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Cover photo: Egg taking activities at Pelican Creek spawning trap, June 1949.

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INTRODUCTION

Yellowstone National Park is located in the northwest corner of Wyoming and small adjacent areas of the states of Montana and Idaho. It occupies an area of almost 915,000 hectares (3,500 mi²) astride the continental divide and is bordered by mountains on the north and east sides which rise to 3,400 m (11,000 ft). The park is characterized by several broad, forested volcanic plateaus containing the world's largest caldera and thousands of thermal features.

Slightly over 5% of the landmass of Yellowstone National Park is covered with water. Specifically, over 150 lakes comprise an area of approximately 43,000 hectares (107,000 acres). Yellowstone Lake, Shoshone Lake, Lewis Lake, and Heart Lake make up 94% of the total lake area. Elevations of park lakes range from 1,700 to 3,000 m (5,500 to 9,700 ft) above sea level. Additionally, over 220 named and hundreds of unnamed streams make up over 4,300 km (2,650 mi) or approximately 2,000 hectares (5,000 acres) of running water.

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 spoliation 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 for the perpetuation of natural processes within the Yellowstone ecosystem, including interactions between and among native fauna, flora, geology, and scenic landscapes (Houston 1971).

Yellowstone National Park represents one of the few remaining pristine aquatic ecosystems in the contiguous United States. These natural systems contain, sustain, and protect many diverse varieties of aquatic organisms.

Angling has always been a major visitor activity in Yellowstone National Park. Although initial regulations were extremely liberal and associated with frontier subsistence, present restrictions have developed over the past 50 years to more closely reflect the park's management mandate. Basic objectives of the aquatic management program are to:

- (1) Manage aquatic systems as an integral part of the park ecosystem.
- (2) Preserve and restore native species and aquatic habitats.
- (3) Provide recreational fishing opportunities for enjoyment of park visitors consistent with the first two objectives.

Attainment of these objectives requires that angler impacts do not alter natural replenishment rates, size and age structure, or significantly reduce numbers from those occurring in unfished populations. This management policy provides the angler with the opportunity to fish for wild trout in a natural setting. It also requires that anglers distinguish between catching fish as a recreational experience and removing fish for consumption.

Protective policies of the National Park Service that have prevented significant degradation of the aquatic habitat have also restricted the use of stocking to native species restoration projects. Special regulations have become the primary means to accomplish park fishery objectives. Regulations used to protect the fishery have included manipulating season dates, bait and terminal gear restrictions, and the use of size and creel limits (including catch-and-release). The implementation of these regulations has improved the angling experience despite substantial angler use, and population structure more closely resembles historic levels. Additionally, some waters have been closed to angling in order to protect threatened species, nesting birds, or provide scenic vistas with undisturbed wildlife and fish.

The Montana Department of Fish, Wildlife, and Parks recently completed a study on the economic value of hunting and fishing in Montana. The study indicated the average expenditure of a typical resident/nonresident fishing trip to be \$97 per trip. The study also indicated a typical resident/nonresident sportsman would be willing to pay an additional \$113 for the same trip over and above his actual expenditures. The total resource value of a fishing trip is the sum of these two figures, or \$210 per trip.

Multiplying \$210 times the 370,900 fishing trips that took place in Yellowstone National Park in 1987 results in a resource value of \$77,889,000 for the park fishing program in 1987. This is exceptional, especially considering that the fishery is totally supported by wild fish.

In order to manage the diverse and complex aquatic resources of Yellowstone National Park, this project conducts annual investigations which provide information necessary to evaluate the fishery management program and monitor its adherence to park objectives. The following report details results of our efforts during 1987.

FISHING REGULATIONS

In 1987, new fishing regulations were implemented by the National Park Service in Yellowstone National Park. The new regulations are based on a management-by-species concept rather than the previous management-by-water system. The new regulations allow for more effective fisheries management; species can now be managed individually even when occurring with other species in a stream or lake. Additionally, the new regulations are easier to read and understand; this fact should enhance public compliance and law enforcement. Under the new system, however, anglers must be able to identify the seven salmonid species that exist in Yellowstone National Park. The new regulations implemented in 1987 are as follows:

(1) Cutthroat trout

Regulation: Parkwide: catch-and-release-only.

- Exceptions:
- (a) Yellowstone Lake and tributaries: two fish under 330 mm (13 in).
 - (b) The Lamar River upstream from Calfee Creek and the Lamar River tributaries upstream from and including Calfee Creek: two fish, any size.
 - (c) Soda Butte Creek drainage (including all lakes and tributaries): two fish over 330 mm (13 in).

(2) Arctic grayling

Regulation: Parkwide: catch-and-release-only.

(3) Mountain whitefish

Regulation: Parkwide: two fish, any size.

(4) Rainbow trout

Regulation: Parkwide: catch-and-release-only.

- Exceptions:
- (a) Soda Butte Creek drainage (including all lakes and tributaries): two fish over 330 mm (13 in).
 - (b) Gardner River and tributaries: two fish, any size.

(5) Brown trout

Regulation: Parkwide: two fish, any size.

- Exceptions:
- (a) Madison River, Firehole River, and Gibbon River below Gibbon Falls: two fish under 254 mm (10 in).
 - (b) Lewis River below Lewis Falls: catch-and-release-only.

(6) Brook trout

Regulation: Parkwide: five fish under 254 mm (10 in).

(7) Lake trout

Regulation: Parkwide: two fish, any size.

PARKWIDE ANGLING

Yellowstone National Park recreational visitation (2.6 million visitors) increased (8.9% more than 1986) in 1987, and issuance of non-fee fishing permits increased 12.6% (Table 1). Approximately 183,900 permits were issued; however, gate survey data indicated that 19.1% of the permit holders did not fish. After adjustments were made for nonanglers, the number of park anglers was estimated at 151,500. This represents a 21.3% increase in the number of anglers since 1986.

The exit gate survey indicated that anglers spent an average of 1.89 d fishing in the park and fished approximately 1.30 waters/d. Estimates of total use (370,900 angler days) and effort (917,800 angler hours) were calculated using the method of Jones et al. (1977). Both figures are the second highest estimates since 1976 (Table 1).

The Volunteer Angler Report (VAR) system estimated that 865,900 fish were landed and 61,510 creeled at a rate of 0.94 and 0.07 fish/h, respectively (Table 2). Of the fish landed, 95% were released and 5% creeled. The number of fish landed per average angler trip (2.47 h) was 2.33, and the number creeled was 0.25 (Table 3).

Species composition was indicated by anglers for 42,079 landed fish; 68.5% were reported to be cutthroat trout, followed by rainbow trout (9.8%), brook trout (9.4%), brown trout (6.8%), and whitefish (2.9%). Small numbers of lake trout, grayling, and unidentified fish were also caught.

Average size of landed fish (311 mm or 13.3 in) decreased from 1986. Of 40,014 fish, about 56% were greater than 305 mm (12 in), and 41% exceeded 356 mm (14 in). Average length of creeled fish was 300 mm (11.8 in). Lake trout were the largest fish landed (427 mm or 16.8 in) followed by cutthroat trout (342 mm or 13.5 in), whitefish (309 mm or 12.2 in), unknown species (274 mm or 10.8 in), brown trout (266 mm or 10.5 in), rainbow trout (249 mm or 9.8 in), grayling (234 mm or 9.2 in), and brook trout (172 mm or 6.8 in).

Prior to 1985, positive bias in mean length was suspected in VAR parkwide estimates because 229 mm (9 in) represented the minimum size which could be reported. In order to improve the sensitivity and accuracy of the VAR system, three new length categories were initiated in 1985; minimum size was reduced to 127 mm (5 in). Since the mean length of all landed fish only declined 7 mm (0.3 in) from 1984 to 1985, it appears that overall effect of the change was not great. Mean length of brook trout, however, declined 23% (55 mm or 2.2 in), suggesting that the added length categories have greatly improved the ability of the system to provide accurate statistics for a variety of species in widely differing habitats.

TABLE 1.--Estimates of park recreational visitation, fishing permits issued, total parkwide anglers, and total parkwide angler days, Yellowstone National Park, 1973-1987.

Year	Total Park Recreational Visitation	Park Fishing Permits Issued	Total Parkwide Anglers	Total Parkwide Angler Days	95% Confidence Limits
1973	2,061,537 -8.2% ^{a)}	169,103 --	121,888 --	230,100 --	225,500- 234,700
1974	1,928,915 -6.4%	164,600 -2.7%	116,518 -4.4%	220,000 -4.4%	215,500- 224,300
1975	2,239,483 +13.9%	191,550 +16.4%	136,322 +17.0%	257,300 +17.0%	248,400- 266,300
1976	2,519,224 +12.5%	213,200 +11.3%	151,730 +9.7%	284,200 +10.5%	278,500- 289,900
1977	2,481,933 -1.5%	217,000 +1.8%	154,581 +1.9%	311,300 +9.5%	304,000- 318,500
1978	2,618,380 +5.5%	218,000 +0.5%	155,700 +0.7%	333,800 +7.2%	326,200- 341,300
1979	1,892,908 -27.7%	195,100 -10.5%	139,100 -10.7%	291,300 -12.7%	274,500- 308,200
1980	2,000,273 +5.7%	184,200 ^{b)} -5.6%	130,800 -6.0%	311,300 +6.9%	287,000 334,600
1981	2,521,831 +26.1%	172,300 -6.5%	160,000 +22.3%	383,400 +23.2%	363,400- 403,300
1982	2,368,897 -5.9%	205,000 +19.0%	152,000 -5.0%	332,500 -13.3%	314,700- 350,300
1983	2,347,242 -0.9%	166,800 -18.6%	120,500 -20.7%	275,900 -17.0%	261,800- 289,900
1984	2,222,027 -5.6%	176,800 +5.7%	135,000 +10.7%	329,200 +16.2%	305,400- 341,000
1985	2,226,159 +0.2%	166,700 -6.1%	123,800 -9.0%	279,000 -18.0%	260,800- 297,200
1986	2,363,756 +6.2%	163,300 -2.0%	124,900 +0.9%	294,800 +5.7%	269,300- 320,400
1987	2,573,194 +8.9%	183,900 +12.6%	151,516 +21.3%	370,933 +25.8%	349,062- 392,804

^a Percent change from previous year.

^b Actual number unknown, figure given is an estimate.

TABLE 2.-Angler use, effort, success, and harvest for Yellowstone National Park, 1973-1987.

Year	x length		Total hours fished	Landing rate	Total fish landed	Creel rate	Total fish creeled	% of anglers satisfied with			Average length of landed fish (in.)	Mean expertise level ^a
	Angler days	angler day						Overall experience	Numbers caught	Sizes caught		
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	333,800	2.23	744,400	0.99	736,900	0.17	126,500	73	66	68	13.4	1.86
1979 ^b	291,300	2.49	725,300	1.01	731,100	0.15	107,300	73	67	68	13.6	1.88
1980	311,300	2.44	758,000	0.96	725,300	0.13	101,000	73	66	68	13.4	1.87
1981	383,400	2.41	923,000	0.93	844,700	0.12	110,800	73	65	66	13.4	1.88
1982	332,500	2.34	777,600	0.95	740,200	0.14	107,500	74	67	68	13.5	1.88
1983	275,900	2.36	652,100	0.95	622,400	0.11	71,600	76	69	68	13.6	1.89
1984	329,200	2.40	790,100	0.93	732,700	0.12	92,100	76	68	69	13.5	1.91
1985	279,000	2.47	688,500	0.92	629,700	0.10	69,800	76	68	71	13.3	1.90
1986	294,800	2.49	734,700	1.01	740,900	0.10	73,400	79	72	72	13.3	1.93
1987	370,933	2.47	917,811	0.94	865,918	0.07	61,572	73	64	66	12.3	1.93

^a Based on: 1.0 = inexperienced angler, 2.0 = experienced, 3.0 = expert.

^b Revised from that reported in Jones et al. (1980).

TABLE 3.-Characteristics of satisfied and unsatisfied anglers, and the influence of the relative expertise of anglers to sportfishing success in Yellowstone National Park, 1987.

	Mean number days fishing	Mean number hours fished per day	Landing rate	Creel rate	Fish landed per angler day	Fish creeled per angler day	Average length fish landed (in)	Average expertise ^a	Number of anglers sampled
Satisfied anglers	--	2.64	1.12	0.08	2.96	0.21	12.59	1.02	3,378
Unsatisfied anglers	--	2.31	0.56	0.04	1.29	0.09	10.53	1.92	1,608 ^b
sum or $\bar{x}$	1.64	2.47	0.94	0.07	2.33	0.17	12.26	1.93	5,825 ^b
Inexperienced anglers	1.51	2.47	0.59	0.08	1.55	0.17	11.96	1.00	1,122
Experienced anglers	1.69	2.09	0.94	0.07	2.37	0.18	12.17	2.00	3,846
Expert anglers	1.59	2.52	1.40	0.05	3.86	0.14	12.79	1.93	744 ^b
sum or $\bar{x}$	1.64	2.47	0.94	0.07	2.33	0.17	12.26	1.93	5,825 ^b

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/h)						
Inexperienced anglers	0.68	0.73	0.63	0.29	0.32	0.49
Experienced anglers	1.10	1.20	1.00	0.44	0.44	0.79
Expert anglers	1.62	1.70	1.55	0.68	0.65	1.01
Creel Rate (fish/h)						
Inexperienced anglers	0.09	0.10	0.09	0.03	0.04	0.05
Experienced anglers	0.08	0.09	0.08	0.03	0.04	0.05
Expert anglers	0.06	0.06	0.05	0.04	0.03	0.06
Fish Size (in)						
Inexperienced anglers	12.00	11.98	12.63	11.49	11.81	9.49
Experienced anglers	12.30	12.22	12.94	10.83	11.83	9.41
Expert anglers	13.00	12.81	13.44	10.88	12.61	10.09

^a Based on 1.0 = inexperienced angler; 2.0 experienced; 3.0 expert.

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

The percentage of anglers that reported satisfaction with their overall fishing experience was 73% in 1987. Satisfaction rates with numbers and sizes of fish landed were 64% and 66%, respectively (Table 3). Anglers indicating satisfaction with their fishing trip landed 3.0 fish, but unsatisfied anglers landed only 1.3 fish. Average length of fish landed was also higher for satisfied anglers (320 mm or 12.6 in) than for unsatisfied anglers (267 mm or 10.5 in).

On the VAR card, anglers are asked to judge their own angling expertise level, and expertise is then estimated for each water by a mean index value as follows: 1.0 is an inexperienced angler, 2.0 is experienced, and 3.0 is an expert. In 1987, mean expertise for 5,825 park anglers was 1.93, indicating that most anglers fall into the inexperienced to experienced category (Table 3).

Comprehensive analyses of VAR data for several fisheries including Yellowstone Lake, the catch-and-release section of the Yellowstone River, Riddle Lake, Sylvan Lake, Firehole River, Gardner River, Madison River, and Soda Butte Creek were completed in 1987. Although it was not possible to expand these analyses to additional waters, data for 26 lakes and streams that made up over 95% of the total park angler use are given in tabular form (Tables 4 and 5).

TABLE 4.--Fishery statistics from Yellowstone National Park waters with over 40 angler days in the sample and which comprise over 95% of the parkwide angler day use in 1987.

	% of total parkwide angler days	Total reported angler days (VAR)	Estimates for the season						Total fish landed	Total fish creeled	X length fish landed (inches)	X length fish creeled (inches)	% anglers landing 1 or more fish	Average expertise	% anglers satisfied with:		
			Anglers	x 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	9,547	151,516	2.47	370,933	917,811	0.94	0.07	865,918	61,572	12.26	11.79	68	1.93	73	64	66
Yellowstone Lake	34.88	3,330	44,922	2.56	129,366	331,033	0.83	0.10	273,888	32,581	14.68	12.34	68	1.80	74	63	73
Yellowstone River	18.60	1,776	23,219	2.74	68,984	180,112	0.85	0.02	160,389	3,636	14.51	11.90	67	2.02	79	69	81
Madison River	7.28	695	11,471	2.25	26,981	60,835	0.65	0.02	39,315	1,335	11.28	11.55	49	1.99	55	42	45
Slough Creek	5.35	511	8,506	2.85	19,832	56,592	1.14	0.01	64,705	730	13.39	17.00	83	2.08	80	72	81
Gibbon River	4.82	460	8,506	1.85	17,850	32,985	0.89	0.09	29,275	2,744	7.35	7.96	64	1.98	66	56	43
Firehole River	4.53	432	8,740	2.24	16,762	37,517	0.77	0.03	28,815	1,063	8.06	9.69	59	2.02	65	59	51
Lamar River	3.42	326	6,061	2.25	12,643	28,485	1.60	0.04	45,459	1,169	10.41	11.21	76	1.95	82	73	63
Gardner River	2.93	280	5,202	2.01	10,856	21,864	1.65	0.19	36,006	4,046	13.55	14.85	43	1.97	82	77	59
Lewis Lake	2.82	269	4,084	3.05	10,428	31,756	0.44	0.13	13,904	4,220	17.57	17.56	78	1.81	59	47	56
Shoshone Lake	2.24	214	2,341	3.01	8,291	24,920	0.64	0.14	15,874	3,476	11.26	9.05	79	1.94	74	65	82
Soda Butte Creek	1.95	186	3,225	2.13	7,203	15,313	1.42	0.06	21,755	846	9.64	13.71	75	1.94	75	63	54
Lewis River	1.51	144	3,043	2.03	5,571	11,309	0.92	0.03	10,411	371	8.80	15.00	57	2.00	55	53	32
Gallatin River	1.27	121	1,977	2.49	4,678	11,655	0.96	0.03	11,168	306	11.10	14.50	86	2.07	79	71	75
Indian Creek	0.94	90	1,873	1.65	3,473	5,734	1.69	0.30	9,690	1,731	6.05	6.97	70	1.86	74	73	470
Grebe Lake	0.61	58	1,275	2.01	2,230	4,486	1.44	0.02	6,458	74	9.06	9.00	75	1.96	88	84	65
Snake River	0.59	56	1,275	2.15	2,152	4,623	0.98	0.06	4,528	267	10.85	11.40	67	1.94	59	52	59

TABLE 5.-Fishery statistics from Yellowstone National Park waters with less than 40 angler days per year represented in the sample, 1987.

	% of total parkwide angler days	Total reported angler days (VFR)	Estimates for the season								x length fish landed (in)	x length fish creeled (in)	% anglers landing 1 or more fish	% anglers satisfied with:			
			Anglers	x length angler day (hours)	Angler days (trips)	Angler hours (effort)	Landing rate	Creel rate	Total fish landed	Total fish creeled				Average expertise	Overall experience	Numbers caught	Fish sizes caught
Trout Lake	0.27	26	572	2.43	986	2.397	0.42	0.02	1.010	49	17.33	17.00	0	1.34	33	0	67
Sylvan Lake	0.26	25	650	1.03	948	1.074	1.67	0.01	1.813	13	10.45	19.00	17	1.82	48	48	52
Obsidian Creek	0.23	22	520	1.43	831	1.185	2.61	0.13	3.095	148	9.06	9.00	75	1.96	88	84	65
Lewis Channel	0.20	19	390	2.03	714	1.447	0.54	0.11	783	164	5.48	7.00	78	1.79	68	79	37
Middle Creek	0.15	14	364	1.21	520	627	2.31	0.05	1.447	30	8.10	13.00	71	1.86	69	69	62
Heart Lake	0.08	8	78	5.60	287	1.608	0.31	0.03	502	46	7.53	0.00	88	1.92	67	67	43

YELLOWSTONE LAKE

Yellowstone Lake supports the largest inland cutthroat trout population in the world, and throughout the past century the lake has remained the most popular fishery in the park. Despite a great surface area (35,400 hectares or 87,450 acres) and once seemingly inexhaustible trout population, extensive spawn-taking operations, commercial fishing, and a 100-year history of almost unabated increases in sport fishery harvest have altered trout stocks from the original state. Managers have attempted to enhance and protect this unique resource, and angling regulations date back to the 1880s. From this date until 1968, periodic reductions in the creel limit failed to have lasting positive effects, and angling success and the condition of the trout stocks declined (Gresswell 1980).

A 356-mm (14 in) minimum-size (3-fish creel) restriction imposed in 1970 helped curb the overfishing which occurred during the 1950s and 1960s. Despite initial benefits, it soon became evident that rising effort and harvests and a rapid decrease of older and larger trout negated positive changes.

Beginning in 1975, regulations allowed the daily harvest of two trout under 330 mm (13 in) total length (TL). Theoretically, this regulation would 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 ideally resemble historic levels. This regulation has remained unchanged since 1975; in 1978 it was extended to Yellowstone Lake tributaries.

In 1987, efforts to monitor the response of the Yellowstone Lake cutthroat trout to the 330-mm maximum-size limit continued. Studies included a creel survey utilizing the Volunteer Angler Report (VAR) system (Jones et al. 1977), operation of the spawning trap at Clear Creek, and an experimental gillnetting program.

Angler Use

During 1987, angler use on Yellowstone Lake comprised 35% of the total parkwide angler use. An estimated 44,922 anglers spent 129,366 angler days and 331,033 angler hours fishing in the lake (Table 6). Use and effort estimates remained below the 13-year average from 1975 through 1987 (139,940 angler days and 338,930 angler hours, respectively). These figures represent 7% and 9% increases, respectively, from 1986 (Figure 1).

Angler use continued to be most heavily concentrated in the accessible areas including the northwest portion of the lake, the West Thumb segment, western shoreline, and eastern

TABLE 6.-Fishing statistics from Yellowstone Lake, 1987.

		Predicted totals for season									† anglers satisfied with:				
Yellowstone	% of	Total		x length	Angler				Total	Total					
Lake area:	lake	VFR use		angler day	days	Angler	Landing	Creel	fish	fish	Overall	Fish	Fish	Mean	
	total	reported	Anglers	(hours)	(trips)	hours	rate	rate	landed	creeled	experience	numbers	sizes	expertise	
1	Shore	3.66	122	1.717	2.05	4.717	9.654	0.55	0.07	5,263	674	70	52	70	1.88
	Boat	0.09	3	78	2.33	93	216	0.73	0.23	158	50	67	67	67	1.33
2	Shore	22.10	736	9.546	1.90	28.574	54.257	0.60	0.07	32,477	3,895	67	54	69	1.81
	Boat	17.30	576	8.142	3.28	22,357	73,346	0.92	0.12	67,600	8,957	78	70	77	1.78
3	Shore	7.27	242	2.627	2.39	9,379	22,399	1.03	0.09	23,019	1,897	80	63	79	1.84
	Boat	1.59	53	910	3.66	2,036	7,451	1.15	0.14	8,560	944	88	79	85	1.77
4	Shore	13.12	437	6.295	1.84	16,956	31,227	0.57	0.07	17,658	2,057	65	49	65	1.80
	Boat	6.46	215	2,211	3.45	8,330	28,749	0.95	0.12	27,217	3,552	77	70	81	1.89
5	Shore	0.30	10	104	1.09	365	397	0.29	0.07	116	28	100	100	0	2.00
	Boat	2.40	80	1,301	4.07	3,085	12,551	1.95	0.15	24,491	1,879	93	89	98	1.92
6	Shore	---	0	---	---	---	---	---	---	---	---	---	---	---	---
	Boat	1.11	37	494	3.04	1,414	4,299	1.33	0.09	5,700	371	78	83	72	1.89
7	Shore	0.18	6	52	2.51	209	524	0.30	0.19	157	101	100	50	50	1.50
	Boat	1.38	46	494	3.67	1,764	6,479	1.99	0.11	12,873	689	94	89	89	1.90
Unknown shore		10.09	336	4,344	1.87	13,032	24,369	0.54	0.09	13,191	2,103	66	59	66	1.83
Unknown boat		10.69	356	5,124	3.51	13,809	48,447	0.86	0.13	41,527	6,179	82	72	76	1.74
All shore		56.73	1,889	24,685	1.95	73,375	143,106	0.65	0.08	92,296	10,791	68	54	69	1.82
All boat		41.02	1,366	18,754	3.43	53,053	182,100	1.04	0.13	188,862	22,744	81	73	79	1.79
Unknown		2.25	75	1,483	1.98	2,890	5,712	0.47	0.05	2,701	305	50	50	100	1.59
Entire lake		100.00	3,330	44,922	2.56	129,366	331,033	0.83	0.10	273,888	32,581	74	63	73	1.80

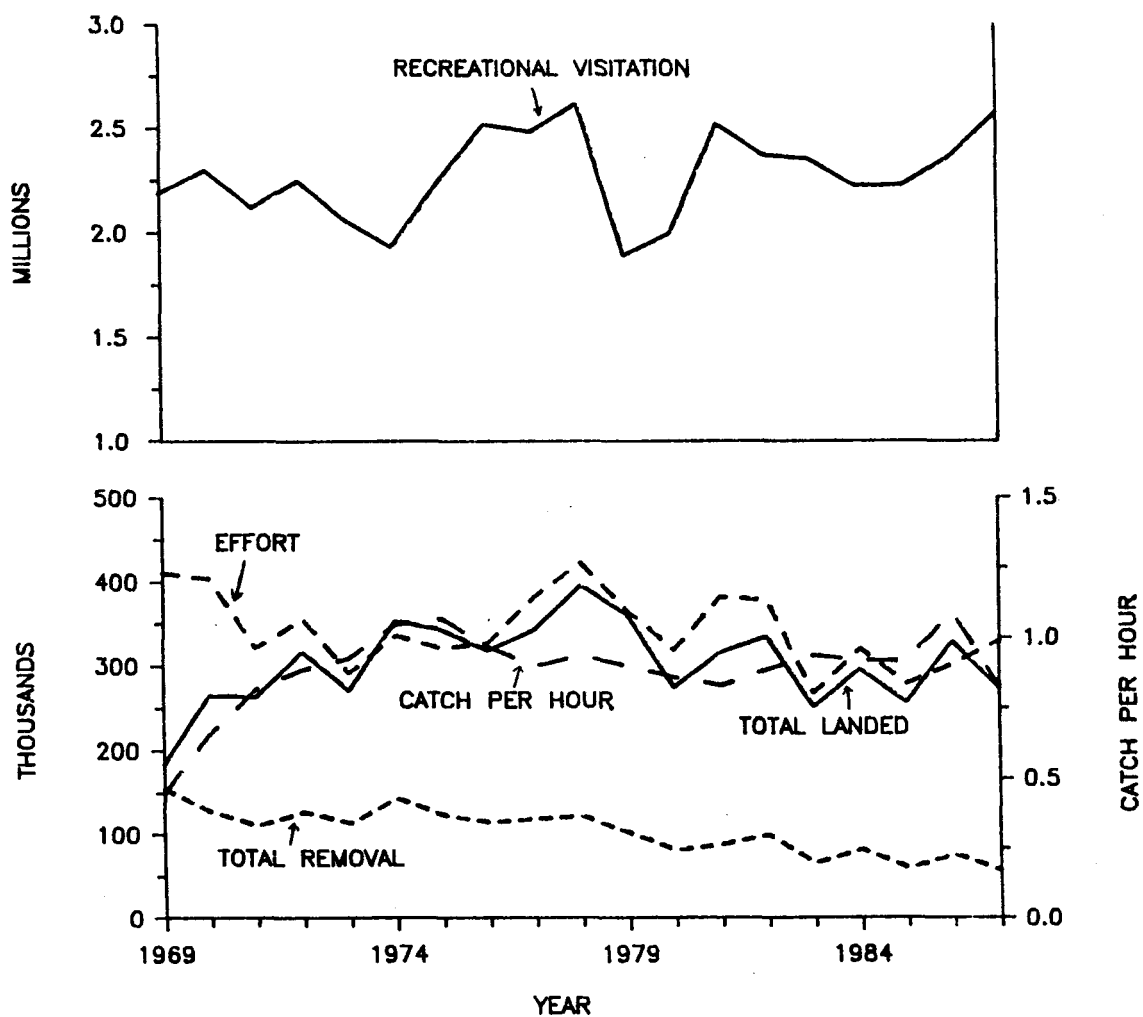


FIGURE 1.-Recreational visitation, catch per hour, total effort (hours), total trout landed, and total trout removed from Yellowstone Lake, 1969-1987.

shoreline. The central and southern areas sustained the lowest proportion of use (Table 6). Success continues to be inversely related to angling pressure; the more remote areas sustain higher landing rates than the more heavily fished accessible areas.

From 1969 through 1974, an average of 86% (range, 84-88%) of angler use occurred in areas with easy access, but since the 330-mm maximum-size limit was implemented in 1975, annual percentages have ranged from 89% to 94%, with a mean of 92%. The effect of the current regulation on this apparent shift in pressure is not clear. The accessible areas have smaller trout and thereby provide a greater chance of creeling a limit; however, changes in survey techniques since 1975 confound comparisons. Regardless of the reason, it has been the more accessible areas of the lake that have been historically overfished.

Yellowstone Lake anglers landed an estimated 273,900 trout and released 241,300. Total angler-caused mortality was estimated at 56,700 (32,600 creeled plus an estimated 24,100 which may have died of hooking wounds following release). Overall landing and creel rates were 0.83 and 0.10 trout/h, respectively. Landing and creel rates from the boat segment (1.04 and 0.13 trout/h, respectively) were significantly higher than those from the shoreline segment (0.64 and 0.08 trout/h, respectively) (Table 6). Sixty-eight percent of one-day anglers landed one or more trout from the lake, and 23% creeled one or more.

Based on length measurements of 11,227 trout reported from Yellowstone Lake, size structure of the cutthroat trout population appears to be approaching equilibrium (Table 7). Average size of landed trout in 1987 was 373 mm. Since 1975, length frequencies have indicated survival of proportionately more fish to older and larger size groups (Table 7). The percentage of landed trout exceeding 406 mm TL (24.5%) is substantially higher than before the regulation change. The percentage of landed trout measuring over 457 mm and 508 mm remain among the highest yet reported.

Like other fishing violations, the illegal harvest of trout over 330 mm is a continuing problem. Length measurements of 538 creeled trout collected by park rangers indicate that approximately 21,100 cutthroat trout over 330 mm were harvested in 1987. About 6,800 of these trout were over 335 mm (13.2 in), and 3,450 were greater than 356 mm (14 in). The later figures suggest that most anglers are attempting to adhere to the regulation; however, the level of violations (21% over 335 mm) is still a concern.

During 1987, the percentage of anglers satisfied with their overall angling experience on Yellowstone Lake was 74%; satisfaction with numbers and sizes landed was 63% and 73%, respectively (Table 6). Average expertise was 1.80.

TABLE 7.-Average length and length frequencies of cutthroat trout landed and creeled from Yellowstone Lake, 1973-1987.

		Percentage of trout reported landed in length groups (inches)							N
		<10	10-12	12-14	14-16	16-18	18-20	>20	
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
	1983	2.9	9.3	23.5	38.9	19.2	4.7	1.6	18,942
	1984	3.1	10.9	25.3	37.1	18.8	3.7	1.2	17,944
	1985	3.2	6.5	22.8	43.5	18.6	4.3	1.2	15,471
	1986	2.1	6.9	23.5	43.8	17.6	5.1	1.1	16,281
	1987	0.1	7.2	21.3	44.0	18.5	4.9	1.1	11,227

		Percentage of trout landed measuring over:					Mean length landed		Mean length creeled	
		>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
	1983	87.8	64.4	25.5	6.3	1.6	14.7	372	12.2	309
	1984	86.0	60.8	23.6	4.8	1.2	14.5	367	12.3	313
	1985	90.4	67.6	24.1	5.5	1.2	14.7	372	12.2	311
	1986	91.0	67.5	23.8	6.2	1.1	14.7	374	12.2	311
	1987	89.7	68.5	24.5	6.0	1.1	14.7	373	12.3	313

Clear Creek Cutthroat Trout Spawning Run

From its source (2,585 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). This stream was utilized for spawn-taking activities almost annually from 1913 to 1950. Since 1951, the fish trap has been used to monitor cutthroat trout spawning in Clear Creek (Jones et al. 1979).

Methods

The upstream trap was installed on 18 May and remained in operation until 21 July. Ascending trout were passed upstream using dipnets until 5 June when a counting chute (Jones et al. 1979) was mounted on the upstream side of the trap box.

The downstream trap was installed on 18 May and was removed when trapping operations ceased on 21 July. 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 in the upstream run consisted of weekly collections of 100 spawners for length and weight measurements. Scales from a subsample of 20 trout were used for age determination. A stratified sample of 10 males and 10 females in each 10-mm size group within the upstream migration was sought, and therefore, additional scales were taken as needed to complete the sample. Length-frequency data (5-mm intervals) were collected from 75 trout daily. Sampling in the downstream migration was limited to length-frequency data. All sampled trout were inspected for fin clips.

Daily water temperatures were obtained with a hand-held thermometer. A staff gage, located approximately 400 m above the weir, was used to monitor stream discharge. Flows were estimated from a stage-discharge prediction equation (Linsley et al. 1982) based on 53 flow measurements obtained at a transect near the gage.

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.

Results

Upstream Migration

A total of 58,663 cutthroat trout were counted through the upstream trap at Clear Creek. The number of migrants fluctuated during the first 16 d (18 May-2 June) varying

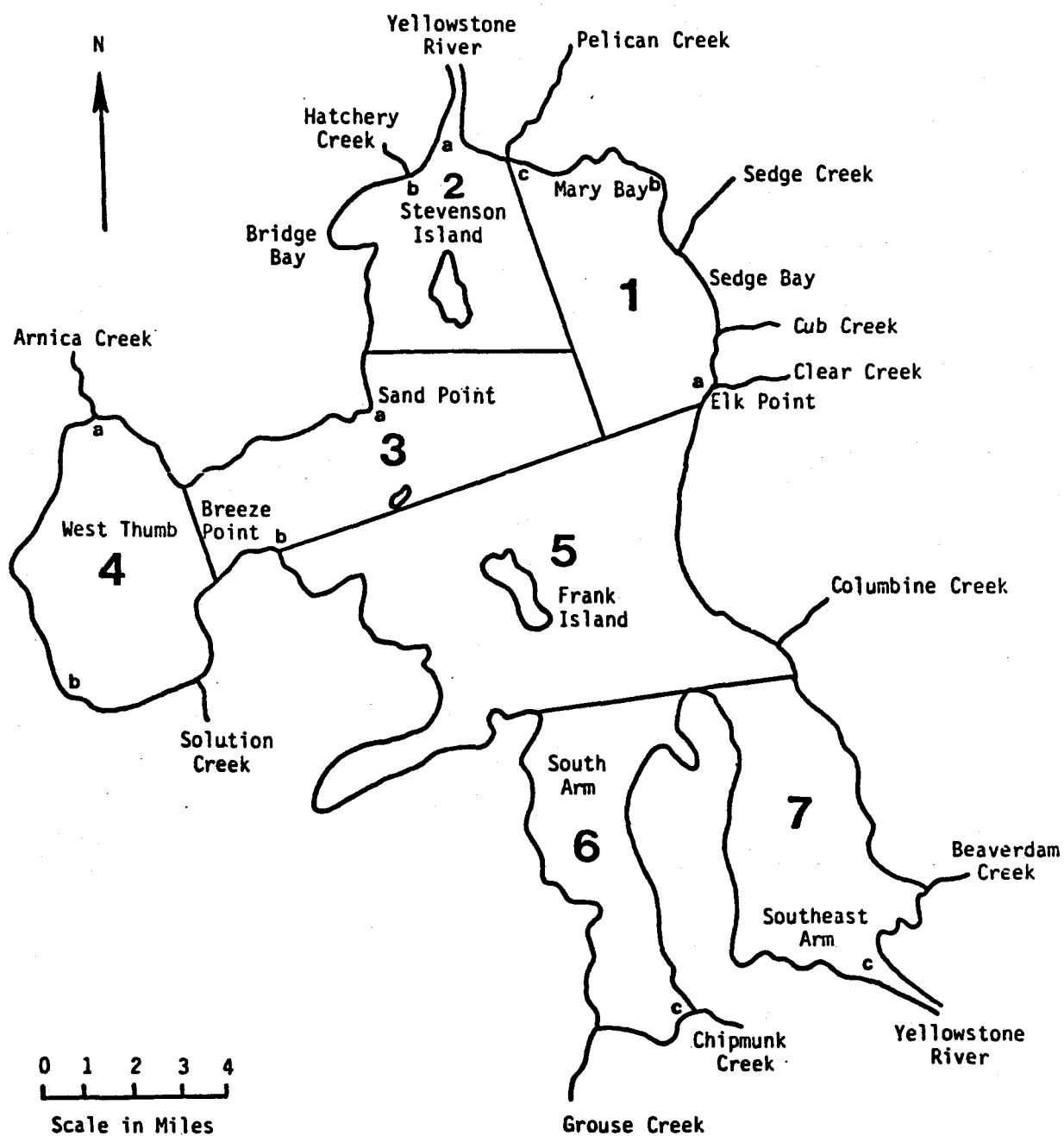


FIGURE 2.-Creel survey, gillnetting, and spawning trap sites, Yellowstone Lake, 1987.

from 2 trout/d on 27 May to 217 trout/d on 1 June (Figure 3). Over 85% of the run (49,986 cutthroat trout) ascended from 1 June to 21 July. After 24 June, the run gradually declined; an average of 7 trout/d were counted during the final 5 d (17-21 July). Although spawning longnose suckers have previously been noted near the mouth of Clear Creek and directly below the weir (Jones et al. 1984), none were observed in 1987.

During the downstream migration in 1979, the adipose fin was removed from 42,229 cutthroat trout at Clear Creek (Jones et al. 1980). In 1987, 4,412 trout in the upstream run were inspected for clips, and only one clipped trout was observed. This result suggests that 0.02% of the trout entering Clear Creek were clipped, yielding a 0.03% return of 1979 spawners.

Mean daily water temperature generally increased throughout the season and ranged from 1.1°C (27 May) to 11.1°C (16 July). Discharge declined steadily from 18 May (3.0 m³/s) to 21 July (0.44 m³/s). Rapid increases in the number of upstream migrants coincided with increasing temperatures and decreasing flows (Figure 3).

Mean total length and weight of upstream cutthroat trout were 382 mm (n = 4,412) and 482 g (n = 886), respectively, and the average condition factor (K) was 0.86. The male:female ratio was 0.75:1. Average total length of males (388 mm) was significantly greater (P < 0.05) than females (376 mm). The weekly average length of all trout decreased as the spawning migration progressed (Table 8).

Average age for an expanded sample of cutthroat trout was 5.2 years. Mean age of males (5.3 years) was significantly greater (P < 0.05) than that estimated for females (5.0 years). Age-9 trout were observed at Clear Creek, and approximately 1% of the upstream migrants were age VIII+ and older.

Downstream Migration

A total of 41,039 cutthroat trout were counted downstream at Clear Creek. During the first 31 d of operation, the lakeward migration varied from 0 trout/d (26 May) to 54 trout/d (16 June) (Figure 3). Approximately 90% of the postspawners were counted from 18 June to 8 July. An average of 20 trout/d were captured during the last 4 d of operation.

The difference between current upstream and downstream spawner counts suggests a total instream mortality of 30% in 1987. Because very few dead fish were observed in the area and fish remains from predators were scant, it is doubtful that this estimate is accurate. It appears more likely that downstream migrants were not completely enumerated; and thus, estimates of instream mortality for 1987 were positively biased.

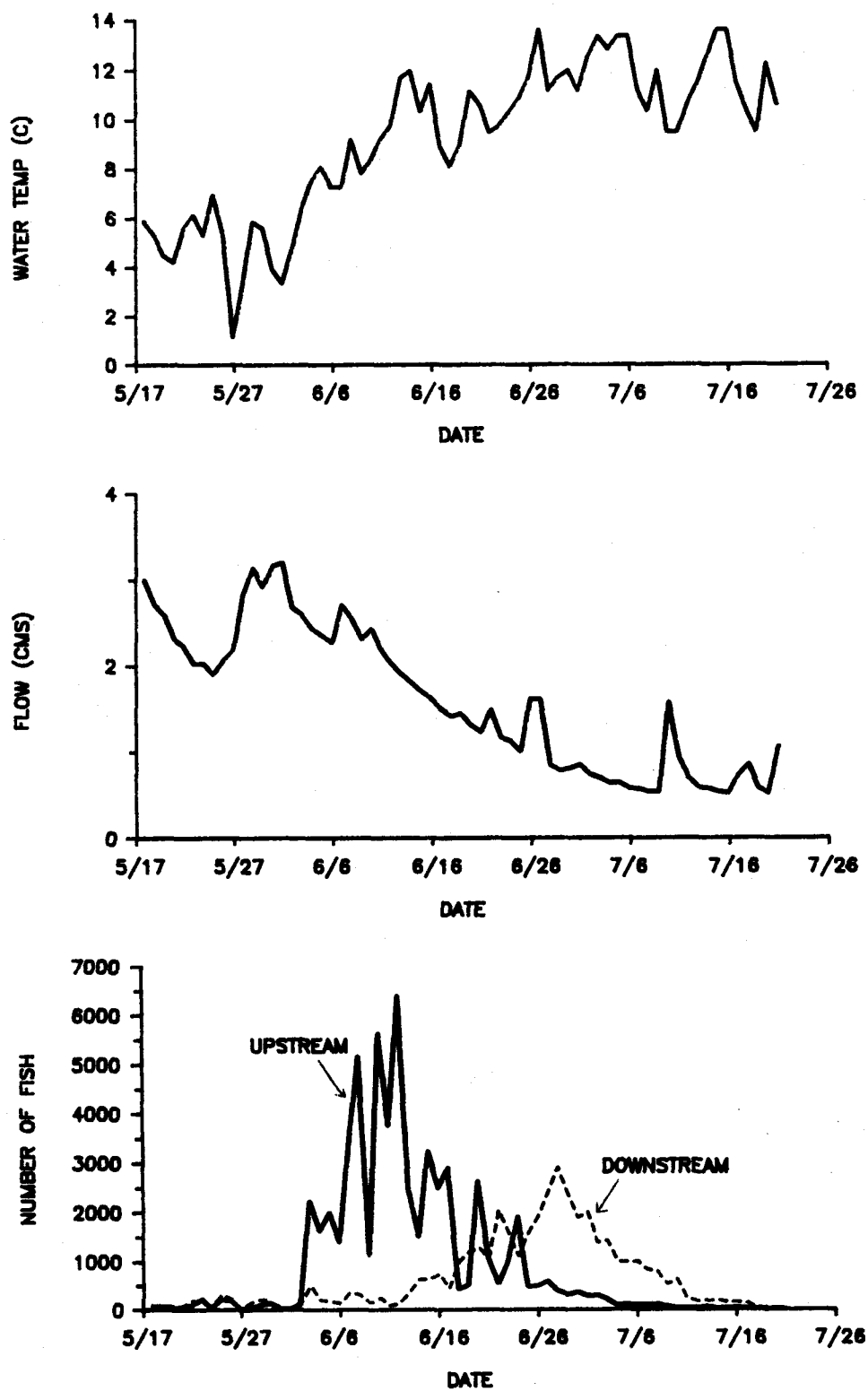


FIGURE 3.-Pattern of daily water temperature, flow, and cutthroat trout spawning migration, Clear Creek, 1987.

TABLE 8.-Weekly mean length, weight, and condition factor of cutthroat trout spawners in the upstream trap in Clear Creek, May 18 - July 21, 1987^a.

Date	Males					Females					Totals					M:F ratio
	Mean length (mm)	N	Mean weight (g)	Mean K factor	N	Mean length (mm)	N	Mean weight (g)	Mean K factor	N	Mean length (mm)	N	Mean weight (g)	Mean K factor	N	
May 18-May 24	406	159	522	0.81	47	390	246	533	0.91	52	396	405	542	0.86	99	0.65:1
May 25-May 31	395	163	501	0.88	36	386	270	528	0.93	64	388	433	518	0.91	100	0.60:1
June 1-June 7	386	251	525	0.86	40	380	251	502	0.90	60	384	502	511	0.88	100	1:1
June 8-June 14	387	293	504	0.86	42	377	334	479	0.90	58	382	627	489	0.88	100	0.88:1
June 15-June 21	385	290	491	0.83	44	375	335	461	0.90	56	380	625	474	0.87	100	0.87:1
June 22-June 28	386	254	503	0.83	29	372	372	459	0.90	71	378	626	472	0.88	100	0.68:1
June 29-July 5	387	217	464	0.83	24	370	411	439	0.86	76	376	628	445	0.85	100	0.53:1
July 6-July 12	382	178	428	0.76	59	370	216	431	0.80	39	375	394	429	0.78	98	0.82:1
July 13- July 19	385	79	441	0.79	40	372	78	455	0.85	49	379	157	449	0.82	89	1.01:1
July 20- July 21	384	7	0	0.00	0	374	8	0	0.00	0	379	15	0	0.00	0	1.14:1
Composite	388	1,891	488	0.82	361	376	2,521	477	0.89	525	382	4,412	482	0.86	886	0.75:1

^a Based on daily samples of cutthroat trout which were both measured and weighed; from May 18 to July 21, no upstream trout were sampled.

Average length of downstream migrants was 381 mm. The male:female ratio was 0.78:1, and males had a significantly greater ($P < 0.05$) mean total length (388 mm) than females (375 mm). There was no significant difference ($P > 0.05$) in the mean length of upstream and downstream migrants. As in the upstream migration, there were significant decreases ($P < 0.05$) in weekly average length throughout the study.

Fingerling trout (presumed yearlings) were first observed near the weir on 4 June. Young-of-the-year cutthroat trout were not seen until 14 July.

A sow grizzly bear with three cubs was sighted near the mouth of Clear Creek on 23 May, but there was no further evidence of bears in the area until 2 July. At that time remains of partially eaten fish were found along the weir. Bear tracks were observed frequently through the middle of July, and a single grizzly bear was sighted on 4 July and again on 9 July. Other wildlife 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 number of spawners entering Clear Creek since 1977, the migration pattern appears to be quite stable. Larger trout enter the stream first; mean length, weight, and condition factor (K) gradually decrease during the season. Most males are ripe when they enter the stream, but females apparently ripen during the upstream migration (Ball and Cope 1961; Jones et al. 1978).

The seasonal migration is strongly influenced by stream flows and water temperatures. Since these factors are interrelated, it is difficult to separate their effects; however, numbers generally increase in June as flow decreases and water temperature exceeds 10°C (Ball and Cope 1961; Jones et al. 1979, 1982; Grant Village, this report).

The daily pattern of upstream migration at Clear Creek also appears to be related to flow and water temperature. The number of trout entering the trap increases from 1300 to 1700 hours as water temperature rises and flow decreases. As flow rises and temperature drops (1700-2100 hours), the number of upstream migrants declines.

Some nocturnal upstream movement has been noted (Jones et al. 1978, 1985), but the majority of cutthroat trout migrants ascend prior to sunset. A similar pattern has been noted at Cub Creek and Pelican Creek (Jones et al. 1979, 1982). Bulkley (USFWS, personal communication), however, reported nocturnal upstream migration in these streams during the 1950s, and Cope (1956) found that cutthroat trout spawners in Arnica Creek also migrated primarily at night.

Reasons for these apparent discrepancies are unknown but may be related to differences in trap operations. The use of electronic fish counters would document movement on a 24-h basis and therefore provide unbiased data necessary to describe daily migration patterns.

Downstream migration during the early weeks of the spawning run is generally nocturnal and appears to follow increases in streamflow between 1900 and 2400 hours. As stream discharge decreases after spring runoff, however, the nocturnal pattern of emigration continues.

Since all spawners leave Clear Creek after spawning, the difference between accurate upstream and downstream counts provides an unbiased estimate of instream spawning mortality. Incomplete counts of downstream migrants have prevented mortality estimates in some years (1980-1982, 1985-1987), but mortality has ranged from 6.7% (1977) to 19.8% (1983) for 5 years with valid estimates.

The mean estimate of 12.9% for 5 years at Clear Creek is much lower than the instream mortality estimate of 48.1% for five tributaries (including Clear Creek) from 1949 to 1953 (Ball and Cope 1961). Only one estimate of 41.2% was made for Clear Creek during that period. These mortality estimates were primarily determined from tag return data, but in 1953, one estimate of 45.6% was based on total upstream and downstream counts in Arnica Creek (Ball and Cope 1961). Although these earlier findings may be biased by tagging mortality and the use of artificially spawned trout in the calculations, significant changes in the population structure may have occurred due to intensive exploitation in the 1950s.

Clip returns from Clear Creek since 1980 indicate that under recent harvest levels at least 23% of the cutthroat trout spawners clipped in 1979 survived to spawn again, and a small number of these trout returned to Clear Creek in 1987. Current instream mortality estimates and increases in the mean age of spawners are also indicative of a higher rate of repeat spawning.

Ball and Cope (1961) suggested that the majority of repeat spawners returned in alternate years, and clip returns from Clear Creek strongly support this hypothesis. 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-year spawners may vary substantially 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 and between stocks within the lake.

A significant decline in the mean length of cutthroat trout spawners was observed in 1987 (Figure 4). Although the mean length of spawners at Clear Creek has been used as an index for monitoring changes in population structure of cutthroat trout in Yellowstone Lake, other indices did not substantiate the apparent decline. Mean age of spawners actually increased slightly in 1987; the current estimate is among the highest reported since 1953 (Figure 5). Mean length of angler-captured cutthroat trout decreased only 1 mm in 1987 and represent the second highest value yet recorded (Figure 6). Mean length of cutthroat trout prespawners captured in largemouth gill nets in 1987 increased from 1986 and was the second highest value reported since the monitoring program began in 1969.

This apparent discrepancy may have been indirectly influenced by the timing of trap installation. Since the mean length of spawners generally declines during the migration period, initiation of trapping activities after peak runoff may have prevented collection of many of the larger individuals in the migration (Jones et al. 1986).

The low snowpack and early runoff may have affected the mean size of upstream migrants by limiting access to other spawning streams along the east shore of Yellowstone Lake. Previous studies have indicated that mean length of upstream migrants in Clear Creek is significantly greater ($P < 0.05$), than similar estimates from other Yellowstone Lake tributaries (Jones et al. 1980, 1982, 1986, 1987). If a substantial number of spawners from other tributaries entered Clear Creek, the mean length of spawners would have been lowered, thus confounding the utility of this value to monitor the general lake population. The sudden increase in the number of spawners entering Clear Creek may reflect straying from other spawning tributaries because of unusual environmental conditions such as low flow in intermittent streams or lack of access due to debris or sediment dams at tributary mouths.

Although the current structure of the cutthroat trout population may not have reached historic levels, spawning migrations at Clear Creek in recent years indicate the biological potential of this native cutthroat trout population under protective regulations (Figure 7). Recent data from Clear Creek emphasize the negative effects of low spawner escapement, due both to egg-taking operations and overharvest, during the 1940s, 1950s, and 1960s. 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.

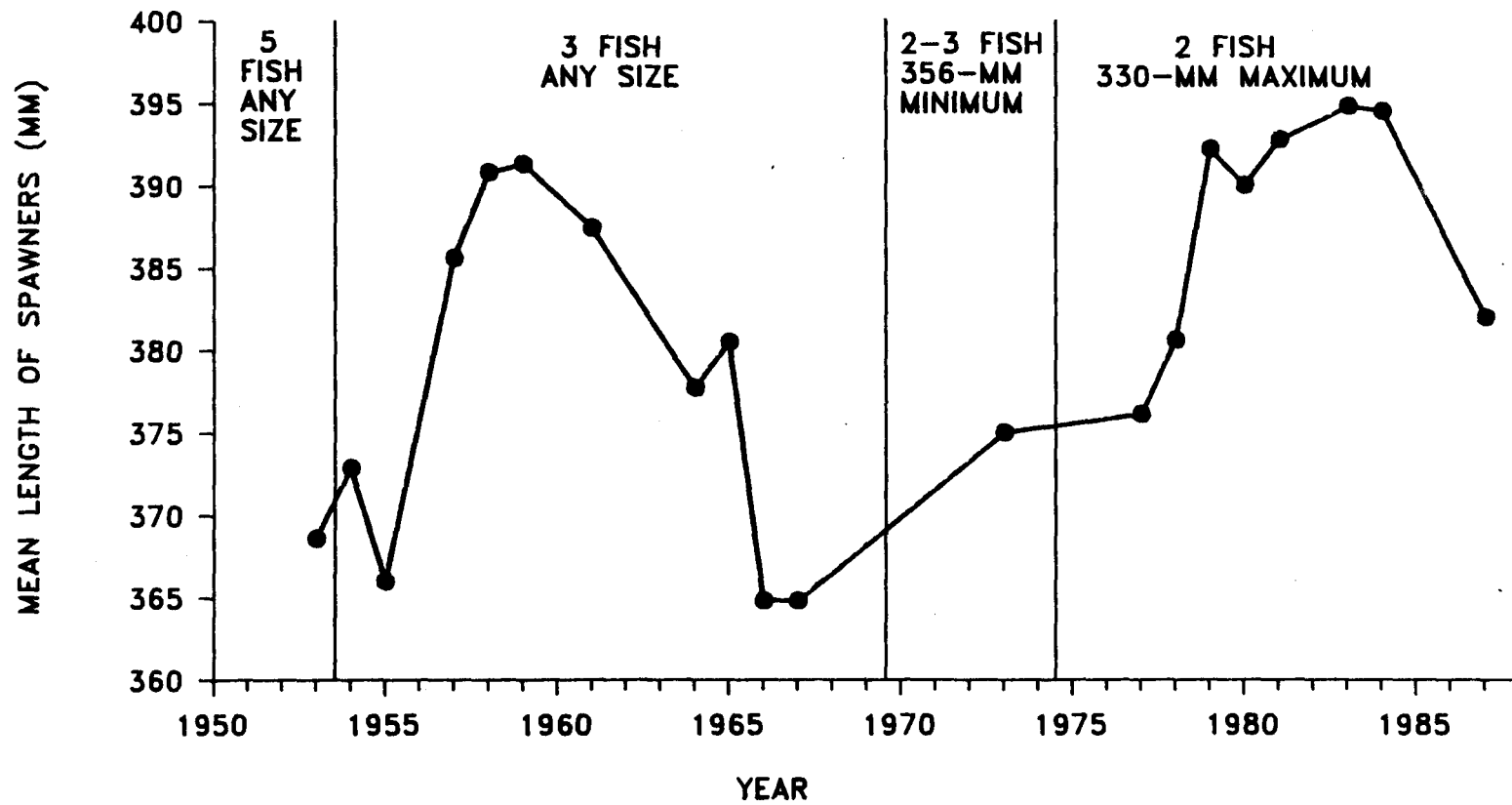


FIGURE 4.-Mean length of cutthroat trout spawners entering Clear Creek, 1953-1987.

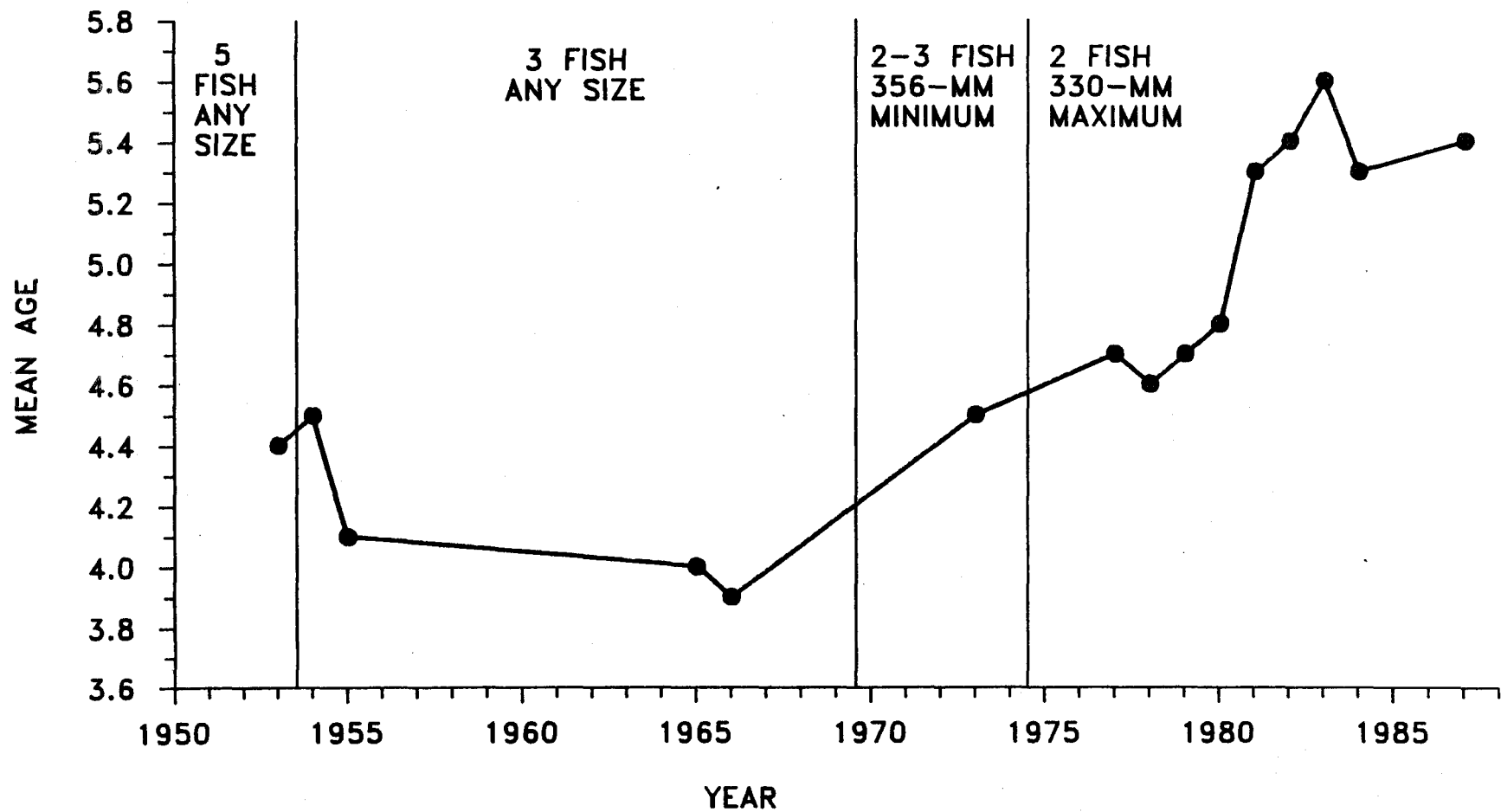


FIGURE 5.-Mean age of cutthroat trout spawners entering Clear Creek, 1953-1987.

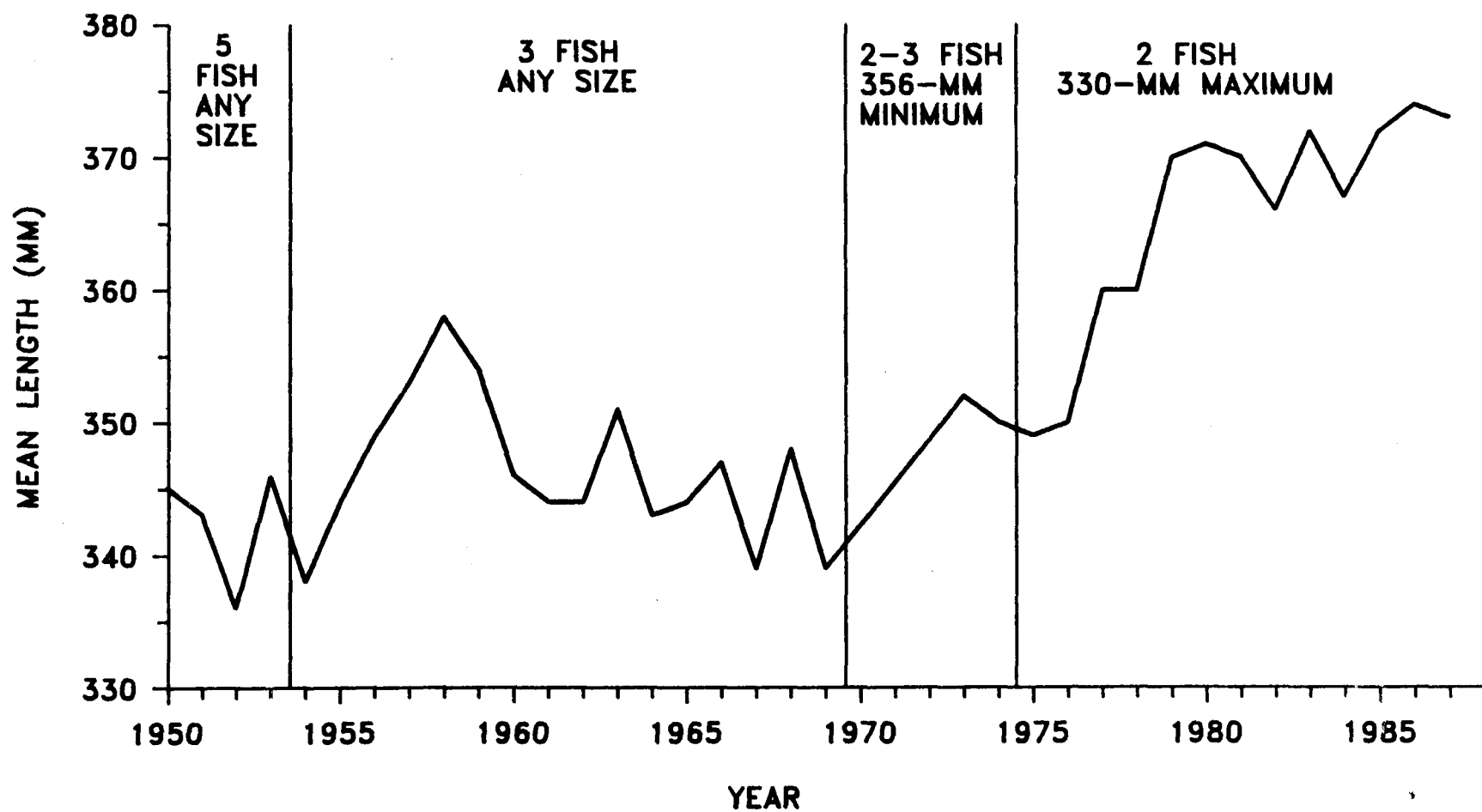


FIGURE 6.-Mean length of cutthroat trout captured in the fishery measured at boatdocks (1950-1962) and shoreline-boatdocks combined (1963-1987).

