ANNUAL PROJECT TECHNICAL REPORT FOR 1993

Fishery and Aquatic Management Program

Yellowstone National Park

Lynn R. Kaeding, Acting Project Leader

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Authors

Lynn R. Kaeding, Acting Project Leader: Yellowstone Lake, Yellowstone River, Other project activities.

Daniel G. Carty, Fishery Biologist: Parkwide angling, Nonangling use of the aquatic resource.

Daniel L. Mahony, Fishery Biologist: Genetics studies, Reese Creek.

Contributors

Glenn Boltz, Biological Sciences Technician: Graphics, Fish age and growth.

Sonya M. Anderson, Office Assistant: Editorial review and report production.

Cover photo: The dry stream bed of Reese Creek, northern boundary of Yellowstone National Park, summer 1985. Because of a minimum streamflow agreement negotiated between the National Park Service and private water users, this reach of Reese Creek is no longer dewatered during the irrigation season.

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INTRODUCTION

Yellowstone National Park, the Nation's first national park, was established by the United States Congress in 1872 ". . . 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." Encompassing the northwest corner of Wyoming and adjacent areas of Montana and Idaho, the 890,000-hectare (3,500 mi^2) park has high mountains, forested plateaus, the world's largest volcanic caldera, and thousands of geysers and other geothermal resources.

About 5% of the surface area of the park is water. More than 150 lakes compose an area of about 43,000 hectares (108,000 acres), of which Yellowstone, Shoshone, Lewis, and Heart lakes make up 94%. More than 220 named and hundreds of unnamed streams form over 4,300 km (2,650 mi) of flowing water.

Yellowstone National Park provides exceptional recreational opportunities for anglers and other visitors. Federal law and National Park Service (NPS) policies have evolved to closely regulate fishing in the park. Although about 3 million people now visit the park each year and an estimated 398,000 angler days were spent fishing park waters in 1993, angling regulations formulated by NPS and the U.S. Fish and Wildlife Service (USFWS)--aquatic resources advisor to NPS in the park--have resulted in self-sustaining fish populations with characteristics resembling those from unfished waters.

In Yellowstone National Park, quality angling is defined as the opportunity to fish for wild trout in a relatively undisturbed environment. Although limited harvest of fish by anglers is allowed, fish are primarily available to grizzly bears, river otters, eagles, ospreys, pelicans, and other animals as food.

The goal of the aquatic management program of Yellowstone National Park is to:

> Pursue an aquatic management policy that allows ecological processes to function as if uninfluenced by modern man, while providing for visitor use and education.

Program objectives are to:

(1) Describe the qualitative and quantitative characteristics of the fish populations, associated biota, and other aquatic resources of Yellowstone National Park;

(2) Determine how visitor use and other factors affect the dynamics

and trends of fish populations, associated biota, and other aquatic resources;

(3) Recommend measures to minimize the effects of human activities on the fish populations and other aquatic resources; and

(4) Maintain or restore, in numbers sufficient to assure their long-term persistence, aquatic ecosystems and their fish-species assemblages representative of those present upon the arrival of European man in Yellowstone National Park.

To assure aquatic management program adherence to NPS policies, the USFWS conducts investigations of the fishery and aquatic ecosystem of Yellowstone National Park. This report describes the results of investigations performed in 1993.

PARKWIDE ANGLING

Between the early 1900s and 1972 the U.S. Fish and Wildlife Service (FWS) infrequently conducted creel surveys to evaluate effects of angling on fisheries in Yellowstone National Park (YNP). In 1973 the FWS began to develop the Volunteer Angler Report (VAR) system, the data base that has since been used to annually monitor parkwide angling. Data from the VAR system have been used to evaluate the efficacy of YNP angling regulations. Objectives of this report were to present current-year estimates of and long-term trends in parkwide visitation (number of park visitors) and 10 characteristics of the parkwide fishery.

Methods

Parkwide visitation and the VAR system.-The National Park Service (NPS) estimates the number of visitors to YNP each year. Visitors ≥12 years old who want to fish in the park must obtain a YNP fishing permit. These free permits are available at park entrance gates, visitor centers, ranger stations, and stores. The NPS estimates the number of fishing permits issued each year.

Attached to each fishing permit is a postal creel survey card--the VAR card. Park anglers are asked to complete one VAR card per stream or lake fished and return the card to the NPS or FWS. Information requested includes (1) dates fished, (2) name of and location on stream or lake fished, (3) number of days fished, (4) number of hours fished per day, (5) numbers and lengths for each species of fish landed and creeled, (6) boat or shore fishing, (7) angler-skill level, and (8) satisfaction with the overall fishing experience and with numbers and sizes of fish caught.

Between mid-June and early October the FWS schedules 37 manned creel surveys at park exit gates. Five surveys are scheduled at the North Gate, 5 at the Northeast Gate, 7 at the East Gate, 10 at the South Gate, and 10 at the West Gate. Each survey lasts about 6 h during which an NPS or FWS employee interviews visitors who are leaving the park. Because of logistical constraints, only about 30 of the surveys are completed each year.

Only one person per vehicle is interviewed, and the number of questions asked depends on the responses of the interviewee. Interviewees are asked (1) whether they fished in YNP during their visit and (2) whether they obtained a YNP fishing permit. If their response to the first question is "yes" then the state, Canadian province, or country of their vehicle license plate is recorded, and they are asked (3) the number of days fished and (4) the number of waters fished on their last day of fishing. If time allows they are asked (5) their angler-skill level, (6) whether they were satisfied with their overall fishing experience, and (7) the numbers of adult and child anglers in the vehicle with and without permits. The number of fishing permits issued, data from VAR cards, and information from exit-gate surveys are subsequently combined in a series of computer programs written by the FWS to estimate characteristics of the parkwide fishery.

Long-term trends.-The Mann-Kendall test for $N \leq 40$ (Hollander and Wolfe 1973; Gilbert 1987) was used to examine trends in parkwide visitation and 10 characteristics of the parkwide fishery from 1973 to 1993. This nonparametric test allows missing values, is distribution-free, and is preferred to a standard *t*-test for zero slope when the data may be serially correlated (Hirsch et al. 1982; Gilbert 1987; Norris and Georges 1993). Tests were conducted at $\alpha = 0.05$.

Results

Current Year (1993)

Over 2.9 million people, the third-most on record, visited YNP in 1993. The NPS issued approximately 161,000 fishing permits this year, and anglers returned 6,164 VAR cards (3.8% of those issued). About 15.5% of permit holders did not fish, resulting in an estimate of 141,000 anglers for 1993.

Parkwide angler use (angler days) and effort in 1993 were 398,100 angler days and 1,026,100 h, increases of 16% over estimates for 1992. Anglers landed approximately 942,600 fish in 1993, but only creeled about 56,600 (6%). The average angler fished 2.1 d, 1.4 waters/d, and 2.6 h/d. Mean-annual landing and creel rates were 0.92 and 0.06 fish/h. Nearly 73% of single-day anglers landed one or more fish.

Relative abundance of fish landed was 71% cutthroat trout *Oncorhynchus clarki*, 11% rainbow trout *Oncorhynchus mykiss*, 8% brook trout *Salvelinus fontinalis*, and 6% brown trout *Salmo trutta*; mountain whitefish *Prosopium williamsoni*, lake trout *Salvelinus namaycush*, Arctic grayling *Thymallus arcticus*, and unidentified fishes made up the remaining 4%. Mean length of 42,916 angler-landed fish was 13.5 in (343 mm); 68% were ≥12 in (305 mm), and 54% were ≥14 in (356 mm). Lake trout had the greatest average length (17.4 in; 442 mm), followed by cutthroat trout (14.7 in; 373 mm), brown trout (12.4 in; 315 mm), mountain whitefish (12.0 in; 305 mm), rainbow trout (11.1 in; 282 mm), Arctic grayling (10.6 in; 269 mm), and brook trout (7.3 in; 185 mm).

An estimated 84% of park anglers reported being satisfied with their overall fishing experience in 1993; 73% and 78%, respectively, reported being satisfied with numbers and sizes of fish landed. Satisfied anglers landed about 1.0 fish/h (mean length, 13.7 in or 348 mm), and unsatisfied anglers landed fewer (mean, 0.5 fish/h) and smaller (mean length, 11.2 in or 284 mm) fish. Mean angler-skill level was 1.91 (experienced).

Fishery statistics for 22 lakes and streams that collectively constituted 95% of parkwide angler use in 1993 are listed in Table 1.

TABLE 1.-Fishery statistics for Yellowstone National Park waters with 40 or more angler days reported that collectively constituted approximately 95% of the estimated parkwide angler use in 1993.

	% of total parkwide angler days	Total reported angler days	Number of Anglers	Mean length of Angler day (h)	Angler days (trips)	Angler effort (hours)	Landing rate (fish/h)	Creel rate (fish/h)	Total fish landed	Total fish creeled	Mean length fish landed (inches)	Mean length fish creeled (inches)	% anglers landing 1 or more fish	Average expertise	% anglers satisfied with: Overall experience	Numbers caught	Sizes caught
Parkwide fishery	100	10,099	141,081	2.58	398,060	1,026,074	0.92	0.06	942,556	56,630	13.5	12.0	73	1.91	84	73	78
Yellowstone Lake	35.32	3,567	43,554	2.53	140,580	356,283	0.94	0.09	333,895	33,592	15.4	12.2	78	1.77	88	78	85
Yellowstone River	16.79	1,696	22,280	2.78	66,829	185,566	0.89	0.02	163,746	2,976	15.5	12.2	75	1.99	86	79	89
Firehole River	7.58	765	11,814	2.56	30,131	77,000	0.78	0.01	60,037	1,016	10.6	10.0	65	1.97	82	67	63
Slough Creek	7.09	716	10,511	3.22	28,199	90,837	0.98	0.01	88,805	1,282	14.8	11.4	84	2.05	92	86	92
Madison River	5.69	575	7,975	2.45	22,641	55,423	0.48	0.02	26,727	1,041	13.1	13.6	49	1.92	65	46	60
Gibbon River	4.40	444	7,769	1.79	17,477	31,269	0.92	0.07	28,770	2,044	7.6	8.1	62	1.91	72	57	46
Lamar River	3.20	323	5,393	2.84	12,708	36,142	1.13	0.03	40,710	1,167	12.6	13.2	76	2.04	87	70	81
Soda Butte Creek	2.11	213	2,948	2.63	8,372	21,980	1.14	0.03	25,068	728	10.5	13.9	78	1.96	83	75	72
Gardner River	2.01	203	3,108	2.19	7,977	17,468	1.17	0.10	20,398	1,813	8,9	8.9	81	1.88	86	74	72
Lewis Lake	1.86	188	2,742	3.23	7,386	23,839	0.42	0.13	9,916	2,980	15.6	16.2	45	1.90	58	45	60
Indian Creek	1.18	119	1,622	1.84	4,666	8,592	0.80	0.14	6,831	1,165	6.4	7.2	80	1.76	70	62	36
Shoshone Lake	1.17	118	1,257	3.34	4,627	15,474	0.76	0.13	11,773	1,970	17.7	17.9	80	1.86	80	65	94
Gallatin River	1.16	117	1,760	2.64	4,588	12,116	0.46	0.02	5,572	292	13.0	13.9	54	2.00	64	47	66

TABLE 1.-Continued.

