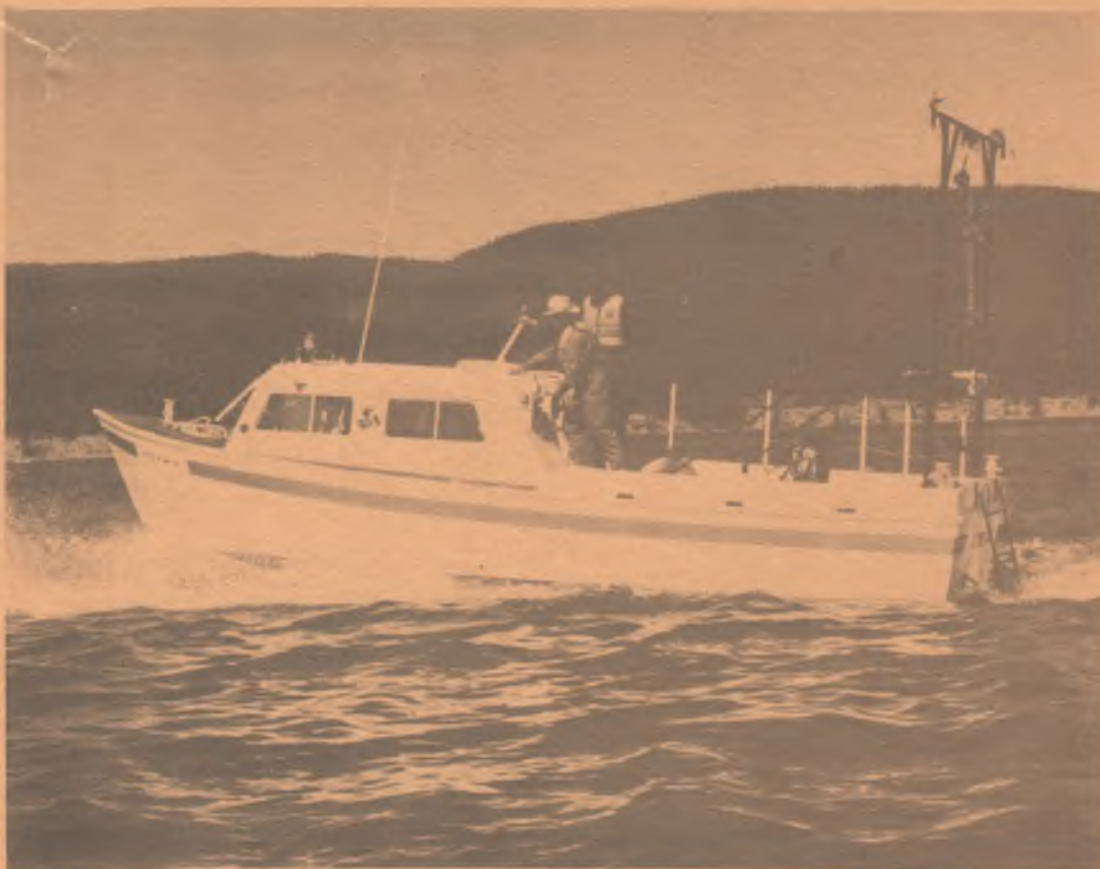


UNITED STATES DEPARTMENT OF THE INTERIOR

FISH AND WILDLIFE SERVICE

Fishery Resources



FISHERY AND AQUATIC MANAGEMENT PROGRAM

in

YELLOWSTONE NATIONAL PARK

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Yellowstone National Park

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INTRODUCTION

In 1872, the United States Congress established Yellowstone National Park "... for the benefit and enjoyment of the people and for the preservation, from injury and spoilation of all timber, mineral deposits, natural curiosities or wonders..., and their retention in their natural condition." From this beginning, federal legislation and policies have evolved to prohibit hunting of all birds and mammals and to regulate fishing. The Park is currently managed as a natural area to perpetuate the native fauna, flora, geology, and scenic landscape as a natural ecosystem.

Fishing has always been a major visitor activity in Yellowstone Park. Although initial regulations were extremely liberal and associated with frontier subsistence, present restrictions have been developed over the past fifty years to more closely reflect the Park's management mandate. The basic objectives of the fishing program are:

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

Attainment of these objectives requires that angler harvests do not alter natural replenishment rates, or significantly reduce numbers, biomass, sizes, and age structure from those occurring in the absence of fishing. This management policy necessitates both a philosophical and literal distinction between recreational angling and removing fish for consumption. This distinction is especially important since maintenance stocking was eliminated in the early 1950's and wild stocks alone must support rising interest in sport angling. Because Park policies have prevented substantial degradation of aquatic habitats often associated with human utilization and development, habitat manipulation has been unnecessary in Yellowstone. Restrictive angling regulations, therefore, have been the primary means by which the Park has met the challenge of increasing Parkwide angler use and back-country visitation.

Regulations used to protect fishes and maintain angling quality have included manipulating season dates, bait and terminal gear restrictions, and the use of creel and size limits (including catch and release-only). Additionally, some waters have been closed to angling in order to protect threatened species, nesting birds, or to provide scenic vistas with undisturbed wildlife (including fishes).

Yellowstone has one fish species (Montana grayling) and over a dozen waters restricted to catch and release-only fishing. Several other waters, including Yellowstone Lake, require the release of some fish as a result of maximum or minimum size

limits. The implementation of these regulations has improved angling quality despite substantial increases in fishing pressure, and population structure has shifted to a state more closely resembling historic levels.

In 1982, approximately 205,000 non-fee permits were issued to potential Park anglers. Although anglers from all 50 states, all Canadian provinces and several other foreign countries fished in Yellowstone Park, the largest single group resided in the local states of Montana, Wyoming, Idaho and Utah (Table 1). Residents of California and Colorado dominated the individual states (15.9% and 8.9%, respectively), but the four local states were all in the top ten.

Of 120 lakes and streams which are annually utilized by Park anglers, 30 support most of the fishing pressure. The quality of at least six of these fisheries has gained national recognition, and several articles, usually complimentary, are published about Yellowstone fishing each year.

The 1980 National Survey of Hunting, Fishing and Wildlife Associated Recreation (USDI 1982) indicates that Yellowstone Park supports approximately 1.3% of the nations total trout anglers. According to recent figures, eight states have fewer licensed anglers than the Park, and in 1981, the number of Park license-holders was greater than 63% of the total licenses issued by Wyoming, over 51% of the total issued by Montana and 39% of the total issued by Idaho (USFWS 1982). The economic impact of Park anglers is evidenced by the estimated 4 million dollars they spend annually in and around Yellowstone Park.

These facts help to elucidate both the importance of the Park fishery resource and the problems encountered in attempting to meet the Park's fishery management objectives. Angler use remained high in 1982, at a level only exceeded twice since these estimates began. Since angler use appears to be directly related to total Park recreational visitation, angler use is expected to rise concomitant with future increases in visitation.

Despite the recommendation of several important regulation changes (Jones et al 1982), the statutes remained unchanged during 1982. We believe these changes are necessary to both protect native fishes and to maintain quality angling, and we urge that these regulations be initiated as soon as possible.

Table 1 . Residency of anglers¹⁾ interviewed when leaving Yellowstone Park, 1976 and 1978-1982

States by geographical groups	Number interviewed at Entrance Station						Percentage of total interviewed					
	1976	1978	1979	1980	1981	1982	1976	1978	1979	1980	1981	1982
"Local states"												
Idaho	37	47	61	23	71	55	2.79	3.91	4.96	3.38	4.64	4.42
Montana	68	46	62	49	79	79	5.14	3.83	5.04	7.20	5.17	6.35
Utah	71	97	112	50	141	103	5.36	8.07	9.10	7.34	9.23	8.28
Wyoming	67	58	58	23	89	62	5.06	4.82	4.71	3.38	5.82	4.98
Total	243	248	293	145	380	299	18.35	25.48	23.80	21.29	24.87	24.04
West coast states												
California	225	158	222	102	228	198	16.99	13.15	18.03	14.98	14.92	15.92
Oregon	24	34	24	23	40	36	1.81	2.83	1.95	3.38	2.62	2.89
Washington	56	49	48	21	54	64	4.23	4.07	3.90	3.08	3.53	5.14
Total	305	241	294	146	322	298	23.03	20.05	23.88	21.44	21.07	23.95
Southwest states												
Arizona	18	28	26	22	41	23	1.36	2.33	2.11	3.23	2.68	1.85
Colorado	65	65	80	47	118	111	4.91	5.41	6.50	6.90	7.72	8.92
Nevada	7	4	10	4	12	7	0.53	0.33	0.81	0.59	0.79	0.56
New Mexico	9	8	9	6	16	18	0.68	0.67	0.73	0.88	1.05	1.45
Total	99	105	125	79	187	159	7.48	8.74	10.15	11.60	12.23	12.78
Central plains states												
Iowa	15	25	17	13	28	21	1.13	2.08	1.38	1.90	1.83	1.69
Kansas	14	12	8	7	26	14	1.06	1.00	0.65	1.03	1.70	1.13
Nebraska	18	15	21	10	22	19	1.36	1.24	1.71	1.47	1.44	1.53
North Dakota	10	12	2	8	10	8	0.76	1.00	0.16	1.17	0.05	0.64
Oklahoma	14	7	10	11	28	18	1.06	0.58	0.81	1.62	1.83	1.45
South Dakota	9	14	8	5	5	11	0.68	1.16	0.65	0.73	0.32	0.88
Texas	42	52	43	30	57	46	3.17	4.32	3.49	4.41	3.73	3.70
Total	122	137	109	84	176	137	9.22	11.38	8.89	12.33	11.52	11.01
North central states												
Illinois	70	48	40	26	56	32	5.29	4.00	3.25	3.82	3.66	2.57
Indiana	20	23	11	3	10	7	1.51	1.91	0.89	0.44	0.65	0.56
Michigan	58	61	47	15	42	27	4.38	5.07	3.82	1.91	2.75	2.17
Minnesota	64	44	31	17	44	39	4.83	3.66	2.52	2.50	2.88	3.14
Ohio	49	40	22	19	32	32	3.70	3.33	1.79	2.79	2.09	2.57
Wisconsin	40	37	31	23	44	25	3.02	3.08	2.52	3.38	2.88	2.00
Total	301	253	182	101	228	162	22.73	21.05	14.78	14.83	14.92	13.02
Southern states												
Alabama	3	3	1	2	2	6	0.23	0.24	0.08	0.29	0.13	0.48
Arkansas	1	4	6	3	5	4	0.08	0.33	0.49	0.44	0.33	0.32
Florida	22	14	20	12	23	13	1.66	1.16	1.62	1.76	1.50	1.05
Georgia	7	10	7	5	7	7	0.53	0.83	0.57	0.73	0.46	0.56
Kentucky	7	2	4	3	7	4	0.53	0.16	0.32	0.44	0.46	0.32
Louisiana	5	4	5	1	6	4	0.38	0.33	0.41	0.15	0.39	0.32
Mississippi	5	8	3	3	5	7	0.38	0.66	0.24	0.44	0.33	0.56
Missouri	19	19	23	12	11	13	1.44	1.58	1.87	1.76	0.72	1.05
North Carolina	9	9	6	2	3	9	0.68	0.79	0.49	0.29	0.20	0.72
South Carolina	5	4	3	1	3	2	0.38	0.33	0.24	0.15	0.20	0.16
Tennessee	7	1	4	0	4	4	0.53	0.08	0.32	0.00	0.26	0.32
Virginia	11	4	7	6	10	9	0.83	0.33	0.57	0.88	0.65	0.72
Washington, D.C.	1	0	0	0	0	0	0.08	0.00	0.00	0.00	0.00	0.00
West Virginia	4	4	1	2	3	3	0.30	0.33	0.08	0.29	0.20	0.24
Total	106	86	90	52	89	85	8.03	7.15	7.31	7.64	5.82	6.83

Continued on next page.

Table 1 . Continued

States by geographical groups	Number interviewed at Entrance Station						Percentage of total interviewed					
	1976	1978	1979	1980	1981	1982	1976	1978	1979	1980	1981	1982
Northeast states												
Connecticut	10	11	13	7	3	7	0.76	0.95	1.06	1.03	0.20	0.56
Deleware	1	0	0	1	1	3	0.08	0.00	0.00	0.15	0.07	0.24
Maine	2	1	0	1	4	2	0.15	0.08	0.00	0.15	0.26	0.16
Maryland	14	9	9	7	8	7	1.06	0.74	0.73	1.03	0.52	0.56
Massachusetts	10	6	9	7	8	4	0.76	0.49	0.73	1.03	0.52	0.32
New Hampshire	3	2	2	2	2	2	0.23	0.16	0.16	0.29	0.13	0.16
New Jersey	14	12	17	10	17	12	1.06	1.00	1.38	1.47	1.11	0.96
New York	28	27	31	12	27	11	2.11	2.24	2.51	1.76	1.77	0.88
Pennsylvania	26	41	25	10	34	29	1.96	3.41	2.03	1.47	2.23	2.33
Rhode Island	1	0	1	0	3	1	0.08	0.00	0.08	0.00	0.20	0.08
Vermont	1	1	3	0	1	2	0.08	0.08	0.24	0.00	0.07	0.16
Total	110	110	110	57	108	80	8.33	9.15	8.94	8.37	7.07	6.43
Isolated states												
Alaska	3	1	1	1	2	1	0.23	0.08	0.08	0.15	0.13	0.08
Hawaii	2	1	1	2	0	2	0.15	0.08	0.08	0.29	0.00	0.16
Total	5	2	2	3	2	3	0.38	0.16	0.16	0.44	0.13	0.24
Canada	33	19	12	11	31	16	2.49	1.58	0.97	1.62	2.03	1.28
Foreign countries	0	0	14	3	5	5	0.00	0.00	1.14	0.44	0.33	0.40
GRAND TOTAL w/o Canada	1291	1182	1205	667	1492	1223						
GRAND TOTAL w/ Canada	1324	1201	1217	678	1523	1239						
GRAND TOTAL w/ Canada and foreign countries	1324	1201	1231	681	1528	1244						

1) Persons who obtained fishing permits.

PARKWIDE FISHING

Although recreational visitation decreased 5.9% from 1981 estimates, the 1982 figure (2.3 million) has only been exceeded four times in Park history. Approximately 205,000 non-fee permits were issued; however, exit gate interviews suggest that almost 29% of the permittees did not fish. After adjustments were made for nonanglers, the number of Park anglers was estimated to be 152,000 in 1982 (Table 2). Despite a 5.0% decrease from 1981 (a Park record of 160,000 anglers), the number of anglers remained among the highest yet encountered in Yellowstone Park (Table 2).

The exit gate survey indicated that anglers spent an average of 1.9 days fishing in the Park and fished approximately 1.16 different waters per day. Computations utilizing these data (Jones et al 1977) yielded estimates of total use (332,500 angler days) and effort (777,600 angler hours). Both figures are among the highest estimates since 1973 (Table 2).

An estimated 740,200 fish were landed and 107,500 creeled at a rate of 0.95 and 0.14 fish per hour, respectively (Table 3). Of the fish landed, 85% were released and 15% creeled.

The number of fish landed per average angler trip (2.34 hours) was 2.3, and the number creeled was 0.32 (Table 4). Anglers indicating satisfaction with their fishing trip landed 2.8 fish, whereas those that were unsatisfied landed only 1.2 fish. The average length of fish landed was also higher for satisfied anglers (348 mm or 13.7 inches) than unsatisfied fishermen (308 mm or 12.1 inches).

Species composition was indicated by anglers for 59,923 landed fish; 70.6% were reported as cutthroat trout, followed by rainbow trout (10.8%), brown trout (8.0%), brook trout (6.6%) and lake trout (1.2%). Small numbers of grayling, mountain whitefish, cutthroat x rainbow hybrid and nongame species were also caught.

The average size of landed fish (343 mm or 13.5 in) increased slightly from 1981. Of 59,263 fish, about 68% were greater than 305 mm (12 in) and 50% exceeded 356 mm (14 in). The average length of creeled fish was 314 mm (12.3 in). Lake trout were the largest fish landed (418 mm or 16.4 in) followed by cutthroat trout (362 mm or 14.3 in), whitefish (328 mm or 12.9 in), cutthroat x rainbow hybrids (326 mm or 12.8 in), brown trout (318 mm or 12.5 in) and brook trout (246 mm or 9.7 in).

The percentage of fishermen that reported satisfaction with their overall fishing experienced were 74% in 1982. Satisfaction rates with numbers and sizes of fish landed were 67% and 68%, respectively (Table 4).

Table 2. Estimates of park recreational visitation, fishing permits issued, total parkwide anglers and total parkwide angler days, Yellowstone National Park, 1972-1982

	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
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	2,521,831	2,368,397
Percent change from previous year:	---	-8.2%	-6.4%	+13.9%	+12.5%	-1.5%	+5.5%	-27.7%	+5.7%	+26.1%	-5.9%
Park Fishing Permits Issued:	-----	169,103	164,600	191,550	213,200	217,000	213,000	195,100	184,200 ¹⁾	172,300	205,000
Percent change from previous year:	---	---	-2.7%	+16.4%	+11.3%	+1.8%	+0.5%	-10.5%	-5.6%	-6.5%	+19.0%
Total Parkwide Anglers:	-----	121,888	116,518	136,322	151,730	154,581	155,700	139,100	130,800	160,000	152,000
Percent change from previous year:	---	---	-4.4%	+17.0%	+9.7%	+1.9%	+0.7%	-10.7%	-6.0%	+22.3%	-5.0%
Total Parkwide Angler Days:	-----	230,100	220,000	257,300	284,200	311,300	333,000	291,300	311,300	363,400	332,500
Percent change from previous year:	---	---	-4.4%	+17.0%	+10.5%	+9.5%	+7.2%	-12.7%	+6.9%	+23.2%	-13.3%
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- 341,300	274,500- 308,200	287,000- 334,600	363,400- 403,300	314,700- 350,300

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

Table 3. Fisherman use, effort, success and harvest for Yellowstone National Park, 1973-1982

Year	Angler days	X length angler day	Total hours fished	Landing rate	Total fish landed	Creek rate	Total fish created	% of anglers satisfied with Overall experience	Numbers caught	Sizes caught	Average total Length of fish landed (in.)	Mean expertise level (95% C.I.) ²⁾
1973	230,100	2.45	564,400	0.86	485,400	0.16	90,300	---	---	---	---	---
1974	220,000	2.42	531,300	0.86	456,900	0.19	101,000	---	---	---	---	---
1975	257,300	2.31	594,400	1.09	647,900	0.23	136,700	77	74	75	13.3	---
1976	284,200	2.36	670,700	1.02	684,100	0.20	134,100	74	69	69	13.2	1.90
1977	311,300	2.33	725,300	0.98	710,800	0.20	145,100	75	68	70	13.4	1.83
1978	333,000	2.23	744,400	0.99	736,900	0.17	126,500	73	66	68	13.4	1.86
1979 ¹⁾	291,300	2.49	725,300	1.01	731,100	0.15	107,300	73	67	68	13.6	1.88 (1.87-1.90)
1980	311,300	2.44	758,000	0.96	725,300	0.13	101,000	73	66	68	13.4	1.87 (1.86-1.88)
1981	363,400	2.41	923,000	0.93	844,700	0.12	110,800	73	65	66	13.4	1.88 (1.87-1.89)
1982	332,500	2.34	777,558	0.95	740,200	0.14	107,500	74	67	68	13.5	1.88 (1.86-1.89)

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 4 . Characteristics of satisfied and unsatisfied anglers, and the influence of the relative expertise of anglers to sportfishing success in Yellowstone National Park, 1982

	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 expertise ¹⁾	Sample anglers (n)
Satisfied anglers		2.47	1.13	0.16	2.8	0.40	13.7	1.01	5,026
Unsatisfied anglers		2.19	0.54	0.08	1.2	0.18	12.1	1.86	2,153
sum or x	1.74	2.34	0.95	0.14	2.2	0.33	13.5	1.88	8,367 ²⁾
Inexperienced anglers	1.55	1.99	0.66	0.17	1.3	0.34	13.3	1.00	1,920
Experienced anglers	1.81	2.40	0.96	0.14	2.3	0.34	13.4	2.00	5,450
Expert anglers	1.79	2.63	1.47	0.12	3.9	0.32	14.0	3.00	893
sum or x	1.74	2.34	0.95	0.14	2.2	0.33	13.5	1.88	8,367 ²⁾

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	0.8	0.8	0.8	0.3	0.3	0.4
Experienced anglers	1.1	1.2	1.0	0.4	0.4	0.6
Expert anglers	1.7	1.7	1.6	0.7	0.6	1.1
Creel Rate (Fish/hr)						
Inexperienced anglers	0.21	0.22	0.20	0.05	0.07	0.09
Experienced anglers	0.16	0.16	0.15	0.07	0.08	0.11
Expert anglers	0.14	0.13	0.14	0.07	0.09	0.08
Fish Size (Inches)						
Inexperienced anglers	13.4	13.3	13.5	12.2	13.2	12.1
Experienced anglers	13.5	13.3	13.9	12.2	12.8	11.6
Expert anglers	14.1	14.1	14.3	12.4	13.0	12.2

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.

On the VFR card, fishermen are asked to judge their own technical expertise level, and expertise is then estimated for each water by a mean index value whereby 1.0 is an inexperienced angler, 2.0 is experienced and 3.0 is an expert. In 1982, the mean expertise for 8,367 Park anglers was 1.88, indicating that most fishermen fall into the inexperienced to experienced category (Table 4).

In depth analysis of several fisheries including Yellowstone Lake, the catch and release section of the Yellowstone River, Lewis and Shoshone Lakes, Cascade Lake, McBride Lake, Lake #1310 and Sedge Creek were completed in 1982. Although it was not possible to expand these analyses to additional waters, data for over 30 lakes and streams that make up over 94% of the total Park angler use are give in tabular form (Tables 5 and 6).

Table 5. Fishery statistics from Yellowstone Park waters with over 40 angler days in the sample and which comprise over 94% of the parkwide angler day use in 1982

	% of total parkwide angler days	Total reported angler days (VFR)	Estimates for the season						Total fish landed	Total fish creel	Y length fish landed (inches)	Y length fish creel (inches)	% anglers landing 1 or more fish	Average expertise	% anglers satisfied with:		
			Anglers	Y length angler day (hours)	Angler days (trips)	Angler hours (effort)	Landing rate	Creel rate							Overall experience	Numbers caught	Fish sizes caught
Parkwide fishery	100.00	14,590	152,027	2.34	332,500	777,558	0.95	0.14	740,200	107,500	13.5	12.4	68	1.88	74	67	68
Yellowstone Lake	46.72	6,817	62,759	2.44	155,349	378,574	0.89	0.20	336,232	74,000	14.4	12.2	71	1.77	78	69	74
Yellowstone River	13.17	1,922	20,732	2.41	43,794	105,388	1.12	0.05	117,882	5,629	15.0	12.6	71	1.98	85	80	87
Firehole River	7.11	1,038	11,938	2.35	23,648	55,489	0.76	0.02	42,068	1,342	11.2	12.4	58	2.00	66	60	47
Madison River	5.74	838	8,667	2.16	19,090	41,336	0.58	0.05	23,765	1,980	13.2	16.0	44	1.99	57	45	52
Gibbon River	4.32	631	8,376	1.84	14,372	26,376	0.94	0.10	24,827	2,552	10.0	10.8	59	1.94	62	53	39
Slough Creek	2.64	415	4,706	2.60	9,450	24,549	1.28	0.02	31,387	475	13.8	12.7	83	2.08	89	86	94
Lewis Lake	2.53	369	3,307	3.00	8,402	25,213	0.43	0.14	10,774	3,597	14.6	15.1	44	1.89	65	50	59
Shoshone Lake	2.47	360	2,417	2.44	8,196	19,965	0.41	0.15	8,270	3,022	17.8	18.2	57	1.84	67	53	82
Gardner River	1.34	196	2,544	1.92	4,459	8,547	1.51	0.29	12,913	2,453	9.8	10.0	80	1.92	64	64	44
Lewis River	0.98	143	2,090	1.88	3,251	6,120	0.96	0.05	5,864	328	10.7	9.5	70	1.86	59	59	45
Soda Butte Creek	0.92	135	1,472	2.05	3,069	6,287	1.98	0.20	12,439	1,252	10.3	14.2	71	1.87	55	59	43
Nez Perce Creek	0.88	129	2,090	1.79	2,932	5,251	0.62	0.06	3,273	346	10.2	11.7	69	1.94	77	72	58
Lamar River	0.82	120	1,145	2.50	2,727	6,814	0.84	0.05	5,742	365	11.6	11.1	49	1.91	47	37	30
Pelican Creek	0.72	105	1,490	2.60	2,385	6,196	1.68	0.02	10,415	98	14.7	11.0	70	1.92	70	70	60
Falls River	0.54	79	1,072	2.19	1,793	3,919	1.35	0.14	5,287	535	9.5	13.0	92	2.01	89	76	91
Grebe Lake	0.52	76	1,217	2.19	1,724	3,781	1.18	0.09	4,455	333	11.3	10.0	81	1.88	53	55	24
Indian Creek	0.49	72	927	1.56	1,633	2,550	1.51	0.38	3,847	977	9.0	9.4	76	1.90	71	66	31
Becnel River	0.49	72	872	1.93	1,633	3,150	0.92	0.19	2,914	585	11.3	11.2	75	1.94	63	60	58
Snake River	0.49	71	908	2.02	1,610	3,260	0.78	0.11	2,552	367	12.3	14.2	66	1.82	67	64	53
Gallatin River	0.49	71	818	2.02	1,610	3,260	0.88	0.36	2,879	1,190	12.0	13.5	48	1.98	60	43	49
Sylvan Lake	0.44	64	1,090	1.40	1,451	2,030	1.84	0.02	3,729	51	10.1	12.0	71	1.87	69	69	49
Heart Lake	0.36	53	400	1.99	1,200	2,393	0.84	0.12	2,015	307	15.7	17.7	75	1.52	85	75	75
Pebble Creek	0.32	47	600	1.91	1,063	2,028	1.26	0.31	2,556	622	9.6	9.8	91	1.97	78	81	59

Table 6. Fishery statistics from Yellowstone Park waters with less than 40 angler days per year represented in the sample, 1982

	% of total parkwide angler days	Total reported angler days (VFR)	Estimates for the season						Total fish landed	Total fish creel	Y length fish landed (inches)	Y length fish creel (inches)	% anglers landing 1 or more fish	Average expertise	% anglers satisfied with:		
			Anglers	Y length angler day (hours)	Angler days (trips)	Angler hours (effort)	Landing rate	Creel rate							Overall experience	Numbers caught	Fish sizes caught
Little Firehole River	0.23	33	454	1.69	744	1,256	1.79	0.12	2,252	144	9.4	11.6	75	2.00	70	70	26
Lewis-Shoshone Channel	0.21	30	327	2.76	676	1,869	0.86	0.18	1,613	338	17.2	16.8	70	1.94	93	64	86
Uosidian Creek	0.20	29	454	1.45	653	945	1.86	0.47	1,763	446	9.1	9.2	77	1.72	75	75	15
Tower Creek	0.18	27	345	1.73	604	1,052	1.83	0.56	1,930	590	9.1	9.3	85	1.79	82	82	59
Caine Creek	0.18	26	236	2.99	585	1,750	1.30	0.25	2,277	442	10.8	11.7	88	2.08	85	92	77
Clear Creek*	—	135	342	2.18	512	1,116	2.96	0.18	3,300	195	15.0	12.6	97	1.91	93	94	82
Hellroaring Creek*	—	117	230	2.10	443	931	1.58	0.29	1,473	274	9.8	10.6	91	1.99	80	79	64
Cascade Creek*	—	39	100	1.63	147	239	1.07	0.28	256	68	10.6	14.9	71	1.85	73	65	50

* Figures represented for these fisheries are an average value for 1977-1982 except for reported use which is the sum of those years.

YELLOWSTONE LAKE

Through the past century Yellowstone Lake has remained the most popular fishery in the Park. Despite its great size (35,400 ha or 87,450 acres) and once seemingly inexhaustable trout population, man continues to have a significant influence on the Yellowstone Lake cutthroat trout fishery. Large scale spawn taking operations, commercial fishing, and a 100 year history of almost unabated increases in 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 cutthroat 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 1981).

A 356 mm (14 inch) minimum size restriction imposed in 1970 helped to curb the intense overfishing which occurred during the 1950's and 1960's. Despite initial benefits, 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 inch) 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. This regulation has remained unchanged since 1975, and allows a daily limit of two cutthroat trout under 330 mm total length. It was not until 1978 that the regulation was applied to lake tributaries.

For over thirty years, fishery biologists have been investigating various aspects of the Yellowstone Lake ecosystem in order to assess human impacts. Since 1969, research has been aimed at evaluating the various regulations and the effect on both angling quality and the cutthroat trout population. In 1982, studies included a creel survey utilizing the VFR system (Jones et al 1977), the operation of two spawning traps, a monthly sampling of limnological parameters, purse seining and two experimental gillnetting programs.

CREEL SURVEY

During 1982, angler use on Yellowstone Lake comprised 47% of the total parkwide fisherman use. An estimated 62,759 anglers spent 155,349 angler days and 378,574 angler hours fishing the lake (Table 7). Angler use and effort declined slightly in 1982 (2% and 1%, respectively), but both levels remain high. Although these values do not approach records set in the 1960's (256,000 angler days and 543,100 hours), the current effort figure has only been surpassed three times since 1970 (Figure 1).

Table 7. Fishing statistics from Yellowstone Lake, 1982

Predicted totals for season															
Yellowstone Lake area:	% of lake total	Total VFR use reported	Predicted totals for season								% Anglers satisfied with:				
			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	4.44	303	3,252	1.96	6,897	13,490	0.74	0.19	9,952	2,621	78	68	72	1.87
	Boat	1.55	106	872	2.74	2,408	6,610	1.53	0.34	10,106	2,273	98	96	87	1.89
2	Shore	31.67	2,159	19,678	2.01	49,195	98,679	0.65	0.15	64,632	14,783	69	59	67	1.77
	Boat	21.71	1,480	14,736	2.96	33,721	99,638	0.96	0.26	95,873	25,894	86	79	81	1.71
3	Shore	2.83	193	1726	2.06	4,391	9,032	0.90	0.19	8,119	1,703	66	64	72	1.91
	Boat	0.32	22	218	3.87	482	1,867	0.86	0.16	1,609	295	67	67	92	1.63
4	Shore	11.74	800	8,376	1.86	18,224	33,842	0.58	0.15	19,612	5,157	74	61	72	1.78
	Boat	6.32	431	2,798	2.93	9,815	28,726	0.84	0.22	24,221	6,316	79	72	74	1.83
5	Shore	0.13	9	127	2.31	197	455	1.38	0.04	628	17	100	100	100	1.86
	Boat	2.79	190	1,762	3.79	4,311	16,338	1.47	0.22	24,070	3,654	95	96	88	1.72
6	Shore	0.10	7	91	1.44	152	218	1.72	0.30	376	66	67	100	67	1.60
	Boat	1.56	107	745	3.84	2,431	9,343	2.47	0.19	23,099	1,735	92	89	82	2.00
7	Shore	0.01	1	18	0.88	15	13	4.67	0.01	62	0	100	100	100	2.00
	Boat	2.02	138	836	3.57	3,137	11,196	1.35	0.17	15,119	1,896	93	93	96	1.89
Unknown	12.79	872	7,522	2.46	19,865	48,845	1.02	0.20	49,823	9,780	75	69	73	1.70	
All shore	57.65	3,930	37,230	1.98	89,555	177,532	0.67	0.15	118,735	27,145	71	61	69	1.78	
All boat	42.35	2,887	25,529	3.06	65,786	201,021	1.15	0.25	231,495	49,665	86	80	81	1.74	
Entire lake	100.00	6,817	62,759	2.44	155,349	378,574	0.89	0.20	336,232	74,000	78	69	74	1.77	

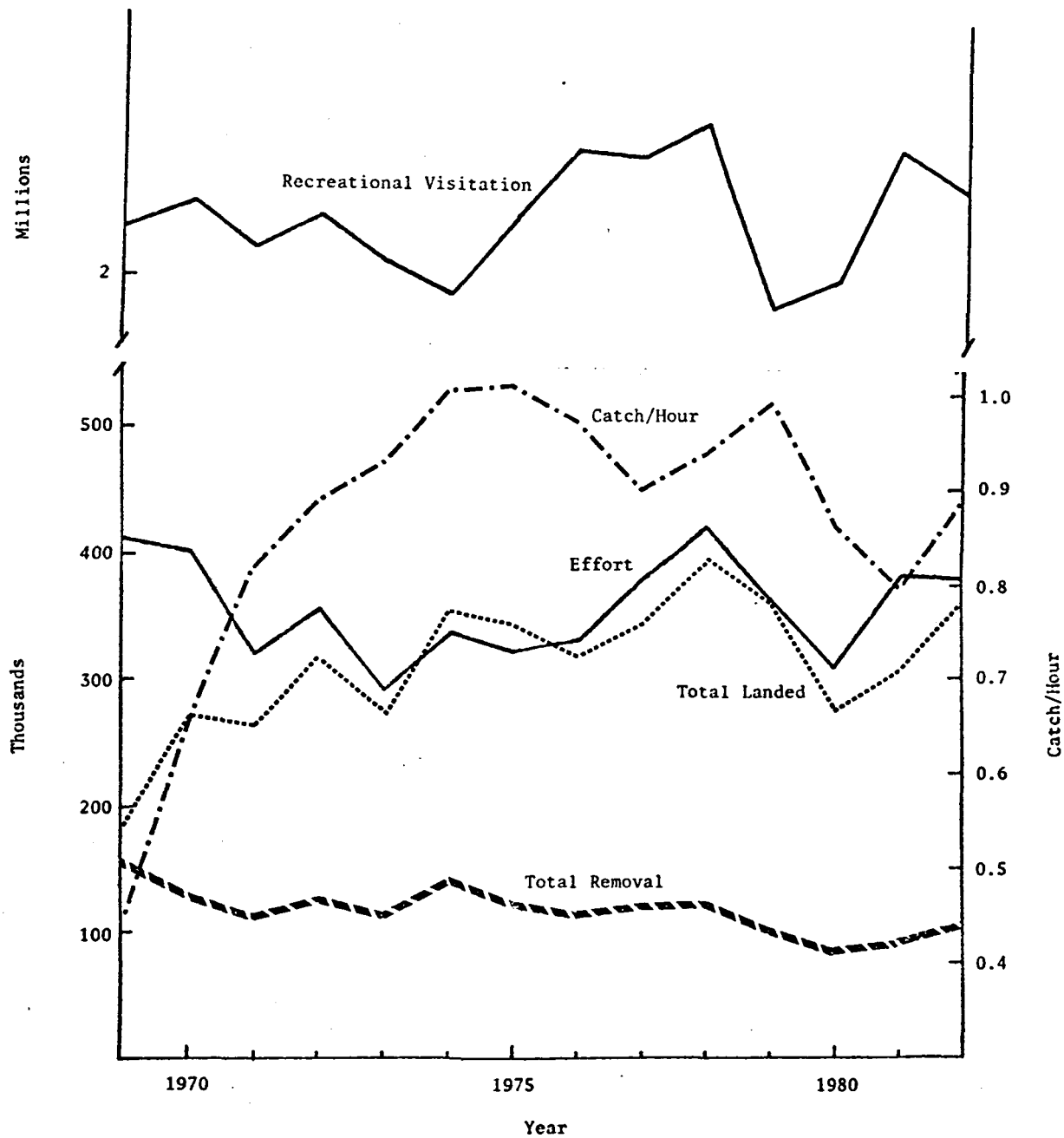


Figure 1 . Recreation visitation, catch per hour, total effort, total trout landed and total trout removed from Yellowstone Lake, 1969-1982.

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, an average of 86% (range: 84% - 88%) of the use occurred in areas with easy access, but since 1975, annual percentages have ranged from 89% to 94%, with a mean of 91%. The effect of the current regulation on this apparent shift in 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 affect this apparent shift in use patterns. Differences in survey techniques since 1975 may also confound such a comparison; however, regardless of the reason, it has been the more accessible areas which have been historically overfished.

Yellowstone Lake fishermen landed an estimated 336,200 trout and released 262,200. The total angler-caused mortality was estimated at 100,300 (74,100 creeled plus an estimated 26,200 which may have died of hooking wounds following release). Overall landing and creel rates were 0.89 and 0.20 trout per hour, respectively. Landing and creel rates from the boat segment (1.15 and 0.25 trout per hour, respectively) were substantially above those from the shoreline segment (0.67 and 0.15 trout/hour, respectively)(Table 7). Success by area continues to be inversely related to angling pressure; the more remote areas continue to sustain higher rates than the more heavily fished accessible areas. Seventy-one percent of the lake's one-day anglers landed one or more trout, and 37% creeled one or more.

Based on length measurements of 24,495 trout reported from Yellowstone Lake, it is apparent that the age-size structure of the cutthroat population continues to improve (Table 8). The average size of trout landed in 1982 was 366 mm. 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 in total length (21.0%) continues to be substantially higher than before the regulation change. The percentage of landed trout measuring over 475 mm and 508 mm are among the highest yet reported.

The illegal harvest of trout over 330 mm is a continuing problem. An estimated 20,800 trout over 330 mm and 3,200 over 356 mm 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 20,800 illegal trout creeled remains far above an acceptable level.

During 1982, the percentage of fishermen which reported satisfaction with their overall fishing experience was 78%;

Table 8. Average length and length frequencies of cutthroat trout landed and creelied from Yellowstone Lake, 1973-1982

Number and percentage of trout in length groups (inches):										
		<10	10-12	12-14	14-16	16-18	18-20	>20	N	
Number of trout reported landed:										
14"	1973	131	364	1,204	1,521	268	9	0	3,497	
min.	1974	823	1,861	6,276	8,296	1,097	90	4	18,447	
size										
13"	1975	686	2,634	8,654	8,366	1,571	155	44	22,110	
max.	1976	816	3,415	10,160	10,123	2,295	349	94	27,252	
size	1977	645	3,029	10,068	11,778	3,619	613	228	29,980	
	1978	1,174	3,878	10,322	14,794	4,523	728	188	35,607	
	1979	781	2,463	7,042	13,193	5,308	912	237	29,936	
	1980	295	1,500	5,418	8,855	3,268	699	212	20,217	
	1981	356	1,646	5,112	8,670	3,570	569	131	20,054	
	1982	771	2,702	9,909	9,965	4,186	736	226	24,495	
Percentage of trout reported landed:										
14"	1973	3.7	10.4	34.4	43.5	7.7	0.3	0.0	3,497	
min.	1974	4.5	10.1	34.0	45.0	5.9	0.5	0.02	18,447	
size										
13"	1975	3.1	11.9	39.1	37.8	7.1	0.7	0.2	22,133	
max.	1976	3.0	12.5	37.3	37.1	8.4	1.3	0.3	27,252	
size	1977	2.2	10.1	33.6	39.3	12.1	2.0	0.8	29,980	
	1978	3.3	10.9	29.0	41.5	12.7	2.0	0.5	35,607	
	1979	2.6	8.2	23.5	44.1	17.7	3.0	0.8	29,936	
	1980	1.5	7.4	26.8	43.8	16.2	3.3	1.0	20,217	
	1981	1.8	8.2	25.5	43.2	17.8	2.8	0.7	20,054	
	1982	3.1	11.0	24.1	40.7	17.1	3.0	0.9	24,495	

Percentage of trout landed measuring over:							Mean length landed		Mean landed creelied	
		>12 in	>14 in	>16 in	>18 in	>20 in	in	mm	in	mm
14"	1973	85.8	51.4	7.9	0.3	0.0	13.8	350	--	--
min.	1974	85.5	51.4	6.5	0.5	0.02	13.8	350	--	--
size										
13"	1975	84.9	45.8	8.0	0.9	0.2	13.7	349	12.4	316
max.	1976	84.8	47.5	14.1	2.0	0.3	13.8	350	12.4	314
size	1977	87.8	54.2	14.9	2.8	0.8	14.2	360	12.6	319
	1978	85.8	56.8	15.3	2.6	0.5	14.2	360	12.4	314
	1979	89.2	65.6	21.6	3.8	0.8	14.6	370	12.4	316
	1980	91.9	64.3	20.5	4.4	1.0	14.6	371	12.6	320
	1981	90.0	64.5	21.3	3.5	0.7	14.6	370	12.5	316
	1982	85.8	61.7	21.0	3.9	0.9	14.4	366	12.2	311

satisfaction with numbers and sizes landed was 69% and 74%, respectively (Table 5). The average expertise in 1982 was measured at 1.76 on the lake.

CLEAR CREEK CUTTHROAT SPAWNING RUN

From its source (2585 m above MSL) in the Absaroka Mountains, Clear Creek flows westward approximately 20.3 km before entering Yellowstone Lake along the east shore (Figure 2). The stream was utilized for spawn-taking activities almost annually from 1913 to 1950. Since that time, a fish trap, located approximately 400 m above the stream mouth, has been used to monitor the dynamics of the cutthroat trout spawning run in Clear Creek.

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 on May 25, but extremely high stream runoff forced the removal of the entire weir on June 15. Continued high stream and lake levels prevented the reinstallation of the trap in 1982. During the 22 days of trap operation, trap gates were open from 0800 to 2000 hours daily. All ascending trout were passed upstream using dipnets.

A downstream trap was constructed below the weir on May 26 and was removed when trapping operations ceased on June 15. During periods of high water, downstream migrants were captured as they congregated above the weir. The downstream run was monitored from 0800 to 2400 hours daily throughout the trapping period.

Fish sampling was limited to the upstream run in 1982. Weekly samples of 100 spawners were collected 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 sample 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. Because of the potential attraction of bears to the area during weir operation, cleanliness procedures (Jones et al 1978) were strictly followed, and bear activities were monitored daily at the trap.

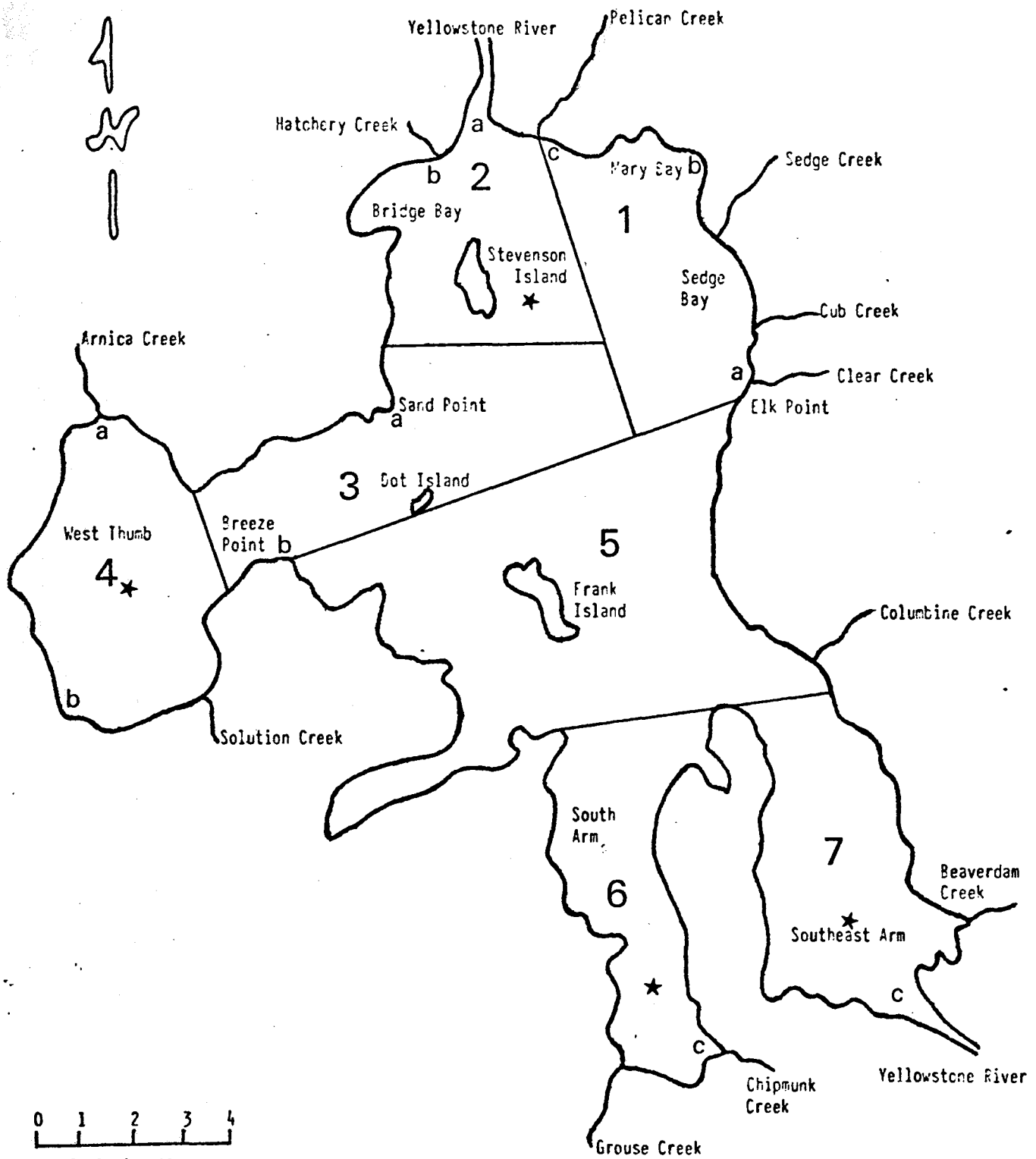


Figure 2 . Creel survey, gillnetting, plankton sampling (*) and spawning trap sites, Yellowstone Lake, 1982.

Results

Upstream Migration

The early removal of the Clear Creek weir prevented any realistic estimation of the upstream spawning migration in 1982. Only 4195 cutthroat trout were counted in the upstream run during the 22 days of trap operation. Daily counts varied from 1 (June 14) to 581 (May 30). A general trend of increasing numbers coincided with increasing water temperature was noted, although high water flow toward the end of the trapping period appeared to reduce numbers.

During the downstream migration in 1979, the adipose fin was removed from 42,229 cutthroat trout at Clear Creek (Jones et al 1980). In 1982, 1541 trout were inspected for clips, and only 9 marks were recorded. These figures suggest that 0.58% of the cutthroat trout entering Clear Creek were clipped; however, the small sample size and limitation of samples to the earliest portion of the run may have underestimated clipped trout in 1982.

Mean daily temperature varied from 1.7 C (May 28) to 6.4 C (June 12) and generally increased throughout the sample period. Flow decreased from May 26 through June 11, but then rose rapidly forcing weir removal. Increases in the number of upstream migrants coincided with increasing temperature and decreasing flow.

Mean total length and weight of upstream cutthroat trout were 409 mm (n=1541) and 664 g (n=300), respectively, and the average condition factor (K) was 0.93. The male:female ratio was 0.63:1. Average total length and weight for males (421 mm and 721 g, respectively) were significantly greater than females (401 mm and 622 g, respectively). The weekly average of length, weight and K decreased significantly as the spawning migration progressed (Table 9).

Average total length of 1532 unclipped cutthroat trout was not significantly greater than the length of 9 clipped trout (409 mm and 402 mm, respectively). Lack of statistical difference is probably due to severe imbalance in sample size. During 1981, length of unclipped trout was significantly greater than clipped trout, but weekly comparisons indicated that these differences were limited to the first two weeks of the run (Jones et al 1982).

Neither immature trout or spawning suckers were noted in Clear Creek during the current study. Since sightings of these fishes has been common in the past, it is assumed the lack of reports in 1982 was linked to the abbreviated sampling period.

Table 9 . Weekly mean length, weight and condition factor of cutthroat trout spawners in the upstream trap in Clear Creek,
May 26-June 1, 1982¹⁾

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 26 - June 1	64	436	779	0.92	36	413	715	0.99	100	420	756	0.95	1.78:1
June 2 - June 8	40	424	689	0.89	60	402	610	0.93	100	411	642	0.92	0.67:1
June 9 - June 15	22	410	609	0.87	78	399	589	0.92	100	399	593	0.91	0.28:1
Composite	126	427	720	0.90	174	403	622	0.94	300	409	664	0.92	0.72:1

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

Downstream Migration

The premature cessation of trap operation prevented enumeration of the total downstream run in 1982, and only 585 cutthroat trout were counted downstream prior to weir removal. Over 90% of the trout were captured as flows increased during the last five days of the sample period. This is quite typical of downstream migrants during high water periods in the early portion of the run.

Since very few downstream fish had begun to move, weekly samples of length and weight for downstream migrants had not begun by the time the weir was removed; however, length frequency was obtained for 292 trout. Average total length for downstream migrants was 406 mm, and the male:female ratio was 0.35:1. Males had a significantly greater mean total length (416 mm) than females (402 mm). Mean total length for unclipped trout did not differ significantly from clipped trout (406 mm and 396 mm, respectively); however, great differences in sample size ($n=289$ and $n=3$, respectively) probably influenced this comparison.

Mean length of downstream migrants (406 mm) was significantly less than upstream trout (409 mm). This result is opposite of what has been reported at Clear Creek in past years (Jones et al 1982) and is probably associated with the reduced sampling in 1982.

Although some bear tracks were observed along the main trail during the first several days of trap operation, evidence of bear activity was not noted in the vicinity of the weir in 1982. One unidentified bear was reported on the north side of Clear Creek several days after the weir was removed. Other wildlife which are commonly associated with the spawning run at Clear Creek include family groups of mink, common loons, common mergansers, California gulls, as well as several osprey, golden and bald eagles, great blue heron and white pelicans.

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 stable. Larger trout enter the stream first; mean length, weight and K factor gradually decrease during the season. Most males are 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. 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. comm. 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 postspawners move downstream during periods of heavy runoff. As stream discharge decreases later in the spawning run, the majority of downstream migration occurred between 1300 and 2000 hours.

Since all spawners leave Clear Creek after spawning, and there are no residents other than a small number of yearling and age II+ cutthroat, the difference between accurate upstream and downstream counts provide an unbiased estimate of instream spawning mortality. Incomplete counts of downstream migrants since 1980 have prevented continued estimates 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.

Ball and Cope (1961) estimated that only 1.22% of spawning trout were repeat spawners. Their estimates were based on the return of Petersen disc tags and logically supported by their instream mortality estimate (48.1%) for cutthroat spawners. Although they found a tagging mortality of 4-12% in Arnica Creek in 1952 and 1953, they were unable to determine whether this mortality continued after spawning. This extremely low estimate of repeat spawning was probably biased by high tagging mortality and/or a higher than expected fishing mortality.

Assuming that few trout required five years to attain sexual maturity, Bulkley (1961) speculated that the proportion of age V+ and VI+ trout (38.4 and 3.8%, respectively) in the Arnica Creek spawning run did not agree with the 1.22% return estimate of Ball and Cope (1961). The 3.8% of age VI+ trout is alone almost three times the 1.22% return of spawners. When Bulkley

(1961) examined 58 trout of age V+ from the 1957 Arnica Creek spawning run for spawning checks (scars from resorption of scales during spawning which may later be distinguished from annuli), he found 25 trout (43%) had definitely spawned previously. Bulkley concluded that although some trout may spawn without scale deterioration (causing an underestimate of repeat spawners), the percentage of repeat spawners was much higher than previous tagging data suggested. Forty-three percent of the age V+ cutthroat trout would amount to 12.4% of the spawning run.

Clip returns from Clear Creek since 1980, indicate that under current harvest levels, at least 23% of the cutthroat spawners clipped in 1979 survived to spawn again. Sample size of recent experiments far exceeds that of Ball and Cope (1961) and adds credibility to present estimates. Current instream mortality estimates are also indicative of a higher rate of repeat spawning.

Results from clip returns at Clear Creek in the past two years strongly support the hypothesis of alternate-year spawning for the majority of repeat spawners (Ball and Cope 1961). Although sample size was small, Bulkley (1961) found that among 25 repeat spawners from Arnica Creek (identified by the spawning checks), five times as many cutthroat trout spawned in consecutive years as alternate. It is possible, however, that the percentage of alternate and consecutive spawners may vary significantly between different tributaries. If Ball and Cope (1961) were correct in their hypothesis that alternate-year spawning was a physiological manifestation of the low productivity of Yellowstone Lake, it is also possible that the number of consecutive and alternate-year spawners may vary slightly with changes in annual growth conditions.

The number of trout which were clipped at Clear Creek and later captured at Pelican Creek averaged approximately 1.15% for 1980-81. Ball (1955) found that approximately 2% of tagged fish which spawned repeatedly had strayed from the stream where they were originally captured. Since Clear Creek spawners may also stray into other streams tributary to Yellowstone Lake, especially those in the northern portion of the lake, current results suggest the estimate of 2% total straying may be reasonably accurate.

Comparison of 11 years of length frequency data collected since 1961 (Figure 3) 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.

Although the current structure of the cutthroat trout population may still be far removed from historic levels, spawning

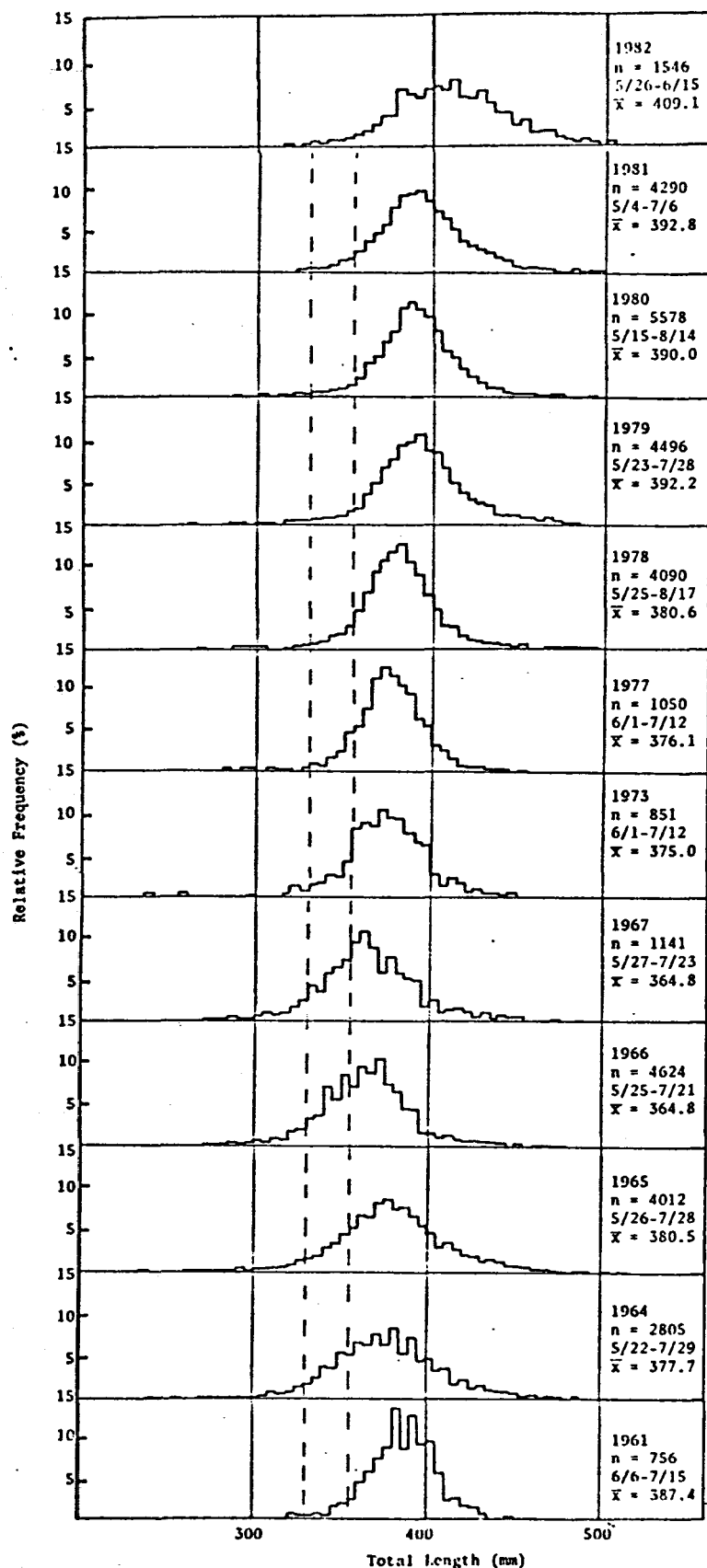


Figure 3. Length frequency of cutthroat trout in the upstream spawning migration in Clear Creek in recent years.

migrations at Clear Creek in recent years indicate the potential of a native cutthroat trout population under protective regulations (Figure 4). Recent data from Clear Creek emphasize the disastrous effects of low spawner escapement, due both to egg-taking operations and overharvest, during the 1940's, 50's and 60's. 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.

PELICAN CREEK SPAWNING RUN

Entering Yellowstone Lake along the north shore about 2.4 km east of Fishing Bridge (Figure 2), 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 spawn-taking 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 present 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). Since the discontinuation of the sucker removal program in 1980, emphasis of the trap operation has 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, age composition and effects of density independent factors, such as water temperature and stream flow.

Methods

The upstream trap was installed on May 4, but high water forced the early removal of the entire weir on June 13. Additionally, portions of the weir were removed from May 23 through June 2 to prevent major erosion. Continued high water levels prevented the reinstallation of the weir after June 13.

During periods of trap operation, the upstream gates were open from 0800 to 1900-2000 hours daily, and ascending fish were passed upstream using dipnets as they accumulated in the trap

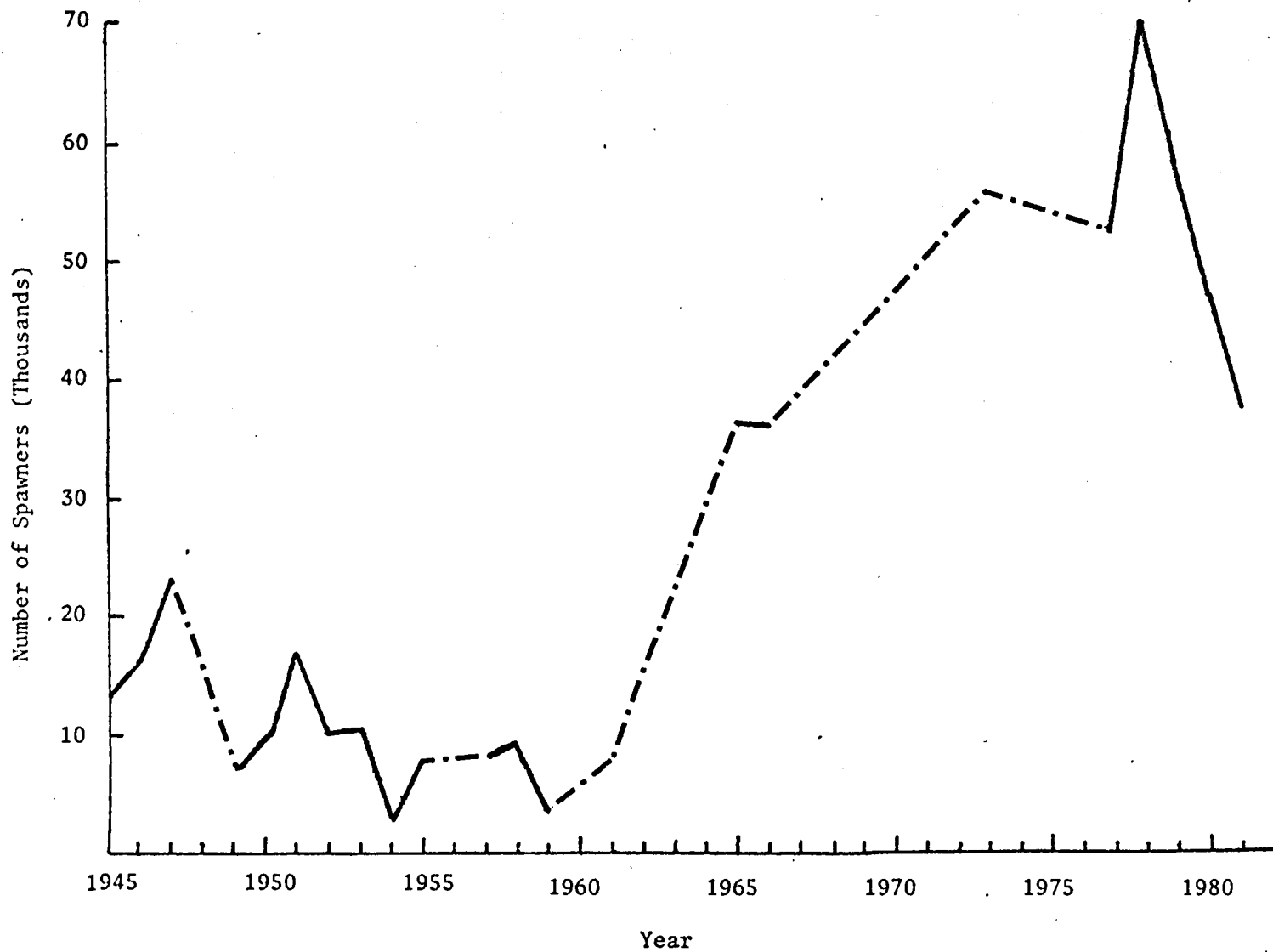


Figure 4 . Number of cutthroat trout spawners entering Clear Creek during various sample years, 1945-1982.

box. Because the downstream migration had not become substantial by June 12, a downstream trap was unnecessary during 1982. Downstream migrants were passed below the weir as they congregated upstream.

Fish sampling was limited to upstream migrants. Up to 100 cutthroat spawners were collected for length and weight measurements each week. Scales from a subsample of 20 trout were used for age determination, and additional scale samples were taken as needed to provide data for population extremes. Length frequency data (5 mm intervals) were collected from 75 trout daily. Since the weir was removed prior to significant upstream sucker movement, samples were not obtained for this species. Prior to May 23, only sampled trout were inspected for fin clips; however, beginning June 3, all trout captured were checked. Both length and weight data were collected from all previously tagged trout and suckers.

Daily water temperature extremes were obtained from frequent observations with a hand thermometer. No attempt was made to measure water level in 1982. Bear activities were monitored daily, and cleanliness procedures were strictly followed (Jones et al 1978).

Results

Cutthroat Trout

Upstream migration. A total estimate of the upstream migration was not possible for Pelican Creek in 1982. When the weir was removed on June 13, 5782 cutthroat trout had been counted upstream. Very few trout moved during May, and by the first period of high water (May 23-June 2) only 155 trout had been passed upstream. Numbers increased steadily in June and 84% (4835) of the total were captured during the final five days of the operation.

Water temperature generally increased during the sample period and daily means varied from 2.2 C (May 6-9) to 9.2 C (June 10). A large peak of water flow occurred between May 23 and June 3, and the number of upstream migrants began to increase as water level dropped. Numbers steadily increased until a sudden rise in flow caused the cessation of trapping activities on June 13.

Mean total length and weight of upstream cutthroat trout were 385 mm (n=1697) and 529 g (n=258), respectively, and the average condition factor (K) was 0.88. The male:female ratio was 0.64:1. Average total length and weight of males (395 mm and 569 g, respectively) were significantly greater than females (378 mm and 496 g, respectively). The weekly average of length, weight and K factor decreased as the spawning migration progressed (Table 10).

Table 10. Weekly mean length, weight and condition factor of cutthroat trout spawners in the upstream trap in Pelican Creek, May 6 - June 15, 1982

Date	Number	Males			Number	Females			Number	Totals			M:F ratio
		Average length (mm)	Average weight (g)	Average K factor		Average length (mm)	Average weight (g)	Average K factor		Average length (mm)	Average weight (g)	Average K factor	
May 6 - May 11	6	400	569	0.88	4	414	664	0.92	10	406	607	0.89	1.50:1
May 12 - May 18	40	406	596	0.87	60	388	529	0.90	100	396	556	0.88	0.67:1
May 19 - May 25	24	402	566	0.87	24	383	491	0.87	48	393	529	0.87	1.00:1
June 9 - June 15	45	401	547	0.84	55	370	452	0.89	100	384	494	0.87	0.82:1
Composite	115	403	569	0.86	143	381	496	0.89	258	391	529	0.88	0.80:1

1) Based on daily samples of cutthroat trout which were both measured and weighed; from May 19 to June 8, no upstream trout were observed in the trap.