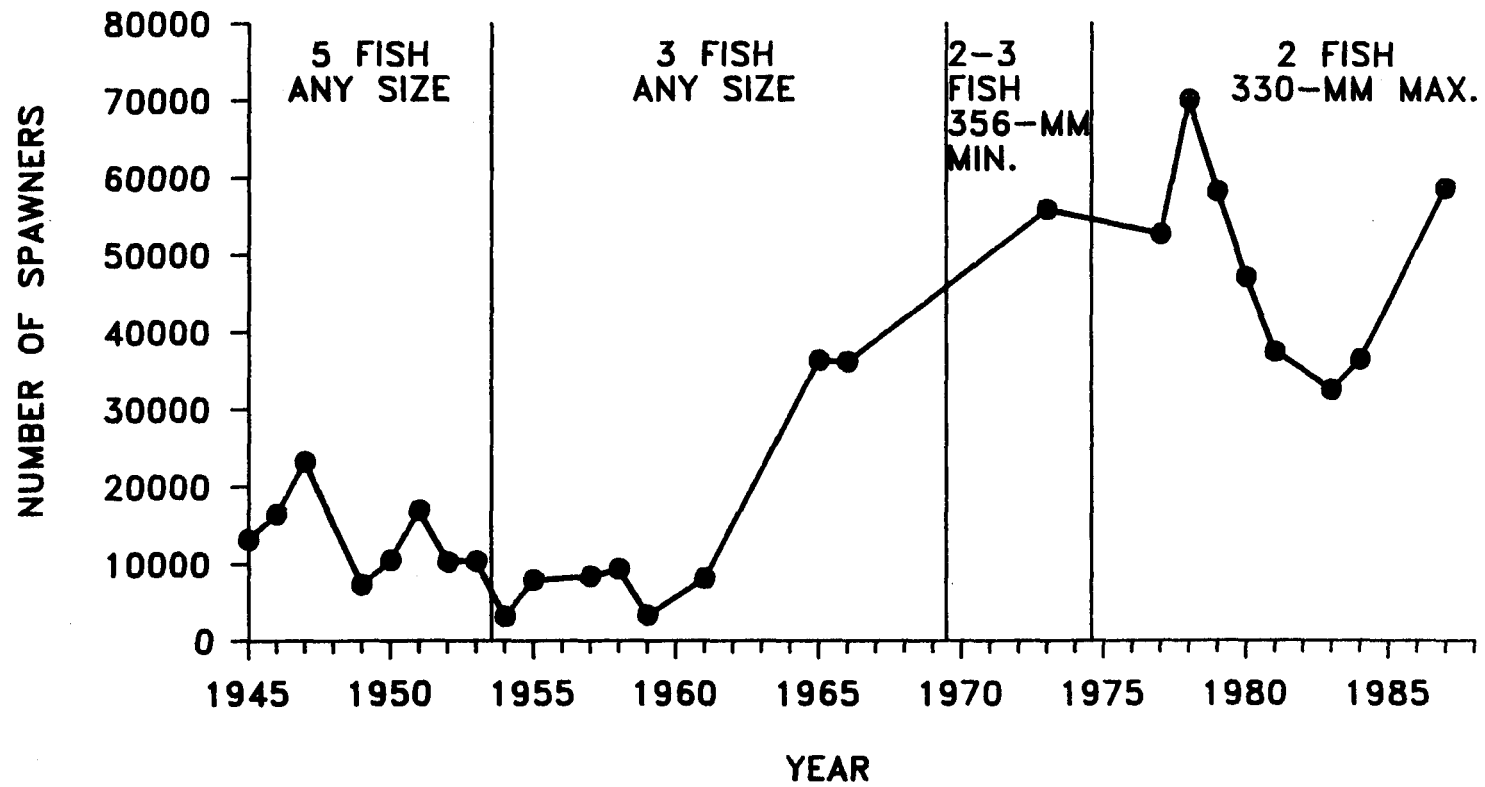


FIGURE 7.-Number of cutthroat trout spawners entering Clear Creek during various sample years, 1945-1987.

Largemouth Gillnetting

With the exception of 1973 and 1975, largemouth gillnetting has been conducted annually on Yellowstone Lake since 1969. The objective of this program is to monitor effects of angler harvest on relative abundance and population structure of cutthroat trout. Dean et al. (1970-1975), Varley et al. (1976), and Jones et al. (1977-1987) detail methods and provide summaries of previous results.

Methods

In 1987, experimental gillnets were set from 14 to 18 September at 11 sites in Yellowstone Lake (Figure 2). Field and laboratory sampling procedures remained identical to those described by Jones et al. (1985).

Cutthroat Trout 1987

A total of 1,017 cutthroat trout were captured in 1987. Average number of trout captured per net was 18.5, and mean length, weight, and condition factor (K) were 306 mm, 301 g, and 0.88, respectively (Tables 9 and 10).

Number of trout captured per net differed significantly between the 11 netting sites (Appendix Table 1). Highest numbers were captured at sites 4b, 6c, 1b, and 1c (28.8, 24.2, 20.4, and 20.0 trout/net, respectively). Catches were lowest at sites 4a, 2a, and 1a (14.4, 14.4, and 13.6 trout/net, respectively).

There were no significant differences in the number of trout captured per net between the four lake zones (North: 1a, 1b, 1c, 2a, 2b; Central: 3a, 3b; West Thumb: 4a, 4b; South: 6c, 7c) (Appendix Table 2). Numbers were greater for West Thumb and South (21.6 and 19.8 trout/net, respectively) than for Central and North (18.0 and 16.9 trout/net, respectively).

Mean length of captured trout differed significantly ($P < 0.05$) among sample sites (Appendix Table 1). Average lengths were greatest at sites 7c, 2a, 3b, 1c, and 4a (334, 329, 322, 320, and 320 mm, respectively), and lowest at sites 2b, 1a, 6c, and 4b (297, 294, 292, and 276 mm, respectively). Mean length of captured trout was not significantly correlated ($P > 0.05$) to number of trout captured per net.

Significant differences ($P < 0.05$) in mean length of captured trout also occurred among lake zones (Appendix Table 2). Mean length was greatest in the Central (315 mm) followed by North (309 mm), South (308 mm), and West Thumb (290 mm).

Approximately 45% of all trout over 304 mm were categorized as prespawners (fish with sufficient gonadal

TABLE 9.-Comparative largemouth gillnetting results, cutthroat trout, 1.52-4.57 m depth interval, Yellowstone Lake, 1969-1972, 1974, 1976-1980, and 1982-1987.

Year	Number of gillnet sets ^a	Average number of trout per net	95% confidence interval of number of trout/net	Mean length (mm)	Condition Factor (K)	% of trout over 356 mm (TL)	% of trout over 406 mm (TL)	% of trout over 457 mm (TL)	Percent of trout over 304 mm (TL) judged as prespawners	Prespawning male:female ratio	Average length of prespawning males (mm)	Average length of prespawning females (mm)
1969	9	12.22	+6.71	311	0.92	29.1	1.8	0.0	48	1.06:1	353	346
1970	11	12.27	+5.90	315	0.92	26.7	3.0	0.0	44	1.73:1	359	351
1971	5	14.40	+9.76	321	0.85	37.5	1.4	0.0	54	1.50:1	360	368
1972	11	13.64	+3.57	313	0.94	32.7	3.3	0.0	39	0.52:1	358	369
1974	11	15.45	+4.75	298	0.86	34.7	0.6	0.0	52	1.00:1	349	359
1976	11	15.00	+3.06	317	0.88	37.6	2.4	0.0	47	1.43:1	370	365
1977	44	15.50	+1.98	290	0.89	33.0	4.7	0.2	73	0.98:1	376	362
1978	55	13.93	+1.06	308	0.92	37.5	5.4	0.3	64	1.06:1	383	372
1979	55	13.60	+1.27	303	0.92	32.3	7.4	0.1	58	0.91:1	387	374
1980	55	13.00	+1.53	309	0.88	40.6	7.1	0.3	50	1.05:1	389	376
1982	55	10.58	+1.05	322	0.01	47.1	12.7	0.7	62	1.10:1	389	379
1983	55	18.05	+1.67	288	0.90	32.5	9.6	0.8	52	1.12:1	396	380
1984	54	19.50	+1.88	281	0.92	26.1	7.6	0.5	51	1.09:1	389	382
1985	55	14.25	+1.90	311	0.93	34.8	11.6	0.5	40	1.41:1	399	384
1986	55	16.75	+2.03	293	0.88	32.7	9.7	1.1	47	1.04:1	386	385
1987	55	18.49	+1.62	306	0.88	34.2	9.9	1.3	45	0.77:1	396	384

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

TABLE 10.-Length-frequency distribution, average lengths, 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, 1987.

Species	Maturity category ^a	Size-group (lower length of interval - mm)								Total number	Average total length	Average weight	Average condition
		100	150	200	250	300	350	400	450	500	(mm)	(g)	factor (K)
Cutthroat trout	Nonspawners	1	102	170	243	106	119	46	5	792	282	234	0.88
	Prespawning males				3	9	39	37	10	98	396	575	0.90
	Prespawning females				2	9	78	36	2	127	384	508	0.89
	TOTALS AND AVERAGES	1	102	170	248	124	236	119	17	1,017	306	301	0.88
Longnose sucker	Nonspawners		16	36	35	51	9	1		148	275	264	1.11
	Prespawning males			1	20	56	51	79	10	217	374	670	1.20
	Prespawning females					15	24	69	57	20	434	934	1.11
	TOTALS AND AVERAGES		16	37	55	122	84	149	67	550	367	649	1.15

^a Prespawning fish defined as those judged to have sufficient gonadal development to spawn in 1988; nonspawners include immature, and mature fish which were judged to lack sufficient gonadal development to spawn in 1988.

development to spawn in 1988). Mean length and weight of cutthroat trout prespawners was 389 mm and 537 g, respectively; mean condition factor (K) was 0.89. Prespawner male:female ratio was 0.77:1. Differences in mean length between male and female prespawners was significant (396 mm and 384 mm, respectively) (Table 10).

Longnose Suckers 1987

Average length and weight were 367 mm and 649 g, respectively, for 550 longnose suckers captured in 1987. Average condition factor was 1.15 (Table 11). *Ligula intestinalis* was observed in 4.7% of the captured suckers. Opaque eye lenses, presumably due to high infestations of eye flukes *Diplostomum spathaceum*, were noted in 57% of a sample of 373 of the captured suckers. No clipped or tagged suckers were noted.

Approximately 87% of all suckers over 310 mm were categorized as prespawners. Mean length and weight of longnose sucker prespawners was 402 mm and 791 g, respectively; mean condition factor (K) was 1.16. Prespawner male:female ratio was 1.17:1. The difference in mean length between male (374 mm) and female (434 mm) prespawners was significant ($P < 0.05$). Males ranged from 230 to 480 mm, and females varied between 310 and 530 mm.

Discussion

Although the experimental design of the largemouth gillnetting program has been modified since the program began in 1969, data are comparable for 16 of 17 years in which studies have been conducted. Significant differences ($P < 0.05$) in efficiency were found between nets used in 1981 and those used in all other years (Jones et al. 1982); therefore, data from 1981 have been deleted to prevent confounding comparisons between years.

Cutthroat Trout 1969-1987

Relative abundance and distribution.-Mean number of trout captured per net has varied significantly since 1969 (Table 9), but when data were grouped by pre-330 mm maximum-size limit (1969-1974; mean, 13.6 trout/net) and post-regulation (1976-1987; mean, 15.3 trout/net) periods, the difference between periods was not significant ($P > 0.05$). There is, however, a significant correlation ($r = 0.56$) between the percentage of trout less than 203 mm captured annually in gillnets and the mean number of trout captured per net per year. This relationship suggests that the total number of trout captured each year in gillnets is influenced by the relative abundance of age-1 and age-2 trout. Such annual fluctuations caused by variations in

TABLE 11. Comparative largemouth gillnetting results, longnose sucker, 1.52-4.57 m depth interval, Yellowstone Lake, 1969-1972, 1974, 1976-1980, and 1982-1987.

Year	Number of gillnet sets ^a	Average number of suckers per net	95% confidence interval of number suckers/net	Mean length (mm)	Condition Factor (K)	% of suckers over 356 mm (TL)	% of suckers over 406 mm (TL)	% of suckers over 457 mm (TL)	Percent of suckers over 310 mm (TL) judged as prespawners	Prespawning male:female ratio	Average length of prespawning males (mm)	Average length of prespawning females (mm)
1969	9	16.33	+10.65	365	1.21	66.0	29.2	6.1	90	1.28:1	382	419
1970	11	6.45	+5.01	393	1.24	83.1	59.2	12.7	97	0.08:1	386	440
1971	5	37.00	+42.17	316	1.21	34.0	17.8	2.7	91	2.00:1	357	417
1972	11	2.54	+1.29	335	1.21	42.9	28.6	7.1	82	2.00:1	378	428
1974	11	15.91	+5.92	370	1.22	69.7	29.1	5.7	97	1.28:1	372	415
1976	11	14.55	+5.36	389	1.23	80.6	44.4	7.5	93	1.07:1	387	425
1977	44	7.25	+1.83	401	1.23	80.9	55.5	14.7	99	1.48:1	390	441
1978	55	7.52	+1.99	363	1.19	58.3	38.9	11.1	90	1.13:1	385	435
1979	55	12.64	+2.07	371	1.20	62.6	45.2	13.0	88	0.99:1	399	440
1980	55	9.98	+1.82	365	1.17	59.3	39.4	12.6	97	1.12:1	370	432
1982	55	8.64	+2.13	356	1.21	51.1	37.2	12.5	89	0.95:1	373	438
1983	55	11.36	+1.87	341	1.18	50.1	36.5	12.8	93	1.21:1	381	442
1984	54	13.65	+2.29	349	1.06	55.2	39.3	14.0	95	0.92:1	386	439
1985	55	6.20	+1.61	362	1.23	57.6	43.3	13.5	94	1.39:1	373	441
1986	55	10.35	+2.80	334	1.15	38.5	25.7	8.4	90	1.57:1	363	438
1987	55	10.00	+2.08	367	1.15	55.8	39.8	13.3	87	1.17:1	374	434

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

year-class strength confound the interpretation of impacts due to angler harvest; however, they have provided some ability to predict cutthroat trout recruitment prior to entry into the fishery.

The combined data from 16 years of gillnetting yielded significant differences between the 11 sample sites in the mean number of trout captured per net. Mean number per net continued to range between 16 and 17 for sites 1b, 1c, 2b, 3a, and 4b, and from 11 to 14 at sites 1a, 2a, 3b, 4a, 6c, and 7c. Differences between lake zones in the mean number of trout captured per net were not significant ($P > 0.05$). Numbers captured in North, West Thumb, and Central were approximately 15-16 trout/net; South yielded a mean of 14 trout/net. Between-site differences are apparently due to factors other than the portion of the lake sampled, and variability between nets in the number of trout captured continues to reduce the sensitivity of comparisons.

Population structure.-Mean length of trout captured in largemouth gillnets has varied significantly ($P < 0.05$) since 1969 (Table 9). Similar results were obtained when data were combined over years and compared by site and zone (Appendix Tables 1 and 2). A significant ($P < 0.05$) correlation ($r = -0.89$) between the percentage of trout less than 203 mm and the mean length of all trout captured in gillnets probably reflects year-class fluctuations of age-1 and age-2 trout.

Because mean length of prespawners is unaffected by the proportion of smaller trout captured in gillnets, comparisons of prespawners can be used to detect length changes in mature trout. Although mean length of prespawners is somewhat less than 1985, the current mean length is the second highest reported since 1969. Mean length of prespawners since implementation of the 330-mm maximum-size limit (383 mm) has increased 26 mm from the mean of pre-regulation years (1969-1974; mean, 357 mm). In 1987, both male and female prespawners displayed the second highest mean length yet recorded (Figure 8).

Analysis of length data based on the prespawner maturity category has definitely reduced factors that confound interpretation; however, this technique is based on subjective criteria for stage of maturity, especially for male cutthroat trout. Anderson (1976) introduced a technique of length frequency analysis based on proportional stock density (PSD) or the proportion of a stock that is greater than or equal to a specific length. The specified length was termed "quality length"; however, both stock and quality lengths varied with species (Anderson 1978). Anderson and Weithman (1978), Anderson (1980), and Gabelhouse (1984) defined minimum stock and quality lengths for numerous species based on percentages of world record lengths.

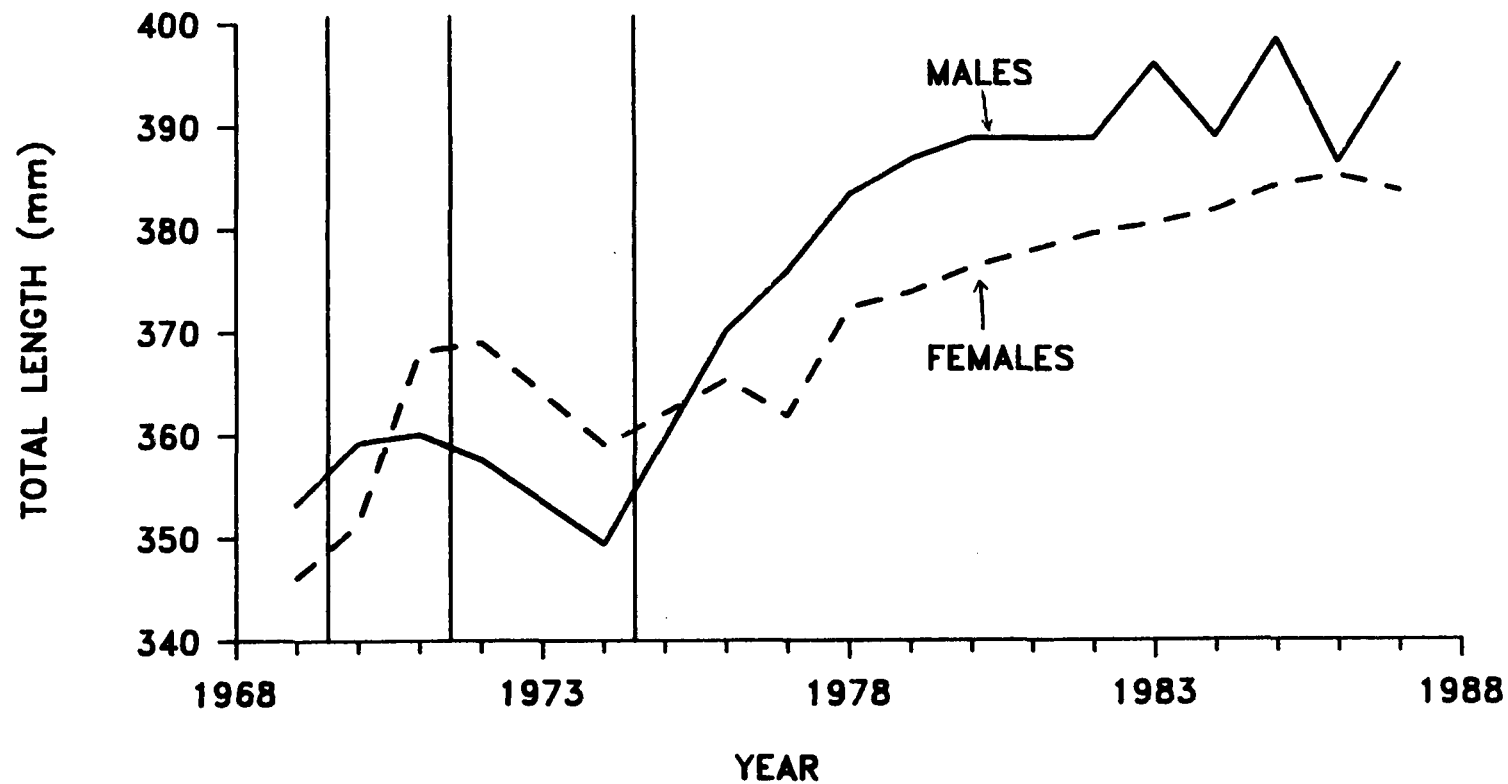


FIGURE 8.-Mean total length of prespawning cutthroat trout captured in largemesh gillnets, Yellowstone Lake, 1969-1987.

Anderson (1980) defined relative stock density (RSD) as the percentage of any defined size group within the stock of a particular species. In an attempt to refine the length-categorization system, Gabelhouse (1984) proposed the terms "preferred", "memorable", and "trophy" to describe length categories with minimum lengths of 45-55%, 59-64%, and 74-80% of world record lengths, respectively, and provided minimum size estimates for 69 species. Stock, quality, and preferred lengths suggested by Gabelhouse (1984) were 198-257 mm, 356-406 mm, and 447-543 mm, respectively, for cutthroat trout.

Gillnetting data since 1969 were compared using 203 mm, 381 mm, and 457 mm for stock, quality, and preferred lengths, respectively. The calculated PSD for the pre-regulation period ranged from 7.04 to 13.71, with a mean of 10.91 (Figure 9). During that period RSD-preferred values equaled 0.0 in all years. Since the implementation of the 330-mm maximum-size limit (1975), both PSD and RSD-preferred estimates have risen significantly. PSD estimates ranged from 18.13 (1977) to 31.79 (1982); mean PSD was 24.4, over twice the pre-regulation mean. RSD-preferred values rose to 1.43 in 1987, and the mean since 1976 was 0.62. These shifts toward larger trout suggest a greater survival of older trout in Yellowstone Lake under the 330-mm maximum-size limit.

There has also been a decline since 1975 in the relative abundance of captured trout between 206 and 330 mm (Figure 10). This decrease may be related to the fact that approximately 57% of all creel-trout from Yellowstone Lake are between 203 and 330 mm. Although this effect appears to be compensated for by increased survival of remaining trout (as evidenced by increase in the proportion of larger trout), this apparent manifestation of harvest should be monitored closely in the future.

Longnose Suckers 1969-1987

Average number per net.-Although differences between years in the average number of suckers captured per net (Table 11) are significant ($P < 0.05$), reasons for these changes remain unidentified. It is doubtful these differences are due to population fluctuations since the longnose sucker is believed to be long-lived in Yellowstone Lake (Jones et al. 1977). These fluctuations may be partially due to schooling behavior; such behavior would intensify variation in the gillnet catch.

Average size.-Comparisons between years (Table 11) yield significant differences ($P < 0.05$) in mean length. Mean length of suckers is inversely correlated to the male:female ratio ($r = -0.61$) and directly correlated to the percentage of suckers over 310 mm ($r = 0.74$). Since the latter two factors are probably related to distribution,

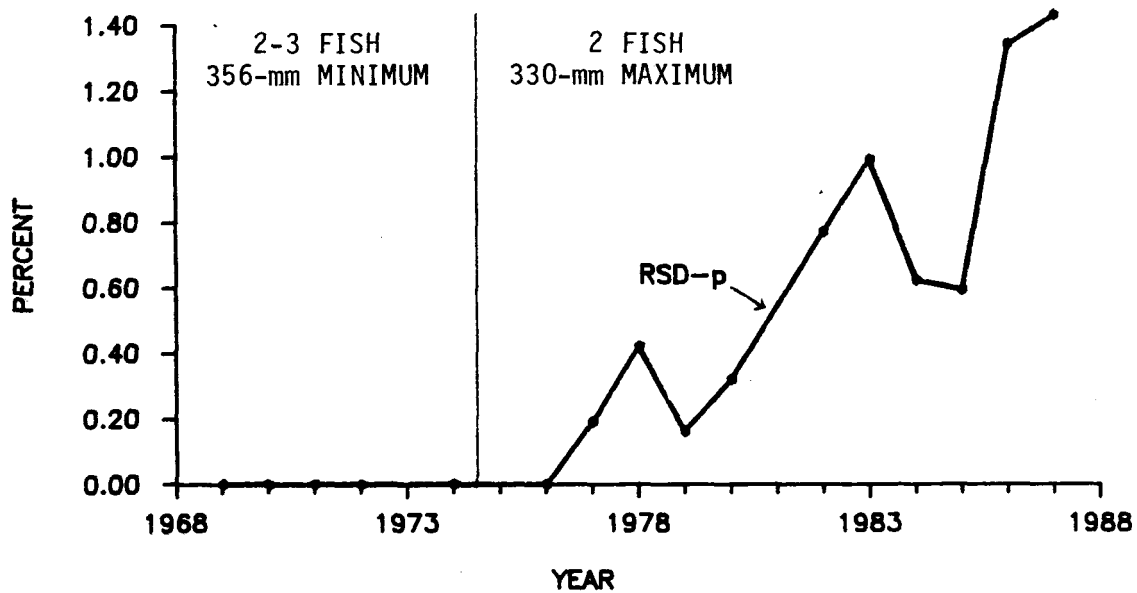
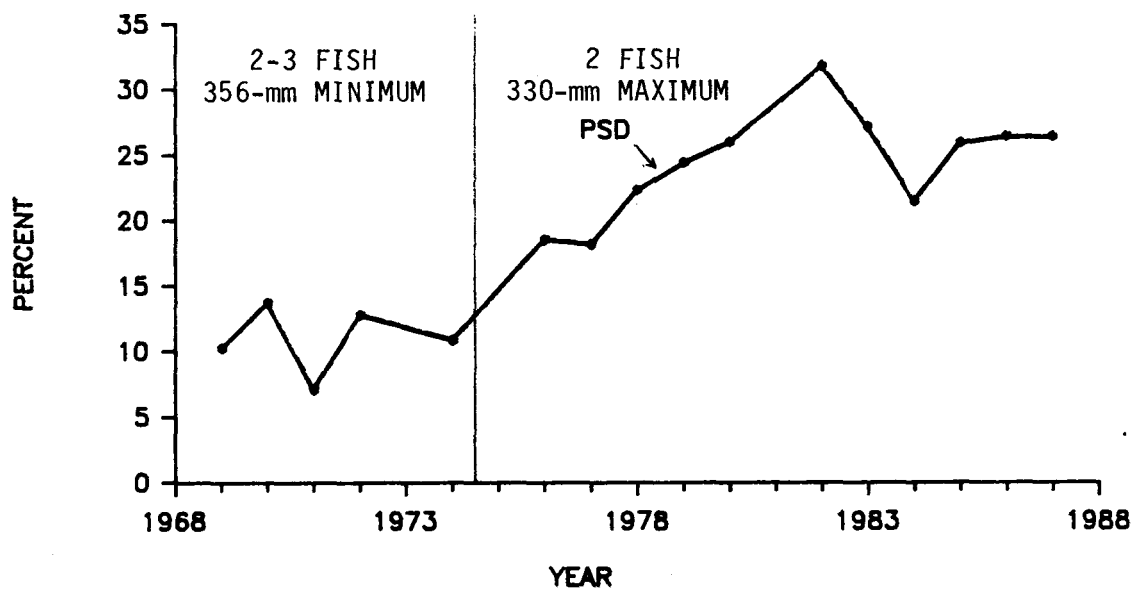


FIGURE 9.-Proportional stock density (PSD) and relative stock density-preferred (RSD-p) for gillnet captured cutthroat trout, Yellowstone Lake, 1969-1987.

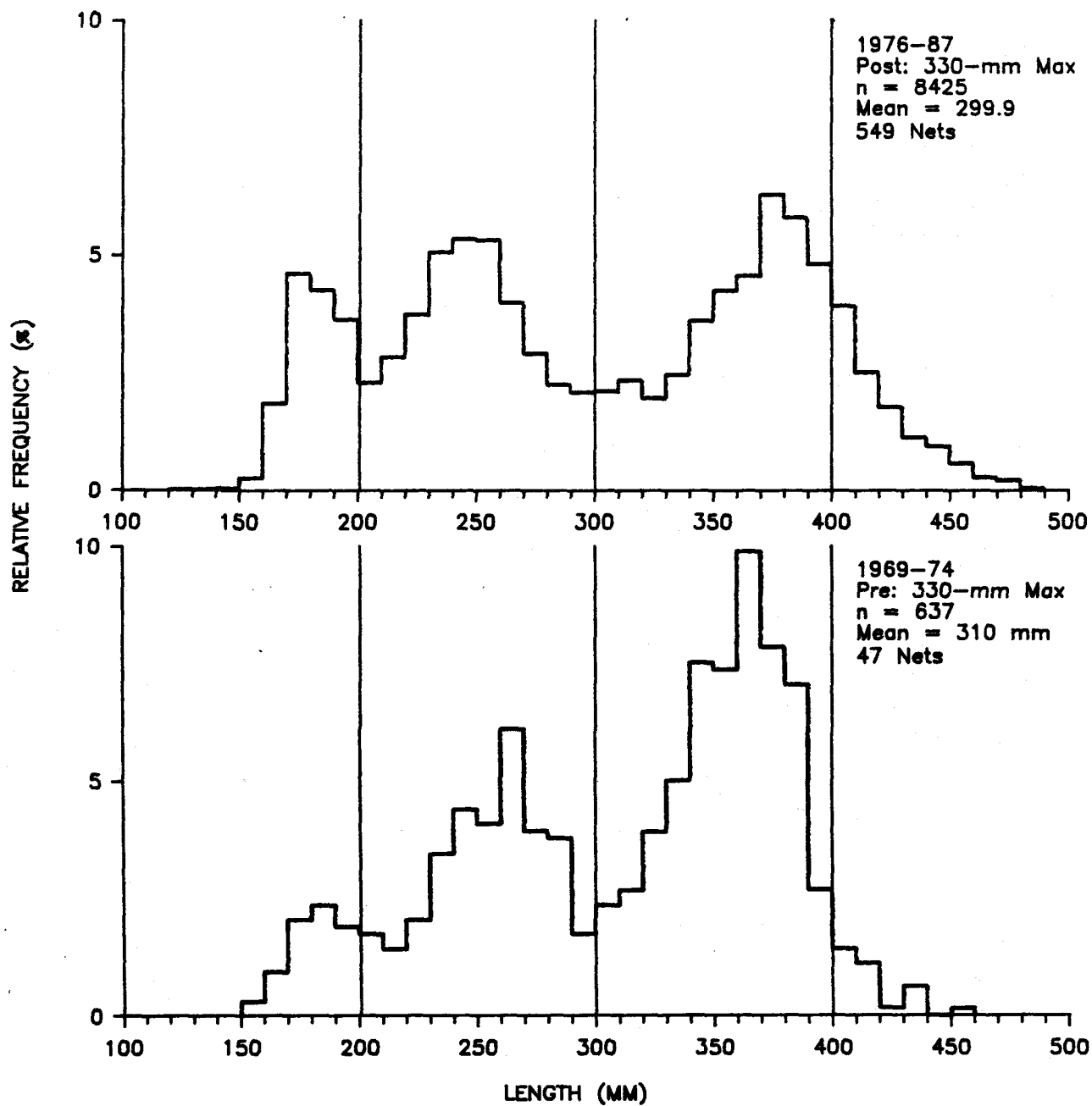


FIGURE 10.-Length frequencies of cutthroat trout captured in largemesh gillnets at the 1.5-4.6 m depth interval in Yellowstone Lake, 1969-1987. (excluding 1981).

annual variations affecting numbers captured may also affect variations 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 (Gresswell and Varley 1988). It would be more beneficial, therefore, to channel future effort to further describing the relationship between the two species.

Conclusions

It appears that the 330-mm maximum-size limit is accomplishing the objective of increasing the proportion of older and larger cutthroat trout in Yellowstone Lake. Historic size data and current estimates utilizing the Walford line (Ricker 1975) suggest a maximum of 11 age groups prior to modern angler exploitation.

Since Ricker (1963) has stated that exploitation as low as 5% annually may significantly alter a pristine population, the cutthroat trout population may never reach historic levels under current regulations. 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 lengths of trout landed in the fishery and prespawners captured in fall-set gill nets are among the greatest yet recorded (Figures 6 and 8). Fecundity estimates suggest that current reproductive potential in Clear Creek is five times greater than it was during the 1950s (Jones et al. 1985).

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, landing rate has been excellent, averaging 0.93 trout/h since 1975. Continued decrease in creel rates during this period may be related to the decline in the proportion of cutthroat trout between 206 and 330 mm observed in largemouth gill nets; however, increased popularity of catch-and-release fishing may also contribute to the decline in rate of harvest.

The biological response to altered harvest patterns associated with the 330-mm maximum-size regulation is not completely understood at present, but harvesting trout prior to maturity shifts fishing mortality to life stages that 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 and are beyond the legal limit within one growing 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 trout population. Fishing closure or "no kill" (catch-and-release) regulations would undoubtedly provide maximum protection; however, the 330-mm maximum-size limit not only provides substantial protection, but allows a daily creel limit that satisfies most 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 the Yellowstone Lake fishery during the first 13 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. Future increases in angler use may affect the cutthroat trout population despite the protection afforded under the current regulation. Continued research is essential to the evaluation of the 330-mm maximum-size limit, especially under higher levels of use.

CUTTHROAT TROUT SPAWNING ACTIVITY IN YELLOWSTONE LAKE TRIBUTARIES AT GRANT VILLAGE

Grant Village is one of the largest developments in Yellowstone National Park. Situated on the southwest shore of the West Thumb of Yellowstone Lake, it occupies an area of approximately 3.75 km². Major visitor services include a ranger station, visitor center, gas station, general store, restaurants, motel-style lodging, and a campground. Sightseeing, picnicking, day-hiking, bicycling, boating, and angling are popular recreational activities. Housing for National Park Service and concessionaire employees is also located in the area.

Conflict between humans and wildlife is a major concern of the National Park Service in Yellowstone National Park. In Grant Village, the potential for human-bear conflict is high in May, June, and July. During these months, cutthroat trout *Salmo clarki bouvieri* spawn in streams that flow through the area (Hoskins 1974, 1975; Jones et al. 1986, 1987), and bears prey on spawning trout (Hoskins 1974, 1975; Reinhart and Mattson 1987).

The National Park Service is attempting to minimize the potential for human-bear conflict in Grant Village by managing human use in the area during the cutthroat trout spawning season. Effective management requires the development of guidelines for determining an opening date for the Grant Village Campground and the appropriate extent of human access to the streams. During the spawning season, the potential for bears to enter the campground increases. Because other facilities in the Grant Village area are popular, encounters between people and bears can also occur in the vicinity of streams even when the campground is closed.

Information concerning cutthroat trout spawning and bear activity patterns is essential to accomplish these goals. Hoskins (1974, 1975) and Jones et al. (1986, 1987) identified spawning streams in the Grant Village area, and Jones et al. (1987) collected limited information on the timing of spawning migrations. Hoskins (1974, 1975) and Reinhart and Mattson (1987) reported on bear activity in the area.

In 1987, a study was initiated to develop simple, yet reliable, procedures for monitoring annual cutthroat trout spawning migrations in the Grant Village area. Methods were evaluated to determine onset, peak periods, and duration of spawning runs; estimate the relative magnitude of runs; and map spawner distribution. Relationships between streamflow, water temperature, and migration patterns were also investigated.

Study Area

Five streams flow through the Grant Village area before entering Yellowstone Lake (Figure 11). Big Thumb Creek borders Grant Village on the north; it is the largest stream and the only perennial stream in the area. Stream 1167 and Sandy Creek lie in the immediate area of the 433-site campground. Stream 1165 enters the lake east of the visitor lodging area, and Sewer Creek borders Grant Village on the southeast. Cutthroat trout spawn annually in Big Thumb Creek, Stream 1167, Sandy Creek, and Sewer Creek but only occasionally in Stream 1165 (Hoskins 1974, 1975; Jones et al. 1986, 1987).

Methods

Cutthroat trout spawning was monitored from May through June 1987. Because Stream 1167 and Sandy Creek lie in the immediate vicinity of the campground and Sewer Creek is near a concessionaire housing area, sampling efforts were concentrated on these three streams. Big Thumb Creek was not sampled because most spawning occurs in areas that are not used extensively by humans (USFWS unpublished data). Stream 1165 was not evaluated because spawners did not enter this stream in 1985, 1986, or 1987 (Jones et al. 1986, 1987).

To detect the onset of spawning, daily visual observations of Stream 1167, Sandy Creek, and Sewer Creek began on 1 May. Once spawning commenced, visual counts were used to monitor spawning runs and examine spawner distribution. Spawner counts were made between 1200 and 1800 hours to maximize comparability between streams.

Each stream was longitudinally stratified into 100-m long sample sections. Weekly, observers walked from the stream mouth upstream as far as spawners were found and counted the number of spawners in each sample section. Sample-section counts were summed to obtain instantaneous counts for each stream.

From early May through mid-June, stream discharges were measured weekly using the midsection method (Buchanan and Somers 1969). Subsequently, streamflows declined to a point where this technique was not applicable. Discharges were then measured using the formula:

$$Q = (\bar{w})(\bar{d})(\bar{v})$$

Q = discharge (m^3/s);

$\bar{w}$ = mean stream width (m);

$\bar{d}$ = mean water depth (m);

$\bar{v}$ = mean water velocity (m/s);

where $\bar{w}$ and $\bar{d}$ were measured directly, and $\bar{v}$ was estimated by the color-velocity method (Hamilton and Bergerson 1984).

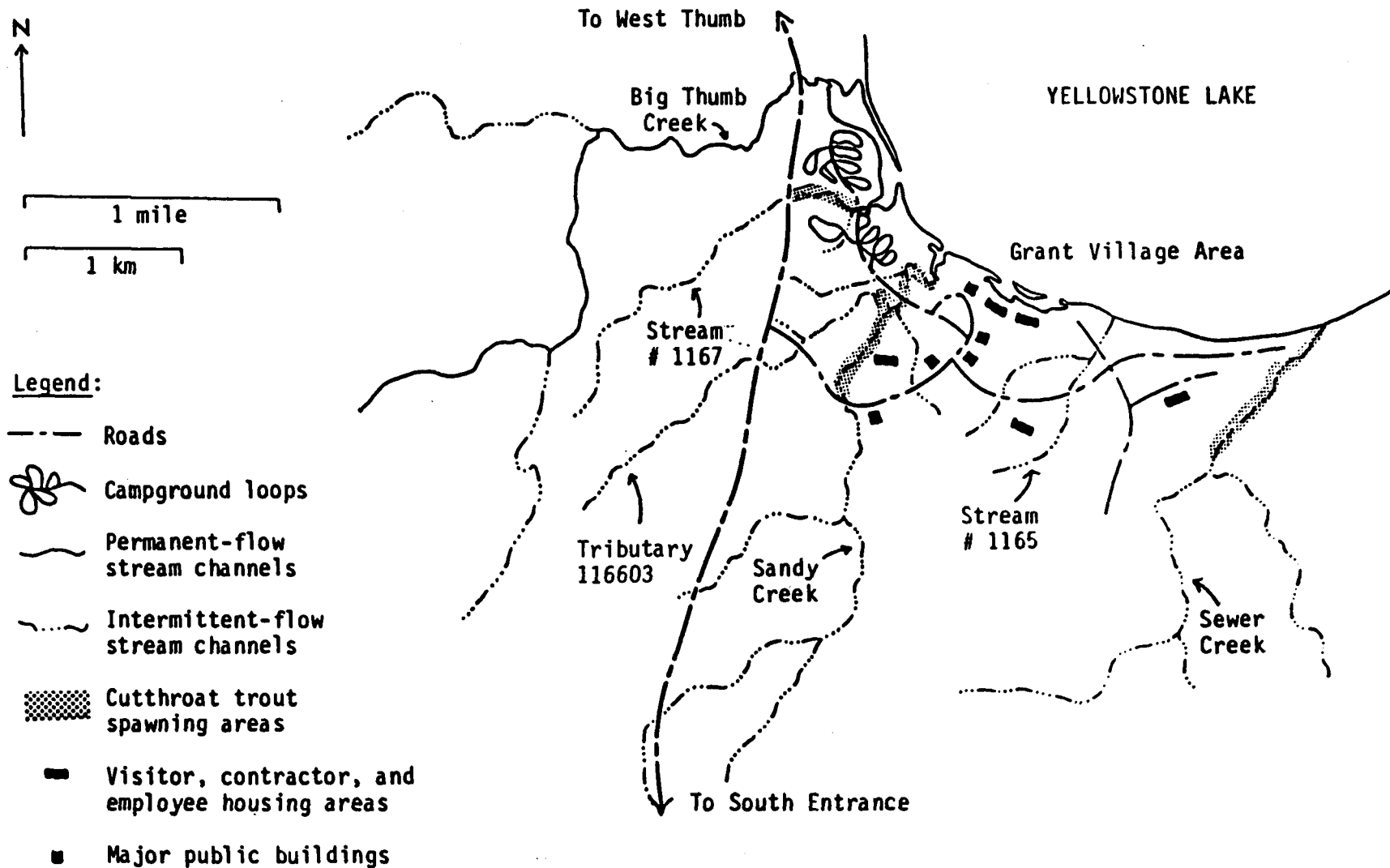


FIGURE 11.-Grant Village area showing major roads, stream channels, buildings, campground loops, housing areas, and cutthroat trout spawning areas.

Staff gages and maximum-minimum thermometers were read each day between 1000 and 1800 hours. Stage-discharge equations were developed (Linsley et al. 1982; Hamilton and Bergerson 1984) to predict daily flows. Daily mean water temperatures were calculated by averaging daily temperature maxima and minima.

Results

Cutthroat trout began spawning in Stream 1167 and Sandy Creek during the week of 3 May and in Sewer Creek about 1 week later. Spawner numbers peaked in Stream 1167 on 18 May, in Sandy Creek on 25 May, and in Sewer Creek on 1 June. Spawning lasted about 8 weeks in Stream 1167 and Sandy Creek, and approximately 7 weeks in Sewer Creek. All three spawning runs ended in late June (Figure 12).

Spawning began as streamflows declined from high spring runoff levels and water temperatures approached 8 to 10°C. Similar relationships between the onset of spawning and streamflow and water temperature have been found in other Yellowstone Lake tributaries (Cope 1957b; Jones et al. 1978-1981). No clear relationships were apparent between peak spawning periods and streamflow or water temperature patterns. All three spawning runs ended when streamflows declined to near zero levels.

In each stream, cutthroat trout spawned within 2 km of the stream mouth. Spawners in Stream 1167 used an 800-m long section between the stream mouth and the South Entrance Road (Figure 11). A circular, steel culvert at this point prevented further upstream migration. Most spawners in this stream were found from 100 to 400 m above the stream mouth (Figure 13).

In Sandy Creek, cutthroat trout spawned in the mainstem and in a small tributary (Stream 116603) that enters the mainstem about 1100 m upstream from the stream mouth. Mainstem spawners used a 1900-m long section between the stream mouth and the entrance road to Grant Village (Figure 11). A steel culvert located at the entrance road appeared to be passable by fish, but suitable spawning habitat upstream of the road was very limited. Most mainstem spawners were found between 300 and 1100 m above the stream mouth (Figure 14). In Stream 116603, only the lower 300 m was used (Figure 11). A small, natural waterfall located at the head of this section probably acts as a partial barrier to upstream fish passage, and suitable spawning habitat upstream of this point is scarce.

Cutthroat trout spawners in Sewer Creek were distributed from the stream mouth to a point about 1200 m upstream (Figure 11); however, spawners congregated between 200 and 700 m upstream of the stream mouth (Figure 15). No obvious barriers to fish passage existed at the upstream limit of spawning; thus, some unknown factor must have limited distribution.

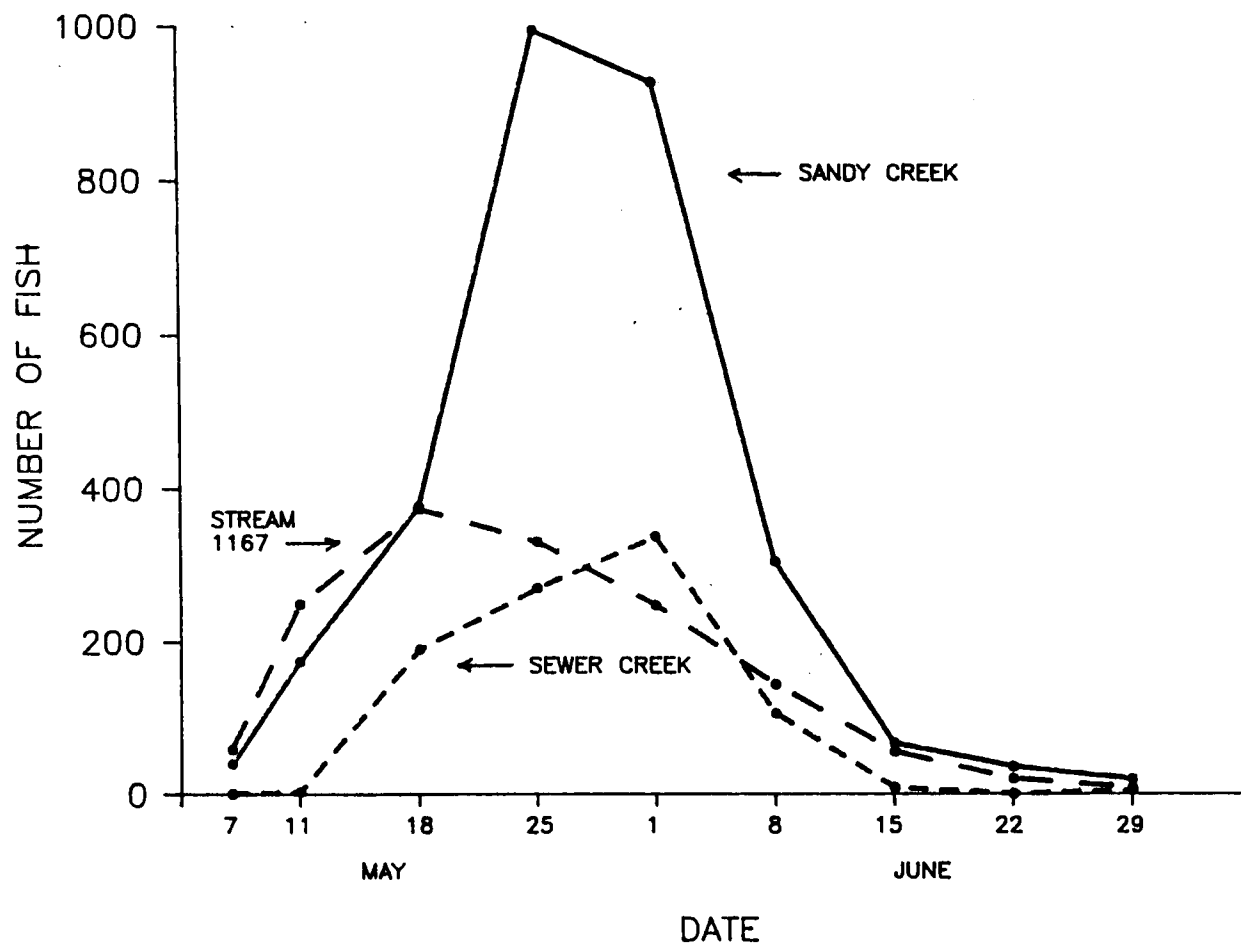


FIGURE 12.-Weekly counts of cutthroat trout spawners in Stream 1167, Sandy Creek, and Sewer Creek, 1987.

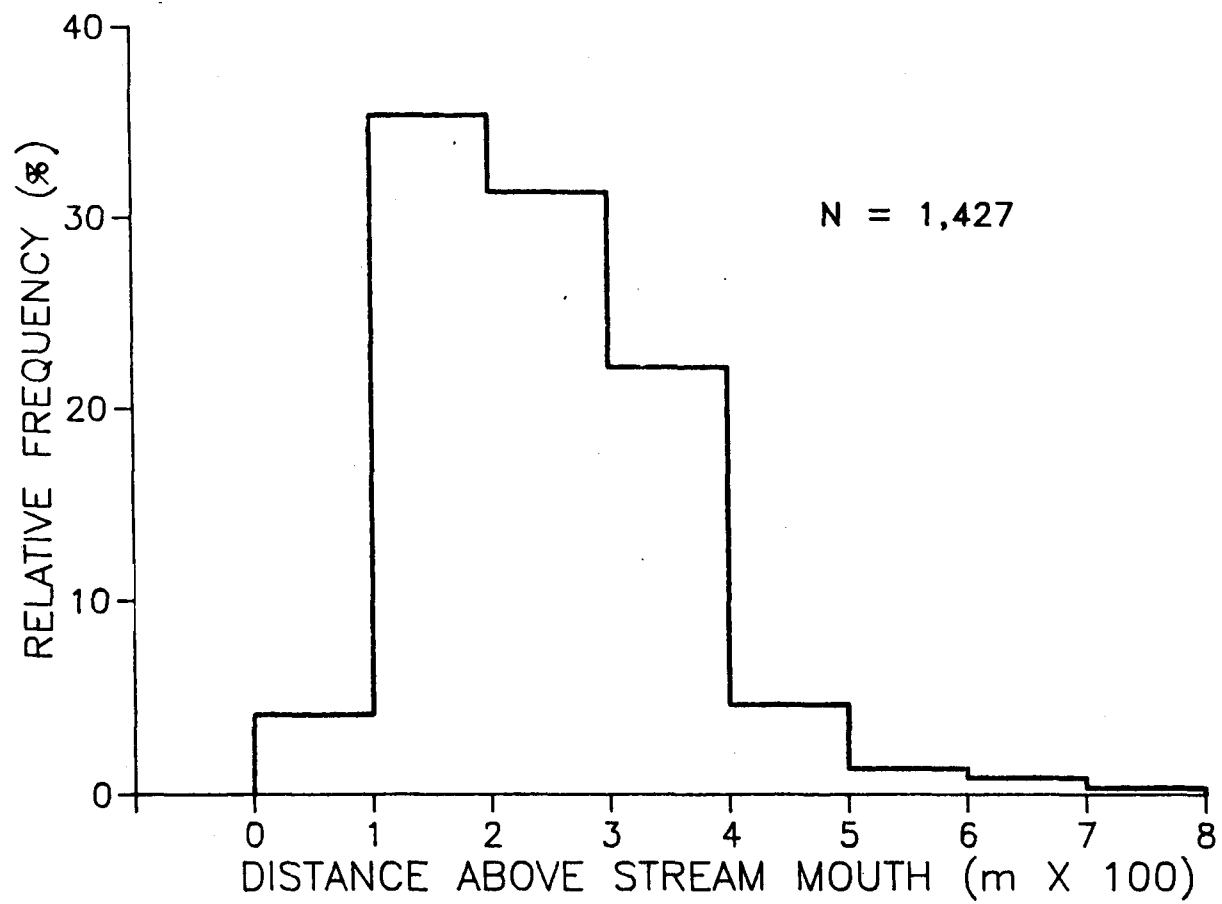


FIGURE 13.-Distribution of cutthroat trout spawners in Stream 1167, 1987.

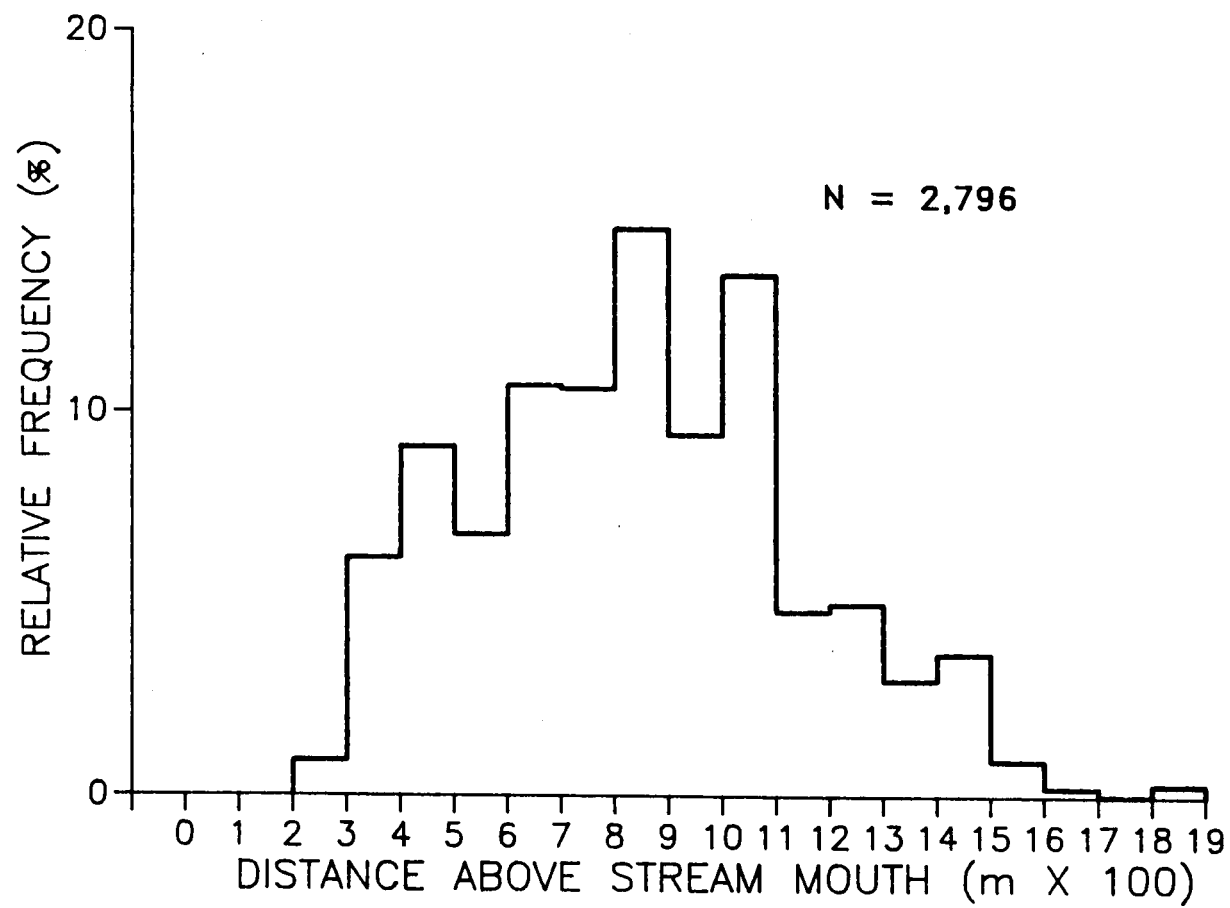


FIGURE 14.-Distribution of cutthroat trout spawners in Sandy Creek, 1987.

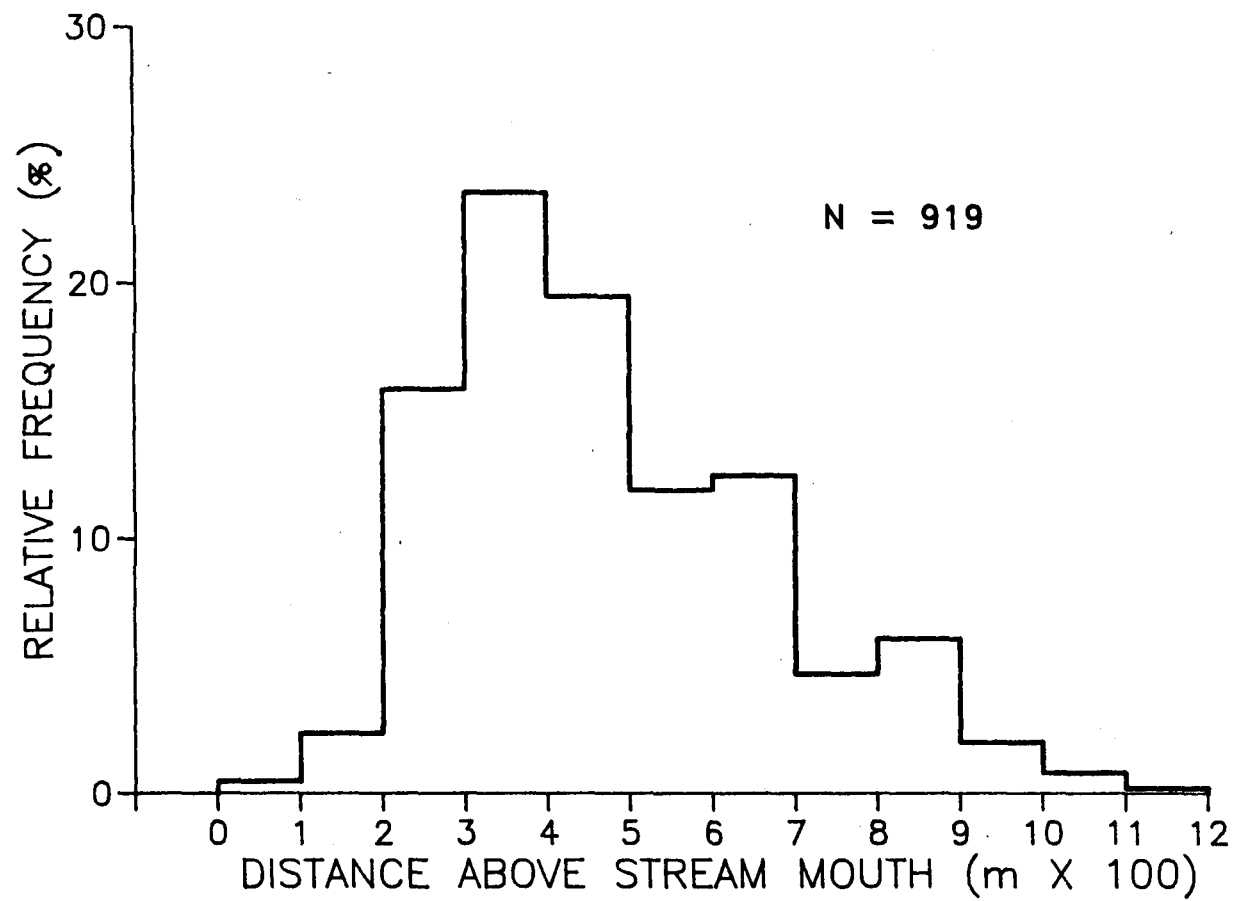


FIGURE 15.-Distribution of cutthroat trout spawners in Sewer Creek, 1987.

Weekly counts indicated that the largest spawning migration occurred in Sandy Creek (Figure 12). Numbers of spawners using Stream 1167 and Sewer Creek appeared to be similar (Figure 12). During peak spawning periods, spawners often congregated in pools, and superimposition of redds commonly occurred.

Discussion

Procedures used to monitor cutthroat trout spawning in Stream 1167, Sandy Creek, and Sewer Creek detected onset, peak period, and duration of spawning migrations; provided a relative index of spawning run magnitude; and allowed mapping of spawner distribution. Data indicated that discharge and water temperature affected onset of spawning. Additionally, streamflow may limit spawning run duration in these three streams. Factors affecting peak spawning periods remain unknown.

Data collected in this study and in 1986 (Jones et al. 1987) on Stream 1167, Sandy Creek, and Sewer Creek can be used to help minimize potential human-bear conflict in the Grant Village area during the spawning season. Because of annual variation in timing and duration of spawning runs in these three streams (Figure 16), it is not practical to establish an annual date for opening the Grant Village Campground nor to allow unregulated human access to spawning areas. Rather, spawning should be monitored each year.

In years when spawning cannot be monitored, timing and duration of spawning runs may be evaluated by visual observations of streamflow patterns and fish abundance. Even casual observations should provide sufficient information to set a reasonable campground opening date and regulate human use near spawning streams.

Recommendations

Information on cutthroat trout spawning activity in Grant Village streams should aid in setting practical campground opening dates and regulating human use in the area. Recognizing that manpower available to obtain this information is limited, the following recommendations are made for the monitoring program begun in 1987:

- (1) Continue annual monitoring of cutthroat trout spawning in Stream 1167, Sandy Creek, and Sewer Creek. In early May, begin daily checks to detect onset of spawning. Once spawning begins, conduct weekly spawner counts to monitor spawner numbers and document spawner distributions. Conduct weekly counts until spawning ends in all three streams.

- (2) Discontinue collection of streamflow and water temperature data. Although streamflow and water temperature affect timing and duration of spawning, spawner counts alone should be sufficient for annual monitoring of cutthroat trout spawning in these three streams.

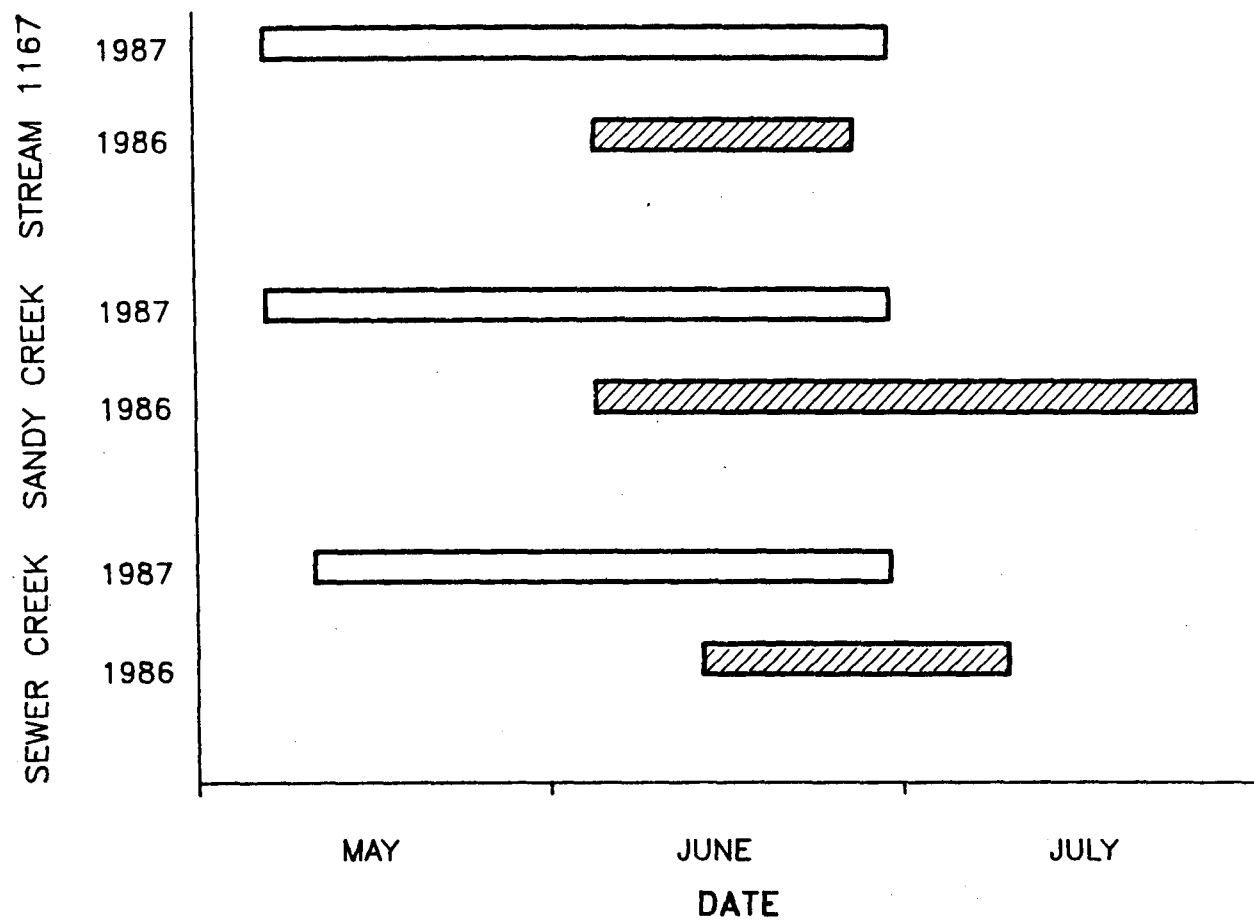


FIGURE 16.-Duration of spawning migrations in Stream 1167, Sandy Creek, and Sewer Creek, 1986 and 1987.