	% of total parkwide angler days	Total reported angler days	Number of Anglers	Mean length of Angler day (h)	Angler days (trips)	Angler effort (hours)	Landing rate (fish/h)	Creel rate (fish/h)	Total fish landed	Total fish creeled	Mean length fish landed (inches)	Mean length fish creeled (inches)	% anglers landing 1 or more fish	Average expertise	% anglers satisfied with: Overall experience	Numbers caught	Sizes caught
Lewis River	0.72	73	1,462	2.29	2,853	6,526	0.64	0.06	4,180	399	12.7	14.3	64	1.88	73	60	66
Pebble Creek	0.66	67	1,166	2.25	2,617	5,882	1.89	0.05	11,078	306	11.0	12.8	88	1.94	92	96	92
Grebe Lake	0.66	67	1,280	2.78	2,617	7,278	1.58	0.08	11,514	591	10.6	14.2	89	1.96	90	80	82
Snake River	0.64	65	777	2.61	2,538	6,624	0.96	0.08	6,374	523	12.2	12.8	81	2.03	66	88	88
Nez Perce Creek	0.64	65	1,166	1.98	2,538	5,025	0.68	0.03	3,433	147	7.9	7.5	58	1.79	65	48	40
Tower Creek	0.57	58	914	2.31	2,262	5,236	1.85	0.19	9,688	983	8.6	7.9	65	1.86	97	92	92
Obsidian Creek	0.57	58	983	1.64	2,262	3,714	1.14	0.08	4,231	291	6.6	7.8	71	1.75	78	69	39
Trout Lake	0.51	51	891	2.28	1,986	4,532	0.80	0.01	3,601	53	16.3	--	84	2.05	89	63	92
Pelican Creek	0.41	41	845	2.93	1,592	4,656	1.40	0.01	6,519	55	14.4	--	94	2.17	86	86	89

Long-term Trends (1973-1993)

Although there has been considerable annual variation in parkwide visitation and in the 10 characteristics of the parkwide fishery examined in this report (Tables 2 and 3), several trends have emerged during the past 21 years (Table 4). Parkwide visitation has increased significantly since 1973; however, the number of park anglers has shown no trend. Angler use and mean length of the angler day have significantly increased, resulting in a significant increase in angler effort. Mean-annual landing rate has shown no trend since 1973, but the number of fish landed annually has increased significantly. Number of fish creeled annually has decreased significantly during the past 21 years.

Analysis of the long-term trend in mean length of angler-landed fish was complicated by a change in the VAR system that occurred in 1985. Between 1975 and 1984, anglers reported their catch in seven length categories (<10, 10-12, 12-14, 14-16, 16-18, 18-20, and >20 in); however, since 1985 anglers have reported their catch in nine length categories (categories of <6, 6-8, and 8-10 in were added). Consequently, mean length estimates of angler-landed fish for the period 1985 through 1993 were recalculated using pre-1985 length groups. Applying the Mann-Kendall test to this modified data revealed that the mean length of angler-landed fish has increased significantly during the past 19 years.

Last, the percentage of anglers satisfied with their overall fishing experience and the mean angler-skill level have increased significantly between 1975 and 1993.

Discussion

The rise in parkwide visitation between 1973 and 1993 was not accompanied by an increase in number of park anglers. It may be that the percentage of visitors to YNP who are also anglers has declined. However, problems with accurately estimating parkwide visitation, number of fishing permits issued, and the percentage of permit holders that did not fish may have contributed to the observed result.

Angler use and mean length of the angler day increased between 1973 and 1993. Given no trend in number of park anglers during the past 21 years, angler use could rise if anglers made longer visits or fished more frequently during visits to YNP. The increase in mean length of the angler day suggests that anglers are fishing longer during each fishing trip.

Increased angler use and mean length of the angler day resulted in an increase in angler effort since 1973. Relatively high levels of angler effort can negatively affect fisheries unless fish populations are protected from excessive harvest (Van Den Avyle 1993). Since the 1970s, angling regulations that emphasize catch-and-release fishing have been implemented for most waters in YNP; consequently, the number of fish creeled annually has declined. A relatively constant mean-annual landing rate and an increase in mean length of angler-landed

TABLE 2.-Estimates of park visitors, fishing permits issued, total parkwide anglers, and total parkwide angler days, Yellowstone National Park, 1973 to 1993.

Year	Total park visitors	Park fishing permits issued	Total parkwide anglers	Total parkwide angler days	95% confidence limits
1973	2,061,500	169,100	121,900	230,100	225,500 - 234,700
1974	1,937,800	164,600	116,500	220,000	215,500 - 224,300
1975	2,246,100	191,600	136,300	257,300	248,400 - 266,300
1976	2,525,200	213,200	151,700	284,200	278,500 - 298,900
1977	2,487,100	217,000	154,600	311,300	304,000 - 318,500
1978	2,623,100	218,000	155,700	333,800	326,200 - 341,300
1979	1,891,900	195,100	139,100	291,300	274,500 - 308,200
1980	2,009,600	184,200	130,800	311,300	287,000 - 334,600
1981	2,544,200	172,300	160,000	383,400	363,400 - 403,300
1982	2,404,900	205,000	152,000	332,500	314,700 - 350,300
1983	2,405,700	166,800	120,500	275,900	261,800 - 289,900
1984	2,263,000	176,800	135,000	329,200	305,400 - 341,000
1985	2,262,500	166,700	123,800	279,000	260,800 - 297,200
1986	2,405,100	163,300	124,900	294,800	269,300 - 320,400
1987	2,618,200	183,900	151,500	370,900	349,100 - 392,800
1988	2,219,100	165,700	134,600	293,800	272,700 - 314,900
1989	2,680,400	159,200	124,400	320,900	301,100 - 340,700
1990	2,857,100	171,700	150,400	422,100	386,700 - 457,500
1991	2,957,900	187,200	161,100	403,100	372,500 - 433,800
1992	3,142,600	157,800	130,800	343,400	324,200 - 362,700
1993	2,912,200	161,000	141,100	398,100	371,400 - 424,700

TABLE 3.-Estimates of angler use, effort, success, and harvest for Yellowstone National Park, 1973-1993.

Year	Angler days	Mean length of angler day (h)	Total hours fished (days x h)	Landing rate	Total fish landed	Creel rate	Total fish creeled	% of anglers satisfied with Overall experience	Numbers caught	Sizes caught	Average length of fish landed (in)	Mean expertise[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	370,900	2.47	917,800	0.94	865,900	0.07	61,600	73	64	66	12.3	1.93
1988	293,800	2.56	753,400	1.05	788,100	0.09	65,300	78	69	70	12.8	1.90
1989	320,900	2.50	801,300	0.92	735,800	0.07	55,400	77	68	71	13.2	1.91
1990	422,100	2.47	1,042,900	0.97	1,009,900	0.06	61,700	80	71	73	13.3	1.88
1991	403,100	2.62	1,059,300	0.98	1,039,700	0.06	66,600	81	72	74	13.4	1.90
1992	343,400	2.57	881,600	0.91	802,700	0.04	37,000	78	68	72	12.9	1.92
1993	398,100	2.58	1,026,100	0.92	942,600	0.06	56,600	84	73	78	13.5	1.91

[a] Based on: 1.0 = inexperienced; 2.0 = experienced; 3.0 = expert.
[b] Revised from that reported in Jones et al. (1980).

TABLE 4.-Trends in Yellowstone National Park visitation and 10 characteristics of the parkwide fishery, 1973-1993 (Trends are based on 21 years of data, except as noted).

Characteristic	Mann-Kendall test statistic (S)	Statistical long-term trend[a]
Parkwide visitation	102	increase
Number of anglers	13	no trend
Number of angler days (angler use)	107	increase
Mean length of angler day (h)	115	increase
Angler effort (h)	135	increase
Landing rate (fish/h)	-34	no trend
Number of fish landed	130	increase
Number of fish creeled	-139	decrease
Satisfied anglers (%)[b]	89	increase
Mean length landed (mm)[b]	74	increase
Mean angler-skill level[c]	75	increase

[a]Tested at $\alpha = 0.05$.

[b]19 years of data (1975-1993).

[c]18 years of data (1976-1993).

fish during the past 21 years suggest that these restrictive angling regulations have helped sustain or improve the parkwide fishery.

Reasons for the observed increase in the percentage of anglers satisfied with their overall fishing experience are undoubtedly varied. Perhaps in addition to using the VAR system to evaluate the efficacy of angling regulations, anglers could be interviewed about sociological issues related to angling in YNP.

THE YELLOWSTONE LAKE FISHERY

The fishery for Yellowstone cutthroat trout *Oncorhynchus clarki bouvieri* in Yellowstone Lake has been greatly affected by human activities during the past 100 years (Gresswell and Varley 1988). During the first half of this century, large numbers of cutthroat trout and their eggs were removed from the lake ecosystem because of liberal angling regulations, a commercial fishery that supplied cutthroat trout to park restaurants, and extensive, hatchery-based spawn-taking operations. Also during that time, three nonnative fishes were introduced into the lake.

Increasingly restrictive angling regulations and elimination of commercial fishing and hatchery operations initiated recovery of the Yellowstone Lake cutthroat trout stock in recent decades (Gresswell and Varley 1988). A two-fish, 330-mm maximum-size limit has been in effect since 1975, and similar or more restrictive regulations have existed on the lake's tributaries since 1978. Today, the cutthroat trout of Yellowstone Lake support the most popular sport fishery in Yellowstone National Park (Table 1).

Objectives of this report were to describe the Yellowstone Lake fishery in 1993 and evaluate long-term trends in the fishery.

Study Area

Yellowstone Lake lies 2,357 m above mean sea level in east-central Yellowstone National Park. The lake has a drainage basin of 2,616 km², a surface area of 354 km², and a mean depth of 40 m (Benson 1961). Ice covers the lake from mid-December through May or early June; summer surface temperatures rarely exceed 18°C. Yellowstone cutthroat trout and longnose dace *Rhinichthys cataractae* are the endemic fishes of the lake, whereas longnose sucker *Catostomus catostomus*, redside shiner *Richardsonius balteatus*, and lake chub *Couesius plumbeus* are introduced species.

Methods

Manned creel surveys and the Volunteer Angler Report (VAR) system (see section on Parkwide Angling, this report) provided information on the Yellowstone Lake sport fishery for 1969 through 1993. The fish trap at Clear Creek was not operated in 1993, nor was gillnet sampling performed on Yellowstone Lake.

Sport-fishery data from manned creel surveys and the VAR system include annual estimates of angler effort (hours of fishing), mean-annual landing rate (average number of fish landed per hour of fishing), angler-caused mortality (estimated number of fish creeled plus an assumed 10% hooking mortality of released fish), and mean total length of angler-landed fish.

Proportional Stock Density (PSD), used to monitor the length structure of the fish population, is an index of relative abundance (percentage) for fish longer than a specified length that are also longer than a minimum length (Gabelhouse 1984). In this study, the minimum length for cutthroat trout was 254 mm, and the two specified lengths were 356 and 406 mm.

Results

Current Year

In 1993 an estimated 43,600 anglers accounted for 141,000 angler days (35% of estimated parkwide angler use) and 356,000 h of angler effort on Yellowstone Lake. Anglers landed an estimated 334,000 Yellowstone cutthroat trout and creeled about 33,600 of these fish. Total estimated angler-caused mortality was 64,000 fish. Estimated mean-annual landing and creel rates were 0.94 and 0.09 fish/h, and mean length of landed fish was 392 mm. The PSD_{356} and PSD_{406} estimates for angler-landed fish were 77 and 39%.

Approximately 88% of the anglers who fished the lake were satisfied with their overall fishing experience, 78% were satisfied with numbers of fish landed, and 85% were satisfied with sizes of fish landed. Mean angling expertise was 1.8 (slightly less than experienced).

Long-term Trends

Estimated annual angler effort on Yellowstone Lake ranged from 368,000 to 426,000 h and showed no long-term trend between 1969 and 1993 (Figure 1). Under the 356-mm minimum-size and two- or three-trout-per-day creel limit, estimated mean-annual landing rate rose from 0.5 trout/h in 1969 to 1.1 trout/h in 1974. Since 1974, mean-annual landing rate has varied little and averaged 0.9 trout/h (Figure 1).

Between 1969 and 1993, the estimated total angler-caused mortality of cutthroat trout has shown two periods of relatively little change and an intervening period of rapid decline (Figure 1). Between 1969 and 1978, these estimates averaged 126,000 fish/year. During the past 11 years, estimates were about 47% lower and averaged 67,000 fish/year. The intervening period of rapid decline in estimated angler-caused mortality coincides with the first several years of the current two-fish, 330-mm maximum-size regulation.