Table 11. Fecundity estimates for various time periods, Clear Creek, 1945-1981

Years	Number of Spawners	Sex Ratio (Males:Females)	Number of Female Spawners (1x2)	Mean Length Females	Estimated Absolute Fecundity (Number of eggs)	Population Fecundity (Millions of eggs)
1945-1961	12,592 ¹⁾	0.73:1 ²⁾	7,256	--	1,018 ³⁾	7.4
	12,592	0.73:1 ²⁾	7,256	379 ⁴⁾	1,198 ⁵⁾	8.7
1965-1966	36,164 ⁶⁾	1.73:1 ²⁾	20,904	372 ⁴⁾	1,133 ⁵⁾	23.7
1973	55,818	0.73:1	88,266	372	1,133	36.6
1977	56,641	0.61:1	32,696	374	1,153	37.9
1978	70,105	0.69:1	41,482	378	1,198	49.7
1979	58,244	0.52:1	38,318	383	1,337	51.2
1980	47,115	0.52:1	30,997	388	1,337	41.4
1981	37,439	0.53:1	24,470	390	1,381	33.8
1977-1981 ⁶⁾	53,108	--	33,592	383	--	42.8

1) Estimated from data (1945-1961) presented by Benson and Bulkley (1953).

2) Estimated from data (1945-1953) presented by Ball and Cope 1961.

3) Cope (1957).

4) Mean length of males and females combined and therefore considered a maximum.

5) Estimated from fecundity-length equation using mean length of males and females and therefore considered a maximum.

6) Values based on arithmetic means.

In 1980, all upstream cutthroat migrants (22,293) were marked by the removal of both the adipose and left pelvic fins (Jones et al 1981). A total of 336 (5.9%) of the 5705 trout inspected for clips in 1982 displayed these marks. Only two of 296 trout tagged in 1979 were recaptured during 1982.

Mean length of 94 clipped trout (390 mm) was approximately 10 mm greater than the sample of 3759 trout clipped in 1980, and represents a 7 mm increase from 1981 (n=351). In 1982, mean length of clipped trout was significantly greater than unclipped trout (390 mm and 384 mm, respectively).

In 1980, 38 tagged trout displayed a mean increase of 11 mm in total length since time of tagging (375 mm and 386 mm, for 1979 and 1980, respectively). Although males were larger than females, both sexes displayed a similar difference in length (380 mm and 392 mm, respectively, for males and 371 mm and 381 mm, respectively for females).

Mean length for seven tagged trout recaptured in 1981 increased from 378 mm at time of tagging (1979) to 404 mm two years later. Three males displayed a much greater difference (388 mm and 420 mm for 1979 and 1981, respectively) than did females (371 mm and 392 mm, respectively). One male which had been recaptured in both years increased in length from 398 mm (1979) to 403 mm in 1980, and to 412 mm in 1981.

Two tagged trout sampled in 1981 displayed a mean increase of 48 mm since 1979 (408 mm and 360 mm, respectively). The increase in length between time of tagging and recapture was greater for the male (355 and 426 mm, respectively) than the female (366 mm and 389 mm, respectively). Total length of the male was also measured in 1980 (377 mm), one year after tagging.

Downstream migration. Only 70 cutthroat trout had moved downstream when the weir was removed on June 13. Numbers were extremely low prior to the first water peak but had begun increasing slightly after June 5. None of the downstream trout were sampled for length and weight in 1982.

Although bear tracks were noted in the vicinity of the weir later in June, neither bears nor their tracks were reported during trap operation. Other wildlife forms were numerous. 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 Pelican Creek flood plain, 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 Sucker

The weir was removed before the spawning migration of the longnose sucker had begun, and only 60 suckers were counted upstream in 1982. Length and weight measurements were not obtained for any of these early upstream migrants.

A total of 12 longnose suckers were passed downstream, and an additional 46 moribund suckers were removed from the weir. Most of these individuals were immature with an estimated mean length of approximately 200 mm. None of the suckers moving in either direction had been previously tagged or clipped.

Discussion

Although above average snowpack and cool spring temperatures greatly retarded the cutthroat trout spawning migration in 1982, upstream movement again began much earlier than at Clear Creek. 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 their continued upstream migration.

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.

The early removal of the Pelican Creek weir greatly influenced the data collected in 1982, and results must be scrutinized carefully to avoid erroneous conclusions. Besides the obvious influence on the estimate of total numbers, estimates of size, percentage return of repeat spawners, and estimates of growth for repeat spawners may all be affected.

Since length and weight generally decreased throughout the run, the mean values calculated in the current study are probably somewhat higher than the true mean for the 1982 cutthroat spawning migration in Pelican Creek. Although these data suggest that mean length was essentially unchanged from 1981, it is quite probable the mean decreased by several millimeters. Such a change would probably be caused by the influence of year class strength since angler harvest has been quite steady during the past eight years. Comparison of seven years of length frequency data since 1960 (Figure 5) 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.

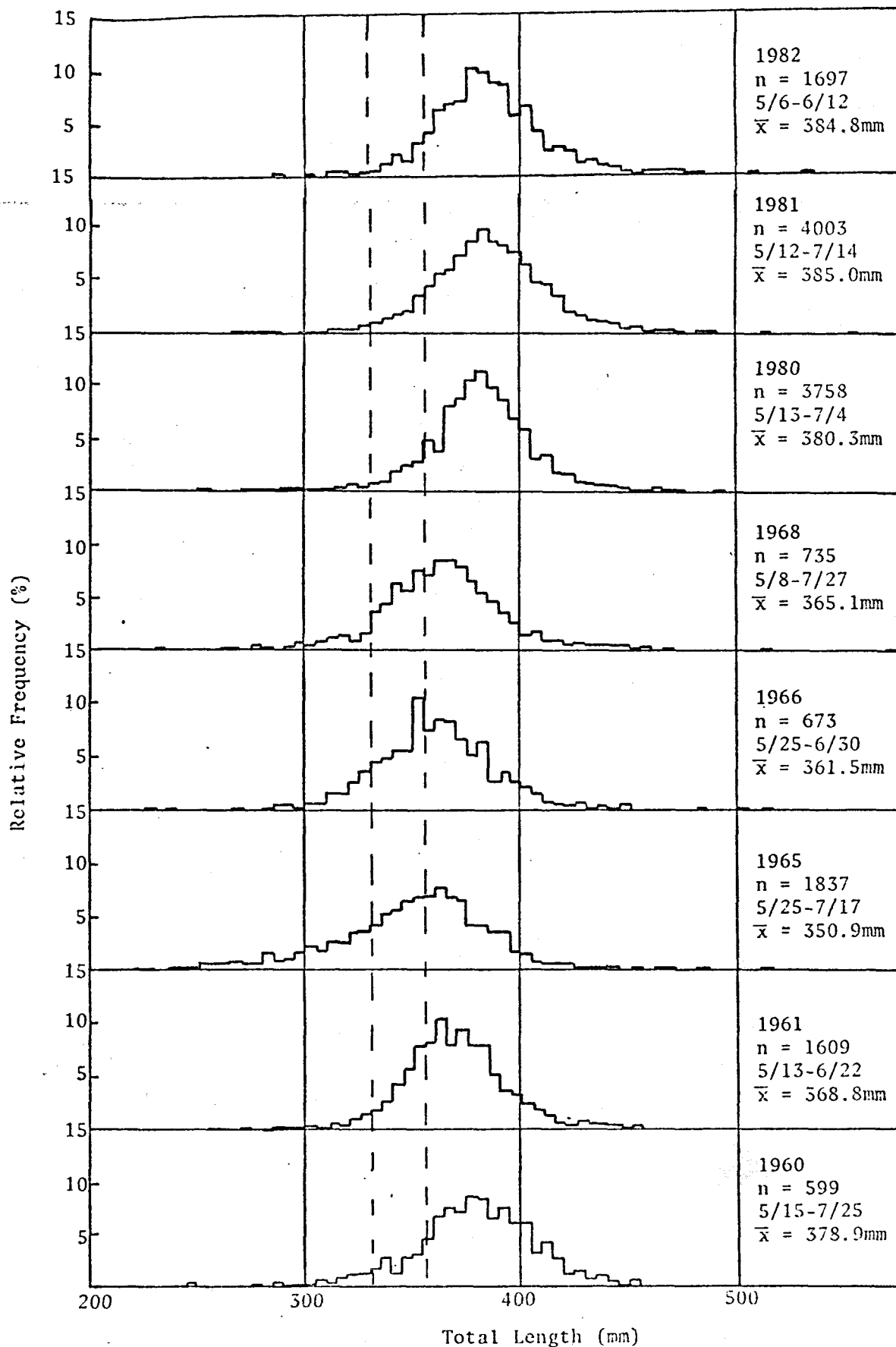


Figure 5. Length frequency of cutthroat trout in the upstream spawning migration in Pelican Creek in recent years.

Data from previous studies indicate that the percentage of clipped and tagged trout (repeat spawners) may have been much greater than the abbreviated sample indicated. Despite an 11.7% consecutive-year return of clipped trout in 1981, only 2.3% of the first 5444 upstream migrating trout had been clipped. Similar results were noted at Clear Creek in 1981. Although a 23.3% alternate-year return of clipped trout was reported (Jones et al 1982), only 8.9% of the 4737 trout ascending prior to peak runoff were clipped.

Growth comparisons of clipped are also confounded by the decrease in mean length observed throughout spawning season. Prior studies at Pelican Creek indicated an increase of 3 mm in the mean length of repeat spawners between 1980 and 1981. Although these data may be influenced by size-selective mortality and/or the inability to identify individual fish, the results are based on trout collected throughout the entire spawning season. Mean length of the 1982 sample is probably higher than the true mean for clipped trout ascending Pelican Creek and therefore, the estimate of an increase of 7 mm in mean length of clipped trout may be exaggerated.

Tag return data is more meaningful for growth comparisons because individual identity is retained. The consecutive-year sample (1979-1980) displayed an average of 11 mm average growth and the smaller alternate-year sample (1979-1981) indicated a 25 mm increase or 12.5 mm annually. Males in this sample revealed a greater increase than females. The one individual captured in both 1980 and 1981 displayed a 5 mm increase the first year and a 9 mm increase the second. Although only two tagged trout were captured in 1982, the male again displayed faster growth. A mean increase of 48 mm since tagging (16 mm annually) was noted for these trout. This value is heavily influenced by the male, however, and this individual increased 22 mm from 1979 to 1980 and 49 mm from 1980 to 1982. It is currently difficult to form conclusions from these small samples, but the current results give some preliminary estimates for adult spawners and emphasize the need to expand this program in the future.

FECUNDITY ESTIMATES

Evaluation of the 330 mm maximum size limit on Yellowstone Lake has suggested several important changes in population structure of the cutthroat trout. The proportion of older and larger trout has increased in the angler catch, gillnet samples of prespawners, and the Clear Creek and Pelican Creek spawning runs. Additionally, the number of spawners entering these two important spawning streams has increased since the cessation of spawn taking activities (1953). During 1982, a pilot study was initiated to determine the effects of these shifts in population structure on the population fecundity or the potential number of eggs which can be laid by all females in one season (Bagenal 1978).

Methods

On July 14, a total of 25 female cutthroat trout were collected by electrofishing in a 200 m section above the Clear Creek weir. Trout were divided into 10 mm length intervals, and five trout were sought for each size category.

Total length and weight measurements were obtained from each trout prior to ovary removal. Weight and volumetric displacement of the intact ovary were also recorded. The total number of eggs was estimated by counting the number of eggs in a 10 ml subsample and expanding this number for the total volume.

Length and fecundity estimates were transformed to logarithms (Bagenal 1978) and fitted to a functional (GM) regression (Ricker 1973, 1975). The number of eggs calculated by this regression for females of various lengths was used to compare population fecundity through time.

Results

Mean length of trout from the Clear Creek sample was 373 mm and mean weight was 442 g. Fecundity was highly variable with a mean of 1164 eggs per female. The average weight for the ovaries was 79.8 grams and the gonadal-somatic index (GSI) (LeCren) was 18.10. The length-fecundity equation was:
 $\text{Log } F = 2.0573 (\text{Log } L) - 7.7174 (R^2 = 0.24).$

The mean number of eggs estimated by the length-fecundity equation for females in the Clear Creek spawning run was 1568 eggs/female. Since mean length of trout normally decreases during the duration of the run, average size was probably overestimated due to the early cessation of sampling at Clear Creek in 1982. An estimate based on mean length of female trout from Clear Creek in 1981 (1381 eggs/female) may be more indicative of current fecundity levels.

Discussion

Although a large amount of data on the cutthroat trout have been collected from Yellowstone Lake, few studies have evaluated fecundity. Cope (1957a) utilized data obtained during spawn taking operations to estimate mean absolute fecundity at Clear Creek. His estimate of 1018 eggs/female represented a mean covering 12 years (1941-1952). It appears that absolute fecundity has increased by almost 36% since the early 1950's.

Unfortunately, length data were not available for evaluation with egg estimates developed by Cope (1957a). By combining spawner counts from Clear Creek for 1953-1955 (Benson and Bulkley 1963) and mean length of spawners for the same years (Bulkley 1961), a weighted mean of 368 mm was estimated for this period. This length represents all spawners, and because males are larger than females, the mean for females was probably

lower. Therefore, a mean of 362 mm for female spawners for the 1941-1952 period estimated by the current length-fecundity equation appears to be realistic. Although there is definitely room for error in this estimate, the current (1977-1981) mean length of 383 mm for female spawners in Clear Creek suggests that the rise in absolute fecundity is directly related to increases in mean length.

This conclusion may appear intuitive and is supported by many other studies (Bagenal 1978, Nikolskii 1969); however, a decrease in the average size of eggs could also increase the absolute fecundity if the total weight of the ovary remained unchanged. Since within any species, larger eggs generally have greater survival (Nikolskii 1969), a decrease in average egg size could affect the population significantly. Comparison with hatchery data presented by Cope (1957a) does suggest there has been a decline in egg size and total ovary weight, but this data was refuted in the same paper. Utilizing a separate data source Cope (1957a) developed regressions with number of eggs and ovary weight for Pelican Creek, Chipmunk Creek, and Grouse Creek. Despite differences between streams, all three equations predicated values very close to those observed in the current study and indicate there has been little change in egg size in the past 30 years.

Bagenal (1978) and Nikolskii (1969) report that fecundity generally increases in repeat spawners, but Ball and Cope (1961) estimated that only 1.22% of spawning trout from Yellowstone Lake tributaries returned to spawn again. Although there may be several reasons for discrepancies (See Clear Creek this report), recent studies with fin clipped trout at Clear Creek indicate a 5.8% first year return and a 23% second year return of 1979 spawners. If there has been an actual increase in repeat spawners due to current angling regulations, the increase in repeat spawners could definitely contribute to increase absolute fecundity.

Historic data for comparisons of population fecundity of Clear Creek spawners is limited. By combining data from various studies, however, estimates of population fecundity were developed for three different periods (Table 11). Although the historic estimates may not be precise, differences between periods are large enough to yield valid comparisons. Current population fecundity at Clear Creek, 42.8 million eggs annually, appears to be almost twice the calculated value for the mid-1960's (23.6 million eggs) and between five and six times that estimated for the period between 1945-1961 (7.4-8.7 million eggs).

It is apparent that in addition to important changes in the population structure observed since the implementation of the 330 mm maximum size limit, there has also been a significant increase in the number of eggs annually produced. Although these estimates are closely linked to changes in spawner numbers and average size (Table 11), they help to elucidate the

importance of these structural shifts. These estimates underscore the ability of the current angling regulations to provide a high degree of protection to this fragile system, while allowing an annual harvest approaching 100,000 trout.

SUMMER GILLNETTING

A fall largemouth gillnetting program was initiated in 1969, to monitor relative abundance and population structure of the cutthroat trout and longnose sucker in Yellowstone Lake. In addition, gonad weights of cutthroat trout were recorded during the 1979-1981 operations to provide insight into the annual cycle of sexual maturation. Results from these studies suggested the need to expand the gillnetting program to investigate seasonal distribution and gain additional knowledge concerning the maturation cycle.

In 1981, largemouth gillnets were set throughout the summer in order to obtain data necessary to supplement the fall surveys (Jones et al 1982). Information collected from this study was also used to test comparability between new experimental gillnets (purchased in 1981) and older Swedish gillnets which had been used since fall operations began. Because catch per net and mean length of trout captured differed significantly between net types, it was determined that continued use of the new nets would jeopardize comparability with past information, and all future operations would use the Swedish type of experimental gillnets.

It was necessary, therefore, to repeat the summer program initiated in 1981, using only Swedish nets. The specific objectives of the program in 1982 were to investigate changes in distribution and sexual maturation throughout the summer and to compare these results with the fall gillnetting program.

Methods

From June 1 to August 24, a total of 35 gillnets were set overnight (5 nets per night) near the old boathouse at Lake Village (site 2B)(Figure 2). Sampling dates were June 1, June 15, June 29, July 13, July 27, August 10 and August 24. All sets were made with Swedish experimental gillnets at the 1.5-4.6 m depth interval. Measurement of length and weight, scale collection, and determination of sex and stage of maturity followed established procedures (Dean et al 1975 and Jones et al 1978).

Gonad samples were limited to trout with total length over 300 mm. Trout were graded from largest to smallest, and the entire gonad was removed from every third individual. Since there were only six trout over 300 mm on August 24, gonads from all of these fish were removed. Excised gonads were weighed (to the nearest 0.5 g) on a balanced beam scale, and the gonad:body weight ratio (Le Cren 1951) or gonadal-somatic index (GSI) was calculated for each trout.

Results

A total of 307 cutthroat trout (14.8 per net) were captured during the summer gillnetting (Table 12). Only two clipped trout were identified, both of which were originally marked at Pelican Creek. Number of cutthroat trout captured per net varied significantly, ranging from 23.4 per net on July 27 to 7.2 per net on August 24. Numbers dropped slightly after June 1, and then rose to a peak in late July (Figure 6). Trout catch decreased precipitously after July 27, although a substantial increase was noted by fall gillnetting (September 14).

The number of longnose suckers varied from one sucker per net (June 15) to 25.8 suckers per net (August 10) with a season total of 370 (Table 13). The trend of suckers captured followed a pattern similar to the cutthroat trout, although the sucker peak followed the rapid decline in trout (Figure 6). Two tagged and three clipped suckers originally marked at Pelican Creek were reported during this study, and all of the marked suckers were obtained on August 24.

Mean length of cutthroat trout did not vary significantly until July 13, when size began to decrease rapidly (Figure 7). Mean length continued to drop throughout the summer; however, substantial increases occurred during the fall survey. Samples from the first three periods are dominated by trout over 300 mm (Figures 8 and 9), suggesting that most of these trout were part of the cutthroat spawning migration. As the season continued, mean length was affected by a shift in length frequency to trout less than 300 mm.

The percentage of trout in various maturity categories reveals a substantial decrease in spawning males and females with concomitant increase in immature trout through time (Figure 10). Decreases in the percentage of postspawning trout during latter samples is probably associated with the decreased ability to detect previous spawning as gonads mature throughout the season.

Despite great variation in sample means, there were no significant differences in the mean length of longnose suckers. Lengths increased to a maximum of 427 mm on June 15, but then declined for several periods before increasing to a second peak on July 27 (Figure 6). After this date, mean length continued to decline through the fall samples. Although there was a general decline in suckers over 304 mm and an increase in suckers under 210 mm throughout the season, mean length appeared to be most affected by percentage of larger suckers (over 406 mm) (Figure 11).

Gonadal-somatic indices (GSI) were calculated for 135 cutthroat trout including 12 from the fall largemouth gillnetting. Ripe trout, prespawners, and postspawners were grouped by sex, but trout which lacked gonadal development and had apparently never spawned were considered immature. GSI values for females were

Table 12 Mean total length of cutthroat trout captured in largemouth gillnets, site 2B, Yellowstone Lake, June - August, 1982

Week	Mean Length	Number	Mean Weight	Mean Condition Factor (K)	Number
6/1	358.3	73	473.3	0.99	73
6/15	349.1	62	415.6	0.93	62
6/29	360.6	69	456.5	0.95	69
7/13	311.3	91	325.4	0.97	91
7/27	285.7	117	252.3	0.90	117
8/10	246.9	69	159.7	0.85	69
8/24	252.9	36	163.2	0.91	36

Table 13 Mean total length of longnose suckers captured in largemouth gillnets, site 2B, Yellowstone Lake, June - August, 1982

Week	Mean Length	Number	Mean Weight	Mean Condition Factor (K)	Number
6/1	386.9	15	821.5	1.29	15
6/15	426.8	5	992.2	1.18	5
6/29	367.1	17	661.2	1.24	17
7/13	351.0	46	617.5	1.30	46
7/27	397.8	52	770.8	1.12	52
8/10	379.7	129	693.3	1.13	129
8/24	366.5	106	650.9	1.19	106

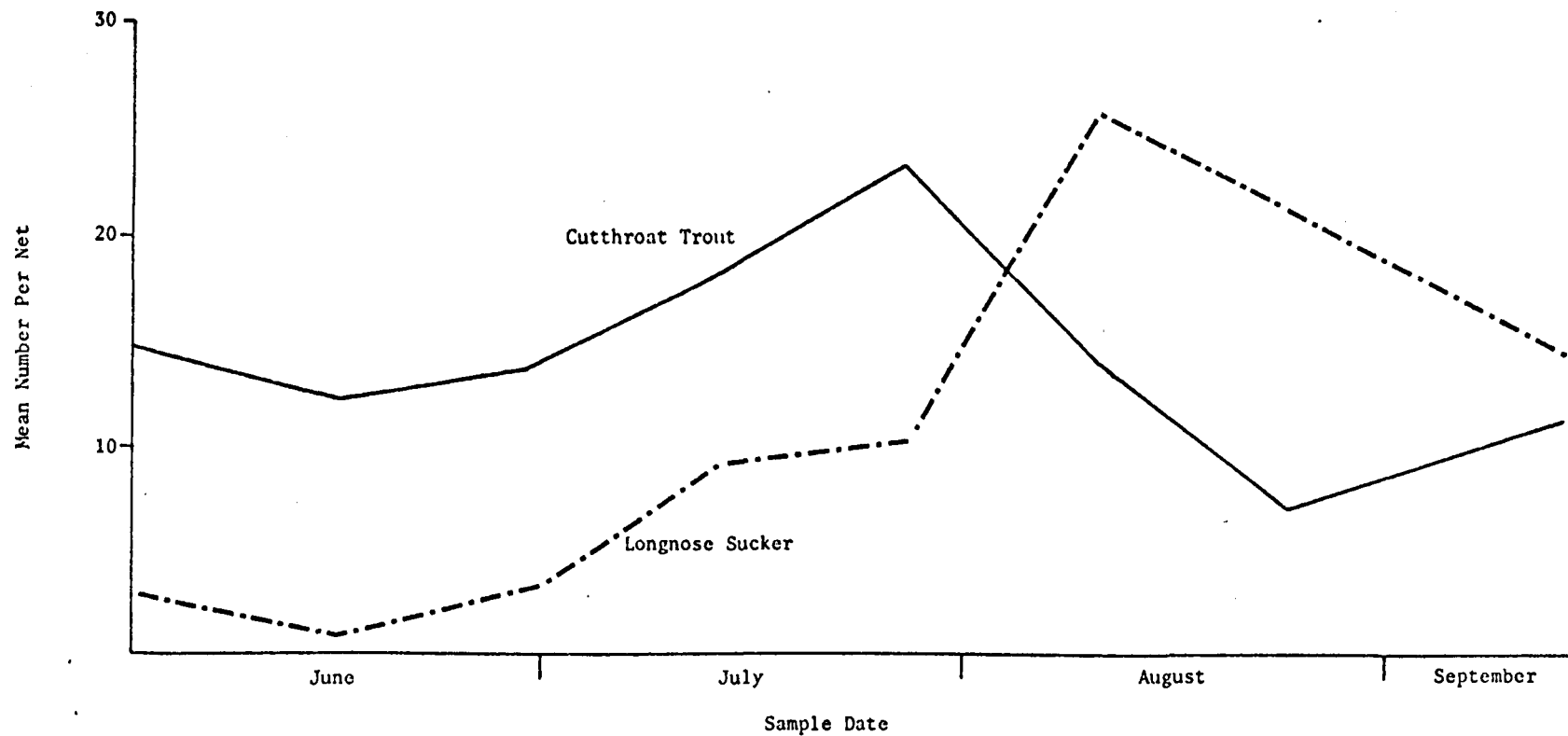


Figure 6 . Mean number of cutthroat trout and longnose suckers captured per net, site 2B, Yellowstone Lake, (Summer sets: June 1 - August 24; Fall set: September 14), 1982.

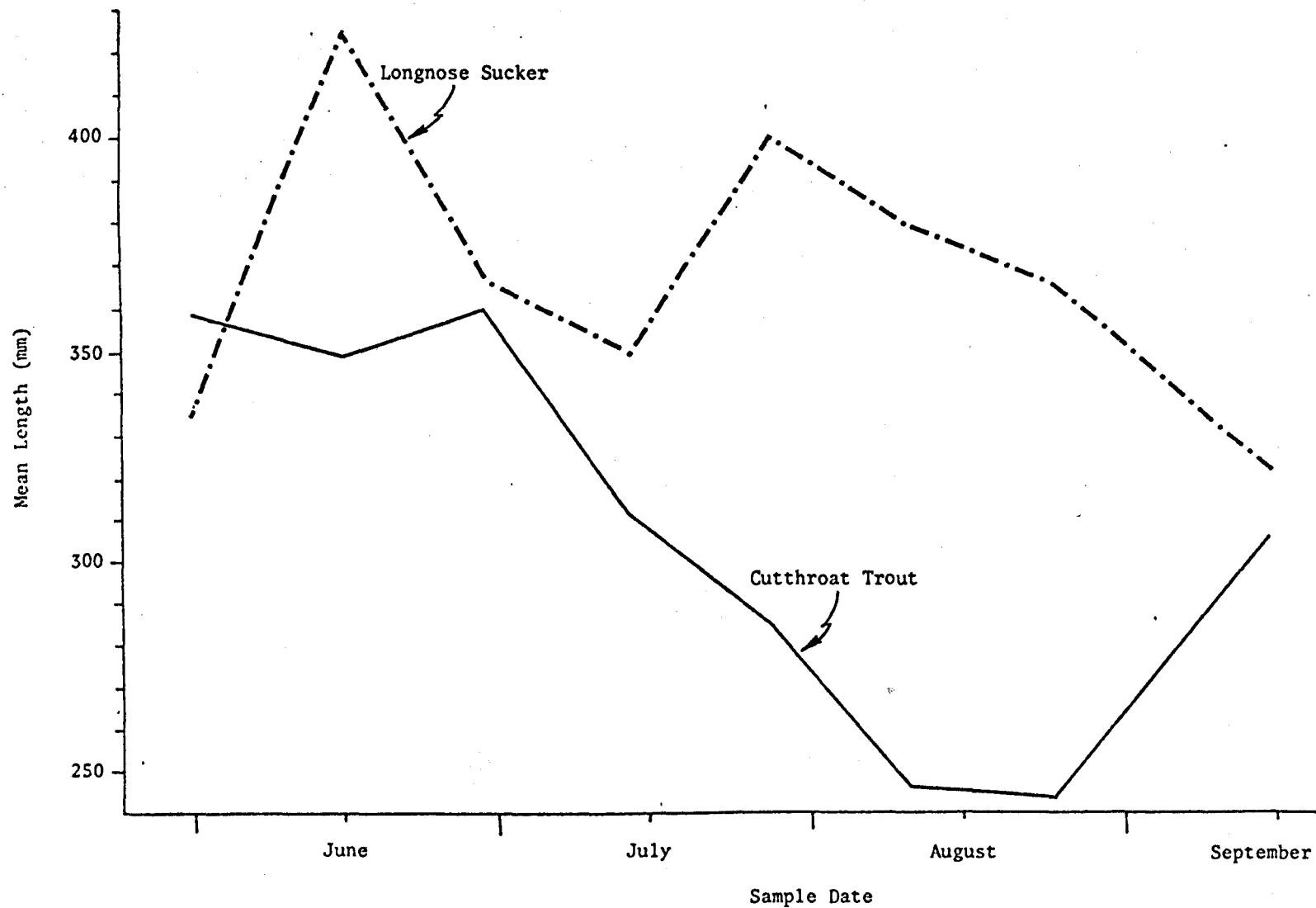


Figure 7 . Mean length of cutthroat trout and longnose suckers captured in gillnets, site 2B, Yellowstone Lake, (Summer sets June 1-August 24, Fall set September 14), 1982.

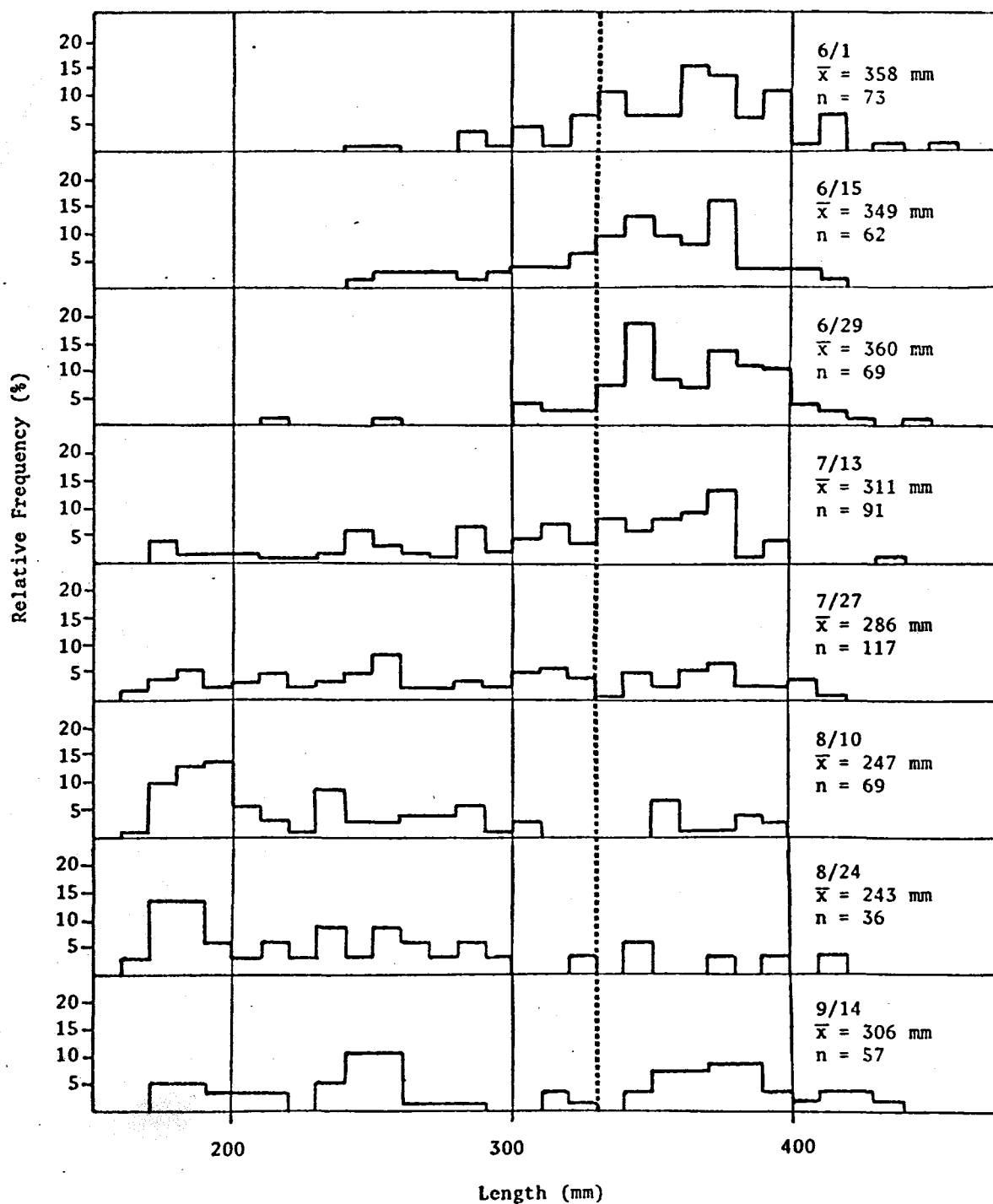


Figure 8 . Length frequency analysis of cutthroat trout captured in largemesh gillnets, site 2B, Yellowstone Lake, (Summer sets June 1-August 24, Fall set September 14), 1982.

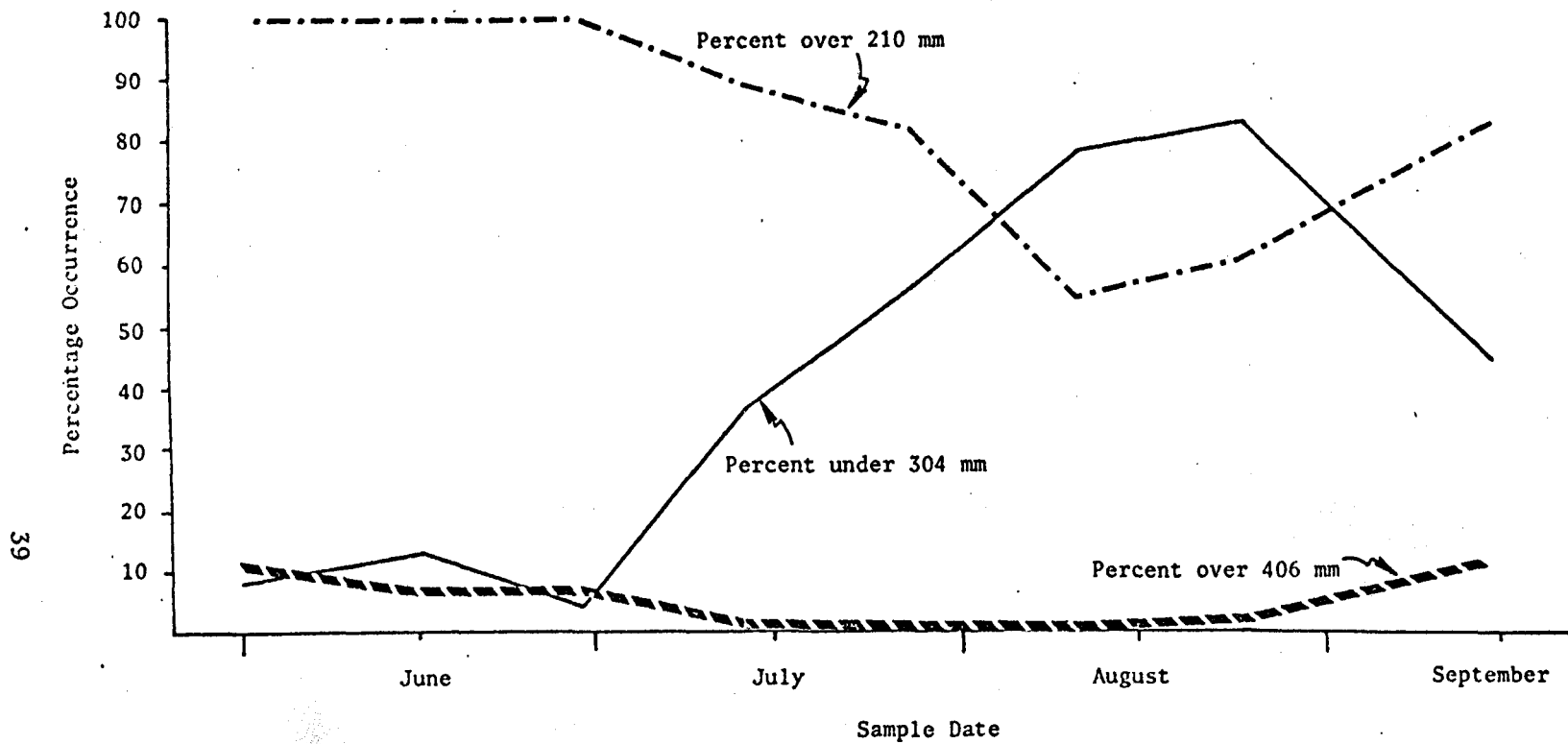


Figure 9 . Percentage of cutthroat trout over 210 and 406 mm, and under 304 mm total length, captured in largemouth gillnets, site 2B, Yellowstone Lake, (Summer sets June 1-August 24, Fall set September 14), 1982.

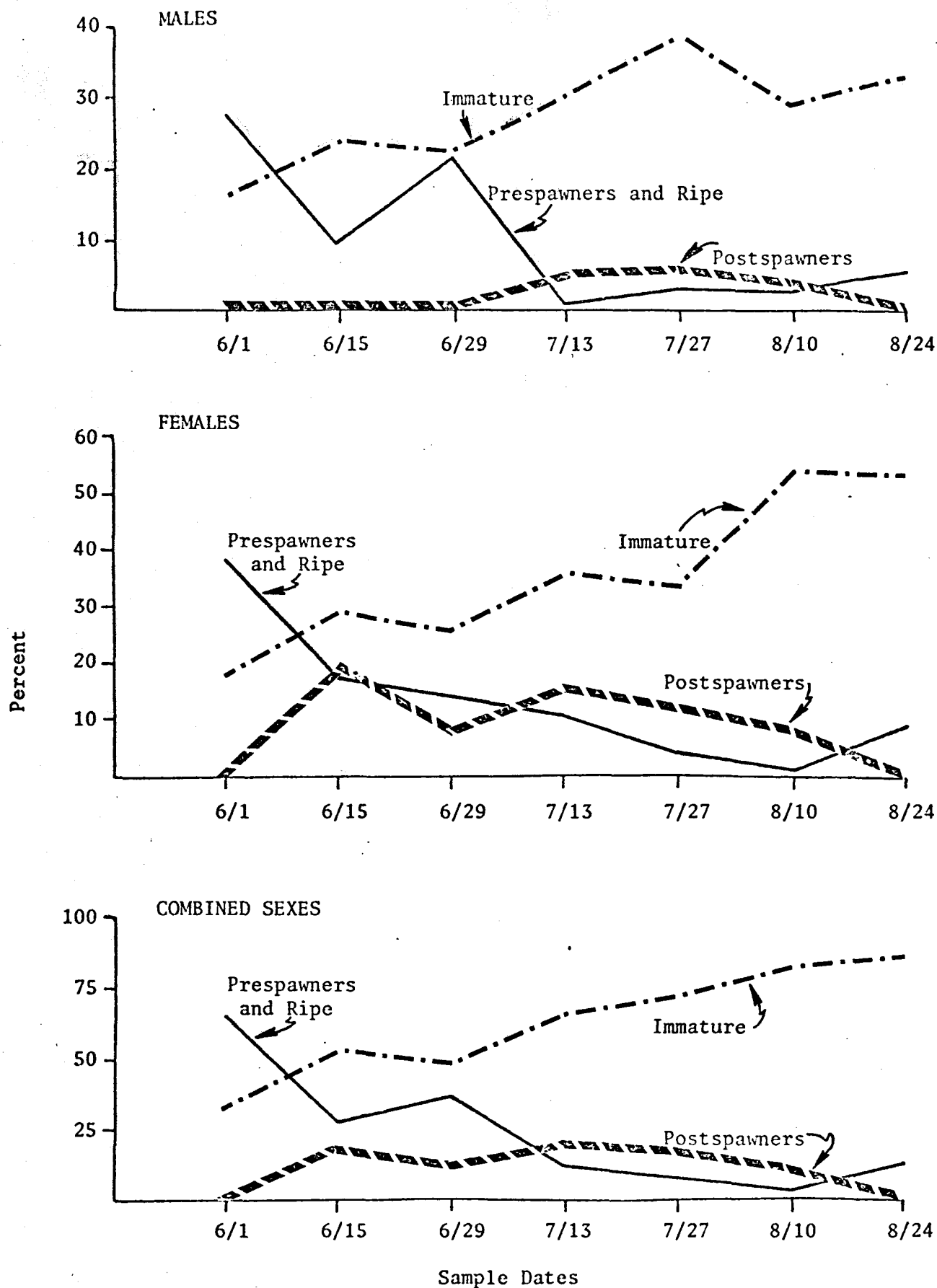


Figure 10. Percentage of trout in various maturity categories, captured in largemouth gillnets, site 2B, Yellowstone Lake, June-August, 1982.

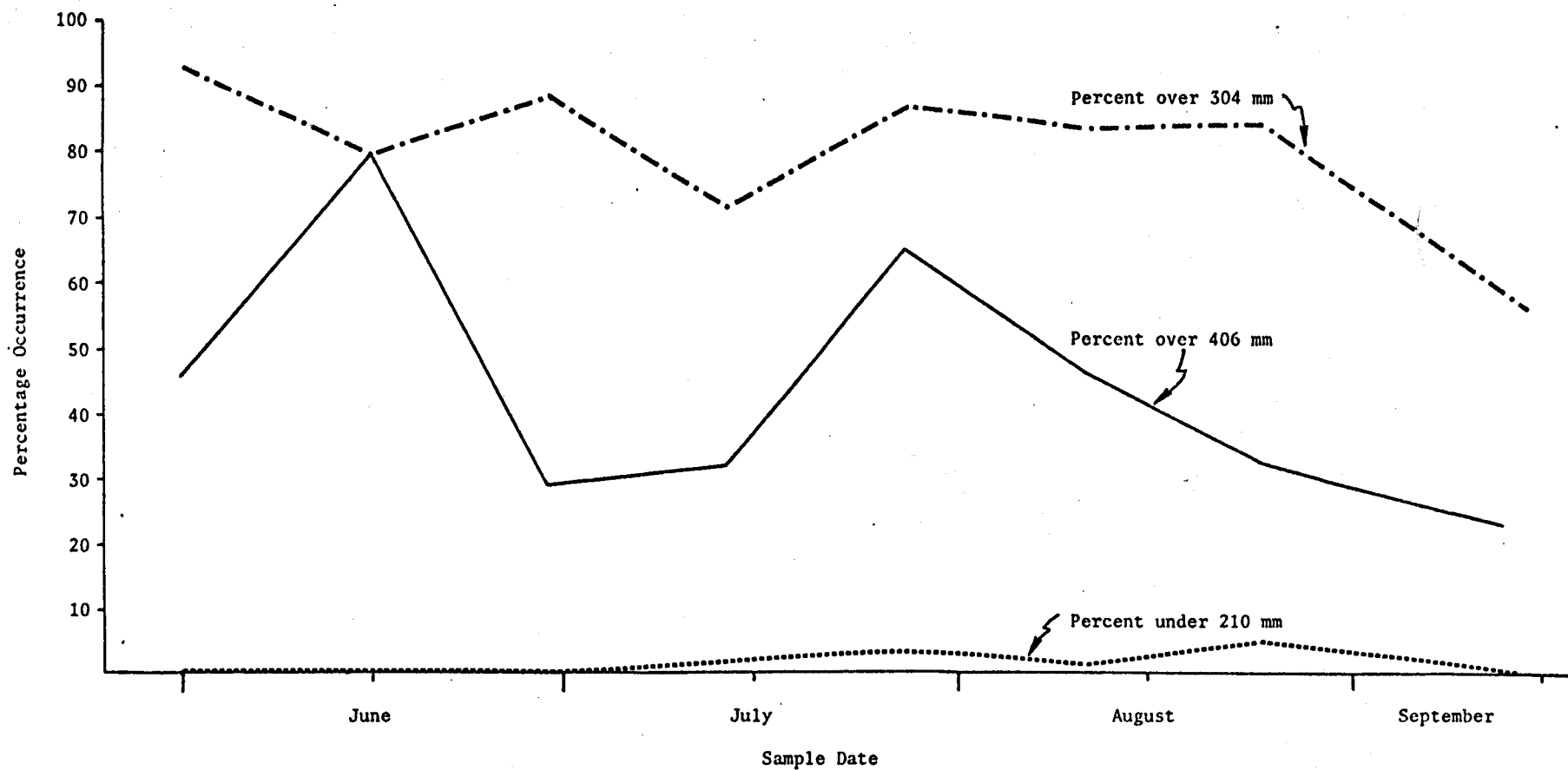


Figure 11. Percentage of longnose suckers under 210 mm and over 304 and 406 mm total length, captured in largemesh gillnets, site 2B, Yellowstone Lake, (Summer sets June 1-August 24, Fall set September 14), 1982.

high during the early periods but dropped drastically after the end of June (Figure 12). After reaching a low on July 27, values increased gradually throughout the remainder of the study. Initial values for males were much smaller than females (below 2.0) and dropped to a low of 0.19 by July 13. A gradual increase in male GSI values after this date culminated in a rating higher than the females by the fall sample; however, females had a significantly higher GSI when samples were combined over time (5.73 and 1.83, for females and males, respectively). Despite a slight increase in mean values during July and August, immatures remained below 0.45.

Discussion

Although the total number of cutthroat trout captured during this study was greater than longnose suckers, trout were most common only during June and July. As trout numbers declined in August, suckers increased rapidly. By the fall gillnetting sample (September 14), it appeared that trout numbers were again increasing with associated decreases in suckers. Number per net was highly variable for both species but was within the range of numbers captured in fall surveys at site 2B since 1969.

Reasons for the apparent inverse relationship between trout and sucker numbers are unknown; however, this pattern has been frequently observed in largemouth gillnets in Yellowstone Lake. Physical changes in water temperature and depth, as well as biological changes in food supply and reproductive condition undoubtedly influence distribution of the two species.

Although gillnet selectivity might also influence the observed pattern, estimates of number per net combined for both species indicate that total catch increased until August 10 and then decreased slightly. If selectivity was an important factor, the combined total would be expected to be constant with variation only in species composition of the total. Changes in mean length throughout the study appear to occur independently for both species suggesting that size selectivity of the gillnets does not influence the observed differences in catch per species either.

Decreases in mean length of cutthroat trout indicate a shift distribution at site 2B during the sampling period. The rapid decline in the percentage of ripe adults and the increase in the proportion of immatures appears to explain the size decrease. Length frequency analysis supports this hypothesis. The presence of larger trout during June is probably associated with cutthroat spawning activities at that time. Although adults apparently move out of the area during July and August, larger trout apparently move back into the area in September.

Longnose sucker numbers increased until late August when numbers began to decrease, but changes in mean length are difficult to interpret. A definitive relationship between numbers and size

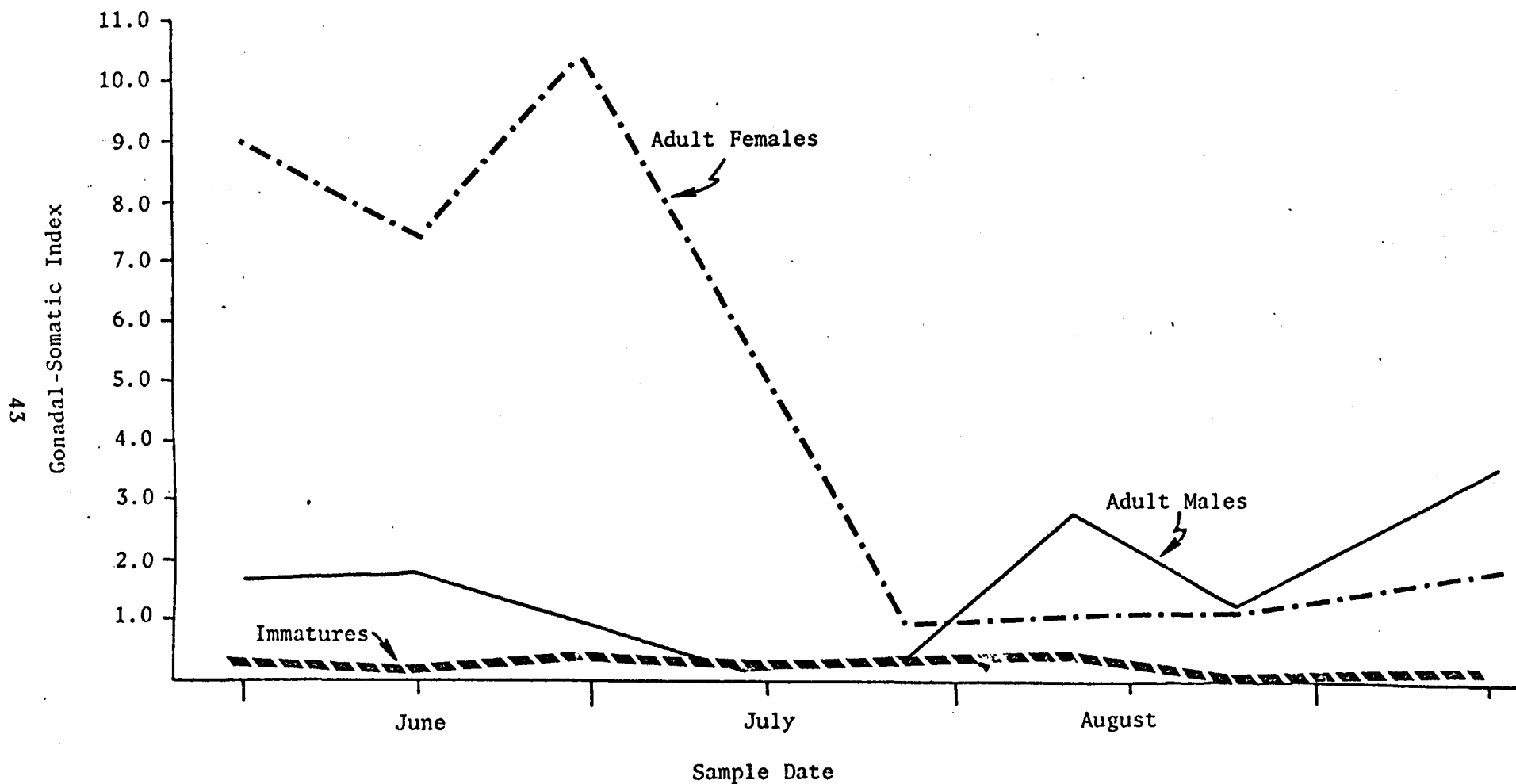


Figure 12. Gonadal-somatic index values for cutthroat trout captured in largemesh gillnets, site 2B, Yellowstone Lake, (Summer sets June 1-August 24, Fall set September 14), 1982.

of suckers is not apparent. Although early scarcity of suckers is presently unexplained, it may be linked to cooler water temperatures early in the study.

Analysis of the GSI data for cutthroat trout indicates that many adult females were still spawning during early July, most males had completed spawning by that time. Increases in GSI values for both sexes during August and September illustrate continued postspawning sexual development. It appears that females recover more gradually than males, and males have exceeded June levels by September.

LARGEMESH GILLNETTING

The objective of the largemesh gillnetting program is 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 eleven of the years in which studies have been conducted. Jones et al (1977- 1982) provide summaries of previous results.

Methods

In 1982, Swedish experimental gillnets were set September 13-17, at eleven sites in Yellowstone Lake (Figure 2). These monofilament nets (38 m long) were comprised of 7.6 m graduated mesh panels of 19, 25, 32, 38 and 51 mm (bar measure). With the exception of several sets in 1969 and all 1981 sets, the same nets have been utilized annually during the fall survey (Jones et al 1977). Because nets used in 1981 confounded comparisons with other years (Jones et al 1982), data from 1981 was deleted from the current evaluation.

Gonad samples were collected from 42 of the cutthroat trout captured. All other sampling procedures, including terms used to describe stage of maturity, have remained unchanged since 1978.

Results

Cutthroat Trout 1982

A total of 582 cutthroat trout (10.6 trout per net) were captured. Average length and weight were 322 mm and 359 g, respectively (Table 14). Average condition factor (K) was 0.99.

Only three clipped trout and no tagged trout were captured during the survey. Two of the clipped trout were originally marked at Clear Creek (1979) and one was clipped at Pelican Creek (1980). The Pelican Creek trout was captured at site 1C, and the Clear Creek trout were found at sites 2B and 3B.

Table 14 Length frequency distribution, average lengths and weights and condition factors of nonspawning and prespawning cutthroat trout and longnose suckers captured in largemouth gillnets, 1.5-4.6 m depth interval, Yellowstone Lake, 1982

Cutthroat trout and longnose suckers captured in largemouth gillnets, 1.9-4.6 m depth interval, Yellowstone Lake, 1962																					
Species	Maturity category ¹⁾	Size-group (lower length of interval - mm)																Total number	Average total length (mm)	Average weight (g)	Average condition factor (K)
		152	178	203	229	254	279	305	330	356	381	406	432	457	483	508	533				
Cutthroat Trout	Nonspawners	18	44	38	60	33	24	24	29	46	24	8	7					355	282	242	0.89
	Prespawning males	1		1		2		1	9	27	43	23	9	3				119	389	571	0.94
	Prespawning females							2	22	36	27	16	4	1				108	380	510	0.91
	TOTALS AND AVERAGES	19	44	39	60	35	24	27	60	109	94	47	20	4				582	322	359	0.91
Longnose Sucker	Nonspawners	3	7	76	53	22	32	30	24	5		1						253	262	237	1.21
	Prespawning males				2	5	19	29	42	20	34	46	30	3	1			231	373	681	1.24
	Prespawning females			1				3	7	21	22	38	64	49	30	5	2	242	438	993	1.18
	TOTALS AND AVERAGES	3	7	77	55	27	51	62	73	46	56	85	94	52	31	5	2	726	356	631	1.21

¹⁾ Prespawning fish defined as those judged to have sufficient gonadal development to spawn in 1982; nonspawners includes immature, and mature fish which were judged to lack sufficient gonadal development to spawn in 1983.

Comparison of length and stage of maturity suggests that trout which do not have sufficient gonadal development to spawn the following year (nonspawners) are common in most 25.4 mm (1 inch) size groups; however, prespawning trout increased substantially in groups over 330 mm (Table 14). Male prespawners were larger than female prespawners, and dominate all size-groups above 381 mm.

The number of trout captured did not differ significantly among the 11 netting sites. Sites 7C, 4B and 1A had the greatest catch per net (12.2, 12.0 and 11.8, respectively) and sites 4A, 2A and 1C had the lowest (8.4, 8.4 and 9.4, respectively) (Table 15).

When net catches were compared between four lake zones (North: 1A, 1B, 1C, 2A, 2B; Central: 3A, 3B; West Thumb: 4A, 4B; South: 6C, 7C), differences between zones were not statistically significant. Central had the greatest mean number per net, while North and West Thumb had the lowest (11.3 and 10.2, respectively) (Table 16).

Average total length of trout differed significantly among the 11 net sites. Sites 6C, 4B and 2A had the largest trout, and sites 3A, 1A, 1B and 2B had the smallest trout (Table 15).

Differences between sites in the length of prespawners were also significant. The relationship between site and the average length of prespawners and the average length of all trout differed; however, site 7C was the largest in both cases.

Length comparisons by zone revealed that West Thumb and South were significantly larger than the other two zones (Table 15). Prespawners were also compared by zone and results were quite different. Cutthroat trout prespawners from Central and South were similar (400 and 393 mm, respectively) but both were significantly larger than the North and West Thumb (379 and 374 mm, respectively).

A gonadal index (GSI) (Le Cren 1951) was calculated for 42 cutthroat trout. Immature trout (0.18) had significantly lower values than adult males and females (2.79 and 1.99, respectively). Since the GSI for prespawning females is usually higher than males (Jones et al 1982), the lower value in the current study suggests a large number of nonspawning females in the sample.

Longnose Suckers 1982

The average length and weight were 356 mm and 631 g, respectively, for the 726 longnose suckers captured (Table 14). The average K factor was 1.21.

Approximately 93% of suckers over 305 mm were categorized as prespawners (Table 14). Males were judged prespawners at a

Table 15 Gillnet catches of cutthroat trout by area, Yellowstone Lake, 1969, 1970
(1971, 1972, 1973, 1976, 1977, 1978, 1979, 1980 and 1982¹⁾)

Area	Number per net ²⁾											Average total length (mm)										Average weight (g)											
	1969	1970	1971	1972	1973	1976	1977	1978	1979	1980	1982	1969	1970	1971	1972	1973	1976	1977	1978	1979	1980	1982	1969	1970	1971	1972	1973	1976	1977	1978	1979	1980	1982
1A	3	10	15	15	11	19	10	14	12	7	12	277	290	291	297	249	315	301	286	276	279	276	213	311	249	269	167	322	273	254	222	357	233
1d	19	13	5	13	12	9	23	9	18	21	10	293	308	363	293	330	322	261	327	281	302	280	272	279	363	276	341	337	214	353	245	312	242
1C	5	10	23	21	25	22	15	15	12	17	9	322	327	306	262	304	306	305	281	312	310	342	317	348	267	231	267	260	292	235	316	316	403
2A	17	11	21	16	21	11	16	10	10	6	8	328	365	326	329	300	337	290	313	322	344	345	354	450	318	350	269	363	268	336	339	416	425
2a	5	15	4	12	26	21	21	17	9	14	11	378	279	379	321	266	291	286	298	306	309	306	527	223	452	352	200	267	258	242	310	314	319
3A	31	20	31	17	6	19	19	16	19	12	11	31	352	31	296	284	302	265	293	280	300	274	31	382	31	262	253	235	219	263	235	349	217
3B	31	9	31	3	12	15	12	14	12	12	11	31	352	31	368	311	324	341	319	306	341	356	31	390	31	410	270	322	399	337	314	410	470
4A	31	2	31	9	19	13	7	15	16	13	8	350	352	31	358	290	331	283	286	268	268	324	411	320	31	405	265	331	246	260	251	217	169
4B	26	32	31	19	12	10	15	18	18	18	12	290	280	31	334	301	324	269	302	294	286	358	261	249	31	358	285	306	245	230	283	255	455
6C	14	7	31	8	6	12	12	13	12	15	10	341	364	31	349	348	330	344	342	374	339	362	403	488	31	459	361	353	420	416	517	430	471
7C	16	1	31	17	20	14	22	13	10	9	12	300	274	31	329	324	337	292	365	335	345	327	249	108	31	349	309	358	270	427	400	414	360
Totals	110	135	72	150	170	165	682	766	748	715	582																						
Averages												311	315	321	313	298	317	290	308	303	309	322	312	320	305	320	266	314	271	315	301	329	255

¹⁾ Experimental gillnets (30.2 m long) set overnight (7.6 m graduated mesh panels 19, 25, 32, 35 and 51) in the 1.5-4.6 m depth interval.

²⁾ From 1970-1974, only 1 set was used in each area at the specified depth interval; for 1977, the number represents an average of 4 sets and for 1978, 1979, 1980 and 1982, represents an average of 5 sets.

³⁾ Areas not sampled.

Table 16. Gillnet catches of cutthroat trout by general area, Yellowstone Lake, 1969, 1970, 1971, 1972, 1974, 1976, 1977, 1978, 1979, 1980 and 1982¹⁾

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
1982	10	11	10	11	307	316	341	342	15.7	15.0	6.9	4.5	11.9
Totals	1983	757	829	726									
Averages	13	14	14	13	300	307	297	338	16.3	14.3	13.3	7.6	14.0

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

smaller size, and females dominated size classes over 432 mm. These results are consistent with previous studies (Jones et al 1978-1982).

Discussion

Cutthroat trout 1969 - 1982

Average number per net. Although initial increases in the number per net between 1970 and 1978 (Table 17) may be confounded by variation of independent variables, it appears to have been a response to increasingly restrictive regulations beginning in 1969. After these preliminary increases in numbers, density has decreased since 1978 (Table 17). This decrease is assumed to be associated with a shift in biomass toward larger trout under the influence of the 330 mm maximum size limit.

The high degree of variation associated with gillnetting data has hampered statistical analysis; however, the mean number per net in 1982 (10.6 trout per net) was significantly lower than the 1977 estimate (15.6 trout per net). Although the lower density suggested by the 1982 data may be the result of density dependent mechanisms, the sudden decrease may also be explained by poor year class strength. Density independent factors which influence gillnetting efficiency (Jones et al 1981) may also partially explain the 1982 estimates since the current survey was conducted a week earlier than usual, and lake water level was at an almost record high in 1982.

When data from the 11 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; however sites 1A, 2A, 3B and 4A 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 11 years were combined (Table 16). Biological interpretation of these results is confounded by the high degree of variation and absence of observable trends.

Average size. The mean total length of cutthroat trout captured in gillnets has varied significantly since 1969. Similar results were observed when data were combined over years and compared by site and zone (Tables 15 and 16 and Figure 13). 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

Table 17. Comparative largemouth gillnetting results, cutthroat trout, 1.52-4.57 m depth interval, Yellowstone Lake, 1969, 1970, 1971, 1972, 1974, 1976, 1977, 1978, 1979, 1980 and 1982

Category	1969	1970	1971	1972	1974	1976	1977	1978	1979	1980	1982
Number of gillnet sets ¹⁾	9	11	5	11	11	11	44	55	55	55	55
Average number of trout caught per net	12.22	12.27	14.40	13.63	15.45	15.00	15.55	13.93	13.60	13.00	10.60
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	± 1.05
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	47.1
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	12.7
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	0.7
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	61.7
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	1.10
Average length (mm) of prespawning males	353	359	360	358	349	370	376	383	387	389	389
Average length (mm) of prespawning females	346	351	368	369	359	365	362	372	374	376	379
Condition factor K	0.924	0.917	0.853	0.937	0.859	0.877	0.892	0.923	0.915	0.884	0.909

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.

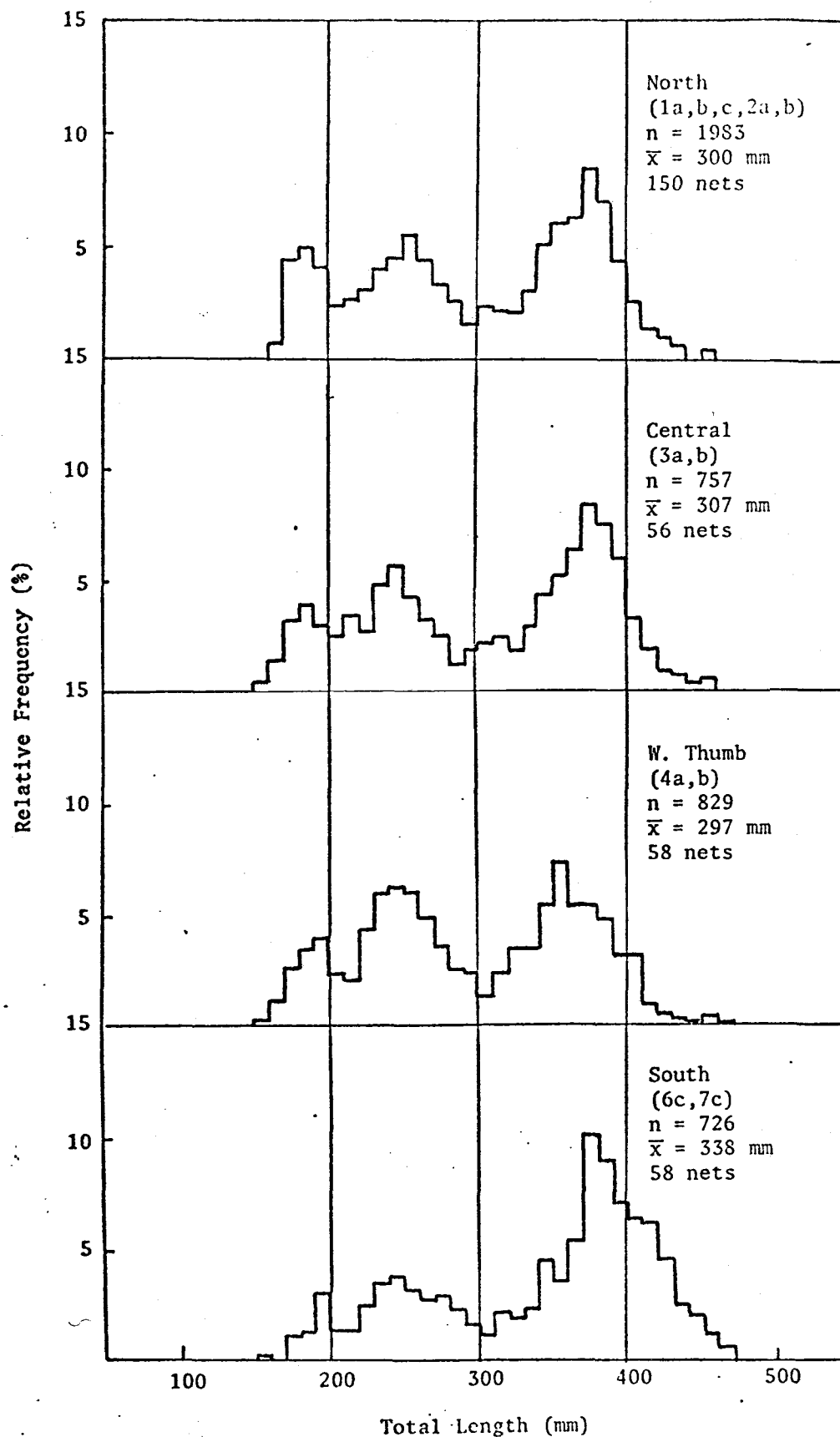


Figure 13. Length frequencies of cutthroat trout captured in largemesh gillnets at the 1.5-4.6 m depth interval in Yellowstone Lake, 1969-1982 (excluding 1981).