YELLOWSTONE RIVER YELLOWSTONE LAKE OUTLET TO UPPER FALLS

Approximately 14 km (8.8 mi) of the Yellowstone River between Yellowstone Lake and Upper Falls have been managed under a catch-and-release regulation since 1973. This area annually supports over 80% of the total angler use on the Yellowstone River and is the second most popular park fishery. Although there may be some interaction with cutthroat trout *Salmo clarki* from Yellowstone Lake, this area is treated as a discrete fishery.

Fishery research on the Yellowstone River between the lake and the falls dates back to 1950 (Moore et al. 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 1987, studies included a voluntary creel survey utilizing the VAR system (Jones et al. 1977) and continued sampling of spawning trout at LeHardy Rapids.

Angler Use

In 1987, angler use on this segment of the Yellowstone River (52,820 angler days) increased to the highest level yet reported. An estimated 18,550 anglers spent 147,800 h and captured 109,850 cutthroat trout. Approximately 280 of these trout were illegally creeled. Landing rate (0.74 trout/h) dropped to the lowest level since 1972 (Table 12).

When the upper and lower portions of the area were examined separately, the upper section (Yellowstone Lake outlet to Sulphur Caldron) (9.8 km) sustained 93% of the angler use for the entire area (49,000 angler days or 5,000 angler days/km). A total of 16,900 anglers captured 104,400 trout while expending 139,700 h of effort. Landing rate was 0.75 trout/h.

The number of angler days in the lower section (Alum Creek to Upper Falls) (3,750 angler days or 840 angler days/km) increased 5% from 1986. Approximately 1,650 anglers expended 8,000 angler hours. Although effort is much lower in this section, landing rate was only 0.67 trout/h. Expanded results indicate that of 5,400 landed trout, none were illegally creeled.

Average size of landed cutthroat trout for the entire section of the Yellowstone River between the lake and the falls was 394 mm (15.5 in). Landed trout from the upper portion were significantly larger than those from the lower section (396 and 356 mm, respectively). Mean length of creeled trout for the entire area was 341 mm.

Approximately 80% of the anglers were satisfied by their overall experience, 69% were satisfied with numbers

TABLE 12.-Creel survey summary, Yellowstone River between Fishing Bridge and Chittenden Bridge, 1951-1955, 1967-1968, 1970, 1972, 1973-1987^a.

		Angler days	Mean length angler day	Angler hours	Landing rate	Total trout landed	Creel rate	Total trout creeled	Angler days per mile	Angler days per acre	Angler hours per acre	Mean angler expertise ^c	Percent trout landed and released ^d	Average length trout landed (mm)
4.2 Fish creel limit ^e No size limit Bait fishing permitted	1951-1955 Average	45,430	1.97	89,500	f	f	0.41	36,700	2.800	99	195	-	f	f
3 Fish creel limit No size limit Bait fishing permitted	1967-1968 Average	44,300	2.00	88,625	f	f	0.43	38,100	4.600	167	334	-	f	343 ^g
3 Fish creel limit 14" Minimum size limit Bait fishing prohibited	1970-1972 Average	45,120	1.87	84,700	0.74	62,500	0.18	14,825	4.700	170	318	-	76.2	373 ^g
Catch and release	1973	25,000	2.35	58,750	1.74	102,200	0.01		2,900	106	250	-	99.4	363
Lures and flies only	1974	23,900	2.31	55,700	2.25	124,200	0.01		2,700	102	235	-	99.9	366
Bait fishing prohibited	1975	27,900	2.48	69,200	2.04	141,100	0.01		3,200	119	295	-	99.5	368
	1976 ^h	30,900	2.45	75,700	1.43	108,200	0.01		3,600	132	322	2.00	99.8	373
	1977 ^h	26,900	2.44	65,600	1.43	93,900	0.02	420	3,100	114	279	1.98	99.6	373
	1978	26,300	2.50	65,700	1.23	80,800	0.02	320	3,000	112	280	1.99	99.6	384
	1979	28,900	2.60	75,300	1.10	82,800	0.02	580	3,300	123	320	2.02	99.3	389
	1980	34,900	2.44	85,100	1.06	88,700	0.02	880	4,000	148	362	2.04	99.0	389
	1981	48,800	2.60	126,800	1.00	127,100	0.01	260	5,600	208	540	2.01	98.6	391
	1982	35,200	2.46	86,600	1.10	95,400	0.02	370	4,000	150	369	2.00	98.5	396
	1983	39,300	2.61	102,400	1.06	109,000	0.01	160	4,500	167	436	1.98	99.8	396
	1984	44,500	2.56	114,000	0.96	109,000	0.02	1,100	5,100	189	485	2.00	97.7	401
	1985	36,600	2.72	99,400	0.91	90,500	0.02	240	4,200	156	423	2.02	98.4	401
	1986	43,900	2.73	119,700	1.00	119,700	0.01	50	5,000	187	509	2.05	100.0	396
	1987	52,800	2.80	147,800	0.74	109,800	0.01	280	6,100	225	629	2.03	99.7	394

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

^b 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 area open was 8.7 miles and 235 acres.

^c Based on formula: 1.0 = inexperienced, 2.0 = experienced, 3.0 = expert.

^d Illegal beginning in 1973.

^e 3 years of 5 fish creel limit plus 2 years of 3 fish creel limit.

^f Not measured.

^g Based on data from creeled trout.

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

landed, and 85% were satisfied with size of fish landed. Levels of satisfaction decreased from 1986, but estimates remain well above most park fisheries (Table 4). The proportion of single day anglers landing one or more trout was 66%; average expertise remained high at 2.05.

LeHardy Rapids

Catch-and-release angling was implemented on the Yellowstone River between Fishing Bridge and Upper Falls in 1973 (Dean et al. 1974). Annual monitoring of cutthroat trout migrating through LeHardy Rapids was initiated in 1974 (Dean et al. 1975) to evaluate the effects of this regulation on cutthroat trout population structure. Sampling techniques established by Dean et al. (1975) have been followed each year, except for scale samples, which are collected in the manner described by Varley et al. (1976).

In 1987, cutthroat trout migrating through LeHardy Rapids were sampled weekly between 19 May and 23 June. Cutthroat trout spawned early in this area of Yellowstone National Park in 1987 in response to mild spring weather (see Clear Creek and Grant Village spawning surveys, this report); thus, it is possible that only the latter portion of the migration was sampled. However, it is also possible that the relatively low discharge of the Yellowstone River in 1987 allowed more fish to ascend mid-channel rapids and thus reduced sampling efficiency. In any case, the small sample size obtained in 1987 may bias comparisons with previous years.

A total of 33 cutthroat trout were captured at LeHardy Rapids in 1987. Mean lengths of all adults (400 mm), males (407 mm, n=21), and females (389 mm, n=12) were among the highest ever reported (Table 13)(Figure 17). The percentage of trout exceeding 406 mm in length (36.4%) was also among the greatest on record (Figure 17). Average age of an expanded sample of 29 trout (5.9 years) was only slightly less than the record high of 6.1 years reported in 1986 (Figure 17).

Increases in mean length, the percentage of fish greater than 406 mm in length, and average age have been observed in most years since 1974 (Figure 17). The general trend towards larger and older fish suggests that the catch-and-release regulation substantially reduced angler-caused mortality and has had a positive impact on cutthroat trout populations in this section of the Yellowstone River.

Conclusion

Angler use and effort have increased steadily since the catch-and-release regulation was implemented in 1973. Despite a precipitous decline in use after this regulation

TABLE 13.-Mean length, weight, and condition of cutthroat trout captured by dip net at LeHardy Rapids, Yellowstone River, 1974-1987.

Year	Adult Males				Adult Females				All Adults			
	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 ^a	177	375	394	0.75	244	352	339	0.78	453	362	363	0.76
1975	338	385	451	0.78	426	359	363	0.78	775	370	401	0.78
1976 ^a	531	384	431	0.75	423	362	360	0.75	964	375	399	0.75
1977 ^a	133	382	429	0.77	111	362	370	0.78	245	373	402	0.77
1978	399	386	458	0.78	358	364	413	0.85	759	376	437	0.81
1979	334	394	514	0.83	237	371	431	0.84	571	385	480	0.83
1980	293	391	488	0.81	190	372	418	0.80	483	384	460	0.81
1981	383	394	496	0.80	188	373	440	0.84	571	387	478	0.82
1982	327	401	517	0.80	367	380	474	0.86	694	389	494	0.83
1983	338	402	546	0.83	232	380	276	0.86	570	394	517	0.84
1984 ^b	321	408	539	0.79	199	386	477	0.82	526	399	515	0.80
1985 ^b	269	408	554	0.82	161	391	513	0.85	431	402	539	0.83
1986 ^b	279	405	565	0.84	316	388	503	0.85	596	396	532	0.85
1987	21	407	586	0.84	12	389	520	0.88	33	400	562	0.86

^a 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.

^b Six adults in 1984, one adult in 1985, and one adult in 1986 were not identified to sex.

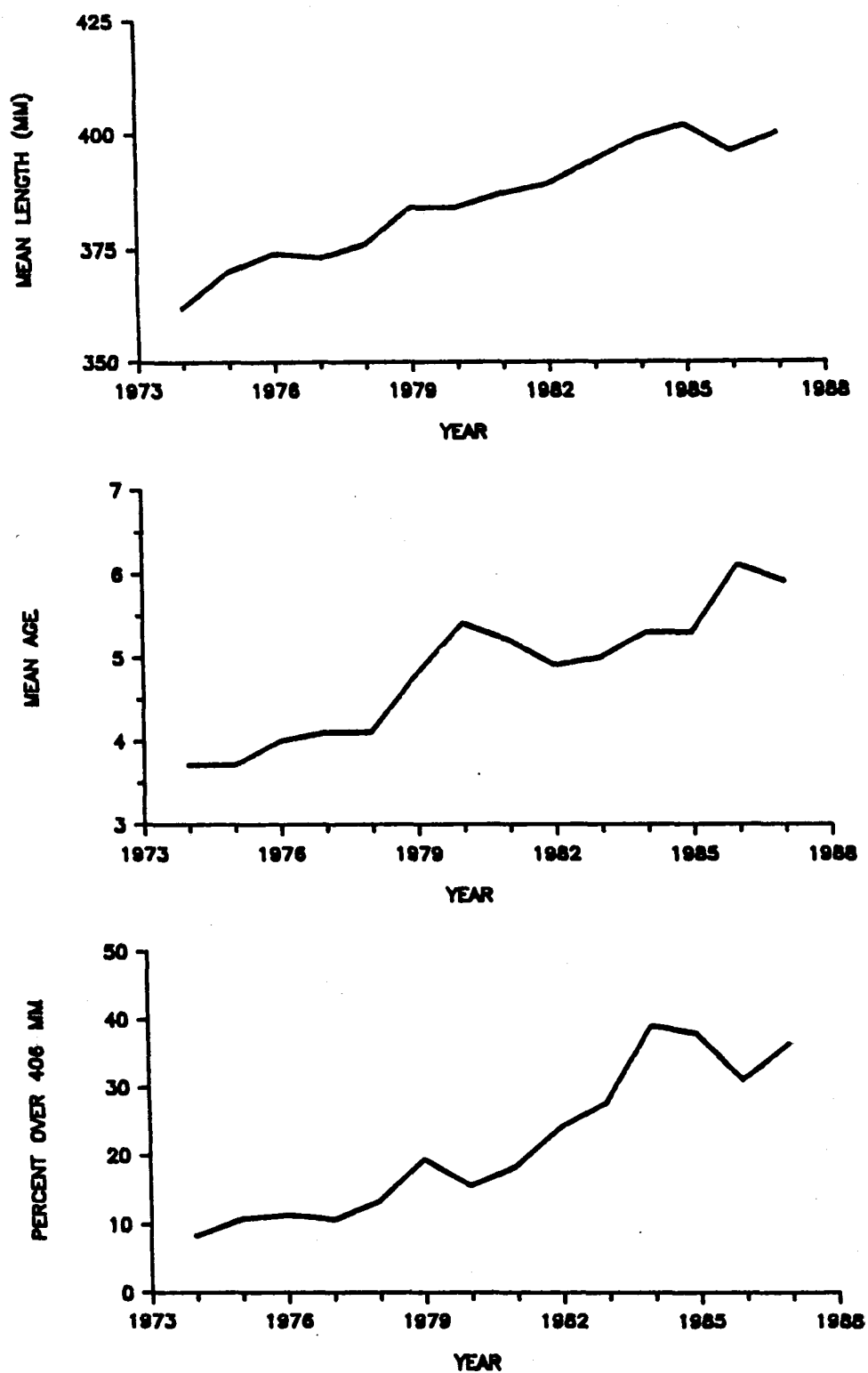


FIGURE 17.-Mean length, mean age, and percentage of cutthroat trout spawners greater than 406 mm (total length) captured at LeHardy Rapids, 1974-1987.

was initiated, current levels remain high (Table 12). These figures equated to 3,770 angler days/km (6,100 angler days/mi), or 557 angler days/hectare (225 angler days/acre) in 1987. According to these data, this portion of the Yellowstone River sustains the highest level of use in the park and is probably one of the most intensively fished wild trout fisheries in North America. Angler effort per unit area on this section of the river in 1987 (1,557 angler hours/hectare or 629 angler hours/acre) was the highest yet recorded (Table 12).

Increasing use and effort have affected the landing rate in this section of the Yellowstone River. As effort declined after implementation of catch-and-release, landing rate more than doubled and rose to a high of 2.25 trout/h in 1974 (Figure 18). As effort increased, landing rates gradually declined. Despite record levels of effort, however, landing rate remained over 0.90 trout/h until 1987. Reasons for the sudden decline are unknown, but the observed decrease may be related to the early runoff and spawning season.

Regardless of increases in effort and concomitant decreases in landing rate, size structure of the population has been moving toward historic proportions. Length-frequency analysis of cutthroat trout captured in the spawning run at LeHardy Rapids reveals a definite shift towards larger trout (Figure 17). A general rise in average age has accompanied the increase in size at LeHardy Rapids. Mean length of cutthroat trout landed by anglers also indicates a substantial increase in larger trout since 1973 (Figure 18).

Although there is an inverse relationship between effort and landing rate, changes in population structure may also have influenced landing rate. As biomass shifts toward older and larger trout, the total number of trout will probably decrease (Nikolskii 1969). The interaction of these two factors (increases in effort and shifts in structure) may continue to lower landing rates in the future.

Hooking mortality and recatchability are critical to the success of the catch-and-release regulation. Schill et al. (1986) reported hooking mortality of 0.3% on a per capture basis, or 3% of the total population for sample sections between the lake outlet and Sulphur Caldron in 1981.

Recatchability of cutthroat trout is evidenced in these estimates. Comparison of total landings for the 4.5-km study area in the upper portion of the catch-and-release section (72,700 cutthroat trout) and population estimates for the same segment (3,125 trout/km) suggested that trout were captured an average of 9.7 times during the 45-day study period (Schill et al. 1986). This figure emphasizes the value of the catch-and-release regulation and

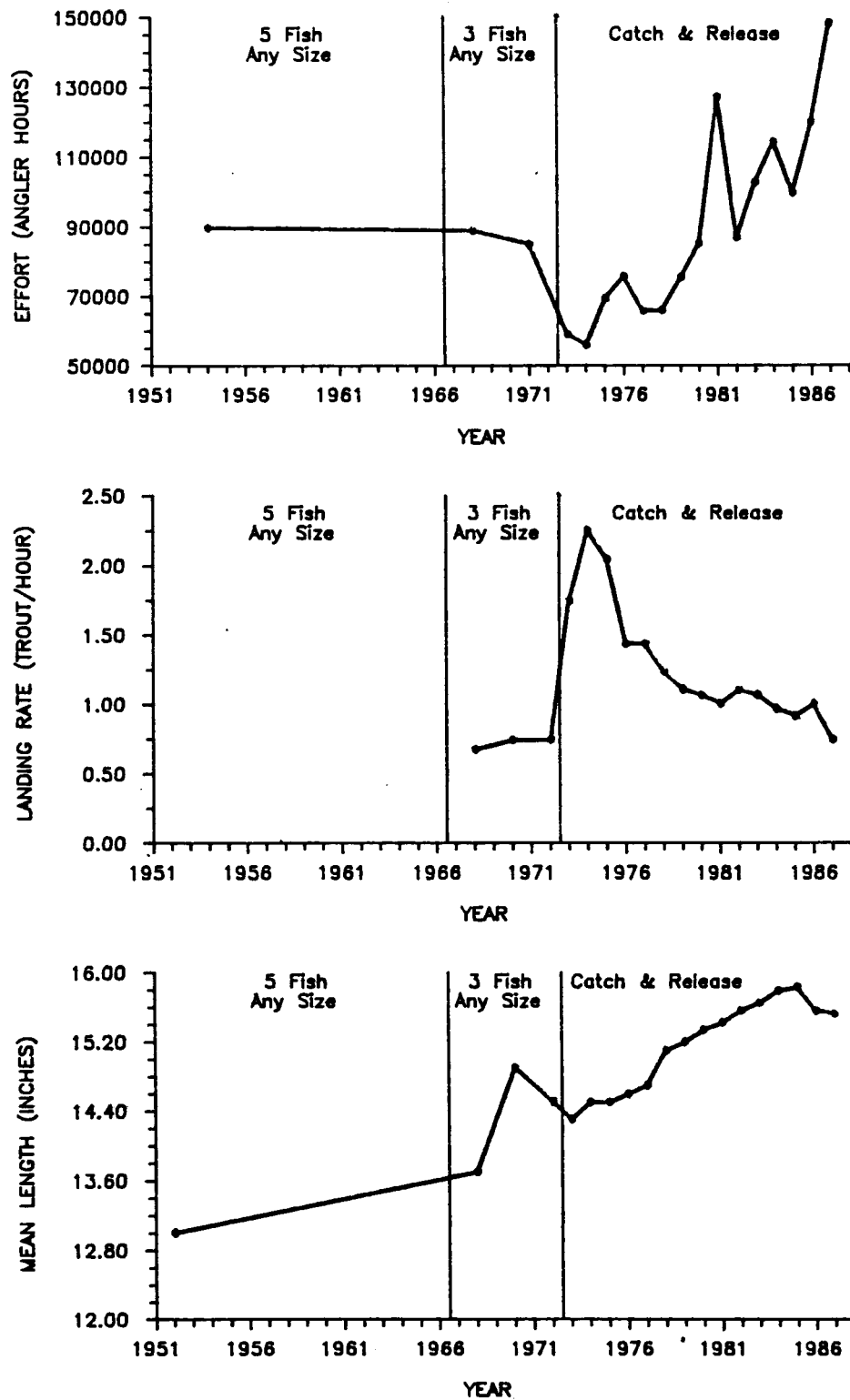


FIGURE 18.-Angler effort, landing rate, and mean length of landed trout, Yellowstone River between the Yellowstone Lake outlet and the Upper Falls, 1951-1987.

illustrates how such a regulation can support high levels of effort on a cutthroat trout fishery.

Although it is possible that effort may rise to a point that the catch-and-release regulation 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 factors are closely related to the species and the habitat involved. The high recatchability of cutthroat trout and excellent habitat conditions in this portion of the Yellowstone River undoubtedly contribute to the continued success of the catch-and-release regulation.

RIDDLE LAKE

Riddle Lake is a moderate size backcountry lake with a surface area of 110.9 hectares. A well-marked trail (3.5-km long) provides easy access from the trailhead located approximately 4 km south of Grant Village on the South Entrance Road. The area is extremely popular for day use, but overnight camping was prohibited beginning in 1985.

The cutthroat trout *Salmo clarki* is native to Riddle Lake and was the only species present historically. Currently both longnose suckers *Catostomus catostomus* and reidside shiners *Richardsonius balteatus* also inhabit the lake. It is assumed that the cutthroat trout and nonnative species originally gained entry from Yellowstone Lake via Solution Creek.

Lake surveys conducted in 1970 and 1971 described physical and chemical properties of the lake and presented data concerning the fish population under the 356-mm minimum-size (2-fish creel) regulation in effect at that time (Dean 1972). The regulation changed to a 356-mm maximum-size limit in 1974, but creel limit remained unaltered. In that year, the lake was resurveyed in order to determine the method of recruitment for the cutthroat trout population and to evaluate angler response to the new regulation (Dean et al. 1975). The size limit was changed again in 1975 to coincide with the 330-mm maximum-size regulation on Yellowstone Lake. A fourth gillnetting survey conducted in 1981 indicated that the 330-mm maximum-size limit had failed to provide adequate protection for the cutthroat trout in Riddle Lake (Jones et al. 1982). Since the recommended catch-and-release regulation could not be initiated, the lake was closed to all sport angling in 1982.

Results of a gillnetting survey conducted in 1983 indicated that the cutthroat trout population had continued to decline (Jones et al. 1984). Lack of Volunteer Angler Report (VAR) data because of the angling closure limited the means of evaluating changes in the Riddle Lake cutthroat trout population. An increase in the number of gill nets was recommended in order to improve documentation and interpretation of current trends. A similar recommendation was made after a subsequent survey was conducted in 1984 (Jones et al. 1985). Some increase in cutthroat trout density was noted, but restoration of this species in Riddle Lake was not proceeding rapidly. Continued protection from sport angling was suggested.

Results from a survey conducted in 1986 were similar to those observed since 1981 (Jones et al. 1987). Mean number of cutthroat trout per gill net declined, but mean length increased slightly. At the same time, the number of longnose suckers remained far above those observed prior to 1981; mean length of longnose suckers continued to increase. Although the reasons for the apparent decline of cutthroat

trout were unclear, the fact that Riddle Lake has been closed to angling since 1982 suggested that angler harvest was not a factor in trends observed since that time. A catch-and-release-only regulation was recommended. This regulation would maintain protection for the cutthroat trout, and reinstating angling would provide an additional data source.

Riddle Lake remained closed to angling in 1987. Studies attempted to evaluate the current status of the cutthroat trout population and determine if the angling closure should be continued.

Methods

Because of apparent declines in cutthroat trout density and mean size, a nonlethal sampling technique was sought for use in Riddle Lake during 1987. Electrofishing was logistically impractical in Riddle Lake, therefore, project personnel attempted to collect samples by angling. Six anglers fished for 3.5 h each on 17 June and five anglers averaged 4.7 h each on 14 July. All cutthroat trout were measured to the nearest millimeter total length, and scales were collected from each individual for age determination. All fish were returned to the lake after processing.

Results

A total of 25 cutthroat trout were captured in the two samples. Overall landing rate was 0.56 trout/h, and mean length of landed fish was 331 mm (Table 14). Mean age was 4.6 years, and 89% of the captured cutthroat trout were age-4 or older (Table 15). Backcalculated lengths for 21 trout were 60, 131, 204, 271, 316, and 338 mm for age-1 through -6, respectively (Table 16); five cutthroat trout lacked a first-year annulus (Laakso 1955).

Because small fish are less vulnerable to angling than to capture in largemesh gill nets, the mean length of the angler-captured cutthroat trout is not directly comparable with gillnetting data collected from 1970 to 1986. Current data are comparable with previous VAR data, however, because they are both based on angler returns.

Angler landing rate estimated by the VAR varied annually between 1973 and 1981 (Figure 19), and the 9-year mean was 0.72 trout/h. Current landing rate for experimental angling (0.56 trout/h) was lower than the mean from the VAR but within the previously observed range of values. Mean length of captured cutthroat trout (331 mm) was significantly different from the mean length reported prior to the angling closure (348 mm). The current value, however, represents an increase from the last 2 years the lake was open to angling (Figure 19).

TABLE 14.-Cutthroat trout samples from Riddle Lake, 1970-1987.

Year	Number of nets ^a		Total number captured	Length (mm)			Weight (g)			Mean K Factor
	Largemesh	Smallmesh		mean	n	range	mean	n	range	
1970 ^b	3	0	50	298	50	175-415	264	50	56-604	0.86
1971 ^b	3	1	63	308	63	90-455	298	63	6-836	0.91
1974 ^c	3	2	77	261	77	117-420	221	77	12-600	0.89
1981 ^d	2	1	35	189	29	75-282	79	29	6-182	0.90
1983 ^e	2	1	13	250	13	138-332	150	13	112-322	0.83
1984 ^f	2	1	25	217	25	140-326	120	24	21-321	0.85
1986 ^g	2	1	22	228	22	156-337	120	20	37-310	0.81
1987	Angling		25	331	25	223-365				

^a 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.

^b Dean 1972.

^c Dean et al. 1975.

^d Jones et al. 1982.

^e Jones et al. 1984.

^f Jones et al. 1985.

^g Jones et al. 1987.

TABLE 15.-Age frequency (by percentage) of cutthroat trout captured in Riddle Lake, 1971-1987.

Year	Sample size	Percentages in each age						Mean age (years)
		I	II	III	IV	V	VI	
1971 ^a	19	5	11	26	53	5		3.4
1983 ^b	13	15	23	62				2.5
1984 ^b	24	42	25	17	17			2.1
1986 ^b	22	0	48	16	27	9		3.0
1987	24	0	0	4	30	54	4	4.6

^a Dean 1972.

^b Jones et al. 1987.

TABLE 16.-Backcalculated total length at annulus formation of cutthroat trout captured in Riddle Lake, 1971-1987.

Year	Sample size	Annulus					
		I	II	III	IV	V	VI
1971 ^a	19	61	130	221	297	351	
1974 ^b	41	66	132	183	249	312	
1983 ^c	13	65	163	235			
1984 ^c	21	63	152	236	298		
1986 ^c	17	56	124	171	251	293	
1987	21	60	131	204	271	316	338

^a Dean 1972.

^b Dean et al. 1975.

^c Jones et al. 1987.

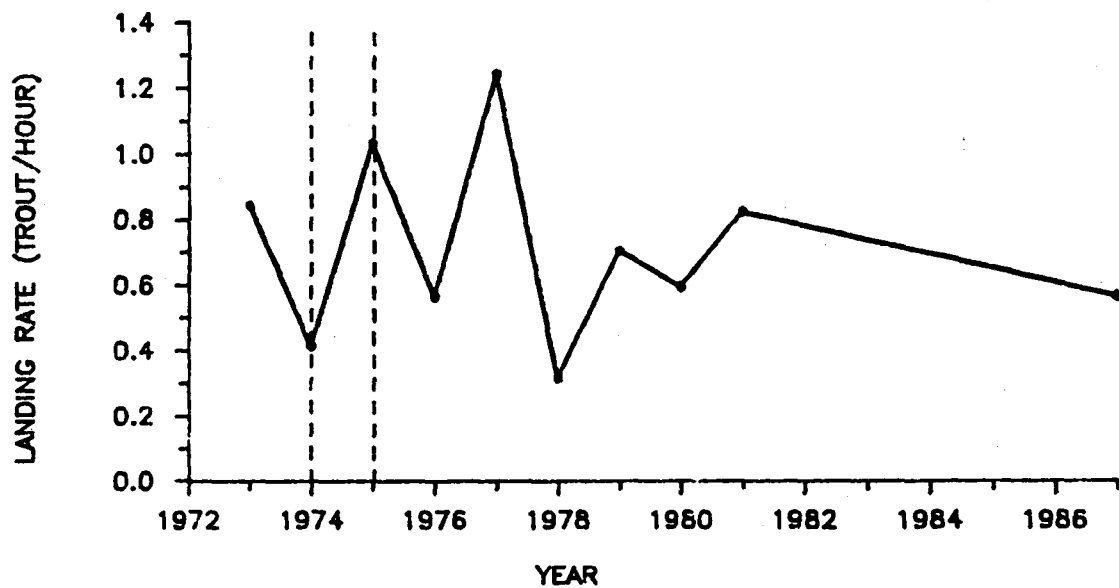
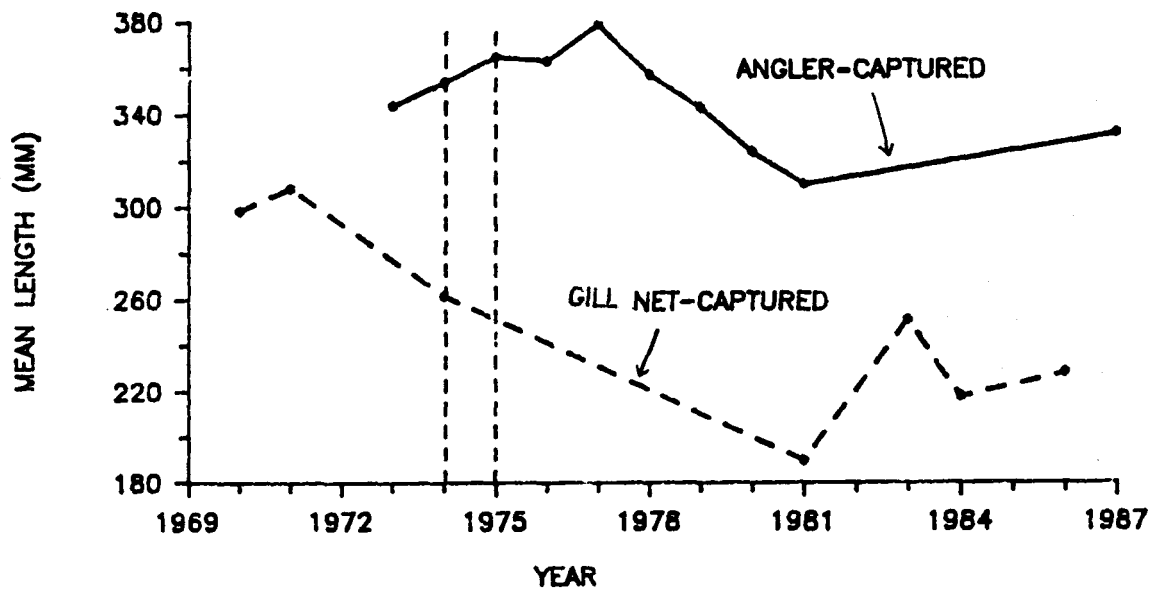


FIGURE 19.-Mean length of cutthroat trout captured in gill nets (1969-1986) and by anglers (1973-1987), and landing rate of angler-captured cutthroat trout, Riddle Lake.

In order to increase comparability of length data, the length-categorization system introduced by Anderson (1976) and modified by Anderson and Weithman (1978) and Gabelhouse (1984) (see Largemesh Gillnetting section, this report) was applied to the Riddle Lake data. Since the world record cutthroat trout reported by Gabelhouse (1984) was uncharacteristic of this species in Yellowstone National Park, the park record for cutthroat trout, a 660-mm specimen from Heart Lake, was used to determine minimum lengths for stock, quality, and preferred size categories (153, 254, and 330 mm, respectively). The resulting comparisons of proportional stock density (PSD) and relative stock density-preferred (RSD-p) vary concomitantly with changes in mean length (Figure 20). Although the proportion of larger trout (> 330 mm) observed in the early 1970s has not been approached in recent years, length data from gill nets and angling suggest that proportion of fish between 254 and 330 mm has not declined as rapidly.

Discussion

Expected increases in cutthroat trout density and improvement in population structure have not been observed since Riddle Lake was closed to angling in 1982. Although some increases in mean length and relative density (measured by catch per unit effort) have been noted in the past 2 years, changes have been less dramatic than those noted in other areas in Yellowstone National Park that are under restrictive angling regulations (see Yellowstone Lake and Yellowstone River, this report).

Longnose suckers have apparently increased in Riddle Lake while cutthroat trout densities declined; however, a causal relationship has not been established (Jones et al 1987). Studies in Yellowstone Lake have failed to substantiate competition between the two species, but it is possible that the habitat of Riddle Lake might be more conducive to competition; small size, shallow average depth, and low productivity combine to limit fish populations in the lake. On the other hand, the longnose sucker has been aged up to 28 years old in Yellowstone Lake (Jones et al. 1977), and therefore, expansion of the population would be slow (Nikolskii 1969). In Yellowstone Lake, significant increases were first noted 10 to 20 years after routine eradication of sucker spawners was curtailed. The current expansion of suckers in Riddle Lake may be associated with increases in Yellowstone Lake and Solution Creek and thus, coincidental to declines in trout numbers.

Angler use more than doubled between 1975 and 1981 (Jones et al. 1982); however, angling closure eliminated fishing beginning in 1982. This sudden decrease in angler use at Riddle Lake was evident in the decline of overnight use at the four campsites between 1982 and 1984 (Jones et

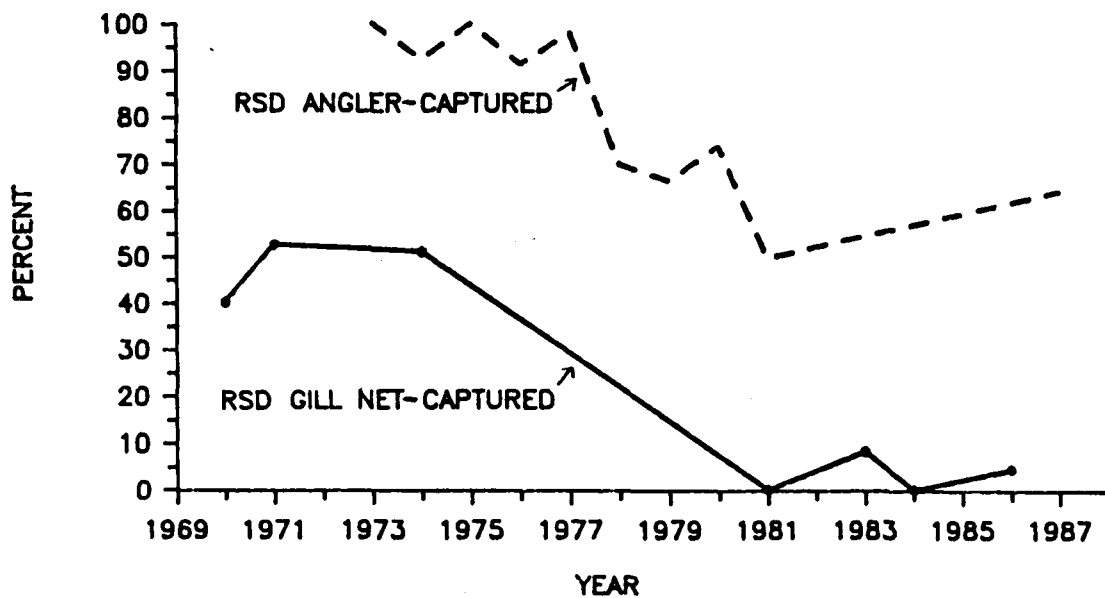
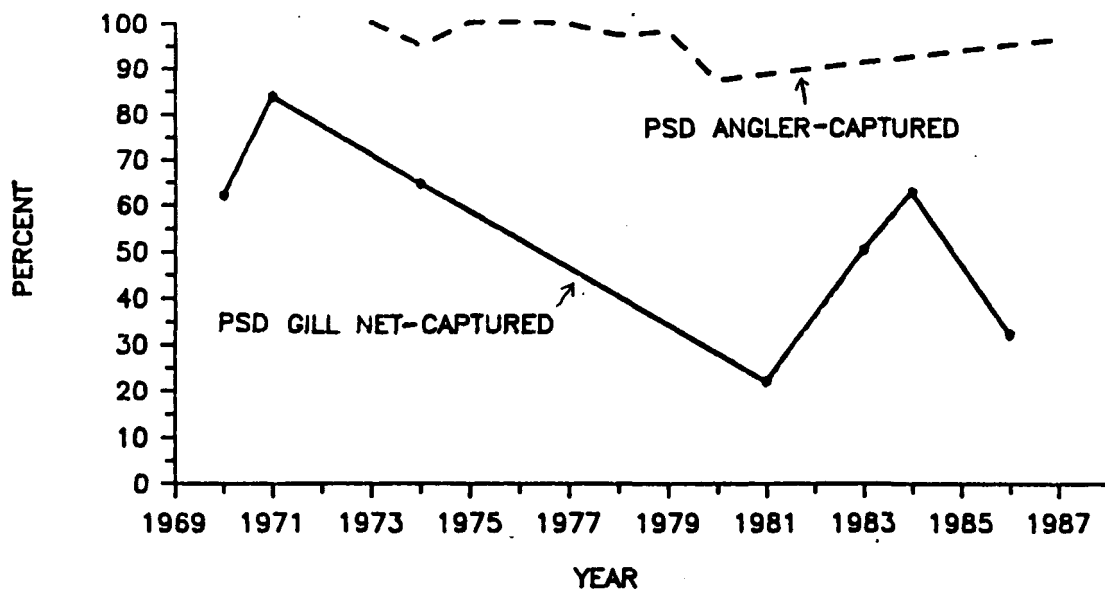


FIGURE 20.-Proportional stock density (PSD) and relative stock density-preferred (RSD-p) values for cutthroat trout captured by anglers and in gill nets, Riddle Lake, 1969-1987.

al. 1985). Overnight use of the area was discontinued in 1985 for bear management purposes. Riddle Lake will reopen to fishing in 1988 under a catch-and-release-only regulation; however, the area will be restricted to day-use only.

Attempts to understand the rather distinct changes that have apparently occurred since the early 1970s have been hampered by the inability to sample effectively. Initiation of the catch-and-release-only regulation in 1988 will provide continued protection to the cutthroat trout, but at the same time, data collected through the VAR will provide an important means of monitoring the cutthroat trout population annually. The potential increase in sample size and frequency is important; additionally, mortality associated with this type of sampling is negligible when compared to gillnetting. Because longnose suckers are not vulnerable to angling with artificial lures and flies, sampling with gill nets will also be necessary to evaluate future changes; however, the availability of VAR data will reduce the necessity for frequent gill-net samples.

SYLVAN LAKE

Sylvan Lake is located 14.2 km from the East Entrance in the headwaters of Clear Creek near Sylvan Pass. Several automobile pullouts and a picnic area provide easy access to this small (11.4 hectares) roadside lake. Ease of access has historically contributed to high levels of angler use for this unproductive subalpine lake.

Yellowstone cutthroat trout *Salmo clarki bouvieri* are native to Sylvan Lake; however, almost 2.6 million cutthroat trout were stocked in the lake from 1913 through 1943 (Varley 1981). Longnose suckers *Catostomus catostomus* were first collected from Sylvan Lake in 1978, and it was assumed that this species gained access through Clear Creek from Yellowstone Lake (Jones et al. 1979).

The creel limit was three fish of any size per day from 1953 to 1972, but beginning in 1973, only two fish per day could be creeled. Catch-and-release regulations were implemented on Sylvan Lake in 1978 because levels of exploitation were no longer compatible with park fishery management objectives (see Introduction; this report). Sylvan Lake remains the only roadside lake in the park under this "no harvest" restriction.

Arnold and Sharpe (1967) conducted the initial survey of Sylvan Lake in 1966. In 1978, the lake was resurveyed to provide baseline data necessary for evaluation of the catch-and-release regulation. A third survey, conducted in 1981, revealed a significant increase in the density of longnose suckers and a decline in cutthroat trout numbers despite the catch-and-release regulation. Trout size structure appeared stable, however, and Volunteer Angler Report (VAR) data indicated a significantly improved landing rate despite increases in angler use.

In 1984, Sylvan Lake was resurveyed for a fourth time. Concern was expressed about the continued decline in the number of cutthroat trout captured per net in gill nets and apparent decreases in older and larger trout in gill nets and VAR data. More comprehensive monitoring of the Sylvan Lake cutthroat trout population was recommended; however, a method of sampling that would not necessitate the removal of additional trout was recommended (Jones et al. 1985).

In accordance with these recommendations, an abbreviated survey was conducted on Sylvan Lake in 1985 (Jones et al. 1986). In addition to the continued evaluation of the cutthroat trout and longnose sucker populations within the lake, a method of population monitoring utilizing electrofishing was developed. Results of the 1985 survey suggested that density of cutthroat trout had actually increased since 1978, but mean length had decreased.

In 1987, cutthroat trout and longnose sucker populations were sampled by electrofishing on 23 July and

11 August. The purpose of this study was to assess the current status of the two species in Sylvan Lake.

Methods

Sampling techniques remained unchanged from 1985 (Jones et al. 1986). Electrofishing from a boat with boom-mounted dropper electrodes (Novotny and Priegel 1974) was used to collect fish in mark and recapture runs. Pulsed direct current (80 pulses/s) was utilized with a voltage between 100 and 200 V. Electrofishing was conducted at night, and sampling was limited to shallow water sections (≤ 1.2 m) of the littoral zone.

During the marking run (23 July), captured fish were measured to the nearest 5 mm total length (TL) and fin-clipped prior to release. The recapture run was conducted on 11 August. Length (nearest 1 mm TL) and weight (nearest 2 g) measurements were obtained from a sample of all fish species; scales were collected from a subsample of these fish for age determination. Remaining fish were measured to the nearest 5 mm (TL). All fish were checked for fin-clips prior to release.

An adjusted Petersen estimate (Ricker 1975), originally proposed by Chapman (1951), was used to estimate fish populations. Confidence limits were calculated utilizing a Poisson distribution (Ricker 1975); sampling bias was estimated according to Robson and Regier (1964). Fish of each species were divided into size-groups, and estimates were calculated separately for each size-group. Totals for each species were determined by adding size-group estimates.

Results

Cutthroat trout

Total length of cutthroat trout ranged from 94 to 405 mm with a mean of 208 mm (Table 17). Mean length of 242 marked trout (211 mm) was significantly greater than mean length of 397 trout in the recapture sample (203 mm). Mean weight and condition factor (K) were 95 g and 0.91, respectively, for 40 trout in the recapture sample; average length in this subsample was 208 mm. The length-weight equation was: $\text{Log } W = 2.7545 (\text{Log } L) - 10.3256$ [GM equation: $\text{Log } W = 2.8056 (\text{Log } L) - 10.5954$].

Age was determined for 43 cutthroat trout using the scale method (Lagler 1956); five of these trout failed to form an annulus at the end of the first growing season (Laakso and Cope 1956). Ages were expanded for 385 trout using an age-length key (Westerheim and Ricker 1978). Mean age was 2.6 years with ages ranging from 1 to 4 years (Table 18). Backcalculated lengths at annulus formation were 64, 137, 202, and 255 mm for age-1 through -4, respectively (Table 19).

TABLE 17.-Results from fishery surveys, Sylvan Lake, 1964 through 1987.

Species	Year	Number of nets ^a		Total number captured	Length (mm)			Weight (g)			Mean K factor
		largemesh	smallmesh		mean	n	range	mean	n	range	
Cutthroat Trout	1964 ^b	-	-	59	239	59	185-300	-	-	-	-
	1966 ^c	2	0	76	242	76	110-365	-	-	-	-
	1978 ^d	2	2	590	177	590	75-330	125	92	16-338	0.96
	1981 ^e	2	1	200	167	190	75-307	81	96	6-216	0.83
	1984 ^f	2	1	132	198	132	88-272	81	132	8-234	0.92
	1985 ^g	electrofishing		933	204	896	80-310	95	91	16-258	1.15
	1987	electrofishing		639	208	616	94-405	95	40	4-302	0.91
Longnose Sucker	1978 ^d	2	2	46	194	40	173-212	96	15	70-118	1.17
	1981 ^e	2	1	123	253	112	125-360	321	77	40-572	1.12
	1984 ^f	2	1	50	294	50	122-387	317	50	22-608	1.12
	1985 ^g	electrofishing		263	162	263	75-435	48	24	22-120	1.36
	1987	electrofishing		227	224	227	60-410	102	14	36-420	1.26

^a 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.

^b Unpublished data collected in 1964; 50 trout captured by electrofishing and 9 trout captured in a single largemesh gillnet.

^c Arnold and Sharpe 1967.

^d Jones et al. 1979.

^e Jones et al. 1982.

^f Jones et al. 1985.

^g Jones et al. 1986.

TABLE 18.-Age frequency (by percentage) of fish captured in Sylvan Lake, 1966-1987.

Species	Year	Sample size	Percentages in each age						Mean age years
			I	II	III	IV	V	VI	
Cutthroat Trout	1966 ^a	9	11	78	11				2.0
	1978 ^b	349	32	47	17	3	<1	<1	1.9
	1981 ^c	161	44	28	25	2	1		1.9
	1984 ^d	132	21	53	26				2.1
	1985 ^e	753	16	28	30	24	2		2.7
	1987	385	2	53	26	18			2.6

^a Arnold and Sharpe 1967.

^b Jones et al. 1979.

^c Jones et al. 1982.

^d Jones et al. 1985.

^e Jones et al. 1986.

TABLE 19.-Backcalculated total length at annulus formation of fish captured in Sylvan Lake, 1966-1987.

Species	Year	Sample size	Annulus					
			I	II	III	IV	V	VI
Cutthroat Trout	1966 ^a	9	96	198	283			
	1978 ^b	67	71	142	202	264	289	290
	1981 ^c	42	58	144	201	229	283	
	1984 ^d	79	64	151	214			
	1985 ^e	45	67	130	193	225	234	
	1987	43	64	137	202	255		

^a Arnold and Sharpe 1967.

^b Jones et al. 1979.

^c Jones et al. 1982.

^d Jones et al. 1985.

^e Jones et al. 1986.

Although sampling methods used to collect trout from Sylvan Lake have differed, similarity in length distribution of trout sampled by gill nets in 1984 and by electrofishing in 1985 suggests that data remain comparable. Current results indicate that the increases in mean length since 1981 (Jones et al. 1985) continued during 1987 (Figure 21). Length-frequency analysis supports this conclusion; the proportion of trout greater than 254 mm is greater than in any year since 1966 (Figure 22). Length-frequency data differ greatly from prior samples and although the influence of sampling technique cannot be ignored, changes may reflect cessation of harvest in 1978. Greatly increased sample size obtained with electrofishing should enhance precision, however, and improve monitoring capabilities.

In order to increase comparability of length data, the length-categorization system introduced by Anderson (1976) and modified by Anderson and Weithman (1978) and Gabelhouse (1984) (see Largemesh Gillnetting section; this report) was applied to the Sylvan Lake data. Since the world record cutthroat trout reported by Gabelhouse (1984) was uncharacteristic of this species in Yellowstone National Park, the park record for cutthroat trout, a 660-mm specimen from Heart Lake, was used to determine minimum lengths for stock, quality, and preferred size categories (153, 254, and 330 mm, respectively). Although mean length of cutthroat trout captured by gillnetting and electrofishing has increased since 1981, both proportional stock density (PSD) and relative stock density-preferred (RSD-p) appear to have declined (Figure 23). The anomalies may be caused by an increase in the number of stock-size cutthroat trout (153-253 mm). An increase in the proportion of cutthroat trout in the upper end of this length interval would cause slight increases in mean length, and additionally, a rise in the proportion of stock-size individuals would cause a decline in PSD and RSD-p values. These data indicate substantial changes in population structure of cutthroat trout in Sylvan Lake since 1978.

Although mean age decreased somewhat in 1987, an increasing trend in mean age since 1978 is evident (Table 18). Backcalculated lengths and growth, however, have not changed greatly during that period (Table 19). Increases in mean age suggest a possible shift towards older trout as a result of reduced harvest under the catch-and-release-only regulation.

Jones et al. (1986) reported that although gill nets were a necessary component of the lake survey program, in smaller lakes (< 20 hectares) electrofishing probably provides a better index of density, causes less mortality, and is directly comparable between years. Additionally, comparison of population estimates calculated from samples collected by electrofishing were more precise than those obtained in 1978 from a study in which fish in the mark sample were collected by electrofishing and those in the

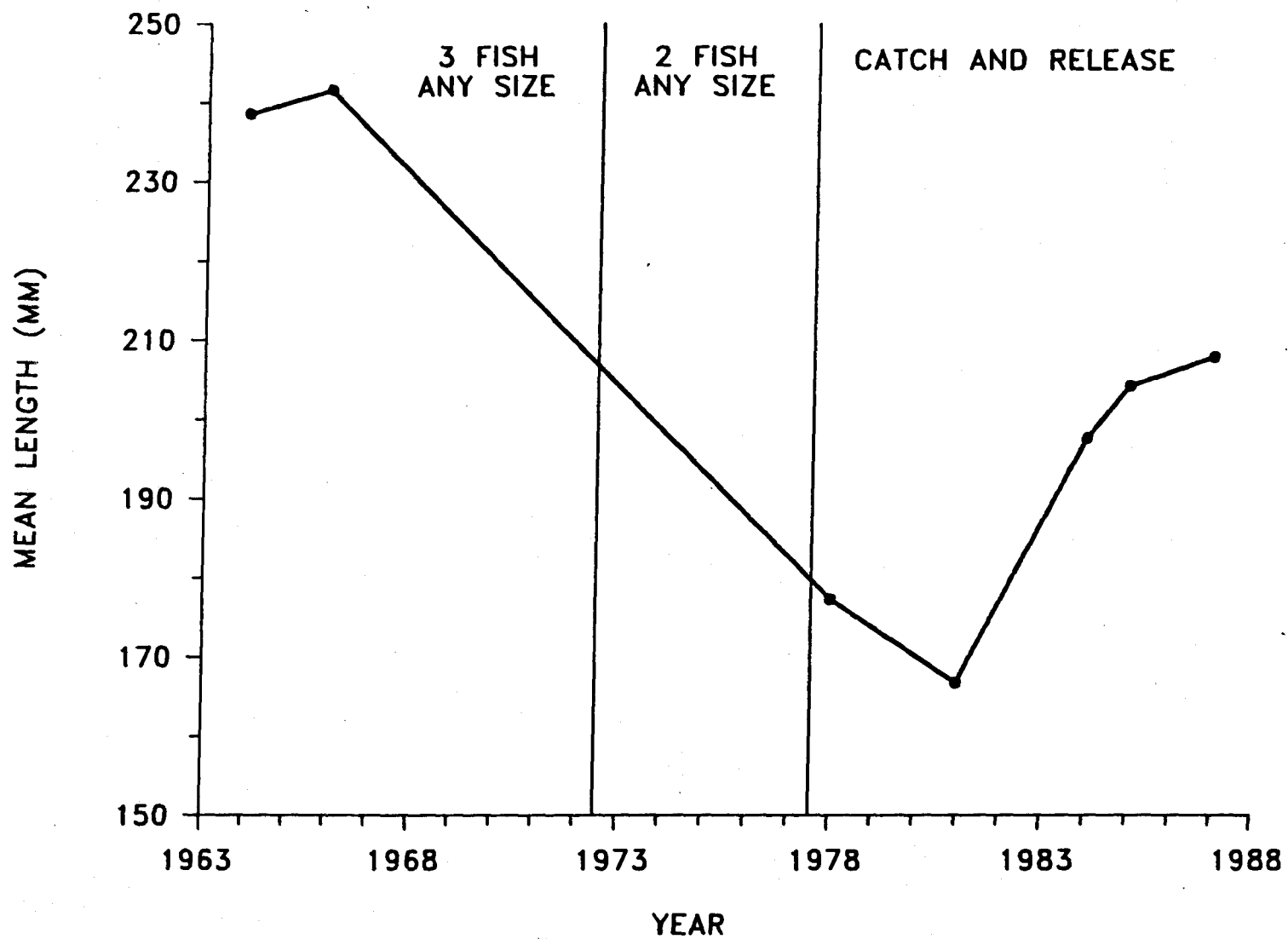


FIGURE 21.-Mean length of cutthroat trout captured in experimental gill nets (1966, 1978, 1981, and 1984) and by electrofishing (1964, 1985, and 1987), Sylvan Lake.

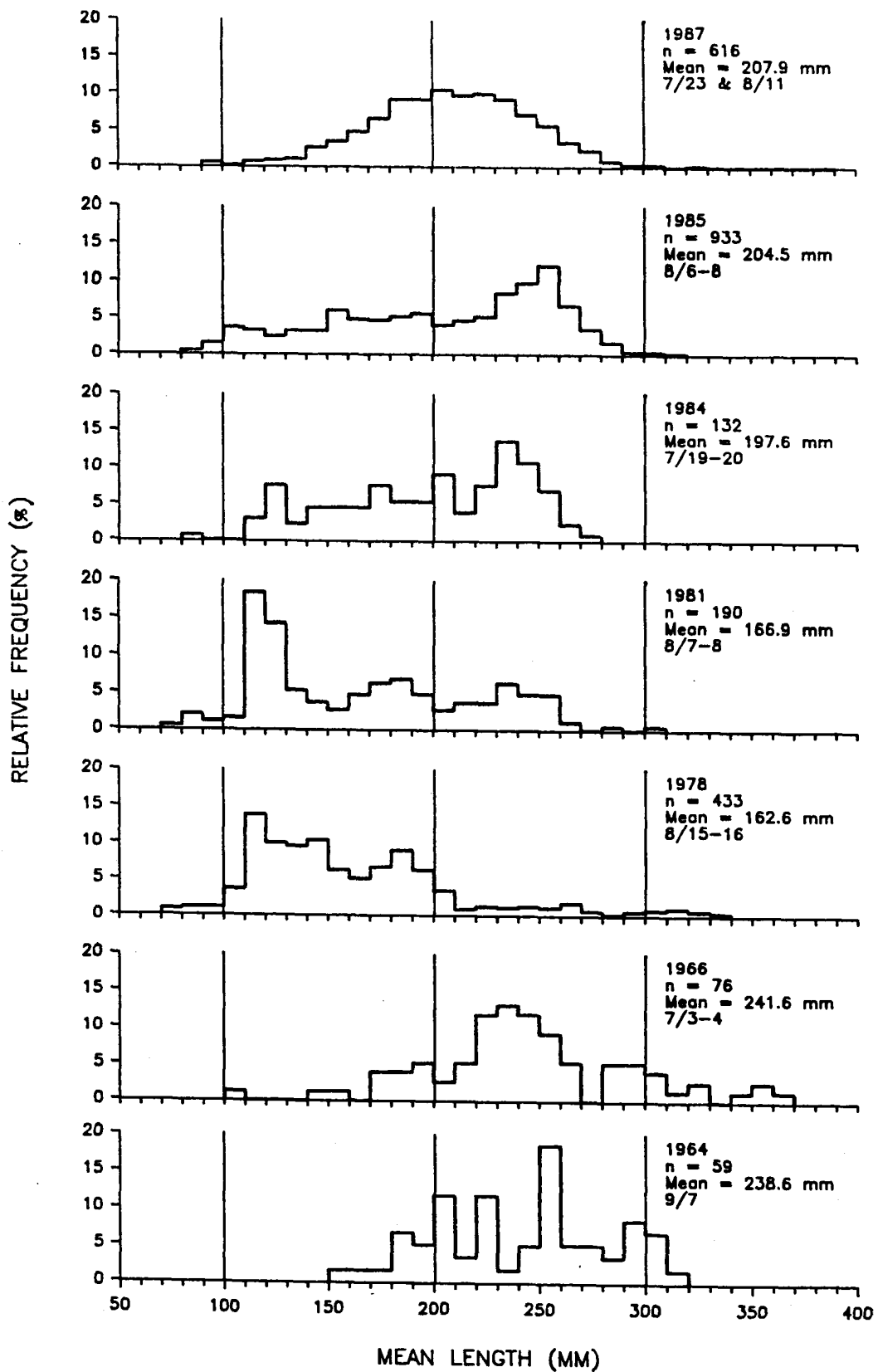


FIGURE 22.-Length frequency of cutthroat trout captured in experimental gill nets (1965, 1978, 1981, and 1984) and by electrofishing (1964, 1985, and 1987), Sylvan Lake.

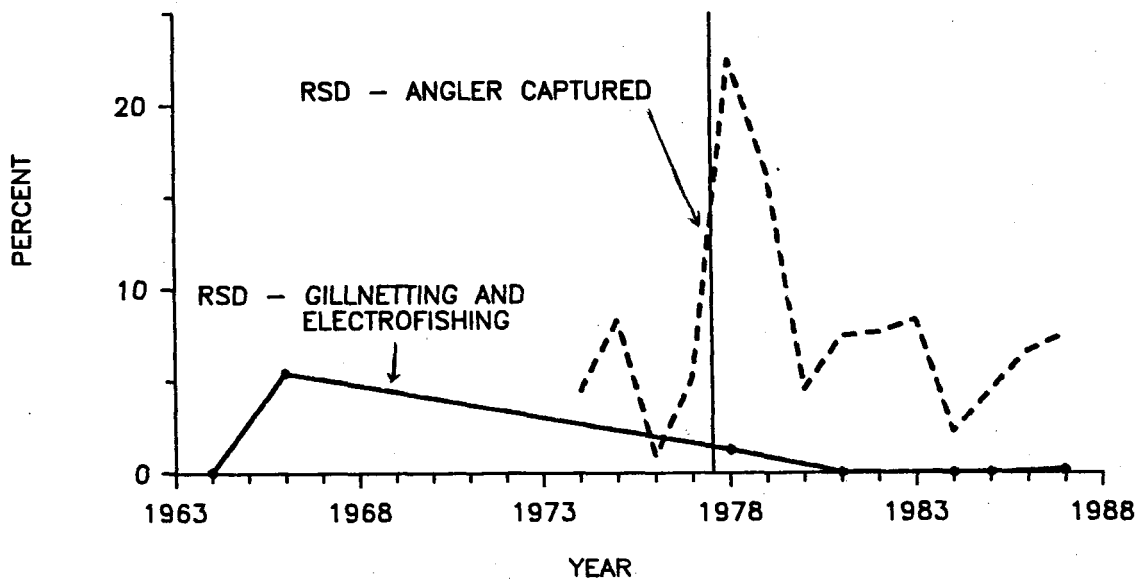
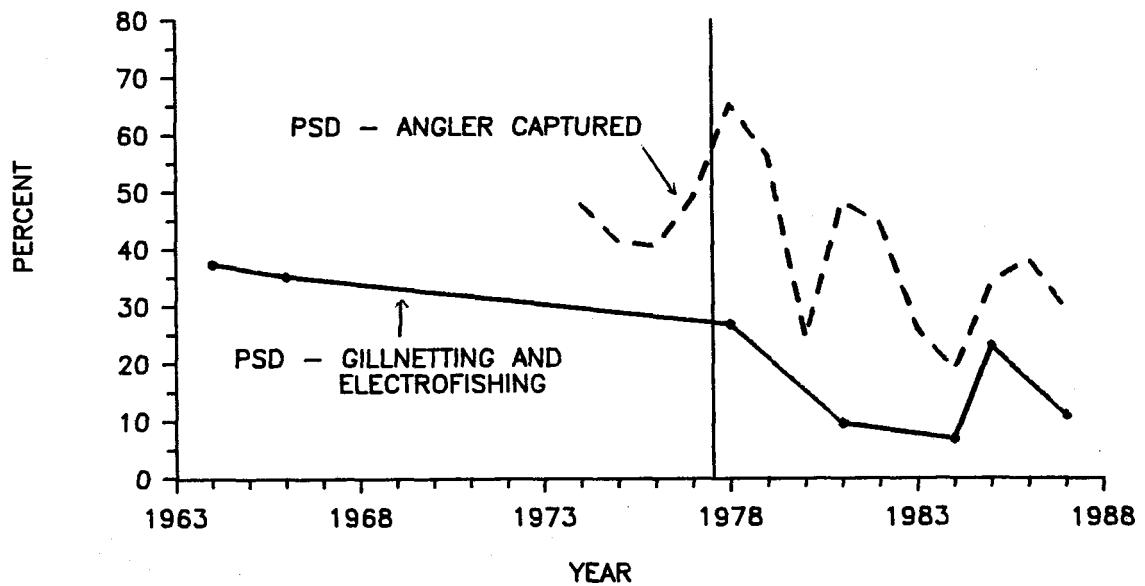


FIGURE 23.-Proportional stock density (PSD) and relative stock density-preferred (RSD-p) for cutthroat trout captured by angling and by gillnetting and electrofishing, Sylvan Lake, 1964-1987.

recapture sample were captured in gill nets (Jones et al. 1986).

In 1987, population estimates were calculated separately for 40-mm length groups in order to maintain comparability with 1985 data. Estimates could not be made for several length categories because of insufficient sample size (Table 20). Estimates were statistically biased (Robson and Regier 1964) for the 130-mm size group, but all other estimates were statistically unbiased. Total population estimate for the sample area (3,720 cutthroat trout) was derived by summing estimates for the various length intervals. A separate estimate calculated from pooled mark and recapture samples yielded 4,030 trout; upper and lower confidence limits were 6,624 and 2,811, respectively.

The sample area in Sylvan Lake covered approximately 27% (3.1 hectares) of the entire surface area. Total biomass of cutthroat trout (322.1 kg) was calculated by multiplying the population estimate for each size interval by the mean weight of fish in the interval. Biomass of trout inhabiting the sample area, therefore, equated to 104 kg/hectare.