Length-structure indices for angler-landed trout showed relatively large increases since the mid-1970s. Mean length has increased from about 350 to 400 mm, PSD_{356} from about 50 to 80%, and PSD_{406} from about 10 to 40% (Figure 2). Correlation analyses revealed significant ($P<0.01$) relations among all these indices.

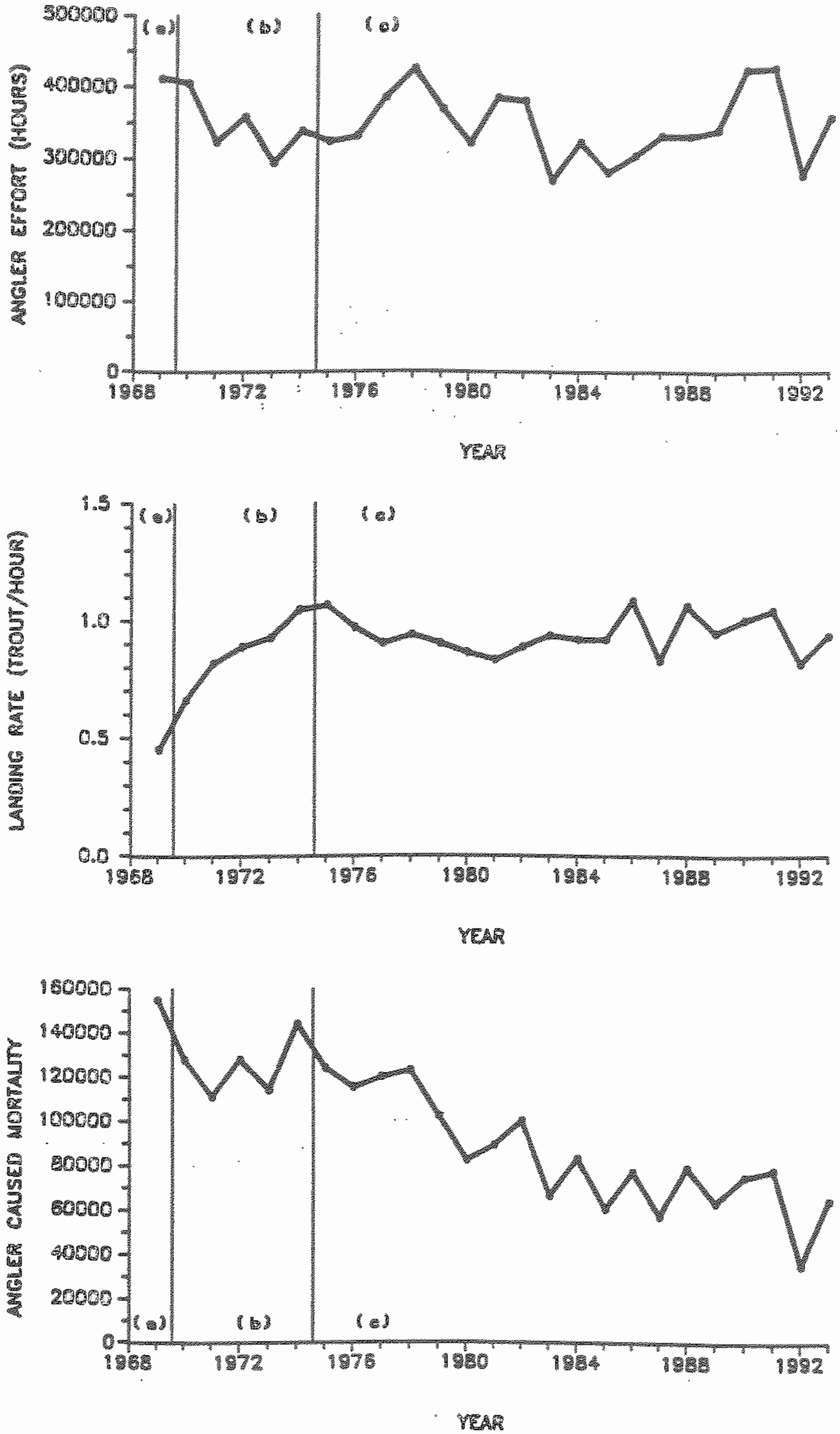

FIGURE 1.-Estimates of total angler effort (upper), mean landing rate (middle), and total fish removed by anglers and angling-related mortality (lower), the Yellowstone Lake cutthroat trout fishery, 1969-1993. Angling regulations: (a) 1969, no size limit and three-trout-per-day creel limit; (b) 1970 to 1974, 356-mm minimum-size limit and two- or three-trout-per-day creel limit; and (c) 1975 to 1993, 330-mm maximum-size limit and two-trout-per-day creel limit.

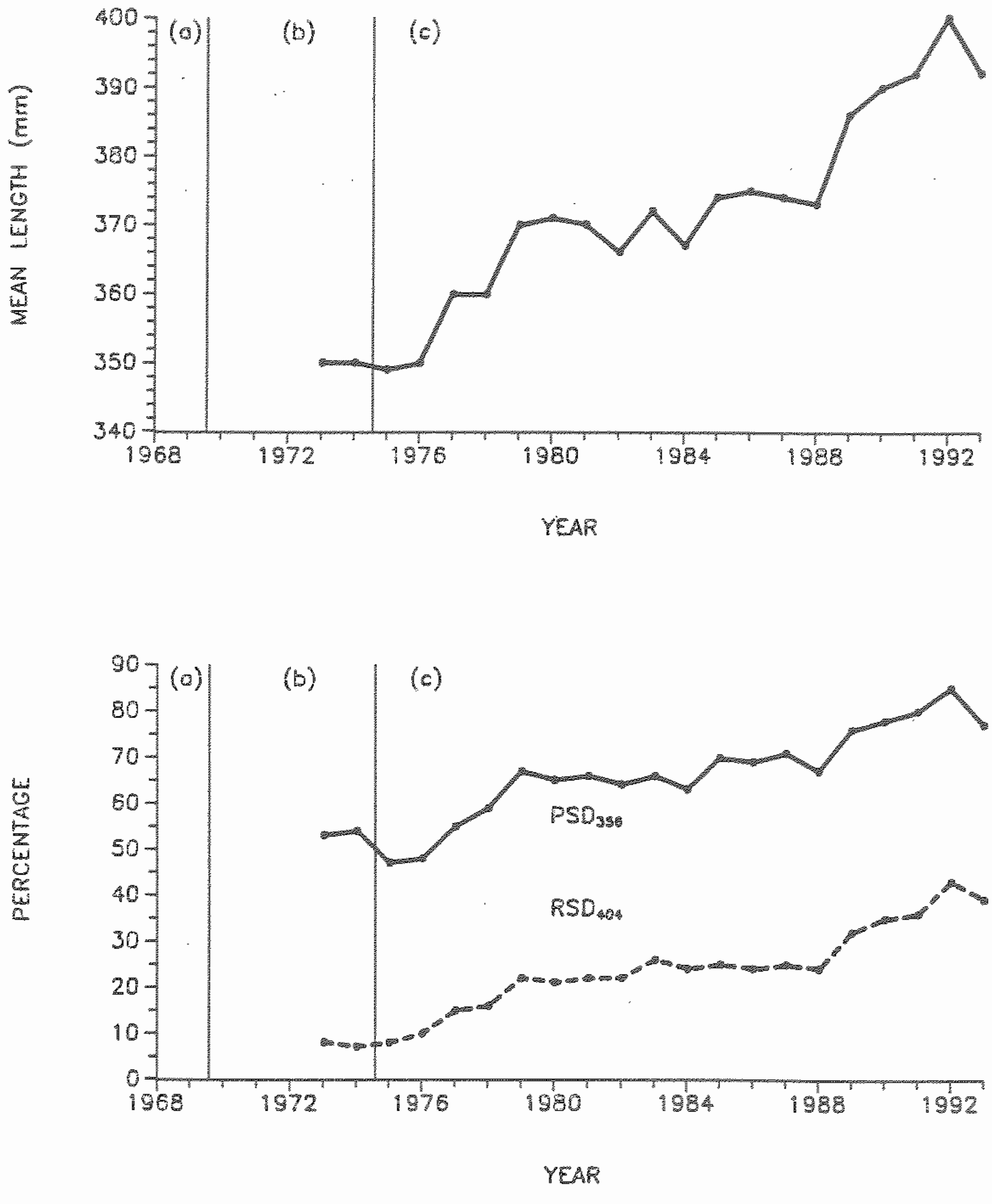

FIGURE 2.-Estimates of mean length (upper) and PSD_{356} and PSD_{406} (lower) for cutthroat trout caught by anglers on Yellowstone Lake, 1973-1993. Angling regulations: (a) 1969, no size limit and three-trout-per-day creel limit; (b) 1970 to 1974, 356-mm minimum-size limit and two- or three-trout-per-day creel limit; and (c)1975 to 1993, 330-mm maximum-size limit and two-trout-per-day creel limit.

Discussion

Benson and Bulkley (1963) considered "overfishing" of the Yellowstone Lake cutthroat trout stock to occur when growth rate of fish is high but mean age decreases to an extent greater than attributable to normal variation, and the spawning stock is "excessively reduced" by the catch. They estimated the maximum equilibrium yield of cutthroat trout for the lake to be 325,000 fish, five times more fish than were estimated to have been removed from the lake by anglers and angling-related mortality in 1993.

The recovery of the Yellowstone Lake cutthroat trout stock during the past 2 decades has been described by Gresswell and Varley (1988), who attributed the former exploitation of the stock primarily to overharvest by anglers and the negative effects of the routine, hatchery-based spawn-taking operations that occurred on several of the lake's major tributaries. On the basis of trends in length-structure indices for fish collected in three concurrent sampling programs and mean age of fish spawning in Clear Creek, Jones et al. (1993) concluded that the cutthroat trout stock of Yellowstone Lake has appreciably recovered from former overexploitation and is not being overharvested under current angling regulations. While presently secure from overharvest by anglers, the cutthroat trout fishery of Yellowstone Lake continues to provide substantial recreational opportunity to the park visitor.

THE FISHERY OF THE YELLOWSTONE RIVER BETWEEN YELLOWSTONE LAKE AND THE UPPER FALLS

The fishery for native Yellowstone cutthroat trout *Oncorhynchus clarki bouvieri* in the Yellowstone River between Yellowstone Lake and the Upper Falls is the second most-popular fishery in Yellowstone National Park (Table 1; Figure 3). Perhaps the most intensively fished stock of wild cutthroat trout in North America (Jones et al. 1982), the cutthroat trout in this river reach have been protected from overharvest by increasingly restrictive angling regulations. Angling regulations that began near the turn of the century with daily creel limits "not to exceed food needs" and no minimum-size restrictions have evolved into the current policy of catch-and-release angling, implemented in 1973 (Jones et al. 1992).

Reductions in angling season length and closure of some river reaches to angling have also provided Yellowstone cutthroat trout protection from angler-caused mortality. Since 1965, opening of the angling season on 15 July has protected cutthroat trout during their early summer spawning season (Dean and Mills 1971). The angling season currently closes on the first Sunday in November. To avoid conflicts between anglers and park visitors who want to view undisturbed fish and other wildlife, a 200-m river reach that includes the LeHardy Rapids area was closed to angling in 1949, a 10-km reach in Hayden Valley was closed in 1965, the reach between Yellowstone Lake and a point 1.6 km downstream from Fishing Bridge was closed in 1973, and a river side channel at Buffalo Ford was closed in 1990 (Figure 3). Although not their primary purpose, these closures helped to protect cutthroat trout in the Yellowstone River from angling.

The objective of this report was to describe the fishery for Yellowstone cutthroat trout in the Yellowstone River between Yellowstone Lake and the Upper Falls in 1993 and evaluate long-term trends in this fishery.