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 mean length of prespawners between sample years were significant. The previously reported trend of increasing length (Jones et al 1981) continued in 1982, and the length of prespawners (384 mm) was the largest reported since the survey began in 1969. This increase is interpreted as a positive response 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 structure changes has been most pronounced in the males; however, it appears that the mean length of prespawning males has begun to approach a limit imposed by current harvest levels and environmental conditions in Yellowstone Lake (Figure 14). It is more difficult to interpret changes in female prespawners because of an apparent slower rate of response, but females also appear to be approaching an equilibrium size.

Differences in length of prespawning trout from the four lake zones were also significant. Prespawners from the South (389 mm) were the largest and West Thumb prespawners (364 mm) were the smallest. Although prespawners from the North and Central zones (372 mm and 376 mm, respectively) differed from the other two zones, there was little difference between them.

Length frequency. A comparison of length frequency data from ten of the survey years illustrates several interesting trends (Figure 15). 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. This is best illustrated by dividing the data into pre- and post-regulation groups (Figure 16). Aside from the general shift toward larger trout, another important change has been an apparent depression in the length frequency curve between 260 mm and 330 mm since 1975. In 1982, the percentage of larger trout (over 354, 405 and 457 mm) was the highest yet recorded to date (Table 17).

Although previous attempts at interpreting annual changes in length frequency distributions have provided insight into trends (Jones et al 1981), it appears that assignment of year-class has been erroneous. Current data indicate that the majority of trout less than 210 mm total length are I+ instead of II+ as previously indicated, and therefore, year-classes mentioned in prior reports (Jones et al 1981) have been increased by one year.

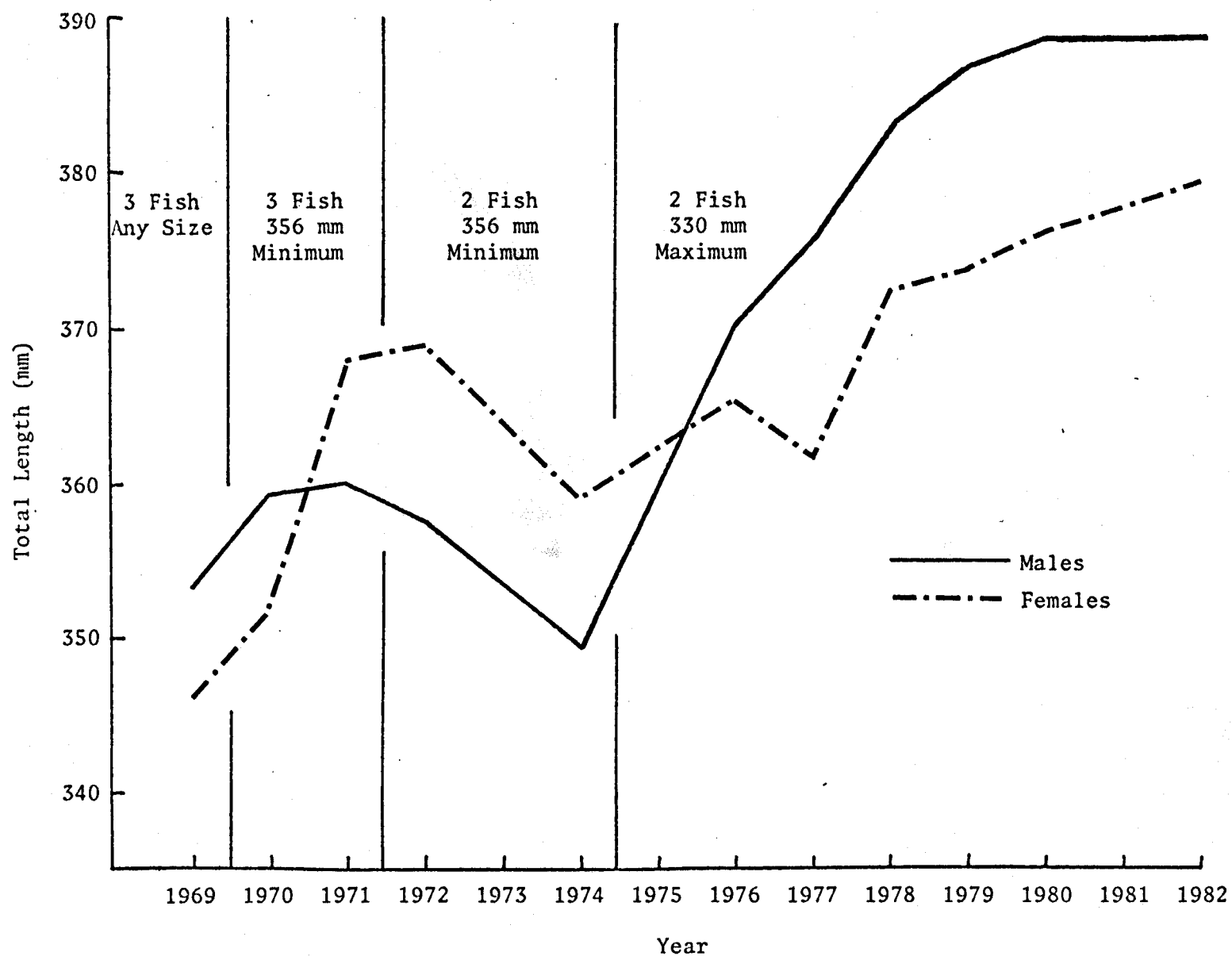


Figure 14. Mean total length of prespawning cutthroat trout captured in largemouth gillnets, Yellowstone Lake, 1969-1982.

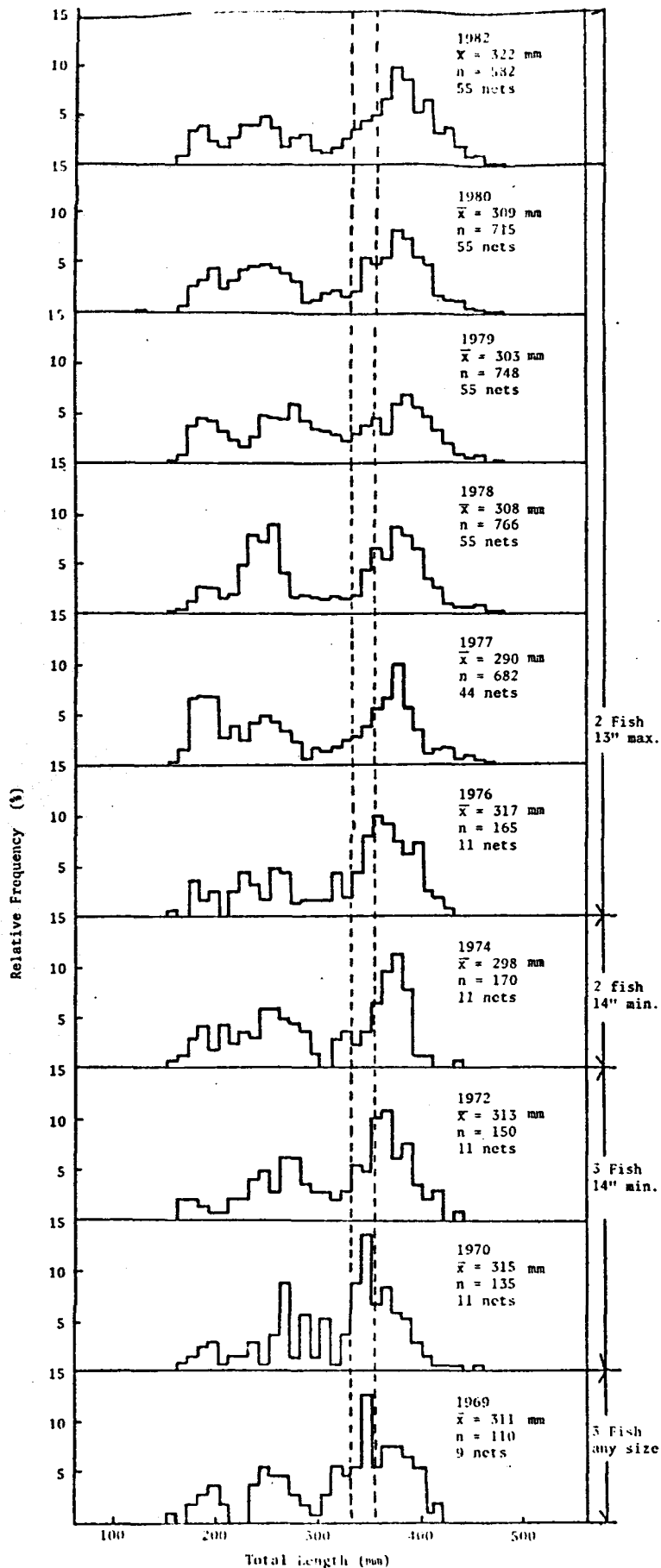


Figure 15 Length frequencies of cutthroat trout captured in largemouth gillnets at the 1.5-4.6 m depth interval, Yellowstone Lake, 1969-1982.

In 1977, a large pulse of trout less than 210 mm suggested that the 1976 year-class was very strong. In 1978, the increased frequency of trout in the 200-270 mm group was interpreted as growth of the year-class (Figure 15). 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. In 1980, the 1976 year-class progressed to the right, making a substantial addition to the proportion of trout over 330 mm. Continued growth of the 1976 year-class may partially explain the large percentage of trout between 406 mm and 456 mm in 1982.

The extreme paucity of trout less than 210 mm in 1978 (the 1977 year-class) may partially explain a decrease in numbers in 1980. The weak 1977 year-class was definitely evident in the 1981 Clear Creek spawning run as predicted by Jones et al (1981), and undoubtedly contributed to poor catch rate in 1981 fishery. This extremely weak year-class is assumed to be the result of abnormally low runoff in 1977. Lake level data reveal that 1977 was the poorest water year since 1940.

Average or slightly above average year-classes were indicated by length frequency in 1978 and 1979 and may have contributed to the increase in landing rate on Yellowstone Lake in 1982. The use of the new nets in 1981 precluded the inclusion of that data in the current analysis, but it appears from the 1982 length frequency, that the 1980 year-class may have been somewhat below average. If this is true, angler success on the lake may decline again in 1983.

GSI estimates prior to 1982 were utilized to determine differences in values between trout of varying maturity levels. Since these samples were not obtained randomly, interpretation of comparisons between samples is difficult. The current estimate was obtained in a stratified fashion and provides values for the adult population at the time of sampling. These data can be used to compare with future samples to determine changes through time.

Longnose Suckers 1969-1982

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 (1976-1979) 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 18).

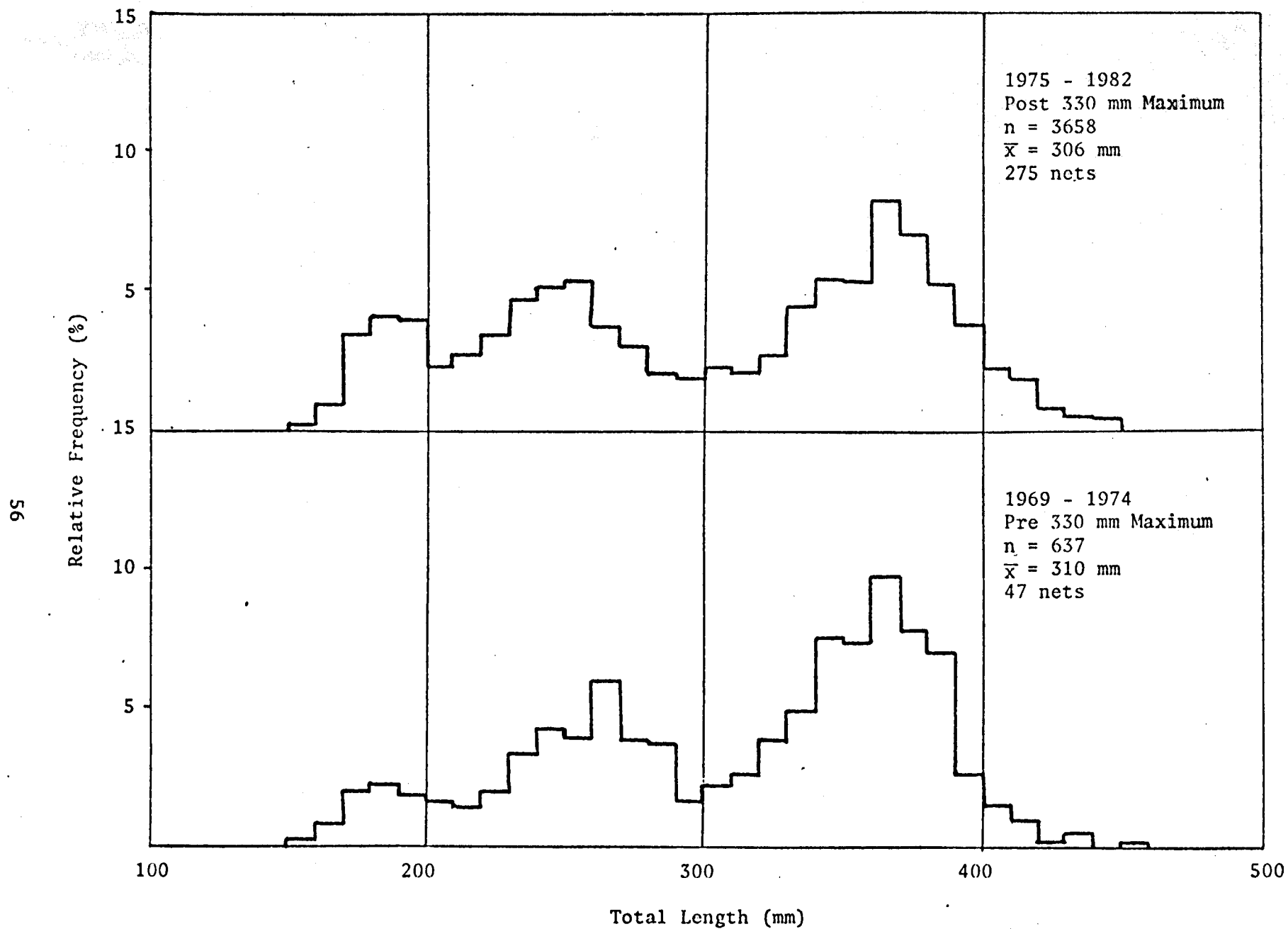


Figure 16 . Length frequencies of cutthroat trout captured in largemesh gillnets at the 1.5-4.6 m depth interval in Yellowstone Lake, 1969-1982 (excluding 1981).

Table 18. Comparative largemouth gillnetting results, longnose suckers, 1.5-4.6 m depth interval, Yellowstone Lake, 1969, 1970, 1971, 1972, 1974, 1976, 1977, 1978, 1979, 1980 and 1982

Category	1969	1970	1971	1972	1974	1976	1977	1978	1979	1980	1982
Number of gillnets set ¹⁾	9	11	5	11	11	11	44	55	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	8.64
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	± 2.13
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	51.1
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	37.2
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	12.5
Percentage of prespawning suckers ²⁾	92.1	100.0	100.0	88.2	100.0	95.2	100.0	92.5	87.8	78.1	65.2
Ratio of prespawning males to females	1.28	0.08	2.00	2.00	1.28	1.07	1.48	1.13	0.99	1.12	0.95
Average length (mm) of prespawning males	382	386	357	378	372	387	390	385	399	370	373
Average length (mm) of prespawning females	419	440	417	428	415	425	441	435	440	432	438
Condition factor K	1.207	1.235	1.207	1.205	1.215	1.227	1.229	1.187	1.197	1.171	1.209

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 19. Gillnet catches of longnose sucker by area, Yellowstone Lake, 1969, 1970, 1971, 1972, 1973, 1974, 1975, 1976, 1977, 1978, 1979, 1980 and 1982

Area	Number per set ¹⁾												Average total length (mm)												Average weight (g)												
	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	
	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	
1A	7	15	17	4	27	15	9	4	16	5	15		431	444	432	446	401	427	440	437	435	422	438		938	1075	953	1012	874	920	995	792	580	529	970		
1B	28	3	75	4	26	30	3	18	21	12	21		319	392	267	291	340	334	408	353	342	330	363		415	971	273	260	561	527	847	594	567	502	462		
1C	29	4	7	0	15	13	8	7	11	9	8		411	427	433	—	428	414	434	424	429	426	432		855	970	935	—	952	551	1247	913	954	957	941		
2A	13	23	13	3	9	25	14	11	18	15	12		394	380	410	242	401	403	407	412	413	410	400		825	773	859	167	774	824	840	839	864	845	852		
2B	31	15	73	2	26	13	13	13	23	13	15		323	415	312	318	345	394	413	307	324	350	323		414	823	413	575	574	550	595	423	553	557	476		
3A	31	3	31	0	6	8	4	0	5	2	17		31	425	31	—	392	396	380	354	396	402	374		31	1033	31	—	775	765	710	513	731	777	701		
3B	31	1	31	0	13	14	8	3	13	15	19		31	306	31	—	355	373	361	329	325	322	316		31	366	31	—	546	651	656	478	464	461	451		
4A	5	6	31	3	5	13	4	5	6	5	7		368	376	31	422	365	411	400	409	397	416	414		621	692	31	961	790	876	810	859	810	850	974		
4B	1	3	31	2	17	14	8	9	12	17	20		425	317	31	358	358	385	431	321	345	312	289		860	367	31	600	317	720	529	457	552	429	344		
5C	1	0	31	5	4	0	0	1	5	6	8		350	—	31	330	369	—	—	235	265	300	261		614	—	31	457	645	—	—	314	335	345	249		
7C	22	1	31	5	22	16	10	2	7	11	3		358	214	31	290	356	396	409	328	362	414	401		597	112	31	286	577	805	859	595	425	625	626		
Totals	147	71	125	28	175	160	119	395	695	548	726		365	398	316	335	370	359	401	363	371	365	356		635	838	459	519	662	735	833	654	693	667	631		
Average																																					

¹⁾ Experimental gillnet (28.1 m long) set overnight (7.6 graduated mesh panels 19, 4.0 19.0 and 10.0) in the 1.5-4.6 m depth interval.
²⁾ Area 1969/70, 60/71, 1 set was made in each area at the specified depth interval; from 1971, the number represents an average of 4 sets and for 1976, 1979, 1980 and 1982, represents an average of 5 sets.
³⁾ Areas not sampled.

51
80

Table 20. Number and size of cutthroat trout captured in purse seine hauls, Yellowstone Lake, September 21-24, 1982

	Area				Depth		
	North	South	West Thumb	Frank Island	18-24 m	33-37 m	>60 m
Number of hauls	7	4	4	2	9	5	3
Number/haul	21.7	69.5	9.5	6.0	42.1	9.2	18.3
Mean length (mm)	335	298	346	388	307	359	340
Mean weight (g)	351	480	573	474	365	480	—
Condition factor K	0.88	0.89	0.93	0.83	0.88	0.89	—

Average size. Comparisons between years (Table 19) yields significant differences in mean length. Mean length of suckers has been inversely correlated to the male:female ratio ($r=0.78$) and directly correlated to the percentage of suckers over 310 mm (TL) ($r=0.94$) (Jones et al 1981). Since the latter two factors are probably related to distribution, annual variations affecting numbers captured may also affect variation in mean length.

The largemouth gillnetting program has provided only minimal information concerning the longnose sucker. Although a more suitable method of monitoring the sucker population might be developed, an increasing amount of evidence suggests that the longnose sucker and cutthroat trout are probably not competing either temporally or spatially in Yellowstone Lake. It would be more beneficial, therefore, to channel future effort to further describing the relationship between the two species.

FALL PURSE SEINE OPERATION

The vast size of Yellowstone Lake (35,630 ha) has historically hindered efforts to sample the pelagic areas. Vertical gillnets were set in 1974 (Dean et al 1975) and 1975 (Varley et al 1976), but low catch/effort limited the effectiveness of this program. In 1979, a purse seining operation by personnel from Wyoming Game and Fish suggested that further evaluation of this method of pelagic sampling would be beneficial (Jones et al 1980). To this end, the operation was essentially repeated when the Wyoming Game and Fish Crew returned in 1982.

Methods

The purse seine utilized in the current study was identical to the previous net and measured 236 m long and 18.3 m deep with 15.2 m tapered leads. The seine was comprised of 10 mm bar mesh nylon except for the bottom 0.9 m, which was 32 mm bar mesh. An area of approximately 0.4 ha (18.3 m deep) was sampled with each haul.

A total of 17 hauls were made at various sites around Yellowstone Lake from September 21-24, 1982 (Figure 2). These hauls were divided by area of the lake as follows: seven from the vicinity of Bridge Bay (North) including Sand Point (1) and Stevenson Island (1); four from West Thumb; four from the South Arm; and two hauls in the vicinity of Frank Island.

Results

In 1982, 480 cutthroat trout were captured during the study (Table 20), and no other fish species were collected. The mean catch was 28.2 trout per haul, but variation was extremely high with catches ranging from 1-154. South Arm and North had the

greatest number per haul (69.5 and 21.7, respectively) while West Thumb and Frank Island had the lowest (9.5 and 6.0, respectively); however, due to the large variation, differences were not statistically significant.

Mean length for 476 trout was 316 mm and mean weight (n=130) was 383 g (Table 20). Trout from South (298 mm) were significantly smaller than those from Frank Island, West Thumb and North (388, 346, and 335 mm, respectively). When depth of water was considered, trout from 18-24 m (307 mm) were significantly smaller than those from depths of 33-37 m (359 mm) and over 60 m (340 mm).

Discussion

Extreme variation continues to confound analysis of purse seine data. As expected, the reduction of sample size to 17 in 1982 (n=19 in 1979) increased variability, and the minimum detectable difference in catch per haul between samples of current size is 157% of the mean (Snedecor and Cochran 1967). Approximately 977 hauls per sample would be necessary to detect differences as low as 20% of the mean.

Although differences were not statistically significant, the number per haul was greater in 1982 than 1979 (28.2 and 22.4 trout per haul, respectively). Discarding two of the 1979 hauls to make sample size equal increased the 1979 mean only slightly (23.2 trout per haul). Mean catch per haul for the two sample years combined was approximately twice the mean catch per net in fall largemouth gillnets during those years (25.2 trout per haul and 12.1 trout per net, respectively); however, variation was almost five times as great for the seine hauls.

Differences between zone changed somewhat between 1979 and 1982, but North and West Thumb, those areas which support the greatest angler exploitation, were below the mean in both years. When samples for the two years were combined, West Thumb and North had the lowest catches per haul.

The inverse relationship between depth and catch observed in 1979 (Jones et al 1980) was not repeated in 1981; however, the number captured in the shallowest water (18-24 m) was the greatest in both years. Decreases in catch were noted with increasing depth in combined samples.

The mean length of trout captured in 1982 (316 mm) was significantly lower than the mean length of trout collected in 1979 (343 mm). These differences were also noted in comparisons between areas for both years. In 1982, trout from the purse seine were smaller than those captured in fall largemouth gillnets; the opposite result was found in a similar comparison in 1979. Samples combined for the two years yielded results similar to 1979.

The previously reported inverse relationship between mean length and depth (Jones et al 1980) was not observed in 1982. Trout from the 33-37 m interval were similar in both years (352 mm and 359 mm, for 1979 and 1982, respectively), but the relationship was reversed for the 18-24 m interval (342 and 307 mm, respectively) and over 60 m (310 and 340 mm, respectively).

Results from these two studies utilizing purse seines have indicated great differences between seine hauls and gillnet catches. The differences were expected since the former was utilized to sample the pelagic portions of the lake and the latter to sample shallow portions of the littoral zone. Mesh size differences between the two gear types also probably affect results. Lack of consistency between studies in zone and depth relationships appear to be much greater with seine hauls and are associated with the greater variability with this method.

Future studies utilizing the purse seine for pelagic sampling will necessitate larger sample sizes and should include site replication. At present, it appears that midwater trawling and associated acoustical sampling may present a better alternative for pelagic samples. Use of the smaller 9 m purse seine in shallower waters would provide additional data needed to further evaluate this technique in Yellowstone Lake.

CONCLUSIONS

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 maximum size limit has been more successful at approaching 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 IX+ trout is significant. Average lengths of trout landed in the fishery, spawners at Clear Creek and prespawners in fall-set gillnets are among the greatest yet recorded (Figures 17 and 18). Fecundity estimates suggest that current reproductive potential in Clear Creek is five times greater than it was during the 1950's.

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

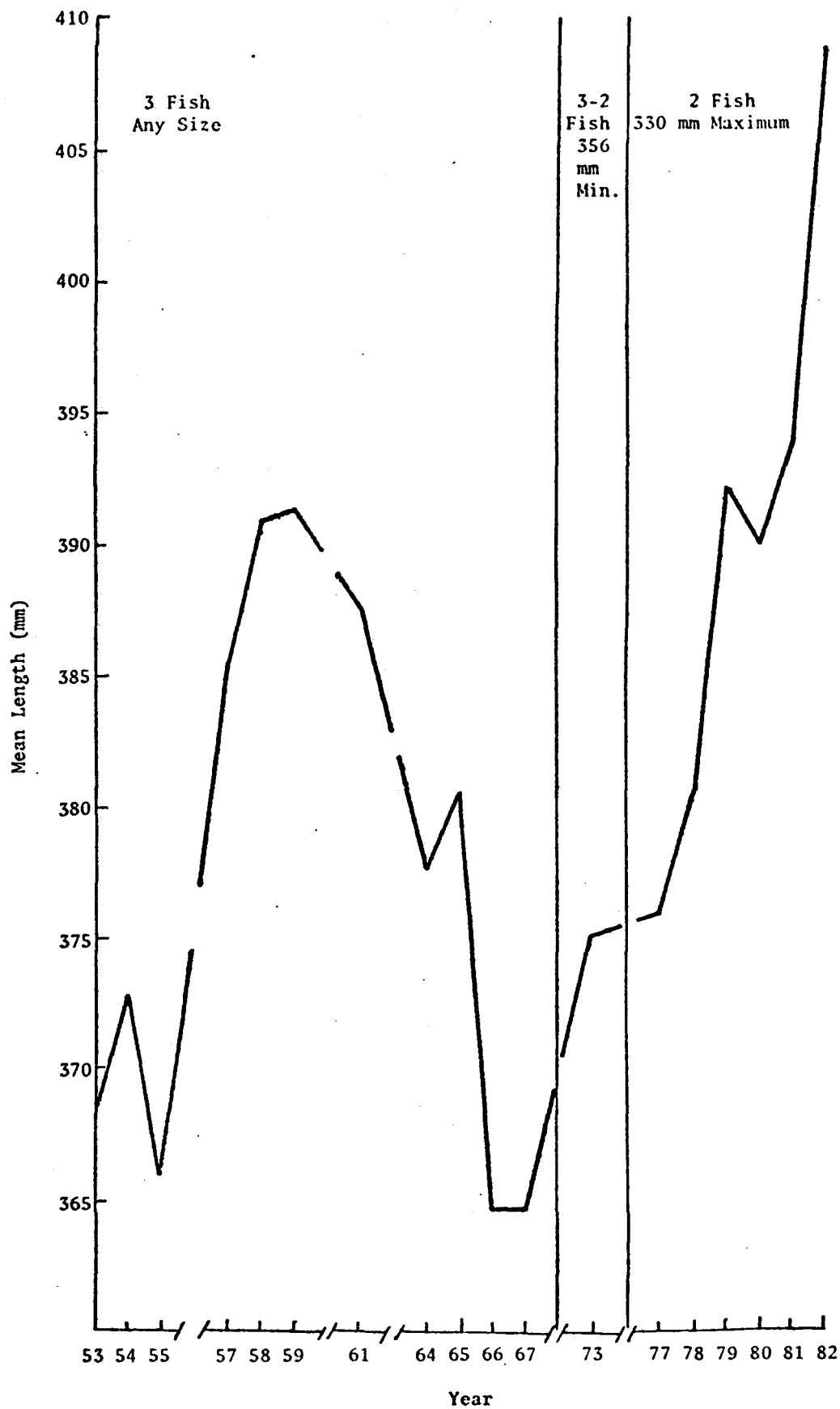


Figure 17. Mean length of cutthroat trout spawners entering Clear Creek, 1953-1982.

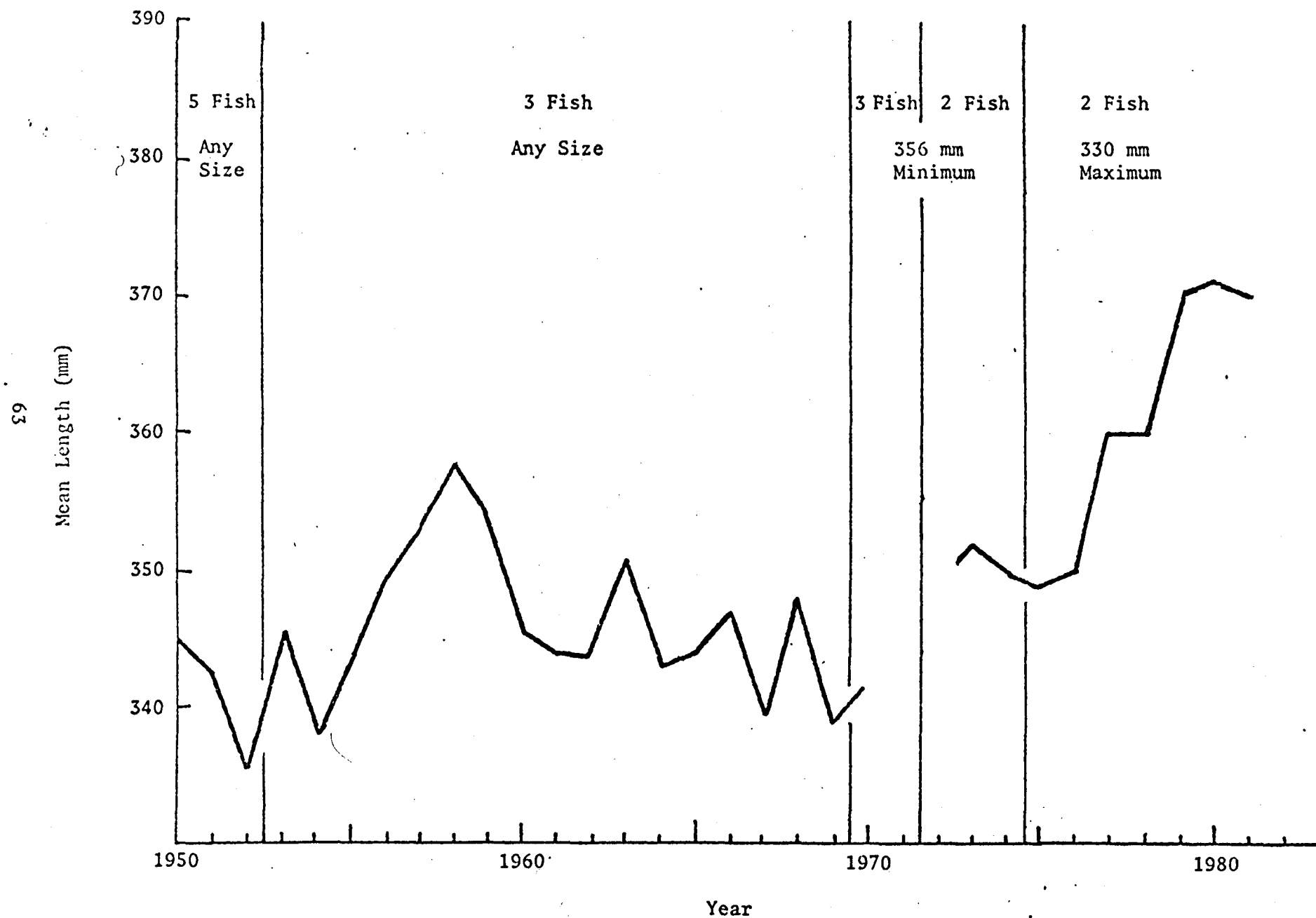


Figure 18. Mean length of cutthroat trout captured in the fishery measured at boatdocks (1950-1962) and shoreline-boatdocks combined 1963-1982.

landing rate has been excellent, averaging 0.94 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 inches) 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) regulations would undoubtedly provide maximum protection. The 330 mm 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) are captured and released for each trout under 330 mm 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 eight years of the 330 mm maximum size limit are indeed encouraging; however, it should be emphasized that these results may not describe an equilibrium condition. The continuing changes associated with the 330 mm maximum size limit underscore the necessity of long term research. Continued increases in angler use may have a profound effect on the cutthroat trout population despite the protection afforded under the current regulation.

YELLOWSTONE RIVER (CATCH AND RELEASE AREA)

Since the 14.0 km (8.7 mile) catch and release section of the Yellowstone River supports over 80% of the total use on the river (114 km or 71 miles in the park) and because this section alone is the second most popular fishery in the park, it will be treated as a separate fishery in this report. Although there may be some interaction with cutthroat trout from Yellowstone Lake, this portion of the Yellowstone River is separated ecologically from the remainder of the river.

The catch and release area is divided by a 10.2 km (6.4 mile) section of river (Sulphur Caldron to Alum Creek) in Hayden Valley which has been closed to angling since 1965. The first 1.6 km (1 mile) below the Yellowstone Lake outlet is also closed, leaving 9.8 km (6.1 miles) of fishable water in the upper portion of the catch and release area. The lower portion (Alum Creek to the Upper Falls) is 4.2 km (2.6 miles) in length.

Fishery research on the Yellowstone River between the lake and the falls dates back to 1950 (More, Cope and Beckwith 1952). Since that time various studies have been conducted to monitor angler impact on this important cutthroat trout fishery. Research since 1973 has been concentrated on the evaluation of the catch and release regulation. In 1982, studies included a creel survey utilizing the VFR system (Jones et al 1977), continued sampling of spawning trout at LeHardy's Rapids, and snorkel surveys in the upper portion of the catch and release section.

CREEL SURVEY

In 1982, the catch and release segment of the Yellowstone River supported the second highest level of use (35,200 angler days) reported since 1973. An estimated 16,500 anglers spent 86,600 hours and captured 95,400 cutthroat trout. Approximately 1,400 of these trout were illegally creeled. Despite the high level of use, catch rate rose to 1.10 trout per hour (Table 21).

When the upper and lower portions were examined separately, the upper section alone (9.8 km) sustained 89% of the use for the entire area (31,300 angler days or 3,200 angler days per km). A total of 14,400 anglers captured 90,500 trout while expending 79,900 angler hours. Catch rate was 1.13 trout per hour.

Despite a 33% decrease in angler use on the upper section during 1982, the number of angler days in the lower section almost doubled (3,900 angler days or 930 angler days per km). Approximately 2,100 anglers expended 6,700 angler hours. Although angler effort is much lower in this section, catch rate was only 0.71 trout per hour. Expanded results indicate that of the 4,700 trout landed, 105 were illegally creeled.

Table 21 Creel survey summary, Yellowstone River between Fishing Bridge and Chittenden Bridge, 1951-55, 1967, 1968, 1970, 1972 and 1973 through 1982¹⁾

	4.2 Fish creel limit ⁴⁾ No size limit Bait fishing permitted 1951 to 1955 average	3 Fish creel limit No size limit Bait fishing permitted 1967 to 1968 average	3 Fish creel limit 14" minimum size limit Bait fishing prohibited 1970 to 1972 average	Catch and release fishing Lures and flies only Bait fishing prohibited			1976	1977 ⁶⁾	1978	1979	1980	1981	1982
	1951 to 1955 average	1967 to 1968 average	1970 to 1972 average	1973	1974	1975							
Angler days (trips) ¹⁾	45,430	44,300	45,120	25,000	23,900	27,900	30,900	26,900	26,300	28,900	34,900	48,800	35,200
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	2.44	2.60	2.46
Total hours fished	89,500	88,625	84,400	58,750	55,700	69,200	75,700	65,600	65,700	75,300	85,100	126,800	86,600
Landing rate (trout/hr)	2)	2)	0.74	1.74	2.25	2.04	1.43	1.43	1.23	1.10	1.06	1.00	1.10
Total trout landed	2)	2)	62,500	102,200	124,200	141,100	108,200	93,900	80,800	82,800	88,700	127,100	95,400
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	0.01	0.02
Total trout creel ⁹⁾	36,700	38,100	14,825	590	550	690	980	1,300	1,100	1,500	2,000	1,800	1,400
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	4,000	5,600	4,000
Angler days per acre ⁸⁾	99	167	170	106	102	119	132	114	112	123	148	208	150
Angler hours per acre ⁸⁾	195	334	318	250	235	295	322	279	280	320	362	540	363
Mean angler expertise ⁷⁾	-	-	-	-	-	-	2.00	1.98	1.99	2.02	2.04	2.01	2.00
% trout landed and released	2)	2)	76.2	99.4	99.9	99.5	99.8	99.6	99.6	99.3	99.0	98.6	98.5
X length trout creel ⁵⁾	3)	13.5"	14.7"	3)	3)	3)	3)	14.3"	13.3"	13.2"	13.5"	13.1"	12.4"
X length trout landed	3)	3)	3)	14.3"	14.4"	14.5"	14.7"	14.7"	15.1"	15.3"	15.3"	15.4"	15.6"

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 miles long and averages 458 acres. Area open to fishing was 9.7 miles and 265 acres between 1965 and 1972. Beginning in 1973, the open area was 8.7 miles and 235 acres.

6.

Average size of cutthroat trout landed for the entire catch and release area rose to a record high of 395 mm (15.6 inches). Trout from the lower portion were significantly larger than those in the upper section (400 mm and 395 mm, respectively). Creeled trout were also larger in the lower segment (381 mm and 327 mm, for lower and upper sections, respectively) and the mean length of creeled trout for the entire catch and release area was 332 mm.

Satisfaction indicies indicated 86% of the anglers were satisfied by their overall experience, with 81% satisfied with number and 90% with sizes. The proportion of single day anglers landing one or more trout was 72%. These figures increased in 1982 and remain well above the Park mean. Average expertise remains high at 2.00.

LE HARDY'S RAPIDS

Annual monitoring of the cutthroat trout spawning run at LeHardy's Rapids was initiated in 1974 in order to provide an alternate means of evaluating the catch and release-only regulation on the Yellowstone River (Fishing Bridge to Upper Falls). This program has provided valuable data concerning the cutthroat trout population structure, independent of the VFR system. During 1982, collections were made weekly from June 15 through August 10. Established sampling procedures (Varley et al 1976) remained unchanged except that all captured trout were tagged with colored internal anchor tags (Dell 1968) prior to release.

Results

The scarcity of trout during the initial collection indicated that the main portion of the run had not yet commenced. Numbers increased between June 24 and July 7, and 100 trout were collected each week. After July 13, numbers dwindled for the remainder of the study.

A total of 694 cutthroat trout adults and 26 subadults were captured in 1982, but no other fish species were observed. Mean length (400 mm) for 328 males was significantly greater than mean length (379 mm) for 369 females (Table 22). There were no significant changes in mean length during the study period.

Mean length of males, females and all adults increased slightly from 1981, and mean length for females and all adults were the highest reported since the program began (Figure 19). The percentage of adult trout over 406 mm also reached a record high (24%) in 1982. Although annual proportion of trout over 406 mm may be influenced by sampling procedures, changes since 1974 are statistically significant (Figure 20).

The male:female ratio dropped to 0.89:1 in 1982. Apparent problems in discerning sex in postspawners during the last two

Table 22. Total number and average length, weight and condition factor of cutthroat trout for each year sampled at LeHardy's Rapids, Yellowstone River, 1974-1982

Year	Adult Males				Adult Females				All Adults				Immatures and Subadults			
	Number captured	Average length (mm)	Average weight (g)	Average K factor	Number captured	Average length (mm)	Average weight (g)	Average K factor	Number captured	Average length (mm)	Average weight (g)	Average K factor	Number captured	Average length (mm)	Average weight (g)	Average K factor
1974 ¹⁾	177	375	394	0.75	244	352	339	0.78	453	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	118	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
1981	383	394	496	0.80	188	373	440	0.84	571	387	478	0.82	7	308	286	0.89
1982	328	400	516	0.80	369	379	474	0.86	694	389	494	0.83	26	281	218	0.90

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 19. Average lengths for the entire season for all adults, LeHardy's Rapids, 1974-1982.



Figure 20. Percentage of adult trout greater than 406 mm captured at LeHardy's Rapids, 1974-1982.

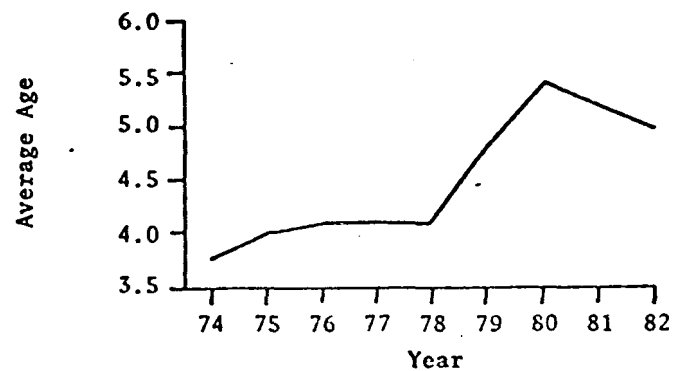


Figure 21. Average age of all adult trout captured at LeHardy's Rapids, 1974-1982.

samples appear to have biased this estimate, and the male:female ratio is 1.05 if these samples are excluded. The dominance of males in samples from LeHardy's Rapids since 1975 is not typical for Park cutthroat trout waters, and M:F ratios from tributaries to Yellowstone Lake such as Clear, Cub and Pelican Creeks have been significantly lower (0.59-0.74:1) since 1945 (Jones et al 1981, Ball and Cope 1961). Although none of the various size and creel limit regulations implemented on Yellowstone Lake since 1945 have appreciably changed the M:F ratio, the change in M:F ratio at LeHardy's Rapids is apparently associated with the elimination of harvest under the catch and release-only regulation. Since the change in the male:female ratio in 1982 may be due to sampling error, it appears that continued monitoring is necessary to enhance the current level of understanding.

A total of 107 cutthroat trout were aged using the scale method (Bagenal and Tesch 1978). Expanded age estimates for the entire sample were calculated using an age-length key (Westerheim and Ricker 1978). Mean age of males, females and all adults were 5.0, 4.8 and 5.0 years, respectively. Although mean age declined somewhat from 1981, a definite trend of increased age since 1974 is evident (Figure 21). Age VII+ trout comprised approximately 8% of the sample in 1982.

SNORKELING

Researchers from Idaho State University used snorkel counts to estimate the cutthroat trout population in the catch and release section of the Yellowstone River during 1980 and 1981. Comparison of population estimates from the Cable Car section with those collected by electrofishing in the same area, suggested that with limited manpower snorkel estimates may provide a more realistic approximation of the population in the study section (Jones et al 1982). Snorkel counts also allow the biologist to gain significant insight into the aquatic environment during the sample period.

Snorkel counts in the Yellowstone River were conducted by project personnel on June 28, July 12, July 26, August 2, August 9, and August 16, 1982. Effort was concentrated on developing a comparative index of the cutthroat population and determining the relative amount of area in the mainstem which was utilized for spawning during 1982.

Methods

Five divers were used in all counts, but spacing between individuals changed during the season. Beginning on August 2, plastic pipe was utilized to maintain interval between divers; the interval was approximately 3 m on August 2 and August 16, and 1.5 m on August 9. Counts were made from the bouys above Fishing Bridge to the lower tip of the islands below the bridge

on July 12, July 26, and August 16. Observations at the Cable Car area occurred on August 2, and Nez Perce (Buffalo) Ford was sampled on July 12 and August 9.

Results

General observations below Fishing Bridge on June 28 provided an approximate count of 500 trout; very few suckers (<300 mm) were noted. By July 26, the mean count for two passes was approximately 170 for each section, above and below the bridge. A significant increase in sucker abundance was noted at that time, but turbid water conditions hampered attempts to count this species. By August 16, the water visability had improved, and 446 cutthroat trout and approximately 800 suckers were counted above the bridge. Only 57 trout and approximately 300 suckers were counted below the bridge.

The mean count of three passes at Cable Car was 69 trout on August 2. No suckers were observed in this section. Counts along the west bank from several hundred meters above and below LeHardy's Rapids indicated many more trout below the rapids (mean=130, 4 tagged) than above (30 trout, 1 tag). Many of the trout below the rapids were postspawners, but small (~100 mm) immature trout were found in both sections.

Only 20 cutthroat trout were counted above the main island at Nez Perce Ford on July 12, but turbid conditions greatly hindered counts. The same section yielded only 17 adult trout and 13 immatures on August 9. Turbidity was still high and greatly impaired counts. The count of 43 adults and 1 immature below the island was also probably low.

It appears that the majority of spawning in the sample section occurs just below (0.8 km) Fishing Bridge, but there is also good gravel for approximatley 100 m above the bridge. Although several other pockets of spawning gravel were noted for about 2.4 km below the bridge, the only other concentration of gravel was at Nez Perce Ford.

Discussion

Studies on the Yellowstone River in 1982 have provided additional information concerning the snorkel method. Although more than five divers are necessary to provide accurate population estimates, current counts provided an index to evaluate seasonal concentrations in the study sections. Valuable data concerning the extent of potential cutthroat spawning area can also be determined accurately with this method.

Snorkel counts were severely hampered by turbidity. This problem has been noted by previous researchers in the catch and release section of Yellowstone River especially following the peak of the Anabaena bloom in Yellowstone Lake (Schill pers. comm.). Turbid conditions caused by above average snow pack and

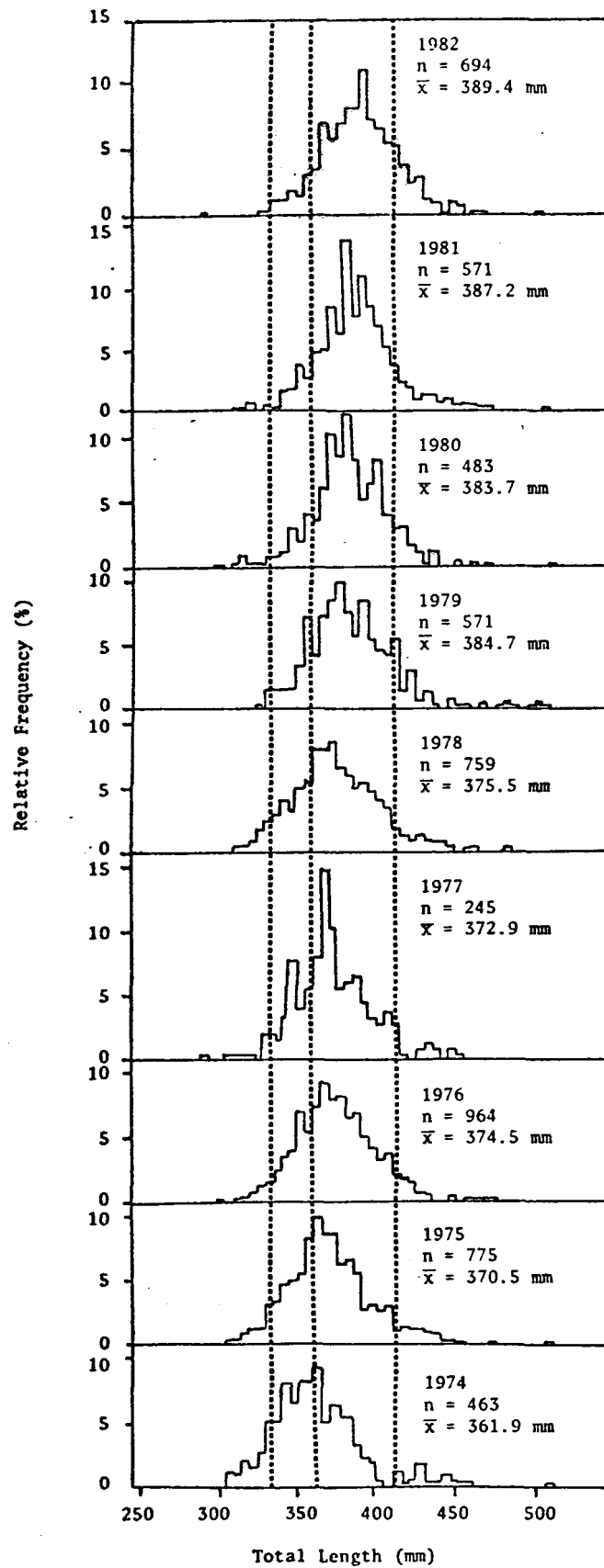


Figure 22. Length frequency of all adult cutthroat trout captured at Lellardy's Rapids, 1974-1982.

Table 23. Percentage of trout in various length categories, Catch and Release Section, Yellowstone River, 1973-1982

Year	305 mm	356 mm	406 mm	457 mm	508 mm
1973	36.3	62.5	17.3	3.1	0.7
1974	89.5	63.3	26.6	6.6	1.2
1975	92.7	60.4	15.4	2.6	0.3
1976	90.0	67.7	24.3	4.4	0.7
1977	89.2	68.7	26.2	5.3	0.9
1978	91.1	71.6	33.2	9.0	1.8
1979	92.5	77.5	35.9	8.7	1.0
1980	93.8	77.8	37.6	9.2	1.2
1981	95.4	82.6	35.8	7.6	1.1
1982	96.4	82.3	40.7	8.6	1.5

Table 24. Mean total lengths of cutthroat trout captured in the Yellowstone River, 1952-1982

Regulations	Year	Mean total length in mm (inches)				Sample size	Area	Source
		Dip net	Electrofishing	Hook and line	Creel			
5 fish bag limit, no size limit	1952 ¹⁾	368 (14.5)				382	LeHardy's Rapids	Cope 1953
	1952				330 (13.0)	107	Above Upper Falls	Cope 1953
3 fish bag limit, no size limit	1967		345 (13.6)			346	Excluding Hayden Valley	Unpublished data
	1967				338 (13.3)	127	Excluding Hayden Valley	Dean and Varley 1973
	1968		351 (13.8)			351	Excluding Hayden Valley	Unpublished data
	1968				348 (13.7)	487	Excluding Hayden Valley	Dean and Varley 1973
3 fish bag limit, 14 inch min. size limit	1970				378 (14.9)	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				368 (14.5)	125	Excluding Hayden Valley	Dean and Varley 1973
	1973				363 (14.3)	2798	Above falls, excluding Hayden Valley	Jones et al 1976
	1974 ¹⁾	362 (14.3)				463	LeHardy's Rapids	Dean et al 1975
	1974				372 (14.6)	3926	Excluding Hayden Valley	Dean et al 1975
Catch and Release	1975 ¹⁾	370 (14.6)				775	LeHardy's Rapids	Varley et al 1976
	1975				366 (14.4)	10540	Above falls, excluding Hayden Valley	Varley et al 1976
	1976 ¹⁾	375 (14.8)				964	LeHardy's Rapids	Jones et al 1977
	1976				373 (14.7)	11062	Above falls, excluding Hayden Valley	Jones et al 1980
	1977 ¹⁾	373 (14.7)				245	LeHardy's Rapids	Jones et al 1978
	1977				373 (14.7)	10239	Above falls, excluding Hayden Valley	Jones et al 1980
	1978 ¹⁾	376 (14.8)				759	LeHardy's Rapids	Jones et al 1979
	1978				382 (15.1)	8550	Above falls, excluding Hayden Valley	Jones et al 1980
	1979 ¹⁾	385 (15.2)				571	LeHardy's Rapids	Jones et al 1980
	1979				387 (15.2)	8495	Above falls, excluding Hayden Valley	Jones et al 1980
	1980 ¹⁾	384 (15.1)				483	LeHardy's Rapids	Jones et al 1981
	1980				390 (15.3)	7789	Above falls, excluding Hayden Valley	Jones et al 1981
	1981 ¹⁾	383 (15.1)				571	LeHardy's Rapids	Jones et al 1982
	1981		397 (15.6)			148	Cable Car Area	Jones et al 1982
	1981				392 (15.4)	9904	Above falls, excluding Hayden Valley	Jones et al 1982
	1982	389 (15.3)				694	LeHardy's Rapids	Current Report
	1982				395 (15.6)	8746	Above falls, excluding Hayden Valley	Current Report

¹⁾ All adults only.

late spring runoff reduced efficiency more than usual during June and July, 1982. It appears that annual variation in turbidity may be the major liability of the snorkel method for monitoring cutthroat trout in this portion of the Yellowstone River.

Trout densities vary significantly within study sections throughout the summer (Schill pers. comm.), and it has been assumed that this variation is linked to annual spawning migrations. Similar changes in distribution have been noted in Yellowstone Lake (see Summer Gillnetting, this report). In general, during the early portion of the season, trout dominated the Fishing Bridge area, both above and below the bridge. By late July sucker numbers had increased; trout numbers declined but were distributed evenly above and below the bridge. Trout numbers rose in August, and sucker numbers also remained high; however, densities of both species, especially trout, were much higher above the bridge. Trout numbers were lower in downstream sections and suckers were not observed in these areas.

The largest concentration of spawning gravel in the catch and release portion of the river occurs below Fishing Bridge. Small pockets of gravel were noted in other sections including a fairly large area at Nez Perce Ford; however, total potential was much greater for the 0.8 km below the bridge. Results from electrofishing of tributary streams (see Stream Surveys, this report) suggest that very few trout ascend these tributaries to spawn. These findings emphasize the importance of the Fishing Bridge area to the perpetuation of the cutthroat trout fishery in the catch and release section of the Yellowstone River and strongly support the closure of the Fishing Bridge to all angling since 1973. Many of the impressive changes in angling quality on both Yellowstone Lake and Yellowstone River may be at least partially due to the protection of this vital spawning area.

CONCLUSION

Angler use and effort increased steadily since catch and release regulations were implemented in 1973. Despite a precipitous decline in use after this regulation was initiated current levels are among the highest yet recorded (Table 21). In terms of fishable water in 1981, these figures equated to 3,486 angler days per km (5,600 angler days per mile), or 514 angler days per hectare (208 angler days per acre). On this basis, the catch and release portion of the Yellowstone River sustains the highest levels of use in the park and is probably one of the most intensively fished wild trout fisheries in North America.

As might be expected, increasing use and effort have affected the landing rate. As effort declined after implementation of catch and release, landing rate more than doubled and rose to a high of 2.25 trout per hour in 1974. When effort began to

increase, landing rates gradually declined. What is most significant however, is that despite record levels of effort, the landing rate remains over 1.00 trout per hour.

Despite increases in effort and concomitant decreases in landing rate, size structure of the population appears to be moving toward historic proportions. Length frequency analysis of cutthroat trout captured in the spawning run at LeHardy's Rapids reveals a definite shift towards larger trout (Figure 22) and mean length of trout captured in this study has risen significantly since 1973 (Table 23). Length frequency and mean length of cutthroat trout landed by anglers also indicates a substantial increase in larger trout (Table 24). A general increase in average age has accompanied the increase in size at LeHardy's Rapids.

Although there is an inverse relationship between effort and landing rate, changes in population structure have also influenced this measure of angler success. It must be remembered that as biomass shifts toward older and larger trout, the actual number of trout will probably decrease (Nikolskii 1969). The interaction of these two factors (increases in effort and shifts in structure) may continue to gradually lower landing rates in the future.

Two variables which are critical to the success of the catch and release regulation are hooking mortality and recatchability. Although hooking mortality studies on this section are not complete, researchers report that mortality may be less than 0.5% on a per capture basis, or 3% of the total population (Schill pers. comm.). The recatchability of the cutthroat trout is evidenced in these estimates. Comparison of total landings for the upper portion of the catch and release section (123,800 cutthroat trout) and population estimates for the 9.8 km segment (1,750 trout per km) suggests that trout may be captured an average of seven times during the 108 day season. This figure emphasizes the value of the catch and release regulation and illustrates why such a regulation can support high levels of effort on cutthroat trout.

Although it is possible that effort may rise to a point that catch and release regulations can no longer maintain angling excellence, it is evident that this regulation currently supports record levels of use while still providing the important elements of quality. Population estimates and creel data reveal the necessity for low mortality and high recatchability to accomplish these management goals. It is evident that both these factors are closely related to the species and the habitat involved. The high recatchability of the cutthroat trout and the excellent habitat conditions in this portion of the Yellowstone River undoubtedly contribute to the continued success of the catch and release regulation.

LEWIS-SHOSHONE LAKES REGION

One of the primary purposes of the fishery management program is to preserve and restore native species and aquatic habitats. This objective dates back to 1936 with the formation of the first formal stocking policy (Varley 1981). This policy not only afforded protection to populations of native species but it also protected the genetic integrity of established populations of non-native fish by preventing genetic contamination. Many of these non-native populations were established prior to 1936 in historically barren waters (providing isolating mechanisms) with pure genetic stocks (Varley 1981). This was the case with the populations of brown, lake, and brook trout established in the Lewis-Shoshone Lakes region (all lakes and streams within the Lewis River drainage above Lewis Falls).

Historically, all waters in the Lewis River drainage above Lewis Falls were fishless (Jordan 1891). The first known stocking occurred in 1890 when brown and lake trout were planted into Lewis and Shoshone Lakes (Varley 1981). These initial plants were followed by two more plants in the 1890's: (1) brook trout in Shoshone Creek (1893), and (2) rainbow trout in DeLacy Creek and Lake (1895). The genetic integrity of the populations that became established by these initial stocking has remained intact to present and these unaltered gene pools are considered a valuable resource.

ANGLER IMPACT

The Lewis-Shoshone Lakes region has been a popular fishing area since the late 1890's and early 1900's. When describing fishing in Yellowstone Park, Clark (1908) referred to this region as "probably the best fishing district in the park". This enthusiasm is probably not shared by all anglers today, however, this region is still revered (Brooks et al 1981) and hosts almost 6% of the total parkwide angler days. Despite rather consistent angler use, this region has not been studied as extensively and the impact of anglers is not as well documented as other park fisheries.

In 1982, angler use was spread over eight areas within the Lewis-Shoshone Lakes region. Of these eight areas, four had a significant amount of angling pressure; Lewis Lake; Shoshone Lake; Lewis River (between Lewis Lake and Lewis Falls, hereafter referred to as the Lewis River); and the Lewis-Shoshone Channel.

Methods

The major method of monitoring the populations of brown and lake trout in the four major fisheries in the Lewis-Shoshone Lakes region has been through use of manned creel census and the VFR system. To identify trends within these fisheries, comparisons

were made for the years 1963-1982 for Lewis Lake; 1973-1982 for Shoshone Lake; 1973-1982 for the Lewis-Shoshone Channel; and 1977-1982 for the Lewis River. To evaluate trends between these fisheries, mean values of the fishery indicators (angler use, ect.) were statistically tested at the 95% level of confidence.

Lewis Lake

Lewis Lake is the third largest lake in the Park (1099 ha). The elevation is 2371 m. It has one major inlet (Lewis-Shoshone Channel) and one major outlet (Lewis River) (Figure 23). The maximum depth has been recorded at 32.9 m (Dean 1972). Approximately 25% (281 ha) of the surface area of the lake has been recorded as over 27.4 m deep (Figure 23).

On an annual basis, Lewis Lake has received more angler use than all of the other major fisheries in this region (Table 25). During 1982, approximately 3300 anglers fished this lake (Table 26). Since 1980, both fishing pressure (angler hours) and angler use (angler days) have been declining (Table 25). An average of 66% of these anglers used boats (Table 25). Average yearly fishing pressure measured in hours/hectare was 8.46.

Brown trout have dominated the catch in this lake. An average of 73% and 24% of the catch has been brown and lake trout, respectively. Brown trout average higher landing and creel rates (0.37 and 0.13 fish/hour, respectively) than lake trout (0.13 and 0.01 fish/hour, respectively). No downward trend in landing or creel rates exist in this fishery (Table 25).

Length frequency distribution of brown and lake trout landed by anglers in the last six years has not changed significantly. On an average yearly basis, 53.9% and 91.8% of the brown and lake trout landed have been longer than 356 mm, respectively.

Shoshone Lake

Shoshone Lake is the second largest lake in the Park (3258 ha). The elevation is 2374 m. It has several major tributaries and one outlet (Lewis-Shoshone Channel) (Figure 24). Major tributaries include Cold Mountain Creek; Delacy Creek, Moose Creek; and Shoshone Creek. Steep contours are characteristic of most shores (Figure 24). The maximum depth has been recorded at 625 m (Sharpe and Arnold 1966). Approximately 56% (1431 ha) of the surface area of the lake is over 27.4 m deep (Figure 24).

Over the past 10 years (1973-1982), Shoshone Lake has received an average of 7000 days of angler use per year (Table 25). During 1982, approximately 2400 anglers fished this lake (Table 26). Since 1980, both angler use (angler days) and fishing pressure (angler hours) have been declining (Table 25). An average of 83% of the anglers who have fished this lake used boats (Table 25). Average yearly fishing pressure measured in hours per hectare was 2.15.

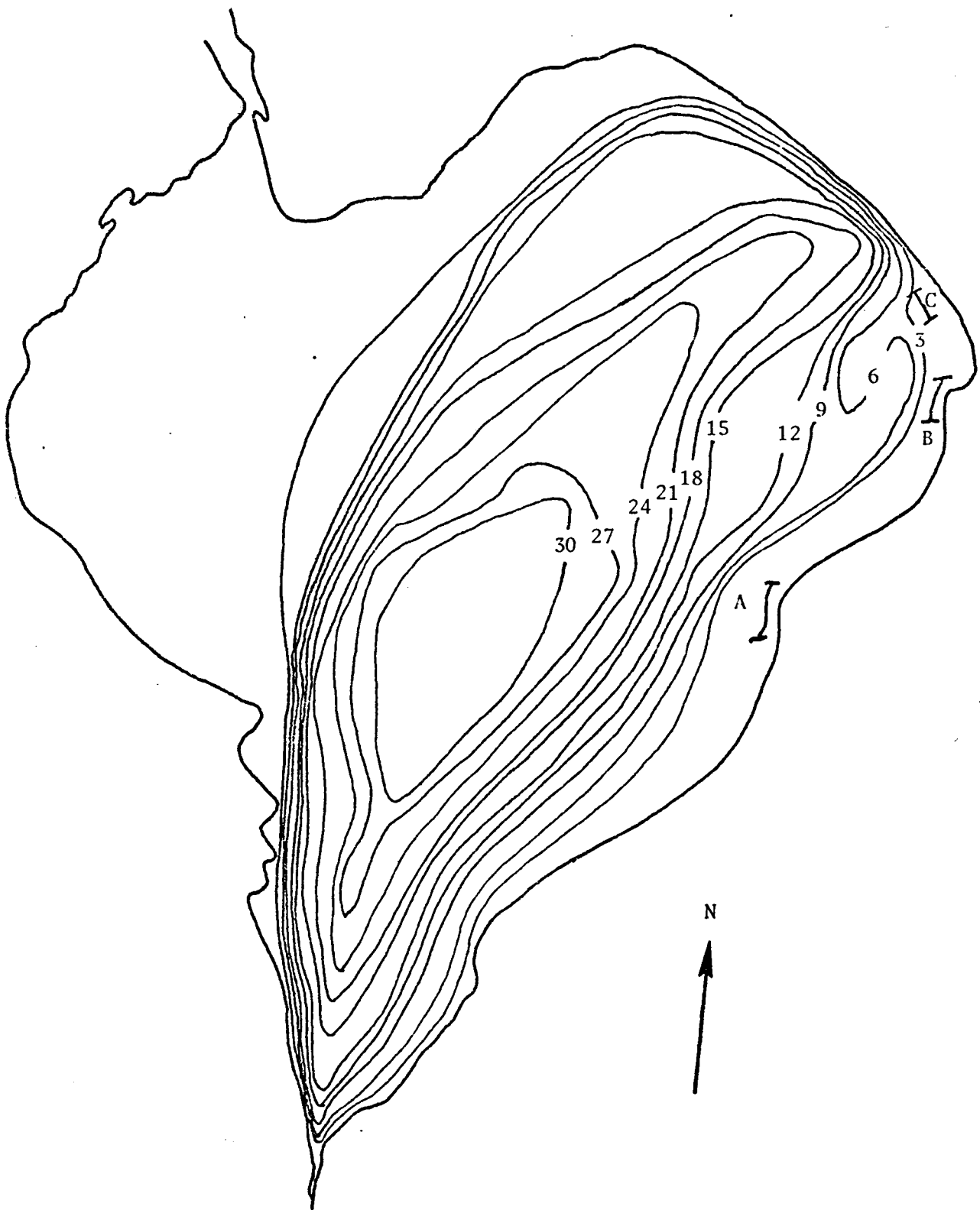


Figure 23. Map of Lewis Lake with the locations of sampling sites for the 1982 spawn taking operation indicated.