Although current estimates suggest a slight decrease in total numbers since 1985 (4,240 cutthroat trout > 80 mm), they are within calculated confidence intervals, and differences may be due to sampling error. Most importantly, there is no evidence of substantial change in population numbers since 1985. It is possible that numbers have declined somewhat in response to slight increases in mean length, but current techniques are probably not sensitive enough to detect such subtle changes.

Longnose Suckers

Mean total length of captured suckers was 224 mm with a range of 60 to 410 mm. Mean weight of 14 suckers in the recapture sample was 102 g, and mean K factor was 1.26 (Table 17). The length-weight equation was $\log W = 2.6798 (\log L) - 9.6850$ [GM equation was $\log W = 2.7141 (\log L) - 9.8214$].

It appears that mark-recapture estimates did not provide a suitable index of relative density of longnose suckers in Sylvan Lake. None of 227 marked suckers were recaptured, and a population estimate was not attempted. Very few suckers (30) were collected during the recapture run.

Comparisons using number of suckers per net from gill nets set in Yellowstone Lake have been unsuccessful due to the variability between nets (Jones et al. 1984). It is doubtful, therefore, that gill nets provide useful estimates of relative density in backcountry lakes where sample sizes are generally smaller. Although mean lengths and size

TABLE 20.-Population estimates^a for cutthroat trout captured by electrofishing shallow (<3 m depth) littoral areas, Sylvan Lake, 1987.

Size class (mm)	Mean length (mm)	Number marked (M)	Number sampled (C)	Number recaptured (R)	Population estimate	Confidence limits		Efficiency ^b (%)
						upper	lower	
90	23	2	14	0	N/A			
130	155	39	40	3	410 ^c	2.733	186	7.7
170	191	68	157	5	1.817	6.814	932	7.4
210	228	97	136	10	1.221	2.857	730	10.0
250	262	33	47	5	272	1.020	139	15.2
290	304	2	3	0	N/A			
370	408	1	0	0	N/A			
Total					3.720			

^a Adjusted Petersen estimates $(M+1)(C+1)/R+1$ (Ricker 1975).

^b R/M (Ricker 1975).

^c Estimate is statistically biased (Robson and Regier 1964).

distribution data may be more comparable, past attempts to utilize this type of data for suckers have also been unreliable (Jones et al. 1984). Size structure and the appearance of sexually mature suckers indicate that longnose suckers have become permanently established in Sylvan Lake, however, and this species appears to be reproducing successfully.

Angler Use

The VAR provides angler use and creel data for Sylvan Lake dating back to 1974. Arnold and Sharpe (1967) had no creel survey records but estimated annual use ranging from 500 to 1,000 angler days. Current data indicate that use levels averaged about 955 angler days during the 4 years prior to the catch-and-release regulation and then dropped to 559 angler days in 1978 (the first year of the new regulation). Angler use rose to a record high of 1,451 angler days in 1982; use has declined to a mean of 890 angler days during the past 4 years. Although angler effort has declined from the pre-regulation mean of 1,719 angler hours to 1,558 angler hours since 1978 (Figure 24), differences were not statistically significant ($P > 0.05$).

Landing rate appeared fairly stable (mean, 0.59 trout/h) during the 4 years preceding the catch-and-release restriction (Figure 24). After the no-harvest regulation was implemented, annual variation has been greater, but the general trend has been increasing, and mean annual landing rate has remained significantly higher ($P < 0.05$) under the catch-and-release regulation (1.44 trout/h).

Despite immediate increase in mean length of angler-captured trout after the catch-and-release regulation was initiated, mean length has been below pre-regulation levels since 1983 (Figure 24). Means for pre-regulation ($n = 4$ years) and post-regulation ($n = 10$ years) periods were equal (253 mm), however, and gillnetting and electrofishing data actually suggest a steady increase in mean length since 1978. Proportional stock density values for angler-captured cutthroat trout reflect declines in mean length measured by the VAR and generally exhibit a decreasing trend similar to RSD values from gillnetting and electrofishing samples (Figure 23). Although RSD values for angler-captured trout have varied considerably, the trend is actually stable (Figure 23). Data suggest that changes in mean length of angler-captured cutthroat trout has been caused by a decline in the proportion of fish within the quality category (254-330 mm).

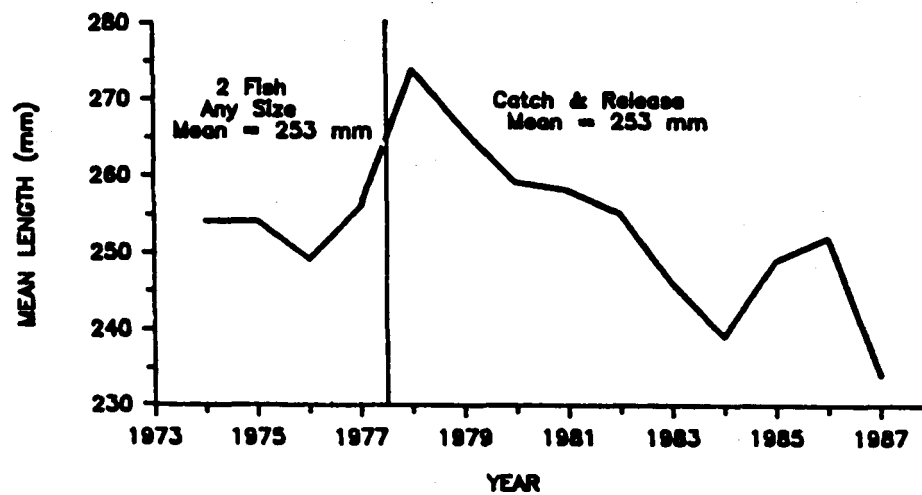
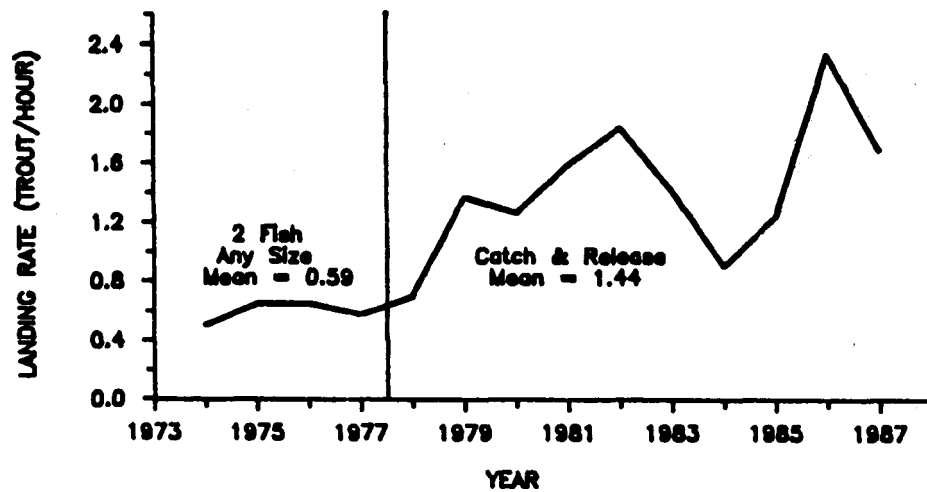
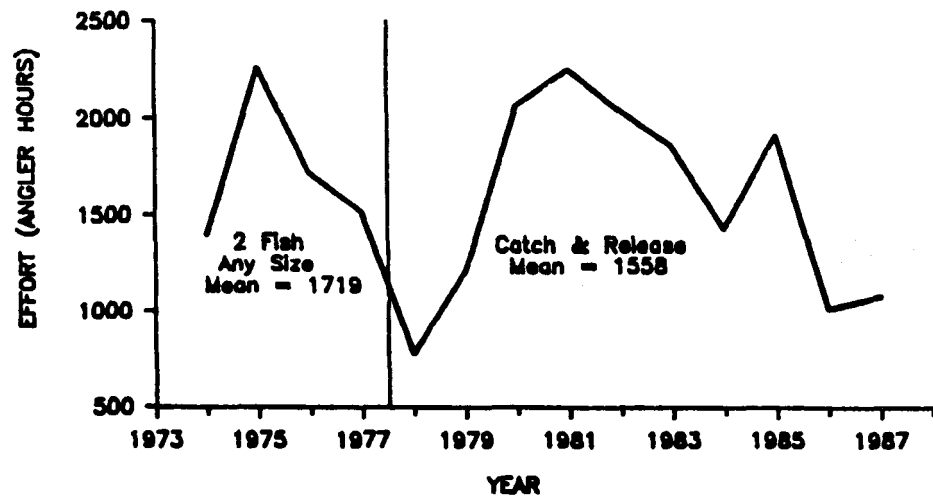


FIGURE 24.-Angler effort, landing rate, and mean length of landed trout, Sylvan Lake, 1974-1987.

Discussion

Jones et al. (1985) suggested a decline in cutthroat trout densities in Sylvan Lake since catch-and-release regulations were implemented in 1978; however, reexamination of previous surveys, in conjunction with additional data collected in 1985 and 1987, do not support this hypothesis. A decrease in density is often associated with a biomass shift towards older and larger fish (Nikolskii 1969), but gillnetting data apparently lack the precision necessary to detect subtle changes in mean number per net. It is apparent, however, that major declines in density have not occurred. Angler landing rates reported by the VAR have actually risen since 1978. Although high recatchability may influence the increase in landing rates under catch-and-release regulations, success would decline if there had been substantial decreases in density.

The effect of no-harvest regulations on the population structure of cutthroat trout in Sylvan Lake is poorly understood. Mean length estimated from angler returns exhibits a positive bias, and in Sylvan Lake, there has been a decline in mean length of angler-captured cutthroat trout in recent years. Gillnetting and electrofishing appear to be selective for smaller fish; mean length estimated from data collected by these techniques has actually increased slowly at Sylvan Lake since 1981. Data suggest that the proportion of larger cutthroat trout has decreased. It appears that density of cutthroat trout may have increased as a result of the catch-and-release-only regulation, and subsequent decrease in size may be related to the decrease in growth. Although mortality of older (larger) trout may be a factor in the observed changes in size, gradual increases in average age suggest that other variables are also important.

It appears that in Sylvan Lake, electrofishing is an effective and efficient means of collecting samples for monitoring purposes. In addition to increased sample size, this method allows fish to be returned to the lake with very little mortality; this factor is especially important as the intensity of the sampling program increases. Population estimates calculated from samples collected by electrofishing have much greater precision than similar estimates that use gill nets for the recapture sample; successful utilization of the population estimates as density indices is dependent on a high degree of precision.

The extent of possible competition between the cutthroat trout and longnose sucker in Sylvan Lake is unknown. If competition for a limited resource does occur between these species, it seems logical that the effects of this interaction would be readily evident in this unproductive lake. Cutthroat trout spawning habitat is limited (Jones et al. 1978); therefore, the reproductive

success of this species may be low. Since the longnose sucker is more fecund (Carlander 1969) and has less stringent spawning requirements (Brown 1971), it may have a reproductive advantage. Food may also be limiting, especially for larger trout that require larger food organisms such as benthic invertebrates. With a distinct adaptation for benthic feeding, suckers may have an additional competitive advantage for a limited food resource. Even if this species is not a more efficient feeder, an increase in the total number of fish alone could cause food availability to decline.

Since a robust cutthroat trout population is probably the best defense against adverse effects, the protection provided by the current catch-and-release regulation may be significant. Continued monitoring is necessary to determine future population trends of these species and evaluate effects of this restrictive angling regulation. Additionally, a comprehensive investigation of reproductive success and suggested competition for a possible limited food resource should be initiated.

STREAM SURVEYS

With few exceptions, streams in Yellowstone National Park represent natural pristine conditions relatively unaltered by human activities. As a result, stream habitat components in the park can be used as reference points for examining carrying capacity, biotic potential, or other aspects of stream conditions. An aquatic resource inventory program was established in the mid-1960s to assist in the goal of obtaining baseline habitat data for the streams and lakes of Yellowstone National Park. Stream habitat surveys yield data that may be useful for assessing changes in the stream environment over time (Jones et al. 1978). Because detailed information is available for only a few streams in Yellowstone National Park, one of the primary considerations of these stream habitat surveys is a description of the physical, chemical, and biological characteristics of a stream and a subsequent evaluation of the ability of the stream to support a fish population. Suitable stream habitat may be devoid of fish; nevertheless, it remains suitable habitat (Dunham and Collotzi 1975).

Stream habitat surveys in 1987 were conducted under unusual streamflow conditions. Because 1987 was a low water year in Yellowstone National Park, data collected during stream surveys may reflect critical aquatic habitat during minimum flow conditions. Low water also afforded an opportunity to identify normally perennial streams that become intermittent during very dry years.

Due to a growing recognition of watersheds as basic ecosystem units (Lotspeich 1980; Lotspeich and Platts 1982); stream habitat surveys have often been conducted within the same drainage basin in Yellowstone National Park for several consecutive years. Stream surveys have focused on the Lamar River drainage since 1984. In order to develop a composite description of a major watershed, stream habitat inventory should be conducted at the tributary watershed level. In 1987, stream surveys were performed on Slough Creek, Soda Butte Creek, and Cold Creek drainages (Figure 25).

Methods

Cursory Survey

Cursory-level surveys (Table 21) yield generalized descriptions and baseline habitat information on perennial streams within a study area. Drainage basin characteristics of each stream (stream order, watershed size, elevation, stream length, and gradient) are determined from U.S. Geological Survey topographic maps (scale 1:62,500). Additional habitat data (Table 21) were usually obtained near the mouth of the tributary or at a trail crossing. Although only a portion of each tributary was surveyed,

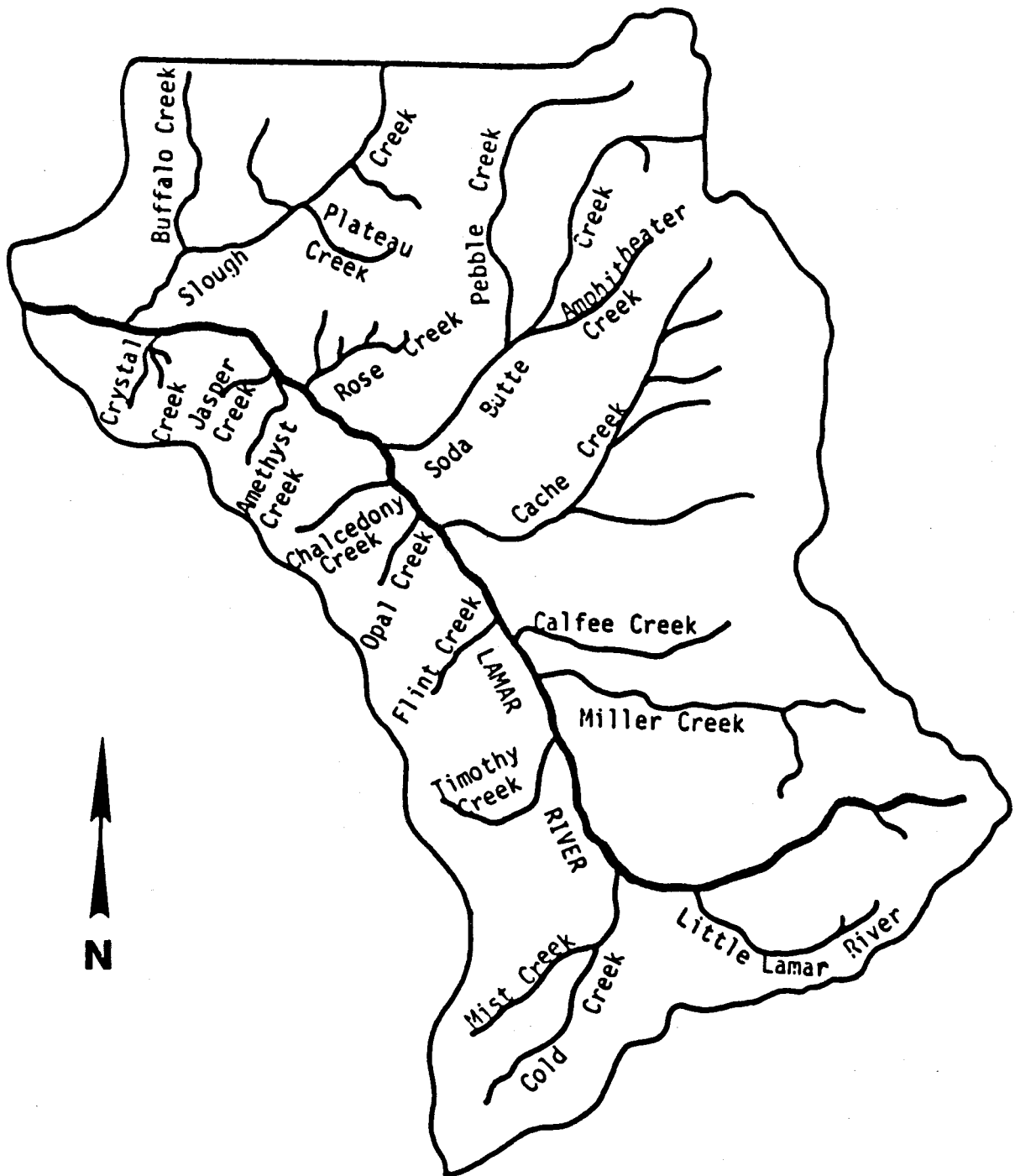


FIGURE 25.-Named streams in the Lamar River drainage, Yellowstone National Park.

TABLE 21.-Data collected during cursory- and reconnaissance-level surveys in Yellowstone National Park, 1987.

<u>Cursory-level</u>	<u>Reconnaissance-level (by reach)</u>
Stream order	Stream Order
Watershed Size	Watershed Size
Elevation	Elevation
Length	Reach Length
Gradient	Beaver Activity
Water Flow	Wildlife Observations
Water Temperature	Weather
pH	Presence or Absence of Fish
Conductivity	Streambottom Contour
Macroinvertebrate	Water Flow
Species Composition	Water Column Features:
Presence or Absence of Fish	Channel Width
	Stream Width
	Water Depth
	Riffle Width
	Pool Width
	Pool Quality
	Solar Angle
	Channel Morphology Features:
	Streambank Alteration
	Vegetative Stability
	Undercut
	Channel-bank Angle
	Stream Bottom Features:
	Gradient
	Sinuosity
	Substrate Particle Size
	Embeddedness
	Channel Vegetative Cover
	Riparian Zone Features:
	Streamside Cover
	Vegetative Use
	Vegetation Overhang
	Habitat Type
	Macroinvertebrate
	Species Composition

collection of data in the lower section of a tributary provides a summary of upstream physical, chemical, and biological influences. In order to evaluate a watershed as a complete ecological unit, drainage basin characteristics are also determined for intermittent streams that have a potential for sediment input, spawning substrate, or nursery value.

Instantaneous water temperatures were measured with a hand-held thermometer. Water pH was determined colorimetrically at each survey site. Conductivity was measured with a Beckman Solu-Bridge meter (Model No. RB-5).

In order to describe macroinvertebrate species composition, a single 0.09 m² Surber sample was taken from a representative riffle at each cursory-level sample site. Although single Surber samples are not amenable to standard statistical analyses, both qualitative and quantitative data are presented for purposes of relative comparisons. In addition to density and species diversity, each sample was evaluated by functional groups (Merritt and Cummins 1978; Krueger and Waters 1983).

Presence or absence of fish was determined visually. If fish were observed, a sample was collected using rotenone. Total length was measured to the nearest millimeter, weight recorded to the nearest 5 g, and scales were taken for age and growth analyses.

Reconnaissance Survey

Reconnaissance-level surveys provide a more detailed description of stream habitat than cursory-level surveys. Streams are subdivided into reaches by differences in gradient, substrate, riparian vegetation, and discharge. An intensive habitat inventory, encompassing a variety of parameters, is conducted in each stream reach (Table 21). General observations of wildlife activity and weather are noted. Drainage basin characteristics are determined by the procedure described for cursory-level surveys.

In each stream reach, three transects were established at the habitat inventory site. Distance between transects was determined as 10 times the stream width of the previous transect. This distance was measured along the streambank with a fiber glass tape parallel to the thalweg. Stream gradient and sinuosity were determined from the mid-channel point of two adjacent transects. Sinuosity was obtained by stretching the tape straight between the two mid-channel transect points. The ratio of streambank length divided by straight line distance was recorded as sinuosity (always greater than 1). Gradient was measured with a clinometer by reading the angle between the same two points used for sinuosity. Two poles of equal length were used to assure accuracy in gradient readings.

A 30.5 m fiber glass tape was secured perpendicular to the direction of streamflow at the first transect. Streamflow was measured by the midsection method (Buchanan and Somers 1969) at the first transect. All depth measurements from the first transect were used to obtain average depth for that transect. At the second and third transects of each stream reach, depths were taken at approximately 0.25, 0.50, and 0.75 of the distance across the stream transect. These three depths were summed and divided by four to obtain an average depth for each transect (Platts et al. 1983).

Solar angle was determined by means of a clinometer. Two readings were taken from mid-channel at each transect. The angle to the highest sunlight obstruction (vegetation or hill) in both an easterly and westerly direction was recorded. These two angles were summed and subtracted from 180° to yield the solar angle for that particular transect.

Remaining habitat inventory parameters (Table 21) were measured according to techniques described in Platts et al. (1983). In 1987, reconnaissance-level surveys were conducted on Elk Tongue Creek, Cutoff Creek, Mist Creek, and Cold Creek.

Macroinvertebrates were collected and analyzed at each reconnaissance-level survey site following procedures described under cursory-level surveys. Fish presence determination and data collection also followed cursory-level techniques.

Slough Creek Drainage

Slough Creek is one of the most popular recreation areas in the northeastern portion of Yellowstone National Park. Although Slough Creek originates outside of the park in the Gallatin National Forest, over 30% of the 56,940-hectare watershed is contained within the boundaries of Yellowstone National Park. Numerous studies and monitoring programs have been conducted on the mainstem of Slough Creek since 1966; however, information on tributaries to Slough Creek is quite limited. Mills and Sharpe (1968b) noted that nursery areas for young-of-the-year fish were found in the low velocity tributaries to Slough Creek. In 1979, Jones et al. (1980) estimated streamflows and measured water temperature in several tributaries. In 1985, an effort was initiated to systematically obtain baseline habitat information on all tributaries in the Slough Creek watershed.

Slough Creek flows through thick glacial and alluvial deposits superimposed upon Paleozoic sedimentary formations (Protska et al. 1975a). Extensive Pinedale glaciation led to the formation of the wide meadow-covered valley that characterizes the Slough Creek drainage. A 2.9-km canyon extending upstream from Slough Creek Campground separates

the lower meadow section from the upper meadow area. Steep peaks bordering Slough Creek were formed by Eocene Absaroka volcanic flows covering Precambrian gneiss at the southern extreme of the Beartooth uplift. Subsequent Pinedale glaciation deposited glacial till on the west-facing slopes, and the east-facing slopes have a rubble veneer surface (Pierce 1974). Landslide-influenced slopes are common on the east side of the Slough Creek valley.

Vegetation in the upper meadow of Slough Creek is dominated by sedges *Carex* spp. and tufted hairgrass *Deschampsia cespitosa*. Upper east-facing slopes are generally big sagebrush *Artemisia tridentata*/Idaho fescue *Festuca idahoensis* and Engelmann spruce *Picea engelmannii*/northern twinflower *Linnaea borealis* interspersed with aspen *Populus tremuloides* and occasional patches of subalpine fir *Abies lasiocarpa*/northern twinflower (Jones et al. 1980). Slopes with a west aspect are primarily covered with older growth lodgepole pine *Pinus contorta*. Above 2,450 m, Douglas fir *Pseudotsuga menziesii* and whitebark pine *Pinus albicaulis* are the dominant conifers.

Unnamed Tributaries to Slough Creek

Physical Characteristics.--Cursory-level surveys were conducted on 10 unnamed tributaries to Slough Creek in 1987. These tributaries were located in the upper meadow area upstream from Plateau Creek. The majority of these tributaries have steep gradients ($> 10\%$) and stream widths less than 1 m (Table 22). Seven of the tributaries are shallow, first order streams on the east side of Slough Creek (Figure 26). Tributaries 10330213, 10330219, 10330221, and 10330222 terminate in wet meadows or backwater sloughs and appear to have a direct confluence with Slough Creek only during peak flow periods.

Generally, the unnamed tributaries to Slough Creek were characterized by small to medium (< 200 mm) substrate sizes and overhanging grassy banks. However, Stream 10330217 (one of the largest unnamed tributaries in the drainage) contains primarily large rubble (245-356 mm) and exhibits evidence of substantial spring flooding. Water temperature in tributary 10330217 was the highest recorded in any of the Slough Creek tributaries (Table 22). Moderately-basic pH values (mean, 8.0) of these tributary streams are possibly a result of the limestone influences in an andesitic basin (Meyer 1986).

Although previous investigators have reported cutthroat trout *Salmo clarki* fry in tributaries to Slough Creek (Arnold and Sharpe 1967), none were observed during the current survey. Substrate seems to be suitable for spawning in many of the unnamed tributaries, particularly in Stream 10330213; however, migration by cutthroat trout spawners into these tributaries from the Slough Creek mainstem has not been investigated. The unnamed tributaries to Slough

TABLE 22.-Physical features of tributaries to Slough Creek, 1987.

Stream	Stream Order	Watershed Size (ha)	Stream Length (km)	Elevation Maximum (m)	Elevation Minimum (m)	Gradient (%)	Stream Flow (m3/s)	Mean Width (m)	Mean Depth (cm)	Mean Velocity (cm/s)	Temperature (C)	pH	Conductivity (umhos/cm)
10330212	II	837.5	4.20	2545.0	1998.0	13.0	a						
10330213	I	105.0	1.87	2225.0	1999.5	12.1	0.007	0.47	3.94	38.40	8	8.2	
10330215	I	350.6	3.47	2607.6	2002.5	17.4	0.009	0.78	6.40	17.70	13	7.8	130
10330216	I	254.6	1.88	2414.0	2004.1	21.8	0.014	0.85	5.33	31.70	12	7.8	80
10330217	II	891.5	6.71	2674.6	2005.6	10.0	0.036b	1.42	6.10	14.43	18	8.1	150
								1.85	8.45	15.24			
10330218	I	76.2	0.87	2185.4	2013.2	17.2	0.002	0.34	4.88	14.32	11	8.2	
10330219	I	126.0	0.72	2026.9	2014.7	1.7	a						
10330220	I	618.2	3.30	2531.4	2016.2	15.6	0.021	0.95	8.13	27.03	14	8.0	
10330221	I	128.6	1.56	2286.0	2016.3	17.3	0.015	0.67	5.49	40.13	9	8.2	
10330222	I	32.7	0.83	2080.3	2019.3	7.4	0.001	0.30	2.98	12.68	16	8.3	

a no field measurements taken

b total of both downstream forks; width, depth, and velocity listed separately

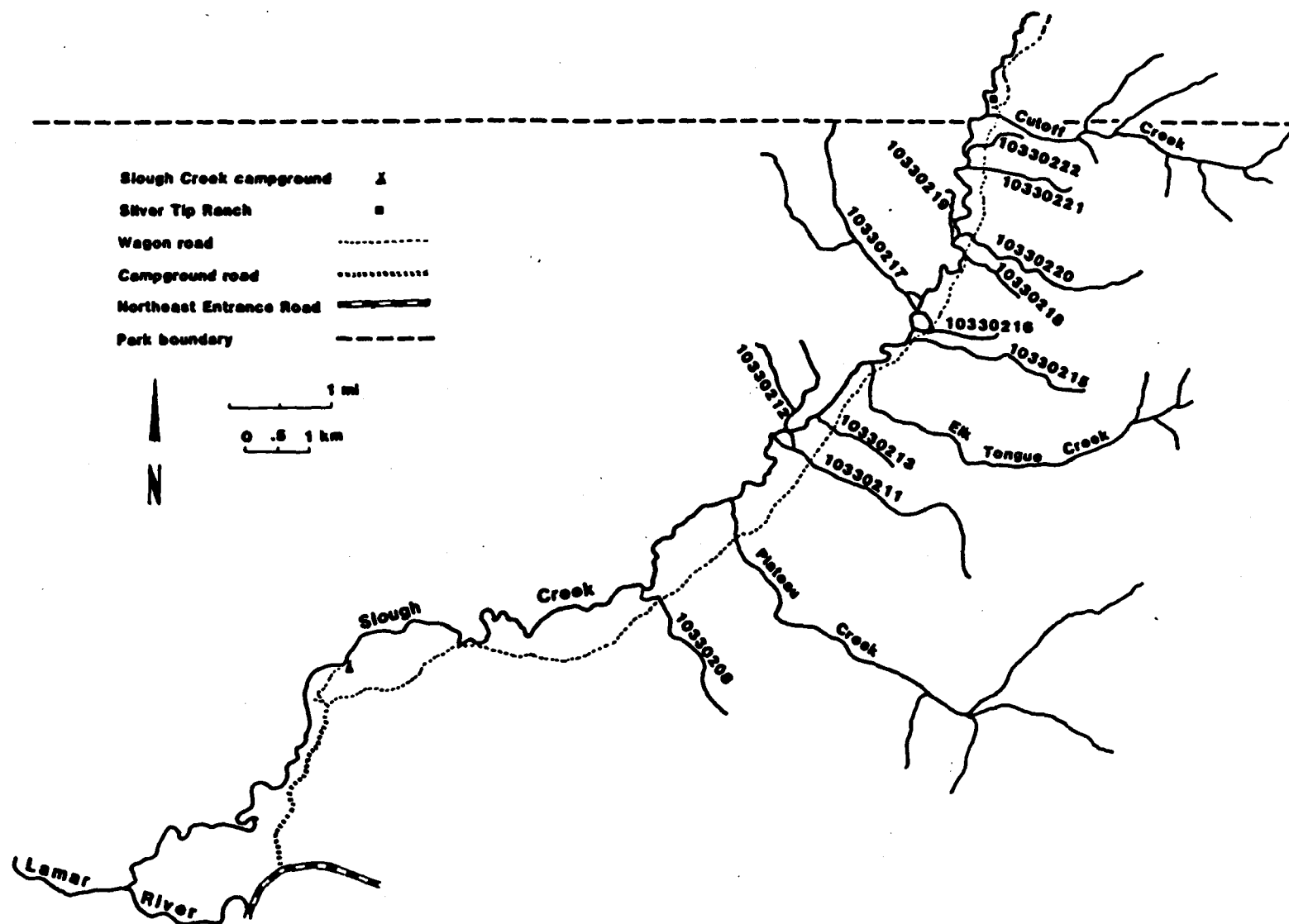


FIGURE 26.-Hydrographic map of tributaries to Slough Creek surveyed in 1987.

Creek appear to be suitable for rearing habitat and may contribute invertebrate production to the mainstem.

Macroinvertebrates.-A total of 22 species of benthic invertebrates were collected from Slough Creek tributaries in 1987. Ephemeropterans comprised the dominant order, and plecopterans and trichopterans were collected in equal numbers (Table 23). The highest species diversity and density of individuals occurred in Stream 10330220. Macroinvertebrate species that require a narrow range of environmental conditions are termed "intolerant" to environmental fluctuations, and those species able to survive a wide range of environmental fluctuations are termed "tolerant" (Winget and Mangum 1981). Stream 10330220 contained the most environmentally sensitive or intolerant species (*Parapsyche* spp.) collected from the tributaries. In contrast, tributary 10330217 was dominated by species moderately tolerant to highly tolerant of environmental fluctuations, particularly Chironomids; this was the only tributary that showed signs of high-water stream instability.

Macroinvertebrate functional groups (Cummins 1977) in most of the surveyed tributaries revealed proportions similar to those expected in first to third order headwater streams (Vannote et al. 1980). In these small streams, shredders reduce coarse riparian vegetation to a size usable by collectors. The functional arrangement in tributary 10330221 (a large proportion of scrapers) is more commonly found in large fourth to sixth order streams. This result may possibly be influenced by higher than normal upstream autochthonous production in this stream. A similar distribution of functional groups was found in Stream 10330208; this tributary had abundant amounts of aquatic vegetation in the stream channel and was dominated almost entirely by scrapers (Jones et al. 1986).

Elk Tongue Creek

The long, high ridge between Mount Hornaday and Cutoff Mountain is the source of Elk Tongue Creek. From here, the stream flows southwest from the base of Cutoff Mountain for approximately 3 km before turning west towards Slough Creek. The lower 4 km of Elk Tongue Creek are separated from Plateau Creek by a secondary ridge. All but one of the tributaries to Elk Tongue Creek originate on these two ridges (Figure 27). The Bliss Pass trail parallels the north side of Elk Tongue Creek and provides scenic vistas of both Buffalo Plateau and Slough Creek valley.

Arnold and Sharpe (1967) surveyed the lower portion of Elk Tongue Creek and reported that the stream provided good cover with its stable banks. They collected juvenile cutthroat trout in the vicinity of Elk Tongue cabin and recorded pH and conductivity. A reconnaissance-level survey

Table 23.-Occurrence and densities of macroinvertebrates found in Slough Creek tributaries, 1987.

	Tributary 103302-							
	13	15	16	17	18	20	21	22
Turbellaria	3	1						
Insecta								
Ephemeroptera (mayflies)								
Siphonuridae								
<u>Ameletus</u> sp.		1						
Baetidae								
<u>Baetis bicaudatus</u>					12	2		
<u>Baetis tricaudatus</u>			1	3				
Heptageniidae								
<u>Cinygmula</u> sp.					1	11	1	
<u>Epeorus deceptivus</u>			4			2		
Ephemerellidae								
<u>Drunella coloradensis</u>	3		2				3	
<u>Serratella mitchneri</u>				1				
Plecoptera (stoneflies)								
Peltoperlidae								
<u>Yoraperla brevis</u>	1					8	7	
Nemouridae								
<u>Zapada</u> sp.			1			1	4	1
Perlodidae								
<u>Megarcys</u> sp.	1	1	8					
<u>Cultus</u> sp.								1
Trichoptera (caddisflies)								
Rhyacophilidae								
<u>Rhyacophila</u> sp.	5			7		2	4	
Hydropsychidae								
<u>Arctopsyche grandis</u>						1		
<u>Parapsyche</u> sp.						2		
Limnephilidae								
<u>Neothremma alicia</u>						6	7	
<u>Psychoglypha</u> sp.					1			
Coleoptera								
Chrysomelidae	1							
Unidentified					3			
Diptera (true flies)								
Tipulidae								
<u>Tipula</u> sp.				1				
Chironomidae		2		8		4	4	
Simuliidae								
<u>Prosimulium</u> sp.						3		
Pelecorhynchidae								
<u>Glutops</u> sp.			1		1	1	3	
TOTAL TAXA:	6	4	6	5	5	12	8	2
TOTAL #/m ² :	151	54	183	215	194	463	355	22
* SHREDDERS	20	0	6	5	0	2	13	50
* COLLECTORS	20	75	47	60	94	60	33	0
* SCRAPERS	20	0	0	0	6	33	42	0
* PREDATORS	40	25	47	35	0	5	12	50

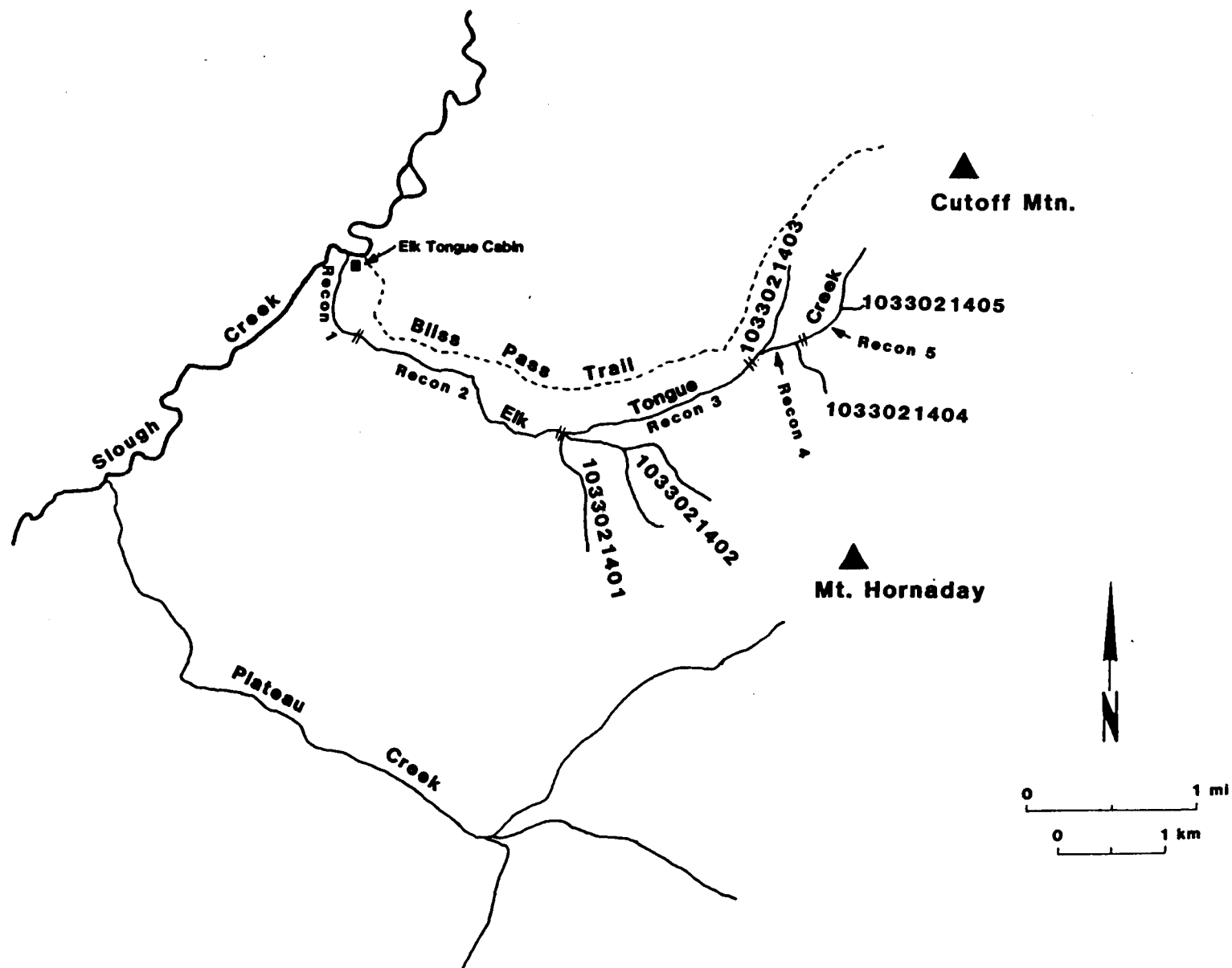


FIGURE 27.-Hydrographic map of Elk Tongue Creek.

on Elk Tongue Creek initiated in 1985 was completed in 1987. Cursory-level habitat data were collected on five tributaries to Elk Tongue Creek, and the mainstem was subdivided into five reaches for a reconnaissance-level survey.

Physical Characteristics.—The narrow V-shaped drainage basin of Elk Tongue Creek is densely forested with older growth lodgepole pine. Above 2,560 m, whitebark pine stands are common in the alluvium covered upper slopes. Moose *Alces alces* were observed in the lower reaches of Elk Tongue Creek, but elk *Cervus elaphus* appeared to be restricted to higher elevations. Gray jays *Perisoreus canadensis* and juncos *Junco* sp. inhabited the upland areas; water ouzels *Cinclus mexicanus* were observed feeding in Reach 4.

Elk Tongue Creek can be characterized as a small, cold, high-gradient stream. Mean water temperature of all five stream reaches was 5.8°C, and the average gradient of Elk Tongue Creek is 10.6%. In spite of the steep gradient, streambank alteration is relatively light throughout most of the stream, and riparian areas are in excellent condition (Table 24). Downed timber in the stream channel is abundant in Reaches 1 and 3 but noticeably lacking in Reach 5. The streambanks most susceptible to undercutting in Elk Tongue Creek are composed of grasses and forbs; however, undercut banks are narrow and provide only marginal cover. Most undercut banks occur in Reaches 1 and 3, and these two reaches had the largest amount of channel instability and the most erosion potential.

Substrate was primarily gravel and cobble in the upper stream sections, but there was a shift to cobble and boulder in the lower two stream reaches of Elk Tongue Creek (Table 24). Substrate embeddedness was low in all stream reaches except Reach 2. Low embeddedness may be a function of high water velocities stemming from the steep stream gradient.

Numerous pools were noted in each stream reach. In general, most of the pools were small, shallow, and formed primarily by boulders. Because pools provided little cover or were "exposed", they were rated low-quality and functioned primarily as velocity shelters for fish. Instream fish cover is mainly restricted to those stream sections where significant amounts of downed timber form debris jams.

Although numerous seeps and small springs contribute to the overall discharge of Elk Tongue Creek, there were only five tributary streams with defined channels over 200-m long (Figure 27). Gradients ranged from 14.7% to 63.2% (Table 25) and precluded use by fish. The four perennial tributaries are all cold water streams (mean temperature 6°C). Mean conductivity of 60 µmhos/cm suggests relatively low productivity in these streams.

TABLE 24.-Habitat characteristics of Elk Tongue Creek, 1985-1987.

Habitat Features	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5
Sample Date	8/21/85	8/22/85	8/22/85	7/28/87	7/28/87
Time	1530	1000	1600	1715	1530
Stream Order	III	III	II	II	II
Length (km)	1.17	2.34	1.83	0.47	1.1
Elevation:					
Maximum (m)	2109.2	2377.4	2575.6	2645.7	2830.1
Minimum (m)	2004.1	2109.2	2377.4	2575.6	2645.7
Drainage Size (ha)	1140.1	1032.5	536.1	180.4	137.8
Water Column:					
Flow (m3/s)	0.078	0.061	0.058	0.051	0.007
Channel Width (m)	5.3	4.2	3.4	5.6	3.3
Stream Width (m)	3.7	2.7	2.1	2.6	1.5
Stream Depth (cm)	10.36	12.50	10.36	9.45	4.57
Stream Shore Water Depth (cm)	6.10	7.92	11.58	1.52	1.22
Riffle Width (m)	2.19	1.10	0.80	1.77	0.60
Pools:					
Width (m)	0.8	2.7	1.0	0.4	0.4
Quality	1.3	1.9	1.6	1.5	2.2
Feature	4.1	4.1	4.1	3.4	3.4
Solar Angle	31.3	25.7	30.0	34.7	38.7
Channel Morphology					
Streambank Alternation	24.2	23.3	33.3	19.2	17.5
Vegetative Stability	3.8	3.3	3.2	3.5	3.7
Undercut (cm)	12.5	4.3	12.2	1.2	1.5
Channel-Bank Angle	85.5	92.7	100.7	121.7	128.3
Stream Bottom:					
Gradient (%)	4.3	9.3	5.5	13.3	20.5
Sinuosity	1.19	1.24	1.25	1.33	1.21
Substrate: (%)					
Boulder >356 mm	35.0	53.7			18.0
Cobble 64-356 mm	49.5	31.0	45.0	54.7	63.0
Gravel 2-64 mm	11.5	9.3	48.0	36.7	19.0
Sand 0.6-2 mm	4.0				
Silt <0.6 mm		6.3	8.0	8.3	
Embeddedness	3.33	2.67	4.00	3.67	4.00
Channel Vegetative Cover (cm)	55.78	10.06	81.38	12.19	0.00
Riparian Zone:					
Streamside Cover	2.0	1.8	2.7	2.2	1.5
Vegetative Use	20.80	14.20	15.80	2.50	10.00
Vegetation Overhang (cm)	3.81	6.71	22.56	3.05	0.00
Habitat Type	14.18	12.13	14.13	9.12	12.18

TABLE 25.-Physical features of tributaries to Elk Tongue Creek, 1985-1987.

Stream	Stream Order	Watershed Size (ha)	Stream Length (km)	Elevation Maximum (m)	Elevation Minimum (m)	Gradient (%)	Stream Flow (m3/s)	Mean Width (m)	Mean Depth (cm)	Mean Velocity (cm/s)	Temperature (C)	pH	Conductivity (umhos/cm)
1033021401	I	84.3	1.27	2731.0	2374.4	28.1	0.005	1.15	5.49	8.53	5	7.2	70
1033021402	II	208.7	1.83	2755.4	2374.5	20.8	0.014	1.29	7.62	14.02	6	7.3	70
1033021403	I	161.4	1.20	2761.4	2584.7	14.7	0.007	1.15	5.21	12.40	8	7.2	50
1033021404	I	42.0	0.67	2779.8	2621.3	23.7	0.014	1.48	5.52	16.76	5	7.1	52
1033021405	I	17.1	0.27	2901.7	2731.0	63.2	a						

a dry channel on survey date

Stream 1033021402, the only second order tributary to Elk Tongue Creek, had the largest drainage basin (Table 25). Like other streams of Lamar River drainage (Jones et al. 1985, 1986) large watershed area was associated with the longest stream length and greatest mean depth of any Elk Tongue Creek tributary (Table 25). Tributary 1033021404 was the only stream in the Elk Tongue Creek watershed with a heavily vegetated channel and substrate of large cobble and small boulder. This stream contributed nearly one third of the total discharge of Elk Tongue Creek in Reach 4.

Fish were not observed in Elk Tongue Creek in 1985 or 1987. In addition, the lack of high quality pools throughout this stream may prohibit the establishment of a resident population. High stream gradients have a significant negative correlation with trout abundance (Kennedy and Strange 1982). Steep gradients may function as a permanent barrier to fish migration from Slough Creek to the upper reaches of Elk Tongue Creek. In contrast, the lower 1 km of Elk Tongue Creek has only a moderate gradient (Table 24); cover is adequate, and siltation appears to be minimal. Therefore, this lower stream section appears to offer spawning and rearing habitat for cutthroat trout from Slough Creek.

Macroinvertebrates.-Five orders of benthic insects were collected from the Elk Tongue Creek watershed (Table 26). In addition, turbellarians were sampled in tributary 1033021402. Species diversity of ephemeropterans and plecopterans was equal in Elk Tongue Creek watershed, but ephemeropteran abundance was greater than plecopterans except in Stream 1033021404. The most diverse sample in Elk Tongue Creek drainage was collected from tributary 1033021403. This stream had the lowest gradient and highest water temperature of any of the tributaries to Elk Tongue Creek. The slower velocity (12.4 cm/s) in this tributary may favor more sedentary forms, such as *Prosimulium*.

The highest mainstem macroinvertebrate density was found in Reach 3, a stream section characterized by a low gradient (5.5%) and substrate composed almost entirely of gravel and cobble (Table 24). A study by Rabeni and Minshall (1977) revealed a strong preference by macroinvertebrates for substrates of small to medium sizes (25 to 70 mm). The highest mainstem species diversity in Elk Tongue Creek occurred in Reach 4. This reach had a substrate composition similar to Reach 3, but the proportion of riffles was much higher in Reach 4 (Table 24). A low species abundance and diversity in Reach 2 may reflect moderately high embeddedness and boulder substrate.

Epeorus deceptivus and *Zapada* sp. were the most widely distributed species. Each was collected from 67% of the sample sites in Elk Tongue Creek drainage. These genera were classified as intolerant by Winget and Mangum (1981), and their wide distribution throughout Elk Tongue Creek is

Table 26.-Occurrence and densities of macroinvertebrates found in stream reaches and tributaries, Elk Tongue Creek, 1985 and 1987.

	Reach Number					Tributary 10330214-			
	1	2	3	4	5	01	02	03	04
Turbellaria							7		
Insecta									
Ephemeroptera (mayflies)									
Siphonuridae									
<u>Ameletus</u> sp.			1		1	8		1	1
Baetidae									
<u>Baetis bicaudatus</u>	7			13				1	6
Heptageniidae									
<u>Cinygmula</u> sp.	3			7	1	3		3	
<u>Rhithrogena</u> sp.		2		2			2	1	
<u>Epeorus deceptivus</u>	21	12	11				11	5	1
Ephemerellidae									
<u>Drumella coloradensis</u>	3		1					1	
<u>Serratella mitchneri</u>			9						
Plecoptera (stoneflies)									
Peltoperlidae									
<u>Yoraperla brevis</u>					1	7	1	6	16
Nemouridae									
<u>Visoka cataractae</u>		4	5				3	1	2
<u>Zapada</u> sp.		7	3	5		4	1		5
Perlodidae		2							
<u>Megarcys</u> sp.				4	1				4
<u>Isoperla</u> sp.			2						
<u>Skwala</u> sp.				1					
Chloroperlidae					1			2	
Trichoptera (caddisflies)									
Rhyacophilidae									
<u>Rhyacophila</u> sp.	1	2					2	2	2
Limnephilidae									
<u>Cryptochia furcata</u>				1					
<u>Neothremma alicia</u>		3	17	1			1		
Coleoptera (Beetles)									
<u>Stenelmis</u> sp.								1	
Diptera (true flies)									
Tipulidae									
<u>Holorusia</u> sp.								1	
Chironomidae	3			2	35				2
Simuliidae									
<u>Prosimulium</u> sp.				3				11	
TOTAL TAXA:	6	7	8	10	6	4	8	13	9
TOTAL #/m2	409	344	527	420	431	237	301	388	420
% SHREDDERS	0	34	16	15	0	18	19	6	18
% COLLECTORS	97	44	45	69	83	50	62	64	26
% SCRAPERS	0	10	35	3	3	32	10	19	41
% PREDATORS	3	12	4	13	14	0	9	11	15

indicative of a relatively stable, high-quality habitat. Abundance of Chironomids in Reach 5 represented the highest density of any taxon in the watershed; however, the headwater area of Reach 5 is exposed and rocky and may present fluctuating environmental conditions that favor highly tolerant species such as Chironomids.

In the majority of collections, the proportion of predators averaged approximately 10%. This is to be expected because predator density is a function of prey density rather than stream order or riparian input (Hawkins and Sedell 1981). Collectors dominated every sample except Stream 1033021404 (Table 26). Grazers dominated this particular tributary, a stream characterized by abundant amounts of autochthonous production. Shredders, which break down riparian vegetation introduced into a stream, were numerous in the majority of samples. Shredders were absent from Reach 5, a headwater area characterized by exposed, rocky areas with diminished riparian influence. The predominance of shredders and collectors in Elk Tongue Creek is typical of headwater streams and their first and second order tributaries.

Cutoff Creek

The sheer cirque walls on the western slope of Cutoff Mountain are the source of Cutoff Creek. This stream parallels the northern boundary of Yellowstone National Park and flows for nearly 5 km through a densely forested narrow valley before entering Slough Creek several hundred meters outside of the park at Silver Tip Ranch, Montana (Figure 28). The wagon road through Slough Creek valley to Silver Tip Ranch and a sagebrush meadow at the park boundary provide easy access to the lower 1 km of Cutoff Creek. Upstream from this point, landslide deposits, cascades, steep canyons, and downed timber limit access to the stream. Because no previous documented surveys of Cutoff Creek have been undertaken, a reconnaissance-level survey was conducted on Cutoff Creek in 1987. cursory-level data were collected on six tributaries to Cutoff Creek.

Physical characteristics.-During the Eocene Absaroka volcanics, andesitic flows of the Wapiti formation produced Cutoff Mountain. Subsequent Pinedale glaciation was nearly 915-m thick and extended to an elevation of 3,050 m, slightly below the summit of Cutoff Mountain (Pierce 1974). Major glacial influences in Cutoff Creek watershed are reflected in the exposed upper reach with talus slopes and landslide deposits, a narrow V-shaped valley of glacial till in the middle reaches, and a large alluvial fan at the lower end of the stream. A drainage basin pattern intermediate between dendritic and parallel (Morisawa 1985) occurs in the present Cutoff Creek watershed.

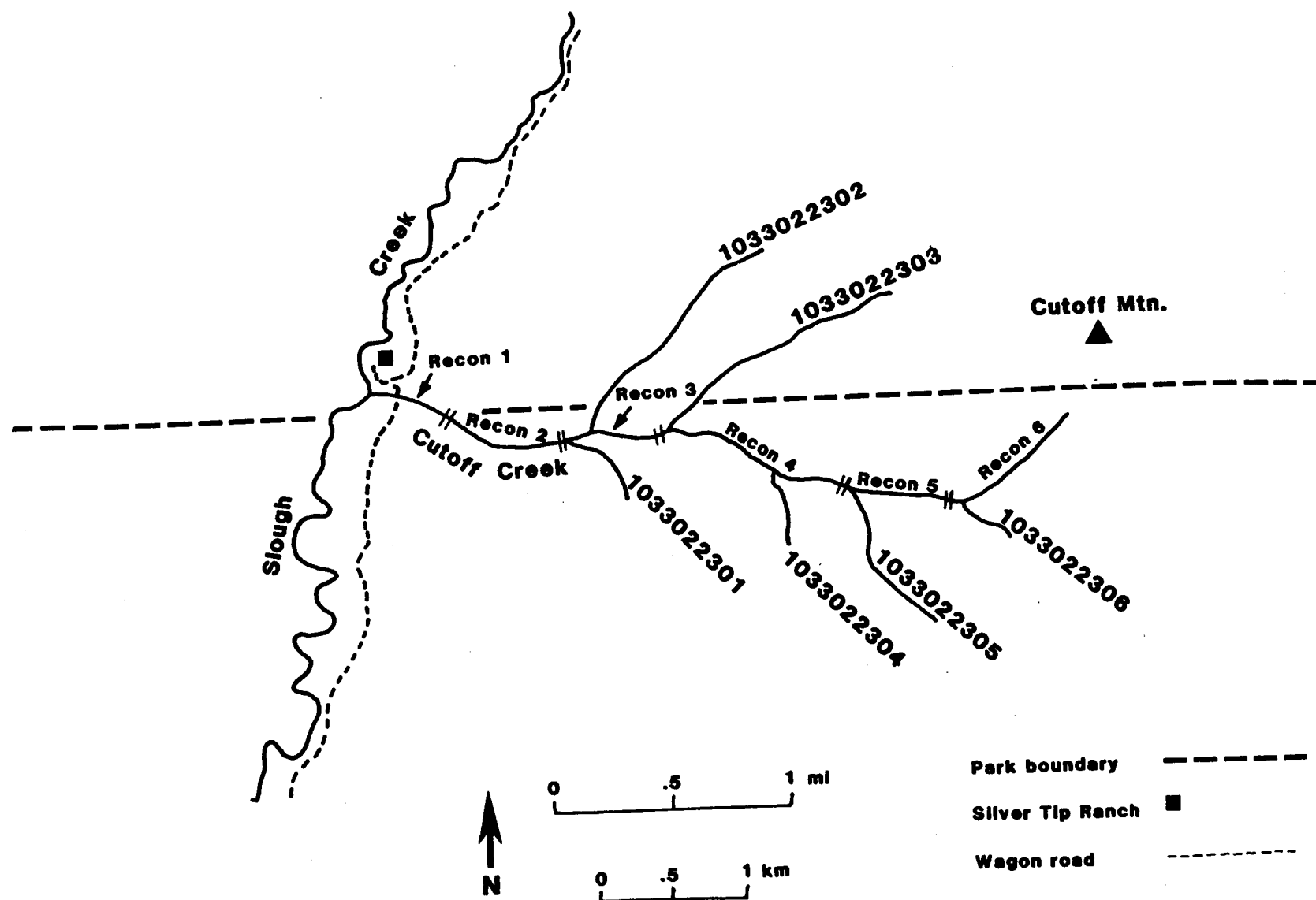


FIGURE 28.-Hydrographic map of Cutoff Creek.

Dense growths of lodgepole pine cover the steep upland slopes to an elevation of 2,500 m. In common with other portions of the Slough Creek drainage, whitebark pine becomes the dominant forest type at higher elevations. A moose calf was observed in the riparian area of Reach 3, and two elk were seen in the high benches bordering Reach 4 during the survey.

The lowest section of Cutoff Creek (Reach 1) has a moderate gradient, a substrate dominated by large cobble and boulder, and a relatively wide and shallow stream channel (Table 27). Cover appears to be limited in Reach 1. A high solar angle (Table 27) indicates only moderate amounts of shading in the stream channel. Numerous small, shallow pools are scattered throughout this reach. These pools are exposed in that they provide very limited shelter for fish. A domestic water supply diversion to Silver Tip Ranch is located at the upper end of Reach 1. Consequently, estimated discharge in Reach 1 was substantially less than the streamflow upstream in Reach 2 (Table 27).

The major portion of Reach 2 is bordered by a vertical-walled canyon ending in a landslide deposit at the lower end of the reach. Gradient in this reach is somewhat higher than Reach 1 (Table 27). Wide pools formed by boulders are common in Reach 2. Plunge pools (Bisson et al. 1981) created by downed timber are the highest quality pools in this reach. Significant amounts of overhanging vegetation and increased riparian shading may provide additional fish cover in this stream reach.

A small series of cascades at the confluence of Cutoff Creek and Stream 1033022301 apparently functions as a permanent barrier to fish migration (Figure 28). A large, unstable area approximately 30 hectares in size and composed of mudstone and sandstone overlying a dolomite base extends upstream from this point and exhibits great potential as a sediment source. Mud cracks up to 5-m long and 2-m deep, and minor amounts of timber growth, characterize this unstable area. A diffuse channel and dense overhanging vegetation prevented a streamflow measurement for tributary 1033022301.

Both Reach 3 and Reach 4 are in a heavily shaded, steep valley. Reach 3 has a substrate of gravel and cobble, but the steep gradient Reach 4 is dominated by boulders (Table 27). Pool quality was rated fair to good in both reaches. The riparian area in Reach 3 is thickly overgrown with mature willows *Salix* sp. that provide abundant amounts of overhanging cover. In contrast, overhanging vegetation was sparse in Reach 4, and downed timber in the channel was essentially absent (Table 27).

Tributaries 1033022302 and 1033022303 flow into this section of Cutoff Creek (Figure 28). These streams originate in large cirque basins north of Yellowstone National Park and flow south to Cutoff Creek. Gradient,

Table 27.-Habitat characteristics of Cutoff Creek, 1987.

Habitat Features	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6
Sample Date	8/01/87	8/01/87	7/31/87	7/31/87	7/30/87	7/30/87
Time	1300	1100	1645	1415	1630	1500
Stream Order	II	II	II	II	II	II
Length (km)	0.93	0.83	0.90	1.57	0.60	1.13
Elevation:						
Maximum (m)	2118.4	2194.6	2270.8	2453.6	2545.1	3017.5
Minimum (m)	2025.4	2118.4	2194.6	2270.8	2453.6	2545.1
Drainage size (ha)	907.1	821.8	728.6	622.3	212.7	131.3
Water Column:						
Flow (m3/s)	0.027	0.043	0.042	0.035	0.009	0.010
Channel Width (m)	6.5	6.8	8.1	7.4	2.9	3.2
Stream Width (m)	2.7	2.5	2.3	2.7	1.5	1.7
Stream Depth (cm)	7.62	10.06	13.11	10.97	6.10	6.10
Stream Shore Water Depth (cm)	1.52	0.00	0.00	0.00	18.29	9.14
Riffle Width (m)	1.10	0.66	0.84	1.36	0.86	0.97
Pools:						
Width (m)	0.6	1.0	0.6	0.7	0.7	0.5
Quality	1.3	2.2	1.9	2.6	1.8	1.7
Feature	3.4	4.1	3.4	4	4.2	1.3
Solar Angle	66.3	35.3	26.3	30.0	23.7	68.0
Channel Morphology						
Streambank Alteration	20.0	26.7	21.7	17.5	22.5	5.8
Vegetative Stability	3.5	2.8	3.3	3.2	3.5	3.8
Undercut (cm)	1.5	0.0	0.0	0.0	3.0	5.2
Channel-Bank Angle	130.8	144.2	126.7	122.5	118.3	111.7
Stream Bottom:						
Gradient (%)	4.2	4.8	7.3	12.0	7.3	19.8
Sinuosity	1.32	1.45	1.27	1.42	1.44	1.50
Substrate: (%)						
Boulder >356 mm	24.0	12.6	13.0	60.6	5.6	33.3
Cobble 64-356 mm	55.4	64.6	57.4	25.9	61.9	27.8
Gravel 2-64 mm	17.6	14.7	21.4	13.5	21.4	34.3
Sand 0.6-2 mm	0.0	4.6				
Silt <0.6 mm	3.0	3.5	8.2		11.1	4.6
Embeddedness	3.67	3.67	3.00	3.67	4.00	2.67
Channel Vegetative Cover (cm)	10.06	12.19	16.15	0.00	3.66	16.15
Riparian Zone:						
Streamside Cover	2.8	3.2	3.0	2.7	1.8	1.8
Vegetative Use	5.00	6.70	1.70	5.80	6.70	0.80
Vegetation Overhang (cm)	7.01	19.81	44.81	8.23	2.13	17.68
Habitat Type	12.16	11.12	12.13	13.4	13.12	8.12

stream length, and elevation are similar, but only stream 1033022303 contained a flow during the survey (Table 28).

Approximately 4.25 km from the mouth, Cutoff Creek is divided into two branches of similar flow. The south fork was designated as Stream 1033022305 and the north fork was considered the mainstem of Cutoff Creek (Figure 28). Reach 5 was characterized by a substrate composed of cobble, gravel, and silt; several pools of poor to fair quality; and minimal amounts of riparian cover (overhanging or in-channel) (Table 27). Although a high overstory provides shade to the stream, streamside vegetation is composed primarily of grasses and forbs.

The uppermost 1 km of Cutoff Creek (Reach 6) flows through a steep (19.8% gradient) boulder field covered with herbaceous vegetation and a large diversity of wildflowers. Substrate was composed of similar proportions of boulder, cobble, and gravel (Table 27); however, the proportion of gravel in Reach 6 was the greatest of any reach in Cutoff Creek. The majority of pools in this reach are formed by gravel (pool feature class #3), are shallow, and were rated poor. The abundant amount of channel vegetative cover (Table 27) consists primarily of riparian herbaceous plants; therefore, the cover value may be seasonal.

