniper	lodgepole pine, some juniper	lodgepole pine, some juniper	lodgepole pine, some juniper	lodgepole pine, some juniper
riparian	lodgepole pine, some juniper	lodgepole pine, some juniper	lodgepole pine, some juniper	lodgepole pine, some juniper	lodgepole pine, some juniper	lodgepole pine, some juniper	lodgepole pine, some juniper	lodgepole pine, some juniper	lodgepole pine, some juniper
Total length of stream (km)	10.3	10.3	10.3	20.3	20.3	20.3	56.2	56.2	56.2
Total length of stream in Park (km)	10.3	10.3	10.3	20.3	20.3	20.3	14.48	14.48	14.48
Total drainage area within Park (ha)	1,555.8	1,555.8	1,555.8	5,895.9	5,895.9	5,895.9	4,571.2	4,571.2	4,571.2
Total surface area of mainstem within Park (ha)	3.3	3.3	3.3	13.0	13.0	13.0	1)	1)	1)

1) Average width not taken to determine calculation.

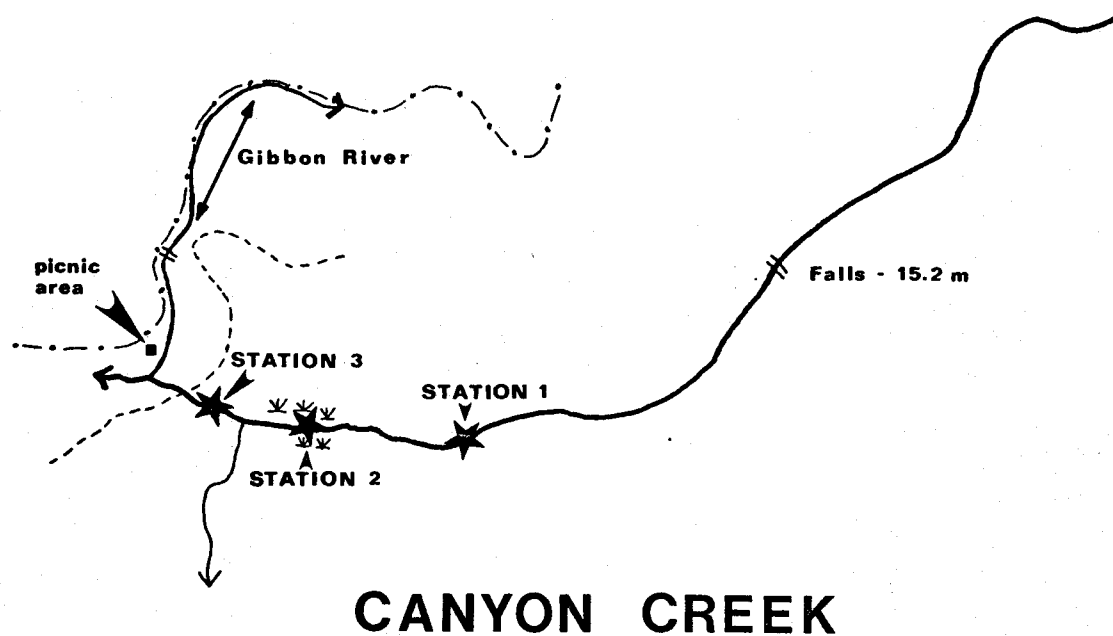


Figure 27. Canyon Creek, Yellowstone National Park, 1980.

Historic and Fish Stocking Records

David Starr Jordan (1891) in 1889 found Canyon Creek "well-stocked" with cutthroat trout and "swarming" with sculpins. In 1973, however, project personnel found the creek to be totally dominated by brown trout; very few sculpins were recovered (Dean and Varley 1974). The stream was first stocked in 1926 with cutthroat and received additional plants in 1927 and 1930. Although brown trout were never officially introduced into the stream, these trout may have gained access to Canyon Creek as early as 1928 when the Gibbon River received its first brown trout plant (Varley 1981). During 1975, an artificial barrier was constructed near the mouth of the creek, and the stream was subsequently poisoned to produce an enclave for grayling (Varley et al 1976). Following this operation, grayling were stocked in the stream in 1976-1978 and 1980. In 1978, however, electroshocking results yielded brown, brook and rainbow trout and only a few grayling (Jones et al 1979). The trout were apparently survivors of the eradication program or immigrants that surmounted the artificial barrier.

Physical and Chemical Characteristics

Canyon Creek originates at an elevation of 2,402 m and derives its main water supply from springs and snowmelt. It has a small drainage area (1,536 ha) and a moderate gradient (20.2 m/km) (Table 31). From the source to the mouth, the stream travels through a dense forest of subalpine fir, Engelmann spruce and lodgepole pine with some juniper and whitebark pine. Approximately 6 km upstream from the mouth is a 15.2 m falls, a definite barrier to upstream fish movement.

Geologically, Canyon Creek is heavily influenced by rhyolitic lava flows of the Pleistocene era. It sits between two flows, the Gibbon River flow to the north and the Nez Perce Creek flow to the south.

A water sample was taken at station 1 on July 30, 1980 (Table 32). On the basis of ionic components, the creek was determined to be a sodium-bicarbonate water with a pH of 7.2 and a conductivity of 140 μ mhos. Most measured chemical parameters were average for Park streams except for lower than average concentrations of sulfate, magnesium, phosphate, and total hardness and higher concentrations of TDS, fluoride, potassium, sodium, silica and TOC. Conductivity was below average for Park streams also.

Habitat Inventory

Three stations were sampled on Canyon Creek (Figure 27). Station 1 was located 2.7 km upstream from the mouth in a heavily forested area. This

Table 32. Chemical characteristics of back-country lakes and streams surveyed in Yellowstone National Park, 1980

	Forest Lake	Ice Lake	Obsidian Lake	Scalp Lake	Canyon Creek	Clear Creek
	2m deep 8/19 - 20/80	2m deep 7/31 - 8/1/80	2m deep 8/12 - 13/80	2m deep 8/21 - 22/80	7/30/80	8/14/80
Water Temp. °C*	12.8	18.3	15.6	12.8	—	—
Spec. Cond. μmhos^*	29	30	16	27	140	78
pH*	7.0	7.1	6.5	6.75	7.2	7.2 - 7.4
Dissolved O_2 *	6.6	7.0	6.2	7.2	—	—
Ferno. Alk. mg/l^*	0	0	0	0	0	0
Total Alk. mg/l^*	9.6	10	4.0	5.2	48	28
Ca Hardness**	9.8	6.8	6.0	5.6	18	26
Total Hardness**	10	8.4	7.8	7.2	20	29
Total Diss. Solids	15	18	17	12	115	56
Carbonate Alk.	0	0	0	0	0	0
Bicarbonate Alk.	9.6	10	4.0	5.2	48	28
Carbonates	12	12	4.9	6.3	59	34
Bicarbonates	0	0	0	0	0	0
Hydroxides	40	16	20	27	25	23
Carbon dioxide	1.5	<1.0	1.5	1.5	4.0	3.0
Chloride	2.1	2.4	5.5	2.5	3.0	7.8
Sulfate	0.65	0.19	0.07	0.02	3.7	0.10
Fluoride	0.25	0.28	0.19	0.19	0.19	0.47
Phosphate	0.4	1.2	0.6	0.8	5.3	0.8
Potassium	1.2	1.6	1.8	1.6	2.0	3.0
Mg Hardness	3.5	2.7	2.4	2.2	7.2	10
Calcium	0.5	0.4	0.4	0.4	0.5	0.7
Magnesium	1.4	1.8	0.8	1.4	19	3.6
Sodium	0.04	0.01	0.10	0.02	0.03	0.01
Iron	0.04	<0.05	<0.05	0.02	<0.05	<0.05
Manganese	<0.1	<0.1	<0.1	<0.1	60	11
Copper	1.5	4.9	4.0	1.1	0	0
Silica	0	0	0	0	0	0
Celot (Cobalt) PCU	3.3	0.69	2.0	1.4	0.75	0.23
Turbidity NTU	13	6.0	16	7.5	16	2.6
ICC	0.16	0.12	0.19	0.12	0.12	0.47
Ortho-phosphate	0.38	0.18	0.63	0.39	0.22	0.15
Nitrate N	0.01	<0.01	<0.01	0.02	0.01	0.01

* Field measurements, all others made by commercial laboratory.
 ** Field measurements for all inlets, others made by commercial laboratory.

station represented the largest habitat type (62.8%). Station 2 was located in a wet meadow area (1.5 km upstream from the mouth) and represented 13.9% of the surveyed area. The lower forested area of station 3 (0.6 km upstream from the mouth) represented 23.3% of the stream habitat type.

The average flow and depth for stations 1, 2, and 3 were 0.11 m³/sec and 0.18 m, 0.15 m³/sec and 0.21 m and 0.21 m³/sec and 0.21 m, respectively, (Table 32). Widths varied from 2.1 m to 7.2 m at the three stations.

The overall percent of optimum for Canyon Creek was 34.9 (Table 33). Although this rating is not high, it is about average for small streams within the Park. All three stations were rated low in pool measure and structure; however, stations 1 and 3 were rated exceptionally high in environment. Station 1 also brought up the overall rating due to the stream bottom values.

The upper slopes at all three stations were predominately subalpine fir and Engelmann spruce with a grouse whortleberry understory and occasional patches of whitebark pine. The lower slopes at stations 1 and 3 were similar with lodgepole pine, grasses and juniper dominating the areas. At station 2, the lower slopes were generally grasses and scattered stands of lodgepole pine. The riparian zone was dominated by lodgepole pine, sedges, grasses and scattered junipers in stations 1 and 3; the meadow area of station 2, however, was made up of sedges, grasses, monkey-flower and fringed gentian. In stations 1, 2 and 3, approximately 33%, 90% and 50%, respectively, of direct sunlight reaches the stream on a clear, summer day.

Canyon Creek was rated fair (79.1) under the Channel Stability Rating System (U.S. Forest Service 1975) (Table 34). The upper banks at all three stations showed no evidence of past or any potential for future mass wasting into the channel. Debris was present, mostly in the form of small twigs and limbs. Vegetative bank protection was excellent at stations 1 and 3 and only slightly less vigorous in station 2. The lower slopes at all three stations showed evidence of significant bank cutting and suggested that the channel barely contains the peak runoff during average years. Although the pool:riffle relationship in station 3 appeared stable with obstructions firmly imbedded in the channel, these features were less stable at the other two stations. In stations 2 and 3, there was little or no evidence of eroding banks or enlargement of point bars. At station 1, however, there was some intermittent cutting along channel outcurves and filling of pools by sediments so that riffle areas predominated. In stations 1 and 3, the channel bottom was found to be only 20-50% stable showing little or no evidence of particle packing. The bottom in station 2 appeared to be 50-80% stable. At all three stations, cuts were mostly at channel constrictions.

Table 33 Station means and optimum habitat ratings for Clear and Canyon Creeks, 1980

	<u>Canyon Creek</u>				<u>Clear Creek</u>			
	<u>Sta. 1</u>	<u>Sta. 2</u>	<u>Sta. 3</u>	<u>weighted avg. survey area</u>	<u>Sta. 1</u>	<u>Sta. 2</u>	<u>Sta. 3</u>	<u>weighted avg. survey area</u>
Pool measure (%)	0.0	13.5	7.6	3.7	26.1	0.0	0.0	13.3
Pool structure (%)	0.0	0.0	0.0	0.0	26.1	0.0	0.0	13.3
Stream bottom (%)	80.0	14.0	29.0	58.9	79.0	54.0	41.0	66.1
Environment (%)	77.5	40.0	97.5	76.9	40.0	88.8	97.5	64.4
Bottom structure (%)								
Bedrock	0	0	0	—	0	0	14	—
Boulder	0	0	0	—	3	13	12	—
Rubble	0	0	0	—	33	42	25	—
Gravel	80	14	29	—	46	12	16	—
Sand	12	19	28	—	11	29	26	—
Silt	8	67	43	—	7	4	7	—
Other	0	0	0	—	0	0	0	—
Mean width (m)	2.44	5.30	3.93	3.17	4.15	5.61	7.83	4.97
Pool (%)	0.0	6.7	3.8	—	17.8	0.0	0.0	—
Run/Riffle (%)	100.0	93.3	96.2	—	82.2	100.0	100.0	—
Mean depth (m)	0.18	0.21	0.21	0.18	0.27	0.15	0.18	0.21
Mean velocity (m/sec)	0.34	0.18	0.30	—	0.18	0.24	0.27	—
Flow (m ³ /sec)	0.11	0.15	0.21	0.14	0.11	0.14	0.30	0.13
% of the habitat represented by each station	63	14	23	100	51	44	5	100
Optimum Habitat Rating (%)	39.4	16.9	33.5	34.9	42.8	35.7	34.6	39.3

Table 34 Stream reach inventory and channel stability evaluation, Canyon and Clear Creeks, 1980

	Station 1				Station 2				Station 3			
	Excellent	Good	Fair	Poor	Excellent	Good	Fair	Poor	Excellent	Good	Fair	Poor
Canyon Creek												
Upper banks	6	8	0	0	7	6	0	0	6	8	0	0
Lower banks	0	12	15	8	8	0	9	8	6	8	3	8
Stream bottom	3	12	12	8	3	20	0	8	3	12	18	0
TOTALS	9	32	27	16	18	26	9	16	15	28	21	8
Station Stability Score:	84				69				72			
Stream Stability Score: ¹⁾ (weighted avg)	79.1				79.1				79.1			
Clear Creek												
Upper banks	5	10	0	0	3	6	12	0	7	6	0	0
Lower banks	0	12	21	0	2	20	3	0	2	20	3	0
Stream bottom	0	14	24	0	1	28	0	0	6	18	0	0
TOTALS	5	36	45	0	6	54	15	0	15	44	3	0
Station Stability Score:	86				75				62			
Stream Stability Score: ¹⁾ (weighted avg)	80.0				80.0				80.0			

1) Ratings: Excellent = 0 - 38; Good = 39 - 76; Fair = 77 - 114; Poor = 115+.

Aquatic vegetation was abundant in stations 2 and 3 and common at station 1 (Table 35). Algae (Chara sp.) was collected at stations 1 and 3; a variety of vascular plants was abundant throughout the stream. Liverworts were collected at station 1 only.

Aquatic Invertebrates

Both surber and drift samples were collected on Canyon Creek. Two surbers were taken from each station and one overnight drift from station 1 (Table 36). A total of 21 taxonomic groups were represented in the combined samples. Problems encountered during storage of these samples prevented a complete quantitative analysis, and the resulting taxonomic list probably encompasses only the most common forms.

Aquatic Vertebrates

In 1980, Canyon Creek was shocked to determine a population estimate employing the capture-removal method (Zippen 1958). Three passes were made through a 366 m section in the big meadow area near station 2 (Figure 27). The first pass was accomplished on July 22 at which time captured fish were counted only and removed. The second and third passes were performed on August 1. Fish captured during the second pass were separated into four length classes and randomly measured for lengths and weights. Thirty scale samples were taken for ageing. Pass 3 fish were counted only and removed.

A total of 1,620 fish were captured ranging in length from 55 mm to 284 mm and averaging 12.03 g/fish. In passes 1 and 2, brown trout averaged 97.4% of the population, rainbow trout 2.5% and cutthroat trout 0.1%. Species composition was not determined on pass 3. No grayling or sculpins were captured.

The sample section had a surface area of 0.22 ha and an average width of 5.94 m. Since pass 1 (736 fish) was made one week prior to passes 2 and 3 (572 fish and 312 fish, respectively), only those fish captured on August 1 were used for the expanded estimates. The expanded population for this area was estimated at 1,258 trout and 15.1 kg. The total number and biomass of trout per hectare was determined at 5,789 trout and 69.5 kg, respectively. The expanded linear estimate was calculated at 3,440 trout/km.