Table 25. Creel survey summary, Lewis Lake (1963-1982), Shoshone Lake (1973-1982), Lewis-Shoshone Channel (1973-1982) and Lewis River between Lewis Lake and Lewis Falls (1977-1982)

Year	Angler days	X Length angler day	Angler hours	Landing rate	Total fish landed	Creel rate	Total fish creeled	% Composition			X size landed	X size creeled	Use		
								Lake	Brown	Brook			% Composition	Boat	Shore
Lewis Lake : Boat and shore combined															
1963	11,000	3.0	33,900	0.42	13,800	0.42	13,800	17	83	0	---	---	--	--	
1975	5,400	2.4	12,800	0.67	8,500	0.28	3,600	22	78	0	361	---	--	--	
1976	8,600	2.6	22,000	0.70	15,400	0.23	5,100	28	72	0	350	---	--	--	
1977	8,300	3.0	25,100	0.53	13,200	0.23	5,900	27	70	3	378	356	70	30	
1978	8,800	2.9	25,000	0.52	13,000	0.21	5,200	29	69	2	363	392	68	32	
1979	9,300	3.2	29,600	0.56	16,600	0.17	5,100	32	62	6	364	400	64	36	
1980	11,800	3.2	37,100	0.48	17,700	0.17	6,200	19	76	5	356	372	66	34	
1981	11,900	2.9	34,900	0.48	16,800	0.18	6,300	16	79	5	350	373	64	36	
1982	8,400	3.0	25,200	0.43	10,800	0.14	3,600	29	69	2	370	383	66	34	
X	9,277	2.9	27,289	0.53	13,978	0.23	6,089	24	73	8	362	379	66	34	
s _x	683	0.08	2,515	0.03	1,003	0.03	1,019	2	2	1	3	6	1	1	
Shoshone Lake : Boat and shore combined															
1973	5,000	3.8	19,200	0.57	10,900	0.12	2,300	84	10	6	---	---	--	--	
1974	4,400	4.2	18,600	0.30	5,500	0.15	2,800	82	12	6	---	---	--	--	
1975	4,300	4.2	18,000	0.38	6,800	0.15	2,700	85	14	1	453	---	87	13	
1976	7,200	3.8	27,000	0.49	13,200	0.15	4,100	78	21	1	441	---	81	19	
1977	8,600	3.6	31,200	0.45	14,000	0.18	5,600	81	15	4	441	442	88	12	
1978	7,700	3.2	25,000	0.45	11,200	0.16	4,000	75	18	7	432	447	83	17	
1979	8,900	3.2	21,700	0.47	12,500	0.16	3,400	85	8	7	438	482	87	13	
1980	10,800	3.3	35,100	0.40	14,200	0.13	4,400	85	14	1	464	457	94	6	
1981	9,000	3.6	32,300	0.58	18,700	0.13	4,200	83	15	2	462	459	87	13	
1982	8,200	2.4	20,000	0.41	8,300	0.15	3,000	78	22	0	453	461	92	8	
X	7,007	3.5	24,790	0.45	11,540	0.15	3,280	82	15	3	448	458	87	13	
s _x	936	0.17	1,994	0.03	1,233	0.01	445	1	1	1	4	5.6	2	2	
Lewis-Shoshone Channel															
1973	700	3.0	2,200	0.53	1,200	0.10	200	42	53	5	---	---	--	--	
1974	1,900	3.2	6,000	0.64	3,800	0.10	600	13	86	1	---	---	--	--	
1975	500	3.0	1,600	0.60	1,000	0.30	500	20	68	12	---	---	--	--	
1976	1,200	2.9	3,600	0.67	2,400	0.17	600	15	84	1	413	---	--	--	
1977	1,600	3.0	5,000	0.55	2,700	0.14	700	15	80	5	408	387	--	--	
1978	1,600	3.3	5,300	1.16	6,100	0.17	900	1	99	0	447	454	--	--	
1979	1,500	2.7	3,900	0.52	2,000	0.12	500	9	90	1	423	452	--	--	
1980	1,700	2.8	4,700	1.42	6,700	0.09	400	6	91	3	432	402	--	--	
1981	1,300	2.2	2,900	0.48	1,400	0.19	500	18	82	0	416	437	--	--	
1982	700	2.8	1,900	0.86	1,600	0.18	300	24	75	1	438	428	--	--	
X	1,280	2.9	3,700	0.74	2,390	0.16	520	16	81	3	425	427	--	--	
s _x	150	0.09	482	0.10	641	0.02	59	4	4	1	5	11	--	--	
Lewis River : Lewis Lake to Lewis Falls															
1977	1,200	2.1	2,500	0.98	2,500	0.16	400	9	80	11	285	330	--	--	
1978	---	---	---	---	---	---	---	1	96	3	282	363	--	--	
1979	800	1.6	1,200	0.47	600	0.07	100	0	92	8	292	370	--	--	
1980	1,000	2.0	2,100	1.03	2,100	0.43	300	7	84	9	350	376	--	--	
1981	1,600	2.3	3,600	1.05	3,800	0.13	500	6	77	17	280	374	--	--	
1982	1,500	2.1	3,200	0.81	2,600	0.07	200	2	71	27	300	422	--	--	
X	1,220	2.0	2,520	0.87	2,320	0.17	293	4	83	13	298	373	--	--	
s _x	153	0.12	421	0.11	515	0.07	66	2	4	3	11	12	--	--	

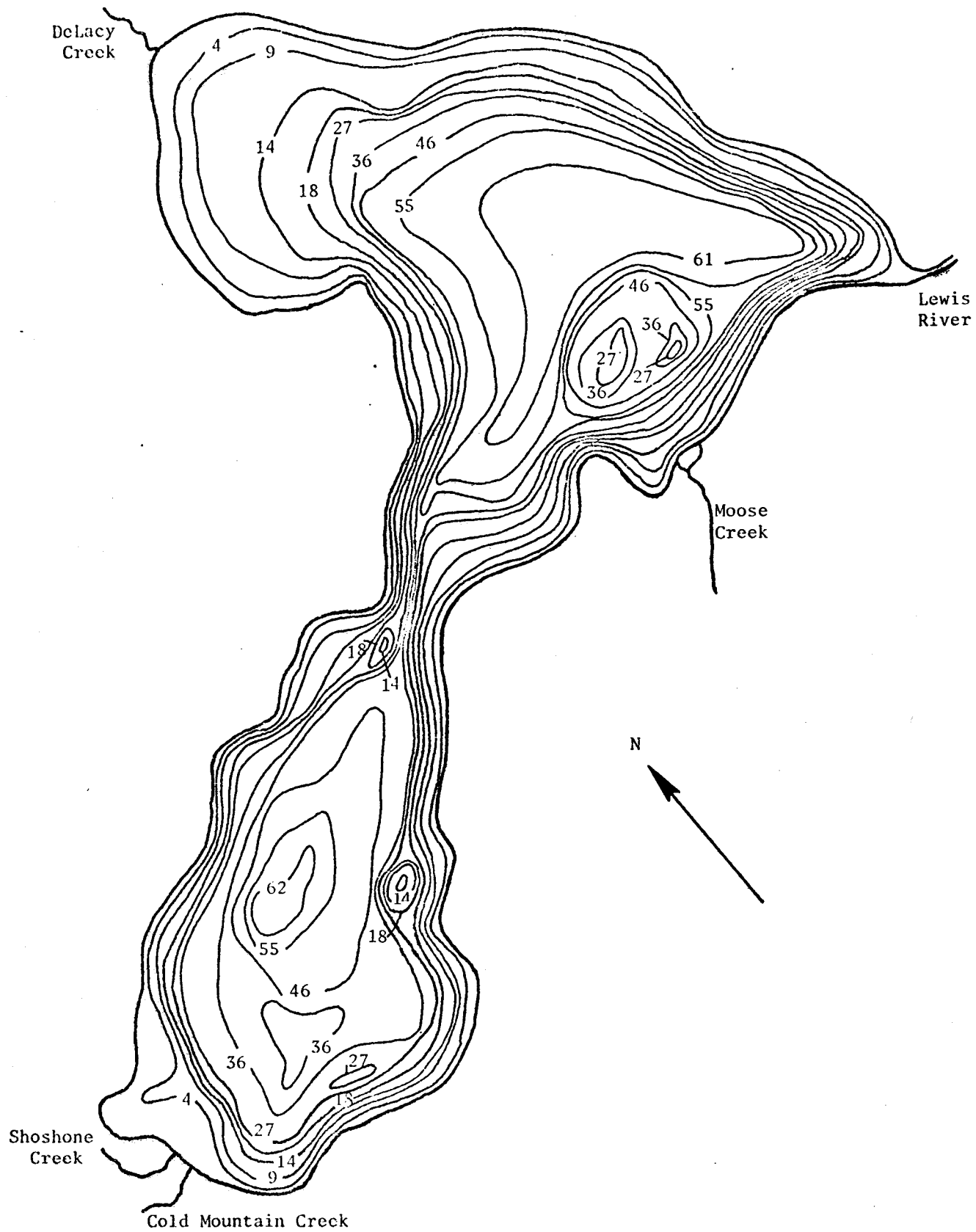


Figure 24. Shoshone Lake, Yellowstone National Park.

Lake trout have dominated the catch in this lake. An average of 82% and 15% of the catch has been lake and brown trout, respectively. Lake trout averaged higher landing and creel rates (0.41 and 0.12 fish/hour, respectively) than brown trout (0.19 and 0.04 fish/hour, respectively). No downward trend in landing or creel rates exist in this fishery (Table 25).

Length frequency distribution of brown and lake trout landed by anglers in the last six years has not changed significantly. On an average yearly basis approximately 97% and 87% of the lake and brown trout landed have been longer than 356 mm, respectively. The two species combined represent the longest average length fish caught in Yellowstone Park during 1982 (Table 5).

Lewis-Shoshone Channel

The Lewis-shoshone Channel has been estimated at approximately 4.8 km in length (Sharpe and Babcock 1964). It is characterized as having three general habitat sections (Sharpe and Babcock 1964). The closest section to Lewis Lake (1.6 km long) generally has slow moving water with a channel width ranging from 22.9 to 38.1 m and depths from 1.8 to 3.7 m. The middle section (1.6 km long) has widths, depths, and water velocities similar to those described for the first section, however, the substrate is composed of fine sand. The upper most section (1.6 km long) has reported widths from 18.3 to 27.4 m, water velocities from 0.9 to 1.8 m/sec, and an average depth of 0.6 m.

Over the past 10 years (1973-1982) the channel has received an average of 1300 days of angler use per year (Table 25). During 1982, approximately 400 anglers fished 676 angler days in this area. Approximately 40% of these anglers fished during September and October. Since 1980, both angler use and effort have been declining (Table 25). Based on Sharpe and Babcock's (1964) physical description of this area, average yearly fishing pressure measured in hours per hectare has been approximately 2500.

Brown trout have dominated the catch in this area. An average of 81% and 16% of the catch have been brown and lake trout, respectively. Landing and creel rates for brown trout from 1977 to 1982 averaged approximately 0.7 and 0.1 fish/hour, respectively. These catch rates, however, are highly variably. Because of this variability, no trends are apparent in landing or creel rates for this fishery.

Length frequency distribution of brown trout landed by anglers in the last six years has not changed significantly. In 1982, approximately 99% of these trout were longer than 356 mm.

Lewis River

Little information is available on the physical and biological characteristics of this section of river because it has not been surveyed. It is approximately 1.9 km long (Jones et al 1979) and is reported to support brown trout spawning activities (Brooks et al 1981).

Since 1977, it has hosted an average of approximately 1200 days of angler use per year (Table 25). During 1982, an estimated 900 anglers expended 1500 angler hours in this area (Table 26). The trend in angler use, for this area, has been increasing since 1979. This is the only fishery in this region where use was increasing in 1982 (Tables 25).

This section of the Lewis River may also be characterized as a brown trout fishery. Brown trout, on the average, have been a larger percentage of the catch (83%) in this area than any of the other areas in this region (Table 25). Landing and creel rates for brown trout since 1977 have averaged 0.8 and 0.2 fish/hour, respectively. Both landing and creel rates tend to have been declining since 1980 (Table 26). This trend, however, is based on limited information.

The majority (63.6%) of brown trout landed in this area, in 1982, were less than 356 mm. The length frequency of landed brown trout has not changed significantly since 1977.

Discussion

At present, there is no evidence to suggest that angler use is adversely affecting the populations of brown and lake trout in this region. This preliminary conclusion, however, is based solely on results from the VFR system. Age and growth information (Table 26) and length frequency information (Table 27) are limited and no conclusions from these sources can be drawn. The affect of shifts in fish species composition on the lake and brown trout populations, also has not been documented.

Lewis Lake. Lewis Lake has generally contained a brown trout fishery with approximately 73% of the catch made up by this species. The catch rate of brown trout, furthermore, is higher than the catch rate of lake trout. The dominance of brown trout in this fishery is probably related to the physical characteristics of Lewis Lake. Brown trout habitat is probably more abundant in the lake than lake trout habitat since 75% of the surface area of the lake is less than 27.4 m deep (Figure 23).

Table 26. Back-calculated lengths at annulus formation for fish collected from the Lewis-Shoshone Lakes region (1960-1975)¹⁾

Location	Year	Species	Sample Size	I	II	III	IV	V	VI	VII	VIII	IX	X
Lewis Lake	1971	brown trout	36	48	150	257	330						
		lake trout	11	66	145	218	297	356	414				
		Utah chub	48	25	51	89	132	168	206				
Shoshone Lake	1960	lake trout	18	79	168	244	325	412	467	518	607	648	
		brown trout	4	46	140	254							
	1965	lake trout	9	89	175	266	344	413	459	523	585		
		brown trout	6	68	159	278	385	497					
	1975	lake trout	39	65	133	213	289	357	400	432	466	517	654
		brown trout	24	100	210	327	426	464	503				
		brook trout	2	27	183	267	371						
		Utah chub	9	30	79	133	171	205	229	261			

¹⁾ References; Benson (pers. comm.) 1960, Sharpe and Arnold 1966, Dean 1972, Varley et al 1976.

Table 27. Summary of information collected from fish sampling activities in the Lewis-Shoshone Lakes region, Yellowstone National Park, 1964-1982

Area	Sample		Length ¹⁾ (mm)		Source
	Year	Method	Brown	Lake	
Lewis Lake					
	1964	Electrofishing	363 (170-480)	414 (380-480)	project files
	1968	Electrofishing	285 (155-350)	444 (370-510)	project files
	1971	Gillnets	350 (185-445)	360 (240-450)	Dean 1972
	1982	Electrofishing	--- ---	463 (334-1070)	current report
Shoshone Lake					
	1960	Gillnets	--- (285-380)	--- (485-660)	Benson pers. comm. 1960
	1965	Gillnets	--- (245-535)	--- (120-545)	Sharpe and Arnold 1966
	1975	Gillnets	327 (121-537)	439 (200-680)	Varley et al 1976
Lewis-Shoshone Channel					
	1963	Electrofishing	419 ---	--- ---	Sharpe and Babcock 1964
	1971	Creel Census Clerk	420 (340-545)	--- ---	Dean 1972
	1976	Creel Census Clerk	457 (378-549)	--- ---	Jones et al 1977

1) Lengths given as means with ranges in parenthesis.

Table 28. Fish species composition of the Lewis-Shoshone Lakes region based on sampling by fishery survey crews (1963-1982)¹⁾

Location	Brown Trout	Lake Trout	Brook Trout	Cutthroat Trout	Utah Chub	Redside Shiner	Longnose Dace
Lewis Lake	1964	1964	1971	----	1964	1971	1982
Snoshone Lake	1965	1965	1975	----	1965	----	----
Pocket Lake	----	----	1972	1978	----	----	----
Lewis-Shoshone Channel	1963	1963	1963	----	1963	----	----
Cold Mountain Creek	----	----	1965	----	----	----	----
Shoshone Creek	1965	----	1965	----	----	----	----
Summit Creek	1979	----	----	----	----	1979	----
Unnamed (#1940)	----	----	----	----	----	1979	----
Unnamed (#1946)	----	----	1979	----	----	----	----

¹⁾ References; Shapre and Babcock 1964, Sharpe and Arnold 1966, Dean 1972, Jones et al 1980.

With the collection of Utan chub (Sharpe and Arnold 1965), redbside shiner (Dean 1972) and the longnose dace (current report), the community composition of fish species in Lewis Lake has changed more than any of the other fisheries in this region (Table 28). If this change has affected the brown and lake trout populations in this lake it cannot be determined on the current amount of information. It is important to note, however, that a fish species never before sampled in this region was found in Lewis Lake during the 1982 spawn taking operation (Table 28). This fact emphasizes the need to closely monitor anglers to prevent the further distribution of fish species in the park.

Shoshone Lake. Shoshone Lake has generally contained a lake trout fishery with approximately 80% of the catch made up by this species. The catch rate of lake trout, furthermore, is higher than the catch rate of brown trout. The dominance of the lake trout in this fishery is also probably related to the physical characteristics of Shoshone Lake. Lake trout habitat is probably more abundant in the lake than brown trout habitat since the lake contours are very steep and 56% of the lake (or 1431 ha) surface area is over 27.4 m deep (Figure 24).

Species composition, landing rates for brown and lake trout, and creel rates for brown and lake trout in Shoshone Lake have been almost the opposite of those in Lewis Lake. As mentioned above, these differences are probably related to the physical characteristics of each lake.

The size of brown and lake trout landed in Shoshone Lake, however, has been larger than the sizes of lake and brown trout landed in Lewis Lake. With the number of possible variables and limited amount of information it is hard to speculate on the reason for this difference. Fishing pressure on Lewis Lake, however, is much greater (8.46 hours/hectare) than Shoshone Lake (2.15 hours/hectare) and might be one possible explanation.

Lewis-Shoshone Channel. The channel has supported a brown trout fishery with almost 81% of the catch made up by this species. Hydrological parameters in the channel allow brown trout spawning in the fall. Approximately 40% of the angler use in 1982 occurred during this period. No determination has been made of the percentage of brown trout migrating from each lake. Observations, however, imply that the majority of the fish in the channel migrate upstream from Lewis Lake. Fishing pressure, in this area, is the highest in the Lewis-Shoshone Lakes region measured in hours/hectare (2500). Landing rates for recent years have been fairly variable (Table 25). If a downward trend in this fishery is occurring it cannot be detected based on current information.

Lewis River (between Lewis Lake and Lewis Falls). The Lewis River may also be characterized as a brown trout fishery, furthermore, brown trout have been a larger percentage of the

catch in this area than any of the other areas. Although brown trout have been reported to utilize this area for spawning, no evidence was present to confirm a spawning migration out of Lewis Lake. The majority (63.6%) of brown trout landed in this area in 1982 were less than 356 mm. In the channel, where a known spawning run exists, approximately 0.9% of the brown trout landed in 1982 were less than 356 mm. The size distribution of brown trout in this area implies, therefore, that the fishery is based on a resident brown trout population. This preliminary hypotheses, however, needs further investigation.

SPAWN TAKING OPERATION

Recognition of the importance of the sustained genetic integrity of the Lewis Lake brown and lake trouts became evident in 1982 when fertilized eggs from these species were requested by the Fish and Wildlife Service. Eggs from the lake trout were requested to establish a hatchery brood stock for eventual restocking of the Great Lakes. Eggs from the brown trout were requested to refurbish hatchery brood stocks by introducing wild brown trout genes into domesticated stocks. A spawn taking operation, therefore, was initiated on Lewis Lake in 1982.

Methods

The collection of fertilized lake trout eggs was attempted on four different dates during 1982: October 4, 13, 20, and 28. Lewis Lake was generally sampled at three sites on these dates. These locations were designated as Sites A, B and C (Figure 23). All fish were captured using boat electrofishing gear. The main objective of the fish capture was to collect fertilized eggs, therefore no set procedure was followed and generally only observations were recorded. The collection of brown trout eggs was not attempted, however, spawning areas were checked for brown trout in spawning condition.

Disease samples were collected from 92 lake trout and 10 brown trout. These samples were sent to the Fish and Wildlife Service Fish Disease Control Center (Ft. Morgan, Colorado) for analysis. Diagnostic tests included evaluation for the following pathogens; Aeromonas salmonicida, Enteric redmouth bacterium, Salmonid kidney disease bacterium, Viral Hemorrhagic Septicemia Virus, Infectious Hematopoietic Necrosis Virus, and Infectious Pancreatic Necrosis Virus.

Results

A total of approximately 490 lake trout and 35 brown trout were captured during the spawn taking operation. The largest number caught and highest catch rate occurred on 20 October (Table 28). Catch rates varied from 20 fish/hour to 87.5 fish/hour (Table 28). Sex ratio varied from 1 male/female (4 October) to 30 males/female (20 October) (Table 28). Most lake trout were

captured over a substrate of large cobble and gravel in a water depth of 2-3 m. A total of approximately 6000 lake trout eggs were collected from 10 females.

Approximately 65% (3900) of the collected eggs were hatched and fry trained to feed. Due to the low number of females that eggs were taken from, the young that survived were not used to establish a brood stock. The low number of ripe females captured was directly related to the spawning behavior of these fish.

Discussion

The peak of spawning activity for lake trout, in Lewis Lake, probably occurred during the week of 20 October. This period was characterized by a high male/female sex ratio (Table 29), high catch rate (Table 29), and a mature sexual condition of captured fish. Large numbers of males were congregated in schools in the spawning area. Females, however, were captured in low numbers. Females have been reported to congregate in deep water away from these spawning areas (Keifling pers. comm., Griest 1977, Walch 1980). When they were ready to spawn, they entered the spawning areas, laid their eggs and left. The numbers that entered at any time was generally reported to be low. This would explain the low catch of females. The females were probably in water too deep to be captured by electrofishing gear. The shift in sex ratios, therefore, should provide a good indicator of the peak of spawning activity.

The sites that the lake trout were selecting to spawn were indicated by catch rates at the various sampling areas (Table 28). Generally, the highest catch rates occurred at Sites A and B. These areas were directly off shore of points on the east side of the lake (Figure 23). They were further characterized by a steep gradient on the inward lake side. Substrate was a large-cobble-sand-silt mixture. Water depths ranged from 1.3 to 2.3 m. Areas where low numbers of lake trout were captured (Site C) had gradual gradients, water depths from 1.3 to 2.3 m, and an almost exclusive sand substrate.

Brown trout spawning patterns were not identified. The one sampling trip to the channel revealed few brown trout. This could have been due to day versus night sampling, however, few brown trout were observed spawning in the channel. The low catch rate, therefore, could have been due to a failure to sample during the peak of spawning activity. In 1963, Sharpe and Babcock (1964) electrofished the channel on several dates in September. They reported a high catch rate (300 fish/hour) during night electrofishing in early September. This could indicate that the peak of the brown trout spawning activity in the channel is during September and not October. Further investigation is needed to correctly identify these patterns.

Table 29 . Summary of catch rates, sex ratios, numbers, and species of fish captured during spawn taking operations on Lewis Lake, 1982

Site	Sample		Number Captured ¹⁾		Effort (hours)	Catch Rate (fish/hour)	Sex Ratio (males:females)	Lake trout			
	date	time	lake trout	brown trout				Length (mm)		Weight (mg)	
								Mean	Range	Mean	Range
Lewis Lake											
A	10/13	2000-2130	35	--	1.0	35.0	3	---	---	---	---
	10/20	1900-2330	75	--	1.0	75.0	30	---	---	---	---
	10/28	1900-2200	50	--	1.0	50.0	2	---	334-485	---	---
B	10/4	2000-2300	60	10	2.5	28.0	1	469	378-1070	---	---
	10/13	1600-1700	--	--	0.5	--	--	---	---	---	---
	10/13	2000-2130	5	10	0.5	30.0	1	---	---	---	---
	10/20	2000-2330	175	--	2.5	87.5	30	---	381-508	---	2.3-9.1
	10/28	1900-2200	50	--	1.0	50.0	2	---	334-485	---	---
C	10/4	2000-2300	10	--	0.5	20.0	1	---	---	---	---
	10/13	2000-2130	10	--	0.5	20.0	1	---	---	---	---
	10/20	2000-2330	20	5	0.5	50.0	30	---	---	---	---
Lewis-Shoshone											
Channel	10/13	1400-1600	--	10	1.0	20.0	--	---	---	---	---

1) Actual number of fish captured was not generally recorded, however, a range of numbers were recorded and the number captured here is the midpoint of those ranges.

LAKE SURVEY PROGRAM

INTRODUCTION

Since 1964, data describing the basic physical, chemical and biological parameters of 112 Park lakes has been collected in conjunction with the lake survey program. The objective of this program has been the fundamental inventory of lacustrine systems to provide baseline data necessary to assess changes through time. Analysis of angler impact has been an integral part of this program and has been utilized to monitor the effects of various angling regulations. In 1982, aquatic surveys were conducted on three lakes.

Although field collection techniques have varied somewhat during the past 18 years, data are reasonably comparable. With few exceptions, current methods are those described by Dean and Mills (1970). Since 1974, one water sample from each lake has been comprehensively analyzed by a commercial laboratory. In order to enhance comparability, additional samples have been collected for many of the lakes surveyed prior to 1974.

Plankton samples have been collected with a Wisconsin plankton net, and a single 9.1 m oblique tow, or its equivalent, was made in each lake since 1973. From 1973 through 1980, plankton were enumerated by a method modified from McNabb (1960). Beginning in 1981, zooplankton and phytoplankton samples were quantified using methods described by Wetzel and Likens (1979).

Both largemouth and smallmouth experimental gillnets have been utilized to sample aquatic vertebrate populations since 1971. The largemouth nets are 38.1 m long with 7.6 m graduated mesh panels of 19, 25, 32, 38 and 51 mm bar mesh. Smallmouth nets are 30.5 m long with four 7.6 m panels of 10, 13, 16 and 19 mm bar mesh. Both types are approximately 1.8 m deep and constructed of monofilament materials.

CASCADE LAKE

Cascade Lake is a popular backcountry lake located near Canyon Village in the central portion of Yellowstone Park. It is the source of Cascade Creek which for many years was the primary culinary water supply for Canyon Village. Two short trails (4 km) in the Canyon Village vicinity provide easy access to the lake and greatly contribute to its popularity.

Cascade Lake was originally barren of fish but may have received a stocking of 50 cutthroat trout from Yellowstone Lake as early as 1889 (Jordan 1891). In 1928, 50,000 fingerling, presumably cutthroat trout, were stocked in Cascade Lake, and Cascade Creek was planted with cutthroat trout in 1889, 1901 and 1922-25 (Varley 1981). Between 1933-43 and 1949-55 the lake received annual plants of grayling (totaling almost 2.5 million) from the Grebe Lake hatchery.

The grayling population has been protected by the Parkwide catch and release-only regulations since 1969. Park angling regulations permitted the possession of 2 cutthroat trout until intense harvest rates forced the change to catch and release regulation in 1978.

A lake survey conducted in 1969 provided a description of the physical and chemical properties of Cascade Lake as well as information concerning the fish populations during the initial year of the grayling catch and release regulation (Dean and Mills 1970). The lake was resurveyed in 1978, to assess the status of the grayling population and provide baseline data on the cutthroat population for future evaluation of the lakewide "no harvest" restriction (Jones et al 1979).

An abbreviated lake survey conducted on August 19-20, 1982, provided information necessary to assess the current status of the two fish species in Cascade Lake.

Physical

A detailed description of the physical properties of Cascade Lake was reported by Jones et al (1979). During the present survey, the tea-brown water of the lake yielded a secchi disc reading of 4.3 m on a calm, sunny day (Table 30). A phytoplankton "bloom" was apparently responsible for the slightly turbid conditions. Water temperature varied from 17.5 C at the surface to 5.6 C at the bottom (7.6 m). The lake was stratified with a thermocline occurring between 3.0-6.0 m.

Chemical

Comprehensive chemical analysis was not conducted in 1982, but those components which were evaluated varied little from previous surveys (Jones et al 1979). Conductivity (49 umhos) and pH (7.2) were typical for dilute sodium-bicarbonate lakes from rhyolitic drainages in the Park. Total hardness, total alkalinity and nitrate nitrogen were 17.1, 2.7, and 0.02 ppm, respectively.

Limnoplankton

Significant differences were noted between the previous plankton sample (Jones et al 1979) and the current sample (Table 31). Such changes are common under natural conditions, however, because of the sensitivity of plankton to extremely small changes in the physical and chemical environment (Wetzel 1975). Changes in the method of plankton analysis beginning in 1981 (Jones et al 1982) may also influence this comparison.

Phytoplankton diversity (7 genera) was over twice as high as 1978 (3 genera) and was well over the Park mean (4 genera). Crustacean diversity (5 forms) increased slightly, but species

Table 30. Physical characteristics of backcountry lakes surveyed in Yellowstone Park, 1982

Lake	Location ¹⁾	Elevation		Drainage Area		Surface Area ²⁾		Maximum Depth		Average Depth		Capacity		Secchi Visibility		Tributary to:	Major Drainage:
		meters	feet	hectares	acres	hectares	acres	meters	feet	meters	feet	m ³	acre ft.	meters	feet		
Cascade Lake	534E 4955N	2432	7980	233	575	14.6	36 ³⁾	7.6	25	4.1	13.5 ⁴⁾	599,539	486 ⁴⁾	4.27	14	Cascade Creek	Yellowstone River
McBride Lake	559E 4979N	1999	6560	130	320	9.3	23 ⁵⁾	6.7	22	3.7	12	326,915	265 ⁵⁾	4.27	14	Slough Creek	Yellowstone River
Lake #1310	496E 4957N	2012	6600	720	1780	2.8	7	1.1	3	0.4	1.4	12,003	9.7	0.91	3	Duck Creek	Hudson River

¹⁾ Coordinates utilizing Universal Transverse Mercator 1000 meter Grid System on USGS map, Yellowstone National Park, N440d-w10942/59x82, 1961

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

³⁾ Reported by Jones et al (1979).

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

⁵⁾ Reported by Varley et al (1976).

Table 31. Occurrence and density (number per liter) of common net plankton from Yellowstone Park, 1982

Genera	Cascade Lake	McBride Lake	Lake #1310
Division Chrysophyta (yellow-green algae)			
<u>Melosira</u>	45	537	X
<u>Synedra</u>	27		
Unidentified diatoms	27	2,326	X
Division Cyanophyta (blue-green algae)			
<u>Anabaena</u>	58	7,157	
<u>Aphanizomenon</u>	7,783	418,404	
<u>Gloeotrichia</u>	121	4,115	
<u>Nostoc</u>			X
Division Chlorophyta (green algae)			
<u>Genicula</u>	13	1,789	
Class Rotatoria (rotifers)			
<u>Conochilus unicornis</u>		41	
<u>Keratella cochlearis</u>		0.2	
<u>Keratella quadrata</u>		3.2	
Order Cladocera (water fleas)			
<u>Alona sp.</u>			X
<u>Bosmina sp.</u>			X
<u>Ceriodaphnia sp.</u>			X
<u>Daphnia pulex</u>	9	3	
<u>Daphnia schødleri</u>	4	9	
<u>Holopedium gibberum</u>	0.2		
Order Copepoda (copepods)			
<u>Cyclops bicuspidatus thomasi</u>			X
<u>Diaptomus shoshone</u>	16	0.3	
<u>Nauplii</u>	1	2	
Total Phytoplankton/liter	8,074	434,628	
Total zooplankton/liter	30.2	58.7	
Total plankters/liter	8,104.2	434,686.7	
Number genera/lake	12	14	7

composition was quite different, and densities were much lower in 1982. Although 2 rotifer genera were reported in 1978 (Jones et al 1979), none were observed in the current sample.

Phytoplankton densities (8074 plankters/liter) were almost 80 times higher in 1982 and reflect the observed bloom in progress during the survey; these densities were above average for Park lakes where blooms have been noted. Numbers of the bloom species, Aphanizomenon, a blue-green algae, may partially explain decrease in zooplankton densities; however, intense grazing by the fishes of Cascade Lake may also influence zooplankton numbers (Hutchinson 1967).

Although blue-green algae, such as Aphanizomenon, Gleotrichia and Anabaena, are often associated with eutrophic waters, the nitrogen fixing ability of these forms often allows them to dominate oligotrophic plankton communities at times when nitrogen becomes limiting (Hutchinson 1967). The observed differences in the plankton samples from Cascade Lake in 1978 and 1982 parallel a concomitant decrease of 79% in the level of nitrate nitrogen.

Although diatoms, such as Melosira and Synedra, are often associated with blue-green algae in eutrophic lakes, they also commonly dominate neutral to slightly alkaline, nutrient poor waters such as Cascade Lake (Wetzel 1975). Wetzel (1975) has cautioned that characterization of waters by plankton associations is confounded by the great number of permutations and the high seasonal variation, but it does provide insight into the relationship between nutrient availability and plankton density and diversity.

The absence of rotifer genera is curious since they were the dominate form in 1978 (Jones et al 1979). Rotifers are generally common when piscine predation is extensive (Hutchinson 1967), but lower densities of other zooplankters and the absence of larger individuals also suggest that substantial grazing occurs in Cascade Lake.

Aquatic Vertebrates

One smallmesh and two largemesh experimental gillnets set overnight yielded 68 cutthroat trout and 21 grayling. No other aquatic vertebrates were captured.

Cutthroat Trout

Mean total length and weight were 225 mm and 121 g, respectively, for the cutthroat trout and mean condition factor (K) was 0.90 (Table 32). The male:female ratio was 1.25:1. The length-weight equation was $\log W = 2.9130 (\log L) - 4.8430$ (GM equation was $\log W = 2.9266 (\log L) - 4.8747$) (Ricker 1975).

Table 32. Gillnetting results from Yellowstone backcountry lakes surveyed in 1982

Location	Species	Year	Number of Nets ¹⁾		Total Number Captured	Length (mm)			Weight (g)			Mean K Factor
			Largemesh	Smallmesh		Mean	n	range	mean	n	range	
Cascade Lake	Cutthroat Trout	1969 ²⁾	3	0	96	229	96	110-400	122	96	--	--
		1978 ³⁾	2	2	180	196	178	78-358	92	63	6-462	0.94
		1982	2	1	68	225	68	126-332	121	68	27-345	0.90
	Grayling	1969	3	0	7	292	7	270-325	--	0	--	--
		1978	2	2	60	221	52	138-362	135	40	26-444	0.88
		1982	2	1	21	300	21	190-393	298	21	66-600	0.99
McBride Lake	Cutthroat Trout	1975 ⁴⁾	2	0	123	268	123	170-416	206	123	50-700	0.92
		1982	2	0	93	271	88	145-385	210	79	36-480	1.01
Lake #1310	Brook Trout	1982	2	1	46	270	44	104-500	409	44	1744-11	1.18

¹⁾ Largemesh: monofilament experimental gillnets 38.7 m long x 1.5 m deep with 7.6 panels of 19, 25, 32, 38 and 51 mm bar mesh; smallmesh: monofilament experimental gillnets 30 m long x 1.8 m deep with 7.6 m panels of 10, 13, 16 and 19 mm bar mesh.

²⁾ Dean and Mills (1970).

³⁾ Jones et al (1979).

⁴⁾ Varley et al (1976).

A sample of 45 cutthroat trout were aged by the scale method, and six displayed a retarded scale growth pattern (failure to form an Age I annulus)(Laakso and Cope 1956). An age-length key (Westerheim and Ricker 1978) provided expanded estimates for 67 trout. Maximum age was IV+ and approximately 87% of the cutthroat trout were age I-III. Mean age was 2.4 years (Table 33). Back-calculated lengths at annulus formation were 58, 130, 211 and 278 for ages I-IV, respectively (Table 34).

Comparisons among sample years of catch per net are confounded by the number and type of gillnets, and by the location of the sets; however, the number per net was lower in 1982 than in the two previous samples (1969 and 1978)(Table 32). Although high variation in numbers per net is often associated with gillnets because of changes in density independent factors (Lagler 1978; summer largemouth gillnetting, this report), current data suggest a slight decrease in the density of cutthroat trout in Cascade Lake.

Differences among sample years in the mean length of trout (Table 32) were statistically significant. Although average size was similar in 1969 and 1982, the mean was over 30 mm smaller in 1978. Comparisons limited to trout over 200 mm were also statistically significant, and trout captured during 1982 were significantly larger than either 1969 or 1978. Length frequency analysis indicates that there has been a shift to larger trout since 1978, and the percentage of trout over 300 mm is the highest yet reported (4.2%, 1.1%, and 15.2% for 1969, 1978, and 1982, respectively).

Average age was slightly higher in 1982 than in the two previous samples (Table 33). More important, however, was the shift in proportion of age IV+ trout from 2% and 3% in 1969 and 1978, respectively, to over 12% in 1982. It appears that the decrease in density of cutthroat trout is associated with an increase in average size and age.

Grayling

Mean length of 21 grayling captured in the 1982 survey was 300 mm; mean weight was 298 g; and mean K was 0.99. The male:female ratio was 1.29:1. The length-weight equation was $\text{Log } W = 3.0003 (\text{Log } L) - 5.0050$ (GM equation was $\text{Log } W = 3.0082 (\text{Log } L) - 5.0244$)(Ricker 1975).

Age was determined for 10 of the captured grayling using the scale method, and none of the fish sampled lacked an annulus at age I (Kruise 1959). Back-calculated lengths at annulus formation were 113, 239, 308, 322, 331, 370 and 381 mm for ages I-VII, respectively (Table 34). Mean age (2.7 years) was estimated by an age-length key (Westerheim and Ricker 1978)(Table 33). Approximately 75% of the grayling were between ages I+-III+, and 7% were age VII+.

Table 33. Age frequency (by percentage) of fish captured in Yellowstone backcountry lakes, 1982

Location	Species	Year	Sample size ¹⁾	Percentages in each age							Mean age (years)
				I	II	III	IV	V	VI	VII	
Cascade Lake	Cutthroat Trout	1969 ²⁾	44 (91)	10	50	38	1	1			2.3
		1978 ³⁾	199 (57)	24	28	46	2	>1			2.3
		1982	67 (45)	14	41	32	>12				2.4
	Grayling	1969 ²⁾	7 (7)	0	71	29					2.3
		1978 ³⁾	62 (30)	81		3	5	7	4		1.8
		1982	14 (10)	36	14	25	11	7		7	2.7
McBride Lake	Cutthroat Trout	1975 ⁴⁾	42 (108)	8	49	23	12	7	1		2.6
		1982	47 (82)	4	39	27	25	6			2.9
Lake #1310	Brook Trout	1982	30 (37)	35	49	8		8			2.0

1) Number of fish used in expanded estimate using an age-length key; the number in parenthesis is the number of aged fish.

2) Dean and Mills (1969).

3) Joens et al (1979).

4) Reread; see current report.

Table 34. Calculated total length at annulus formation of fish captured in Yellowstone backcountry lakes, 1982

Location	Species	Year	Sample Size	Annulus						
				I	II	III	IV	V	VI	VII
Cascade Lake	Cutthroat Trout	1969 ¹⁾	44	84	159	223	287	366		
		1978 ²⁾	57	74	148	212	252	306		
		1982	45	58	130	211	278			
	Grayling	1969 ¹⁾	7	107	227	292				
		1978 ²⁾	30	122	221	297	310	325	343	
		1982	10	113	239	308	322	331	370	381
McBride Lake	Cutthroat Trout	1975 ³⁾	42	70	141	233	288	324	384	
		1982	47	60	133	239	311	336		
Lake #1310	Brook Trout	1982	30	67	129	264	348	405		

1) Dean and Mills (1969).

2) Jones et al (1979).

3) Reread; see current report.

Although comparisons of number per net may be confounded as mentioned above, there appears to have been a decrease in grayling density since 1978. The mean number per net, however, is currently three times greater than 1969. Changes in grayling numbers appear to be consistent with changes in cutthroat trout density since 1969 (Table 32).

Mean length of grayling has also followed a pattern similar to that observed for the trout (Table 32). Mean length decreased significantly in 1978, but rose to a peak in 1982. Length frequency analysis reveals that over twice as many grayling were greater than 300 mm in 1982 than in 1969 (62% and 29%, respectively), and only 17% of the grayling collected in 1978 were greater than 300 mm.

Mean age of the grayling samples has also risen since 1978 (Table 33). Back-calculated lengths have varied somewhat through time, but small sample size greatly confounds interpretation of these results (Table 34). The most significant change has been an increase in maximum age from III+ in 1969 to VII+ in 1982.

Angler Use

Angler use and creel survey information for Cascade Lake have been collected utilizing the Volunteer Fishermen Report (VFR) system since 1973. Although there are no previous creel data, Dean and Mills (1970) estimated that between 400-450 angler days were expended on the lake annually. Current data indicates that use was increasing dramatically in the three years prior to the lakewide catch and release regulation (1978), and over 1200 angler days were reported in 1977 (Figure 25). Since 1978, use has dropped precipitously with a mean of less than 300 angler days annually since 1979. Similar results have been noted in other backcountry lakes in Yellowstone Park after the implementation of catch and release-only regulations (See McBride Lake, this report); however, periodic restrictions in backcountry use as part of the Park's grizzly bear management program may also be reflected in estimates for Cascade Lake.

Extreme variation in landing rate makes interpretation of these data difficult (Figure 26), and results are further confounded by reduced sample size associated with decreases in use since 1978. Despite this variation, mean landing rate for the five year period since the regulation change (1.15 fish/hour) was almost twice that estimated for the five years prior to the change (0.60 fish/hour).

Mean length of landed fish has also increased since 1978 (Figure 27). The change is most evident in grayling which increased from 265 mm to 284 mm. Cutthroat size estimates have exhibited a greater variation, but an increase from 261 mm to 267 mm was reported.

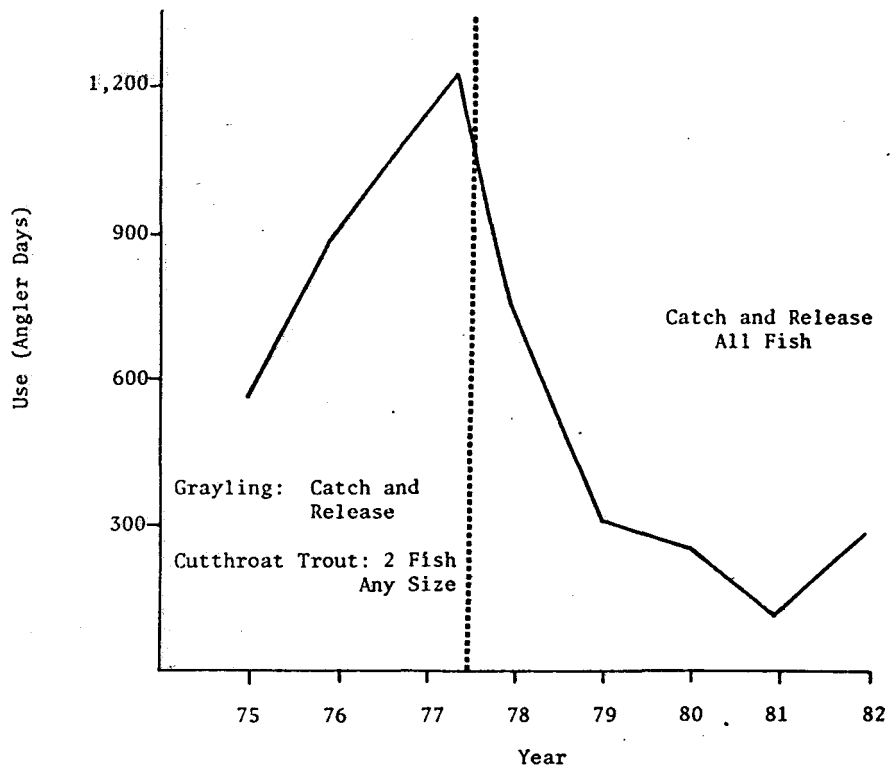


Figure 25. Angler use estimates for Cascade Lake, 1975-1982.

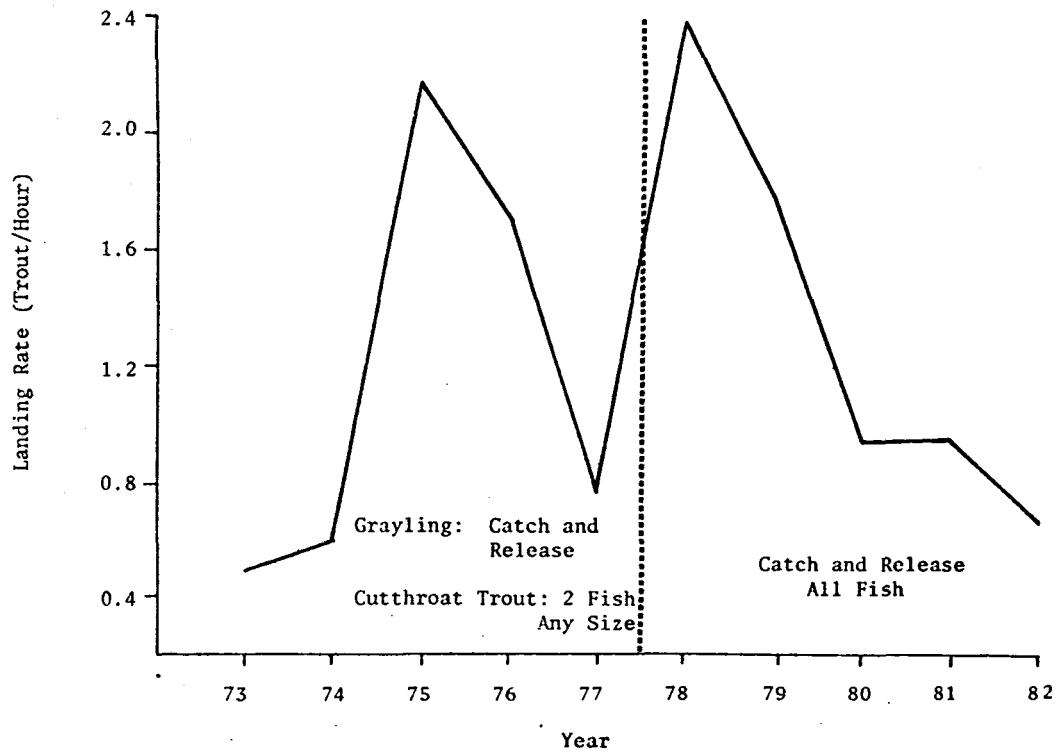


Figure 26. Landing rate estimates, Cascade Lake, 1973-1982.

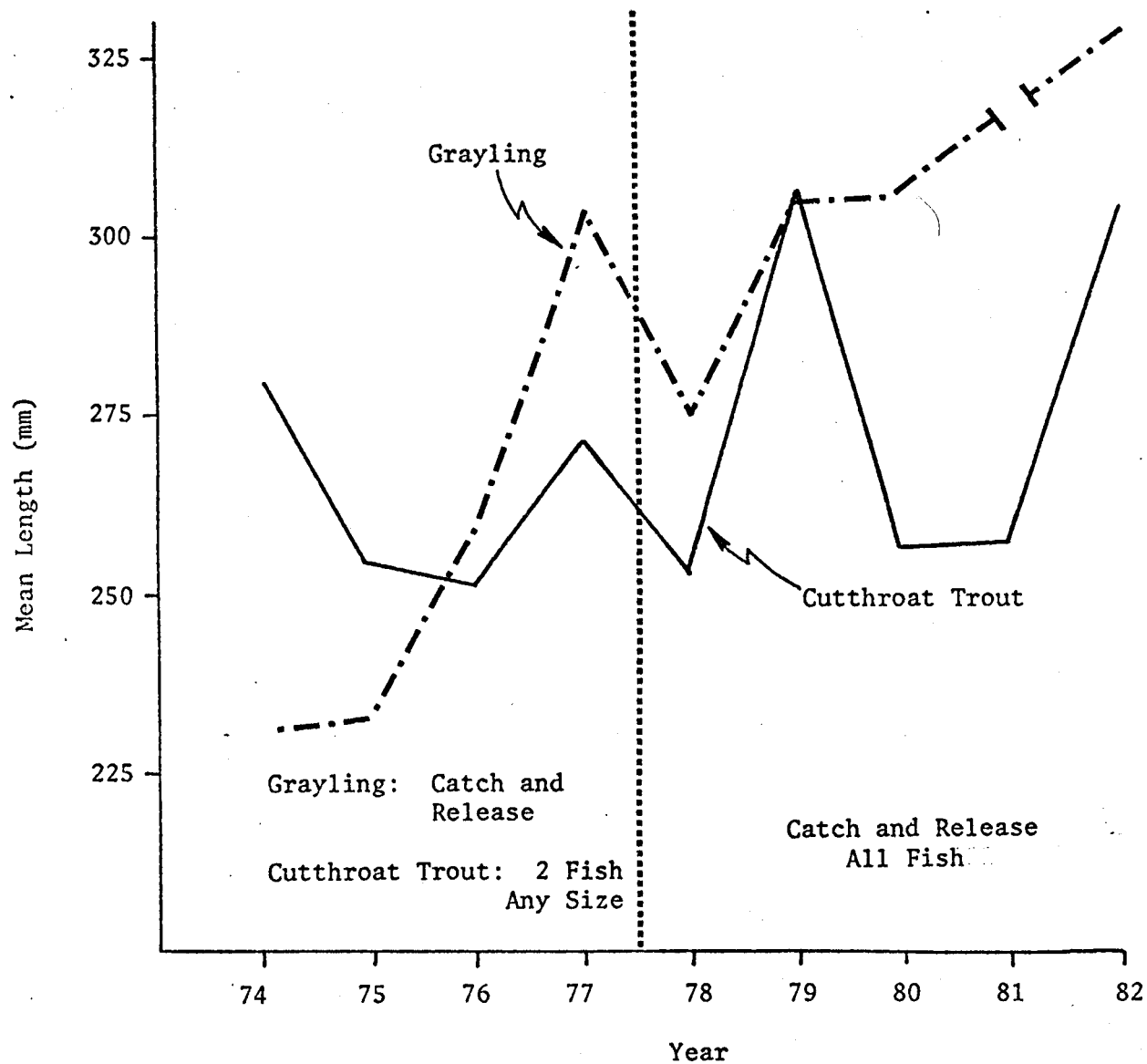


Figure 27. Mean length of fish captured by anglers, Cascade Lake, 1974-1982.

Discussion

Cascade Lake was originally barren, but it currently supports cutthroat trout and the only population of grayling in the Yellowstone River drainage. The biomass of the catchable segments (170-340 mm) of the combined populations was estimated at 32.8 kg/ha in 1978 (Jones et al 1979). Relative abundance (unchanged since 1978) is approximately 3:1, cutthroat:grayling. Reduced zooplankton densities and the predominance of smaller forms in the plankton samples suggests intensive grazing by the fish populations in Cascade Lake.

Subtle changes in the cutthroat trout population have occurred since the lakewide catch and release regulation was implemented in 1978. Density has decreased, but average size and the proportion of trout over 300 mm has increased significantly. The proportion of age IV+ cutthroat trout has increased over 3 times from previous studies. The relationship between numbers and sizes is well documented (Nikolskii 1969 and 1963, Ricker 1978, and Backiel and LeCren 1978, among others), and decreases in density are a result of the shift in biomass to larger individuals.

The grayling population has apparently benefited from the catch and release regulation implemented in 1969. Despite a lack of complete comparability, relative abundance appears to have increased since Dean and Mills (1970) reported a cutthroat:grayling ratio of 14:1. The consistency of the relative abundance between 1978 and the current study indicates that the two species may be approaching some level of interspecific equilibrium. A ratio of 4:1 (cutthroat:grayling) in 1959 more closely resembles current levels but suggests that overharvest of grayling may have been significant at that time.

Current results indicate that the grayling population has continued to improve since the catch and release regulation was extended to cutthroat trout in 1978. Density remains much higher than 1969, and declines in numbers per net since 1978 are probably associated with the shift in biomass to older and larger fish. The percentage of grayling greater than 300 mm is currently over twice the level reported in 1969, and maximum age has continued to increase to VII+ in 1982.

Ageing studies suggest that survival past age I+ continues to improve; however, there are indications of extensive variation in the levels of annual reproduction. In 1978, Jones et al (1979) noted the complete absence of the 1976 year-class. This year-class was also absent from the current sample. Since relative abundance has remained relatively stable since 1978 despite a substantial decrease in angler use, poor reproductive success may limit the grayling in Cascade Lake.

In 1978, Cascade Lake became the first lake in Yellowstone Park which completely prohibits the harvest of two sport species.

Under the current regulations relative abundance appears to be stable at 3:1, cutthroat:grayling. It is interesting to note that in Wolf and Grebe Lakes, where grayling coexist with rainbow trout, the grayling is the dominant species. The continued dominance of the cutthroat trout despite periods of harvest inequity, and the relatively stable growth patterns of the two species even at high exploitation levels, suggest that it is reproduction and not competition for the food resource which limits the grayling in Cascade Lake.

MC BRIDE LAKE

McBride Lake is located in the Slough Creek drainage in the northeastern corner of Yellowstone Park. Access is gained by traveling 3.2 km along the Slough Creek trail and then turning north for approximately 2 km on a partially marked foottrail. Since Slough Creek must be forded, access is restricted when stream flow is high during spring runoff.

Cutthroat trout are native to McBride Lake, and 52,600 cutthroat trout were stocked there in 1940-1941 (Varley 1981). Approximately 9180 rainbow trout and 150,000 grayling were also planted in the lake in 1936-1937. Currently, cutthroat trout are the only salmonids in the lake (Varley et al 1976, Phelps 1981). Behnke (pers. comm.) has reported that this cutthroat genotype is genetically distinguishable from the Yellowstone Lake cutthroat trout.

In 1969, Lake Abundance, which lies in the headwaters of Slough Creek outside the Park in Montana, was chemically treated to eradicate the non-native lake chub (Couesius plumbeus) (Dean and Mills 1970). The purpose of this project was to prevent the distribution of this introduced minnow into other lakes and streams in the drainage. The Park provided approximately 15,000 cutthroat trout eggs from McBride Lake to the Montana Department of Fish, Wildlife and Parks (MFWP) for restocking Lake Abundance; the McBride stock was desired in order to provide for the genetic integrity of the cutthroat trout throughout the drainage. Although the eradication was apparently successful in Abundance Lake, lake chub have been reported in McBride Lake since 1975 (Varley et al 1976).

Because of initial rearing success and post-planting survival of the McBride Lake strain, the MFWP developed a brood stock utilizing 9,000 eggs collected from McBride Lake in 1971 (Dean 1972). In 1980, approximately 13,000 eggs were collected for backcrossing into the original brood stock. At that time electrophoretic analysis indicated that the brood stock had retained the genetic characteristics of the wild donor stock, and there was no evidence in either group of hybridization with other species or subspecies of the genus Salmo (Phelps 1981). An additional 14,000 fertilized eggs were obtained in 1982 to provide a second backcross for the hatchery brood stock.

Arnold and Sharpe (1967) conducted a basic survey of McBride Lake in 1966, including an evaluation of the cutthroat trout population under the 2 fish, any size regulation. In 1975, the lake was resurveyed to assess changes following the implementation of the catch and release-only regulation (1973) (Varley et al 1976). Monitoring activities continued when McBride Lake was surveyed for a third time, August 3-4, 1982.

Physical

Detailed accounts of the physical characteristics of McBride Lake and the surrounding drainage are provided by Arnold and Sharpe (1967) and Varley et al (1976). During the present survey, the dark green-brown water of the 9.3 ha lake yielded a secchi disc visibility of 4.3 m on a clear, windy day (Table 30). Water temperature decreased from 17.2 C at the surface to 11.1 C at 4.9 m. Stratification was evident with uniform temperature between the surface and 3.4 m, but temperature dropped rapidly (4.1 C/m) from that point to the bottom. Arnold and Sharpe (1967) reported a flow of 0.028 m³/sec from the outlet at the southwestern end of McBride Lake, but Varley et al (1976) indicated the channel was dry in September, 1975. Although the high water mark (1.0 m above surface) in 1982 indicated the highest lake level yet reported, this channel was also dry during the current survey. Flows from the northeastern outlet (0.044 m³/sec) and the inlet (0.019 m³/sec) increased in 1982, reflecting a higher snowpack and earlier sampling date. The disparity between inflow and outflow has been noted previously (Arnold and Sharpe 1967 and Varley 1976) and strongly suggests the presence of substantial subaqueous springs.

Chemical

McBride Lake has been classified as a calcium-bicarbonate lake with a TDS = 118ppm (Varley et al 1976). Although high levels of calcium are found in granitic gneiss which is the dominant bedrock material in the lake drainage (Prostka et al 1975), decomposition of this type of rock is slow (Hem 1970). Small pockets of highly soluble limestone are also found in this drainage (Pierce 1974), however, and the ground water sources for both the inlet stream and subaqueous springs in the lake are probably rich in both calcium and bicarbonate ions.

Calcium-bicarbonate lakes are the most common among natural fresh waters (Hutchinson 1975), and in Yellowstone Park, these waters appear to be the highly productive. Values reported by Varley et al (1976) reveal that many of the chemical components in McBride Lake are above the Park mean for calcium-bicarbonate lakes, therefore indicating substantial nutrient availability and production potential for the lake.

A comprehensive chemical analysis was not obtained in 1982; however, field measurements (Table 35) appear to be similar to

Table 35. Chemical characteristics of backcountry lakes surveyed in Yellowstone National Park, 1982

	Cascade Lake 8/19	McBride Lake 8/3	Lake #1310 9/1
Water temp. °C	15.9	17.0	13.3
Spec. cond. umhos	49	130	162
pH	7.2	8.75	7.4
Dissolved O ₂	6.6	8.0	9.2
Secchi (meters)	4.27	4.27	0.91
Pheno. alk.	0	-	0
Total alk.	-	68.4	87
Ca hardness	-	-	60
Total hardness	17.1	85.5	72
Total diss. solids			110
Carbonate alk.			0
Bicarbonate alk.			87
Carbonates			0
Bicarbonates			106
Hydroxides			0
Carbon dioxide			36
Chloride			<1.0
Sulfate			5.5
Fluoride			1.8
Phosphate			0.25
Potassium			0.36
Mg hardness			12
Calcium			24
Magnesium			2.9
Sodium			8.4
Iron			<0.05
Manganese			<0.05
Copper			<0.01
Silica			10.2
Color (PCU)			0
Turbidity (NTU)			0.48
TOC			<0.2
Ortho-phosphate			0.12
Total Kjeldahl N			0.23
Nitrate N	0.015	0.03	0.04

previous studies (Varley et al 1976 and Arnold and Sharpe 1967). Alkalinity (68ppm) and hardness (86ppm) vary somewhat between years, but such variation is commonly associated with differences in sampling date and analytical procedures.

The pH value was again higher for the lake (8.75) and northeast outlet (9.5) than the inlet (8.5). The lake pH was lower than reported by Arnold and Sharpe (1967) (10+), but "bloom" conditions, such as those reported in 1966, often cause severe temporal increases in pH (Hem 1970). Differences may also be related to the depth of the sample because photosynthesis by plankton and algae often cause a substantial increase in pH near the surface of productive waters (Hem 1975).

Aquatic Vegetation

As noted by Arnold and Sharpe (1967), sedges (Carex sp.) border most of the lake except where the steep cliffs drop directly into the lake. Bulrushes (Scirpus sp.) were most common near the outlets at the southwestern and northeastern ends of the lake. Although Arnold and Sharpe (1967) reported that hornwort (Ceratophyllum sp.) and starred duckweed (Lemna trisulca) were very abundant in certain areas, hornwort was not collected in 1982, and duckweed was found only near the southwestern (dry) outlet.

During the current survey, spiked water-milfoil (Myriophyllum spicatum), a species often associated with nutrient rich waters, was the most abundant aquatic macrophyte in McBride Lake (Table 36). It was found at both ends of the lake and in several small coves. White water-buttercup (Ranunculus aquatilis) was also very common around the lake margin. Berchtold's pondweed (Potamogeton berchtoldii) was growing submerged near the northeast end of the lake; northern water-starwort (Callitriche hermaphroditica) and spring water-starwort (C. verna), both submergents, were also found growing near shore in a silt substrate, typical of that portion of the lake. Common mares tail (Hippuris vulgaris), an emergent form which is capable of surviving severe dessication (Hutchinson 1975b), was associated with the delta area near the inlet.

Limnoplankton

Apparently the present survey preceded the peak of the annual Aphanizomenon bloom reported by Varley et al (1976), and although this blue-green alga was the dominant plankton form (over 400,000 per liter), species diversity (14 genera) was over four times greater than in 1975 (3 genera). Two other blue-green algae, Anabaena and Gleotrichia, were also in bloom proportions in 1982 (Table 31).

The presence of moderate numbers of Melosira (537 per liter) and other unidentified diatoms (1789 per liter) suggests a eutrophic

Table 36. Qualitative checklist of aquatic plants collected during lake surveys,
Yellowstone National Park, 1982

Species (common name)	McBride Lake	Lake #1310
<u>Callitriche hermaphroditica</u> L. (northern water-starwort)	X	
<u>Callitriche verna</u> (spring water-starwort)	X	
<u>Eleocharis</u> sp. (spike-rush)		X
<u>Hippuris vulgaris</u> L. (common mare's-tail)	X	X
<u>Lemna minor</u> L. (water lentil)		X
<u>Lemna trisulca</u> L. (star duckweed)		X
<u>Mimulus guttatus</u> DC. (yellow monkey-flower)		X
<u>Myriophyllum spicatum</u> L. (spiked water-milfoil)	X	X
<u>Polygonum amphibium</u> L. (water smartweed)		X
<u>Potamogeton berchtoldii</u> Fieb. (Berchtold's pondweed)	X	X
<u>Potamogeton filiformis</u> Pers. (slender-leaved pondweed)		X
<u>Ranunculus aquatilis</u> L. (white water-buttercup)	X	
<u>Ranunculus natans</u> C.A. Meyer (floating water-buttercup)		X
<u>Utricularia vulgaris</u> L. (common bladderwort)		X

diatom plankton association (Hutchinson 1967) in McBride Lake. According to Wetzel (1975), blue-green algae often become dominant in this type of plankton association during periods of warmer temperatures. The presence of the desmid, Genicula supports this supposition because desmids are also common in this association when dissolved organic matter is moderately high (Wetzel 1975).

The eutrophic nature of the McBride Lake was also evident in above average diversity of both Crustacea (4 genera) and rotifers (3 genera); however, below average density and numerical dominance of rotifers suggest substantial grazing by the cutthroat trout population (Moss 1980). The increased diversity and reduced density of zooplankton forms since 1975 is probably related to the extensive Aphanizomenon bloom (over 2 million trichomes per liter) reported at that time (Varley et al 1976). Although a similar phenomenon might occur if trout density increased drastically, current data do not support this theory.

Littoral and Benthic Organisms

An increase in the number of macroinvertebrate taxonomic groups since 1975 (Varley et al 1976) is directly related to an increase in sampling effort and the addition of dredge hauls. It is assumed that the current sample provides a more representative qualitative summary of littoral and benthic organisms (Table 37).

The highly productive nature of McBride Lake is reflected in above average diversity (12 groups) and densities of aquatic macroinvertebrates. Scuds (Gammarus lacustris and Hyalolella azteca) were very abundant and most often associated with dense vegetation. Mayflies (Ameletus sp.) were numerous among the sedges in the infralittoral zone. Chironomid larvae dominated the benthic samples and densities were high. Snails (Lymnaeidae and Planorbidae) were abundant in the vicinity of the northeast outlet where the substrate was dominated by large gravel and rubble. Clams (Sphaeriidae) were also associated with this type substrate, but aquatic earthworms (Oligochaeta) were limited to the clay-silt substrate.

Aquatic Vertebrates

Two largemouth experimental gillnets (set overnight) yielded 93 cutthroat trout and one lake chub. A net set off the steep cliffs along the east shore captured only 15 fish, but the net set in shallower water along the northwest shore caught 79 cutthroat trout.

The mature female chub measured 165 mm and weighed 5 g. This individual was not aged; however, Varley et al (1976) reported that a lake chub from McBride Lake of approximately the same size was 5 years old. Mean length for 88 of the cutthroat trout

Table 37. Aquatic invertebrates collected from McBride Lake and Lake #1301, 1982

Taxon	McBride Lake		Lake #1301	
	Littoral	Benthic	Littoral	Benthic
Hirudinea	X	X	X	X
Oligochaeta		X		X
Crustacea				
Amphipoda (scuds)				
<u>Gammarus lacustris</u>	X		X	X
<u>Hyallorella azteca</u>	X		X	X
Insecta				
Ephemeroptera (mayflies)				
Siphonuridae				
<u>Ameletus sp.</u>	X			
Plecoptera (stoneflies)				X
Trichoptera (caddisflies)				
Limnephilidae	X			
Hemiptera (true bugs)				
Corixidae (water boatman)			X	
Diptera (true flies)				
Chironomidae	X	X	X	X
Culicidae		X		
Muscidae	X			
Gastropoda (snails)				
Lymnaeidae	X	X		
Planorbidae	X	X		
Pelecypoda (clams)				
Sphaeriidae		X	X	X
NUMBER TAXONOMIC GROUPS	9	7	6	7
TOTAL NUMBER OF GROUPS PER WATER		12		8

was 271 mm, and mean weight was 264 g (n=79). Condition factor was 1.01 (Table 32). The length-weight equation was $\log W = 2.6740 \log L - 4.2129$ (GM equation: $\log W = 2.6839 \log L - 4.2365$) (Ricker 1975).