Cutoff Creek was rated as a very stable stream. Streambank alteration was low to moderate throughout the entire stream, and vegetation stability was good to excellent. Of particular interest is the noticeable lack of undercut banks along Cutoff Creek (Table 27). The lower four reaches exhibited streambanks with channel bank angles greater than 120° . As a result, the ability to contain peak flows may be limited in these reaches. Embeddedness was relatively low throughout Cutoff Creek; a lack of fine sediment in the channel indicates adequate flushing flows during periods of runoff.

No fish were observed in Cutoff Creek. The upper four reaches are inaccessible to fish due to the cascades at the lower boundary of Reach 3. The factors related to the absence of fish in Reach 1 are undetermined. Gradient is moderate (4.2%), and late summer water temperature (12.7°C) does not appear to be limiting to fish survival. The very low summer flows ($0.027 \text{ m}^3/\text{s}$) apparently limit suitable habitat in Reach 1. Average stream depth of three transects was 7.6 cm (Table 27). This stream depth is below recommended minimum levels for trout survival. Bovee (1978) estimated that 12.2 cm is the minimum depth required by cutthroat trout fry, juveniles, and adults. In a study by Wesche (1976), trout under 152 mm needed a minimum water depth of 15.2 cm. Thus, it appears that the shallow stream depth and resulting lack of cover in Reach 1 may prevent the establishment of a resident cutthroat trout population. Reach 2 appears to be suitable habitat for trout; however, this reach was rated the least stable of the Cutoff Creek

Table 28.-Physical features of tributaries to Cutoff Creek, 1987.

Stream	Stream Order	Watershed Size (ha)	Stream Length (km)	Elevation		Gradient (%)	Stream Flow (m3/s)	Mean Width (m)	Mean Depth (cm)	Mean Velocity (cm/s)	Temperature (C)	pH
				Maximum (m)	Minimum (m)							
1033022301	I	53.9	0.87	2359.1	2186.9	19.8	a					
1033022302	I	111.5	1.70	2668.5	2209.8	27.0	b					
1033022303	I	196.9	1.80	2657.9	2278.4	21.1	0.017	0.92	7.81	22.96	8	7.2
1033022304	I	30.2	0.63	2529.8	2362.2	26.6	0.012	0.88	9.02	15.14	11	7.3
1033022305	I	116.9	1.00	2743.2	2453.6	29.0	0.016	1.71	7.92	11.99	9	7.2
1033022306	I	10.5	0.40	2819.4	2621.2	49.6	a					

a no field measurements taken

b dry channel

survey sections. Although the gradient in this reach is not excessive, high peak streamflow velocities may deter salmonids from occupying this stream area. The lower two reaches of Cutoff Creek contain only limited sites for spawning. Consequently, Slough Creek cutthroat trout in the vicinity of Cutoff Creek may spawn elsewhere.

Winter stream conditions may be unsuitable for trout in Cutoff Creek. Shallow riffles in open areas are conducive to the formation of anchor ice (Benson 1955). Subsequent displacement of the stream discharge can be highly detrimental to trout populations if deep pools do not occur in the stream section (Butler 1979).

Macroinvertebrates.-Nine benthic invertebrate samples were taken in the Cutoff Creek watershed in 1987 (Table 29). The 29 species of macroinvertebrates that were collected represent the highest species diversity of any tributary to Slough Creek. The largest sample density and species diversity occurred in Reach 4. This section of Cutoff Creek was characterized as a stable reach with light streambank alteration, wide riffles, and a relatively silt-free substrate.

Ephemeropterans and plecopterans were the dominant orders in every sample from Cutoff Creek (Table 29). Although *Baetis bicaudatus* was present in 78% of the samples, *Epeorus deceptivus* and other Heptageniid mayflies were the most abundant species collected. Because the Heptageniids were collected primarily in the higher quality habitat (Reaches 3 and 4), these differences in distribution and density may reflect less restrictive environmental requirements of Baetidae. Plecopterans were widely distributed throughout the Cutoff Creek drainage, but density was low. The predatory *Megarcys* sp. occurred in 67% of the mainstem samples.

Trichopteran species were restricted to the mainstem and represented only a minor group in the invertebrate samples from Cutoff Creek. *Rhyacophila* sp. (a predator) was the most widespread caddis species. The majority of the remaining trichopteran species are classified as shredders or grazers (Merritt and Cummins 1978) and are dependent upon riparian input or attached algae for a food source. *Neothremma alicia* was the most environmentally sensitive benthic insect collected in Cutoff Creek. This species was found only in Reach 4, which was rated as high quality habitat. Other sampled species were active feeders. *Arctopsyche grandis* and Simuliids were the only passive filtering collectors. A predominance of gathering type collectors and a paucity of filter feeders is commonly found in medium-sized rivers (Minshall et al. 1985). Mean pH (7.3) in Cutoff Creek is below the Lamar River watershed average of 7.6. This would suggest somewhat decreased production in Cutoff Creek. However, the composition of macroinvertebrate functional groups in Cutoff Creek would indicate excess primary production and an autotrophic system.

Table 29.-Occurrence and densities of macroinvertebrates found in stream reaches and tributaries of Cutoff Creek, 1987.

	Reach Number						Tributary 10330223-		
	1	2	3	4	5	6	03	04	05
Turbellaria							2		
Insecta									
Ephemeroptera (mayflies)									
Siphonuridae									
<u>Ameletus</u> sp.		1	4		1	3	2		
Baetidae									
<u>Baetis bicaudatus</u>		2	3	2	4	7	2		7
Heptageniidae									
<u>Cinygmula</u> sp.	1		6	12		16		1	11
<u>Rhithrogena</u> sp.									4
<u>Epeorus albertae</u>		4							
<u>Epeorus deceptivus</u>	9		19	20	11	4	3		10
Ephemerellidae									
<u>Drunella coloradensis</u>	2	5				1			3
<u>Drunella doddsi</u>		1		2					
Plecoptera (stoneflies)									
Peltoperlidae									
<u>Yoraperia brevis</u>			1			6			1
Nemouridae									
<u>Zapada</u> sp.	2			2	2	1	1	1	
<u>Visoka cataractae</u>								1	1
Perlodidae									
<u>Megarcys</u> sp.		3	2		2	4			
<u>Cultus</u> sp.				1					
Chloroperlidae	1						2		
Perlidae									
<u>Doroneuria theodora</u>		2							
Trichoptera (caddisflies)									
Rhyacophilidae									
<u>Rhyacophila</u> sp.	1	1		1		1			
Hydropsychidae									
<u>Arctopsyche grandis</u>		2							
Limnephilidae									
<u>Neothremma alicia</u>				3					
<u>Ecclisomyia</u> sp.						1			
<u>Psychoglypha</u> sp.					1				
Lepidostomatidae									
<u>Lepidostoma</u> sp.				2					
Diptera (true flies)									
Tipulidae									
<u>Hexatoma</u> sp.						1			
<u>Holorusia</u> sp.					1		1		
Chironomidae	8			4	6	2	3		3
Simuliidae									
<u>Prosimulium</u> sp.					2				4
<u>Simulium</u> sp.				2					
Pelecorhynchidae									
<u>Glutops</u> sp.				1					
Empididae					1				
TOTAL TAXA:	7	9	6	12	10	12	8	3	10
TOTAL #/m ² :	258	226	377	560	334	506	161	32	495
† SHEEDERS	8	0	0	8	10	2	14	67	2
† COLLECTORS	79	71	91	82	77	72	72	33	92
† SCRAPERS	0	0	3	6	0	13	0	0	2
† PREDATORS	13	29	6	4	13	13	14	0	4

Soda Butte Creek Drainage

The extreme northeastern section of Yellowstone National Park encloses 19,425 hectares of the Soda Butte Creek drainage. Soda Butte Creek is one of the largest tributaries to the Lamar River and supports one of the 10 most popular stream fisheries in the park (Table 4). Studies have been conducted on Soda Butte Creek since 1966 to monitor both habitat and fishery responses to pollution effluents from the McLaren mine tailings located outside of the park and to assess angler impacts on the resident trout populations (Arnold and Sharpe 1967; Mills and Sharpe 1968a; Dean and Mills 1971; Jones et al. 1977-1987; Decker-Hess and White 1987).

Only a limited number of surveys have been conducted on minor tributaries to Soda Butte Creek. Several tributaries were mapped during a habitat survey of the mainstem in 1981, but detailed habitat measurements were not taken (Jones et al. 1982). In 1986, cursory-level data were collected on 11 tributaries between the mouth of Soda Butte Creek and Pebble Creek (Jones et al. 1987). During 1987, a cursory-level survey was conducted on Warm Creek (Stream 10331732) and 20 unnamed tributaries to Soda Butte Creek upstream from Pebble Creek (Figure 29). The section of Soda Butte Creek upstream from Pebble Creek was termed "upper" Soda Butte Creek.

Physical characteristics.—The portion of Soda Butte Creek upstream from Pebble Creek is bordered by Barronette Peak on the west and Abiathar Peak on the east. These steep mountains are composed of massive Absaroka volcanic flows overlying numerous layers of sedimentary material (Lodgepole limestone, Three Forks-Jefferson carbonates and shales, and Bighorn dolomite formations) (Protska et al. 1975a). Pleistocene glaciation deposited a mixture of glacial till and rubble veneer on the uplands and covered the stream valley floor with glaciofluvial deposits (Protska et al. 1975a). The present form of Abiathar Peak has also been influenced by large landslide deposits on the west and northwestern slopes.

In contrast to the wide sagebrush meadows characteristic of Soda Butte Creek downstream from Amphitheater Creek, the section of Soda Butte Creek upstream from Pebble Creek is bordered by a densely forested, narrow valley. Lodgepole pine stands cover the majority of this valley floor and some of the more unstable areas of Abiathar Peak. Lodgepole pine may become the dominant conifer in soils of sandstone parent materials or glacial alluvium sites (Steele et al. 1983). Douglas fir is normally found at lower elevations; however, in some situations, andesitic flows may provide preferred habitat for this species at higher elevations (Steele et al. 1983). The steep uplands of Soda Butte Creek present these conditions; consequently, a band of Douglas fir parallels both sides of upper Soda

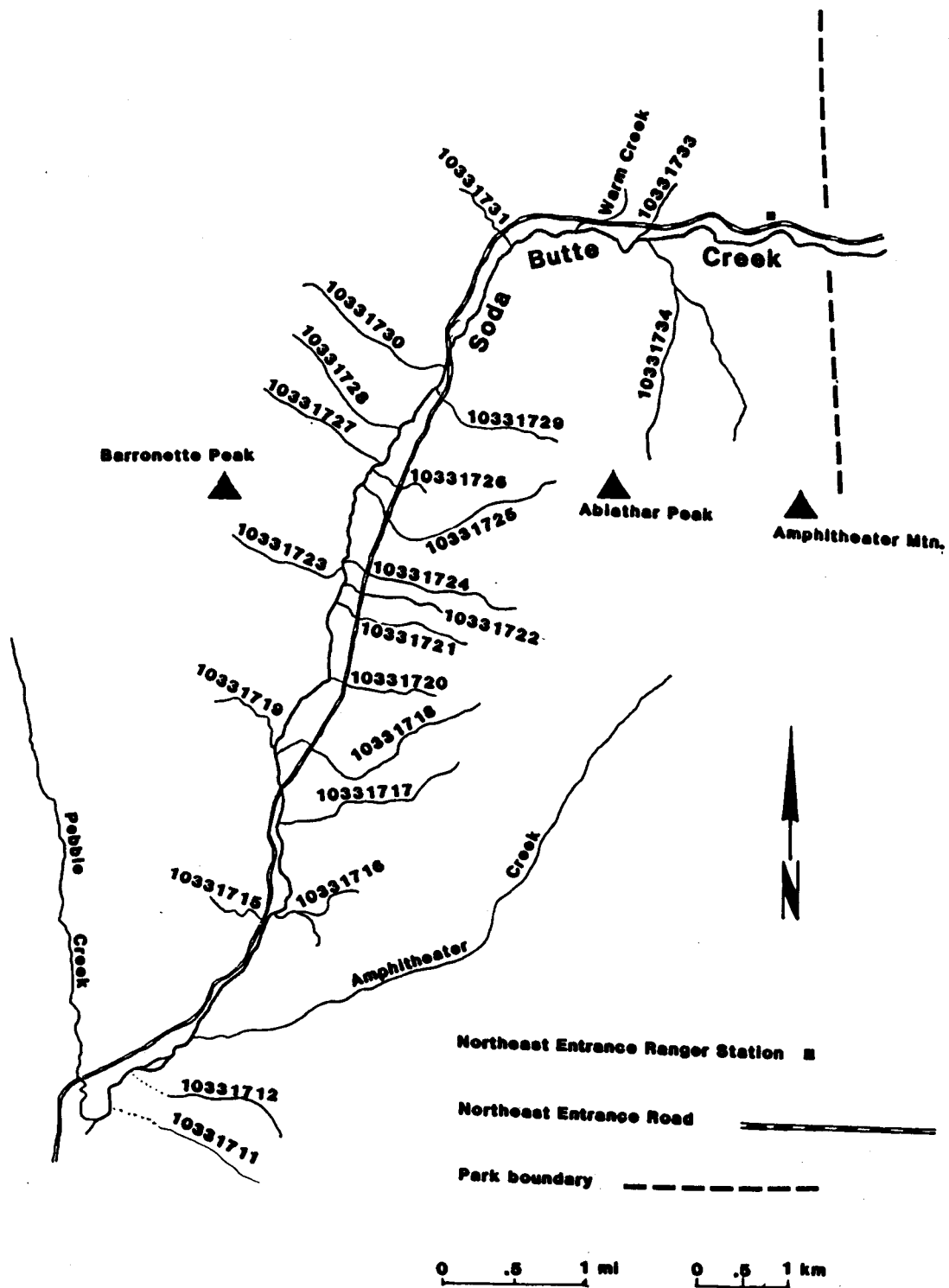


FIGURE 29.-Hydrographic map of tributaries to Soda Butte Creek surveyed in 1987.

Butte Creek. Above 2,500 m, whitebark pine dominates the forest community.

Moose were the most commonly observed ungulates in the upper reaches of Soda Butte Creek. Mule deer *Odocoileus hemionus* and elk were also seen. Bighorn sheep *Ovis canadensis* inhabit Abiathar Peak and Amphitheater Mountain. Water ouzels, red-tailed hawks *Buteo jamaicensis*, and a goshawk *Accipiter gentilis* were noted in the drainage basin during 1987.

The majority of the tributaries to upper Soda Butte Creek are high gradient streams less than 2 km in length (Table 30) and have channels characterized by abundant rocky debris. Although most of these tributary streams are intermittent or ephemeral and have only a seasonal discharge, seven of the 21 tributaries to upper Soda Butte Creek contained a streamflow in 1987 (Table 30). Several of the tributaries draining Abiathar Peak, e.g., streams 10331721, 10331724, and 10331725, are located in fan gravel deposits (Pierce 1974) and appear to flow on an irregular basis in response to major runoff events. Although the stream channels are well defined, they appear to be quite unstable.

In contrast, tributary channels from Barronette Peak (particularly Stream 10331723) contain considerable amounts of downed timber and woody debris jams. Only one tributary (Stream 10331719) from Barronette Peak was perennial (Figure 29).

The great majority of the tributary streams from Abiathar Peak and Barronette Peak have the potential to introduce large amounts of sediment and debris into the Soda Butte Creek mainstem. Stream 10331725 forms a large debris fan at the confluence with Soda Butte Creek. Material from this tributary extends almost entirely across the Soda Butte Creek mainstem and upstream for a distance of approximately 25 m.

In addition to being intermittent, many tributaries in the upper section of Soda Butte Creek exhibit steep gradients that probably are barriers to upstream fish movement during periods of streamflow. However, the lower 50-200 m of streams 10331716, 10331719, and 10331726 are low gradient and may provide rearing habitat. Stream 10331711 (Figure 29) subsides into a sagebrush meadow and does not directly connect with Soda Butte Creek except during exceptionally high flows (Jones et al. 1987).

The upper three tributaries of Soda Butte Creek are perennial streams which differ from the other surveyed tributaries in several respects. Stream 10331733 is a narrow, silty bottom stream with overhanging grassy banks. Although this stream had the smallest discharge (0.003 m³/s) of Soda Butte Creek tributaries, gradient (9.1%) is considerably less than most other tributaries (Table 30). In small trout streams, shallow water depth may

Table 30.-Physical features of tributaries to Soda Butte Creek, 1987.

Stream	Stream Order	Watershed Size (ha)	Stream Length (km)	Elevation Maximum (m)	Elevation Minimum (m)	Gradient (%)	Stream Flow (m3/s)	Mean Width (m)	Mean Depth (cm)	Mean Velocity (cm/s)	Temperature (C)	pH	Conductivity (umhos/cm)
10331711	I	279.6	1.30	2316.5	2060.5	19.7	0.006	0.48	4.06	31.50	8	7.1	75
10331715	I	76.1	1.23	2388.1	2109.2	22.7	a						
10331716	II	51.2	1.60	2584.7	2118.4	29.1	0.006	0.61	4.83	18.49	17		245
10331717	I	148.3	2.00	2560.3	2130.6	21.5	a						
10331718	I	97.1	2.23	2773.7	2136.6	28.6	a						
10331719	I	106.3	1.40	2450.5	2138.1	22.3	0.012	1.00	8.06	14.63	11	6.9	220
10331720	I	99.8	1.33	2560.3	2144.3	31.3	a						
10331721	I	93.2	1.77	2560.3	2151.9	23.1	a						
10331722	I	31.5	1.20	2438.4	2154.9	23.6	a						
10331723	I	94.5	1.20	2804.2	2158.0	53.6	a						
10331724	I	122.1	2.00	2682.2	2159.5	26.1	a						
10331725	I	292.7	2.77	2682.2	2164.1	18.7	a						
10331726	II	2.2	0.76	2280.0	2167.1	14.9	0.009	0.63	5.21	29.06	7	6.9	150
10331727	I	95.8	1.60	2731.0	2168.7	35.2	a						
10331728	I	141.8	1.90	2685.3	2171.7	27.0	a						
10331729	I	147.0	1.87	2682.2	2179.3	26.9	a						
10331730	I	225.8	1.97	2511.6	2182.4	16.7	a						
10331731	I	61.7	1.17	2423.2	2200.7	19.0	a						
10331732	I	32.8	0.32	2225.5	2208.3	5.4	0.053	1.53	10.35	33.43	9	7.2	260
10331733	I	28.8	0.32	2240.3	2211.3	9.1	0.003	0.50	3.62	14.33	6	8.0	290
10331734	II	451.7	3.00	2731.0	2214.4	17.2	0.058	1.70	7.92	43.18	9	7.8	127

a dry stream channel during survey

be limiting to adult trout (Kennedy and Strange 1982). However, Stream 10331733 may serve as a rearing site.

Warm Creek (Stream 10331732) had the lowest gradient (5.4%) and deepest channel (mean depth, 10.53 cm) of the Soda Butte Creek tributaries surveyed in 1987 (Table 30). Abundant aquatic vegetation and several tree stumps provide cover for fish in Warm Creek. Possibly because of its spring source, this stream appears to have minimal annual streamflow variation, a desirable attribute of quality trout habitat (Binns and Eiserman 1979).

Stream 10331734 was the largest perennial tributary to Soda Butte Creek examined in 1987. This is a high velocity, second order tributary that exhibits substantial peak flow impacts. Numerous old channels, a 200-m wide flood plain completely covered with glacial alluvium, and unstable banks composed of loose unconsolidated materials of varying sizes characterize this stream. The riparian zone consists of isolated conifer stands. Understory vegetation is practically nonexistent, except near the confluence with Soda Butte Creek. Because of the unstable channel and lack of cover, Stream 10331734 appears to have little value in terms of supporting any life history stages of trout. In addition, the sediment inputs from this stream into Soda Butte Creek could cause significant stress to the resident trout populations in Soda Butte Creek mainstem and decrease mainstem spawning and rearing habitat.

Macroinvertebrates.-In June 1987, benthic macroinvertebrate samples were collected from five tributary streams to Soda Butte Creek (Table 31). An additional sample was collected from stream 10331719 in September. A modified Surber sampler and a saturated salt solution that facilitates separation of insects from sample debris (Winget and Mangum 1981) were used in the September sample. This additional sample allowed for comparisons of selectivity of different collection techniques and seasonal differences in species abundance and composition.

Nine species each of Plecoptera, Trichoptera, and Diptera were collected from upper Soda Butte Creek tributaries (Table 31). *Rhyacophila* sp., a predacious caddis fly, occurred in five of the six samples. Although ephemeropteran diversity was comparatively low, mayfly density was highest in 67% of the samples (Table 31).

Streams 10331716 and 10331726 both exhibited low macroinvertebrate abundance and species diversity. High water temperature (17°C) and steep gradient (29.1%) (Table 30) may be limiting to macroinvertebrates in Stream 10331716. Low production levels in Stream 10331726 are more puzzling. Gradient, temperature, and substrate appear suitable for benthic macroinvertebrates; however, the small watershed (2.2 hectares) may provide only a minor amount of organic material to the stream channel. Although Simuliids are a primary prey source for *Rhyacophila* sp. (Pennak 1978),

TABLE 31.-Occurrence and densities of macroinvertebrates found in Soda Butte Creek tributaries, 1987.

	Stream 103317-					Warm Creek
	11	16	19	19 ^a	26	
Turbellaria		8	4	18		
Insecta						
Ephemeroptera (mayflies)						
Siphonuridae						
<u>Ameletus</u> sp.	2					
Baetidae						
<u>Baetis bicaudatus</u>	18	7	3			16
Heptageniidae						
<u>Cinygmula</u> sp.			3			
Ephemerellidae						
<u>Caudatella hystrix</u>			12			
<u>Drunella coloradensis</u>			4			35
Plecoptera (stoneflies)						
Peltoperlidae						
<u>Yorsperia brevis</u>	3					
Nemouridae						
<u>Visoka cataractae</u>			8			
<u>Zapada</u> sp.				7		
Perlidae						
<u>Isoperla fulva</u>						1
<u>Megarcys</u> sp.						1
<u>Cultus</u> sp.	4		3			
<u>Skwala</u> sp.		1				
Unidentified				2		
Chloroperlidae		1				
Trichoptera (caddisflies)						
Rhyacophilidae						
<u>Rhyacophila</u> sp.	1		7	1	12	2
Glossosomatidae						
<u>Glossosoma</u> sp.	1					1
Brachycentridae						
<u>Amiocentrus aspilus</u>			1			
Limnephilidae						
<u>Chyranda centralis</u>	1					
<u>Cryptochia furcata</u>				1		
<u>Hesperophylax</u> sp.			10			
<u>Neothremma alicia</u>						1
<u>Psychoglypha</u> sp.						1
Pupa						4
Coleoptera						
Unidentified					1	
Diptera (true flies)						
Tipulidae						
<u>Hexatoma</u> sp.				1		
<u>Tipula</u> sp.			1	2		3
Chironomidae			7	46	2	7
Simuliidae						
<u>Prosimulium</u> sp.	4	1				
<u>Twinnia</u> sp.					3	
Pelecorhynchidae						
<u>Glutopa</u> sp.						1
Dixidae						
<u>Dixa</u> sp.	2					
Athericidae						
<u>Atherix aspilus</u>			1			1
Empididae				5		
TOTAL TAXA:	9	5	13	9	4	13
TOTAL #/m ² :	388	194	689	893	194	797
‡ SHREDDERS	3	0	32	15	0	4
‡ COLLECTORS	72	80	50	63	12	86
‡ SCRAPERS	11	0	0	0	18	3
‡ PREDATORS	14	20	18	22	70	7

^a September sample with salt solution.

a high proportion (70%) of predators is unusual, because the predatory component of the macroinvertebrate community is normally a minor group (Vannote et al. 1980; Hawkins and Sedell 1981).

Above-average macroinvertebrate density (797 individuals/m²) and a diverse community structure (13 taxa) were found in Warm Creek (Stream 10331732). This spring-fed stream appears to have only minor annual variations in streamflow and water temperature. Moderate current velocity favors both Ephemeroptera and filter feeding Trichoptera (e.g., *Glossosoma* sp.) (Rabeni and Minshall 1977).

A similar community structure occurred in the June macroinvertebrate sample from Stream 10331719. Filtering collectors composed the dominant trophic group, and shredders, represented by *Visoka cataractae* and *Hesperophylax* sp., were more abundant when compared to other upper Soda Butte Creek tributaries (Table 31).

The September sample from this same stream (10331719) contained a much different community structure. A lower discharge produced only minor amounts of riparian detritus. As expected, the proportion of shredders declined by over 50% in the September sample (Table 31). In September, stream velocity was low, and the stream channel was silt-covered and contained numerous pools and abundant autochthonous vegetation. The September sample was dominated by dipterans (primarily Chironomids). A low velocity shallow habitat normally is preferred by Chironomids (Needham and Usinger 1956), and the smaller mesh size used in this sampling procedure facilitates the collection of small dipterans.

An increase in the number of Turbellaria in the September sample is possibly a reflection of a different methodology. Turbellaria are often difficult to detect and may be overlooked when sorting by hand.

Perhaps the most striking difference between the June and September samples in Stream 10331719 was the decrease in mayfly abundance. Although ephemeropterans were the dominant group in the June sample, density was zero in September. Adult emergence may have affected species abundance and diversity. Heaton (1966) found that Ephemeroptera in the Madison River of Yellowstone National Park were at their lowest levels in late summer and early fall. In addition, low velocities and pool habitats are often negatively correlated with Ephemeroptera abundance (Rabeni and Minshall 1977). These factors may partially explain the total absence of mayflies in the September sample from Stream 10331719.

Fish.—Warm Creek was the only upper Soda Butte Creek tributary in which fish were observed. During a previous survey, three cutthroat trout were captured by electrofishing (Jones et al. 1987). Angler use in Warm

Creek is difficult to estimate precisely because Volunteer Angler Report returns are sporadic. It appears that angler use in this open meadow stream is low, averaging 20-25 days annually since 1974. Approximately 12 cutthroat trout/year are landed in Warm Creek. In addition to providing an abundant food base and instream fish cover, Warm Creek may possibly serve as a cool water refuge for trout from the Soda Butte Creek mainstem during late summer when habitat and water temperatures in Soda Butte Creek are less than optimum.

Cold Creek Drainage

Cold Creek is a large tributary of the Lamar River (Figure 25). The southern portion of the Cold Creek drainage basin divide forms a section of the eastern boundary of Yellowstone National Park. From an elevation of 2,900 m on the western slope of Cathedral Peak, Cold Creek flows in a northeasterly direction through a heavily-wooded, V-shaped valley before joining the Lamar River at an elevation of 2,215 m. Lodgepole pine dominates the dense forest cover of Cold Creek and associated uplands. Whitebark pine is restricted to the higher elevation (> 2,680 m) slopes of Cathedral Peak and Pyramid Peak. Large stands of Engelmann spruce-subalpine fir are located in the northeastern cirque basins of these two peaks. A spruce-fir association at higher elevations generally suggests moist habitat conditions (Steele et al. 1983). Well-defined game trails in the upper reaches of Cold Creek watershed indicate suitable habitat for large numbers of elk.

Arnold and Sharpe (1967) rated the lowest reach of Cold Creek as a stable stream providing excellent fish habitat. This study also yielded qualitative data on macroinvertebrates and substrate composition. Cold Creek is a slightly basic, moderately dilute (TDS < 100 mg/L), sodium bicarbonate stream (Jones et al. 1980, 1985). cursory-level quantitative information was collected from Cold Creek in 1984 (Jones et al. 1985). In order to obtain more complete habitat data, a reconnaissance-level survey was conducted on Cold Creek and its major tributary, Mist Creek, in 1987.

Cold Creek

*Physical.-*Geological influences in Cold Creek drainage were dominated by Eocene volcanic flows. Trout Creek trachyandesite borders the eastern slopes of the Cold Creek watershed. Rhyolitic Lava Creek tuff formed the western ridges upstream from the confluence with Mist Creek (Protska et al. 1975b). The highest portions of Cathedral Peak and Pyramid Peak were formed from alluvial facies. The valley floor downstream from tributary 10334306 (Figure 30) was

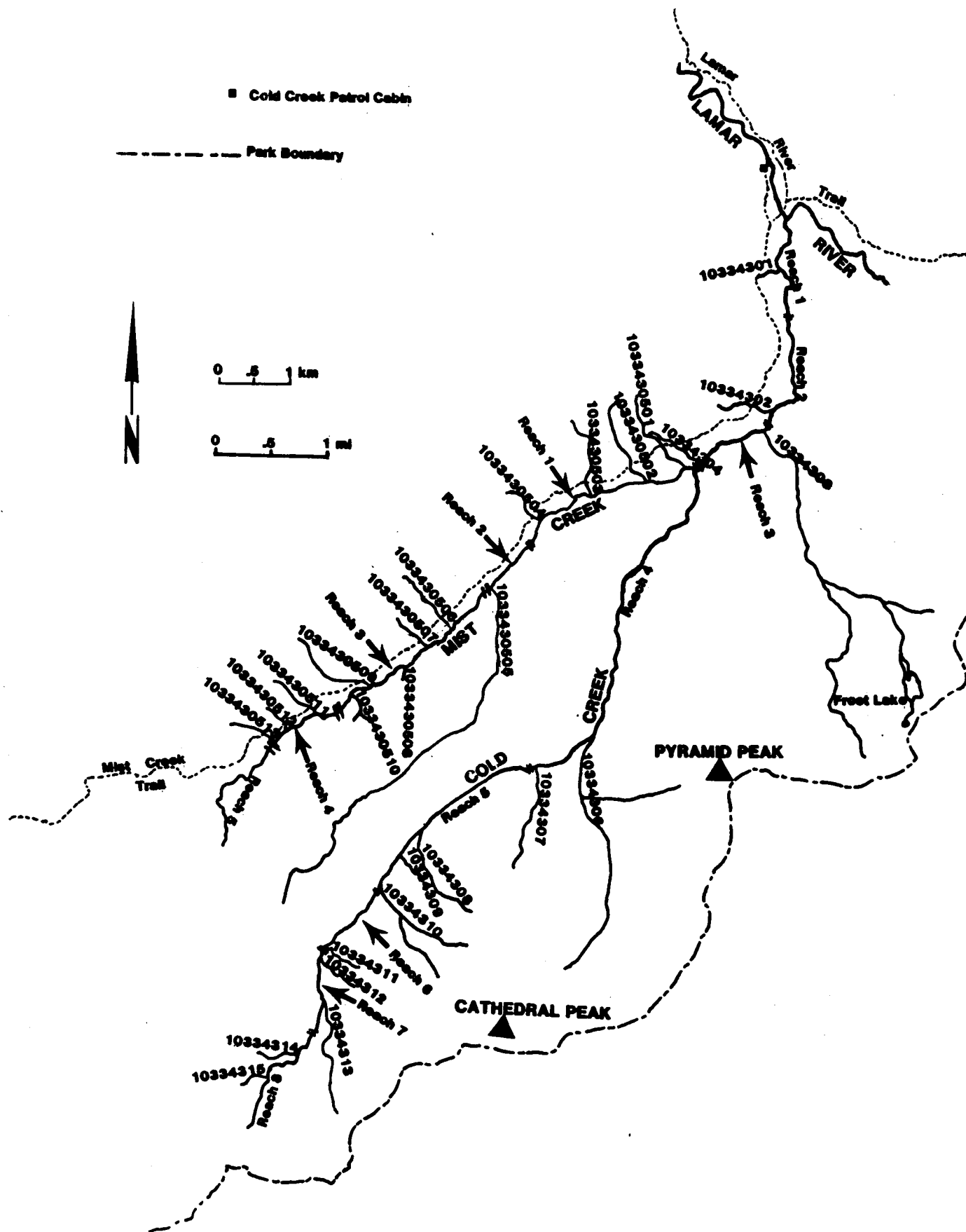


FIGURE 30.-Hydrographic map of stream reaches and tributaries surveyed in Cold Creek and Mist Creek.

composed of alluvial and colluvial deposits. Subsequent Pinedale glaciations deposited till in the uplands, eroded cirque basins on Cathedral Peak and Pyramid Peak, and covered the valley floor with a mixture of kame gravels and sand (Richmond and Waldrop 1972). Landslides on the north slopes of Cathedral Peak and debris flows in the lower section of Cold Creek have also contributed to the present topography.

Cold Creek can be characterized as a relatively straight, low-gradient stream. Sinuosity values were only slightly above 1.0, and gradient was $\leq 3.0\%$ in all but the uppermost reach of the stream (Table 32). The two lowest reaches of Cold Creek (Figure 30) are similar in appearance and have a substrate dominated by boulders. Streambanks are composed of a boulder base overlain with grass and sod (Table 32). Several high, eroded banks were noted in these stream sections and streambank alteration was rated moderate. The predominance of boulders in the downstream reaches of a low-gradient stream is unusual; however, the roundness of the boulders indicate they are glacial products rather than the result of recent stream flood events. Numerous good quality pools formed by boulders are found in the lower reaches of Cold Creek. The pools appear to provide fish with adequate cover and resting areas.

At the lower end of Reach 3, Stream 10334303 enters Cold Creek (Figure 30). This tributary from Frost Lake is one of the larger streams entering Cold Creek and contributes a significant amount of discharge to the mainstem (Table 33). In addition to being one of the widest tributaries to Cold Creek, stream 10334303 had the greatest mean velocity (39.9 cm/s).

Reach 3 exhibited several habitat variables that were similar to the downstream reaches: stream width, stream depth, vegetative stability, streambank alteration, and numerous good quality pools. Although boulder is still the dominant substrate material (73%), there was a shift towards smaller substrate particles as gravel and sand composed nearly 20% of bottom materials (Table 32). The dense overstory of the riparian zone provides a high degree of shading in this reach. There is an inverse relationship between solar angle (Table 32) and degree of shading; that is, a low solar angle indicates a large amount of shade at a transect. The solar angle in Reach 3 was one of the lowest in Cold Creek.

The confluence of Mist Creek (Stream 10334305) and Cold Creek represents the lower boundary of Reach 4 (Figure 30). This third-order stream section flows approximately 5 km through a relatively straight V-shaped forested valley. Downed timber is a common channel feature throughout the reach, and debris jams were frequent. Abundant timber in a stream channel may increase erosion during periods of peak streamflow (Pfankuch 1975). Streambank alteration is

TABLE 32.-Habitat characteristics of Cold Creek, 1987.

Habitat Features	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8
Sample Date	8/15/87	8/16/87	8/16/87	8/16/87	8/13/87	8/13/87	8/12/87	8/12/87
Time	1000	1000	1600	1500	1245	1030	1500	1300
Stream Order	IV	IV	IV	III	III	II	II	II
Length (km)	1.93	1.83	1.50	5.53	3.27	1.23	1.47	2.03
Elevation:								
Maximum (m)	2243.3	2278.4	2304.3	2484.1	2590.8	2603.0	2703.6	2731.0
Minimum (m)	2215.9	2243.3	2278.4	2304.3	2484.1	2590.8	2603.0	2703.6
Drainage Size (ha)	7957.6	7808.0	6045.1	3402.9	1156.3	682.5	559.1	232.3
Water Column:								
Flow (m ³ /s)	0.553	0.852	0.692	0.311	0.084	0.054	0.061	0.029
Channel Width (m)	14.5	11.5	10.9	10.4	3.7	4.3	5.0	5.0
Stream Width (m)	11.1	9.5	7.9	6.8	2.7	2.9	3.7	2.5
Stream Depth (cm)	20.12	22.86	21.95	17.07	10.06	7.92	15.54	8.23
Stream Shore Water Depth (cm)	0.91	13.41	0.91	8.23	0.91	5.49	7.01	2.44
Riffle Width (m)	10.85	8.63	6.89	6.37	1.95	2.56	2.07	0.91
Pools:								
Width (m)	0.2	1.4	1.0	0.6	0.5	1.0	1.5	1.4
Quality	3.0	3.0	3.3	3.0	3.1	4.0	4.7	3.4
Feature	4	4	4	4	3,4	3	1,4	1,3
Solar Angle	71.0	63.0	45.7	52.0	56.0	68.0	40.7	55.7
Channel Morphology								
Streambank Alternation	55.0	38.3	35.8	50.0	34.2	35.8	37.5	50.0
Vegetative Stability	1.3	1.5	1.7	1.3	2.7	1.7	1.5	1.7
Undercut (cm)	3.4	0.0	0.0	7.0	0.0	6.7	7.6	3.0
Channel-Bank Angle	125.8	126.7	140.0	91.7	111.7	103.3	103.3	120.0
Stream Bottom:								
Gradient (%)	1.5	2.0	1.7	2.0	3.0	0.7	2.5	6.0
Sinuosity	1.06	1.12		1.08	1.05	1.05	1.12	1.10
Substrate: (%)								
Boulder >356 mm	91.3	82.7	73.3	67.7	78.3		8.7	21.7
Cobble 64-356 mm	4.3	6.3	6.0	33.3	21.7		51.3	58.7
Gravel 2-64 mm			9.7			100.0	23.3	6.3
Sand 0.6-2 mm		11.0	11.0				16.7	13.3
Silt <0.6 mm	4.3							
Embeddedness	3.33	3.00	3.67	3.00	3.33	4.00	3.00	2.67
Channel Vegetative Cover (cm)	20.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Riparian Zone:								
Streamside Cover	1.8	1.3	2.0	2.3	1.3	2.0	2.0	2.0
Vegetative Use	3.00	4.00	3.80	3.17	3.00	4.70	3.80	3.00
Vegetation Overhang (cm)	3.35	0.00	1.08	15.24	0.00	0.00	8.23	3.96
Habitat Type	12,9	6,12	8,9	13,14	12,9	13,9	13	13,11

TABLE 33.-Physical features of tributaries to Cold Creek, 1987.

Stream	Stream Order	Watershed Size (ha)	Stream Length (km)	Elevation Maximum (m)	Elevation Minimum (m)	Gradient (%)	Stream Flow (m3/s)	Mean Width (m)	Mean Depth (cm)	Mean Velocity (cm/s)	Temperature (C)	pH	Conductivity (umhos/cm)
10334301	I	40.7	0.77	2292.1	2231.1	7.9							
10334302	I	45.9	0.90	2438.4	2273.8	18.3							
10334303	II	1375.7	5.80	2790.4	2278.4	8.8	0.165	4.44	10.67	39.91	7	7.3	65
10334304	I	52.5	0.80	2484.1	2292.1	24.0	0.006	0.78	5.72	15.95	5	7.3	105
10334305	II	2424.3	10.60	2657.9	2304.3	3.3							
10334306	II	1136.7	4.00	2697.5	2462.8	5.9	0.134	3.48	13.46	32.77	10	7.2	50
10334307	I	193.7	1.58	2825.5	2482.3	21.7	0.004	0.62	5.84	13.72	8	7.3	60
10334308	I	570.8	0.88	2974.8	2529.8	31.8							
10334309	I	40.7	0.93	2792.0	2557.2	25.2							
10334310	II	367.0	1.50	2950.4	2587.8	24.2	0.003	0.89	4.32	7.52	5	7.3	50
10334311	I	81.4	1.23	2828.5	2603.0	18.3							
10334312	I	103.7	1.40	2828.5	2607.6	15.8							
10334313	I	220.5	1.70	2894.4	2650.2	14.4	0.009	1.09	6.86	13.51	4	7.2	55
10334314	I	9.2	0.47	2709.7	2688.3	4.6							
10334315	I	7.9	0.67	2709.7	2703.6	0.9	0.018	1.61	7.62	16.36	8	7.3	57

significant in Reach 4 (50%); however, the alterations have resulted in some undercut banks that provide suitable habitat for fishes. The high-quality pools in this stream section are generally formed by boulders, but several are also formed by embedded timber. Additional cover for fish is provided by overhanging vegetation (mean, 15 cm/streambank transect). A large second order tributary (Stream 10334306) and several large springs contribute a majority of the discharge in Reach 4. The discharge in Reach 4 ($0.311 \text{ m}^3/\text{s}$) was over three times that measured in Reach 5 ($0.084 \text{ m}^3/\text{s}$).

Reach 5 is contained in a narrow, straight canyon over 3 km in length at the northwest base of Cathedral Peak (Figure 30). This reach was rated the most stable portion of Cold Creek (Table 32). A predominance of riffles with interspersed high-quality pools formed by boulders typified this reach. Streambanks in this stream section generally had a boulder and grass composition similar to Reach 1.

A low gradient (0.7%) and a grassy meadow riparian area were distinctive characteristics of Reach 6. In addition, this stream section has a substrate composed almost entirely of gravel (Table 32). The low substrate embeddedness indicates suitable spawning habitat; however, water velocity (mean, 22 cm/s) in this stream reach may be insufficient to adequately wash silt from inter-gravel spaces. Although the gravel and sod streambanks are fairly stable, frequent undercut banks indicate some susceptibility to erosion.

The headwaters of Cold Creek were divided into two reaches during the reconnaissance survey (Figure 30). Both Reach 7 and Reach 8 were similar in many habitat features, including a variety of substrate sizes (Table 32). However, Reach 7 is bordered by a steep-walled canyon resembling Reach 5. Although not reflected in the transect data, downed timber is abundant in the channel of Reach 8. Numerous small tributaries, seeps, and springs contribute substantially to stream discharge in these uppermost stream sections.

Tributary streams of the upper Lamar River are characterized by their instability and severe channel degradation (Jones et al. 1987). Although geological influences are very similar between Cold Creek (Richmond and Waldrop 1972) and the closest major tributary, the Little Lamar River (Pierce 1974), Cold Creek is generally stable and seems to be little affected by erosive forces. Although suitable fish habitat is present throughout the stream, the only fish observed in Cold Creek was seen in Reach 2. The relatively large size of the stream precluded sampling with rotenone.

The debris jams in Reach 4 may be barriers to fish migration and restrict fish to the portions of Cold Creek below the confluence with Mist Creek. The upper three reaches of Cold Creek had no barriers to fish migration, and

the substrate was suitable for spawning habitat. However, because large substrate particles are dominant throughout the majority of the stream, suitable spawning sites may be limited in Cold Creek.

One additional factor affecting fish distribution in Cold Creek may be water temperature. The mean instantaneous temperature recorded in August 1987 was only 7.8°C. Because August temperatures are normally high, low values suggest a short growing season and limited productivity, particularly in the upper reaches.

Macroinvertebrates.-Mainstem macroinvertebrate samples in Cold Creek yielded a mean abundance of 613 individuals/m² (Table 34). Species diversity in all mainstem samples (Table 34) exceeded the mean species diversity (5.1 taxa/sample [Jones et al. 1987]) found in the Lamar River upstream of Cold Creek. Ephemeropterans dominated most samples and heptageniid mayflies comprised a major family group in all sections except Reach 8. *Rhithrogena* sp. was not only one of the most widely distributed taxa, but was also the most abundant species collected from Cold Creek mainstem.

Plecopterans were a major group in samples from the upper sections of Cold Creek (Reaches 5-8) but diminished in importance in the lower reaches (Table 34). Because Nemouridae are generally shredders or grazers (Merritt and Cummins 1978), this distribution may be a reflection of increasing stream order or decreased riparian influence and detrital input. In contrast, *Cultus* sp., *Megarcys* sp., and *Skwala* sp. are predators whose distribution is independent of stream order.

Cold Creek contained only limited numbers of Trichopterans; a similar community structure has been found in other tributaries of the Lamar River (Jones et al. 1985, 1986, 1987). The most widespread caddis fly was *Rhyacophila* sp., a predator. Grazing forms, such as *Neothremma alicia*, were generally found in the upper reaches of Cold Creek.

One of the more unusual features of the macroinvertebrate collections from Cold Creek was the distribution of *Stenelmis* sp. (Table 34). Past collections from Lamar River tributaries have only occasionally yielded Coleopterans (Jones et al. 1985-1987) and the collection of Coleopterans from several adjacent stream reaches is very rare. Although Elmidae can survive in a wide range of environmental conditions (Winget and Magnum 1981), they may have preferred habitats that are similar to those found in Cold Creek. Reasons for their relatively high abundance in Cold Creek are unknown; however, collections of beetles in the Lamar River tributaries were generally taken in third- or fourth-order streams with low to moderate gradients (1-10%).

A general decreasing trend in macroinvertebrate density was noted in an upstream direction in Cold Creek (Table 34).

TABLE 34.-Occurrence and densities of macroinvertebrates found in stream reaches of Cold Creek, 1987.

	Reach No.							
	1	2	3	4	5	6	7	8
Arachnida								
Hydracarina (water mites)						2		
Insecta								
Ephemeroptera (mayflies)								
Siphonuridae								
<u>Ameletus</u> sp.	1		3			6	3	1
Baetidae								
<u>Baetis bicaudatus</u>	3	6	8	7	3		7	2
<u>Baetis tricaudatus</u>			1					
Heptageniidae								
<u>Cinygmula</u> sp.	12		5	4	4	9	5	1
<u>Rhythrogena</u> sp.	5	24	2	14	5		2	1
<u>Epeorus</u> <u>deceptivus</u>		12		23	11	1	8	
Ephemerellidae								
<u>Drunella coloradensis</u>	4		3			1	3	
<u>Drunella doddsi</u>	4	21	1	1				
<u>Serratella mitchneri</u>	1		7					
Plecoptera (stoneflies)								
Peltoperlidae								
<u>Yoraperia brevis</u>					1	6	4	12
Memouridae								
<u>Visoka cataractae</u>						4	2	
<u>Zapada</u> sp.		3		3	11	1	19	7
Perlodidae		1						
<u>Cultus</u> sp.			1					1
<u>Megarcys</u> sp.				1	1	2		
<u>Skwala</u> sp.							5	
Chloroperlidae			4		3	2	1	
Trichoptera (caddisflies)								
Rhyacophilidae								
<u>Rhyacophila</u> sp.	7	10	8		2		1	1
Glossosomatidae								
<u>Glossosoma</u> sp.		1			9			
Brachycentridae								
<u>Amiocentrus aspius</u>			2					
Lepidostomatidae								
<u>Lepidostoma</u> sp.						3		
Limnephilidae								
<u>Apantia</u> sp.		2						
<u>Neethromma alicia</u>			3			5		6
<u>Psychoglypha</u> sp.							3	
Hydropsychidae								
<u>Arctopsyche grandis</u>		4						
Coleoptera (beetles)								
<u>Stenelmis</u> sp.	3	2	10 ⁴					
Diptera (true flies)								
Tipulidae								
<u>Dicraneta</u> sp.							1	
<u>Hexatoma</u> sp.			1					
Chironomidae	7		6		3	3	3	
TOTAL TAXA:	10	11	16	7	11	13	15	9
TOTAL #/m ² :	578	926	710	570	570	484	721	344
* SHREDDERS	0	3	0	6	21	19	31	22
* COLLECTORS	77	78	59	92	49	46	51	16
* SCRAPERS	6	6	20	0	19	26	6	56
* PREDATORS	17	13	21	2	11	9	12	6

The one notable exception occurred in Reach 7, which exhibited the second highest density and species diversity. This may be a reflection of substrate composition in this reach (Table 32). A mixture of substrate sizes, with cobble and gravel predominating, may provide a larger variety of macroinvertebrate niches (Rabeni and Minshall 1977).

Shredders formed an important portion of the community structure in the upper second and third order stream reaches. This arrangement suggests significant riparian detrital contributions to the stream (Vannote et al. 1980). In Reaches 1-4, large proportions of collectors indicate a shift towards autochthonous production commonly associated with a larger stream order.

Macroinvertebrate species composition in the tributary streams was similar to that of the mainstem. Heptageniid mayflies were the dominant group in the majority of samples (Table 35). In contrast to the mainstem, plecopterans and trichopterans were found in relatively equal abundance.

Streams 10334313 and 10334315 had above average macroinvertebrate density and diversity (Table 35). Both of these streams contained abundant amounts of downed timber in the channel and a dense overstory. Shredders and gathering collectors comprised the majority in these two samples. The highest density in any tributary to Cold Creek occurred in stream 10334306; however, *Glossosoma* sp. represented 50% of the sample. This species prefers higher velocity streams (Rabeni and Minshall 1977). Tributary 10334304 had a significant proportion of shredders, reflecting the major riparian influence of the overhanging willows and alders of this stream.

Very low species diversity was found in streams 10334307 and 10334310. Chironomids were abundant in the latter sample. Both of these tributary streams had a low streamflow (Table 33) that may restrict macroinvertebrate production. However, low velocity associated with lower flows provides a preferred habitat for Chironomids (Needham and Usinger 1956). The abundance of Chironomids in Stream 10334310 (269/m²) indicates preferred environmental conditions.

The vast majority of macroinvertebrates collected from Cold Creek require high quality stream conditions. *Drunella doddsi* is a species that is extremely intolerant of environmental fluctuations. The collection of this species throughout the lower reaches of Cold Creek (Table 34) indicates that Cold Creek is a stable, high-quality stream. In addition, macroinvertebrate production levels in Cold Creek are much higher than that observed in nearby major tributaries of the Lamar River. Despite the cold temperatures, macroinvertebrate density in Cold Creek is sufficient to support a trout population. Macroinvertebrate abundance in the lower reaches of Cold Creek (925/m²) is only slightly lower than the approximately 1,000/m² reported

TABLE 35.-Occurrence and densities of macroinvertebrates found in Cold Creek tributaries, 1987.

	Stream No. 103343-						
	03	04	06	07	10	13	15
Turbellaria (Planarians)		2					
Insecta							
Collembola (springtails)					1		
Ephemeroptera (mayflies)							
Siphonuridae							
<u>Ameletus</u> sp.		2				8	1
Baetidae							
<u>Baetis bicaudatus</u>	2	1			2	1	3
Heptageniidae							
<u>Cinygmula</u> sp.	4	2		1		13	7
<u>Rhithrogena</u> sp.	9		7				
<u>Epeorus</u> <u>deceptivus</u>	6		5			2	
Ephemerellidae							
<u>Drunella coloradensis</u>		1					
Plecoptera (stoneflies)							
Peltoperlidae							
<u>Yorasperia brevis</u>				2		3	2
Nemouridae							
<u>Podmosta</u> sp.							3
<u>Visoka cataractae</u>	1						4
<u>Zapada</u> sp.		2					8
Perlodidae							
<u>Cultus</u> sp.							2
<u>Megarcys</u> sp.					1		1
Chloroperlidae	1	3	3			5	3
Hemiptera							
Saldidae							
<u>Pentacora</u> sp.				1			
Trichoptera (caddisflies)							
Rhyacophilidae							
<u>Rhyacophila</u> sp.	1		2				1
Glossosomatidae							
<u>Glossosoma</u> sp.			23				
Limnephilidae							
<u>Chyranda centralis</u>		2					
<u>Apatania</u> sp.	3		3				
<u>Glyptopsyche</u> sp.							3
<u>Neothreuma alicia</u>		3					1
<u>Psychoglypha</u> sp.				1			
Hydropsychidae							
<u>Arctopsyche grandis</u>	1						
<u>Parapsyche</u> sp.							
Coleoptera							
<u>Stenelmis</u> sp.	1						
Diptera (true flies)							
Tipulidae							
<u>Limonia</u> sp.						1	
Chironomidae			3		25		
Simuliidae							
Pupa						2	
Pelecorhynchidae							
<u>Glutops</u> sp.		1					
TOTAL TAXA:	10	10	7	4	4	10	12
TOTAL #/m ² :	312	183	495	54	312	409	398
% SMREDDERS	3	20	0	0	0	6	48
% COLLECTORS	76	40	33	40	90	67	30
% SCRAPERS	14	20	57	40	0	8	8
% PREDATORS	7	20	10	10	10	19	14

by Armitage (1958) for the Firehole River, which is noted for its macroinvertebrate production.

Fish.—Only limited sampling for fish has occurred on Cold Creek. In 1966, Arnold and Sharpe sampled the lowest portion of Cold Creek for fish, and captured seven cutthroat trout ranging from 130 to 275 mm total length and several trout fry approximately 20 mm total length. The seven cutthroat trout were aged as age I, II, or III.

Data from the Volunteer Angler Report (VAR) is limited, and detailed angler information cannot be defined with any certainty. However, it appears that angler use on Cold Creek is light and represents less than 1% of the total parkwide angling (Jones et al. 1985). Use appeared to be increasing between 1980 and 1984; reported angler days have varied from 15 in 1980 to 240 in 1984. The number of fish landed has also increased from 55 in 1980 to nearly 300 in 1984. The number of creeled fish followed a similar pattern and was estimated to be 135 fish in 1984. Lack of VAR returns since 1984 suggests a decline in angler use. Anglers in Cold Creek consistently creeled only smaller fish. Although cutthroat trout in the 406-457 mm range were landed, creeled fish were in the 254-304 mm size group or smaller. With only a modest amount of angler use in Cold Creek and the voluntary harvest of only smaller size cutthroat trout, it appears that the present regulation of two fish, any size, is meeting management objectives.

Mist Creek

Mist Creek (Stream 10334305) is the major tributary of Cold Creek (Figure 30). From the headwaters on the east side of Mist Creek Pass, Mist Creek flows northeast for 10 km to the confluence with Cold Creek. The majority of Mist Creek is contained in a gently sloping U-shaped valley. Generally, a dense lodgepole pine forest borders the stream; however, the middle portion of the stream flows through a large meadow approximately 3 km in length that is covered with sedges (*Carex* spp.) and hairgrass (*Deschampsia* sp.). Elk and moose frequent the riparian areas and uplands of Mist Creek. Although Mist Creek is located in a remote area of Yellowstone National Park, Mist Creek Trail parallels the stream and provides access to the area.

Jones et al. (1986) initiated a preliminary survey of Mist Creek. A reconnaissance-level survey was conducted on the lower two reaches and a cursory-level survey was performed on several tributaries to Mist Creek. Fish were observed downstream from tributary 1033430503 (Figure 30), but no fish were seen above this point. In 1987, both reconnaissance-level and cursory-level surveys were conducted on the unsurveyed sections of Mist Creek. Data from 1985 and 1987 have been combined in this report.

Physical.--Topography of Mist Creek has been determined by the same geological activities that formed Cold Creek (Richmond and Waldrop 1972). Parent materials of the valley floor and surrounding ridges are composed primarily of Eocene Absaroka volcanic flows. The upper half of tributary 1033430505 is located in Lava Creek tuff. Because Pinedale glaciation reached a thickness of 2,896 m, the entire Mist Creek drainage was glaciated. Most of the watershed was covered with till. Gravel and sand glaciofluvial deposits are located in the higher gradient sections of Mist Creek. The large meadow in the middle portion of the stream is the result of a major solifluction deposit. Another geologic influence manifested in Mist Creek is the presence of several landslide deposits on the north slopes of the lower portions of the stream (downstream from tributary 1033430505).

Mist Creek is a relatively-low gradient (mean, 2.0%), third-order stream. A dense riparian lodgepole pine overstory in Reach 1 provides almost continuous shading (solar angle, 49°). Downed timber was abundant in this reach that contained more channel vegetative cover than any other reach in Mist Creek (Table 36). Numerous debris jams have formed good quality pools; however, some of the debris jams may function as barriers to fish passage during periods of low streamflow. Pools formed by boulders or cobble in Reach 1 were rated fair quality because they provided only a limited amount of cover (Table 36).

Reach 2 is located in a gently sloping canyon (gradient, 2.2%). This stream section is characterized by numerous cascades and riffles and a few shallow pools of fair quality. Substrate is composed almost entirely of boulders and large cobble (Table 36). This substrate composition may be a reflection of landslide activity on the northern side of the stream. Although only one tributary enters Reach 2, a considerable amount of the discharge in this stream section comes from numerous seeps.

Tributary 1033430505 joins Mist Creek at the upper boundary of Reach 2 (Figure 30). This stream is the major tributary to Mist Creek and has the greatest watershed size, stream length, discharge, and mean width of any Mist Creek tributary (Table 37). Several cutthroat trout estimated to be 150-200 mm total length were observed in the upstream portion of this stream.

The upper three reaches of Mist Creek are located in wet meadow habitat, but Reach 4 includes extensive stands of lodgepole pine. The higher sinuosity values in these upper reaches are indicative of the semi-meandering channel pattern. Substrate is comprised of smaller particle sizes than those found in Reach 2 (Table 36). Streambanks in these upper reaches are generally composed of gravel, silt, and sod. Undercut banks with overhanging grass provide the majority of cover for fish in Reaches 3 and 5. In Reach 4,

TABLE 36.-Habitat characteristics of Mist Creek, 1985-1987.

Habitat Features	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5
Sample Date	7/30/85	7/30/85	8/11/87	8/11/87	8/11/87
Time	1000	1315	1145	1345	0930
Stream Order	III	III	III	II	I
Length (km)	2.00	1.70	3.0	1.1	2.20
Elevation:					
Maximum (m)	2380.5	2437.0	2484.1	2499.4	2657.9
Minimum (m)	2304.3	2380.5	2437.0	2484.1	2499.4
Drainage Size (ha)	2424.3	2155.2	964.7	395.0	233.6
Water Column:					
Flow (m3/s)	0.122	0.094	0.010	0.006	0.002
Channel Width (m)	8.0	7.3	2.8	2.7	1.0
Stream Width (m)	4.6	4.7	1.0	2.1	0.6
Stream Depth (cm)	12.19	12.19	11.28	14.63	3.96
Stream Shore Water Depth (cm)	6.10	6.10	2.44	0.00	2.44
Riffle Width (m)	2.13	3.08	0.62	0.00	0.27
Pools:					
Width (m)	1.2	1.0	0.4	2.1	0.3
Quality	1.7	1.5	2.9	4.0	2.4
Feature	3,4	3,4	3,2	2	7,3
Solar Angle	49.3	123.3	99.0	87.0	74.3
Channel Morphology					
Streambank Alternation	16.7	18.3	32.5	28.3	19.2
Vegetative Stability	3.2	3.3	2.2	1.8	3.8
Undercut (cm)	0.0	9.1	4.6	0.0	4.6
Channel-Bank Angle	120.8	119.2	121.7	111.7	100.0
Stream Bottom:					
Gradient (%)	2.7	2.2	1.3	1.3	2.5
Sinuosity	1.20	1.16	1.25	1.23	1.22
Substrate: (%)					
Boulder >356 mm	27.5	47.5	16.0		15.7
Cobble 64-356 mm	31.9	50.4	48.0		62.0
Gravel 2-64 mm	35.2	2.1	18.0	83.3	12.0
Sand 0.6-2 mm	5.5		18.0	16.7	10.3
Silt <0.6 mm					4.00
Embeddedness	3.00	3.30	4.70	4.30	0.20
Channel Vegetative Cover (cm)	36.58	9.14	0.00	0.00	
Riparian Zone:					
Streamside Cover	2.8	2.0	2.0	2.0	2.0
Vegetative Use	5.00	10.80	5.00	5.00	5.00
Vegetation Overhang (cm)	1.70	0.70	0.00	8.53	2.44
Habitat Type	13	9	13,9	14,13	14,13

TABLE 37.-Physical features of tributaries to Mist Creek, 1987.

Stream	Stream Order	Watershed Size (ha)	Stream Length (km)	Elevation Maximum (m)	Elevation Minimum (m)	Gradient (%)	Stream Flow (m ³ /s)	Mean Width (m)	Mean Depth (cm)	Mean Velocity (cm/s)	Temperature (C)	pH	Conductivity (umhos/cm)
1033430501	I	106.3	1.23	2560.3	2305.8	20.7							
1033430502	I	111.6	1.33	2560.3	2328.7	17.4							
1033430503	I	84.0	1.23	2560.3	2366.8	15.7							
1033430504	I	49.9	0.90	2572.5	2401.8	19.0							
1033430505	I	708.8	6.30	2631.9	2436.9	3.1	0.017	1.79	7.18	13.00	14	7.5	65
1033430506	I	52.5	1.05	2609.1	2458.2	14.4							
1033430507	I	57.8	0.70	2529.8	2459.7	10.0	0.003	0.81	3.05	12.20	14	7.5	100
1033430508	I	14.4	0.40	2490.2	2475.0	3.8							
1033430509	I	94.5	1.63	2731.0	2481.1	15.3	0.010	0.83	5.33	20.90	13	7.7	88
1033430510	II	55.1	0.87	2499.1	2484.1	1.8	0.001	0.62	5.72	3.35	13	7.4	71
1033430511	I	45.9	0.93	2609.1	2485.6	13.3							
1033430512	I	44.6	0.70	2584.7	2487.2	12.2	0.011	1.36	7.62	10.36	9	7.2	71
1033430513	I	43.3	0.9	2682.2	2491.7	21.9							

downed timber in the channel provides additional shelter. Pools in the upper reaches were rated good quality.

Several tributaries and small springs enter Mist Creek in Reach 3. This area is characterized by slow water velocity, small substrate size, and abundant cover. Because cutthroat trout fry prefer these habitat conditions (Hickman and Raleigh 1982), Reach 3 may serve as important rearing habitat in Mist Creek. Substrate embeddedness is very low in this section of Mist Creek, suggesting that the upper reaches may be utilized as spawning habitat.

The headwaters of Mist Creek arise in the meadow that encloses Reach 5. The mainstem flows out of a seep in the middle of the meadow. Although there is a defined channel at this point, the first 100 m of stream channel are filled with grasses and algae and smaller substrate particles with a predominance of silt, sand, and gravel.

Mist Creek was stable in the lower two reaches and in the headwater section. Besides exhibiting minimal streambank alteration, vegetative stability in these three reaches was rated excellent (Table 36). In the large meadow section (Reaches 3 and 4), erosion potential is substantially greater, but not extensive. Peak runoff flows may contribute some sediment to Cold Creek, but higher flows may also flush out fine sediments from the spawning sites in the upper reaches of Mist Creek. Mean instantaneous water temperature in Mist Creek was 11.2°C. This is within the preferred temperature range of cutthroat trout (Hickman and Raleigh 1982).

