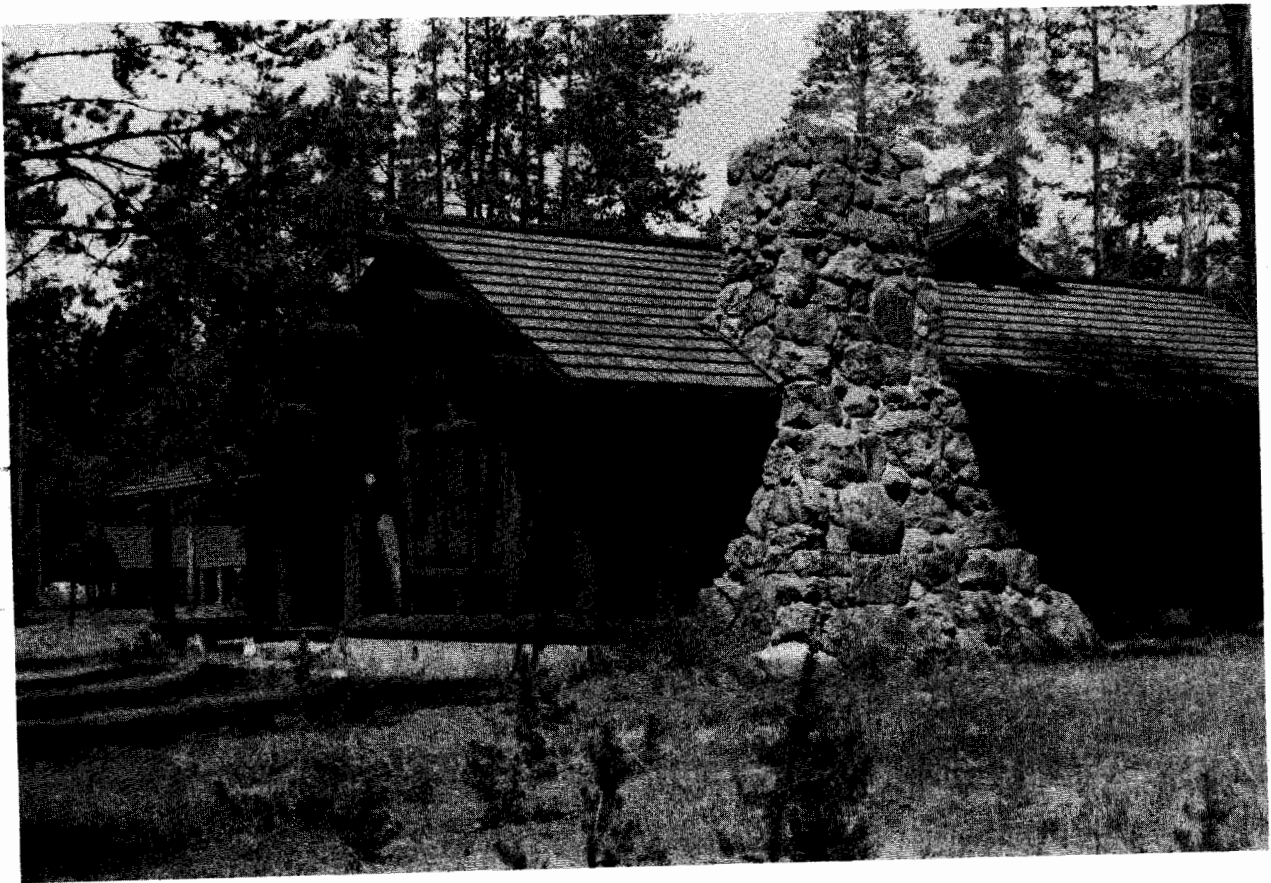


UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
Fishery Resources



FISHERY AND AQUATIC MANAGEMENT PROGRAM
in
YELLOWSTONE NATIONAL PARK
Technical Report for Calendar Year 1988
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Fishery and Aquatic Management Program

Yellowstone National Park

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Cover photo: Hatchery complex, Lake area, Yellowstone National Park, 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 890,000 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 area 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 and 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 or 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/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/trip.

Multiplying \$210 times the 293,800 fishing trips that took place in Yellowstone National Park in 1988 results in a resource value of \$61,698,000 for the Park fishing program in 1988. 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 1988.

Effects of the 1988 Fires

In 1988, Yellowstone National Park suffered the worst drought in recorded history which produced the lowest streamflows on record. No rain fell from late June through September, and record high winds whipped the Park. Nearly 45% of the 890,000 hectares in Yellowstone National Park were affected by fire. Looking down on the Park from a

plane you see a mosaic pattern of burned and unburned areas. Within each burned area, fire intensity varied from light to severe.

Fire activity may have caused some changes in the aquatic systems which will cause some deviation from what we have seen in the recent past. Should these be called detrimental impacts? Perhaps deviations from the short-term norm would be a better description. We will see muddy water, and in some cases, black water carrying tons of sediment down the streams. Stream channels will change; gravel bars will fill in here, and banks will wash out there. Spawning areas will be buried and new, clean gravel will be deposited. Cutthroat trout eggs will be swept away by the current or buried by silt, others will develop normally in the clean gravel. These processes normally occur every year. The degree of change has already been reduced by the lack of precipitation in the fall. Future change will be determined by weather patterns. U.S. Geological Survey predicts a minor increase in runoff for the Yellowstone River drainage because of fires in the watershed, but the increase should not play a major role in spring runoff. If snowmelt is gradual, impacts will be less than if snowmelt occurs rapidly.

The potential for the greatest changes to take place are in the first- to fourth-order streams in the Lamar River drainage, especially Cache Creek.

Over the next few years, fish populations in small, high-gradient streams in severely-burned areas may decline in response to decreases in habitat quality and food supply. In contrast, fish populations in larger streams that flow through moderately burned or unburned areas may be unaffected or even increase as nutrients flushed into the system raise productivity. Within 5 years or so, many small and large streams will in fact become more productive than they have been in the recent past. It is doubtful that measurable changes in fish populations will occur in the major fisheries (Yellowstone, Madison, Firehole, or Gibbon rivers).

Things will be different than they were the previous year, they always are. It is a matter of where you are coming from, whether the fires made things better or worse. But from a biological, or especially a geological perspective, the fires represent a small bump on the scale.

The drought has caused the fisheries some problems including low streamflows which stranded a few spawning fish in the spawning streams and greatly reduced habitat during the late summer and winter. Some fish mortality did occur as a result of the fires and/or fire suppression. A few hundred fish were killed as a result of slurry drops in the Little Firehole River, Fan Creek, and a few other places. Some mortalities appear to have been caused by short-term chemical changes from the fires, especially in Cache Creek and a few other small headwater streams.

This winter's low temperatures coupled with record low streamflows may increase winter mortality rates to some degree, especially in the smaller streams. This will probably cause greater change in the fishery than the fires. The environmental changes mentioned will affect the smaller streams more than the larger ones and for a longer period of time.

We really do not expect changes in the major fisheries significant enough to affect fishing regulations or angling success in 1989.

PARKWIDE ANGLING

Yellowstone National Park recreational visitation (2.2 million visitors) decreased (15.2% less than 1987) in 1988, and issuance of non-fee fishing permits decreased 9.9% (Table 1). Approximately 165,700 permits were issued; however, gate survey data indicated that 20.4% of the permit holders did not fish. After adjustments were made for nonanglers, the number of Park anglers was estimated at 134,600. This represents a 11.2% decrease in the number of anglers since 1987.

The exit gate survey indicated that anglers spent an average 1.85 d fishing in the Park and fished approximately 1.18 waters/d. Estimates of total use (293,800 angler days) and effort (753,400 angler hours) were calculated using the method of Jones et al. (1977). Both figures are below mean estimates for total use and effort since 1976 (314,700 angler days and 758,500 angler hours, respectively).

The Volunteer Angler Report (VAR) system estimated that 788,100 fish were landed and 65,300 creeled at a rate of 1.05 and 0.09 fish/h, respectively (Table 2). Of the fish landed, 92% were released and 8% creeled. The number of fish landed per average angler trip (2.56 h) was 2.68, and the number creeled per average angler trip was 0.22 (Table 3).

Species composition was indicated by anglers for 41,625 landed fish; 72.4% were reported to be cutthroat trout *Oncorhynchus clarki*, followed by rainbow trout *Oncorhynchus mykiss* (9.9%), brown trout *Salmo trutta* (6.6%), brook trout *Salvelinus fontinalis* (6.0%), and mountain whitefish *Prosopium williamsoni* (3.5%). Small numbers of lake trout *Salvelinus namaychus*, arctic grayling *Thymallus arcticus*, and unidentified fish were also caught.

Average size of landed fish (326 mm or 12.8 in) increased from 1987. Of 39,784 fish, about 64% were greater than 305 mm (12 in), and 45% exceeded 356 mm (14 in). Average length of creeled fish was 305 mm (12.0 in). Lake trout were the largest fish landed (454 mm or 17.9 in), followed by cutthroat trout (345 mm or 13.4 in), mountain whitefish (323 mm or 12.7 in), unknown species (300 mm or 11.8 in), brown trout (297 mm or 11.7 in), arctic grayling (280 mm or 11.0 in), rainbow trout (276 mm or 10.9 in), and brook trout (179 mm or 7.0 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,

TABLE 1.-Estimates of Park recreational visitation, fishing permits issued, total parkwide anglers, and total parkwide angler days, Yellowstone National Park, 1973-1988.

Year	Total Park recreational visitation	Park fishing permits issued	Total parkwide anglers	Total parkwide angler days	95% confidence limits
1973	2,061,537	169,103	121,888	230,100	225,500-234,700
1974	1,928,915	164,600	116,518	220,000	215,500-224,300
1975	2,239,483	191,550	136,322	257,300	248,400-266,300
1976	2,519,224	213,200	151,730	284,200	278,500-298,900
1977	2,481,933	217,000	154,581	311,300	304,000-318,500
1978	2,618,380	218,000	155,700	333,800	326,200-341,300
1979	1,892,908	195,100	139,100	291,300	274,500-308,200
1980	2,000,273	184,200 ^a	130,800	311,300	287,000-334,600
1981	2,521,831	172,300	160,000	383,400	363,400-403,300
1982	2,368,897	205,000	152,000	332,500	314,700-350,300
1983	2,347,242	166,800	120,500	275,900	261,800-289,900
1984	2,222,027	176,800	135,000	329,200	305,400-341,000
1985	2,226,159	166,700	123,800	279,000	260,800-297,200
1986	2,363,756	163,300	124,900	294,800	269,300-320,400
1987	2,573,194	183,900	151,500	370,900	349,062-392,804
1988	2,182,133	165,700	134,600	293,800	272,716-314,917

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

TABLE 2.-Angler use, effort, success, and harvest for Yellowstone National Park, 1973-1988.

Year	Angler days	x length angler day	Total hours fished	Landing rate	Total fish landed	Creel rate	Total fish creeled	% of anglers Overall experience	satisfied Numbers caught	with Sizes caught	Average	
											length of landed fish (in.)	Mean expertise level ^a
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	917,800	0.94	865,900	0.07	61,600	73	64	66	12.3	1.93
1988	293,835	2.56	753,400	1.05	788,100	0.09	65,300	78	69	70	12.8	1.90

^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, 1988.

	Mean number		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)		Number of anglers sampled
	days fishing	number		rate	per day	rate	per day	per angler day	per angler day	per angler day	per angler day	length fish landed (in)	Average ^a expertise	
Satisfied anglers			2.72	1.19		0.01		3.24		0.27		13.08	0.81	3,071
Unsatisfied anglers			2.32	0.54		0.04		1.25		0.09		10.67	1.82	1,169 ^b
sum or x	1.66		2.56	1.05		0.09		2.69		0.23		12.85	1.90	4,917 ^b
Inexperienced anglers	1.48		2.22	0.70		0.11		1.55		0.24		13.04	1.00	1,065
Experienced anglers	1.70		2.57	1.04		0.09		2.67		0.23		12.76	2.00	3,148
Expert anglers	1.73		3.11	1.41		0.05		4.39		0.16		13.09	3.00	588 ^b
sum or x	1.66		2.56	1.05		0.09		2.69		0.23		12.85	1.90	4,917 ^b

Satisfaction Matrix									
	Satisfied Anglers				Unsatisfied Anglers				
	Overall satisfaction		Satisfaction with numbers landed		Satisfaction with sizes landed		Overall satisfaction		Satisfaction with sizes landed
Landing rate (fish/h)									
Inexperienced anglers	0.76		0.65		0.67		0.24		0.33
Experienced anglers	0.77		0.68		0.71		0.23		0.29
Expert anglers	0.85		0.78		0.75		0.15		0.25
Creel rate (fish/h)									
Inexperienced anglers	0.13		0.14		0.13		0.03		0.06
Experienced anglers	0.10		0.10		0.10		0.03		0.05
Expert anglers	0.06		0.06		0.06		0.03		0.04
Fish size (in)									
Inexperienced anglers	13.09		13.10		13.36		11.12		11.64
Experienced anglers	12.87		12.78		13.39		10.88		9.11
Expert anglers	13.21		13.15		13.51		10.85		10.63

^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.

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.

The percentage of anglers that reported satisfaction with their overall fishing experience was 78% in 1988. Satisfaction rates with numbers and sizes of fish landed were 69% and 70%, respectively (Table 3). Anglers indicating satisfaction with their fishing trip landed 3.2 fish, but unsatisfied anglers landed only 1.2 fish. Average length of fish landed was also higher for satisfied anglers (333 mm or 13.1 in) than for unsatisfied anglers (272 mm or 10.7 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 1988, mean expertise for 4,801 Park anglers was 1.90, 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, Bechler River, Firehole River, Gardner River, Lamar River, Slough Creek, and Soda Butte Creek were completed in 1988. Although it was not possible to expand these analyses to additional waters, data for 16 lakes and streams that made up over 94% of the total Park angler use are given in tabular form (Table 4).

TABLE 4.-Fishery statistics from Yellowstone National Park waters with over 40 angler days in the sample and which comprise over 94% of the parkwide angler day use in 1988.

	Total reported angler days (VAR)	% of total parkwide angler days	Estimates for the season										x length angler day (hours)	x length fish landed (inches)	x length fish creeled (inches)	# anglers landing 1 or more fish	# anglers satisfied with:		
			Anglers	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	
Parkwide fishery	8,138	100.00	134,593	2.56	293,835	733,390	1.05	0.09	788,083	65,340	12.85	12.00	70	1.90	78	69	70		
Yellowstone Lake	43.11	3,508	49,052	2.61	126,658	330,271	1.07	0.15	353,358	48,765	14.66	12.37	73	1.76	81	72	80		
Yellowstone River	16.40	1,335	21,543	2.76	48,170	132,982	1.00	0.02	133,306	2,543	14.07	13.22	71	2.02	83	76	85		
Madison River	8.84	719	11,278	2.72	25,943	70,526	0.68	0.02	46,323	1,592	13.67	12.64	52	1.95	62	48	53		
Gibbon River	4.44	361	7,528	1.92	13,015	25,034	0.95	0.09	23,796	2,300	8.21	8.24	63	1.96	68	59	44		
Firehole River	4.04	329	6,816	2.38	11,860	28,238	0.73	0.02	20,686	688	9.83	8.78	56	2.00	61	51	43		
Slough Creek	3.44	280	5,310	2.88	10,090	29,012	1.30	0.01	37,655	342	11.99	--	84	2.02	85	77	81		
Lamar River	2.95	240	5,064	2.54	8,646	21,945	1.21	0.03	26,599	670	11.02	11.10	83	2.04	83	72	67		
Gardner River	2.36	192	4,133	2.01	6,912	13,881	1.47	0.19	20,768	2,677	7.97	8.98	84	2.04	83	75	61		
Lewis Lake	1.94	158	2,956	3.22	5,684	18,284	0.56	0.14	10,266	2,598	15.42	14.89	56	1.94	65	53	56		
Gallatin River	1.78	145	2,436	2.37	5,215	12,374	1.22	0.05	15,115	560	11.78	11.19	81	2.00	82	73	77		
Soda Butte Creek	1.44	117	2,026	2.07	4,204	8,693	2.03	0.06	17,601	522	9.17	13.48	75	1.94	78	72	57		
Shoshone Lake	0.87	71	903	3.65	2,543	9,283	0.83	0.13	7,670	1,163	18.44	18.21	62	1.79	68	58	84		
Lewis River	0.64	52	1,204	2.11	1,857	3,908	1.11	0.06	4,342	244	7.74	9.80	56	1.91	58	56	36		
Bechler River	0.63	51	1,013	2.48	1,821	4,508	1.50	0.01	6,749	53	9.48	--	81	2.30	65	68	47		
Indian Creek	0.59	47	1,040	1.74	1,676	2,924	1.01	0.37	2,948	1,091	6.50	7.42	65	1.68	76	59	41		
Trout Lake	0.57	46	1,068	2.13	1,640	3,500	0.58	0.15	2,026	516	13.09	14.89	75	1.90	95	68	78		

YELLOWSTONE LAKE

Yellowstone Lake supports the largest inland cutthroat trout *Oncorhynchus clarki bouvieri* 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 (three-fish creel) restriction imposed in 1970 helped curb the overfishing that 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 1988, 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 1988, angler use on Yellowstone Lake was 43% of the total parkwide angler use. An estimated 49,052 anglers spent 126,658 angler days and 330,271 angler hours fishing in the lake (Table 4). Use and effort estimates were below the 14-year average from 1975 through 1988 (138,990 angler days and 338,311 angler hours, respectively) and represent 2% and 0.2% decreases, respectively, from 1987 (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 shoreline. The central and southern areas (Figure 2) sustained the lowest proportion of use (Table 5). Success

TABLE 5.-Fishing statistics from Yellowstone Lake, 1988.

Yellowstone Lake area:	% of lake total	Predicted totals for season										% anglers satisfied with:				Mean expertise
		VFR use reported	Anglers	x length angler day (hours)	Angler days (trips)	Angler hours	Landing rate	Creel rate	Total fish		Overall experience	Fish numbers	Fish sizes			
									landed	creeled						
1 Shore	3.42	120	1,889	1.81	4,312	7,824	0.73	0.10	5,721	784	82	72	75	1.80		
Boat	1.51	53	465	3.17	1,893	6,000	1.08	0.28	6,480	1,701	88	81	88	1.71		
2 Shore	22.75	798	11,935	1.96	28,796	56,554	0.75	0.10	42,477	5,639	67	58	68	1.71		
Boat	21.61	758	10,894	3.09	27,351	84,490	1.19	0.18	100,894	15,107	89	77	85	1.74		
3 Shore	10.52	369	3,613	2.13	13,304	28,358	1.79	0.16	33,418	4,552	88	81	84	1.77		
Boat	1.71	60	1,150	2.55	2,146	5,480	1.30	0.22	7,105	1,180	95	90	92	1.56		
4 Shore	9.89	347	5,420	2.08	12,510	25,980	0.63	0.08	16,313	2,131	71	66	76	1.87		
Boat	5.10	179	2,026	3.34	6,443	21,515	1.46	0.21	31,472	4,498	96	82	94	1.86		
5 Shore	0.06	2	55	1.53	51	78	1.29	0.01	101	1	50	50	50	1.00		
Boat	2.22	78	1,232	3.58	2,796	10,023	1.47	0.23	14,769	2,327	93	83	95	1.75		
6 Shore	0.06	2	27	2.83	51	145	1.78	0.01	258	2	100	100	100	2.00		
Boat	1.37	48	493	4.81	1,712	8,240	1.72	0.13	14,171	1,074	88	82	82	1.83		
7 Shore	0.11	4	27	2.18	123	269	1.95	0.26	524	71	100	100	100	2.00		
Boat	1.48	52	356	4.67	1,857	8,676	1.49	0.13	12,889	1,080	85	85	92	2.15		
Unknown shore	6.19	217	3,394	2.05	7,815	16,046	0.62	0.08	9,867	1,313	65	55	69	1.81		
Unknown boat	12.00	421	6,077	3.27	15,182	49,696	1.38	0.18	68,679	9,146	92	87	89	1.73		
All shore	53.00	1,859	26,360	2.02	67,110	135,561	0.81	0.11	109,124	14,533	72	64	73	1.77		
All boat	47.00	1,649	22,692	3.27	59,527	194,653	1.32	0.19	257,218	36,215	91	82	88	1.75		
Entire lake	100.00	3,508	49,052	2.61	126,658	330,271	1.07	0.15	353,358	48,765	81	72	80	1.76		

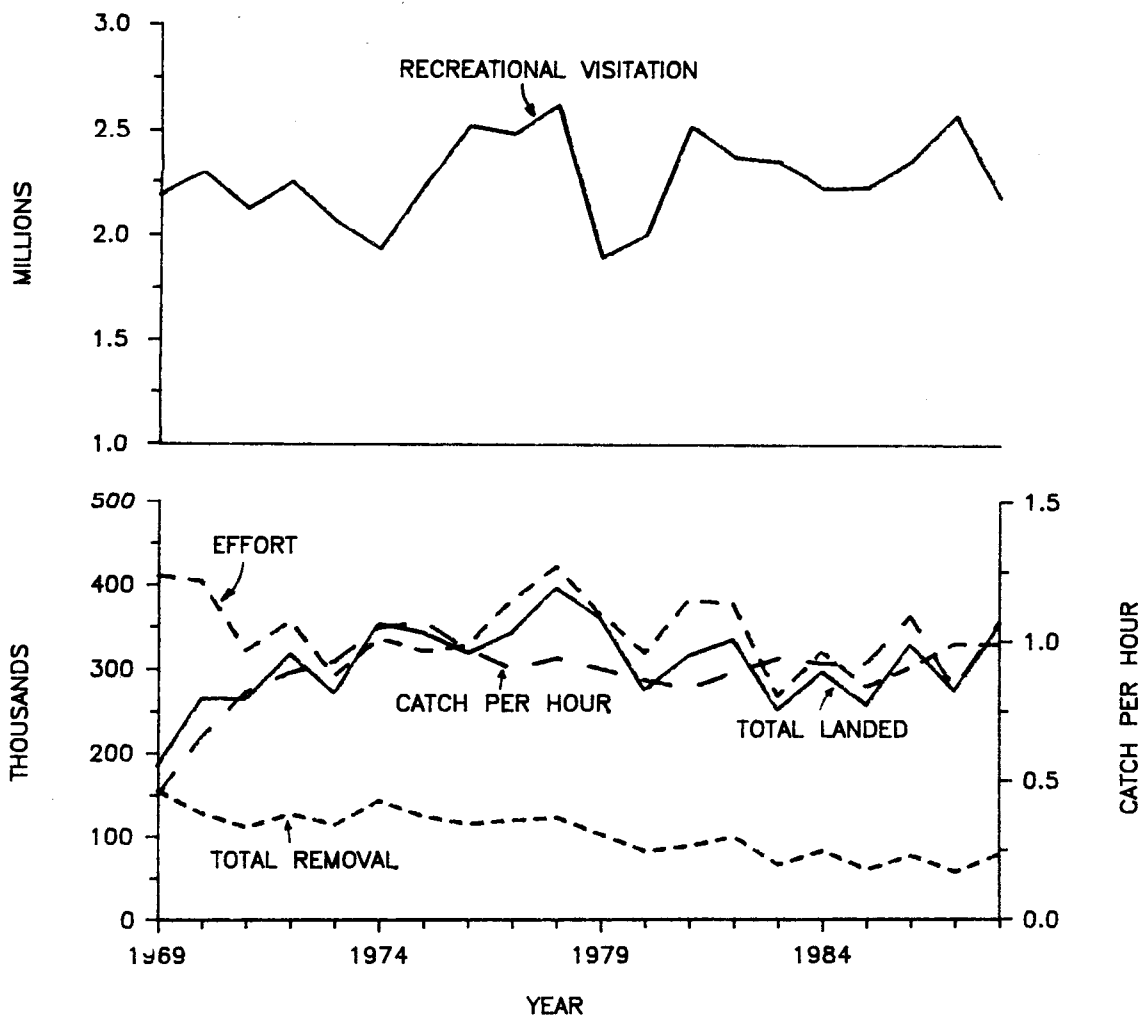


FIGURE 1.-Recreational visitation, catch per hour, total effort (hours), total trout landed, and total trout removed from Yellowstone Lake, 1969-1988.

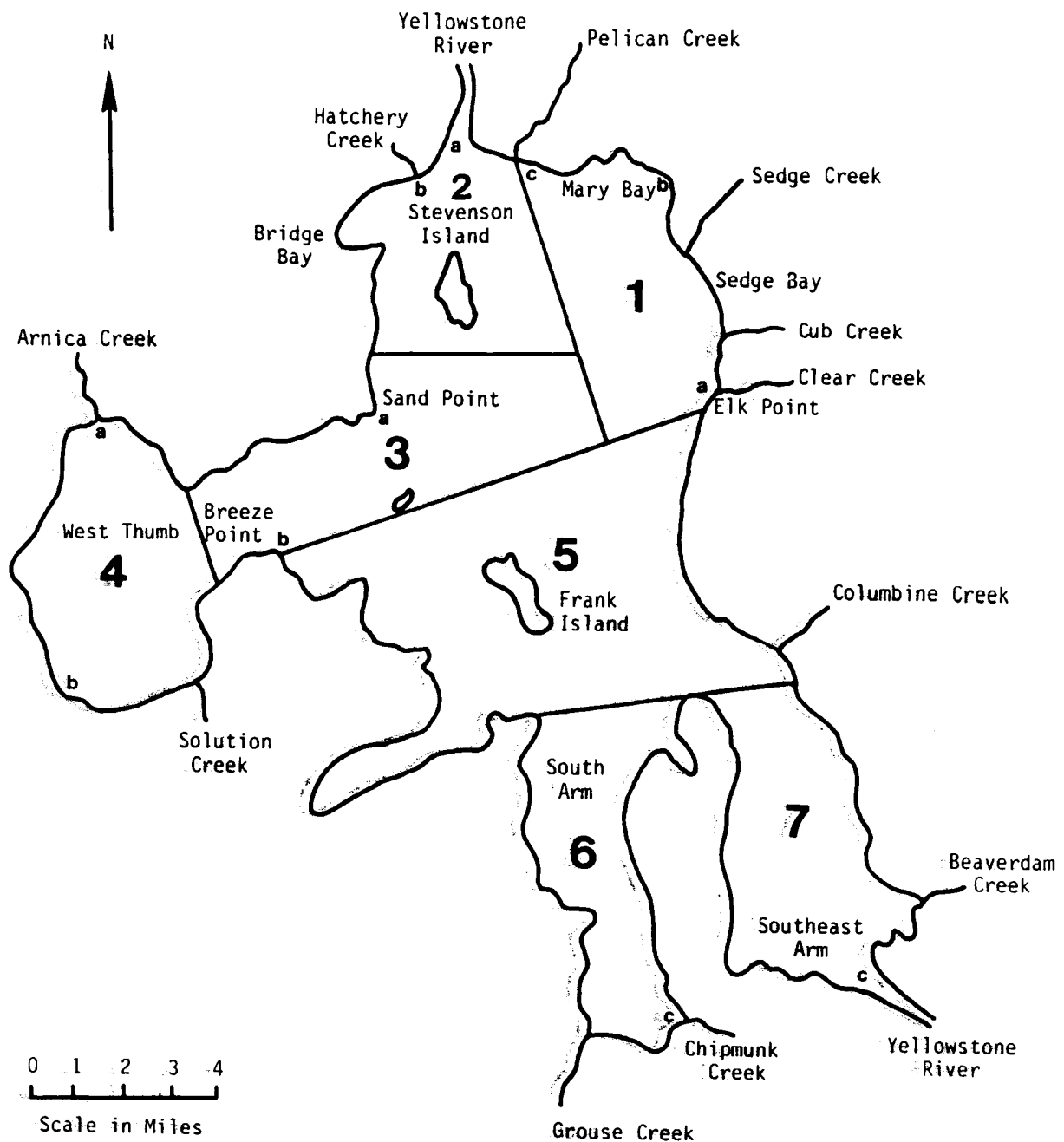


FIGURE 2.-Creel survey, gillnetting, and spawning trap sites, Yellowstone Lake, 1988.

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 353,358 trout and released 304,593. Total angler-caused mortality was estimated at 79,224 (48,265 creeled plus an estimated 30,759 that may have died of hooking wounds following release). Overall landing and creel rates were 1.07 and 0.15 trout/h, respectively. Landing and creel rates from the boat segment (1.32 and 0.19 trout/h, respectively) were significantly ($P < 0.05$) higher than those from the shoreline segment (0.81 and 0.11 trout/h, respectively) (Table 5). Seventy-three percent of one-day anglers landed one or more trout from the lake, and 29% creeled one or more.

Based on length measurements of 16,034 trout reported from Yellowstone Lake, size structure of the cutthroat trout population appears to be approaching equilibrium (Table 6). Average size of landed trout in 1988 was 372 mm. Since 1975, length frequencies have indicated survival of proportionately more fish to older and larger size groups (Table 6). The percentage of landed trout exceeding 406 mm TL (23.1%) 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 in 1987 indicated that approximately 21,100 cutthroat trout over 330 mm were harvested in that year. About 6,800 of these trout were over 335 mm (13.2 in), and 3,450 were greater than 356 mm (14 in). The latter 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 1988, the percentage of anglers satisfied with their overall angling experience on Yellowstone Lake was 81%; satisfaction responses for numbers and sizes landed were 72% and 80%, respectively (Table 5). Average expertise was 1.76.

TABLE 6.-Average length and length frequencies of cutthroat trout landed and creeled from Yellowstone Lake, 1973-1988.

		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	3.1	7.2	21.3	44.0	18.5	4.9	1.1	11,227
	1988	1.7	7.6	25.1	42.5	18.3	3.7	1.1	16,034

		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
	1988	90.7	65.5	23.1	4.8	1.1	14.7	372	12.4	314

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 14 July. Ascending trout were passed upstream using dip nets until 15 June when a counting chute (Jones et al. 1979) was mounted on the upstream side of the trap box. The trap was open from 0800 until 1900 hours daily.

The downstream trap was installed on 18 May and was removed when trapping operations ceased on 14 July. During periods of high water, downstream migrants were captured as they congregated above the weir. A counting chute was installed on the downstream trap 25 June. 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 (black bear *Ursus americanus* and grizzly bear *Ursus arctos horribilis*) 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 54,928 cutthroat trout were counted through the upstream trap. The number of migrants fluctuated during the first 22 d (18 May-8 June) varying from 7 trout/d on 30 May to 780 trout/d on 4 June (Figure 3). Almost 93% of the run (45,399 cutthroat trout) ascended from 9 to 26 June. After 4 July, the run gradually declined; an average of 22 trout/d were counted during the final 8 d (7-14 July).

Although spawning longnose suckers *Catostomus catostomus* have previously been noted near the mouth of Clear Creek and directly below the weir (Jones et al. 1984), none were observed in 1988. Young-of-the-year cutthroat trout were first observed near the weir on 2 July.

During the downstream migration in 1979, the adipose fin was removed from 42,229 cutthroat trout at Clear Creek (Jones et al. 1980). In 1988, 4,244 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; these fish would be at least 11 years old in 1988.

Mean daily water temperature generally increased throughout the season and ranged from 3.3°C (18 May) to 16.1°C (8 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 393 mm (N = 4,243) and 558 g (N = 859), respectively, and the average condition factor (K) was 0.90. The male:female ratio was 0.68:1. Average total length of males (401 mm) was significantly (P < 0.05) greater than females (389 mm). The weekly average length of all trout decreased as the spawning migration progressed (Table 7).

Downstream Migration

A total of 40,826 cutthroat trout were counted downstream at Clear Creek. During the first 31 d of operation, the lakeward migration varied from 0 trout/d (18 and 22 May) to 767 trout/d (4 June) (Figure 3). Approximately 86% of the postspawners were counted from 18 June to 12 July. An average of 134 trout/d were captured during the last 2 d of operation.

The difference between current upstream and downstream spawner counts suggests a total instream mortality of 25.7% in 1988. A total of 2,544 dead fish were collected in the trap area. This figure only accounts for 18% of the 14,102 cutthroat trout that did not migrate downstream during the

TABLE 7.-Weekly mean length, weight, and condition factor of cutthroat trout spawners in the upstream trap in Clear Creek, 17 May-14 July 1988^a.

Date	Males			Females			Totals			M:F ratio
	Mean length (mm)	N	Mean weight (g)	Mean length (mm)	N	Mean weight (g)	Mean length (mm)	N	Mean weight (g)	
17 May-23 May	426	182	776	409	294	701	415	476	733	0.62:1
24 May-30 May	408	165	643	400	293	617	402	458	627	0.56:1
31 May-6 June	402	198	582	392	275	585	396	473	583	0.72:1
7 June-13 June	396	247	539	388	379	539	391	626	539	0.65:1
14 June-20 June	396	238	532	386	377	549	390	615	542	0.63:1
21 June-27 June	395	380	556	380	345	518	387	625	535	0.81:1
28 June-4 July	395	246	521	378	379	495	385	625	505	0.65:1
5 July-11 July	395	130	502	378	156	453	386	286	481	0.83:1
12 July-14 July	390	32	461	364	27	367	378	59	418	1.19:1
Composite	401	1,718	569	389	2,525	549	393	4,243	558	0.68:1

^a Based on daily samples of cutthroat trout which were both measured and weighed.

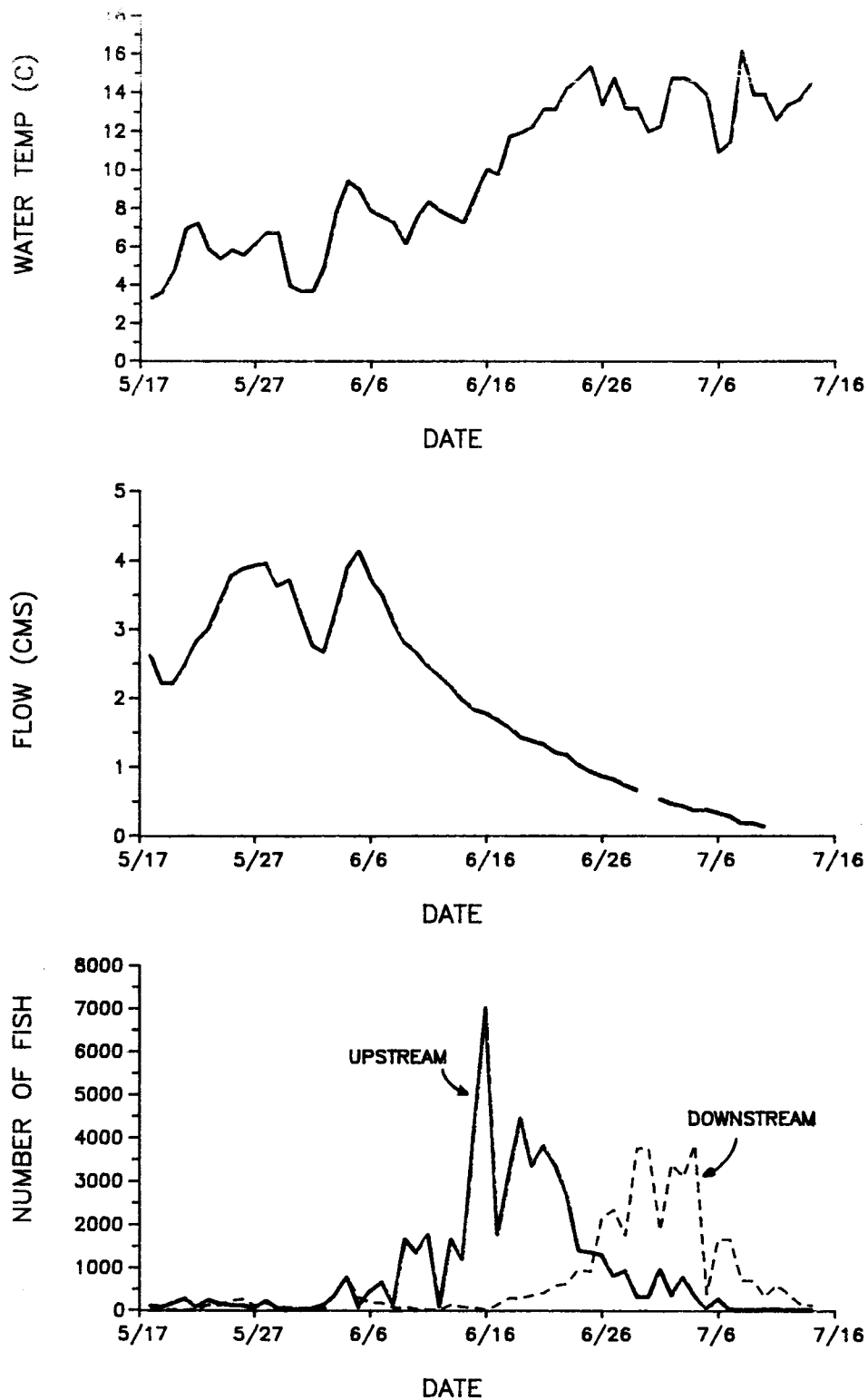


FIGURE 3.-Pattern of daily water temperature, flow, and cutthroat trout spawning migration, Clear Creek, 1988.

study period. Fish remains from predators were scant within the stream above the weir. Because the mean number of fish passing downstream during the final 7 d of the trapping period was still high (425), it appears that many of the downstream migrants were not enumerated, and thus, estimates of instream mortality were positively biased in 1988.

Average length of downstream migrants was 391 mm. The male:female ratio was 0.59:1, and males had a significantly ($P < 0.05$) greater mean total length (399 mm) than females (386 mm). There was no significant ($P > 0.05$) difference in the mean length of upstream and downstream migrants. As in the upstream migration, there were significant ($P < 0.05$) decreases in weekly average length throughout the study.

Grizzly bear sightings and signs of bear activity were frequent in 1988. It is estimated that six or seven different bears visited the weir during the period it was installed. Partially eaten fish were collected daily, and 2,429 carcasses were assumed to be the result of bear predation. This number represents 95% of the fish mortalities recovered at the trap in 1988. Other wildlife commonly associated with the spawning run at Clear Creek include family groups of mink *Mustela vison*, common loons *Gavia immer*, common mergansers *Mergus merganser*, California gulls *Larus californicus*, as well as several osprey *Pandion haliaetus*, golden eagle *Aquila chrysaetos*, bald eagle *Haliaeetus leucocephalus*, great blue heron *Ardea herodias*, and white pelicans *Pelecanus erythrorhynchos*.

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, 1988).

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 (U.S. Fish and Wildlife Service, 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.

Because virtually 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, 1985-1988), 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 1988. 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 mean length of cutthroat trout spawners at Clear Creek was noted in 1987, but Jones et al. (1988) suggested that the decline was not directly related to the integrity of the cutthroat trout population in Yellowstone Lake. They noted other indicies used to monitor population structure had not changed. Late installation of the fish trap or limited entry to other spawning streams (a resultant use of Clear Creek) may have influenced the observed results. Current results support the hypotheses that the structure of the cutthroat trout population in Yellowstone Lake has not changed significantly in recent years; however, reasons for anomaly observed in 1987 remain unexplained.

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 4). 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.

Largemesh Gillnetting

With the exception of 1973 and 1975, largemesh 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 and Mills (1970, 1971), Dean (1972), Dean and Varley (1973, 1974), Dean et al. (1975), Varley et al. (1976), and Jones et al. (1977-1987) detail methods and provide summaries of previous results.

Methods

In 1988, experimental gill nets were set from 12 to 16 September at 11 sites in Yellowstone Lake (Figure 2). Field and laboratory sampling procedures remained identical to those described by Jones et al. (1985)

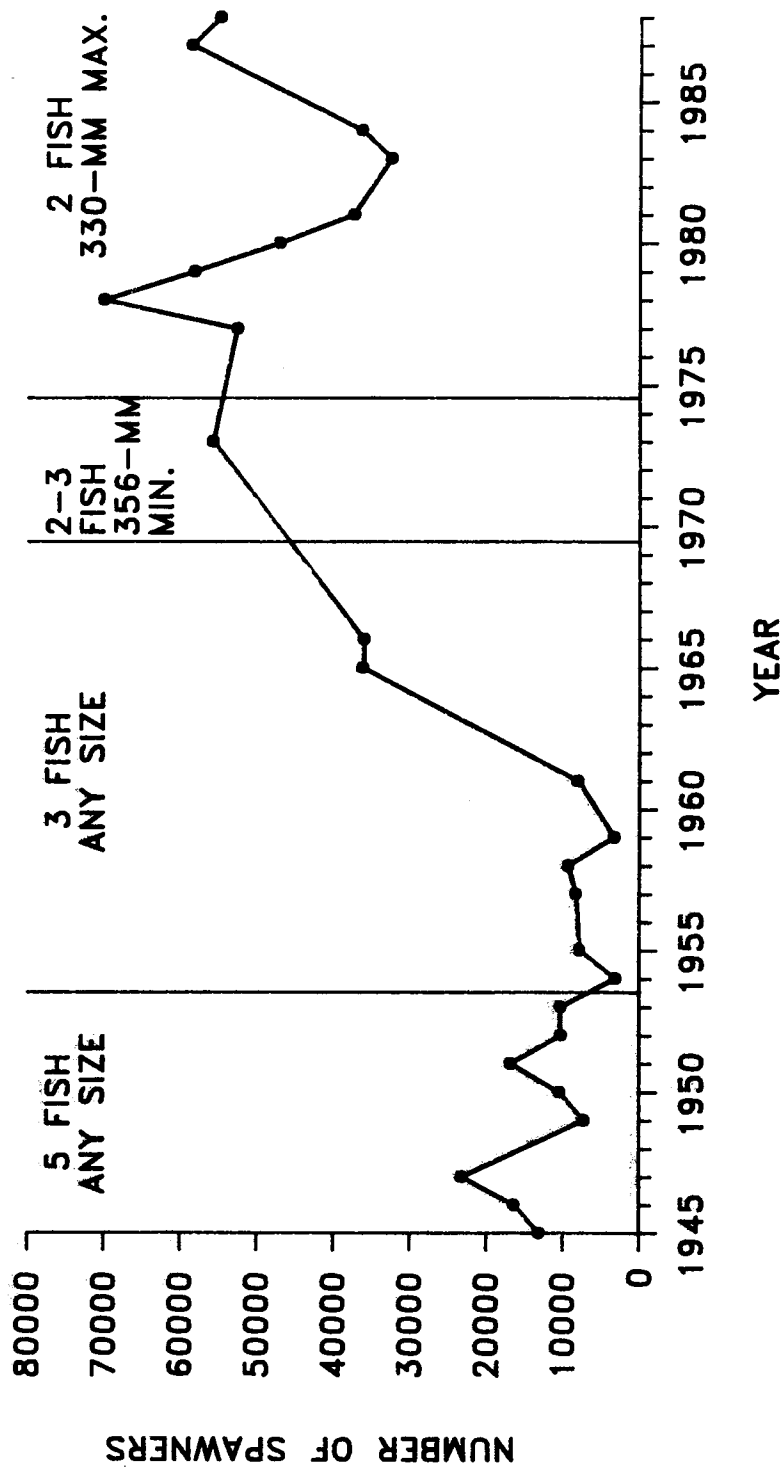


FIGURE 4.-Number of cutthroat trout spawners entering Clear Creek during various sample years, 1945-1988.

Results

Cutthroat Trout 1988

A total of 883 cutthroat trout were captured in 1988. Average number of trout captured per net was 16.1, and mean length, weight, and condition factor (K) were 322 mm, 355 g, and 0.89, respectively (Tables 8 and 9).

Number of trout captured per net differed significantly ($P < 0.05$) between the 11 netting sites (Appendix Table 1). Highest numbers were captured at sites 1a, 6c, 4b, and 3b (21.6, 19.0, 18.4, and 16.8 trout/net, respectively). Catches were lowest at sites 2a, 7c, and 3a (13.4, 13.2, and 12.8 trout/net, respectively).

There were no significant ($P > 0.05$) 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 North, West Thumb, and South (16.4, 16.3 and 16.1 trout/net, respectively) than for Central (14.8 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, 1b, 2a, 6c, and 1c (356, 346, 341, 337, and 337 mm, respectively), and lowest at sites 4b, 4a, and 1a (311, 296, and 278 mm, respectively). Mean length of captured trout was not significantly ($P > 0.05$) correlated to number of trout captured per net.

Significant ($P < 0.05$) differences in mean length of captured trout also occurred among lake zones (Appendix Table 2). Mean length was greatest in the South (345 mm) followed by Central (321 mm), North (321 mm), and West Thumb (304 mm).

Approximately 50% of all trout over 304 mm were categorized as prespawners (fish with sufficient gonadal development to spawn in 1989). Mean length and weight of cutthroat trout prespawners was 392 mm and 546 g, respectively; mean condition factor (K) was 0.91. Prespawner male:female ratio was 0.88:1. Differences in mean length between male and female prespawners (398 mm and 386 mm, respectively) was significant ($P < 0.05$) (Table 9).

Longnose Suckers 1988

Average length and weight were 357 mm and 629 g, respectively, for 430 longnose suckers captured in 1988. Average condition factor was 1.18 (Table 10). *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 56% of a sample of 374 of the captured suckers. No clipped or tagged suckers were noted.

TABLE 8.-Comparative largemouth gillnetting results, cutthroat trout, 1.52-4.57 m depth interval, Yellowstone Lake, 1969-1972, 1974, 1976-1980, and 1982-1988.

Year	Number of gillnet sets ^a	Average number of trout per net	95% confidence interval	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	0.91	47.1	12.7	0.7	62	1.10:1	389	379
1983	55	18.05	+1.67	299	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
1988	55	16.05	+1.12	322	0.89	39.5	17.2	1.9	50	0.88:1	398	386

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

TABLE 9.-Length-frequency distribution, average lengths, weights, and condition factors of nonspawning and prespawning cutthroat trout and longnose suckers captured in largemouth gill nets, 1.5-4.6 m depth interval, Yellowstone Lake, 1988.

Species	Maturity category ^a	Size-group (lower length of interval - mm)										Total number	Average total length (mm)	Average weight (g)	Average condition factor (K)
		100	150	200	250	300	350	400	450	500					
Cutthroat trout	Nonspawners	1	49	148	169	102	87	61	10		627	294	270	0.88	
	Prespawning males			2	2	11	38	56	10	1	120	398	599	0.91	
	Prespawning females				1	18	69	47	1		136	386	536	0.91	
	TOTALS AND AVERAGES	1	49	150	172	131	194	164	21	1	883	322	355	0.89	
Longnose sucker	Nonspawners		19	49	36	30	4	1			139	257	224	1.15	
	Prespawning males				14	42	29	53	12		150	378	704	1.24	
	Prespawning females				1	6	23	57	47	7	141	433	949	1.13	
	TOTALS AND AVERAGES		19	49	51	78	56	111	59	7	430	357	629	1.18	

^a Prespawning fish are defined as those that appear to have sufficient gonadal development to spawn in 1989; nonspawners include immature, and mature fish which were judged to lack sufficient gonadal development to spawn in 1989.

TABLE 10.-Comparative largemouth gillnetting results, longnose sucker, 1.52-4.57 m depth interval, Yellowstone Lake, 1969-1972, 1974, 1976-1980, and 1982-1988.

Year	Number of gillnet sets ^a	Average number suckers per net	95% confidence interval of number of suckers/net	Mean length (mm)	Condition factor (K)	% of suckers over		% of suckers over		Percent of suckers over 310 mm (TL) judged as prespawners	Prespawning ratio male:female	Average length of prespawning	
						356 mm (TL)	406 mm (TL)	457 mm (TL)	males (mm)			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
1988	55	7.82	+1.91	357	1.18	53.0	38.8	10.7	93	1.06:1		378	433

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

Approximately 67% of all suckers over 310 mm were categorized as prespawners. Mean length and weight of longnose sucker prespawners were 405 mm and 822 g, respectively; mean condition factor (K) was 1.19. Prespawner male:female ratio was 1.06:1. The difference in mean length between male (378 mm) and female (433 mm) prespawners was significant ($P < 0.05$). Males ranged from 256 to 465 mm, and females varied between 296 and 540 mm.

Discussion

Although the experimental design of the largemouth gillnetting program has been modified since the program began in 1969, data are comparable for 17 of 18 years in which studies have been conducted. Significant ($P < 0.05$) differences 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 1969-1988

Relative abundance and distribution.—Mean number of trout captured per net has varied significantly ($P < 0.05$) since 1969 (Table 8), and when data were grouped by pre-330 mm maximum-size limit (1969-1974; mean, 13.6 trout/net) and post-regulation (1976-1987; mean, 15.4 trout/net) periods, the difference between periods was significant ($P < 0.05$). There is a significant correlation ($r = 0.51$) between the percentage of trout less than 203 mm captured annually in gill nets and the mean number of trout captured per net per year. This relationship suggests that the total number of trout captured each year in gill nets is influenced by the relative abundance of age-1 and age-2 trout. Such annual fluctuations caused by variations in 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 17 years of gillnetting yielded significant ($P < 0.05$) differences between the 11 sample sites in the mean number of trout captured per net. Mean number per net ranged between 17 and 18 for sites 1b, 1c, 2b, 3a, and 4b, and from 11 to 15, 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. Differences between sites 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 gill nets has varied significantly ($P < 0.05$) since 1969 (Table 8). 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 ($r = -0.90$) between the percentage of trout less than 203 mm and the mean length of all trout captured in gill nets 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 gill nets, comparisons of prespawners can be used to detect length changes in mature trout. Although mean length of prespawners is somewhat less than in 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 (382 mm) has increased 25 mm from the mean of pre-regulation years (1969-1974; mean, 357 mm). In 1988, both male and female prespawners displayed the second highest mean length yet recorded (Figure 5).

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 (1980), and Gabelhouse (1984) defined minimum stock and quality lengths for numerous species based on percentages of world record lengths.