Age was determined for a sample of 47 of the captured trout using the scale method (Table 33). Retarded scales (failure to form an annulus at Age I) (Laakso and Cope 1956) were noted for 16 (34%) of the aged trout. Back-calculated lengths were 60, 133, 239, 311, and 336 mm for ages I-V, respectively. An age-length key (Westerheim and Ricker 1978) was utilized to expand estimates to 82 trout. Mean age was 2.9 years, and approximately 31% of the sample was age IV+ and over (Table 33).

Problems were apparent with age estimates for cutthroat trout captured in 1975; therefore, to increase comparability, the sample of 42 trout was aged a second time (Table 34). Backcalculated lengths were 70, 141, 233, 288, 324, and 384 mm for ages I-VI, respectively, and 10 trout (24%) displayed the retarded scale type. Expanded estimates for 108 fish yielded a mean of 2.6 years; only 24% were age IV+ and older (Table 33).

Catch per net increased from 1966 (22 trout per net) to 1975 (61.5 trout per net) but then declined in 1982 (45.6 trout per net) (Table 32); however, comparisons of relative catch are confounded by net location. When the two nets set along the north shore (1975 and 1982) were compared alone, the number of trout per net actually increased from 1975 (62 per net) to 1982 (79 per net). The two nets (1966 and 1982) which were set in the vicinity of the cliff along the east shore varied from 22 trout per net (1966) to 14 trout per net (1982). Given the high amount of variability in gillnet samples, it appears that trout density has actually remained relatively stable through time.

Cutthroat trout captured in 1982 were slightly larger than those sampled in 1975, but differences in mean length and weight were not statistically significant. Condition factor (K), however, was significantly greater in the current sample. The slight increase in length may be associated with the rise in mean age from 1975 to 1982 (2.6 and 2.9 years, respectively). Growth appears to be quite similar in both years, and although the current sample appears to be growing somewhat slower at ages I+ and II+, growth is slightly higher for age IV+ and older.

Angler Use

The volunteer Fisherman Report (VFR) system provides angler use and creel survey data dating back to 1976. Arnold and Sharpe (1967) reported an average of 3 anglers per day for August 3-12, 1966; however, they estimated that between 500-700 angler days per season were expended on McBride Lake. Recent VFR returns revealed a drastic drop in angler use to less than 50 angler days in 1977, but use has increased to over 100 angler days annually during the past two years (Figure 28).

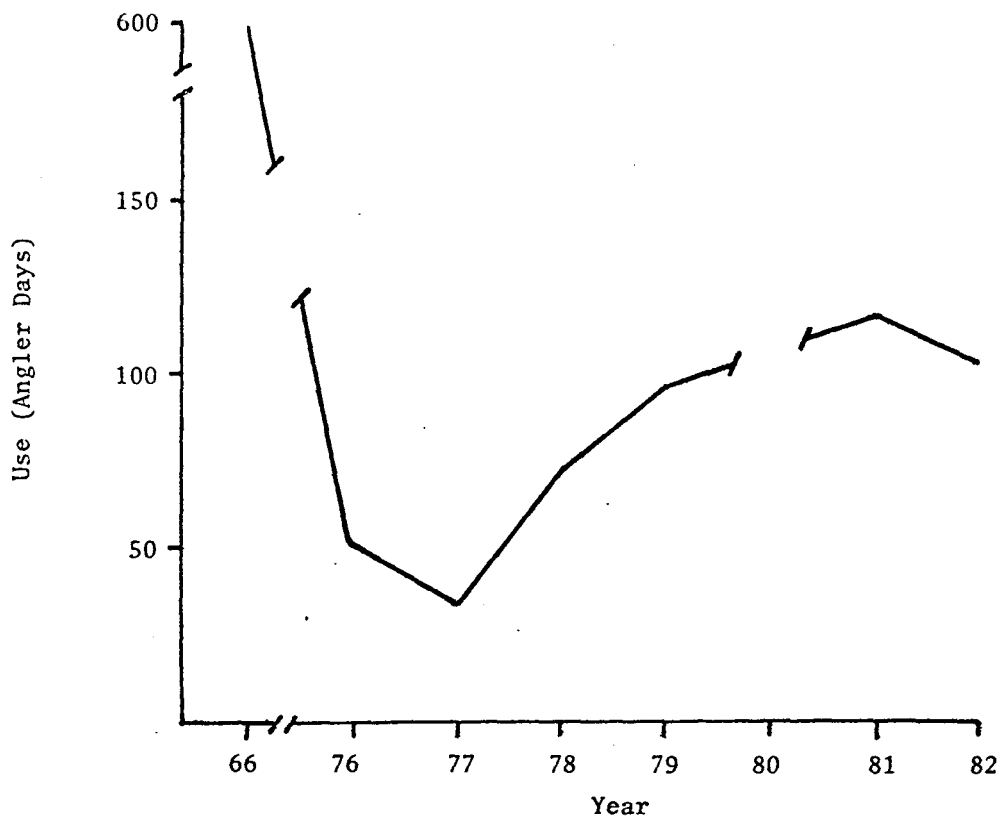


Figure 28. Angler use estimates for McBride Lake, 1966 and 1976-1982.

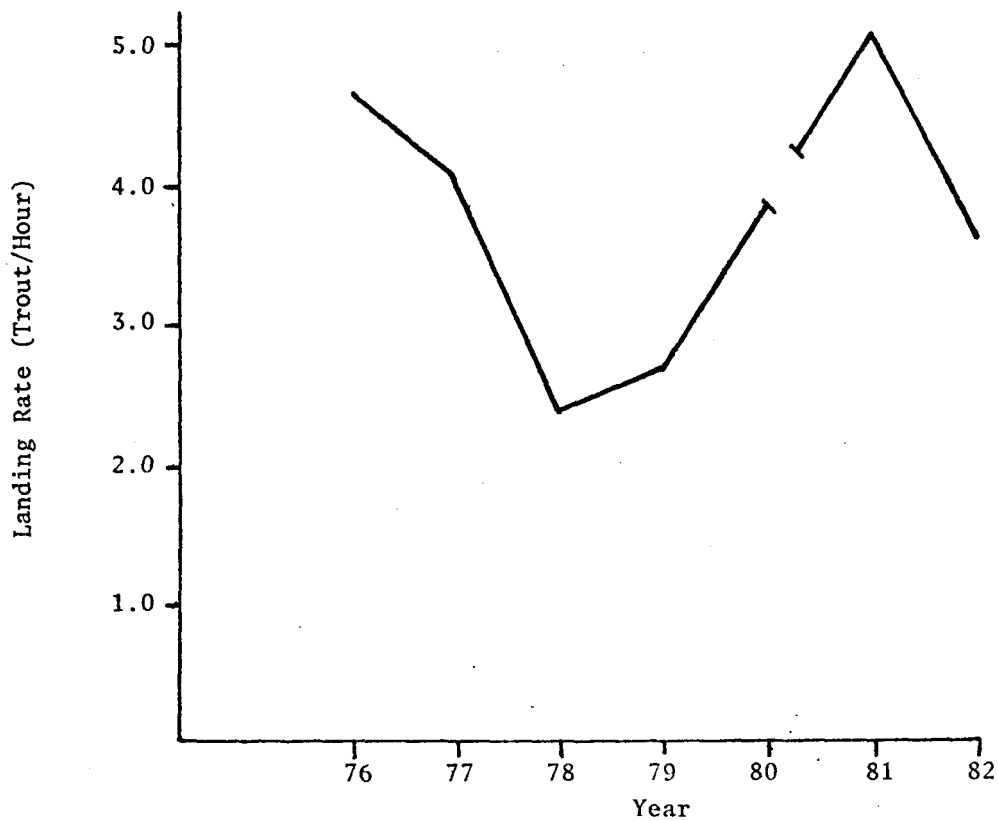


Figure 29. Landing rate estimates for McBride Lake, 1976-1982.

Catch rate has varied drastically since 1976, but has been well above 2 trout per hour each year (Figure 29). The variation is undoubtedly linked to small sample size, although the Aphanizomenon bloom may have negative affects on angler success during some portions of the season. The mean landing rate (3.78) for the past seven years far exceeds the Park mean and illustrates the potential of an extremely productive cutthroat fishery under catch and release regulations.

Mean length of trout landed has also varied during the past seven years (Figure 30). Although average size has been above 350mm in most years, it fell to 309 mm in 1982. The small numbers of VFR returns undoubtedly influence the results, and because gillnet data has indicated very little change in mean length since 1975, the 1982 VFR estimate may not be truly representative.

When the lengths of landed trout for all years were combined, the mean (345 mm) was approximately equal to the Parkwide average for all fish landed (343 mm), but the combined mean for McBride Lake is smaller than the Parkwide mean for cutthroat trout alone. If Yellowstone Lake and Yellowstone River are removed from the total, however, average length of cutthroat trout in the remaining waters is only 325 mm. This comparison helps illustrate the relative importance and productive potential of the McBride Lake fishery.

Discussion

Based on nutrient levels alone, McBride Lake may have the greatest productive potential of any cutthroat trout water in Yellowstone Park. The eutrophic nature of the diatom-blue-green algae plankton association is a reflection of nutrient availability. Diversity of littoral and benthic organisms is above average, and densities of scuds and dipterian larvae, two important trout foods, are very high. The population density of the cutthroat trout in McBride Lake has not been equaled in Yellowstone Park, and yet, condition factors are above average for this species.

The catch and release regulation on McBride Lake appears to be maintaining a rather stable trout population. Although great changes have not been observed during the past seven years, there has been a slight shift to older trout, a direct result of lower mortality rates of mature individuals. Growth rates have not changed significantly and densities show little variation since 1966.

The presence of the introduced lake chub in McBride Lake is disturbing; however, numbers do not appear to have increased greatly since 1975. If the lake chub and cutthroat trout have significant niche overlap, the high density of cutthroat trout should provide a significant competitive advantage. Larger, piscivorous cutthroat may also impact the density of this small minnow.

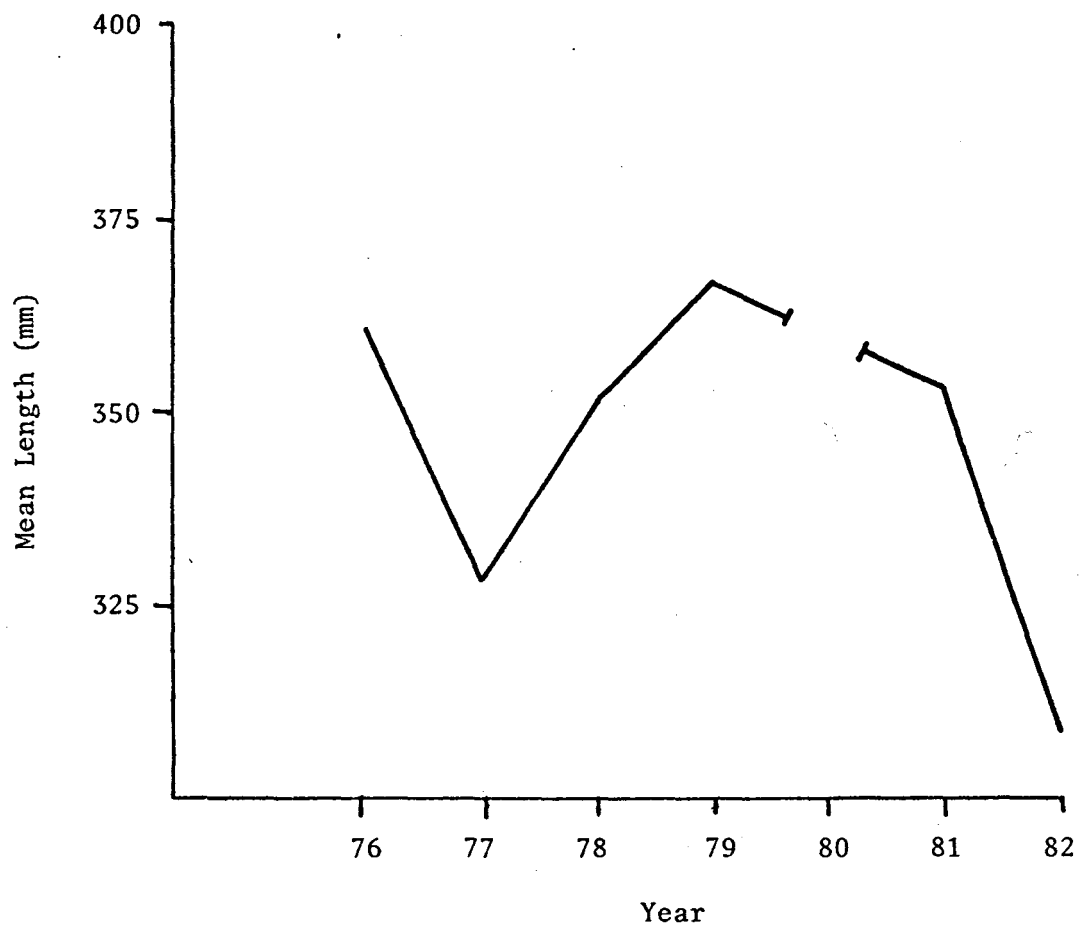


Figure 30. Mean length of trout landed by anglers, McBride Lake, 1976-1982.

Although angler use was estimated to be approximately 600 angler days annually in 1966, current evidence suggests this estimate was probably high. It appears now that use has been low for many years and is not directly attributable to the angling regulation. Restrictions on overnight camping in the vicinity of McBride Lake may contribute to the apparent low level of human visitation; the campsite at the lake was closed in 1981 and had been limited to horse parties for the preceding two years. Although the level of historic use is questionable, VFR results indicate that angler use has doubled since the mid-1970's.

The stabilizing effects of the catch and release regulation are especially important for this unique strain of cutthroat trout. Although the lake chub does not presently pose a threat to McBride Lake, a "healthy" cutthroat population is probably the best defense against the introduced minnow. If use continues to increase, the restrictive "no harvest" regulation should provide adequate protection to ensure the integrity of the McBride Lake cutthroat trout.

LAKE #1310 (RICHARD'S CREEK DRAINAGE)

Lake #1310 (Richard's Creek drainage) is located within 2.5km of the west boundary of Yellowstone National Park, approximately 11km north of West Yellowstone, Montana. There is actually a series of five small ponds along Richard's Creek, but the current survey is limited to the largest pond (#1310) near the headwaters of the stream. Access was gained by following an unmarked fisherman's trail for about 2 km from the Duck Creek parking area to the junction with Richard's Creek. A second trail turned southward at this point and followed the creek approximately 2 km before reaching lake #1310.

The entire series of ponds has had a local reputation for large brook trout (over 1.8 kg), and therefore, its location and details concerning the area were known to only a few local anglers until recently. As more people learned of the ponds, several anglers became concerned that a significant increase in use would have detrimental effects on the brook trout populations.

The historical fish distribution in the Richard's Creek drainage has not been documented, but it has been assumed that Duck Creek, into which Richard's Creek empties, originally supported Upper Missouri River cutthroat trout (Salmo clarki lewisi), grayling, and mountain whitefish (Varley 1980). There are no fish planting records for Richard's Creek or the ponds; however, the portion of Duck Creek in the Park was planted with 160,000 cutthroat in 1927-1928 and 31,625 brown trout in 1938 (Varley 1981). Additionally, the Montana Department of Fish, Wildlife, and Parks (MFWP) stocked Duck Creek outside the Park with 114,900 rainbow trout between 1934-1939 and 230,500 brown trout between 1939-1947.

In 1982, the entire Richard's Creek drainage was closed to human visitation because of potential conflicts with grizzly bears. It was decided, however, that an initial survey of Lake #1310 was needed to describe the current conditions in the lake and to determine the status of the reported brook trout population. To this end, a lake survey was conducted on Lake #1310, September 1-2, 1982.

Physical

Most of the drainage of Lake #1310 (720 ha) lies on ancient alluvial deposits which cover the Madison Valley; however, several outcroppings of Madison River Basalt occur near the headwaters (USGS 1972). A sparse lodgepole pine forest covers most of the drainage and provides moderate wind protection. The area within several hundred meters of the lake supports a wet sedge meadow.

This small (2.8 ha) lake was extremely shallow with a mean depth of only 0.4 m (Table 30). The secchi disc was easily observed on the bottom of the deepest portion of the lake (1.1 m). Water temperature (13.3 C) was uniform throughout the water column. The light green color darkened as depth increased toward the outlet (Figure 31).

The substrate of clay-silt covered gravel was quite uniform throughout the pond. The amount of silt increased somewhat in the deeper portions, and some accumulation of decaying organic matter occurred along the north shore. The irregular shape of this elongated lake yielded good shoreline development. Water level appeared to be quite stable with fluctuations of approximately 0.2 m.

The water source of Lake #1310 is almost exclusively ground water. Subaqueous springs were numerous, and a large springhead provided water for a several hundred meter long inlet channel. Flow in the shallow (0.1 m) channel was approximately 0.02 m³/sec. Spawning gravel was abundant in the low gradient channel. Sand and silt also occurred in the channel, and sedges were growing along the stream bank.

The outlet stream (Richard's Creek) displayed very little flow for almost a kilometer below the lake. Although gravel was evident in a narrow strip in the deepest portion of the channel, much of the area was choked with vegetation; detritus and decaying plant matter dominated the substrate. Subaqueous springs apparently kept the gravel clean in those areas where it occurred. The average width of the outlet channel was approximately 25 m with a mean depth of about 1 m. Productivity was high and brook trout of all sizes were numerous.

Chemical

Calcium and bicarbonate were the dominant ions found in the chemical analysis of Lake #1310. The level of total

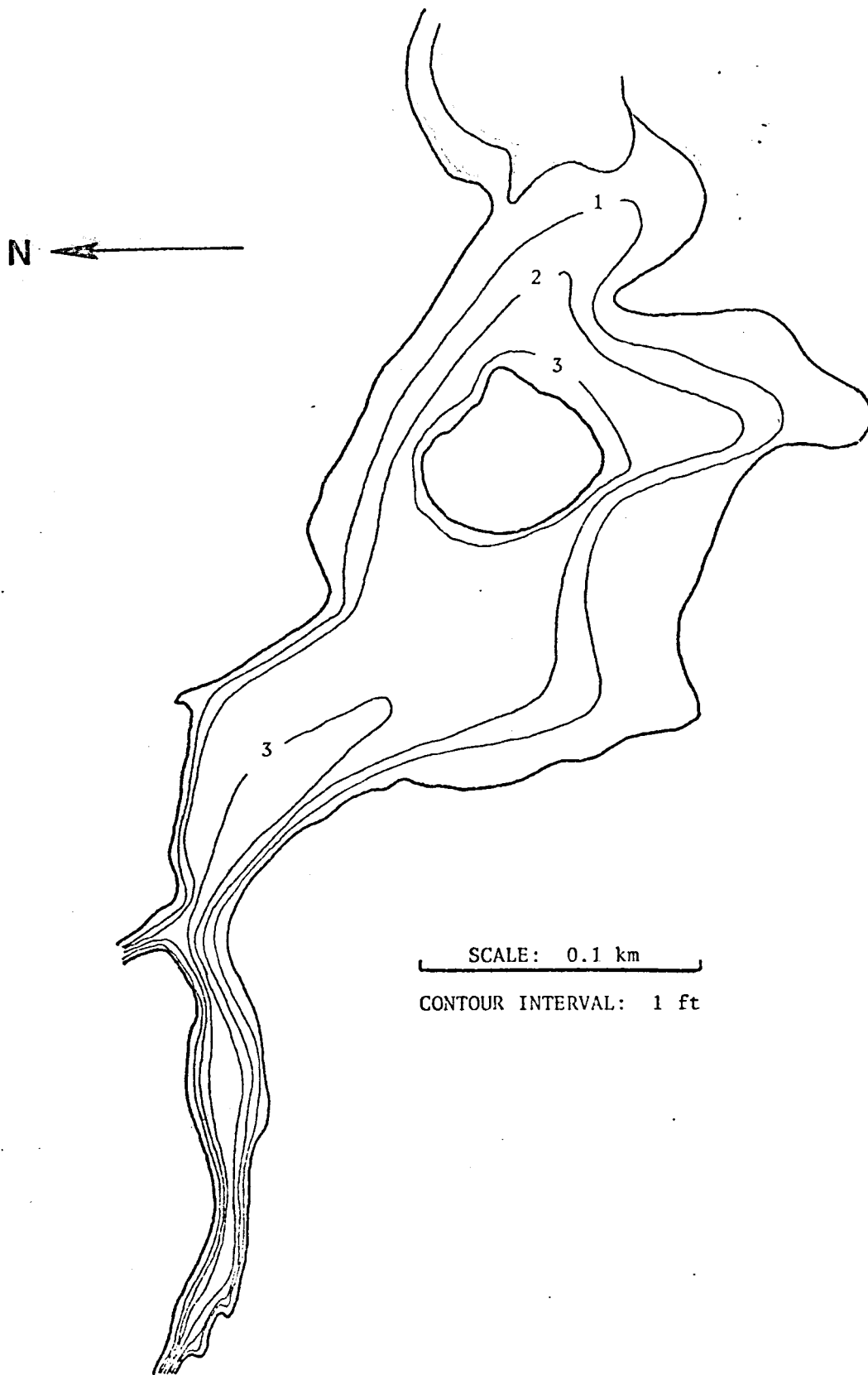


Figure 31. Lake #1310, Yellowstone National Park, 1982.

solids (TDS) was 110 ppm, slightly above the Park average for calcium-bicarbonate lakes. These ions are the most common in natural fresh water (Hem 1970), and in Yellowstone Park lakes of this chemical type are generally the most productive (see McBride Lake, this report).

Conductivity (162 umhos), total alkalinity (87 ppm), total hardness (72 ppm), total dissolved phosphate (0.25 ppm), and nitrates (0.04 ppm) were among those chemical components which were above the Park mean for lakes of this type. Only chloride, sulfate, iron, and total organic carbon yielded values well below the Park mean. The pH (7.4) was slightly alkaline, typical of calcium-bicarbonate waters.

Aquatic Vegetation

Aquatic macarophytes of Lake #1310 are characterized by eutrophic forms (Hutchinson 1975b) which reflect the nutrient rich quality of the environment (Table 36). Most of these plants are also capable of enduring extended periods of dessication. Although diversity and density of the aquatic plants was greatest in the deeper water near the outlet, slender leaved pondweed (Potamogeton filiformis) was scattered in a small cove along the east shore and near seeps on the north shore where the substrate contained more organic matter. Water lentil (Lemna minor) and star duckweed (Lemna trisulca) were both found floating in moderate numbers around the shoreline but were most common near the outlet. Three plants, water smartweed (Polygonum amphibium), yellow monkey flower (Mimulus glittatus), and floating water buttercup (Ranunculus natans), were found in the shallow water near shore, and terrestrial forms of these species were collected from the eulittoral zone. Common bladderwort (Utricularia vulgaris) is another species which was collected from shallow water near shore; in order to overcome unfavorable conditions, this species produces turions (specialized buds) which are capable of survival if the remainder of the plant decays (Hutchinson 1975b). Spiked rush (Eleocharis sp.), a rosulate form, appeared to be restricted to the gravelly, undeveloped substrate; however, Berchtold's pondweed (Potamogeton berchtoldii) was only collected in organic laden substrate near the outlet. Biomass of spiked water milfoil (Myriophyllum spicatum) appeared to be extremely high, and this eutrophic form choked the outlet area. Common mare's tail (Hippuris vulgaris) was limited to the deeper holes of the lake. Aquatic mosses (Musci) are dependent on CO₂ as a carbon source (Hutchinson 1975b) which probably explains their abundance near the subaqueous springs in the outlet and seeps along the shore.

Limnoplankton

Because of the shallowness of Lake #1310, only qualitative plankton samples were collected. These data probably represent only the most common of the plankton species which occur in the lake. The number of phytoplankton genera (3) was below the Park

average (4 genera), but the diversity of crustacea (4 genera) was almost twice the mean (2 genera). Rotifers were not collected from Lake #1310 (Table 31).

Without quantification the interpretation of the phytoplankton sample is difficult. Diatoms and blue-green algae, the only phytoplankters collected in the lake, are found in association in both oligotrophic and eutrophic waters (Wetzel 1975). The chemical composition of Lake #1310 suggests a productive environment, however, and high levels of silica definitely favor diatoms (Moss 1980).

The zooplankton found in Lake #1310 are all small varieties suggesting intense piscine predation (Moss 1980). Ceriodaphnia is a typical pond form which commonly feeds on dinoflagellates (Hutchinson 1967). Species of the genera Cyclops are generally benthic (Hutchinson 1967) and may have selective advantage in this shallow water environment. Although copepods are generally larger than cladocerans or rotifers, Cyclops are usually less than 1 mm, a size comparable with the other zooplankton collected in the lake. The absence of rotifers is difficult to explain; however, Hutchinson (1967) has stated that rotifers are most commonly limited by the quality of food.

Littoral and Benthic Organisms

Macroinvertebrate diversity (8 taxa) was well below the Park mean (11 taxa) (Table 37). Most organisms were scarce in the lake itself, but densities were much greater in the outlet channel. Midges (Chironomidae) dominated the benthic samples, although aquatic earthworms (Oligochaeta) were also plentiful. Clams (Sphaeriidae) were most common in the gravel substrates, and their presence in Lake #1310 is probably related to the availability of calcium in the lake (Moss 1980). Stoneflies (Plecoptera) were limited to areas where vegetation was dense near the outlet. Scuds (Gammarus lacustris and Hyallela azteca) were found in both benthic and littoral samples and dominated samples in the outlet. Water boatman (Corixidae), a predaceous littoral form, were common throughout the lake, but densities were highest near the outlet.

Aquatic Vertebrates

Two largemouth and one smallmouth gillnets were set overnight. Both the largemouth nets were placed in the lake near the outlet, and the smallmouth net was set in the outlet channel. Since fish observations had been limited to the channel area, all nets were set parallel to shore in order to prevent substantial impact to the population in that area.

A total of 46 brook trout and 1 unidentified minnow were captured in Lake #1310. Mean length and weight for 44 of the trout (2 trout were released unharmed) were 270 mm and 409 g, respectively (Table 32). Mean condition factor (K) was 1.18. Length varied from 104 mm to 500 mm, and weight ranged from 11 g

to 1744 g. Estimated weight for the two released trout was over 1000 g each. A total of 11 trout (25%) were between 400-500 mm and 13 (30%) were less than 200 mm. Length weight equation was $\text{Log } W = 3.1459 (\text{Log } L) - 5.2791$ [GM equation was $\text{Log } W = 3.1560 (\text{Log } L) - 5.3030$] (Ricker 1975). Male:female ratio was 0.79:1.

A sample of 30 of the brook trout were aged by the scale method (Bagenal and Tesch 1978), and none of the aged fish failed to form an annulus at age I. Back-calculated lengths were 67, 129, 264, 348, and 405 mm for ages I-V, respectively (Table 34). An age-length key (Westerheim and Ricker 1978) was used to expand the ages to 37 trout (Table 33). Mean age was 2.0 years, and 84% of the sample were age II+ or less. Although both age III+ and age V+ trout were collected, age IV+ were absent from the sample.

Growth of young-of-the-year and age I brook trout was similar to trout from other Park waters, but annual increments began to increase greatly between annuli II and III (Table 34). The acceleration in growth at age II+ is probably related to a change in diet; scuds dominated the stomach samples of all trout over 200 mm. Despite the great size (460-500 mm) attained by some individuals, there was no evidence of piscivorous feeding in larger trout.

Angler Use

VFR cards have never been received from Lake #1310 or any of the ponds in the Richard's Creek drainage; however, a low level of local angler use has been reported. The well worn trail from the mouth of Richard's Creek to the ponds is evidence of human visitation. Until recently, the angling quality of the area was a well guarded secret, but it appears that use may be rising. Although the small size of the ponds and the channels which connect them provide excellent angling opportunity, if use continues to increase, the potential for overharvest is great under the 5 fish (any size) limit. The closure of this area to human visitation for most of 1982, provided maximum protection for the fish population, but a substantial rise in use is expected when the closure is lifted.

Discussion

Shallow water limits production in most of the 2.8 ha of Lake #1310 despite an above average content of essential nutrients. As depth and substrate organic matter increase near the outlet, the potential of the system becomes apparent. The density and diversity of aquatic macrophytes in this area are evidence of the nutrient availability. The phytoplankton association of diatoms and blue-green algae also characterizes enriched waters. The dominance of smaller (<1 mm) zooplankton forms suggests intense piscine predation by young brook trout. The tremendous density of scuds which are concentrated in the areas of vegetation appear to be the primary food source for age II+ and

older brook trout, and growth for these trout is above average for Park lakes.

Considering apparent abundance of reproductive habitat, the absence of age IV+ trout is curious. Above average growth rates also suggest that reproduction may be limiting. It may be that overwinter survival of eggs in the shallow water is low when winter temperatures are extreme; however, apparent poor survival past age II may also explain the observed growth and age structure. Angler harvest may severely impact the proportion of larger trout in the population. Continued sampling in other portions of the Richard's Creek pond system should improve the current understanding of the dynamics of the brook trout population.

The impact of a substantial increase in angler use under the current permissive regulations would probably be devastating to brook trout of the Richard's Creek system. The area is easily accessed, and brook trout are comparatively easy to catch by the average angler. Current data from Lake #1310, the uppermost pond in the system, suggest the angler caused mortality may already be high.

It is not known at present whether the closure of this area because of grizzly bear activity will continue, but if these restrictions are removed, the number of anglers in the area can be expected to rise. Since the ability of this system to produce large (>1000 g) brook trout is uncommon for the Park, and in fact the western United States, regulations to restrict the harvest and protect the structure of this vulnerable population are of greatest importance. It is recommended, therefore, that a 254 mm maximum size limit be placed on the entire Richard's Creek drainage beginning in 1983.

CYPRINID TAXONOMY

Difficulties in the identification of two minnow species, the reidside shiner (Richardsonius balteatus hydrophlox) and the lake chub (Couesius plumbeus) were noted during the 1981 lake survey of Indian Pond (Squaw Lake) (Jones et al 1982). Although the lake chub had previously been collected from Indian Pond in 1957 and 1971 (Dean 1972), minnows collected during 1981 were identified as reidside shiners. In order to clarify this apparent anomaly, a sample of minnows was collected from Indian Pond using a smallmesh gillnet on June 30. Smallmesh nets were also set in Beach Springs Lake (August 11), Riddle Lake (September 20-21), and Alder Lake (September 22-23) to confirm reports of reidside shiners in these three lakes of the Yellowstone Lake drainage. Identification of minnows from the mouth of the Indian Pond outlet stream (#0089) and from Arnica Creek Lagoon (June 30) were included in this survey for comparative purposes. Three fish keys (Brown 1971, Eddy 1969, and Simpson and Wallace 1978) were utilized to insure proper

identification and to establish distinctive characteristics for future use in separating these two species.

Results

Lake chub were the only cyprinid species captured in Indian Pond. Minnows from Beach Springs Lake, previously identified as reidside shiners (Jones et al 1980), were also lake chubs. The presence of reidside shiners was verified in Alder Lake, but minnows were not captured at Riddle Lake. Although most of the fish from the mouth of stream #0089 were reidside shiners, one was identified as a lake chub. Samples from Arnica lagoon also contained both reidside shiners and lake chubs.

Discussion

The current study substantiated the presence of reidside shiners in Alder Lake, but minnows from Beach Springs Lake and Indian Pond were lake chubs. The occurrence of lake chub in these lakes and at the mouth of stream #0089 and in Arnica Lagoon suggest that this species may have expanded its range since it was first found in the Yellowstone drainage. Great similarity upon cursory inspection, coupled with numerical dominance of the reidside shiner in the Yellowstone Lake drainage may have contributed to misidentification in other samples.

During this study, three key characteristics were found to provide positive identification with minimal effort. The use of these characteristics is quite often necessary because individuals of the two species, especially at smaller sizes, resemble each other greatly. The presence of a maxillary barbel on the lake chub is the first of the key characteristics, although this barbel is often extremely small and hard to detect. The second characteristic utilizes the difference in principal fin ray counts for the lake chub (8 principal rays; Simpson and Wallace 1978) and the reidside shiner (10 or more principal rays; Brown 1971 and Eddy 1967). The relationship between dorsal and pelvic fin insertion provides a third characteristic which can aid in separation of these two species; the pelvic fin insertion is anterior to the dorsal fin in reidside shiners, but insertion points for both fins is quite similar in the lake chub (Simpson and Wallace 1978)

Further assessment of the distribution of fishes in Yellowstone Lake should be initiated in the near future. Data collected from smallmesh gillnets from 1969-1973 (excluding 1972) (Dean and Varley 1974) is available for comparison and would provide a baseline to evaluate changes in the range of various species within the lake. The use of these suggested characteristics to provide reliable separation of the reidside shiner and lake chub also requires continued evaluation.

STREAM SURVEYS

In the early 1960's the National Park Service requested this office to initiate a program to inventory all aquatic resources in the Park. The objectives included a basic assessment of the number and types of waters, analysis on angler exploitation, and preparation of baseline data. Baseline surveys of the streams in the Park have progressed on an annual basis since this request.

During 1982, work continued on the acquisition of baseline data and development of hydrographic maps of stream systems and their tributaries. These surveys combined elements of previous hydrographic surveys and habitat elevation procedures. Each stream was stratified longitudinally according to habitat types, and a sample station was chosen to represent each stratum. Physical, chemical, and biological attributes of each station were measured. Surveys were conducted in three major drainages: (1) Yellowstone River, (2) Madison River, and (3) Gallatin River.

TRIBUTARIES TO YELLOWSTONE RIVER

Seven tributaries of the Yellowstone River in the vicinity of Hayden Valley were surveyed in 1982. These included Trout Creek, Elk Antler Creek, Cottongrass Creek, Sour Creek (including tributaries Bluff and Bog Creeks), Alum Creek, Otter Creek, and Thistle Creek (Figure 32). Physical, chemical, and biological characteristics of these streams are largely influenced by the unique geological history of the area.

Hayden Valley is part of a huge caldera that formed in the Yellowstone area following a cataclysmic series of volcanic eruptions about 600,000 years ago. The caldera was partly refilled by subsequent lava flows but the resulting thin earth's crust and thermal activity, unique to Yellowstone remained. The area was then overrun by icecaps of three glacial periods which formed large lakes when they receded and melted. Hayden Valley was periodically inundated by these lakes with the most recent draining about 11,000 years ago.

Today, Hayden Valley is a wide, shallow, mostly treeless valley resulting from many years of glacial scour and deposits. It has numerous meandering streams draining into the Yellowstone River that continue to reflect the cataclysmic geological history. Numerous thermal areas, indicating wrinkles and fissures in the earth's thin crust, yield heated waters and elevated levels of sulfur. Low stream production also suggests a watershed underlaid with rhyolite, a volcanic product low or absent of phosphates. Some areas are underlaid with basalt, an iron-bearing rock, that, when combined with low pH levels, may elevate iron in streams to toxic levels.

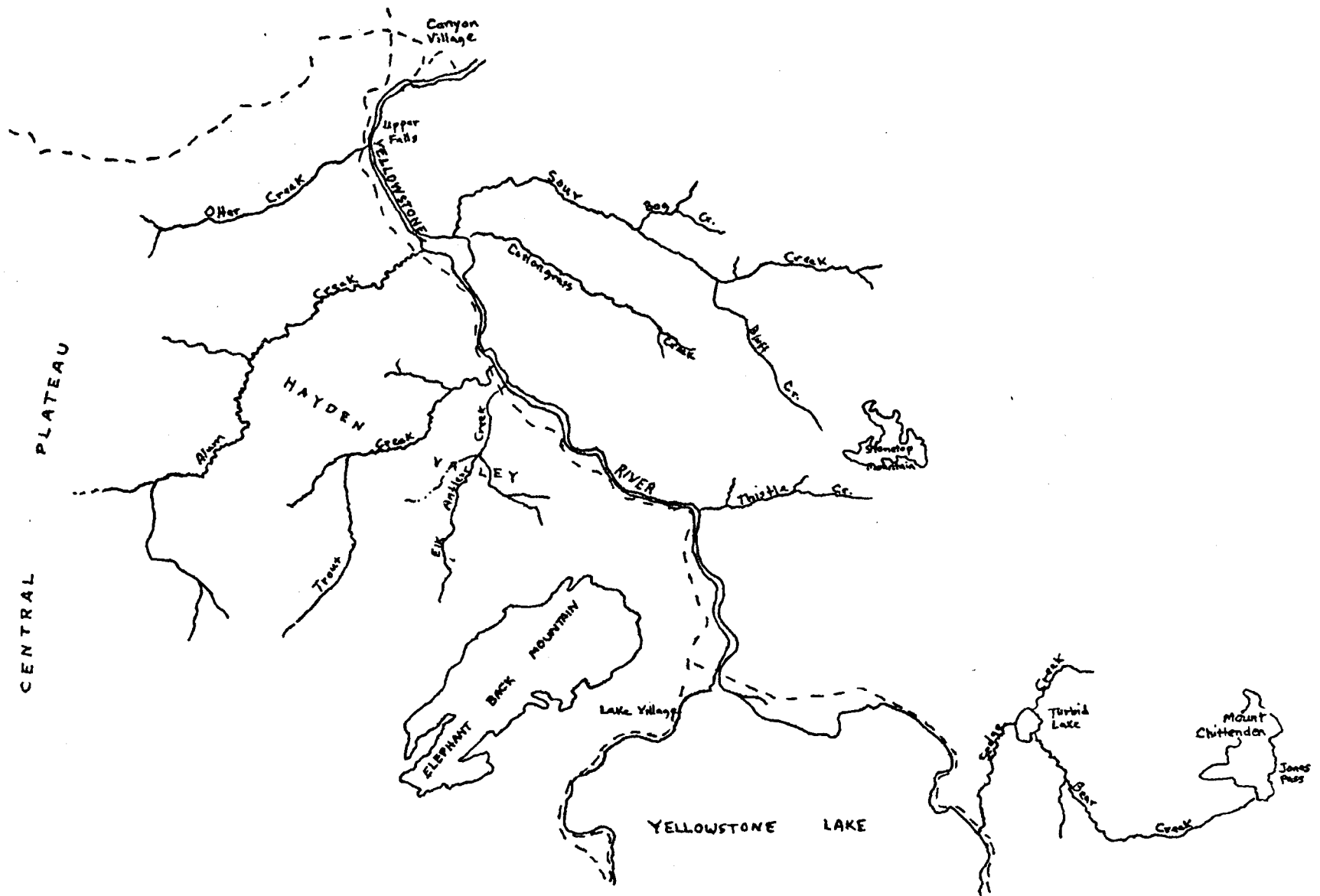


Figure 32 . Tributaries of the Yellowstone River and Yellowstone Lake surveyed in 1982.

A stream-by-stream account is offered of the seven streams surveyed to present a picture of their physical, chemical and biological aspects. Four streams (Trout, Elk Antler, Alum and Otter) drain the area of the Central Plateau, meander through Hayden Valley and flow into the west bank of the Yellowstone River. The three remaining major streams of Hayden Valley (Cottongrass, Sour and Thistle) flow from the area of Stonetop Mountain into the east bank of the Yellowstone River. All seven streams encounter thermal areas of some nature that either significantly elevate stream temperature or contribute to chemical conditions, some of which are toxic to fish and macroinvertebrate life.

Trout Creek

Trout Creek is fed by a series of cold water streams and one thermal area, Sulfur Mountain (Figure 33). It is one of the more visible streams in Hayden Valley where its banks are frequented by large herds of free-roaming bison. Trout Creek was surveyed July 6-7, 1982.

Physical and Chemical Characteristics

The main stem of Trout Creek is 16.0 km long with an average gradient of 9.25 m/km. The stream is small with an average overall width of 2.64 m and a depth of 0.28 m. Flow at the outlet, during this early July survey, was 0.42 m³/sec. Trout Creek originates in a long, narrow grassy finger of southern Hayden Valley at about 2530 m elevation. Numerous small cold-water springs feed into the stream from the east slope of the Central Plateau and thermal springs originate in the area of Sulfur Mountain. The headwaters (stratum 1) is a small, narrow, curving stream with grassy banks and sand/gravel deposits. The steep gradient and a P:R:R ratio of 10:20:70 (Table 38), limits the fishery potential of this stratum. Further downstream (stratum 2), the stream is substantially deeper and swifter with a predominantly gravel substrate. A P:R:R ratio of 10:30:60 still precludes much habitat for adult fish, although some of this 5 km of stream represents the best spawning/nursery habitat observed for any stream in Hayden Valley. However, the gravel beds (10-50 mm particle size), are limited in area and probably support few spawning fish. Spawning activities in Trout Creek probably do not contribute significantly to the Yellowstone River stocks. Ranunculus sp. is abundant in this stratum and provides cover for numerous cutthroat trout observed from the bank.

The third stratum is characterized by long deep pools, more numerous than in strata 1 and 2. A P:R:R ratio of 30:30:40 was the best measured for this stream indicating that fish habitat is suitable for rearing and holding juveniles and adults. Gravel content in the substrate is low, and the area does not appear to support spawning activity.

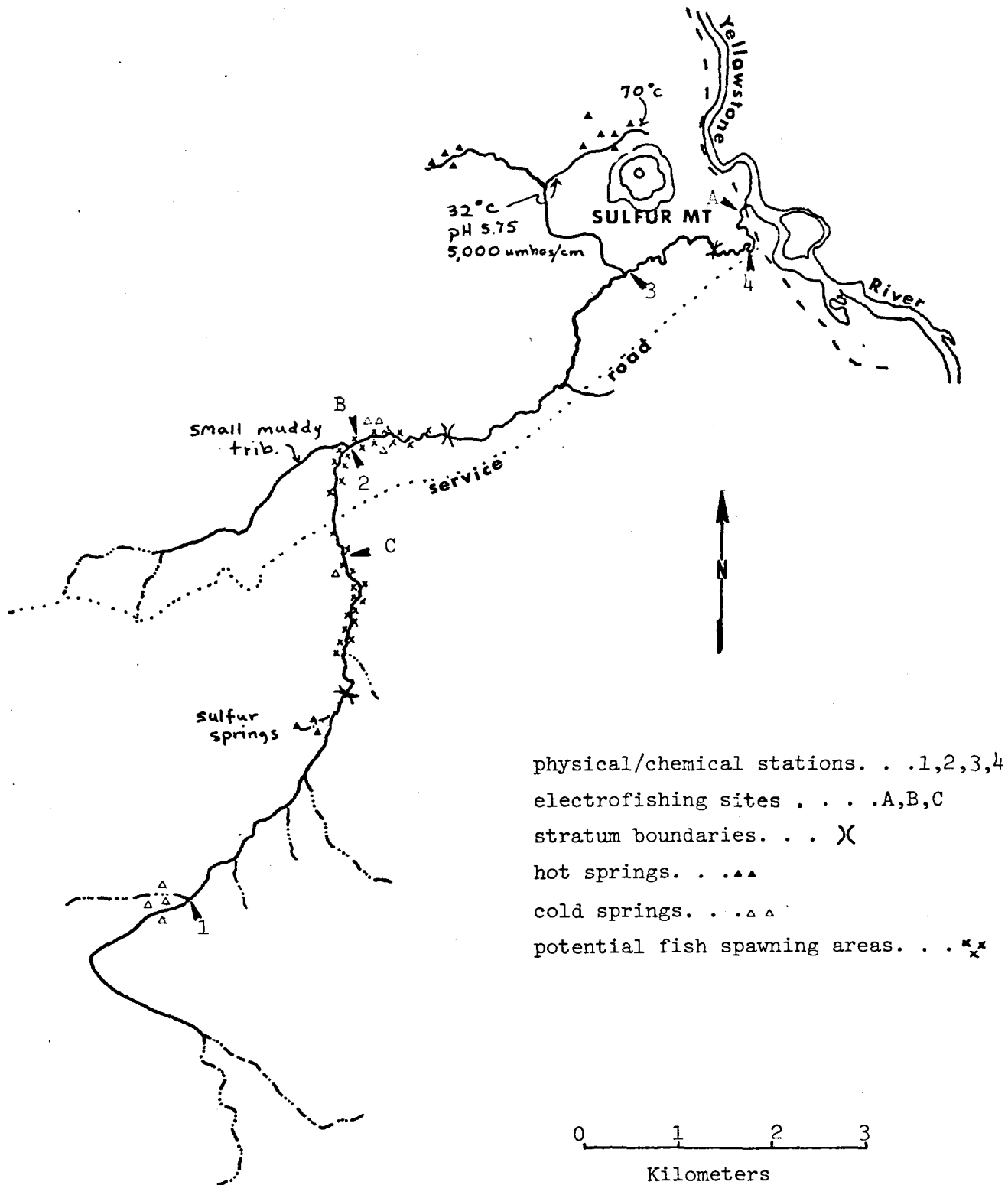


Figure 33. Trout Creek, Yellowstone National Park, 1982.

2.0: 3.8 Physical parameters for stations of streams in Hayden Valley, Yellowstone National Park, 1982

Parameters	Alus Creek					Bays Creek			Cottonwood Creek			Six Antler Creek					Gibbs Creek				
	1	2	3	4	5	1	2	3	1	2	3	1	2	3	4	5	1	2	3	4	5
Elevation (m)	2951	2408	2377	2353	2381	2804	2551	2408	2347	2402		2377	2390	2311	2359		2493	2481	2463	2432	2347
S-gradient (m/m)	13	7	11	5	1	66	47	22	5	6		8	9	11	5		7	2	21	30	11
Stream Length (km)	6.4	3.4	3.2	4.0	7.2	2.4	5.2	2.8	4.9	2.8		2.3	1.8	2.6	2.4		1.8	1.4	1.0	2.6	1.9
Average Velocity (m/sec)	0.38	0.23	-	0.36	0.55	0.15	0.27	0.14	0.023	-		0.21	-	-	0.21		0.04	-	-	-	0.11
Average Depth (m)	0.07	0.12	-	0.23	0.23	0.16	0.06	0.18	0.44	-		0.15	-	-	0.20		0.32	-	-	-	0.04
Average Slope (m)	1.64	1.68	-	8.51	6.99	3.03	4.83		2.01	-		1.02	-	-	1.58		2.82	-	-	-	2.14
Average Flow (m ³ /sec)	0.028	0.046	-	0.705	0.884	0.034	0.049	0.122	0.02	-		0.037	-	-	0.044		0.046	-	-	-	0.161
Average Depth (m)	0.50	0.40	-	1.93	1.38	0.09	0.18	0.40	0.44	-		0.18	-	-	0.38		0.44	-	-	-	0.13
Proportionate Distance	GR-2A-21	GR-2A	GR-3A	VE-0A-3A	VE-0A-31	VE	RU-40	CR	31-VE	81-CR							SA-CR-31	SA-04	GR-3A	VE-0A-3A	
Proportionate Flow Ratio (S)	15:10:75	20:10:50	20:20:60	20:10:50	10:10:60	10:40:50	10:40:50	60:20:20	20:10:80	40:10:60		-	-	-	-		15:10:45	10:20:70	40:40:20	40:40:20	20:10:50
Proportionate Instability (S)	25:10	10:40	10:30	10:25	5:10	0:15	5:15	-	10:10	10:20		-	-	-	-		30:5	5:20	15:10	10:10	2:10

* ϕ = ϕ_{50} = 0.4
 S₅ = boulder, > 305 mm
 G₅ = gravel, 3-76 mm
 S₁ = silt, fine gritty
 S₂ = sand, < 3 mm
 V₅ = vegetation

Parameters	Lower Creek					Middle Creek					Upper Creek				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Elevation (m)	2487	2430	2390	2347	2341	2426	2384	2353	2438	2377	2367	2332			
Gradient (x/m)	14	6	6	6	5	19	19	47	19	7	6	5			
Stream Length (km)	8.1	3.2	1.9	3.6	1.8	1.3	1.3	0.7	5.5	5.0	3.6	1.9			
Average Velocity (x/sec)	0.14	0.47	0.31	0.43	0.54	0.03	0.03	0.21	0.25	0.48	0.30	0.32			
Average Depth (m)	0.16	0.24	0.34	0.42	0.30	0.16	0.10	0.28	0.15	0.27	0.24	0.42			
Average slope (°)	2.62	4.75	6.45	6.02	8.41	1.47	0.94	1.60	0.56	2.13	2.87	4.98			
Average Flow (x/sec)	0.06	0.54	0.68	1.09	1.36	0.008	0.003	0.096	0.04	0.22	0.25	0.42			
Maximum Depth (m)	0.30	0.34	0.44	0.67	0.41	0.07	0.12	0.15	0.20	0.34	0.36	0.44			
Percentage Dissimilarity	CR	CR-NU	CR-NU	GR	GR	GR-SA	NU-GR	CR-NU	SA-NU-SI	CR	SA-NU-SI	SA-SI			
Flowing/Static Ratio (%)	85/15	50/50	-	-	40/30/30	30/50/20	20/20/60	10/80/10	10/20/70	10/30/60	30/30/60	10/10/60			
Base Discharge/Infiltrability (%)	5/20	20/20	10/15	5/10	5/10	10/10	30/10	15/5	20/10	15/20	10/30	10/10			

Stratum 4 encompasses the lowermost 1.9 km of Trout Creek. The stream here has a mild gradient of 5 m/km and a substrate that is predominantly sand and silt. With a P:R:R ratio of 10:10:80, the stream is characterized by long, deep, slow-flowing runs through a meandering/curving channel. Bank stability, which decreased downstream, was lowest (60%) in stratum 4 (Table 38). The alluvial nature of the soils of Hayden Valley are highly susceptible to sloughing and erosion, and in conjunction with high seasonal concentrations of bison, probably contribute to the turbid and silt-laden conditions in the lower reaches.

Water quality conditions in Trout Creek appeared normal during the July survey (Table 39). But, a tributary draining Sulfur Mountain had a water temperature of 32 C, a pH of 5.75, and a conductivity of 5,000 mhos/cm during July. The effect of this tributary on these three parameters in Trout Creek was greatly diluted by the 0.42 m³/sec flow of the main channel. Under reduced flow conditions, however, the Sulfur Mountain tributary could degrade the water quality of lower Trout Creek and, together with heavy siltation, further discourage use by fishes. Water samples show high levels of total dissolved solids, iron, and manganese as well as high turbidity (Table 39). These components may be toxic in the lower reaches of the stream during the low-flow periods.

Macroinvertebrates

Nineteen taxa of macroinvertebrates were found in Trout Creek (Table 40). Included are an array of mayflies, stoneflies, caddisflies, true flies and beetles common to most western montane streams. An abundance of amphipods (Hyallela azteca and Gammarus sp.) were found associated with a small thermal area in stratum 2.

The silt-sand substrate probably contributes to the fewer taxa seen in strata 3 and 4. The forms found in these strata (tipulids, chironomids, free-living caddisflies) suggest that the habitat is silted to the exclusion of the more upstream forms.

Fishes

Trout Creek, between 1924 and 1926, was stocked with 370,000 blackspotted (cutthroat) trout of unknown origin (Varley 1981).

Trout Creek was sampled with electrofishing gear May 21, June 16, and June 23, 1982. Only cutthroat trout were found during these surveys. The first two dates included work on the lowermost 300 m of stream above the Grand Loop Road (stratum 4). The third effort included about 400 m of the stream (stratum 2) about 5.5 km upstream from the Grand Loop Road (Figure 33).

Table 39. Chemical characteristics of back-country streams and lakes surveyed in Yellowstone National Park, 1982

	Alum Creek	Bear Creek	Bluff Creek	Cottongrass Creek	Elk Antler Creek	Gardner River	Grayling Creek	Nez Perce Creek
	9/30	9/8	7/21	9/29	9/30	9/30	8/1	10/6
Water temp. °C	11.1	15.6	14.4	5.0	11.1	13.9	6.0	10.0
Spec. cond. uahos	1000	93	73.5	560	220	170	120	360
pH	8.5	7.5	7.2	-	7.25	7.375	7.75	8.0
Dissolved O ₂	-	-	-	-	-	-	-	-
Secchi (meters)	-	-	-	-	-	-	-	-
Pheno. alk.	0	0	0	0	0	0	0	0
Total alk.	186	41	0	0	62	80	66	74
Ca hardness	42	24	42	36	60	52	30	
Total hardness	60	40	60	54	84	64	36	
Total diss. solids	690	49	380	120	139	80	225	
Carbonate alk.	0	0	0	0	0	0	0	
Bicarbonate alk.	186	41	0	62	80	66	74	
Carbonates	0	0	0	0	0	0	0	
Bicarbonates	226	50	0	75	97	80	91	
Hydroxides	0	0	0	0	0	0	0	
Carbon dioxide	18	1.8	>1000	40	9	4.5	12	
Chloride	104	1.98	<1.0	9	12	1.96	56	
Sulfate	165	2	270	34	16	2	39	
Fluoride	8.2	0.18	0.24	1.76	1.54	0.39	6	
Phosphate	0.28	0.22	0.16	0.31	0.12	0.16	0.22	
Potassium	39	1.2	12	4.6	3.12	1.12	8.4	
Mg hardness	18	16	18	18	24	12	6	
Calcium	16	9.6	16	14	24	20	12	
Magnesium	4.3	3.8	4.3	4.3	5.8	29	1.4	
Sodium	186	5	10	16	10	2.2	75	
Iron	0.10	0.13	18	0.86	<0.05	<0.05	<0.05	
Manganese	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	
Copper	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	
Silica	47	6.3	77	2.4	2	5.3	8.4	
Color (PCU)	20	0	15	40	0	0	0	
Turbidity (NTU)	5.4	0.38	20	4	0.2	0.31	0.23	
TOC	4.1	3	6.4	6.6	8.45	2.5	3.3	
Ortho-phosphate	0.93	0.19	0.43	0.62	0.15	0.16	0.22	
Total Kjeldahl N	1.1	0.33	0.48	0.76	0.16	0.15	0.11	
Nitrate N	<0.02	<0.02	<0.02	<0.02	0.02	0.02	<0.02	

Table 39, cont.

	Otter Creek	Sour Creek	Tepes Creek	Thistle Creek	Trout Creek	Stream #1234	Stream #1340	Stream #1346
	9/30	9/30	8/10	9/29	10/7	8/19	8/24	8/17
Water temp. °C	7.0	5.0	6.7	5.0	-	2.78	9.0	11.4
Spec. cond. umhos /460		460	160	150	-	175	70	73.5
pH	-	-	7.75	7.5	-	8.0	7.75	7.25
Dissolved O ₂	-	-	8.8	-	-	-	8.2	8.4
Secchi (meters)	-	-	-	-	-	-	-	-
Pheno. alk.	0	0	-	0	0	0	-	-
Total alk.	0	0	75	74	156	74	34	34
Ca hardness	24	24	-	18	60	60	-	-
Total hardness	30	24	68	18	114	66	34	28.4
Total diss. solid.	260	265		38	470	105		
Carbonate alk.	0	0		0	0	0		
Bicarbonate alk.	0	0		74	156	74		
Carbonates	0	0		0	0	0		
Bicarbonates	0	0		90	190	91		
Hydroxides	0	0		0	0	0		
Carbon dioxide	>1000	>1000		190	63.6	16		
Chloride	29	12		1	<1.0	3		
Sulfate	84	155		3	130	17		
Fluoride	0.84	1.02		1.4	0.93	0.18		
Phosphate	0.19	0.4		0.22	1.7	0.22		
Potassium	7.3	10		3.2	1.7	2		
Mg hardness	6	<1.0		<1.0	54	6		
Calcium	9.6	9.6		7.2	24	24		
Magnesium	1.4	<1.0		<1.0	13.1	1.4		
Sodium	28	10		3.6	9.9	4.2		
Iron	0.84	1.85		<0.05	0.78	<0.05		
Manganese	<0.05	<0.05		<0.05	23.5	<0.05		
Copper	<0.01	<0.01		<0.01	<0.3	<0.01		
Silica	4.3	7.6		6	15	4.7		
Color (PCU)	20	15		10	-	0		
Turbidity (NTU)	1	1.65		0.33	707	0.74		
TOC	4.2	2.55		2.55	5.3	1.1		
Ortho-phosphate	0.5	0.43		0.31	0.09	0.22		
Total Kjeldahl N	0.68	0.52		0.08	8.4	0.19		
Nitrate N	0.02	0.04		0.02	0.02	<0.02		

Table 40. Occurrence and densities of macroinvertebrates in stations of selected streams in Yellowstone National Park, 1982

Taxa (common name)	Alum Creek Stations					Pear Creek Stations			Bluff Creek Station	Elk Antler Creek Stations			
	1	2	3	4	5	1	2	3	1	1	2	3	4
Hirudinea (leeches)						X	X						
Crustacea													
Amphipoda (scuds)													
Gammarus sp.				X						X	X		X
Hyalolella azteca													
Hydracarina (watermites)						X							
Insecta													
Ephemeroptera (mayflies)													
Baetidae													
Baetis sp.	X	X		X						X	X	X	
Baetis bicaudatus								X	X	X		X	
Baetis tricaudatus	X					X	X						
Cloeon									X				
Ephemerellidae													
Ephemerella sp. 1													
Ephemerella sp. 2													
Ephemerella sp. 3													
Ephemerella bicolor								X					
Ephemerella caddisi													
(Drunella) sp.									X				
(Serratella) sp.										X		X	
Heptageniidae													
Cinygmula sp.		X								X		X	
Cinygmula sp.						X			X			X	
Epeorus sp.													
Rhithrogena sp.						X			X				
Leptophlebiidae													
Leptophlebia sp.													
Siphonuridae													
Ameletus sp.	X	X		X		X			X	X			
Siphonurus sp.		X											
Tricorythidae													
Tricorythodes sp.	X	X		X									
Odonata (damselflies)													
Coenagrionidae													
Enallagma sp.				X	X								
Plecoptera (stoneflies)													
Chloroperlidae													
Chloroperla sp.	X	X				X			X	X		X	
Perlidae													
Acroneuria sp.						X			X				
Perlodidae													
Isoperla sp.									X	X			
Nemouridae													
Nemoura sp.	X												

continued on next page

Table 40. Occurrence and densities of macroinvertebrates in stations of selected streams in Yellowstone National Park, 1982

Taxa (common name)	Otter Creek Stations					Sour Creek Stations					Tnistle Creek Stations			Trout Creek Stations			
	1	2	3	4	5	1	2	3	4	5	1	2	3	1	2	3	4
Hirudinea (leeches)																	
Crustacea																	
Amphipoda (scuds)																	
Gammarus sp.																X	
Hyallia azteca																X	
Hydracarina (watermites)																	
Insecta																	
Ephemeroptera (mayflies)																	
Baetidae																	
Baetis sp.		X	X	X							X	X	X		X	X	X
Baetis bicaudatus																	
Baetis tricaudatus									X								
Cloeon											X		X				
Ephemerellidae																	
Ephemerella sp. 1									X								
Ephemerella sp. 2									X								
Ephemerella sp. 3											X		X				
Ephemerella bicolor																	
Ephemerella doddsi																	
(Drunella) sp.							X						X				
(Serratella) sp.																	
Heptageniidae																	
Cinysmula sp.											X	X	X			X	
Cinysma sp.																	
Epeorus sp.																	
Rhithrogena sp.														X	X		
Leptophlebiidae																	
Leptophlebia sp.											X	X	X				
Siphonuridae																	
Ameletus sp.	X										X	X	X		X		
Siphonurus sp.						X											
Tricorythidae																	
Tricorythodes sp.																	
Odonata (damselflies)																	
Coenagrionidae																	
Enallagma sp.																	
Plecoptera (stoneflies)																	
Chloroperlidae																	
Chloroperla sp.											X		X		X		
Perlidae																	
Acroneuria sp.												X	X				
Perlodidae																	
Isoperla sp.									X		X	X	X			X	
Nemouridae																	
Nemoura sp.									X		X	X					

continued on next page

Table 40. continued

	Alum Creek					Bear Creek			Bluff Creek	Elk Antler Creek			
	Stations					Stations			Station	Stations			
	1	2	3	4	5	1	2	3	1	1	2	3	4
Trichoptera (caddisflies)													
Brachycentridae													
Brachycentrus sp.												X	
Micrasema sp.						X							
Glossosomatidae													
Glossosoma sp.													
Hydropsychidae													
Arctopsyche grandis									X				
Cheumatopsyche sp.											X		
Limnophilidae													
Hesperophylax sp.	X	X											
Limnophilus sp.													
Moselyana sp.									X				
Neothrerma sp.						X			X				
Onocosmoecus sp.												X	X
Rhyacophilidae													
Rhyacophila sp.													
Rhyacophila angelita									X				
Rhyacophila verrula										X		X	X
Sericostomatidae													
Gumaga sp.											X	X	
Diptera (true flies)													
Ceratopogonidae													
Bezzia sp.										X			X
Chironomidae	X	X		X	X	X			X				
Simuliidae													
Simulium sp.	X									X			
Tipulidae													
Hexatoma sp.													
Prinocera sp.	X												
Tipula sp.	X												
Coleoptera (beetles)													
Carabidae							X						
Dytiscidae													
Agabus sp.	X			X	X								
Dytiscus sp.										X			X
Elmidae													
Narpus sp.													
Rhizelmis sp.		X							X	X	X	X	
Hemiptera (true bugs)													
Belostomatidae				X									
Corixidae													
Graptocorixa sp.				X									
Gerridae													
Gerrus sp.				X									
Naucoridae											X		
Ambrusus sp.				X									
Gastropoda (snails)													
Physa sp.				X	X								
										X	X	X	X
Pelecypoda (clams)													
Sphaeriidae				X	X								
NUMBER INVERTEBRATES	31	51	0	176	0	2	4	9					
NUMBER TAXONOMIC GROUPS	12	9	0	13	5	4	8	4	15	15	6	12	7
TOTAL NUMBER OF GROUPS PER WATER			23				14		15		21		

Table 40. continued

	Otter Creek					Sour Creek					Thistle Creek			Trout Creek			
	1	2	3	4	5	1	2	3	4	5	1	2	3	1	2	3	4
Trichoptera (caddisflies)																	
Brachycentridae																	
Brachycentrus sp.									X	X	X	X	X	X			X
Microstema sp.											X	X		X	X		
Glossosomatidae																	
Glossosoma sp.															X	X	
Hydropsychidae																	
Arctopsyche grandis																	
Cheumatopsyche sp.																	
Limnophilidae																	
Hesperophylax sp.					X		X	X		X					X	X	
Limnephilus sp.		X	X													X	
Moselyana sp.																	
Neotoma sp.	X		X			X				X	X	X		X	X		X
Unocosmoeus sp.																	
Rhyacophilidae																	
Rhyacophila sp.															X		X
Rhyacophila angelita																	
Rhyacophila verrula						X	X	X	X								
Sericostomatidae																	
Gumaga sp.																	
Diptera (true flies)																	
Ceratopogonidae																	
Bezzia sp.						X											
Chironomidae	X	X	X								X	X	X		X	X	X
Simuliidae																	
Simulium sp.																	
Tipulidae																	
Hexatoma sp.																	X
Prinocera sp.																	
Tipula sp.															X		X
Coleoptera (beetles)																	
Carabidae																	
Dytiscidae																	
Agabus sp.																	
Dytiscus sp.																	
Elmidae																	
Narpos sp.						X											
Enizelmis sp.						X								X	X	X	
Hemiptera (true bugs)																	
Belostomatidae																	
Corixidae																	
Graptocorixa sp.																	
Gerridae																	
Gerrus sp.																	
Maucoptidae																	
Ambrusus sp.																	
Gastropoda (snails)																	
Pyysa sp.																	
Pelecypoda (clams)																	
Sphaeridae																	
NUMBER INVERTEBRATES																	
NUMBER TAXONOMIC GROUPS	3	4	4	2	1	4	4	2	7	4	13	11	12	9	14	7	7
TOTAL NUMBER OF GROUPS PER WATER			7					14				15			19		

The May 21 effort yielded one female cutthroat trout in prespawning condition (site A). By June 16, three spawned-out males were taken from the same area. All four fish probably ascended from the Yellowstone River to spawn in the gravel areas further upstream. On June 23, a total of eight cutthroat trout were collected from 400 m of stream (site B). All of these fish were judged to be residents, based on size and markings. On July 6, 0.5 angler-hours in stratum 2 (site C) yielded six cutthroat trout 102-152 mm total length. No other fish species besides cutthroat trout were found in Trout Creek.