Study Areas

Catch-and-Release River Reaches

Two reaches of the Yellowstone River between Yellowstone Lake and the Upper Falls are open to catch-and-release angling. The upper, 10-km reach begins 1.6 km below Fishing Bridge and extends downstream to Sulphur Caldron. The areas closed to angling at LeHardy Rapids and Buffalo Ford are in this upper river reach. The lower, 5-km catch-and-release reach extends from Alum Creek to Chittenden Bridge (Figure 3).

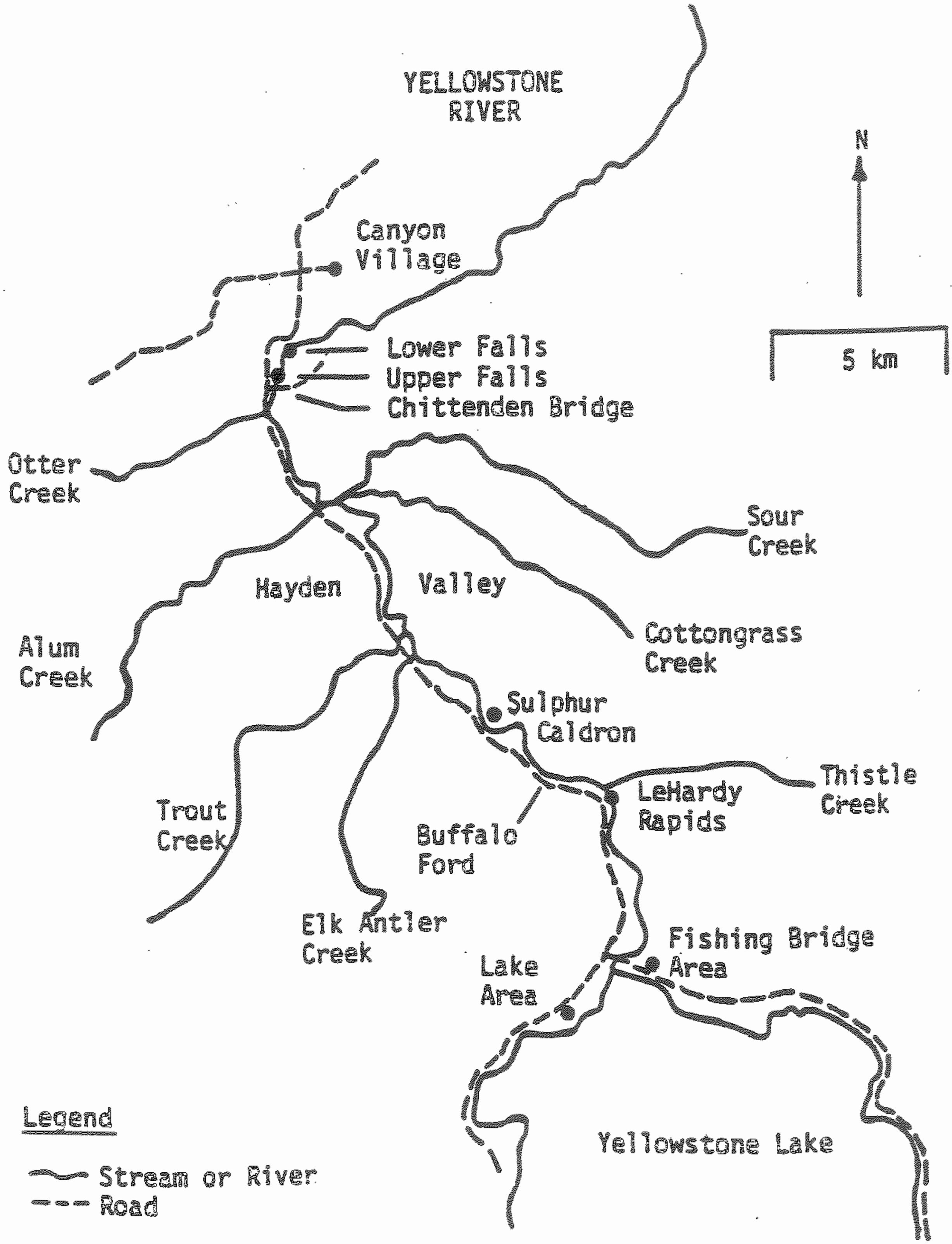

FIGURE 3.-The Yellowstone River and its tributaries between Yellowstone Lake and the Upper Falls.

LeHardy Rapids

LeHardy Rapids is 6 km downstream from Yellowstone Lake (Figure 3). During the period of high river flows and cutthroat trout spawning (May through July), trout often congregate in pools on the west bank of the river immediately below the rapids. A nearby viewing platform allows park visitors to watch fish ascend the rapids.

Methods

Data sources and field procedures.--Information on the cutthroat trout fishery of the Yellowstone River was provided by manned creel surveys and (since 1973) the Volunteer Angler Report (VAR) system (see section on Parkwide Angling, this report). Because estimates based on VAR data are for the entire angling season, data from manned creel surveys conducted during summer only were made comparable by conversion to "season-long" estimates, which were averaged for the periods 1951-1955, 1967-1968, and 1970-1972.

For 1993, the VAR system provided estimates of the number of anglers, angler use (number of fishing trips), angler effort (number of hours fished), number of fish landed, mean-annual landing rate, mean length of landed fish, number of fish illegally harvested, percentage of anglers satisfied with their angling experience, and mean skill level of anglers. Long-term analyses were restricted to angler effort, mean-annual landing rate, and length structure of fish landed.

Since 1974, data have been collected on cutthroat trout at LeHardy Rapids, where fish are sampled weekly during the spawning season. Each week, up to 100 fish are collected by dip net from pools along the west bank of the river, just downstream from the rapids. Captured fish are classified by sex and reproductive condition, measured to total length (mm), and weighed (g). Scales for age-growth analyses are collected from fish in a subsample. Fish age is estimated by the scale method (Bagenal and Tesch 1978), and an age-length key (Westrheim and Ricker 1978) is used to estimate mean fish age based on the age-length relation and the length structure of the fish population.

Length-structure analysis.--Proportional Stock Density (PSD) is an index of relative abundance (percentage) for fish longer than a specified length that are also longer than a minimum length (Gabelhouse 1984). In this study, the minimum length for cutthroat trout was 254 mm and the two specified lengths were 356 and 406 mm.

Results

Current Year

Sport fishery.--An estimated 15,900 anglers made 48,500 fishing trips (angler days) and spent 137,000 h fishing the Yellowstone River in 1993. An estimated 113,000 Yellowstone cutthroat trout were landed. Average landing rate was 0.83 fish/h, and mean length of landed fish was 424 mm. Forty-two fish were estimated to have been illegally creeled. Eighty-seven percent of the anglers reported that they were satisfied with their overall fishing experience, and 78% with the number and 91% with the size of fish landed. About 73% of single-day anglers landed one or more fish. Average angler expertise was 2.0 (experienced).

LeHardy Rapids.--Cutthroat trout (N = 403) were sampled at LeHardy Rapids between early June and late July. Mean age, total length, weight, and condition (K) of these fish were 6.1 years, 409 mm (males, 417 mm; females, 400 mm), 560 g, and 0.82 (Table 5). Estimates of PSD_{356} and PSD_{406} were 99 and 52% for these fish.

Long-term Trends

Sport fishery (1950s to 1993).--Estimated annual angler effort averaged 88,000 h between the 1950s and 1972, then declined to about 57,000 h in 1973 and 1974, the first 2 years of the catch-and-release regulation (Figure 4). Since 1974, annual angler effort has shown a generally increasing trend, although variation among years has sometimes been large. During the past 5 years, annual angler effort has averaged 127,000 h.

Under the catch-and-release regulation, mean-annual landing rate rose rapidly from about 0.7 fish/h to a high of 2.3 fish/h in 1974 (Figure 4). However, since 1974 mean-annual landing rates have declined and averaged 0.8 fish/h over the past 5 years. Current mean-annual landing rates are similar to those that occurred before implementing the catch-and-release regulation.

Mean length of landed fish has generally increased since the late 1960s (Figure 5). Increasing trends were also evident in estimates of PSD_{356} and PSD_{406}, which have ranged between 62 and 95% and 16 and 70%, respectively (Figure 5).

LeHardy Rapids (1974 to 1993).-Mean total length of cutthroat trout captured at LeHardy Rapids has shown a generally increasing trend since 1974 (Figure 6). Increasing trends were also evident in estimates of PSD_{356} and PSD_{406}, which have ranged between 51 and 100% and 8 and 52%, respectively (Figure 6).

Youngest mean age (3.7 years) was observed in 1974 and 1975 and has generally increased since then. Oldest mean age (6.1 years) occurred in 1986, 1989, 1992, and 1993 (Figure 6).

Discussion

Implementation of increasingly restrictive angling regulations has had substantial effects on the fishery of the Yellowstone River between Yellowstone Lake and the Upper Falls. Annual angler effort declined by one-third, and mean-annual landing rate increased nearly fourfold shortly after the catch-and-release

TABLE 5.-Mean length, weight, and condition of Yellowstone cutthroat trout captured by dip net at LeHardy Rapids, Yellowstone River, 1974 to 1993.

	Adult males				Adult females				All adults			
Year	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
1989	186	411	578	0.83	199	387	495	0.85	386	398	535	0.84
1990	223	407	582	0.86	188	385	502	0.88	411	397	546	0.87
1991	326	412	572	0.81	308	393	504	0.83	634	402	539	0.82
1992	44	415	598	0.83	27	397	511	0.81	71	408	565	0.83
1993	209	417	601	0.83	194	400	517	0.81	403	409	560	0.82

[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 one female from 1977, and one male from 1988.
[b] Six adults in 1984, one adult in 1985, one adult in 1986, and one adult in 1989 were not identified to sex.

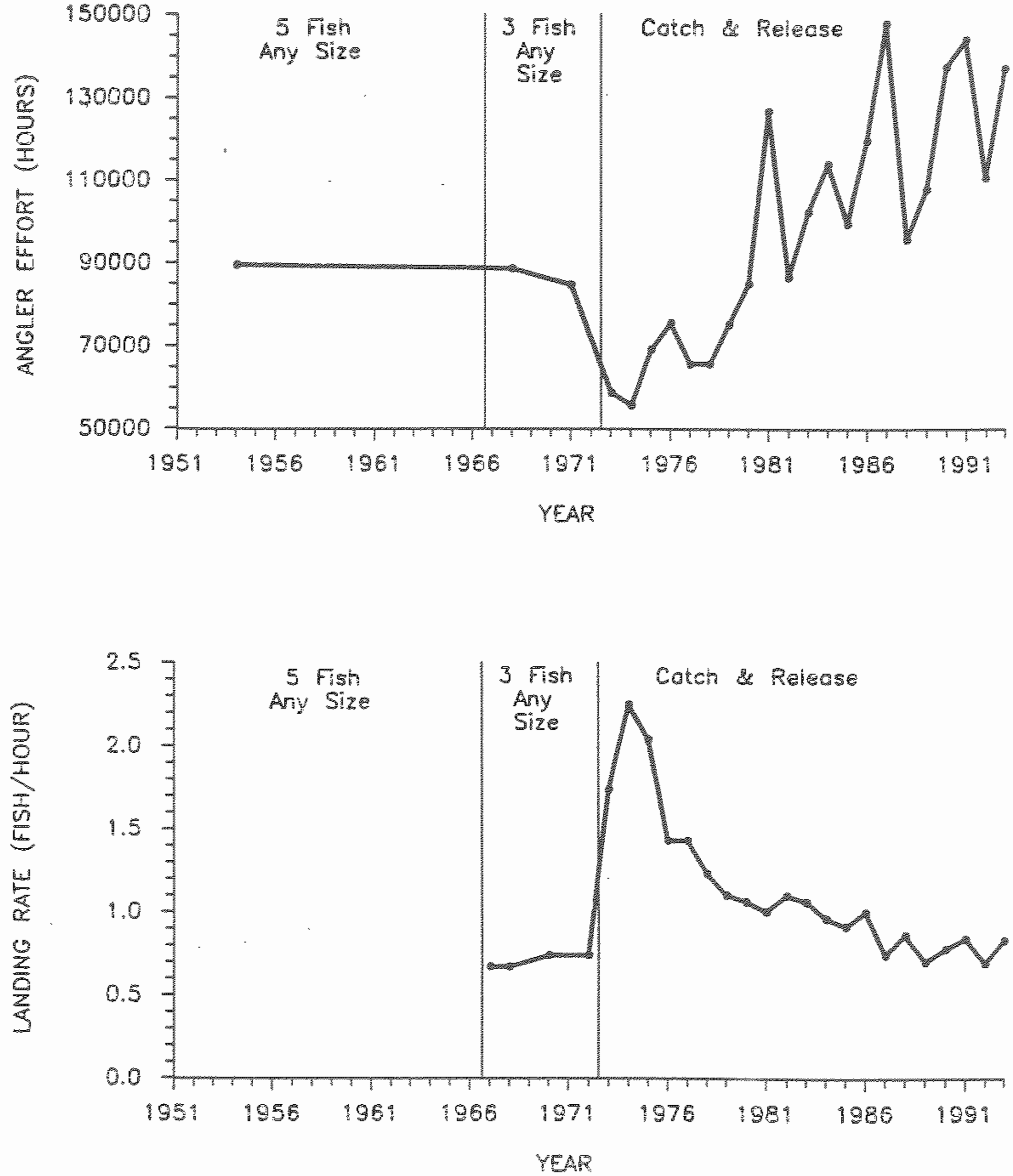

FIGURE 4.-Estimated annual angler effort and mean landing rate for cutthroat trout in the Yellowstone River, 1951-1993.