Ages were determined on 30 of the 96 brown trout captured and measured during the second pass, using the scale method. Ages and lengths were then fitted to an age-length key in order to expand ages for the entire

Table 35 Terrestrial and aquatic plants, Canyon and Clear Creek, YNP, 1980

Name	Canyon Creek 7/30-31/80			Clear Creek 8/14-15/80		
	Sta 1	Sta 2	Sta 3	Sta 1	Sta 2	Sta 3
Terrestrial plants:						
<u>Ledum glandulosum</u> Nutt.			X			
<u>Vaccinium occidentale</u> A. Gray			X			
Willows:						
<u>Salix bootii</u> Dorn.				X	X	
<u>Salix drummondiana</u> Barratt					X	X
<u>Salix farriae</u> Ball					X	
<u>Salix wolfii</u> Beeb				X		X
Aquatic plants:						
<u>Chara</u> sp.	X		X			
Mosses:						
<u>Fontinalus hypnoides</u> C.J. Hartm.					X	
<u>Fontinalus neo-mexicana</u> S. NL.	X			X	X	X
<u>Pylasiasielliella polyantha</u> (Hedw.) Grout						X
Liverwort:						
<u>Jungermannia exsertifolia</u> Steph.					X	
<u>Scapania undulata</u> (L.) Dum.	X					
Vascular plants:						
<u>Agrostis exarata</u> Trin.	X					
<u>Equisetum arvense</u> L.					X	
<u>Juncus</u> sp.		X				
<u>Juncus tracyi</u> Rybd.	X	X				
<u>Mimulus guttatus</u> DC.	X	X				
<u>Potamogeton epihydrus</u> Raf.			X			
<u>Potamogeton filiformis</u> Pers.	X	X				
<u>Ranunculus aquatilis</u> L.	X			X		
<u>Utricularia minor</u> L.		X				

Table 36 Aquatic invertebrates collected from Canyon and Clear Creeks, 1980

Taxon (common name)	Canyon Creek				Clear Creek			
	Sta. 1 Surber	Sta. 2 Surber	Sta. 3 Surber	Drift	Sta. 1 Surber	Sta. 2 Surber	Sta. 3 Surber	Drift
Insecta								
Ephemeroptera (mayflies)								
Baetidae								
Baetis sp.			X		X			X
Baetis tricaudatus				X				
Ephemerellidae								
Ephemerella sp.			X		X			
Ephemerella coloradensis					X			
Ephemerella tibialis						X	X	
Heptageniidae								
Cinygmula sp.					X		X	X
Epeorus sp.					X	X	X	X
Rhithrogena haageni					X			
Heptagenia sp.					X		X	
Leptophlebiidae								
Paraleptophlebia sp.	X		X	X				
Siphonuridae								
Ameletus validus					X			X
Odonata								
Anisoptera (dragonflies)								
Corduliidae								
Somatochlora sp.								
Plecoptera (stoneflies)								
Nemouridae								
Malenka sp.	X		X	X		X		
Perlodidae								
Isoperla sp.								X
Tricoptera (caddisflies)								
Brachycentridae								
Brachycentrus sp.	X	X						
Micrasema sp.	X		X	X		X	X	
Glossosomatidae								
Glossosoma sp.					X	X	X	
Hydropsychidae								
Parasyche sp.					X	X		
Lepidostomatidae								
Lepidostoma sp.			X	X				
Limnephilidae								
Onocogmoecus sp.					X			
Philopotamidae								
Dolophilodes sp.			X	X				
Polycentropodidae								
Nyctiophylax sp.					X	X		X
Rhyacophilidae								
Rhyacophila sp.			X				X	
Coleoptera (beetles)								
Dytiscidae								
Elmidae	X	X		X	X	X	X	

continued on next page

Table 36 continued

Taxon (common name)	Canyon Creek				Clear Creek			
	Sta. 1 Surber	Sta. 2 Surber	Sta. 3 Surber	Drift	Sta. 1 Surber	Sta. 2 Surber	Sta. 3 Surber	Drift
Diptera (true flies)								
Chironomidae	X	X		X		X		
Rhagionidae		X						
Atherix sp.			X	X				
Simuliidae					X			
Tipulidae								
Amphipoda (scuds)								
Gammarus sp.		X						
<u>Hyalalea azteca</u>		X		X				
Gastropoda (snails)								
<u>Rhyss</u> sp.			X					
Pelecypoda (clams)								
Sphaeriidae		X	X					
Hirudinea (leeches)					X		X	
Hydracarina (water mites)				X				
Oligochaeta (aquatic earthworms)	X	X	X	X	X			
NUMBER TAXONOMIC GROUPS	7	9	12	12	16	10	9	6
TOTAL NUMBER OF GROUPS PER WATER		21				23		

measured sample (Kimura 1977). The average age and length for brown trout was 0.7 and 134 mm, respectively, and included individuals from 0+ to III+ years. Since 90% of all captured trout were <100 mm, this is probably a true average age for all brown trout captured in the shocked area.

Angler Use and Pressure

Although no VFR cards have been returned for Canyon Creek and no fisherman trails were evident along the stream course, Canyon Creek receives light use. Its close proximity to Gibbon Falls picnic area enables fishermen to gain easy access to the creek's lower section.

Clear Creek

Clear Creek originates in the Absaroka Range near Sylvan Pass, 12.9 km west of the East Entrance Ranger Station. A reconnaissance survey was conducted on August 12, 1980. The stream was revisited on August 14 and 15, 1980 to conduct a habitat survey on three separate stations (Figure 28). Although no wildlife was observed during the surveys, beaver activity was evident and game trails and beds were prominent.

Due to its close proximity to the East Entrance road, the upper reaches of Clear Creek are easily accessible. Other access to the stream can be gained by two well-marked and maintained trails. The Clear Creek pack trail parallels the creek from Sylvan Lake to the mouth. The Thorofare trail crosses the stream 5.2 km from its start on the East Entrance Road. The mouth and lower reaches of the stream are also easily accessible to the many boaters who frequent Yellowstone Lake.

Historic and Fish Stocking Records

Historically and presently, Clear Creek is a cutthroat fishery. From 1912, and almost annually until 1953, Clear Creek was utilized for spawn-taking activities. The creek itself was stocked with Yellowstone Lake cutthroat repeatedly from 1913 to 1950. After 1953, the fish trap, located near its mouth, was used primarily to monitor the cutthroat spawning run in the creek. Data was collected in 1963-1967, 1973 and 1977-1980. Operation of the Clear Creek fish trap enables data collection concerning cutthroat migration, spawning activities, homing and food habits (see Clear Creek spawning run, this report).

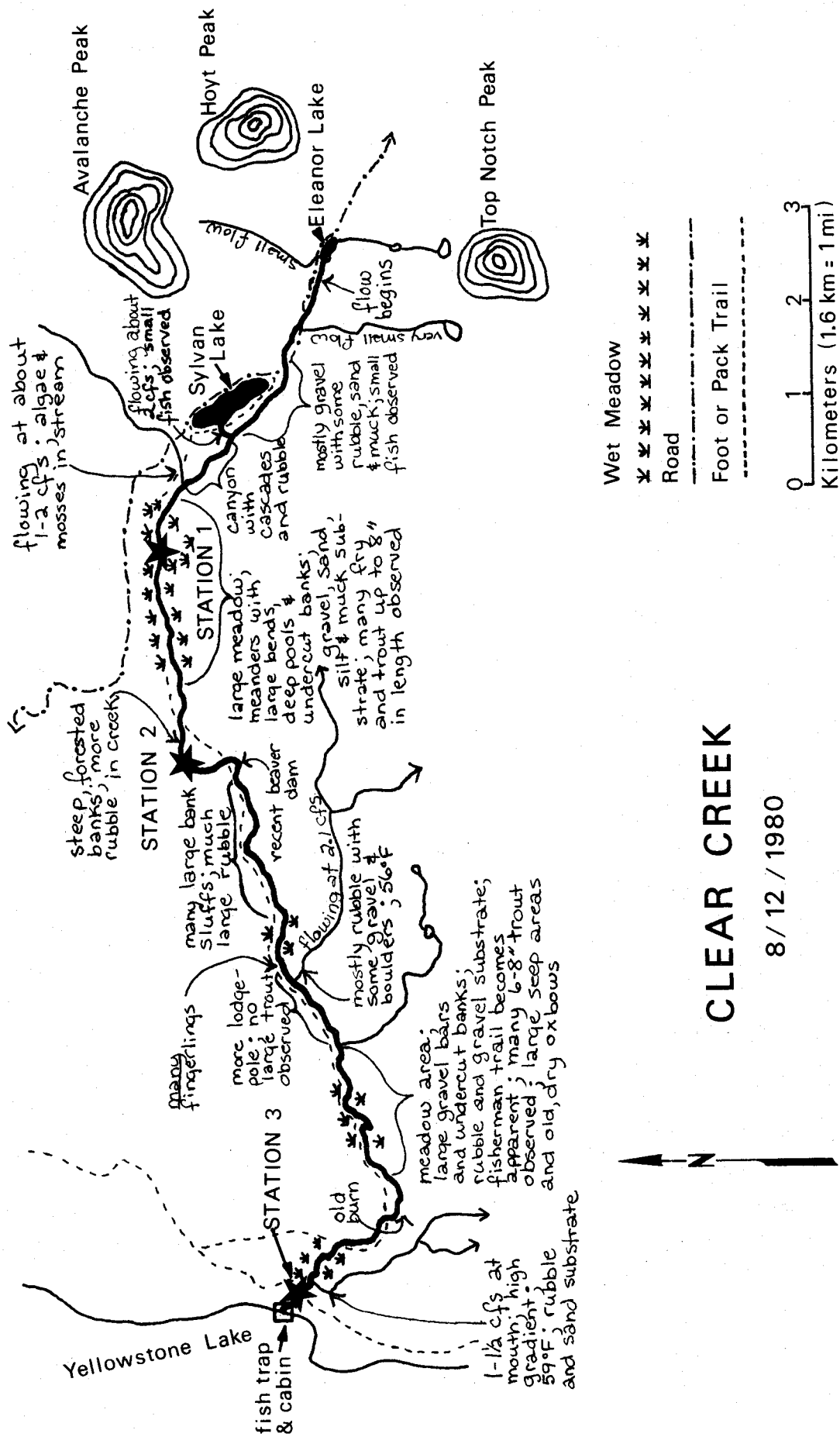


Figure 28. Clear Creek, Yellowstone National Park, 1980.

Physical and Chemical Characteristics

Clear Creek originates at an elevation of 2,585 m on the western slope of the Absaroka Range and derives its main water supply from snowmelt and springs. The creek has a drainage area of 5,896 ha and travels at a low gradient (10.8 m/km). From the source to the upper meadow (station 1), the stream travels for 4.7 km past Sylvan Lake through a dense, wet forest area of lodgepole pine, Engelmann spruce and subalpine fir. The hillsides are steeply sloped in this area with a small rock-walled canyon located immediately downstream from Sylvan Lake. The next 3.5 km of stream meanders through a large, grass and sedge meadow surrounded by lodgepole pine, Engelmann spruce, subalpine fir and some whitebark pine. From the meadow to 10.4 km downstream, the creek flows through a generally dense, wet forest area of subalpine fir, lodgepole pine, Engelmann spruce and willows interspersed with small sedge bog meadows. The last 1.7 km of stream downstream to the mouth travels through a subalpine fir, lodgepole pine and Engelmann spruce forest.

Geologically, the creek is highly influenced by andesite of the Langford Formation (Eocene era). Near the mouth, the stream flows over rhyolitic Lava Creek tuff of the Pleistocene era.

Chemical analysis on the water sample taken at station 1 indicated that Clear Creek was a calcium-bicarbonate type water (Table 32). Compared to other Park streams, the creek had average concentrations in most chemical parameters except for lower concentrations of total alkalinity, TDS, bicarbonates, fluoride, potassium, sodium, magnesium and Kjeldahl N. Conductivity was also below average for Park streams.

Habitat Inventory

Three stations were selected and analyzed on Clear Creek (Figure 28). Station 1 was located in a large meadow area 15.1 km upstream from the mouth and represented 50.8% of the entire stream. Both stations 2 and 3 were in forested areas (11.5 km and 0.6 km, respectively, upstream from the mouth) and represented 44.4% and 4.8%, respectively, of the entire stream habitat.

The average flow and depth for stations 1, 2 and 3 were 0.11 m³/sec and 0.27 m, 0.14 m³/sec and 0.15 m, and 0.30 m³/sec and 0.18 m, respectively (Table 31). Widths varied from 2.4 m to 10.3 m at the three stations.

The overall percent of optimum for Clear Creek was 39.3 (Table 33). This is next to the highest rating given to any Park water to date. The high

individual optimum rating at station 1 was probably due to the large percentage of both quality pools and gravel-rubble bottom found there. Both stations 2 and 3 were rated high in environment because of the forested terrain and dense understory in those areas.

The upper slopes at all three stations were predominately a wet forest type of subalpine fir and Engelmann spruce with scattered stands of lodgepole pine and whitebark pine. The lower slopes of the three stations were generally lodgepole pine, Engelmann spruce and willows. Additionally, a variety of grasses were found at station 1; globe huckleberry was common in station 2; and pinegrass occurred in station 3. At station 1, the riparian zone was dominated by grasses, willows and sedges. The riparian zone at both stations 2 and 3 were generally Engelmann spruce, grasses, willows and sedges. Lodgepole pine was also frequent at station 3. At stations 1, 2 and 3, approximately 90%, 40% and 60%, respectively, of direct sunlight reaches the stream on a clear, summer day.

Clear Creek was rated fair (80.0) under the Channel Stability Rating System (U.S. Forest Service 1975) (Table 34). The upper banks at stations 2 and 3 showed evidence of infrequent and very small slumps into the stream. Only in station 1 was there no potential mass-wasting. Vegetative bank protection was excellent in stations 2 and 3 (90%) and only slightly less vigorous in the meadow area of station 1 (70-90%). Debris jam potential was almost nonexistent in stations 1 and 3; however, there was a noticeable accumulation of debris along the upper banks in station 2. The lower banks at all three stations showed evidence of bank cutting and suggested that the channel barely contains the peak runoff during average years. Deposition of fresh, coarse sands and gravels was observed with moderate frequency throughout the surveyed areas. Sediment traps were also present throughout, causing cross currents and some minor bank and bottom erosion. The channel bottom at station 3 was 80-100% stable, and the bedrock, boulder and rubble bottom was tightly packed together and difficult to dislodge. Progressively upstream, however, the channel bottom became less stable (station 2 = 50-80%; station 1 = 20-50%) as bottom sediments changed from generally rubble-gravel to gravel-sand/silt. At all three stations, cuts were found mostly at channel constrictions and sediments tended to move through pools causing only slight changes in depth.

Aquatic vegetation was common in stations 2 and 3 but rare at station 1 (Table 35). Only mosses and white water buttercup were collected at station 1. Mosses were common at stations 2 and 3, but liverworts and

vascular plants were rare. At station 2, the liverwort, Jungermannia exsertifolia Steph, was collected for the first time in Yellowstone Park and within the state of Wyoming. No algae were collected in Clear Creek.

Aquatic Invertebrates

Both surber and drift sampling methods were conducted on Clear Creek. Two surbers were collected from each station and one overnight drift from station 1 (Table 36). A total of 23 taxonomic groups were represented in the combined samples. Problems encountered during storage of these samples prevented a complete quantitative analysis, and the resulting taxonomic list probably encompasses only the most common forms.

Aquatic Vertebrates

During the survey, fry and small cutthroat trout (200 mm in length and smaller) were observed throughout the stream course. Larger trout were only seen in the lower 1.5 km; however, Cope (1957), LaBar (1971) and Jones et al (1978) have observed spawners up to within 1.5 km of the source. This discrepancy is probably due to a later survey date in 1980. Although Clear Creek is used for spawning, there is thought to be no resident fluvial population (see Clear Creek spawning run, this report).

Angler Use and Pressure

Due to easy access by boat and the existence of short and well-maintained trails, Clear Creek receives moderate use. During the survey, six fishermen were observed along the lower 1.5 km of stream. Fishermen trails were evident along both banks from the mouth upstream 2 km to a small meadow area.

VFR data from 1973 to 1980 show an average of 956 anglers spent 1,263 angler days fishing the creek. Average landing and creel rates were 2.07 and 0.23 trout/hour/year, respectively, which is excellent by Yellowstone standards.

Conclusions and Recommendations

The fish species composition of Hellroaring Creek remains unknown. Since this large creek receives frequent human visitation, and varying VFR reports, a complete habitat survey, including an electroshocking operation, is recommended to assess the fish population and habitat type.

Canyon Creek was found to be a nursery area for brown and rainbow trout. Historical fish species have been replaced, and the recent plants of grayling have not taken. Since eradication of the existing trout species and grayling plants have repeatedly failed, we recommend that Canyon Creek be allowed to return to its original condition prior to the 1975 restoration project.

Clear Creek remains a major spawning area for Yellowstone Lake cutthroat trout. Fry and small cutthroat (200 mm and smaller) were observed throughout the stream and larger trout were seen only in the lower 1.5 km. Spawning gravel and sufficient cover were noticed throughout the stream course. We recommend a visual survey be conducted on the mainstem and its major tributaries during spawning season to compare current spawner utilization to prior studies.