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 6). During that period RSD-preferred values equaled 0.0 in all years. Since the implementation of the 330-mm maximum-size limit in 1975, both PSD and RSD-preferred estimates have risen substantially. PSD estimates ranged from 18.13 (1977) to 31.79 (1982); mean PSD

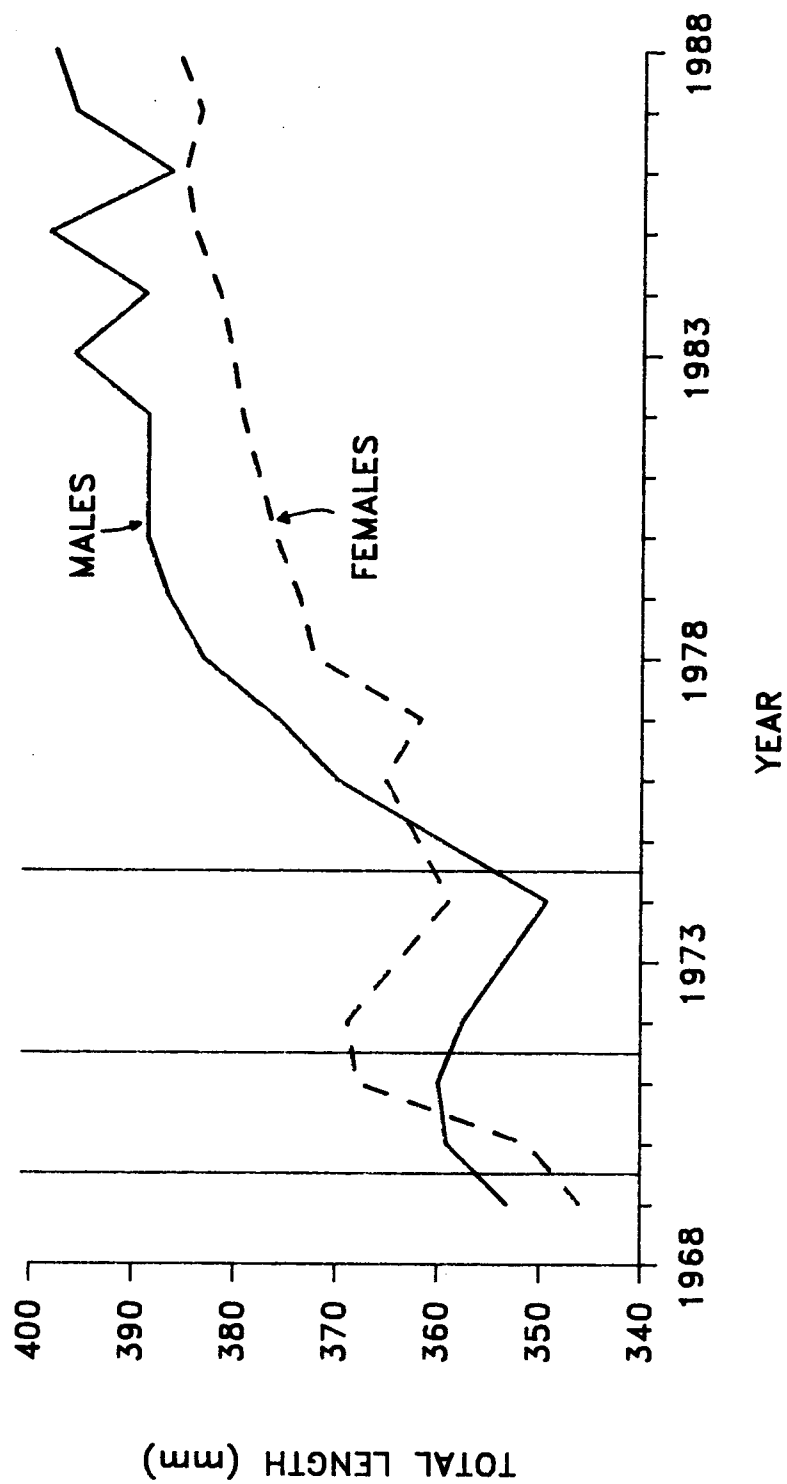


FIGURE 5.-Mean total length of prespawning cutthroat trout captured in largemouth gill nets, Yellowstone Lake, 1969-1988.

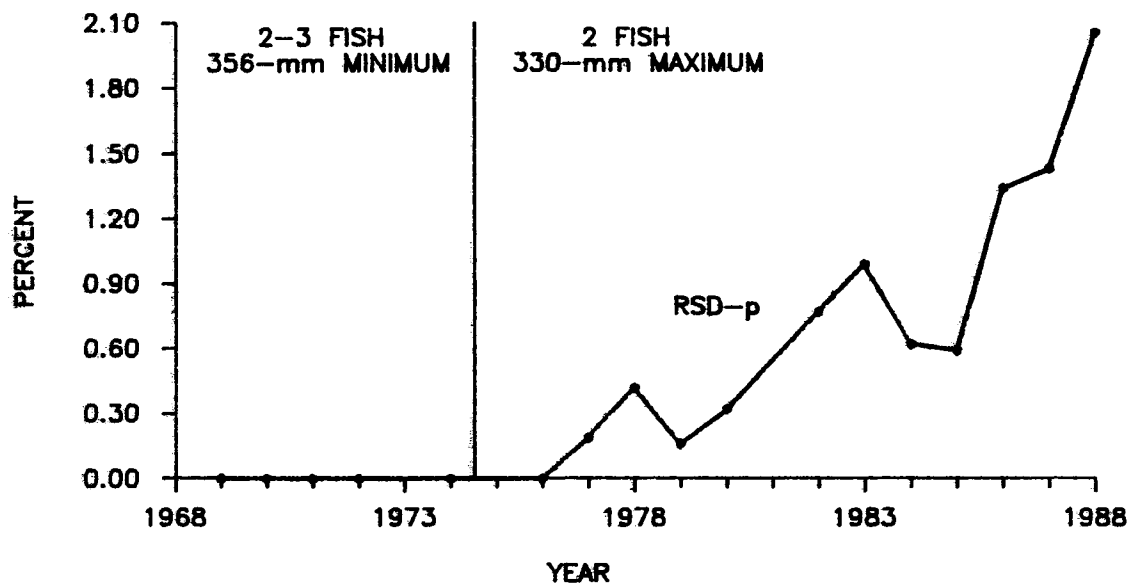
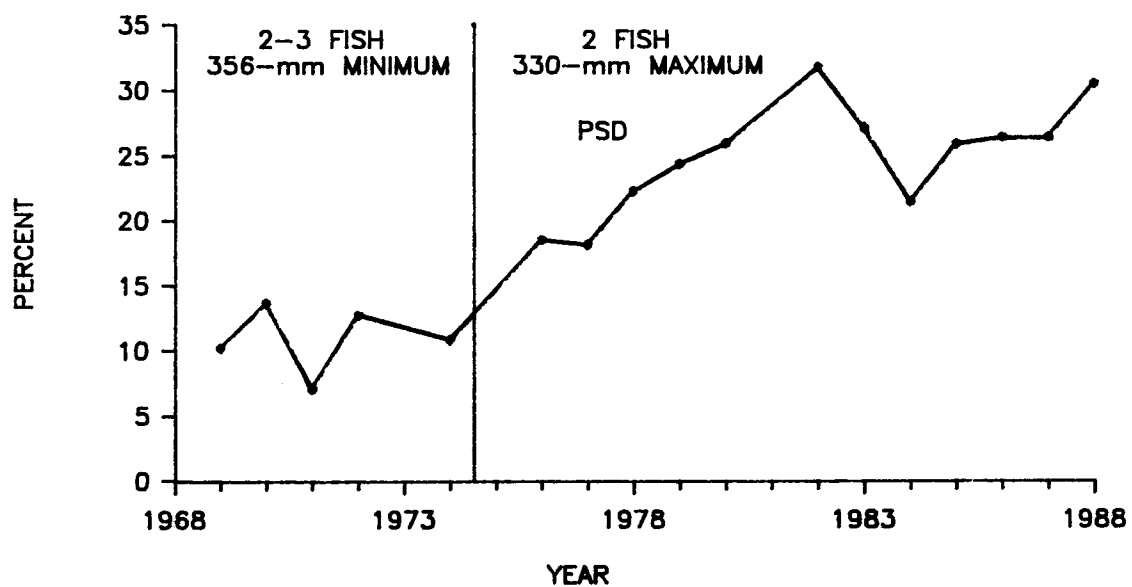


FIGURE 6.-Proportional stock density (PSD) and relative stock density-preferred (RSD-p) for cutthroat trout captured in largemouth gill nets, Yellowstone Lake, 1969-1988.

was 24.9, over twice the pre-regulation mean. RSD-preferred values rose to 2.05 in 1988, and the mean since 1976 was 0.74. 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 7). This decrease may be related to the fact that approximately 57% of all creeled 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), monitoring will continue.

Longnose Suckers 1969-1988

Average number per net.-Although differences between years in the average number of suckers captured per net (Table 10) 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 gill net catch.

Average size.-Comparisons between years (Table 10) yield significant ($P < 0.05$) differences in mean length. Mean length of suckers is inversely correlated to the male:female ratio ($r = -0.59$) and directly correlated to the percentage of suckers over 203 mm ($r = 0.74$). Since the latter two factors are probably related to distribution, annual variations affecting numbers captured may also affect variations in mean length.

The largemesh 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 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.

Conclusion

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

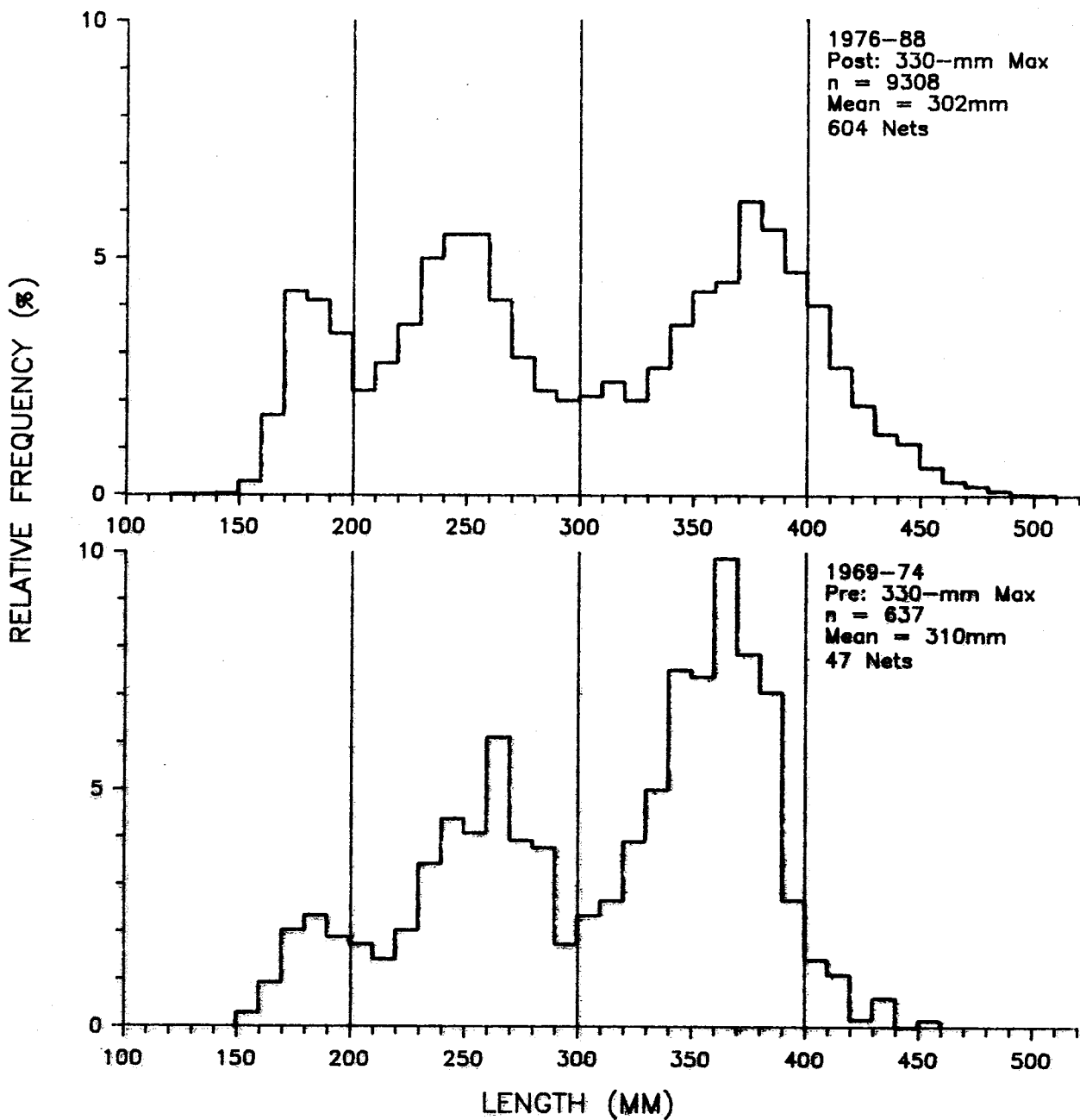


FIGURE 7.-Length frequencies of cutthroat trout captured in largemouth gillnets at the 1.5-4.6 m depth interval in Yellowstone Lake, 1969-1988 (excluding 1981).

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 (Figure 5). 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 use and effort, 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 largemesh 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 regulations 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 14 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 monitoring is essential to the evaluation of the 330-mm maximum-size limit, especially under higher levels of use.

GRANT VILLAGE SPAWNING SURVEY: 1986-1988

Conflict between humans and wildlife is a major concern of the National Park Service in Yellowstone National Park. At Grant Village, a Yellowstone Lake shoreline development, the potential for human-bear conflict is high in May, June, and July. During these months, adfluvial Yellowstone cutthroat trout *Oncorhynchus clarki bouvieri* from Yellowstone Lake spawn in streams that flow through the Grant Village area (Hoskins 1974, 1975; Jones et al. 1986, 1987, 1988) and are preyed on by bears (Hoskins 1974, 1975; Reinhart and Mattson 1987).

The National Park Service is attempting to minimize the potential for human-bear conflict at Grant Village by managing human use in the area during the cutthroat trout spawning season. Effective management requires information on cutthroat trout spawning and bear activity patterns. At issue are the development of guidelines for determining an opening date for the Grant Village Campground and the appropriate extent of human access to 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 occur in the vicinity of streams even when the campground is closed.

Hoskins (1974, 1975) and Jones et al. (1986, 1987) identified spawning streams in the Grant Village area, and Jones et al. (1987) collected limited data on the timing of spawning migrations. Jones et al. (1988) developed procedures to determine the onset, peak periods, and duration of spawning runs; estimate of the relative magnitude of runs; and map spawner distribution. Analysis of past data suggested a high degree of annual variation in the timing and duration of spawning runs in streams at Grant Village (Jones et al. 1988).

Based on the joint recommendation of the U.S. Fish and Wildlife Service and the National Park Service, cutthroat trout spawning migrations in streams at Grant Village were again monitored in 1988. Because of manpower limitations, objectives in 1988 were limited to determining the timing, duration, and relative magnitude of spawning runs.

Study Area

Grant Village (Figure 8) 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

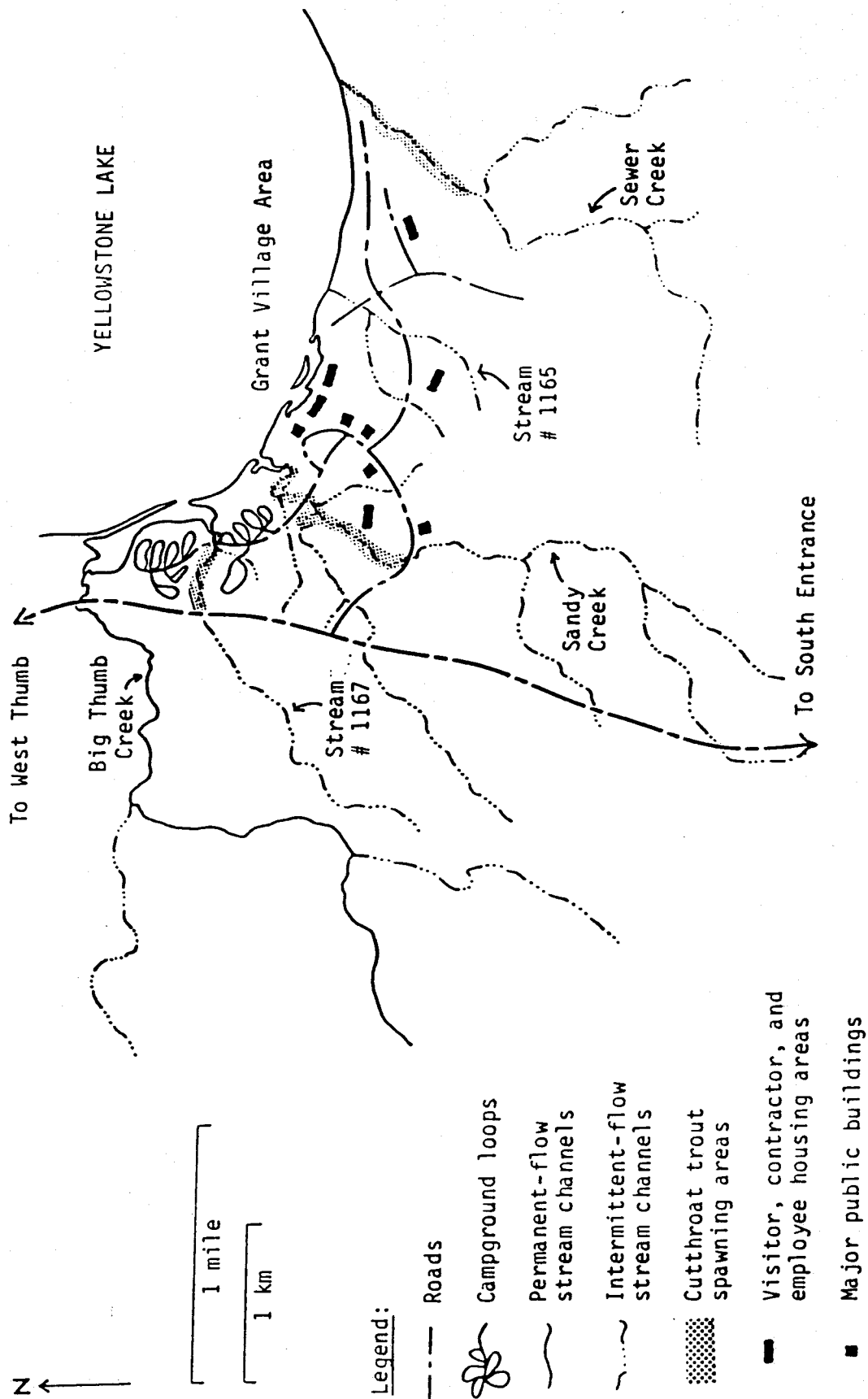


FIGURE 8.-Grant Village area showing major roads, stream channels, buildings, campground loops, housing areas, and cutthroat trout spawning areas.

activities. Housing for National Park Service and concessionaire employees is also located in the area.

Five streams flow through the Grant Village area before entering Yellowstone Lake (Figure 8). 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, 1988). Adult cutthroat trout return to Yellowstone Lake after spawning. Once eggs hatch and young trout emerge from the gravel, they usually emigrate to the lake within a few days or weeks.

Methods

Cutthroat trout spawning was monitored from May through June 1988. 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 (U.S. Fish and Wildlife Service unpublished data). Stream 1165 was not evaluated because spawners did not enter this stream in 1985, 1986, or 1987 (Jones et al. 1986, 1987, 1988).

To detect the onset of spawning, daily visual observations of Stream 1167, Sandy Creek, and Sewer Creek began on 8 May. Once spawning commenced, weekly visual counts were used to monitor spawning runs. On each sample day, observers walked from the stream mouth upstream as far as spawners were found and counted the number of spawners in each stream; sampling continued weekly until the spawning season ended. All counts were made between 0900 and 1630 hours. Casual observations of bear activity along streams were made during weekly spawner counts.

Results

Cutthroat trout began spawning in Stream 1167 and Sandy Creek during the week of 15 May and in Sewer Creek about 1 week later. Peak spawner counts occurred in Stream 1167 and Sandy Creek on 27 and 28 May, respectively, and in Sewer Creek on 4 June. Spawning lasted about 8 weeks in Stream 1167 and Sandy Creek and approximately 7 weeks in Sewer Creek. All spawning ended in late June (Figure 9) when flow in all three streams became intermittent. Weekly spawner counts indicated that the largest spawning migration occurred in Sandy Creek, followed by Sewer Creek and Stream 1167 (Figure 9).

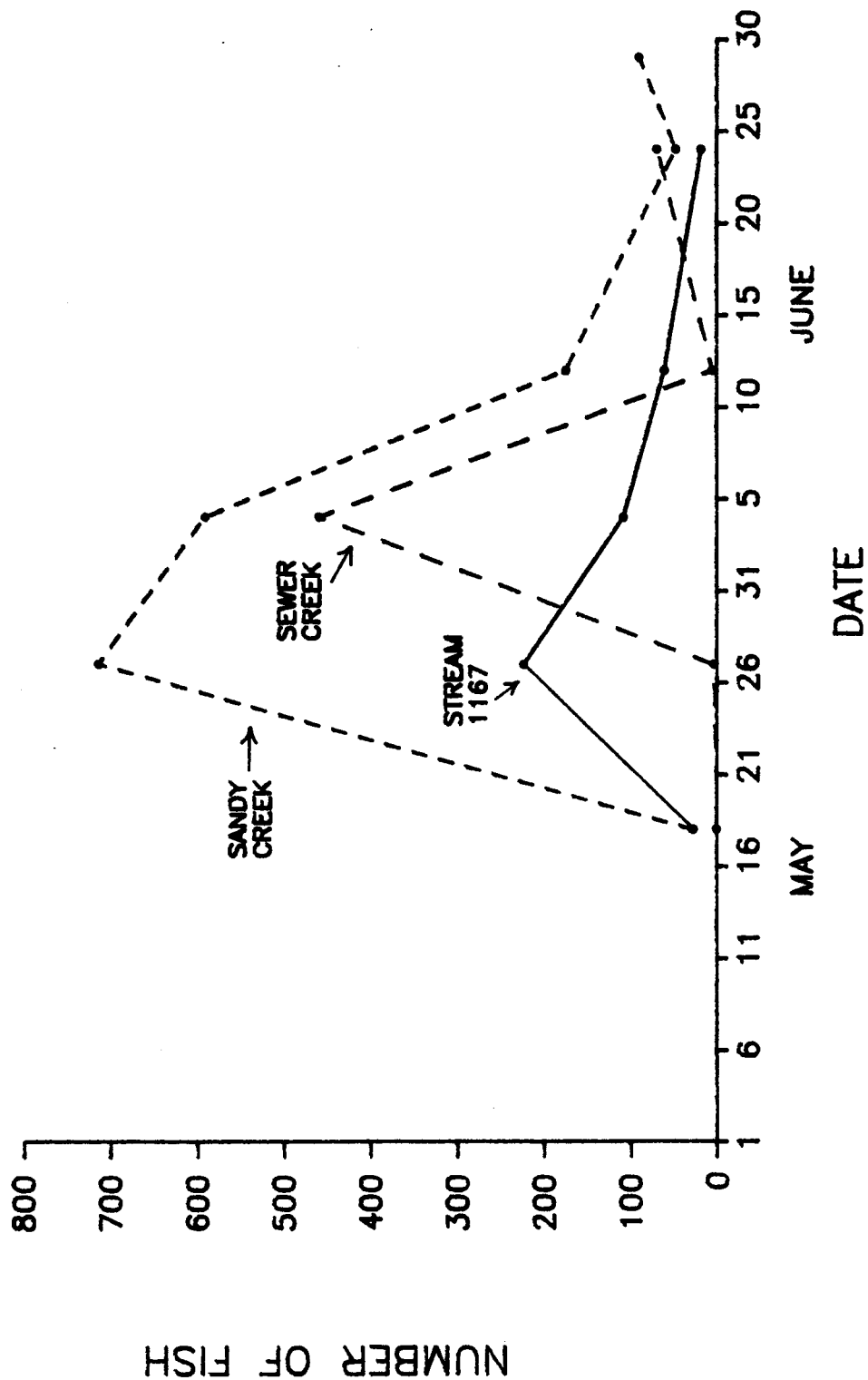


FIGURE 9.-Counts of cutthroat trout spawners in three streams at Grant Village, 1988.

Because of intermittent flow conditions in all three streams, many adults were stranded. The National Park Service decided that the large number of fish stranded in Sandy Creek created an extraordinary potential attractant to bears; consequently, a salvage operation was conducted in Sandy Creek on 29 June. Approximately 267 dead spawners were removed from the stream channel and 90 live spawners were returned to Yellowstone Lake. Salvage operations were not conducted in either Stream 1167 or Sewer Creek.

Observations of bear activity revealed grizzly bear *Ursus arctos horribilis* tracks along Stream 1167, Sewer Creek, and Sandy Creek. Black bear *Ursus americanus* tracks were found along Sandy Creek and Sewer Creek. Observations also indicated bear predation on spawning trout in Stream 1167 and Sewer Creek. It is probable that bears also fed on spawning trout in Sandy Creek.

Discussion

Annual Variation in Spawning Migrations 1986-1988

During the past 3 years, onset of spawning in Stream 1167, Sandy Creek, and Sewer Creek has occurred as early as the first week of May and as late as the second week of June (Figure 10). Annual variation in onset of spawning is probably influenced by annual variation in climatic conditions. In Stream 1167, Sandy Creek, and Sewer Creek (Jones et al. 1988), as in many other Yellowstone Lake tributaries (Cope 1957; Jones et al. 1978-1981), cutthroat trout usually enter spawning streams as streamflows decline from peak spring flows and water temperatures increase to 8-10°C.

During the past 3 years, the spawning migration in Sewer Creek began about 1 week later than in Stream 1167 and Sandy Creek (Figure 10). Prior to forest fire activity in the Grant Village area in the summer of 1988, Sewer Creek appeared to be more heavily shaded by dense timber than the other two streams; consequently, spring runoff and favorable water temperatures occurred later in this stream (U.S. Fish Wildlife Service unpublished data). Forest fire activity undoubtedly reduced canopy cover in all three streams; thus, a new spawning pattern may emerge in the next few years.

Factors affecting duration of spawning in Stream 1167, Sandy Creek, and Sewer Creek are less apparent; however, it may be that duration of spawning in these three streams is regulated by streamflow. In 1986, spawning in Sandy Creek and Sewer Creek extended into mid-to-late July (Figure 10). In 1987 and 1988, however, low-water conditions apparently curtailed spawning activity in all three streams by the end of June (Figure 10).

Relative magnitude of spawning migrations in Stream 1167, Sandy Creek, and Sewer Creek may be a function

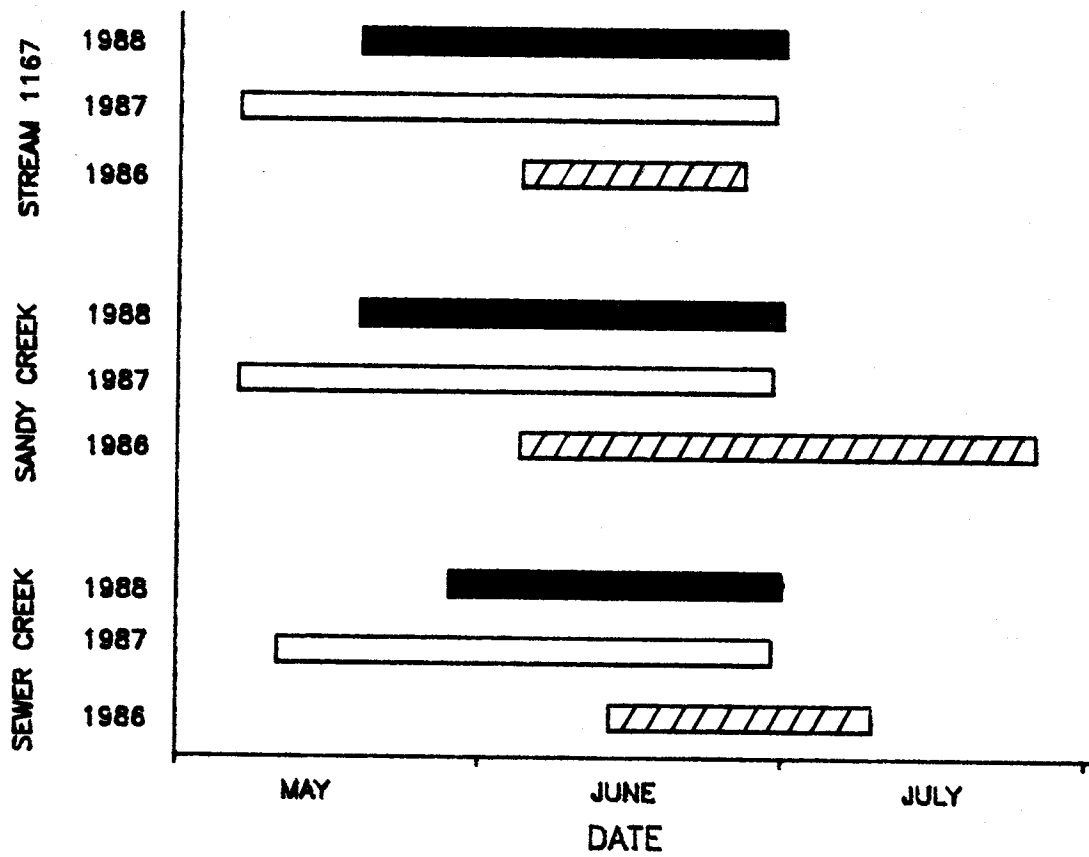


FIGURE 10.-Duration of cutthroat trout spawning runs in three streams at Grant Village, 1986-1988.

of suitable spawning habitat. Over the past 2 years (no data are available for 1986), Sandy Creek apparently has had the largest spawning runs (Jones et al. 1988 and Figure 9). Sandy Creek is the largest of the three streams and may simply possess the greatest amount of suitable spawning habitat. Sewer Creek is somewhat larger than Stream 1167; in 1987 spawning runs in these two streams seemed to be of equal size (Jones et al. 1988), but Sewer Creek appeared to have a larger run in 1988 (Figure 9).

Management Options

Data collected over the past 3 years (Jones et al. 1987, 1988, and the current study) 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 cutthroat trout spawning season. Because of annual variation in timing and duration of spawning runs in these three streams (Figure 10), it is not practical to establish a predetermined date for opening the Grant Village Campground nor to allow unregulated human access to spawning areas. Rather, spawning should be monitored each year. The following recommendations are made within the constraints of limited time and manpower:

- (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 counts to monitor spawner numbers and document spawner distribution. Conduct weekly counts until spawning ends in all three streams.

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

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 Yellowstone cutthroat trout *Oncorhynchus clarki bouvieri* 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 1988, studies included a voluntary creel survey utilizing the Volunteer Angler Report (VAR) system (Jones et al. 1977) and continued sampling of spawning trout at LeHardy Rapids.

Angler Use

In 1988, angler use on this segment of the Yellowstone River was 34,122 angler days, a decrease of 35% from the record-high estimate in 1987. An estimated 14,480 anglers spent 95,657 h and captured 81,972 cutthroat trout. Approximately 190 of these trout were illegally creeled. Landing rate increased to 0.86 trout/h in 1988. This was a 16% increase over the 1987 landing rate (Table 11).

When the upper and lower portions of the area were examined separately, the 9.8-km long upper section (Yellowstone Lake outlet to Sulphur Caldron) sustained 98% of the angler use for the entire area (33,400 angler days or 3,400 angler days/km). A total of 14,000 anglers captured 81,211 trout while expending 94,600 h of effort. Landing rate was 0.86 trout/h.

The number of angler days in the 4.8-km long lower section (Alum Creek to Upper Falls) (737 angler days or 175 angler days/km) decreased 80% from 1987. Approximately 465 anglers expended 1,050 angler hours. Although effort is much lower in this section, landing rate was only 0.70 trout/h. Expanded results indicate that of 724 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 384 mm. Differences in mean length of landed trout from the upper and lower portion were not statistically significant ($P > 0.05$; 384 and 387 mm, respectively). Mean length of creeled trout for the entire area was 305 mm.

TABLE 11.-Creel survey summary, Yellowstone River between Fishing Bridge and Chittenden Bridge, 1951-1955, 1967-1968, 1970-1972, 1973-1988^a.

	Angler days	Mean length angler (h)	Angler hours	Landing rate (trout/h)	Total trout landed	Creel rate (trout/h)	Total creel (trout/h)	Angler days per acre	Angler hours per acre	Mean angler expertise	Percent trout landed and released	Average length trout landed (mm)
4.2 Fish creel limit ^e	1951-1955 Average	45.430	1.97	89.500	f	0.41	36.700	2.800	99	195	f	f
No size limit												
Bait fishing permitted												
3 Fish creel limit	1967-1968 Average	44.300	2.00	88.625	f	0.43	38.100	4.600	167	334	f	343 ^g
No size limit												
Bait fishing permitted												
3 Fish creel limit	1970-1972 Average	45.120	1.87	84.700	0.74	0.18	14.825	4.700	170	318	-	373 ^g
14" Minimum size limit												
Bait fishing prohibited												
Catch and release	1973	25.000	2.35	58.750	1.74	0.01	102.200	2.900	106	250	-	363
Lures and flies only	1974	23.900	2.31	55.700	2.25	0.01	124.200	2.700	102	235	-	366
Bait fishing prohibited	1975	27.900	2.48	69.200	2.04	0.01	141.100	3.200	119	295	-	368
	1976 ^h	30.900	2.45	75.700	1.43	0.01	108.200	3.600	132	322	2.00	373
	1977	26.900	2.44	65.600	1.43	0.02	93.900	3.100	114	279	1.98	373
	1978	26.300	2.50	65.700	1.23	0.02	80.800	3.000	112	280	1.99	384
	1979	28.900	2.60	75.300	1.10	0.02	82.800	3.300	123	320	2.02	389
	1980	34.900	2.44	85.100	1.06	0.02	88.700	4.000	148	362	2.04	389
	1981	48.800	2.60	126.800	1.00	0.01	127.100	5.600	208	540	2.01	391
	1982	35.200	2.46	86.600	1.10	0.02	95.400	4.000	150	369	2.00	396
	1983	39.300	2.61	102.400	1.06	0.01	109.000	4.500	167	436	1.98	396
	1984	44.500	2.56	114.000	0.96	0.02	109.000	5.100	189	485	2.00	401
	1985	36.600	2.72	99.400	0.91	0.02	90.500	4.200	156	423	2.02	401
	1986	43.900	2.73	119.700	1.00	0.01	119.700	5.000	187	509	2.05	396
	1987	52.800	2.80	147.800	0.74	0.01	109.800	6.100	225	629	2.03	394
	1988	34.100	2.80	95.700	0.86	0.01	82.000	3.900	145	407	2.04	384

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

^b Illegal beginning in 1973.

^c 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.

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

^e Three years of five fish creel limit plus 2 years of three fish creel limit.

^f Not measured.

^g Based on data from creel trout.

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

Approximately 83% of the anglers were satisfied with their overall experience; 75% were satisfied with numbers landed, and 86% were satisfied with size of fish landed. Levels of satisfaction increased from 1987, and estimates remain above most Park fisheries (Table 4). The proportion of single-day anglers landing one or more trout was 66%; average expertise remained high at 2.04.

LeHardy Rapids

The catch-and-release regulation instituted in 1973 encompasses the section of the Yellowstone River extending from a point 1.6 km below the Yellowstone Lake outlet downstream to Sulphur Caldron. Since 1974, the spawning migration of cutthroat trout through LeHardy Rapids has been monitored on an annual basis to provide a method (independent of the VAR system) for examining effects of the catch-and-release regulation on the cutthroat trout population structure. Sampling techniques have generally followed those established by Dean et al. (1975). Scales were collected according to procedures of Varley et al. (1976); however, time constraints prevented age analysis in 1988.

In 1988, weekly sampling was conducted at LeHardy Rapids from 31 May through 26 June. Mean length and weight of 106 adult trout were 394 mm and 537 g, respectively. Mean length of males (400 mm) was significantly greater than females (385 mm), and average weight of males was also significantly greater than females (Table 12). Although all of these values decreased from those obtained in 1987, they remain high compared to pre-1982 values (Table 12). The percentage of cutthroat trout over 406 mm declined by one-third from the 1987 level (Figure 11). Age groups were not assigned to the 1988 sample; however, the larger fish in the sample are presumably older-age fish. In general, mean length and percentage of fish greater than 406 mm have shown an increasing trend since the population has been managed under catch-and-release. Fluctuations of these parameters in the past several years may indicate that the population is approaching equilibrium (Figure 11).

Results from 1988 may not represent the actual status of the spawning population. Because 1988 was a low-water year (Farnes 1988; SCS 1988), migrating trout were able to ascend many portions of LeHardy Rapids (Jones et al. 1979) and sampling efficiency declined accordingly. The low streamflow may have also initiated an earlier than normal spawning migration. The first post-spawning female was captured during the second week of sampling (8 June). Consequently, a major portion of the spawning migration may not have been sampled and results from 1988 sampling may be biased downward.

TABLE 12.-Mean length, weight, and condition of cutthroat trout captured by dip net at LeHardy Rapids, Yellowstone River, 1974-1988.

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
1988 ^a	60	400	559	0.88	46	385	508	0.88	106	394	537	0.88

^a Due to erroneous measurements, fish were deleted from average weight and K factor calculations only, as follows: six males and two females from 1974, one male and two females from 1976, one male and 1 female from 1977, and one male from 1988.

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

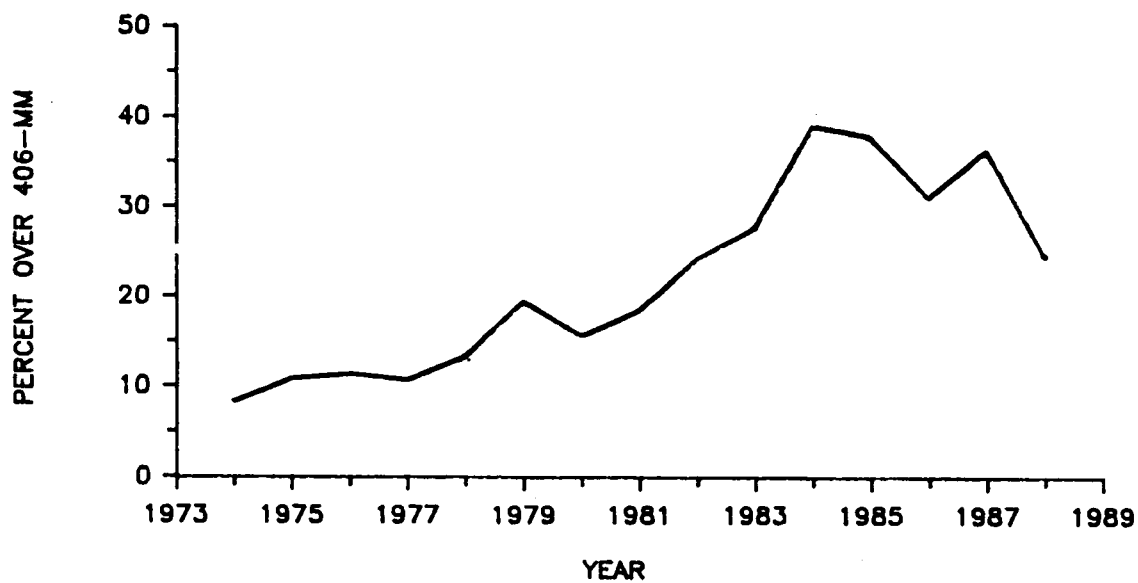
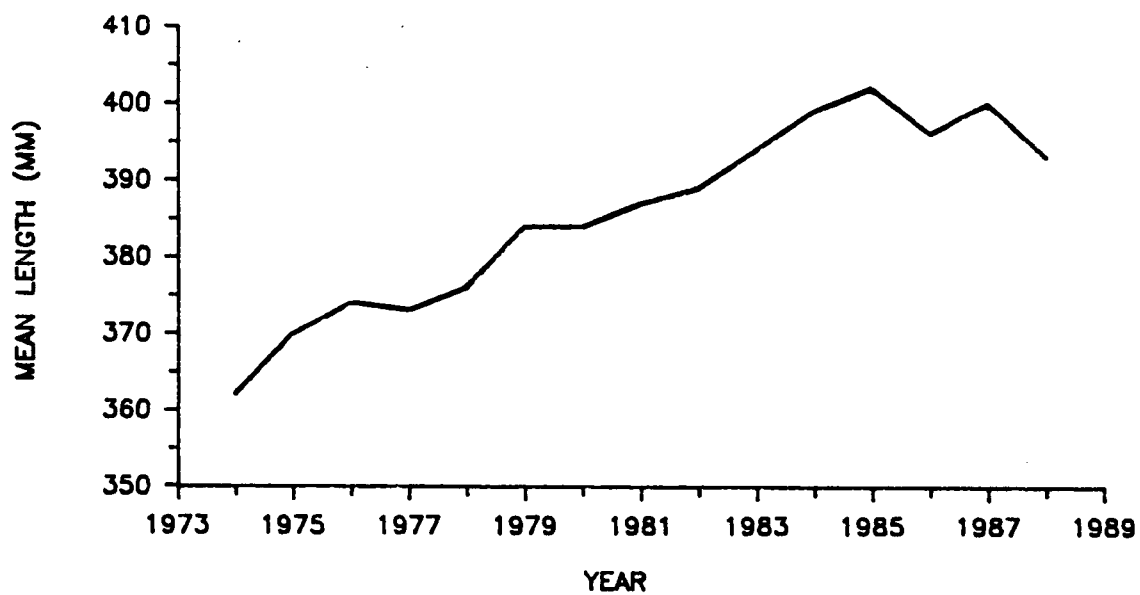


FIGURE 11.-Mean length and percentage of cutthroat trout over 406 mm (total length) captured at LeHardy Rapids, 1974-1988.

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 the catch-and-release regulation was initiated in 1973, use and effort have continued to increase since 1974 (Table 11). These figures equated to 2,440 angler days/km (3,900 angler days/mi), or 360 angler days/hectare (145 angler days/acre) in 1988. 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 11).

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 12). 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. Landing rate increased in 1988 but remains below 0.90 trout/h.

Mean length of cutthroat trout captured in the spawning run at LeHardy Rapids increased steadily since 1974 (Figure 11). A gradual rise in average age has accompanied the increase in size at LeHardy Rapids. Although mean length of cutthroat trout landed by anglers increased between 1973 and 1985, a decline in mean length has been noted since 1986. Monitoring in this section of the Yellowstone River should be scrutinized closely in the next few years in order to determine if the trend toward smaller fish is a response to increased mortality in recent years.

Although there is an inverse relationship between effort and landing rate in the Yellowstone River, changes in population structure may 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.

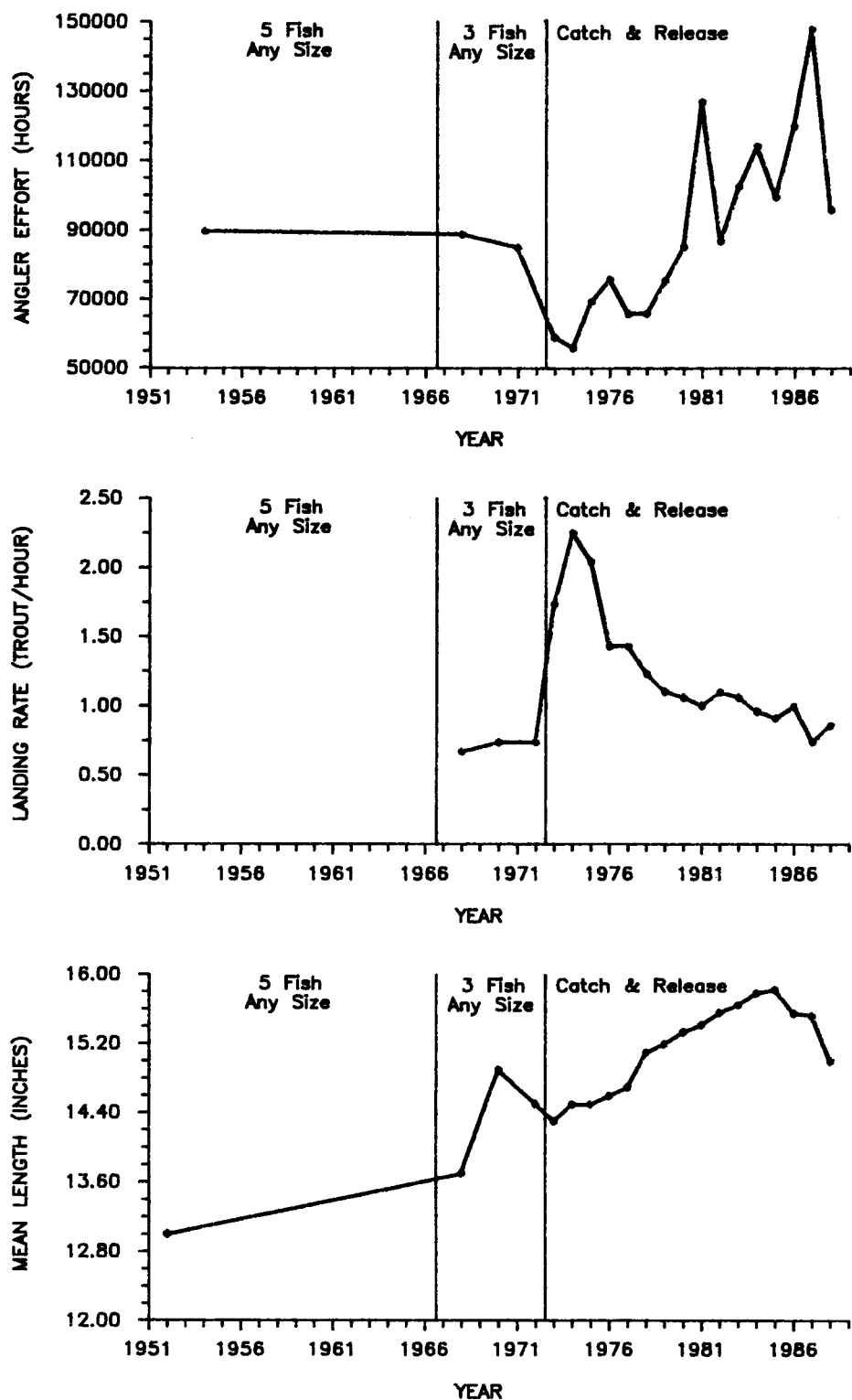


FIGURE 12.-Angler effort, landing rate, and mean length of landed trout, Yellowstone River between the Yellowstone Lake outlet and the Upper Falls, 1952-1988.

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 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 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.

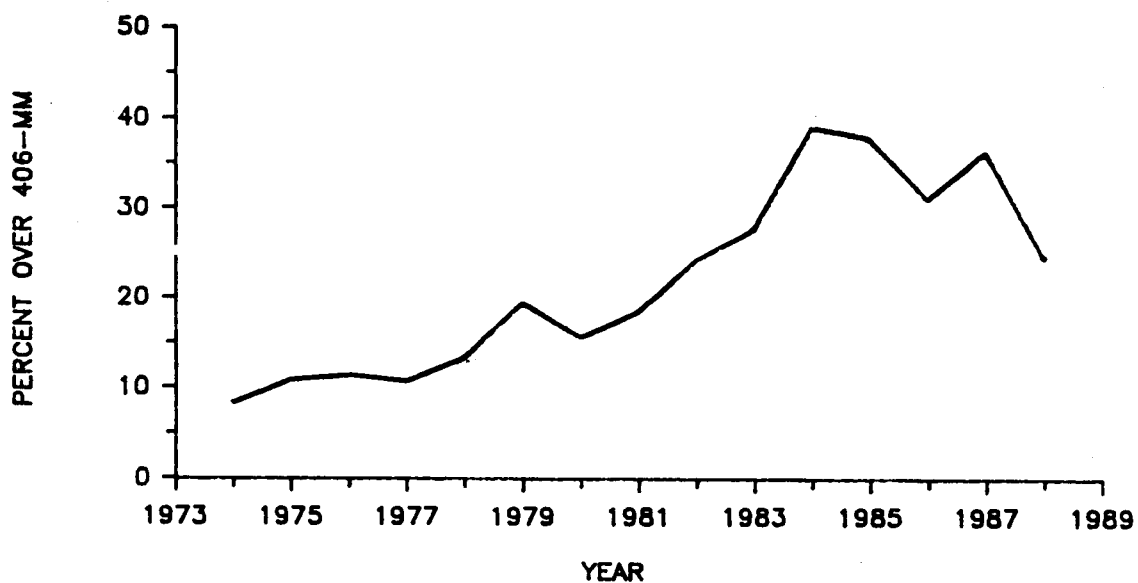
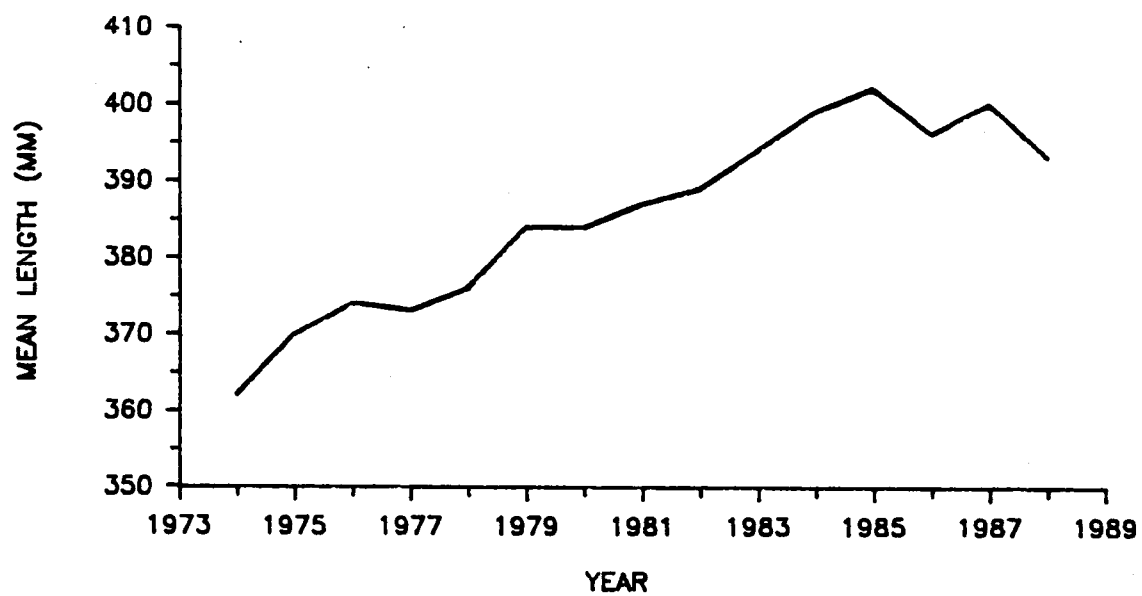


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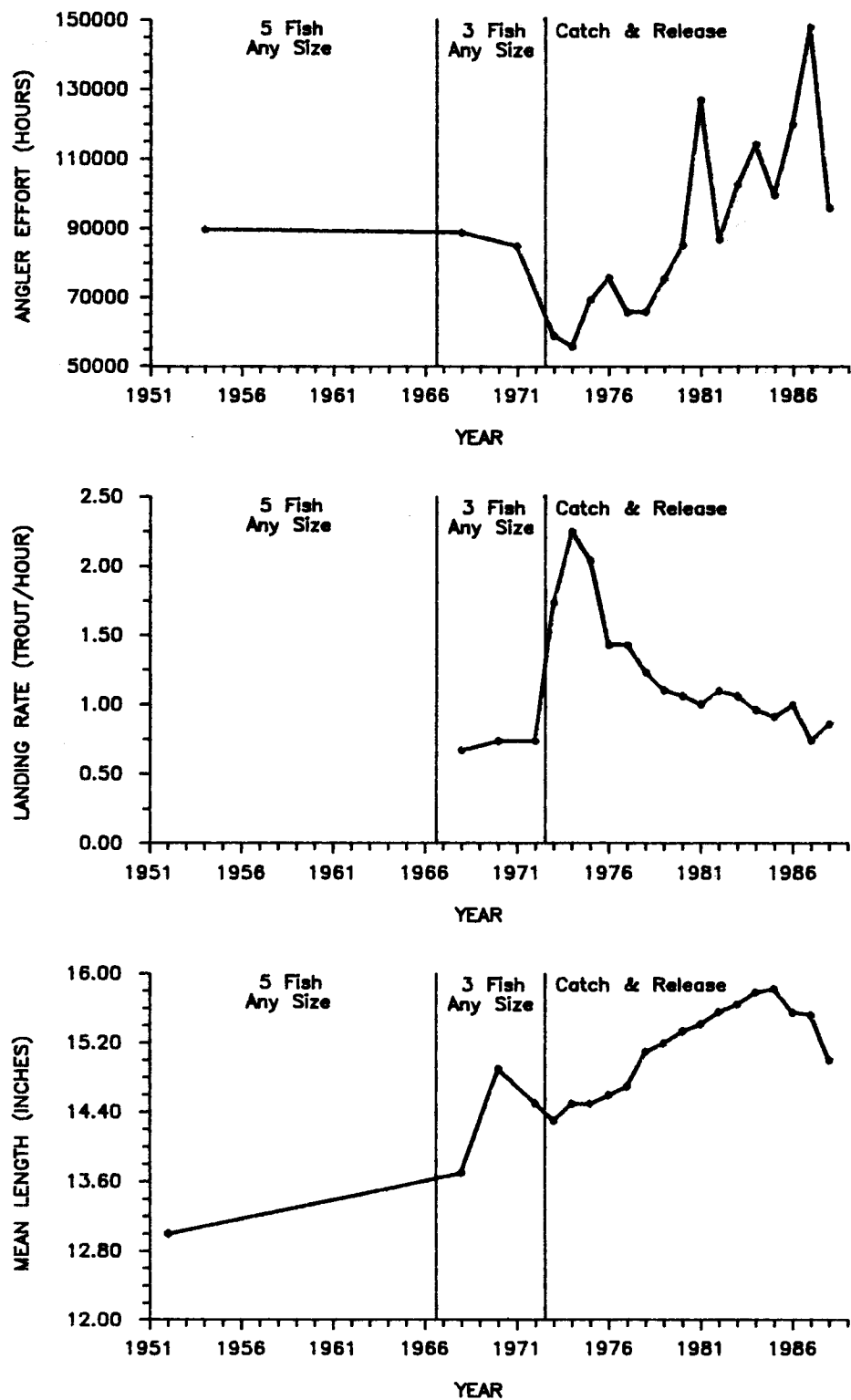


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STREAM SURVEYS

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. Additionally, waters in a national park may serve as a baseline against which impacted areas may be compared (Hester 1976). 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 not available for all streams in Yellowstone National Park, primary objectives of stream habitat surveys include on-site preparation of watershed-level hydrographic maps, a description of the physical, chemical, and biological characteristics of a stream, and a subsequent evaluation of the ability of the stream to support fish. Suitable stream habitat may be devoid of fish; nevertheless, it remains suitable habitat (Dunham and Collotzi 1975).