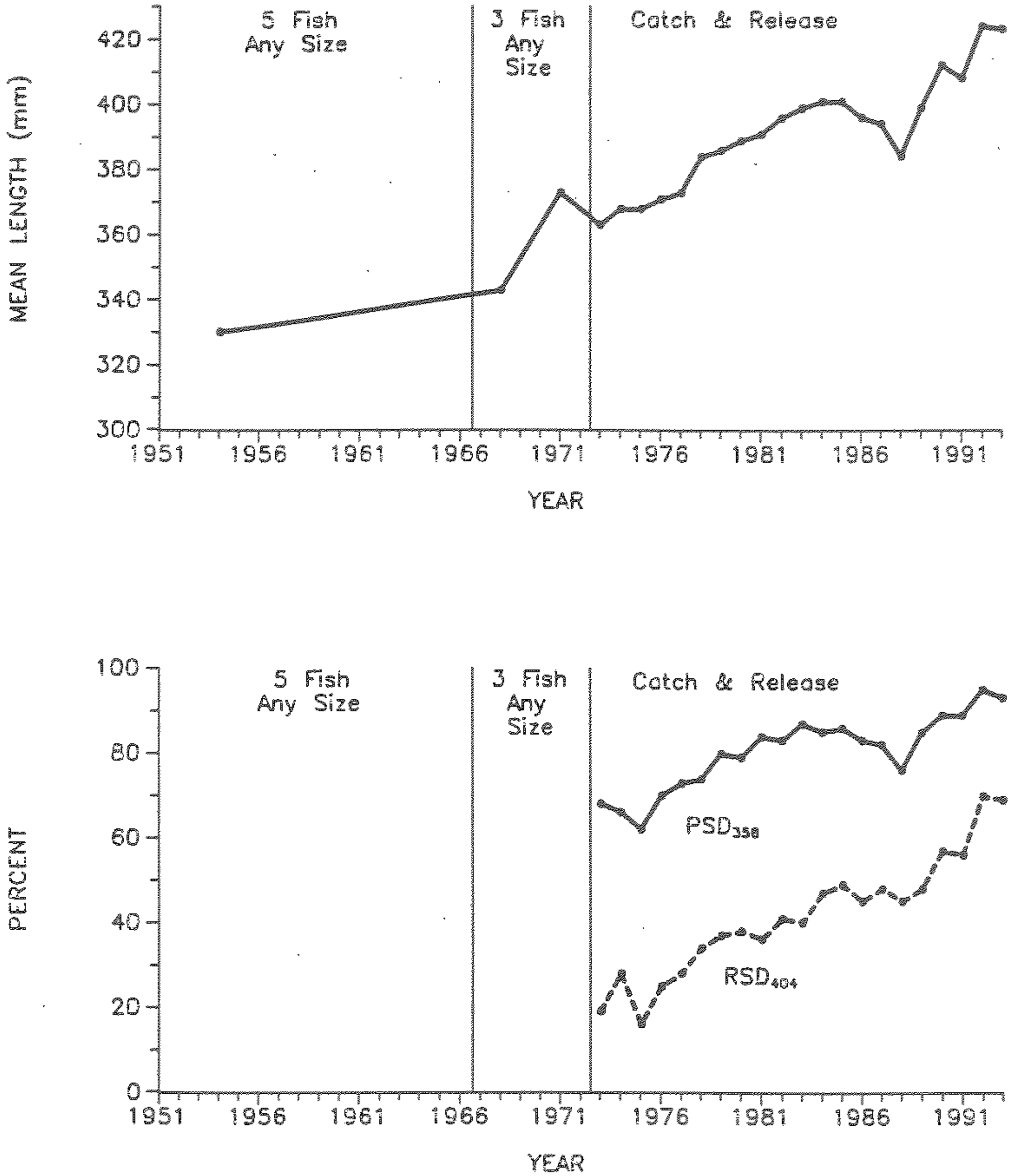

FIGURE 5.-Mean total length and PSD_{358} and PSD_{404} for cutthroat trout reported landed by anglers on the Yellowstone River, 1951-1993.

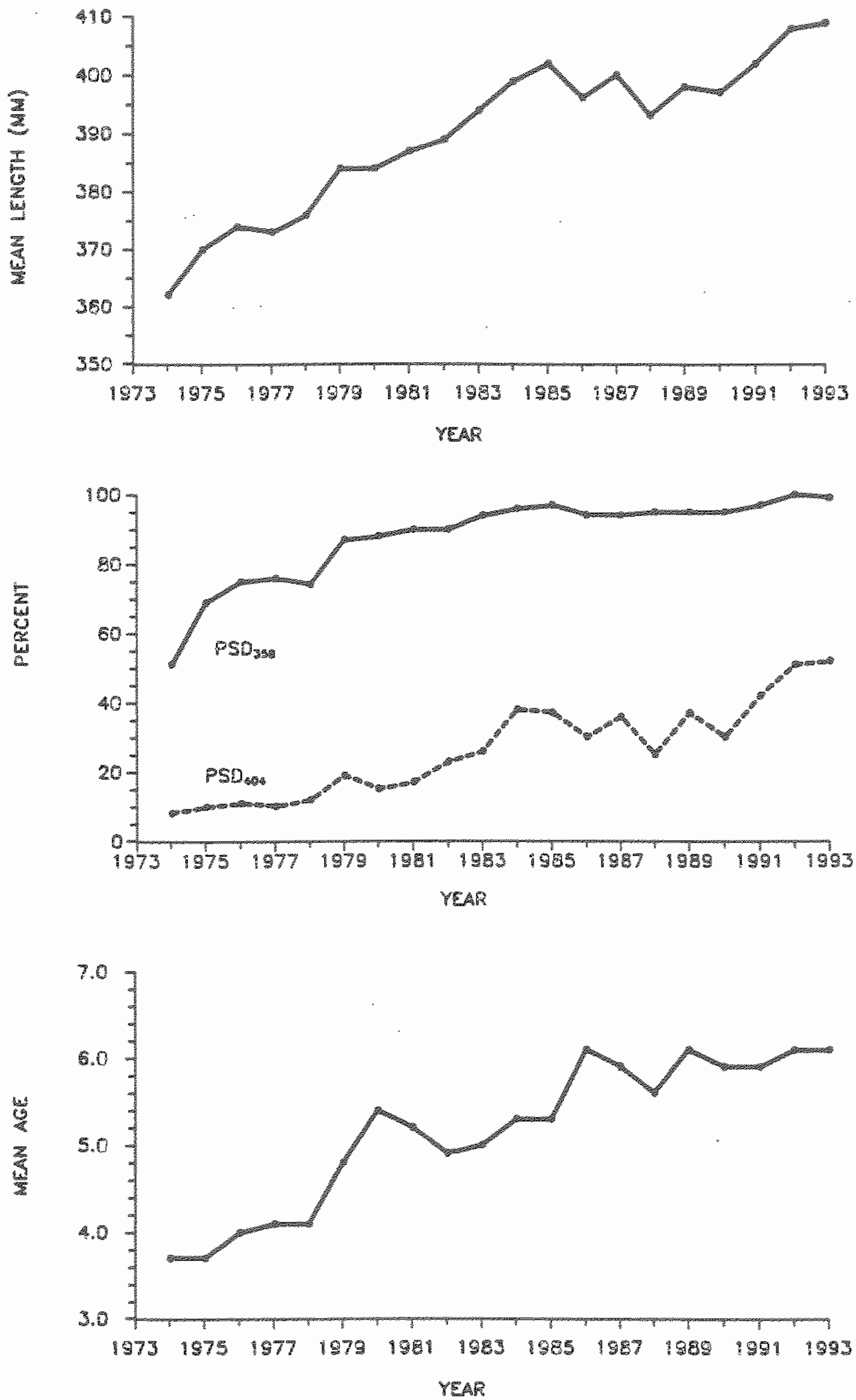

FIGURE 6.-Mean total length, PSD_{356} and PSD_{404}, and mean age of cutthroat trout caught by dip net at LeHardy Rapids, Yellowstone River, 1973-1993.

regulation began. This suggests that anglers who continued to fish under catch-and-release were more successful at catching fish, perhaps as the result of less competition with other anglers. However, concurrent development of the VAR system might also have affected these data. During the mid-1970s several important modifications were made to the VAR system, which was considered complete in 1977 (Jones et al. 1978).

The generally increasing trend in mean length of angler-landed fish (a trend paralleled by PSDs after they began to be calculated in 1973) indicates that substantial numbers of large fish were being removed from the stock under the five-fish-of-any-size regulation in effect through 1966. Similar trends in mean total length and PSDs were evident in fish caught in dip nets at LeHardy Rapids. Harvest of large fish by anglers was reduced under the three-fish-of-any-size regulation, as revealed by the increase in mean length of landed fish. The increases in mean total length and PSDs evident today that might have been achieved without implementation of the catch-and-release regulation are unknown. Trends in these indices during recent years give no indication that relative stability in length structure of the fish stock has been achieved.

It is unclear whether the observed improvement in the Yellowstone River cutthroat trout fishery can be accounted for solely by changes in angling regulations on the river itself. Movements of tagged fish led Ball and Cope (1961) to conclude that many Yellowstone Lake fish move downstream into the river to spawn below Fishing Bridge and then return to the lake after spawning. Their findings supported Benson and Bulkley's (1963) conclusion that the Yellowstone River fishery was "almost wholly dependent" upon an influx of spawning fish from Yellowstone Lake. Because postspawning lake fish may remain in the river for some time and be caught by anglers (e.g., Schill and Griffith 1984), VAR data from anglers fishing the Yellowstone River may represent fish originating from both the river and Yellowstone Lake, where angling regulations have also become more restrictive (see section on Yellowstone Lake, this report).

GENETICS STUDIES

Widespread stocking of non-native rainbow trout *Oncorhynchus mykiss* and native cutthroat trout *O. clarki* subspecies (Jordan 1891; Varley 1981) has led to hybridization of cutthroat trout and rainbow trout. Such hybridization is a major factor in the decline in the distribution of native cutthroat trout subspecies within their historical ranges in North America (Behnke and Zarn 1976; Leary et al. 1987; Liknes and Graham 1988; Varley and Gresswell 1988; Behnke 1992). Stocking and hybridization have also affected westslope cutthroat trout *O. c. lewisi* and Yellowstone cutthroat trout *O. c. bouvieri* within their historical ranges in Yellowstone National Park (YNP; Figure 7). The probable genetic basis for unique behavioral traits (Cope 1957; Raleigh and Chapman 1971; Bowler 1975) or morphological variation (Laakso 1956; Bulkley 1963; Roscoe 1974) in Yellowstone cutthroat trout and westslope cuttthroat trout emphasizes the need for preservation of remaining genetically pure populations. Accurate information on genetic status and distribution would be valuable for preserving or recovering these native fish populations.