LAKE SURVEY PROGRAM

Introduction

In the early 1960's, the National Park Service requested this office to initiate an investigation of all aquatic resources in the Park. The objectives included a basic inventory of the number and types of waters, analysis of angler exploitation and preparation of baseline data to enable future researchers to assess changes in habitats over time. In 1980, complete and abbreviated aquatic surveys were conducted on 4 lakes, bringing the total number of lakes surveyed thus far to 111.

Surveys were carried out from July through September, and approximately two days were spent on each water. Although various methods have been used over the years to quantify data, overall results are reasonably comparable. Current methods are described in detail by Dean and Mills (1970); plankton enumeration since 1973 follows a method modified from McNabb (1960). Beginning in 1974, one water sample from each lake was given an extensive chemical analysis by a commercial laboratory.

FOREST LAKE

Forest Lake is located in the south-central portion of the Park, approximately 3.5 km due north of the south boundary. Access is accomplished by traveling on foot or horseback about 4 km north on the South Entrance trail and then east another 0.5 km cross-country through a thick forest. The lake was surveyed on August 19-20, 1980.

Physical

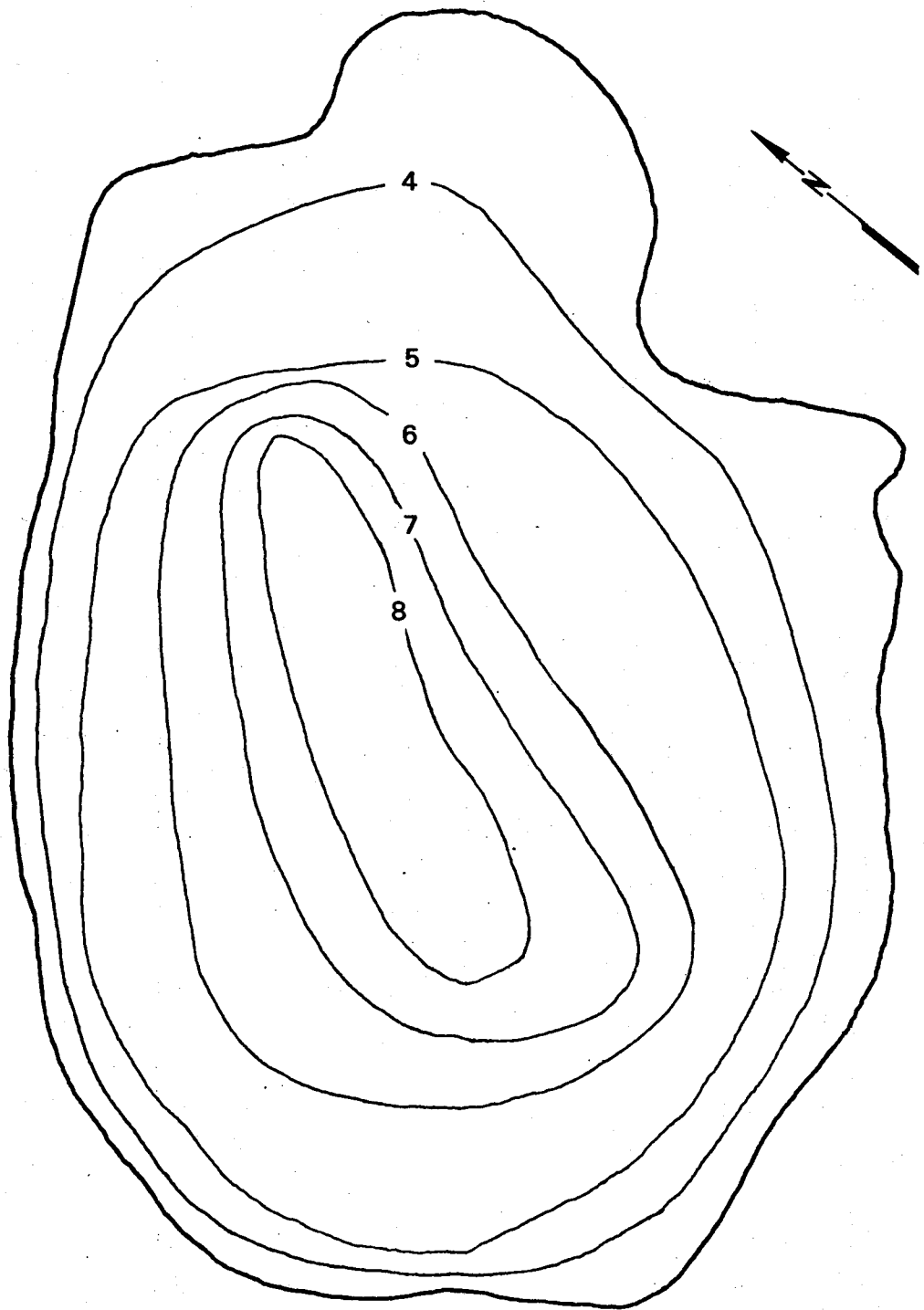
The bedrock geology of the Forest Lake drainage (49 ha) is entirely rhyolitic, comprised of Lewis River rhyolite on the east and Lava Creek Tuff of the Yellowstone Group on the west (USGS 1972). Sandy, glacial till from the Pinedale glaciation dominates the surficial deposits. Clasts are mostly rhyolite, but quartzite erratics are also found in the area (Richmond 1973).

The lake is completely surrounded by the lodgepole pine forest. The forest on the west portion of the drainage appears to be at a later successional stage, and Engelmann spruce and subalpine fir are abundant in this portion. The small meadow separating the lake and the forest varied from several meters to over 100 m; this area was sparsely vegetated with terrestrial grasses and forbes.

At an elevation of 2,262 m, Forest Lake had a surface area of 4 ha, and mean depth was 1.5 m (Table 37). Maximum depth was 2.4 m. The secchi disc was visible to the bottom on an overcast day. Water temperature (12.8o C) was constant from surface to bottom.

Shoreline development of this somewhat circular lake was fair, and signs of erosion were absent. Shallow water substrate was generally clay-silt with large amounts of gravel and rubble. A thin (several mm) layer of organic detritus was evident in some places. Small boulders were locally common along the exposed shore. Profundal sediments were mainly clay-silt with varying amounts of organic detritus and decaying plant matter.

Although current water level fluctuations were small (0.3 m), high-water marks on surrounding trees indicated historical lake levels 2-3 m greater than present. At that level, the current shore would be inundated and the lake would reach the forest. A small, wet meadow lying east of the lake would have been part of the lake during that



SCALE: 0.1 km
CONTOUR INTERVAL: 1 ft

Figure 29 Forest Lake, Yellowstone National Park, 1980.

Table 37 Physical characteristics of back-country lakes in Yellowstone Park, 1980

Lakes	Location ¹⁾	Elevation		Drainage Area		Surface Area ²⁾		Maximum Depth		Average Depth		Capacity		Secchi Visibility		Tributary to: ³⁾	Major Drainage
		meters	feet	hectares	acres	hectares	acres	meters	feet	meters	feet	m ³	acre ft.	meters	feet		
Forest	528.9E 4953.9N	2262	7420	49	122	4	10	2.4	8	1.5	4.9	60,447	49.0	to bottom		Snake River	Snake River
Ice	529.5E 4952.2N	2402	7879	91	226	26	64.3	16.4	54	6.9	22.5 ⁴⁾	1,784,801	1446.8	8.5	28	#1431	Sibbon River
Obsidian	522.6E 4964.8N	2365	7760	394	973	11.3	28	7.6	25	1.3	4.1	141,620	114.8	2.0	6.5	Obsidian Creek	Gardner River
Scarp	518.6E 4919.5N	2420	7940	125	308	2.3	5.8	2.7	9	1.6	5.1	36,515	29.6	to bottom		Spring Creek	Firehole River

1) Coordinates utilizing Universal Transverse Mercator 1000 meter Grid System on USGS map, Yellowstone National Park, 84408-A-10948/59ad2, 1961.

2) As calculated from USGS maps, Wyoming-Yellowstone National Park, 15 min. series, 1:62,500.

3) Estimated from maps and aerial photos for those lakes without flowing outlets.

4) Estimated from bathymetric map in Dean and Wills (1970).

period; windrowed logs were numerous along the windward side of the meadow.

There were no inlets or outlets to the lake during the survey. The historical outlet was located in the southwest corner of the wet meadow and apparently emptied into a steep channel which dropped over a cascade (approximately 20 m). It is assumed the outlet would have been tributary to the Snake River. It would appear that the current water source is snowmelt as spring activity was absent. It may have been historic changes in spring flows which caused the substantial change in lake level.

Chemical

Although the predominant ions in the 2 m water sample were calcium and bicarbonate, Forest Lake was classified as dilute on the basis of its low nutrient concentration (TDS: 15 ppm) (Table 32). When compared to other Park calcium-bicarbonate waters, levels of almost all constituents were below the group average. Only carbon dioxide and total organic carbon (TOC) were above the mean, and total phosphate was about average for calcium-bicarbonate waters. These somewhat higher levels may be associated with the blue-green algae bloom which was in progress during the survey. The dilute nature of the water sample is typical of waters from rhyolitic drainages.

Aquatic Vegetation

Two rosulate plant forms, Bolander's quillwort (Isoetes bolanderi) and alwort (Subularia aquatica) were very common in the shallow areas around the entire lake. Large mats of floating leaves of pondweed (Potamogeton epihydrus) were observed in the northern portion of the lake; two smaller clusters were growing in 1-2 m of water in the southern portion of the lake. White water buttercup (Ranunculus aquatilis) was found in protected shoals, mostly along the southern and eastern shores. Porterella (Porterella carnulosa) was uncommon and limited to very shallow areas at the north end of the lake (Table 38).

Limnoplankton

Considering the low nutrient availability in Forest Lake, the limnoplankton community was quite rich (Table 39). The number of phytoplankton genera (3) was below average (4 genera) for Park backcountry lakes, but the number of rotifer genera (4) was twice

Table 38. Qualitative checklist of aquatic plants collected during lake surveys, Yellowstone National Park, 1980

Species (common name)	Forest Lake	Ice Lake	Obsidian Lake	Scaup Lake
<u>Carex aquatilis</u> (Wahl.) (watersedge)		X		
<u>Drepanocladus adunus</u> (Hedw.) Warnst. (an aquatic moss)		X		
<u>Elatine americana</u> (Pursh.) Arnott. (American waterwort)			X	
<u>Eleocharis acicularis</u> (L.) R. & S. (needle spike rush)			X	
<u>Isoetes bolanderi</u> Englem. (Bolander's quillwort)	X	X		
<u>Isoetes lacustris</u> L. (lake quillwort)				X
<u>Myriophyllum spicatum</u> L. (spiked water-milfoil)		X		
<u>Polygonum amphibium</u> L. (water smartweed)			X	
<u>Porterella carnulosa</u> (H. & A.) Torr. (Porterella)	X			
<u>Potamogeton epihydrus</u> Raf. (upon the water pondweed)	X		X	
<u>Ranunculus aquatilis</u> L. (white water buttercup)	X	X		
<u>Sagittaria cuneata</u> Sheld. (Arrowleaf arrowhead, wapato)			X	
<u>Sparganium</u> sp. (bur-weed)		X	X	X
<u>Sparganium angustifolium</u> Michx. (narrowleaf bur-weed)		X		
<u>Subularia aquatica</u> L. (awlwort)	X	X		X

Table 39. Occurrence and density (number per liter) of common net plankton from Yellowstone Park in 1980

Genera	Ice Lake	Forest Lake	Obsidian Lake	Scaup Lake
Division Pyrophyta (Brown algae)				
<u>Ceratium</u>	16		12	
<u>Ceratium hirudinella</u>		12		2
Division Chrysophyta (Yellow-green algae)				
<u>Asterionella</u>	12			
<u>Cymbella</u>		4		
Division Cyanophyta (Blue-green algae)				
<u>Anabeana</u>		2662		
<u>Coelosphaerium</u>	16			324
Division Chlorophyta (Green algae)				
<u>Desmidium</u>			12	
<u>Staurostrum</u>	4			
<u>Xanthidium</u>	2			
Unident. grn. filam.	4			
Class Rotatoria (Rotifers)				
<u>Asplanchna</u>		157	12	
<u>Conochilus</u>		99	65	
<u>Kellicottia</u>	8			
<u>Keratella cochlearis</u>	2	99	133	65
<u>Polyarthra</u>		12	16	
Order Cladocera (Water fleas)				
<u>Ceriodaphnia</u>		8		
<u>Daphnia</u>	2		12	4
<u>Holopedium</u>			12	
Order Copepoda (Copepods)				
<u>Diaptomus</u>	4	4		12
<u>Diaptomus s.</u>			4	
<u>Nauplii</u>		8	12	4
Order Diptera (Midges)				
<u>Chaoborus</u>	P	P	P	
Total Phytoplankton/liter	54	2678	28	326
Total Zooplankton/liter	16	375	266	85
Total Plankters/liter	70	3053	294	411
Number genera/lake	11	11	11	6

P = Present in sample, not enumerated.

the Park mean. Crustacean diversity (2 genera) was about average by Park standards. Overall plankton diversity (11 genera) was well above average (9 genera), and overall densities were also high. Crustacean densities were slightly below average, but rotifer and phytoplankton numbers were quite high.

The phytoplankton was dominated by a blue-green alga, Anabeana, which was in bloom stage during the survey. This alga, along with other blue-green algae, are known nitrogen fixers and commonly dominate the phytoplankton in nutrient poor lakes or in richer lakes at periods when nitrogen is limited (Hutchinson 1967). The armored dinoflagellate, Ceratium hirudinella, is a cold water form found in many unproductive Park lakes. The fact that Cymbella, the only diatom sampled, was quite uncommon, may be related to the extreme paucity of silica.

Asplanchna was the most prevalent rotifer form, followed by Conochilus and Kellicottia. These are all common forms, but their high densities were unusual for mid-August. As might be expected, the large predator Polyarthra were least common.

Among the crustaceans, Ceriodaphnia is a rather common pond form known to feed on dinoflagellates (Hutchinson 1967). The low densities of this cladoceran and the copepods may be partially explained by the presence of Chaoborus. The appearance of this phantom midge in plankton samples has been limited to fishless waters in the Park, and it is thought to be the top planktonic predator in these instances.

Littoral and Benthic Organisms

Macroinvertebrate diversity (16 genera) was far above the Park mean (10 genera). Scuds (Hyalella azteca) were the most numerous organisms in littoral samples, but predaceous diving beetle densities were quite high as was their diversity (4 genera) (Table 40). The dytiscids are usually limited to lakes with shallow protected areas and rather clean substrates such as Forest Lake (Pennak 1978); the high densities of this voracious predator suggests a fishless condition. The presence of free-swimming leeches (Hirudinea) also is indicative of a lack of fish. Two caddisfly grazers (Agrypnia and a Limnephilidae) were common among the rocks. Other littoral predators which were quite common included waterboatmen (Corixidae), backswimmers (Notonecta) and dragonfly larva (Aeshna). Callibaetis coloradensis, a climbing mayfly, was usually restricted to protected

Table 40. Qualitative checklist of littoral and benthic invertebrates found in four back-country lakes, 1980

Taxon - Common name	Forest Lake	Ice Lake	Obsidian Lake	Scaup Lake
Hirudinea - Leeches	X	X	X	X
Oligochaeta - Aquatic earthworms	X	X	X	X
Crustacea				
Amphipoda - Scuds				
<u>Hyalella azteca</u>	X	X	X	X
Hydracarina - Watermites	X			
Insecta				
Ephemeroptera - Mayflies				
Baetidae				
<u>Callibaetis coloradensis</u>	X			
Odonata				
Anisoptera - Dragonflies				
Aeshnidae				
<u>Aeshna</u>	X	X		X
Corduliidae				
<u>Cordulia</u>		X		
Libellulidae				
<u>Sympetrum</u>			X	
Zygoptera - Damselflies				
Coenagrionidae				
<u>Ischnura</u>		X		
<u>Enallagma</u>			X	
Hemiptera - Truebugs				
Gerridae - Waterstrider				
Gerrinae		X		X
Corixidae - Waterboatmen	X	X	X	X
Notonectidae - Backswimmers				
<u>Notonecta</u>	X	X	X	
Trichoptera - Caddisflies				
Phryganeidae				
<u>Agrypnia</u>	X			
Molannidae				
<u>Molanna</u>		X		
Limnephilidae	X	X		X
continued on next page				

Table 40 continued

Taxon - Common name	Forest Lake	Ice Lake	Obsidian Lake	Scaup Lake
Coleoptera - Beetles				
Dytiscidae	X			X
<u>Acilius</u>	X	X		X
<u>Agabus</u>			X	X
<u>Carphyrus</u>	X			X
<u>Deronectes</u>	X			
<u>Hydaticus</u>				X
Diptera - Trueflies				
Chironomidae	X	X	X	
Ceratopogonidae		X		X
Chaoboridae				X
Gastropoda - Snails				
<u>Helisoma</u>		X		
Pelecypoda - Clams				
Sphaeriidae	X	X	X	X
Number of taxa	16	16	10	15

areas where vegetation was abundant. Watermites (Hydracarina) were also represented in the littoral sample. Scuds, leeches, clams (Sphaeriidae) and midges (Chironomidae) were all found in the benthic samples.