Following an early description and preliminary classification of streams by Muttkowski (1929), a formal 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. Sharpe and Babcock (1964) initiated the stream survey program by providing a physical description of the Lewis River between Lewis and Shoshone lakes. As the program expanded, stream habitat surveys were often conducted within the same drainage basin in Yellowstone National Park for several consecutive years in response to a growing recognition of the concept of watersheds as basic ecosystem units (Lotspeich 1980; Lotspeich and Platts 1982). In order to develop an integrated description of a major watershed, stream habitat inventory should be conducted at both the mainstem and tributary watershed level.

Stream habitat surveys in 1988 were conducted under unusual streamflow conditions. Because 1988 was a record 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 extremely dry years. Since 1984, stream survey efforts have been concentrated in the Lamar River drainage; however, forest fire activity and associated logistic constraints precluded extensive surveys in this watershed in 1988. While some fire-related habitat data were collected in the Lamar and Madison river drainages, standard habitat surveys were restricted to the Gardner River watershed in 1988. Since the inception of the aquatic resource inventory program, preliminary habitat data have

now been collected on 580 named and unnamed streams in Yellowstone National Park.

Methods

Cursory survey.-Cursory-level surveys (Table 13) 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) were determined from U.S. Geological Survey topographic maps (scale 1:24,000). Additional habitat data (Table 13) were usually obtained near the mouth of the tributary or at a trail crossing. Although only a portion of each tributary was surveyed, collection of data in the lower section of a tributary provides an integrated summary of upstream physical, chemical, and biological influences. In order to evaluate a watershed as a complete ecological unit, drainage basin characteristics were also determined for intermittent streams that have a potential for sediment input, spawning substrate, or nursery value. All surveyed streams were assigned numbers according to the revised SONYEW system (Jones et al. 1986).

Instantaneous water temperatures were measured with a hand-held thermometer, and 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 (Surber 1937) 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 comparison. In addition to density and species diversity, each sample was evaluated by functional groups (Merritt and Cummins 1978; Krueger and Waters 1983).

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, was conducted in each stream reach (Table 13). General observations of wildlife activity and weather were noted. Drainage basin characteristics of each survey section were 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, except for streams with a wetted width greater than 30.5 m. In this case, distance between transects was shortened to 4 or 5 times the stream width of the previous

TABLE 13.-Data collected during cursory- and reconnaissance-level surveys in Yellowstone National Park, 1988.

<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

transect so that the maximum distance between any two transects was 305 m. The distance between transects 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 metal poles of equal length were used to assure accuracy in gradient reading. Gradient, sinuosity, substrate composition, and stream width:depth ratio were used to classify streams according to Rosgen (1985).

Stream discharge was measured by the midsection method (Buchanan and Somers 1969) at the first transect of each study site. Generally, all depth measurements from each transect were used to obtain average depth for that transect; however, in the Gardner River 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). This procedure provides a rapid, yet reliable, method of obtaining average depth.

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. Additional habitat inventory parameters (Table 13) were measured according to techniques described in Platts et al. (1983).

In 1988, reconnaissance-level surveys were conducted on the Gardner River, and portions of Slough Creek, Soda Butte Creek, Lamar River, Gibbon River, Firehole River, and Madison River. Macroinvertebrates were collected and analyzed at each reconnaissance-level survey site in the Gardner River according to procedures described under cursory-level surveys. In the other six streams, three macroinvertebrate samples were collected at each study site. These will be analyzed by an independent consultant and results will be described in a later report.

Presence or absence of fish in the upper Gardner River was determined visually. Fish population characteristics for the Gibbon River and Madison River were described in 1987 (Jones et al. 1988). Populations in Slough Creek, Soda Butte Creek, Lamar River, and Firehole River are described elsewhere in this report.

Results

Upper Gardner River

The Gardner River supports one of the more popular fisheries in Yellowstone National Park. The majority of angling effort is concentrated in areas accessible by road between the mouth of the river and the confluence with Panther Creek. Although numerous fishery studies have been implemented in this section of the river (Jones et al. 1987, 1988; this report), habitat or fishery surveys upstream from Panther Creek are lacking. In accordance with the objectives of the stream survey program, the portion of the Gardner River from the headwaters downstream to the confluence with Panther Creek was surveyed at the reconnaissance level in 1988. This section of the Gardner River was termed "upper Gardner River" for purposes of the baseline habitat survey.

Physical characteristics.-The headwaters of the Gardner River are located on the eastern slope of the Gallatin Mountains in the northwestern section of Yellowstone National Park. The river flows out of the basin formed by Joseph Peak and Gray Peak and northeasterly along the base of Little Quadrant Mountain for 5.25 km before making a right angle turn to the southeast (Figure 13). The river then courses through a canyon before meandering across the wide meadows of Gardner's Hole on the eastern side of Quadrant Mountain. Major tributaries to the upper Gardner River are Fawn Creek and Stream 100726. Access to the upper Gardner River is provided by the Bighorn Pass trail, Fawn Pass trail, and Sportsman Lake trail. Several campsites are located adjacent to the upper Gardner River and Fawn Creek.

The underlying sedimentary layers of Jurassic and Cretaceous shales and sandstones form an important geologic feature of the upper Gardner River watershed. Some areas of the eastern Gallatin Mountains have very thick sedimentary layers (e.g., the Pennsylvanian sandstones of the Quadrant Mountain formation; USGS 1972). Eocene Absaroka volcanic activity was moderate in the upper Gardner River watershed and current manifestations are restricted to localized outcroppings. Electric Peak and a ridge east of the confluence with Fawn Creek reflect this past volcanic activity.

The overriding geologic influences in the upper Gardner River have been glacial processes. Although Bull Lake glaciation was minor, surficial geology of the upper Gardner River has been thoroughly affected by successive Pinedale glaciers (Pierce 1973). The majority of the watershed is covered by glacial till deposited by glaciers nearly 305 m thick. Rubble veneer deposits are common at higher elevations above 2,590 m. The highest portions of mountains such as Gray Peak and Joseph Peak are characterized by

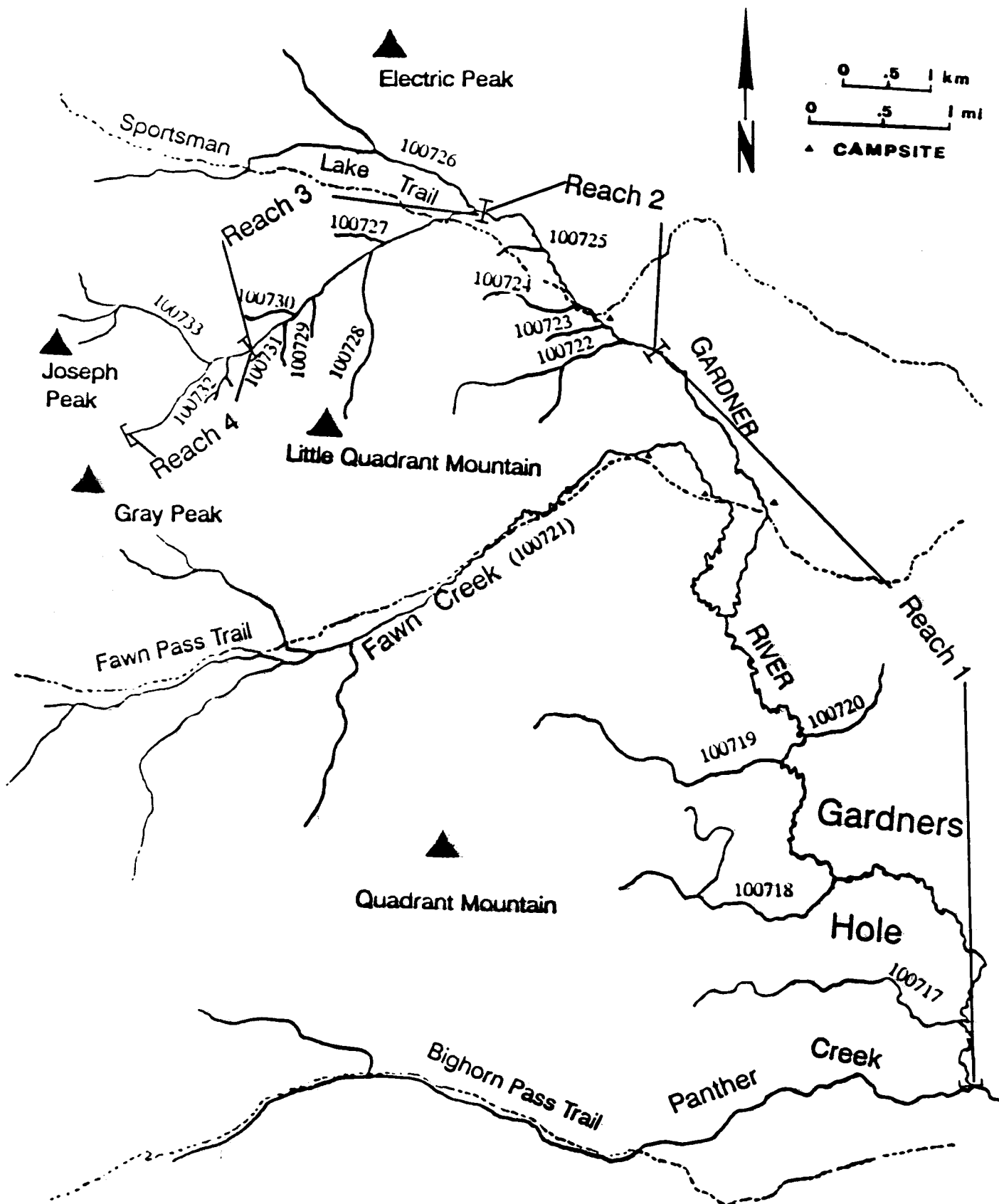


FIGURE 13.-Hydrographic map of upper Gardner River.

landslides, talus slopes, and rubble block deposits that have resulted from movement of Mesozoic sedimentary materials. Floodplain areas of Gardner's Hole are composed primarily of fine grained humic alluvium. The stream channel in this area has varied only slightly in elevation since Pleistocene glacial activity (Pierce 1973).

Large areas within the drainage are non-forested. The broad alluvial terraces and floodplain of Gardner's Hole are covered with sagebrush *Artemisia* sp. Wheatgrass *Agropyron* sp. and Idaho fescue *Festuca idahoensis* are often associated with sagebrush in an alluvial terrace environment (Hansen et al. 1987). Sedges *Carex* spp., are abundant in the riparian zone in the Gardner's Hole area.

Major forest types in the upper Gardner River watershed exhibit a patchy distribution. The primary forest types are large stands of Engelmann spruce *Picea engelmanni*/subalpine fir *Abies lasiocarpa* associations interspersed with whitebark pine *Pinus albicaulis*. Several factors may influence this patchy distribution. Although elevation and associated climatic factors constitute a major effect, soil particle size, pH, and water content may affect the type and distribution of dominant forest trees (Steele et al. 1983). Whitebark pine becomes dominant in the high elevation (above 2,650 m), relatively dry, rubble veneer-covered slopes, and subalpine fir is more commonly found in the lower elevation moist soils derived from sandstone parent material (Steele et al. 1983). Medium-age lodgepole pine *Pinus contorta* stands are found in the narrow canyon area of Reach 2 and up to an elevation of 2,530 m on the northeastern slopes of Quadrant Mountain adjacent to Fawn Creek. Above 2,835 m, severe climatic conditions, as indicated by the presence of krumholz (stunted alpine vegetation), preclude establishment of any significant forest stands.

The survey area provides habitat for numerous elk *Cervus elaphus*. A large bull moose *Alces alces* was observed feeding near Stream 100722. An unidentified sandpiper was noted in the riparian area in the Gardner's Hole section of the stream. A sow grizzly bear *Ursus arctos horribilis* with cubs was encountered by the survey party in the headwater section of the upper Gardner River.

Historically, the upper Gardner River was barren of fish (Varley 1981). Rainbow trout *Oncorhynchus mykiss* and brook trout *Salvelinus fontinalis* were stocked upstream from Osprey Falls. Presently, brook trout are the only salmonids found in the upper Gardner River (Jones et al. 1979).

During the 1988 survey, the upper Gardner River was subdivided into four reaches based primarily on differences in discharge, stream gradient, and degree of shading (Table 14). Reach 1 is a low gradient meandering section of stream that encompasses two thirds of the upper Gardner River including Gardner's Hole. This reach extends from the confluence with Panther Creek upstream to a point

TABLE 14.-Drainage basin characteristics and habitat features of the upper Gardner River, 1988.

Habitat features	Reach 1	Reach 2	Reach 3	Reach 4
Sample date	8/5/88	8/2/88	8/4/88	8/3/88
Time	1025	1245	0935	1435
Stream order	IV	III	II	II
Length (km)	15.60	2.44	2.88	2.37
Elevation:				
Maximum (m)	2,407.9	2,508.5	2,670.0	2,889.5
Minimum (m)	2,247.9	2,407.9	2,508.5	2,670.0
Drainage Size (hectares) ^a	9,775.0	2,560.6	2,020.1	559.4
Stream type	C3	A3	A3	A3
Water column:				
Flow (m ³ /s)	0.336	0.162	0.038	0.003
Channel width (m)	10.1	13.5	4.8	3.9
Stream width (m)	6.9	5.5	3.3	1.2
Stream depth (cm)	35.66	11.89	9.75	3.96
Stream shore water depth (cm)	2.44	0.00	0.00	0.00
Riffle width (m)	1.87	4.39	1.95	0.10
Pools:				
Width (m)	3.0	0.6	0.6	0.7
Quality ^b	4.1	1.6	1.0	1.0
Feature	3	3	3	3
Solar angle (°)	168.7	141.7	113.7	91.7
Channel morphology				
Streambank alteration (%)	66.7	39.2	15.0	10.8
Vegetative stability	4.0	1.5	2.5	2.5
Undercut (cm)	0.0	0.0	0.0	0.0
Channel-bank angle (°)	128.3	155.5	147.2	160.8
Stream bottom:				
Gradient (%)	1.7	6.5	6.1	6.6
Sinuosity	1.24	1.09	1.15	1.16
Substrate:				
Bedrock				
Boulder (> 305 mm)			4.9	
Cobble (64-305 mm)	10.3	92.1	62.0	53.0
Gravel (2-64 mm)	36.4	5.2	33.1	47.0
Sand (0.6-2 mm)	10.6	2.6		
Silt (< 0.6 mm)	43.2			
Embeddedness (%)	30.00	20.00	5.00	20.00
Channel vegetative cover (cm)	0.00	8.23	0.00	0.00
Riparian zone:				
Streamside cover type	2.0	1.3	1.7	2.0
Vegetative use (%)	70.00	36.67	12.50	15.80
Vegetation overhang (cm)	4.57	11.28	2.44	2.13
Habitat type	2	6.9	9	8

^a After Rosgen (1985).

^b 1 = log, tree, root, stump, brush, or debris; 2 = channel meander; 3 = rubble or gravel; 4 = boulder or bedrock; 5 = stream channel; 6 = fire sediments; 7 = streambank; 8 = culvert, bridge, or other manmade objects; 9 = beaver dam or tunnel.

approximately 0.5 km downstream from the Sportsman Lake trail crossing (Figure 13). Streambanks in Reach 1 are composed of fine materials (Habitat Type 2; Table 14). Consequently, streambank alteration has been extensive. The predominance of finer substrate materials extends to the stream channel, where nearly 90% of the stream bottom is composed of materials smaller than 64 mm in size (Table 14). Although several slumped banks were noted in Reach 1, similar numbers of undercut banks were found. This unstable, dynamic condition is characteristic of C3 stream types occurring in glacial materials (Rosgen 1985).

Many pools in Reach 1 were rated high quality (4.1 on a scale of 1-5) because pool depth provided more than adequate cover for fish in this section of the upper Gardner River. Other types of cover for fish are lacking in this stream reach.

The second study reach of the upper Gardner River is characterized by an increased stream gradient and a substantial change in substrate composition compared to Reach 1 (Table 14). A major portion of Reach 2 is bordered by a straight canyon consisting of sedimentary layers that were baked by adjacent volcanic activities. These materials are extremely resistant to erosion (Meyer in press). As a result, the stream channel has undergone a right angle turn at the upstream end of the canyon (Figure 13). Downstream from the canyon, a moderate degree of streambank alteration has occurred, and vegetation stability was rated very low. Several sections of streambank are devoid of vegetation and are composed of materials that provide only limited resistance to erosive forces. Cover for fish throughout this reach is restricted primarily to overhanging shrubs. Pools are small, few in number, lacking in cover, and generally, rated poor in quality (Table 14). Riffle areas predominate throughout Reach 2, and mean stream velocity (28.4 cm/s) in this reach was the highest of any of the four study sections.

The third habitat study reach is a second order section nearly 3 km long that flows along the northern slopes of Little Quadrant Mountain (Figure 13). Steep uplands bordering Reach 3 contain several debris flow channels and springs. Sediment input potential is significant throughout the reach; however, sediment transport through an A3 stream type is very efficient (Rosgen 1985). As a result, larger substrate sizes dominate, and finer particles are flushed through the system. Reach 3 was the only study area to exhibit a substantial portion of boulders and large cobble in the stream channel (Table 14). The very low substrate embeddedness and a high proportion of gravel may provide suitable spawning habitat. However, a small waterfall at the downstream end of Reach 3 is a probable barrier to upstream fish migration, particularly during periods of low flow.

Mean stream depth of 11.9 cm in Reach 3 would provide only limited cover for fish. Suitable refuges and resting areas were sparse throughout the reach. Possibly as a result of drought conditions, pools were small, shallow, and appeared to constitute only marginal fish habitat.

The uppermost survey reach was characterized by a small stream channel and a very low discharge (Table 14). Although steep, erodable valley walls characteristic of an A3 stream type occur in this section of the upper Gardner River, streambanks and associated vegetation displayed a stable condition. The influence of the steep valley slopes in Reach 4 is reflected in a small solar angle. Because a negative correlation exists between solar angle and degree of shading to the stream channel, the small solar angle of Reach 4 indicates the greatest amount of shading in this stream reach. Bottom substrate in Reach 4 was restricted to equivalent proportions of cobble and gravel and lacked fine sediments (Table 14).

Pools in Reach 4 were similar to those in Reach 3 (Table 14). Pools in both habitat survey sections were rated poor with respect to their ability to provide adequate cover for fish or to support various life history stages of resident fish.

In 1988, cursory-level surveys were conducted on 10 perennial tributary streams and 7 intermittent tributaries to the upper Gardner River. Sixty-five percent of the tributaries are first-order streams, 29% are second order, and Fawn Creek is a third-order stream (Table 15). The majority of these tributaries originate on Quadrant Mountain or Little Quadrant Mountain and flow northerly or easterly into the upper Gardner River (Figure 13). Fawn Creek, which contributes over half of the discharge of the upper Gardner River, is nearly three times longer than the other surveyed tributaries. Conversely, the first-order streams have stream lengths ranging from 0.21 km to 3.74 km (Table 15).

With the exception of Stream 100730, which had an extremely small discharge ($0.001 \text{ m}^3/\text{s}$), all perennial tributaries in the upper Gardner River drainage had a mean velocity greater than 13 cm/s and mean water temperature was 9.7°C . Tributary streams in the lower two reaches of the upper Gardner River (100717-100726) generally were much larger than upstream tributaries with respect to discharge, mean width, and mean depth (Table 15). Mean gradient of the perennial tributaries (11.1%) was slightly higher than that of the intermittent streams (9.3%).

Correlation analysis of perennial stream parameters revealed significant positive correlations between watershed size and stream length ($r = 0.98$), watershed size and discharge ($r = 0.97$), and discharge versus mean stream width ($r = 0.89$). A positive relationship between mean stream velocity and mean stream depth ($r = 0.91$) may reflect strong erosive forces in the unconsolidated channel materials of

TABLE 15.-Habitat characteristics of tributaries to upper Gardner River, 1988.

Stream	Stream order	Watershed		Stream length (km)	Elevation		Gradient (%)	Stream flow (m3/s)	Mean width (m)	Mean depth (cm)	Mean velocity (cm/s)	Temperature (C)	pH	Conductivity (umhos/cm)
		size (ha)	length (km)		maximum (m)	minimum (m)								
100717	I	444.10	3.74	2,331.7	2,250.9	2.2	0.012	1.00	8.23	17.37	16	8.0	270	
100718	II	998.70	4.50	2,898.6	2,296.7	13.4	0.046	1.23	12.95	33.22	13	7.6	250	
100719	I	271.40	3.23	2,755.4	2,318.0	13.5	a							
100720	I	120.60	1.57	2,359.1	2,322.6	2.3	a							
Fawn Creek	III	4,014.60	14.30	2,971.8	2,330.2	4.5	0.254	4.45	17.07	38.30	7	7.6	460	
100722	II	328.70	2.13	2,645.7	2,418.6	9.9	a							
100723	I	13.70	0.66	2,456.7	2,420.1	5.5	a							
100724	I	95.10	0.86	2,523.7	2,438.4	9.9	0.029	1.85	6.86	25.50	8	8.0	210	
100725	I	11.80	0.33	2,496.3	2,447.5	14.8	0.045	1.74	11.89	25.10	10	7.2	270	
100726	II	906.70	4.98	2,932.2	2,508.5	8.5	0.058	2.96	11.35	20.22	8	7.6	230	
100727	I	38.40	0.41	2,651.8	2,578.6	17.9	0.004	0.77	4.19	13.31	6	7.2	150	
100728	I	183.10	2.02	2,859.0	2,584.7	13.6	a							
100729	I	13.90	0.51	2,648.7	2,603.0	9.0	a							
100730	I	48.80	0.34	2,667.0	2,621.3	13.4	0.001	0.72	2.90	4.47	7	7.6	285	
100731	I	18.90	0.21	2,654.8	2,630.4	11.6	a							
100732	II	100.10	0.34	2,743.2	2,691.4	15.2	0.005	1.02	4.19	13.51	9	7.6	120	
100733	II	245.20	2.40	2,987.0	2,728.0	10.8	0.014	2.02	6.10	13.21	13	7.6	500+	

^a Channel dry on survey date.

the upper Gardner River during periods of increased streamflow. A significant negative correlation was found between stream length and gradient ($r = -0.65$). A non-significant negative correlation was also expressed between gradient and mean velocity of the perennial streams ($r = -0.35$). This was somewhat puzzling, because a positive association between these two parameters was initially expected. However, in the higher gradient tributaries of upper Gardner River watershed, the tributaries are characterized by a high incidence of small pools that exhibit a cascade-like appearance with reduced mean velocity. Thus, the steepest portions of this drainage generally exhibit only moderate velocities.

Gradients of the tributaries may influence fish distribution in the upper Gardner River watershed. Lanka et al. (1987) showed that a negative correlation existed between stream gradient and standing crop of brook trout in Wyoming streams with physical characteristics similar to those of the upper Gardner River tributaries. Gradients below 17% do not prevent brook trout residency, but populations may decline rapidly above the optimum gradient of 4% (Platts 1976). With the exception of Fawn Creek and Stream 100717, the tributaries of the upper Gardner River may have gradients that are unsuitable for occupancy by brook trout. The primary fishery value of these tributaries may be in providing nursery areas in their lower sections and contributions of invertebrate drift into the mainstem.

Chemical features.-Baseline water chemistry determinations revealed that all tributaries to the upper Gardner River were slightly basic (mean pH, 7.6) (Table 15). Conductivity ranged from 120 $\mu\text{mhos/cm}$ in Stream 100732 to over 500 $\mu\text{mhos/cm}$ in Stream 100733; however, most of the tributaries had conductivity values close to the mean value of 275 $\mu\text{mhos/cm}$. High conductivity in Fawn Creek may be a reflection of a large watershed draining several different types of geologic formations. Mean pH (7.2) and mean conductivity (235 $\mu\text{mhos/cm}$) in the mainstem reaches were both somewhat lower than in the tributaries.

The mainstem upper Gardner River is a dilute stream with total dissolved solids less than 50 mg/L. Analyses by a commercial laboratory indicated that calcium and bicarbonate are the major ions in Reach 4 (Table 16). Most chemical components from this sample, including alkalinity, sulfates, and hardness, are substantially below parkwide mean values. A notable exception is turbidity, which is at the same level as most other streams in Yellowstone National Park (mean: 1.86 NTU). Previous analyses of water samples from the Gardner River (Jones et al. 1983) showed an increasing trend in chemical constituents in a downstream direction. A sample taken just downstream of Reach 1 had chemical concentrations similar to or slightly above the parkwide mean for streams. These higher values (compared to

TABLE 16.-Chemical characteristics of backcountry streams surveyed,
Yellowstone National Park, 1988.

	Gardner River		Gardner River		Firehole River		Firehole River		Firehole River		Firehole River	
	Reach 4	8/3/88	100733	8/3/88	Reach 1	6/14/88	Reach 2	6/14/88	Reach 3	6/14/88	Reach 4	6/14/88
Spec. cond. (umhos)	100		500+		-		-		-		-	
Total alkalinity	21		31		77		108		29		58	
Ca hardness	13.4		385		8.39		6.27		9.01		8.59	
Total hardness	17.5		433		12.5		10.4		13.1		12.7	
Total dissolved solids	25		460		230		510		140		220	
Carbonate alkalinity	3.8		0		12		12		0		3.8	
Bicarbonate alkalinity	17		31		65		96		29		54	
Carbonates	2.3		0		7.3		7.3		0		2.3	
Bicarbonates	26		38		94		130		35		71	
Hydroxides	0		0		0		0		0		0	
Carbon dioxide	<1.0		1.1		<1.0		<1.0		<1.0		<1.0	
Chloride	<1.0		2.8		40		59		14		32	
Sulfate	2		320		4		5		2		-	
Flouride	<0.1		<0.1		6.50		7.6		4.10		4.9	
Potassium	0.79		0.88		5.20		4.39		3.72		4.81	
Mg hardness	4.12		48.2		<4.12		<4.12		<4.12		<4.12	
Calcium	5.37		154		3.36		2.51		3.61		3.44	
Magnesium	<1.0		11.7		<1.0		<1.0		<1.0		<1.0	
Sodium	<0.50		1.47		65.0		54.2		32.5		43.0	
Iron	0.35		0.11		<0.10		<0.1		<0.10		<0.1	
Manganese	<0.05		<0.05		<0.05		<0.05		<0.05		<0.05	
Copper	<0.01		<0.01		<0.01		<0.01		<0.01		<0.01	
Silica	1.3		2.7		100		13		29		86	
Color (PCU)	<5		<5		12		<5		<5		<5	
Turbidity (NTU)	1.9		1.4		<1		<1		<1		<1	
TOC	<1		16.9		1.6		2.2		1.7		44	
Ortho-phosphate	0.03		<0.03		<0.03		<0.03		<0.03		0.04	

1988 results) may be a reflection of contributions from tributary streams.

Chemical analysis of Stream 100733 showed some unusual features. Although alkalinity was low, conductivity, hardness, total dissolved solids, calcium, and sulfate concentrations were all relatively high (Table 16). Concentrations of calcium and sulfates in this stream may reflect a gypsum source upstream from the sample site. Calcium-sulfate streams are rare in Yellowstone National Park. To date, only two other surveyed streams (Hellroaring Creek and Red Creek) have been placed in this category.

Macroinvertebrates.—Twenty-two taxa of macroinvertebrates were collected from the upper Gardner River mainstem (Table 17). Both abundance and species richness (number of taxa collected) increased in an upstream direction. This parallels a pattern frequently observed in streams in Yellowstone National Park (Jones et al. 1984-1988). Abundance in Reach 4 was more than double that of Reach 1. This may be a reflection of more suitable substrate sizes in the uppermost reach. Gravel and cobble are optimum substrate sizes for many riffle dwelling species (Rabeni and Minshall 1977). Species richness was very similar in the two samples from Reach 2. Reach 4 had the highest species richness and community diversity, as measured by the Shannon-Wiener diversity index (Cook 1976).

Ephemeroptera (mayflies) were the dominant group in all four stream reaches. Although Ephemerellids were most abundant in the lower two reaches, Heptageniidae and Siphonuridae were dominant in the uppermost reach. Plecopterans (stoneflies) were restricted to the upper two reaches. This distribution may be a response to a large proportion of gravel and cobble with minimal amounts of silt present. Stoneflies are commonly located in silt-free, large substrate (Pennak 1978; Hynes 1970). Although *Rhyacophila* sp. was common in three of the four reaches sampled, other Trichopterans (caddisflies) were uncommon in the upper Gardner River mainstem.

From a trophic standpoint, collectors were the most abundant groups in each sample. In contrast, shredders were collected only in Reach 3 (Table 17). This reach contained the largest substrate particles of any surveyed reach (Table 14). Larger substrate particles trap larger detritus particles (Rabeni and Minshall 1977) that shredders depend upon (Vannote et al. 1981). Additionally, allochthonous riparian detrital inputs to the mainstem were only moderate or minimal throughout most of the upper Gardner River. The predominance of collectors and scrapers (Table 17) is characteristic of streams with diminished riparian influence (Cummins 1977). The large proportion of predators in Reaches 2, 3, and 4 may reflect an adequate prey base. Hawkins et al. (1982) noted a strong positive correlation between predators and the abundance of collectors,

TABLE 17.-Occurrence and densities of macroinvertebrates found in stream reaches, upper Gardner River mainstem, 1988.

Reach No.	01	02		03	04
		A	B		
Turbellaria (Planarians)					
Tricladida					5
Insecta					
Ephemeroptera (mayflies)					
Siphonuridae					
<u>Ameletus</u> sp.					8
Baetidae					
<u>Baetis bicaudatus</u>				4	1
<u>Baetis tricaudatus</u>	3				
Heptageniidae					
<u>Cinygmula</u> sp.	2				5
<u>Rhithrogena</u> sp.					1
<u>Epeorus albertae</u>		4		4	
<u>Epeorus deceptivus</u>			1		
Ephemerellidae					
<u>Attenella margareta</u>	1				
<u>Drunella coloradensis</u>	6	4	2	3	
<u>Drunella doddsi</u>		3			
<u>Ephemeralla infrequens</u>	2				
Plecoptera (stoneflies)					
Nemouridae					
<u>Zapada</u> sp.				1	
Perlodidae					
<u>Megarcys</u> sp.					5
Chloroperlidae				2	2
Trichoptera (caddisflies)					
Rhyacophilidae					
<u>Rhyacophila</u> sp.		3	4	3	6
Glossosomatidae					
<u>Glossosoma</u> sp.				2	
Limnephilidae					
<u>Apatania</u> sp.	1	3	2		
Diptera (true flies)					
Tipulidae					
<u>Dicranota</u> sp.				1	
<u>Hexatoma</u> sp.		1	1		
Chironomidae		6	4		7
TOTAL TAXA:	6	6.5*		8	9
TOTAL #/m ²	161	205*		215	431
% SHREDDERS	0	0*		5	0
% COLLECTORS	87	46*		45	51
% SCRAPERS	13	26*		20	9
% PREDATORS	0	28*		30	40

* Mean value of two replicate samples (A and B)

particularly Baetidae and Chironomidae, in small Oregon Cascade Range streams. A similar association may be occurring in the upper Gardner River.

All samples were evaluated according to a Biotic Condition Index (BCI) (Winget and Mangum 1979). Values ranged from 1.01 to 1.84 and indicated excellent habitat and water quality. The vast majority of the taxa collected have a restricted range of habitat conditions; that is, they are only slightly tolerant of environmental fluctuations. Despite the indication of optimum habitats in the upper Gardner River, macroinvertebrate production levels are apparently low in relation to other streams surveyed in Yellowstone National Park in recent years (Jones et al. 1984-1988). Because the discharge and elevation of the upper Gardner River is similar to many of these streams, lower production levels in the upper Gardner River may indicate natural disturbances and fluctuations in the stream channel. Abundance of many macroinvertebrate taxa may decline significantly in unstable substrates dominated by smaller size particles (Gurtz and Wallace 1984).

The total number of macroinvertebrate taxa collected from the tributaries was over 60% greater than that sampled in the upper Gardner River mainstem (Table 18). However, mean macroinvertebrate abundance in the tributaries (222 individuals/m²) was less than the mean level found in the mainstem (253 individuals/m²). Stream 100718 exhibited the highest species richness of any sample in the upper Gardner River. Despite its large size, Fawn Creek ranked only sixth in macroinvertebrate abundance and third in species richness. Stream 100730 ranked last in both categories; however, this stream was nearly dry on the survey date (Table 15). Stream 100724 had a higher Shannon-Wiener diversity index than Stream 100726, even though species richness was lower in Stream 100724 (Table 18).

Ephemeroptera and Trichoptera were both well represented by 10 species each in the tributaries to the upper Gardner River. Baetids exhibited a widespread distribution, but were not found in the upper three tributaries. *Rhyacophila* sp. was sampled in 70% of the tributaries throughout the upper Gardner River drainage (Table 18). Plecopterans were collected only in relatively low numbers. Dipterans were a minor group with the exception of Chironomids.

The majority of samples revealed a dominant collector-scraper association characteristic of medium sized (third- to fifth-order) streams (Figure 14). This result is somewhat puzzling because all but one of the tributaries in the upper Gardner River watershed are first- or second-order streams (Table 15) that would be expected to have a dominant riparian influence. However, most of these streams are located in open areas with only moderate amounts of

TABLE 18.-Occurrence and densities of macroinvertebrates found in Gardner River tributaries, 1988.

Tributary #	100717	100718	Fawn Creek	100724	100725	100726	100727	100730	100732	100733
Turbellaria (Planarians)										
Tricladida							3		3	
Insecta										
Ephemeroptera (mayflies)										
Siphonuridae										
<u>Ameletus</u> sp.						1	2			
Baetidae										
<u>Baetis bicaudatus</u>				3	5	2	2			
<u>Baetis tricaudatus</u>	3	3	3							
Heptageniidae										
<u>Cinygmula</u> sp.				5			5			4
<u>Rhithrogena</u> sp.										2
<u>Epeorus albertae</u>					6					
<u>Epeorus deceptivus</u>						9				
<u>Epeorus longimanus</u>										1
Ephemerellidae										
<u>Attenella margarita</u>			1							
<u>Drunella coloradensis</u>				4			4			
Plecoptera (stoneflies)										
Peltoperlidae										
<u>Yoraperia brevis</u>				4					3	
Nemouridae										
<u>Zapada</u> sp.		2			2	2	1		1	1
Perlidae										
<u>Doroneuria theodora</u>									1	
<u>Hesperoperia pacifica</u>	1	1								
Perlodidae										
<u>Megarcys</u> sp.									2	
Chloroperlidae			1				2	2		
Trichoptera (caddisflies)										
Hydropsychidae										
<u>Arctopsyche grandis</u>										2
<u>Parapsyche</u> sp.					3	7				
Rhyacophilidae										
<u>Rhyacophila</u> sp.		4	4		4	7		4	3	6
Glossosomatidae										
<u>Glossosoma</u> sp.				3	2	3				
Brachycentridae										
<u>Amiocentrus</u> sp.	1	1								
<u>Brachycentrus</u> sp.	4									
Lepidostomatidae										
<u>Lepidostoma</u> sp.							1			
Limnephilidae										
<u>Apatania</u> sp.			3	2			2			
<u>Dicosmoecus</u> sp.								1		
<u>Hesperophylax</u> sp.			1							
Coleoptera (beetles)										
Dytiscidae	1	4	1							
Elmidae										
<u>Stenelmis</u> sp.		5								
Diptera (true flies)										
Tipulidae										
<u>Dicranota</u> sp.		1								
<u>Hexatoma</u> sp.			1							
Chironomidae		6	3							
<u>Cricotopus nostocki</u>							4	4		
Simuliidae								2		
<u>Prosimulium</u> sp.	3									
Gastropoda										
Lymnaeidae										
<u>Lymnea stagnalis</u>		2								
Pelecypoda										
Sphaeriidae		4								
TOTAL TAXA:	6	11	9	6	6	7	10	5	6	6
TOTAL #/m ²	140	355	194	226	237	334	280	140	140	172
% SHREDDERS	8	9	6	19	9	6	9	15	40	6
% COLLECTORS	77	36	39	45	50	47	63	31	0	34
% SCRAPERS	0	22	17	36	23	24	20	8	0	22
% PREDATORS	15	33	39	0	18	23	9	46	60	38

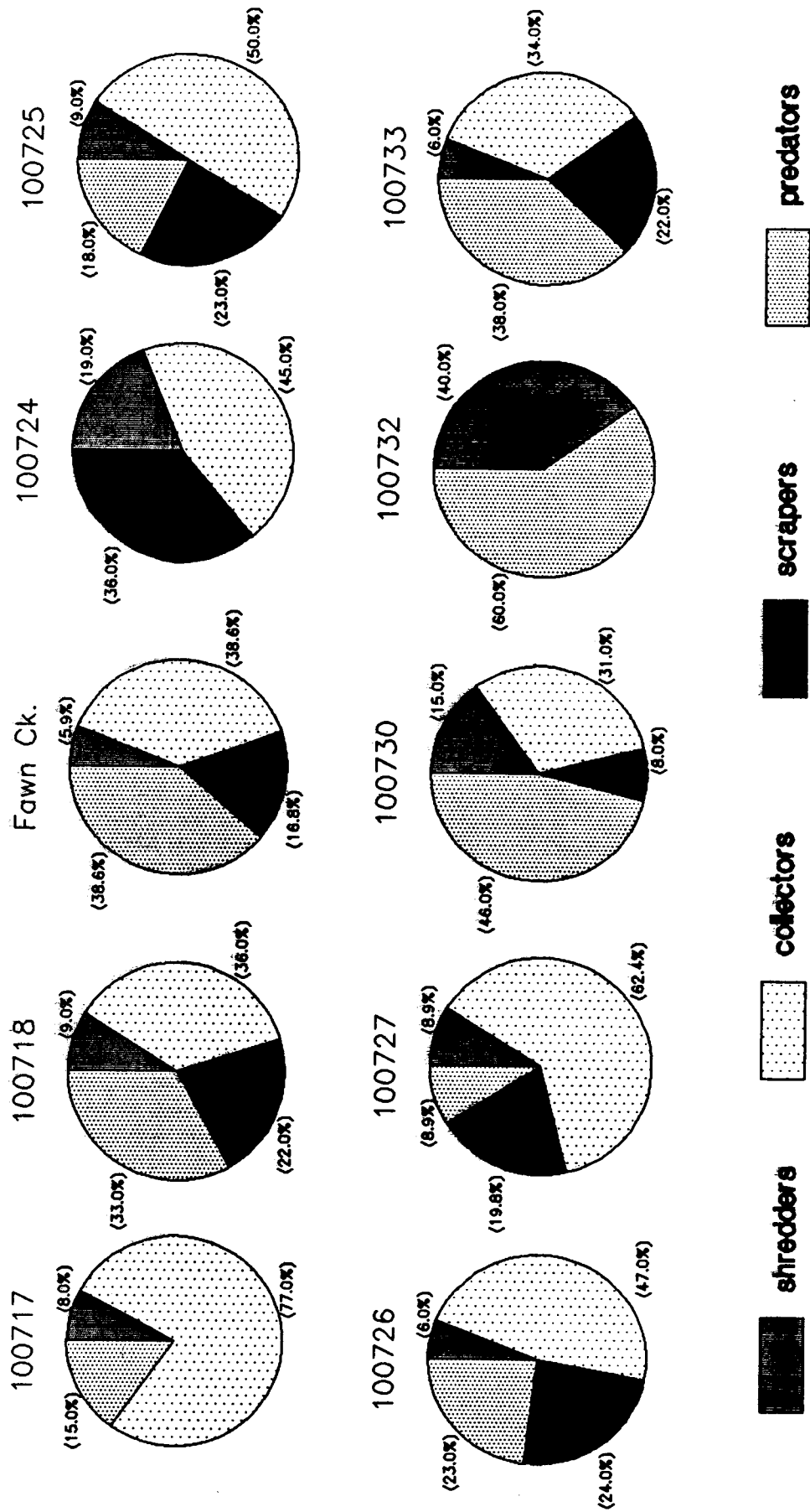


FIGURE 14.-Trophic groups of macroinvertebrate samples collected from tributaries to upper Gardner River, 1988.

coniferous canopy. Consequently, allochthonous detrital input is reduced in these streams, and proportions of shredders would be expected to be lower than in other systems. The highest proportions of shredders, primarily Plecopterans, occurred in Stream 100732, which is a high gradient stream containing abundant amounts of autochthonous algae. These conditions may be preferred by shredders in open canopy settings (Hawkins et al. 1982). Predators normally comprise a minor proportion of the total macroinvertebrate community (Cummins 1977). The relatively high incidence of predators in many of the tributary samples may be attributable to the abundance of the predatory caddisfly *Rhyacophila* sp. and abundant prey base.

All tributaries were rated excellent quality by the BCI (Winget and Mangum 1979). The macroinvertebrate community in Stream 100718 may be more tolerant of environmental fluctuations. Although this situation would normally occur in a system that is being degraded (Winget and Mangum 1979), the community in Stream 100718 may reflect unstable conditions resulting from unconsolidated geological materials. Streams 100725 and 100726 both contained *Parapsyche* sp. This species requires quite specific environmental conditions and is classified as a clean water indicator species (Mangum 1988). The presence of *Parapsyche* sp. indicates high quality macroinvertebrate habitat in these two streams.

The macroinvertebrate community in Stream 100733 yielded an extremely high BCI. All taxa in this stream are only slightly tolerant of fluctuating environmental conditions, but they occurred in a stream with sulfate levels over 300 mg/L. The reason for the presence of sensitive macroinvertebrate species in this stream is unknown. Generally, the macroinvertebrate communities presently found in tributaries of the upper Gardner River are indicative of high quality habitat, even though sampled standing crops were low. Emergence of adults in response to decreased discharges or an abbreviated growing season may partially explain the low production levels.

Fish.-During the 1988 habitat survey, fish were observed but not sampled in Reaches 1 and 2 of the upper Gardner River. All observed fish were judged to be brook trout. No fish were observed upstream from the water fall located in the lower portion of Reach 3.

Previous fish sampling in the upper Gardner River has been limited to one electrofishing survey of a 100-m section in Reach 1 in 1978. Fifty-five brook trout were captured. Mean length of fish over 115 mm was 176 mm (Jones et al. 1979).

Data for the upper Gardner River has provided creel survey estimates from Volunteer Angler Report (VAR) returns. However, interpretation is somewhat confusing because the 1988 survey area is included in analyses of downstream

sections that probably sustain much higher levels of angler use due to ease of access and proximity to a major campground. Consequently, data from the major tributaries in the survey area may more accurately reflect true angler-use levels in the mainstem. Panther Creek and Fawn Creek, combined, sustain angler use levels ranging from less than 100 angler days per year to over 300 angler days annually. Since 1976, the estimated annual harvest from Panther Creek has been 135 brook trout. Comparable estimates for Fawn Creek are much less precise because of limited VAR returns. However, number of fish landed, number of fish creeled, and landing rate have declined considerably in Fawn Creek since the mid-1970s. In the past 10 years, 94% of the fish landed in Panther Creek and 100% of the brook trout landed in Fawn Creek have been less than 250 mm total length. If these same trends are occurring in the upper Gardner River mainstem, then it would appear that the current harvest regulation of five brook trout under 254 mm has the potential to protect larger fish in the population. However, the upper Gardner River is a popular fishery for local resident anglers, so that actual angler use and impacts may be considerably greater than indicated by VAR returns (Jones et al. 1979). Continued monitoring of this fishery is suggested.

Fire-Affected Watersheds

Forest fire activity of 1988 in Yellowstone National Park affected over 400,000 hectares and influenced aquatic as well as terrestrial ecosystems (GYCC 1989). Prior to 1988, studies on the effects of forest fires on aquatic systems in Yellowstone National Park have focused on small scale fires in the southern portion of the Park (Albin 1979; Stottlemeyer 1983). In 1988, six study areas were established to monitor effects of fire activity on fish population-aquatic habitat associations. Three sites were located in the Lamar River drainage (Figure 15) and three sites were located in the Madison River drainage (Figure 16). All of the 1988 sample sites support important fisheries (Table 4).

Potential habitat impacts on these aquatic systems may occur during higher streamflows. The information presented here represents post-fire, pre-runoff conditions. In addition, only one reconnaissance-level survey was conducted on each stream, so the data presented should be regarded as baseline and preliminary in scope.

The six sample sites include one fourth-order stream (Soda Butte Creek), four fifth-order streams (Slough Creek, Lamar River, Gibbon River, and Firehole River), and one sixth-order stream (Madison River). The Gibbon River site was classified as a moderate gradient, stable B1 stream type (Rosgen 1985) (Table 19). This study section differed from

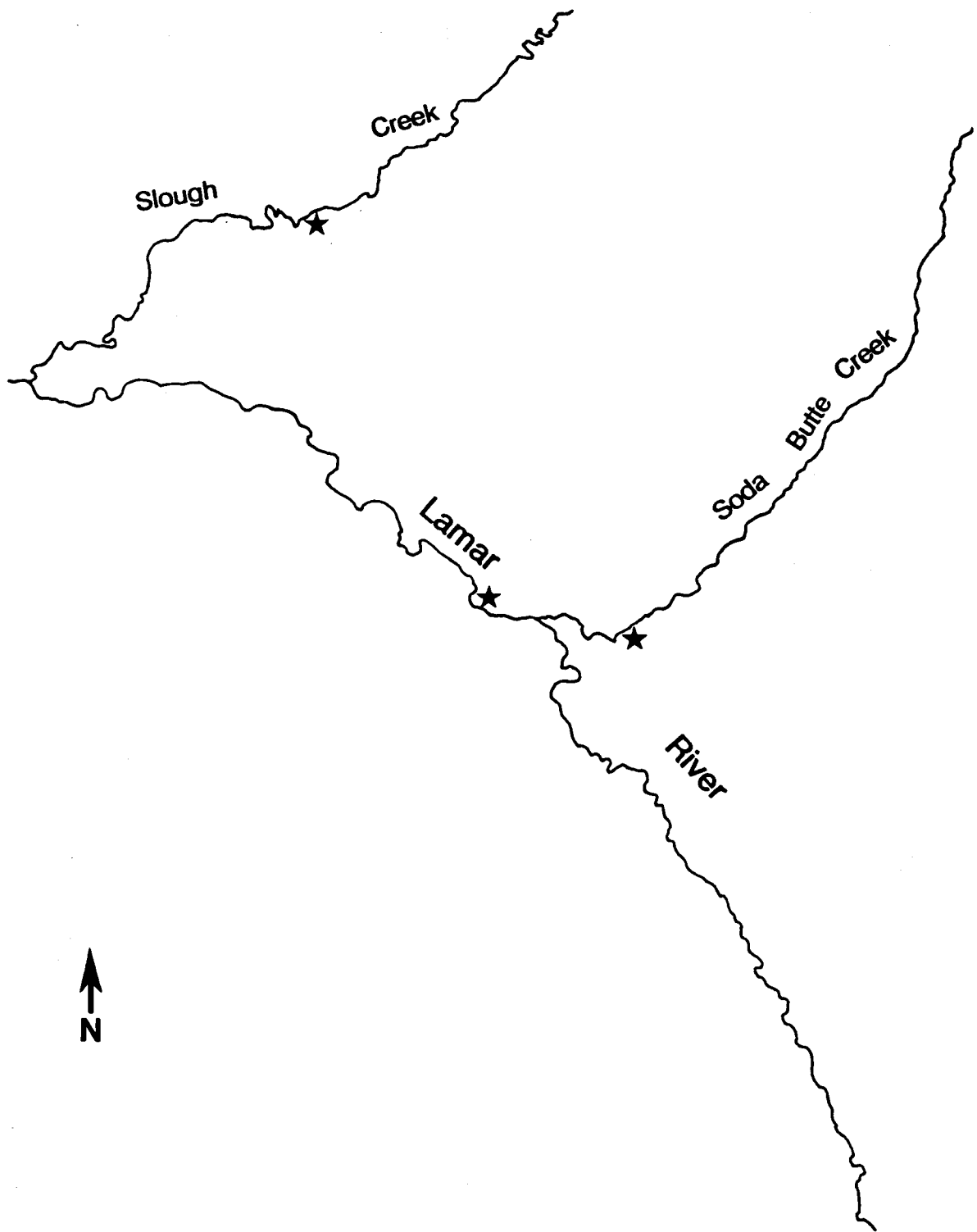


FIGURE 15.-Lamar River drainage showing location of Fall 1988 sampling sites.