Elk Antler Creek

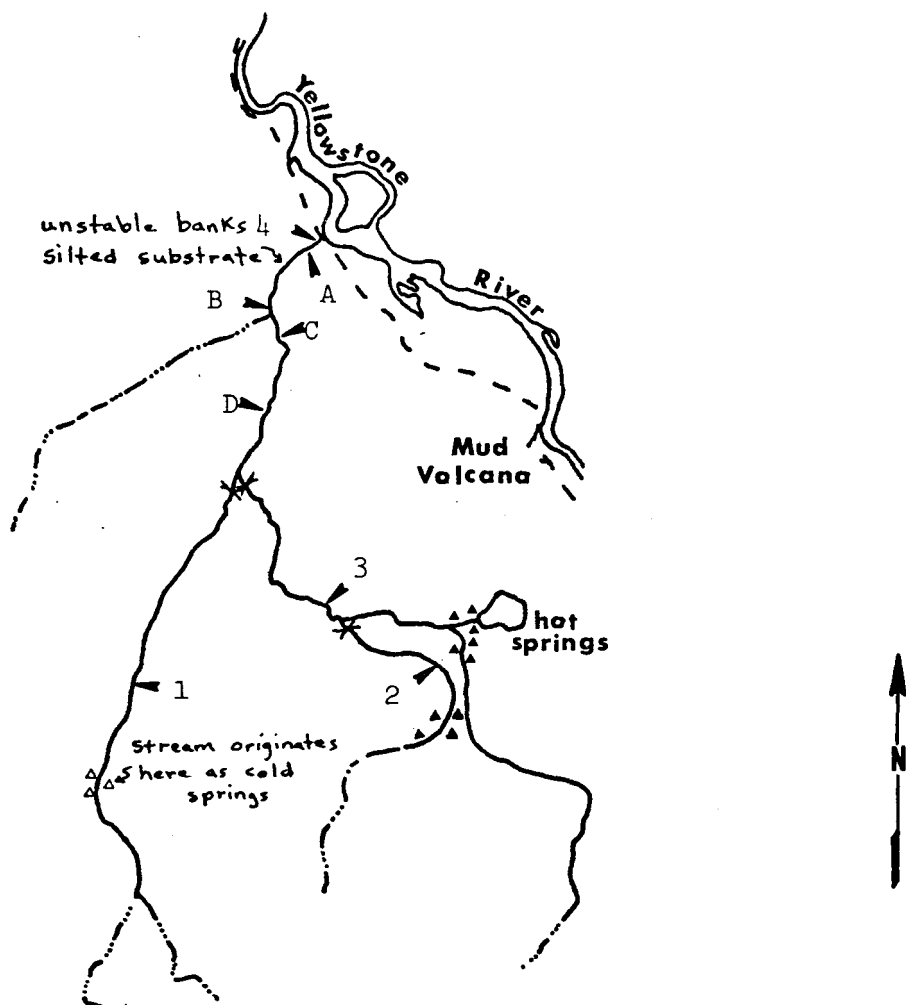
Elk Antler Creek drains the north slope of Elephant Back Mountain and flows through the southern end of Hayden Valley into the Yellowstone River. This stream was surveyed July 6, 1982 (Figure 34).

Physical and Chemical Characteristics

Elk Antler Creek is a small meandering stream with an average gradient of 8.25 m/km, average width of 1.45 m and average depth of 0.18 m. Flow at the outlet to the Yellowstone River, during this survey, was 0.084 m³/sec. The main stem of this stream is 9.1 km long. Elk Antler Creek originates from cold and warm water springs supplemented by snow melt from Elephant Back Mountain. Flow in the southwest branch (stratum 1) starts as cold springs just above the treeline. The stream is small (Table 38), and flows through an open grassy rolling valley. Water chemistry (Table 39) yielded a July water temperature of 8.8 C, pH of 7.4, and conductivity of 140 mhos/cm (station 1).

Flow in the southeast branch (stratum 2) also originates as cold springs but is fed by hot sulfur springs from the vicinity of Mud Volcano (Figure 34). Water temperature below these hot springs (station 2) in July was 25.5 C, pH was 7.8 and conductivity 135 mhos/cm.

At station 3, further downstream, water temperature was cooled to 13.9 C, pH was 7.0, and conductivity was up to 475 mhos/cm. The stream in stratum 3 has a relatively steep gradient (11 m/km) as it carves its way through low rolling grassy hills. Elk Antler Creek in stratum 4, before it enters the Yellowstone River, meanders considerably through a lush, grassy, open valley. Water temperature at station 4 on July 6 was 12.8 C, pH was 7.75, and conductivity was 250 mhos/cm. On September 30, water temperature was 11 C, pH was 7.25, and conductivity was 220 mhos/cm. Water analysis (Table 39) revealed no major water chemistry problems in Elk Antler Creek during late summer low flows. Minor problems included slightly elevated water temperatures, siltation and turbidity.



physical/chemical stations. . .1,2,3,4
 electrofishing stations. . .A,B,C,D
 stratum boundaries. . .X
 hot springs. . .▲▲
 cold springs. . .△△

0 1 2 3
 Kilometers

Figure 34. Elk Antler Creek, Yellowstone National Park, 1982.

Macroinvertebrates

Twenty-one taxa of macroinvertebrates were found in Elk Antler Creek, including several genera of mayflies, stoneflies and caddisflies (Table 40). Also found were true flies, beetles, true bugs, scuds and clams; these groups were usually associated with the thermal and sulfur areas near the upper watershed. The middle and lower reaches of Elk Antler Creek (stratum 3) support a compliment of stream invertebrates common to many western montane streams, although some forms (Serratella sp., Onocosmoecus sp., Rhyacophila verrula, Brachycentrus sp., Gumaga sp.) suggest a silted habitat.

Fishes

No record of fish stocking is listed for Elk Antler Creek (Varley 1981). The present survey suggests that most of Elk Antler Creek and its tributaries are inhabited by fish.

Elk Antler Creek was electrofished May 20 and June 18, 1982. Only one fish, a small cutthroat trout, was taken on the first effort from a 100 m section of the stream near the Grand Loop Road (site A). Three 400 m sections (sites B,C,D), from 1 to 3 km upstream from the Grand Loop Road, yeilded 2, 10, and 11 cutthroat trout respectively. All fish were judged to be residents based on size and markings. No other species of fish was observed or captured in Elk Antler Creek.

Warm water temperatures and a paucity of spawning areas may preclude use of Elk Antler Creek by Yellowstone River spawners. High turbidity and silt levels, especially in the lower stream reaches, also negate desirable spawning and rearing areas.

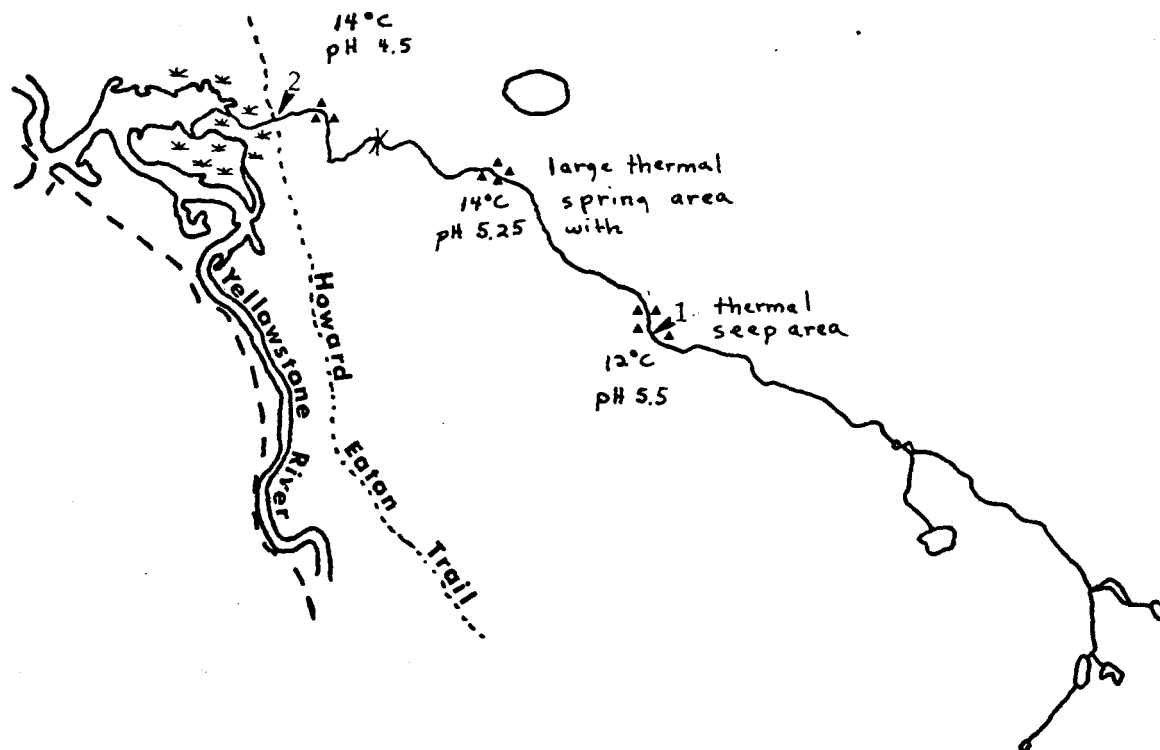
Cottongrass Creek

Cottongrass Creek flows parallel to Sour Creek and enters the Yellowstone River through an extensive marsh system used by many ducks, geese, swans and pelicans (Figure 35). Cottongrass Creek was surveyed July 13, 1982.

Physical and Chemical Characteristics

Cottongrass Creek is a small stream that flows through rolling hills with dense stands of lodgepole pine and intermittent small meadows before entering the Yellowstone River through an extensive marsh system shared with Sour Creek. The outlet flow during the July survey was only 0.02 m³/sec (Table 38).

The stream in stratum 1 meanders through a shallow valley lined with standing and fallen lodgepole pines. The stream bank in many places, was barren with scattered fallen and charred trees which suggests thermal activity of a recent origin. Associated with these thermal areas are pools and seeps oozing with warm turbid waters laced with brown and yellow colors indicating iron and sulfur.



physical/chemical stations. . . 1,2
 stratum boundaries. . . X
 hot springs. . . ▲▲
 meadow. . . * *

0 1 2 3
 Kilometers

Figure 35. Cottongrass Creek, Yellowstone National Park, 1982.

The stream banks in several places of stratum 2, near the outlet, are lined with small bubbling seeps of warm water. The banks are generally lined with grasses and sedges and the stream channel is deeply cut with overhanging banks. The substrate is primarily mud and silt with no live instream vascular plants and a brown rust-like coating of ferric hydroxide. The water chemistry (Table 39) in this stratum was characterized by warm temperature (14.4 C), low pH (4.5) and moderate conductivity (157). Measurements taken at this same station 1 on October 1, 1982, revealed a water temperature of 5 C, pH of 3.0 and a conductivity of 560 mhos/cm. The difference in these three parameters for the two flow periods suggests a dilution effect from spring runoff in Cottongrass Creek.

Water analysis suggests that the low pH values may be primarily of a gaseous nature with CO₂ levels in excess of 1000 mg/l (Table 39). High sulfate levels of 270 mg/l also indicate a sulfuric acid problem. The low pH resulting from these two elements enhances iron toxicity in Cottongrass Creek. The level of 18 mg/l far exceeds levels (0.9 mg/l) toxic to carp (McKee and Wolf 1963). Apparently, the low pH enables the high level of colloiddally dissolved humates in Cottongrass Creek to incorporate the dissolved form of iron (ferrous) for transport considerable distances downstream from its source. Once the ferrous ion is exposed to oxygen, it is converted to insoluble ferric hydroxide, which forms the characteristic brown precipitate. This oxidation process usually occurs near the iron source, except in cases like Cottongrass Creek with low pH and a high level of colloidal humates.

Macroinvertebrates

No macroinvertebrates were found in Cottongrass Creek during this survey. It appears that poor water quality (warm temperatures, low pH, high CO₂ levels, high SO₄ levels, high iron) precludes macroinvertebrate life.

Fishes

No record exists of fish stocking in Cottongrass Creek (Varley 1981). This survey indicates that the entire stream and its tributaries are fishless and that it is unlikely to support fish in view of its poor chemical condition. However, this survey did not fully investigate all tributaries and ponds in the headwaters where an enclave population of fishes could exist.

Sour Creek

Sour Creek originates in Ponuntpa Springs near Fern Lake and flows northwest into the Yellowstone River at the northeast end of Hayden Valley (Figure 36). It is fed by Bluff Creek and other tributaries draining Stonetop Mountain as well as Bog Creek which drains a hot springs area north of Sour Creek. Sour Creek enters the Yellowstone River in a lowland area of

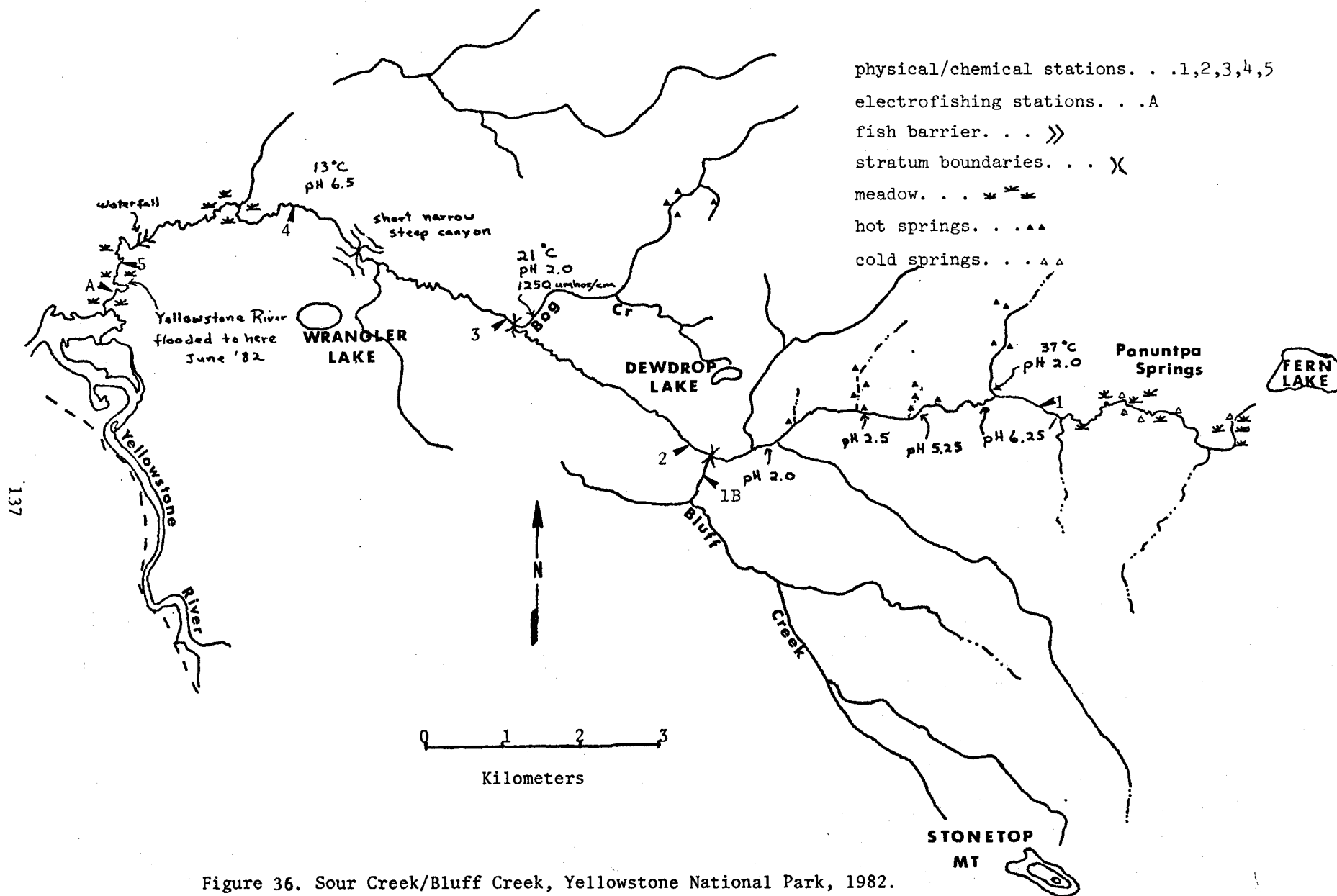


Figure 36. Sour Creek/Bluff Creek, Yellowstone National Park, 1982.

sagebrush, sedges and Vaccinium which is usually flooded during spring runoff. This stream was surveyed July 13 and 21-22, 1982.

Physical and Chemical Characteristics

Sour Creek is a medium-size stream with a gradient of 7.4 m/km. In only two locales is the gradient steep: a short narrow canyon with cascading flow about 5 km above the mouth and an abrupt waterfall about 1.5 km from the mouth (Figure 36). Average stream width in July was 5.6 m, depth was 0.4 m, and the flow was 1.36 m³/sec. Five distinct longitudinal habitat strata were identified in Sour Creek.

In stratum 1, the stream originates from springs in an open wet meadow and flows through a deeply cut channel lined with overhanging grasses and sedges. The substrate here is predominately gravel with a P:R:R ratio of 85:15:0 (Table 38). The stream is then fed by several thermal springs, and water temperature was quickly elevated from 12.0 C to 22.2 C at station 1, but pH remained at 7.8 and conductivity was 300 mhos/cm (Table 39).

Further downstream, in stratum 2, the gradient is mild with substantial flow of 0.54 m³/sec. Gravel still dominates the substrate and P:R:R ratios were 50:50:0. Bank instability was common here and there was extensive thermal activity along the stream course. Station 2 exhibited cooler temperatures (14.4 C) than station 1, but a higher conductivity of 400 mhos/cm, and a dramatically lower pH of 2.0.

At station 3, Sour Creek is fed by several thermal areas and by Bog Creek. Gravel is the dominant substrate type and bank stability is increased by a more rocky stream bank. The stream flows through a steep and narrow gorge midway through this stratum, but this feature is not judged to be a barrier to fish travel. Thermal activity was still prevalent and pH remained at 2.0, a factor probably greatly influenced by the outflow from Bog Creek.

Stratum 4 characterizes a stream of mild gradient with a July flow of 1.09 m³/sec. About 80% of the substrate was gravel and there was high bank stability. The lower end of this stratum is marked by a 10 to 12-m waterfall; a definite fish barrier. Water quality in this stratum was substantially improved over that of the previous two upstream strata. Temperature was still relatively warm at 13.3 C, but pH was 6.5 and conductivity 275 mhos/cm. This difference in water chemistry may be a function of sample time relative to spring runoff. The stream when sampled at stations 4 and 5 on July 13 was at full runoff stage which had subsided somewhat by the July 21-22 samples further upstream.

The stratum represented by station 5 extends from the falls downstream to the Yellowstone River. Sour Creek at this point

is a stream with average depth of 0.30 m, average width of 8.41 m, and flow of 1.36 m³/sec. The predominantly gravel (particle size 10-50 mm) substrate and a P:R:R ratio of 40:30:30 renders this 1.78 km stratum a good potential spawning/nursery area accessible to Yellowstone River fishes. However, no fish were sighted or captured by electrofishing in July when water chemistry seemed favorable; temperature, 15.5 C; pH, 6.5; and conductivity, 300 mhos/cm. A second water quality sample October 1, 1982, revealed a water temperature of 5 C, pH of 4.25 and conductivity of 460 mhos/cm. Like other streams in and around Hayden Valley, fish life in Sour Creek appears to be limited by poor water quality.

Water analysis reveals that the major cause of low pH in Sour Creek may be of a gaseous nature; the carbon dioxide level was in excess of 1000 mg/l, while sulfate level was moderate at 155 mg/l (Table 39).

It was also noted that after spring runoff, much of the gravel in stratum 5, previously inundated by the swollen Yellowstone River, was covered by a heavy layer of silt left by the receding waters. This eliminated nearly 1 km of seemingly good gravel areas for spawning.

Macroinvertebrates

Fourteen taxa of macroinvertebrates were found in Sour Creek during this survey (Table 40). Samples from strata 1, 2, and 3 revealed a low diversity of invertebrates, presumably because of the poor water quality from streamside thermal activity. In spite of poor water quality, some invertebrates were able to find microhabitats suitable for life. The seven taxa found in station 4 indicate a recovery of water chemical conditions. Only four taxa, all caddisflies, were found in station 5, an area mostly inundated during runoff by water and silt of the Yellowstone River. Compared to the other streams of Hayden Valley, Sour Creek supports a low diversity of macroinvertebrates, presumably because of poor water quality throughout and siltation in the lower reaches.

Fishes

No record of fish stocking was found for Sour Creek (Varley 1981). No fish were observed in Sour Creek or its tributaries during the survey of July 13 and 21-22, 1982. Stratum 5, below the waterfall, was intensively electrofished with a backpack unit July 13 but no fish were observed or captured.

Bluff Creek

Bluff Creek is a tributary of Sour Creek that drains the northwest slope of Stonetop Mountain (Figure 36). This stream was visited during the Sour Creek survey of July 21-22, 1982. Only the lower 1 km of the stream was surveyed.

Physical and Chemical Characteristics

Bluff Creek is a small tributary of Sour Creek that does not exhibit the poor water quality conditions of the latter. The lower end of Bluff Creek (stratum 1B) is a series of cascades and plunge pools that appear to be good potential fish habitat. Average stream width during the July survey was 2.03 m. Many deep pools were present with some instream vegetation of Fontinalis sp. and Ranunculus sp. providing habitat for a healthy macroinvertebrate fauna.

Water temperature in July was 14.4 C, pH was 7.2 and conductivity was 40 mhos/cm. No evidence of thermal activity was found in Bluff Creek.

Macroinvertebrates

The macroinvertebrate fauna of Bluff Creek was moderately rich for its small size. Fifteen taxa were found in this survey (Table 40). The presence of several genera of mayflies, stoneflies, and caddisflies indicates that Bluff Creek is capable of supporting a small population of fishes. Especially notable in Bluff Creek is the presence of Acroneuria sp., a predaceous stonefly that is generally an indicator of a good stable invertebrate fauna.

Fishes

Bank observations and minimal sampling failed to reveal the presence of any fish in the lower 1 km of Bluff Creek. Considering the good water quality, invertebrate fauna, and habitat quality, fish would probably fare well if they could gain access to Bluff Creek. Poor water quality in Sour Creek appears to be preventing this entry.

Bog Creek

Bog Creek is a tributary of Sour Creek that drains hot springs in the area of Dewdrop Lake (Figure 36). Maps indicate a connection between this lake and Bog Creek, but on-site reports (Jones et al 1980) show no perennial outlet. Only the lowermost 1 km of stream was surveyed during the work on Sour Creek July 21-22, 1982.

Physical and Chemical Characteristics

Lower Bog Creek flows through a dense lodgepole pine forest. The stream is lined with grasses and sedges but the bank is denuded in several places by numerous thermal springs and seeps. Just above Sour Creek, Bog Creek flows through a steep and narrow rocky canyon with a substrate of 40% rubble, 40% gravel, 10% boulder, and 10% sand. The gradient here is steep and the habitat mostly riffles. Water quality in July was poor;

temperature was 21.1 C, pH was 2.0 and conductivity was 1250 mhos/cm.

No macroinvertebrates or fishes were found in lower Bog Creek during this survey. It is unlikely that this stream supports much life because of the poor water quality measured near its outlet and observed further upstream.

Alum Creek

Alum Creek originates in the Central Plateau of Yellowstone National Park and flows north and east across the northern end of Hayden Valley (Figure 37). It enters the Yellowstone River through a small flooded swale which is crossed by the Grand Loop Road. This ponded area attracts large numbers of waterfowl and ungulates, a popular attraction to park visitors. Alum Creek was surveyed July 27-29, 1982.

Physical and Chemical Characteristics

Alum Creek is chemically one of the most interesting streams in Hayden Valley. It originates as a cold-water stream which is disrupted by a spectacular instream thermal area, two major thermal tributaries (Highland Hot Springs and Violet Creek), and several small streamside thermal areas. In spite of these conditions, cutthroat trout inhabit the headwaters and longnose dace (Rhinichthys cataractae) and reidside shiner (Richardsonius balteatus) the middle and lower reaches.

Alum Creek was divided into five longitudinal habitat strata based primarily on thermal features. The main stem flows for about 25 km with a relatively mild gradient of 7.4 m/km. Average overall stream width was 4.56 m, average depth was 0.85 m and the outlet flow during this late July survey was 0.884 m³/sec.

Alum Creek originates as springs in a large open grassy meadow at about 2500 m elevation (stratum 1). It meanders through grassy meadows as a first order stream for about 6.4 km before entering a small canyon. In the meadows, the stream is small with a July flow of 0.028 m³/sec (Table 38). The substrate is primarily gravel pockets with some sand and silt. A P:R:R ratio of 15:10:75 and a bank overhang of 25% suggests that the stream in this stratum provides good spawning/nursery habitat for the numerous small cutthroat trout seen in the stream. Temperature, pH, conductivity, dissolved oxygen, hardness, and alkalinity (Table 39) were similar to other Park headwater streams.

The section of stream represented by stratum 2 is also first order with a flow of 0.046 m³/sec. The stream here curves through a narrow grassy valley. On its bank is the remains of a small log cabin. The substrate in stratum 2 is primarily gravel with sand and silt. Fish habitat is fair with a P:R:R ratio of

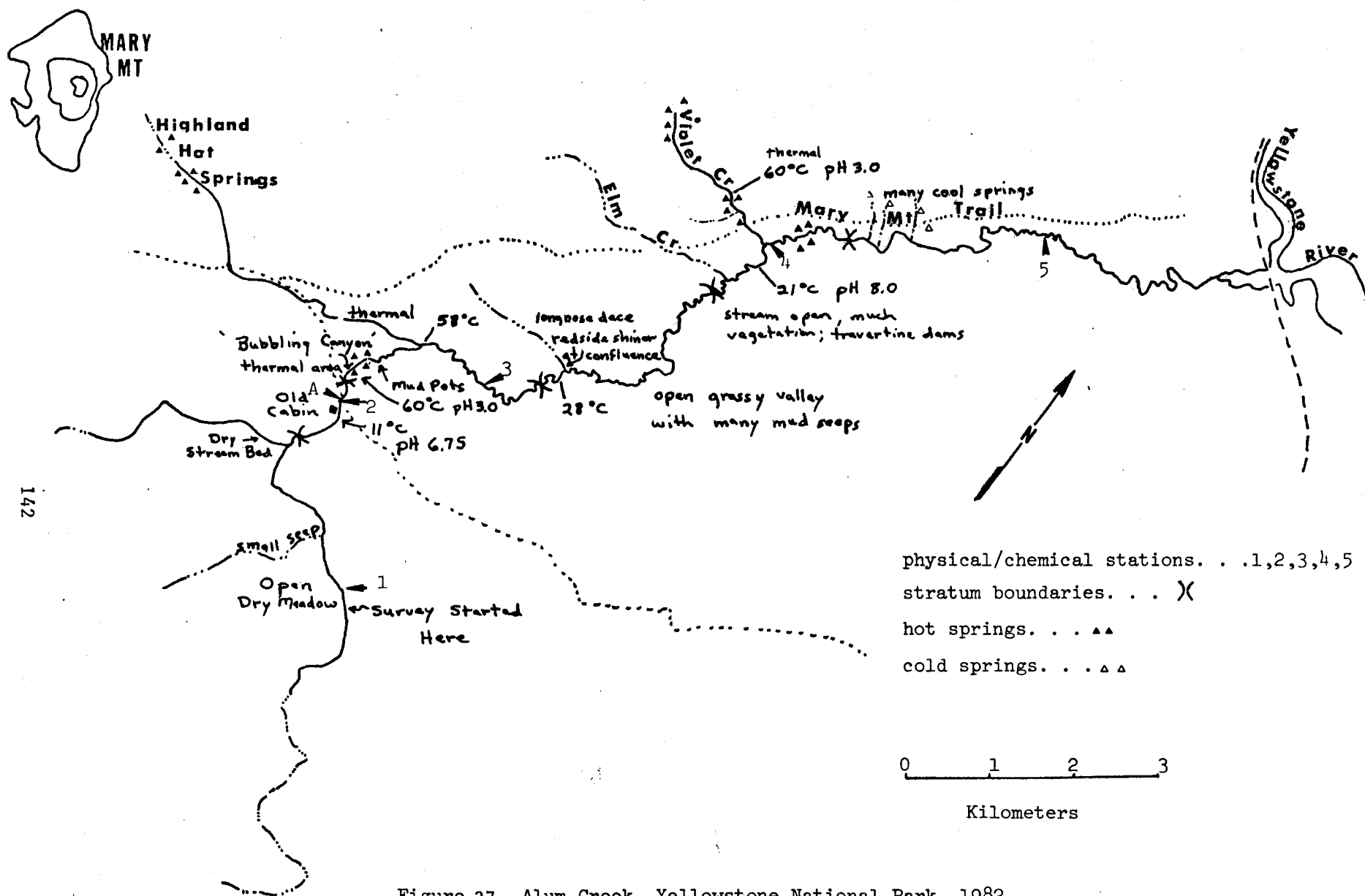


Figure 37. Alum Creek, Yellowstone National Park, 1982.

20:30:50, but bank instability is high. Bison and elk activity, observed during this survey, contributes to sloughing. Water chemistry in stratum 2 was nearly identical to that of stratum 1. Stratum 2 supports most of the cutthroat trout inhabiting the headwaters of Alum Creek. These fish are presently restricted to the upper 9.8 km of stream by a sizeable thermal area.

The stream from this thermal area to below the confluence of the Highland Hot Springs tributary was designated stratum 3. The small, narrow, steep canyon is lined with rock outcrops and a few sparse patches of grass. The area is apparently used by overwintering bison as indicated by four carcasses found in the canyon and another three just downstream. Fresh signs of grizzly bears feeding on these carcasses were present. This thermal area is characterized by several streamside pots spurting and oozing hot mud and water from travertine domes. Alum Creek receives the heated effluent from these as well as that of several small thermal seeps. The stream is also heated by hot gases that pulsate as large bubbles from cracks in the stream bed. In the lower end of the canyon, several medium-sized thermal pots also feed heated water into the stream. In late July, stream temperatures of 11 C were heated to 60 C and pH was changed from 6.75 to 3.0 in a distance of about 100 m. Below the thermal activity, Alum Creek is lined with mud bogs used as wallows by bison.

A tributary from Highland Hot Springs enters Alum Creek about 1 km below the thermal area. Water temperature in both branches was 58 C. The stream below this tributary (stratum 3) is open and meandering with grassy banks and a gravel/sand/bedrock substrate. The bedrock substrate appears to be deposits of travertine that form small dams progressively downstream. The water slowly cooled downstream of the Highland tributary and at 48 C, long filamentous Ranunculus sp. began to appear. Also, water striders (Gerridae) were seen as the first forms of invertebrates past the thermals.

Stratum 4 was absent of any substantial thermal activity. Alum Creek begins to meander considerably here through a wide grassy valley surrounded by treeless rolling hills. Several small travertine dams occur in the stream and cooling water temperatures allow for an increasing amount of aquatic vegetation and macroinvertebrates.

Stratum 5 of Alum Creek includes the thermal tributary Violet Creek and a small thermal area with hot pots along the stream banks. The confluence of these two streams is used heavily by geese, cranes and bison. Alum Creek in this stratum had a July flow of 0.705 m³/sec. Aquatic vegetation was abundant and fish habitat was fair with a P:R:R ratio of 20:30:50, but salmonid fishes appear to be excluded by the warm stream temperatures. Violet Creek, at its warmest, about 400 m above Alum Creek, was 60 C. As it flowed into the 21 C water of Alum Creek, its temperature was 40 C. Below Violet Creek, Alum Creek was warmed

to 25.5 C. Like temperature, the pH of Alum Creek was also influenced by Violet Creek. The lowest pH of Violet Creek was 2.0. As it entered Alum Creek, pH of Violet Creek was 3.0. Above Violet Creek, pH of Alum Creek was 8.0 and that below was 7.5.

A fourth thermal area was located about 1 km downstream of Violet Creek. It consisted of several hot pots and thermal seeps, most oozing through small travertine domes that heated the stream from 25.5 C to 34 C.

The stream in stratum 5 is an open channel choked with mosses and aquatic plants. Flow in July was 0.884 m³/sec and P:R:R ratio was 10:30:60. The limiting factor precluding trout appeared to be stream temperature. Temperature in late July was 27.8 C, pH was 8.75 and conductivity was 1000 mhos/cm. The same parameters measured afield September 30 were temperature, 11 C; pH, 8.5; and conductivity, 1000 mhos/cm. Alum Creek in fall appears to remain warm compared to other nearby streams.

Alum Creek is moderately buffered by a bicarbonate system (226 mg/l), with a total alkalinity of 186 mg/l (Table 39). Chlorides (104 mg/l) and sulfates (165 mg/l) were high but not at toxic levels (McKee and Wolf 1963). Reportedly, high calcium levels can moderate such toxicity. Nitrate and phosphate levels in Alum Creek apparently stimulate the heavy growth of aquatic plants seen during this survey.

Macroinvertebrates

Twenty-three taxa representing ten orders and twenty families of macroinvertebrates were found in Alum Creek in this survey (Table 40). Stream invertebrates were found in four of the five strata sampled. The station devoid of invertebrates represented stratum 3, the area within and just below the upper thermal region.

Invertebrates in the upper stream reaches (strata 1 and 2) were represented by mayflies (Baetis sp., Ameletus sp.), stoneflies (Chloroperla sp.), and beetles (Rhizelmis sp.). Some forms (Tricorythodes sp., Hesperophylax sp., Prinocera sp., Tipula sp.) are indicators of siltation and vegetated areas. The forms found in the lower reaches (strata 4 and 5) were primarily dwellers of mud/silt substrate (Tricorythodes sp., Chironomidae, Sphaeriidae, Physa sp.) and forms common to mats of aquatic vegetation (Agabus sp., Graptocorixa sp., Belostomatidae, Ambrysus sp., Gerris sp., Enallagma sp., Gammarus sp.). These invertebrate forms appear to provide an abundant food source for longnose dace and redbreast shiner of lower Alum Creek.

Fishes

Three species of fish were found in Alum Creek during this survey; cutthroat trout, longnose dace and redbreast shiner. The

cutthroat trout were restricted to the upper 9.8 km of the main stream. The absence of stocking records for Alum Creek suggest that these cutthroat trout may form an enclave population isolated by thermal areas after recession of the large Pleistocene lake once thought to inundate Hayden Valley. Four fish were captured after 0.6 angler-hours. The fish were measured (105-168 mm) and scales taken for age determination. The color of these fish appears to vary slightly from that of the typical Yellowstone cutthroat trout (Salmo clarki bouvieri); more rosey opercles, a more yellowish belly and parr marks were observed on all sizes. Fish from upper Alum Creek, examined by Loudenslager (1981) did not differ genetically from the typical Yellowstone form.

The longnose dace and redbside shiner were found in the lower 11.0 km of Alum Creek. They were abundant during this survey from near the upper end of stratum 4 (Figure 37) and downstream, especially in side streams where water temperature was 21-28 C. Large numbers of these two species were found in small pools near these tributaries. These concentrations may have constituted spawning activity as indicated by the brilliant coloration of the males, although no eggs could be extracted from females.

Otter Creek

Otter Creek originates as springs in wet meadows of the Central Plateau and flows east into the Yellowstone River about 2 km above the Upper Falls (Figure 38). This stream was surveyed July 2, 1982.

Physical and Chemical Characteristics

Otter Creek is a small Park stream with an average width of 2.81 m and depth of 0.46 m. Flow at the outlet in early July was 0.181 m³/sec. Stream gradient varies from 2 to 30 m/km (Table 38). The steepest gradient occurs at about 2370 m elevation where the stream flows through a steep-walled canyon and over a 10-15 m waterfall; a definite fish barrier (Figure 38).

Otter Creek starts in stratum 1 as two branches fed by a large wet open meadow lined with lodgepole pine, Douglas fir and Englemann spruce. The stream also collects water from a series of deep, clear streamside pools and meanders through a deeply cut channel with overhanging grasses and sedges. Stream width in July was 2.82 m, depth was 0.44 m and the flow was 0.036 m³/sec (Table 38). The predominantly sand substrate and a P;R:R ratio of 15:20:65 reflects a stratum with little pool or fish spawning habitat.) Basic water chemistry in this stratum (Table 39) yielded water temperature (8 C), pH (6.8), conductivity (38 mhos/cm), and dissolved oxygen (8.0 mg/l).

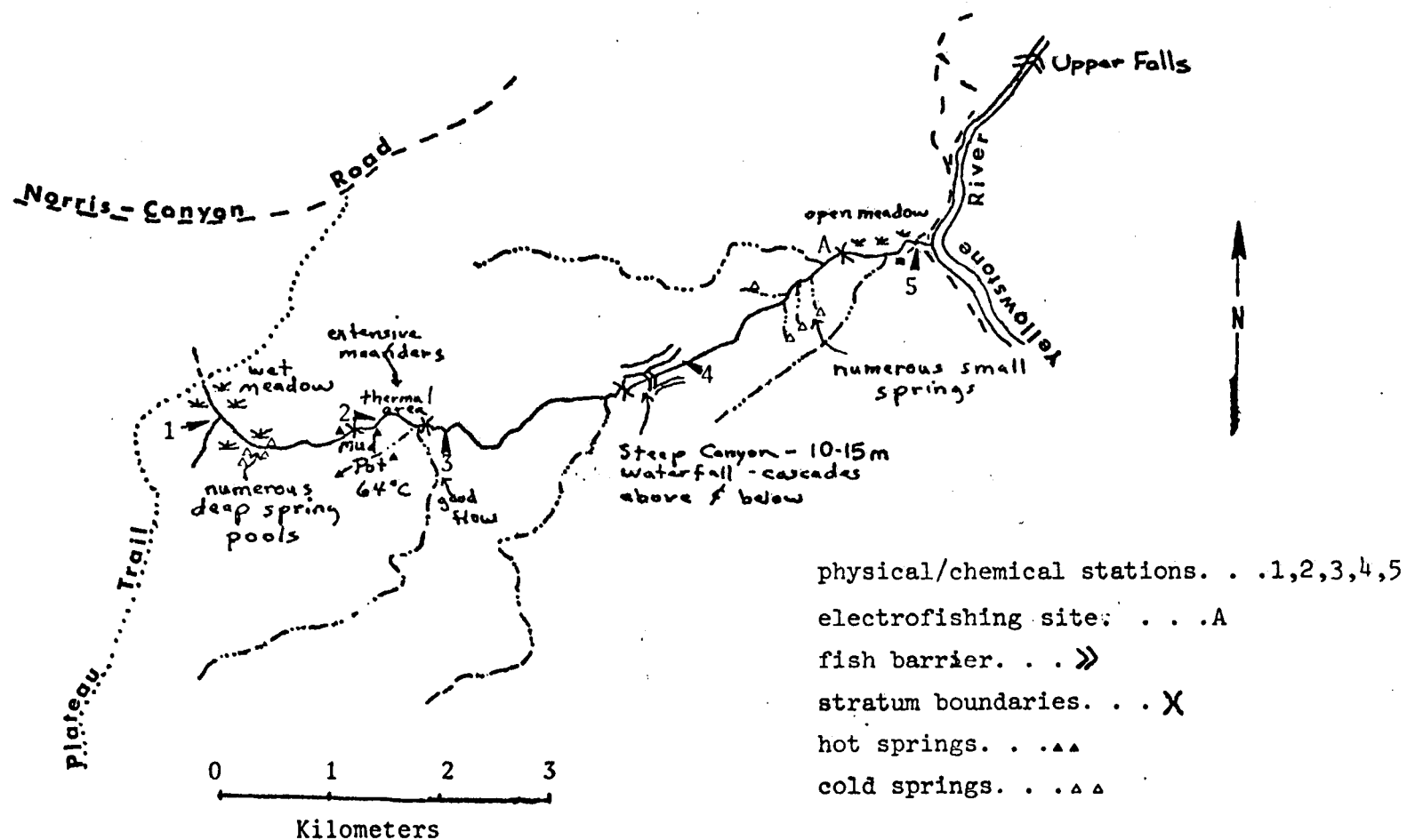


Figure 38. Otter Creek, Yellowstone National Park, 1982.

About 2 km from its headwaters (stratum 2), Otter Creek flows through a small thermal area identified on maps as a "mud pot". A 0.5 m drop in the stream channel marks the beginning of the thermal area and the banks are abruptly barren of vegetation. The substrate is primarily sand and pea-size (5-10 mm) gravel. Stream temperatures before flowing into this thermal area were 8 C. Several small hot pots and seeps with temperatures of up to 65 C warmed the main stem to 20 C. Conductivity was similarly elevated from 38 mhos/cm to 550 mhos/cm and the stream acquired a humic color.

After leaving the thermal area, Otter Creek flows through a densely forested area with increasing steepness in terrain (stratum 3). The substrate becomes coarse gravel (10-50 mm) with some sand and silt. The P:R:R ratio of 20:60:20 reflects the steep gradient and predominantly riffle habitat. Water chemistry in this stratum (station 3) was influenced by the thermal features upstream at the lower end of stratum 2.

About 5 km from its headwaters, the canyon walls steepen considerably and the stream cascades over large angular rhyolitic rock layered with obsidian. The stream flows over a 10-15 m waterfall and the overall stratum gradient is 30 m/km. The substrate here is bedrock, boulder and rubble. A P:R:R ratio of 40:40:20 reflects a plunge-pool situation with good fish habitat in the more moderate gradients above and below the falls. There is little bank vegetation and some bank instability indicating severe scouring during spring runoff. Water quality (station 4) appears to have recovered somewhat from the thermal conditions seen at station 3.

Otter Creek in the lowermost reaches (stratum 5) meanders through a series of narrow wet meadows lined with dense stands of lodgepole pine. Average stream width and flow in July were 2.79 m and 0.181 m³/sec, respectively. Substrate was primarily gravel, rubble and sand with a P:R:R ratio of 20:20:60. A bank overhang of 20% and the above parameters suggest that Otter Creek in this stratum could provide good holding and spawning habitat for salmonids.

Water chemistry of station 5 on July 2 appeared good for fishes with a water temperature of 12 C, pH of 6.8, conductivity of 78 mhos/cm and dissolved oxygen content of 7.6 mg/l. Water chemistry at this same station recorded September 30 yielded a water temperature of 7 C, pH of 2.5 and conductivity of 460 mhos/cm. The difference in pH and conductivity between the high-flow period of early July and low-flow period of late September is dramatic. Snow melt and recharged springs in July probably dilute the thermal effluents from the mud pot region. But, by late September, snow melt is nil and flow from the

springs is greatly reduced. The thermals at this time apparently exert a substantial influence on water chemistry to render low pH values.

Macroinvertebrates

Only seven taxonomic groups of macroinvertebrates occurred in Otter Creek, including two genera of mayflies, three genera of caddisflies, one group of true flies, and one genus of beetles (Table 40). Few taxa were found in any one stratum indicating that, except for the upper 2 km, much of Otter Creek is affected by thermal areas and an apparent acid condition causing low pH levels.

Fishes

A total of 115,000 cutthroat trout were introduced into Otter Creek in 1922 (Varley 1981). This is the only historic record of introductions in this stream. This survey shows that all but the lowermost 200 m of Otter Creek is fishless.

About 1000 m of Otter Creek were sampled with electrofishing gear on June 22, 1982. Six cutthroat trout, all under 100 mm length, were collected or sighted in a 200 m section from the Yellowstone River upstream to a small bridge leading to the campground. No fish were observed upstream from this bridge on either this June survey or that conducted on the entire stream on July 2.

Volunteer Fishermen Reports (VFR), since the inception of the program in 1973, have annually reported fishing pressure, although light, in Otter Creek. It is possible that some fish stray into a small pond forming near the confluence with the Yellowstone River where they are caught by anglers. It is also possible that fish are caught in the Yellowstone River and reported from Otter Creek since they were caught near the confluence of the two. A sign designating Otter Creek is located at a parking area often used by Yellowstone River fishermen and provides a convenient landmark for anglers completing the VFR cards.

Thistle Creek

Thistle Creek is a tributary of the Yellowstone River that drains the southwest slope of Stonetop Mountain (Figure 39). It enters the Yellowstone River just below LeHardy's Rapids. Thistle Creek was surveyed July 14, 1982.

Physical and Chemical Characteristics

Thistle Creek flows west for about 3.2 km through low rolling hills of lodgepole pine and into the Yellowstone River. It is a

small stream with average width of 1.34 m, average depth of 0.19 m, and an overall gradient of 28 m/km. Discharge in mid-July was 0.094 m³/sec. Three habitat strata were identified for Thistle Creek.

Thistle Creek originates amidst a lodgepole pine forest from clear, cold, creek-bed springs at about 2500 m elevation (stratum 1). The creek bed above these springs was dry during this survey but well-formed and scoured indicating that runoff flows are high. The stratum represented by station 1 is first order with a moderate gradient of 19 m/km and a mid-July flow of 0.008 m³/sec (Table 38). The substrate is predominately gravel, P:R:R ratios were 30:50:20 and bank stability was high. Water temperature was 7.8 C, pH was 6.5, and conductivity was 36 mhos/cm (Table 39).

In stratum 2, Thistle Creek continues to flow through the lodgepole pine forest and into several long, narrow, open meadows where the channel meanders considerably through overhanging grasses and sedges. The stream is fed by several small springs and one major tributary that is apparently perennial. The gradient is moderate and the substrate predominantly rubble with some small gravel deposits. It is mostly a run type habitat with 30% bank overhang. Water chemistry in station 2 was similar to that of station 1 with respect to temperature (7 C), pH (7.2), and conductivity (73 mhos/cm).

The gradient in stratum 3 increased dramatically to 47 m/km although no fish barriers were encountered. The stream cascades over moss-covered rubble and downed trees and enters the Yellowstone River after flowing through a deep grassy valley just below the Howard Eaton Trail. Flow in mid-July was 0.094 m³/sec and similar when observed again in October; springs feeding Thistle Creek are apparently perennial. The substrate in this stratum is primarily gravel and occurs in pockets suitable for spawning. The P:R:R ratio was 10:80:10 indicating a scant habitat for adults, but good nursery habitat.

Water analyses taken September 29, near the outlet showed a field pH of 7.5 (Table 39).

Macroinvertebrates

Fifteen macroinvertebrate taxa were found in Thistle Creek during this survey (Table 40). An even distribution of these forms was evident. All 15 forms belong to four families: mayflies, stoneflies, caddisflies, and true flies. Some

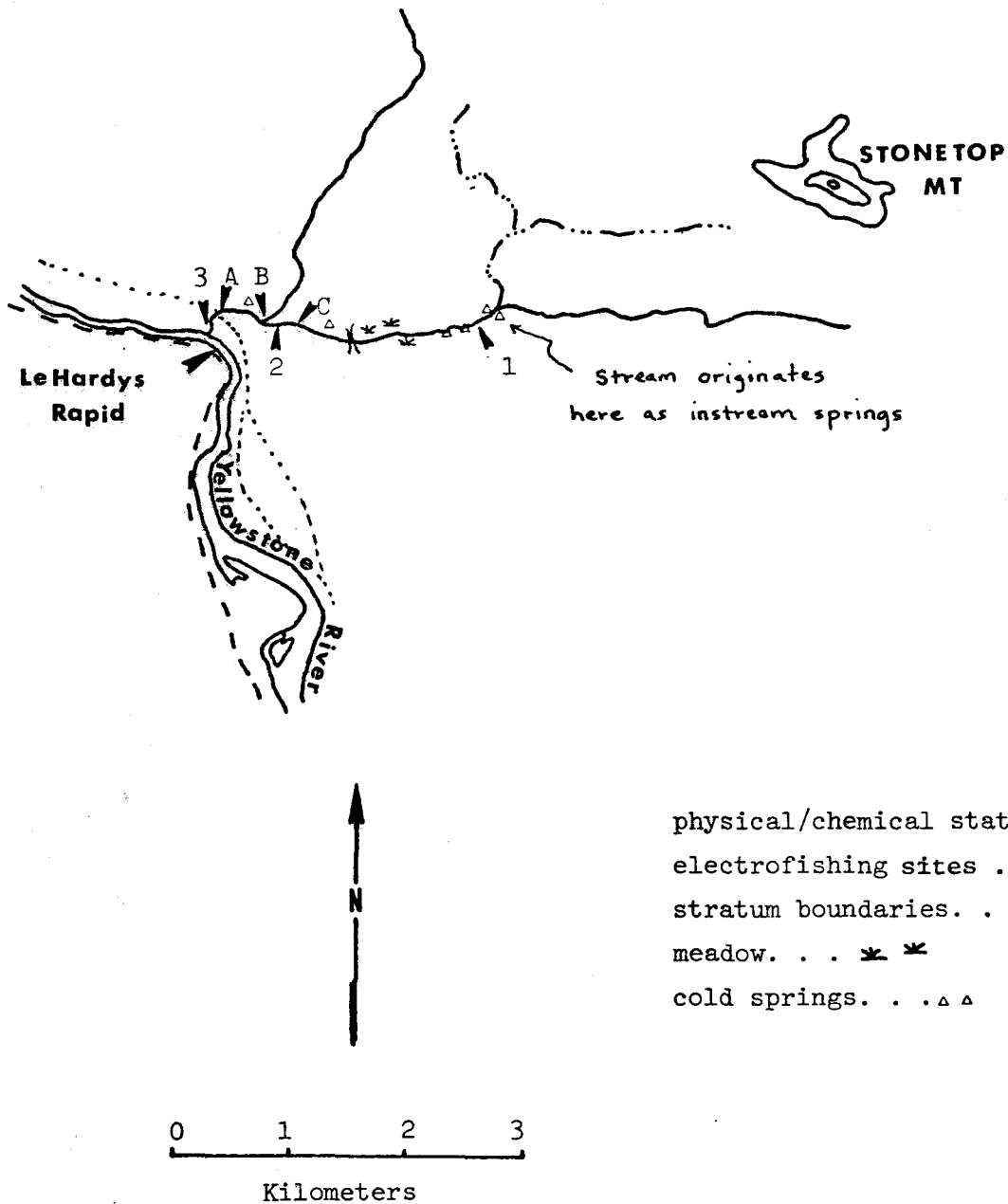


Figure 39. Thistle Creek, Yellowstone National Park, 1982.

these forms, particularly some genera of mayflies (Cloeon sp., Ephemerella sp., Cinygmula sp., Ameletus sp.) are indicators of good water quality. The occurrence of the predaceous stonefly Acroneuria sp. in the two lower strata (2 and 3) indicates a stable invertebrate population and a good food source for fish.

Fishes

No fish stocking records are available for Thistle Creek (Varley 1981). This survey shows that only the lowermost 2 km of the main stem supports fish.

Thistle Creek was electrofished July 14, 1982 (sites A,B,C). Only cutthroat trout were found from the outlet upstream for about 2 km. No fish were found in any tributary. Numerous cutthroat trout (73-100 mm) were captured representing three length-frequency groups. It could not be determined if these were of resident origin or progeny of Yellowstone River cutthroats. Only two adult cutthroat trout, believed to be from the Yellowstone River, were found in Thistle Creek. Both were spent males 352 and 264 mm total length.

Thistle Creek is a small stream with good quality water and fair small fish habitat. It appears to support some spawning cutthroat trout from the Yellowstone River, although the number does not appear to be significant. Certainly, many fish have the opportunity to ascend this stream since large numbers of fish usually gather beneath LeHardy's Rapids.

TRIBUTARIES TO YELLOWSTONE LAKE

Bear Creek

Bear Creek is a tributary of Turbid Lake near the northeast shore of Yellowstone Lake (Figure 40). It drains the south ridge of Mt. Chittenden in the area of Jones Pass and flows west. Bear Creek was surveyed September 8, 1982.

Physical and Chemical Characteristics

Bear Creek emerges as a series of springs at about 2800 m elevation near Jones Pass on the eastern Park boundary. The stream is fed from above by snow melt as is indicated by several dry stream beds seen during this survey. The stream flows through some small meadows but mostly through forested slopes. Bear Creek has an average width of 3.09 m, average depth of 0.13 m and a September discharge of 0.122 m³/sec. Three habitat strata were identified.

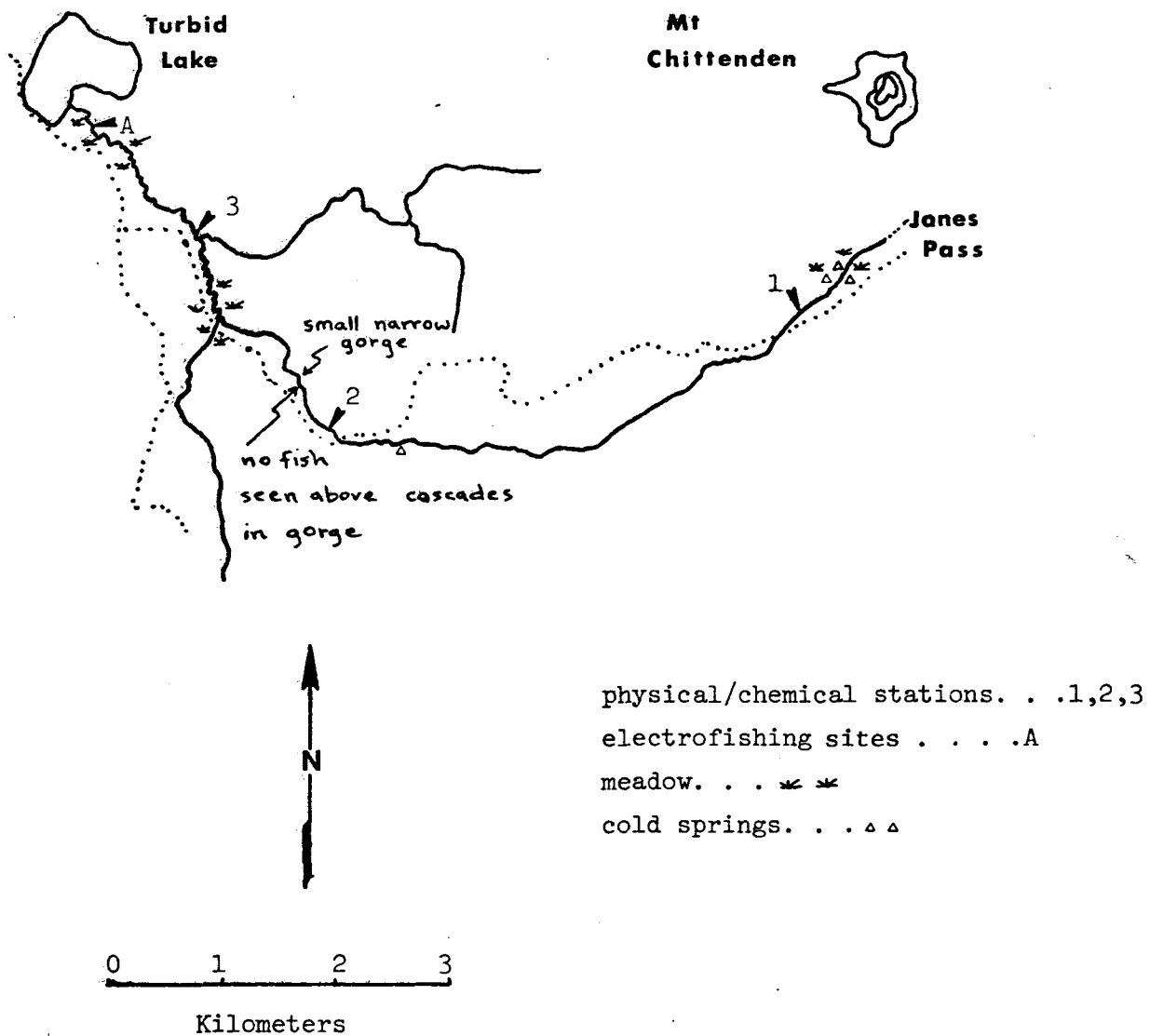


Figure 40. Bear Creek, Yellowstone National Park, 1982.

In stratum 1, Bear Creek cascades from sparsely forested rubble-strewn slopes with a steep gradient of 66 m/km (Table 38). The average stream depth was 0.16 m, width was 1.42 m and flow was 0.034 m³/sec. The substrate was composed of dense growths of vegetation (Ranunculus sp., Fontinalis sp.) over rubble, boulder and gravel. The P:R:R ratio was 10:40:50 with little bank overhang and thus, little fishery habitat. Water chemistry here (Table 39) indicates low total dissolved solids (conductivity, 60 mhos/cm) and a low buffering capacity (alkalinity, 62 mg/l).

The stratum represented by station 2 is still a cascading stream but with a more moderate gradient of 47 m/km. The stream banks are heavily forested with lodgepole pine and covered with grasses and sedges. The stream is shallow (0.06 m), swift (0.27 m/sec) and wide (3.03 m) with a flow of 0.049 m³/sec. The substrate is primarily rubble with boulder, gravel and vegetation. The P:R:R ratio was 10:40:50. Like stratum 1, stratum 2 lacked pool habitat for fish cover but has a lower gradient. Water quality of station 2 was similar to that of station 1.

The stream in stratum 3 meanders considerably through narrow grassy valleys and has a gradient of 22 m/km, average depth of 0.18 m, width of 4.83 m and a flow of 0.122 m³/sec. The substrate was mostly gravel (10-50 mm) and the P:R:R ratio was 60:20:20 indicating good spawning and holding habitat. Water chemistry at station 3 was similar to that of the two upstream stations.

Water chemistry for Bear Creek is characterized by a water sample taken from station 3 (Table 39). The water of Bear Creek has low total dissolved solids (49 mg/l), a low buffering capacity (alkalinity, 41 mg/l), low sulfates (2 mg/l), and fluorides (0.18 mg/l), and a pH of 7.7. Total hardness (40 mg/l) was low with calcium (24) and magnesium (16) the only contributors. All phosphates and nitrates were low indicating low instream production.

Macroinvertebrates

Fifteen taxa of macroinvertebrates were found in Bear Creek (Table 40). These represent 7 orders and 12 families which occurred primarily in station 2. The paucity of macroinvertebrates in station 1 may explain historic reports of Bear Creek being barren in its headwaters, although the invertebrate production in Bear Creek appears low throughout. This observation is supported by the occurrence of low nitrate levels, total dissolved solids and alkalinity.

Fishes

Bear Creek has probably always supported a monospecific fish fauna of cutthroat trout. These fish are presently confined to the stream by the thermal nature and poor water quality of

Turbid Lake. Although fish have always been known to inhabit Bear Creek, a total of 252,000 cutthroat trout were introduced into this stream from the Yellowstone Lake hatchery from 1920 to 1941 (Varley 1981). Prior to the first year of introductions, it is reported that the headwaters were barren. It is not known how far upstream fish were introduced into Bear Creek.

About 800 m of Bear Creek was electrofished August 26, 1982, to capture fish for transport to the Blacktail Ponds in the Park. Only cutthroat trout were seen during this operation and the current survey, although no fish were seen above a small narrow gorge at the lower end of stratum 2 (Figure 40). It appears from this survey that fish are confined to the lowermost 4 km of stream. For details on numbers and sizes of fish captured, see section on Blacktail Ponds, Native Species Restoration Program in this report.

TRIBUTARIES TO MADISON RIVER

Tributaries of the Madison River were surveyed in August 1982 to establish baseline data and assess their water quality and fish habitat.

This survey included two small unnamed tributaries in the Madison Canyon and Grayling Creek, a tributary of the Madison River via Hebgen Lake. Grayling Creek was visited to determine if grayling are still present in this stream and to assess the effectiveness of existing natural fish barriers, especially to brown trout from Hebgen Lake.

Grayling Creek

Grayling Creek drains the area of Crowfoot Ridge, Three Rivers Peak and the Craggs near the northeast corner of Yellowstone National Park (Figure 41). It flows west out of the Park and empties into Grayling Arm of Hebgen Lake. Grayling Creek was surveyed August 3-6 and 10, 1982.

Physical and Chemical Characteristics

Grayling Creek flows for about 31 km with an average overall gradient of about 13 m/km. The stream is primarily an open shallow stream with an average width of 8.70 m and an average depth of 0.32 m. Flow on August 10 near the Park boundary was 3.326 m³/sec.

The headwaters of Grayling Creek were not visited during this survey. The highest point sampled was at an elevation of about 2304 m, perhaps 6 km below its origin. Five habitat strata were identified in Grayling Creek.

The stream in the uppermost stratum 1 was heavily shaded in places by conifers and some overhanging willows. The gradient

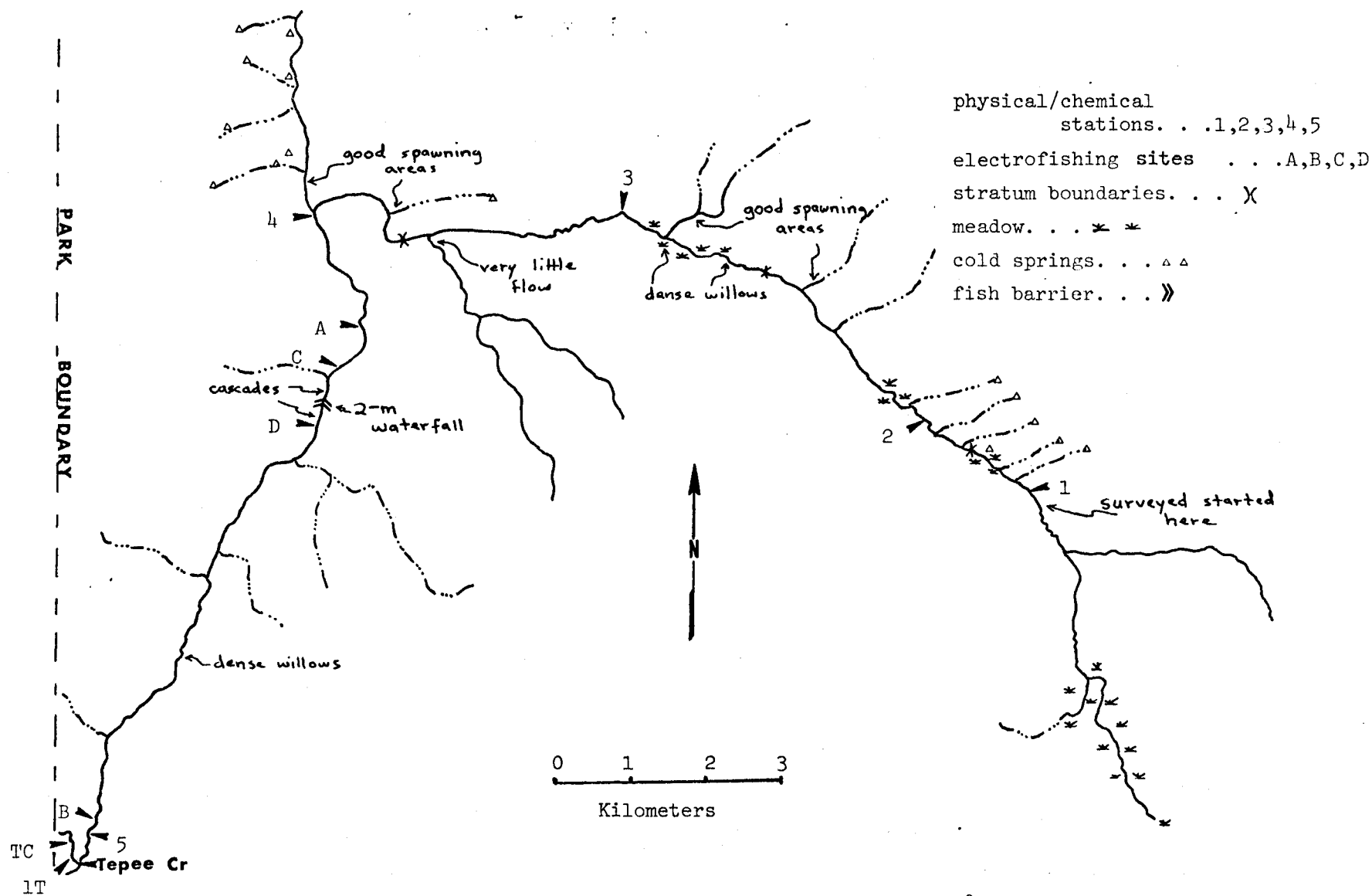


Figure 41. Grayling Creek, Yellowstone National Park, 1982.

was 22 m/km, average depth was 0.27 m, average width was 6.28 m, and average flow 1.848 m³/sec (Table 41). The substrate was predominantly rubble, the P:R:R ratio was 20:20:60, and bank overhang was 15%. Fish habitat in this stratum was fair because of a paucity of pools.

Water chemistry at station 1 yielded a temperature of 13.3 C, pH of 7.75, conductivity of 115 mhos/cm (Table 39). The stream alkalinity was low (41 mg/l) indicating a low buffering capacity, and nitrates were also low (0.03 mg/l) indicating low production.