Meristic and electrophoretic characteristics of cutthroat trout in YNP have been studied since the late 1970s. Previous investigators (Loudenslager and Kitchin 1979; Jones et al. 1984; Shiozawa and Williams 1992) found that although pure Yellowstone cutthroat trout still occupied most of their historical range in YNP, populations downstream from 94-m high Lower Falls of the Yellowstone River, in the lower reaches of the Lamar River, and in Slough and Soda Butte creeks had become hybridized with rainbow trout. The presence of genetically pure populations of westslope cutthroat trout in the Gallatin River and Madison River drainages has not been verified.

Genetic sampling was renewed in YNP in 1990 (Jones et al. 1993) in recognition of the value of preserving genetic diversity of native fish populations (Nelson and Soule' 1987; Kreuger and May 1991). The goal of the current program is to establish a data base that can be used to assess threats to the genetic integrity of native cutthroat trout populations in YNP. More accurate electrophoretic methods (i.e., more diagnostic loci) are now available for separating Yellowstone cutthroat trout, westslope cutthroat trout, and rainbow trout. Specific objectives of this report were to present results from samples of trout collected 1993 and compare them to previously collected data.

Methods

Sample sites were selected based on two criteria: (1) The need to verify putative genetically pure populations of cutthroat trout that are separated by geological barriers from areas that have been stocked with rainbow trout or non-native cutthroat trout subspecies, and (2) the need for updated genetic assessment of cutthroat trout populations that are not separated from introduced

HISTORICAL CUTTHROAT DISTRIBUTION

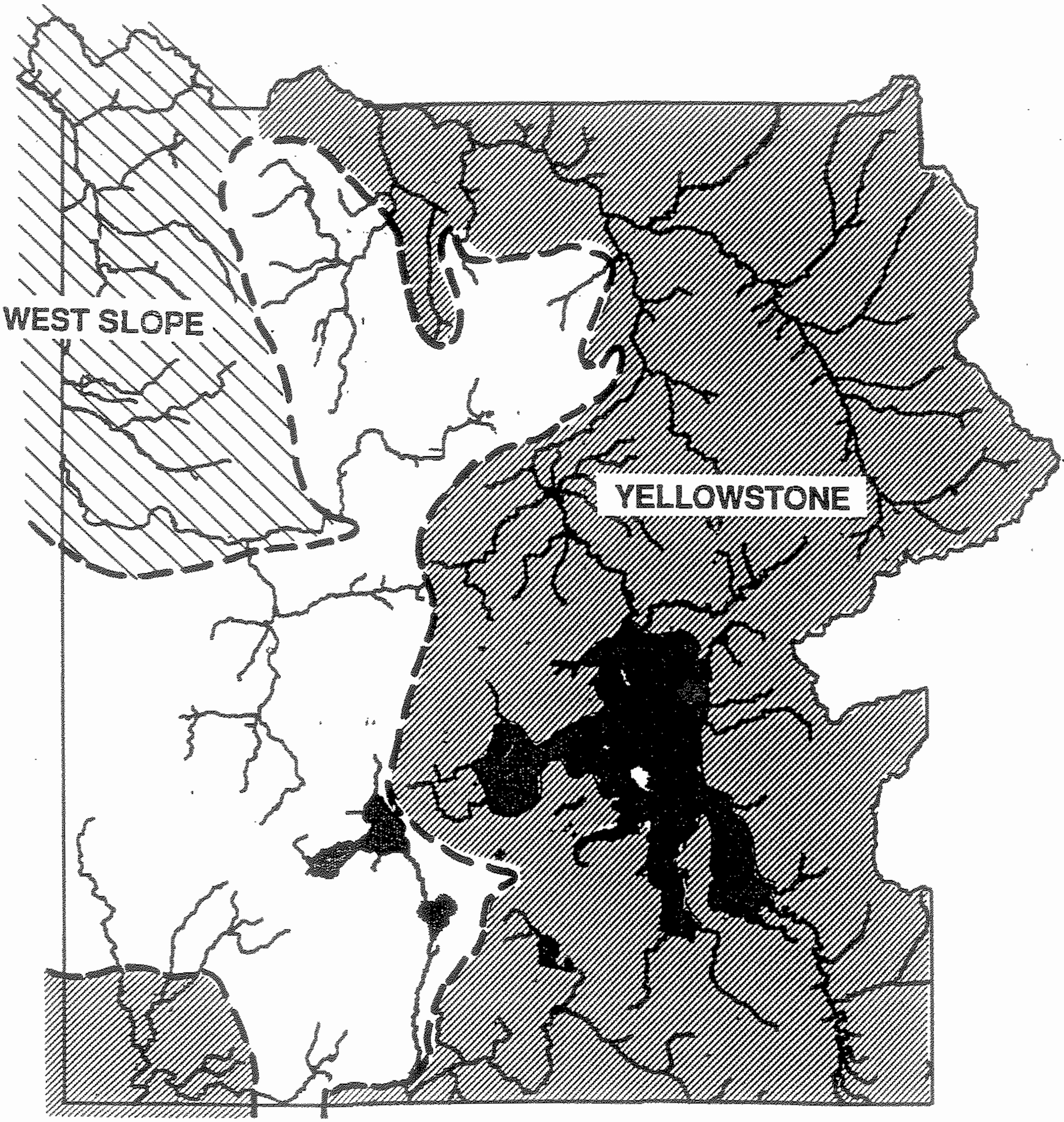

FIGURE 7.-Historical distribution of Yellowstone cutthroat trout and westslope cutthroat trout in Yellowstone National Park.

species or subspecies by geological barriers. Sites in the first category that were sampled for Yellowstone cutthroat trout included Chipmunk Creek (a tributary of the South Arm of Yellowstone Lake), the Lamar River upstream and downstream from a geological feature near Flint Creek that Arnold and Sharpe (1967) described as a "major barrier to fish migration," Soda Butte Creek upstream from Icebox Canyon, and Pebble Creek (Figure 8). Cougar Creek (Roscoe 1974) and a section of Grayling Creek upstream from Highway 191 (Dean and Mills 1971) were thought to contain pure westslope cutthroat trout. Sites with no apparent geological barriers included Arnica Creek (a tributary of the West Thumb of Yellowstone Lake where approximately 6,800 rainbow trout were stocked in the early 1900s [Varley 1981]), lower Lamar River sites next to the introgressed cutthroat trout of Soda Butte Creek (Loudenslager and Gall 1981), Reese Creek (tributary of the Yellowstone River at the northern boundary of YNP), and two sites in the Gallatin River drainage (Figure 9).

Fish were collected by angling or electrofishing. Sample size necessary to achieve a 99% probability of detecting a 1% frequency of non-native alleles varies with cutthroat trout subspecies or number of diagnostic alleles (R. Leary, University of Montana Trout and Salmon Genetics Laboratory, personal communication). The 99% level of statistical confidence can be obtained with 25 Yellowstone cutthroat trout. For westslope cutthroat trout, confidence probability decreases to 95% with a sample size of 25 fish. At Chipmunk Creek, Arnica Creek, Reese Creek, and all sites where westslope cutthroat trout genes were detected, confidence probability in the current study was ≤95%. Electrophoretic analyses of 45 loci (approximately 12 were diagnostic) were done at the University of Montana Trout and Salmon Genetics Laboratory. Genetic variability among genetically pure populations was examined with contingency table analyses of polymorphic loci.

Results

Yellowstone River Drainage

Electrophoretic analyses suggested that Yellowstone cutthroat trout in Chipmunk and Arnica creeks were genetically pure; however, insufficient sample size precluded definitive classification. All but two sites in the Lamar River drainage contained genetically pure Yellowstone cutthroat trout (Table 6). Contingency table analyses revealed significant differences in allele frequencies of two of the variable loci in the Arnica Creek and Lamar River drainage populations ($X^2 > 19.65$, $P < 0.01$).

Similar to the results of Loudenslager and Gall (1981), cutthroat trout at the Lamar River site adjacent to Soda Butte Creek were hybridized with rainbow trout. In Soda Butte Creek, westslope cutthroat trout genes were found in several putative Yellowstone cutthroat trout collected near Silver Gate, Montana, (Sage and Leary 1990) and upstream from Icebox Canyon. Reese Creek cutthroat trout were hybridized with rainbow trout.

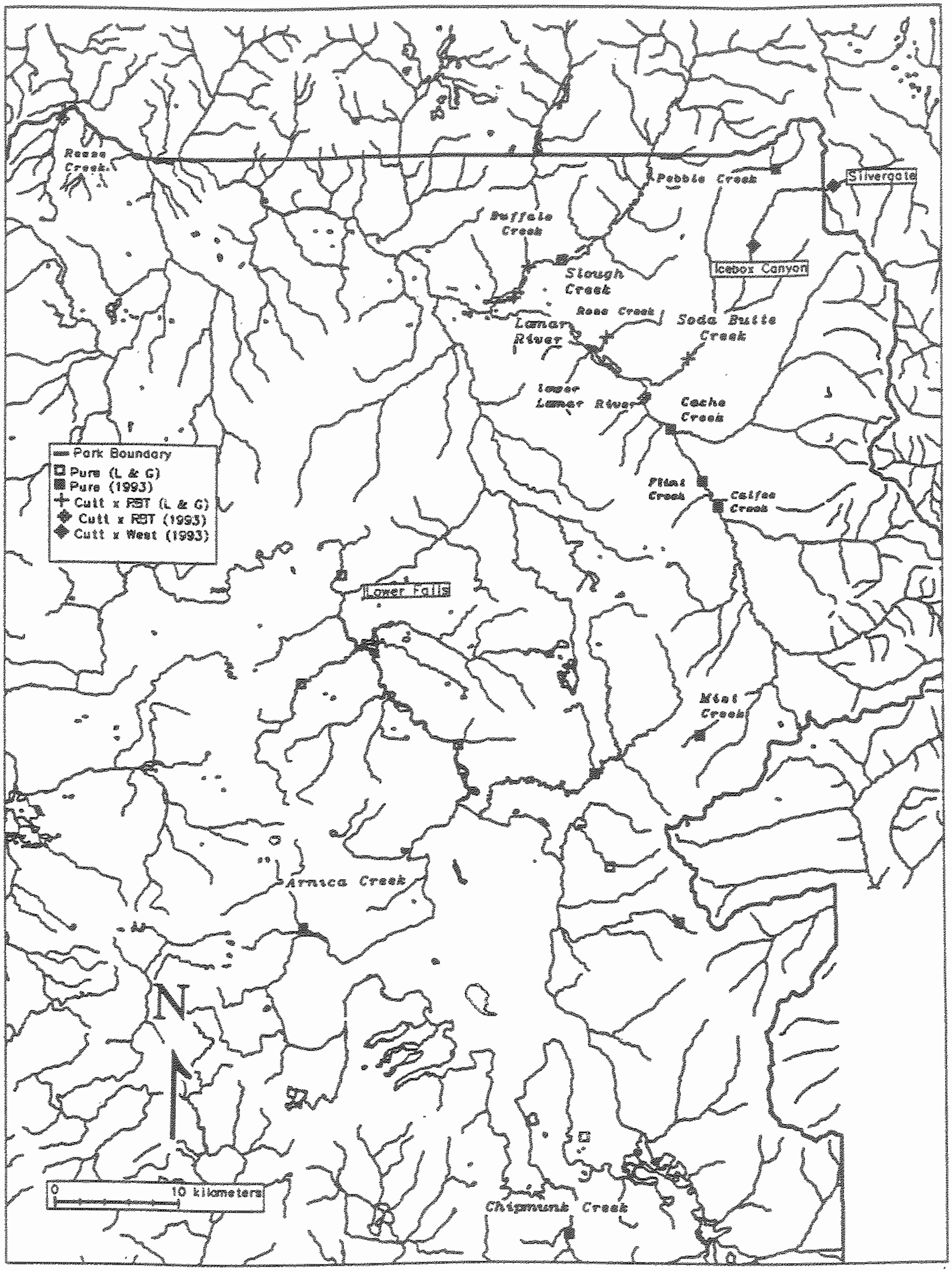

FIGURE 8.-Genetic status of cutthroat trout populations in the historical range of Yellowstone cutthroat trout. Classification based on current electrophoretic analyses ("1993") and previous studies by Loudenslager and Gall ("L & G"). Categories include samples classified as genetically pure, populations hybridized with rainbow trout ("Cutt X RBT"), and Yellowstone-westslope cutthroat intergrades ("Cutt X West").