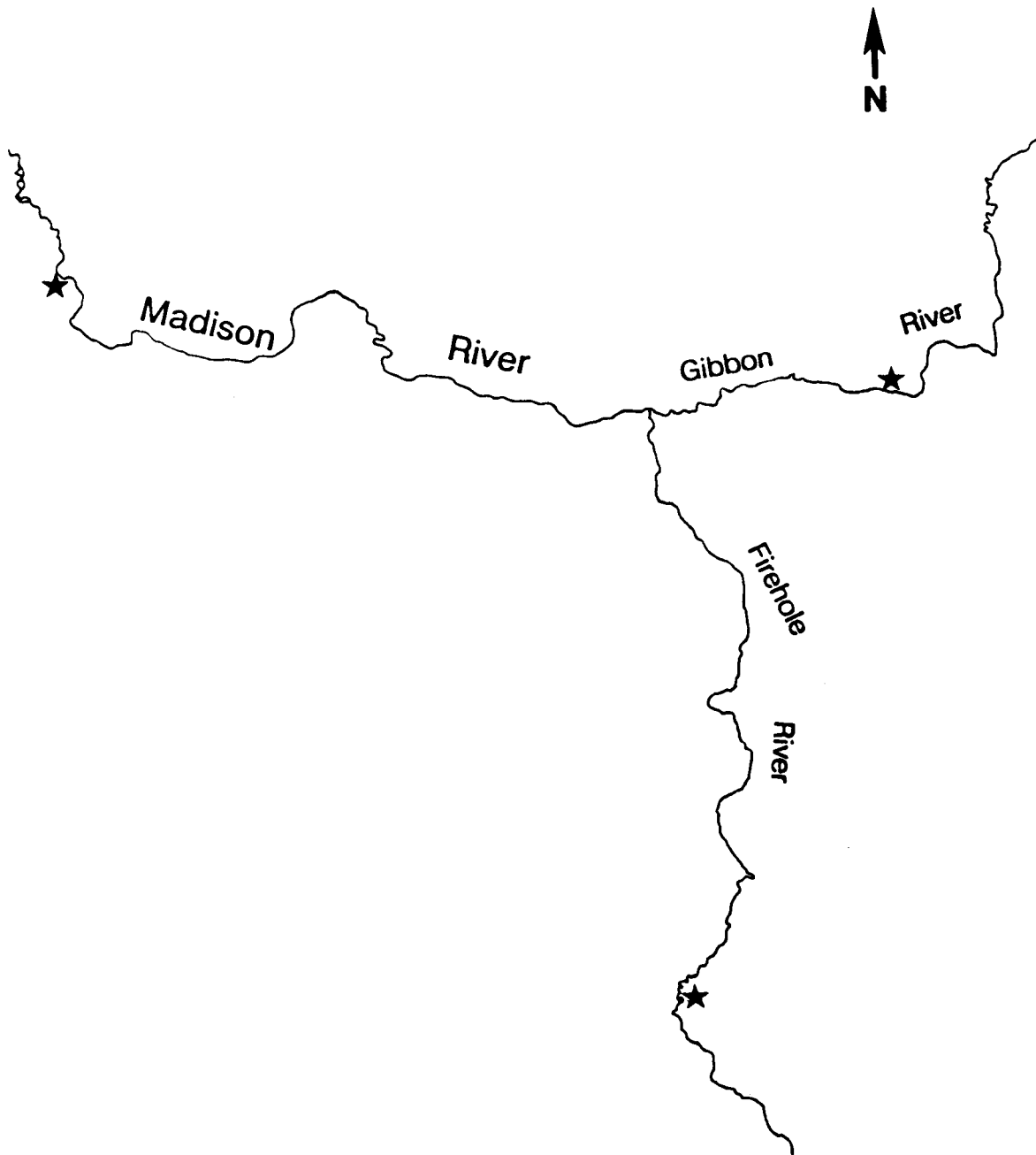


FIGURE 16.-Madison River drainage showing location of Fall 1988 sampling sites.

TABLE 19.-Drainage basin characteristics and habitat features of fire affected streams, Yellowstone National Park, 1988.

Habitat features	Slough Creek	Soda Butte Creek	Lamar River	Gibbon River	Firehole River	Madison River
Sample date	10/19/88	11/3/88	11/6/88	10/24/88	11/1/88	10/25/88
Time	1410	1030	0945	1045	1020	1100
Stream order	V	IV	V	V	V	VI
Length (km)	2.06	3.26	2.27	1.52	2.37	3.52
Elevation:						
Maximum (m)	1,973.6	2,016.3	2,002.5	2,124.5	2,211.3	2,017.1
Minimum (m)	1,966.0	2,002.5	1,988.8	2,110.7	2,209.8	2,004.1
Drainage size (hectares) ^a	36,033.5	20,938.2	99,816.1	26,804.6	23,702.7	111,213.5
Stream type	C3	C1	C1	B1	C3	C2
Water column:						
Flow (m ³ /s)	1.454	0.684	1.599	2.158	3.300	9.174
Channel width (m)	32.9	24.4	41.7	19.3	21.5	52.9
Stream width (m)	21.4	13.3	24.9	17.1	16.2	51.4
Stream depth (cm)	18.59	16.76	27.74	20.42	32.31	28.04
Stream shore water depth (cm)	0.00	0.00	0.00	5.79	10.67	4.57
Riffle width (m)	9.97	10.70	2.14	10.18	5.61	39.08
Pools:						
Width (m)	8.6	1.2	17.1	2.3	5.3	3.1
Quality ^b	2.5	1.2	3.8	2.2	30.3	1.5
Feature	2	3.4	4.2	1.4	2.7	3.6
Solar angle (°)	145.3	155.7	152.3	63.3	139.7	149.3
Channel morphology						
Streambank alteration	45.8	38.3	52.5	23.3	11.7	21.7
Vegetative stability	3.5	2.5	3.2	3.5	4.0	3.0
Undercut (cm)	0.0	0.0	0.0	6.7	12.2	2.4
Channel-bank angle (°)	144.2	149.2	156.7	112.5	90.8	128.3
Stream bottom:						
Gradient (%)	0.1	0.7	1.1	3.9	0.5	0.3
Sinuosity	1.15	1.18	1.03	1.33	1.43	1.21
Substrate:						
Bedrock				56.0		
Boulder (> 305 mm)		2.3	9.6	10.2	8.3	2.8
Cobble (64-305 mm)	8.0	70.4	54.8	13.1	0.5	74.5
Gravel (2-64 mm)	59.5	18.4	6.9	2.4	48.2	5.7
Sand (0.6-2 mm)	28.4	2.3	10.9	13.6	18.3	11.6
Silt (< 0.6 mm)	4.0	6.8	17.4	4.2	24.3	5.3
Embeddedness	10.00	50.00	21.70	70.00	23.30	41.70
Channel vegetative cover (cm)	0.00	13.11	0.00	131.06	240.79	548.64
Riparian zone:						
Streamside cover	1.8	2.2	2.5	2.0	2.0	1.5
Vegetative use	33.30	13.30	25.80	9.17	27.50	13.30
Vegetation overhang (cm)	0.00	0.00	0.00	0.61	3.05	0.00
Habitat type	4.2	12.6	8.12	18.9	12	8.13

^a After Rosgen (1985).

^b 1 = log, tree, root, stump, brush, or debris; 2 = channel meander; 3 = rubble or gravel
4 = boulder or bedrock; 5 = stream channel; 6 = fire sediments; 7 = streambank;
8 = culvert, bridge, or other manmade object; 9 = beaver dam or tunnel.

the other fire sites in substrate composition, gradient, amount of shading (solar angle), and degree of embeddedness (Table 19). The other five study sites were all low gradient, C-type channels (Rosgen 1985) (Table 19).

Sites in the Lamar River drainage were noticeably lacking in channel vegetation cover and undercut banks (Table 19). The Madison River contained the greatest amount of channel vegetation; however, vascular plants comprised the majority of the instream vegetation. At the Firehole River site and the Gibbon River, channel vegetation consisted primarily of downed timber.

Although C-type channels can transport large amounts of bedload sediment, they are susceptible to erosion (Rosgen 1985). Structures, such as logs, that modify direction of streamflow in unstable channels may lead to some additional erosion (Pfankuch 1975). Thus, increased inputs of trees into the stream due to fire activity could potentially accelerate erosion processes at some of the study sites. However, if erosion results in undercutting of banks, additional cover for fish may be created. Introduction of more downed timber into the stream channel following a forest fire may result in an increased sediment retention rate and additional detritus available to macroinvertebrates (Molles 1982).

Potential post-fire impacts to all six study sites include loss of riparian vegetation, increased sedimentation, and more intense peak flows (GYCC 1989). The current study will examine these concerns through habitat and fish population monitoring. Fire affected riparian vegetation may become less stable. Streambank alteration could increase substantially if riparian stability is decreased. Increased sedimentation may cause a major shift in substrate composition towards smaller size particles. In conjunction with future water chemistry and macroinvertebrate analyses, the fish and habitat data from 1988 may provide a baseline against which both short-term and long-term fire effects may be measured.

BECHLER RIVER

The Bechler River lies in a 348-km² watershed in the southwest portion of Yellowstone National Park. Formed by the confluence of the Phillips Fork, Gregg Fork, and Ferris Fork rivers at the Three Rivers Junction (elevation 2,250 m), the Bechler River flows southwest for approximately 27 km before joining the Falls River at an elevation of 1,920 m near the southern boundary of Yellowstone National Park (Figure 17). Although average stream gradient of the Bechler River is only 1.3%, three waterfalls (Bechler Falls, Colonnade Falls, and Iris Falls) (Figure 17) on the mainstem are barriers to upstream fish passage.

Because Bechler Falls on the Bechler River and Cave Falls on the Falls River (Figure 17) are barriers to upstream fish passage, it is probable that the Bechler River was originally barren of fish life. Initial fish introductions were apparently unofficial, and the dates are unknown (Jones et al. 1979); however, by the late 1800s, trout (species unknown) were present as far upstream as Colonnade Falls (Jordan 1891). Smith and Kendall (1921) also found trout (probably cutthroat trout *Oncorhynchus clarki*) in the Bechler Meadows area (Figure 17) during a survey in 1919.

Stocking records (Varley 1981) indicate that only cutthroat trout were officially planted in the Bechler River; however, unofficial introductions of rainbow trout *Oncorhynchus mykiss* must also have occurred at some time. Presently, an apparently pure population of cutthroat trout inhabits the river upstream of Colonnade Falls, and cutthroat trout x rainbow trout hybrids occur below the falls (Jones et al. 1979).

Angling regulations on the Bechler River were rather liberal prior to 1970, e.g., as late as 1968 the daily creel limit was five trout of any size (U.S. Fish and Wildlife Service unpublished data). Although the daily creel limit was reduced to two trout of any size in the early 1970s (Jones et al. 1977), Jones et al. (1979) reported that angler harvest was negatively impacting fish populations. To offer greater protection to the assumed genetically pure cutthroat trout population upstream of Colonnade Falls, a catch-and-release-only regulation was implemented in this area in 1979; the daily creel limit below Colonnade Falls remained at two trout of any size (Jones et al. 1980). These regulations stayed in effect until 1987, when new regulations implemented throughout the Park (Jones et al. 1988) extended catch-and-release-only fishing to the entire Bechler River.

The objective of this study was to document the current status of fish populations and the sport fishery in the section of river between Colonnade Falls and Bechler Falls.

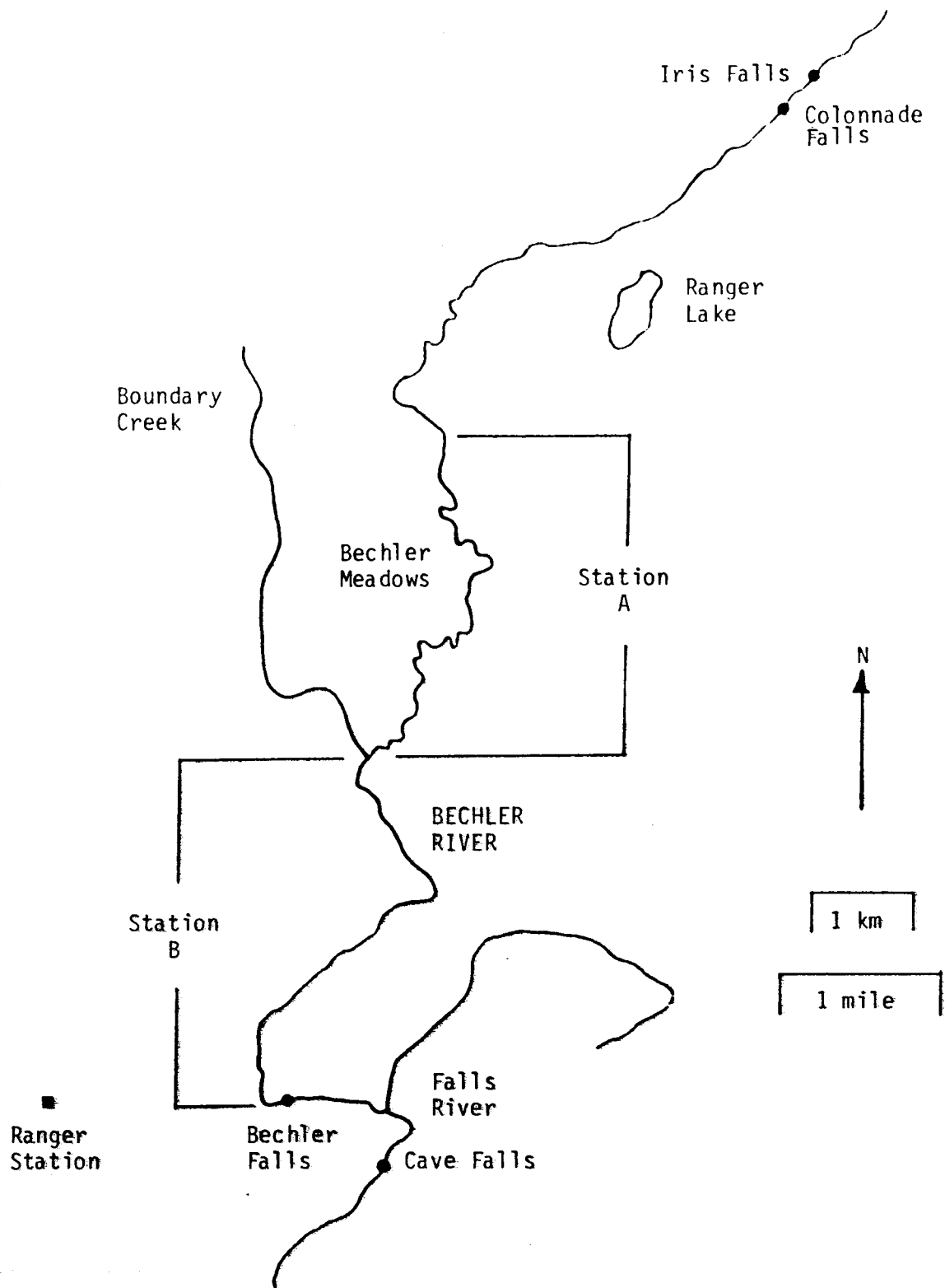


FIGURE 17.-Bechler River showing electrofishing stations A and B.

This section was selected because most of the annual angler effort occurs in this area, and because of logistic constraints. These data provide a baseline for the evaluation of long-term effects of the catch-and-release regulation implemented in 1987.

Study Area

The study area included the Bechler River from Colonnade Falls downstream to Bechler Falls (Figure 17). From the base of Colonnade Falls, the river flows through the lower portion of Bechler Canyon for 2.9 km before passing through a 3.2-km long forested area. Upon leaving the forest, the river meanders through Bechler Meadows for 6.6 km prior to reaching the confluence with Boundary Creek. At the confluence with Boundary Creek, the Bechler River enters another forested area and flows for 4.7 km before passing over Bechler Falls. Jones et al. (1979) and Meyer (1987) discuss the physical, chemical, and biological characteristics of this river segment. Access to this portion of the Bechler River (as well as to the entire river) is by foot or horse.

Methods

Two sample stations were established in the study area to investigate fish populations. Station A, located in the Bechler Meadows, began 0.6 km downstream from Bechler Ford and continued 6.0 km downstream to the confluence of the Bechler River and Boundary Creek (Figure 17). Station B began at the confluence with Boundary Creek and extended 4.7 km downstream to the head of Bechler Falls (Figure 17).

Fish were sampled at Station A on 15-16 August and at Station B on 17 August. In both sample stations, fish were captured during nighttime electrofishing from a 4-m long rubber raft. The raft was equipped with two stationary dropper electrodes (one positive, one negative), fish-holding tanks, a 3.5-kw AC generator, and a Coffelt VVP-15 rectifying unit that output pulsed, direct current.

Because of the difficulty in visually distinguishing genetically pure cutthroat trout and rainbow trout from cutthroat trout x rainbow trout hybrids, all trout captured were classified as hybrids. All captured trout were measured to the nearest 1 mm total length. Weights to the nearest 2 g were taken from five trout in each 25-mm length group, and a geometric-mean regression technique (Ricker 1975) was used to calculate the length-weight equation.

Creel survey data from the Volunteer Angler Report (VAR) system (Dean and Varley 1974) for the period 1980-1988 were used to evaluate the sport fishery.

Statistical procedures used herein are described in Zar (1984). All statistical tests were performed at an alpha

level of 0.05. Computer programs developed by the U.S. Fish and Wildlife Service (unpublished) and those in the commercial statistical package Number Cruncher Statistical System (Hintze 1987) were used to analyze data.

Results

Fish Populations (1988)

Station A.-A total of 140 cutthroat trout x rainbow trout hybrids were captured by electrofishing at Station A in 1988. Captured trout ranged in length from 83 to 583 mm (Figure 18) and averaged 306 mm. Approximately 34% of the fish captured at Station A exceeded 350 mm in length (Figure 18).

Based on a stratified subsample of 76 fish, the length-weight equation was $\ln W = 2.99(\ln L) - 11.50$ ($r^2 = 0.99$) and mean condition (K) was 0.97. Average weight of fish at Station A, calculated by inserting the mean length of 306 mm into the length-weight equation, was 274 g.

Station B.-A total of 165 cutthroat trout x rainbow trout hybrids were caught at Station B in 1988. Length of captured fish varied between 92 and 547 mm (Figure 18). Mean length of captured trout at Station B was 194 mm; the difference in length between stations was statistically significant (t-test; $P < 0.00001$). At Station B, only 4% of captured trout exceeded 350 mm in length (Figure 18).

Based on a stratified subsample of 46 fish, the length-weight equation was $\ln W = 2.72(\ln L) - 9.88$ ($r^2 = 0.99$), and mean condition (K) was 1.14. Average weight of fish at Station B, again derived by inserting mean weight into the length-weight equation, was 86 g.

The Sport Fishery (1980-1988)

Between 1980 and 1988, an average of 485 anglers spent 2,537 h (angler effort) annually fishing the Bechler River between Colonnade Falls and Bechler Falls. During this 9-year period, the average annual number of fish landed was 2,942 at a mean rate of 1.3 fish/h. From 1980 through 1986, approximately 293 fish were creeled each year. The catch-and-release regulation implemented in 1987 has virtually eliminated all angler harvest; however, a few fish are illegally creeled each year.

Angler effort, landing rate, and mean length of fish landed are the three parameters from the VAR system that can best be used to evaluate the sport fishery in this section of the Bechler River. These three parameters have varied considerably between 1980 and 1988, but no obvious increasing or decreasing trends are evident (Figure 19). Angler effort ranged from a high of 5,690 h in 1980 to a low of 904 h in 1987. Concomitantly, landing rate varied

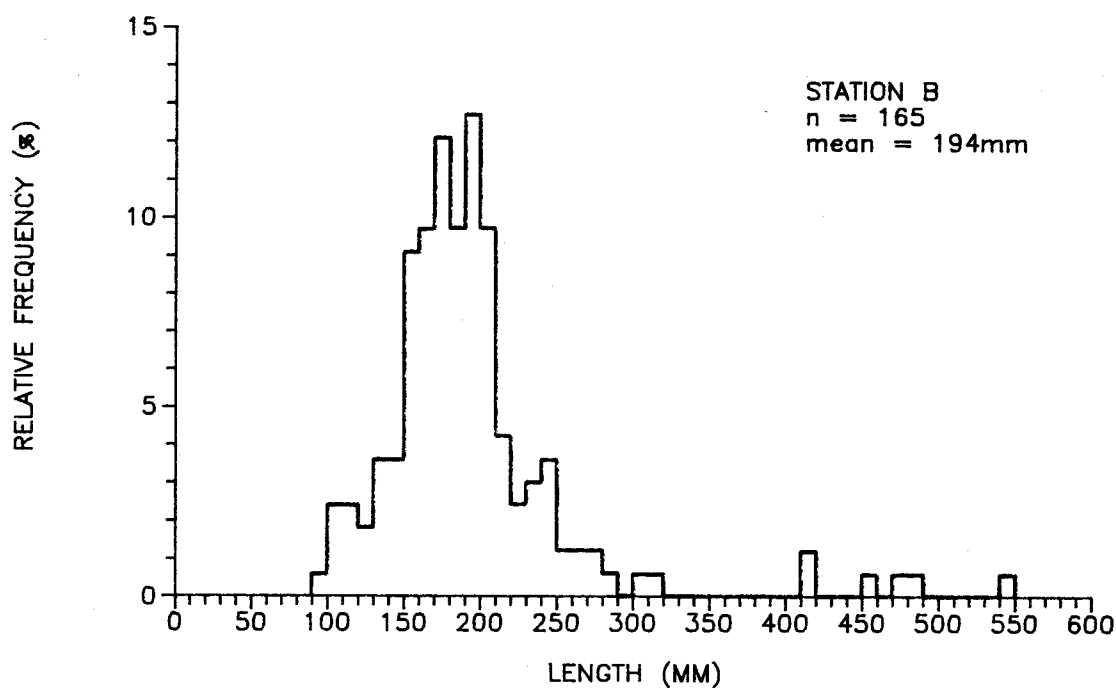
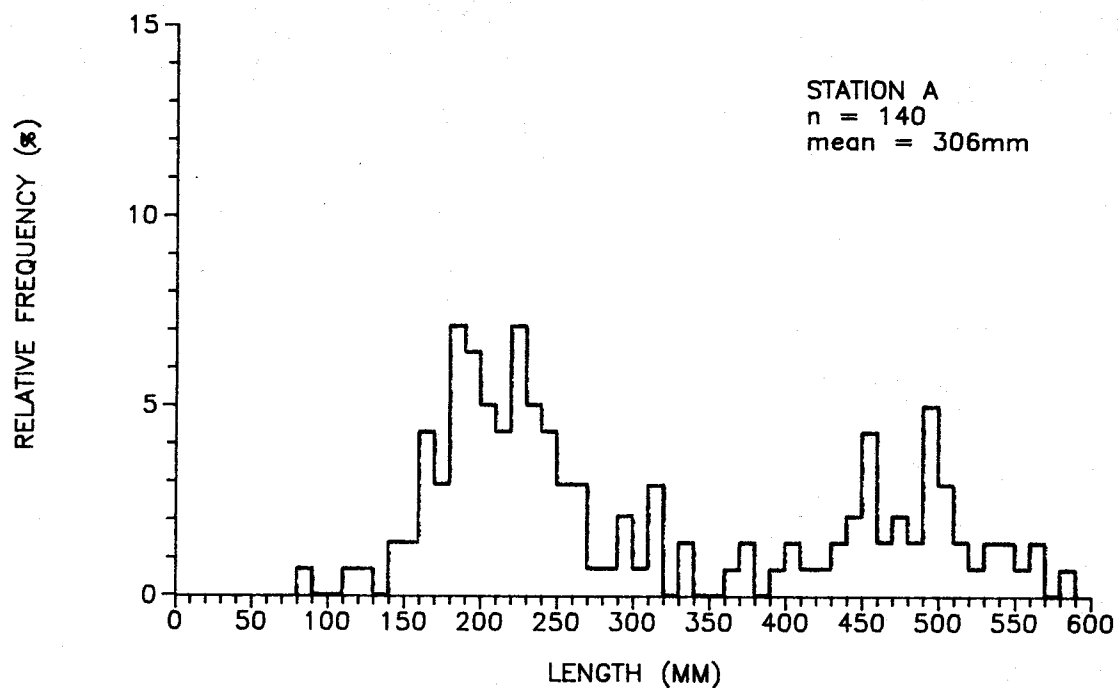


FIGURE 18.-Length frequencies of cutthroat trout x rainbow trout hybrids captured by electrofishing in the Bechler River, 1988.

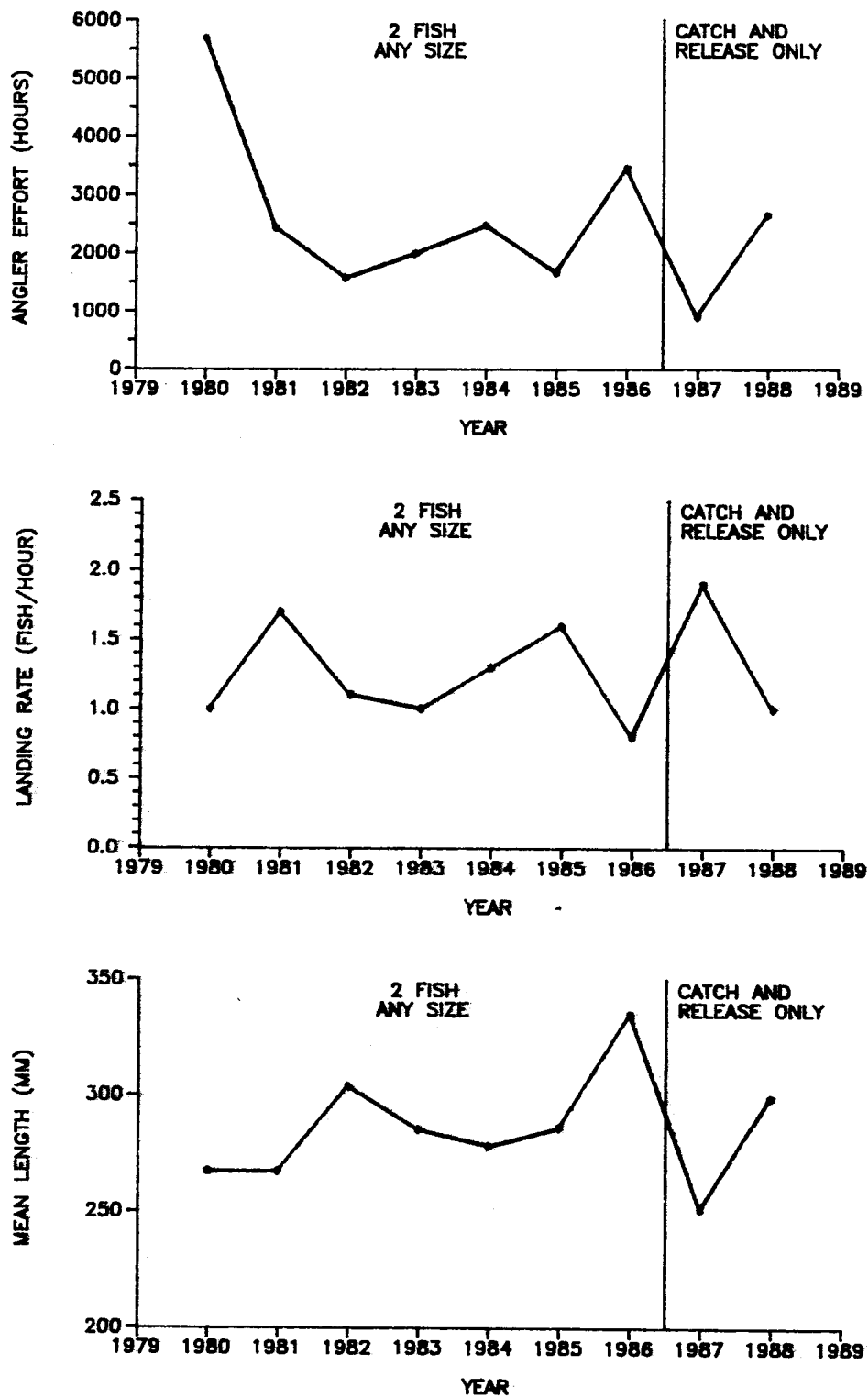


FIGURE 19.-Angler effort, landing rate, and mean length of fish landed on the Bechler River between Colonnade Falls and Bechler Falls, 1980-1988.

between a low of 0.8 fish/h in 1986 to a high of 1.9 fish/h in 1987. Mean length of fish landed was smallest in 1980 and 1981 at 267 mm and largest in 1986 at 335 mm.

Angler effort, landing rate, and mean length of fish landed were separated into the periods 1980-1986 and 1987-1988 to test for changes in the sport fishery since the implementation of the catch-and-release regulation in 1987. Although the data suggest mean annual angler effort (2,754 h in 1980-1986 and 1,781 h in 1987-1988) and mean length of fish landed (281 mm in 1980-1986 and 250 mm in 1987-1988) have declined, and mean annual landing rate (1.21 fish/h in 1980-1986 and 1.45 fish/h in 1987-1988) has increased, the changes are not statistically significant (Table 20).

Discussion

Fish Populations (1988)

Because of the difficulty in visually distinguishing genetically pure cutthroat trout and rainbow trout from hybrid trout, results from this study give no indication of the relative proportion of each genotype in the Bechler River between Colonnade Falls and Bechler Falls. This fact may be rather unimportant to anglers; however, studies (e.g., electrophoresis or mitochondrial DNA) directed at determining the genetic integrity of trout in this section of river could prove useful to fishery managers and researchers in the future.

Based on electrofishing data collected in 1988, trout at Station A and Station B appear to represent different populations. Trout between 80 and 600 mm long are well represented at Station A; however, conditions at Station B appear to favor relatively smaller trout, i.e., those between 80 and 300 mm. Future work should include age-and-growth analysis and fish habitat studies in order to fully compare trout populations between sections and changes in each section through time.

The Sport Fishery (1980-1988)

Analysis of creel survey data from the VAR system for the years 1980-1988 revealed a relatively high degree of variability in angler effort, landing rate, and mean length of fish landed; however, no long-term increasing or decreasing trends were evident. Also, no statistically significant differences were detected in angler effort, landing rate, and mean length of fish landed when the data were partitioned into the periods 1980-1986 and 1987-1988. These results suggest that in the Bechler River between Colonnade Falls and Bechler Falls, no detectable changes have occurred in the fishery since the catch-and-release-only regulation was implemented in 1987.

TABLE 20.-Angler effort, landing rate, and mean length of fish landed on the Bechler River between Colonnade Falls and Bechler Falls for the periods 1980-1986 and 1987-1988. (Means for each parameter were compared using a t-test at $\alpha = 0.05$).

Sport-fishery parameter	Period				P-value
	1980-1986 ^a		1987-1988 ^b		
	Mean	SE	Mean	SE	
Angler effort (h)	2,754	545	1,781	877	0.41
Landing rate (fish/h)	1.21	0.13	1.45	0.45	0.48
Mean length (mm)	281	10	250	34	0.23

^a Daily creel limit of two fish of any size.

^b Catch-and-release only.

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 20). 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 et al. 1975; Jones et al. 1978; Burkhalter 1979; Thompson 1979; Stauffer et al. 1980) (Figure 20). An unnamed cascade near the headwaters (Jones et al. 1977), Kepler Cascades, Firehole Cascades, and Firehole Falls (Figure 20) are barriers to upstream fish passage.

The Firehole River was originally barren of fish life above Firehole Falls (Evermann 1892; Jordan 1891); 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 as a means of supporting high levels of angler harvest. The river above the unnamed cascade near the headwaters is apparently still fishless (Jones et al. 1977), but self-sustaining populations of brown trout *Salmo trutta*, rainbow trout *Oncorhynchus mykiss*, and brook trout *Salvelinus fontinalis* inhabit the mainstem between the unnamed cascade and Firehole Falls. Distribution of these three species is substantially influenced by physical barriers and thermal gradients (Kaeding 1976, 1980; Kaya 1978a; 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 five-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 two-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 (1978b), and the Volunteer Angler Report (VAR) system revealed a scarcity of fish ≥ 400 mm in length. In 1987, therefore,

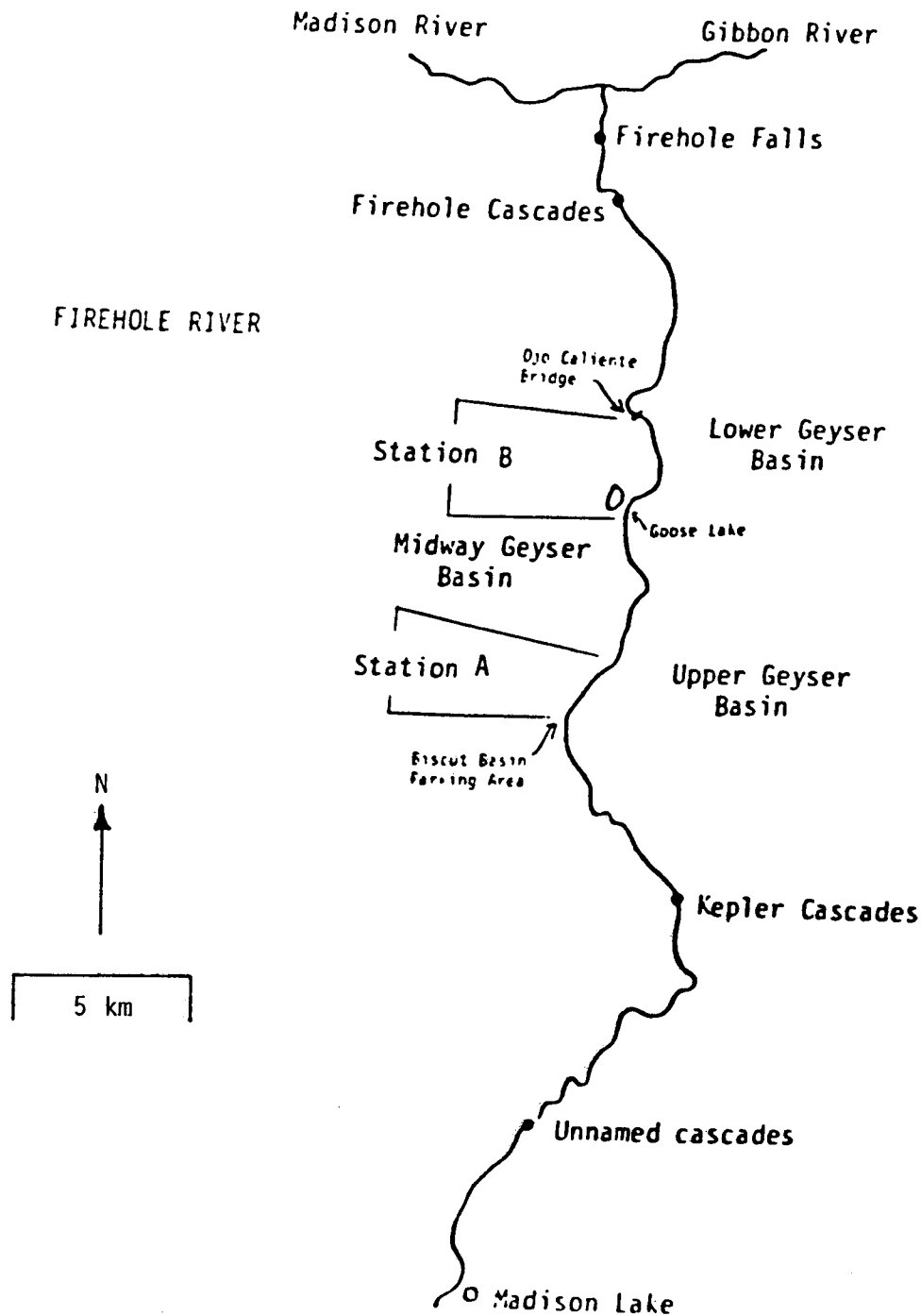


FIGURE 20.-Firehole River showing major geyser basins, physical barriers to upstream fish passage, and general locations of electrofishing stations A and B, 1988.

brown trout were placed under a two-fish, 254-mm maximum-size limit, and rainbow trout were restricted to catch-and-release only. Brook trout are currently under a five-fish, 254-mm maximum-size restriction.

Fishery management studies on the Firehole River date back to the late 1800s. Jordan (1891) reported on the historical distribution of fishes in the drainage, and Evermann (1892) discussed the success of early introductions of fishes into previously fishless areas. Fromm (1941) compiled the known history of fish stocking through 1940, and Varley (1981) provides a complete stocking history. Benson et al. (1959) were the first to study angler use; Dean and Mills (1970, 1971), Erman (1972), and Dean and Varley (1973) also studied angler use in detail. Since 1974, angler use has been monitored annually through the VAR system (Dean et al. 1975; Jones et al. 1976-1988).

Benson et al. (1959) also conducted the first extensive fish-population studies. Intensive investigations of fish distribution, abundance, movement, growth, reproductive biology, food habits, and thermal tolerance were completed in the 1970s (Kaya 1974, 1977, 1978a, 1978b; Kaeding 1976, 1980, 1981; Kaya et al. 1977; Kaeding and Kaya 1978; Kaya and Kaeding 1979). Sonski (1984) tested thermal tolerances of fishes from the Firehole River, and Cameron et al. (1978) reported on genetics. Jones et al. (1978) conducted an extensive hydrographic survey of the entire Firehole River drainage from 1975 to 1977.

The U.S. Fish and Wildlife Service and Idaho State University are presently studying thermally influenced areas of the Firehole River. The U.S. Fish and Wildlife Service is evaluating habitat, aquatic macroinvertebrate communities, fish populations, and long-term trends in the sport fishery. Research by Idaho State University includes analysis of current angler use patterns, fish populations, hooking mortality, seasonal movement of fishes, and temperature selection by fishes.

Preliminary data were collected in the fall of 1987 and discussed by Jones et al. (1988). Data collection continued in the spring and fall of 1988. Spring samples were obtained prior to any wildfire activity in the Firehole River drainage. Fall samples were taken after approximately 49% of the drainage was affected by fire (Patten et al. 1988) but before any significant runoff occurred. This progress report discusses only fish-population and sport-fishery data collected by the U.S. Fish and Wildlife Service and makes some comparisons to information collected in previous investigations.

Study Area

Station A.-Station A, located in the Upper Geyser Basin, began at the Biscuit Basin parking lot and extended

downstream for approximately 3.78 km (Figure 21). From the upper boundary of the study section, the river flows along the edge of Biscuit Basin thermal area for 0.3 km before branching into two channels (hereafter referred to as the Main Channel and East Channel). The Main Channel meanders along a forest-meadow interface for 0.85 km, and then rejoins the 0.43-km long East Channel in the middle of a large meadow. The Main Channel continues through the meadow for another 0.8 km before entering a forested area that is interspersed with small meadows; the lower 1.83 km of the Main Channel lie in this forested area. The road between Madison Junction and Old Faithful parallels this stream segment, thus providing easy access for anglers.

Station B.-Station B was situated in the Midway and Lower geyser basins (Figure 22). In spring, this study section extended from the Excelsior Geyser parking area to the head of a small cascade approximately 4.3 km downstream. The section was shortened in fall because of study design changes and ended about 3.1 km below the Excelsior Geyser parking area.

From the parking area downstream for 3.1 km, the river is bordered by a relatively narrow meadow surrounded by forest. The next 1.2 km flow through a sparsely vegetated area of active and inactive thermal features. Major angler access points to this section of the Firehole River are the Excelsior Geyser parking area, parking and picnic areas near Goose Lake and Feather Lake, and the Ojo Caliente Springs parking area on the Fountain Freight Road.

Methods

Water temperature.-Water temperatures at Station A and Station B were continuously monitored during 1988 with Ryan Model J 90-d thermographs (limits, 0 to 30°C). The thermograph at Station A was located near the downstream boundary of the section. Because of logistic constraints, the thermograph at Station B was installed downstream of the lower boundary of the study site under the Ojo Caliente Bridge.

Fish populations.-Fish were sampled at Stations A and B in the spring (24 May-2 June) and fall (22 September-2 October) of 1988. Trout abundance at both sample sites was estimated in spring and fall by the Chapman modification of the Peterson method (Ricker 1975).

Mark and recapture samples were obtained by nighttime electrofishing from a 4-m long rubber raft. Trout captured during mark runs were identified to species, measured to the nearest millimeter (total length), and fin-clipped. During recapture runs, all trout were again identified to species and measured for length, and the number of recaptures was recorded.

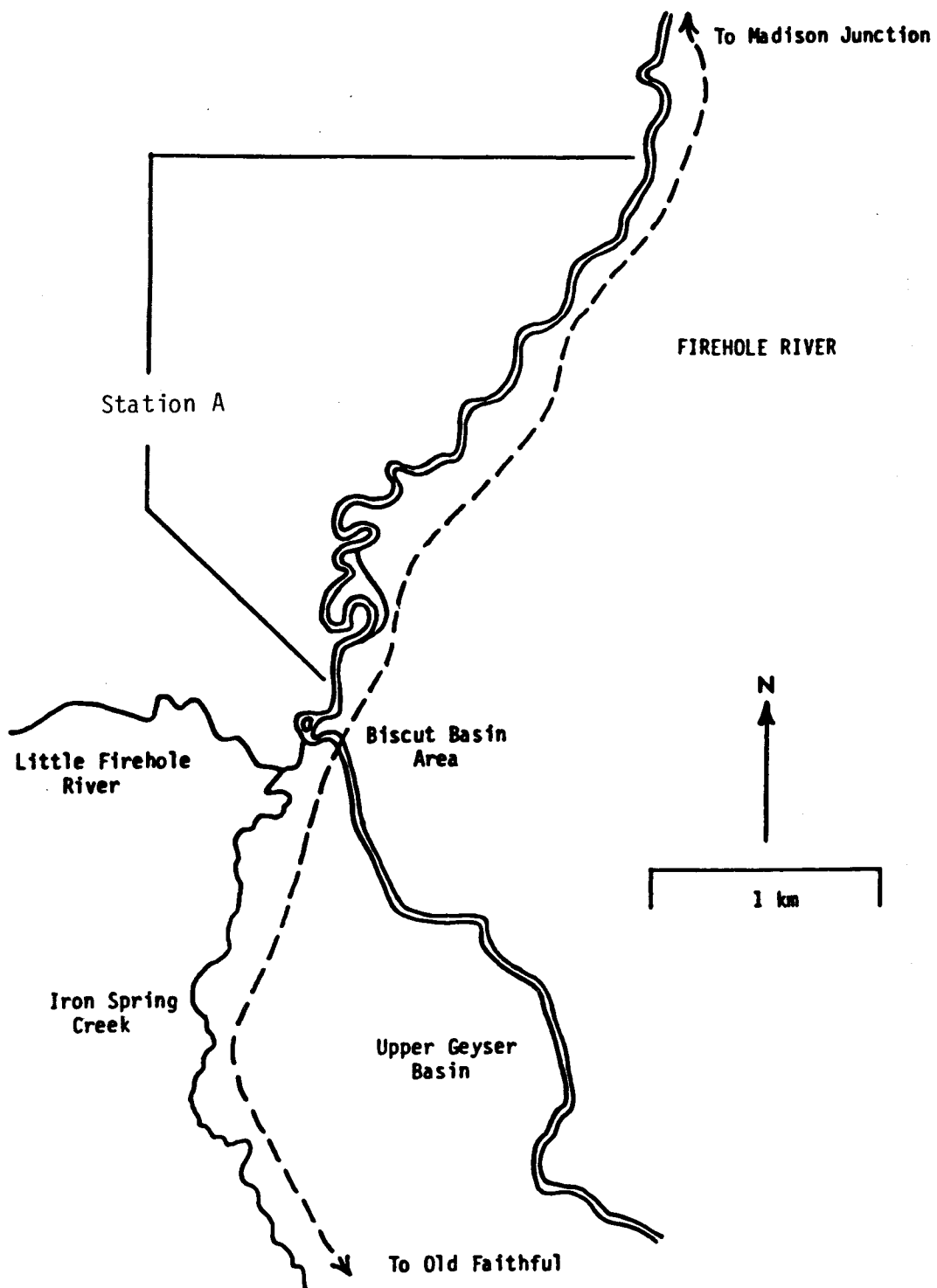


FIGURE 21.-Station A on the Firehole River, 1988.

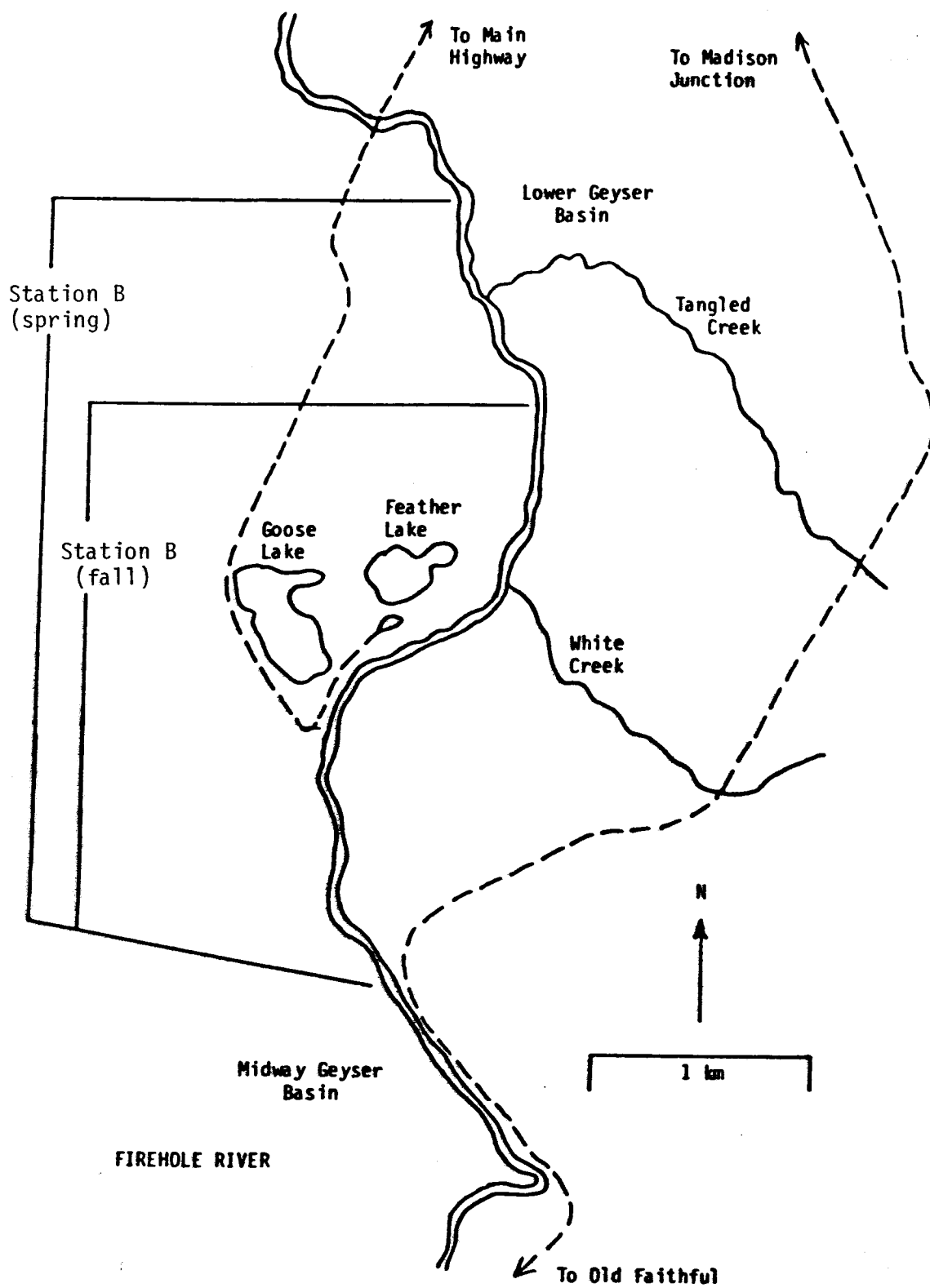


FIGURE 22.-Station B on the Firehole River, 1988.

On both mark and recapture passes, weights to the nearest 2 g were taken from 10 "unmarked" trout of each species in each 10-mm length group (a trout caught for the first time is defined as an "unmarked" trout). A geometric-mean regression technique (Ricker 1975) was used to calculate length-weight equations for each species, station, and season, i.e., eight separate length-weight equations were calculated. Mean weights for each species, station, and season were estimated by inserting respective mean lengths of all "unmarked" trout into the appropriate length-weight equation. Total biomass estimates were then calculated by multiplying estimated mean weights by estimated total abundance.

The sport fishery.-Creel survey data from the Volunteer Angler Report (VAR) system (Dean and Varley 1974) for the period 1979-1988 were used to analyze the sport fishery between Kepler Cascades and Firehole Falls.

Statistical analyses.-Statistical procedures used herein are described in Zar (1984). All tests were evaluated at $\alpha = 0.05$. The Number Cruncher Statistical System (Hintze 1987) and computer programs written by the U.S. Fish and Wildlife Service (unpublished) were used to analyze data.

Results

Water Temperature

Station A.-Geothermal runoff from hot springs and geysers in the Upper Geyser Basin (Figure 21) affect water temperature at Station A. Data for the period January-September revealed a minimum mean monthly temperature of 9.5°C in January and a maximum mean monthly temperature of 22.4°C in July (Figure 23).

Station B.-Water temperature at Station B is influenced by geothermal inputs from the Upper, Midway, and Lower geyser basins (Figure 22). For the period January-December, the minimum mean monthly temperature was 12.9°C in January and the maximum mean monthly temperature was 26.0°C in July (Figure 23). For the comparable months January through September, mean monthly temperatures at Station B averaged 3.4°C higher than at Station A; mean monthly temperatures at the two sample sites differed significantly (t-tests; $P < 0.00001$) for all 9 months.