Aquatic Vertebrates

One smallmesh and two largemesh gillnets (overnight sets) failed to catch fish or salamanders. The lack of salamanders is curious since several dead individuals were found along the shore. The assumed absence of fish life is supported by the occurrence of planktonic Chaoborus, free-swimming leeches and high densities of macro-invertebrate predators. The lack of inlets or outlets and the shallow depth precludes the natural occurrence of fish in the lake. Although there have been no official stocking attempts, there is at least one hearsay account of an unofficial fish introduction.

Angler Use

No VFR cards have been returned from Forest Lake, and there were no signs of angler activity. Since the South Entrance trail is no longer maintained, future visitation will probably remain low.

Discussion

The paucity of chemical nutrients in Forest Lake is quite common for lakes with rhyolitic drainages. The aquatic plants are dominated by two rosulate forms which are adapted for life in nutrient poor environments. According to Hutchinson (1975b), these plants are able to absorb CO₂ into their roots directly from the substrate. These forms are usually limited to sandy or rocky substrates in the neutral zone, free from both erosion or sedimentation (Hutchinson 1975b). These two physical requirements also explain their abundance in Forest Lake.

Despite the nutrient poor environment, the lake appears to be quite productive. Most of the planktonic species are either eurytopic or adapted to low nutrient availability. The nitrogen fixing capabilities of the blue-green alga, Anabeana, helps to explain the observed bloom. High densities of planktonic Chaoborus may partially explain the low densities of larger zooplankton and the abundance of rotifers.

The reason for the great change in depth from historic highs is unknown. Windrowed logs along the historic shoreline and near the original outlet indicate a rather lengthy existence at that depth. It may be that springs, which once fed the lake, have dried or shifts in the earth's crust have diverted tributary flow. Regardless, there are no longer flowing inlets or outlets and no evidence of ground-water input.

The recovery of several dead salamanders along the shore is curious since none were captured in the gillnets. It may be that while most of the adults were utilizing terrestrial habitat, larva were either too small or at densities too low to be represented in the sample.

It appears that the lake is now barren of fishlife. The lack of fish in the gillnets, the planktonic Chaoborus and the presence of free-swimming leeches support this conclusion. Besides the lack of suitable spawning habitat, shallow depth would probably prevent their survival in Forest Lake. Even at historic lake level, it is doubtful that fish could have ascended the high gradient outlet stream, and if they gained entry, shallow depth probably prevented a year-round existence.

The location of Forest Lake probably will continue to prevent all but incidental human visitation. The lack of fishlife is also a deterrent to many hikers. It is this barren condition, however, which allows the examination of the extensive capabilities and adaptations of aquatic life in nutrient poor environments.

ICE LAKE

At an elevation of 2,402 m, Ice Lake lies on the Solfatara Plateau in the Central portion of the Park. It is easily accessible by a marked trail 4.8 km east of Norris on the Norris-Canyon Road. The lake is only 0.4 km from the trailhead, but the trail continues on to Wolf Lake and Grebe Lake.

Ice Lake was historically barren of fish, but was stocked heavily from 1905-1961 (Varley 1981). Grayling were the most commonly planted species (almost 3.5 million); however, cutthroat trout were also released in substantial numbers (389,000). Cutthroat plants were sporadic (1930, 1932 and 1936), but grayling were stocked frequently (1933-1943, 1949-1955 and 1960-1961). Other trout species planted in Ice Lake include rainbow trout (1943 - 4,000) and brook trout (1905 - 11,000).

Dean and Mills (1970) completed the most recent survey of Ice Lake in 1969, capturing only seven grayling in three overnight (15 hours) gillnet sets. Since natural reproduction was absent due to the lack of inlet streams and a rather undefined outlet channel, these fish were thought to be migrants from the Gibbon River. Two rainbow trout fingerling were found in the outlet stream near its confluence with the Gibbon River, and they were also assumed to be migrants. The authors speculated that few fish entered Ice Lake via the outlet stream because of the undefined character of the channel for 200-250 m below the lake.

Ice Lake was resurveyed on July 31-August 1, 1980, with additional gillnet sets August 6-8, 1980. The objectives of this survey were to determine if the lake has returned to its historically barren condition and to collect additional baseline limnological information.

Physical

The bedrock of the lake drainage (91 ha) is entirely rhyolite (Lava Creek Tuff of the Yellowstone Groups). A ground fault which runs along the west shore of the lake (Christiansen 1975) may have caused the formation of the basin. Surficial deposits are comprised of a sandy, silty till of the Pinedale Glaciation. Although primarily rhyolitic, the till contains erratics of basalt and andesite from the Washburn Range (Richmond and Waldrop 1975).

Partial wind protection is provided by the forest which surrounds the lake. Lodgepole pine dominates the overstory while grouse whortleberry (Vaccinium scoparium) is the most common of the understory plants. Western huckleberry (Vaccinium occidentale) grows heavily in moist areas around the margin of the lake.

Mean depth (6.9 m) was estimated from the bathymetric map of Dean and Mills (1970). At the time of survey, maximum depth was 16.4 m and secchi disc reading was 8.5 m on a clear day. Water temperature varied from 18.3°C at the surface to 7.8°C near the bottom. Thermal stratification was pronounced; the thermocline occurred between 6.7-9.1 m.

Shoreline development of this oblong lake (Figure 30) was good, and water level appeared quite stable with minimal fluctuations. Although small amounts of silt and detritus were present, obsidian sand and gravel were the predominant substrate materials in shallow regions. Profundal sediments were also dominated by obsidian sand, but silt and detritus increased toward the west end of the lake.

Ground water is the exclusive water source for Ice Lake. Seeps were prevalent along the west shore, and an additional area was found on the eastern extremity of the north shore. Collection of aquatic moss indicated the occurrence of subaqueous springs also.

A permanent outlet located at the east end of the lake had an estimated flow of less than 0.03 m³/sec. This low gradient stream dissipates into a sedge meadow for 200-250 m before entering a shallow (0.1 m) channel with an average width of 0.5 m. Substrate was obsidian sand with some detritus in backwater areas. The outlet stream flows approximately 0.4 km before emptying into the Gibbon River.

Chemical

On the basis of the water sample taken at 2 m depth, Ice Lake was classified as a dilute (<50 ppm TDS) calcium-bicarbonate lake (TDS: 18ppm) (Table 32). Most chemical parameters were substantially below the mean for Park lakes of this type; however, pH (7.1) was slightly higher than the average, and potassium, phosphate and silica were well above the mean. Since the latter three parameters are sufficiently high, it appears that extremely low levels of nitrogen (both Kjeldahl and nitrate) may be a limiting factor in Ice Lake. Low level of carbon

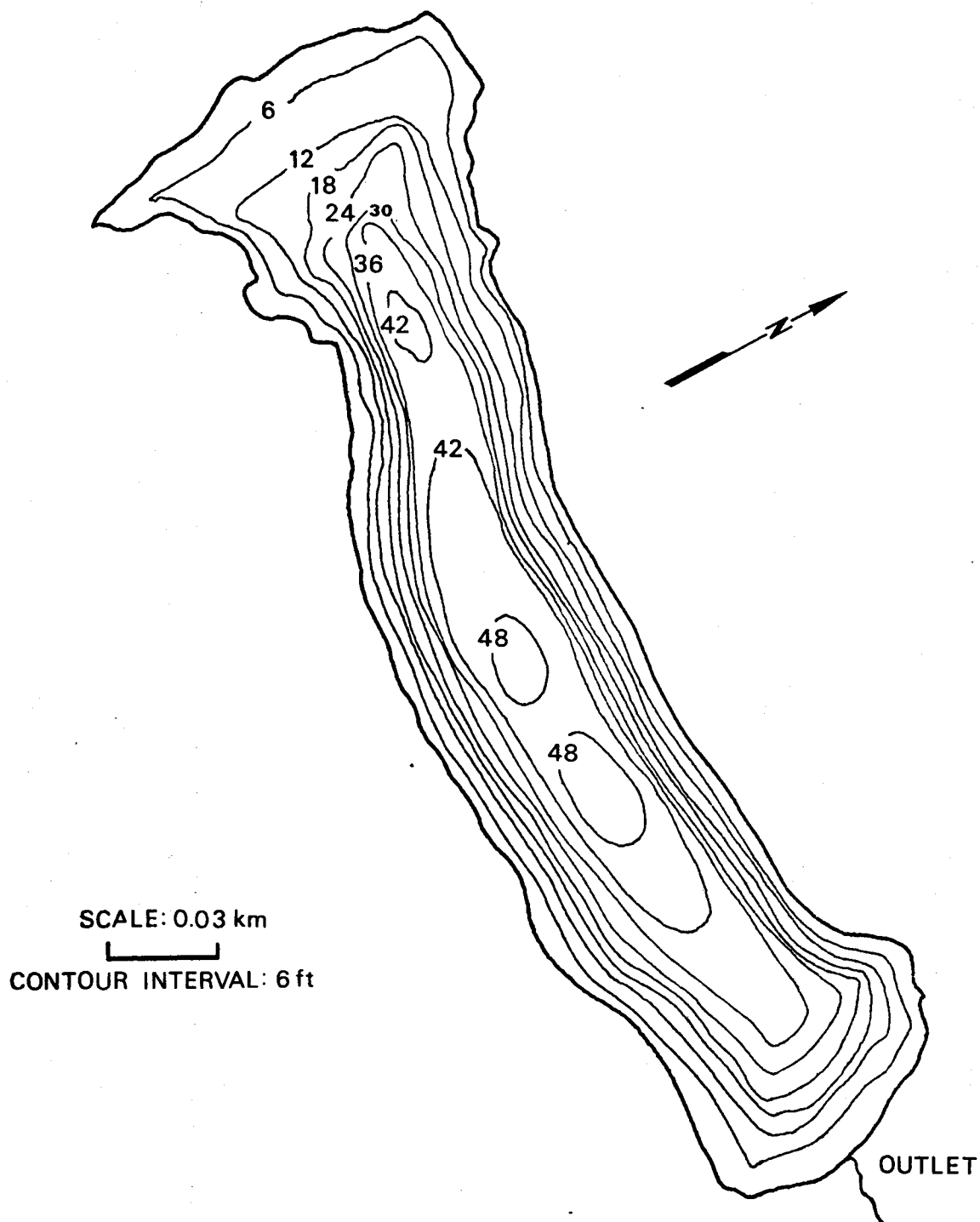


Figure 30. Ice Lake, Yellowstone National Park, 1980.

dioxide is curious considering the water source, but may indicate an extremely high level of photosynthesis at the time of sampling.

Aquatic Vegetation

The aquatic vegetation collected from Ice Lake generally reflected the dilute nature of this oligotrophic lake (Table 38). The aquatic moss, Drepanocladus adunatus, is an oligotrophic form found in waters with high levels of carbon dioxide (Hutchinson 1975b), and is indicative of groundwater. Two rosulate plant forms, Bolander's quillwort (Isoetes bolanderi) and alwort (Subularia aquatica), are also well adapted for life in nutrient poor environments. These species were distributed sparsely throughout the littoral zone. Two species of burweed (Sparganium angustifolium and Sparganium sp.) were also common around the lake margin. White water buttercup (Ranunculus aquatilis) was collected in protected areas near the shore, often among exposed roots of huckleberry bushes growing on the bank. Spiked water-milfoil (Myriophyllum spicatum), usually associated with eutrophic waters (Hutchinson 1975b), was an apparent anomaly in the vegetation sample and was only found windrowed near the outlet.

Limnoplankton

Although the number of rotifer and crustacean genera (2 each) equaled the Park average for back-country lakes, the abundance of phytoplankton genera (6) raised the total diversity (11 genera) above the Park mean (9 genera). Densities, however, were extremely low for all forms (Table 39).

The phytoplankton was comprised of forms well adapted for life in nutrient poor waters. The desmids (Staurastrum and Xanthidium) are both soft water forms; desmids in general are common in oligotrophic lakes (Hutchinson 1967). The armored dinoflagellate, Ceratium, has often been associated with dilute Park waters. Although the blue-green alga, Coelsphaerium (Gomphosphaeria), is frequently associated with eutrophic waters, blooms usually occur when levels of nitrogen are extremely low (Hutchinson 1967).

All of the zooplankton collected are eurytopic forms widely distributed in a variety of Park lakes. The occurrence of planktonic Chaoborus strongly suggests a fishless system. Low zooplankton densities are a definite manifestation of the low nutrient availability in Ice Lake.

Littoral and Benthic Organisms

Diversity of macroinvertebrate fauna was about average for Park lakes sampled since 1976 (Table 40). Scuds (Hyalella azteca) were the most abundant organisms in the littoral sample. A damselfly nymph (Ischnura) and two dragonflies (Aeshna and Cordulia) were commonly collected in organic detritus and decaying plants along the south and west shores. Waterstriders (Gerrinae), water-boatmen (Corixidae) and backswimmers (Notonecta) were very abundant but usually associated with protected areas along the south shore. Caddisflies (Molanna and a Limnephilidae) were also common. Both of these larvae are omnivorous, the former a scraper and the latter a grazer (Pennak 1978). Another common littoral predator was the predaceous diving beetle (Acilius). The presence of free-swimming leeches suggests that fish no longer inhabit the lake. Snails (Helisoma), clams (Sphaeridae) and midges (Chironomidae) were found in both littoral and benthic samples, but aquatic earthworms were limited to the latter.

Aquatic Vertebrates

Neither fish nor salamanders were captured in 9 overnight gillnet sets. Despite the rather intensive stocking efforts, the lake has apparently returned to its originally barren condition. During the previous survey (Dean and Mills 1970), it was speculated that the seven grayling captured had migrated up the outlet stream from the Gibbon River; however, if this were the case, one would expect a consistent, although low density, population. It would appear that the fish captured in 1969 may represent an extremely limited recruitment of the final stocking of 30,000 grayling in 1960 and 1961.

Angler Use

Combined VFR data from 1977-1980 revealed an average annual angler use and effort of 28 angler days and 37 angler hours, respectively. No fish were reported in the catch during that period. The close proximity to the Norris-Canyon Road and location next to a heavily used trail leading to significant lake fisheries, probably accounts for most of the current use.

Discussion

Low nutrient level due to the surrounding geological substrates, reduced allochthonous input because of the lack of flowing tributaries and a relatively restricted trophogenic zone caused by great mean depth, all contribute to the oligotrophic nature of Ice Lake. The

dominance of blue-green alga, despite above average (for dilute calcium-bicarbonate waters) levels of total phosphorus, potassium and silica suggests a nitrogen limited system; extremely low levels of nitrogen support this hypothesis. Estimates of the morphoedaphic index (MEI) (Ryder et al 1964) yielded one of the lowest values (0.80) yet established for Park lakes. The corresponding fish yield (Ryder et al 1964) was only 1.56 kg/ha/year.

This rather sterile environment has definitely affected the biotic community. Most of the plankton forms are well adapted for nutrient poor conditions, and densities are below average. The aquatic plants collected from the lake are dominated by species often associated with unfavorable environments. Although macroinvertebrate diversity is high, densities also appear to be low.

Despite the harsh, unproductive aspects of the lake, it is apparently the lack of suitable spawning habitat which has prevented the establishment of a viable fish population. Dean and Mills (1970) found excellent growth from the seven grayling in 1969; however, low densities undoubtedly inflated these values considerably. The presence of grayling in 1969 may be the result of partially successful spawning following the final plants in 1960 and 1961, but it is evident that fish no longer inhabit Ice Lake.