Stratum 2 was similar to stratum 1, except that the stream in the former was more open with a more mild gradient of 12 m/km. Average depth was 0.27 m and width was 8.78 m. The substrate was primarily rubble and the P:R:R ratio 10:60:30. There was little bank overhang and considerable bank instability (25%) from apparently high scouring spring flows. Stratum 2 had some small gravel deposits for spawning but there were few pools and little bank overhang caused by the high bank instability. Water quality at station 2 was similar to that of station 1 (Table 41).

Grayling Creek in stratum 3 was a wide shallow, low-gradient stream lined with dense stand of willows. The stream flowed through several long narrow valleys surrounded by rolling hills with stands of lodgepole pine. The predominant stream substrate was boulders and the P:R:R ratio was 5:75:20. Like strata 1 and 2, the stream here lacked pool habitat but had some gravel pockets for possible spawning. Water quality was similar to that of strata 1 and 2.

Much of stratum 4 was paralleled by highway 191 near the northwest boundary of the Park. Grayling Creek here is a wide, low-gradient stream (3 m/km) with an average depth of 0.26 m, average width of 11.22 m and an August flow of 3.326 m³/sec. The substrate was 30% rubble, 30% boulder and about equal proportions of gravel, sand, silt and some vegetation. The P:R:R ratio was 5:50:45 with a bank overhang of 15% and high bank stability. Fish spawning habitat was minimal and adult resting habitat was restricted to a few long deep open pools which occurred more frequently toward the lower end of the stratum near a short section of cascading water and a 2 m waterfall. The waterfall at this flow stage was considered a fish barrier. Water quality at this station 4 was similar to that of stations 1, 2, and 3 (Table 41).

The stream immediately below the falls, the upper end of stratum 5, was characterized by a few deep pools with fallen trees and root overhangs. The gradient in this stratum was 13 m/km, average depth was 0.43 m and average width 9.27 m. The substrate was 45% rubble, 30% gravel and 20% boulders. The P:R:R ratio was 10:40:50; a ratio that continues to show a paucity of pools for holding and resting fish habitat. Water

Table 41 Physical parameters for stations of streams in the Madison and Gallatin River drainages, Yellowstone National Park, 1982

Parameters	Fan Creek		Grayling Creek					Tepee Creek	#1340		#1343		
	1	2	1	2	3	4	5	1	1	2	1	2	3
Elevation (m)	2219	2198	2304	2286	2225	2170	2057	2067	2134	2060	2097	2070	2063
Gradient (m/km)	11	8	22	12	11	8	13	13	66	38	45	6	19
Stream Length (km)	2.9	1.6	4.4	3.6	4.5	4.9	7.6	0.2	0.97	2.43	4.05	1.46	0.32
Average velocity (m/sec)	0.91	0.91	1.09	-	0.95	1.14	-	0.76	0.70	0.76	0.91	0.51	-
Average Depth (m)	0.15	0.13	0.27	0.27	0.37	0.26	0.43	0.19	0.10	0.10	0.31	0.17	0.37
Average Width (m)	1.27	2.70	6.28	8.78	7.95	11.22	9.27	4.86	4.00	3.51	2.40	6.22	3.32
Average flow (m ³ /sec)	0.17	0.32	1.848	-	2.79	3.326	-	0.702	0.28	0.27	0.677	0.54	-
Maximum Depth (m)	0.43	0.30	0.45	0.36	0.52	0.49	0.58	0.34	0.19	0.28	0.43	0.40	0.49
Predominate Substrate*	GR-SI	BO	RU	RU	BO	BO-RU	RU-GR	RU-GR	GR-RU	GR	BO-RU-GR	SA-GR	SA-SI
Pool:Riffle:Run (%)	30:50:20	40:40:20	20:20:60	10:60:30	5:75:20	5:50:45	10:40:50	15:55:30	10:80:10	10:70:20	0:0:100	30:50:20	30:50:20
Bank Overhang/Instability (%)	30/10	20/10	15/10	10/25	15/10	15/0	10/2	20/0	10/10	15/5	5/0	15/10	25/10

* BE = bedrock
BO = boulder, > 305 mm

GR = gravel, 3-76 mm
RU = rubble, 76-305 mm

SA = sand, < 3 mm
SI = silt, fine gritty

VE = vegetation

quality did not change dramatically for all stations sampled in August (Table 41). A subsequent sample taken on August 12, yielded a field temperature of 6 C, pH of 7.75 and conductivity of 120 μ hos/cm (Table 39). The analysis showed low total dissolved solids (80 mg/l) and low alkalinity (66 mg/l) indicating that Grayling Creek has a low buffering capacity and could be subject to sudden pH changes. All other chemical parameters examined appear typical for a high mountain stream of low to moderate production.

Fish habitat in Grayling Creek appears limited. Gravels for spawning are limited throughout the main channel. Resting habitat and escape cover is also limited since the stream is characteristically open, wide and shallow. Autochthonous production also appears low as indicated by water chemistry.

Macroinvertebrates

A total of 39 taxa were found in Grayling Creek during this survey (Table 42). This compares with 37 found by Dean and Mills (1971) in an earlier survey. Grayling Creek appears to have a diverse macroinvertebrate fauna but densities seem to be low. Apparently, allochthonous inputs, probably originating from leaves of the dense riparian willow stands, contribute to most of the instream organic load.

Fishes

Grayling Creek has a long history of fish stockings inside and out of Yellowstone National Park. The total number of fish planted from 1923 to 1980 is 1,304,050 cutthroat trout; 857,668 grayling; 2,848,991 grayling shared with other waters; and 123,000 fry of unknown species (Varley 1981). The last introduction of 15,930 cutthroats in 1980 were the Missouri Basin form, S. c. lewisi. Historically, Grayling Creek supported cutthroat trout, grayling and whitefish. The present species include cutthroat trout, rainbow trout and brown trout. This survey also yielded mottled sculpin (Cottus bairdi) as did the earlier survey in 1970 (Dean and Mills 1971).

Grayling Creek was electrofished August 3-4, near stations 4 and 5 and fish were sampled with fishing gear near stations 1 and 2 on August 4. Cutthroats, rainbow x cutthroat hybrids, and brown trout were found along with mottled sculpin. No grayling or whitefish were seen or captured.

Four cutthroat trout (163-350 mm TL), one brown trout (109 mm TL) and two mottled sculpin were captured at electrofishing site A, about 150 m of stream. Many more sculpin were seen but not netted. The fish population at this site appears to be limited by a lack of pools; nearly every pool sampled yielded fish. The capture of a brown trout in this station is significant since it

Table 42 Occurrence and densities of macroinvertebrates in stations of streams in the Madison and Gallatin River drainage, Yellowstone National Park, 1962

Taxa (common name)	Stream #1234		Grayling Creek					Tepce Creek		#1340		#1343		
	1	2	1	2	3	4	5	1	2	1	2	1	2	3
Hirudinea (leeches)										X				X
Oligochaeta (aquatic earthworms)												X		
Crustacea														
Amphipoda (scuds)														
Hyalella azteca														X
Hydracarina (watermites)		X										X		
Insecta														
Ephemeroptera (mayflies)														
Baetidae														
Baetis sp.		X	X	X	X	X	X	X		X	X			
Baetis bicaudatus	X	X	X	X	X			X		X	X			
Baetis tricaudatus				X	X									
Cloeon sp.						X								
Ephemerellidae														
Ephemerella sp.	X		X	X	X	X	X				X			
Ephemerella doddsi			X	X	X	X		X						
(Brunella) sp. 1			X		X	X		X						
(Brunella) sp. 2					X	X				X	X			
(Brunella) sp. 3	X	X												
(Serratella) sp.	X	X	X		X	X	X	X		X		X		
Heptageniidae														
Cinygmula sp.	X	X	X	X	X	X	X	X		X	X		X	
Epeorus sp.		X	X	X	X	X	X	X			X			
Rhythrogena sp.	X	X	X	X	X	X	X							
Siphonuridae														
Ameletus sp.			X	X										
Plecoptera (stoneflies)														
Capniidae														
Capnia sp.								X						
Chloroperlidae														
Chloroperla sp.	X	X	X		X	X	X	X		X	X	X	X	
Nemouridae														
Nemoura sp.	X	X		X		X	X	X		X	X	X		
Perlidae														
Acroneuria sp.		X		X	X	X	X	X		X	X			
Perlodidae														
Isoperla sp.			X		X	X	X	X		X	X	X	X	
Trichoptera (caddisflies)														
Brachycentridae														
Brachycentrus sp.						X	X							
Microseta sp.						X		X		X	X		X	
Glossosomatidae														
Anagapetus sp.		X				X	X	X						
Glossosoma sp.		X	X		X	X	X	X				X	X	
Hydropsychidae														
Arctopsyche grandis	X	X	X		X	X	X	X		X	X	X		
Limnephilidae														
Hesperophylax sp.	X							X						
Tronoxia sp.														X
Limnephilus sp.			X	X										
Neothremma sp.						X				X				
Onocosaecus sp.		X	X	X		X	X							
Psychomyia subborealis										X			X	X
Rhyacophilidae														
Rhyacophila sp.					X									
Rhyacophila aeropedes	X	X	X			X		X		X	X			
Rhyacophila angelita								X						
Rhyacophila coloradensis			X			X	X							
Rhyacophila rotunda								X						
Rhyacophila vacca								X						
Rhyacophila vagrita			X							X	X		X	
Sericostomatidae														
Gnaga sp.						X								
Diptera (true flies)														
Blattellidae														
Blattella sp.			X			X								
Ceratopogonidae														
Beetia sp.				X	X					X			X	
Chironomidae	X	X	X	X	X	X	X	X		X		X	X	X
Deuteromyiidae														
Deuteromyia coloradensis				X										
Ephyrae							X							
Ptychoptera														
Ptychoptera sp.	X													
Simuliidae														
Simulium sp.	X	X	X			X	X	X						
Tipulidae														
Hexatoma sp.	X		X	X	X	X	X	X						
Holotrichia sp.							X							
Lipula sp.								X						X
Coleoptera (beetles)														
Elmidae														
Amelanus sp.	X	X	X	X		X				X		X		
Hemiptera (true bugs)														
Coreidae														X
Gerridae														X
Hymenoptera (ants)														
Formicidae					X									
Pelecypoda (clams)														
Sphaeriidae														X
NUMBER OF INVERTEBRATES	70	56	23	40	21	104	33	32		7	11	247	17	27
NUMBER OF TAXONOMIC GROUPS	16	19	24	17	19	27	21	24		12	9	7	19	15
TOTAL NUMBER OF GROUPS PER WATER		23			39			24		22		24		

is above the previously described 1-2 m waterfall that during this survey was judged to be a fish barrier. The first brown trout caught above this barrier were 8 fish up to 8 inches in length reported September 28, 1978, by John D. Varley (unpublished document). Since there is no record of brown trout being introduced in Grayling Creek within the Park, it is assumed that brown trout in upper Grayling Creek ascended from Hebgen Lake, past the waterfall or were introduced by fishermen. Large numbers of brown trout in upper Grayling Creek could create competition for the native species.

Site B (Figure 41) near the western Park boundary yielded one rainbow x cutthroat hybrid (129 mm TL) and one brown trout (347 mm TL) from 150 m of stream. Several other salmonids were seen but not captured and many mottled sculpin were seen.

Site C, the area immediately above the waterfall on Grayling Creek, yielded seven cutthroat trout (138-222 mm TL), one rainbow x cutthroat hybrid (250 mm TL) and two mottled sculpin. Mottled sculpin were abundant but not all seen were captured. The habitat in this site C was similar to that of site A; the fewer number of fish caught and observed in the latter may be the result of greater fishing pressure near the highway.

Electrofishing in site D, below the falls, yielded five cutthroat trout (94-204 mm TL) and one large brown trout (413 mm TL). Several other large fish were seen but not captured in the deep pools below the falls. This area is probably not frequented by many fishermen because of dense streamside willows and the steep canyon walls.

The cutthroat taken from Grayling Creek in this survey were unlike the Yellowstone cutthroat trout (Salmo clarki bouvieri) seen elsewhere in the Park. The body spots were smaller and irregular in outline and the color more silver but with pronounced gold and crimson on the ventral regions and rose colored opercles. Twelve specimens were collected and sent to Dr. Robert Behnke at Colorado State University for his opinion on subspecific identity. According to Dr. Behnke (1982), "...specimens...from Grayling Creek...are typical of S. c. lewisi, but...exhibit a more profuse anterior spotting pattern...". Regarding previous samples from Grayling Creek, he writes "In view of the known stocking of massive numbers of Yellowstone cutts in most waters of YNP I hesitated to declare the YNP lewisi samples as pure, but there is no real evidence (except possibly more profuse spotting) that S. c. bouvieri genes (or S. gairdneri) are incorporated into present populations."

Tepee Creek

Tepee Creek is a tributary of Grayling Creek that enters that stream from the west about 0.5 km inside the west Park boundary near highway 191 (Figure 41). Only about 1 km of Tepee Creek is

within Yellowstone National Park. That portion of the stream was surveyed August 8, 1982.

Physical and Chemical Characteristics

Tepee Creek as it enters Grayling Creek is lined with dense willow stands and surrounded by low hills with dense stands of lodgepole pine. The gradient was moderate at 13 m/km, and average depth was 0.19 m, width was 4.86 m and flow 0.702 m³/sec (Table 41). The substrate was predominantly rubble with some pockets of gravel. The P:R:R ratio was 15:55:30 and bank overhang was 20% with high stability. Tepee Creek in the Park has some spawning habitat and fair holding habitat for small salmonids. Low nitrate and alkalinity levels show low production potential and low buffering capacity (Table 39).

Macroinvertebrates

Twenty-four taxa of macroinvertebrates were found in Tepee Creek during this survey (Table 42). These taxa represent four orders (mayflies, stoneflies, caddisflies and true flies) and 15 families. The occurrence of five species of detrital-feeding, free-living caddisflies in the families Hydropsychidae and Phycophilidae is notable. Apparently, detrital load in Lower Tepee Creek is considerable, perhaps as a result of the dense riparian willow stands.

Fishes

About 300 m of Tepee Creek was electrofished during this survey seven cutthroat x rainbow hybrids (75-184 mm TL), two rainbow trout (64-93 mm TL) and six mottled sculpin were caught. Few other fish were seen but not netted.

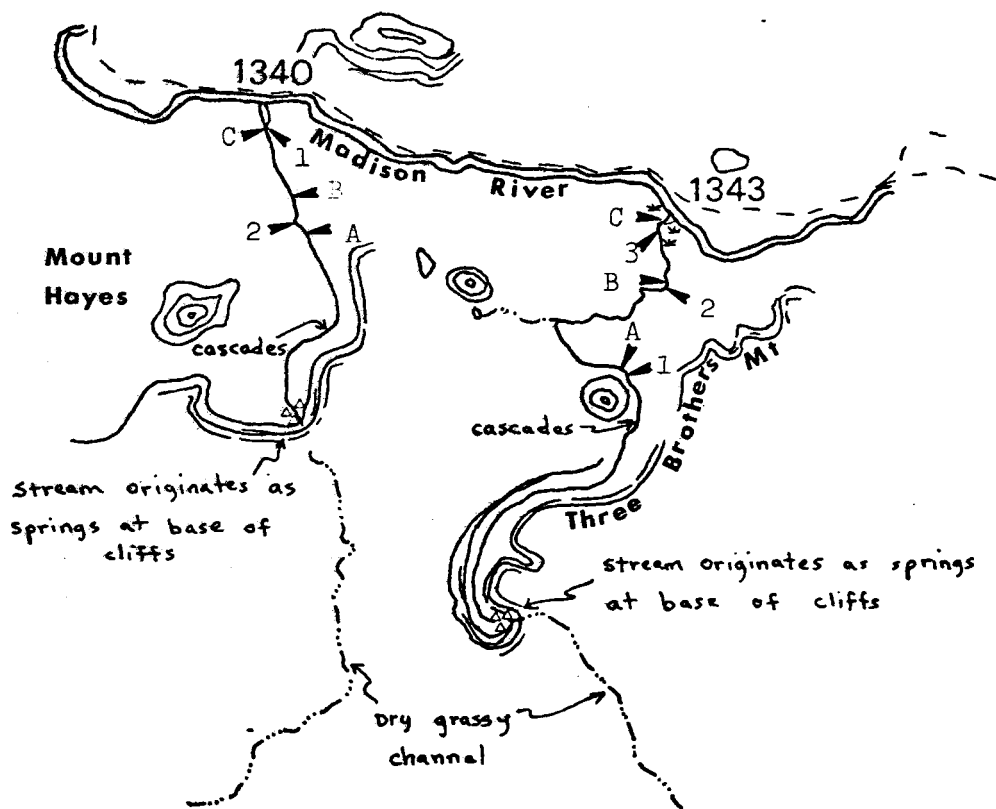
Tepee Creek, like several other tributaries of Grayling Creek, probably serves as a spawning area and a source of recruitment to the main stream. The fish residing in Tepee Creek at the time of this survey exhibited less defined characters of cutthroat trout than those of main Grayling Creek and were classified as cutthroat x rainbow hybrids. These fish may have influence of S. c. lewisi, S. c. bouvieri, S. gairdneri or all three.

Madison River Tributary #1340

This stream drains the east face of Mount Hayes in Madison Canyon (Figure 42). The stream was surveyed on August 24, 1982.

Physical and Chemical Characteristics

Tributary #1340 begins as a large spring area at the base of steep cliffs off the Madison Plateau and flows north for about



physical/chemical stations. . .1,2,3
 electrofishing sites A,B,C
 meadow. . . * *
 cold springs. . . Δ Δ

0 1 2 3
 Kilometers

Figure 42. Madison River Tributaries #1340 and #1343, Yellowstone National Park, 1982.

4 mm into the Madison River. It is a small stream with an average overall width of 3.76m, depth of 0.10 m and a late August discharge of 0.28 m³/sec. The stream cascades over moss-covered boulders and through dense stands of lodgepole pine. It flows through a small narrow flat valley bordered by Vaccinium and lodgepole pine. The stream here is wide and shallow with little pool habitat and a substrate of pea-size gravel. About 2 km from its source, the stream cascades over a steep boulder-strewn area, apparently a fish barrier since no fish were found above this point.

The stream represented by station 1 is characterized by plunge pools with a steep gradient of 66 m/km (Table 41). Average depth was only 0.10 m, width was 3.51 m and volume was 0.27 m³/sec. The substrate was predominantly gravel and the P:R:R ratio 10:70:20. There was little bank overhang and high bank stability. Water chemistry showed low buffering capacity (Table 39).

The stratum represented by station 2 had a gradient of 38 m/km, average depth of 0.10 m, width of 4.00 m and flow of 0.28 m³/sec. The substrate was primarily gravel and there was little pool habitat. Water chemistry in station 2 was like that of 1, revealing a cold stream of low buffering capacity and low autochthonous production.

Macroinvertebrates

Twenty-one taxa of macroinvertebrates representing six orders and 16 families were found in stream #1340 (Table 42). There was much similarity in the forms found at both sample stations. The mayflies, stoneflies and large number of caddisflies indicate low to moderate production, probably arising mostly as detritus from the sloughing mats of algae growing on boulders around the headwater springs.

Fishes

Two 100 m sections of stream were electrofished in this survey. Brown trout and mottled sculpin were collected or observed in all of the 3.5 km below the cascades. None were found above.

Twenty brown trout (mean length 75.7 mm, range 29-123 mm) were collected from site A (Figure 42). No sculpin were seen in this area. None of the brown trout caught in this stream were believed to be mature fish. All were juveniles and probably the progeny of fish from the Madison River.

Six brown trout (mean length 61.6 mm, range 35-87 mm) and five mottled sculpin were collected at site B. Numerous other small salmonids were seen and not captured. The numbers of juvenile brown trout in this stream suggests that it is used by the species as a spawning and nursing area.

Madison River Tributary #1343

This stream drains the area of the Three Brothers Mountains in the Madison Canyon (Figure 42). It was surveyed August 17, 1982.

Physical and Chemical Characteristics

Stream #1343 starts at a large spring area at the base of cliffs overlooking the Madison Canyon and flows north for about 5 km into the Madison River. It is a small stream with an average overall width of 3.98 m, depth of 0.28 m and a mid-August discharge of about $0.7 \text{ m}^3/\text{sec}$. Three longitudinal habitat strata were identified in this stream.

In stratum 1, the stream cascades over moss-covered boulders and rubble. From this origin at the base of the steep cliffs, the stream slows into a narrow, flat valley with dense stands of lodgepole pine and Vaccinium. The canyon walls are vertical rock pillars with talus slopes strewn with large boulders. The stream here is wide, shallow and with a marked lack of fish habitat. The substrate is pea-size gravel of mostly black obsidian.

At about 2110 m elevation, the stream cascades abruptly into a narrow shaded canyon. This cascade was apparently a fish barrier since no fish were observed above this point. Below the cascade, the stream was steep (45 m/km), relatively deep (0.31 m) and narrow (2.40 m) with a flow of $0.667 \text{ m}^3/\text{sec}$ (Table 41). The substrate was mostly boulder with some rubble and gravel. The P:R:R ratio was 30:50:20 with a bank overhang of 25% and high stability. This stratum represents some fish holding habitat but limited spawning area. Water chemistry (Table 39) revealed an alkalinity of 34 mg/l, nitrates of 0.04 mg/l and conductivity of 75 mhos/cm.

The stream represented by station 2 has a low gradient (6 m/km), with an average depth of 0.17 m and average width of 6.22 m. The substrate was primarily sand with some pockets of gravel. The P:R:R ratio was 30:50:20, identical to that of stratum 1 above. Adult resting habitat was noted, but spawning habitat was limited. Water chemistry for station 2 was nearly identical to that of station 1.

Stratum 3, had a moderate gradient and flowed through dense stands of lodgepole pine and heavy streamside growths of Vaccinium. Average stream depth here was 0.37 m, average width was 3.32 m and the substrate was sand and silt. The stream here was continuous deep run with holding habitat for small fishes. Water chemistry at station 1 was like that of the two previous stations.

Macroinvertebrates

Twenty-one taxa of macroinvertebrates were found in stream #1343 during this survey (Table 42). Eleven orders and 21 families represented a diversity of forms from a variety of water condition. The macroinvertebrates in stations 1 and 2 showed a high diversity with forms common to good water quality. The forms in station 3 were dominated by the amphipod Hyalolella azteca. Also found were midges, a cased caddisfly, clams and water bugs, forms typical of the slow-moving slough-like conditions at this station 3.

Fishes

Brown trout, brook trout, mottled sculpin, and an unidentified sucker were found in stream #1343. The fish were small and occurred primarily in the lower 2 km of stream.

A section of about 100 m (site A) was electrofished in stratum 1 (Figure 42). Six brook trout (mean length 150 mm, range 116-205 mm) and 9 brown trout (mean length 86.5 mm, range 41-118 mm) were captured. A second 100 m section (site B) was electrofished further downstream and yielded 64 brown and brook trout ranging from 33 to 133 mm total length and 6 mottled sculpin. A 100 m section near the mouth (site C) yielded a total of 37 brown trout (mean length 59 mm, range 40-92 mm), 8 mottled sculpin, and 1 unidentified sucker (49 mm). This stream has a limited amount of habitat occupied by small brown and brook trout and mottled sculpin. It appears to be used by spawning brown trout from the Madison River or perhaps as far as Hebgen Lake, as indicated by the large number of young fish.

TRIBUTARIES TO GALLATIN RIVER

Stream #1234 (Fan Creek Drainage)

A survey was conducted August 19-20, 1982, on Stream #1234, of an unnamed tributary of Fan Creek. This stream drains the area of Fawn Pass in the Upper Gallatin Drainage (Figure 43).

Physical and Chemical Characteristics

Stream #1234 flows for about 5 km through open meadows and sparse stands of lodgepole pine. The stream has an average gradient of 9.5 m/km, average depth of 0.14 m, average width of 1.99 m, and a late August discharge of 0.32 m³/sec. Two longitudinal habitat strata were selected to represent the stream.

The stream originates in stratum 1 as many small springs in a large meadow near Fawn Pass. It flows through deeply cut sodden banks into a second large meadow with numerous springs and lined

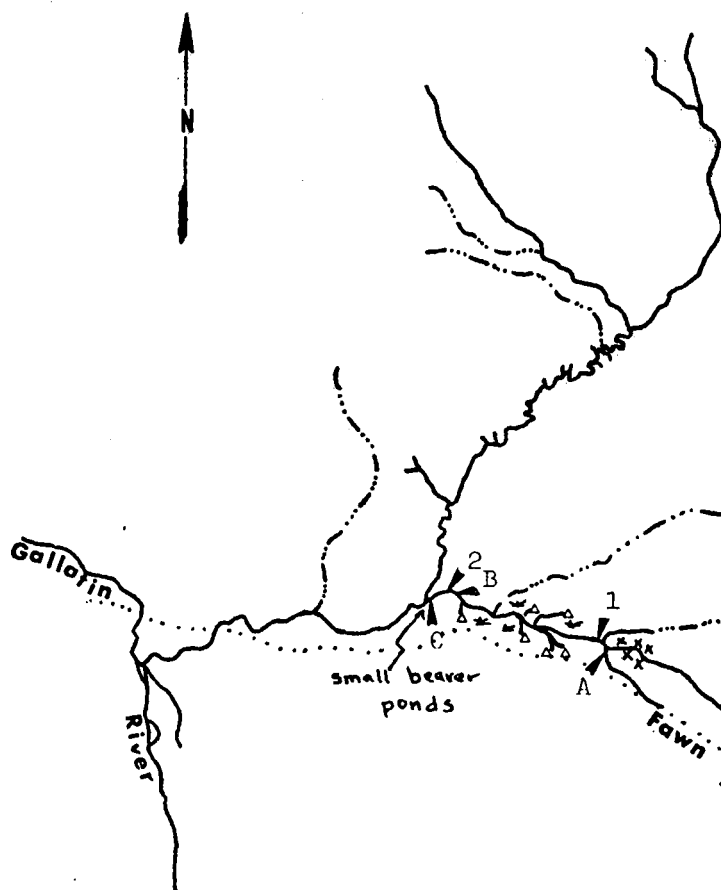
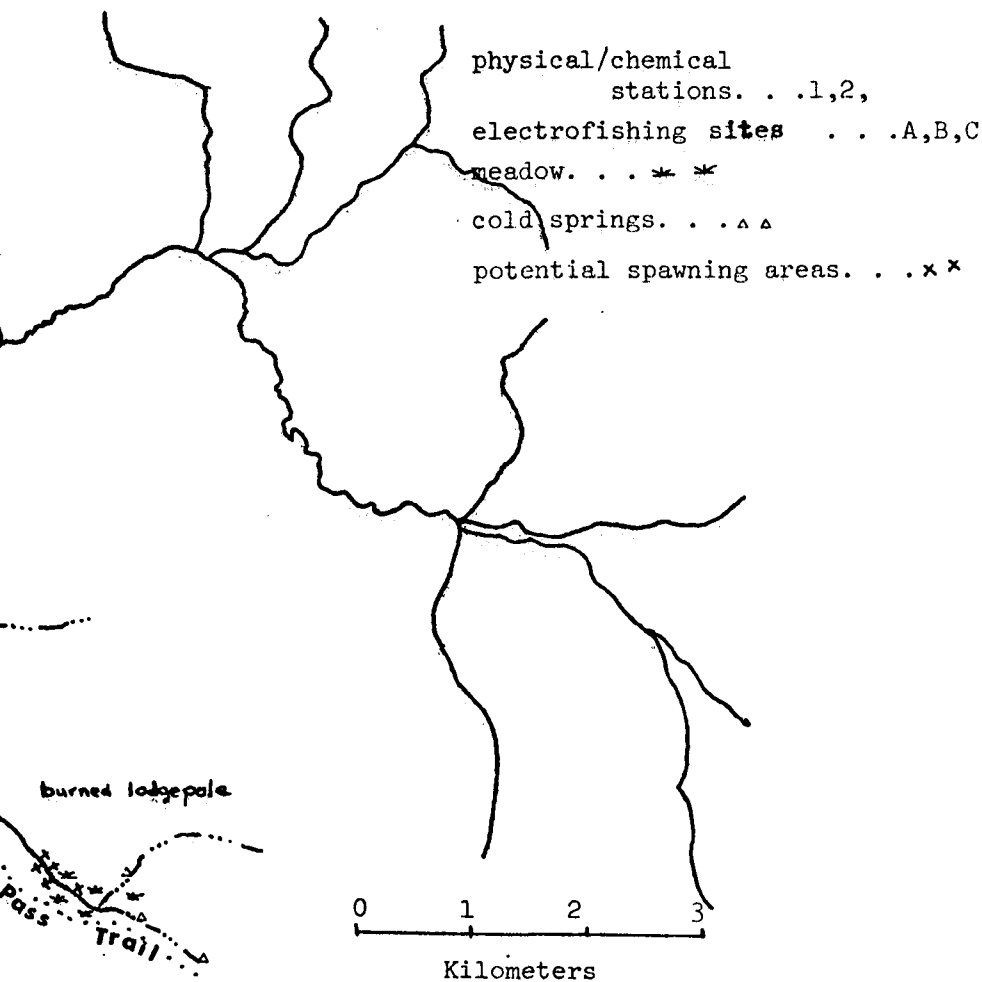


Figure 43. Fan Creek-



, Yellowstone National Park, 1982.

with dense stands of lodgepole pine. A forest fire in 1975 blackened the north slope of Stream #1234 near its origin. The stream represented by station 1 had a gradient of 11 m/km, an average depth of 0.15 m, width of 1.27 m, and a flow of 0.17 m³/sec (Table 41). The substrate was 10-30 mm gravel (30%), silt (30%), rubble (20%) and sand (10%). The high proportion of gravel substrate, a P:R:R ratio of 30:50:20 and a bank overhang of 30% shows that this stream section suitable for spawning and rearing of salmonids. Water chemistry (Table 39) in station 1 revealed a water temperature of 7.8 C, pH of 8.0, and conductivity of 240 mhos/cm.

In stratum 2, the stream flows through a large open wet meadow fringed with lodgepole pine. The many springs form numerous small tributaries overgrown by grasses and sedges. The stream here had a low gradient (8m/km) with an average depth of 0.13 m and average width of 2.70 m. The late August flow was 0.32 m³/sec and the substrate mostly boulders (75%). A P:R:R ratio of 40:40:20 indicates that the stream in this stratum has good holding habitat for juveniles and adults, but spawning conditions are limited. Water chemistry at station 2 was like that of station 1, except for a higher water temperature of 12.8 C, probably because of a greater light penetration to the stream.

Macroinvertebrates

A total of 23 taxa of macroinvertebrates were found in Stream #1234 (Table 42). Included were six orders and 16 families representing forms normally associated with moderate to high water quality. The diversity of mayflies, stoneflies and caddisflies indicate moderate instream production. High nitrate levels and moderate invertebrate populations suggest that this stream is capable of supporting a fish population.

Fishes

Three 100 m sections of stream were electrofished on Stream #1234 on August 17-20. Cutthroat trout and mottled sculpin were collected. Eight cutthroat trout (mean length 221.5 mm, range 185-257 mm) and one mottled sculpin were collected at site A about 0.5 km upstream from Fan Creek. Seven of the eight fish had large distinct spots suggesting that they had S. c. bouvieri influence and one fish had small diffuse spots suggestive of S. c. lewisi. These fish were taken from pools in the stream well represented by station 1.

Twelve cutthroats (mean length 117.2 mm, range 81-250 mm) and two mottled sculpin were collected from site B about 2 km upstream from site A. All but one of these cutthroats showed markings distinct to S. c. lewisi; small diffuse spots with irregular margins.

A third electrofishing site, site C, was selected in and around some small beaver ponds near the mouth of Stream #1234. Three cutthroat trout (mean length 171.7 mm, range 162-264 mm) and eleven mottled sculpin were collected from these ponds. Two of the three cutthroats had large, regular spots characteristic of S. c. bouvieri and the third had smaller, diffuse spots.

AGE AND GROWTH ANALYSIS

During 1982 a preliminary study was initiated to evaluate current procedures for identifying age and growth patterns of cutthroat trout inhabiting Yellowstone Lake, and current procedures for determining the age of fish inhabiting backcountry lakes and streams in Yellowstone Park.

YELLOWSTONE LAKE

Identifying, characterizing, and understanding age and growth patterns of cutthroat trout from Yellowstone Lake continues to be a perplexing problem (Laakso and Cope 1956, Bulkley 1961, Bulkley and Benson 1962). Since 1969, the standard procedure for back-calculating lengths at annulus formation has been through use of the Dahl-Lea direct proportional method (Lagler 1956). Lee's phenomenon (length at a given age are smaller for older fish), however, was evident when this method was used. The current analysis of age and growth procedures on Yellowstone Lake was initiated to evaluate this method of estimating length at annulus formation, and evaluate methodologies for identifying characteristic age and growth patterns of cutthroat trout from different areas of the lake.

Back-Calculated Length Evaluation

Methods

Scale samples were collected from three major sources: (1) Clear Creek spawning run, (2) Pelican Creek spawning run, and (3) fall-largemouth gillnetting (current report). In the spawning runs, a stratified sample of 20 scales was collected from migrating fish every week. During gillnetting, the trout were sorted from largest to smallest in length. Scale collection started with the largest trout in each net and continued with every third fish thereafter. During scale reading, distance to each annulus and scale radius measurements were made on the magnified image of each scale at an angle of less than 10° off of a straight line from the focus radius to the center of the anterior edge.

Scale radius versus body length were plotted for all aged fish captured in largemouth gillnetts in 1982 utilizing three procedures: (1) empirical measurements of individual fish, (2) means determined by stratifying the sample into 10-mm body length size classes, and (3) means determined by stratifying the sample into 1-mm scale radius size classes.

To determine the affect of the selected sample on the resulting body-scale relationship, a mathematical representation of the relationship was made for all aged fish captured from 1969-1982. For each year, aged fish were combined (gillnets and spawning runs) into pooled samples. Body-scale relationship equations

were derived for these samples utilizing Richer's GM straight line regression methodologies (Ricker 1975).

From the 1982 pooled sample, fish were stratified into 10-mm body length intervals. A standardized sample was developed by randomly selecting a maximum of five fish from each interval. All plots made on the 1982 largemouth gillnetted fish were repeated for these fish. This sample was further utilized for statistical curve type testing by calculating coefficients of determination for eight curve types.

For each of the 1982 aged cutthroat trout captured in largemouth gillnets a back-calculated length at each annulus formation was estimated utilizing the Dahl-Lea equation (Lagler 1956). These values were combined and a mean annulus value was determined. For the years 1969-1982, these mean values were combined and a mean annulus value for the entire time period was developed. From these values mean yearly growth increments were determined. Empirical age class lengths for aged fish from 1969-1982 were calculated and representative growth increments were also determined.

Statistical comparisons (t test) were made on mean back-calculated lengths at annulus formation and mean empirical age-class lengths at the 95% level of significance.

Results

Graphic representations of body length versus scale radius for all fish captured in 1982 gillnets, were highly variable linear patterns for individual fish or fish stratified into 10-mm body length intervals, whereas, a sigmoid pattern (S-shaped) was evident, when these fish were stratified into 1-mm scale radius intervals (Figure 44). In all three plots, the tightest grouping of points occurred for fish less than 300 mm. Similar patterns were observed for all three plots when fish from the standardized sample was used for graphic representations of the body-scale relationship (Figure 45).

Linear index of determination values, for the samples of all aged trout from Yellowstone Lake (1969-1982) were highly variable. The average value of the index of determination, all years combined, for males was 0.52, females was 0.49, immatures was 0.73, and all fish combined was 0.65. Intercept values were also variable and averaged 39.2 for males, 18.6 for females, -35.3 for immatures; and 44.7 for all fish combined.

Index of determination values calculated for the eight curve types were close in magnitude with a range of 0.72 to 0.83. A third degree polynomial best described this relationship ($r^2 = 0.83$). The index value for the straight line, furthermore, was higher (0.76) for this sample of all aged trout (1969-1982) than for 1982 aged trout (0.56).

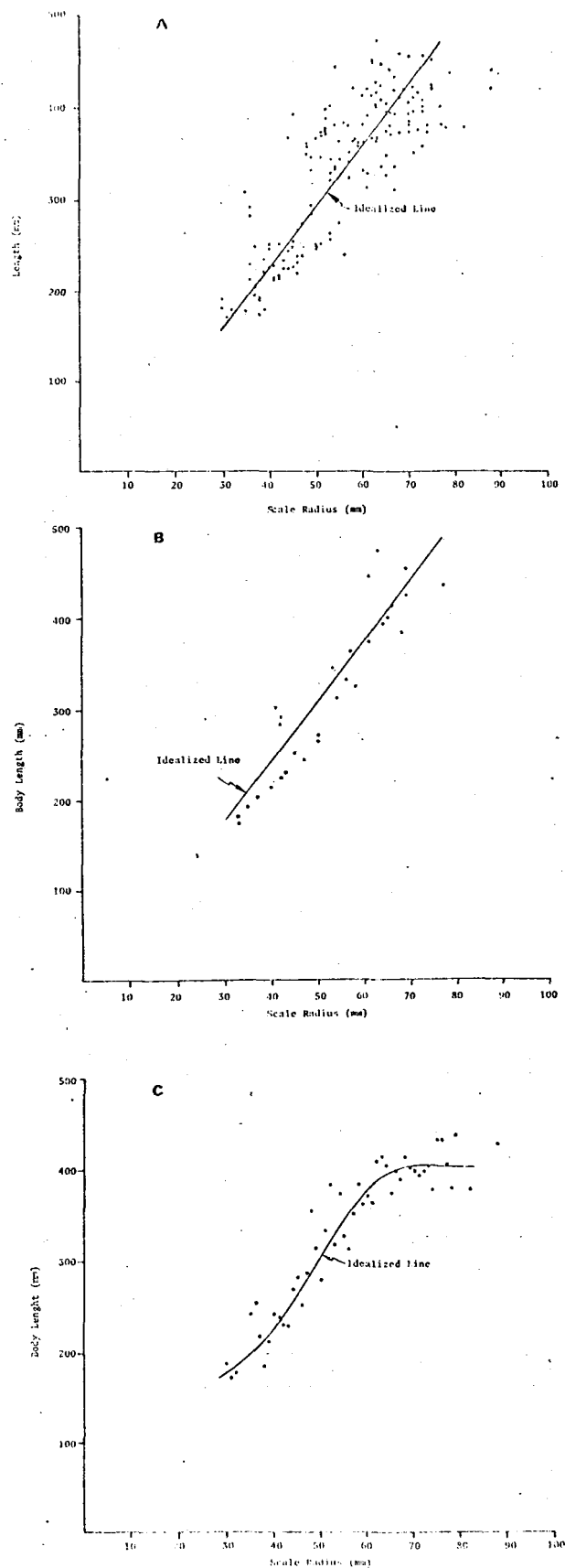


Figure 44 Body-length relation hip plotted for cutthroat trout captured in
 Columbia River Delta, 1964-1965. Plot A was based on
 body length (mm), Plot B, and C were based on mean values determined
 by dividing the sample into 10 mm body length and 1 mm scale
 radius intervals, respectively.

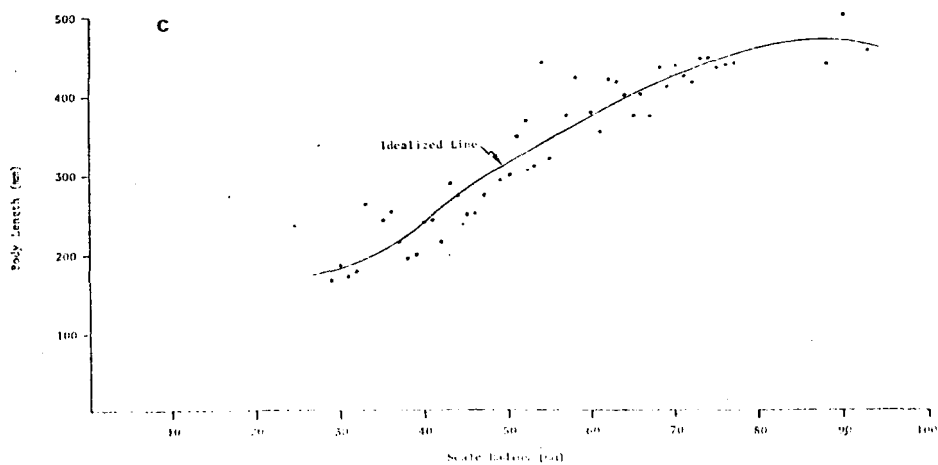


Figure 45 Karyotype of a human karyotype prepared from a study of cells of a patient with a confirmed diagnosis of Down's syndrome. The cells that were used were cultured in the presence of colchicine, which causes cells to arrest in metaphase. The cells were then treated with trypsin, which digests the proteins, and then stained with Giemsa stain. The karyotype was prepared by arranging the chromosomes in order of length and sex chromosome. Interstitial, respectively.

Mean empirical age class lengths for growing seasons II-VIII were similar to mean back-calculated lengths at annulus formation for annuli I-VII (Table 43). When plotted, mean back-calculated lengths at annulus formation and mean empirical age class lengths had comparable patterns (Figure 46). Mean back-calculated growth increment for all growing seasons I-VII was 57 mm/year (Table 43). Mean empirical growth increment for growing seasons I-VIII was also 57 mm/year. When plotted, mean back-calculated growth increments had an unimodal pattern, whereas, mean empirical growth increments had a bimodal pattern (Figure 47).

Discussion

The body-scale relationship for cutthroat trout captured in Yellowstone Lake during 1982, was best described statistically by a sigmoid curve. The curve was most evident graphically when the sample was stratified by 1-mm scale radius intervals and was plotted against mean body length (Figures 44 and 45). Bulkley (1961) also described the body-scale relationship with a sigmoid curve, however, his sample was stratified by 20 mm body-length intervals and contained smaller fish. Laakso (1956) described the body-scale relationship for juvenile fish as linear. This characterization would also apply to 1982 aged cutthroats if only fish less than 300 mm were used to describe the relationship.

Standardizing the sample produced better estimates than utilizing all aged fish from a given year (pooled sample). Using the pooled sample to describe the body-scale relationship on a linear basis produced a large amount of variation from year to year. This variation was probably a function of the distribution of length classes in a given year. When the standardized sample was utilized, each length class was "weighted" as equitably as possible. When the linear relationship equation was tested on this sample a higher index of determination value was obtained. This procedure should also obtain higher index of determination values for mathematically describing sigmoid curves. A more accurate description of the body-scale relationship could improve back-calculated length procedures.

The Dahl-Lea method of back-calculating lengths at annulus formation provided a fair estimate of those lengths when compared to empirical age class lengths. Both methods predicted that growth rates averaged approximately 57 mm/year. Growth patterns, however, were considerably different between the two estimates. Empirical growth increments followed a bimodal pattern with the second growing season the fastest growth period and the fourth season the second fastest growth period. Mean back-calculated growth increments, however, followed a unimodal pattern with the third growing season as the fastest growth period. This difference could be based on several factors. Two possible explanations are: (1) selective sampling for the

Table 43. Mean back-calculated lengths at annulus formation, mean empirical age class lengths, and representative growth increments, calculated for all cutthroat trout captured in largemouth gillnets from Yellowstone Lake, 1969-1982

Growing season	Mean empirical age class			Mean back-calculated		
	Length	Range	Growth Increment	Length	Range	Growth Increment
I	---	---	---	57	53-63	57
II	175	88-191	120	148	131-161	91
III	230	206-256	55	255	240-268	109
IV	314	301-326	84	318	303-329	63
V	365	340-375	50	356	346-366	38
VI	391	376-410	27	395	377-400	39
VII	424	403-485	33	400	398-402	5
VIII	454	435-441	30	---	---	---

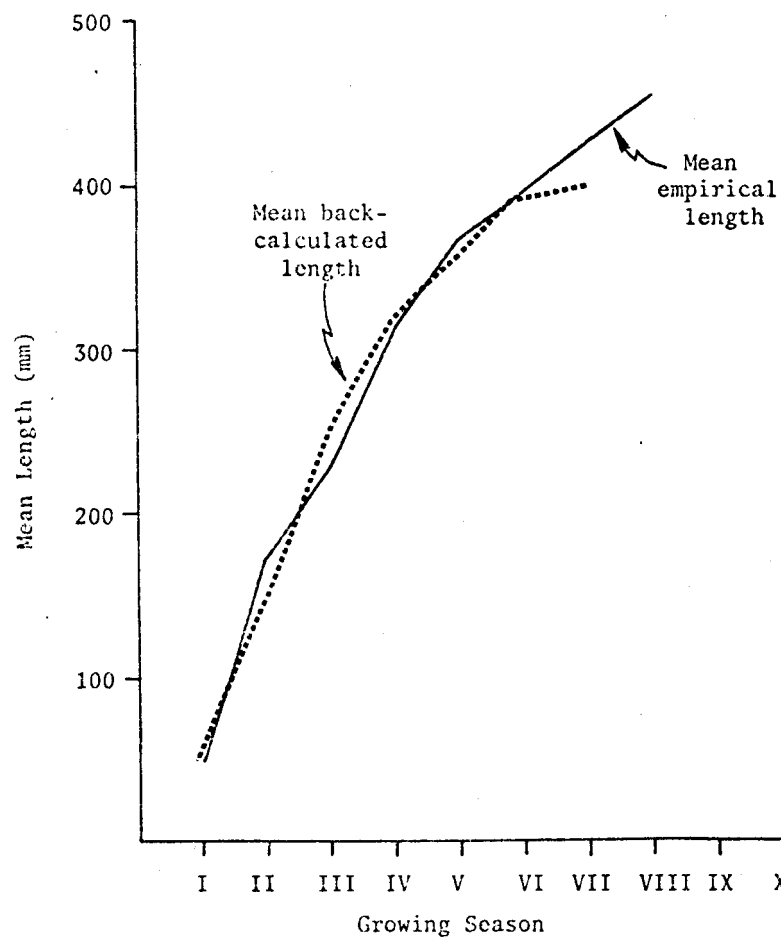


Figure 46. Mean back-calculated lengths at annulus formation versus mean empirical age class lengths for all cutthroat trout captured in gillnets, 1969-1982.

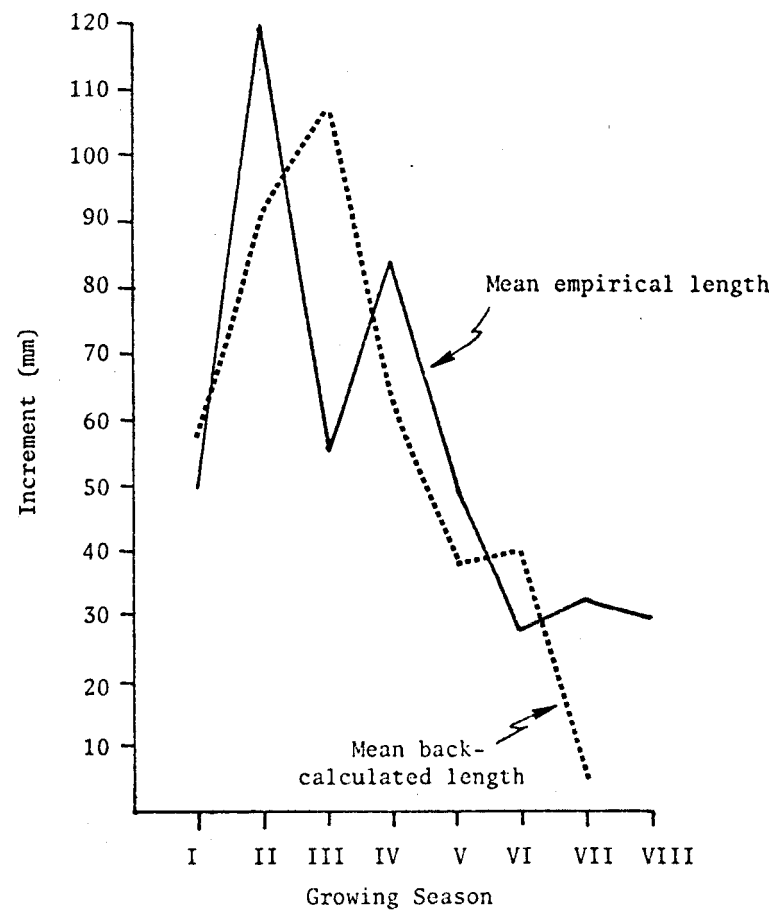


Figure 47. Mean back-calculated growth increments versus mean empirical growth increments for all cutthroat trout captured in gillnets, 1969-1982.

fastest growing younger fish (less than 300 mm) in the empirical data, and (2) failure of back-calculating length procedures to accurately predict lengths for age classes I-III: (Lee's phenomenon). Both these factors are probably based on the failure of sampling procedures to adequately capture a random sample of the youngest age classes (0-II). Historically, gillnets have captured age classes I and II, however, these classes were not represented in the sample in the same proportion that exists in the population. Back-calculated length procedures, however, are probably more representative of growth patterns than the empirical aged class lengths since they generally utilize a larger number of fish to predict age class lengths (particularly young age classes) and empirical age class lengths are dependent on sample size of each age class. Care should be taken, therefore, when utilizing empirical age class lengths to describe growth patterns of young age classes (age I-III) of Yellowstone Lake cutthroat trout.

This preliminary study illustrates the need for further clarification of procedures for describing age and growth patterns of Yellowstone Lake cutthroat trout. This might include stratified sampling aimed at achieving an equivalent number of samples per size category, rather than a random sample which has generally been subject to fluctuations in age and length class strength and biased towards older larger fish.

Characterization of Age and Growth Patterns

Methods

Scale collection occurred during fall largemouth gillnetting (current report). Measurements obtained on each scale followed the same procedures outlined in the Back-calculated length evaluation section of this report.

Scale measurement analysis, separated for each net site (for net sites see Fall Largemouth Gillnetting), included, frequency of circuli to the first and second annulus; frequency of circuli between first and second annulus: mean back-calculated lengths at annulus formation (Dahl-Lea's method), and mean incremental growth patterns.

Results

Circuli counts varied from site to site. Mean number of circuli to the first annulus ranged from 5.14 at 6C to 7.64 at 1B (Figure 48). Mean number of circuli to the second annulus ranged from 14.14 at 6C to 18.73 at 1B (Figure 49). Mean number of circuli between the first and second annulus ranged from 8.53 at 7C to 12.86 at 1B.

Mean back-calculated lengths at annulus formation also varied from site to site (Table 44). This variability was generally small between estimated lengths at the first three annuli

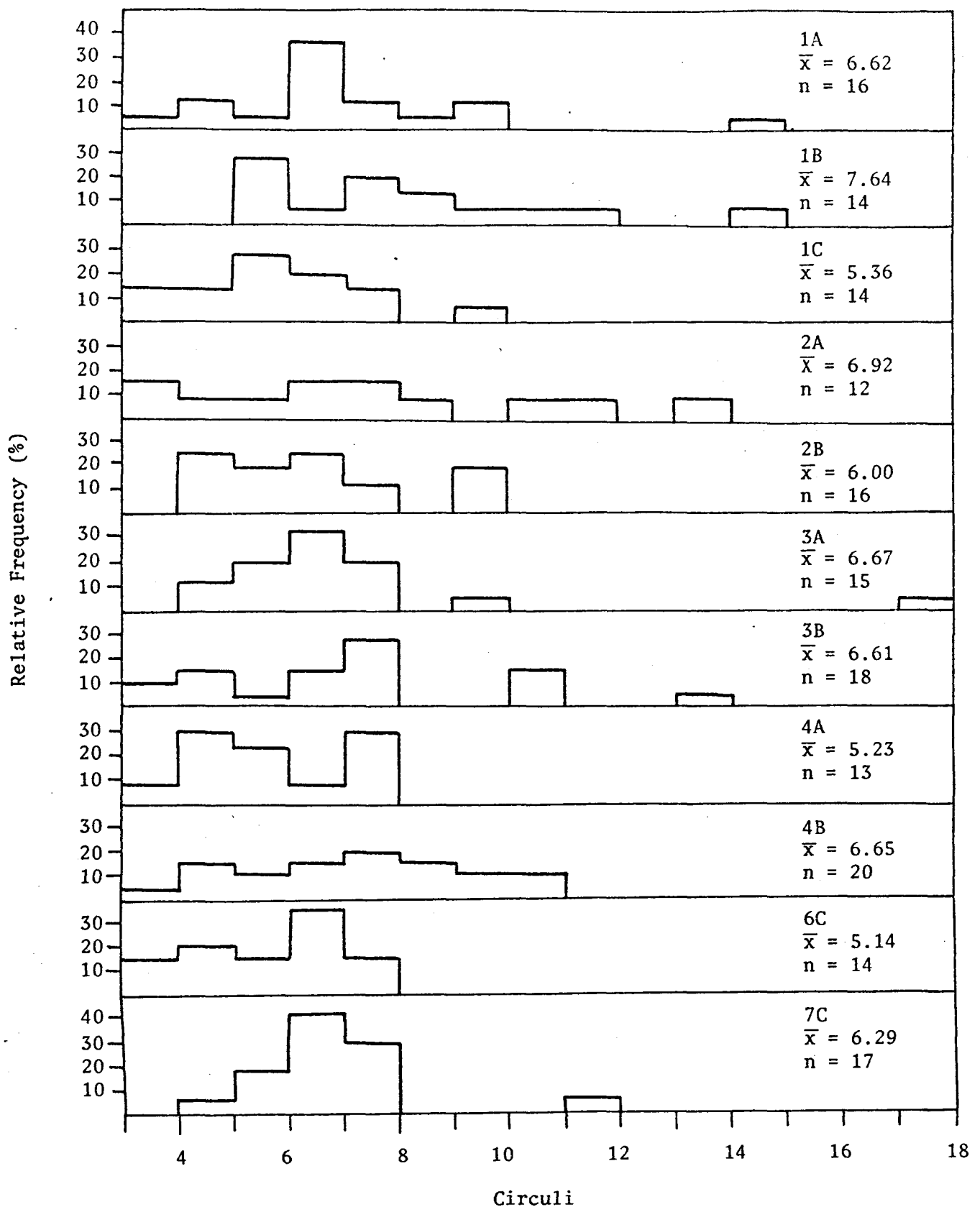


Figure 48. Frequency of circuli to the first annulus, by net site, for cutthroat trout captured in largemesh gillnets, Yellowstone Lake, 1982.

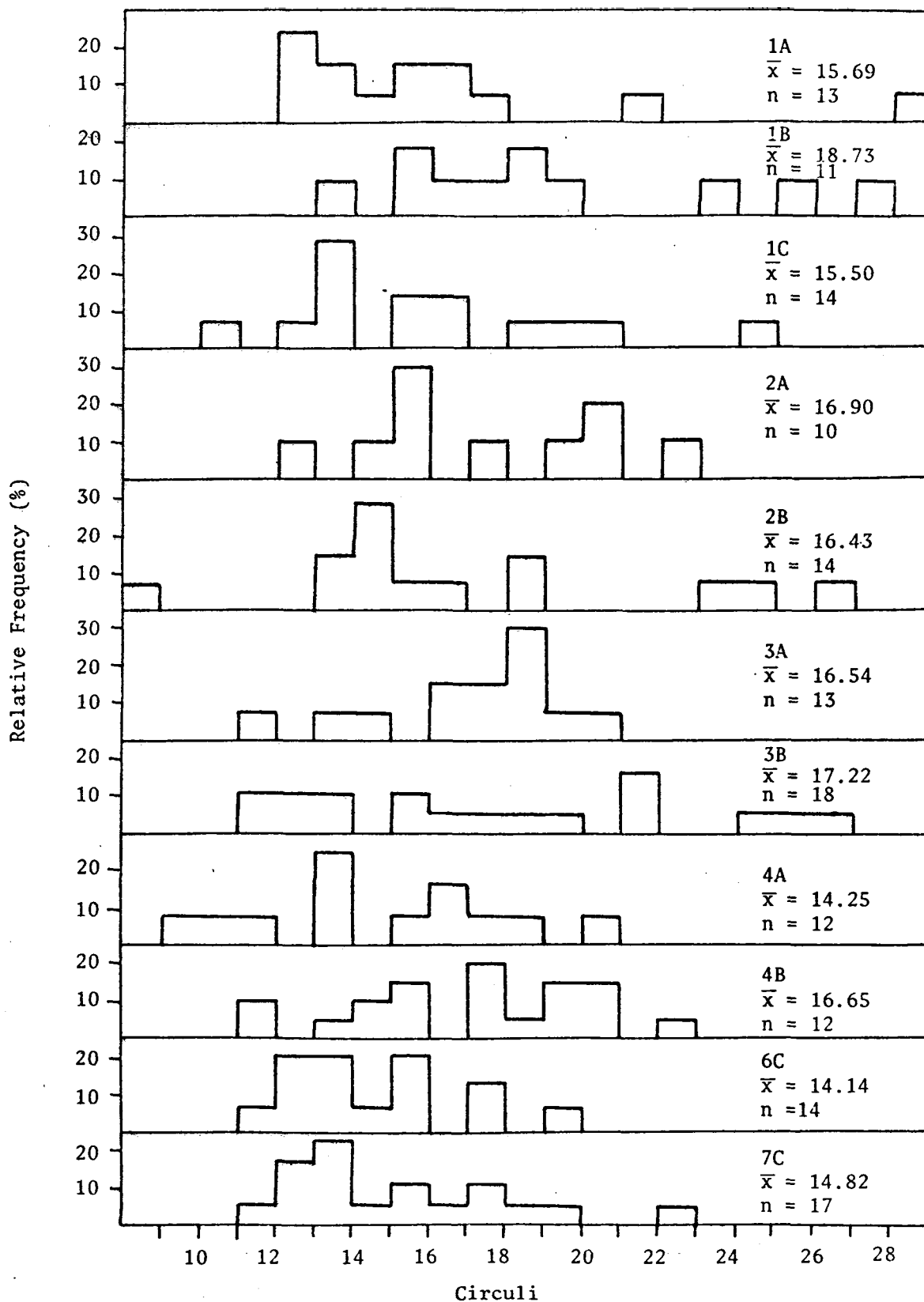


Figure 49. Frequency of circuli to the second annulus, by net site, for cutthroat trout captured in largemouth gillnets, Yellow Lake, 1982.

Table 44. Mean back-calculated lengths at annulus formation by net site for cutthroat trout captured in gillnets, Yellowstone Lake during 1982

Area	Annulus						
	I	II	III	IV	V	VI	VII
1A	60	151	265	342	383	--	--
1B	46	136	250	278	303	349	--
1C	55	144	238	297	334	368	382
2A	47	140	231	299	323	371	397
2B	47	138	218	282	305	364	--
3A	52	155	240	316	--	--	--
3B	52	141	247	331	377	397	--
4A	58	136	235	285	348	389	--
4B	48	142	236	287	329	368	428
6C	60	159	234	302	358	405	--
7C	66	153	246	324	358	365	--
All areas mean	54	145	240	304	342	375	402

compared to annuli four through seven. Trout captured at site 1A generally had the largest lengths at annulus formation, whereas trout captured at site 2B had the smallest (Table 44).

Incremental growth patterns were highly variable, but male incremental growth rates were more variable than females. Females tended to have high growth increments during the first three growing seasons. Males, however, were variable throughout all growing seasons. The highest and lowest growth increments for males were observed at 4A (approximately 160 mm) and 2B (approximately 38 mm), respectively. The highest and lowest growth increments for females was observed from 1C (approximately 170 mm) and 1B (approximately 20 mm), respectively.

Discussion

Circuli counts, mean back-calculated growth rates and incremental growth patterns were all variable for different areas of the lake. No set pattern, furthermore, was evident between the different sample sites. Circuli counts tended to have the lowest values in the arms and the highest values in the northern zone of the lake (Figure 50). Mean back-calculated lengths at annulus formation indicated fish captured at 1A had the fastest growth rates, but the rest of the fish captured in the northern end of the lake generally had the slowest. No correlation existed between the estimated size attained at the end of the first growing season and the number of circuli to the first annulus ($r^2 = 0.26$). Although, circuli counts have been utilized as first year growth indicators (Major et al 1972) they may not be applicable for Yellowstone Lake or the back-calculated length procedure may need modification.

The importance of these differential growth patterns could be manifested in the response of fish inhabiting different areas of the lake to the 330 mm maximum size limit. For example, fish migrating into Clear Creek to spawn had a growth pattern similar to site 1A and fish migrating into Pelican Creek to spawn had a growth rate more similar to fish inhabiting the northern end of the lake (Sites 1B, 1C, 2A, 2B). The average size of fish migrating into Clear Creek has increased by approximately 30 mm since the inception of the regulation, whereas the average size of fish migrating into Pelican Creek has increased by approximately 20 mm (Yellowstone Lake section current report).

Further investigation is needed to identify these growth patterns and understand their influence on the Yellowstone Lake cutthroat trout population. It is recommended, therefore, that age and growth analysis for Yellowstone Lake continue to be separated by sample site.

AGE DETERMINATION

Laakso and Cope (1956) outlined procedures for separating cutthroat trout from Yellowstone Lake which formed an annulus on

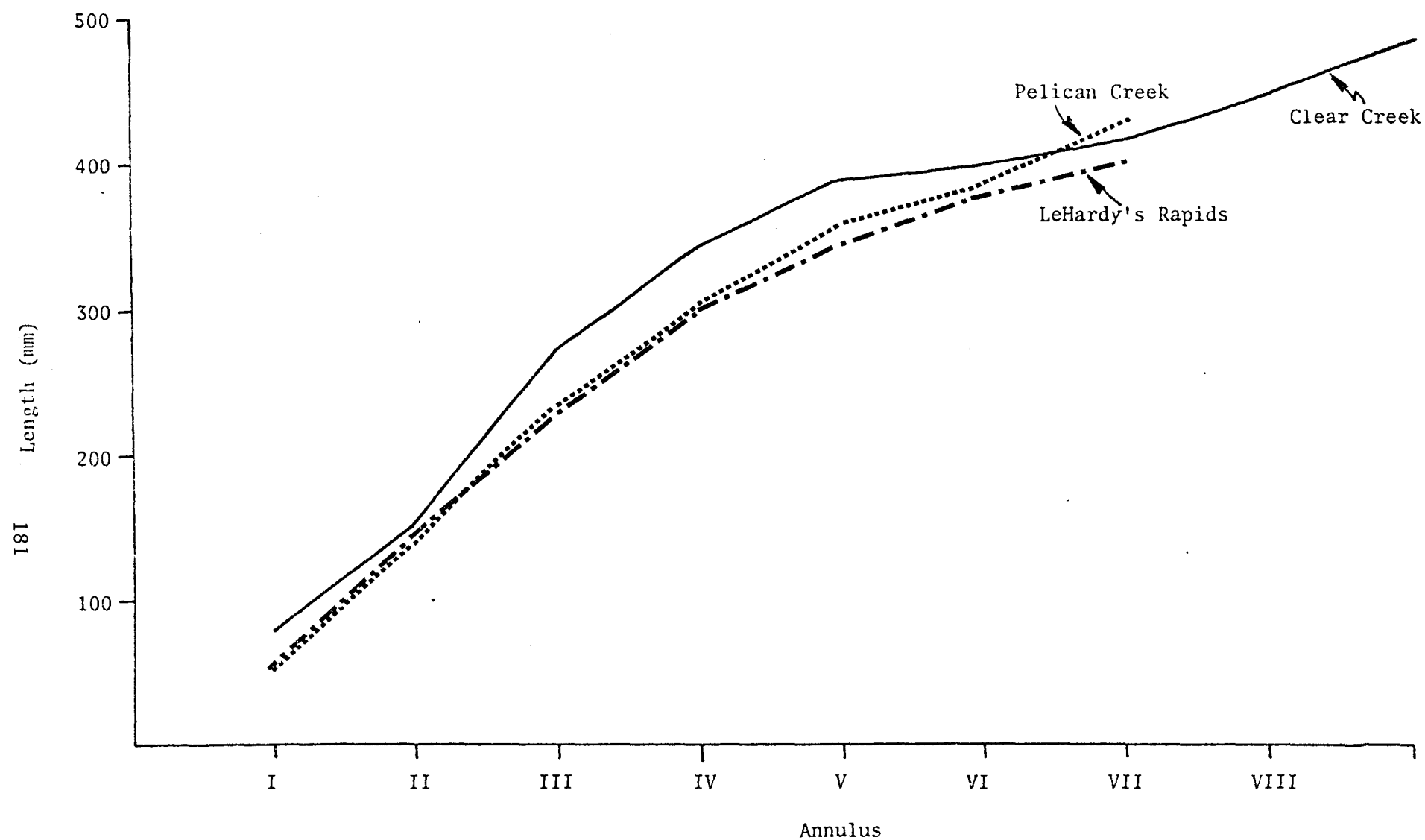


Figure 50. Mean back-calculated lengths at annulus formation, by selected site, for cutthroat trout captured in Yellowstone National Park, 1982.

their scales (normal scales) from fish which did not form an annulus on their scales (retarded scales) after their first growing season. These procedures utilized the number of circuli to the first annulus as the discriminating factor. They defined retarded scales as having eight or more circuli to the first annulus and normal scales as having less than seven circuli to the first annulus. These criteria have generally been applied to all cutthroat trout populations in Yellowstone Park. This preliminary study was initiated to evaluate the application of these criteria to cutthroat trout populations inhabiting backcountry streams surveyed during 1982 (current report).