Fish Populations

Station A.-In spring 1988, a total of 495 "unmarked" brown trout were captured during mark and recapture electrofishing samples (Table 21). Length ranged from 56 to 593 mm and averaged 223 mm. The stratified subsample of 202 fish yielded a mean condition (K) of 1.1. Spring abundance

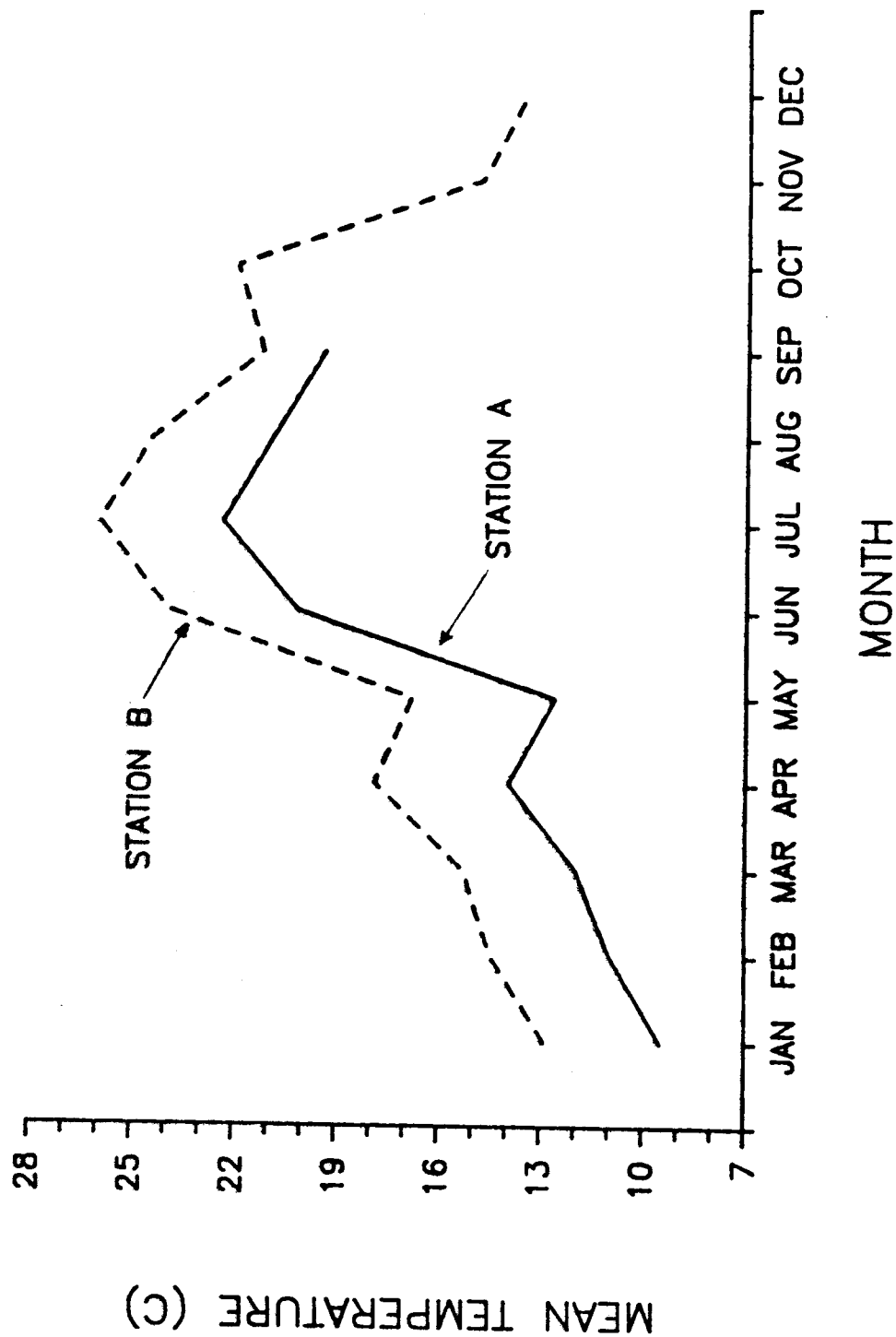


FIGURE 23.-Mean monthly water temperatures at Station A and Station B in the Firehole River, January-December 1988 (no temperatures available at Station A for October-December because of thermograph malfunction).

TABLE 21.-Catch statistics for brown trout and rainbow trout captured by electrofishing at Station A in the Firehole River, spring and fall, 1988.

Species and season	Length characteristics			Stratified subsample for condition, length-weight equation, and mean weight estimate					
	Sample size	Mean length (mm)	Length range (mm)	SE (mm)	Sample size	Mean condition (K)	Length-weight equation	r ²	Mean ^a weight (g)
Brown trout									
Spring	495	223	56-593	4	202	1.1	lnW = 2.91(lnL) - 10.90	0.99	126
Fall	518	218	85-591	4	215	1.0	lnW = 2.94(lnL) - 11.26	0.99	97
Rainbow trout									
Spring	330	178	48-484	5	146	1.2	lnW = 2.96(lnL) - 11.20	0.98	63
Fall	508	198	93-423	3	234	1.0	lnW = 2.94(lnL) - 11.17	0.98	80

^a Mean weight estimated by inserting mean length into length-weight equation.

and biomass estimates were 201 fish/hectare and 25.7 kg/hectare, respectively (Table 22).

In fall, length of 518 "unmarked" brown trout averaged 218 mm and varied between 85 and 591 mm (Table 21). Mean condition, based on the stratified subsample of 215 fish, was 1.0. Fall abundance and biomass estimates were, respectively, 177 fish/hectare and 17.2 kg/hectare (Table 22).

Mean length of brown trout in spring and fall did not differ significantly (t-test; $P = 0.38$), but the decrease from spring to fall in mean condition was significant (t-test; $P < 0.00001$). Fall abundance and biomass estimates were, respectively, 13% and 33% less than in spring; however, the changes may not be statistically significant because confidence limits for respective estimates overlapped (Table 22).

The catch of "unmarked" rainbow trout in spring totaled 330 (Table 21). Mean length was 178 mm, and length ranged from 48 to 484 mm. A mean condition (K) of 1.2 resulted from the stratified subsample of 146 fish. Approximately 227 rainbow trout/hectare were estimated to inhabit this study section; the biomass estimate was 14.3 kg/hectare (Table 22).

In fall, 508 "unmarked" rainbow trout were captured (Table 21). Length averaged 198 mm and ranged from 93 to 423 mm. Mean condition (K) from the stratified subsample of 234 fish was 1.0. Fall number and biomass estimates were, respectively, 255 fish/hectare and 20.4 kg/hectare (Table 22).

Rainbow trout mean length in spring and fall differed significantly (t-test; $P = 0.0009$), and decline in mean condition from spring to fall was significant (t-test; $P < 0.00001$). Fall number and biomass estimates were, respectively, 12% and 46% greater than in spring; however, overlapping confidence limits (Table 22) suggest that these differences are not statistically significant.

Station B.—A total of 308 "unmarked" brown trout were captured during mark and recapture electrofishing samples in spring 1988 (Table 23). Length varied between 128 and 521 mm and averaged 275 mm. Mean condition (K) was 1.2 based on the stratified subsample of 170 fish. Approximately 54 brown trout/hectare were estimated in the study section in spring; the accompanying biomass estimate was 12.5 kg/hectare (Table 24).

In fall, 215 "unmarked" brown trout were captured (Table 23). Mean length was 271 mm, and length ranged from 121 to 482 mm. The stratified subsample of 168 trout yielded a mean condition (K) of 1.0. Abundance and biomass estimates were 39 brown trout/hectare and 7.8 kg/hectare, respectively (Table 24).

Brown trout mean lengths in spring and fall did not differ significantly (t-test; $P = 0.52$); however, the

TABLE 22.-Abundance and biomass estimates for brown trout and rainbow trout at Station A^a in the Firehole River, spring and fall, 1988.

Species and season	Abundance estimate (fish/hectare)			Biomass estimate (kg/hectare)		
	Point estimate	Confidence limits lower	Confidence limits upper	Point estimate	Confidence limits lower	Confidence limits upper
Brown trout						
Spring	204	156	266	25.7	19.7	33.5
Fall	177	141	223	17.2	13.6	21.6
Rainbow trout						
Spring	227	149	363	14.3	9.4	22.9
Fall	255	191	350	20.4	15.3	28.0

^a Station A encompassed approximately 6.72 hectares of surface area.

TABLE 23.-Catch statistics for brown trout and rainbow trout captured by electrofishing at Station B in the Firehole River, spring and fall, 1988.

Species and season	Length characteristics				Stratified subsample for condition, length-weight equation, and mean weight estimate				
	Sample size	Mean length (mm)	Length range (mm)	SE (mm)	Sample size	Mean	Length-weight equation	r ²	Mean ^a weight (g)
						condition (K)			
Brown trout									
Spring	308	275	128-521	4	170	1.2	$\ln W = 2.79(\ln L) - 10.23$	0.97	231
Fall	215	271	121-482	4	168	1.0	$\ln W = 2.67(\ln L) - 9.65$	0.98	202
Rainbow trout									
Spring	672	222	62-404	3	414	1.2	$\ln W = 2.89(\ln L) - 10.79$	0.98	124
Fall	456	240	86-381	3	242	1.2	$\ln W = 2.90(\ln L) - 10.79$	0.98	165

^a Mean weight estimated by inserting mean length into length-weight equation.

TABLE 24.-Abundance and biomass estimates for brown trout and rainbow trout at Station B^a in the Firehole River, spring and fall, 1988.

Species and season	Abundance estimate (fish/hectare)			Biomass estimate (kg/hectare)		
	Point estimate	Confidence limits lower	Confidence limits upper	Point estimate	Confidence limits lower	Confidence limits upper
Brown trout						
Spring	54	40	76	12.5	9.1	17.6
Fall	39	29	54	7.8	5.8	10.9
Rainbow trout						
Spring	160	123	210	19.9	15.2	26.0
Fall	143	105	197	23.5	17.4	32.5

^a Station B encompassed approximately 14.6 hectares of surface area in spring and 10.6 hectares of surface area in fall.

decline in average condition (K) was significant (t-test; $P < 0.00001$) from spring to fall. Fall abundance and biomass estimates were, respectively, 28% and 38% less than in spring, but overlapping confidence limits (Table 24) indicate the differences are not statistically significant.

The number of "unmarked" rainbow trout captured in spring was 672 (Table 23). Length varied between 62 and 404 mm and averaged 222 mm. The subsample of 414 fish had a mean condition (K) of 1.2. Spring abundance and biomass estimates were, respectively, 160 rainbow trout/hectare and 19.9 kg/hectare (Table 24).

In fall, length of 456 "unmarked" rainbow trout ranged from 86 to 381 mm and averaged 240 mm (Table 23). Mean condition (K), based on the subsample of 242 trout, was 1.2. Abundance of rainbow trout in the study section in fall was estimated at 143 trout/hectare; the biomass estimate was 23.5 kg/hectare (Table 24).

Differences in mean length of rainbow trout in spring and fall were significant (t-test; $P < 0.00001$); however mean condition in both seasons was the same (t-test; $P = 0.24$). The fall abundance estimate was 11% less than in spring, but biomass in fall actually increased 18%. Because of the large overlap in respective confidence limits in spring and fall (Table 24), the changes are probably not statistically significant.

The Sport Fishery

From 1979 through 1988, an average of 5,980 anglers spent 28,500 h (angler effort) annually fishing the Firehole River between Kepler Cascades and Firehole Falls. During this 10-year period, anglers annually landed 22,700 trout at a mean rate of 0.79 fish/h. Rainbow trout constituted 59% of the annual number of fish landed and were followed by brown trout (31%), brook trout (5%), and unidentified fishes (5%). Mean length of fish landed during the past 10 years was 277 mm. Approximately 628 fish have been creelied each year.

Angler effort, landing rate, and mean length of fish landed are the three variables that best describe trends in the sport fishery from 1979 through 1988. Angler effort (Figure 24) was quite variable between 1979 and 1984, but has been declining rather steadily since then. Angler effort in 1988 was 13,714 h, the lowest during the past 10 years. Despite the relatively large variation in angler effort, overall and individual species landing rates have been quite stable (Figure 24). Overall landing rate has fluctuated between 0.60 and 0.92 fish/h, rainbow trout from 0.41 to 0.59 fish/h, and brown trout between 0.32 and 0.41 fish/h (Figure 24). Mean length of all fish landed, and mean lengths of rainbow trout and brown trout landed have declined almost continuously over the past 10 years

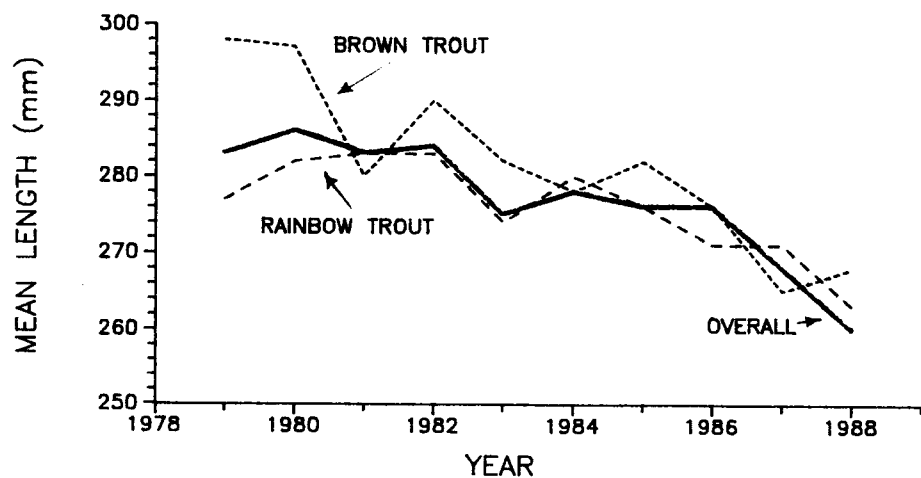
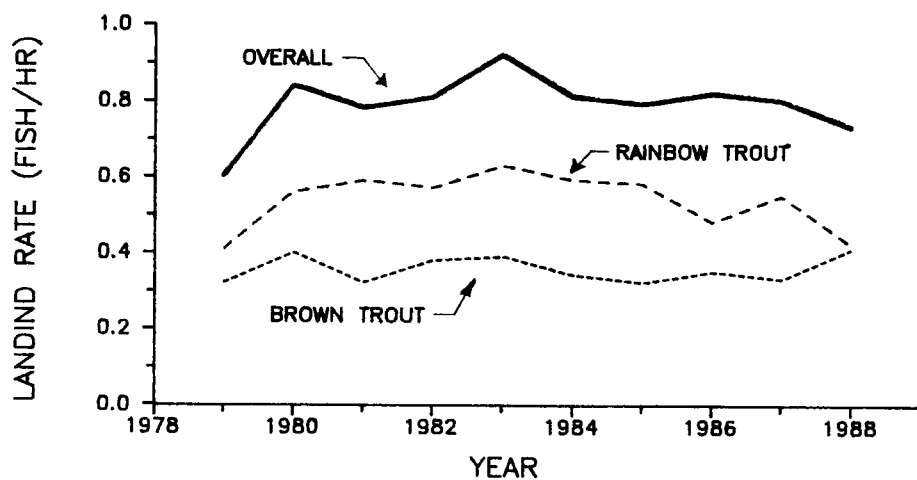
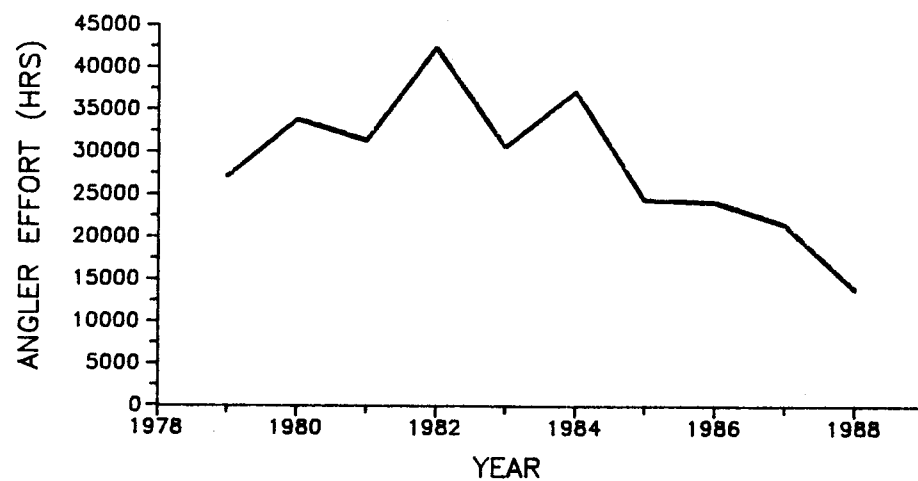


FIGURE 24.-Angler effort, landing rate, and mean length of fish landed on the Firehole River between Kepler Cascades and Firehole Falls, 1979-1988.

(Figure 24). In 1988, overall mean length (260 mm) and mean length of rainbow trout (263 mm) were the lowest on record; brown trout mean length in 1988 (268 mm) is the second lowest on record (Figure 24).

To evaluate possible changes in the sport fishery under different angling regulations, selected VAR data were partitioned into the periods 1979-1986 (8 years) and 1987-1988 (2 years) (Tables 25 and 26). Although average annual angler effort in 1987-1988 (17,512 h) differed significantly (t-test; $P = 0.02$) from 1979-1986 (31,257 h), overall landing rate and individual landing rates for brown trout and rainbow trout remained statistically unchanged (Table 25). Differences in percentage of brown trout and rainbow trout landed were not significant between periods (Chi-square test; $P = 0.40$); however, because rainbow trout cannot be legally creeled under the new regulations, the percentage of brown trout and rainbow trout in the harvest has changed significantly (Chi-square test; $P < 0.00001$) (Table 26). Also because of the new regulations, the estimated average annual number of fish creeled has dropped from 680 in 1979-1986 to 422 in 1987-1988; this difference is not significant (t-test; $P = 0.05$) (Table 25). Decreases in overall mean length and mean lengths of brown trout and rainbow trout landed in 1987-1988 were statistically significant compared to 1979-1986 (Table 25).

Discussion

Water Temperature

Many investigators have studied water temperature in the Firehole River and surrounding geyser basins (see for example Allen and Day 1935; Argyle 1966; Burkhalter 1979). The purpose of the current study, however, was not to collect data directly comparable to past studies, but to determine if water temperature differed at Station A and Station B.

Results from the current study indicated that water temperature at Station B was 3 to 4°C warmer than at Station A on any given day. Kaeding (1976) and Kaya (1978a) found a similar temperature difference between these two areas of the river in 1974 and 1975, and stated that the difference was large enough to affect fish species composition. These authors speculated that the temperature regime in the Biscuit Basin area favored brown trout and that below Midway Geyser Basin favored rainbow trout.

Fish Populations

Station A.-Although comparisons may be biased by different sample methods, relative abundance of brown trout and rainbow trout in this area of the Firehole River has

TABLE 25.-Angler effort, landing rate, and mean length of fish landed on the Firehole River between Kepler Cascades and Firehole Falls for the periods 1979-1986 and 1987-1988. (Means for each parameter were compared using a t-test for equal or unequal variances).

Sport-fishery parameter	Period				P-value ^c
	1979-1986 ^a		1987-1988 ^b		
	Mean	SE	Mean	SE	
Angler effort (h)	31,257	2,251	17,512	3,798	0.02*
Landing rate (fish/h)					
All species	0.80	0.03	0.77	0.04	0.65
Brown trout	0.35	0.01	0.37	0.04	0.57
Rainbow trout	0.55	0.03	0.49	0.07	0.29
Mean length (mm)					
All species	280	2	264	4	0.002*
Brown trout	285	3	267	2	0.02*
Rainbow trout	278	2	267	4	0.02*
Number of fish creeled	680		422		0.05

^a Fly-fishing only; daily creel limit of two fish (brown trout or rainbow trout) greater than 406 mm.

^b Fly-fishing only; daily creel limit of two brown trout less than 254 mm; catch-and-release-only for rainbow trout.

^c An "*" indicates a significant difference at alpha = 0.05.

TABLE 26.-Percentage of brown trout and rainbow trout landed and creeled in the Firehole River between Kepler Cascades and Firehole Falls, 1979-1986 and 1987-1988.

Species	Percentage of brown trout and rainbow trout landed		Percentage of brown trout and rainbow trout creeled	
	1979-1986 ^a	1987-1988 ^b	1979-1986 ^a	1987-1988 ^b
Brown trout	30	34	28	67
Rainbow trout	61	53	54	0

^a Fly-fishing only; daily creel limit of two fish greater than 406 mm.

^b Fly-fishing only; daily creel limit of two brown trout less than 254 mm; catch-and-release-only for rainbow trout.

changed significantly (Chi-square test; $P < 0.00001$) since the 1950s. Benson et al. (1959) stated that the Firehole River above Midway Geyser Basin was populated principally by brown trout, and Kaeding (1976) reported that brown trout accounted for 90% of an electrofishing sample in the Biscuit Basin area. In 1987, however, brown trout accounted for about 50% of the electrofishing catch at Station A (Jones et al. 1988), and in the current study brown trout constituted 60% and 50%, respectively, of spring and fall electrofishing samples. These data suggest that although brown trout were once the dominant salmonid, brown trout and rainbow trout are now co-dominant species in this section of the Firehole River.

Reasons for the change in species composition are not fully understood, but may be related to the cessation of stocking in 1955 coupled with differential reproductive success in a thermally-enriched environment. Kaya (1978a) found that elevated water temperatures negatively affected brown trout reproduction in the Firehole River. In contrast, he reported that rainbow trout, which spawn in the fall in the Firehole River, reproduced successfully even in the warmest areas.

Aside from the current study, Benson et al. (1959) conducted the only successful fish-abundance estimates in this area of the Firehole River. Using a mark-recapture method, they reported approximately 371 "catchable-size" (assumed definition; trout ≥ 152 mm total length) brown trout per kilometer of stream; no biomass estimate was reported. No abundance or biomass estimates were reported for rainbow trout, probably because of insufficient sample sizes.

To compare results from the current study with those of Benson et al. (1959), 1988 spring and fall brown trout abundance estimates (originally calculated on a per hectare basis for all sizes of fish) were recalculated on a per kilometer basis using only fish ≥ 152 mm long. In spring 1988, there were approximately 270 brown trout/km (95% CI; 206-351), and the fall estimate was 213 brown trout/km (asymmetrical 95% CI; 169-270). Spring and fall 1988 estimates are, respectively, 27% and 43% less than those of Benson et al. (1959); however, it is not possible to determine if the estimates differ significantly because Benson et al. (1959) provided no confidence limits.

Benson et al. (1959) and Kaeding (1976) found by electrofishing that less than 2% of brown trout and virtually no rainbow trout in the Biscuit Basin area 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 coupled with a diet limited primarily to aquatic macroinvertebrates.

In 1987, Jones et al. (1988) reported that the percentages of brown trout and rainbow trout in the electrofishing catch exceeding 400 mm long were 14% and 4%, respectively. The authors speculated that this area of the Firehole River had the potential to produce relatively larger brown trout if given sufficient protection from angler harvest. The validity of this speculation requires more investigation, however, because in 1988 the percentages of brown trout and rainbow trout in the electrofishing catch exceeding 400 mm in length (spring and fall combined) dropped, respectively, to approximately 5% and 1%.

Station B.-Although relative abundance of brown trout and rainbow trout in this section of the Firehole River has varied significantly (Chi-square test; $P < 0.00001$) since the 1950s, rainbow trout appear to be the dominant species. Benson et al. (1959) found that rainbow trout accounted for 58% of an electrofishing sample below Midway Geyser Basin. Kaeding (1976) and Jones et al. (1988) reported that rainbow trout constituted 80% and 87%, respectively, of electrofishing samples between the Midway and Lower geyser basins. In the current study, rainbow trout accounted for 69% and 68%, respectively, of the spring and fall electrofishing catch. Reasons for the dominance of rainbow trout are not fully understood, but as at Station A, may be related to the cessation of stocking in 1955 coupled with differential reproductive success in a thermally enriched environment (Kaya 1978a).

Kaya (1978a) conducted the only other trout-abundance estimates in this area of the Firehole River. Using the Chapman modification of the Peterson method (Ricker 1975), he estimated spring 1975 abundance at 146 brown trout/km (95% CI; 93-199) and 1,170 rainbow trout/km (95% CI; 736-1,604). Fall 1975 abundance estimates were 275 brown trout/km (95% CI; 107-443) and 856 rainbow trout/km (95% CI; 458-1,254). No biomass estimates were reported.

To maximize comparability between Kaya (1978a) and the current study, 1988 spring and fall estimates (originally calculated on a per hectare basis with asymmetrical confidence limits) were recalculated on a per kilometer basis with symmetrical confidence limits. In spring 1988, there were an estimated 184 brown trout/km (95% CI; 132-236) and 544 rainbow trout/km (95% CI; 410-678). Fall 1988 abundance estimates were 132 brown trout/km (95% CI; 98-166) and 487 rainbow trout/km (95% CI; 350-624). Comparisons between 1975 and 1988 for each species and season reveal that confidence intervals overlap for all estimates except rainbow trout in spring. Therefore, it appears that brown trout and rainbow trout abundance has changed little in this area of the Firehole River since the 1970s.

Benson et al. (1959) and Kaeding (1976) found by electrofishing that about 1% of brown trout and no rainbow trout in this area of the Firehole River were greater than

400 mm long. Consistent with these earlier investigations, fewer than 5% of brown trout and no rainbow trout captured by electrofishing in 1987 (Jones et al. 1988) and in the current study exceeded 400 mm in length. Perhaps the speculation by Kaya and Kaeding (1979) that growth in thermally-enriched waters of the Firehole River is limited by the high metabolic demands of warm water and a diet consisting principally of macroinvertebrates is particularly applicable at Station B.

The Sport Fishery

Angler harvest apparently negatively impacted brown trout and rainbow trout populations under the five-fish-of-any-size, fly-fishing only regulation in effect from 1951 through 1969 (Benson et al. 1959; Dean and Mills 1970; Erman 1972). Early evaluations of the two-fish, 406-mm minimum-size, fly-fishing only restriction implemented in 1970 detected no significant increases in total number or average size of fish landed (Dean and Mills 1971; Dean and Varley 1973). Data from the VAR system from 1973 through 1986 (the last year of the two-fish, 406-mm minimum-size, fly-fishing only regulation) revealed a rather steady decline in mean length of landed fish. Decreases in mean length of fish landed have continued under the current regulation of fly-fishing only for two brown trout less than 254 mm and catch-and-release only for rainbow trout.

Reasons for the long-term decline in average size of landed fish are not known. It is possible that excessive harvest of relatively larger fish occurred between 1970 and 1986. It appears more probable, however, that long-term population structure changes are occurring under growth limitations as discussed by Kaya and Kaeding (1979) or because of other undiscovered reasons.

GARDNER RIVER

In 1987, the National Park Service implemented new angling regulations in Yellowstone National Park (Jones et al. 1988). Under the new regulations, creel limits on the Gardner River downstream of Osprey Falls are more liberal than for any other stream fishery in the Park. Fishery managers are thus concerned that angler effort on this section of the Gardner River will disproportionately increase in future years compared to other Park waters and negatively impact the fishery.

To provide baseline data in the first year of the new regulations, Jones et al. (1988) evaluated fish populations and the sport fishery. Field investigations revealed that brown trout *Salmo trutta* and rainbow trout *Oncorhynchus mykiss* were the dominant salmonids. Analysis of data from the Volunteer Angler Report (VAR) system (Dean and Varley 1974) for the period 1979-1987 showed that mean lengths of these two species in the angler catch had declined rather steadily since 1983-1984. Final recommendations included close monitoring of the fishery over the next few years.

Fish-population studies were continued in 1988, and sport-fishery trends were reanalyzed. Originally, 1988 investigations were conducted only to provide data comparable to that collected in 1987. However, in 1988, forest fires burned approximately 67% of the Gardner River watershed (Patten et al. 1988). Thus, data collected in both years may serve as indicators of pre-fire conditions in the Gardner River below Osprey Falls.

Study Area

The study area extended from Osprey Falls downstream to the confluence with the Yellowstone River (Figure 25). 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 Survey gaging station for a 43-year period of record ranged from 2.6 to 21.2 m³/s (USGS 1940-1972, 1986, 1987). 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.

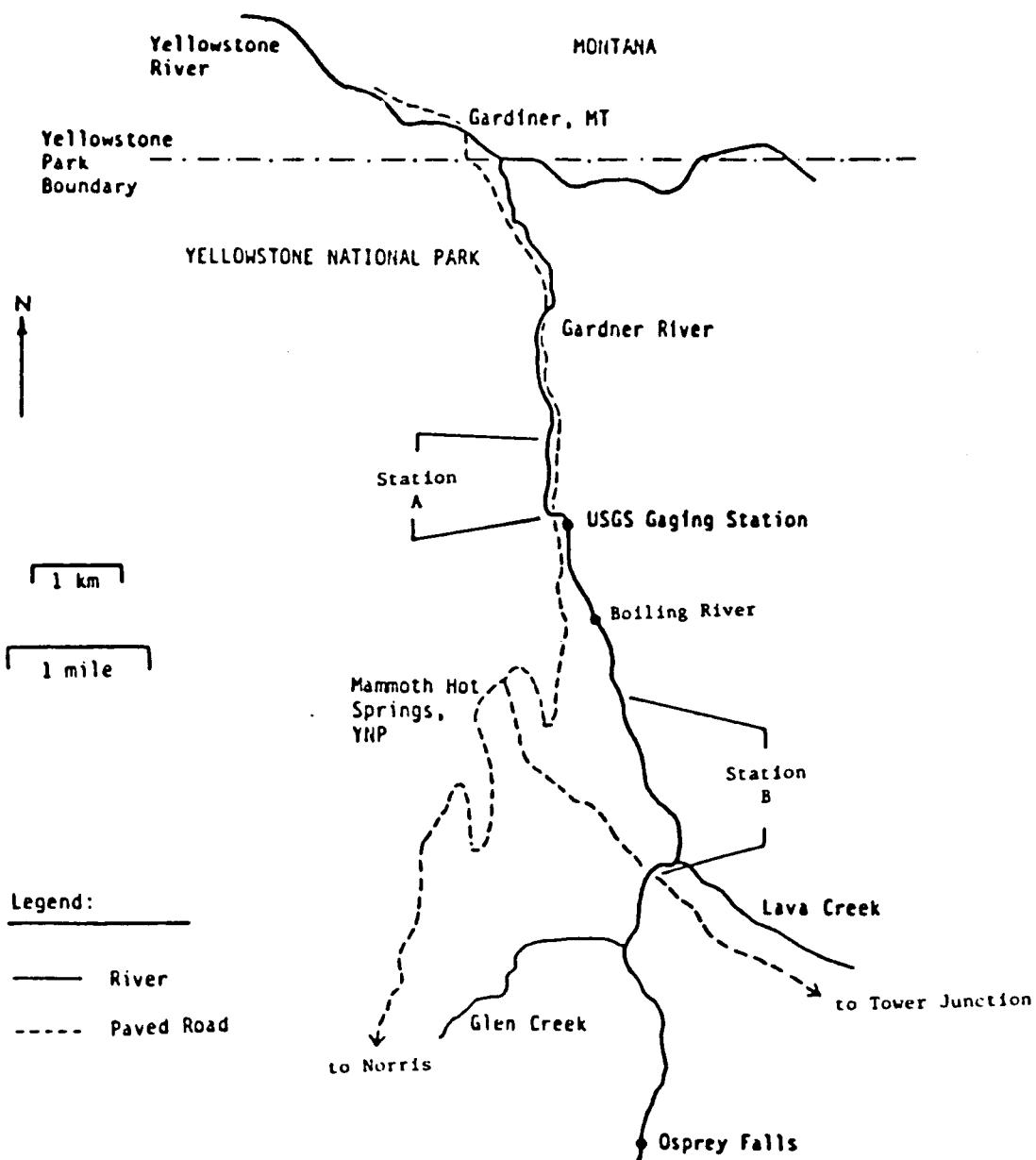


FIGURE 25.-Gardner River below Osprey Falls showing electrofishing stations A and B, 1988.

Water temperature regimes in the Gardner River 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). 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.

Historically, Yellowstone cutthroat trout *Oncorhynchus clarki bouvieri* and mountain whitefish *Prosopium williamsoni* were the only salmonids inhabiting the Gardner River below Osprey Falls (Evermann 1892; Jordan 1891). The introduction of several species of nonnative salmonids between 1889 and 1943 (Varley 1981), however, produced lasting changes in fish species composition. Brown trout, rainbow trout, Yellowstone cutthroat trout, rainbow trout x cutthroat trout hybrids, brook trout *Salvelinus fontinalis*, and mountain whitefish are now found below the falls.

Presently, species creel limits on the Gardner River are two brown trout, rainbow trout, or mountain whitefish of any size or five brook trout under 254 mm (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.

Methods

In 1988, two sample stations were established in the study area to investigate fish populations (Figure 25). Station A, located below Boiling River, extended from the U.S. Geological Survey gaging station to a point approximately 0.9 km downstream. Station B, situated above Boiling River, began at the confluence of the Gardner River and Lava Creek and extended to a point approximately 1.5 km downstream. Although geothermally-heated runoff from the Mammoth Hot Springs flows into the lower portion of Station B, it is largely a cold-water area.

Fish population data were collected by daytime electrofishing between 13 and 15 July. Because physical habitats at the two stations differed, two different electrofishing systems were used. At Station A, a 4-m long rubber raft was fitted with two stationary dropper electrodes (one positive, 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 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, 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 employed at Station A.

At both sample stations, captured salmonids were identified to species and measured to the nearest 1 mm total length. Species composition of the electrofishing catch and resultant length-structure data were used to compare fish population information collected in 1987 (Jones et al. 1988) with that obtained in the current study. Creel survey data from the VAR system for the period 1979-1988 were used to examine the sport fishery.

Statistical procedures used herein are described in Zar (1984), and all statistical tests were performed at $\alpha = 0.05$. Statistical programs developed by the U.S. Fish and Wildlife Service (unpublished) and those in the Number Cruncher Statistical System (Hintze 1987) were used to analyze data.

Results

Fish Populations (1987-1988)

Station A.-Salmonid species composition of the electrofishing catch did not differ significantly (Chi-square test; $P = 0.28$) in 1987 and 1988. In both years, brown trout comprised nearly 90% of the catch. Rainbow trout annually accounted for about 9%, and cutthroat trout and rainbow trout x cutthroat trout hybrids made up only 1% of the electrofishing catch.

Mean length of brown trout captured by electrofishing in 1988 (231 mm) was significantly greater (t-test; $P < 0.0001$) than that observed in 1987 (207 mm). Very few brown trout less than 89 mm long (age-0 fish, Jones et al. (1988)) were captured in 1988. In fact, if all brown trout less than 89 mm long are removed from both data sets, the resultant mean lengths (232 mm in 1988 and 224 mm in 1987) no longer differ significantly (t-test; $P = 0.09$). Rainbow trout mean length in 1988 (235 mm) did not differ significantly (t-test; $P = 0.13$) from that found in 1987 (210 mm). This comparison suggests that the rainbow trout population has remained unchanged over the past 2 years. Sample sizes for cutthroat trout and rainbow trout x cutthroat trout hybrids were too small to make meaningful length comparisons at this sample site (Table 27).

Station B.-Salmonid species composition of the electrofishing catch differed significantly (Chi-square test; $P = 0.0008$) in 1987 and 1988. This difference may be

TABLE 27.-Length-structure characteristics of salmonids captured by electrofishing at Station A in the Gardner River below Osprey Falls, 1987 and 1988. (Mean lengths were tested using a t-test allowing for equal or unequal variances).

Species	1987				1988				P-value ^a
	n	Mean length (mm)	Range (mm)	Standard error (mm)	n	Mean length (mm)	Range (mm)	Standard error (mm)	
Brown trout	297	207	51-385	4	245	231	70-446	4	<0.0001*
Rainbow trout	25	210	47-291	12	28	235	96-333	10	0.13
Cutthroat trout	2	135	130-140	5	3	245	219-282	19	-
Rainbow trout x cutthroat trout hybrids	1	228	-	-	4	245	215-273	12	-

^a An "*" indicates a significant difference at $\alpha = 0.05$.

related to alteration of upstream and downstream boundaries of Station B in 1988. In both years, however, rainbow trout constituted the highest percentage of the electrofishing catch (57% in 1987 and 49% in 1988). Brown trout were the next most frequently caught salmonid (21% in 1987 and 34% in 1988) and were followed by mountain whitefish (20% in 1987 and 15% in 1988). Brook trout and cutthroat trout each accounted for 2% or less of the electrofishing catch in both years.

Although species composition differed significantly between years, length structure of captured fish remained unchanged. Mean lengths of rainbow trout in 1988 and 1987 were identical (156 mm). Similarly, mountain whitefish mean length in 1988 (368 mm) was virtually identical (t-test; $P = 0.96$) to that found in 1987 (369 mm). Mean length of brown trout in 1988 (208 mm) also did not differ significantly (t-test; $P = 0.24$) from that observed in 1987 (223 mm). Sample sizes for brook trout and cutthroat trout at this sample site were too small for valid comparisons (Table 28).

The Sport Fishery (1979-1988)

Between 1979 and 1988, an average of 1,902 anglers spent 6,691 h (angler effort) annually fishing the Gardner River between Osprey Falls and the confluence with the Yellowstone River. During this 10-year period, anglers annually landed an average of 8,725 fish and creeled 1,245. Brown trout, rainbow trout, and brook trout accounted for about 90% of the total number of fish landed and creeled between 1979 and 1988. Other species caught by anglers included cutthroat trout, rainbow trout x cutthroat trout hybrids, and mountain whitefish. Average overall landing rate and mean length of fish landed for the 10-year period were 1.3 fish/h and 262 mm, respectively.

Graphical analyses of angler effort, landing rate, and mean length of fish landed provide a summary of trends in the sport fishery over the past 10 years. Angler effort (Figure 26) never exceeded 7,500 h from 1979 through 1986; however, it has climbed above 8,700 h in each of the past 2 years. Overall landing rate (Figure 27) exhibited a slow, but rather steady increase from 1979 to 1988. Landing rates for brown trout and brook trout have been quite variable, but the landing rate for rainbow trout tended to increase between 1979 and 1988 (Figure 28). Overall mean length of fish landed (Figure 29) was highest in 1984 (274 mm), but has declined rather steadily since then to a low of about 250 mm in 1979 and 1988. Declines in the mean lengths of brown trout and rainbow trout may partially account for the decline in overall mean length (Figure 30).

To test whether significant changes have occurred in the sport fishery since the new parkwide angling regulations

TABLE 28.-Length-structure characteristics of salmonids captured by electrofishing at Station B in the Gardner River below Osprey Falls, 1987 and 1988. (Mean lengths were tested using a t-test allowing for equal or unequal variances).

Species	1987				1988			
	n	Mean length (mm)	Range (mm)	Standard error (mm)	n	Mean length (mm)	Range (mm)	Standard error (mm)
Brown trout	92	223	118-411	8	83	208	115-470	10
Rainbow trout	244	156	73-309	4	120	156	81-310	5
Cutthroat trout	2	285	274-295	11	5	198	150-255	22
Brook trout	8	204	125-277	23	1	180	-	-
Mountain whitefish	85	369	55-460	7	38	368	251-485	10
								0.96



FIGURE 26.-Angler effort on the Gardner River below Osprey Falls, 1979-1988.

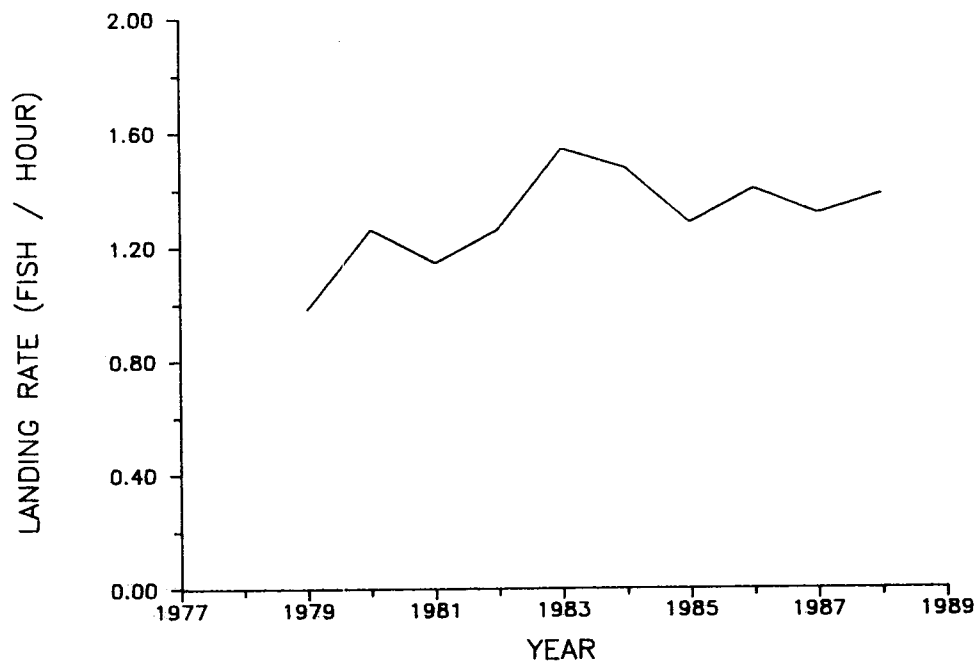


FIGURE 27.-Overall landing rate on the Gardner River below Osprey Falls, 1979-1988.

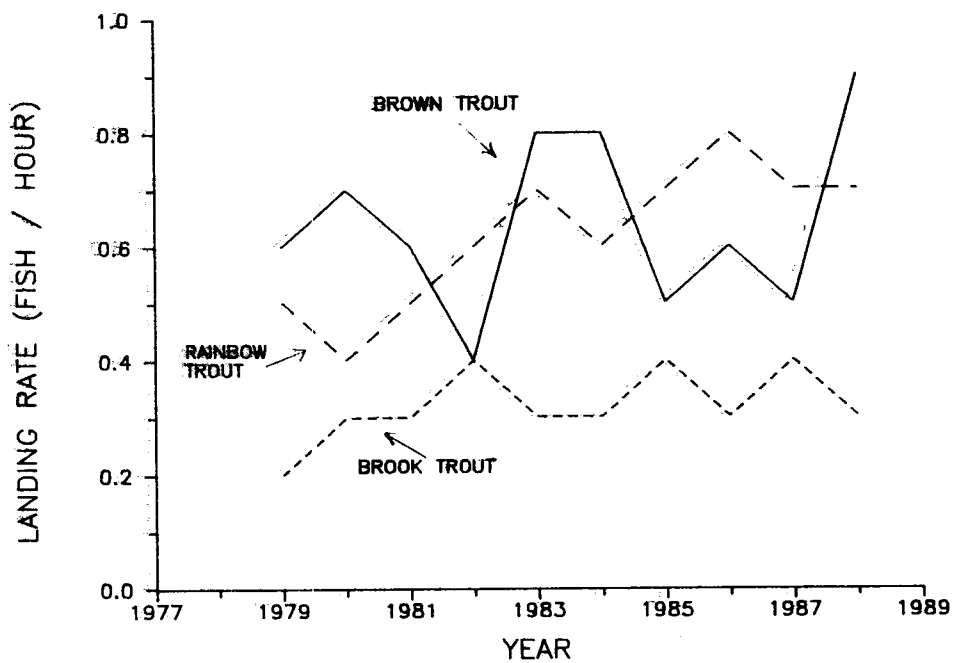


FIGURE 28.-Individual species landing rates on the Gardner River below Osprey Falls, 1979-1988.

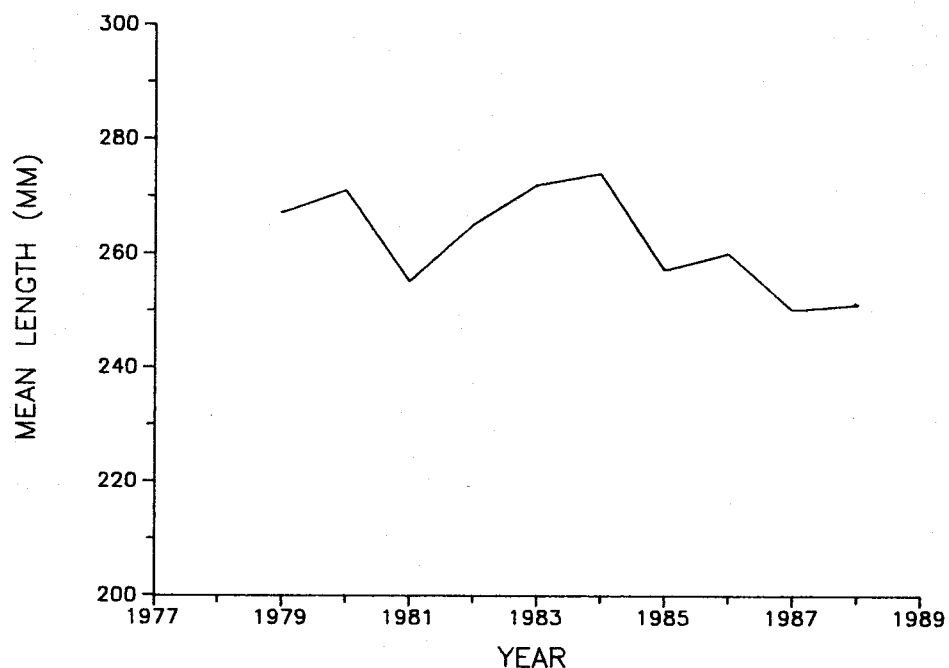


FIGURE 29.-Overall mean length of fish landed in the Gardner River below Osprey Falls, 1979-1988.

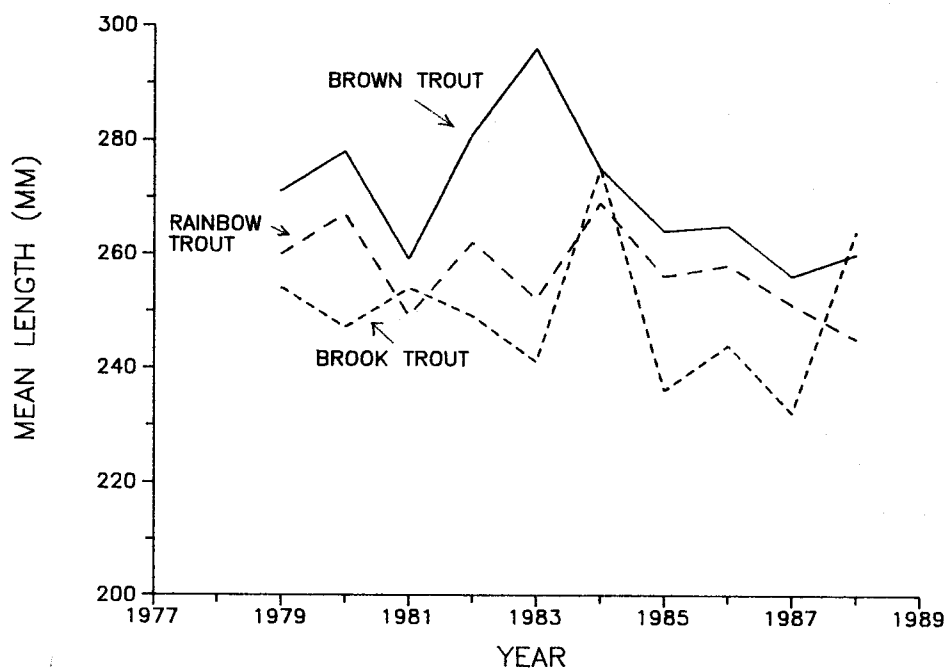


FIGURE 30.-Mean lengths of species landed in the Gardner River below Osprey Falls, 1979-1988.

were implemented in 1987, angler effort, landing rate, and mean length of fish landed were partitioned into the periods 1979-1986 (8 years) and 1987-1988 (2 years). The only significant difference found was in mean length of all species combined; however, the difference could not be attributed to any individual species (Table 29).

Discussion

Fish Populations (1987-1988)

Based on fish population data obtained by electrofishing in 1987 and 1988, brown trout are the dominant salmonid at Station A and rainbow trout are the dominant salmonid at Station B. Factors resulting in the dominance of brown trout at Station A are unknown but may be partly related to the geothermal input of Boiling River. Brown trout occur in nearly equal proportion with rainbow trout in a geothermally-influenced area of the Firehole River (Jones et al. 1988) with a water temperature regime similar to that at Station A of the Gardner River. At Station B, habitat conditions apparently favor rainbow trout. Additional water temperature and fish-habitat studies may provide insight into species composition at each sample site.

Excessive angler harvest can alter fish species composition and negatively impact the size structure of fish populations (Nikolski 1969). Data collected over the past 2 years at both Station A and Station B, however, indicate that fish populations have remained fairly stable. At Station A, species composition of the electrofishing catch did not change significantly between years. The significant difference in species composition at Station B can probably be attributed to the slight change in sample-site location. Changes in mean lengths of rainbow trout at Stations A and B, respectively, and brown trout at Station B did not differ significantly between years. The mean length of brown trout captured at Station A significantly increased in 1988, probably because very few fish less than 89 mm (age-0 fish) were captured. Small fish are generally less susceptible to capture by electrofishing; however, they may have been absent from the study area at the time of sampling.

The Sport Fishery (1979-1988)

Analyses of creel survey data from the VAR system over the past 10 years revealed that average annual angler effort for the period 1987-1988, although not statistically greater than that for the period 1979-1986, is still the highest on record. Although causes for the increase are not known, it is possible that anglers are responding to the liberal creel

TABLE 29.-Angler effort, landing rate, and mean length of fish landed on the Gardner River for the periods 1979-1986 and 1987-1988. (Comparisons of means for the two periods were made using a t-test allowing for equal or unequal variances).

Sport-fishery parameter	Period				P-value ^a
	1979-1986		1987-1988		
	Mean	SE	Mean	SE	
Angler effort (h)	5,478	457	11,544	2,774	0.28
Landing rate (fish/h)					
All species	1.29	0.06	1.35	0.04	0.70
Brown trout	0.63	0.05	0.70	0.20	0.78
Rainbow trout	0.60	0.05	0.70	0.01	0.08
Brook trout	0.31	0.02	0.35	0.05	0.49
Mean length (mm)					
All species	265	3	251	1	0.0005*
Brown trout	273	4	258	2	0.11
Rainbow trout	259	2	248	3	0.07
Brook trout	250	4	248	16	0.92

^a An "*" indicates a significant difference at alpha = 0.05.

limits on this section of the Gardner River. The rather steady decline in overall mean length of fish landed and decreases in mean lengths of brown trout and rainbow trout landed since 1984-1985 are also cause for concern. Overall landing rate has increased rather steadily over the past 10 years, apparently reflecting the steady increase in landing rate for rainbow trout. If overall or species landing rates begin to decline while angler effort remains high and mean lengths continue to drop, it may indicate that angler harvest is negatively impacting fish populations.