Macroinvertebrates.-Twenty-seven macroinvertebrate taxa were collected from the Mist Creek mainstem. Ephemeropterans were the most abundant order and Ephemerellids were the most abundant mayflies collected (Table 38). Species diversity of Ephemeroptera and Trichoptera was equal in Mist Creek mainstem, and plecopterans and dipterans were minor groups in the macroinvertebrate samples. Although coleopterans have been infrequently collected in tributary streams of the Lamar River (Jones et al. 1985-1987), two species of Elmidae were widely distributed throughout Mist Creek. In Reach 4, *Stenelmis* sp. had the highest species density of any taxon in Mist Creek. This suggests that the mixed meadow and forest habitat of Reach 4 may be a preferred habitat of aquatic coleopterans.

Shredders were a minor group throughout Mist Creek (Table 38). This may be a reflection of the openness and large amount of sunlight that Mist Creek receives. Hawkins and Sedell (1981) reported that shredders had a decreased abundance in unshaded streams due to diminished riparian influence. Leaves and woody debris are important food sources for shredders, and grasses are of secondary value. The grassy riparian areas of Mist Creek may limit shredder abundance. In contrast, the smaller size of the riparian

TABLE 38.-Occurrence and densities of macroinvertebrates found in stream reaches and tributaries of Mist Creek, 1987.

	Reach No.					Tributary 10334305-				
	1	2	3	4	5	05	07	09	10	12
Turbellaria					7			2		
Arachnida										
Hydracarina (water mite)					3					
Thomisidae (crab-spider)									1	
Insecta										
Ephemeroptera (mayflies)										
Siphonuridae										
<u>Ameletus</u> sp.	1	3								1
Baetidae										
<u>Baetis bicaudatus</u>		4			7	1				5
<u>Baetis tricaudatus</u>								1		
Heptageniidae										
<u>Cinygmula</u> sp.	1	3		4	3	2	3	2	2	
<u>Rhithrogena</u> sp.						2				
<u>Epeorus deceptivus</u>		2				5				
<u>Epeorus longimanus</u>						4				
Ephemerellidae										
<u>Drumella coloradensis</u>	2	2	3	2			3			
<u>Drumella grandis</u>			2							
<u>Serratella mitchneri</u>		7	6							
Plecoptera (stoneflies)										
Nemouridae										
<u>Visoka</u> sp.					1					
<u>Zapada</u> sp.				1						
Perlidae										
<u>Doroneuria theodora</u>			1	1		3				
Perlodidae										
<u>Cultus</u> sp.					2					
<u>Megarcys</u> sp.				2		2				
Chloroperlidae			2	2	2					
Trichoptera (caddisflies)										
Hydropsychidae										
<u>Arctopsyche grandis</u>			1			1				
Rhyacophiliidae										
<u>Rhyacophila</u> sp.			5	7	7		1	2		
Glossosomatidae										
<u>Glossosoma</u> sp.		3				2				
Brachycentridae										
<u>Amiocentrus aspius</u>			3							
Limnephiliidae										
<u>Amphicosmoecus</u> sp.			3							
<u>Dicosmoecus</u> sp.					1					
<u>Neoperophylax</u> sp.	1									
<u>Neothremma alicia</u>										3
<u>Psychoglyphe</u> sp.			1							
Coleoptera										
Elmidae										
<u>Cleptelmis ornata</u>	1				2					
<u>Stenelmis</u> sp.			4	12		1	5	4		
Diptera (true flies)										
Tipulidae										
<u>Hexatoma</u> sp.	1									
Simuliidae										
<u>Prosimulium</u> sp.						1				
Chironomidae			4					3	1	
TOTAL TAXA:	6	7	12	8	10	11	4	6	3	3
TOTAL #/m ² :	75	258	377	334	377	258	129	151	3	7
‡ SHREDDERS	14	0	0	3	4	0	0	0	0	0
‡ COLLECTORS	72	87	57	19	48	67	50	50	100	67
‡ SCRAPERS	0	13	20	39	4	13	42	33	0	33
‡ PREDATORS	14	0	23	39	44	20	8	17	0	0

detritus in these areas is suitable forage for scrapers and gathering collectors, which formed a majority of each sample in Mist Creek (Table 38). The higher macroinvertebrate densities and species diversities of Reach 3 and Reach 5 reflect these conditions.

The majority of samples from tributaries to Mist Creek revealed low macroinvertebrate density and species diversity (Table 38). Ephemeropterans were the dominant order in most collections. Plecopterans were sampled only from one tributary. The low streamflow in the tributaries could be a limiting factor in these macroinvertebrate populations. Only tributary 1033430505 had macroinvertebrate abundance and species diversity resembling the mainstem reaches (Table 38). As in the mainstem, the lack of shredders and predominance of scrapers and gathering collectors indicates diminished riparian influence.

Macroinvertebrate density and diversity in the mainstem of Mist Creek is similar to that found in nearby Lamar River tributaries, e.g., Little Lamar River. However, density of macroinvertebrates in tributaries to Mist Creek was generally about 50% of that observed in Little Lamar River tributaries (Jones et al. 1987). This suggests that macroinvertebrate production in Mist Creek is only fair.

The majority of species collected in Mist Creek have restrictive environmental requirements; yet, they are able to withstand some environmental fluctuations. Although some very sensitive species (e.g., *Neothremma alicia*) were collected, their overall distribution was limited, indicating that Mist Creek may undergo moderate environmental changes on a regular basis.

Fish.—In contrast to 1985, cutthroat trout were observed throughout Mist Creek in 1987; thus, any barriers in the mainstem are of a temporary nature. Several trout were seen in the headwaters and sought cover in the dense grass and algae of this stream section. A rotenone sample in Reach 3 yielded 30 cutthroat trout. Mean total length of these fish was 115 mm (range, 72-198 mm). Age analysis revealed that the oldest captured fish were three-year-olds (Table 39).

TABLE 39.—Mean backcalculated length at annulus formation for cutthroat trout in Mist Creek, 1987.

Sample Size	Length (mm) at Annulus		
	I	II	III
19	59	110	175

The predominance of younger age fish in the upper reaches of Mist Creek suggests these areas are dominated by spawning and rearing habitat. Larger and older fish may also inhabit Mist Creek, and several cutthroat trout observed in the lower reaches of the stream were estimated to be 200-250 mm total length. None of the captured fish were examined for maturity, but the collection of only three age classes suggests maturity at a young age. It is equally likely, however, that older cutthroat trout reside in the lower reaches of Mist Creek or Cold Creek mainstem and only utilize the upper portions of Mist Creek during spawning.

Estimates of angler use in Mist Creek are based on extremely limited Volunteer Angler Report data. It appears that use is very light and averages 15 to 20 d annually. All landed or creeled fish have been less than 250 mm total length. Estimated harvest has ranged from a high of 74 fish in 1977 to a low of zero fish creeled in 1982. Mean annual estimated harvest is approximately 15 fish. Thus, it appears that angler use in Mist Creek is minimal. Widespread distribution of cutthroat trout throughout Mist Creek suggests that angling impacts on the fish population have been slight.

FIREHOLE RIVER

The Firehole River lies in a 68,000-hectare watershed in west-central Yellowstone National Park. The river originates near Madison Lake at an elevation of 2,550 m and flows north for 44 km before joining the Gibbon River to form the Madison River at an elevation of 2,070 m (Figure 31). Mean annual discharge of the Firehole River is 9.8 m³/s (USGS 1986-1988), and average gradient is 1.1%.

From its headwaters to a point 3 km downstream from Kepler Cascades, the Firehole River is a cold-water stream (Argyle 1966; Burkhalter 1979). Below this point, the thermal and chemical properties of the river are substantially altered by discharges from hot springs and geysers in the Upper, Midway, and Lower geyser basins (Gooch and Whitfield 1888; Allen and Day 1935; Argyle 1966; Thompson and Presser 1975; Burkhalter 1979; Thompson 1979; Stauffer et al. 1980) (Figure 31). An unnamed cascades near the headwaters (Jones et al. 1977), Kepler Cascades, Firehole Cascades, and Firehole Falls (Figure 31) are barriers to upstream fish passage.

The Firehole River was originally barren of fish life above Firehole Falls (Evermann 1892; Jordan 1892); however, several salmonid species were introduced above the falls between 1889 and 1955 (Varley 1981). Initially, the purpose of stocking was to populate fishless areas, but stocking was continued to support put-grow-and-take angling. The river above the unnamed cascades near the headwaters is apparently still fishless (Jones et al. 1977), but self-sustaining populations of brown trout *Salmo trutta*, rainbow trout *Salmo gairdneri*, and brook trout *Salvelinus fontinalis* inhabit the river between the unnamed cascades and Firehole Falls. Distribution of these three species is substantially influenced by physical barriers and thermal gradients (Kaeding 1976, 1980; Kaya 1978; Kaya and Kaeding 1979).

Trout fishing on the Firehole River has been popular since the turn of the century (King 1897; Clark 1908). Liberal angling regulations in effect from the late 1800s through 1950 (U.S. Fish and Wildlife Service unpublished data) were replaced by a 5-fish, any-size, fly-fishing-only restriction in 1951. Despite this regulation, rainbow trout populations showed signs of overharvest shortly after stocking ceased in 1955 (Benson et al. 1959), and brown trout populations exhibited signs of overharvest by the late 1960s (Erman 1972). Consequently, a 2-fish, 406-mm minimum-size restriction was implemented in 1970 and remained in effect through 1986. Brown trout and rainbow trout populations apparently improved between 1970 and 1986; however, data from Kaeding (1976), Kaya (1978), and the Volunteer Angler Report system revealed a scarcity of fish ≥ 400 mm in length. In 1987, therefore, brown trout were placed under a 2-fish, 254-mm maximum-size limit, and

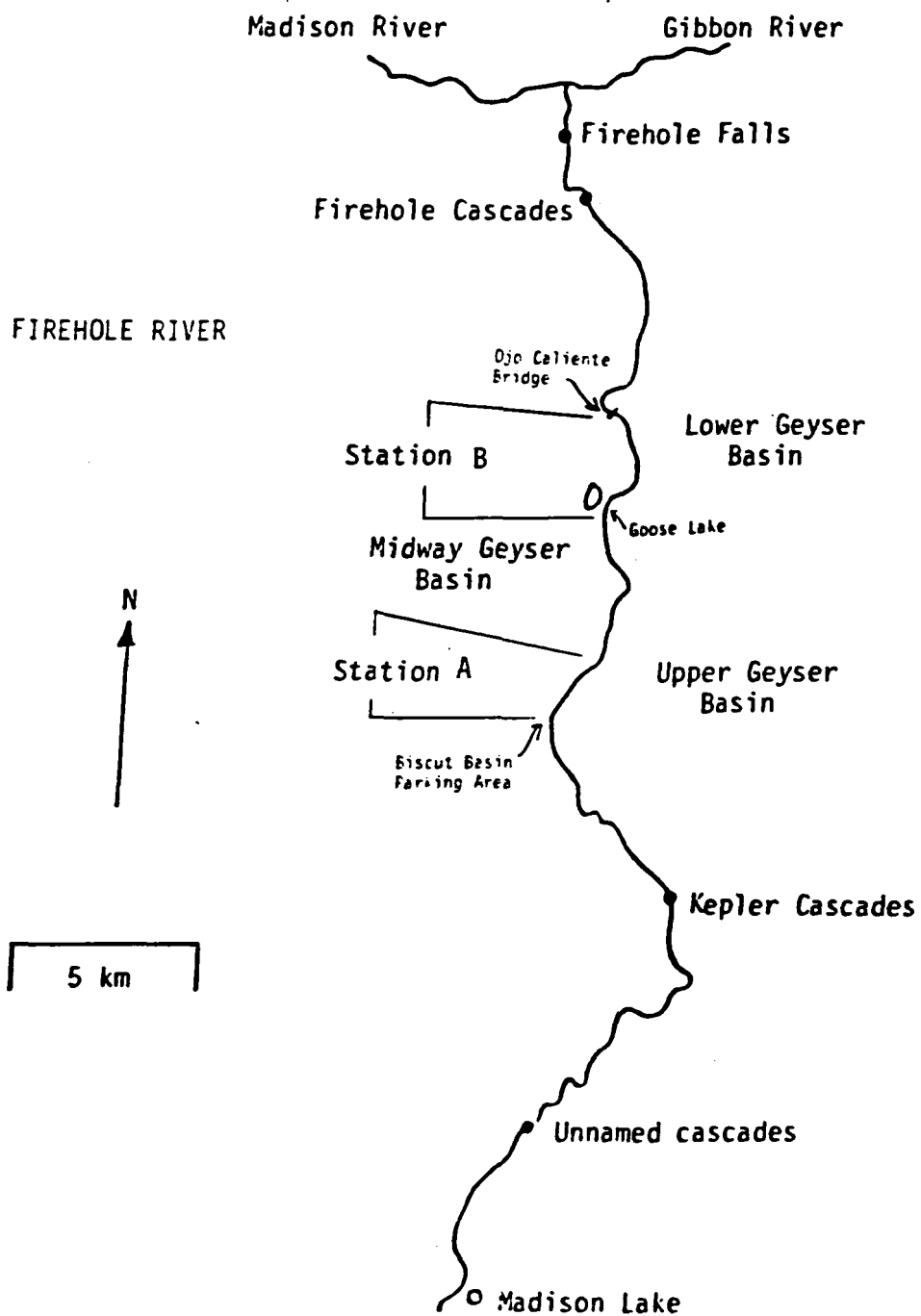


FIGURE 31.-Firehole River showing major geyser basins, physical barriers to upstream fish passage, and electrofishing stations A and B, 1987.

rainbow trout were restricted to catch-and-release only. Brook trout are currently under a 5-fish, 254-mm maximum-size restriction.

In 1987, fish populations in the thermally-enriched portion of the Firehole River were investigated in preparation for a hooking-mortality study that will be conducted by an independent researcher in 1988 and 1989.

Study Area

The study area extended from the Upper Geyser Basin downstream to Ojo Caliente Bridge in the Lower Geyser Basin (Figure 31). Mean annual water temperature at the upper end of the study area is about 18°C and 21°C at the lower end (Armitage 1958). Brown trout and rainbow trout are the only fishes inhabiting this section of river.

Methods

Two sample stations were established in the study area to investigate fish populations (Figure 31). Station A extended from the Biscuit Basin parking area to a point approximately 2.4 km downstream. Station B began just south of Goose Lake and ended 3.4 km downstream at Ojo Caliente Bridge.

Fish were sampled at Station A on 23 September and at Station B on 24 September. At both stations, fish were captured by nighttime electrofishing from a 4.6-m long rubber raft. The raft was fitted with two stationary dropper electrodes, fish-holding tanks, a 3.5 kW AC generator, and a Coffelt VVP-15 rectifying unit that produced pulsed, direct current.

Captured fish were identified to species and measured to the nearest 1 mm total length. For each species, a subsample of five fish in each 25-mm length group were weighed to the nearest 2 g, and scales were collected for age-growth determinations. To monitor movement in future studies, fish under 250 mm in length received a fin-clip, and fish 250 mm or longer were tagged.

Aging techniques used in this study were based on procedures developed by Kaeding (1976). Kaeding (1976) found that trout residing in the Firehole River in the vicinity of the Upper Geyser Basin (Station A in the current study) formed two growth checks on their scales each year (spring and summer), and he used the spring check as an annulus mark. Kaeding (1976) also found that some trout formed a spring check in their first year of life, and designated this initial spring check as annulus-1. In the current study, however, trout had to complete one full year of life before the spring check was designated as annulus-1.

In the vicinity of the Lower Geyser Basin (Station B in the current study) Kaeding (1976) reported that three growth

checks per year formed on trout scales (winter, spring, and summer); he designated the spring check as annulus-1 for trout in their first year of life and used the winter check as an annulus mark for older trout. In the current study, however, only the winter check was used as an annulus mark, and a trout had to complete one full year of life before the winter check was used as an annulus.

Results

At Station A, brown trout and rainbow trout each comprised about 50% of the total catch. At Station B, however, rainbow trout made up nearly 87% of the total catch. For each species, the number of fish captured per kilometer differed between sample stations. The number of brown trout captured at Station A (50 fish/km) was greater than at Station B (12 fish/km). Rainbow trout, however, were more abundant at Station B (81 fish/km) than at Station A (49 fish/km).

Brown trout mean length at Station A (260 mm) was less than at Station B (278 mm) (Table 40). The smaller mean length at Station A and differences in length frequencies at the two sample sites (Figure 32) appeared to be primarily related to differences in age composition (Table 41). At Station A, age-0 and age-1 fish comprised 55% of the sample; however, age-0 and age-1 fish made up only 32% of the catch at Station B. Mean backcalculated lengths (Table 42) revealed that growth of brown trout at Station A was slower than at Station B through age-1; thereafter, growth at the two sample sites appeared similar.

Rainbow trout mean length at Station B (220 mm) was less than that at Station A (248 mm) (Table 40). The smaller mean length at Station B and differences in length-frequencies (Figure 33) at the two sample sites again appeared related to differences in age composition (Table 43). At Station B, age-0 and age-1 fish made up nearly 72% of the total catch; however, age-0 and age-1 fish comprised only 46% of the sample at Station A. Mean backcalculated lengths (Table 44) indicated that rainbow trout growth at Station B was faster than at Station A through age-2.

Discussion

Benson et al. (1959) stated that the Firehole River above Midway Geyser Basin was populated primarily by brown trout, and Kaeding (1976) reported that brown trout made up 90% of an electrofishing sample obtained in the vicinity of Station A. At Station A in 1987, however, brown trout and rainbow trout each comprised about 50% of the electrofishing catch. Kaya (1978) found that elevated water temperatures negatively affected brown trout reproductive success in the

TABLE 40.-Mean length, weight, and condition of fish captured by electrofishing in the Firehole River, 1987.

Species	Station A				Station B			
	n	Mean length (mm)	Mean weight (g)	Mean condition (K)	n	Mean length (mm)	Mean weight (g)	Mean condition (K)
Brown trout	121	260	258	0.95	41	278	218	0.93
Rainbow trout	118	248	192	0.95	276	220	132	1.02

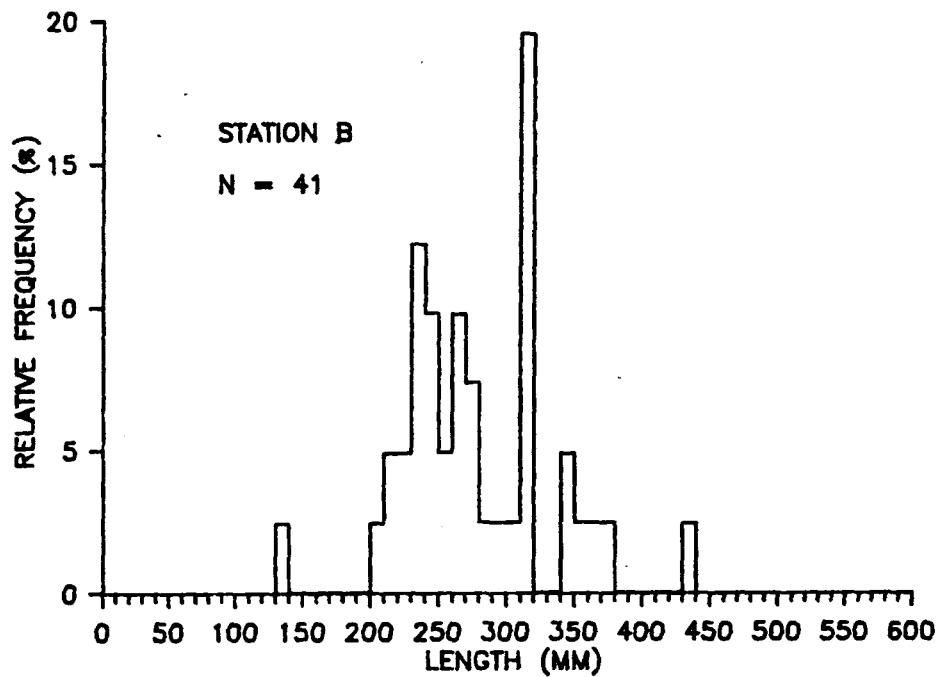
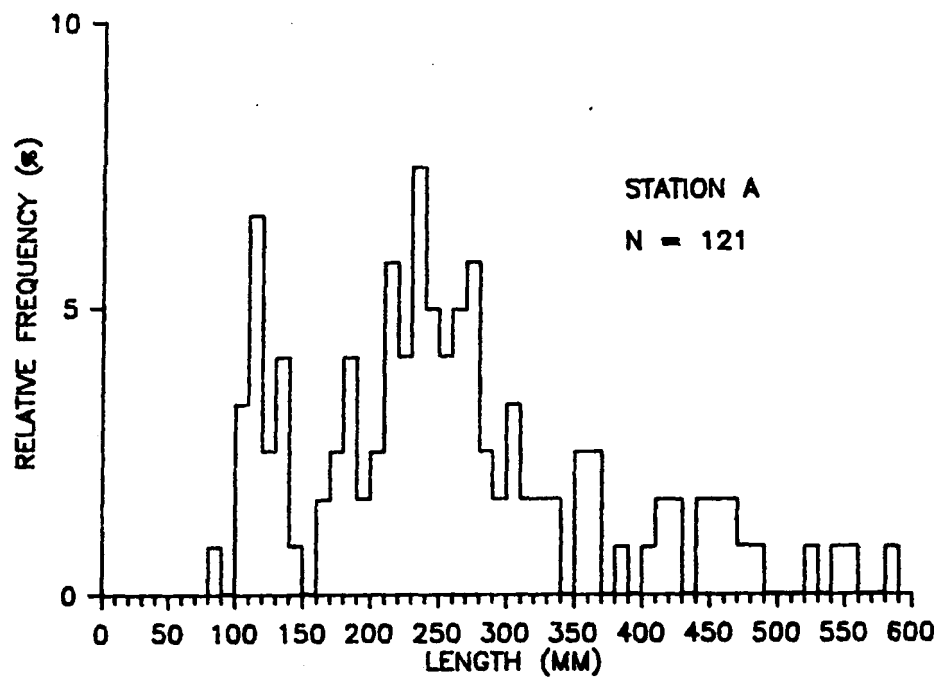


FIGURE 32.-Length frequencies of brown trout captured by electrofishing in the Firehole River, 1987.

TABLE 41.-Age composition of brown trout captured by electrofishing in the Firehole River, 1987.

Sample site	n	Percent of sample classified as age:				
		0	1	2	3 ^a	4-and-older
Station A	121	17.4	37.6	23.6	7.0	14.4
Station B	41	2.4	29.3	53.7	14.6	-

^a Represents age-3 at Station A and age-3-and-older at Station B.

TABLE 42.-Mean length (mm) at annulus for brown trout captured by electrofishing in the Firehole River, 1987.

Sample site	n	Annulus			
		1	2	3	4
Station A	35	135	245	331	400
Station B	21	146	247	335	-

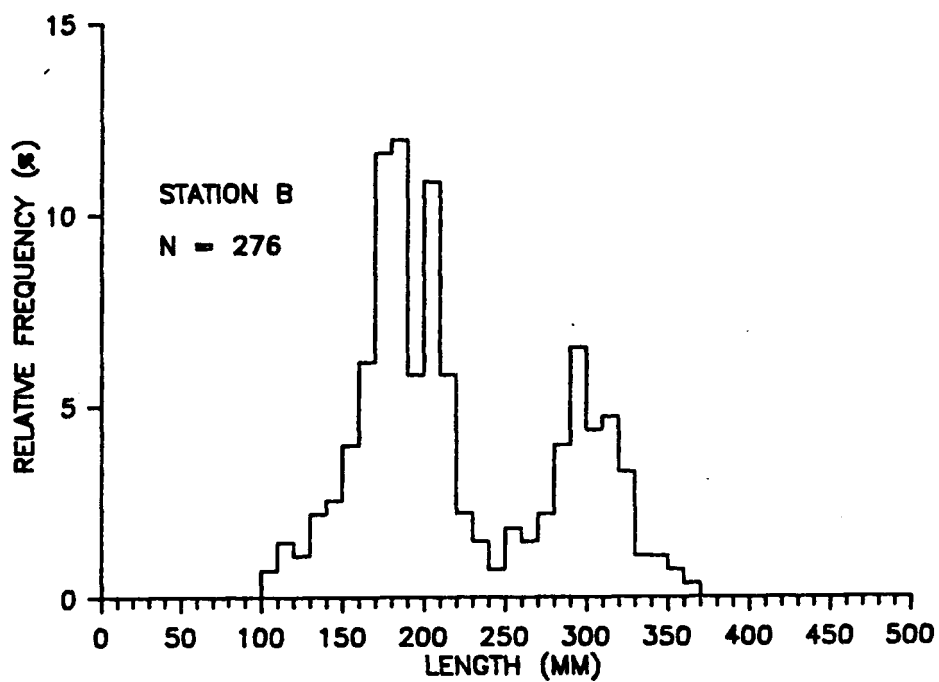
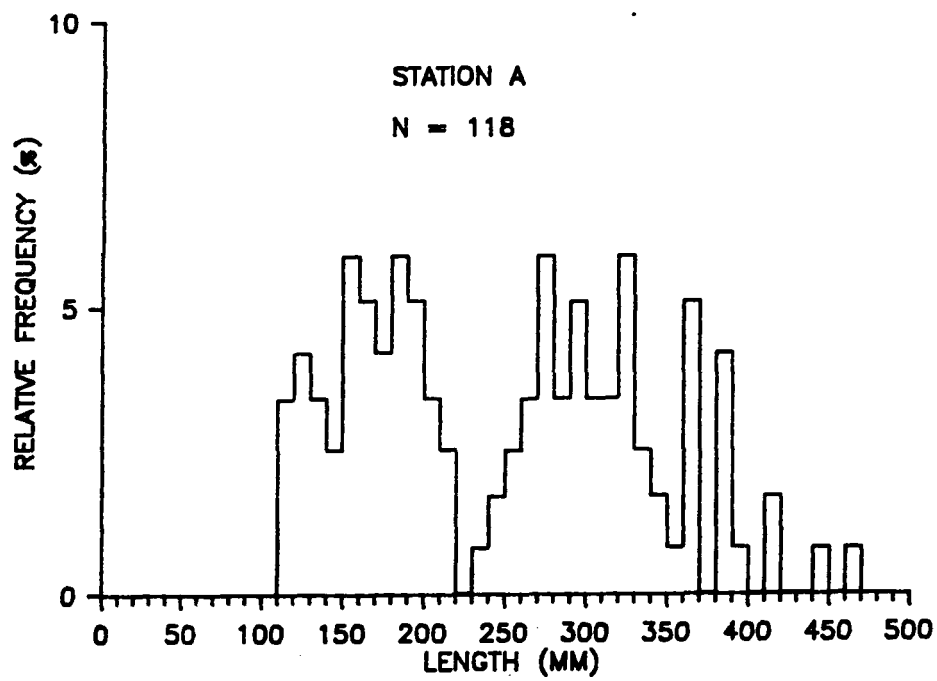


FIGURE 33.-Length frequencies of rainbow trout captured by electrofishing in the Firehole River, 1987.

TABLE 43.-Age composition of rainbow trout captured by electrofishing in the Firehole River, 1987.

Sample site	n	Percent of sample classified as age:				
		0	1	2	3	4-and-older
Station A	118	11.0	34.7	36.9	13.9	3.8
Station B	276	29.7	42.3	28.3	-	-

TABLE 44.-Mean length (mm) at annulus for rainbow trout captured by electrofishing in the Firehole River, 1987.

Sample site	n	Annulus			
		1	2	3	4
Station A	42	136	235	325	399
Station B	36	176	272	-	-

Firehole River. Additionally, Kaya (1978) reported that rainbow trout, which in the Firehole River are also fall spawners, reproduced successfully even in the warmest areas. Thus, rainbow trout may be slowly displacing brown trout in the Firehole River between the Upper and Midway Geyser basins.

At Station B in 1987, rainbow trout comprised about 87% of the electrofishing catch. In this thermally-influenced area of the Firehole River, Benson et al. (1959) found that brown trout and rainbow trout occurred in nearly equal proportions, but Kaeding (1976) reported that rainbow trout comprised 80% of an electrofishing sample. These data indicate that rainbow trout became dominant over brown trout in this area between the cessation of stocking in 1955 and the mid-1970s and also suggest that an equilibrium condition has been reached.

Benson et al. (1959) and Kaeding (1976) found that fewer than 5% of brown trout and rainbow trout captured by electrofishing in thermally-influenced areas of the Firehole River exceeded 400 mm in length. Prior to 1970, angler harvest of larger fish may have been excessive (Benson et al. 1959; Erman 1972); however, Kaya and Kaeding (1979) speculated that the scarcity of fish greater than 400-mm long was due to limitations on growth set by high metabolic demands in warm water and a diet limited primarily to aquatic macroinvertebrates. Length data collected in 1987 were similar to previous studies except for brown trout at Station A where 14% of the electrofishing sample exceeded 400 mm in length. Thus, this particular area of the Firehole River apparently has the potential to produce larger brown trout if they are given sufficient protection from angler harvest.

Kaeding (1976) found that trout captured in the Firehole River in the vicinity of Station B were larger at any given age (due to more rapid growth in the first year of life) than trout caught in the area of Station A. Results from 1987 investigations were similar to the previous study for rainbow trout; however, brown trout captured at Station B in 1987 were larger than brown trout caught at Station A only at age-1. It is not known whether the growth relationship for brown trout from the two study sites has really changed, or if difficulty in recognizing true annuli on trout from thermally-enriched areas of the Firehole River (Kaeding 1976) may account for different findings in the two studies.

Mean backcalculated lengths of brown trout and rainbow trout at Stations A and B in 1987 were slightly less than those reported by Kaeding (1976). Again, difficulty in identifying true annuli (Kaeding 1976) may preclude meaningful comparisons between studies; however, these data suggest that trout growth has slowed somewhat over the past decade. Slower growth may indicate that trout populations

reached a new equilibrium under the 2-fish, 406-mm minimum-size restriction in effect between 1970 and 1986.

Brown trout and rainbow trout populations in the thermally-influenced portion of the Firehole River have changed since the cessation of stocking in 1955. Data from Kaeding (1976), Kaya (1978), and the current study indicate that rainbow trout are becoming the dominant species. Kaya and Kaeding (1979) concluded that hot water temperatures favored rainbow trout. Although the 2-fish, 406-mm minimum-size limit in effect from 1970 to 1986 benefited both brown trout and rainbow trout, it is expected that the new regulations implemented in 1987 will offer greater protection to both species while still providing a high-quality angling experience. Investigations scheduled for 1988 and 1989 will provide additional information on the Firehole River fishery and assist in future management decisions.

GARDNER RIVER

The Gardner River lies in a 55,400-hectare watershed in the northwest corner of Yellowstone National Park. The river originates at an elevation of 2,900 m and flows southeast for nearly 26 km before passing over 46-m high Osprey Falls. Below the falls, the river flows north for another 13 km before entering the Yellowstone River near Gardiner, Montana, at an elevation of 1,619 m. Mean annual discharge of the river is 6.1 m³/s (USGS 1940-1972, 1986, 1987), and average gradient is 3.3%.

Historically, the Gardner River was barren of fish life above Osprey Falls; Yellowstone cutthroat trout *Salmo clarki bouvieri* and mountain whitefish *Prosopium williamsoni* inhabited the river below the falls (Evermann 1892; Jordan 1892). The introduction of several species of nonnative salmonids between 1889 and 1943 (Varley 1981) produced lasting changes in fish species composition and distribution. Jones et al. (1979) reported that brook trout *Salvelinus fontinalis* are the only salmonid inhabiting the river above Osprey Falls; but brown trout *Salmo trutta*, rainbow trout *Salmo gairdneri*, Yellowstone cutthroat trout, rainbow trout x cutthroat trout hybrids, brook trout, and mountain whitefish are found below the falls.

Presently, the fishing season on the Gardner River begins on the Saturday before Memorial Day and ends after 31 October when snows close the road between West Yellowstone, Montana, and Madison Junction. Species creel limits on the Gardner River are two brown trout, rainbow trout, or whitefish of any size or five brook trout under 254 mm (park possession limit is five fish, three of which must be brook trout). Cutthroat trout are under a catch-and-release regulation. Although children under 12 years old may fish with worms, all other anglers must use artificial lures or flies. Similar regulations have been in effect on the Gardner River since the early 1970s (U.S. Fish and Wildlife Service unpublished data).

Under current fishing regulations, the Gardner River drainage is one of only two watersheds in Yellowstone National Park where rainbow trout can be creeled, and it is the only watershed where there is no size limit on creeled rainbow trout. Managers have thus become concerned that angler effort on the Gardner River may disproportionally increase in future years compared to other park waters and negatively impact the fishery. Of particular concern is that portion of the Gardner River downstream of Osprey Falls; anglers favor this area because much of it is paralleled by a road.

The objective of this study was to describe the current status of the Gardner River fishery between Osprey Falls and the confluence with the Yellowstone River, which should provide a baseline for evaluating future effects of angling in this area of the Gardner River.

Study Area

The study area extended from Osprey Falls downstream to the confluence with the Yellowstone River (Figure 34). The major tributary in this section of the Gardner River is Lava Creek, a cold-water stream that contributes about one-third of the discharge of the Gardner River in this area (Seamans 1940). Geothermally-heated water enters the Gardner River via Boiling River, which is located about 2 km downstream of Lava Creek. Discharge of Boiling River varies between 0.36 and 0.70 m³/s, and water temperature ranges from 41 to 58°C (Allen and Day 1935; Seamans 1940; U.S. National Park Service unpublished data). Minor inputs of geothermally-heated water also enter the Gardner River via Terrace Creek which drains the Mammoth Hot Springs.

Mean monthly discharge of the Gardner River measured at the U.S. Geological gaging station (Figure 34) for a 43-year period of record ranged from 2.6 to 21.2 m³/s (USGS 1940-1972, 1986, 1987) (Figure 35). Mean monthly flows are usually less than 4 m³/s from January through April; discharge increases sharply in May during snowmelt and peaks in June. Flow declines rapidly in July and August and is again below 4 m³/s from September through December.

Water temperature regimes in the Gardner River below Osprey Falls are considerably different downstream and upstream of Boiling River. Downstream of Boiling River, mean monthly water temperatures for the period October 1984-September 1985 ranged from a low of 6.5°C in December to a high of 18°C in July (USGS 1986) (Figure 35). Upstream of Boiling River, water temperatures are much colder. Fromm (1940) reported winter water temperatures just above Boiling River in the range of 0.6 to 1.6°C, and Seamans (1940) reported a fall water temperature above Boiling River of 9°C when water temperature below Boiling River was 15°C.

Methods

Three sample stations were established in the study area to investigate fish populations (Figure 34). Station A, located below Boiling River, extended from the U.S. Geological Survey gaging station to a point approximately 0.9 km downstream. Average stream gradient at Station A was 1.3%. Stations B and C were located above Boiling River. Station B began where the Mammoth-to-Tower road crosses the Gardner River and ended at a point about 2.3 km downstream. Although geothermally-heated runoff from the Mammoth Hot Springs flows into the lower portion of this station, it is largely a cold-water area. Mean gradient of Station B was 2.0%. Station C began at a point approximately 1.5 km downstream of Osprey Falls and continued downstream for another 1.1 km. Station C is a cold-water area with a mean gradient of 3.3%.

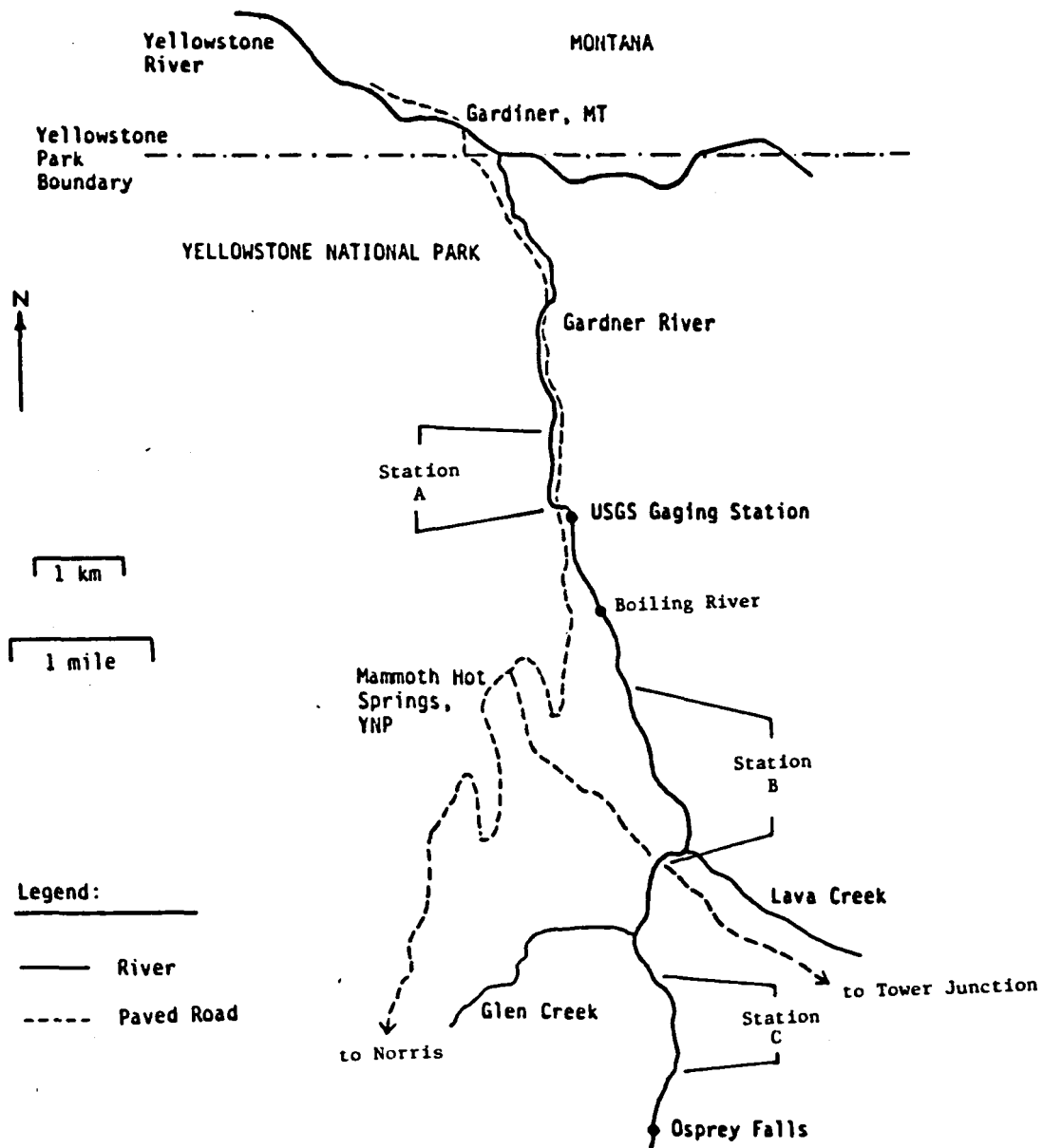


FIGURE 34.-Gardner River downstream of Osprey Falls showing electrofishing stations A, B, and C, 1987.

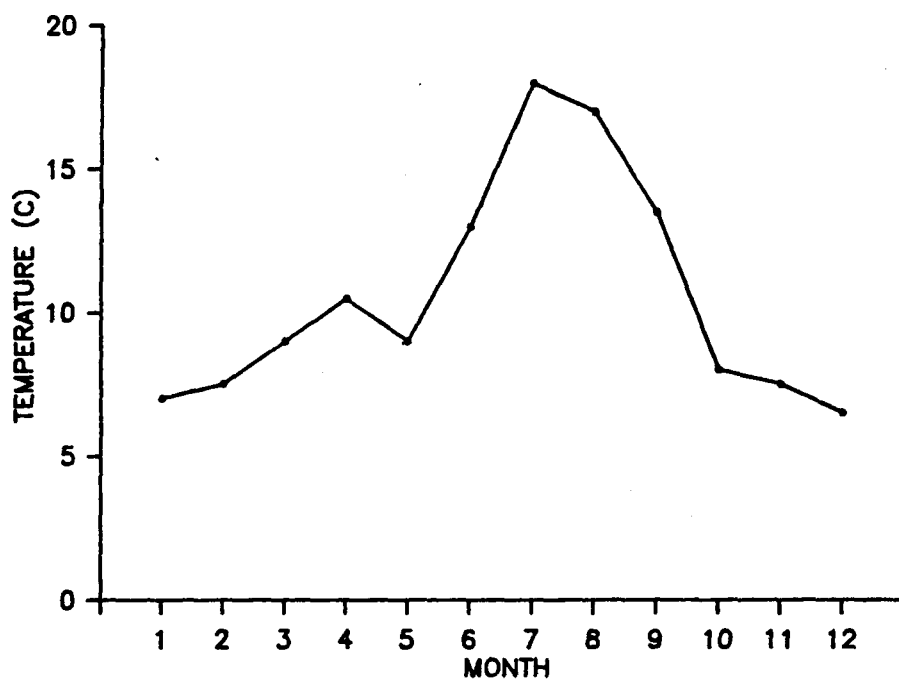
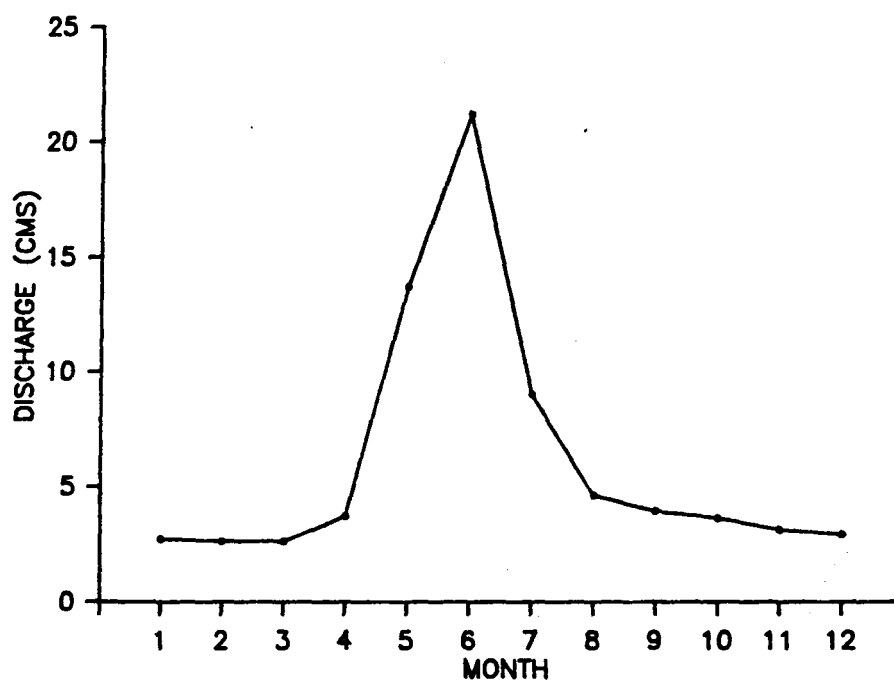


FIGURE 35.-Mean monthly discharge and temperature of the Gardner River at the USGS gaging station below Boiling River (Discharge data based on the years 1939-1971, 1985-1986; Temperature data based on the period October 1984-September 1985).

At all three sample stations, fish were captured during daytime electrofishing. Because physical habitats at the three stations differed, three different electrofishing systems were used. At Station A, a 4-m long rubber raft was fitted with two stationary electrodes (one positive and one negative) and one mobile positive electrode. The raft contained fish-holding tanks, a 3.5 kW AC generator, and a Coffelt VVP-15 rectifying unit that produced pulsed, direct current. Sampling at Station A occurred on 7 July. Electrofishing began at the upstream boundary of the sample station and proceeded downstream. Two crew members stood in the river at the upstream end of the raft and guided it slowly downstream as other personnel stood near the positive electrodes and netted stunned fish.

At Station B, sampling occurred on 30 June and 15-16 July. A 2-m long plastic boat held the fish tank, generator, and rectifying unit. The boat was fitted with two mobile positive electrodes and a trailing negative electrode. Other procedures used at Station B were identical to those at Station A.

A Coffelt BP-1C backpack electrofishing system was used to capture fish at Station C on 17 July. Electrofishing began at the downstream boundary of the sample station and proceeded upstream. Because of the relatively steep gradient, high water velocity, and deep water, only a few near-shore areas were sampled.

At each sample station, all salmonids captured were anesthetized in MS-222, identified to species, and measured to the nearest 1 mm total length. For each salmonid species, five individuals in each 10-mm length group were weighed to the nearest 2 g, and scale samples (excluding mountain whitefish) were collected from five fish in each 25-mm length group for age-growth analysis. After being revived in fresh water, fish were returned to the river.

Creel survey data from the Volunteer Angler Report System (Dean and Varley 1974) for the period 1979-1987 were used to examine the sport fishery.

Results

Fish Populations 1987

Species composition of the electrofishing catch differed among the three sample stations (Table 45). At Station A, brown trout comprised about 91% of the catch. Other species captured at Station A included rainbow trout, cutthroat trout, and rainbow trout x cutthroat trout hybrids. Rainbow trout were the most frequently caught salmonid at Stations B and C. At Station B, rainbow trout made up approximately 57% of the catch. Brown trout, cutthroat trout, brook trout, and mountain whitefish were also found at this sample site. At Station C, rainbow trout

TABLE 45.-Species composition of salmonids captured by electrofishing in the Gardner River below Osprey Falls, 1987.

Species	Station A		Station B		Station C	
	Number captured	Percent of catch	Number captured	Percent of catch	Number captured	Percent of catch
Brown trout	297	91.4	92	21.3	7	12.7
Rainbow trout	25	7.7	244	56.6	47	85.5
Cutthroat trout	2	0.6	2	0.5	0	0.0
Rainbow trout x cutthroat trout hybrids	1	0.3	0	0.0	0	0.0
Brook trout	0	0.0	8	1.9	0	0.0
Mountain whitefish	0	0.0	85	19.7	1	1.8
All species	325	100.0	431	100.0	55	100.0

comprised nearly 86% of the catch. Brown trout and mountain whitefish were the only other salmonids captured at Station C.

For each species, the number of fish captured per kilometer differed between Stations A and B (Table 46). Brown trout were most abundant at Station A (330 fish/km), and rainbow trout were most numerous at Station B (106 fish/km). Cutthroat trout, rainbow trout x cutthroat trout hybrids, and brook trout were less than 4 fish/km at both Station A and Station B. Sampling at Station C was much less efficient than at Stations A and B because of the use of a backpack electrofishing system and difficult electrofishing conditions; hence, numbers of brown trout (6 fish/km) and rainbow trout (43 fish/km) captured at Station C were not directly comparable to the other two sample sites (Table 46).

Population structure comparisons were limited to brown trout and rainbow trout because sample sizes for other salmonids were too small. Brown trout mean length at Station B (223 mm) was greater than that at Station A (207 mm) (Table 47), and length-frequency distributions of brown trout at the two sample sites were different (Figure 36). The larger mean length and the absence of fish less than 118 mm long at Station B reflect differences between the two sample sites in age composition and growth. No age-0 fish were captured at Station B; however, age-0 fish comprised 11.5% of the brown trout sample at Station A (Table 48). Mean backcalculated lengths at annulus-1, -2, -3, and -4 (Table 49) suggest that growth of brown trout is faster at Station B than at Station A.

Rainbow trout mean length was greatest at Station A (210 mm), intermediate at Station C (170 mm), and least at Station B (156 mm) (Table 47). Length-frequency distributions differed at all three sample sites (Figure 37). The larger mean length at Station A and differences in length-frequency distributions again reflect differences in age composition and growth between sample sites. Age-0, age-1, and age-2 fish comprised 64% of the sample at Station A (Table 50). No age-0 fish were captured at Stations B and C; however, nearly 85% of fish captured at each of these sites were age-1 or age-2 (Table 50). Mean backcalculated lengths at annulus-1 and -2 (Table 51) suggest that growth of juvenile rainbow trout at Station A is faster than at Stations B and C.

The Sport Fishery (1979-1987)

Between 1979 and 1987, an average of 1,824 anglers spent 6,460 h (angler effort) annually fishing the Gardner River between Osprey Falls and the confluence with the Yellowstone River. Anglers annually landed an average of 8,333 fish and creelied 1,281. Under the new fishing

TABLE 46.-Number of fish captured per kilometer by electrofishing in the Gardner River below Osprey Falls, 1987.

Species	Number captured/km at:		
	Station A	Station B	Station C
Brown trout	330.0	40.0	6.4
Rainbow trout	27.8	106.1	42.7
Cutthroat trout	2.2	0.9	0.0
Rainbow trout x cutthroat trout hybrids	1.1	0.0	0.0
Brook trout	0.0	3.5	0.0
Mountain whitefish	0.0	37.0	0.9
All species	361.1	187.5	50.0

TABLE 47.-Mean length, weight, and condition of salmonids captured by electrofishing in the Gardner River below Osprey Falls, 1987.

Species	Station A				Station B				Station C			
	n	Mean Length (mm)	Mean weight (g)	Mean condition (K)	n	Mean Length (mm)	Mean weight (g)	Mean condition (K)	n	Mean Length (mm)	Mean weight (g)	Mean condition (K)
Brown trout	297	207	119	1.03	92	223	149	1.01	7	280	244	1.07
Rainbow trout	25	210	129	1.09	244	156	62	1.08	47	170	70	1.13
Cutthroat trout	2	135	30	1.22	2	285	207	0.90	0	-	-	-
Rainbow trout x cutthroat trout hybrids	1	228	126	1.06	0	-	-	-	0	-	-	-
Brook trout	0	-	-	-	8	204	112	0.97	0	-	-	-
Mountain whitefish	0	-	-	-	85	369	585	1.10	1	353	444	1.01

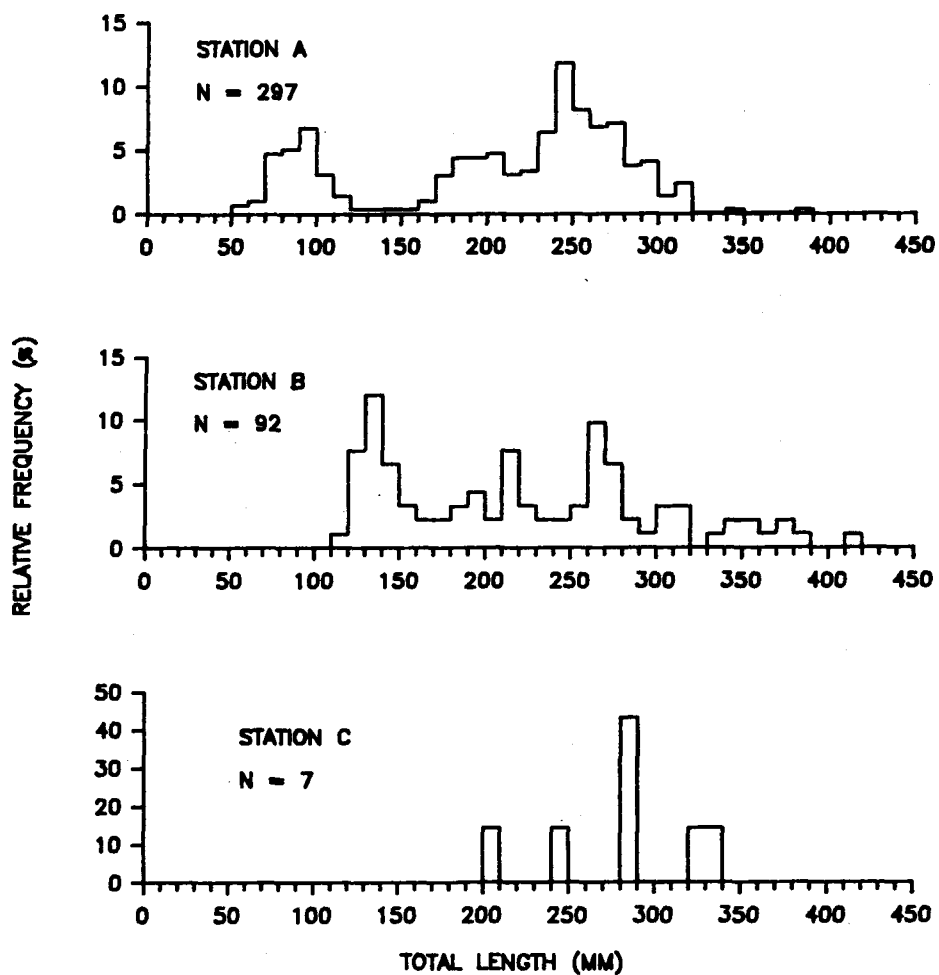


FIGURE 36.-Length frequencies of brown trout captured by electrofishing in the Gardner River below Osprey Falls, 1987.

TABLE 48.-Age composition of brown trout captured by electrofishing in the Gardner River below Osprey Falls, 1987.

Sample site	n	Percent of sample classified as age:					
		0	1	2	3	4	5
Station A	297	11.5	12.3	22.4	53.5	0.0	0.3
Station B	92	0.0	36.4	20.1	40.2	3.3	0.0
Station C	7	0.0	0.0	28.6	71.4	0.0	0.0

TABLE 49.-Mean length (mm) at annulus for brown trout captured by electrofishing in the Gardner River below Osprey Falls, 1987.

Sample site	n	Annulus				
		1	2	3	4	5
Station A	36	71	148	222	297	359
Station B	39	75	165	250	371	-
Station C	6	75	166	254	-	-

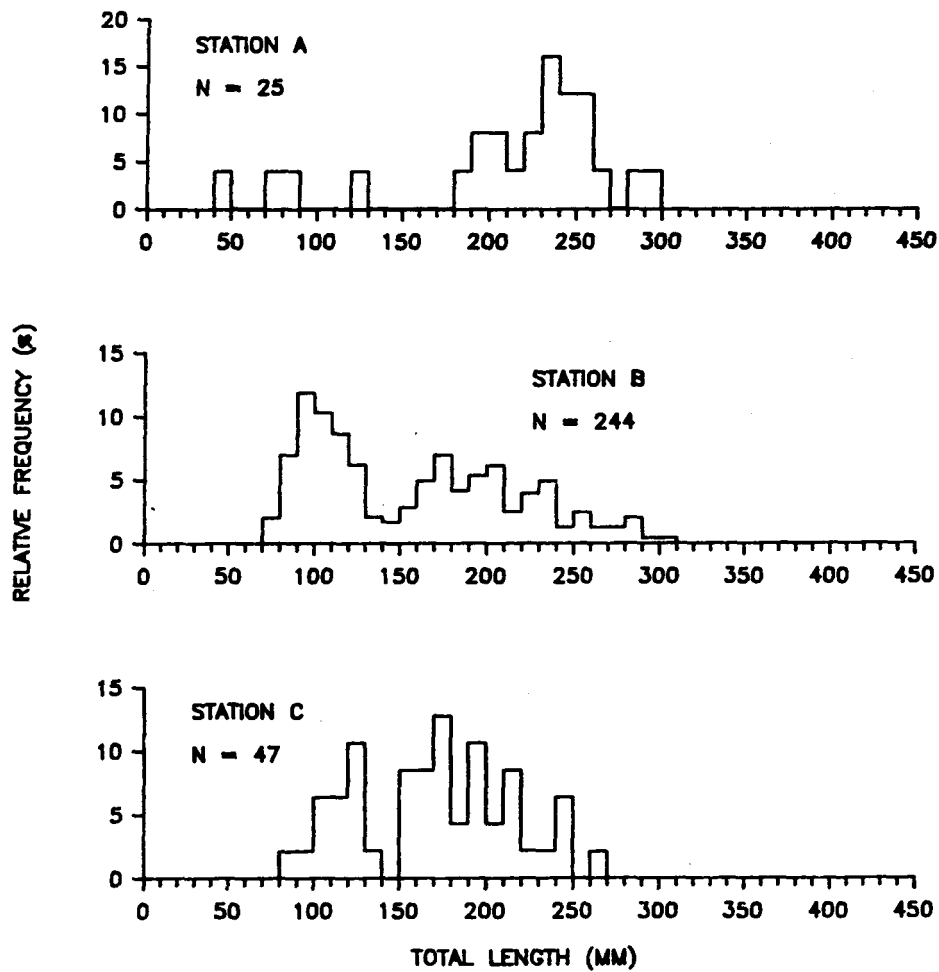


FIGURE 37.-Length frequencies of rainbow trout captured by electrofishing in the Gardner River below Osprey Falls, 1987.

TABLE 50.-Age composition of rainbow trout captured by electrofishing in the Gardner River below Osprey Falls, 1987.

Sample site	n	Percent of sample classified as age:				
		0	1	2	3	4
Station A	25	12.0	4.0	48.0	28.0	8.0
Station B	244	0.0	49.6	34.6	15.0	0.8
Station C	47	0.0	29.8	53.2	17.0	0.0

TABLE 51.-Mean length (mm) at annulus for rainbow trout captured by electrofishing in the Gardner River below Osprey Falls, 1987.

Sample site	n	Annulus			
		1	2	3	4
Station A	15	84	167	216	273
Station B	39	67	140	210	279
Station C	29	68	136	205	-

regulations implemented in 1987, the number of anglers (3,277), angler effort (14,317 h), and the number of fish landed (18,731) were the highest ever recorded. Additionally, the number of fish creeled in 1987 (1,723) was the second highest ever recorded (Figures 38 and 39).

Brown trout, rainbow trout, and brook trout accounted for about 90% of the total number of fish landed and creeled between 1979 and 1987. Annually, brown trout or rainbow trout comprised most of the fish landed. Other species caught by anglers included cutthroat trout, rainbow trout x cutthroat trout hybrids, brook trout, and mountain whitefish.

Average landing rate for all species from 1979 through 1987 was 1.29 fish/h. Average landing rates were highest for rainbow trout and brown trout (0.61 and 0.60 fish/h, respectively), followed by brook trout (0.33 fish/h). Landing rates for cutthroat trout, rainbow trout x cutthroat trout hybrids, and mountain whitefish were below 0.20 fish/h. The overall landing rate increased during the 9-year period, apparently reflecting the steady increase in landing rate for rainbow trout (Figure 40).

Average length of fish landed for all species from 1979 through 1987 was 263 mm. Mean length was greatest for mountain whitefish (319 mm), followed by brown trout (272 mm), rainbow trout x cutthroat trout hybrids (265 mm), rainbow trout (258 mm), cutthroat trout (255 mm), and brook trout (248 mm). Overall mean length of landed fish appeared stable between 1979 and 1984, but has been declining steadily since then (Figure 41). The decrease in overall mean length reflects declines in the mean length of brown trout, rainbow trout, and brook trout (Figure 41).

Discussion

Species distribution, relative abundance, length structure, age structure, and growth of salmonids differed among the three sites sampled in 1987. The dominance of brown trout at Station A is probably related to elevated water temperatures resulting from the geothermally-heated input of Boiling River. Brown trout are also the dominant salmonid in a geothermally-influenced area of the Firehole River (Kaeding 1976; Kaya 1978) that has a similar temperature regime. At Stations B and C in the Gardner River, habitat conditions are apparently best suited to rainbow trout.

Adult salmonids were captured at all three sample sites; however, the occurrence of age-0 and age-1 brown trout and rainbow trout at Station A indicates that this is an important trout-rearing area. Because age-1 trout were also found at Stations B and C, other trout rearing areas undoubtedly exist in the Gardner River downstream of Osprey Falls. The presence of age-0 trout at Station A may also

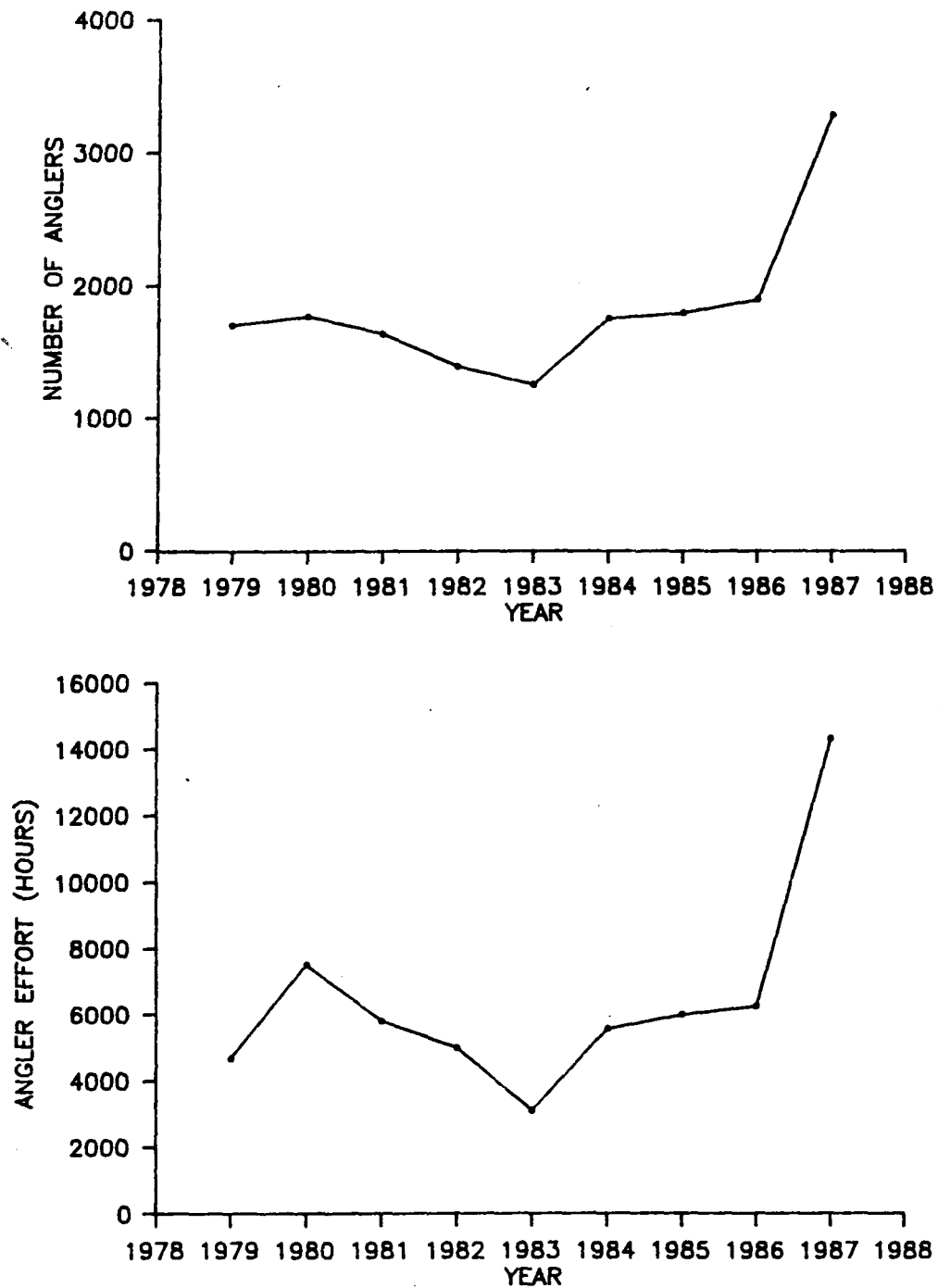


FIGURE 38.-Number of anglers and angler effort on the Gardner River below Osprey Falls, 1979-1987.