It may seem incredible that after stocking over 3.8 million fish in a 56 year period, a self sustaining population was never established; however, this may provide a measure of uniqueness for Ice Lake. Despite a rather intensive human effort, the lake has maintained a condition similar to that when whitemen first visited the area. The biotic community definitely represents an extreme in aquatic evolution in the absence of fish and provides an interesting system for intensive investigation. It is also possible that future human impact may be minimized on this lake due to the fishless condition.

OBSIDIAN LAKE

Located in the north-central portion of the Park, Obsidian Lake lies approximately 2.5 km east of the Norris-Mammoth Road, at an elevation of 2,365 m. The only access is by overland travel, either on foot or horseback, from the Winter Creek trailhead (29 km south of Mammoth). The lake was surveyed on August 12-13, 1980.

Physical

Volcanic deposits dominate the bedrock geology of the Obsidian Lake drainage (394 ha). Swan Lake Flat basalt surrounds most of the lake, but the largest portion of the drainage (southeast) is rhyolite (Roaring Mountain Member) (USGS 1972). Surficial deposits include a narrow band of fine grain humic alluvium surrounding almost the entire lake and fan gravels along the east shore; however, the majority of the drainage is covered by till and rubble from the Pinedale Glaciation. Common erratics are primarily basalt and quartzite (Pierce 1973).

Obsidian Lake is situated on a plateau above, and slightly north of, Obsidian Cliff. The lake is one of few open areas in a very dense lodgepole pine forest. The forest is at late stage 1 (Despain 1977) in forest succession; a large forest fire spread through the area in 1893. Very little understory vegetation was evident in this "doghair" stand. Sedges (*Carex* spp.) formed a boundary strip (100 m) between the forest edge and the lake.

Obsidian Lake has a surface area of 11.3 ha. Maximum depth was 7.6 m with an average depth of 1.3 m (Table 37). The tea-brown water was slightly turbid, and secchi disc visibility was 2.0 m on an overcast day. Water temperature varied from 15.6°C at the surface to 6.1°C at the bottom. Stratification was evident with a thermocline between 2.4 m-5.8 m.

Lack of shore erosion suggests that moderate wind protection is provided by the lodgepole pine forest. Lake level fluctuations are currently about 0.3 m, but it was apparent that historically the lake level was at least 1 m higher. The irregular shape of the lake (Figure 31) provided good shoreline development. Shoal substrate consisted of varying amounts of organic detritus and decaying plants covering a firm base of rubble and gravel. Profundal sediments were exclusively decaying organic debris.

There were no flowing inlets or outlets at the time of survey. Ground water from subaqueous springs appears to be the primary water source; however, snowmelt undoubtedly contributes somewhat in the spring.

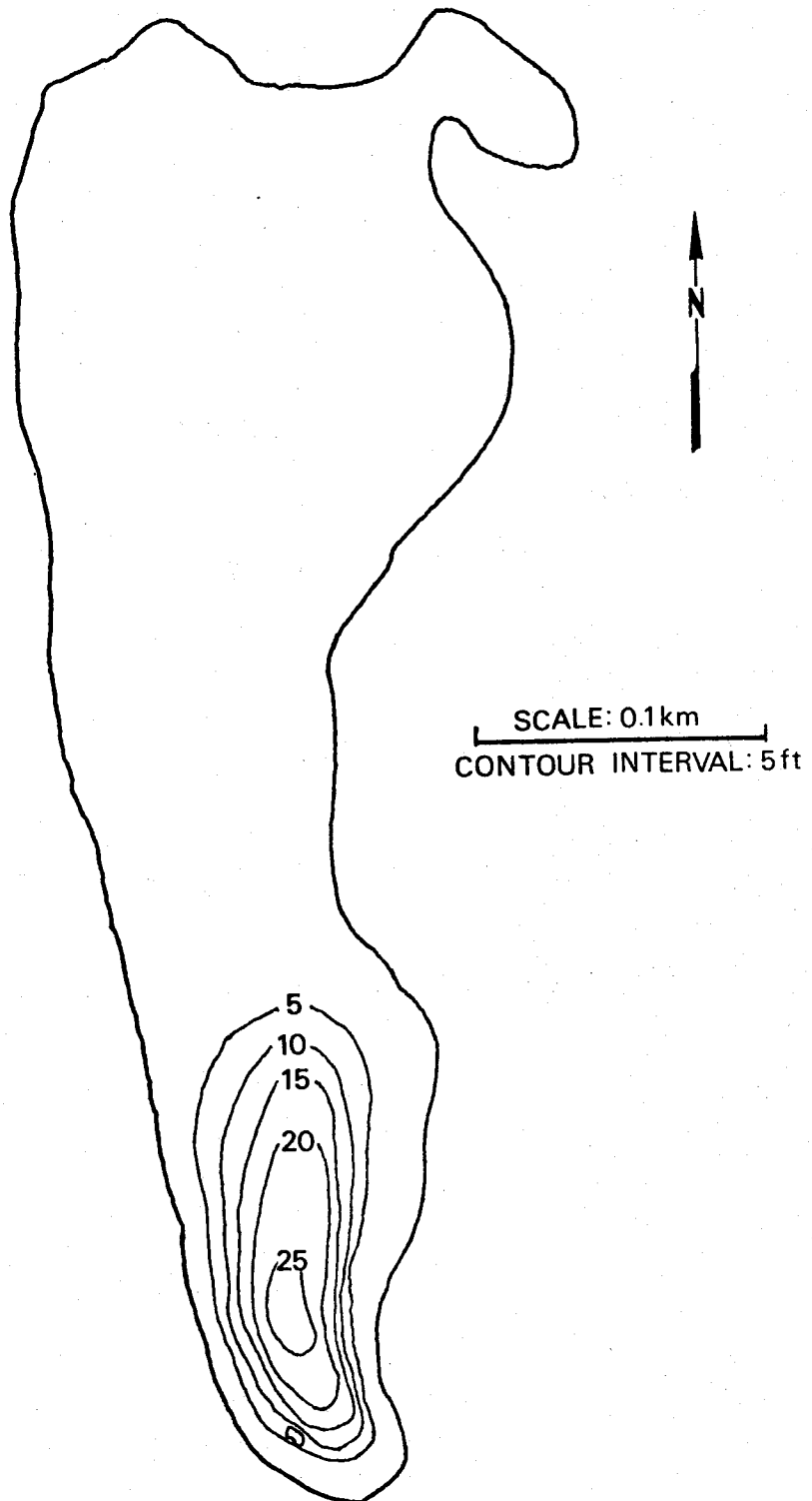


Figure 31. Obsidian Lake, Yellowstone National Park, 1980.

Chemical

On the basis of the 2 m water sample, Obsidian Lake was classified as a dilute lake (TDS: 17 ppm) with calcium and sulfate as the major ions. There have been only three other Park lakes with these predominant ions (CaSO_4), and two of these, Buffalo Lake and High Lake, were dilute. These lakes appear to have a much lower concentration of chemical constituents than other dilute Park waters, such as dilute calcium-bicarbonate and sodium-bicarbonate lakes. Although many of the chemical components were actually higher than found in either Buffalo or High Lakes, values were still extremely low by Park standards.

The acidic pH (6.5), high carbon dioxide (CO_2), total organic carbon (TOC) and orthophosphate values (Table 32) are common in bog or swamp type (dystrophic) waters. These values and the brown color of the water are related to the high humic acid content of dystrophic waters (Strumm and Morgan 1970). Although excess amounts of CO_2 are often associated with lakes high in organic acids (Hutchinson 1975a, Ruttner 1963), both CO_2 and orthophosphate may also be related to the sub-aqueous ground water (Strumm and Morgan 1973).

Aquatic Vegetation

Sedges (Carex) formed a boundary between the forest and the lake for its entire circumference (epilitoral zone). Bulrushes (Scirpus), typical marsh plants (helophytes) (Hutchinson 1975b), were found in localized clusters along the eastern and northern shores. Although water lilies (Nuphar polysepalum) covered most of the open water less than 2 m deep, they were absent in close proximity to shore; it is assumed that the rubble-gravel substrate in this area was not suitable for this plant species. Pondweed (Potamogeton epihydrus) was sporadic, but most common along the west shore. Needle spike rush (Eleocharis acicularis), typical of most rosulate forms, covered most of the shallow shoal bottom where the substrate was rocky. American waterwort (Elatine americana), a quite cosmopolitan form (Hutchinson 1975b), was found scattered in the shallow water where accumulations of organic detritus were minimal. Water smartweed (Polygonum amphibium), arumleaf arrowhead (Sagittaria cuneata) and burweed (Sparganium sp.), all have both aquatic and terrestrial forms and were scattered around the lake in the infralittoral and eulittoral zones. An unidentified aquatic moss was also collected in benthic dredge samples.

Limnoplankton

Despite low phytoplankton diversity (2 genera) and average crustacean diversity (2 genera), the number of rotifer genera (4) were well above

average (2 genera). The overall plankton diversity (11 genera) was above the mean for Park back-country lakes. Similarly, phytoplankton densities were very low, but crustacean densities were high (Table 39). Since phytoplankton are usually the dominant plankton forms in terms of density, their low numbers in Obsidian Lake reduce overall plankton densities well below average.

Considering the phytoplankton, Ceratium, an armored dinoflagellate, is one of the most common phytoplankters found in Park waters, but Desmidium is one of the least common. Both forms are found in cold, dilute and slightly acidic waters (Hutchinson 1967). The dominance of the zooplankton by rotifers is symptomatic of slightly acidic Park lakes. All of the rotifer genera collected are quite universal forms; all are perennial and usually diacmic (two population peaks annually) (Hutchinson 1967). Among the crustaceans, Holopedium is the least common in Park lakes. Planktonic Chaoborus suggest the absence of fish in Obsidian Lake.

Littoral and Benthic Organisms

Macroinvertebrate diversity was much lower than other Park lakes (Table 40), and benthic forms were extremely scarce. The most common littoral forms were scuds (Hyaella azteca) and free-swimming leeches (Hirudinea). Predaceous littoral forms such as waterboatmen (Corixidae), backswimmers (Notonecta) and predaceous diving beetles (Agabus) were all numerous. Two littoral carnivores associated with the decaying plant matter were Sympetrum, a dragonfly, and Enallagma, a damselfly. Midges (Chironomidae) and clams (Sphaeriidae) were collected in both littoral and benthic samples, but aquatic earthworms (Oligochaeta) were limited to the benthic samples.

Aquatic Vertebrates

Neither fish nor salamanders were captured in one smallmesh and two largemesh gillnets set overnight. According to Varley (1981), fish have never been introduced to Obsidian Lake, and the lack of either inlets or outlets certainly prevented historical fish immigration.

Angler Use

VFR cards have never been received for Obsidian Lake, and signs of angler activity, or even human presence, were totally absent. The thick lodgepole forest and the lack of maintained trails probably deter most humans despite the relatively short distance from the Norris-Mammoth Road to the lake.

Discussion

In most characteristics, Obsidian Lake is a typical dystrophic lake. The brown color and acidic nature are due to the high concentration of humic acids. The vast amounts of decaying plant matter have actually formed peat islands in the southern portion of the lake. This type of substrate is especially suitable for pond lilies which cover most of the surface; however, at least seven other plant species were found in the littoral zone. The presence of subaqueous springs was indicated by aquatic moss; groundwater is the usual water source for dystrophic lakes since they typically lack flowing inlets or outlets.

Chemically, the dystrophic nature of the lake is also apparent. Nutrient concentration is well below that of most Park waters, although somewhat higher than the other two dilute calcium sulfate waters. Because it is doubtful that the level of sulfate in the epilimnion is due to anaerobic decomposition (Hutchinson 1975a, Strumm and Morgan 1970), percolation of groundwater through the basaltic bedrock probably explains its pre-dominance (Hutchinson 1975a). The dominance of phosphate forms by orthophosphate and presence of high levels of CO₂ are also probably related to the groundwater, while high TOC concentration is related to the humic acids.

The dystrophic nature of the lake is also evident biologically. Plant species diversity was high, but densities, aside from pond lilies, were not great. This diversity/density relationship was also seen in the plankton sample. Macroinvertebrates, which are often associated with specific substrates, revealed a lower diversity, but densities appeared substantial. The absence of fish is indicated by the presence of planktonic Chaoborus and free-swimming leeches; fish are not usually found in this type of environment due to the lack of suitable spawning habitat and absence of a means for historical entry.

Other forms of wildlife were abundant in the Obsidian Lake area. Two beaver lodges were found in the open water at the southwestern end of the lake, and fresh cuttings were noted in the forest along the west shore. Waterfowl, including common goldeneye and bluewing teal, were frequently seen moving around the lake. Spotted sandpipers were common in the eulittoral zone. Frogs and tadpoles were very abundant, which may suggest the lack of significant predation. Heavily used game trails attest to the importance of the lake as a water source for ungulates on this thickly forested plateau.

Although lack of access may act as a deterrent to human visitation, it would probably be quickly overcome if sportfish were present. The barren condition of the lake helps to provide protection for this pristine environment, and provides another opportunity to study an aquatic community in the absence of fish.

SCAUP LAKE

Scaup Lake lies adjacent to the West Thumb-Old Faithful Road about 5.8 km southeast of Old Faithful. The lake was previously surveyed by Arnold and Sharpe (1967) in 1966. They found the lake barren of fishlife and reported that shallow depth and lack of suitable spawning habitat precluded the existence of ichthyofauna. Additionally, "several" salamanders (Ambystoma) were collected during this initial survey.

On July 16, 1980, an explosive charge was set in Scaup Lake in conjunction with geophysical studies being conducted in the Park. The lake was resurveyed on August 21-22, 1980 in order to investigate possible disturbances resulting from the explosion and to collect additional baseline limnological data on Scaup Lake.

Physical

The bedrock of the Scaup Lake drainage (125 ha) is exclusively rhyolite of the Scaup Lake flow (Christiansen and Blank, Jr. 1974). Rhyolite also dominates till from the Pinedale Glaciation which comprises the surficial deposits for the entire drainage (Waldrop 1975). A late stage 4 lodgepole pine forest (Despain 1977) covers this rolling terrain and completely surrounds the lake.

Average and maximum depths of this small lake (2.3 ha) were 1.6 m and 2.7 m, respectively (Table 37). On a cloudless day, the secchi disc was visible to the bottom in the dark green water. Water temperature (12.8°C) was uniform throughout the water column.

The surrounding lodgepole pine forest provides moderate wind protection as evidenced by the lack of shore erosion. Water fluctuations appear to be about 0.3 m currently, although bathymetric data and high water marks substantiate a 1 m decrease in depth since the last survey. Shoreline development for this rather elongated lake was fair. Substrate materials varied from obsidian sand and gravel with intermittent larger rocks and rubble in the shoal areas to organic muck with silt and decaying plant material in the profundal zone. There were no flowing inlets or outlets at the time of the survey, and snowmelt appears to be the primary water source.