Conclusion

At this time, it appears that angler harvest on the Gardner River below Osprey Falls is not negatively impacting fish populations. However, it is expected that the fishery will remain popular. There is easy access to much of this section of the 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 periodically monitored to evaluate continued compliance with current goals of the fishery management program in Yellowstone National Park.

LAMAR RIVER

The Lamar River is the largest tributary of the Yellowstone River in Yellowstone National Park. Located in the northeastern portion of the Park, the 129,500-hectare Lamar River watershed represents nearly 15% of the Park area and contains approximately 20% of the total stream length in the Park. At the confluence with the Yellowstone River, the Lamar River is a sixth-order stream.

The headwater portions of the Lamar River drainage were formed by Eocene Absaroka volcanic flows and subsequent Pinedale glacial activity. The Lamar River valley is composed of loose unconsolidated alluvial deposits up to 30.5 m thick (Pierce 1974), that cover an undivided layer of upper Mississippian to middle Cambrian rocks (Protska et al. 1975). This wide valley is utilized extensively by elk *Cervus elaphus* and bison *Bison bison*. Occasionally, pronghorn antelope *Antilocapra americana*, coyote *Canis latrans*, or peregrine falcon *Falco peregrinus* may be observed in this area.

Native fish species in the Lamar River include Yellowstone cutthroat trout *Oncorhynchus clarki bouvieri*, mountain sucker *Catostomus platyrhynchus*, and longnose dace *Rhinichthys cataractae*. In 1938, 70,600 rainbow trout *Oncorhynchus mykiss* were stocked into the Lamar River (Varley 1981). Consequently, the genetic integrity of the cutthroat trout has been compromised. The current population appears to be composed primarily of rainbow trout x cutthroat trout hybrids (D. Shiozawa, personal communication).

The Lamar River supports one of the most popular stream fisheries in the Park. Since 1973, the section from Cache Creek downstream to the confluence with the Yellowstone River has been managed under a catch-and-release regulation. In 1987, the catch-and-release boundary was extended upstream to Calfee Creek. In the backcountry portion of the Lamar River (confluence with Calfee Creek upstream to the headwaters), there is a daily creel limit of two fish of any size.

The majority of angler use in the Lamar River occurs between Cache Creek and Lamar Canyon. A wide, picturesque valley and highway access heighten the appeal of this area to anglers. This catch-and-release area has been one of the major subdivisions of the fishery for Volunteer Angler Report analyses (Jones et al. 1978). Arnold and Sharpe (1967) rated fish abundance in this portion of the Lamar River as poor to fair. Jones et al. (1977-1980) evaluated responses of the fishery to catch-and-release regulations and concluded that the Lamar River contained a healthy trout population. Since 1984, alternate-year studies have examined population size and structure in a portion of the valley catch-and-release section (Jones et al. 1985, 1987). Studies of this population were continued in 1988.

Methods

The sample section extended from the confluence with Soda Butte Creek downstream for 2.2 km (Figure 31). Population estimates and population structure information were obtained through use of mark-and-recapture electrofishing. Samples were collected with a 4.2 m raft equipped with boom-mounted electrodes. All captured fish were measured to the nearest millimeter total length. A stratified subsample (based on 25-mm length groups) of fish were individually weighed to the nearest 2 g. Scales were collected from these fish for age and growth analyses; however, scales were not analyzed due to time constraints. An adjusted Peterson estimate was used to determine population size, and several length groups were combined to obtain an unbiased estimate (Ricker 1975).

Results

In 1984, there were an estimated 748 ± 571 rainbow trout x cutthroat trout hybrids in the sampling section (Jones et al. 1985). In 1988, the estimated population was 4,675 fish (95% C.L.: 3,215-7,157). Mean total length in 1988 was 267 mm ($N = 966$). This was a significant decrease from 1984 (mean total length: 309 mm, $N = 113$); however, the decrease from 1986 was only slight (mean total length: 277 mm, $N = 48$). Unlike the decreasing trend noted in mean total lengths, changes in mean weight have shown more variation; however, none of the mean weight changes were significant. Values have ranged from 340 g ($N = 50$) in 1984 to 267 g ($N = 4$) in 1986. In 1988, mean weight increased to 298 g ($N = 120$).

Examination of length-frequency distributions from the three sample years provides additional evidence of the decreased mean length observed in 1988 (Figure 32). Although the actual number of trout greater than 330 mm in the 1988 sample was a threefold increase over 1984 levels, proportional stock density (PSD) (Gablhouse 1984) decreased from 19.8% in 1984 to 6.1% in 1988. If 153 mm, 254 mm, and 330 mm are used (based on the Park record cutthroat trout) for stock length, quality length, and preferred length, respectively, comparable PSD values increased to 79.3% in 1984 and 56.1% in 1988. Two-thirds of the fish in the 1988 sample were between 200 and 300 mm (Figure 32).

Four rainbow trout were collected during the 1988 sampling period in the Lamar River. Mean total length, mean weight, and mean condition factor (K) of these fish were 294 mm, 222 g, and 0.84, respectively. In addition, 218 mountain suckers and 275 longnose dace were captured. No length or weight measurements were taken from these fish.

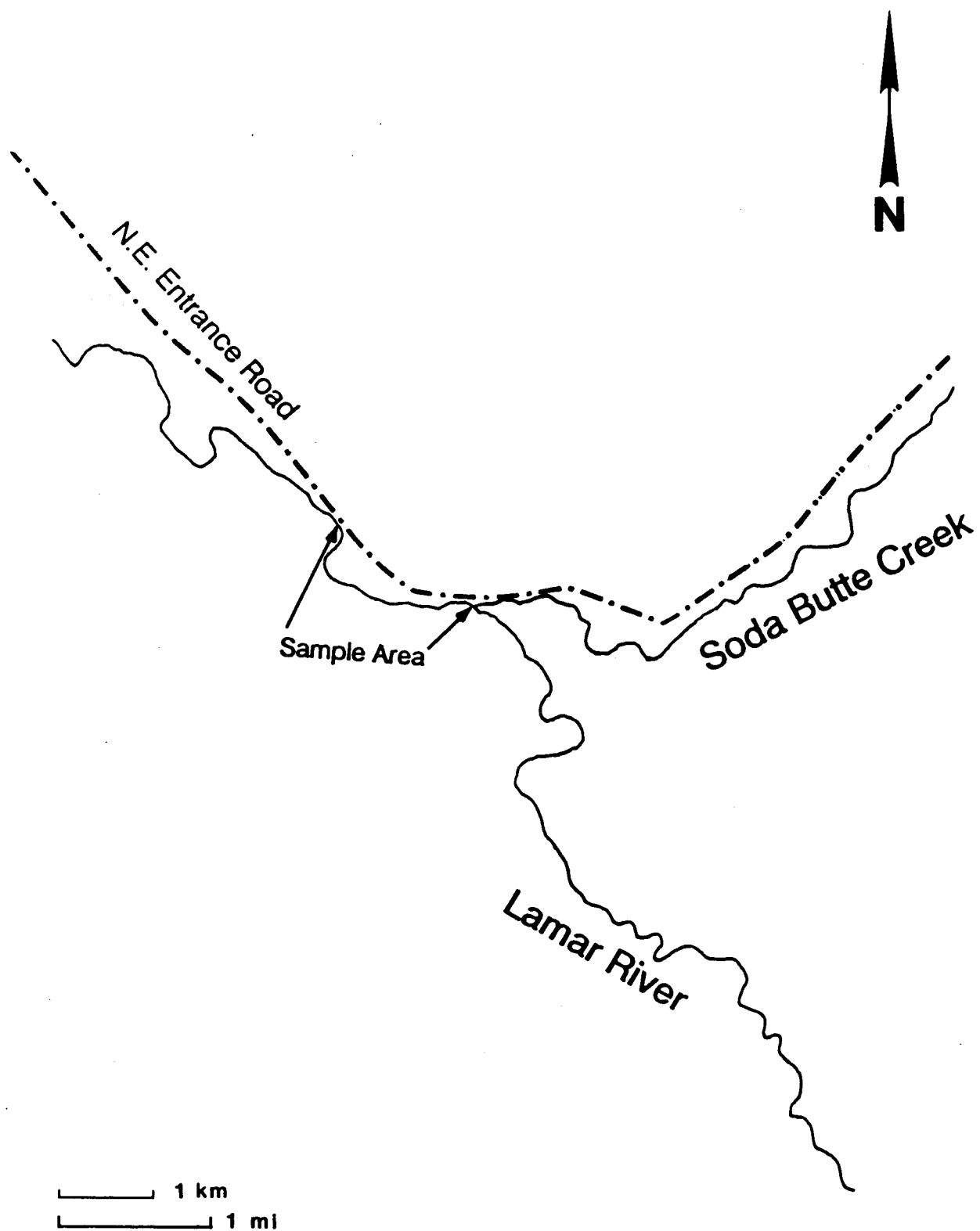


FIGURE 31.-Lamar River valley showing site of electrofishing sample section, 1988.

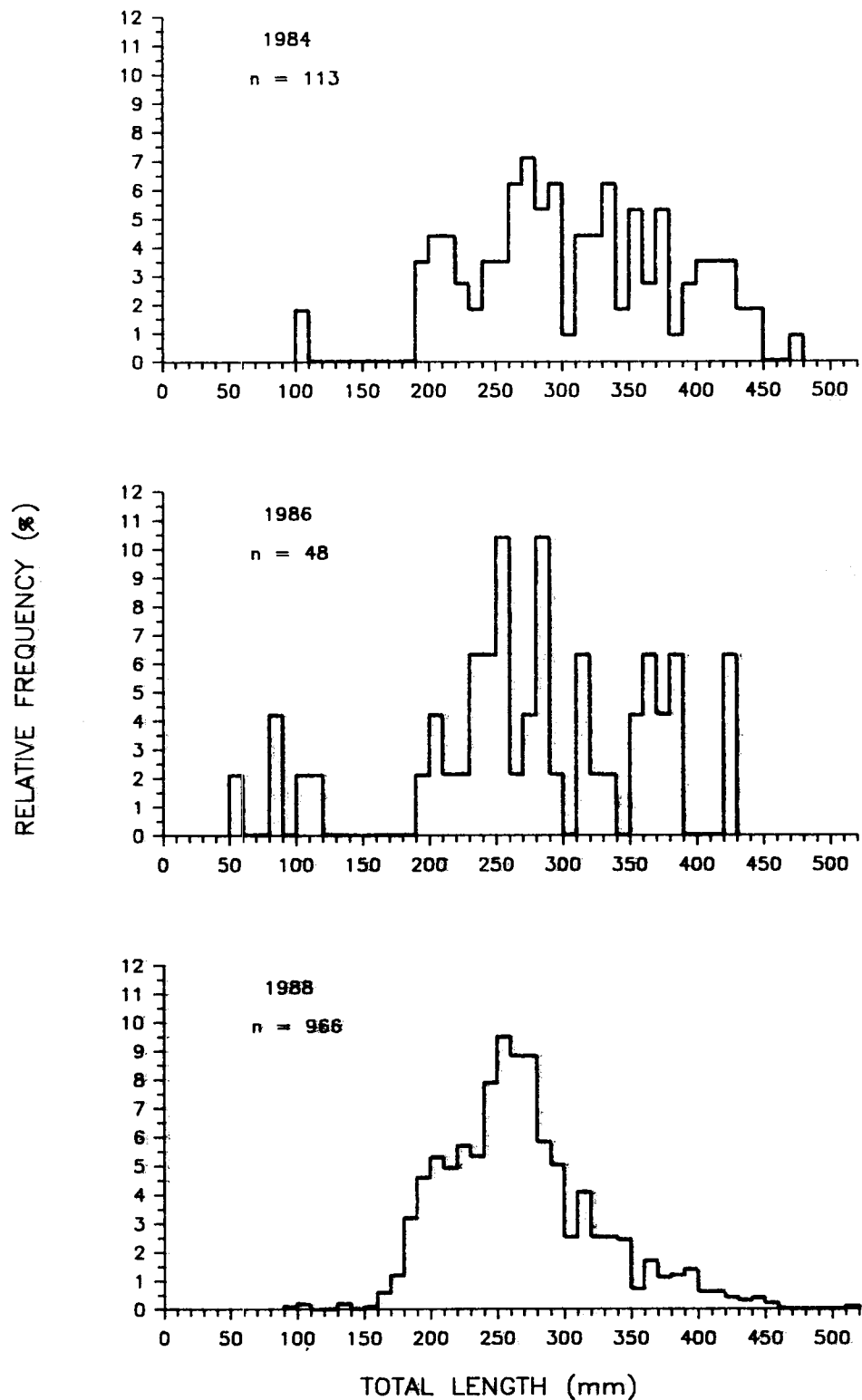


FIGURE 32.-Length-frequency distributions of rainbow trout x cutthroat trout hybrids captured by electrofishing in the Lamar River, 1984, 1986, and 1988.

Angler Use

In 1988, the Lamar River was the sixth most popular stream fishery in Yellowstone National Park, and 5,064 anglers accounted for nearly 3% of the total parkwide angler days (Table 4). In the catch-and-release portion of the Lamar River valley, an estimated 2,464 anglers spent 11,047 h fishing. This level of angler effort is 50% higher than the annual mean effort for the period from 1976 to 1988 (7,167 h/year) and represented the third highest level of angler effort since 1976.

An estimated 13,971 trout were landed in this section of the Lamar River in 1988. Mean length of landed fish was 300 mm. This mean length was only slightly below the average mean length from 1976 to 1988 (305 mm).

Discussion

The decreased mean length observed in the 1988 electrofishing sample and declining PSD values since 1984 may signify a change in the population structure of cutthroat trout in the Lamar River valley. However, the large variability in sample sizes may have influenced results. In addition, it appears that the extremely low streamflows in 1988 contributed to greater electrofishing efficiency. Summer streamflows in the Lamar River in 1986 (Mohrman et al. 1988) were nearly double those of 1988, and the number of trout captured in an electrofishing run was only half of the number collected per run in 1988.

Habitat may be partially limiting trout abundance in the Lamar River. Suitable cover for fish appears to be restricted to large pools, and undercut banks and overhanging vegetation are lacking (Table 19). Diminished streamflows in 1988 may have resulted in crowding of fish into available pools. As a result, electrofishing efficiency increased dramatically.

In the catch-and-release portion of the Lamar River, there has been a significant ($P < 0.001$) relationship between angler effort (hours) and the number of fish landed (Figure 33). The decline in 1988 from record use levels and number of trout landed in 1987 may partially be explained by a drop in landing rate from 2.04 fish/h in 1987 to 1.27 fish/h in 1988. Mean annual landing rate for the period from 1976 to 1988 was 1.63 fish/h. Another factor influencing reduced angler use on the Lamar River in 1988 may have been angler responses to forest fire activity. In 1987, 74% of the fishing activity in the catch-and-release section occurred prior to September. In 1988, over 85% of angler use had occurred by September. Fire activity and associated road and area closures were greatest in September. Thus, the decreased amount of angler use noted in 1988 may be associated with fire activity.

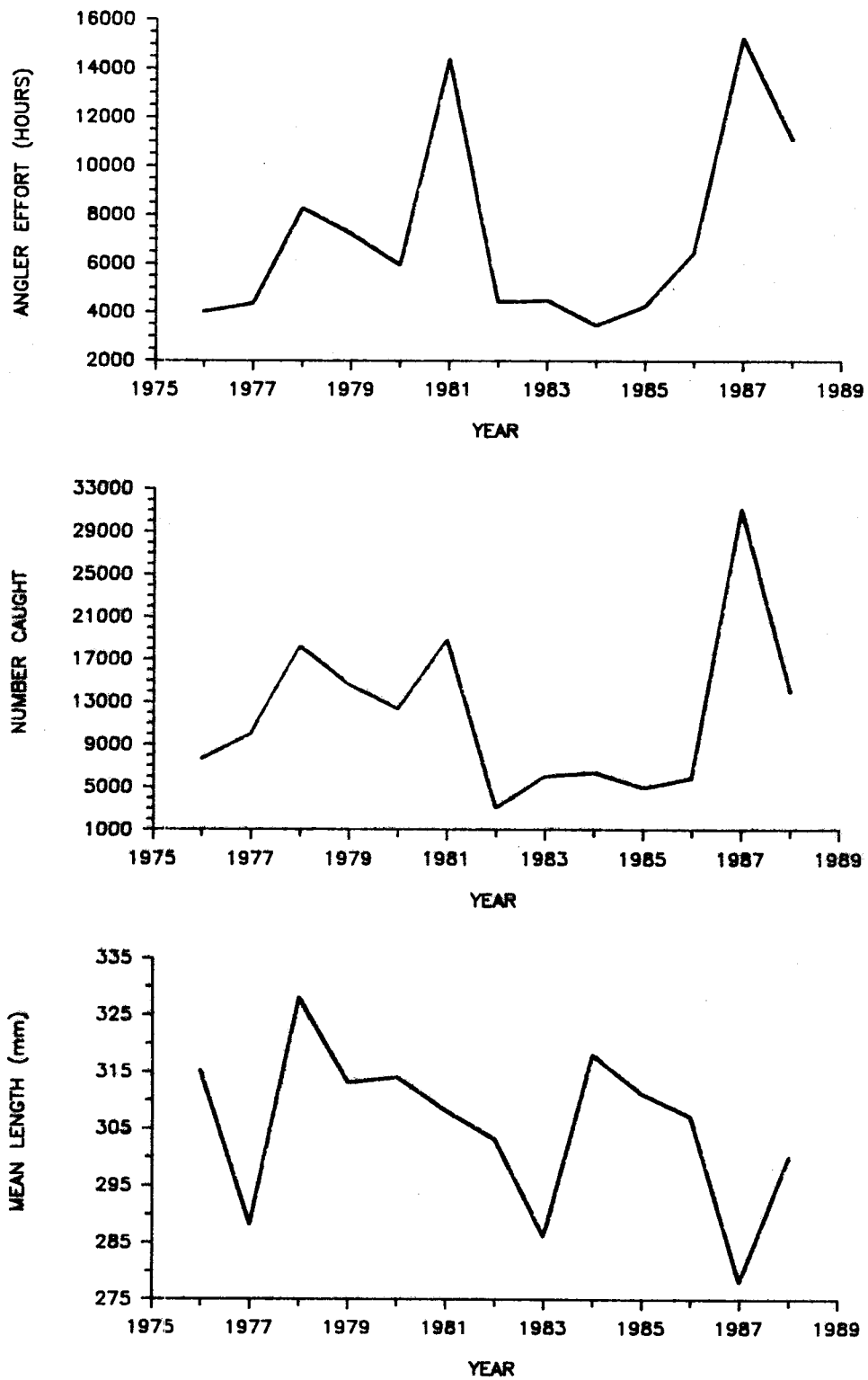


FIGURE 33.-Angler statistics from catch and release section of Lamar River, 1976-1988.

Decreasing mean lengths of cutthroat trout captured by electrofishing, as well as reduced landing rates and number of fish landed may be a cause for concern; however, these factors merit further examination. Drought conditions may be causing displacement of trout to available habitat in downstream areas. Because the Lamar River sample section is adjacent to the confluence with Soda Butte Creek (Figure 31), migratory interchange of fish between the two streams is possible. Fifteen trout that were marked in 1987 in lower Soda Butte Creek were captured in the Lamar River in 1988. Comparison of length-frequency distributions from these two sampling areas revealed a highly significant ($P < 0.001$) relationship between the two samples (Figure 34), suggesting that a large portion of cutthroat trout from Soda Butte Creek moved downstream into the Lamar River in 1988. The small number of trout captured in the lower sample section of Soda Butte Creek in 1988 (see Soda Butte Creek, this report) provides additional evidence of downstream displacement from Soda Butte Creek. Thus, population structure and mean length of cutthroat trout captured in 1988 in the Lamar River may have been strongly influenced by populations from Soda Butte Creek. Continued monitoring of this fishery may provide insight into the dynamics of these populations.

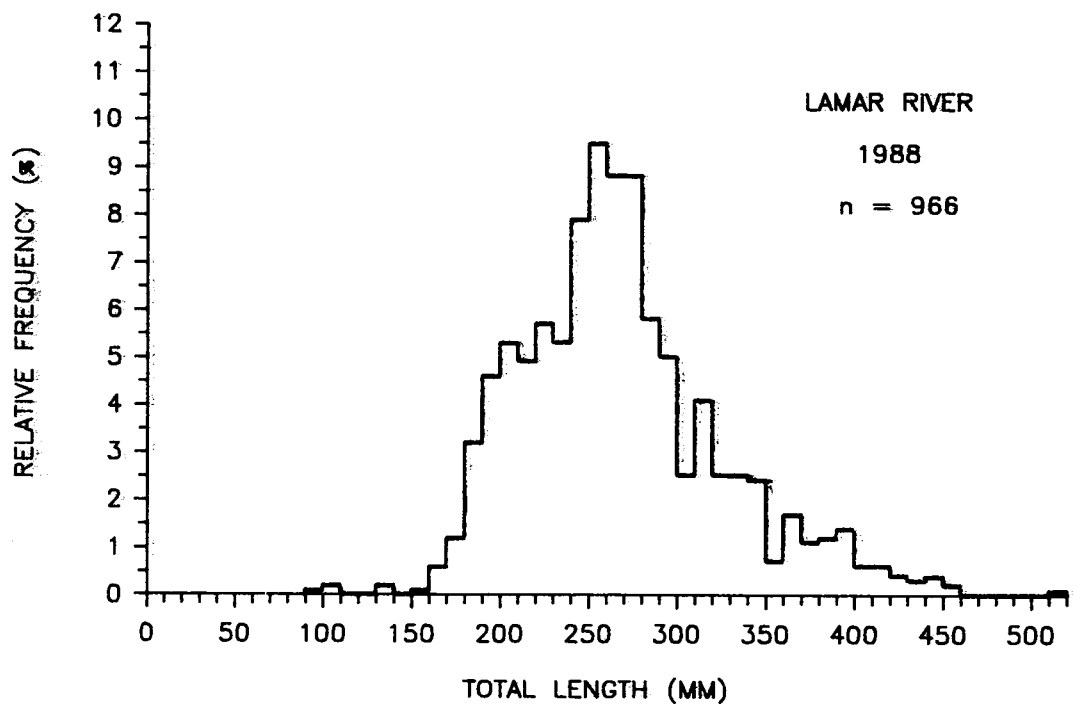
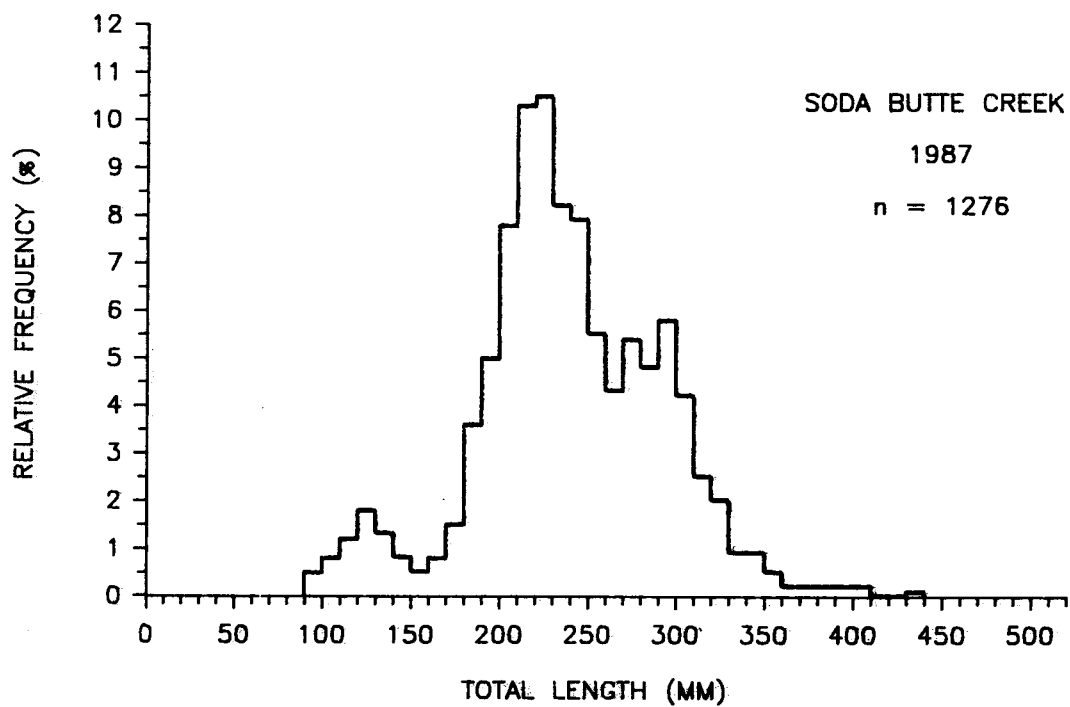


FIGURE 34.-Length-frequency distributions of cutthroat trout captured by electrofishing in adjacent sample areas (Soda Butte Creek, 1987, and Lamar River, 1988).

SLOUGH CREEK

Slough Creek originates as the outlet of a small, unnamed lake (elevation, 2,960 m) near Pinnacle Mountain in the Gallatin National Forest, Montana. From the origin, the creek flows south for 26 km before crossing into Yellowstone National Park. Near the Park boundary, Slough Creek turns southwest and flows for 16 km before passing over a 1-km long series of cascades; these cascades are a barrier to upstream fish passage (Jones et al. 1980). From the base of the cascades, Slough Creek continues southwest for another 8 km before reaching the confluence with the Lamar River (elevation, 1,870 m) (Figure 35). Average gradient of Slough Creek is 2.2%. An 8-km long gravel road provides access to Slough Creek below the cascades, and terminates at a 29-site campground (Figure 35). Access to the remaining portion of Slough Creek is by foot or horse from the trailhead located near the campground.

Annual discharge pattern of Slough Creek is rather typical of streams in this area (Jones et al. 1979). Base flow in winter is followed by a sharp increase in discharge during the spring snowmelt period. Discharge declines gradually over summer and returns to near base flow by late fall. Jones et al. (1979) recorded a minimum discharge of $0.29 \text{ m}^3/\text{s}$ in March and estimated a maximum flow of $16.7 \text{ m}^3/\text{s}$ in mid-June. Water temperature data are limited, but a minimum of 0°C has been recorded in winter (U.S. Fish and Wildlife Service unpublished data), and a maximum of 17°C has been observed in late summer (Arnold and Sharpe 1967; Pickett and Chadwick 1973; Jones et al. 1979).

Total area of the Slough Creek watershed is 562 km^2 ; nearly 376 km^2 are located in the Gallatin National Forest and about 186 km^2 lie in Yellowstone National Park. North of the Yellowstone National Park boundary, the watershed is composed predominantly of Precambrian gneiss, andesitic rocks, and Lower Paleozoic sedimentary rocks (Wedow et al. 1975). Within the Park, the drainage is mostly andesitic Absaroka volcanic rocks and Paleozoic sedimentary rocks (Meyer 1987). Also within the Park, thick glacial sediments cover the valley floor and there are large landslide deposits on portions of the valley walls (Meyer 1987).

Chemically, Slough Creek is a calcium-bicarbonate water; however, one sample in late winter revealed magnesium as the dominant cation (Jones et al. 1979). Major sources of calcium, magnesium, and bicarbonate are the limestone and dolomite within Paleozoic sedimentary rocks (Meyer 1987). Field pH ranges from 7.3 to 8.6 (Pickett and Chadwick 1973), and conductivity varies between $150 \text{ } \mu\text{mhos/cm}$ (Arnold and Sharpe 1967) and $200 \text{ } \mu\text{mhos/cm}$ (Jones et al. 1979).

Instream vegetation studies in Slough Creek have been largely qualitative. Arnold and Sharpe (1967), Mills and Sharpe (1968), and Jones et al. (1979, 1980) identified

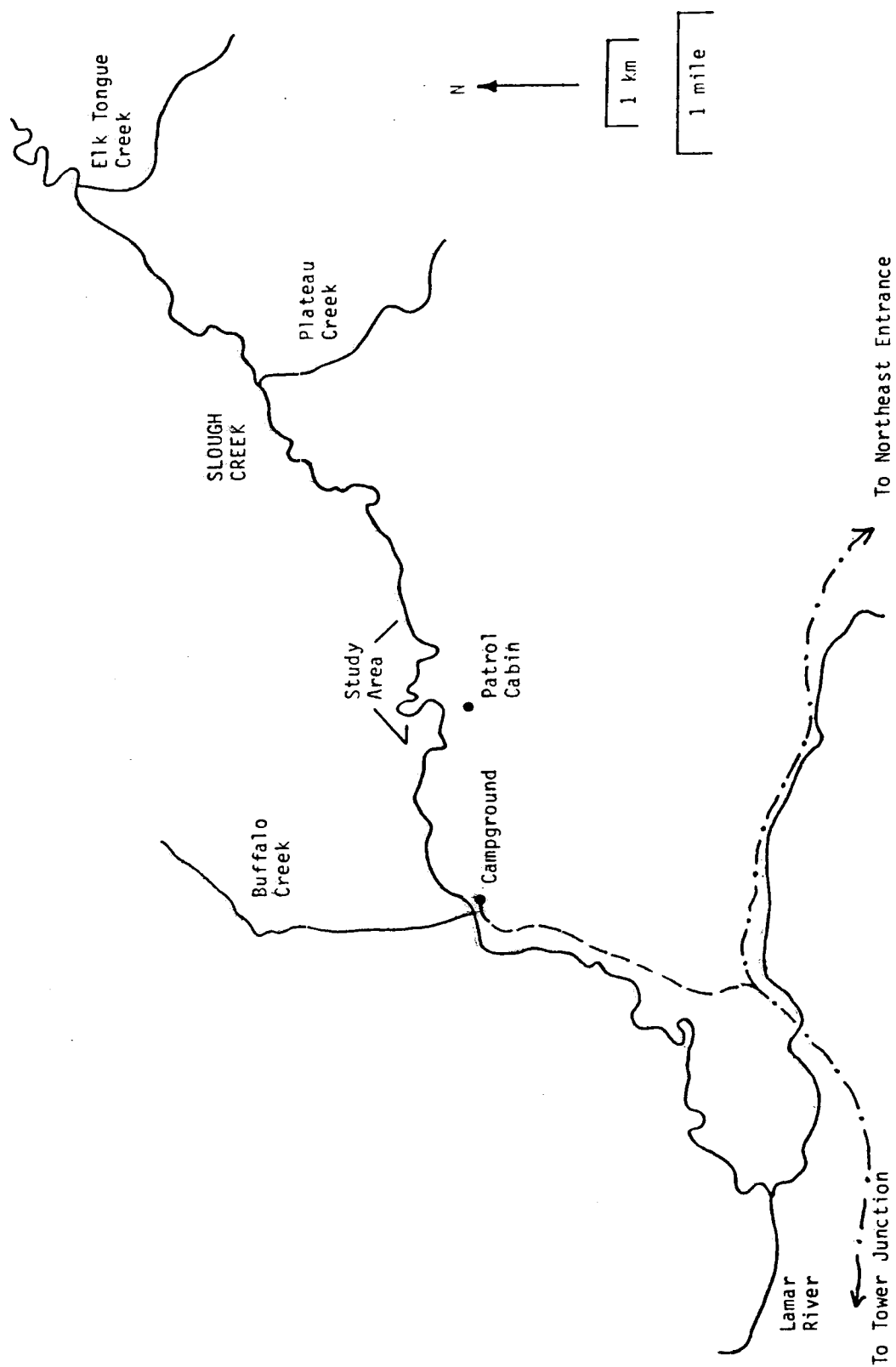


FIGURE 35.-Slough Creek, Yellowstone National Park, showing location of study area.

stream periphyton and macrophytes. Pickett and Chadwick (1973) quantitatively sampled periphyton from a single riffle area and found a "normal" balance between autotrophic and heterotrophic organisms.

Aquatic macroinvertebrate studies in Slough Creek have also been mostly qualitative. Specimens of the orders Ephemeroptera, Trichoptera, Plecoptera, Coleoptera, Diptera, and Amphipoda were collected by a number of investigators (Arnold and Sharpe 1967; Pickett and Chadwick 1973; Jones et al. 1979, 1980). Arnold and Sharpe (1967) also noted the presence of *Physa* sp., and Jones et al. (1979, 1980) found members of Hemiptera, Collembola, Hydracarina, and Oligochaeta.

Jordan (1891) found Slough Creek to be "well-stocked" with native cutthroat trout *Oncorhynchus clarki*; however, large-scale stocking with various subspecies and strains of cutthroat trout between 1920 and 1943 (Varley 1981) undoubtedly altered the genetic integrity of historic stocks. Nonnative rainbow trout *Oncorhynchus mykiss* became established in Slough Creek below the cascades as a result of an introduction in 1932 into Buffalo Creek (a tributary of Slough Creek) by fishery personnel from Montana (Varley 1981). Although Hanzel (1960) reported rainbow trout in a section of upper Slough Creek in Montana, there is no evidence to suggest that rainbow trout have yet entered the Park. Loudenslager and Gall (1981) reported that genetically pure cutthroat trout inhabit Slough Creek upstream of the cascades; cutthroat trout, rainbow trout, and cutthroat trout x rainbow trout hybrids exist below the cascades. Other fishes in Slough Creek below the cascades are the longnose sucker *Catostomus catostomus*, longnose dace *Rhinichthys cataractae* (Arnold and Sharpe 1967), and mottled sculpin *Cottus bairdi* (Jones et al. 1986).

The Slough Creek sport fishery in Yellowstone National Park has been popular for many years. Arnold and Sharpe (1967) speculated that Slough Creek was the most heavily fished stream in the northeast section of the Park. In the 1980s, Slough Creek has consistently been among the top five most popular stream fisheries in the entire Park (Jones et al. 1981-1988).

Liberal creel limits in effect prior to the early 1960s (U.S. Fish and Wildlife Service unpublished data) were replaced by a creel limit of five trout of any size in 1964. In 1970, this regulation was amended so that only three of the five trout creeled could be cutthroat trout. From 1971 through 1972, a three-trout, 356-mm minimum-size limit was in effect. Catch-and-release-only angling was instituted in 1973 and has remained in effect to the present.

Fishery management investigations on Slough Creek date back to the 1960s and can be separated into four periods. From 1966 through 1971, studies focused on collecting baseline habitat and fish population data; manned creel

surveys to monitor the sport fishery were also conducted during this period (Arnold and Sharpe 1967; Mills and Sharpe 1968; Mills 1969; Dean and Mills 1970, 1971; Dean 1972). During the years 1973 through 1977, data from the Volunteer Angler Report (VAR) system were used to monitor the sport fishery and recommend changes in angling regulations (Dean and Varley 1974; Dean et al. 1975; Varley et al. 1976; Jones et al. 1977, 1978). Extensive habitat and fish population surveys accompanied VAR analysis from 1978 through 1980 (Jones et al. 1979-1981). Data from the VAR system were used exclusively to monitor the sport fishery between 1981 and 1987, and one fish population study was conducted in 1985 (Jones et al. 1982-1988).

In 1988, the Hellroaring Creek and Storm Creek wildland fires affected approximately 63% of the entire Slough Creek watershed (Patten et al. 1988). Both of these fires originated in the Gallatin National Forest; the Hellroaring Creek fire was man-caused, and the Storm Creek fire originated from natural causes.

In response to forest fire activity in 1988, physical habitat conditions, cutthroat trout populations, and the cutthroat trout sport fishery were evaluated in Slough Creek upstream of the cascade barrier. Physical habitat and fish population data were collected at a single study site on 19, 20, and 27 October. This information and data from previous studies were used to document changes in the fishery since 1980 and describe pre-fire conditions in this area of Slough Creek.

Study Area

The study area was situated at an elevation of approximately 1,970 m in an unburned meadow immediately upstream of the cascades (Figure 35). Meadow vegetation is dominated by sedges *Carex* spp. and tufted hairgrass *Deschampsia cespitosa* (Jones et al. 1980). The stream reach studied was a 2.1-km long, fifth-order stream segment. Average gradient was 0.04%, and sinuosity was 1.2. Average stream width and depth on 19 October were 21 m and 19 cm, respectively. Discharge was 1.5 m³/s, and water temperature was 8°C. Field pH and conductivity were 8.6 and 190 µmhos/cm, respectively.

Methods

Physical and chemical.--Stream order, drainage area, elevation, and stream-reach length at the study site were determined from U.S. Geological Survey maps (scale 1:24,000). Other parameters of the water column, streambank, streambottom, and riparian zone were measured at each of three transects according to methods described by Jones et al. (1988, Stream Survey this report) and Platts et al. (1983).

Cutthroat trout.-Cutthroat trout population abundance was estimated by the Chapman modification of the Peterson method (Ricker 1975). Mark and recapture samples were obtained by electrofishing from a rubber raft. The 4-m long raft was fitted with two stationary dropper electrodes (one positive, one negative), a 3.5-kW AC generator, and a Coffelt VVP-15 rectifying unit that produced pulsed, direct current. Electrofishing was conducted at night.

Trout captured during the mark run on 20 October were measured to the nearest millimeter (total length) and fin-clipped. During the recapture run on 27 October, all trout were again measured to the nearest millimeter, and the number of recaptures was recorded. Weights to the nearest 2 g were taken from five fish in each 25-mm length group to develop a length-weight relationship; a geometric-mean regression (Ricker 1975) was used to calculate the length-weight equation.

Creel survey data from the VAR system for the period 1980-1988 were used to analyze the sport fishery between the cascade barrier and the northern boundary of the Park.

Statistical analyses.-Statistical procedures used herein are described in Zar (1984), and all statistical tests were conducted at $\alpha = 0.05$. The Number Cruncher Statistical System (Hintze 1987) and computer programs written by the U.S. Fish and Wildlife Service (unpublished) were used to analyze data.

Results

Physical Habitat (1980 and 1988)

Physical habitat parameters measured in 1988 at the three transects were averaged to provide a summary of streambottom, water column, streambank, and riparian zone characteristics (Table 30). Gravel and sand made up approximately 80% of channel substrate. Cobble and silt were present in lesser amounts. Embeddedness of substrate particles was low (10%). There was no vegetation on the streambottom that could be used as cover by fry, juvenile, or adult trout.

Pools in the study reach, formed from the process of natural channel meandering, averaged 8.6 m wide and were rated slightly below average as cover for juvenile and adult trout. Water depth at the streambank was 0 cm, which suggested a paucity of habitat for trout fry. A relatively high solar angle (145°) indicated that solar radiation is probably not a limiting factor to primary production.

Estimated streambank soil alteration (45%) revealed that about one-half of the streambank was in a naturally stable condition, and vegetative stability was rated good to excellent (3.5). Absence of undercut banks suggested a lack of cover for all life stages of trout.

TABLE 30.-Means of selected physical habitat parameters measured at three transects in a 2.1-km long study reach of Slough Creek, 19 October 1988.

Habitat parameter	Measured, estimated, or ranked value
Water column:	
Discharge	1.5 m ³ /s
Channel width	33 m
Stream width	21 m
Stream depth	19 cm
Stream shore water depth	0 cm
Riffle width	10 m
Pools:	
Width	9 m
Quality	2.5
Feature	2
Solar Angle	145°
Streambank:	
Streambank soil alteration	46%
Vegetative stability	3.5
Undercut bank	0 cm
Channel-bank angle	144°
Streambottom:	
Gradient	0.04%
Sinuosity	1.15
Substrate:	
Bedrock	
Boulder (> 305 mm diameter)	
Cobble (64-305 mm diameter)	8%
Gravel (2-64 mm diameter)	60%
Sand (0.6-2 mm diameter)	28%
Silt (< 0.6 mm diameter)	4%
Embeddedness	10%
Channel vegetative cover	0 cm
Riparian zone:	
Streamside cover	1.8
Vegetative use by animal	33%
Vegetative overhang	0 cm
Habitat type	4,2

Riparian vegetation was dominated by grass and forbs. There was no vegetative overhang; hence, no cover or shade were provided by riparian vegetation. Grazing by wild ungulates was moderate (33.3), suggesting that at least one-half of the potential plant biomass was on site at the time of sampling (Platts et al. 1983).

The only previous habitat data from this area of Slough Creek were collected in 1980. Binns (1981) reported a relatively high level of natural bank erosion and substrate dominated by coarse gravel and fines.

Cutthroat Trout (1980 and 1988)

A total of 133 "unmarked" cutthroat trout were captured during mark and recapture electrofishing runs in 1988. Trout in this sample ranged in length from 95 to 480 mm (Figure 36) and averaged 378 mm. Based on the stratified subsample of 40 trout, the length-weight equation was $\ln(W) = 2.91 \ln(L) - 11.09$ ($r^2 = 0.99$). Mean weight, estimated by inserting mean length into the length-weight equation, was 483 g.

Jones et al. (1981) collected the only previous length and weight data from this reach of Slough Creek in August 1980. Based on an electrofishing sample of 73 trout from a 366-m long sample site, lengths ranged from 75 to 499 mm (Figure 36) and averaged 301 mm. Differences in mean lengths of cutthroat trout between years was significant (t-test; $P < 0.00001$). Mean weight of cutthroat trout in 1980 was 355 g, but comparisons of mean weights from the two studies are confounded by the method used to calculate mean weight in 1988.

In 1988, the statistically unbiased population estimate (Robson and Regier 1964) was 49 trout/hectare. Using the mean weight determined from the length-weight equation, the 1988 biomass estimate was 23.5 kg/hectare (Table 31). Number and biomass estimates in 1988 were lower than in 1980; Jones et al. (1981) estimated numbers at 84-85 trout/hectare and biomass at 38-52 kg/hectare by three different methods (Table 31).

The Sport Fishery (1980-1988)

From 1980 through 1988, an annual average of 2,300 anglers spent 14,200 h (angler effort) fishing Slough Creek between the cascades and the northern boundary of Yellowstone National Park. During this 9-year period, anglers annually landed an average of 21,200 trout at a mean landing rate of 1.5 fish/h and an average length of 349 mm.

Angler effort, landing rate, and mean length of landed fish have varied considerably over the past 9 years. Angler effort, rather stable from 1980 through 1983, rose sharply during the next 4 years to a record high 23,700 h in 1987 (Figure 37). In 1988, angler effort dropped to 13,600 h

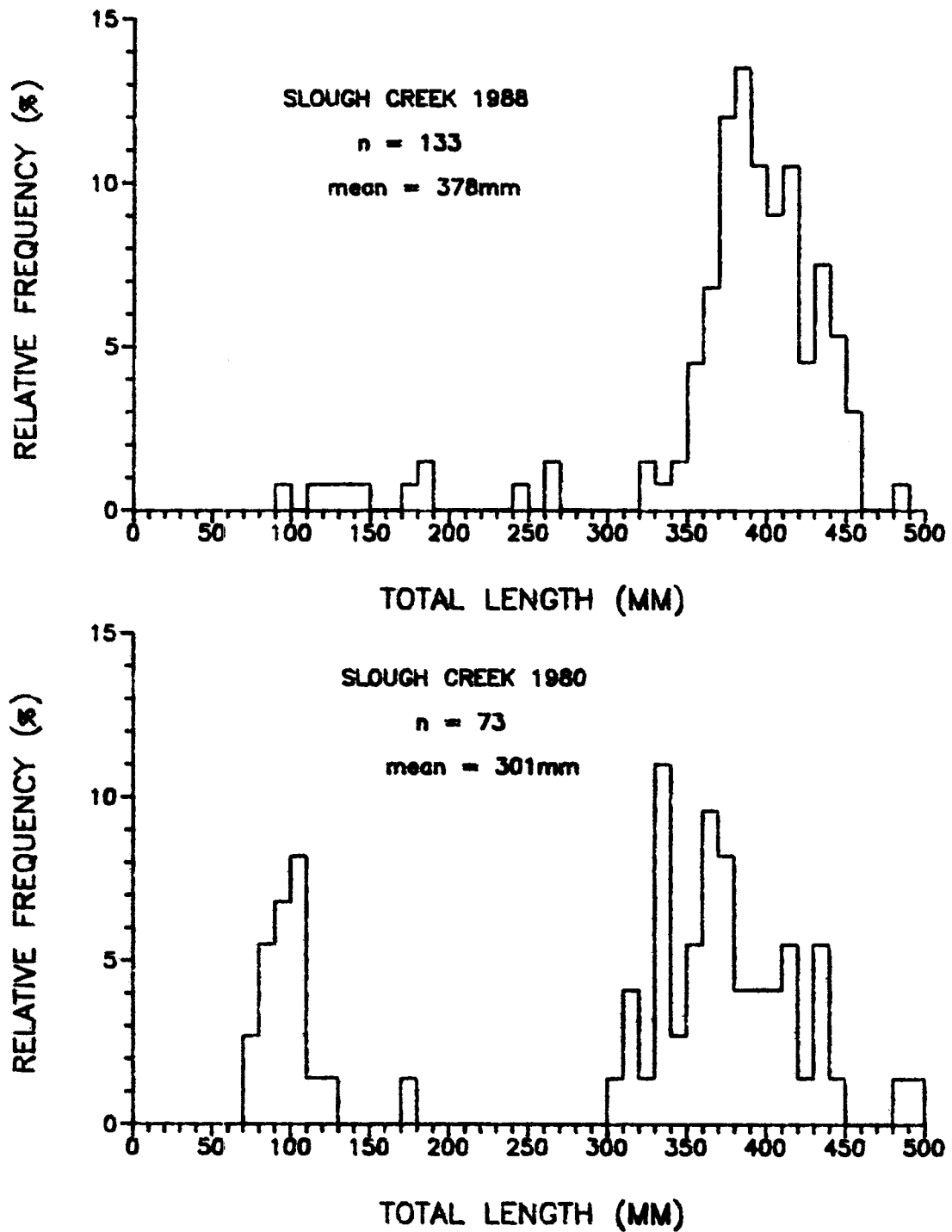


FIGURE 36.-Length frequencies of cutthroat trout captured by electrofishing in the first meadow above the cascades, 1980 and 1988.

TABLE 31.-Fish-population estimates for Slough Creek, 1980 and 1988.

Year and method of population estimate	Number (fish/hectare)	95%		Biomass (kg/hectare)	95%	
		confidence limits			confidence limits	
		upper	lower		upper	lower
1988						
1. Chapman modification of Peterson method (Ricker 1975)	49	71	34	23.5	34.3	16.6
1980 ^a						
1. Removal method (Zippin 1958)	85	-	-	45.0	-	-
2. Snorkle direct counts	84	-	-	52.3	-	-
3. Habitat Quality Index (HQI) (Binns and Eiserman 1979)	-	-	-	38.0	-	-

^a Data summarized from Jones et al. (1981).

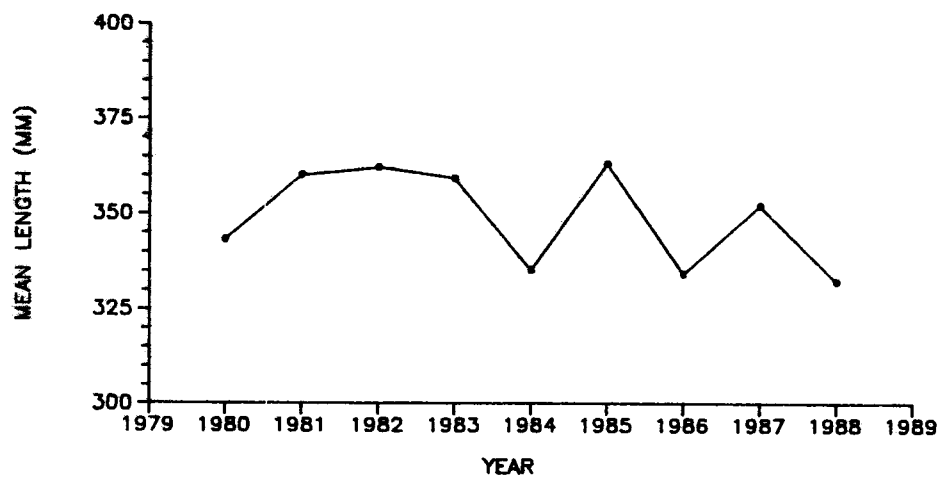
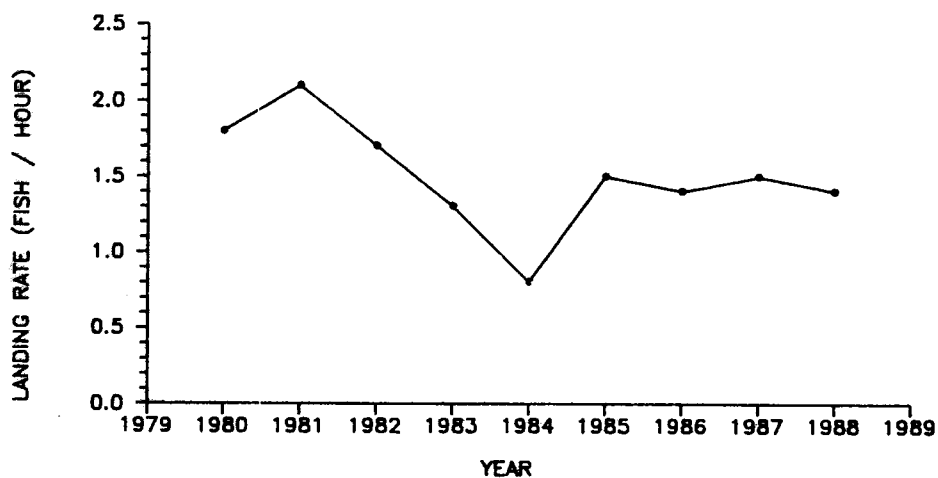
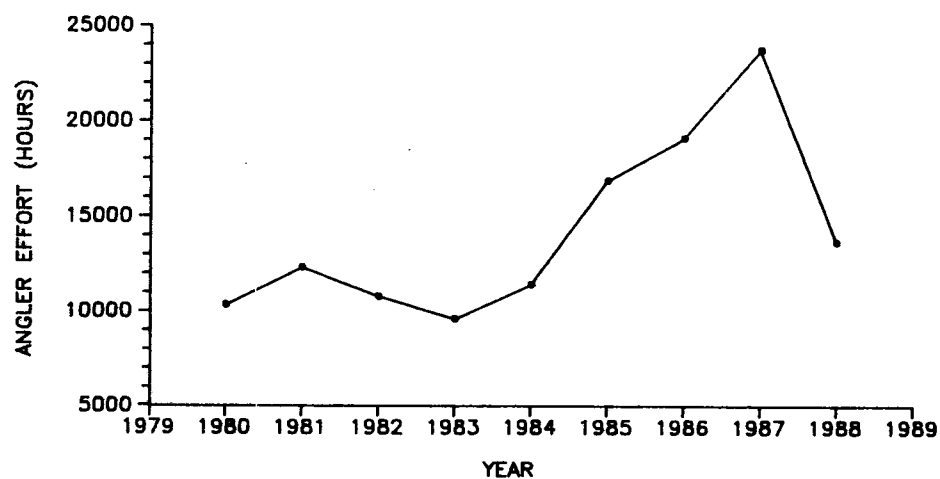


FIGURE 37.-Angler effort, landing rate, and mean length of fish landed on Slough Creek between the cascades barrier and the northern boundary of Yellowstone National Park, 1980-1988.