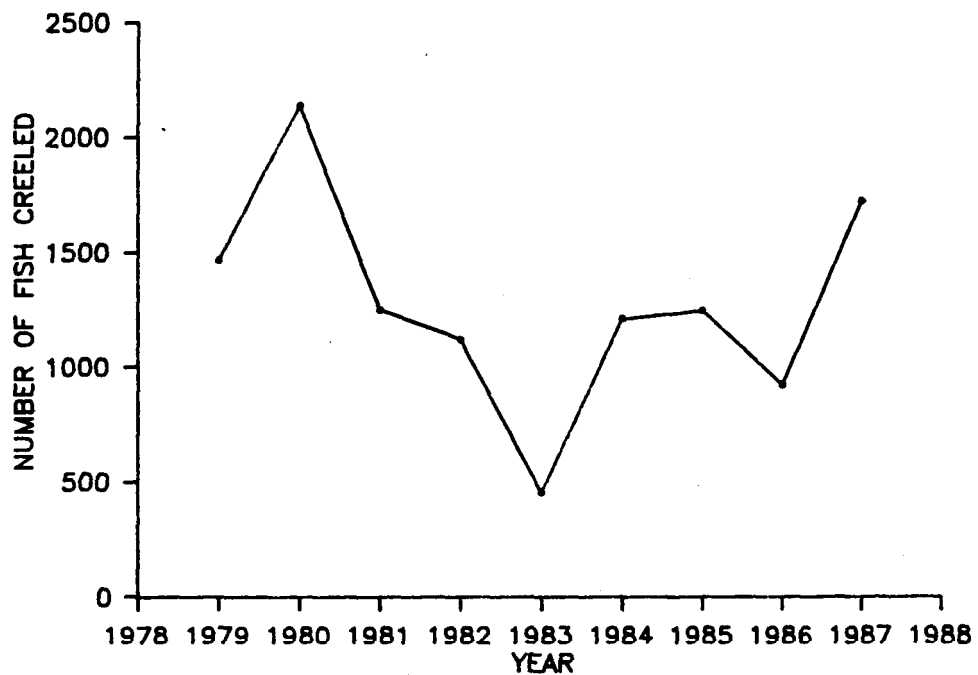
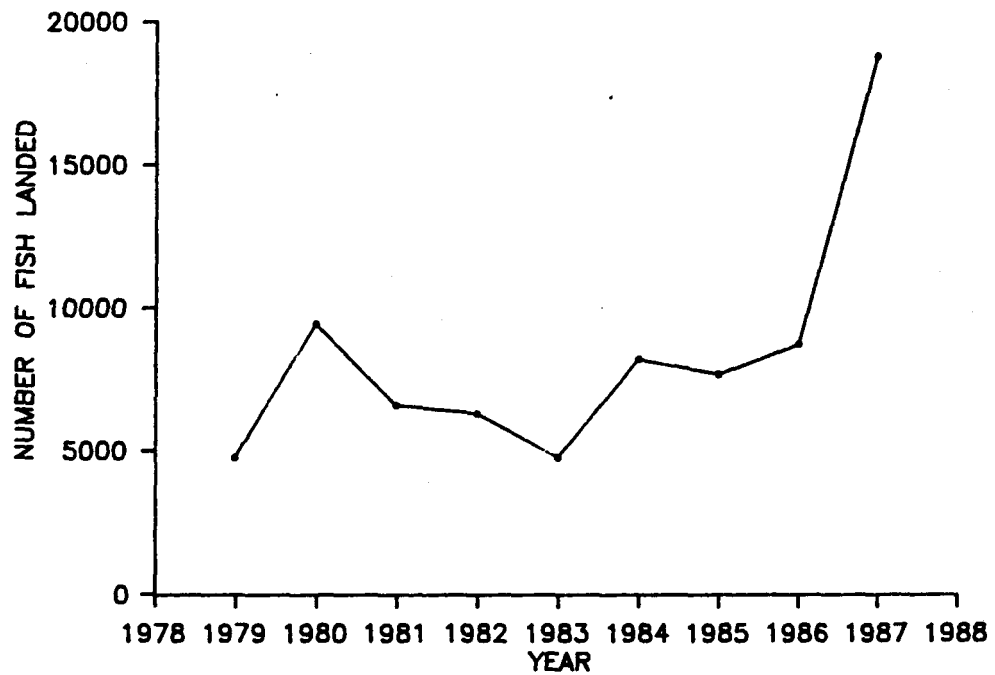


FIGURE 39.-Number of fish landed and creeled on the Gardner River below Osprey Falls, 1979-1987.

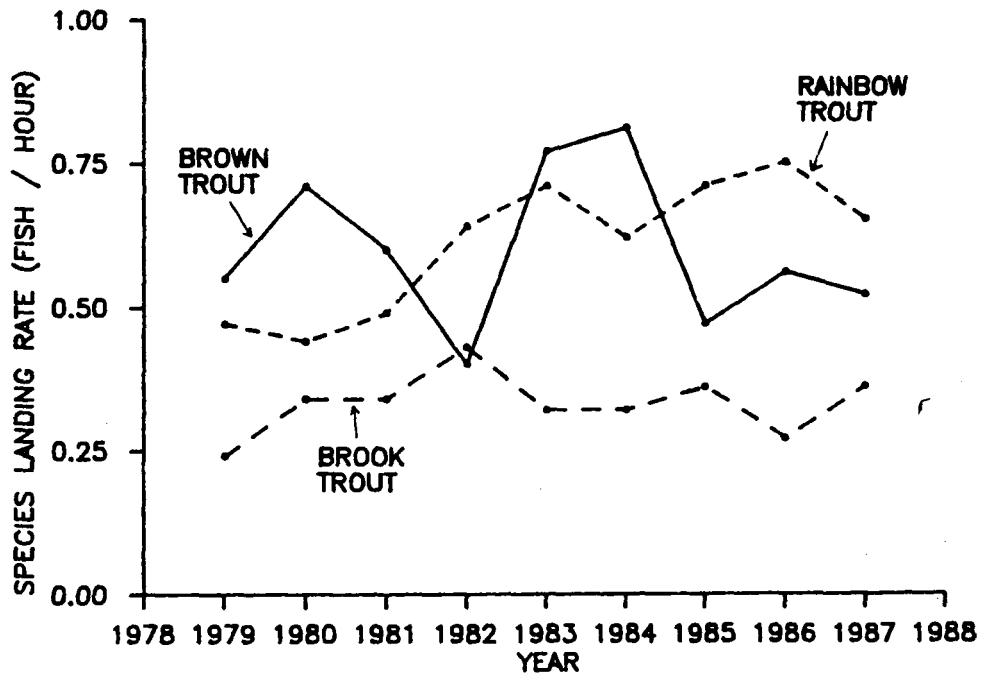
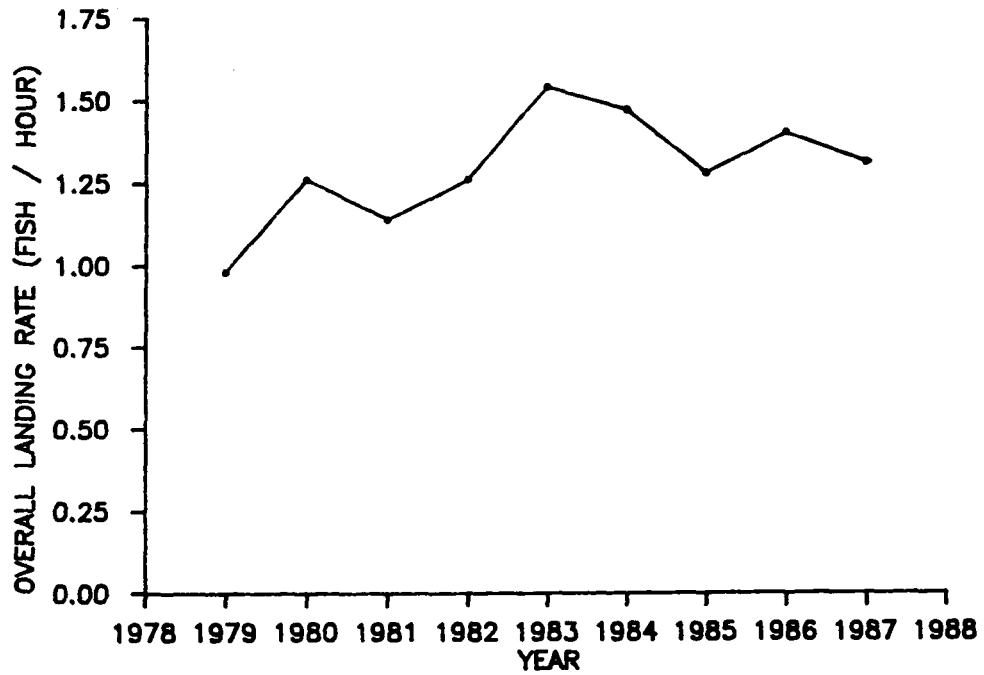


FIGURE 40.-Overall landing rate and landing rates of brown trout, rainbow trout, and brook trout for the Gardner River below Osprey Falls, 1979-1987.

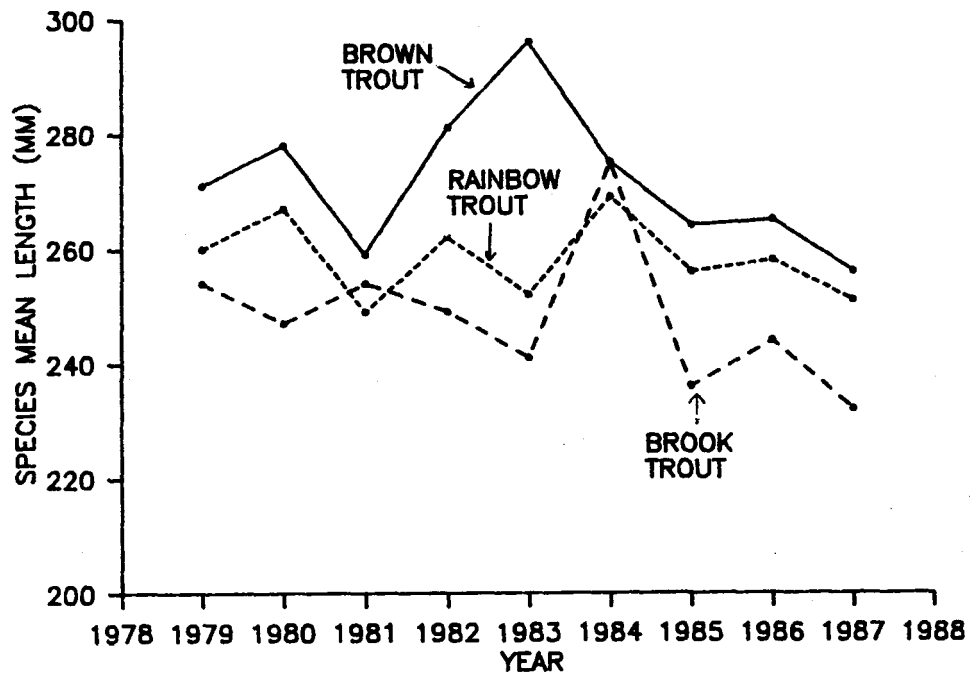
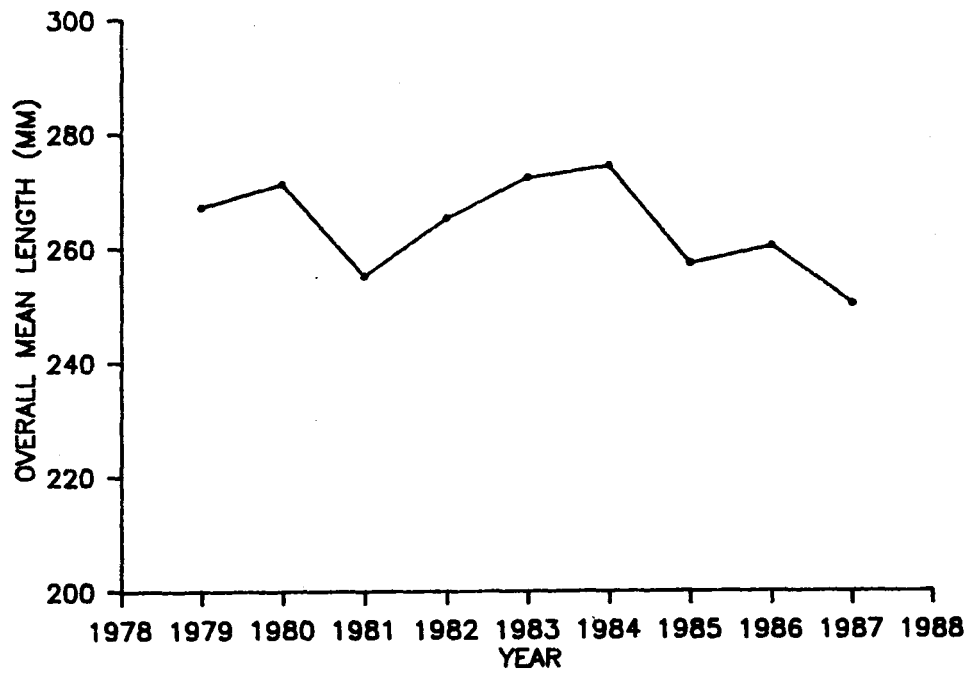


FIGURE 41.-Overall mean length of fish landed and mean lengths of brown trout, rainbow trout, and brook trout landed for the Gardner River below Osprey Falls, 1979-1987.

reflect the use of this area for spawning. Each fall, brown trout residing in the Yellowstone River migrate into the Gardner River to spawn (Jones et al. 1987); rainbow trout residing in the Yellowstone River may do the same each spring. Other important trout spawning areas in the Gardner River downstream of Osprey Falls have not been identified.

Seamans (1940) reported that fish food (i.e., macroinvertebrates) in the Gardner River was more abundant downstream of Boiling River than upstream of it. Consequently, trout residing downstream of Boiling River might be expected to grow faster at least until maturity. Indeed, rainbow trout at Station A exhibited faster growth than at Stations B and C through age-2; however, brown trout at Station A apparently grew slower than brown trout at the other two sample sites through age-4. The result for brown trout is puzzling because accelerated growth for brown trout has been found in thermally-enriched areas of the Firehole River (Kaeding 1976; Kaya 1978).

Under the new angling regulations implemented by the National Park Service in 1987, creel limits on the Gardner River downstream of Osprey Falls are more liberal than for any other stream fishery in Yellowstone National Park. Anglers apparently realized this, because the number of anglers, angler effort, and the number of fish landed in 1987 in this section of river were the highest yet recorded. Additionally, the number of fish creeled in 1987 was the second highest recorded. Species composition of fish landed and creeled, overall landing rate, and landing rates for individual species in 1987 were similar to the previous 8 years; however, overall mean length and mean lengths of individual species landed in 1987 continued the declining trend begun in 1984-1985. Declines in mean length suggest that angler harvest may be excessive.

In future years, the Gardner River fishery between Osprey Falls and the confluence with the Yellowstone River will probably remain popular with anglers. There is easy access to much of this section of river, and creel limits are liberal. Because this is a multispecies fishery, anglers can potentially harvest the legal possession limit of five fish during a single fishing trip. Families are attracted to the area because children under 12 years old may use worms as bait. Consequently, this fishery should be monitored closely during the next few years to evaluate continued compliance with current goals of the fishery management program in Yellowstone National Park.

MADISON RIVER

The Madison River is one of the three most popular stream fisheries in Yellowstone National Park. There is roadside access to about 80% of the river within the park, and anglers may fish its wide, shallow riffles and deep pools amidst picturesque landscapes and undisturbed wildlife. These factors, coupled with excellent trout fishing, have earned the Madison River a nation-wide reputation for providing a high-quality angling experience.

Historically, westslope cutthroat trout *Salmo clarki lewisi*, fluvial Arctic grayling *Thymallus arcticus*, and mountain whitefish *Prosopium williamsoni* were the only salmonids native to the Madison River in Yellowstone National Park (Evermann 1892; Jordan 1892); however, several nonnative salmonid species were introduced into the drainage between 1889 and 1955 (Varley 1981). Stocking was initially used to populate fishless areas and later to support put-grow-and-take angling; the end result was that fish species composition drastically changed. Self-sustaining populations of brown trout *Salmo trutta*, rainbow trout *Salmo gairdneri*, and mountain whitefish currently dominate the Madison River fishery; a few cutthroat trout and brook trout *Salvelinus fontinalis* are also present. Arctic grayling are rarely caught and are considered to be downstream migrants from lacustrine populations in Grebe Lake and Wolf Lake.

Liberal angling regulations in effect on the Madison River between the late 1800s and 1950 (U.S. Fish and Wildlife Service unpublished data) were replaced by a 5-fish, any-size, fly-fishing-only restriction in 1951. Despite the greater protection afforded by this regulation, rainbow trout showed signs of overharvest shortly after stocking ceased in 1955 (Benson et al. 1959), and brown trout showed signs of overharvest by the late 1960s (Dean and Mills 1970; Erman 1972). Consequently, these two species were placed under a 2-fish, 406-mm minimum-size restriction in 1970. Brown trout and rainbow trout populations improved under this regulation (Dean and Mills 1971; Dean 1972; Dean and Varley 1973; Jones et al. 1979); however, subsequent investigations (Jones et al. 1981, 1985, 1986, 1987) revealed that additional protection might increase the relative abundance of fish ≥ 406 mm in length. In 1987, therefore, brown trout were placed under a 2-fish, 254-mm maximum-size limit, and rainbow trout were restricted to catch-and-release-only. Presently, two mountain whitefish of any size may be harvested, brook trout are under a 5-fish, 254-mm maximum-size limit, and cutthroat trout and Arctic grayling are restricted to catch-and-release-only.

The objective of this study was to document the current status of resident brown trout and rainbow trout populations in the Madison River. Results from this study should

provide a baseline to evaluate effects of the new regulations on the fishery.

Study Area

The Madison River lies in a 174,800-hectare watershed in west-central Yellowstone National Park. Formed by the union of the Firehole River and Gibbon River near Madison Junction at an elevation of 2,070 m, the river flows west for about 30 km before entering the state of Montana at an elevation of 2,000 m (Figure 42). Mean annual discharge of the Madison River in Yellowstone National Park is 13.7 m³/s (USGS 1915-1917, 1920, 1921, 1924-1973, 1985, 1986), and average gradient is 0.2%.

Water temperature of the Madison River is higher than most rivers and streams in the Rocky Mountain region due to thermal discharges of hot springs and geysers into its tributaries (Allen and Day 1935). Temperature ranges from 1 to 4°C from November through February and increases to 20-25°C in July and August. Temperature again drops below 4°C by the end of October (Agaard 1969).

Chemically, the Madison River has been characterized as a sodium-bicarbonate chloride type; calcium and magnesium are present in small amounts (Roeder 1966). Phosphate levels are much higher than those found in highly eutrophic waters (Wright and Mills 1967), but concentrations of inorganic nitrogen are low and may limit plant growth (Wright et al. no date).

Methods

Two sections of the Madison River were sampled in 1987 to obtain data on fish populations. Station A extended from the confluence of the Firehole River and Gibbon River to a point 3.1 km downstream, and Station B began at The Barns parking area and continued downstream for 4.3 km (Figure 42). Fish were sampled at Station A on 27-28 July and at Station B on 29-30 July.

At both sample sites, fish were collected by electrofishing at night from a 4.6-m long rubber raft. The raft was fitted with two stationary dropper electrodes, fish-holding tanks, a 3.5 kW generator, and a Coffelt VVP-15 rectifying unit that produced pulsed, direct current.

Captured fish were anesthetized in MS-222, identified to species, and counted. Brown trout and rainbow trout were measured to the nearest 1 mm total length. A subsample of five brown trout and rainbow trout in each 25-mm length group was weighed to the nearest 2 g, and scale samples were collected from each of these fish for age-growth analysis. After processing, all fish were returned to the river.

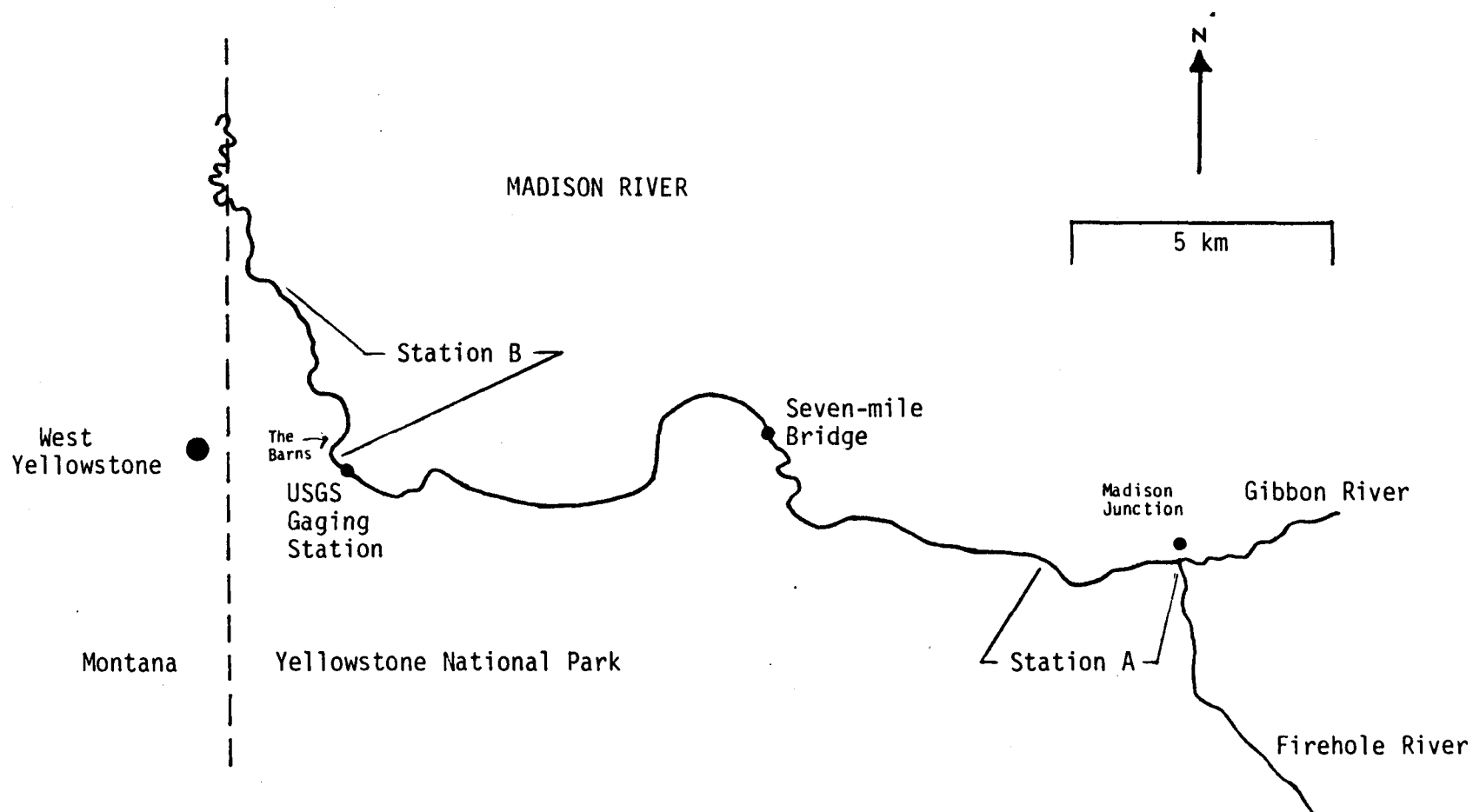


FIGURE 42.-Madison River showing electrofishing stations A and B, 1987.

Results

Three salmonid species were captured by electrofishing in 1987 (Table 52). At Station A, brown trout comprised 61% of the catch, and mountain whitefish and rainbow trout accounted for smaller proportions. At Station B, mountain whitefish made up 86% of the catch, and brown trout and rainbow trout comprised the remainder of the sample.

Based on the number of fish captured per kilometer, brown trout and rainbow trout were more abundant at Station A (89 and 24 fish/km, respectively) than at Station B (24 and 8 fish/km, respectively). Mountain whitefish, however, were more numerous at Station B (189 fish/km) than at Station A (33 fish/km).

Brown trout length at Station A ranged from 61 to 602 mm and averaged 269 mm. At Station B, however, brown trout varied in length from 182 to 537 mm and average length was 337 mm (Table 53). Length-frequency distributions differed at the two sample sites (Figure 43).

The smaller mean length at Station A, and differences in length ranges and length-frequency distributions appeared due to differences in age composition and growth. Brown trout at Station A ranged from age-0 to age-4-and-older (brown trout past age-4 could not be accurately aged at Station A), and 53% of the sample was $\leq$ age-2. At Station B, brown trout varied from age-1 to age-5-and-older (brown trout past age-5 could not be accurately aged at Station B), and only 33% of the catch was $\leq$ age-2 (Table 54). Mean backcalculated lengths (Table 55) revealed that brown trout at Station A were slightly smaller than at Station B for age-1 through age-4.

Rainbow trout length at Station A varied from 78 to 372 mm and averaged 235 mm. At Station B, rainbow trout length ranged from 97 to 413 mm and averaged 189 mm (Table 53). Length-frequency distributions at the two sample sites were different (Figure 44).

The smaller mean length at Station B, and differences in length ranges and length-frequency distributions appeared primarily due to differences in age composition. At both sample sites, captured rainbow trout ranged from age-0 to age-3; however, 83% of the sample at Station B was age-1 or younger, and only 47% of the catch at Station A was age-1 or younger (Table 56). Mean backcalculated lengths (Table 57) revealed that rainbow trout growth was similar at both sample sites.

Discussion

In the upper 3-5 km of the Madison River (upper Madison River), brown trout appear to be the most abundant salmonid. This species has dominated the electrofishing catch in all but one of the samples obtained in this river reach between

TABLE 52.-Species composition of salmonids captured by electrofishing in the Madison River, 1987.

Species	Station A		Station B	
	n	Percent	n	Percent
Brown trout	275	61.1	102	10.7
Rainbow trout	73	16.2	35	3.7
Whitefish	102	22.7	814	85.6
Totals	450	100.0	951	100.0

TABLE 53.-Mean length, weight, and condition of brown trout and rainbow trout captured by electrofishing in the Madison River, 1987.

Species	Station A				Station B			
	n	Mean length (mm)	Mean weight (g)	Condition (K)	n	Mean length (mm)	Mean weight (g)	Condition (K)
Brown trout	275	269	254	1.01	102	337	468	1.05
Rainbow trout	73	235	171	1.08	35	189	115	1.16

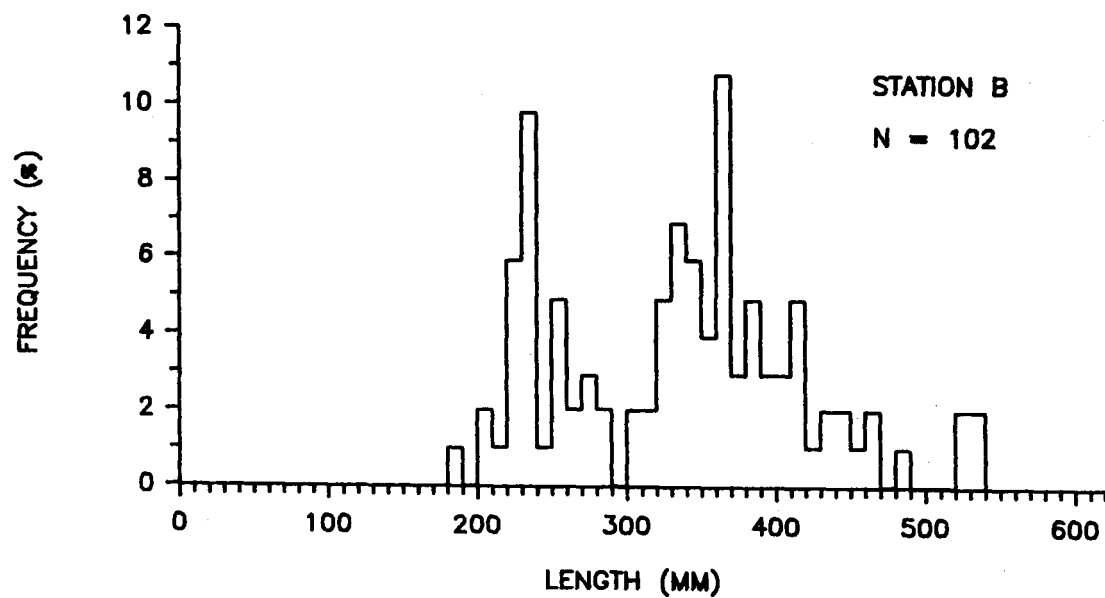
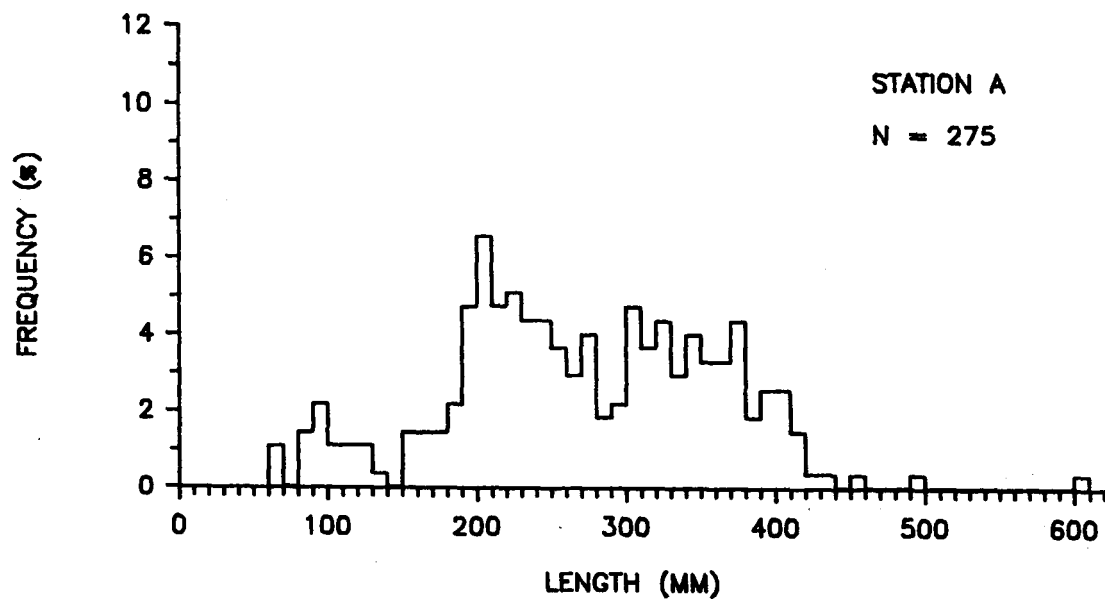


FIGURE 43.-Length frequencies of brown trout captured by electrofishing in the Madison River, 1987.

TABLE 54.-Age composition of brown trout captured by electrofishing in the Madison River, 1987.

Sample site	n	Percent of sample classified as age:					
		0	1	2	3	4 ^a	5 ^b
Station A	275	1.1	10.2	42.2	35.3	11.3	-
Station B	102	0.0	6.9	26.5	46.1	9.8	10.8

^a Represents age-4-and-older fish at Station A, and age-4 fish at Station B.

^b Represents age-5-and-older fish at Station B.

TABLE 55.-Mean length (mm) at annulus for brown trout captured by electrofishing in the Madison River, 1987.

Sample site	n	Annulus				
		1	2	3	4	5
Station A	56	84	178	273	364	-
Station B	35	96	200	290	375	426

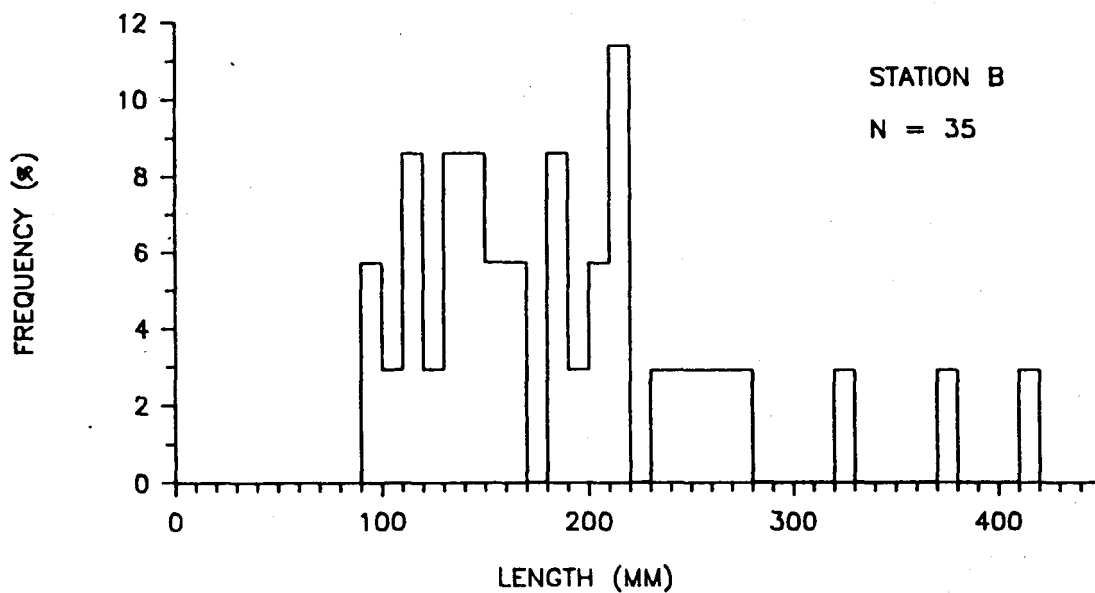
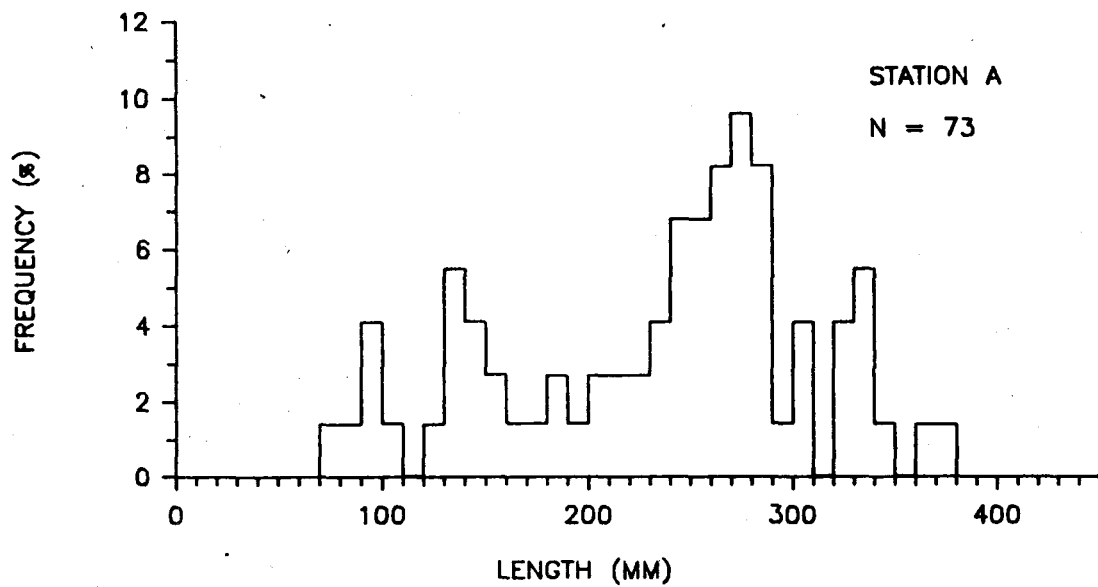


FIGURE 44.-Length frequencies of rainbow trout captured by electrofishing in the Madison River, 1987.

TABLE 56.-Age composition of rainbow trout captured by electrofishing in the Madison River, 1987.

Sample site	n	Percent of sample classified as age:			
		0	1	2	3
Station A	73	19.2	28.1	50.0	2.7
Station B	35	28.6	54.3	11.4	5.7

TABLE 57.-Mean length (mm) at annulus for rainbow trout captured by electrofishing in the Madison River, 1987.

Sample site	n	Annulus		
		1	2	3
Station A	32	134	241	338
Station B	21	125	244	364

1957 and 1987 (Benson et al. 1959; Jones et al 1979, 1985-1987, and the current study). The ratio of rainbow trout to mountain whitefish has fluctuated; however, data suggest that mountain whitefish are present in slightly greater numbers than rainbow trout.

In the lower 6 km of the Madison River in Yellowstone National Park (lower Madison River), mountain whitefish seem to be the most abundant salmonid. Mountain whitefish have accounted for the largest percentage of electrofishing samples collected in this section of river between November 1978 and 1987 (Jones et al. 1979, 1985-1987, and the current study). Brown trout appear to outnumber rainbow trout in this area.

Numerous studies since 1980 (Jones et al. 1981, 1985-1987) have indicated that although brown trout and rainbow trout populations benefited from the 2-fish, 406-mm minimum-size restrictions, there was a scarcity of brown trout ≥ 406 mm in length in the upper Madison River and few rainbow trout ≥ 406 mm in the upper and lower Madison River. Current regulations should substantially reduce angler-caused mortality and thus allow brown trout and rainbow trout populations to approach their full biological potential in all portions of the Madison River within Yellowstone National Park. Mountain whitefish populations should continue to flourish because they are subject to minimal harvest by anglers and apparently coexist well with brown trout and rainbow trout.

Important questions about the Madison River fishery remain unanswered. The influence of adfluvial populations of brown trout and rainbow trout from Hebgen Lake on resident Madison River fish populations and the unusual fall spawning habits of rainbow trout in the Madison River (Jones et al. 1979) both require further investigation. Also, the habitat requirements for brown trout, rainbow trout, and mountain whitefish should be studied in order to gain a more complete understanding of the Madison River fishery.

SODA BUTTE CREEK

Soda Butte Creek is among the 10 most popular stream fisheries in Yellowstone National Park. A paved road parallels the entire creek, and anglers fish against a backdrop of sharply rising, rugged mountains. Anglers and other visitors in this area of Yellowstone National Park also have the opportunity to view elk *Cervus elaphus*, moose *Alces alces*, bison *Bison bison*, and other wildlife.

Historically, the Yellowstone cutthroat trout *Salmo clarki bouvieri* was the only salmonid inhabiting Soda Butte Creek (Evermann 1892; Jordan 1892); however, the introduction of various subspecies of cutthroat trout between 1920 and 1943 and a single introduction of nonnative rainbow trout *Salmo gairdneri* in 1937 (Varley 1981) altered the genetic purity of historic stocks. Presently, cutthroat trout populations in Soda Butte Creek are introgressed with rainbow trout genes, but rainbow trout are no longer present (Loundenslager and Gall 1981). The frequency of angler reports of brook trout *Salvelinus fontinalis* in the upper reaches of Soda Butte Creek and in Warm Creek, a tributary of Soda Butte Creek, has increased in recent years; however, these reports have never been confirmed (Jones et al. 1982, 1987).

Liberal angling regulations in effect on Soda Butte Creek from the late 1800s through 1972 (U.S. Fish and Wildlife Service unpublished data) were replaced by a creel limit of two fish of any size in 1973. Although this regulation probably reduced angler-caused mortality, Jones et al. (1982) concluded that angler harvest was still excessive, and catch-and-release-only angling was recommended. In 1987, a 2-fish, 330-mm minimum-size limit went into effect; it is hoped that this regulation will benefit cutthroat trout populations in Soda Butte Creek while allowing limited angler harvest.

The objective of this study was to describe the current status of cutthroat trout populations in Soda Butte Creek. Data presented should provide a baseline against which to evaluate future effects of angling under the current regulation.

Study Area

Soda Butte Creek originates at an elevation of 2,347 m from a small, unnamed lake above Cooke City, Montana (Jones et al. 1982). From its origin, the creek flows west for nearly 8 km and passes through the tailings of a gold mine (abandoned in 1953) and the small towns of Cooke City and Silver Gate, Montana, before reaching the northeast corner of Yellowstone National Park (Figure 45).

Acid drainage from the mine tailings severely degrades the water quality of Soda Butte Creek (Mills and Sharpe

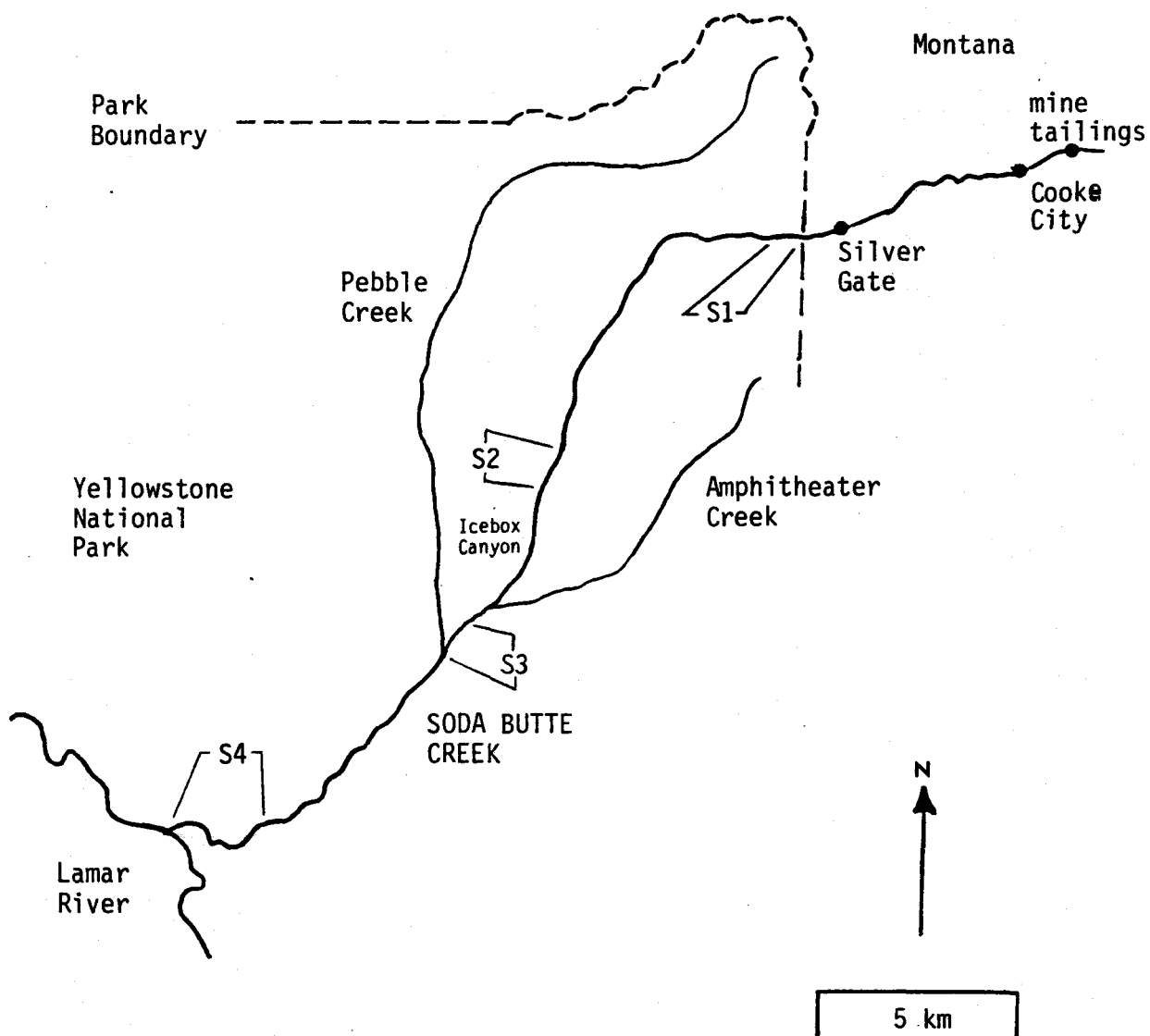


FIGURE 45.-Soda Butte Creek showing electrofishing stations S1, S2, S3, and S4, 1987.

1968b; Hill 1970, 1977; Kerr 1986; EPA 1987). Specifically, acidic groundwater leaches heavy metals (particularly iron) from the tailings into the stream. Once in the stream, the acidic groundwater is neutralized by streamwater and the associated metal complexes precipitate on the streambottom (EPA 1988). Aquatic macroinvertebrate communities and fish populations are negatively impacted downstream from the tailings for a distance of 7-8 km (Mills and Sharpe 1968b; Davenport 1972; Duff 1972; Pickett and Chadwick 1973; Marcuson and Bishop 1975; Mangum 1986, 1988).

Upon entering Yellowstone National Park, Soda Butte Creek turns southwest and flows for approximately 12 km before passing through Icebox Canyon. This 3-km long canyon contains small waterfalls and cascades that are not complete barriers to upstream fish passage (Jones et al. 1982). Below Icebox Canyon, Soda Butte Creek continues southwest for another 11 km before joining the Lamar River at an elevation of 1,951 m (Figure 45).

The size of the Soda Butte Creek watershed is 26,020 hectares, and average gradient is 1.2% (Jones et al. 1981). Mean annual flow of the creek near Silver Gate, Montana, was 1.7 m³/s for the period 1976-1980; however, tributary inputs (particularly Amphitheater Creek and Pebble Creek) increase discharge nearly two-fold by the time Soda Butte Creek reaches its confluence with the Lamar River (Decker-Hess and White 1987).

Methods

Four sample stations were established in Soda Butte Creek in 1987 to investigate fish populations; two of these areas (S1 and S2) were upstream of Icebox Canyon and two (S3 and S4) were downstream of Icebox Canyon (Figure 45). Sampling was conducted from 4 to 6 August and from 24 to 27 August.

At all four sample stations, fish were collected by electrofishing; however, differing habitats necessitated the use of three different electrofishing systems. At S1 and S2 (0.3 and 1.1 km in length, respectively), a 2-m long plastic boat was fitted with two mobile positive electrodes and a trailing negative electrode. The boat contained a fish-holding tank, 3.5 kW AC generator, and Coffelt VVP-15 rectifying unit that produced pulsed, direct current. Electrofishing was conducted during daylight hours, and began at the upstream boundary of the study section and proceeded downstream. One crew member stood in the creek at the upstream end of the boat and guided it slowly downstream as other personnel stood near the positive electrodes and netted stunned fish.

At S3 (1.0 km in length), a 4-m long rubber raft was fitted with two stationary electrodes (one positive and one negative) and one mobile positive electrode. The raft

contained fish-holding tanks, generator, and rectifying unit. Other procedures followed at S3 were identical to those at S1 and S2.

At S4 (2.3 km in length), fish were collected at night by electrofishing from the rubber raft. The raft in this case was fitted with two stationary dropper electrodes and held the electrofishing crew, fish-holding tanks, generator, and rectifying unit. One crewmember maneuvered the raft as it floated downstream, and two crewmembers stood in the bow and netted stunned fish as they floated to the surface.

Captured trout at all four sample sites were anesthetized in MS-222, measured to the nearest 1 mm total length, and fin-clipped. Additionally, five trout in each 25-mm length group were weighed to the nearest 2 g, and scale samples were collected from each of these fish for age-growth analysis. Ages were estimated by the scale method (Bagenal and Tesch 1978), and results were expanded using an age-length key (Westerheim and Ricker 1978). After revival in fresh water, all trout were returned to the river.

Because sampling time was limited, data collected at S1 and S2 were used only to examine trout population structure. Additionally, fish population estimates were calculated at S3 and S4 using the Chapman modification of the Peterson method (Ricker 1975).

Results

At all four sites sampled in 1987, cutthroat trout was the only salmonid captured. Based on the number of fish captured per kilometer during initial electrofishing runs at each sample site (4 August at S1, 25 August at S2, 5 August at S3, and 5 August at S4), cutthroat trout were most abundant at S4 (344 fish/km), followed by S3 (119 fish/km), S1 (83 fish /km), and S2 (77 fish/km). Extremely turbid water conditions during sampling at S2 resulted in an underestimate of relative abundance at this sample site.

Based on statistically unbiased population estimates (Robson and Reiger 1964) (Table 58), there were 2,219 trout/km at S4 and 1,003 trout/km at S3. Interestingly, the ratio of trout at S4 compared to S3 derived from population estimates (2.2:1) was similar to that calculated from the number of fish captured during initial electrofishing passes through each station (2.8:1). This result suggests that in Soda Butte Creek, reliable estimates of relative abundance may be obtained without population estimates.

Data collected from fish captured in mark runs and unmarked fish caught during recapture runs were used to examine length structure, age structure, and growth. Mean lengths of cutthroat trout were greater at S1 and S4 (256 and 238 mm, respectively) than at S2 and S3 (202 and 175 mm,

TABLE 58.-Estimated number of cutthroat trout per kilometer at two sample sites in Soda Butte Creek, 1987.

Sample site	Estimated number of fish per kilometer	95% Confidence limits	
		Lower	Upper
S3	1,003	630	2,035
S4	2,219	1,822	2,765

TABLE 59.-Mean length, weight, and condition of cutthroat trout captured by electrofishing in Soda Butte Creek, 1987.

Sample Station	n ^a	Mean length (mm)	Mean weight (g)	Mean condition (K)
S1	26	256	203	1.15
S2	77	202	120	0.95
S3	222	175	64	1.00
S4	1,276	238	169	1.08

^a Based on the sum of all fish captured during mark runs and all unmarked fish caught during recapture runs.

respectively) (Table 59), and length-frequency distributions (Figure 46) revealed that the percentage of cutthroat trout ≥ 330 mm in length ranged from a high of 6.5% at S2 to a low of 0.0% at S1. The percentages of cutthroat trout ≥ 330 mm in length at S4 and S3 were 3.1 and 1.4%, respectively.

Greater mean lengths at S1 and S4 appear due to differences in age structure of cutthroat trout populations at these two sample sites compared to age structure at S2 and S3. At S1 and S4, respectively, 92 and 89% of all fish captured in mark runs and all unmarked fish caught during recapture runs were classified as $\geq$ age-3. However, only 49 and 33% of fish captured at S2 and S3, respectively, were classified as $\geq$ age-3 (Table 60). Mean backcalculated lengths (Table 61) revealed that trout growth was similar at all four sample sites.

Discussion

Cutthroat trout apparently are more abundant in the stream section below Icebox Canyon than above it (Jones et al. 1982, 1985, 1986, 1987, and the current investigation). Reasons for this distribution pattern may be related to quantity and quality of fish habitat. Below Icebox Canyon, inputs from Amphitheater Creek and Pebble Creek substantially increase the discharge of Soda Butte Creek and thus increase the quantity of available fish habitat. Above the canyon, fish habitat quality between Cooke City, Montana, and the northeast corner of Yellowstone National Park is severely degraded by the heavy-metal pollution from the mine tailings (Mills and Sharpe 1968b; Davenport 1972; Duff 1972; Marcuson and Bishop 1975; Jones et al. 1982). Although there are no supporting data, fish populations below Icebox Canyon may be augmented by upstream migrants from the Lamar River.

The relative abundance of cutthroat trout ≥ 330 mm in length is low throughout Soda Butte Creek (Jones et al. 1982, 1985, 1986, 1987, and the current study). Scarcity of larger and older fish upstream of Yellowstone National Park is probably due to chemical pollution and natural physical habitat limitations. Within Yellowstone National Park, however, angler harvest and natural physical habitat conditions may be the major limiting factors. Although the current angling regulation should substantially reduce angler-caused mortality, angler harvest will still be directed on the larger and older fish.

Because of past excessive angler harvest and continued pollution from the mine tailings, Decker-Hess and White (1987) concluded that cutthroat trout populations were not reaching their full biological potential in Soda Butte Creek. Maddox and Killingsworth (1983) reported that the mine tailings above Cooke City, Montana, were in a state of imminent failure, and the EPA (1988) reported that failure

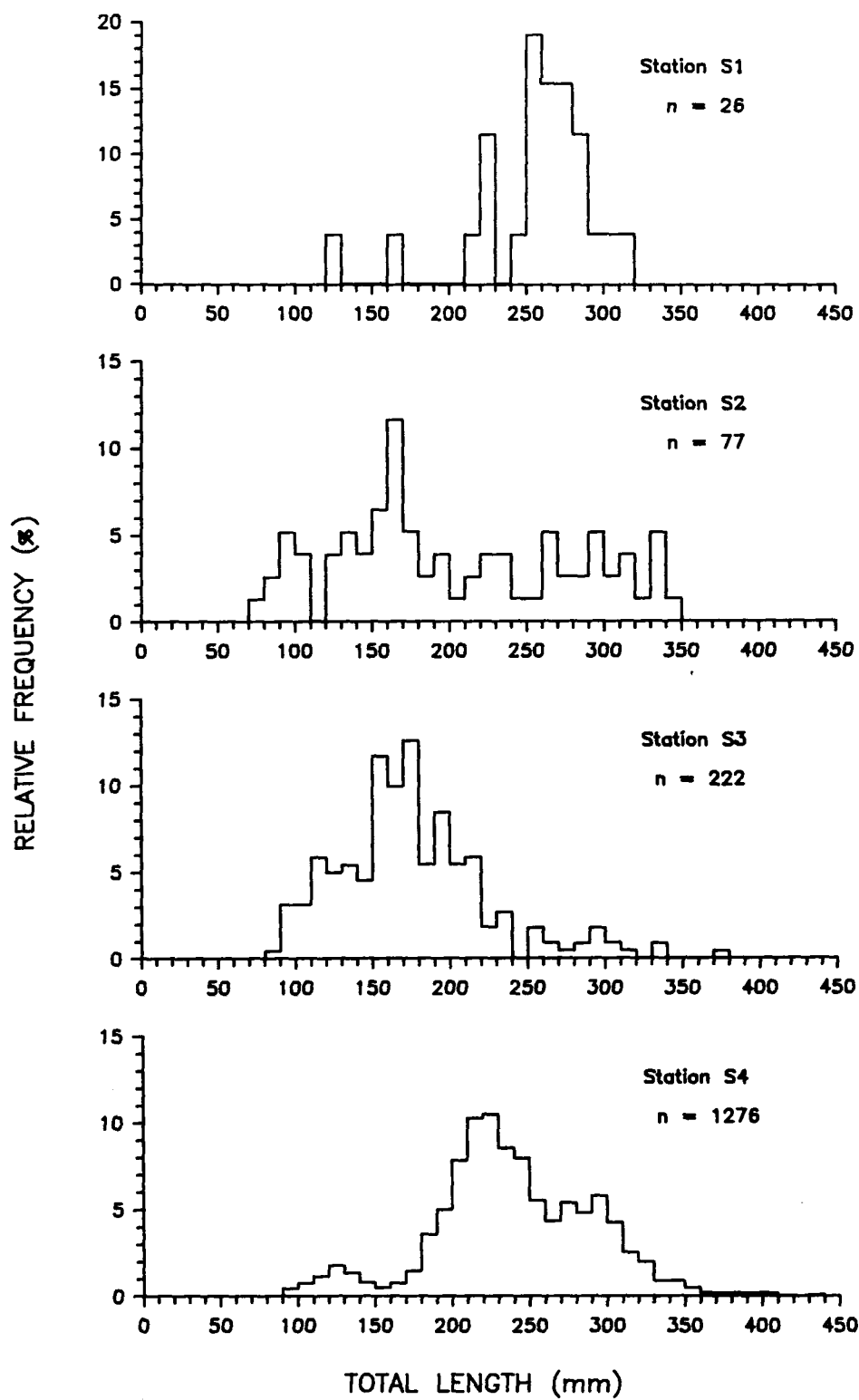


FIGURE 46.-Length frequencies of cutthroat trout captured by electrofishing in Soda Butte Creek, 1987.

TABLE 60.-Age composition of cutthroat trout captured by electrofishing in Soda Butte Creek, 1987.

Sample site	n	Percent classified as age:						
		0	1	2	3	4 ^a	5	6
S1	26	0.0	3.8	3.8	23.1	65.4	3.8	0.0
S2	77	0.0	16.9	33.8	16.9	24.7	7.8	0.0
S3	222	0.0	17.6	49.5	25.2	7.7	0.0	0.0
S4	1,276	0.0	3.6	7.3	51.6	33.5	3.4	0.6

^a Represents age-4 trout at S1, S2, and S4, and age-4-and-older trout at S3.

TABLE 61.-Mean backcalculated length (mm) at annulus for cutthroat trout captured by electrofishing in Soda Butte Creek, 1987.

Sample site	n	Annulus					
		1	2	3	4	5	6
S1	19	67	132	199	248	303	-
S2	53	62	127	191	255	311	-
S3	38	61	126	193	251	-	-
S4	59	56	120	190	259	325	365

of the tailings would carry heavy-metal contaminants downstream into Yellowstone National Park. The impacts of such an occurrence would no doubt be disastrous to all aquatic life in Soda Butte Creek. Additionally, Decker-Hess and White (1987) reported that if all current water-right claims on Soda Butte Creek in the state of Montana were approved, the water from the creek would be over-appropriated from August through April at the point where the creek reaches Silver Gate, Montana. These findings emphasize the need for continued monitoring of the Soda Butte Creek fishery, and efforts to ensure the continued quantity and quality of Soda Butte Creek should remain a high priority.

LEWIS LAKE

Between 1982 and 1986, gametes were collected annually from lake trout from Lewis Lake as part of an international effort to reestablish naturally-reproducing populations of lake trout in Lake Michigan (Jones et al. 1987). Gametes were not collected in 1987, but project personnel assisted researchers from the University of Wisconsin (Milwaukee) Center for Great Lakes Studies and the U.S. Fish and Wildlife Service Disease Control Center (Fort Morgan, Colorado) by collecting lake trout on 5 October 1987. Over 300 lake trout were examined for stage of maturity and released alive. Fecal material was collected from a sample of 150 lake trout. Tests were completed for the following pathogens: *Aeromonas salmonicida*, enteric redmouth bacterium, salmonid kidney disease bacterium, and infectious pancreatic necrosis virus; all trout tested negative for selected pathogens.

Most trout were approximately 450 mm in length, but several individuals between 800 and 900 mm were collected. Only four ripe females were collected. These fish were artificially spawned, and equal volumes (300 ml) of fertilized eggs were placed in artificial substrate incubators. Artificial incubators were submerged in approximately 10 m of water; they will be retrieved after ice-off in 1988. Hatching success will be evaluated, and resulting fry will be compared to fry from hatchery stocks.

ARNICA CREEK RESTORATION PROJECT

Yellowstone Lake supports what may be the largest remaining population of native inland cutthroat trout *Salmo clarki bouvieri* in the world. Arnica Creek, a tributary of the lake, sustains one of the larger spawning migrations of this important sport species. An introduced population of brook trout *Salvelinus fontinalis* was first detected in Arnica Creek in May 1985. Electrofishing surveys conducted on 40 other tributaries to Yellowstone Lake revealed that brook trout were limited to the Arnica Creek drainage. Because of negative ecological consequences that would result from the establishment of brook trout in Yellowstone Lake, including the possible demise of the endemic Yellowstone cutthroat trout, the National Park Service decided to eliminate all fish in the Arnica Creek drainage. The entire drainage, including a 23.6-hectare lagoon, was initially treated with antimycin in August 1985. A second application was completed on the stream in August 1986.

Portions of Arnica Creek were surveyed on three occasions in 1987, and no brook trout were observed. Electrofishing with a backpack shocker on 19 May 1987 was concentrated approximately 4 km above the mouth near the intersection of the three main forks of Arnica Creek. Cutthroat trout spawners were abundant in this sample. On 25 June and 10 September 1987 rotenone was used to collect samples from the same area; additionally, tributaries 118303, 118304, and 118305 were sampled on the latter date. Juvenile cutthroat trout were abundant during the June sample, but few were collected in September.

Although current evidence suggests that brook trout have been removed from the Arnica Creek drainage, monitoring will continue. If brook trout are found in the drainage in the future, the renovation project will be limited to problem sections (Jones et al. 1987).

REESE CREEK

In recent years, concern has been expressed about extensive dewatering of spawning tributaries to the upper Yellowstone River (Clancy 1984). Decreased hatching success and depressed recruitment resulting from inadequate instream flows in the spawning tributaries may be limiting to migratory trout populations from the Yellowstone River. Since 1978, the state of Montana has been involved in a statewide water rights adjudication process. Reese Creek is the only stream in Yellowstone National Park that has had water diverted from it for private irrigation use. Consequently, the water adjudication process has prompted the National Park Service to determine adequate flows necessary to protect aquatic life in Reese Creek.

In order to evaluate the aquatic resources of Reese Creek and the effects that dewatering has on those resources, a preliminary study was initiated by U.S. Fish and Wildlife Service in 1984. Data collected in 1984 and 1985 revealed use of Reese Creek by salmonids (Lentsch 1986), and also yielded streamflow data, instream flow recommendations for salmonid spawning migrations, and minimum flow requirements for fish for the remainder of the water year. An additional study in 1986 (Mahony 1987) described the physical habitat of Reese Creek, the duration and magnitude of the cutthroat trout spawning migration from the Yellowstone River into Reese Creek, and general patterns of both natural and diverted streamflows.