Chemical

The water sample from 2 m indicated that Scaup Lake was dilute (TDS: 12 ppm) with calcium and bicarbonate as major ions, typical of waters lying on volcanic bedrock. Although lakes of this water type usually

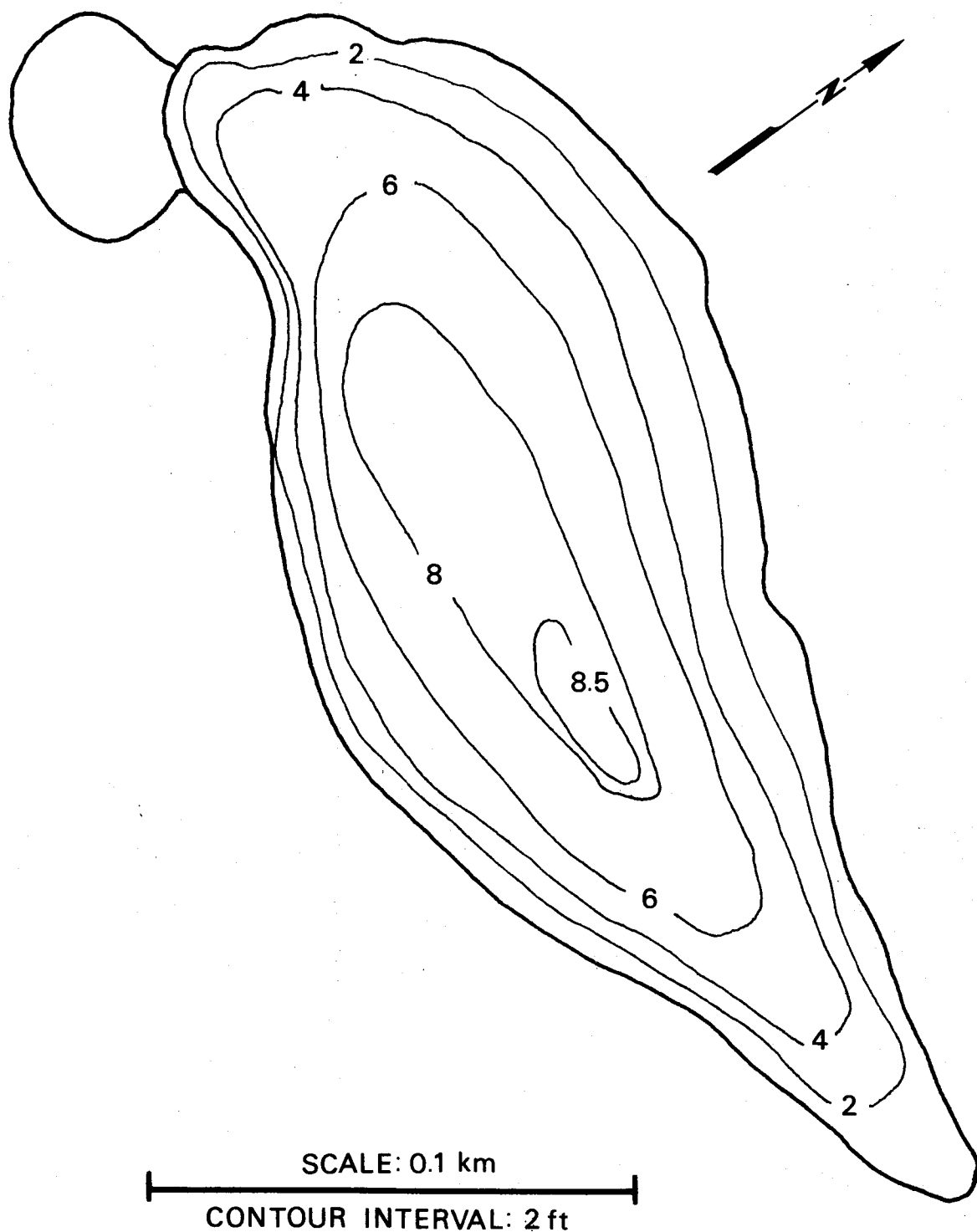


Figure 32. Scaup Lake, Yellowstone National Park, 1980.

exhibit below average concentrations of nutrients, chemical parameters from Scaup Lake were even lower than the group mean. Chloride, fluoride, potassium and sodium were about average for this type, but only phosphate levels were above average. The apparent abundance of phosphate suggests that it is not limiting production in Scaup Lake.

Aquatic Vegetation

Diversity of aquatic macrophytes was extremely low with only three species present. Lake quillwort (Isoetes lacustris) was the dominant species, and it covered the shoal area throughout most of the lake. Another rosulate species, alwort (Subularia aquatica), was much less common but occurred in similar habitat. Both of these species are well adapted for nutrient poor environments and are usually limited to rocky substrates in the infralittoral between erosion and sedimentation zones (Hutchinson 1975b). Arnold and Sharpe (1967) suggested that their presence in Scaup Lake indicated substantial fluctuations in lake level. The third plant species, burweed (Sparganium sp.), has both aquatic and terrestrial forms (Hutchinson 1975b). Such adaptability would definitely enhance perpetuation of the species in a lake experiencing wide fluctuations in water level.

Limnoplankton

The extreme nutrient paucity of Scaup Lake was reflected in the limnoplankton sample. The number of phytoplankton genera (2) was only half of the Park mean and rotifer genera (1) were also less than average (2 genera). Crustacean diversity equals the Park mean (2 genera), but overall plankton diversity (6 genera) was much below average (9 genera) for the Park waters. All plankton densities were also depressed.

Ceratium hirudinella, an armored dinoflagellate usually associated with cold waters, was uncommon in Scaup Lake. The bloom proportion of the blue-green alga Coelosphaerium is definitely indicative of the lack of nutrients since most blue-green blooms occur at times when nutrients, especially nitrogen and phosphorus, are extremely low (Hutchinson 1967). The single rotifer species (Keratella cochlearis), which dominated the zooplankton, is rather ubiquitous in Park waters. Diaptomus was the most prevalent crustacean and, along with Daphnia, is also quite common in the Park. The lack of planktonic Chaoborus in this fishless lake is curious.

Littoral and Benthic Organisms

Diversity of macroinvertebrates (15 taxa) was higher than the Park average (11 taxa), but densities, especially in the benthic samples, were low. Scuds (Hyaella azteca) were the most common of the littoral organisms, but waterboatmen (Corixidae) were also relatively abundant. The caddisflies (Limnephilidae) were collected among rocks and gravel, but the dragonfly (Aeshna) was usually associated with organic detritus. The occurrence of five genera of predaceous diving beetles (Dytiscidae) Table 40) is quite unique and suggests their position as top predator in the lake. Another littoral predator, the water strider (Gerridae) (Pennak 1978), was collected from sheltered areas along the shore. Leeches (Hirudinea) were found in the littoral sample and were the most common benthic organisms, but clams (Sphaeriidae) were also numerous. Aquatic earthworms (Oligochaeta) were limited to the softer substrate of the profundal zone. Although phantom midges were present in the benthic sample, it is obvious that their densities are extremely low in Scaup Lake.

Aquatic Vertebrates

An overnight set of one smallmesh gillnet yielded neither fish nor salamanders. The absence of salamanders in the sample does not conclusively suggest that they no longer occur in the lake. The previous survey indicated low salamander densities, and the current sample was limited to a single net.

Angler Use

Despite the lack of VFR returns, angler use does occur on Scaup Lake. During the present study, four anglers fished briefly on August 21. Arnold and Sharpe (1967) also observed several anglers, but it appears that they were correct in suggesting that use was incidental, primarily by anglers who feel the water "looks good". The amount of litter in and around the lake is definitely substantial on the southern shore bordering the road.

Discussion

Like most Park lakes having rhyolitic drainages, Scaup Lake is extremely nutrient poor. The disparity of essential elements is reflected in low plankton diversity and densities. The limited macrophyte diversity is probably due to additional factors such as rocky substrate and lake level fluctuations. Shallow depth and lack of spawning habitat prevented the existence of a self sustaining fish population in the lake.

Absence of salamanders in the current sample is curious but does not provide irrefutable evidence that they no longer occur in Scaup Lake. Since previously reported densities were low, one gillnet does not represent a definitive sample. If salamanders no longer occur, the reason for their disappearance is questionable. Although the seismic test conducted in July may have affected the population, other signs of perturbation were absent. Turbidity analysis revealed normal values for dilute calcium-bicarbonate lakes. Even if the blast killed all of the salamander larvae, adult forms are terrestrial and reestablishment would be eminent. A more plausible explanation for their hypothetical disappearance would be the drastic change in water level since 1966; current shallowness could possibly prevent over-winter survival of salamanders in the lake.

The close proximity to a main Park road definitely influences human use patterns at Scaup Lake. Most angler use is thought to be incidental and due mostly to its location and subsequent effortless access. Current impact appears to be largely manifested in the unsightly accumulation of litter. Since a primary objective of the Park is to preserve the natural features for the use and enjoyment of the people, future removal of the litter would certainly be indicated. Once the accumulated trash were removed, occasional visits by litter crews could maintain a much improved appearance. Although current chemical analysis did not indicate water quality problems, future samples should be analyzed specifically for those pollutants commonly associated with heavy automobile use such as lead and asbestos.

NATIVE SPECIES RESTORATION PROGRAM

Introduction

The native fishes of Yellowstone Park consist of eleven species. The Montana grayling, three or more subspecies or races of cutthroat trout and the mountain whitefish are the best known. In addition, three species of suckers, four species of minnows (Cyprinidae) and the mottled sculpin are also native. The range and densities of these fishes have been altered substantially in the past century.

The restoration of native fish species in natural areas of the National Park system is a matter of policy (U.S. Dept. Interior 1975). Yellowstone has a number of species, subspecies or races of sport fish that are threatened with extinction (Varley et al 1976). At present, an active program of restoration is underway in the Park that seeks to expand the ranges of these threatened fishes. The management strategies developed to attain restoration objectives consist of the enclave concept and the selective exploitation concept (Varley et al 1976).

During 1980, the native species restoration program included the following projects: 1. the Montana grayling restoration project; 2. the Heart Lake cutthroat restoration project; 3. the Sedge Creek cutthroat transplant program; and 4. the cutthroat trout restoration project in Blacktail Deer Creek.

Montana Grayling Restoration Project

A review of the historical background and rationale of the Montana grayling restoration program has been presented in previous reports (Varley et al 1976 and Jones et al 1978). Canyon Creek, a tributary of the lower Gibbon River, was chemically treated in 1975 to provide a suitable enclave for this species. A barrier-falls was also constructed to prevent upstream recontamination. In June 1976, 2,863 grayling averaging 229 mm (9 in) were transplanted from the Bozeman Fish Cultural Development Center to the Park and airlifted to Canyon Creek. These fish came from eggs taken from Grebe Lake in the spring of 1975. Permission was obtained from the Montana Fish and Game Commission to electrofish the Big Hole River (the last stronghold for fluvial Montana grayling) and transplant no more than 200 grayling into Canyon Creek. This operation was carried out in late August 1976 when approximately 120 live grayling were airlifted into Canyon Creek. During 1977,

an additional plant of Montana grayling was made. The source of eggs was from an outlet spawning population of grayling from Deer Lake, Gallatin National Forest, Montana. In this planting, an unknown number (believed to be 2,000-4,000 eggs) of advanced eyed eggs were set out in Vibert-type boxes in springs tributary to Canyon Creek.

In 1978, 5,000 swimup fry from Red Rock Lakes stock were obtained from Montana Department of Fish and Game and planted in upper Canyon Creek on June 13.

In 1979, several attempts to obtain grayling eggs proved futile and no plants were made.

Approximately 30,000 swimup grayling fry from Meadow Lake, Wyoming were obtained from Wyoming Game and Fish Department and planted in Canyon Creek in June, 1980. Unfortunately no grayling were found when Canyon Creek was electrofished in September.

The objective of the grayling restoration program continues to be directed toward the behavioral and/or genetic engineering of a wild, self-reproducing population of true fluvial stock, similar to that which once existed in the drainage. No new plants will be made in 1981 due to poor survival of past plants and the expanding exotic fish population in Canyon Creek. Canyon Creek will be monitored for a few years to further assess the restoration attempt.

The search for new streams and a new source of fluvial grayling stock will begin in 1981 in cooperation with the Montana Department of Fish, Wildlife and Parks.

Heart Lake Cutthroat Restoration Project

In 1977, Pocket Lake was selected to provide an enclave for the Heart Lake cutthroat. At that time, the lake sustained an exotic brook trout population which was destroyed by Antimycin in August, 1977. In September, 1977, 993 cutthroat trout from Beaver Creek, a tributary of Heart Lake, were captured and transplanted to Pocket Lake by helicopter. A similar operation took place in September, 1978, when approximately 900 young-of-the-year and age I+ trout were captured and transplanted to the lake. Also in 1978, Pocket Lake was placed under catch-and-release-only regulations to protect the cutthroat stock.

On July 24, 1980, Pocket Lake was revisited. Although fish were observed rising throughout the lake, no fry or fingerlings were noted in the outlet stream or inlet springs. Eight fishermen were later interviewed at the lake who reported catching several 250-355 mm cutthroat. In August, rangers confiscated nine illegally creeled cutthroat from Pocket Lake. Although these trout had been cleaned, a total length and scale sample were taken from each. Lengths ranged from 231-352 mm, and mean age was 2.78 (ranging from II+ to IV+ years).

Although the cutthroat originally planted in 1977 and 1978 appear to be healthy, perpetuation of the population is uncertain. Cutthroat spawning habitat is limited, and evidence of successful reproduction was not observed in 1980. We recommend that a more intensive search for young trout be conducted by use of seines or electroshocking gear in 1981.

Sedge Creek Cutthroat Transplants

The Yellowstone River originates outside the Park boundaries in the Teton Wilderness Area. The branches of the Yellowstone above Woodard Canyon were fishless due to falls preventing upstream fish movement. The Wyoming Game and Fish Department, who have management jurisdiction over fishes in this area, have aspired to establish cutthroat trout in this region for many years. Previous transplants using stocks from Yellowstone Lake have proven fruitless. These fish apparently have strong inherent instincts to drift downstream to the lake. Due to these instincts, a search was made for a suitable and pure Yellowstone cutthroat strain for transplant. Trout from Sedge Creek were ultimately chosen for a variety of reasons. In recent geologic time Sedge Creek was directly connected to Yellowstone Lake but as the depth diminished, upper Sedge Creek was isolated from Yellowstone Lake proper by Turbid Lake, a geothermal body of water. In subsequent years, the population evolved to become a fluvial form adapted to a very harsh, subalpine environment. Some morphological changes in the fish also occurred (Bulkley 1963), but there is no evidence that this population has been altered by fish stocking or fishing pressure; therefore, it is truly a distinctive and pristine strain.

Using this strain for transplant to the upper Yellowstone River area served two purposes: it provided an optimally adapted population of Yellowstone cutthroat for another harsh, subalpine environment, and it provided a second, secure enclave for this unique genotype.

During June, 1977, 457 trout were collected and transplanted by helicopter. The planted trout varied in size from 51 to 221 mm total length. Ageing suggested the group included yearlings through five year-olds. Numerous prespawning individuals were present in the group, although it is not known whether they would spawn in their new environment following transplant. On July 7, 1978, 413 trout were transplanted. Of one hundred measured for length, the average length for these cutthroats was 113 mm, ranging from 58-254 mm. On July 24, 1979, electrofishing on Sedge Creek yielded 604 cutthroat trout of which approximately 550 were successfully airlifted to the South Fork.

On July 16, 1980, approximately 350 cutthroat trout were collected from Sedge Creek by electrofishing and airlifted to the South Fork of the Yellowstone River. Recent observations made in the area of the South Fork confirm the establishment of a cutthroat population in the river. Several fish in the 300 to 355 mm size range were observed and two ripe females were examined. Natural reproduction has been confirmed at this time. This program will be continued in 1981.

Blacktail Ponds Cutthroat Transplant

Adjacent to the road about 10.6 km east of Mammoth, the Blacktail Ponds have been a popular fishery since the late 1800's. These small ponds (3.56 ha) originally held an indigenous cutthroat trout population (Jordan 1891), although brook trout stockings and heavy angling pressure have extirpated the cutthroat from the drainage. In an attempt to restore this valuable native population, a total of 200 cutthroat were electroshocked and transported from Bear Creek (inlet to Turbid Lake-Yellowstone Lake drainage) to the ponds on July 7-8, 1980. These trout were chosen because of their theoretically pure Yellowstone cutthroat lineage and known survival ability within a harsh environment. Although restrictive regulations enforcing catch-and-release on the endemic cutthroat and catch-and-keep on the exotic brook trout have been proposed, the cutthroat remain unprotected under the current regulation (five fish any size of which three or more must be brook trout). Since Park policy dictates that the ultimate management goal for any water where an exotic fish replaces an indigenous species should aim toward restoration of the original species, we recommend that the proposed protective regulations be initiated as soon as possible.

OTHER PROJECT ACTIVITIES

Young Adult Conservation Corps

Yellowstone's resident Y.A.C.C. camp provided four enrollees to assist in data analysis and report typing during the winter and seven enrollees to help collect field data during the summer. In the past year, approximately 60% of our summer field program and 50% of the winter data analysis would not have been possible without them. The Y.A.C.C. program has become an essential part of this project, but they do not totally replace seasonal employees who are trained in the fisheries field.

Assistance to Independent Researchers

Project personnel frequently assist independent researchers working on aquatic related studies in the Park. We provide administrative liason and logistical support at the request of either the National Park Service or the Fish and Wildlife Service. During 1980, aid was given to Dr. Jack Griffith and graduate student Dan Schill, Idaho State University, who conducted snorkel counts on the Yellowstone River catch-and-release area to collect data on hooking mortality.

Youth Conservation Corps

The Y.C.C. provided a valuable service to the fisheries program in the Park, and its participants received a diverse educational experience as a result. A short orientation and training session was presented to the participants prior to each work assignment. The purpose and objectives of each project were explained, and they were trained on methods and equipment to be used. In 1980, they assisted in the operation of the Pelican and Clear Creek fish traps.