(Figure 37). Landing rate, highest in 1981 at 2.1 fish/h, dropped to a low of 0.8 fish/h in 1984 (Figure 37). Since 1985, however, landing rate has been quite steady at about 1.5 fish/h (Figure 37). Mean length of landed fish has fluctuated between 332 and 360 mm, but no long-term trends are evident (Figure 37).

Discussion

Because the study section was situated in an unburned meadow and sampling occurred prior to precipitation events that could produce substantial surface runoff in burned areas upstream, results from the current study are probably reliable indicators of pre-fire conditions. However, annual precipitation for the 1988 water year (45 cm) in the northeast part of the Park was 30% less than the 1964-1988 average (64 cm) (U.S. Soil Conservation Service unpublished data). Therefore, current results should be viewed within the constraint of extreme low-water conditions.

Physical Habitat (1980 and 1988)

Streambottom and streambank characteristics as measured by Binns (1981) and in the current study were similar. Although the comparison between studies may be biased by differences in sample methods, it appears that physical habitat in this section of Slough Creek has changed little over the past 9 years. Binns speculated that streambottom and streambank characteristics in this area were limiting factors to trout production. Data from the current study also suggest that a paucity of cover components may limit trout production in this section of Slough Creek.

Cutthroat Trout (1980 and 1988)

Results from Jones et al. (1981) and the current study suggest that habitat conditions in the study section are best suited to adult trout. Although comparisons between studies may again be biased by different sample methods, the significantly greater mean length in 1988 may indicate greater survival of older and larger fish under 15 years of catch-and-release fishing. Lower numbers and biomass in 1988 may reflect reduced carrying capacity under extreme low-water conditions.

The Sport Fishery (1980-1988)

Increasing popularity of the Slough Creek fishery upstream of the cascades is evidenced by the sharp rise in angler effort from 1984 through 1987. The temporary closure of the trail and campground may have caused the observed decline in angler effort in 1988. Forest fire posed a safety hazard to visitors; consequently, the National Park

Service closed the trail to upper Slough Creek from 20 August through 4 October, and the Slough Creek Campground closed on 31 August and did not reopen in 1988 (National Park Service unpublished data). Barring recurrence of forest fire in 1989, it is probable that angler effort will again be relatively high. A virtually unchanging landing rate since 1985 and lack of trend in mean length of fish landed since 1984 indicate a rather stable fishery under current levels of angler effort.

SODA BUTTE CREEK

Soda Butte Creek is a major tributary of the Lamar River and is located in the northeastern corner of Yellowstone National Park. The drainage basin is a product of Absaroka volcanic flows combined with Pleistocene glaciation. Massive landslides from both Druid Peak and The Thunderer have had a major influence on present topography. The Madison limestone formation underlies the majority of the stream, and sporadic outcroppings of this material occur throughout the drainage (Parsons 1978).

Surveys have been conducted on Soda Butte Creek since 1965 to monitor habitat and associated fishery responses to pollution effluents from the McLaren mine tailings outside of the Park boundaries at Cooke City, Montana. These surveys have included habitat measurements (Sharpe and Arnold 1966; Jones et al. 1981; Decker-Hess and White 1987), fish population estimates (Jones et al. 1982, 1985-1988) and macroinvertebrate monitoring (Mangum 1986, 1988).

Soda Butte Creek contains one of the more popular stream fisheries in the Park. Scenic mountains and highway access along Soda Butte Creek enhance the angling experience. Monitoring angler impacts on the fish populations in Soda Butte Creek has been an important component of the survey programs.

In 1988, three sections of Soda Butte Creek were sampled for fish. The lower (footbridge) section has been sampled by electrofishing in four previous years and the upper (northeast) area has been sampled on five separate occasions. A third section near Icebox Canyon has been sampled by electrofishing twice previously, and was sampled with rotenone in 1988. This section will be treated separately.

Methods

Because discharge and associated depth were quite small in the northeast section, two Coffelt BP-1 backpack electroshockers were used to sample the fish population. All fish were measured to the nearest 1 mm total length, weighed to the nearest 2 g, and marked with a fin clip. A scale sample was collected from each fish for age and growth analyses; however, time constraints did not allow analyses for inclusion with this report.

In the footbridge sampling section, electrofishing was conducted from a 4.3 m rubber raft that contained boom-mounted electrodes, a portable generator, and a pulsed DC shocking system. All captured fish were measured to the nearest 1 mm total length and marked with a fin clip. A stratified subsample (based on 25-mm length groups) of fish were individually weighed to the nearest 2 g. Scales were collected from these fish for future age and growth

analyses. The population in this section was estimated by applying the adjusted Peterson formula (Ricker 1975) to the results of the mark and recapture electrofishing samples.

Results

Northeast Section

The upper sampling section begins at the northeastern boundary of Yellowstone National Park and extends downstream for 305 m (Figure 38). In 1988, one electrofishing pass through this section yielded 23 cutthroat trout *Oncorhynchus clarki bouvieri*. This continued the trend of significantly smaller sample sizes observed in the past few years, which have been only 14 to 16% of 1984 levels (Table 32). Mean total length in 1988 was 223 mm, mean weight was 146 g, and mean condition factor (K) was 1.09. This mean length represented a 13% significant decrease from that observed in 1987. However, mean length in the 1988 sample did not decline significantly below the average mean length of 231 mm for the period from 1984 to 1988.

Additionally, the 1988 sample encompassed a much wider range of size groups than previous samples. Examination of length frequencies indicate that nearly 35% of the cutthroat trout from the northeast section were less than 200 mm total length in 1988 (Figure 39). The percentage of fish greater than 330 mm has continued to remain at a very low level (Table 32). Proportional stock density (PSD) as defined by Gabelhouse (1984) was 0.0 in 1988 in the northeast sample section; however, by using stock, quality, and preferred lengths of 153 mm, 254 mm, and 330 mm, respectively (see gillnetting section, this report), PSD was 35.0 and relatively stock density-preferred (RSD-preferred) was 5.0.

Footbridge Section

The lower sampling section on Soda Butte Creek begins at the Lamar River Trail footbridge and extends downstream for 2.3 km (Figure 38). Two electrofishing runs yielded 319 introgressed cutthroat trout. The population in this section was estimated to be 480 fish (95% confidence limits: 391-603). Because lengths were not obtained for recaptured fish, all size groups were combined for a statistically unbiased estimate (Ricker 1975). Despite a similar level of sampling effort, sample size and estimated population in 1988 were the lowest obtained in 4 years of sampling (Table 33).

Mean length of fish captured in 1988 was 236 mm; mean weight and condition factor (K) of a subsample were 227 g and 0.95, respectively. Although sample size has varied considerably in this sampling area, mean length in 1988 has

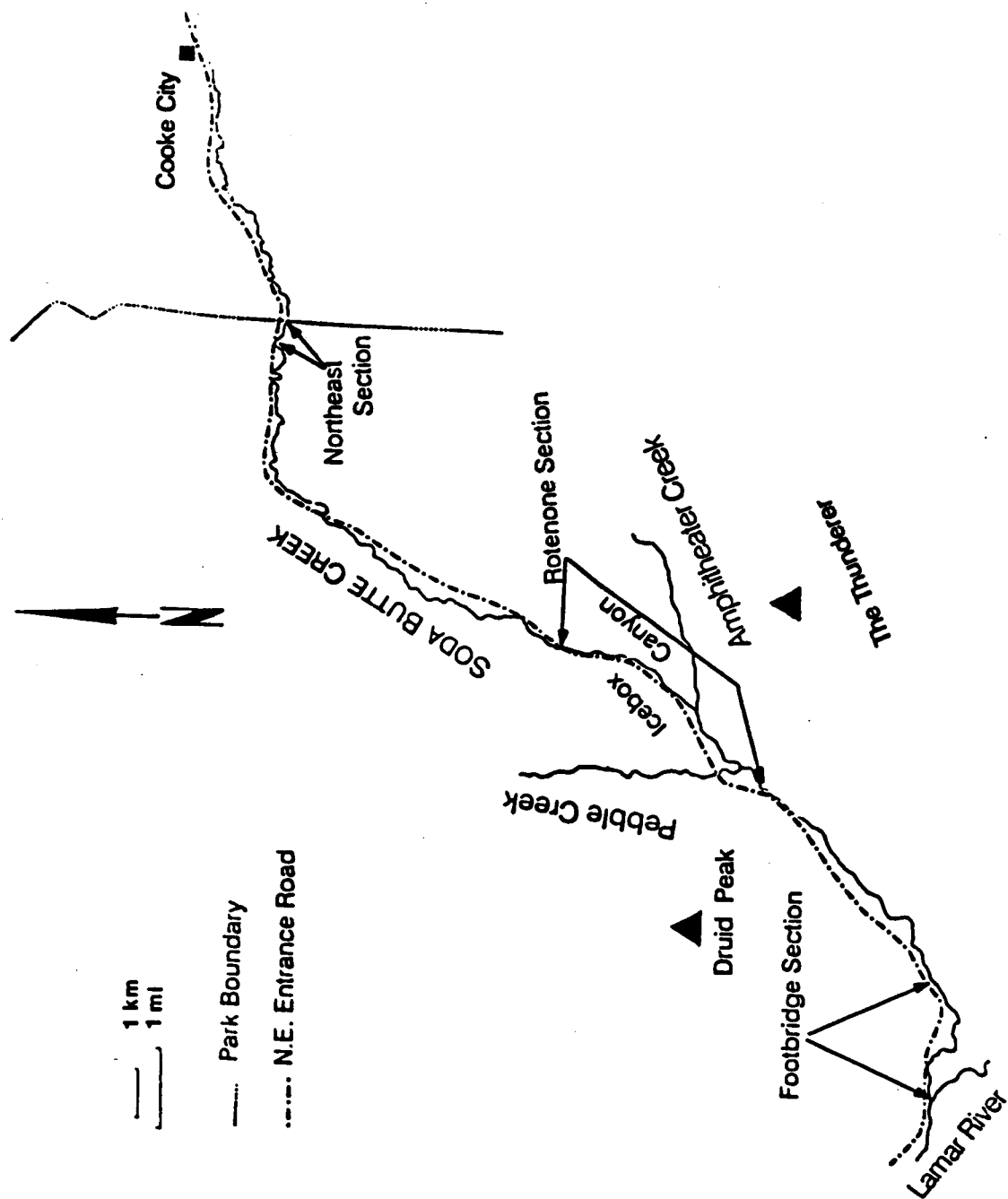


FIGURE 38.-Hydrographic map of Soda Butte Creek showing locations of sampling stations, 1988.

TABLE 32.-Sample size and length data for cutthroat trout from the northeast electrofishing section, Soda Butte Creek, 1984-1988.

Year	n	Mean total length (mm)	Percent $\geq$ 330 mm
1984	163	205	0.6
1985	88	222	1.1
1986	23	250	4.3
1987	26	256	0
1988	23	223	4.3

TABLE 33.-Sample size and length data for cutthroat trout from the footbridge electrofishing section, Soda Butte Creek, 1984, 1986-1988.

Year	n	Mean total length (mm)	Percent $\geq$ 330 mm
1984	511	243	7.2
1986	345	234	6.7
1987	1,276	238	3.1
1988	319	236	14.1

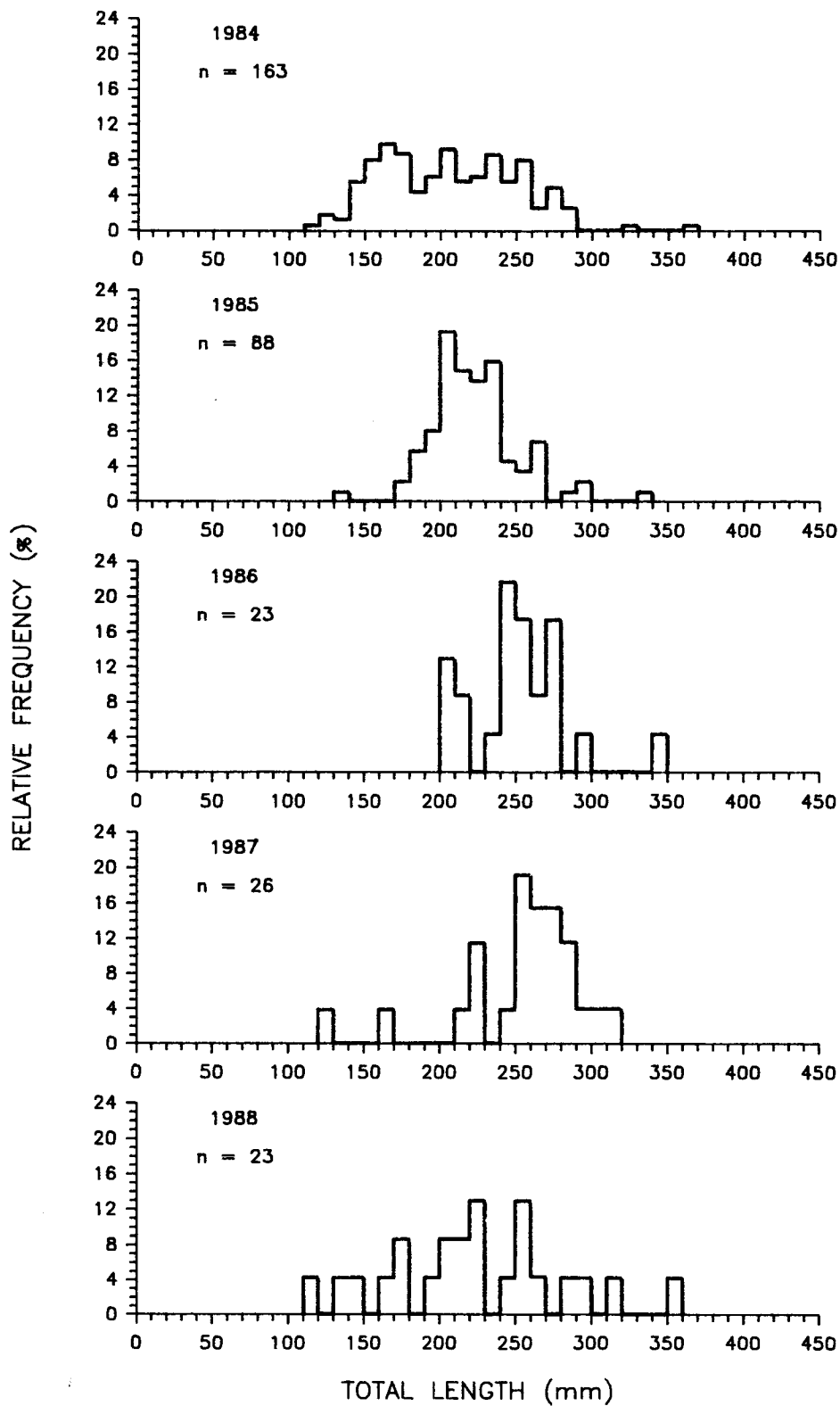


FIGURE 39.-Length-frequency distributions of cutthroat trout captured by electrofishing in the northeast sample section of Soda Butte Creek, 1984-1988.

not changed significantly from the average mean length (1984 to 1988) of 238 mm (Table 33). Examination of length frequencies shows that 39% of the fish captured in 1988 were less than 200 mm total length. In 1987, only 18% were less than 200 mm (Figure 40). In contrast, over 14% of the fish captured in 1988 were greater than or equal to 330 mm in length. This suggests a substantial reversal in the decreasing abundance of cutthroat trout in this size group (Table 33). PSD and RSD-preferred values (Gabelhouse 1984) were 3.6 and 0.0, respectively. Comparable values using 153 mm, 254 mm, and 330 mm as stock, quality, and preferred lengths, respectively, are 65.2 and 18.0.

Angler Use

Soda Butte Creek has sustained a high level of angler use for many years. From 1973 to 1986, Soda Butte Creek was managed under a two-fish, any-size creel limit. Concern about the high rate of angler exploitation (Jones et al. 1985) prompted a regulation change in 1987 to a two-fish, 330-mm minimum-size creel limit. Data from Volunteer Angler Report returns has been subdivided into two sections: above Icebox Canyon and below Icebox Canyon.

Angler effort (hours) decreased substantially in 1988 in both sections of Soda Butte Creek. Reduced effort may be partially due to closures associated with fire activity. Despite the reduction, angler effort in both sections remained above the mean annual effort for the period from 1977 to 1985 (2,678 h/year above Icebox Canyon and 4,335 h/year below Icebox Canyon). Angler effort below Icebox Canyon continues to be higher than above Icebox Canyon (Figure 41).

Numbers of fish landed under the new regulation have also remained above the pre-1987 annual mean (Figure 41). Above Icebox Canyon, dramatic fluctuations in annual numbers of trout landed have been observed (Figure 41). The mean annual number of trout landed below Icebox Canyon during 1987 and 1988 (10,144 fish/year) was more than 250% greater than the levels maintained during the last 5 years of the old regulation. Despite the lack of definitive patterns, mean annual number of trout landed during 1987 and 1988 has been 43% greater above Icebox Canyon and 84% greater below Icebox Canyon than during the 1977 to 1986 period. High landing rates during 1987 and 1988 have undoubtedly contributed to the increased number of fish landed. Mean total length of trout landed above Icebox Canyon during the post-regulation change period has increased by 1.4% over the 1977 to 1986 average mean. A decrease in harvest to one-third of pre-1987 levels paralleled this increase in mean length. Despite a significant reduction in harvest below Icebox Canyon, mean total length of trout landed in 1988 below Icebox Canyon (257 mm) was 1.7% below the average mean total length for the period from 1977 to 1986 (262 mm).

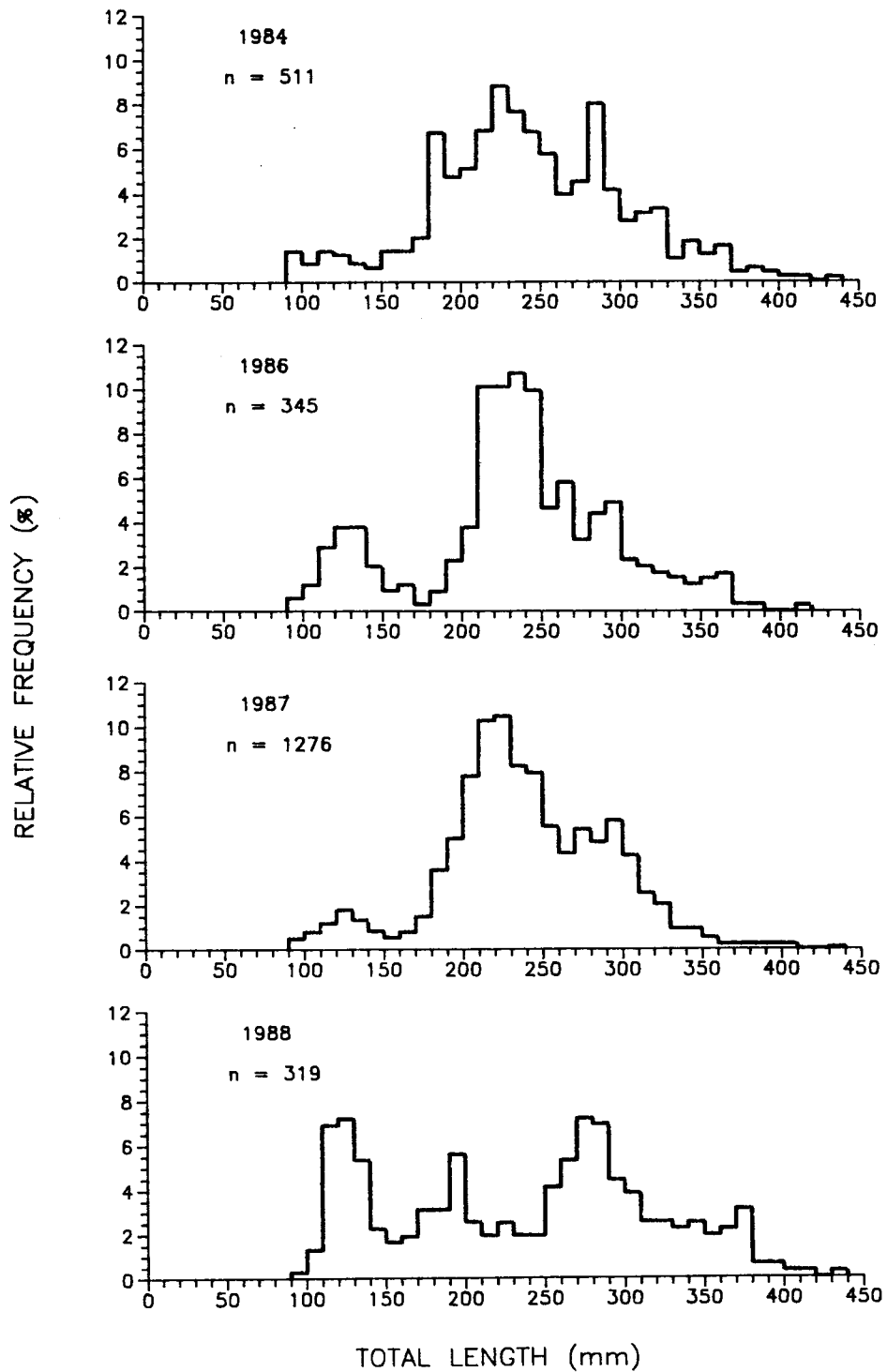


FIGURE 40.-Length-frequency distributions of cutthroat trout captured by electrofishing in the footbridge sample section of Soda Butte Creek, 1984-1988.

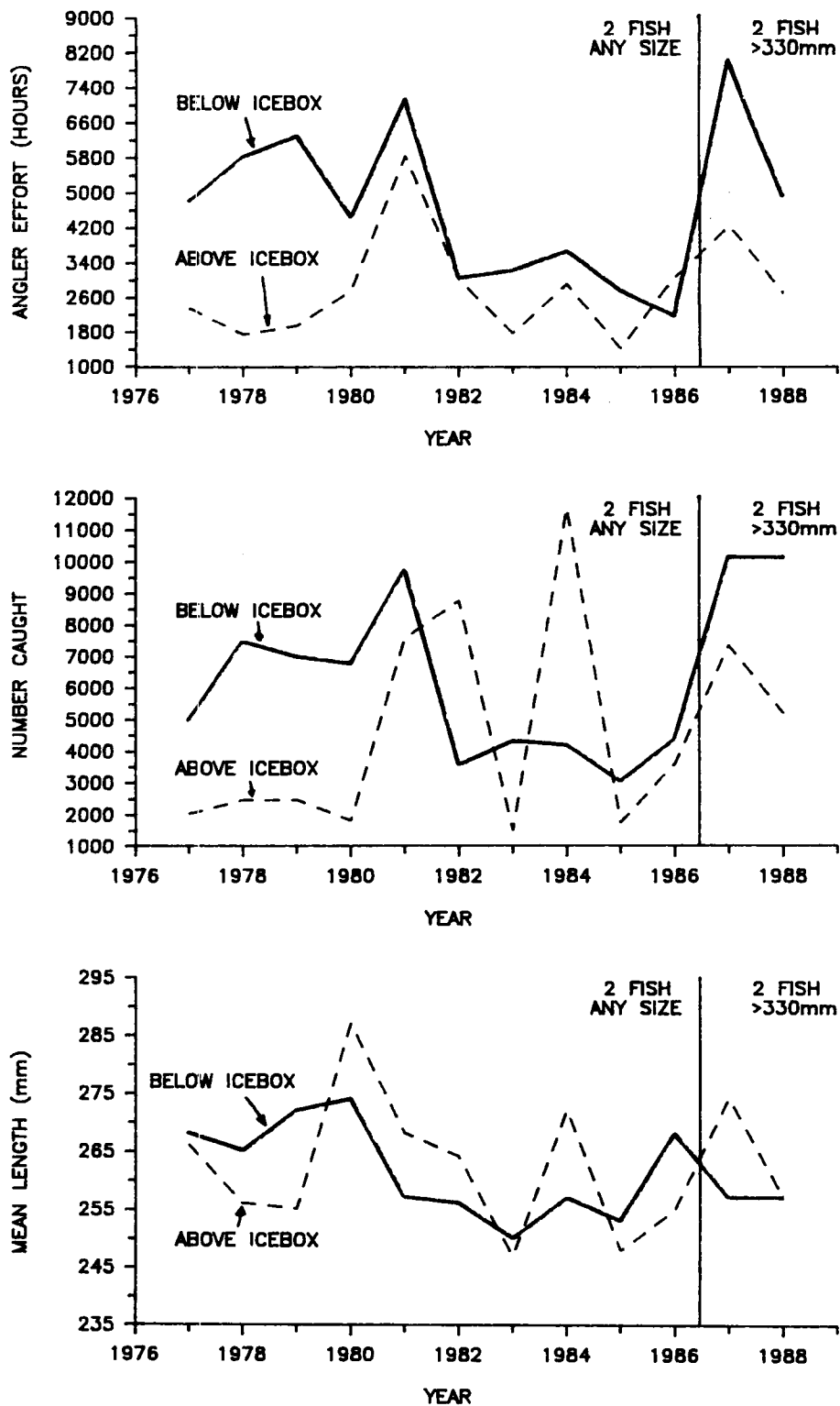


FIGURE 41.-Angler effort (hours), number of fish caught, and mean length of landed fish in Soda Butte Creek, 1976-1988.

Discussion

The northeast and footbridge sample areas are located above Icebox Canyon and below Icebox Canyon, respectively. Consequently, general comparisons of angling effects on existing cutthroat trout populations may be made. In both sample sections in 1988, sample sizes were quite small in comparison to previous years. Continued drought conditions and the associated reduction in suitable habitat may be negatively impacting trout by diminishing the trout population or affecting displacement of trout into unsampled areas of Soda Butte Creek. Additionally, length frequencies of the sampled populations indicate a wider range of size groups is currently occupying Soda Butte Creek (Figures 39 and 40).

Because the current regulation is more restrictive, harvest of cutthroat trout has declined dramatically since the regulation change in 1987. An estimated 467 trout were creel in 1988. This represents only 25% of the harvest level from 1977-1986. Although harvest is concentrated on larger trout, the percentage of fish greater than 305 mm landed above Icebox Canyon increased from 15% (1977-1986 mean) to 20.8% in 1988. In contrast, comparable values below Icebox Canyon showed a slight decrease from 15.4% (1977-1986 mean) to 13.8% in 1988. These data indicate that the vast majority of the cutthroat trout are smaller than the minimum harvest size. As a result, most of the landed fish are returned to the stream, rather than being creel.

Because cutthroat trout have a high degree of recatchability (Jones 1987), the high numbers of fish landed in 1987 and 1988 (Figure 41) suggest that cutthroat trout in Soda Butte Creek may be caught several times throughout the angling season. Initial results indicate that the minimum-size regulation is providing protection for a larger proportion of the cutthroat trout population in Soda Butte Creek. However, these preliminary findings should be viewed with caution, because harvest is still targeted on the older and larger trout. In addition, potential impacts from mine tailings, as well as effects of drought and fire activity, could compound the difficulty of interpreting present and future results.

Rotenone Sampling

Historically, cutthroat trout have been the only salmonid present in Soda Butte Creek. Stocking of rainbow trout *Oncorhynchus mykiss* in 1937 (Varley 1981) left the genetic integrity of the native cutthroat trout stocks in doubt. A subsequent study revealed that the cutthroat trout population has become introgressed with rainbow trout genes (Loudenslager and Gall 1981). However, the genetic purity of cutthroat trout upstream from Icebox Canyon is questionable because Icebox Canyon may be a permanent

barrier to upstream fish migration (Sharpe and Arnold 1966; Jones et al. 1982). As part of an independent research project being conducted to determine degree of hybridization or introgression of cutthroat trout in Soda Butte Creek, U.S. Fish and Wildlife Service collected a sample of fish on 11 August 1988.

Methods

Rotenone, a toxin that inhibits respiration in fish (Rounsefell and Everhart 1953), was used to collect the trout sample. Rotenone works most effectively at temperatures from 10.0°C (50°F) to 23.8°C (75°F) (Davies and Shelton 1983). Required concentrations for obtaining an adequate sample range from 0.5 to 2.0 ppm of rotenone (Everhart et al. 1975).

At the sample site in Soda Butte Creek, streamflow was estimated to be 0.84 m³/s. The estimated dispensing rate of rotenone for this flow was 25 mL/min (Davies and Shelton 1983). Approximately 400 mL of 5% rotenone (95% water) formulation were applied at the upstream boundary of the sampling section. After 30 min there was no observable effect on the fish in the stream. An additional 500 mL were added to the stream and fish were stressed within 15 min. Following the appearance of stressed fish, approximately 950 g of potassium permanganate were applied to the lower end of the sampling section to prevent rotenone toxicity downstream of the sampling section.

To determine the extent of rotenone toxicity, Soda Butte Creek was sampled by electrofishing 3 weeks after the application of rotenone. The section above Icebox Canyon was electrofished with two Coffelt BP-1 backpack shockers. Equipment used below Icebox Canyon consisted of a plastic 2 m boat, hand-held electrodes, and an electrical system identical to that used in the footbridge electrofishing section. All captured trout were measured to the nearest 1 mm total length, weighed to the nearest 2 g, and scales were collected for age and growth analysis.

Results and Discussion

Because the effects of rotenone in streams can be variable (Lagler 1956; Davies and Shelton 1983), a miscalculation in dosage can result in fish kills. In Soda Butte Creek, it appears that a rotenone dosage of approximately 0.25 ppm may be sufficient to disable cutthroat trout; however, the applied dosage in 1988 was nearly four times this concentration. In addition, the concentration of potassium permanganate needed to detoxify the rotenone was underestimated by approximately one order of magnitude. As a result, the rotenone was not confined to the sampling area, and approximately 3.6 km of the stream were affected. The treated area extended from the highway

bridge above Icebox Canyon downstream to an area below the confluence with Pebble Creek (Figure 38).

Numerous stressed fish may have drifted downstream from Icebox Canyon. Due to the impossibility of separating fish by location of origin, all collected fish were combined for purposes of analysis. A total of 1,848 cutthroat trout were measured for total length; an additional 367 trout could not be measured due to their stage of decomposition. An estimated 400 additional trout were not collected from the stream. Thus, the total number of trout killed by rotenone was approximately 2,700.

Mean total length of 1,848 cutthroat trout was 151 mm. Expanded mean weight using Ricker's GM length-weight equation (Ricker 1975) was 32.9 g. Total estimated trout biomass for the treated section was 60.9 kg or 18.1 kg/km of stream.

The area treated with rotenone in 1988 encompassed two sampling sections from a 1987 survey. The section above Icebox Canyon was termed S2 and the section below Icebox Canyon was termed S3 (Jones et al. 1988). Comparison of length-frequency distributions from these three sampling sites shows that rotenone primarily affected smaller fish (Figure 42). Over 95% of the cutthroat trout killed by rotenone were smaller than 250 mm total length, and only two trout were longer than 330 mm total length. In contrast, nearly 30% of the sampled fish at station S2 were greater than 250 mm total length. The smaller trout in the rotenone sample represent younger age classes.

In 1987, a population estimate in the S3 sampling section was 1,003 fish/km (Jones et al. 1988). Rotenone sampling in 1988 killed approximately 750 cutthroat trout/km in Soda Butte Creek. This fact, along with examination of length-frequency distributions, indicate that a major portion of the smaller and younger fish were lost as a result of rotenone application.

Electrofishing 3 weeks after rotenone sampling yielded four cutthroat trout in the section above Icebox Canyon. Mean total length was 195 mm (range: 83-253 mm). Below Icebox Canyon, 27 cutthroat trout were captured. These fish ranged in size from 76 to 276 mm total length (mean total length = 197.4 mm). In addition, 17 mountain suckers *Catostomus platyrhynchus* were captured below Icebox Canyon. These data suggest that rotenone applied to Soda Butte Creek appears to have had a more deleterious effect above Icebox Canyon than below Icebox Canyon.

Several factors contributed to this inadvertent fish kill. In large streams, such as Soda Butte Creek, rotenone is very difficult to control because localized variations in streamflow may concentrate the toxins; and the effects may take a long time to appear. During the sampling of Soda Butte Creek, inadequate time was used to monitor the effects of the rotenone. Tributary streams may be expected to dilute the toxicity of the rotenone; however, with low

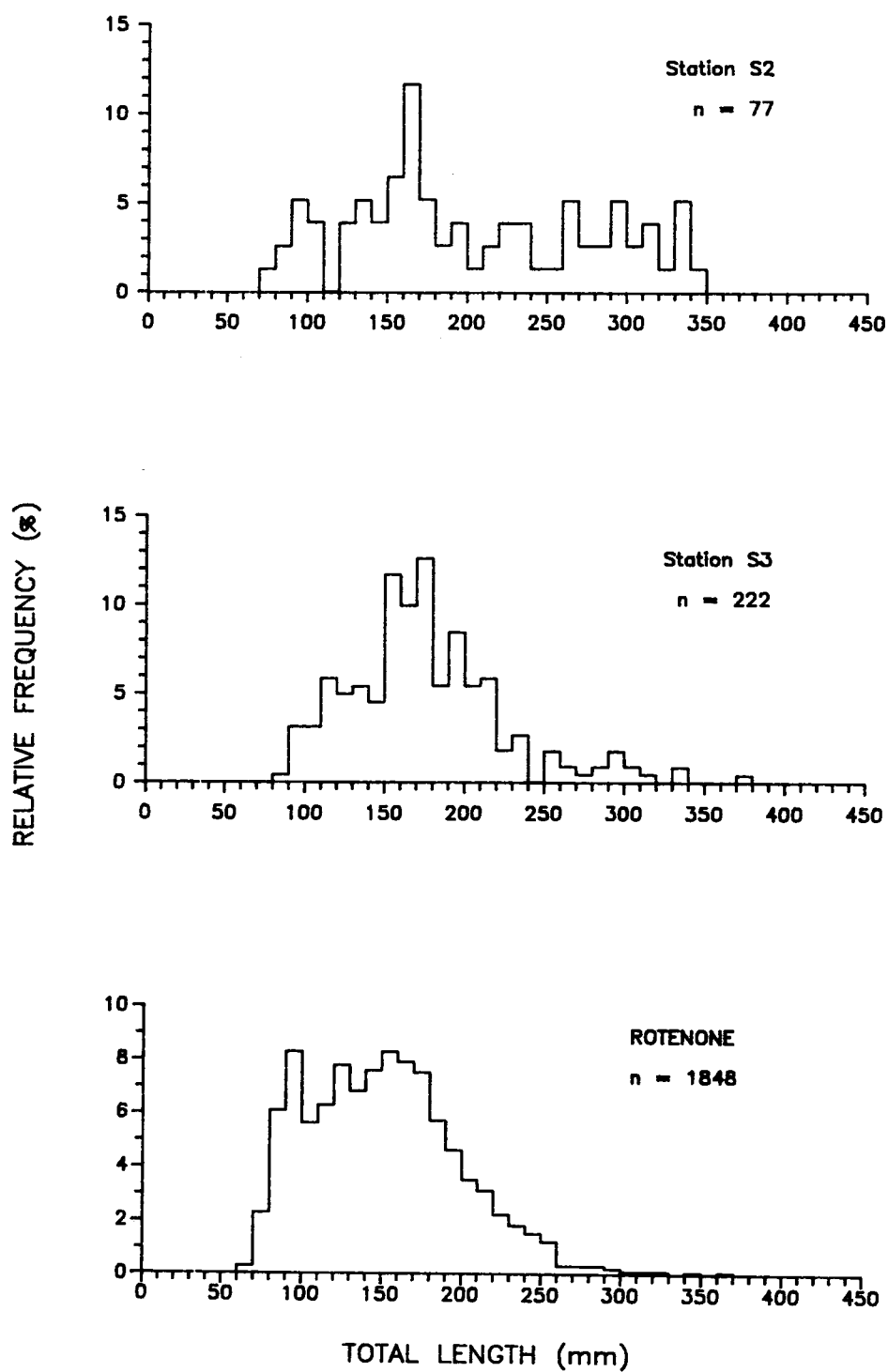


FIGURE 42.--Length-frequency distribution of cutthroat trout collected in Soda Butte Creek by electrofishing in 1987 (Stations S1 and S2) and by rotenone in 1988.

streamflows during 1988, both Pebble Creek and Amphitheater Creek appear to have only slightly dampened the toxicity of the applied dose.

Although a large number of cutthroat trout were accidentally killed in Soda Butte Creek, the effects should be temporary. Rotenone is biodegradable and breaks down in a relatively short period of time (Davies and Shelton 1983). The cutthroat trout population in this area of Soda Butte Creek has been substantially reduced. However, within a few years, affected areas in the stream should be repopulated. Continued monitoring of this population may lead to a better understanding of shifts in community structure and repopulation rates in populations that have been seriously and suddenly reduced.

LAKE TROUT SPAWN-TAKING OPERATION

Lewis Lake was historically fishless (Jordan 1891), and initial introductions of lake trout *Salvelinus namaycush* and brown trout *Salmo trutta* occurred in 1890 (Varley 1981; Visscher 1984). Lake trout for this introduction were collected from spawning reefs near the Beaver Islands in Lake Michigan (Visscher 1984). Since Lewis Lake is only 4.8 km downstream from Shoshone Lake, rainbow trout *Oncorhynchus mykiss* and brook trout *Salvelinus fontinalis* may have gained access to Lewis Lake after they were stocked into tributaries of Shoshone Lake in 1893 and 1895, respectively (Varley 1981). The only other occasion when fish were planted into either lake occurred in 1941; 5,890 lake trout fingerlings were obtained from Bozeman, Montana, Fisheries Station and released into Lewis Lake (Visscher 1984).

Efforts to reestablish lake trout in the Great Lakes have been hampered by the use of poorly suited donor stocks. These failures have resulted in current strategies that include selecting fish stocks that prefer habitat characteristics similar to those of the receiving habitat (Ihssen 1984). Limited lake trout introductions in Lewis Lake have reduced the potential for genetic mixing within this species, and thus, the integrity of the Beaver Island stock has probably been maintained. Virtual genetic isolation of lake trout in Lewis Lake, therefore, made this stock an excellent candidate for reestablishment efforts in Lake Michigan.

To this end, annual collection of sex products from Lewis Lake lake trout was initiated in 1982 (Jones et al. 1983). Both eggs and sperm were collected in 1982, 1983, and 1985, but 1984 and 1986 collections were limited to sperm alone. Gametes were not collected for this project in 1987; however, in 1988, both eggs and sperm were obtained.

Methods

On 28 September, lake trout were collected by electrofishing from a boat with boom-mounted dropper electrodes (Novotny and Priegel 1974). Pulsed direct current (80 pulses/s) was utilized with a voltage between 100 and 200 V. Trout were captured at three sites along the east shore of Lewis Lake (Figure 43). Stunned fish were netted and placed into a boat-mounted livewell to recuperate. Periodically, trout from the electrofishing boats were transferred to a 9-m barge for processing. Females were injected with gonadotrophin, and all fish were held in holding-nets 7 d prior to spawning by personnel from Ennis National Fish Hatchery (NFH), Jackson NFH, and Creston NFH. Fertilized eggs were shipped to Saratoga NFH for incubation.

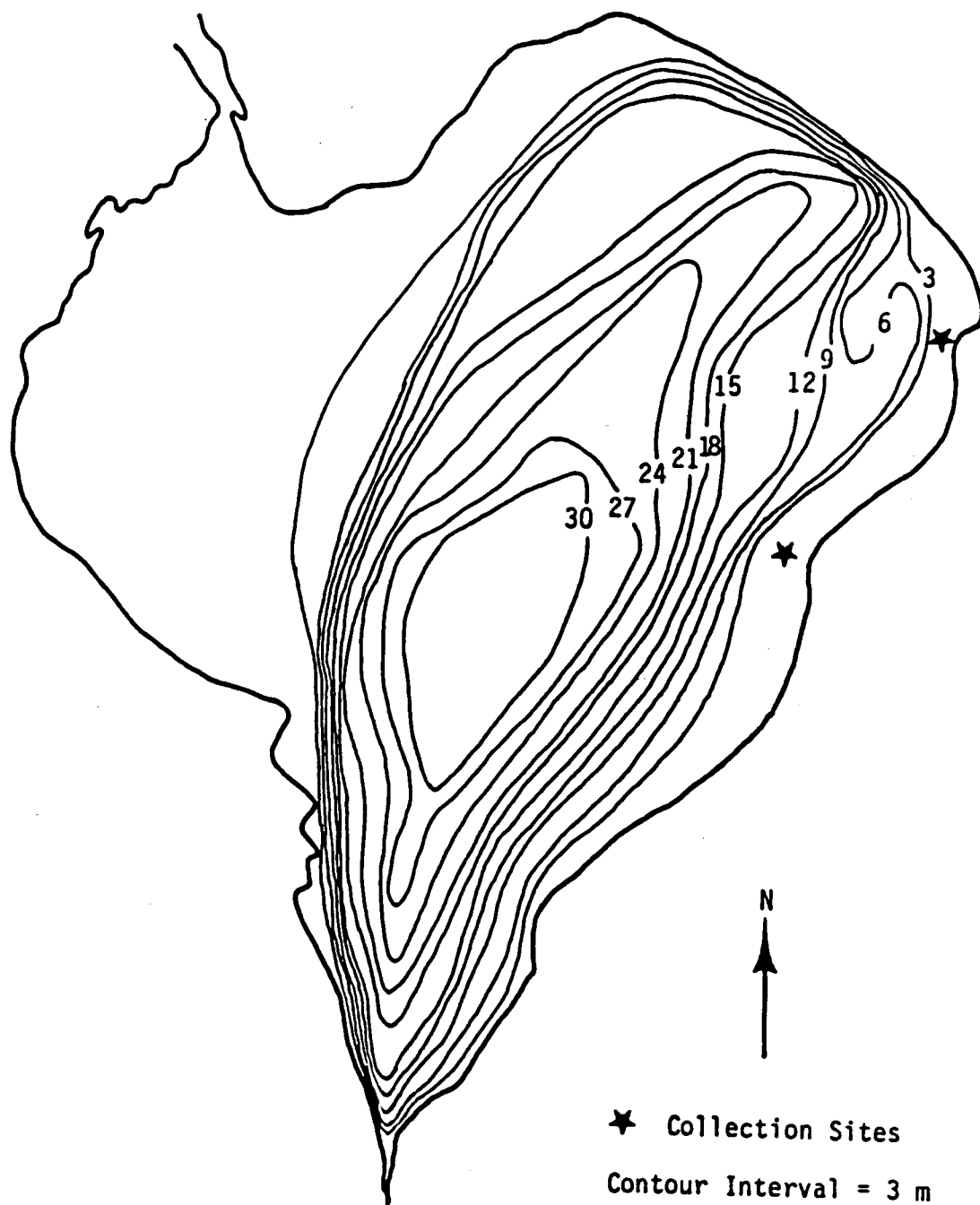


FIGURE 43.-Collection sites for spawn-taking operations, Lewis Lake, 1988.

Disease samples were obtained from 75 of the lake trout used for gamete collection on 6 October 1988. Nonlethal samples of fecal matter and ovarian fluid were also collected. Samples were shipped to the U.S. Fish and Wildlife Service Disease Control Center (Ft. Morgan, Colorado) for analysis. Tests were made for viral hemorrhagic septicemia virus.

Sex determination, total length measurements (to the nearest 1 mm), and weight (to the near 2 g) were recorded for 176 lake trout. Scale samples were collected from 170 of these fish for age determination.

Results

A total of 101 females and 173 males were collected on 28 September. On 6 October, gametes were obtained from 66 male-female pairs. An approximate 90% eye-up of 66,000 eggs yielded about 60,000 eyed eggs from the Lewis Lake lake trout. All of these eggs remained at Saratoga NFH for use in the brood-stock program

All trout in the disease sample tested negative for viral agents. Mean lengths of 90 males and 86 females were 436 and 442 mm, respectively. Mean length for the combined sample was 439 mm. Difference in mean weight between males (622 g, N = 83) and females (550 g, N = 80) was not statistically significant ($P > 0.05$).

The existing lake trout production program at Saratoga NFH produced 80,000 eyed-eggs in 1988 for the Lake Michigan lake trout restoration program. A total of 700,000 eyed-eggs were shipped from Saratoga NFH to Iron River NFH in Michigan. An additional 100,000 eggs were shipped to Pendills Creek NFH.

Discussion

Collection of a sufficient number of ripe females is still the most difficult part of the lake trout spawn-taking operation on Lewis Lake. Limiting collections to ripe males greatly reduces field time necessary to complete the operation. Because of disease problems at Jackson NFH that caused the destruction of the entire Lewis Lake lake trout brood stock, all brood-stock operations have been shifted to Saratoga NFH. As females from this broodstock mature, the need for females from Lewis Lake should decrease.

ARNICA CREEK RESTORATION PROJECT

Yellowstone Lake supports what may be the largest remaining population of native inland cutthroat trout *Oncorhynchus 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 detected in Arnica Creek in May 1985. Electrofishing surveys conducted on 40 other tributaries to Yellowstone Lake suggested 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 one occasion in 1988, and no brook trout were observed. Electrofishing with a backpack shocker on 21 June 1988 was concentrated approximately 4 km above the mouth near the intersection of the three main forks of Arnica Creek.

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 irrigation and dewatering of tributaries to the upper Yellowstone River (Clancy 1984). Decreased hatching success and depressed recruitment resulting from inadequate instream flows in tributaries used for spawning may be limiting to migratory trout populations from the Yellowstone River. Reese Creek is the northernmost tributary of the Yellowstone River in Yellowstone National Park and provides suitable spawning habitat for trout populations from the Yellowstone River mainstem.

Since 1978, the state of Montana has been involved in a statewide water rights adjudication process that has included the Yellowstone River drainage. Reese Creek is the only stream in Yellowstone National Park that has 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 the presence of 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. Later studies have described the physical habitat of Reese Creek, population characteristics of resident cutthroat trout *Oncorhynchus clarki bouvieri*, 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 Reese Creek (Mahony 1987; Jones et al. 1988).

In 1988, streamflow monitoring continued in Reese Creek. Macroinvertebrates were sampled to document the effects of reduced streamflow on the benthic community of Reese Creek.

Study Area

Reese Creek flows approximately 11.5 km from the outlet of Cache Lake to the confluence with the Yellowstone River (Figure 44). 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 45). These diversions are referred to as the first diversion, second diversion, and third diversion, respectively. Staff gages were located on the mainstem of

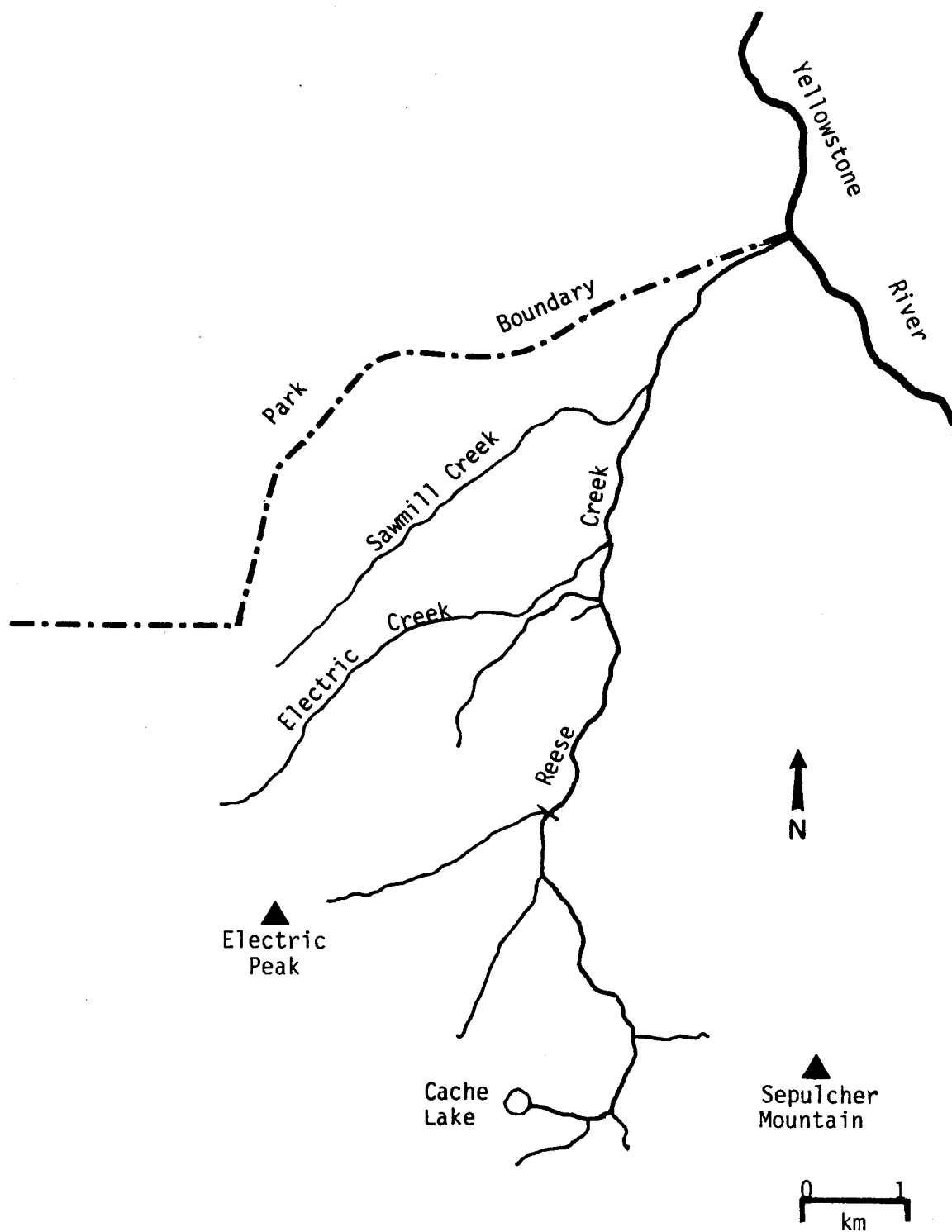


FIGURE 44.-Hydrographic map of Reese Creek.