In 1987, monitoring continued on Reese Creek. The goal of this project was to collect supplemental information on the streamflow regime in Reese Creek and to broaden the existing database. Specific objectives were to:

- (1) Obtain daily flow records for Reese Creek mainstem and diversion ditches.
- (2) Gather annual temperature data for mainstem.
- (3) Assess the magnitude of resident populations above the diversions and migratory populations from the Yellowstone River.
- (4) Monitor macroinvertebrate communities in sections affected by dewatering.

Study Area

Reese Creek is the northernmost tributary of the Yellowstone River in Yellowstone National Park. This stream flows approximately 11.5 km from the outlet of Cache Lake to the confluence with the Yellowstone River (Figure 47). Electric Peak and Sepulcher Mountain form the west and east boundaries, respectively, of the Reese Creek drainage basin.

Irrigation diversions are located approximately 0.8, 1.6, and 2.0 km upstream from the mouth of Reese Creek (Figure 48). These diversions are referred to as the first

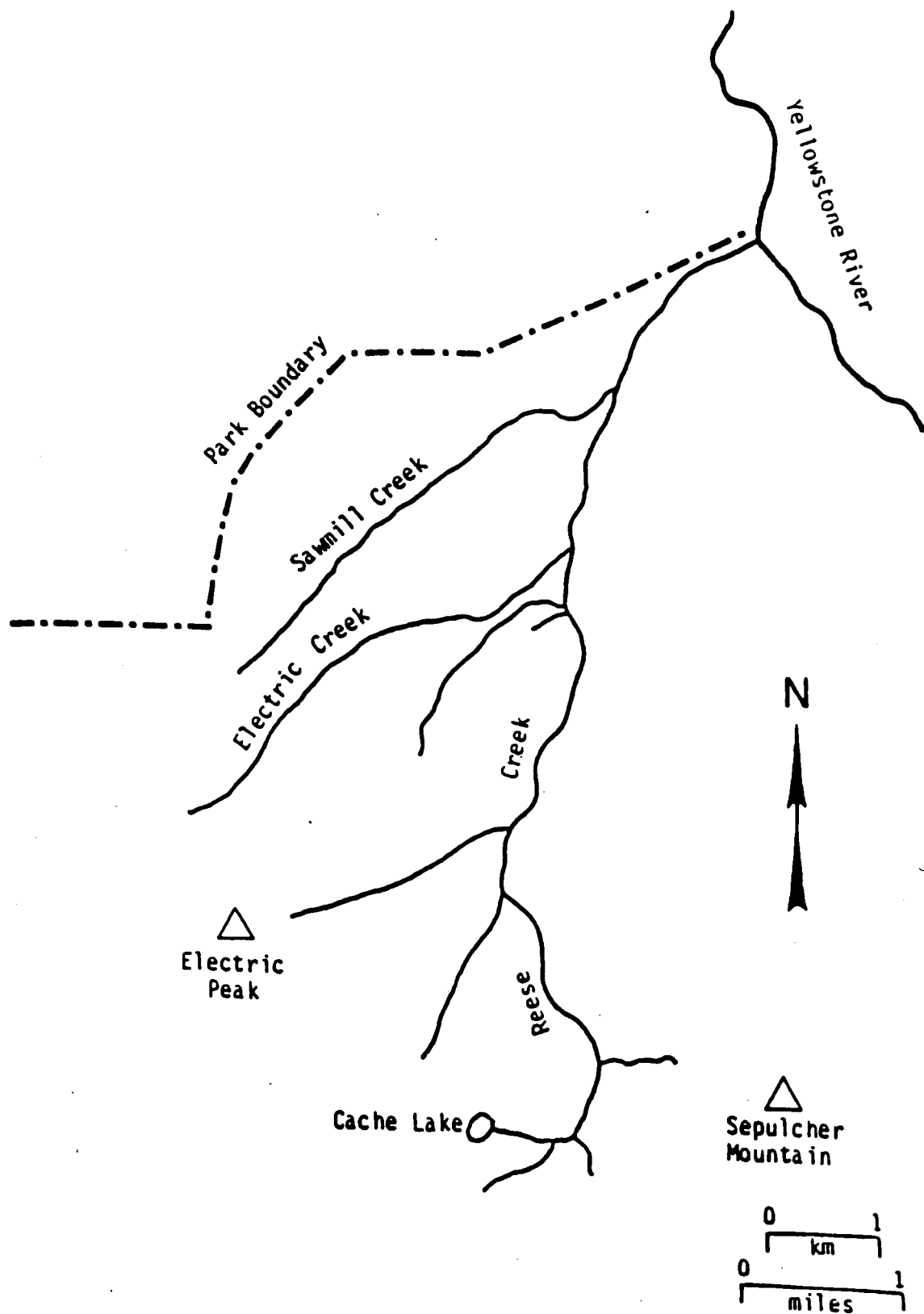


FIGURE 47.-Hydrographic map of Reese Creek.

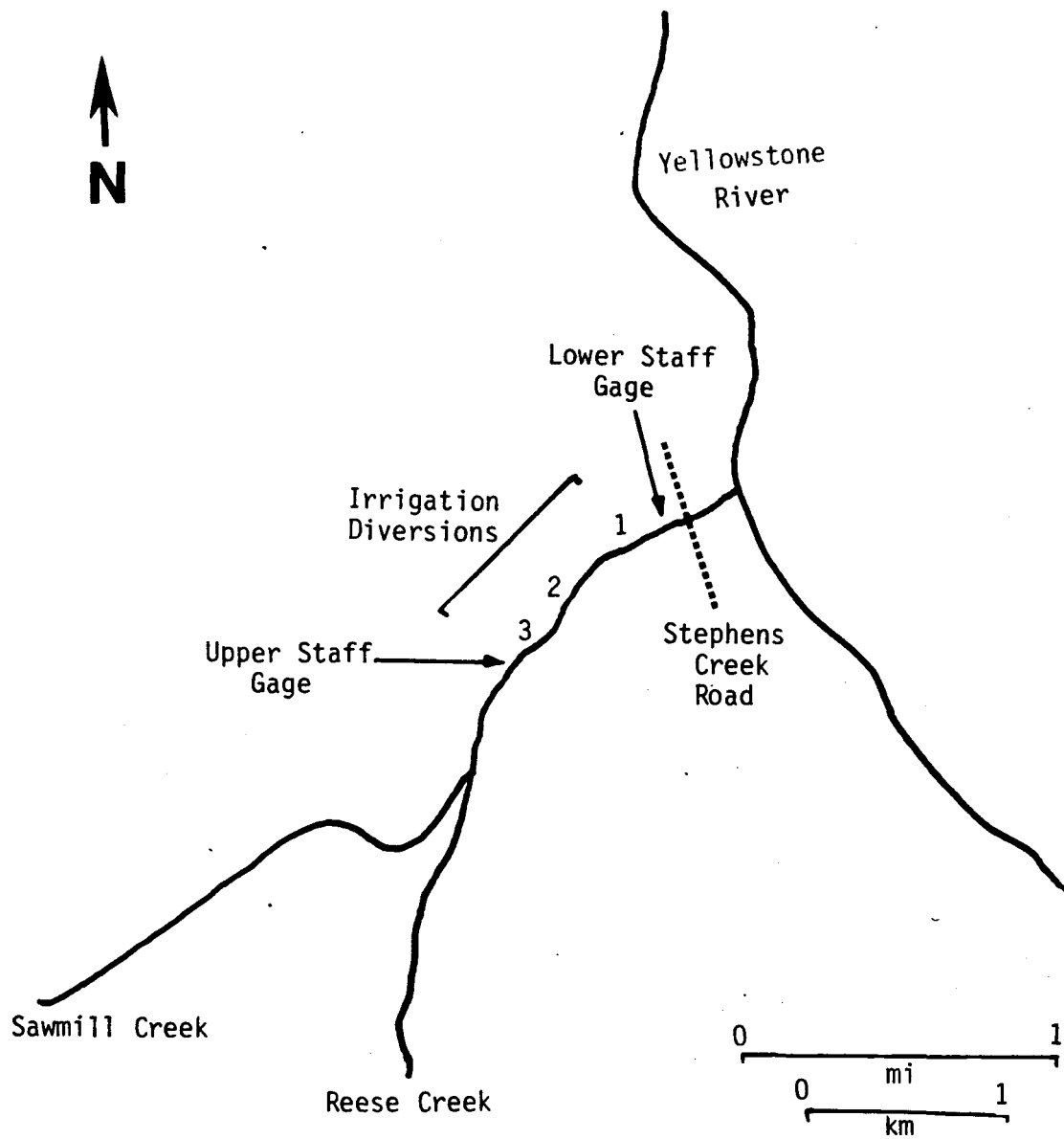


FIGURE 48.-Reese Creek study area showing locations of irrigation diversions and staff gages.

diversion, second diversion, and third diversion, respectively.

Methods

Streamflow

In order to monitor natural streamflows in Reese Creek, a staff gage was installed and calibrated on 17 April approximately 200 m upstream from the third diversion. Discharge was measured at this site once a week using the midsection method (Buchanan and Somers 1969). A stage-discharge relationship was developed to predict daily flows. Staff gage level was recorded daily from 8 May to 11 November 1987, and on days when staff gage readings were not made, the mean value of the preceding and subsequent estimated streamflow was used in determining a predicted discharge. A second staff gage (lower gage) was located approximately 0.6 km upstream from the mouth of Reese Creek. Discharge in the section subject to dewatering was estimated from the stage-discharge relationship developed in 1986 at this lower staff gage.

Flow transects were also established in the second and third diversion ditches. Discharge was estimated weekly by the midsection method and by using a cross-sectional area, color-dye velocity procedure (Hamilton and Bergersen 1984). Daily depth readings and predicted flows followed the same procedures as those for the upper staff gage.

Temperature

On 17 April, a Ryan 90-day thermograph was installed near the upper staff gage to obtain an annual water temperature profile in Reese Creek. Maximum and minimum daily water temperatures were averaged to obtain mean daily water temperature. Daily minimum and maximum water temperatures were also recorded with a maximum-minimum thermometer downstream from the first diversion to monitor influences of dewatering on stream temperature.

Fish

Sampling for resident cutthroat trout was restricted to sections of Reese Creek mainstem above the upper diversion. Fish were collected by means of a Coffelt BP-1 backpack electrofishing unit. On 8 and 17 April 1987, a section extending a reach from the upper staff gage to a point 0.5 km upstream was sampled. More extensive sampling occurred on 8-9 July 1987 when the mainstem of Reese Creek was electrofished from the upper staff gage to approximately 1 km upstream from the confluence with Electric Creek.

Captured fish were measured to the nearest 1 mm total length and weighed to the nearest 5 g. Scales were collected from all fish on 17 April and the July samples for age and growth determination.

In order to monitor the spawning migration of cutthroat trout from the Yellowstone River into Reese Creek and subsequent hatching and emigration of fry, a wooden, V-shaped, two-way trap was installed approximately 0.3 km upstream from the mouth of Reese Creek on 14 May. Due to early dewatering in Reese Creek, no spawning migration occurred in 1987.

Aquatic Macroinvertebrates

In response to the need for more extensive data on macroinvertebrate communities in the portions of Reese Creek subject to dewatering, a monitoring program consisting of replicate samples taken at regular intervals was designed. However, due to rapid and extended dewatering commencing at the beginning of the study period, sampling of aquatic macroinvertebrates could not be accomplished.

Results and Discussion

Streamflows

Estimated streamflows in the Reese Creek mainstem at the upper staff gage ranged from a high of 0.25 m³/s in mid-July to a seasonal minimum flow of slightly less than 0.11 m³/s in late August (Figure 49). Mean streamflow for the study period was 0.15 m³/s.

Water was diverted from Reese Creek into the third diversion every day of the sampling period. Discharge in this ditch ranged from 0.01 m³/s to a maximum of 0.21 m³/s. Mean discharge in this diversion was 0.08 m³/s, representing an average of 56% of the mean Reese Creek streamflow. In mid-July and mid-September, the discharge in the third diversion approached 100% of the instream flow of Reese Creek (Figure 49).

In the second diversion, average discharge was 0.04 m³/s, and maximum estimated discharge was 0.17 m³/s. Streamflow in the second diversion was a function of available water remaining in Reese Creek. Although for 22 d of the study period no water was diverted into this diversion, on most days all available water was diverted (Figure 49). On 88% (112 d) of the days when Reese Creek was totally dewatered, the majority of water was diverted through the third diversion ditch. At both the second and third diversions, mainstem channel alterations and plastic tarps helped to assure complete removal of discharge from the mainstem.

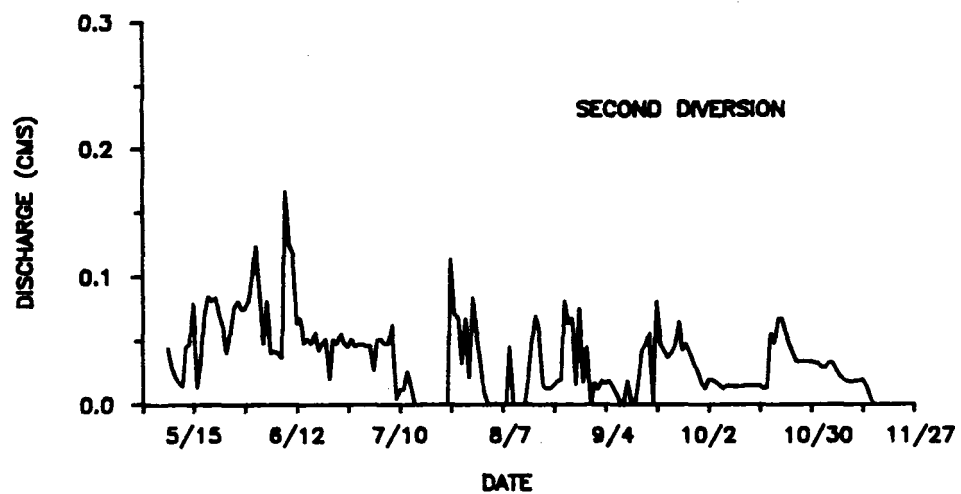
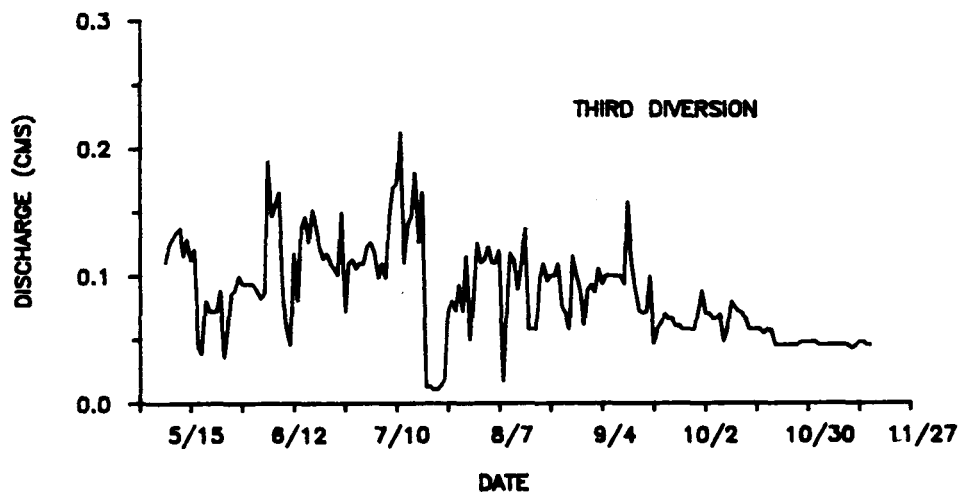
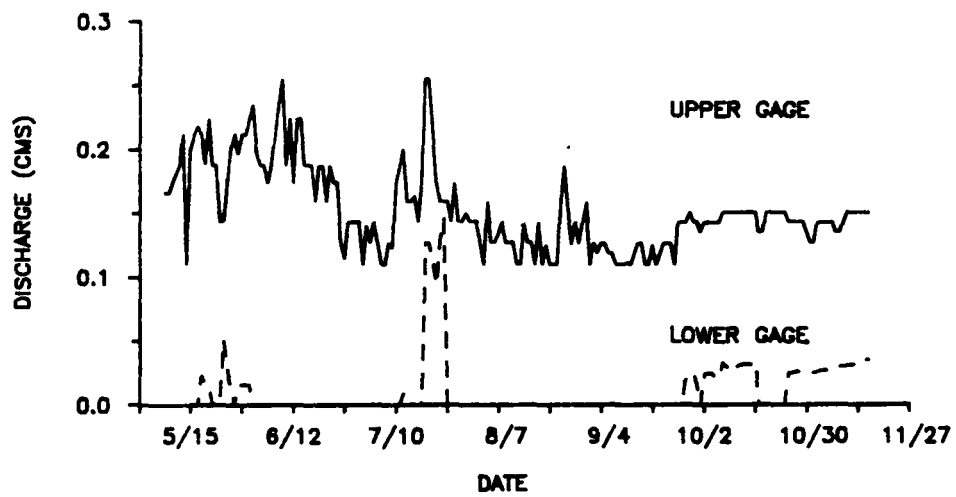


FIGURE 49.-Stream discharge in Reese Creek mainstem (upper and lower gages) and diversion ditches, 1987.

Downstream from the irrigation diversions, the mainstem of Reese Creek was completely dewatered for 127 days (77% of the study period) between 12 May and 26 October. Daily readings of zero flow at the lower staff gage reflected this complete dewatering (Figure 49).

Recommended instream flows for Reese Creek are $0.12 \text{ m}^3/\text{s}$ from 15 May to 31 July (Lentsch 1986). Mean discharge of $0.12 \text{ m}^3/\text{s}$ in the portion subject to dewatering occurred for only 6 d during the study period (Figure 49). Dramatic decreases in irrigation withdrawals for these 6 d coincided with several days of heavy precipitation. Precipitation in the northwest portion of Yellowstone National Park during the summer months of 1987 was nearly 170% of the 30-year average from 1951-1980 (NOAA 1982, 1988). Although there were additional days when Reese Creek was not completely dewatered in 1987, at least some water was diverted daily until ice formation in mid-November. Discharge below the diversions exceeded $0.03 \text{ m}^3/\text{s}$ on only 15 d; however, minimum recommended flow levels ($0.05 \text{ m}^3/\text{s}$) did not occur on any of these days.

Previous studies on Reese Creek have documented that salmonids from the Yellowstone River use Reese Creek for spawning provided that adequate streamflows are present (Lentsch 1986; Mahony 1987). The complete dewatering of Reese Creek in 1987 occurred before, during, and after the normal time of salmonid spawning. As a result, any opportunity for spawning or recruitment to the Yellowstone River fishery in 1987 was eliminated.

Temperature

Mean daily water temperatures in Reese Creek ranged from a maximum of 10.75°C on 31 July to 0°C during the winter months (Figure 50). Average water temperature during the study period was 5.0°C . Data collected in the section subject to dewatering was limited.

Previous water temperature data from Reese Creek is very limited (Mahony 1987); however, it appears that peak migration of salmonids from Yellowstone River into Reese Creek occurs as temperatures approach 7 to 8°C . In 1987, temperatures reached this range on 1 June (Figure 50) and coincided with the extended total dewatering of the lower portions of Reese Creek. Thus, although water temperatures appeared conducive to successful spawning, incubation, and emigration, lack of streamflow prevented migratory populations from utilizing Reese Creek during spawning season.

Fish

Resident population.-Electrofishing upstream from the third diversion yielded 50 cutthroat trout in 1987. Mean

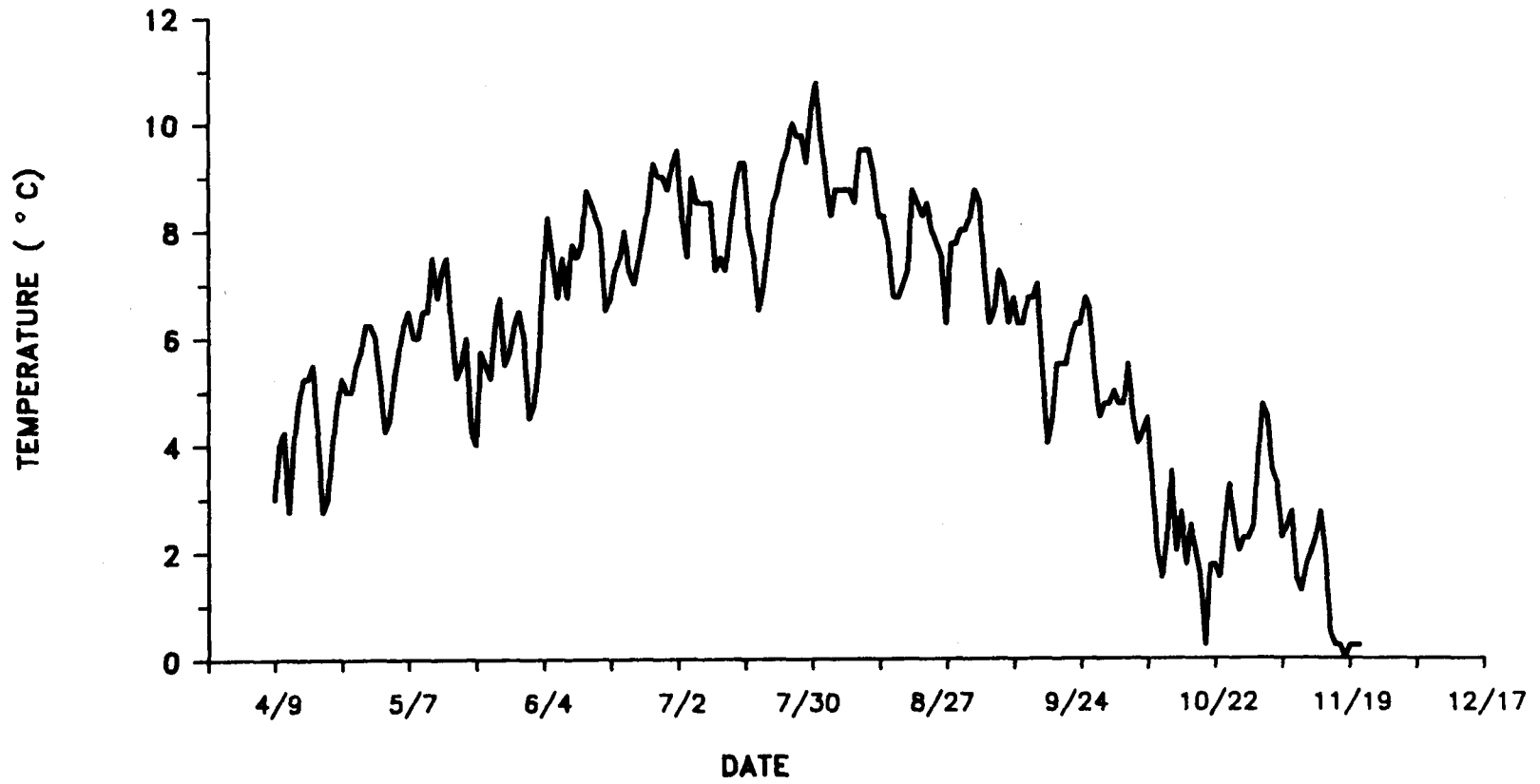


FIGURE 50.-Mean daily water temperature of Reese Creek, 1987.

total length of all captured fish was 166 mm. The largest cutthroat trout (290 mm) was collected upstream from the confluence with Electric Creek and appeared to be a mature spawner. Approximately 0.5 km upstream from Electric Creek a series of cascades appears to function as a permanent barrier to fish migration. No trout were collected upstream of this point.

Age determinations revealed that age-2 cutthroat trout were most common. Age-5 fish were collected with the second highest frequency. Mean age of cutthroat trout in Reese Creek was 3.1 years. Growth analyses indicate that the resident salmonids in Reese Creek are slow-growing trout characteristic of cold headwater streams (Table 62).

TABLE 62.-Backcalculated mean length at annulus formation for Reese Creek cutthroat trout, 1987.

Sample size	Mean length (mm) at age					
	I	II	III	IV	V	VI
33	59	115	176	229	258	273

The collection of six age groups suggests a self-sustaining population of cutthroat trout in portions of Reese Creek not subject to dewatering. Although the population does not appear to be large, the potential exists for expansion of this population if Reese Creek was not totally dewatered.

FLUVIAL ARCTIC GRAYLING

The historic distribution of fluvial Arctic grayling *Thymallus arcticus* in Yellowstone National Park included portions of the Madison River and Gallatin River drainages. No known fluvial populations of Arctic grayling remain in the park; however, the species is found in Grebe Lake and Wolf Lake in the Madison River drainage and Cascade Lake in the Yellowstone River drainage. Most recent attempts to reestablish fluvial populations occurred between 1976 and 1980 in the Madison River drainage when Arctic grayling were stocked in Canyon Creek, a tributary of the Gibbon River (Varley et al. 1976; Jones et al. 1977-1981).

Early in summer 1987, several local anglers reported regularly catching Arctic grayling in Canyon Creek and in the Gibbon River near Canyon Creek (Figure 51). The reports were unusual because Arctic grayling are very rarely caught in the Gibbon River, and those that are caught have been considered to be downstream migrants from Grebe Lake or Wolf Lake. Therefore, in late summer 1987, the U.S. Fish and Wildlife Service attempted to determine whether the stocking of Arctic grayling in Canyon Creek had been successful and whether a self-sustaining, fluvial population had become established.

The study area encompassed portions of Canyon Creek and the Gibbon River. Canyon Creek was sampled by electrofishing on 31 August from the mouth to a point approximately 1.2 km upstream (Station A) (Figure 51). On 1 September, two sections (Station B and C) of the Gibbon River were sampled by electrofishing. Station B on the Gibbon River extended from its confluence with Canyon Creek to a point nearly 2.4 km downstream, and Station C began near Terrace Spring and continued downstream for about 2.6 km (Figure 51).

No Arctic grayling were captured by electrofishing in Canyon Creek or in the Gibbon River in 1987. These results suggest that if angler reports were accurate, the Arctic grayling population in Canyon Creek does not appear to be a viable one. In 1988, however, additional portions of Canyon Creek and the Gibbon River will be sampled to confirm results obtained in 1987.

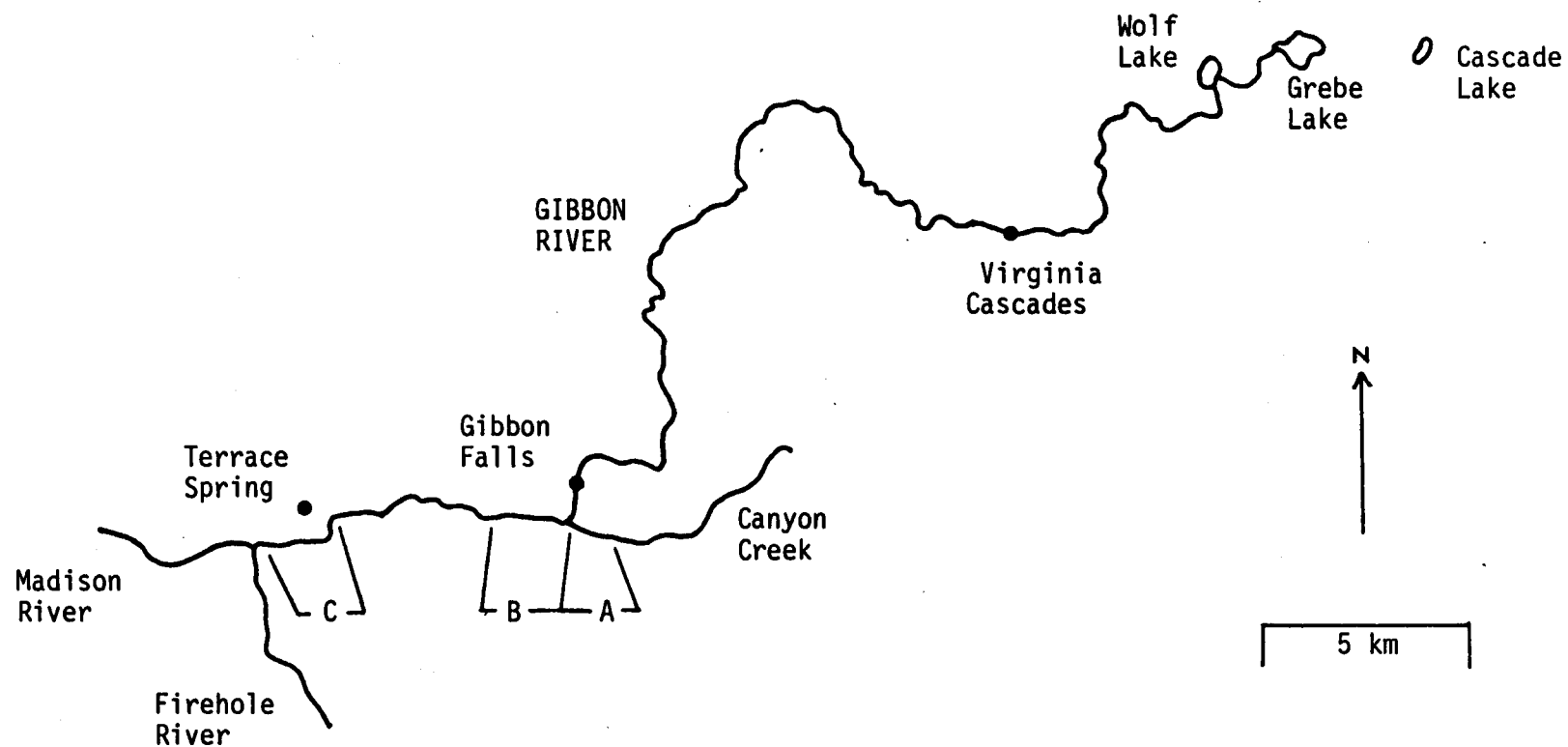


Figure 51.-Gibbon River and Canyon Creek showing electrofishing Stations A, B, and C, 1987.

NONCONSUMPTIVE USE OF THE AQUATIC RESOURCE

In Yellowstone National Park there are presently two sections of the Yellowstone River which are closed to angling for the protection of spawning trout. These areas yield an excellent opportunity to study the level of visitation to aquatic habitats that are available only to nonangling uses, such as wildlife photography or viewing.

Fishing Bridge spans the Yellowstone River at the outlet of Yellowstone Lake; the area from the lake outlet to a point 1.6 km downstream of the bridge has been closed to fishing 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/h, varying from a high of 0.48 trout/h during the first week of July to a low of 0.00 trout/h during the first week of September. In 1966, Sharpe and Arnold (1967) reported that the catch per unit effort was lower than most park waters. Dean and Varley (1973) concluded that few anglers returned to the bridge after an initial experience because of crowding and low success rates.

LeHardy Rapids, located approximately 5.7 km downstream from the lake outlet on Yellowstone River, has been closed to fishing for 90 m upstream and downstream from the rapids since 1949. During spring runoff (May through July) fish congregate 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. In 1984, a new boardwalk and viewing platform were constructed at LeHardy Rapids to facilitate visitor access and prevent continued erosion of the trail to the rapids. A sign identifying LeHardy Rapids was placed at the vehicle pullout in 1985.

Effects of angling closures were monitored at Fishing Bridge and LeHardy Rapids for the tenth consecutive year in 1987. Visitor use and mean length of stay were estimated at both areas.

Methods

Since effort available for counts was limited, a "time available" method (Mathisen 1949; Bulkley 1966; Geiger 1972; Brown 1978) of data collection was employed. Instantaneous counts of visitors were made whenever possible at both Fishing Bridge and LeHardy Rapids, usually while en route to a work site. The location of project activities affects sampling effort at each site; therefore, sample size varies between years. In 1987, both ranger and naturalist employees also made counts at both sites; their participation helped to increase the number of observations.

Critical aspects of this method are accurate estimates of average time spent per person and daily use pattern.

Accuracy increases as the number of time intervals increase; however, if interval sizes become too small, the increase in time periods without counts causes a decrease in the resulting estimate. Using these criteria, a 15-minute time interval appears to be optimum for Fishing Bridge and LeHardy Rapids use estimates.

A daily use curve was determined by averaging all counts for each interval. Total visitor hours for each interval were then calculated using the following formula:

Effort (visitor hours) = $1/2 I (t_1 + t_1 + 1)$,
where I is the time interval, and t_1 is the mean number counted t 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. 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 1987, mean length of stay at Fishing Bridge for 2,461 people was 11.4 min/person. Total number of visitors decreased from 1986 (approximately 13%) to 163,570 visitors. Total visitor hours increased (approximately 8%) from 1986 to 31,187 h (Table 63).

Mean length of stay at LeHardy Rapids was 9.8 min/person in 1987 (n = 2,248). Total number of visitors was estimated to be 105,907 people, and total time spent at the rapids was 17,364 h. Both values represent a decline from 1986 estimates (51% and 41% for total number of visitors and total time spent, respectively).

Discussion

Creel census data for the last 8 years (1965-1972) of angling on Fishing Bridge yielded an average of 33,275 total anglers and 36,714 total angler hours/year (Table 64). While the 1987 nonconsumptive use figures represent slightly lower total hours on Fishing Bridge, the number of people enjoying this area has increased almost 400% since the bridge was closed to fishing; concomitantly, current park visitation has only risen approximately 18% from 1965-1972 levels.

Although visitor use at LeHardy Rapids decreased substantially in 1987, current levels of use are significantly greater than the mean for the 7 years prior to

TABLE 63.-Nonconsumptive use of the aquatic resource, 1978-1987.

	Year	Number of 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
	1983	421	208,672		33,580
	1984	430	178,009	10.7	31,686
	1985	253	158,360	12.8	33,915
	1986	587	188,674	9.2	28,773
	1987	206	163,570	11.4	31,187
LeHardy 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
	1983	93	12,245		1,647
	1984	131	26,768	8.1	3,600
	1985	212	185,467	5.1	15,827
	1986	286	217,371	8.2	29,454
	1987	140	105,907	9.8	17,369

TABLE 64.-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

1985. Reasons for the decline are not known, but early spawning by Yellowstone River cutthroat trout may have resulted in fewer trout for observation in 1987.

Jones et al. (1985) suggested that the boardwalk completed late in 1984 might attract a larger number of visitors to LeHardy Rapids in future years. The boardwalk undoubtedly contributed to current visitation in the area; however, the addition of the location sign may actually have had a greater effect on use in the area. The rapids are not visible from the road, and although access was improved by the boardwalk, it was also difficult to see from passing cars. The sign identifies the location and signifies an area of interest to the park visitor.

Comparing nonangler use to park fisheries, more people utilize Fishing Bridge than any single fishery in the park (Tables 4 and 63). LeHardy Rapids ranks eleventh and Fishing Bridge eighth when compared, in terms of total hours, to angler effort among park fisheries.

Estimates of nonangler use during the past 10 years emphasize the value of these viewing sites and the demand for this type of visitor activity. Observing the interactions of fish in their natural habitat, including reproduction and feeding, is truly an educational experience for anglers and nonanglers alike.

OTHER PROJECT ACTIVITIES

Assistance to Independent Researchers

Yellowstone National Park is the largest intact ecosystem in the temperate zone of the earth, comprising 890,000 hectares of near pristine wilderness. The park was designated a biosphere reserve in 1976 and contains some of the most diverse geothermal, geological, and biological features in the world. Scientists are recognizing the critical role of natural systems in political, economic, and social problems of the world and are coming to Yellowstone National Park in increasing numbers to study its natural systems.

The Yellowstone fishery project functions as an administrative liaison and provides logistical support to independent researchers working on aquatic-related studies in Yellowstone National Park. Project personnel work closely with researchers in order to facilitate economical and timely completion of research in the park. Project equipment, manpower, and facilities are provided without compensation for small studies, and on a reimbursable basis for larger ones.

In 1987, the project provided assistance to Dr. Dennis Shiozawa, Associate Professor of Zoology at Brigham Young University, Provo, Utah for a genetics study of Yellowstone cutthroat trout. The project provided 27 man-days of assistance, logistical support, and fish sampling equipment to make collections from 10 populations of Yellowstone cutthroat trout. The objective of the study is to determine the amounts and patterns of genetic divergence among populations by using morphological and meristic characters, electrophoresis, and mitochondrial DNA analysis. This project represents the first time that mitochondrial DNA analysis has been used to genetically differentiate cutthroat trout in Yellowstone National Park. It also represents the first attempt to use more than one differentiation technique on Yellowstone cutthroat trout.

The project provided 4 man-days of assistance to Professor Shi-Kuei Wu and Dorothy Pillmore of the University of Colorado at Boulder, Colorado by making field collections of *Physa* spp. snails from eight locations in Yellowstone National Park. These collections were a part of a taxonomic study of *Physa* spp. snails in Wyoming being conducted by the University of Colorado at Boulder.

The project provided laboratory space to Lewis T. Nielsen and Mark Blackmore of the University of Utah for their study on "Biological Control of Mosquitoes with Mermithid Nematode Parasites."

The project provided data and planning assistance to H.E. Wright of the University of Minnesota for his study of "The Relationship of Climate to Sedimentation Rates in Lakes and Ponds in Yellowstone National Park."

The project provided assistance to R.O. Fournier of the U.S. Geological Survey with water chemistry data on the aquatic systems of Yellowstone National Park. Mr. Fournier is assisting with an aquatic classification of the waters in the park based on chemical analysis of water samples.

Assistance was provided to Dave Blackwell, Department of Geological Sciences, Southern Methodist University, Dallas, Texas. This project is a continuation of a study on "Heat Flow in Yellowstone Lake." Lab and shop space was provided to Blackwell's personnel along with 3 d of boat use on Yellowstone Lake.

Remote Operated Vehicle (ROV) studies of Unique Aquatic Environments in Yellowstone National Park.

The project provided laboratory space, boats and 12 man-days of assistance to J.V. Klump, Fred P. Binkowski, and Jerry L. Kaster of the University of Wisconsin-Milwaukee Center for Great Lake studies. This research, "ROV Studies of Unique Aquatic Environments in Yellowstone National Park", was conducted with a Deep Sea Mini-Rover MK1 under contract with Eastern Oceanics, Inc. The Rover is designed to dive to depths of 152 m and collect several types of data including video pictures.

Twenty-two dives were completed in Yellowstone Lake during the course of the mission, and a wide variety of bottom environments were found between shallow water and 91 m. During the course of these investigations, a new maximum depth of 111 m was recorded in Yellowstone Lake, and it is possible that even greater depths may be present. The lake bottom is very complex, and video footage of the bottom shows evidence of recent faulting and slumping. The Yellowstone Lake basin is tectonically very active with micro-earthquakes a daily phenomena. This rugged topography was previously unseen and raises questions with regard to the geological processes active on the lake bottom.

Three dives were completed within Lewis Lake over a wide range of bottom types in order to assess Lake trout habitat. Lake trout usually spawn in relatively deep water, but Lewis Lake optimal spawning substrate occurs at much shallower depths. This spatial distribution may increase the density of the early life stages of lake trout and may provide optimal foraging conditions for predators. Being in shallow water, these early stages will also be subjected to high energy wave action and ice movement.

The upper reach of Soda Butte Creek from Cooke City, Montana, downstream to the northeast corner of Yellowstone National Park is polluted by heavy metals (particularly iron) that are leached into the stream from the tailings of a long-abandoned gold mine. Since 1984, the project has collected macroinvertebrate samples from five locations in Soda Butte Creek that represent a high-to-low pollution gradient. Samples are collected quarterly and sent to Dr.

Fred Mangum of the U.S. Forest Service for analysis. Dr. Mangum has prepared two reports discussing impacts of the pollution on aquatic macroinvertebrates in Soda Butte Creek. Copies of these reports are available from this office or the U.S. Forest Service, Provo, Utah.

Information Distribution

Information produced by the Yellowstone Fishery and Aquatic Management Program is made available to the scientific field and the general public in several ways. The annual fishery and aquatic management program technical report has a distribution of approximately 130 copies annually.

The project receives 50-100 information requests each year by phone or mail. Response time on these requests requires from 10 min to an hour on the phone to several days on a research request. Project personnel are also very active in the American Fisheries Society and other fishery organizations. In 1987, papers were given at the Western Division of the American Fishery Society, the Montana chapter of the American Fishery Society, and a Catch-and-Release Fishing: A Decade of Experience symposium at Humboldt State University, Arcata, California.

The following talks and presentations were given:

(1) Presentations were made to Gardiner Fly Fishers, Gardiner, Montana, and the Federation of Fly Fishers National Conclave, West Yellowstone, Montana.

(2) Angling regulations in Yellowstone National Park. Talks given 2 March 1987 to Trout Unlimited, Deer Lodge, Montana; 14 April 1987 to Trout Unlimited, Pocatello, Idaho.

(3) Identification of Yellowstone Sport Fishes. Talks given March 1987, Resource Management Training, Yellowstone National Park; 10 March 1987 to North Pacific International Chapter, American Fisheries Society.

(4) Fishery Management in Yellowstone National Park. Talks given 18 May 1987; Fisheries class from Colorado State University; 22 June 1987 to National Park Service new employees' orientation; 30 June 1987 to managers of Hamilton Stores, Yellowstone National Park; 28 September 1987 to Bureau of Land Management, Prineville, Oregon.

(5) Ecology of stream insects in the Gardner River. Field trips on 4 and 9 June 1987; National Park Service naturalist training, Yellowstone National Park.

(6) Cutthroat trout spawning in tributaries of Yellowstone Lake, Yellowstone National Park. Talk given February 1986 at Montana State University, Bozeman, Montana to Fish and Wildlife students; February 1987 at Research-Resource Management seminar, Mammoth Hot Springs, Yellowstone National Park.

(7) Cutthroat trout spawning at Grant Village, Yellowstone National Park. Talk given March 1988 at National Park Service Resource Management Meeting, Mammoth Hot Springs, Yellowstone National Park.

Volunteer Program

Volunteer programs of the Fish and Wildlife Service, the National Park Service, and the Student Conservation Association have been utilized for many years. The program provides a needed manpower source for the project and a valuable training experience for the volunteer. In 1987 the project utilized 96 man-days of volunteer work and 140 man-days of student conservation association work. These volunteers were involved in all phases of project work including angler interviews, gillnetting, electrofishing, backcountry stream and lake surveys, and a variety of clerical and maintenance jobs. The effort and dedication of these volunteers is very important to the Yellowstone fishery program.

Youth Conservation Corps

The Yellowstone Fishery Project had its own Youth Conservation Corps (YCC) program in 1987. The project had two enrollees who provided 110 man-days of work to the project. These enrollees were involved in many aspects of project activities, including backcountry stream surveys, angler interviews and counts, fish population sampling, and maintenance. The enrollees were also involved in National Park Service activities such as naturalist programs, working in visitor centers, and some aspects of the ranger operation. Efforts of the YCC enrollees were important to the Fish and Wildlife Service, the National Park Service, and enrollees. The project also utilized 35 man-days of National Park Service YCC labor in the repair of the Cub Creek fish trap.

The Yellowstone fishery project would not be able to function at its present level without the volunteer programs. In 1987, 230 man-days of labor were provided by volunteers. At minimum wage, it was worth \$6,440.00 to the project.

TECHNICAL PAPERS

The project has started a series of numbered technical reports which are published separate from this annual progress report. Additionally, several papers are generally published each year which appear in other reference sources. Abstracts of these reports and papers which were completed during the current year are reported in this section.

Gresswell, R.E. In Press. Special regulations as a fishery management tool in Yellowstone National Park. Proceedings of the second Science in the Parks Conference, July 1986.

Given National Park Service policy and increasing angler use, restrictive angling regulations have become the most successful method of accomplishing fishery management objectives in Yellowstone National Park. Species and habitat differences greatly affect results of these regulations. Vulnerable native species such as cutthroat trout *Salmo clarki* and grayling *Thymallus arcticus* have responded positively to catch-and-release-only (no-kill) regulations in all cases. A 330-mm maximum-size limit has also worked well for cutthroat trout in Yellowstone Lake, but the same regulation failed on Riddle Lake where population structure and habitat were significantly different. Although restrictive regulations have improved population structure for brown trout *Salmo trutta*, landing rates have remained low. Brown trout apparently have an extremely low catchability where secure habitat is abundant. Brook trout *Salvelinus fontinalis* seem to be limited by nutrient-poor conditions in most park waters, but the use of a maximum-size limit has been proposed to protect populations inhabiting waters which produce large individuals.

Gresswell, R.E. In Press. Response of Yellowstone Lake cutthroat trout to a 330-mm maximum-size limit: 12 years of success. In R.A. Barnhart and T.D. Rollofs, editors. Catch-and-release fishing; a decade of experience. Humboldt State University, Arcata, California.

As angler use and effort increased on Yellowstone Lake, periodic creel limit reductions between the 1880s and 1960s failed to protect the structure of the cutthroat trout *Salmo clarki bouvieri* population. A 356-mm minimum-size restriction imposed in 1970 initially helped to curb overharvest which occurred during the 1950s and 1960s, but decreases in the proportion of older and larger trout negated positive changes within 4 years. In 1975, a 330-mm maximum-size limit was implemented, and after 12 years, it

appears that this regulation is accomplishing the objective of restoring and maintaining trout population size and structure. Average lengths of trout landed in the fishery, of spawners in tributaries, and of mature trout in fall-set gill nets are among the greatest yet recorded.

Gresswell, R.E., editor. In Press. Ecology, status, and management of interior strains of cutthroat trout. American Fisheries Society Symposium 4.

This volume describes ecology, status, and management of interior stocks of cutthroat trout. All major interior subspecies (the Yellowstone cutthroat trout *Salmo clarki bouvieri*, westslope cutthroat trout *S. c. lewisi*, and Lahontan cutthroat trout *S. henshawi*) and four of the minor subspecies (the Bonneville cutthroat trout *S. utah*, Colorado River cutthroat trout *S. pluriticus*, the greenback cutthroat trout *S. stomias*, and the Rio Grande cutthroat trout *S. virginalis*) are discussed. Several important stocks of these subspecies including the McBride Lake cutthroat trout, Bear Lake cutthroat trout, and the Alvord cutthroat trout are also included. Additional papers cover phylogeny and classification of cutthroat trout, the history of the discovery of cutthroat trout, and the role of competition between cutthroat trout and other salmonids.

Gresswell, R.E., and J.D. Varley. In Press. Effects of a century of human influence on the cutthroat trout of Yellowstone Lake. American Fisheries Society Symposium 4.

Over the past century, human activities have had an adverse influence on the Yellowstone cutthroat trout *Salmo clarki bouvieri* of Yellowstone Lake. Direct effects have included introductions of nonnative fishes, hatchery operations, and angler harvest. It appears that hatchery operations and angler harvest have been the most deleterious. Three of four nonnative fishes introduced to the system apparently filled empty niches in the lake ecosystem, and there is no evidence of direct competition between these introduced nongame fishes and native Yellowstone cutthroat trout. Potential competition from introduced nonnative brook trout *Salvelinus fontinalis* was thwarted by chemical removal of this species from Arnica Creek, a tributary to Yellowstone Lake. Although egg-taking and hatchery operations were terminated over 30 years ago, it is now apparent that egg removal, genetic mixing, and greatly reduced natural spawner escapement led to a gradual reduction in reproductive potential and undermined the complex mosaic of reproduction and recruitment. Angler harvest had a negative impact as it became excessive. During the past decade, increasingly restrictive regulations

have helped to restore population numbers and age structure. Current policies prohibit exotic species introductions, emphasize natural wild stocks, and restrict angler harvests; these policies are products of continued effort to manage Yellowstone Lake as an ecological unit.

Jones, R.D. In Press. The Yellowstone experience; a decade of catch-and-release. In R.A. Barnhart and T.D. Rollofs, editors. Catch-and-release fishing: a decade of experience. Humboldt State University, Arcata, California.

Catch-and-release regulations have been a part of the Yellowstone National Park angling scene for over a decade and have been the most successful method of accomplishing fishery management objectives. In most cases they have permitted substantial increases in landing rates and average size of fish landed. These changes have occurred with increasing angler use and effort. Catch-and-release regulations usually improve the population structure and permit the population to more nearly reflect a natural state or what you would have in the absence of angling. This is especially important in a natural area of the National Park system, where fisheries are managed as an integral part of the ecosystem. In Yellowstone National Park, first priority for fishery use is to maintain natural reproduction with sufficient numbers to maintain genetic diversity, and supply food for other wildlife in the system such as eagles, ospreys, otters, and grizzly bears. This management approach also provides robust fish populations and a quality angling experience. Species and habitat differences can also greatly affect the success or failure of these regulations.

Jones, R.D., and L.D. Lentsch. In Press. Yellowstone National Park's maintenance of genetic diversity among native and nonnative salmonids. Proceedings of the second Science in the Parks Conference, July 1986.

This paper describes selected species of salmonids, including several unique strains, in Yellowstone National Park and discusses their cultural, scientific, and management values. Salmonids native to the park include the Montana grayling *Thymallus arcticus*, mountain whitefish *Prosopium williamsoni*, and two subspecies comprising four strains of cutthroat trout *Salmo clarki*. Approximately 40% of the waters were fishless when the park was established in 1872. Four nonnative species (brown trout *Salmo trutta*, rainbow trout *S. gairdneri*, brook trout *Salvelinus fontinalis*, and lake trout *Salvelinus namaycush*) were subsequently introduced into fishless waters, and in many cases, into waters harboring indigenous populations. For

nearly a century, park managers have protected distinctive ecotypes of salmonids, including both native and nonnative species. This has produced many tangible benefits including (1) maintenance of genetic diversity in unique salmonid stocks, (2) recovery of depressed trout populations both inside and outside of the park, and (3) enhancement of sport fishing opportunities in Yellowstone National Park and elsewhere throughout the western United States. The present goals of the fishery management in Yellowstone National Park are to manage fish populations and their habitats as functioning components of the greater Yellowstone ecosystem, and preserve and restore native species and aquatic habitats.

Mahony, D.L. 1987. Aquatic resource inventory and fisheries habitat assessment in Reese Creek, Yellowstone National Park. Aquatic Ecology Technical Report Number 3, U.S. Fish and Wildlife Service, Yellowstone National Park, Wyoming.

Reese Creek is the only stream in Yellowstone National Park that is periodically dewatered by private landowners for irrigation purposes. To investigate potential impacts of dewatering on fish habitat and trout spawning, an aquatic resource inventory and habitat assessment were conducted on Reese Creek from May through August 1986. Weekly electrofishing surveys were used to determine whether a spawning migration of trout from the Yellowstone River was occurring in Reese Creek. Natural and diverted streamflows were monitored throughout the study period.

With the exception of the portion of Reese Creek subject to dewatering, fisheries habitat was rated as moderately high quality. Cutthroat trout *Salmo clarki*, rainbow trout *Salmo gairdneri*, and rainbow trout x cutthroat trout hybrids of Yellowstone River origin spawned in Reese Creek from late May through mid-July 1986. Brown trout *Salmo trutta*, brook trout *Salvelinus fontinalis*, and mottled sculpin *Cottus bairdi* were also captured.

Major dewatering of Reese Creek coincided with the spawning migration, and as much as 91% of the streamflow was diverted during the spawning run. Reese Creek was totally dewatered 2 weeks after the peak migration. As a result of dewatering, successful incubation, hatching, emergence from gravel, and rearing of trout fry in Reese Creek, as well as emigration of fry to the Yellowstone River appears to be negligible. Since there are only a limited number of spawning tributaries in the upper Yellowstone River, it is concluded that streamflow withdrawals in Reese Creek may have a negative impact on the Yellowstone River trout fishery.

Mohrman, J., R. Ewing, and D. Carty. 1988. Sources and quantities of suspended sediment and turbidity in the Yellowstone River and selected tributary watersheds between Yellowstone Lake outlet, Yellowstone National Park, Wyoming, and Livingston, Montana: 1986 annual progress report. Aquatic Ecology Technical Report Number 4, U.S. Fish and Wildlife Service, Yellowstone National Park, Wyoming.

This study was initiated in 1985 to investigate sources and quantities of suspended sediment and turbidity in the Yellowstone River drainage from Yellowstone Lake outlet, Yellowstone National Park, Wyoming, downstream to Livingston, Montana. Data collected during the 2 years of the study related to precipitation, streamflow, suspended sediment, turbidity, and sediment yield. This report discusses data collected in 1986. During the 1986 water year, annual precipitation in the study area averaged 22.2 in, nearly 5.0 in more than in 1985 and 2.5 in greater than the 1951-1980 average. Since 1982, precipitation during the winter (October-March) and snowmelt (April-June) seasons has fluctuated around the 1951-1980 average; however, above-normal precipitation has occurred each summer (July-September). In 1986, highest levels of streamflow, suspended sediment, turbidity, and sediment yield in the Yellowstone River mainstem occurred during the snowmelt period. In summer, periods of relatively high sediment input and turbidity were associated with rain events. The Lamar River drainage was the tributary watershed that had the most influence on the streamflow, suspended sediment, and turbidity of the Yellowstone River. The Gardner River system also substantially affected amounts of suspended sediment and turbidity in the Yellowstone River during snowmelt and rain events in summer. Major point sources of sediment production were found in the Grand Canyon of the Yellowstone River, Soda Butte Creek near the Northeast Entrance to Yellowstone National Park, and the Mount Everts area of the Gardner River.

Varley, J.D., and R.E. Gresswell. In Press. Ecology, status, and management of the Yellowstone cutthroat trout. American Fisheries Society Symposium 4.

The Yellowstone cutthroat trout *Salmo clarki bouvieri* is the most abundant and widely dispersed subspecies of inland cutthroat trout. The historic range of the subspecies included the Yellowstone River drainage in Montana and Wyoming and portions of the Snake River drainage in Wyoming, Idaho, Nevada, Utah, and perhaps Washington. Introductions of nonnative fishes, environmental degradation, and human exploitation have severely reduced this range. The subspecies is estimated to presently exist

in a genetically pure form in about 85% of the historic lake habitat but only about 10% of the estimated original stream range. Additionally, Yellowstone cutthroat trout populations have been established outside the historic range in at least seven western states and two Canadian provinces. High landing rates and angler success, coupled with relatively large mean length make the Yellowstone cutthroat trout a valuable recreational resource; however, vulnerability to angling has often led to overharvest of wild stocks. Current management of the Yellowstone subspecies includes wild trout programs for native and introduced populations and fisheries supported by maintenance stocking from hatchery broodstocks. Genetic integrity, habitat management, and special angling regulations are important elements that influence the success of these programs. The status of the Yellowstone cutthroat trout is encouraging, but future management must emphasize protection of the full range of genetic diversity.

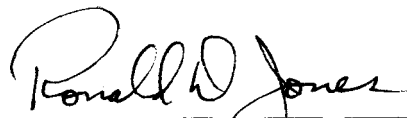
ACKNOWLEDGMENTS

Our sincere thanks to those who assisted the project during the past year. Glenn Boltz and Karl Biastoch were critical to our summer field program as paid seasonals; Glenn returned in the winter to "age fish scales" and prepare figures for the report. Ron Thevenin and Ken Bosse (members of the Student Conservation Association program), along with Chris Jones and Mark MacKenzie (enrollees in the Youth Conservation Corps program), worked as full-time volunteers during the summer field season. Although not participating on a full-time basis, Marion Jones volunteered her time whenever possible, and Liz Colvard provided assistance on several field projects. During the winter, Liz transferred large amounts of data from our old to our new computer system and assisted in the preparation of study area figures for this report. Crystal Hudson, who from 1982 to July 1988 was the project administrative assistant and a valuable member of the field crew, is now at Leadville National Fish Hatchery, Colorado. We wish her well in her continuing career with the U.S. Fish and Wildlife Service. Our current administrative assistant is Karrie West, who has worked for the project for 8 years. Karrie's responsibilities include data entry and overseeing the production of this report; her efficiency and patience are deeply appreciated. Kim West converted VAR cards into data on computer tapes, filled in for Karrie as administrative assistant in March, April, and May, and assisted extensively with the preparation of this report, and Emily Anderson provided valuable and timely "emergency" assistance with the preparation of this report. Kim's and Emily's skills and patience are also deeply appreciated. Jack Brooks and Wade Miller returned for the annual fall gillnetting; Wade helped with the nets, and Jack prepared gourmet meals for the crew. Dale Bast from the Jackson National Fish Hatchery and John Gravning from the Ennis National Fish Hatchery were also valuable members of the fall gillnetting crew. Dr. George Roemhild identified macroinvertebrates, and personnel from the Jackson National Fish Hatchery expedited lake trout sampling at Lewis Lake.

The National Park Service (NPS) also provided manpower and assistance in 1987. Reese Creek streamflows were monitored by Craig McClure, Therese Johnson, Jeff Henry, Laurie Williams, John Donaldson, and others. Doug Ridley, Collette Daigle-Berg, and Lynn Wadkins facilitated the collection of cutthroat trout spawning survey data at Grant Village. Other NPS personnel conducted angler surveys at the entrance gate to Yellowstone National Park and also assisted in visitor counts at Fishing Bridge and LeHardy Rapids. Treisa Pierce calculated drainage basin characteristics and assisted in the preparation of study area figures for this report.

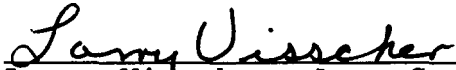
Again, we appreciate the help of all of those above and also those who contributed but have not specifically been mentioned.

This report was submitted by:



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APPENDIX

APPENDIX TABLE 1.-Gillnet catches of cutthroat trout by site, Yellowstone Lake, 1969-1972, 1974, 1976-1980, and 1982-1987^a.

	Number per net ^b											Total
	1a	1b	1c	2a	2b	3a	3b	4a	4b	6c	7c	
1969	3	19	5	17	5	c	c	3	28	14	16	110
1970	10	18	10	11	15	20	9	2	32	7	1	135
1971	15	5	23	21	8	c	c	c	c	c	c	72
1972	15	13	21	16	12	17	3	9	19	8	17	150
1974	11	12	25	21	26	6	12	19	12	6	20	170
1976	19	9	22	11	21	19	15	13	10	12	14	165
1977	10	23	15	16	21	19	12	7	15	12	22	682
1978	14	9	15	10	17	16	14	15	18	13	13	766
1979	12	18	12	10	9	19	12	16	18	12	10	748
1980	7	21	17	6	14	12	12	13	18	15	9	715
1982	12	10	9	8	11	11	11	8	12	10	12	582
1983	23	18	24	16	22	22	13	18	14	14	13	993
1984	25	165	23	16	32	17	20	14	15	16	21	1053
1985	14	15	19	1	13	23	13	23	12	16	9	784
1986	14	26	23	9	20	18	7	15	24	13	15	921
1987	14	20	20	14	17	19	17	14	29	24	15	1017

	Average total length (mm)											Average
	1a	1b	1c	2a	2b	3a	3b	4a	4b	6c	7c	
1969	277	293	322	328	378	c	c	360	290	341	300	311
1970	290	308	327	365	279	352	352	352	280	364	224	315
1971	291	363	306	326	379	c	c	c	c	c	c	321
1972	297	293	262	329	321	296	368	358	334	349	329	313
1974	249	330	304	300	266	284	311	290	301	348	324	298
1976	315	322	306	337	291	302	324	331	324	330	337	317
1977	301	261	305	290	286	265	341	283	269	344	292	290
1978	286	327	281	313	298	293	319	286	302	342	365	308
1979	276	281	312	322	306	280	306	288	294	374	335	303
1980	279	302	310	344	309	308	341	268	286	339	345	309
1982	276	280	342	345	306	274	356	324	358	362	327	322
1983	256	276	263	297	290	249	328	276	324	353	323	288
1984	263	317	298	271	239	259	306	282	325	307	271	281
1985	297	296	323	327	297	275	353	274	331	362	355	311
1986	288	268	328	317	260	291	327	274	265	338	328	293
1987	294	303	320	329	297	309	322	320	276	292	334	306

	Average weight (g)											Average
	1a	1b	1c	2a	2b	3a	3b	4a	4b	6c	7c	
1969	213	272	317	359	527	c	c	411	261	403	249	312
1970	311	279	348	450	223	382	390	320	349	488	108	320
1971	249	363	267	318	452	c	c	c	c	c	c	305
1972	269	276	231	350	352	262	410	405	358	459	349	320
1974	167	341	267	269	200	253	290	265	285	361	309	266
1976	322	337	280	363	267	285	322	331	306	353	358	314
1977	273	214	292	268	258	219	399	256	215	430	270	271
1978	254	360	235	336	292	283	337	260	290	415	497	316
1979	222	245	316	339	300	239	304	255	280	517	400	301
1980	357	302	316	418	314	309	410	217	255	430	414	329
1982	233	240	403	406	319	239	470	369	455	471	360	359
1983	188	226	216	294	272	168	375	248	347	455	378	271
1984	199	399	250	244	165	191	318	250	354	375	227	259
1985	281	280	344	343	279	234	470	237	365	524	458	332
1986	242	208	354	313	194	265	365	220	207	414	391	274
1987	253	284	319	358	267	302	339	342	228	293	400	301

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

^b From 1969-1974, only 1 set was made in each area at the specified depth interval; for 1977, the number represents an average of 4 sets, and 1978-1986 represents an average of 5 sets.

^c Areas not sampled.

APPENDIX TABLE 2.-Gillnet catches of cutthroat trout by general area, Yellowstone Lake, 1969-1972, 1974, 1976-1980, and 1982-1987^a.

Year	Number/net				Average total length (mm)				Percentage under 210 mm				Total
	North	Central	W. Thumb	South	North	Central	W. Thumb	South	North	Central	W. Thumb	South	
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
1983	21	18	16	14	275	278	297	339	26.4	21.6	13.7	8.0	20.9
1984	22	19	15	18	272	286	304	286	30.3	18.0	12.4	24.2	24.8
1985	12	18	17	12	305	303	294	360	11.3	20.8	16.4	5.7	13.7
1986	18	13	20	14	289	301	268	332	22.4	19.8	27.0	12.1	21.5
1987	17	18	22	20	309	315	290	308	7.8	6.1	21.8	15.2	11.9
Averages	15	15	16	14	293	302	293	329	18.8	15.7	16.2	10.5	16.4

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