Yellowstone, Lewis, Shoshone, Heart Lakes Limnology

In 1980, limnological sampling was conducted on all four of Yellowstone's large, oligotrophic lakes. This concluded the fifth year of sampling Yellowstone Lake and the fourth year on Lewis Lake. As a result of the diligent efforts of the rangers stationed at Shoshone and Heart Lakes, sampling on a regularly scheduled basis, which began in 1978, continued in 1980.

Table 41 Beaver Creek water chemistry, 1979 - 1980

	1979					1980							
	8/9	8/9 1400 hrs.	8/19	8/20	8/27	8/28	8/31	11/1	6/12	6/30	7/13	8/1	9/26
Water temp °C													
Spec. Cond. µmhos													
pH								7.2					
Secchi (meters)													
Pheno. alk.	0	0	0	0	0	0	0	0	0	0	0	0	0
Total alk.	32	35	27	30	24	34	28	38	20	18	24	24	34
Ca hardness	22	20	33	14	22	16	20	24	12	14	18	16	24
Total hardness	24	23	36	18	24	22	24	29	14	20	35	20	28
Total diss. solids	38	62	53	50	63	75	78	78	37	41	54	57	61
Carbonate alk.	0	0	0	0	0	0	0	0	0	0	0	0	0
Bicarbonate alk.	32	35	27	30	24	34	28	38	20	18	24	24	34
Carbonates	0	0	0	0	0	0	0	0	0	0	0	0	0
Bicarbonates	39	43	33	37	29	42	34	46	24	22	30	29	41
Hydroxides	0	0	0	0	0	0	0	0	0	0	0	0	0
Carbon dioxide	21	29	35	10	24	29	31	24	16	4.6	3.2	6.1	27
Chloride	2.3	<1	5	1.4	<1	3	2	5	<1	2	1	2	1
Sulfate	2	2	2	2	14	4	10	5.5	3.1	3	8.5	2.9	3
Fluoride	1.5	1.2	1.2	1.24	1.4	1.69	1.49	1.9	0.52	0.72	0.89	1.1	1.3
Phosphate	<0.06	0.34	0.06	<0.06	0.37	0.62	0.43	0.16	-	-	0.16	0.09	0.09
Potassium	1.6	1.8	1.5	1.7	1.7	2.5	2.1	2.1	1.5	1.1	1.5	1.8	1.8
Mg hardness	2	3	3	4	2	6	4	5	2	6	17	4	4
Calcium	8.8	8	13	5.6	8.9	6.4	8	9.6	4.8	5.6	7.2	6.4	9.6
Magnesium	0.5	0.7	0.7	1	0.5	1.5	1	1.2	0.5	1.5	4.1	1	1
Sodium	6	6.9	5.7	4.7	5.7	6.4	5.4	8.8	4	4.6	4.5	5	6
Iron	0.09	0.07	0.09	0.07	<0.01	0.12	0.14	0.14	0.05	0.05	0.07	0.07	0.18
Manganese	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.05
Copper	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.05	<0.1	<0.1
Silica	41	30	0.65	10	26	38	38	35	14	17	24	33	19
Color (PCU)	0	0	0	0	0	0	0	0	0	0	0	0	0
Turbidity (NTU)	0.66	0.67	0.68	0.72	1	0.75	0.78	0.85	1	0.85	0.75	0.80	1
TOC	2	7.4	3.2	2.4	3.1	2.6	1.9	3.1	3.7	4.9	2.5	2.9	3.7
Ortho-phosphate	<0.06	0.31	<0.06	<0.06	0.31	0.62	0.37	<0.16	<0.06	<0.03	0.12	<0.03	0.06
Kjeldahl N	*0.03	*0.14	*0.14	*0.18	*0.23	*0.31	*0.13	*0.46	*0.06	*0.12	*0.09	0.21	-
Nitrate N	<0.01	0.02	<0.01	0.02	<0.01	0.04	0.04	0.04	0.01	<0.01	0.02	0.01	<0.01

*Total Kjeldahl N

Table 42 Heart Lake water chemistry, 1978 - 1980

	1978					1979					1980								
	7/13	7/30	8/20	9/7	9/17	6/23	7/7	7/21	8/4	8/13	8/19	8/25	9/7	11/1	6/13	6/25	7/18	7/31	9/26
Water temp. °C	14.4	16.6	14.4	15.5	12.2	10	12.2	17.7	16.6	16.6	16.6	15.5	11.1		7.7	11.1	15	18.3	10
Spec. cond. µmhos	195	-	170	174	160	200	200	210	200	200	205	195	210		200	210	210	195	200
pH	7.6	7.8	7.8	7.6	7.4	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.4	7.4	7.4	7.4	7.4	7.4
Secchi (meters)	6.7	8.8+	5.5	8.2	7.3	4.3	6.9	8.4	8.9	8.2	8.4	7.9	7.5		5.2	5.3	7.7	8.2	7.0
Pheno. alk.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total alk.	36	20	50	40	48	0	35	48	42	42	48	48	44	48	46	36	36	53	53
Ca hardness	18	15	35	6	18	17	10	11	13	13	18	18	14	17	12	12	16	18	18
Total hardness	21	20	40	8	24	23	14	35	17	17	33	24	20	18	14	20	20	41	41
Total diss solids	122	110	100	150	165	45	145	160	148	148	132	137	130	151	132	140	140	150	150
Carbonate alk.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bicarbonate alk.	36	20	50	40	48	0	35	48	42	42	48	48	44	48	46	36	36	53	53
Carbonates	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bicarbonates	44	24	61	49	59	0	43	59	51	51	59	59	54	59	56	44	44	65	65
Hydroxides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carbon dioxide	7.4	2	6.5	2.6	5	<1	36	7.8	34	34	16	20	11	9.9	15	29	29	11	11
Chloride	32	28	28	30	28	26	25	28	27	27	24	41	28	24	21	40	40	26	26
Sulfate	14	15	15	14	19	5.5	17	22	14	14	17	2	12	15	21	17	17	14	14
Fluoride	2.9	2.8	2.8	2.8	2.9	2.7	3.1	2.7	3.0	3.0	2.8	2.9	3.0	3.0	2.7	2.7	2.7	2.9	2.9
Phosphate	0.09	0.22	<0.06	<0.06	0.19	0.78	0.62	0.62	0.16	0.16	0.19	0.25	<0.06	0.19	-	-	0.06	0.03	0.03
Potassium	2.9	2.8	2.6	0.6	3.7	3.8	3.5	3.6	3.7	3.7	3.4	3.6	3.3	3.8	3.3	3.3	3.4	3.8	3.8
Mg hardness	3	5	5	2	6	5	4	24	4	4	15	6	6	1	2	4	4	23	23
Calcium	7.2	6	14	2.4	7.2	7	4.1	4.4	5.3	5.3	7.2	7.2	5.6	6.8	4.8	6.4	6.4	7.2	7.2
Magnesium	0.7	1.2	1.2	0.5	1.5	1.2	1	5.8	1	1	3.6	1.5	1.5	0.2	0.5	3.8	3.8	5.6	5.6
Sodium	33	31	30	35	38	43	40	41	38	38	31	38	28	42	38	38	38	37	37
Iron	<0.01	0.03	<0.01	0.02	0.01	0.04	0.03	<0.01	<0.01	<0.01	<0.01	0.99	0.04	<0.01	0.02	<0.01	<0.01	0.01	0.01
Manganese	<0.05	<0.05	<0.05	0.02	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Copper	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Silica	3.5	30	39	38	32	35	36	27	29	29	13	27	24	25	21	15	15	11	11
Color (PCU)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Turbidity (NTU)	0.42	0.40	0.54	0.56	0.52	0.67	0.73	0.25	0.85	0.85	0.90	1	0.44	0.33	0.30	0.30	0.51	0.31	0.31
TOC	6.1	3	5.2	4.3	1.4	4.2	4.6	3.7	10	10	12.7	11	12	3.5	4.8	3.4	3.4	3.7	3.7
Ortho-phosphate	<0.09	0.11	<0.06	<0.06	0.12	0.16	0.31	0.31	0.12	0.12	0.12	0.18	<0.06	0.16	0.09	<0.03	<0.03	0.03	0.03
Kjeldahl N	0.05	0.04	0.50	0.02	0.14	*0.14	*0.21	*0.14	*0.44	*0.23	*0.33	*0.33	*0.02	0.22	0.10	0.33	0.33	-	-
Nitrate N	<0.01	0.02	0.01	<0.01	<0.01	0.32	0.05	0.01	<0.01	<0.01	<0.01	0.01	<0.01	0.02	0.01	<0.01	<0.01	0.01	0.01

*Total Kjeldahl N

Table 43 Lewis Lake water chemistry, 1977 - 1980

	1977				1978				1979				1980			
	7/18	8/11	10/4	6/29	7/27	8/31	10/4	6/23	7/20	8/28	10/6	6/25	7/30	9/9	9/26	
STA. 2																
Water temp. °C	16	9.3	14.5	17	14	9.5	10.5	18	15	12	13.5	17	12	10.2		
Spec. Cond. μ mhos	95	88.5	97	91	88	81	84	90	86	85	84	84	80	84		
pH	7.4	7.2	7.2	7.4	7.4	7.2	7.2	7.4	7.4	7.4	7.4	7.2	7.6	7.4	7.2	
Secchi (meters)	13.1	12.2	7.6	10.1	7.6	10.6	9.8	10.7	7.3	9.5	9.5	8.5	7.9	8.5	11.0	
Pheno. alk.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Total alk.	36	30	28	15	18	32	42	0	26	36	30	26	21	32		
Ca hardness	10	12	8	5	6	18	10	10	8	11	8	10	11	16		
Total hardness	12	15	12	10	8	30	17	13	12	17	10	12	12	22		
Total diss. solids	110	100	85	70	70	110	90	95	84	85	70	77	94	74		
Carbonate alk.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Bicarbonate alk.	36	30	28	15	18	32	42	0	26	36	30	26	21	32		
Carbonates	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Bicarbonates	44	37	34	18	22	39	51	0	32	44	37	32	25	39		
Hydroxides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Carbon dioxide	7.8	0.8	1.4	1.0	3.7	21	34	<1	27	19	7.8	8.5	17	16		
Chloride	1	20	9	9.1	9	6.4	6	3.3	8	5.9	5.1	8.1	10	5.8		
Sulfate	5	2	7	3	2.5	16	5	6.9	7	6.9	1	6.1	<1.0	3.2		
Fluoride	1.5	2.9	2.4	2.6	2.7	2.77	2.6	2.7	2.7	2.8	2.4	2.6	2.7	2.5		
Phosphate	0.40	0.01	0.22	0.09	<0.06	0.19	0.43	0.12	<0.06	0.16	-	0.29	0.12	0.09		
Potassium	3.3	3.10	4	2.8	3.8	1.6	3.5	3.1	3.3	3.9	3.2	3.6	0.8	3.5		
Mg hardness	2	3	4	5	2	12	7	3	4	6	2	2	0.2	6		
Calcium	4	4.8	3.2	2	2.4	7.2	4.1	4	3.2	4.4	3.2	4	4.4	6.4		
Magnesium	0.5	0.7	1	1.2	0.5	2.9	1.7	0.7	1	2.6	1.9	0.5	0.2	1.5		
Sodium	16	19	15	15	14	9.6	17	14	17	17	16	16	16	16		
Iron	0.03	0.03	0.04	0.02	<0.01	<0.01	<0.05	0.03	0.03	0.03	0.01	<0.01	0.01	0.02		
Manganese	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05		
Copper	<0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.2	<0.1		
Silica	46	33	39	16	40	52	43	38	17	30	26	36	77	19		
Color (PCU)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Turbidity (NTU)	0.50	0.30	0.27	0.34	0.30	1.4	0.56	0.43	0.37	0.35	0.30	0.33	0.30	0.40		
TOC	2.45	2.40	3.5	2.8	1.4	1.26	16	13	5.1	8.5	17	11	9.8	3.9		
Ortho-phosphate	0.40	0.01	0.06	<0.06	<0.06	0.19	0.25	0.07	<0.06	0.12	0.12	0.28	0.12	0.09		
Kjeldahl N	0.44	0.07	0.14	0.26	0.13	0.04	0.08	0.16	0.08	0.25	0.07	0.33	0.03	-		
Nitrate N	0.03	0.02	0.03	0.08	0.01	<0.01	0.02	0.01	<0.01	0.01	0.01	<0.01	<0.01	<0.01		

Table 44 Shoshone Lake water chemistry, 1978 - 1980

	1978				1979				1980							
	7/20	8/3	8/18	9/3	9/17	7/9	7/15	7/28	8/25	9/6	7/10	7/22	7/27	8/6	8/10	8/24
Water temp. °C	11.7	14.4	11.1	13.3	11.1	13.3	12.2	15.5	15.5	15.5	14.4	15.0	15.5	15.5	15.2	13.3
Spec. Cond. µmhos	90	77	78	80	77	80	75	79	70	78	74	73	77	76	78	77
pH	7.3	7.4	7.8	7.4	7.4	6.0	6.0	6.0	7.0	7.0	7.4	7.4	7.4	7.3	7.3	7.3
Secchi (meters)	9.1	9.7	9.7	13.1	12.2	10.0	22.8	12.1	14.9	15.2	10.2	11.8	13.1	12.5	12.1	12.8
Pheno. alk.	0	0	0	0	0			0		0	0				0	
Total alk.	21	15	20	16	30			30		24	27				24	
Ca hardness	12	5	5	6	12			10		21	15				6	
Total hardness	21	10	15	8	18			17		24	18				9	
Total diss. solids	75	65	70	70	85			70		46	68				72	
Carbonate alk.	0	0	0	0	0			0		0	0				0	
Bicarbonate alk.	21	15	20	16	30			30		24	27				24	
Carbonates	0	0	0	0	0			0		0	0				0	
Bicarbonates	26	18	24	20	37			37		29	33				29	
Hydroxides	0	0	0	0	0			0		0	0				0	
Carbon dioxide	22	1.5	63	1.7	7.8			31		10	11				7.7	
Chloride	8.2	8.5	7.3	8.5	7.8			9.1		8.0	12				12	
Sulfate	5	2	2	2	4			5		2	3.1				2.6	
Fluoride	2.4	2.4	2.4	2.3	2.3			2.2		2.4	2.2				2.4	
Phosphate	0.12	<0.06	0.37	<0.06	0.18			0.28		0.31	0.09				0.09	
Potassium	1.9	3.3	3.3	3.3	2.8			2.4		2.8	2.4				3.1	
Mg hardness	11	5	10	2	6			7		3	3				3	
Calcium	4.8	2	2	2.4	4.8			4		8.4	6				2.4	
Magnesium	2.7	1.2	2.4	0.5	1.5			1.7		0.7	0.7				0.7	
Sodium	12	13	11.5	11.8	14			14		10	12				13	
Iron	<0.01	<0.01	<0.01	0.02	<0.01			0.01		0.07	<0.01				<0.01	
Manganese	<0.05	<0.05	<0.05	<0.05	<0.05			<0.05		<0.05	<0.05				<0.05	
Copper	<0.1	<0.1	<0.1	<0.1	<0.1			<0.1		<0.1	<0.1				<0.1	
Silica	32	33	22	40	37			26		41	22				35	
Color (PCU)	0	0	0	0	0			0		0	0				0	
Turbidity (NTU)	0.35	0.20	0.31	0.25	0.35			1.0		0.40	0.15				0.21	
TOC	1.6	0.8	1.9	0.9	0.5			8.8		1.2	5.8				5.5	
Ortho-phosphate	0.09	<0.06	0.18	<0.06	0.12			0.25		0.31	0.06				0.06	
Kjeldahl N	0.09	0.11	0.3	0.05	0.09			*0.19		*0.14	<0.061				0.06	
Nitrate N	<0.01	0.01	<0.01	0.02	0.01			0.02		0.02	<0.01				<0.01	
Arsenic	-	-	-	-	-			-		<0.01	-				-	

*Total Kjeldahl N

Data collection began on Yellowstone Lake as a direct result of the 1976 Divide fire; however, the overall objective of the limnology program on all four lakes is to provide long-term baseline limnological data. These data are especially important as a result of the Park's natural fire program. Results from these sampling programs will be reported in the future as time, funds and manpower become available.

Yellowstone Aquatic Library

In 1980, efforts to collect and catalog the substantial written material on aquatic resources in Yellowstone Park continued. The project began in 1973 and presently has about 670 titles which are cross-referenced by author, species, water (locale) and subject. This achievement was possible largely because of the availability of Y.A.C.C assistance.