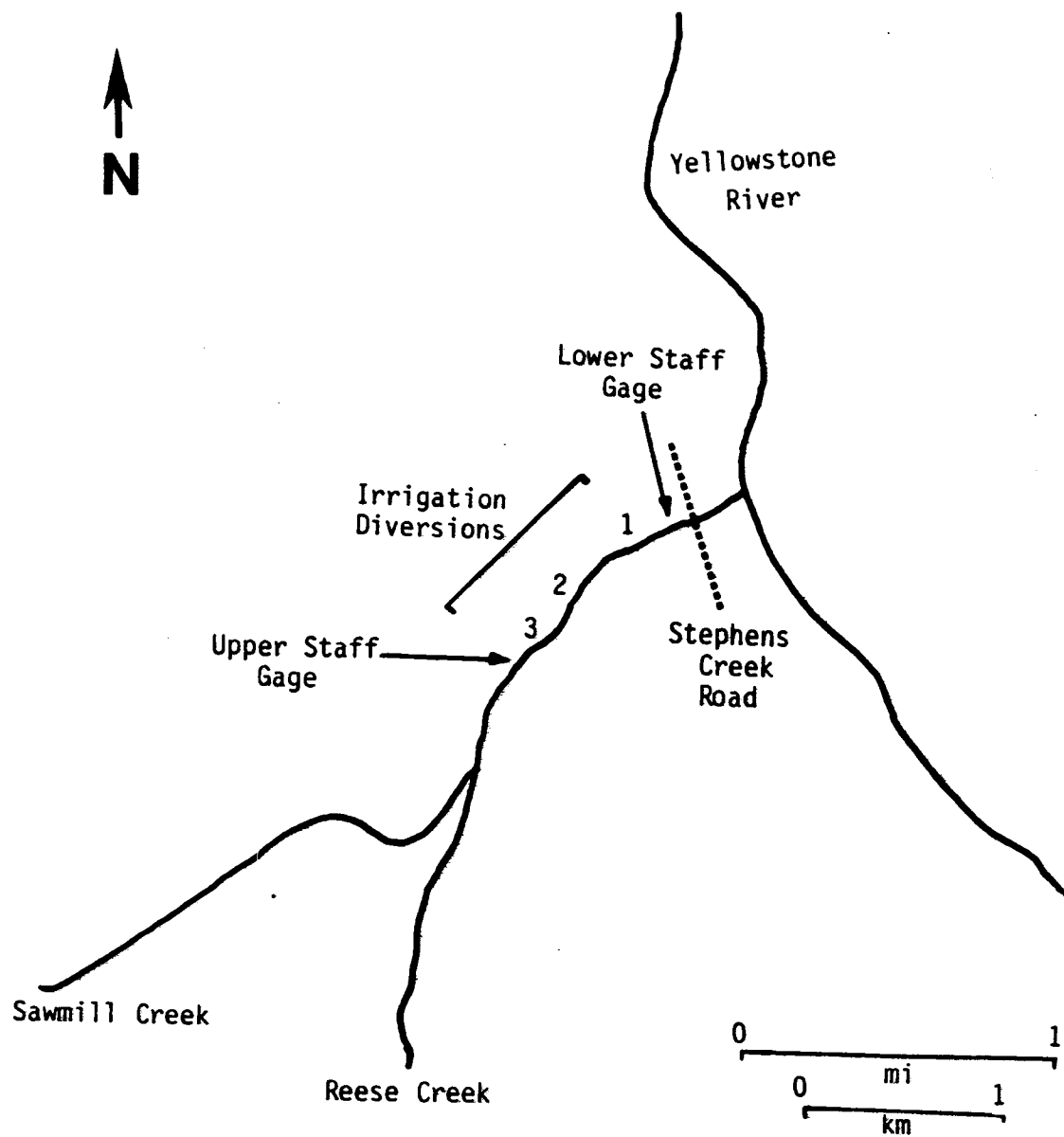


FIGURE 45.-Reese Creek study area showing locations of irrigation diversions and staff gages, 1988.

Reese Creek adjacent to Stephens Creek Road (lower gage) and 200 m upstream from the third diversion (upper gage) (Figure 45). Macroinvertebrate sampling sites were located near the staff gages.

Methods

In order to monitor streamflows in Reese Creek, a staff gage (lower gage) was installed and calibrated in May 1988 at a site approximately 0.6 km upstream from the mouth of Reese Creek. Discharge was measured at this site by the midsection method (Buchanan and Somers 1969) on four separate occasions during the 1988 study period. From these streamflows, a stage-discharge relationship was developed to predict daily flows. Staff gage level was recorded at least once a week (range: 1-8 readings/week) from 5 May to 11 November. Because of this variability in number of readings, all staff gage readings for a particular week were averaged, and all discharge values represent estimated mean weekly flows derived from the stage-discharge relationship.

A second staff gage (upper gage) was used to monitor natural streamflows in Reese Creek 1988. Discharge was measured at this site on three occasions in 1988, and the stage-discharge relationship developed in 1987 at this site (Jones et al. 1988) was used to predict daily flow. Mean weekly flow was estimated according to techniques described for the lower staff gage. However, time and logistic constraints did not allow for staff gage levels to be recorded during all weeks of the study period (14 May to 12 November 1988). In these cases, the mean value of the preceding and subsequent estimated streamflows was used in determining a predicted discharge for that particular week.

At the lower staff gage, three macroinvertebrate samples were collected monthly during May and June. Each sample was obtained with a 0.09 m³ Surber sampler in a riffle area near the staff gage. Macroinvertebrates from each sample were assigned to functional feeding groups (Cummins 1977; Merritt and Cummins 1978) and evaluated by the Biotic Condition Index (BCI) (Winget and Mangum 1979). Procedures at the upper staff gage were identical, except that macroinvertebrates were sampled on five separate occasions (Table 34).

Results

Streamflows

Staff gage level was recorded at the lower staff gage on 119 days of the study period. Maximum daily recorded discharge was 0.154 m³/s on 7 June. In contrast, a completely dewatered channel was observed on 61 separate days. Maximum mean weekly streamflow (0.094 m³/s) occurred

TABLE 34 .-Occurrence and densities of macroinvertebrates found in Reese Creek, 1988. Each value is the mean from three samples.

	5/18/88	5/18/88 ^a	6/30/88	6/30/88 ^a	8/4/88	8/26/88	9/30/88
Turbellaria (Planarians)	100.5		61.0		53.8	3.6	35.9
Annelida		3.6					
Ostracoda	269.1	25.1	111.2	21.5	68.2	53.8	125.6
Insecta							
Ephemeroptera (mayflies)							
Siphonuridae							
<u>Ameletus sp.</u>	3.6		3.6		3.6		
Baetidae							
<u>Baetis bicaudatus</u>	39.5	728.4	28.7	3.6	154.3	107.6	161.5
Heptageniidae							
<u>Cinygmula sp.</u>	14.4		32.3		43.1	32.3	25.1
<u>Epeorus albertae</u>					43.1	68.2	17.9
<u>Epeorus grandis</u>							3.6
<u>Rhithrogena morrisoni</u>	14.4						
<u>Rhithrogena sp.</u>							7.2
Ephemerellidae							
<u>Drunella coloradensis</u>			61.0	3.6	111.2	28.7	
<u>Drunella doddsi</u>							3.6
<u>Ephemerella infrequens</u>	46.7	28.7	17.9				32.3
<u>Serratella teresa</u>					7.2		
Plecoptera (stoneflies)							
Taeniopterygidae							
<u>Taenionema sp.</u>							50.2
Nemouridae							
<u>Amphinemoura sp.</u>							25.1
<u>Zapada sp.</u>					3.6		
Capnidae							
<u>Isocapnia sp.</u>	7.2		7.2				3.6
Perlodidae (unknown)						3.6	21.5
<u>Cultus sp.</u>							3.6
<u>Megarcys sp.</u>	7.2		3.6			3.6	14.4
Chloroperlidae	3.6		10.8		10.8	21.5	10.8

TABLE 34.-Continued.

	5/18/88	5/18/88 ^a	6/30/88	6/30/88 ^a	8/4/88	8/26/88	9/30/88
Trichoptera (caddisflies)							
Hydropsychidae							
<u>Arctopsyche grandis</u>	10.8						
Rhyacophilidae							
<u>Rhyacophila</u> sp.	71.8		68.2	10.8	46.6	21.5	32.3
Glossosomatidae							
<u>Glossosoma</u> sp.			7.2		7.2		3.6
Lepidostomatidae							
<u>Lepidostoma</u> sp.				3.6			
Limnephilidae							
<u>Apatania</u> sp.	660.2		441.3		86.1	7.2	122.0
<u>Cryptochia furcata</u>		3.6	3.6				
<u>Ecclisomyia</u> sp.	7.2		136.3				
<u>Neothremma alicia</u>	89.7	17.9	165.1		53.8	25.1	143.5
Diptera (true flies)							
Tipulidae							
<u>Antocha</u> sp.	3.6						
<u>Hexatoma</u> sp.						7.2	
Psychodidae							
<u>Pericoma</u> sp.	17.9	3.6					7.2
Pelecorhynchidae							
<u>Glutops</u> sp.	7.2					3.6	3.6
Simuliidae							
<u>Prosimulium</u> sp.		3.6	3.6	17.9		3.6	39.5
Chironomidae	61.0	566.9	125.6	35.9	96.9	57.4	89.7
Dixidae							
<u>Dixa</u> sp.				3.6	3.6		
Athericidae							
<u>Atherix pachypus</u>	7.2		7.2				
Empididae	17.9		7.2				
TOTAL TAXA	21	9	20	8	16	16	24
TOTAL #/m ²	1460.7	1381.4	1302.6	100.5	793.1	448.5	983.3
% SHREDDERS	0.7	0.3	1.0	4.5	0.5	0.0	3.5
% COLLECTORS	18.3	94.2	27.6	77.2	61.1	62.7	43.2
% SCRAPERS	70.4	1.3	61.7	0.0	28.3	21.1	42.1
% PREDATORS	10.6	4.2	9.7	18.1	10.0	16.1	11.1

^a Lower sample station.

during the week ending 7 May. Discharge level subsequently decreased to zero flow by the week ending 16 July (Figure 46). With the exception of 3 d, the stream channel remained dry at the lower gage site until 9 October. Estimated mean discharge for the period from 5 May to 22 November was $0.065 \text{ m}^3/\text{s}$; however, the stream channel was dry for 36% of the study period. Late fall flows (October and November) at the lower gage resembled the levels observed in May (Figure 46).

Staff gage level was recorded at the upper gage on 25 d during 1988. Mean weekly streamflow at the upper site varied from a maximum of $0.234 \text{ m}^3/\text{s}$ to a low of $0.026 \text{ m}^3/\text{s}$ in late September (Figure 46). Estimated mean discharge for the entire study period from 13 May to 12 November was $0.123 \text{ m}^3/\text{s}$.

In conjunction with staff gage readings at the upper staff gage, observations of dewatering into the irrigation ditches were also recorded. The first diversion contained water on 14 d during May through August, and the second irrigation diversion was used on 8 d in June and July. The third ditch was open on all days when observations were made ($N = 26$).

During periods of low streamflow, Reese Creek can be completely dewatered by these three irrigation diversion (Jones et al. 1988). Consequently, differences in the amount of stream discharge between the upper gage and the lower gage (Figure 46) reflect the amount of water diverted into the three irrigation diversions. From 24 August to 7 October, the main channel of Reese Creek was dry at the lower staff gage site. On five occasions during this period, the entire discharge of Reese Creek was diverted into the third ditch. This suggests that complete dewatering of the main channel for up to 35 consecutive days may be attributable to irrigation withdrawals into the third diversion.

Macroinvertebrates

At the lower gage site, macroinvertebrate collections were terminated after the July sample because extended total dewatering in July (Figure 46) probably resulted in complete aquatic macroinvertebrate mortality. The 18 May sample revealed a high species abundance comparable to the upper site (Table 34). However, two taxa (*Baetis bicaudatus* and Chironomidae) composed nearly 94% of this sample. As a result, species richness (number of taxa) and the Shannon-Weiner diversity index (Cook 1976) were both low. By the end of June, irrigation withdrawals resulted in very low flows at this lower site (Figure 46) and macroinvertebrate abundance was lower than any other sample collected in 1988 (Table 34). Although species richness was lower than that of the May sample, a 70% increase in the

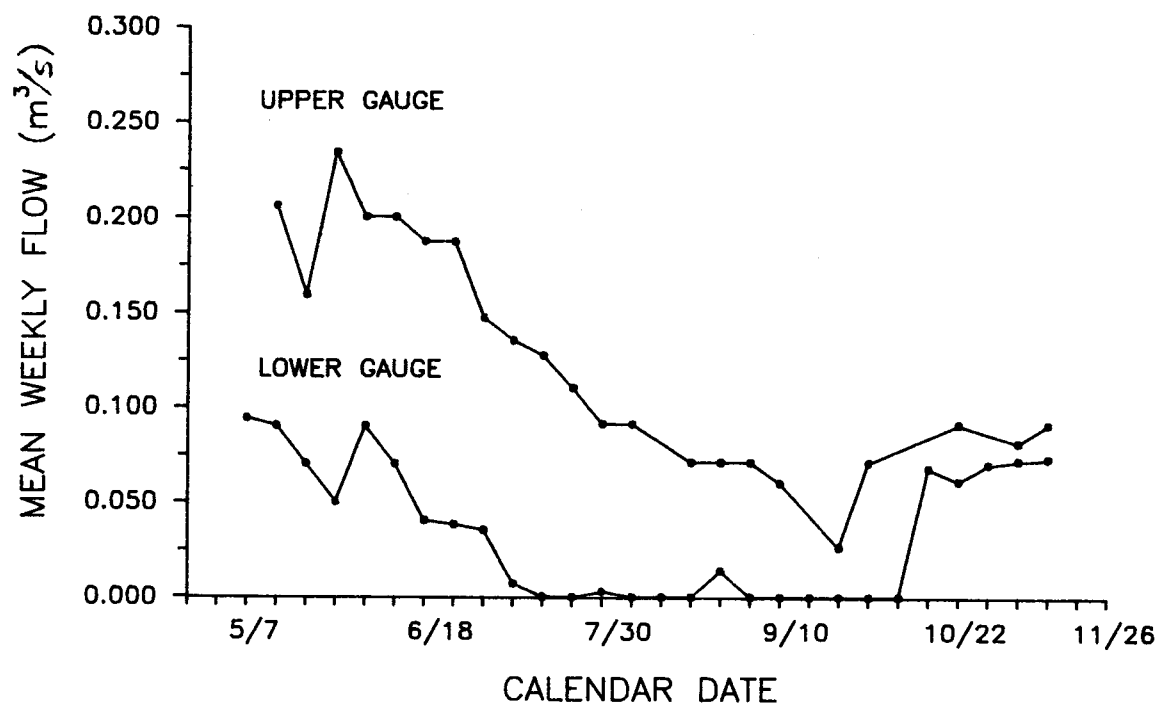


FIGURE 46.-Estimated mean weekly streamflows in Reese Creek, 1988.

diversity index in the 30 June sample indicates a substantial reduction in dominance by any particular taxon.

The aquatic insect community at the lower site was comprised primarily of collectors in both sample periods (Table 34, Figure 47). Reese Creek is a 3rd order stream, yet collectors normally predominate in larger 6th to 10th order rivers. Autotrophic production is limited in large rivers because fine sediments may increase turbidity (Cummins 1977). Because of its relatively small size in these larger systems, riparian zone input into the mainstem is minimal (Vannote et al. 1981). The macroinvertebrate community in lower Reese Creek is suggestive of a large river with a limited riparian influence.

The BCI value (Winget and Mangum 1979) for both samples at the lower gage was relatively low, suggesting that the aquatic habitat in the lower section of Reese Creek is poor. Although a few environmentally sensitive species (e.g., *Neothremma alicia*) were collected at the lower sample station, the majority of taxa collected are commonly associated with environmental fluctuations and degrading habitat.

At the upper gage site, macroinvertebrate abundance ranged from a maximum of 1,460 individuals/m² in May to a low of 450 individuals/m² in late August (Table 34). *Baetis bicaudatus* and *Apatania* sp. were the most abundant species collected. Ephemeroptera (mayflies) were well represented in each sample with a minimum of four taxa per sample. Plecopterans (stoneflies) were a minor group until September. Trichopterans (caddisflies) exhibited moderate species richness in the majority of samples, but abundance was consistently high. With the exception of Chironomids, Dipterans were collected only occasionally. The sample from 30 September was highest in species richness and diversity. The 8 August sample ranked second in diversity and lowest in species richness, indicating a lack of dominant taxa. In contrast, the sample from 18 May had the second highest species richness, but was last in Shannon-Weiner diversity index. The dominance of *Apatania* sp. (45% of total abundance) contributes to the low diversity value.

All five samples at the upper site exhibited a major proportion of collectors and scrapers (Figure 47). This arrangement is common in third- to fifth-order streams (Cummins 1977). The high incidence of scrapers in the May and June samples may be indicative of abundant instream production of attached algae (Vannote et al. 1981). A major decrease in scrapers in August may be partially attributable to the decreased abundance of Limnephilid caddisflies, particularly *Apatania* sp. and *Neothremma alicia*. Whether the reduction in abundance is due to emergence of adults or restricted habitat accompanying diminished streamflows is unknown; however, high elevation Trichoptera may have two generations per year (Pennak 1978), and therefore emergence

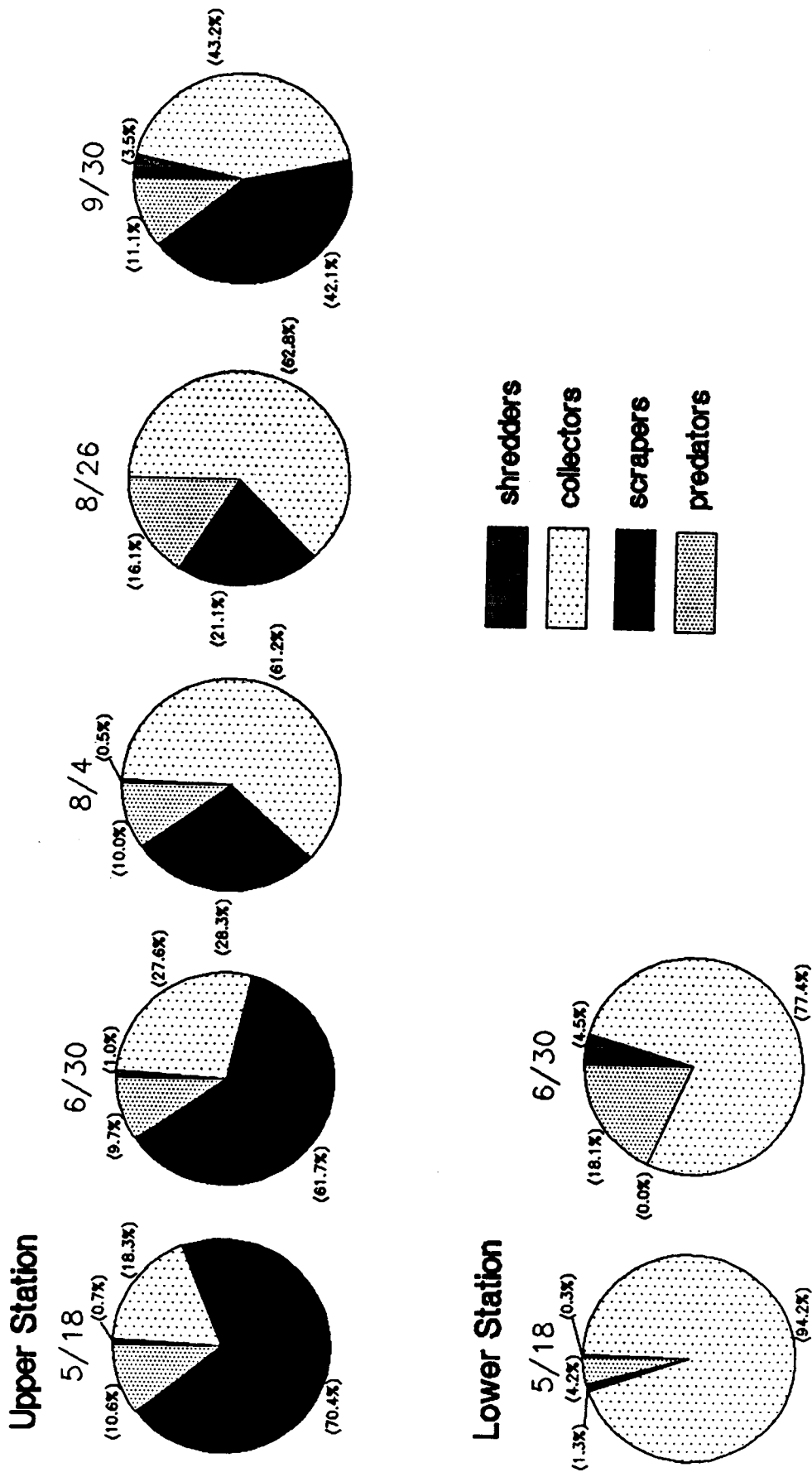


FIGURE 47.-Trophic groups of aquatic insects collected from Reese Creek, 1988.

may be the dominant influence. Proportions of scrapers and collectors were equivalent in the 30 September sample (Figure 47). In addition, the proportion of shredders (primarily Plecoptera) in this sample was at the highest level of any upper station sample (Table 34). This increase could be in response to autumn input of deciduous leaves that serve as a food source for shredders.

Examination of BCI values for the upper station samples revealed that high quality aquatic habitat was present during each sample period. Several taxa (e.g., *Neothremma alicia* or Chloroperlidae) that require specific environmental conditions were collected in all samples in moderate to great abundance. However, the May and September samples contained numerous species that are able to adapt to moderate environmental fluctuations, so these communities show evidence of becoming more tolerant to environmental change.

Discussion

Previous studies of Reese Creek have documented the existence of resident cutthroat trout (Jones et al. 1988) in Reese Creek and spawning migrations of cutthroat trout from Yellowstone River during periods of adequate streamflow in Reese Creek (Mahony 1987). Recommended instream flows to support these populations are 0.122 m³/s from 15 May to 30 July and 0.045 m³/s from 1 August to 30 September (Lentsch 1986). Although natural streamflows at the upper site were adequate to maintain this level of discharge (Figure 46), 1988 was the second consecutive year that total dewatering occurred in lower Reese Creek and precluded a spawning migration from the Yellowstone River into Reese Creek. Drought conditions required a substantial reduction in irrigation withdrawals to maintain instream flow, but this did not occur in 1988.

Examination of the macroinvertebrate communities throughout the study period revealed the inherent variability in community structure through time. Macroinvertebrate communities at the upper site exhibited high production levels and maintained a species composition indicative of high quality aquatic habitat. In contrast, macroinvertebrate community organization (revealed through BCIs and trophic groups) in the section of Reese Creek subject to dewatering exhibited evidence of stress in a degrading habitat. Although downstream drift and overwinter replenishment of macroinvertebrates could lead to the establishment of a community similar to those at the upper site, the 18 May macroinvertebrate sample was characteristic of a stressed community.

Because suitable spawning sites are limited for the cutthroat trout in the Yellowstone River (Clancy 1984), elimination of any existing spawning areas can be

detrimental to trout populations. Extensive dewatering in Reese Creek will continue to negatively impact not only the trout populations, but also the habitat and macroinvertebrate communities that support the trout.

LITTLE FIREHOLE RIVER FISH-KILL INVESTIGATION

During the summer of 1988, forest fires affected nearly 45% of the 9,150 km² in Yellowstone National Park. For most of the summer, attempts were made to control these fires. Aerial-applied fire retardant is one method used to control wildfires; a plane is used to drop retardant onto potentially burnable forest vegetation.

There are various types of retardant. The most common is an ammonium-sulfate based product similar to fertilizer. One type used in Yellowstone National Park in 1988 is produced by Chemonics Industries, Inc., and is sold under the name FIRE-TROL GTS-F. The ingredients are ammonium sulfate, diammonium phosphate, gum thickener, preservative, red dye, and corrosion inhibitor (Chemonics 1988).

Fire retardant applied near streams has virtually no impact due to the low migratory nature of the chemical (Chemonics 1988); however, retardant is toxic to fish if applied directly to a body of water. Presumably, ammonium in high concentrations is the lethal agent (Borovica 1974). The LC-50 value at 96 h for juvenile rainbow trout *Oncorhynchus mykiss* is 1,000 mg/L (Chemonics 1988).

A fish kill that occurred in the north fork of the Little Firehole River in August 1988 appeared to result from retardant dropped directly into the stream. A 1.75-km long stream segment at the forest-meadow interface in Little Firehole Meadows was affected. All fish in this section appeared to have been killed. The drop zone was identified by the red dye used in the retardant.

Study Area and Methods

On 8 August, three sites were sampled in the impacted area. Site 1 was 50 m above the drop zone, Site 2 was 200 m below the drop zone, and Site 3 was 300 m below where the north fork entered the meadow (Figure 48). Dissolved oxygen was measured at all sites with an electronic oxygen meter supplied by National Park Service personnel. The meter was calibrated on-site for the estimated barometric pressure for that day and elevation. A HACH colorimeter was used to measure pH. Water temperature, a water sample, and a benthic macroinvertebrate sample were taken at each site. The macroinvertebrate sample was taken with a makeshift net, and approximately 0.09 m² of stream bed was sampled. Macroinvertebrate samples are currently being analyzed and will not be discussed in this report. Discharge was measured at the lower sample site by the color-velocity method (Hamilton and Bergersen 1984). Observations were made between 1100 and 1500 hours.

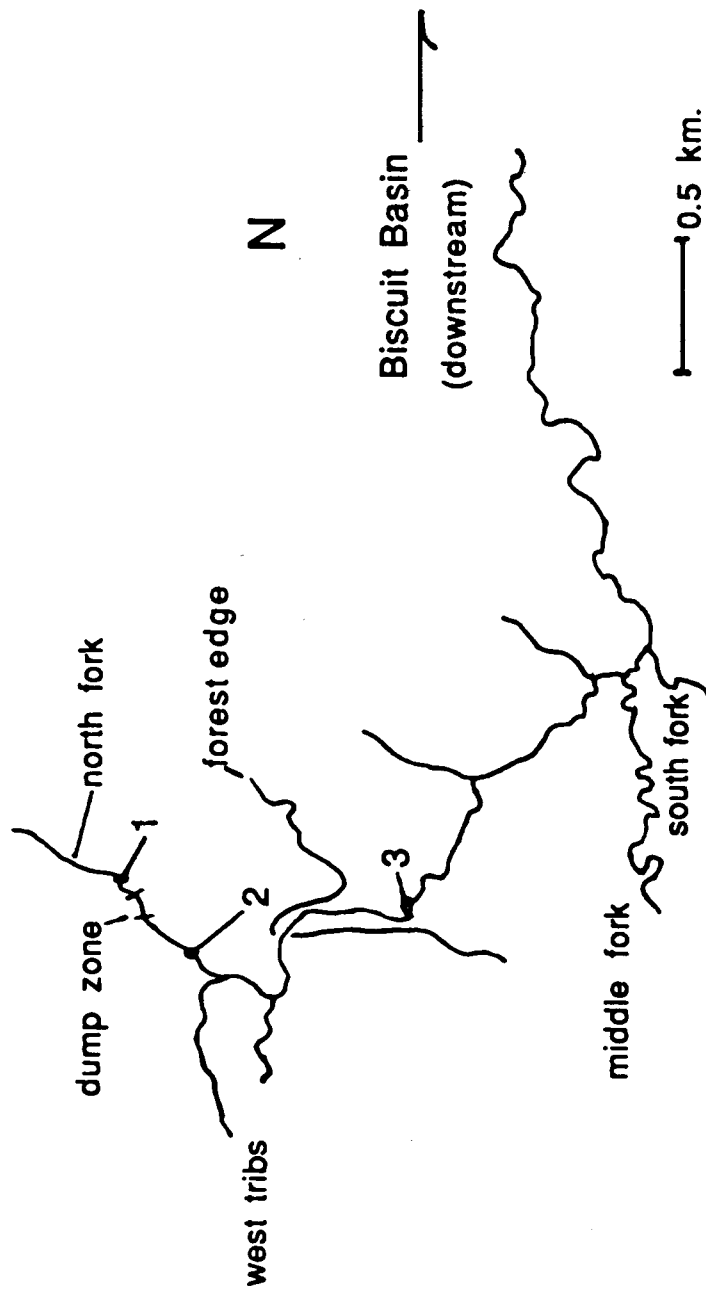


FIGURE 48.-Upper Little Firehole River above Mystic Falls showing dump zone and sample stations, 1988.

Results and Discussion

Oxygen measurements indicated that dissolved oxygen was at or near saturation levels for this elevation and temperature. Water temperature increased with distance downstream, possibly because the upper site was sampled first in the day when water temperatures are naturally cooler. Also, water temperatures may have increased downstream due the influence of solar radiation. Measured pH appeared to be within acceptable limits to fish (Table 35). A discharge of 0.085 m³/s was probably close to the flow 0.9 km upstream at the drop site. Two small, unnamed tributaries were observed entering the north fork from the west, but flow was minimal.

TABLE 35.-Temperature, dissolved oxygen, and pH at three sample sites, north fork of the Little Firehole River, 8 August 1988.

Sample site	Temperature (°C)	Dissolved O ₂ (mg/L)	pH
1	9.0	10.5	6.6
2	11.0	9.2	6.8
3	13.0	9.2	6.9

Forty-five dead fish were collected in the 1.75 km section. Of these, 39 were identified as Yellowstone cutthroat trout *Oncorhynchus clarki bouvieri*, three may have been rainbow trout or cutthroat trout, and three were unidentifiable due to their advanced state of decomposition. The largest fish collected was approximately 225 mm long; all others were between 100 and 180 mm. There appeared to be dead fish smaller than 100 mm long, but none were collected due to their advanced state of decay.

Live fish in the top 10 m of the drop zone and upstream suggested recolonization of the fish-kill area. An unnamed tributary enters the north fork from the west 0.25 km below the drop zone, and a second spring tributary feeds into the north fork another 0.2 km below that. No fish were observed in these tributaries, but dead trout were found in mainstem pools created by these input sources. The tributary channels were probably too small to harbor trout, but their flow created a plume of fresh water. It is not likely that these water sources were affected by the retardant drop upstream because the red zone appeared to be confined to the mainstem of the north fork.

Many large, stone-cased caddis larvae were observed consuming the soft body parts of the dead fish. Also, 14 western spotted frogs *Rana pretiosa* were observed in the

meadow section of the stream. No dead frogs were found. A dipper *Dolichonyx oryzivorus* was seen within the affected zone, as well as other birds and recent mammal sign.

It appeared that the impact of this fish kill was not substantial and is probably temporary. Repopulation of the affected area should occur within the next few years. Angling effort in this part of the Firehole River drainage is probably low; thus, angling quality in this area will probably be little affected.

YELLOWSTONE RIVER SEDIMENT STUDY PROGRESS REPORT

Introduction

At the 1988 meeting of the upper Yellowstone sediment study group, a study was designed using low-altitude aerial photographs of the study area to classify the streams in the Lamar River drainage by the system developed by Rosgen (1985). Subsequently, David Rosgen was hired as a consultant to oversee the classification project and gave a training in field techniques in July 1988. This classification project was made possible by the 1987 low-altitude (1:6,000 and 1:3,000 scale) aerial photographs of the Yellowstone River and selected watersheds between Yellowstone Lake outlet and Livingston, Montana. This photography was funded by the sediment study steering group.

The stream classification system developed by Rosgen (1985) initially divides streams into categories (A through F) based on the gradient of the stream water surface, with A-type streams having the steepest gradient and F-type streams the lowest. Stream types are further divided according to the material through which the stream flows, including bedrock, boulder, and cobbles, heterogeneous-sized sediments, sand, and silt/clay. Further subtypes are developed using meander patterns, depositional features, bank vegetation, and organic debris accumulations.

Methods

The methods used for stream classification in this project involve three steps: initial classification, site description, and reclassification/mapping.

Initial classification.-Using aerial photos and geologic and topographic maps, project personnel divided streams into initial reaches to locate sites for measurements. Initial classification was based on stream entrenchment, confinement, meander patterns, gravel bar patterns, and near-stream landforms. Stream gradient and sinuosity were estimated from topographic maps and aerial photos.

Site measurements.-Sites were established at representative reaches in streams to measure classification parameters. At each site, channel cross-sections were leveled, substrate size measured, and slope of water surface measured. Both banks were described according to types of soil or sediment present and the type of riparian vegetation. Banks, channel, and cross-section location at each site were photographed. Cross-sections were permanently marked by rebar stakes.

Reclassification.-Initial stream classifications were then modified or extrapolated using site measurements. Maps of measurement sites and classified reaches were prepared

and sent to Rosgen for verification and interpretation. Aerial photos of streams, site descriptions, and site photographs were also sent.

Work Progress

Field work on Soda Butte Creek and Slough Creek drainages lasted from July through September 1988. Nineteen sites on Soda Butte Creek and 13 on Slough Creek were measured. Sites in the upper Lamar River region were established using helicopters in October and November. Measurements were taken at 12 sites on the Lamar River mainstem and 15 sites on the tributaries (Calfee, Miller, Timothy, and Cold/Mist creeks, and Little Lamar River). Lamar River mainstem sites were located near the confluences of major tributaries to allow same day measurements of the tributary mouths. When weather conditions and helicopter availability allowed, additional sites were measured in the interior of each drainage. In Lamar River tributaries, sites were again chosen at confluences of the particular tributary and one of its major tributaries. Field work continued until repeated snows fell in November. A total of 46 permanent cross sections are in place and marked by rebar (Figure 49).

Stream classification maps and materials have been prepared for Soda Butte and Slough creeks and have been sent to Rosgen. Stream classification and tabulation of data for the upper Lamar River region is currently in progress and nearing completion.

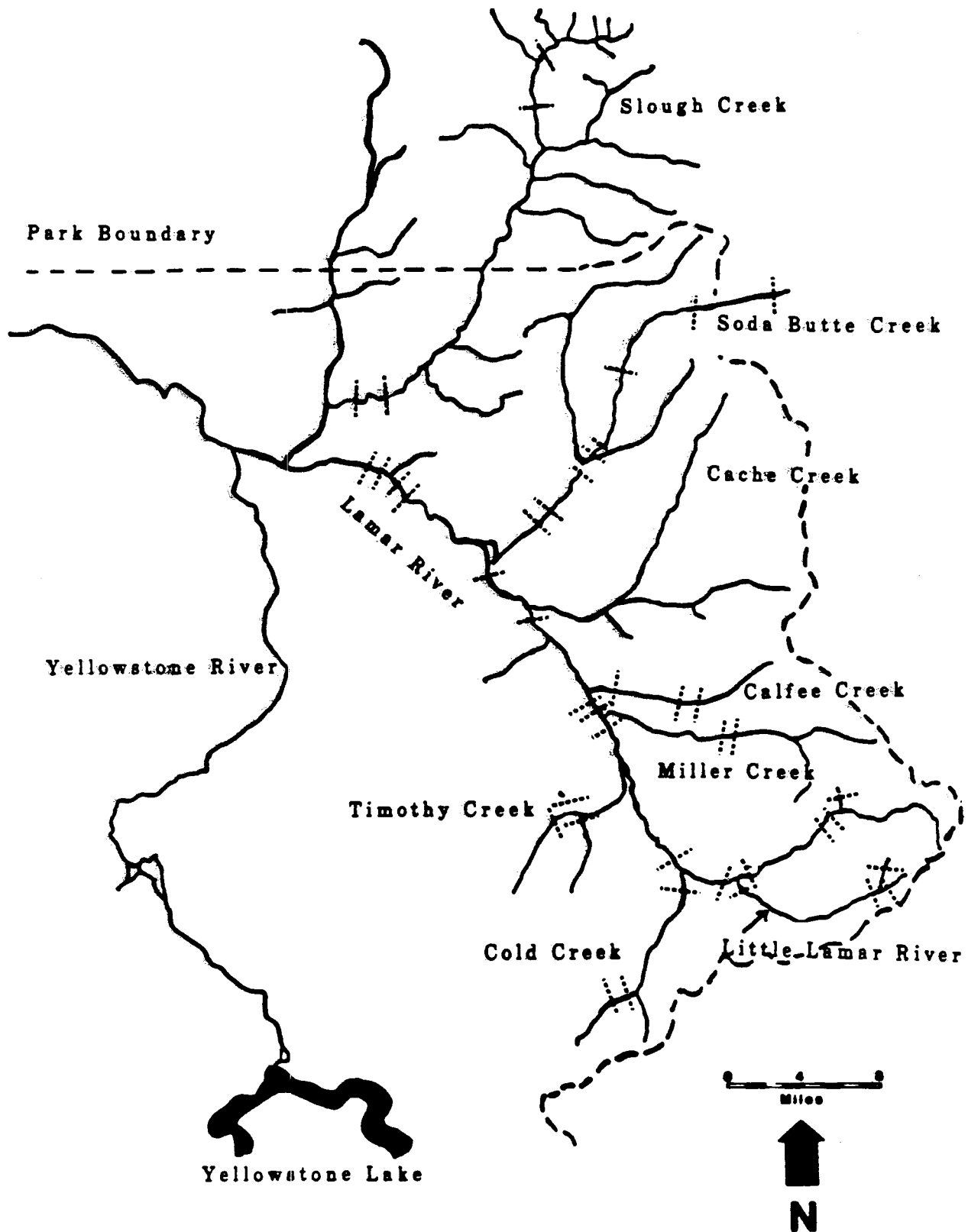


FIGURE 49.-Permanent cross-sections measured in the Lamar River drainage, 1988.

NONCONSUMPTIVE USE OF THE AQUATIC RESOURCE

In Yellowstone National Park there are presently two sections of the Yellowstone River that 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, and provide 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 11th consecutive year in 1988. 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 by U.S. Fish and Wildlife Service personnel 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 1988, ranger and naturalist employees of the National Park Service 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:

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

where I is the time interval, and t_i is the mean number counted in 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

Because mean length of stay was not estimated at Fishing Bridge in 1988, a weighted mean length of stay (11.2 min) was estimated from seven prior sample years (1980-1982, 1984-1987). Total number of visitors reached a record high of 225,928 visitors in 1988 (Table 36). Numbers increased over 56% from 1987 estimates. Total visitor hours (47,773 h) increased approximately 53% since 1987.

Mean length of stay at LeHardy Rapids was 10.7 min/person in 1988 (N = 1,321). Total number of visitors was estimated to be 133,487 people, and total time spent at the rapids was 23,805 h. Both values represent a increase from 1987 estimates (26% and 37% 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 37). The 1988 nonconsumptive use figures represent slightly greater total hours on Fishing Bridge, and the number of people enjoying this area has increased almost 800% since the bridge was closed to fishing. Concomitantly, current Park visitation has only risen approximately 18% from 1965-1972 levels.

TABLE 36.-Nonconsumptive use of the aquatic resource, 1978-1988.

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
1988	683	255,928		47,773
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
1988	260	133,487	10.7	23,805

TABLE 37.-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

Despite a 15.2% decline in recreational visitation during 1988, the number of visitors at both Fishing Bridge and LeHardy Rapids increased from 1987 estimates, and use (visitor days) at Fishing Bridge was the highest yet reported. Although the reasons for this increase are not known, road closures in portions of the Park that were more affected by fire and fire-fighting activities may have caused a concentration of use in areas where the effects of fire were less.

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 36). LeHardy Rapids ranks seventh and Fishing Bridge fourth when compared, in terms of total hours, to angler effort among Park fisheries.

Estimates of nonangler use during the past 11 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 1988, 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 3 man-days of assistance, logistical support, and fish sampling equipment to make collections from two populations of Yellowstone cutthroat trout. The objective of the study is to differentiate 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 a wide range of differentiation techniques on Yellowstone cutthroat trout.

The project provided laboratory space to Lewis T. Nielsen and Mark Blackmore, University of Utah, for their study on "Biological control of mosquitoes with Merithid nematode parasites".

The project provided laboratory space, boats, and 12 man-days of assistance to J.V. Klump of the University of Wisconsin-Milwaukee Center for Great Lakes 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.

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, this 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.

The project provided Fred Binkowski of the University of Wisconsin-Milwaukee Center for Great Lake Studies with laboratory space, boats, equipment, and 3 man-days of personnel assistance. Mr. Binkowski is studying the life history of lake trout in Lewis Lake.

The project provided Dr. Wayne Minshall, Idaho State University, with 35 man-days of assistance in setting up permanent cross-sections to study the effects of the Yellowstone fires on primary and secondary productivity in the aquatic systems of Yellowstone. This is a joint study between Dr. Minshall and the Yellowstone Fishery Assistance Office. This was a major effort in October with helicopter support from the National Park Service in an effort to establish sampling stations and collect pre-fire data before winter.

The project provided 3 man-days of assistance to Dr. Bill Gould of the Montana Cooperative Fishery Research Unit, Montana State University, Bozeman, Montana. Dr. Gould conducted a fish population study on Cache Creek to collect pre-fire fishery data. This project was funded by the U.S. Fish and Wildlife Service, and the National Park Service provided helicopter support.

The project provided Dr. Frank Vertucci, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado, with 5 man-days of assistance to collect 68 water samples in Yellowstone National Park. The sample sites covered a wide range of waters, habitats, and watershed burn conditions. The Experiment Station will provide funding to analyze the samples. The National Park Service provided helicopter support.

Project personnel participated in several research planning meetings which included field trips by bus and helicopter in an effort to assess fire damage and assist in planning pre- and post-fire research. Approximately 40 man-days were involved in these activities.

The project assisted Dr. Paul Morgan and Matt Kaplinski, Northern Arizona University, with the second year of a 2-year masters study on Yellowstone Lake. Mr. Kaplinski is producing a new bathymetric map of Yellowstone Lake. This has been a cooperative study involving the U.S. Fish and Wildlife Service, National Park Service, Northern Arizona University, and the University of Wisconsin.

The project provided Wayne Hamilton, a geologist with Yellowstone National Park, with a boat and equipment to support his research on Yellowstone Lake.

Office space and a vehicle were provided to National Park Service soil scientist Henry Shovic in support of his soil survey studies in Yellowstone National Park.

The project is cooperating in a masters study on the Firehole River with Dr. Jack Griffith and Ted Koch of Idaho State University. Mr. Koch is a masters student and the title of the study is "Examining the ecology of brown trout and rainbow trout in the Firehole River in Yellowstone National Park". The project contributed electrofishing equipment, thermographs, and approximately 75 man-days of personnel assistance. The study is funded by the project's "Fishery Fund", and the money is donated by Yellowstone anglers.

U.S. Fish and Wildlife Service personnel spent approximately 15 man-days coordinating the project's sedimentation study on the Yellowstone River. We have contracted with David Rosgen, a wildland hydrology consultant, to do a river classification study on the Lamar River system. The field work is being conducted by the Park hydrologist staff under the U.S. Fish and Wildlife Service project supervisor. The study is funded by the National Park Service and several other state and federal agencies, plus Trout Unlimited in Livingston, Montana.

Project personnel provided transportation and assistance to Dan Woodward, U.S. Fish and Wildlife Service research station in Jackson, Wyoming, to collect fish tissue samples from cutthroat trout for physiological studies. This study is designed to assess physiological impacts to fish from the 1988 fires. Approximately 4 man-days of assistance was provided.

The project provided housing, equipment, and 2 days of personnel assistance to Cathy W. Barnosky, Assistant Curator of Paleobotany at Carnegie Institute, Museum of Natural History, Pittsburgh, Pennsylvania. Cathy is looking at post-glacial fire frequency and its relation to long-term vegetational and climatic changes in Yellowstone National Park. She is examining core samples taken from lakes in Yellowstone National Park and studying the pollen records.

The project provided housing and lab space for Stephen Klein, a PhD candidate of the Civil and Environmental Engineering School at the University of Colorado. Mr. Klein is working on an "Environmental assessment of heavy metal contamination in Yellowstone National Park".

Information Distribution

Information produced by the Yellowstone Fishery and Aquatic Management program is distributed to the scientific field and the general public in several ways.

The project receives 50 to 100 information requests each year by phone or mail. Response time on these requests requires from 10 min to 1 h on the phone or as much as several days on a research request.

In 1988, papers were given at the Western Division of the American Fishery Society, the Montana Chapter of the American Fishery Society, and a brown trout workshop in Asheville, North Carolina.

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) A presentation was given to the student forum at Montana State University.

(3) Presentations were made at National Park Service resource management training, naturalist training, ranger training, and outfitters meeting.

(4) Numerous Trout Unlimited, radio, and personal interviews were presented to the press in 1988.

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 1988, the project utilized 63 man-days of volunteer work and 100 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.

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., B.A. Barton, and J.L. Kershner. 1989. Proceedings of the practical approaches to riparian resource management workshop. U.S. Bureau of Land Management, Billings, Montana.

Jones, R.D. In press. A review of regulations and angler catch characteristics on selected Yellowstone National Park brown trout streams. In Proceedings of the Brown Trout Workshop - Biology and Management. Southern Division of the American Fisheries Society, Asheville, North Carolina.

Brown trout *Salmo trutta* first came to Yellowstone National Park in 1890 with the introduction of the Loch Leven strain into Lewis Lake and Shoshone Lake and the Von Behr strain into Nez Perce Creek. From 1890 through 1955 (cessation of fish stocking activities), over 5 million brown trout were stocked in Yellowstone National Park. Wild (self-reproducing) populations now exist in 23 streams and 2 lakes. Regulations have ranged from none early on to catch-and-release regulations on the Lewis River at the present time. Catch-and-release regulations on the Lewis River have maintained the highest catch rate for brown trout in the Park. Almost 21% of the brown trout caught on the Lewis River were over 406 mm with 3% over 508 mm in length. In general, however, brown trout inhabiting water with abundant cover are less susceptible to angling pressure. In these waters, some harvest may be possible with no adverse impact to the fishery. Brown trout regulations in Yellowstone National Park, as with all other species, are set in response to both biological and political needs but must in all cases serve the biological needs of the Park ecosystem.

ACKNOWLEDGMENTS

Our sincere thanks to those who assisted the project during the past year.

Karrie West, Biological Technician, continues to occupy an important role in the overall success of the project. In addition to her many administrative duties, Karrie's responsibilities include data entry and overseeing the production of the report. Karrie's skills, efficiency, and patience are deeply appreciated.

Glenn Boltz, Biological Technician, has also been critical to the overall success of this project. In summer, Glenn supervises field crews at Clear Creek and on stream surveys. Over the past two winters, Glenn has "aged fish scales", reorganized our age-growth files, and prepared computer-generated graphics for this report. Glenn also provided valuable field assistance to several independent researchers who sampled streams and lakes during summer and winter.

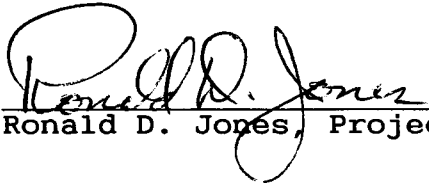
Karl Biastoch, Biological Technician, was an important member of our summer operation. Karl maintained much of our equipment along with being a member of our field crew. Scott Relyea and Rob Morrow, members of the Student Conservation Association, worked as full-time volunteers during the summer field season. We trust that the experience they gained will be useful as their fishery careers continue. Randy Elliott, detailed to us in September from the Bozeman Fish Technology Center, provided much-needed assistance during the hectic period when fire activity threatened the Lake Area. Randy also participated in fall gillnetting. Jack Brooks and Wade Miller returned again for the fall gillnetting operation; Wade helped with the nets, and Jack prepared gourmet meals for the crew. Pat Bigelow (Olympia Fisheries Assistance Office, Washington), Beth MacConnell (Bozeman Fish Technology Center), Janet Lewis (NPS), Janet Wood, and Jerry Perez also assisted us during the fall gillnetting operation. Janet Wood, a Volunteer-in-Parks participant, also acted as a field-crew member through October. Although not participating on a full-time basis, Marion Jones volunteered her time whenever possible. Personnel from three national fish hatcheries (Ennis, Jackson, and Creston) expedited lake trout spawning at Lewis Lake. In winter, Kim West assisted in transforming VAR cards into data on computer disks. Kim also typed portions of this report. Ken Barbalace, another Volunteer-in-Parks participant, worked full-time from mid-March through early May transferring fish-population, water temperature, and stream habitat data from out-dated field forms to new computer-ready data sheets. Dr. George Roemhild, professor emeritus at Montana State University, and Dr. Fred Mangum, U.S. Forest Service, analyzed macroinvertebrate samples.

The National Park Service also provided manpower and assistance in 1988. Jana Mohrman and Roy Ewing, Research Division, began the geomorphological classification of stream channels in the Lamar River drainage as the newest phase of a sediment and turbidity study initiated in 1985. Liz Colvard, Research Division, collected monthly samples of aquatic macroinvertebrates from Reese Creek. Ann Rodman and Dean Neprud prepared macroinvertebrate graphics. Other National Park Service employees from the Research, Resource Management, and Law Enforcement divisions assisted with the following projects:

(1) Monitoring water flows in Reese Creek;
(2) interviewing anglers at exit gates to Yellowstone National Park; (3) monitoring cutthroat trout spawning runs at Grant Village; (4) assisting with electrofishing operations on streams and lakes; and (5) counting visitors at Fishing Bridge and LeHardy Rapids.

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

This report was submitted by:


Ronald D. Jones, Project Leader

Reviewed by:


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APPENDIX

APPENDIX TABLE 1.-Gillnet catches of cutthroat trout by site, Yellowstone Lake, 1969-1972, 1974, 1976-1980, and 1982-1988^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	c	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	16	23	16	32	17	20	14	15	16	21	1,053
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	1,017
1988	22	14	16	13	17	13	17	14	18	19	13	883

	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
1988	278	346	337	341	323	321	322	296	311	337	376	322

^a Experimental gill nets (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 1978-1988 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 1982-1988^a.

Year	Number/net				Average total length (mm)				Percentage under 210 mm				
	North	Central	W. Thumb	South	North	Central	W. Thumb	South	North	Central	W. Thumb	South	Total
1969	10	--	16	15	316	--	296	319	12.2	--	9.7	10.0	10.9
1970	13	14	17	4	311	352	285	346	7.8	0.0	17.6	0.0	8.1
1971	14	--	--	--	321	--	--	--	1.4	--	--	--	1.4
1972	15	10	14	12	297	307	342	336	11.7	0.0	0.0	4.0	6.7
1974	19	9	16	13	289	302	294	329	14.7	16.7	25.8	0.0	14.7
1976	16	17	13	13	310	311	328	333	11.0	5.9	4.3	7.7	8.5
1977	17	15	11	17	284	293	273	309	28.2	23.1	30.3	13.3	24.6
1978	13	15	17	13	298	305	294	353	13.2	8.6	5.4	0.8	8.5
1979	12	15	17	11	297	290	291	356	18.1	21.0	14.5	6.1	16.0
1980	13	12	15	12	307	325	278	341	14.0	11.0	16.0	11.0	13.4
1982	10	11	10	11	307	316	341	342	15.7	15.0	6.9	4.5	11.9
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
1988	16	15	16	16	321	321	305	345	7.1	2.7	9.8	8.7	7.1

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