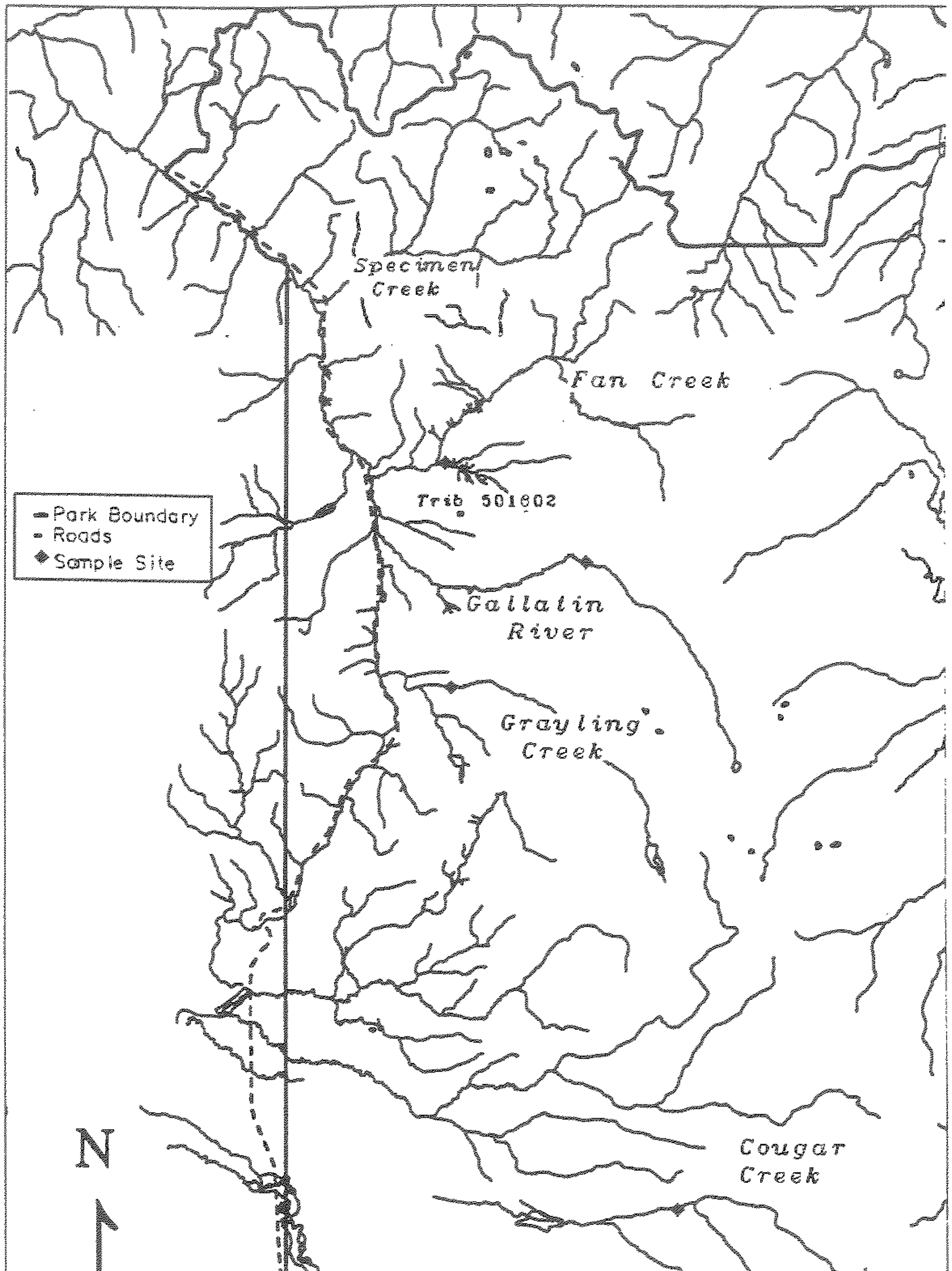

FIGURE 9.-Genetic status (based on current electrophoretic analyses) of cutthroat trout populations in the historical range of westslope cutthroat trout in Yellowstone Park.

TABLE 6.-Sample locations, number captured, year of capture, and genetic composition of cutthroat trout captured in the Yellowstone and Lamar river drainages, 1990-1993, Yellowstone National Park.

			Genetic composition		
Stream	*N*	Date	Average percent Yellowstone cutthroat	Average percent westslope cutthroat	Average percent rainbow trout
Tributaries to Yellowstone Lake or Yellowstone River					
Chipmunk Creek	13	1990	Pure population[a]	**	**
Arnica Creek	22	1993	Pure population[a]	**	**
Reese Creek	22	1990	0.962	**	0.038
Streams in the Lamar River drainage					
Soda Butte Creek	25	1992	0.984	0.016	**
Pebble Creek	25	1993	Pure population	**	**
Lamar River (lower)	25	1993	0.992	**	0.008
Lamar River at Cache Creek	25	1993	Pure population	**	**
Lamar River at Flint Creek	25	1993	Pure population	**	**
Lamar River at Calfee Creek	25	1993	Pure population	**	**
Mist Creek	26	1992	Pure population	**	**

** diagnostic alleles not detected.

[a] Preliminary assessment with low statistical confidence because $N < 25$.

Madison River and Gallatin River Drainages

Putative westslope cutthroat trout populations in the Madison River and Galllatin River drainages that were sampled between 1990 and 1993 were found to be hybridized with Yellowstone cutthroat trout (Table 7). Grayling Creek, Gallatin River, and Fan Creek tributary #501602 cutthroat trout populations were also hybridized with rainbow trout. No rainbow trout genes were found in 26 cutthroat trout collected from Cougar Creek, a Madison River tributary that lacks above-ground connections to other streams. Because of insufficient sample size, the amount of hybridization in these westslope cutthroat trout populations could be even larger than presently indicated.

Discussion

Yellowstone Cutthroat Trout

Current analyses support conclusions from previous studies regarding distribution of genetically pure populations of Yellowstone cutthroat trout in YNP. There is no evidence that stocking of rainbow trout in Yellowstone Lake led to genetic contamination of Yellowstone cutthroat trout in the Yellowstone River drainage upstream from the Lower Falls of the Yellowstone River. Genetic integrity of the Yellowstone cutthroat trout upstream from the falls will be protected as long as introductions of non-native salmonids are prohibited.

Classification of Yellowstone cutthroat trout populations as hybridized or introgressed with rainbow trout has been consistent among studies. For example, Loudenslager and Gall (1981) classified trout collected in the late 1970s from the lower Lamar River drainage (Rose Creek, lower Slough Creek, Buffalo Creek, and Soda Butte Creek sites; Figure 8) as Yellowstone cutthroat trout hybridized or introgressed with rainbow trout. In 1988 trout examined from the lower Lamar River drainage lacked the basibranchial teeth characteristic of cutthroat trout (D. Shiozawa, personal communication). Cutthroat trout in the "lower Lamar River" sample in the current study were also hybridized with rainbow trout.

Geological barriers near the mouth of Pebble Creek and in Icebox Canyon (Soda Butte Creek) appear to prevent upstream movement of fish. No rainbow trout genes were detected at these sites, and Yellowstone cutthroat trout upstream from the barrier in Pebble Creek were classified as genetically pure in 1979 and 1993.

Distribution of genetically pure Yellowstone cutthroat trout in other portions of the Lamar River drainage is not influenced solely by geological barriers. The geological feature near Flint Creek does not appear to restrict upstream fish passage. Trout sampled at sites downstream (Flint Creek, Cache Creek) and upstream from this geological feature (Calfee Creek, Mist Creek) were classified as genetically pure (Table 6). The most anomalous result of Yellowstone cutthroat

TABLE 7.-Sample locations, number captured, year of capture, and genetic composition of cutthroat trout captured from the Madison and Gallatin river drainages, 1990-1993, Yellowstone National Park.

			Genetic composition		
Stream	*N*	Date	Average percent Yellowstone cutthroat	Average percent westslope cutthroat	Average percent rainbow trout
			Streams in the Madison River drainage		
Cougar Creek	26	1992	0.058	0.942	**
Grayling Creek	27	1990	0.065	0.820	0.130
			Streams in the Gallatin River drainage		
Gallatin River headwaters	16	1993	0.067[a]	0.787	0.100
Tributary 501602 to Fan Creek	30	1993	0.075	0.863	0.067

** diagnostic alleles not detected.

[a] Preliminary assessment with low statistical confidence because $N < 25$.

trout distribution in the Lamar River is the genetic separation between the hybridized lower Lamar River population and the genetically pure trout in Cache Creek, although there are no geological barriers between these sites.

The source of westslope cutthroat trout genes in upper Soda Butte Creek is unknown; however, Yellowstone cutthroat trout x westslope cutthroat trout hybrids have been found in the East Fork of the Boulder River, which is near the headwaters of Slough Creek (Sage and Leary 1990). Hybridized trout in the East Fork of the Boulder River are a potential source of genetic contamination to pure Yellowstone cutthroat trout in the Lamar River drainage.

Current data indicate that pure Yellowstone cutthroat trout still occupy a large portion of their historical range in YNP (Figure 6); however, limited sampling precludes fully delineating their distribution in the park. Variation in polymorphic allele frequency provides an estimate of genetic diversity among populations; however, because interpopulation variability is small (< 4%), pure Yellowstone cutthroat trout stocks in YNP can be considered as members of the same population (Leary 1993).

Agreement between current genetic assessments and previous meristic examinations in the lower Lamar River and Mist Creek suggests that pure Yellowstone cutthroat trout populations exist at sites where basibranchial teeth have been present in all captured specimens (e.g., Lamar River headwaters, Little Lamar River; W.Gould, personal communication). Updated genetic assessments of other potentially threatened populations (e.g., upper Slough Creek; Loudenslager and Gall 1981) would resolve uncertainties arising from creel census records of rainbow trout near Lake Abundance Creek (Slough Creek tributary) in 1957 and 1958 (Hanzel 1960) and recent angler reports of "hybrids" being caught in the "Third Meadow" section of Slough Creek.

Westslope Cutthroat Trout

Genetically pure populations of westslope cutthroat trout may no longer exist in YNP. Cougar Creek was the stream most likely to contain pure westslope cutthroat trout; however, hybridization of Cougar Creek westslope cutthroat trout with Yellowstone cutthroat trout (Jones et al. 1993) invalidates their former classification as genetically pure (Roscoe 1974; Loudenslager and Gall 1980). Other sites where pure westslope cutthroat populations were hypothesized to exist (e.g., Fan Creek tributary #501602; Jones et al. 1984) have been subjected to multi-species hybridization.

Few headwater areas remain unsampled in the historical range of westslope cutthroat trout in YNP. Based on meristic characters and the presence of possible geological barriers, Jones et al. (1984) recommended that investigations be conducted on the main tributaries (i.e., North and East Forks) of Fan and Specimen creeks. An updated genetic assessment of cutthroat trout populations in these streams would eliminate discrepancies in past classifications, which are based solely on meristic characters, and add to the genetic database for westslope cutthroat trout in YNP.