Medicine Lake Bathymetry

By request of the Billings Area Office and Medicine Lake National Wildlife Refuge, fish population sampling and a lake bathymetry were conducted on Medicine Lake, located in north-central Montana, in October of 1980. A total of four gillnets were set overnight at two locations on the lake. The bathymetry was conducted utilizing the project 23 foot boat and sportsman straight line depth finder. Gillnet findings and a detailed bathymetric map were completed and relayed to the refuge for their use.

Assistance to States

Assistance was given to Texas Parks and Wildlife personnel in collecting 50 adult rainbow trout from the Firehole River. These fish were transported to Texas for establishment of a hatchery broodstock to be used in tailwater trout fisheries. Since tailwater tributary fisheries in Texas cool to only 10°C in December, it was necessary to obtain a winter spawning rainbow trout to establish a viable, reproducing trout population. In an attempt to retain the December spawning cycle, these rainbows are being held in a laboratory under environmental conditions approximating those experienced in the Firehole River.

Project personnel assisted Montana Department of Fish, Wildlife and Parks in obtaining eggs from McBride Lake cutthroat. The eggs were collected for the state hatchery in Big Timber. This hatchery uses the McBride Lake strain of cutthroat for production purposes, and wildfish were required in their broodstock for genetic purposes.

ACKNOWLEDGEMENTS

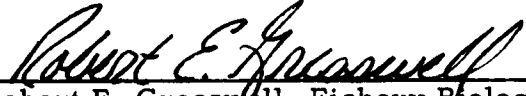
This report was made possible by the collective efforts of numerous individuals who deserve credit for their efforts. We thank the following persons: Bob Wolak contributed significantly to our field operation and should receive special recognition for his work on the Medicine Lake bathymetric map, VFR compilation and back-country lake tables and graphics; Bill Noble provided dependable service with our field operations, aquatic invertebrate library and back-country stream graphics; Karrie West receives our heart-felt thanks for partially typing the report and its tables and her efforts toward the updating of our aquatic library; Mary Wunderlich performed professional identification of our back-country lake zooplankton and developed the first zooplankton key for Yellowstone Park; Y.A.C.C. enrollees Mike Stermitz, Kevin Adams, Rico Ricardi and Sue Devan worked for us during the field season and made our operations viable; Dennis Kaleta is primarily responsible for insect identification found herein; Don C. Despain again freely gave his time and talents identifying aquatic plants; Ruth Cothrun punched all our VFR data into the computer for analysis; Phyllis Vining, Marion Jones and Laurie Pitts did VIP work for us during our hectic summer field season and deserve special thanks; the Heart and Shoshone Lake rangers, Tim Stone and Don Yestness, collected limnological data from those lakes in a highly competent manner; Fish and Wildlife Service personnel from Billings Area Office and stations in Ennis and Bozeman made the fall gillnetting a pleasure; Wyoming Game and Fish personnel, USFWS Instream Flow people, USFWS-HEP group personnel, James Mullen-USFWS and Russ Thurow-Idaho Fish and Game, and Jack Griffith and Dan Schill-Idaho State University contributed their time in demonstrating the different trout habitat evaluation and population estimation methods used on Casade and Slough Creeks.

Our special thanks to all of the above and also to those who contributed, but have been unfortunately forgotten.

This report was submitted by:

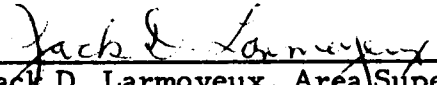


Ronald D. Jones, Project Leader



Robert E. Gresswell, Fishery Biologist

Reviewed by:



Jack D. Larmoyeux, Area Supervisor
Fishery Resources, Billings Area Office

LITERATURE CITED

- Agaard, F.C. 1969. Temperature of the surface waters of Montana. Montana Department of Fish and Game, Helena, MT. 613 p.
- Allen, E.T. and A.L. Day. 1935. Hot springs of the Yellowstone National Park. Carnegie Institute, Washington, D.C. Pub. No. 466. 525 p.
- Anonymous. 1972. Yellowstone National Park baseline water quality survey report. Environmental Protection Agency. Doc. No. EP 2.2: Y3. 89 p.
- Arnold, B.B., and F.P. Sharpe. 1967. Summary report of lake and stream investigations for 1966. U.S. Fish and Wildlife Service. Unpublished mimeo. 102 p.
- Ball, O.P., and O.B. Cope. 1961. Mortality studies on cutthroat trout in Yellowstone Lake. U.S. Fish and Wildlife Service, Research Report 55. 62 p.
- Benson, N.G., O.B. Cope, and R.V. Bulkley. 1959. Fishery management studies on the Madison River system in Yellowstone National Park. U.S. Fish and Wildlife Service, BSFW, Special Scientific Report - Fisheries No. 307. 27 p.
- Binns, N.A. 1981. Habitat evaluations at Slough and Cascade Creeks, Yellowstone National Park, Wyoming. Wyoming Game and Fish Commission, Project Report 7080-01-7101.
- Binns, N.A., and F.M. Eiserman. 1979. Quantification of fluvial trout habitat in Wyoming. Transactions of the American Fisheries Society 108(3): 215-228.
- Brown, L. 1978. Opening day creel census models for trout management lakes. Washington State Game Department, Fisheries Research Report.
- Bulkley, R.V. 1966. Catch of the 1965 tidewater cutthroat sport fishery and notes on the life history of the coastal cutthroat trout in the Sinslaw River, Oregon. Oregon State University, Fishery Research Report No. 4.
- Carlander, K.D. 1969. Handbook of freshwater fishery biology. Iowa State University Press, Ames, Iowa. 752 p.

- Carlson, R.E. 1977. A trophic state index for lakes. *Limnology and Oceanography* 22(2): 361-369.
- Chapman, S. No date. Fishing and hunting notes, 1941-1965. Unpublished diary. Bureau of Sport Fisheries and Wildlife files.
- Christiansen, R.L. 1975. Geologic map of the Norris Junction quadrangle, Yellowstone National Park, Wyoming. U.S. Geological Survey Map GQ-1193. Reston, Virginia.
- Christiansen, R.L. and H.R. Blank. 1974. Geologic quadrangle map of Old Faithful, Wyoming. U.S. Geological Survey. Reston, Virginia.
- Cope, O.B. 1957b. The choice of spawning sites by cutthroat trout. *Utah Academy of Science Proceedings* 34: 73-79.
- Dean, J.L. 1972. Annual Project Report, Fishery Management Investigations, Yellowstone National Park, Calendar Year 1971. Bureau of Sport Fisheries and Wildlife. Unpublished mimeo. 75 p.
- Dean, J.L. and L.E. Mills. 1970. Annual Project Report, Fishery Management Program, Yellowstone National Park, Calendar Year 1969. Bureau of Sport Fisheries and Wildlife. Unpublished mimeo. 100 p.
- Dean, J.L. and L.E. Mills. 1971. Annual Project Report, Fishery Management Investigations, Yellowstone National Park, Calendar Year 1970. Bureau of Sport Fisheries and Wildlife. Unpublished mimeo. 75 p.
- Dean, J.L. and J.D. Varley. 1973. Annual Project Report, Fishery Management Program, Yellowstone National Park, Calendar Year 1972. Bureau of Sport Fisheries and Wildlife. Unpublished mimeo. 170 p.
- _____. 1974. Annual Project Report, Fishery Management Program, Yellowstone National Park, Calendar Year 1973. Bureau of Sport Fisheries and Wildlife. Unpublished mimeo. 170 p.
- Dean, J.L., J.D. Varley and R.E. Gresswell. 1975. Annual Project Report, Fishery Management Program, Yellowstone National Park, Calendar Year 1974. U.S. Fish and Wildlife Service. Unpublished mimeo. 170 p.
- Despain, D.G. 1977. Forest successional stages in Yellowstone National Park. U.S. National Park Service, Informational Paper No. 32. Yellowstone National Park, Wyoming.

- Dunham, D.K. and A. Collotzi. 1975. The transect method of stream habitat inventory - guidelines and application. U.S. Forest Service, Intermountain Region. 39 p.
- Erman, D.C. 1972. A fisherman survey of the Madison - Firehole Rivers in Yellowstone National Park, 1969. Transactions of the American Fisheries Society 101(2): 352-355.
- Fromm, R.J. 1941. An open history of fish and fish planting in Yellowstone National Park. U.S. National Park Service. Unpublished mimeo. 31 p.
- Geiger, R.D. 1972. Ecology and management of coastal cutthroat trout in Oregon. Oregon State Game Commission. Fisheries Research Report No. 6. 61 p.
- Gresswell, R.E. In Press. Yellowstone Lake - a lesson in fishery management. In: W. King, editor. Proceedings of the second Wild Trout Symposium at Yellowstone National Park, September, 24-25, 1979.
- Hanzel, D.A. 1960. The distribution of the cutthroat trout (Salmo clarki) in Montana. Proceedings of the Montana Academy of Science 19: 32-71.
- Heaton, J.R. 1966. The benthos and drift fauna of a riffle in the Madison River, Yellowstone National Park. Ph.D. thesis. Montana State University, Bozeman, Montana. 59 p.
- Hutchinson, G.E. 1967. A treatise on limnology, Vol. 2. John Wiley and Sons, Inc., New York, New York.
- _____. 1975a. A treatise on limnology, Vol. 1, Part 1. John Wiley and Sons, Inc., New York, New York.
- _____. 1975b. A treatise on limnology, Vol. 3. John Wiley and Sons, Inc., New York, New York.
- Hem, J.D. 1970. Study and interpretation of the chemical characteristics of natural water. Second edition. Geological Survey Water Supply paper No. 1473. U.S. Government Printing Office, Washington, D.C.
- Jones, R.D., J.D. Varley, D.E. Jennings, S.M. Rubrecht and R.E. Gresswell. 1977. Annual Project Report, Fishery and Aquatic Management Program, Yellowstone National Park, Calendar year 1976. U.S. Fish and Wildlife Service. Unpublished mimeo. 201 p.

- Jones, R.D., J.D. Varley, R.E. Gresswell, D.E. Jennings and S.M. Rubrecht. 1978. Annual Project Report, Fishery and Aquatic Management Program, Yellowstone National Park, Calendar year 1977. U.S. Fish and Wildlife Service. Unpublished mimeo. 206 p.
- _____. 1979. Annual Project Report, Fishery and Aquatic Management Program, Yellowstone National Park, Calendar year 1978. U.S. Fish and Wildlife Service. Unpublished mimeo. 311 p.
- _____. 1980. Annual Project Report, Fishery and Aquatic Management Program, Yellowstone National Park, Calendar Year 1979. U.S. Fish and Wildlife Service. Unpublished mimeo. 195 p.
- Jordan, D.S. 1891. A reconnaissance of the streams and lakes of Yellowstone National Park, Wyoming in the interest of the U.S. Fish Commission. Bulletin of the U.S. Fish Commission, 9: 42-63.
- Kimura, D.K. 1977. Statistical assessment of the age-length key. Journal of the Fisheries Research Board of Canada 24: 317-324.
- LaBar, G.W. 1971. Movement and homing of cutthroat trout (Salmo clarki) in Clear and Bridge Creeks, Yellowstone National Park. Transactions of the American Fisheries Society 100(1): 41-49.
- Laakso, M. and O.B. Cope. 1956. Age determination in Yellowstone cutthroat trout by the scale method. Journal of Wildlife Management 20 (2): 138-153.
- LeCren, E.D. 1951. The length-weight relationship and seasonal cycle in gonad weight and condition in the perch (Perca fluviatilis). Journal of Animal Ecology 20: 201-219.
- Mathisen, L.M. 1949. Lower Umpqua River investigations. In: Oregon State Game Commission annual report, 1949: 15-18.
- McNabb, C.P. 1960. Enumeration of fresh water phytoplankton concentrated on the membrane filter. Limnology and Oceanography 5: 57-61.
- Nikolskii, G.V. 1969. Theory of fish population dynamics as the biological background for rational exploitation and management of fishery resources. Oliver and Boyd, Edinburgh, Scotland.
- Pennak, R.W. 1978. Fresh-water invertebrates of the United States. 2nd edition, John Wiley and Sons, Inc. New York, New York.

- Pierce, K.L. 1974. Surficial geologic map of the Tower Junction quadrangle, Wyoming and Montana. Miscellaneous geologic investigations. U.S. Geological Survey. Reston, Virginia.
- Richmond, G.M. 1973. Surficial geologic map of the West Thumb quadrangle, Wyoming. Miscellaneous geologic investigations. U.S. Geological Survey. Washington, D.C.
- Richmond, G.M. and H.A. Waldrop. 1975. Surficial geologic map of the Norris Junction quadrangle, Yellowstone National Park, Wyoming. Miscellaneous geologic investigations map I-650. U.S. Geological Survey. Reston, Virginia.
- Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Fisheries Research Board of Canada Bulletin 191. 382 p.
- Roeder, T.S. 1966. Ecology of the diatom communities of the upper Madison River system, Yellowstone National Park. Ph.D. thesis. Montana State University, Bozeman, Montana. 85 p.
- Ruttner, F. 1963. Fundamentals of limnology. 3rd edition. Translated by W.G. Frey and R.E.J. Fry. University of Toronto Press. Toronto, Canada.
- Ryder, R.A. 1965. A method for estimating the potential fish production of north-temperate lakes. Transactions of the American Fisheries Society 94(3): 214-218.
- Ryder, R.A., S.R. Kerr, K.H. Loftus and H.A. Reiger. 1974. The morphoedaphic index, a fish yield estimator - review and evaluation. Journal of the Fisheries Research Board of Canada 31(15): 663-688.
- Stauffer, R.E., E.A. Jenne and J.W. Ball. 1980. Chemical studies of selected trace elements in hot-spring drainages of Yellowstone National Park. Geological Survey professional paper 1044-F. 20 p.
- Strumm, W. and J.J. Morgan. 1970. Aquatic chemistry: an introduction emphasizing chemical equilibria in natural waters. Wiley - interscience. New York, New York.
- Thompson, J.M. 1979. Arsenic and flouride in the upper Madison River system: Firehole and Gibbon Rivers and their tributaries, Yellowstone National Park, Wyoming and southeast Montana. Environmental Geology 3: 13-21.

- Thompson, J.M., T.S. Presser, R.B. Barnes and D.B. Bird. 1975. Chemical analysis of the waters of Yellowstone National Park, Wyoming from 1965 to 1973. U.S. Geological Survey open file report No. 75-25. 59 p.
- Todd, E.H. 1967. Primary productivity of the Madison River in Yellowstone National Park, Wyoming. Ph.D. thesis. Montana State University, Bozeman, Montana.
- U.S. Department of Agriculture, Forest Service/Northern Region. 1975. Stream reach inventory and channel stability evaluation. Report 1-75-002. 26 p.
- U.S. Department of Interior, Fish and Wildlife Service. 1977. The 1975 national survey of hunting, fishing and wildlife associated recreation. Washington, D.C. 96 p.
- U.S. Department of Interior, Geological Survey. 1948-73. Surface water records of Montana.
- _____. 1972. Geologic map of Yellowstone National Park. Miscellaneous geologic investigations map I-711. Washington, D.C.
- U.S. Department of Interior, National Park Service. 1975. Administrative policies for natural areas of the National Park system. USDI, NPS, Washington, D.C.
- Varley, J.D. 1981. A history of fish stocking activities in Yellowstone National Park between 1881 and 1980. U.S. National Park Service - informational paper No. 35. Yellowstone National Park, Wyoming.
- Varley, J.D., R.E. Gresswell, S.M. Hoskins, R.B. Mathias, D.E. Jennings, M.D. Carpenter and J. Dolan. 1976. Annual Project Report, Fishery and Aquatic Management Program, Yellowstone National Park, Calendar year 1975. U.S. Fish and Wildlife Service, Unpublished mimeo. 148 p.
- Waldrop, H.A. 1975. Surficial geologic map of the Old Faithful quadrangle, Yellowstone National Park, Wyoming. Miscellaneous geologic investigations map I-649. U.S. Geological Survey. Reston, Virginia.
- Westerheim, S.J. and W.E. Ricker. 1978. Bias in using an age-length key to estimate age frequency distributions. Journal of the Fisheries Research Board of Canada 35: 184-189.
- Wright, J.C. and I.K. Mills. 1967. Productivity studies on the Madison River, Yellowstone National Park. Limnology and Oceanography 12(4): 568-577.

Wright, J.C., R. Erickson and E. Todd. No date. A report on the effect of the Madison Junction sewage plant effluent on the Madison River. Montana State University, Bozeman, Montana. Unpublished mimeo. 10 p.

Zippen, C. 1958. The removal method of population estimation. Journal of Wildlife Management Vol. 22(1): 82-90.