Methods

Scale samples were randomly collected from cutthroat trout populations inhabiting five streams: (1) Alum Creek, (2) Bear Creek, (3) Unnamed tributary to Fan Creek (Stream #1234), (4) Sedge Creek, and (5) Thistle Creek. Number of circuli to the first annulus and fish age were determined for each collected scale. These values were summarized for each population and a mean value was calculated. An age-length key was developed for each population following procedures of Westerheim and Ricker (1977).

Results

Number of circuli to the first annulus ranged from 2 to 6 (mean 4.25) for Alum Creek; 2 to 8 (mean 4.95) for Bear Creek; 3 to 10 (mean 5.00) for Stream #1234; 2 to 7 (mean 7.67) for Sedge Creek; and 4 to 7 (mean 4.6) for Thistle Creek.

Some of the trout from Bear Creek and Stream #1234 did not have an annulus and circuli counts were made to the scale radius. These counts ranged from 4 to 5 (mean 4.3, n=3) for Bear Creek fish and 3 to 7 (mean 4.5, n=6) for fish from Stream #1234. Both of these samples were taken in August (25 and 20, respectively) and, the average length of these trout were 78 and 86 mm, respectively.

Total length of aged fish ranged from 105-168 mm (mean 149 mm) in Alum Creek; 73 to 239 mm (mean 131 mm) in Bear Creek; 81-264 mm (mean 171 mm) in Stream #1234; 75-267 mm (mean 215 mm) in Sedge Creek; and 73-352 mm (mean 131 mm) in Thistle Creek.

Discussion

Population growth characteristics generally do not apply from one population to the next (Carlander 1969). Laakso and Cope's (1956) criteria developed for separating normal and retarded growth patterns of cutthroat trout in Yellowstone Lake has been applied to other cutthroat trout populations in the Park. At least for some of these other populations, these criteria might not apply.

In Sedge Creek, fish in the length class range 30-70 mm were not aged (Figure 51). Based on the sample date (July 15), it is highly unlikely that these fish were age 0. Fish in the length class range 70-130 mm had one annulus on their scales. The number of circuli to the first annulus on the scales of these fish averaged 4.7. It is probable that the fish in the size category 30-70 mm were age I and fish in the 70-130 mm length range were age II. This would indicate that an annulus does not form on the scales of fish after the first growing season in the Sedge Creek population. All scales sampled, therefore, were probably retarded scales. The criteria, then, for distinguishing retarded scales from normal scales developed for the Yellowstone Lake population does not appear to apply to the Sedge Creek population.

Other cutthroat trout populations where the Yellowstone Lake criteria for distinguishing normal from retarded scales may not apply are from Bear Creek and Stream #1234. In Bear Creek, three fish were captured that did not have an annulus on August 25. The number of circuli to the scale radius on the scales of these fish ranged from 4 to 5. In Stream #1234, six fish were captured that did not have an annulus on August 20. The number of circuli to the scale radius for these fish ranged from 3 to 7. The average lengths of the fish from these two locations were 78 and 86 mm, respectively. It is highly unlikely that these fish attained such large sizes in their first growing season. Laakso and Cope (1956) reported an average size of Yellowstone Lake fish as approximately 50 mm during October 1953. The fish from these streams, therefore, probably represent fish whose scales did not form an annulus after their first growing season.

For the populations of cutthroat trout inhabiting Alum and Thistle Creeks, no determination could be made as to the application of retarded and normal scale criteria. Their age-length distributions, however, were similar to the populations where the criteria did not apply (Figure 51).

Summary

The normal procedure, for cutthroat trout populations in the Park, has been to increase the age of fish with retarded scales by one year. This procedure, therefore, made up for the year the scale lost. Since the Yellowstone Lake circuli count criteria does not appear to apply to all cutthroat trout populations in the Park, it might be more equitable not to adjust ages for cutthroat trout from other waters. A technique comparing growing seasons (distance between annuli) instead of ages may have greater analytical importance for many of these populations, and future studies should address this concept.

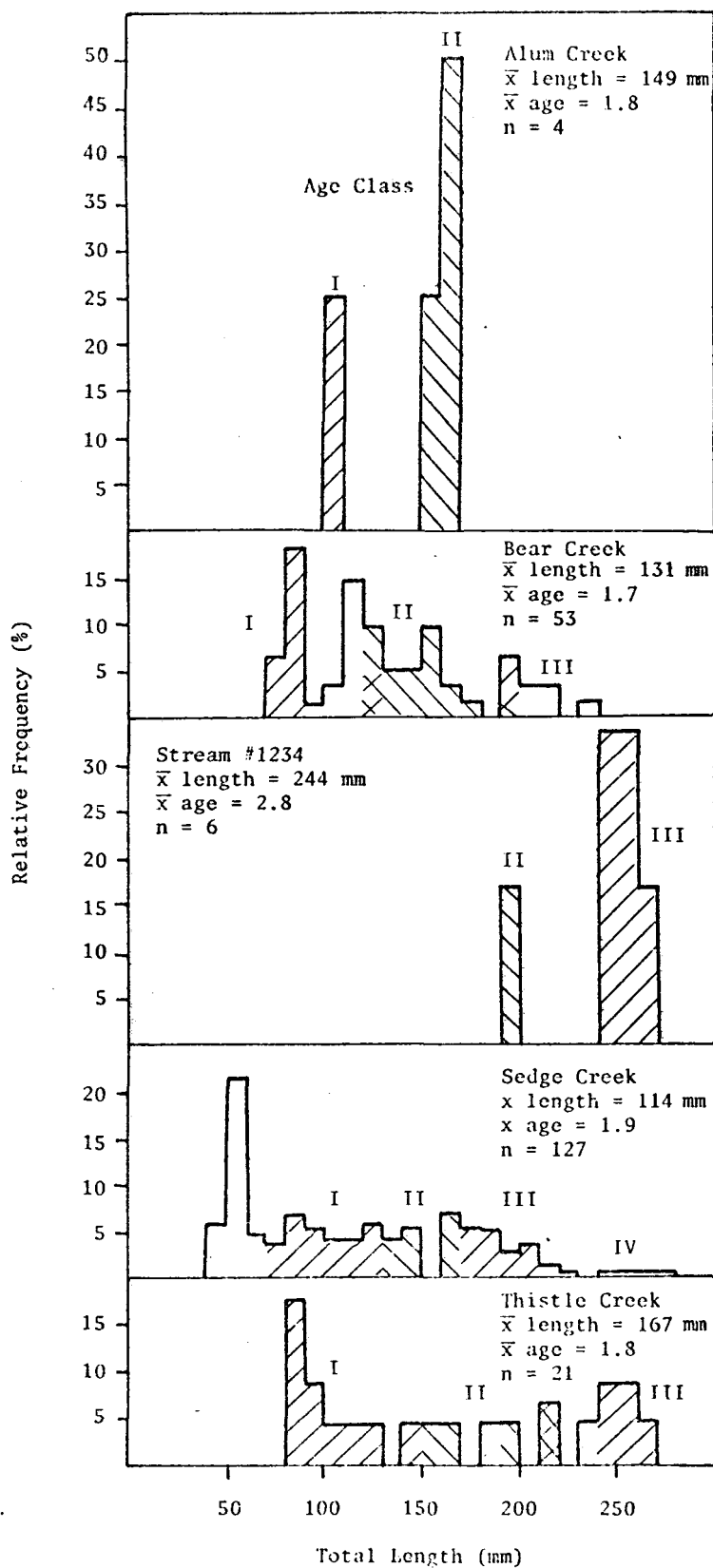


Figure 51. Age-length distribution of cutthroat trout captured in Alum Creek, Bear Creek, Stream #1234, Sedge Creek and Thistle Creek, Yellowstone National Park, 1982.

NATIVE SPECIES RESTORATION PROGRAM

The native fishes of Yellowstone Park consist of eleven species. The Montana grayling, three or more genotypes 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 several 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, genotypes 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).

In 1982, the native species restoration program consisted of: (1) Sedge Creek cutthroat trout transplants, and (2) Blacktail Ponds cutthroat trout restoration.

SEGE CREEK CUTTHROAT TRANSPLANTS

Since 1977, Yellowstone National Park and the Wyoming Game and Fish Department have had a cooperative agreement to transplant trout from Sedge Creek to the headwaters of the Yellowstone River outside the Park. This agreement served three objectives: (1) Wyoming's Game and Fish Department desire to establish trout populations in the barren headwaters of this area, (2) the Park's desire to protect the unique cutthroat trout gene pool found in Sedge Creek, and (3) the Park's desire to preserve the genetic integrity of the upper Yellowstone River drainage.

The Wyoming Game and Fish Department has fishery management jurisdiction over the headwaters of the Yellowstone River in the Teton Wilderness. In this area, the South Fork of the Yellowstone River above Woodard Canyon was historically fishless due to falls preventing upstream fish movement. Wyoming Game and Fish personnel first attempted to establish cutthroat trout in this region during 1965-1967 when Yellowstone cutthroat trout fingerlings and eyed eggs were stocked in the river above Woodard Canyon (Erickson, pers. comm.). These plants were unsuccessful. Game and Fish personnel attributed the failure of these plants to the strong inherent instinct of the progeny to migrate downstream. This led Game and Fish personnel to search for a strain of trout native to the Yellowstone drainage, that produced progeny which lacked strong downstream migratory tendencies.

Within the Yellowstone Lake drainage, two populations of cutthroat trout have been identified as having significantly different taxonomic characteristics from trout inhabiting Yellowstone Lake (Bulkley 1963). These fish are from Sedge and Bear Creeks. The taxonomic characteristics which separated them from Yellowstone Lake fish were hyoid teeth counts and number of spots below the lateral line:

	Hyoid Teeth ($\bar{x}$)	Spots ($\bar{x}$)
1. Sedge Creek	5.3	22.4
2. Bear Creek	9.2	43
3. Yellowstone Lake	13.5	84.3

The differences in the average values of these characters is assumed to be the result of isolation over geologic time.

In recent geologic history, Sedge and Bear Creeks were directly connected to Yellowstone Lake. Over time, Yellowstone Lake diminished in size. As a result, upper Sedge Creek and Bear Creek were isolated from Yellowstone Lake proper by Turbid Lake, a geothermal body of water. This isolation is assumed to have promoted the adaptation of fish inhabiting these streams to forms more suited for a lotic environment. With the presence of Turbid Lake downstream, any fish migrating out of these streams were killed. Selective pressure should have favored individuals which produced progeny that did not migrate downstream after hatching. The shift in morphometric characters outlined above are assumed to be representative of this corresponding shift in behavioral characteristics.

The original populations in Sedge and Bear Creeks have remained relatively unaltered by stocking. Some stocking occurred in Bear Creek during 1939 and 1940 (Bulkley 1963). This population was well established prior to stocking, however the influence of these events is probably manifested in the morphometric character values. No records exist of stocking ever occurring in Sedge Creek (Varley 1981). The Sedge Creek population represented a pure unaltered (by man) gene pool as manifested in the morphometric character values.

The protection of these unique strains was the major concern of the Park. Establishment of additional populations in areas secure from genetic contamination would provide that protection. It was Park policy, however, that any barren streams remaining in the Park would not be stocked. Prior to 1977, the Park applied this policy to surrounding lands (especially a "Park" drainage) (Varley 1977, pers. comm.). Because barren waters have historically been planted with fish, either by biologists or sportsmen, Park attitudes concerning planting fishless waters outside the Park changed. It was decided that stocking fish of the correct genetic origin for a drainage, would preserve the integrity of fish populations in that drainage. These actions set the framework for stocking trout from Yellowstone Park into the headwaters of the Yellowstone River drainage.

Wyoming Game and Fish personnel requested consideration of two groups of fish for transplanting: Bear Creek and Sedge Creek strains were the primary candidates, and fish captured at LeHardy's Rapids were the secondary candidates. The Sedge Creek strain was selected because it was considered to be the most divergent strain from the Yellowstone Lake population. It was expected, therefore, that its chances of success were the highest. The transplanting operation was divided into two project periods: (1) transplanting fish from Sedge Creek, and (2) if transplants from Sedge Creek were unsuccessful, transplanting progeny from LeHardy's Rapids fish.

Transplanting Operations

Transplanting operations usually occurred after spawning had ceased in Sedge Creek. All fish were removed by electrofishing. The electrofishing procedures were assumed to be from 80-90% effective at removing all fish in the section of Sedge Creek shocked. Captured fish were held in holding pens located throughout the section. These fish were transported, the day after the electrofishing operation, by helicopter to the stocking site. Over the period of six years that these operations have occurred on Sedge Creek, approximately 2325 live trout have been transplanted (Table 45). Approximately 1770 of these fish were transplanted into South Fork (1977-1980) and 525 were transplanted into Senecio Creek (1981-1982).

Success of Transplanting Operations

Evaluation of the success of transplanting operations has been conducted by Wyoming Game and Fish personnel. On July 29, 1981, a fishery crew sampled the South Fork area. Introduced trout were present throughout Boulder Basin. Redds were observed. Some fish were sacrificed for gonadal inspection. This inspection revealed that spawning had occurred in 1981. No young-of-the-year or yearling fish, however, were observed or sampled. Based on this survey, Wyoming Game and Fish personnel felt the transplants had been successful and a viable population was establishing in South Fork.

The 1981 and 1982 transplants were made into Senecio Creek. Senecio Creek, like South Fork, has a natural fish barrier, was fishless, and provided a third secure enclave for Sedge Creek fish. No fish have been sampled in Senecio Creek, however, based on visual observation made during 1982, these plants appear to be establishing a viable population.

Effect on the Sedge Creek Population

To assess the effects of removal of approximately 2380 trout (including fish killed during operation) from the Sedge Creek population, lengths, weights, and scales were collected from a representative sample of the fish transplanted during

Table 45. Summary of number, size, and density of cutthroat trout removed from Sedge Creek, 1977-1982

Date	Fish Transplanted			Electrofishing Section		
	Number	Length (mm)	Weight (g)	Length (km) ¹⁾	fish/km	fish biomass (kg/km)
6/22/1977	457	175 (51-221)	61	4.8	95	6.1
7/7/1978	413	113 (58-254)	---	1.3	318	---
7/24/1979	550	---	---	1.3	472	---
7/15/1980	350	---	---	1.3	273	---
7/17/1981	330	---	---	1.2	276	---
7/15/1982	225	114 (58-254)	43	1.3	173	7.4

1) For the years 1978-1980 the length of stream electrofished was not recorded, therefore, section length was estimated based on field notes and recollections of biologists.

1982. Information obtained from this data was compared to fish sampling which occurred prior to and during the transplanting activities.

Results

In 1977, length and weight measurements were made on 59 fish, and 18 of these fish were aged. The mean length of trout captured was 175 mm (Table 45). Approximately 11.8% of these fish were less than 100 mm (Figure 54). Average weight of an individual fish was 61 g. Fish density was estimated at 95 fish/km based on electrofishing 4.8 km (Table 45). Fish biomass was estimated at 6.1 kg/km based on 365 m of electrofishing. The average growth rate was approximately 49.6 mm/year based on empirical age class lengths and 42.4 mm/year based on back-calculated lengths at annulus formation. The mean age was estimated at 3.1 years.

In 1978, length measurements were made on 100 fish. Weight measurements and age determination were not made. The mean length of measured fish was 113 mm (Table 45). Approximately 58% of these fish were less than 100 mm (Figure 54). The length of stream electrofished was estimated at 1.3 km. Fish density, in that section, was approximately 318 fish/km (Table 45).

For the years 1979-1981 fish length and weight data were not taken on removed fish. The length of stream electrofished for removing the cutthroat, furthermore, was not recorded for the years 1979-1980, however section length was estimated based on field notes and recollections of biologists. The removal section generally started just above the lake and extended to where the stream turns east (Figure 55), a length of approximately 1.3 km. In 1981, the length of the removal section was measured and determined to be 1.2 km. During this time period (1979-1981) the highest estimated fish density in the removal section was recorded in 1979 (Table 45).

In 1982, length measurements were made on 225 fish, weight measurements were taken on 52 fish, and 36 fish were aged. The mean length of captured trout was 114 mm (Table 45). Approximately 51% of these fish were less than 100 mm (Figure 54). Average weight of an individual fish was 43 g. Fish density was estimated at 173 fish/km and fish biomass was estimated at 7.4 kg/km based on 1.3 km of electrofishing. The average growth rate was approximately 64.5 mm/year based on empirical age class lengths and 54.3 mm/year based on back-calculated lengths at annulus formation. The mean age was estimated at 1.9 years.

Angler activities were analyzed (VFR) for the transplanting period (1977-1982). No angler use was reported for 1977 or 1982. During 1978-1981 an estimated average of 37 anglers fished the creek. No determination could be made if these anglers were fishing above or below Turbid Lake, but because of

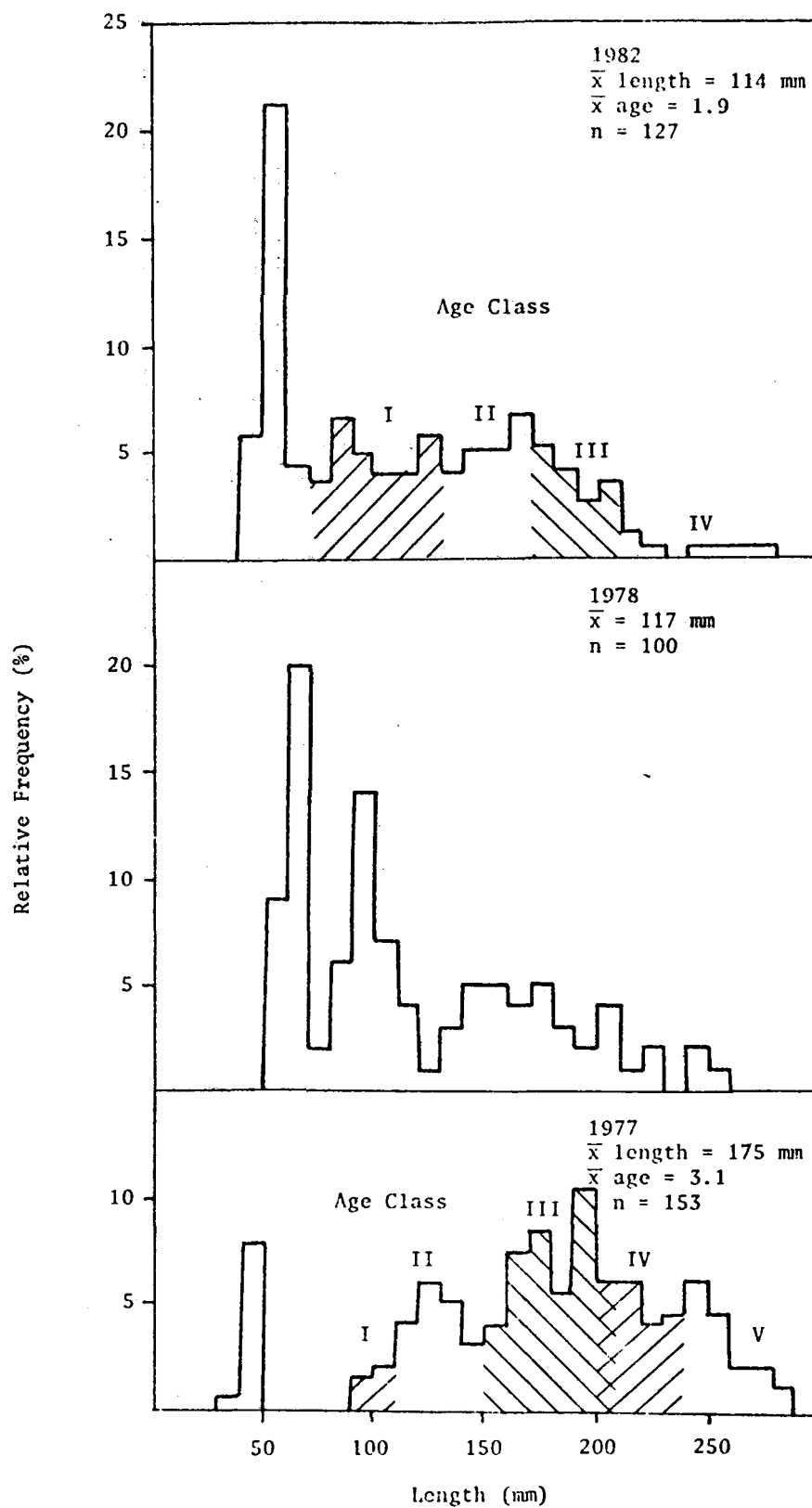


Figure 52. Length and age class distributions of cutthroat trout captured in Sedge Creek, 1977-1982.

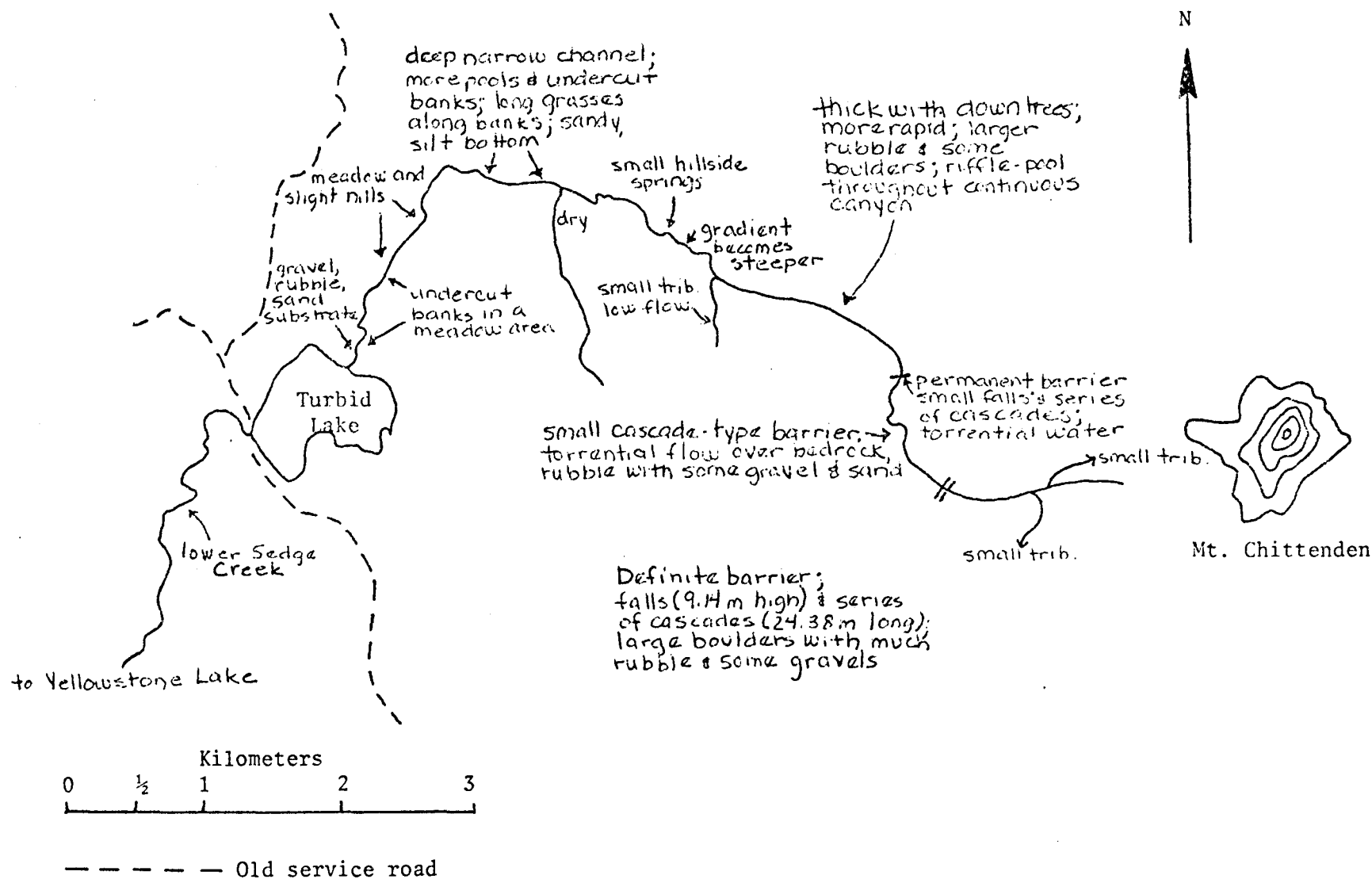


Figure 53. Hydrographic survey, upper Sedge Creek, July 7, 1978, Yellowstone National Park.

of the chemical characteristics of the stream below Turbid Lake, they are assumed to have fished above (Figure 55). From 1978-1981, the number of trout caught averaged 12.5 fish/year varying from four in 1980 to twenty three in 1981. The highest number of creel trout (15) occurred in 1981.

Discussion

The effect of six years (1977-1982) of continual fish removal on the Sedge Creek cutthroat trout population has been manifested in shifts in length distributions; age distributions; growth rates; and fish densities. These inter-related indicators demonstrate a shift in overall population structure.

Prior to removal of any fish (1977) the population was well represented throughout the length and age class range (Figure 54). In particular, a large percentage (38.4%) of the fish were moderately large individuals (>200 mm) and 11.8% were small individuals (<100 mm) (Figure 54). The percentage of older fish (>4 years) was also high (27%). Because of this population structure, fish densities were low at 95 fish/km.

After the removal of the 457 fish in 1977, the population shifted towards an increase in the proportion of smaller fish. In 1978, only 10% of the fish were larger than 200 mm, whereas, 58% of the fish were smaller than 100 mm (Figure 54). The number of fish removed decreased to 413, however, the length of stream electrofished also decreased from 4.8 km in 1977 to 1.3 km in 1978. Fish densities, therefore, had increased from 95 fish/km in 1977 to 318 fish/km in 1978 (Table 45). This rise in densities was reflective of the shift in population structure.

In 1982, the population structure had not changed significantly since 1978. The average length of fish in 1982 was 114 mm compared to an average length of 113 mm in 1978. The length distribution, however, continued to shift towards a smaller percentage (6.9%) of fish over 200 mm (Figure 54).

Emperical age class lengths were compared for the sample years 1963, 1977 and 1982 (Figure 54). Both the 1977 and 1982 emperical age class lengths were considerably different than those determined by Bulkley (1963). This variation could be due to differential growth rates or to scale reading prodecures. Methods used during 1982 adhered to 1977 methods as closely as possible. These methods, however, could have varied slightly from the 1963 prodecures.

During 1977 and 1982, fish in the length class range 30-70 mm were not aged (Figure 54). Based on the sample dates, it is highly unlikely that these fish were age 0. If they were age I, it is probable that fish in the length class 70-130 mm (in the 1982 sample) were not age I but age II. This would mean that all fish aged in both 1977 and 1982 should be increased by one

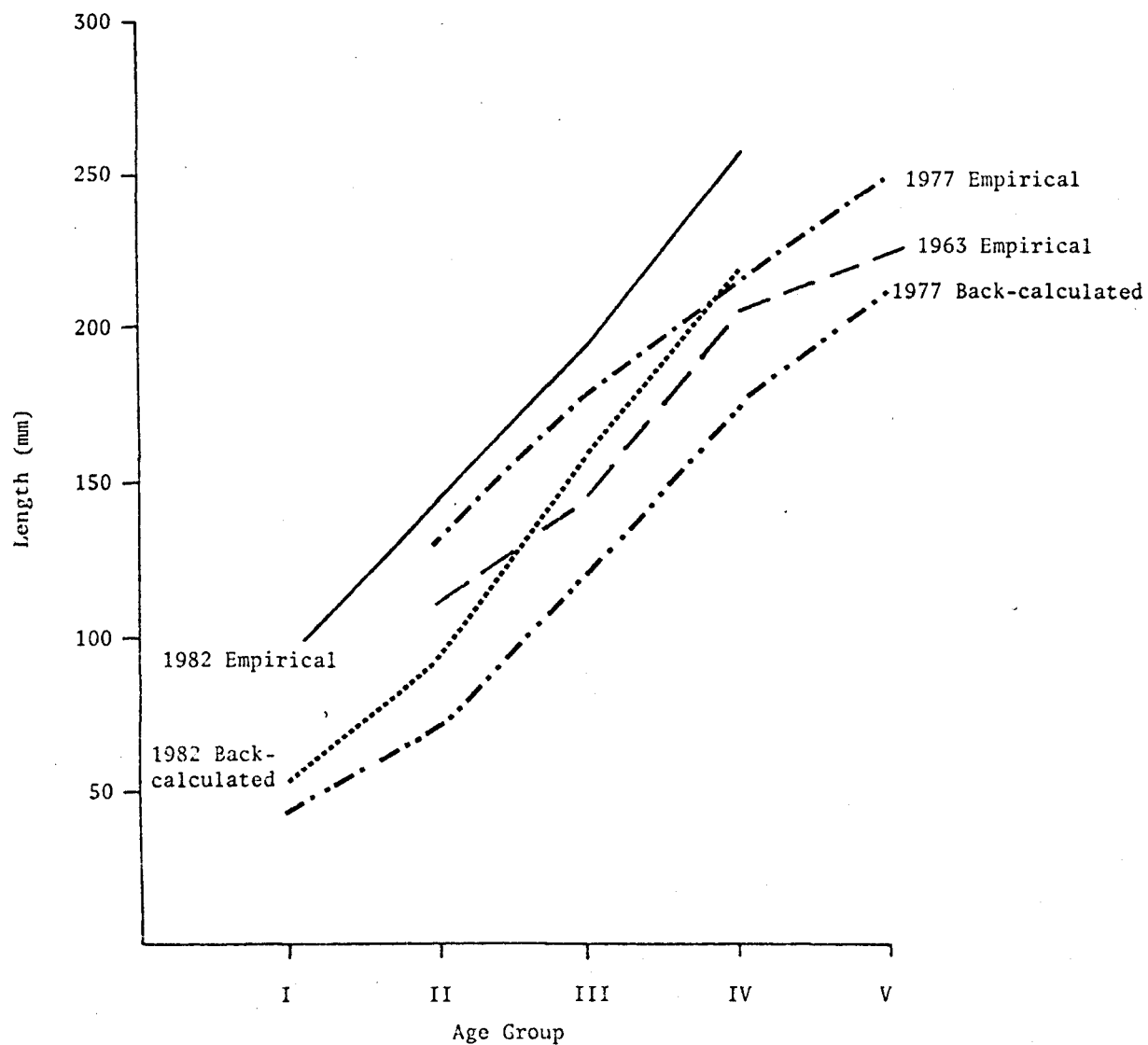


Figure 54. Comparison of empirical age class lengths and back-calculated lengths at annulus formation for aged cutthroat trout from Sedge Creek, 1963-1982.

year. This would also indicate that these scales did not form an annulus after the first growing season (retarded scales) (Laakso and Cope 1956). Circuli counts to the first annulus were below seven for all scales examined in 1982, however, and therefore did not meet the criteria for retarded scales from Yellowstone Lake (eight or more circuli to the first annulus) (Laakso and Cope 1956). Bulkley (1963) might have recognized the failure of fish in Sedge Creek to form an annulus after their first growing season and compensated for it. Comparisons for changes in age structure and growth rate can be made for 1977 and 1982, however, because similar methods were used.

Age distribution and growth rate of 1982 aged fish corresponded with the shifts in length distribution observed in both 1978 and 1982 measured fish (Figures 52 and 54). Only one percent of these fish were age IV or older (Figure 52), and the average age was 1.9 years. Growth rates were faster in 1982 than 1977 (Figure 54), this is also an apparent reflection of continual fish removal.

The largest shift in the cutthroat population in recent years (1979-1982) has been the decline in fish densities (Figure 55). Fish densities peaked in 1979 at 472 fish/km and have declined to 173 fish/km in 1982. This decline is not due to an increase in the proportion of larger individuals in the population (Figure 55) or to a decrease in fish biomass estimates (Table 45), therefore, it is probably related to a reduced number of reproducing individuals. If consecutive year removal was to continue, fish densities and numbers would be expected to continue to decline. As a consequence of this, the number of reproducing individuals could be reduced to a low enough number that the population could be altered genetically through random drift. Although this event may seem unlikely, it is evident in small isolated populations with low numbers of reproducing individuals (Stansfield 1977).

At present, the Sedge Creek operation appears to be a success. All management objectives have been met: (1) establishment of a trout population in South Fork, (2) establishment of a second secure population of Sedge Creek cutthroat trout and (3) preservation of the genetic integrity of the upper Yellowstone River drainage. The major effect on the Sedge Creek population has been a shift in population structure to an increase in the percent of smaller fish. At present, this shift does not appear to be detrimental to the overall population. If transplanting operations continued, however, a detrimental effect could occur. Fish transplanting operations are not scheduled for the 1983 field season. It is recommended, therefore, that the recovery of the Sedge Creek population be evaluated in 1984 by monitoring shifts in the age and length class distribution.

BLACKTAIL PONDS CUTTHROAT RESTORATION

Adjacent to the road about 10.6 km east of Mammoth, the Blacktail Ponds have been a popular fishery since the late

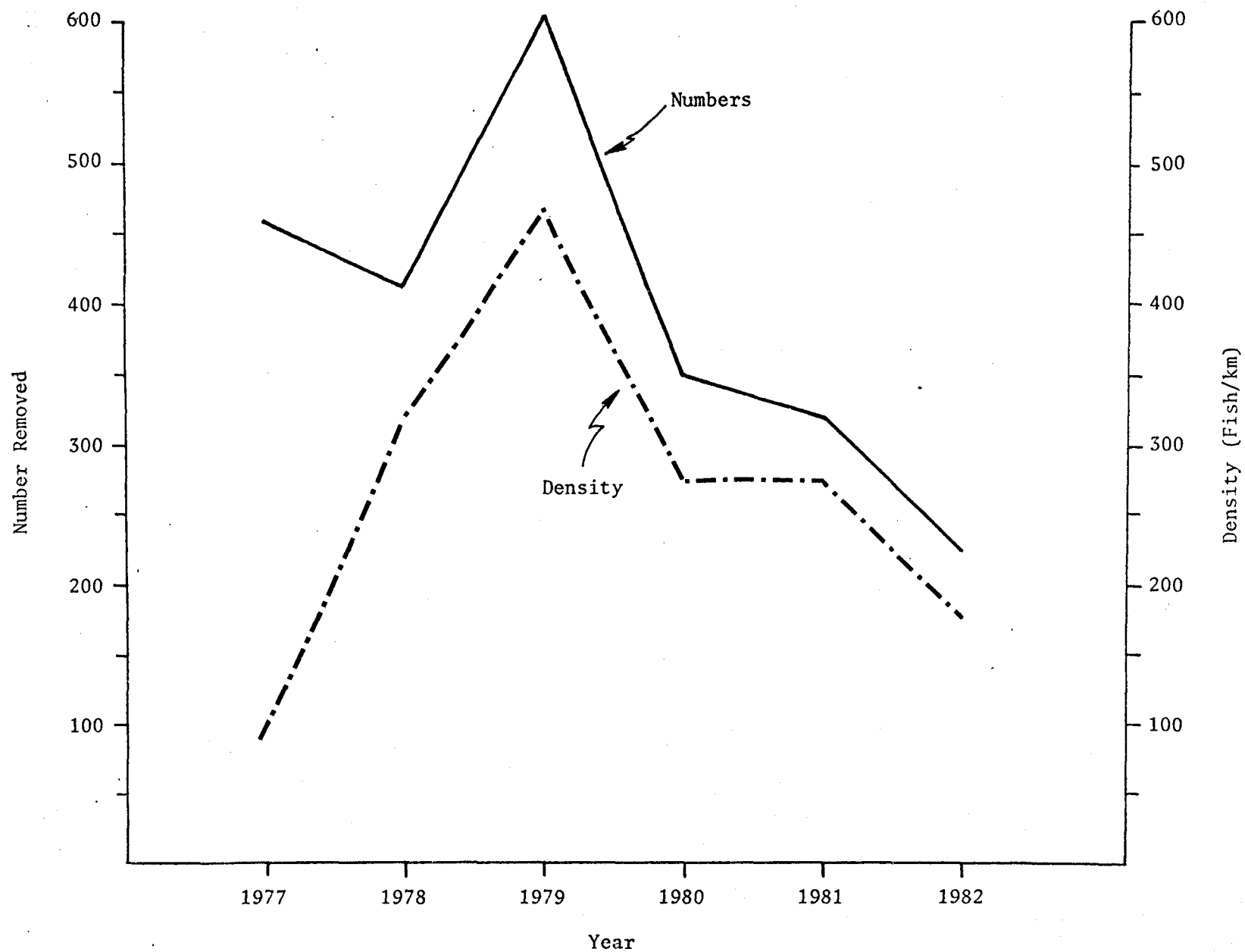


Figure 55. Trend in numbers of fish removed from Sedge Creek during transplanting activities (1977-1982).

1800's. These small ponds (3.56 ha) originally held an indigenous cutthroat trout population (Jordan 1891), however, brook trout stockings and heavy angling pressure have extirpated the cutthroat from the drainage. In an attempt to restore this native population, cutthroat trout from Bear Creek (inlet to Turbid Lake, Yellowstone Lake drainage) have been stocked into these ponds. The Bear Creek strain of Yellowstone cutthroat trout were selected for two reasons: (1) their known survivability within a harsh environment, and (2) Blacktail Ponds would provide a secure enclave for this unique strain (see Sedge Creek section this report).

Bear Creek cutthroat trout have been transplanted twice into these ponds. In 1980, a total of 200 trout were electrofished and transported. These fish averaged approximately 152 mm in length (Varley 1980). In 1982, a total of 276 fish were electrofished in Bear Creek. Of these; 253 were transplanted into Blacktail Ponds and 23 died in transit. The mean length and weight for 61 of the captured fish was 139 mm and 33 g, respectively.

No evaluation has been made on the success of this operation. A catch and release restriction, however, has been implemented to protect cutthroat trout in these ponds. It is recommended that an evaluation of these two transplants be made to determine the future of this operation.

NONCONSUMPTIVE USE OF THE AQUATIC RESOURCE

In Yellowstone Park, there are presently two sections of Yellowstone River which are closed to angling to provide protection to the spawning trout. These areas have provided an excellent opportunity to study the level of visitation in an area available only to nonconsumptive uses, such as photography or observation.

Spanning Yellowstone River at the outlet of Yellowstone Lake, Fishing Bridge has been closed to fishing from the lake to a point 1.6 km downstream since 1973. Although once very popular with anglers, Fishing Bridge was not considered a high quality fishery. Average landing rate for 1963 (Sharpe 1964) was 0.20 trout per hour, varying from a high of 0.48 during the first sample day to a low of 0.00 trout per hour during the last sample day. In 1966, Arnold (1967) reported the catch per unit effort low compared to other park waters.

In 1972, Dean and Varley (1973) conducted a study to determine the number of years of prior fishing experience for Park anglers. Of the 346 anglers interviewed at Fishing Bridge, the average experience was only 0.27 years, the lowest figure obtained in the park. Only 12% had fished from the bridge in previous years. Dean and Varley (1973) concluded that few anglers returned to the bridge after an initial experience because of crowding and low success rates.

LeHardy's Rapids, located approximately 5.7 km downstream from the lake on Yellowstone River, has been closed to fishing for 90 m upstream and downstream from the rapids since 1949. 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 effects of angling closures has been monitored at both Fishing Bridge and LeHardy's Rapids. For the fifth consecutive year, estimates of visitor use, including total time spent and number of visitors, have been made at these sites. Mean length of stay was determined in 1978, 1980, 1981 and 1982.

Methods

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 for counts was limited. Instantaneous counts of visitors were made whenever possible at both Fishing Bridge and LeHardy's Rapids, usually while en route to a work site. The location of project activities, precluded an equal sampling effort at each site, however, and sample size at LeHardy's Rapids was small.

The critical aspects of this type of estimate are the average time spent per person and the accurate determination of the daily use pattern. Accuracy also increases as the number of time intervals increase; however, if interval sizes become too small, the increase in time periods without counts causes an decrease in the resulting estimate. Using these criteria, a 15 minute time interval appeared to be optimum, and all data from prior years was recalculated to improve comparability.

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:

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

I = interval
 t_i = mean number counted at interval i

To obtain a 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 number of visitor hours was used. The total number of visitors for each day was obtained by dividing visitor hours by the mean length of stay. Season totals were calculated by summing daily totals and then expanding by the proportion of days actually counted.

Results

In 1982, mean length of stay at Fishing Bridge for 1,310 people was 9.7 minutes per person. Total number of visitors using Fishing Bridge for viewing in 1982 decreased from 1981 (approximately 4%) to 167,333 visitors. These changes led to a subsequent drop in total visitor hours (approximately 24%) from 1981 to 26,941 hours (Table 48).

At LeHardy's Rapids, length of stay for 214 people was calculated to be 8.1 minutes. Total number of visitors was estimated at 26,768 people and total time spent at the rapids was 3,600 hours. Both values increased (122% and 11%, respectively) from 1981.

Discussion

Creel census data for the last eight years (1965-1972) of angling on Fishing Bridge yields an average of 33,275 total anglers and 36,714 total angler hours per year (Table 49). While the 1982 figures represent slightly lower total hours on Fishing Bridge, the number of people enjoying this area has increased over 300%. At the same time, Park visitation has only risen approximately 16%.

At LeHardy's Rapids, use shows a great deal of variation over the five year period. Because LeHardy's Rapids is not as visible from the road and is less accessible, (visitors must

Table 46. Nonconsumptive use of the aquatic resource, 1978-1982

	Year	Number Counts	Total Number of Visitors	Mean Minutes per Person	Total Visitor Hours
Fishing Bridge	1978	582	132,966	10.8	23,934
	1979	670	170,383	--	30,669
	1980	551	130,305	10.7	23,238
	1981	1,015	173,679	12.3	35,604
	1982	425	167,333	9.7	26,941
LeHardy's Rapids	1978	222	17,287	8.4	2,420
	1979	206	17,627	--	2,798
	1980	94	45,610	5.3	4,029
	1981	155	12,056	16.2	3,255
	1982	154	26,768	8.1	3,600

Table 47. Fishing Bridge creel census data, 1965-1972

Year	Total Anglers	Total Hours
1965	41,387	41,387
1966	30,135	30,135
1968	40,153	40,262
1970	25,699	31,644
1972	22,824	38,079

descend a short but steep bank), use here would be expected to be lower and more variable. While not necessarily a major factor, low sample sizes would tend to accentuate the fluctuations.

Next to Park visitation, weather conditions may be the most influential factor affecting use of these viewing sites. Although there is great variation in the weather, increased cloudiness and duration of precipitation, generally lead to decreased use, with more people staying longer during good weather.

Comparing nonconsumptive use to Park fisheries, more people made use of Fishing Bridge than any single fishery in the Park (Table 5). LeHardy's Rapids ranks only behind Yellowstone Lake and Yellowstone River in total use. Looking at the total number of man hours spent, Fishing Bridge ranks fourth and LeHardy's Rapids sixteenth Parkwide. These figures emphasize the importance of these areas used as viewing sites.

Conclusions

The prohibition of angling from Fishing Bridge has not only provided the much needed protection for spawning trout but also developed an unique viewing platform for the Park visitor. As pressures and demands on our natural surroundings have increased steadily, nonconsumptive use has become a very important utilization of our aquatic resources. The challenge we face today is how to find ways of enjoying our natural aquatic areas without destroying them. Even a very minimal impact made by each individual, when multiplied by the millions of visitors passing through the park in one summer, can severely impact the aquatic system. Although catch and release fishing does not allow the creeling of any fish, hooking mortalities and the mere presence of the anglers do have negative effects. Nonconsumptive use provides each visitor with the opportunity to enjoy and appreciate nature with negligible side effects.

The educational value of nonconsumptive use is also quite important. People who ordinarily might not have any contact with fish or their environment are provided an excellent chance to view fishes going through their natural life cycle. Visitors can also learn the importance of fish in the food chain as they observe the abundant piscivorous birds and mammals feeding. Other wildlife including moose, muskrat and beaver, are often attracted to these areas as well.

The number of people actually making use of this area has increased dramatically since its closure to fishing. 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 the visitor with another unique viewing site. As the native cutthroat trout are passing upstream on their annual spawning migration, visitors are able to observe these trout in full coloration as they ascend the rapids. The visitor may also hear, feel and see the pulse of the river descending the rapids and observe water fowl which frequent the area.

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. These areas provide the National Park Service with an excellent opportunity for educating the public in various aspects of fish in their natural habitat and should be utilized to the fullest degree possible. With continuing high numbers of Park visitors, nonconsumptive use affords an exceptional experience which can be enjoyed repeatedly by many without depleting the resource.

OTHER PROJECT ACTIVITIES

Assistance to Independent Researchers

This project continues to function as administrative liason and provides logistical support to independent researchers working on aquatic related studies in Yellowstone Park. In 1981, we assisted Dr. William H. Romme of Fort Lewis College, Colorado and Dr. D. H. Knight of the University of Wyoming with a study on Yellowstone Lake. The study "An Analysis of Patterns in Productivity", will attempt to determine if recent changes in the nutrient content of the lake are related in part to the effects of large forest fires in the watershed. The project also responded to numerous requests for data, reprints of papers and information concerning the aquatic systems of the park.

Yellowstone, Lewis, Shoshone and Heart Lake Limnology

Limnological monitoring of the four large oligotrophic lakes in Yellowstone Park continued in 1982. Data has been collected for seven years on Yellowstone Lake, six years on Lewis Lake and four years on Heart and Shoshone Lakes (Tables 48 - 50). It has been the persistent efforts of Park Rangers stationed at the latter two lakes which has enabled a consistant sampling program on these backcountry waters. The overall objective of this program has been to provide continuous baseline limnological data for these four major lakes. Such data provide information necessary for the evaluation of the effects of the natural fire program and baseline data for future limnological investigations. Analysis of these data has been and continues to be hampered by funding and man power constraints.

Yellowstone Aquatic Library

The Yellowstone Aquatic Library currently consists of over 700 titles concerning the aquatic resources in Yellowstone Park. Each paper is cross-referenced by author, species, water and subject. The library was begun in 1973 and almost all historical works are now included. The success of this project was largely due to the efforts of the Y.A.C.C. program during its tenure in the park. Substantial effort has been expended this year by project personnel to include recent works.

Formal Presentations

Project personnel are frequently called upon to make formal presentations to various groups concerning the fisheries program in Yellowstone Park. In 1982, papers were presented at the Federation of Flyfishermen Conclave, the Montana Chapter of American Fishery Society, the Snake River Fly Fishers, the Pocatello Chapter of the Federation of Flyfishermen (FFF), the Gardiner Chapter of the FFF, and the Hamilton Stores employees at Lake. Student-faculty seminars were conducted at Idaho State University and Montana State University.

Project personnel also participated in the Yellowstone Park Rangers conference, spring Naturalists training, the Naturalist Seminar series and made a presentation at the U.S.F.W.S project leaders meeting in Denver, Colorado.

VIP Program

The project has been utilizing the park VIP (Volunteers in Parks) program for many years. In 1982, the project signed up twelve VIP's who contributed 357 man-days of labor to the project. They were involved in creel census, fishermen interviews, fish trap operations, gillnettings, electrofishings, backcountry stream and lake surveys and a variety of clerical and maintenance jobs. Two of our VIPs worked full time 40 hours a week throughout the field season, with the others working a variety of different tours. The dedication and effort of these volunteers enabled the project to complete a normal field season which would not have been possible without them. We extend our sincere thanks to a dedicated crew for their tireless effort.

Table 48 Heart Lake water chemistry, 1978-1982

	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 umhos	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
Total alk.	36	20	50	40	48	0	35	48		42	48	48	44	48		46		36		53
Ca hardness	18	15	35	6	18	17	10	11		13	18	18	14	17		12		16		18
Total hardness	21	20	40	8	24	23	14	35		17	33	24	20	18		14		20		41
Total diss. solids	122	110	100	150	165	45	145	160		148	132	137	130	151		132		140		150
Carbonate alk.	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	48	48	44	48		46		36		53
Carbonates	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	59	59	54	59		56		44		65
hydroxides	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	<1.0	36	7.8		34	16	20	11	3.3		15		29		11
Chloride	32	28	28	30	28	26	25	28		27	24	41	28	24		21		40		26
Sulfate	14	15	15	14	19	5.5	17	22		14	11	4	14			21		17		14
Fluoride	2.9	2.8	2.8	2.8	2.9	2.7	3.1	2.7		3.0	2.8	2.9	3.0	3.0		2.7		2.7		2.9
Phosphate	0.09	0.22	<0.06	<0.06	0.19	0.78	0.62	0.62		0.16	0.19	0.25	<0.06	0.19		-		0.06		0.03
Potassium	2.9	2.8	2.6	0.6	3.7	3.8	3.5	3.6		3.7	3.4	3.6	3.3	3.8		3.3		3.4		3.8
Mg hardness	3	5	5	2	6	5	4	24		4	15	6	6	1		2		4		23
Calcium	7.2	6	14	2.4	7.2	7	4.1	4.4		5.3	7.2	7.2	5.6	6.8		4.8		6.4		7.2
Magnesium	0.7	1.2	1.2	0.5	1.5	1.2	1	5.8		1	3.6	1.5	1.5	0.2		0.5		3.8		5.6
Sodium	33	31	30	35	38	43	40	41		38	31	38	28	42		38		38		37
Iron	<0.01	0.03	<0.01	0.02	0.01	0.04	0.03	<0.01		<0.01	<0.01	0.99	0.04	<0.01		0.02		<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
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
Silica	35	30	39	38	32	35	36	27		29	13	27	24	25		21		15		11
Color (PCU)	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	0.90	1	0.44	0.33		0.30		0.51		0.31
TOC	6.1	3	5.2	4.3	1.4	4.2	4.6	3.7		10	12.7	11	12	3.5		4.8		3.4		3.7
Ortho-phosphate	<0.09	0.11	<0.06	<0.06	0.12	0.16	0.31	0.31		0.12	0.12	0.18	<0.06	0.16		0.09		<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	*0.02	*0.22		0.10		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	0.02		0.01		<0.01		0.01

Table 48 Continued

	1981													1982	
	6/18 ¹⁾	7/4 ¹⁾	7/4 ²⁾	7/16 ¹⁾	7/16 ²⁾	8/2 ¹⁾	8/22 ¹⁾	8/16 ¹⁾	8/16 ²⁾	8/30 ¹⁾	8/30 ²⁾	9/18 ¹⁾	9/18 ²⁾	7/26 ¹⁾	9/24 ¹⁾
Water temp. °C		15.0	15.0	17.8	17.2	16.7	16.1	15.6	16.7	17.2	16.7	14.4	15.6	16.7	12.2
Spec. Cond. u/mhos		190	190	200	190	210	200	210	200	210	210	210	200	180	175
pH	7.2	7.0	7.6	7.6	7.6	7.6	7.4	7.6	7.6	7.6	7.6	7.6	7.6	7.4	7.4
Secchi (meters)		6.2	5.9	8.1	8.7	8.1	8.4	7.9	8.1	7.3	7.5	9.1	8.5	5.9	7.5
Pheno. alk.	0	0		0		0		0		0		0		0	0
Total alk.	44	54		44		40		40		54		42		43	43
Ca hardness	20	18		16		24		24		18		18		18	18
Total hardness	28	24		24		40		24		18		18		24	18
Total diss. solids	140	146		140		142		150		150		151		120	130
Carbonate alk.	0	0		0		0		0		0		0		0	0
Bicarbonate alk.	44	54		44		40		48		54		42		43	43
Carbonates	0	0		0		0		0		0		0		0	0
Bicarbonates	44	54		44		40		48		54		42		52	44
Hydroxides	0	0		0		0		0		0		0		0	0
Carbon dioxide	6	22		7.2		4.1		5		1.4		0.7		3	7
Chloride	18	19		26		33		34		23		29		20	23
Sulfate	16	21		13		18		24		19.4		15		12	18
Fluoride	3.7	3.8		3.8		3.3		3.4		4.26		5		2.33	2.85
Phosphate	0.25	0.28		0.28		-		0.74		0.28		1.1		0.19	0.19
Potassium	3.2	3.3		3.1		1.6		6.3		0.33		4.4		3.48	3.84
Mg hardness	8	6		8		16		<1.0		<1.0		0		6	<1.0
Calcium	8	7.2		6.4		9.6		9.6		7.2		7.2		7.2	7.2
Magnesium	1.9	1.5		1.9		3.9		<0.2		<0.1		<1.0		1.4	<1.0
Sodium	35	35		36		35		39		64		29		30	32
Iron	0.08	1.6		0.02		0.02		<0.01		<0.01		<0.01		<0.05	<0.05
Manganese	<0.05	<0.05		<0.05		<0.05		<0.1		<0.05		<0.05		<0.05	<0.05
Copper	<0.2	<0.3		<0.2		<0.2		<0.3		<0.3		<0.03		<0.01	<0.01
Silica	2.9	13		18		15		19.5		2.5		9.5		6.9	0.6
Color (PCU)	0	0		0		0		0		0		0		0	10
Turbidity (NTU)	1.7	1.6		0.95		0.4		0.4		0.28		0.27		0.50	0.20
TUC	13.8	4.7		4.7		3.6		21		5.4		3.4		2.6	2.5
Ortho-phosphate	0.25	0.28		0.28		-		0.56		0.28		0.93		0.19	0.22
Kjeldahl N	*0.24	*0.34		*0.08		*0.11		*0.42		*0.64		*0.55		*0.72	*0.20
Nitrate N	<0.02	0.03		<0.02		<0.02		<0.02		<0.02		<0.02		<0.02	<0.02

Table 49 Lewis Lake water chemistry, 1977-1982

Table 4.9 Lewis Lake water chemistry, 1977-1982																							
	1977		1978		1979		1980		1981		1982		1983		1984		1985		1986				
	7/16	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	6/26	7/23	8/29	10/2	6/27	8/6	8/31	5/23
water temp. °C	-	16	9.3	18.5	17	14	9.5	10.5	18	15	12	13.5	17	12	10.2	11	16.5	17	-	11.1	17.7	15.6	10.6
Spec. Cond. umho	-	95	88.5	97	91	88	81	84	90	86	85	84	84	80	84	120	98	115	138	73.5	88.75	-	112
pH	-	7.4	7.2	7.4	7.4	7.4	7.2	7.2	7.4	7.4	7.4	7.2	7.6	7.4	7.2	7.2	7.4	7.4	7.2	7.0	7.4	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	8.5	7.9	8.5	11.0	6.1	10.7	9.7	-	-	-	-	-
Phosph. alk.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total alk.	36	30	33	28	15	18	32	42	0	26	36	30	26	21	32	32	32	28	20	24	12	29	24
Ca hardness	10	12	21	8	5	6	18	10	10	8	11	8	10	11	16	10	12	12	12	12	12	8	12
Total hardness	12	15	24	12	10	8	30	17	13	12	17	10	12	12	22	12	16	16	16	16	16	12	24
Total diss. solids	110	100	85	85	70	70	110	90	95	84	85	70	77	94	74	90	42	65	70	48	60	60	82
Carbonate alk.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Bicarbonate alk.	36	30	33	26	15	18	32	42	0	26	36	30	26	21	32	32	32	28	20	24	12	29	24
Carbonates	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Di-carbonates	44	37	40	34	18	22	39	51	0	32	44	37	32	25	39	39	39	34	24	29	14	35	30
Hydroxides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Carbon dioxide	7.8	0.8	9.2	1.4	1.0	3.7	21	34	<1.0	27	19	7.8	8.5	17	16	<1.0	10.3	1.1	3	1.8	1.5	4.7	5
Chloride	1	20	6.6	9	9.1	9	6.4	6	3.3	8	5.9	5.1	8.1	10	5.8	6.1	5.2	7.3	7	5.8	19	7.9	6
Sulfate	5	2	3	7	3	2.5	16	5	6.9	7	6.9	1	6.1	<1.0	3.2	2	4	1.9	8	6.5	3	2	5.5
Fluoride	1.5	2.9	2.4	2.5	2.6	2.7	2.77	2.6	2.7	2.7	2.8	2.4	2.6	2.7	2.5	3.4	3.4	3.82	3.45	2.15	2.97	2	2.5
Phosphate	0.40	0.01	3.41	0.22	0.09	<0.06	0.19	0.43	0.12	<0.06	0.16	0.49	0.12	0.09	0.09	0.43	<0.03	0.31	0.19	0.12	0.14	0.29	0.09
Potassium	3.3	3.1	4	3	2.8	3.8	1.6	3.5	3.1	3.3	3.9	3.4	3.0	0.8	3.5	0.32	3.1	0.32	4	2.8	3.04	2.6	3
Mg hardness	2	3	3	6	5	2	12	7	3	4	6	2	2	0.2	6	2	1	1	4	4	4	4	12
Calcium	4	4.8	8.4	3.2	2	2.4	7.2	4.1	4	3.2	4.4	3.2	4	4.4	6.4	4	4.8	4.8	4.8	4.8	4.3	3.2	4.8
Magnesium	0.5	0.7	0.7	1	1.2	0.5	2.9	1.7	0.7	1	2.6	1.9	0.5	0.2	1.5	0.5	1	1	1	0.9	0.97	0.9	2.9
Sodium	16	19	16	15	15	14	9.6	17	14	17	17	16	16	16	16	15	14.4	16.5	11.6	11	13	14	14
Iron	0.03	0.03	<0.02	0.04	0.02	<0.01	<0.01	<0.05	0.03	0.01	0.03	0.01	<0.01	<0.01	0.02	0.04	<0.01	0.04	<0.01	<0.05	<0.05	<0.05	<0.05
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	<0.05	<0.05	0.27	<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	<0.2	<0.1	<0.1	<0.2	<0.3	<0.03	<0.01	<0.01	<0.01	<0.01
Silica	46	33	24	39	16	40	52	43	38	17	30	26	36	77	19	19	8.7	2.8	10	11	16	11.7	2.7
Color (PCU)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0
Turbidity (NTU)	0.5	0.3	0.27	0.37	0.34	0.3	1.4	0.56	0.43	0.37	0.35	0.3	0.33	0.3	0.4	0.6	0.5	0.37	0.29	0.45	0.55	0.4	0.56
TDS	2.6	2.4	3.5	2.8	1.4	1.26	1.7	16	13	5.1	8.5	17	11	9.8	3.9	2.7	3.4	1.8	2.3	1.7	2	<0.2	4.2
Ortho-phosphate	0.01	0.01	3.1	0.66	<0.06	<0.06	0.19	0.25	0.07	<0.06	0.12	0.12	0.28	0.12	0.09	0.37	<0.03	0.16	0.16	0.08	0.19	0.29	<0.36
Ammonia-N	0.44	0.07	0.14	0.3	0.26	0.13	0.04	0.04	0.16	0.08	0.25	0.07	0.33	0.03	-	0.4	0.11	0.38	0.16	0.24	0.24	0.16	0.16
Nitrate-N	0.03	0.02	0.03	0.08	0.01	<0.01	<0.01	0.02	0.01	<0.01	0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.02	<0.02	0.01	<0.02	<0.02	<0.02	<0.02

Table 50 Shoshone Lake water chemistry, 1978-1982

	1978					1979				
	7/20	8/3	8/18	9/3	9/17	7/9	7/15	7/28	8/25	9/6
Water temp. °C	11.7	14.4	11.1	13.3	11.1	13.3	12.2	15.5	15.5	15.5
Spec. Cond. umhos	90	77	78	80	77	80	75	79	70	78
pH	7.3	7.4	7.8	7.4	7.4	6.0	6.0	6.0	7.0	7.0
Secchi (meters)	9.1	9.7	9.7	13.1	12.2	10.0	22.8	12.1	14.9	15.2
Pheno. alk.	0	0	0	0	0			0		0
Total alk.	21	15	20	16	30			30		24
Ca hardness	12	5	5	6	12			10		21
Total hardness	21	10	15	8	18			17		24
Total diss. solids	75	65	70	70	85			70		46
Carbonate alk.	0	0	0	0	0			0		0
Bicarbonate alk.	21	15	20	16	30			30		24
Carbonates	0	0	0	0	0			0		0
Bicarbonates	26	18	24	20	37			37		29
Hydroxides	0	0	0	0	0			0		0
Carbon dioxide	22	1.5	63	1.7	7.8			31		10
Chloride	8.2	8.5	7.3	8.5	7.8			9.1		8
Sulfate	5	2	2	2	4			5		2
Fluoride	2.4	2.4	2.4	2.3	2.3			2.2		2.4
Phosphate	0.12	<0.06	0.37	<0.06	0.18			0.28		0.31
Potassium	1.9	3.3	3.3	3.3	2.8			2.4		2.8
Mg hardness	11	5	10	2	6			7		3
Calcium	4.8	2	2	2.4	4.8			4		8.4
Magnesium	2.7	1.2	2.4	0.5	1.5			1.7		0.7
Sodium	12	13	11.5	11.8	14			14		10
Iron	<0.01	<0.01	<0.01	0.02	<0.01			0.01		0.07
Manganese	<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
Silica	32	33	22	40	37			26		41
Color (PCU)	0	0	0	0	0			0		0
Turbidity (NTU)	0.35	0.2	0.31	0.25	0.35			1		0.4
TOC	1.6	0.6	1.9	0.9	0.5			8.8		1.2
Ortho-phosphate	0.09	<0.06	0.18	<0.06	0.12			0.25		0.31
Kjeldahl N	0.09	0.11	0.3	0.05	0.09			*0.19		*0.14
Nitrate N	<0.01	0.01	<0.01	0.02	0.01			0.02		0.02
Arsenic										0.01

Table 50. continued.

	1980						1981						1982		
	7/10	7/22	7/27	8/6	8/10	8/24	6/24 ¹⁾	7/8 ¹⁾	7/10 ²⁾	8/3 ¹⁾	8/20 ²⁾	8/29 ¹⁾	7/10	8/5	8/23
Water temp °C	14.4	15.0	15.5	15.5	15.2	13.3	8.9	13.3	13.3	16.6	16.7	16.7	10.0	17.8	18.3
Spec. Cond. umhos	74	73	77	76	78	77	75			70	68	69	50	96	
pH	7.4	7.4	7.4	7.3	7.3	7.3	7.2	7.4	7.4	7.4	7.2	7.2		7.4	7.3
Secchi (meters)	10.2	11.8	13.1	12.5	12.1	12.8	9.7	10.7	10.4	11.6	11.0	11.0	8.8	11.9	11.9
Phenol. alk.	0				0				0			0	0	0	0
Total alk.	27				24				33			32	29	16	29
Ca hardness	15				6				11			12	16	8	8
Total hardness	16				9				18			20	16	16	12
Total diss. solids	68				72				67			83	60	60	60
Carbonate alk.	0				0				0			0	0	0	0
Noncarbonate alk.	27				24				33			32	29	16	29
Carbonates	0				0				0			0	0	0	0
Noncarbonates	33				29				40			39	35	19	35
Hydroxides	0				0				0			0	0	0	0
Carbon dioxide	11				7.7				21			1.6	7	1	2
Chlorine	12				12				6.1			8	5.8	20	7.9
Sulfate	3.1				2.6				<1			2.4	7.5	2	3
Fluoride	2.2				2.4				2.9			3.1	3.7	3.35	2.2
Phosphate	0.09				0.09				0.5			0.65	0.09	0.16	0.12
Potassium	2.4				3.1				2.8			2.8	3.16	2.96	2.4
Mg hardness	3				3				7			2	<1.0	8	4
Calcium	6				2.4				4.4			4.8	6.4	3.2	3.2
Magnesium	0.7				0.7				1.7			2	<1.0	1.9	0.9
Sodium	12				13				13			14	12	13	9
Iron	<0.01				<0.01				0.03			0.02	<0.05	<0.05	<0.05
Manganese	<0.05				<0.05				<0.05			<0.05	<0.05	<0.05	<0.05
Copper	<0.1				<0.1				<0.3			<0.2	<0.01	<0.01	<0.01
Silica	22				35				19			5.5	15	9.5	8.5
Color (PCU)	0				0				0			0	0	0	0
Turbidity (NTU)	0.15				0.21				0.28			0.23	0.24	0.28	0.33
TSS	5.8				5.5				0.8			4.6	1.7	2.95	<0.2
Ortho-phosphate	0.06				0.06				0.4			0.25	0.06	0.16	0.09
Kjeldahl N	0.061				0.06				*0.37			*0.22	*0.42	*0.21	*0.24
Nitrate N	0.01				<0.01				0.02			<0.02	<0.02	<0.02	<0.02
Arsenic															

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