REESE CREEK

About 12 tributaries of the Yellowstone River between Yellowstone National Park (YNP) and Livingston, Montana, are used by salmonids for spawning (Clancy 1988). Agricultural irrigation withdraws water from these tributaries, often limiting the reproductive success of resident and fluvial-adfluvial salmonid populations (Berg 1975; Lentsch 1986; Clancy 1984, 1985, 1986; Hedrick 1989; Vincent et al. 1989; Byorth 1990). When Reese Creek, a Yellowstone River tributary that has had water withdrawn for irrigation (Evermann 1892), became part of YNP in 1932 (Haines 1977), private landowners retained irrigation rights. Consequently, withdrawal of water from Reese Creek for irrigating private lands has continued.

In 1978 the state of Montana began water rights adjudications for the Yellowstone River basin. The need to document effects of water withdrawal (dewatering) on aquatic resources in YNP prompted the National Park Service (NPS) and the U.S. Fish and Wildlife Service (USFWS) to initiate stream-discharge monitoring on Reese Creek in 1984. The USFWS sampled Reese Creek for fish and other aquatic resources between 1984 and 1991 (Jones et al. 1985, 1988, 1989, 1990; Lentsch 1986; Mahony 1987); the most extensive survey (12 weeks) occurred in 1986.

Data from these studies suggested that without adequate streamflow, spawning success of salmonids moving from the Yellowstone River into Reese Creek and subsequent survival of fry would be severely reduced. Amount of water diverted varied by year, but generally by mid-August streamflow downstream from the lowest irrigation diversion was reduced to a series of isolated pools. When streamflow decreased as a result of extensive water withdrawals, trout often congregated downstream from the diversion structures, suggesting that these structures were low-water barriers to upstream fish passage (Mahony 1987). When dewatering was severe, trout occasionally entered the irrigation ditches (Lentsch 1986). In years of below-normal precipitation, the lower 0.5 km of Reese Creek was completely dry.

In the early 1980s the NPS began instream flow negotiations with private landowners who use Reese Creek water. Minimum flow recommendations were derived by the Wetted Perimeter Method (Leathe and Nelson 1986) in 1985 (Lentsch 1986); however, the landowners did not accept them (0.122 m^3/s during the spawning season and 0.045 m^3/s for the remainder of the year). In 1991 a new agreement stipulated minimum flows of 0.037 m^3/s between April 15 and October 15 (if discharge upstream from the diversions is at least 0.079 m^3/s) and 50% of the available discharge for the other 6 months of the year.

In fall 1991 the old diversion structures on Reese Creek were replaced with adjustable V-notched fish ladders, cylindrical rotating fish screens to prevent movement of fish downstream into irrigation ditches, and irrigation ditch headgates in concrete foundations (Jones et al. 1992). An old diversion structure near the middle of the study area was removed, but barrier capabilities at the uppermost diversion were enhanced to prevent upstream movement of non-native fishes.

The goal of the current study was to document the responses of salmonids to year-long flows in sections of Reese Creek that are normally dewatered by irrigation. Objectives were to (1) determine which normally dewatered areas were used as spawning sites, (2) estimate the magnitude of the spawning migration of fluvial-adfluvial salmonids from the Yellowstone River into Reese Creek, (3) document timing and extent of fry emergence, (4) determine effectiveness of the recently installed fish passageways and screens, and (5) compare 1992 results to those of previous studies.

Study Area

Reese Creek originates at the outlet of Cache Lake on the southeast slopes of Electric Peak. For most of its length, Reese Creek flows north through a steep valley bordered by Electric Peak on the west and Sepulcher Mountain on the east. Dense stands of old-growth lodgepole pine *Pinus contorta* grow on the upland slopes and riparian zones in the uppermost reaches of the stream; mature Douglas fir *Pseudotsuga menziesii* covers about half of the 3,450-hectare drainage (unpublished data, NPS GIS Laboratory). The lower 2-3 km of Reese Creek flow through a lower-gradient area of poorly sorted alluvial fan gravel deposits (Pierce 1973) covered with sagebrush *Artemesia* sp. and grasses. Riparian width in the dewatered section is generally narrow (<25 m) and contains sparse amounts of cottonwoods *Populus* sp., Rocky Mountain juniper *Juniperus scopulorum*, and various willow *Salix* spp. Elk *Cervus canadensis,* moose *Alces alces*, mule deer *Odocoileus hemionus*, pronghorn antelope *Antilocapra americana*, coyote *Canis latrans*, grizzly bear *Ursus arctos horribilis*, and black bear *U. americanus* inhabit the Reese Creek watershed. Bull snakes *Pituophis melanoleucas* and rattlesnakes *Crotalus viridis viridis* have been observed in the drier portions of the sagebrush upland areas.

Annual precipitation in the drainage is normally about 40 cm, and most typically falls between May and July. Reese Creek averages 1.25 to 2.40 m wide (Mahony 1987), and undiverted annual flow varies between 0.026 and 0.87 m^3/s (Jones et al. 1985, 1989). Summer water temperature rarely exceeds 10°C (Jones et al. 1988). Weekly water samples collected from April through September 1990 indicated that total dissolved solids ranged between 140 and 230 mg/L, total alkalinity was ≥ 90 mg/L, pH varied between 7.7 and 8.5, and total hardness was ≥ 100 mg/L (J. Lewis, unpublished data, NPS Water Quality Laboratory, YNP).

Headgates and irrigation ditches are located about 0.8, 1.6, and 2.0 km upstream from the confluence of Reese Creek and the Yellowstone River (Figure 10). In this study the irrigation ditches are numbered sequentially in an upstream direction. Since 1984 staff gauges have been in place upstream from Diversion 3 and downstream from Diversion 1; differences in discharge at these sites have been used to estimate the amount of water diverted from Reese Creek.

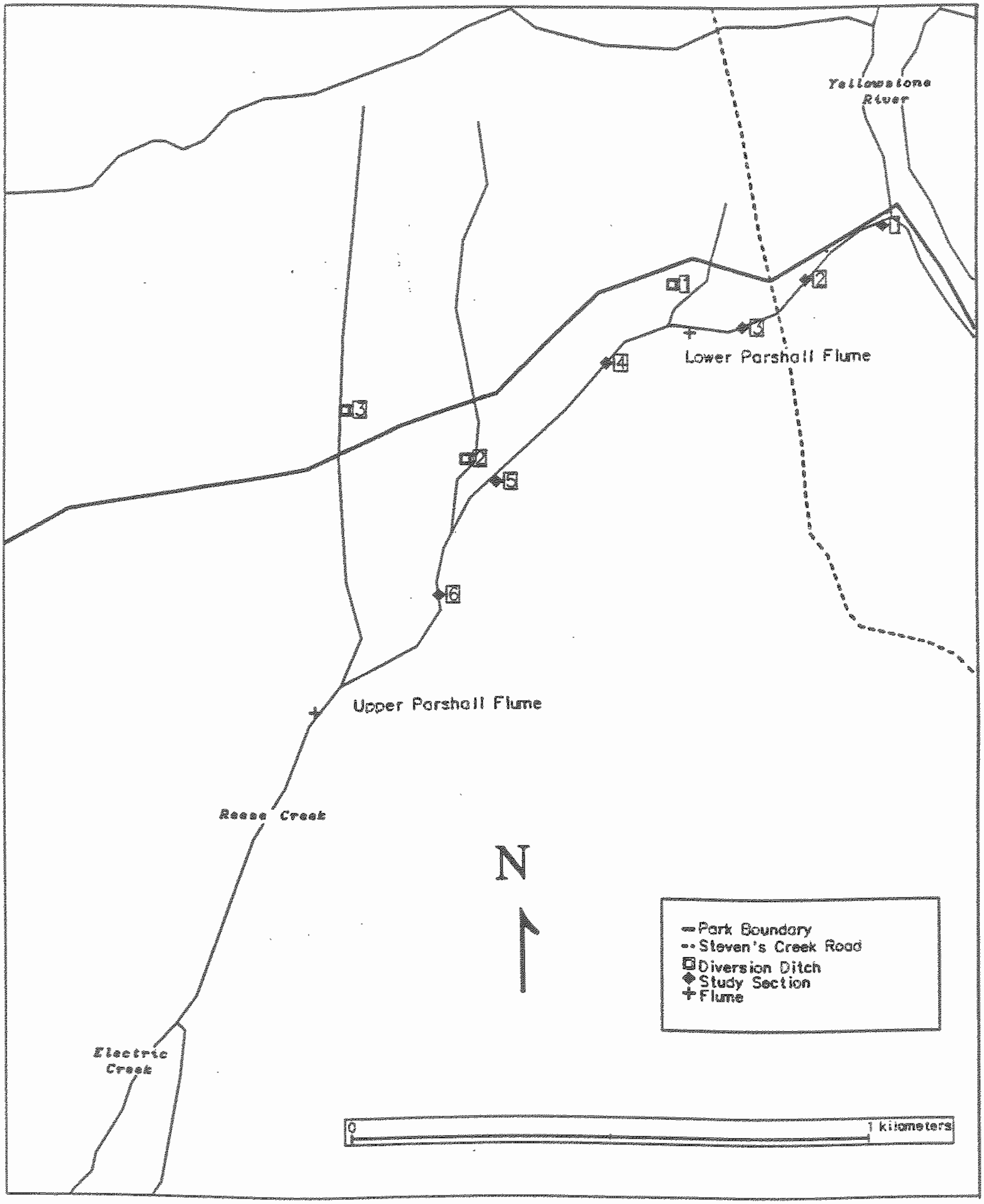

FIGURE 10.-Reese Creek, Yellowstone National Park, showing locations of irrigation diversions, Parshall flumes, and study sections.

Upstream from Diversion 3 to the confluence with Electric Creek, Reese Creek contains trout that visually appear to be pure Yellowstone cutthroat trout *Oncorhynchus clarki bouvieri* (Jones et al. 1990). Recent electrophoretic analyses, however, suggest hybridization of cutthroat trout and rainbow trout *O. mykiss* (Leary 1990). Rainbow trout genes were found in 6 of 22 trout tested, which suggests that insufficient time has elapsed for hybridization to affect the entire population. In this report, captured trout were classified as cutthroat trout unless they visually appeared to be rainbow trout.

Approximately 1.5 km upstream from Electric Creek is a series of cascades and vertical drops which apparently are barriers to upstream fish migration (Varley et al. 1976). No fish have been captured or observed upstream from these cascades. Consequently, the area upstream from the cascades is presumed to be fishless.

Methods

Precipitation and Streamflow

Precipitation records for Mammoth Hot Springs, YNP, (approximately 7 km east of Reese Creek) were assumed to be representative of precipitation at Reese Creek. Before 1992 stream discharge in Reese Creek was estimated by stage-discharge relationships developed for each staff gauge. In fall 1991 Parshall flumes (Rantz et al. 1982) were installed about 200 m upstream from Diversion 3 and about 10 m downstream from Diversion 1 (Figure 10). Staff gauges were installed in each diversion structure so that streamflow could be estimated in each ditch and mainstem diversion site. Staff gauges and Parshall flumes were read weekly (usually during the fish sampling survey) from June through August. Comparisons of readings from the lower staff gauge and the lower Parshall flume were significantly related ($N = 10$, $r = 0.87$, $P = 0.001$). Consequently, standardized rating tables for Parshall flumes (USGS 1967) were used to estimate streamflows at the Parshall flume sites.

Fish Populations

1984-1991.-Before 1992 study reaches were bounded by the road bridge or diversion structures (Figure 10), and sampling occurred between May and July. Except for 1991, sampling was discontinued after the sections downstream from Diversion 1 were dewatered. In August 1991 several isolated pools in the nearly dry channel downstream from the first diversion and the partially watered areas between the Diversions 1-3 were electrofished.

A Coffelt BP-1 backpack shocker was used to electrofish in an upstream direction. Because of difficulty in distinguishing young cutthroat trout from rainbow trout (Carl et al. 1967; Scott and Crossman 1973), captured trout <50 mm total length (TL) were assumed to be age-0 cutthroat trout. Captured fish were measured to the nearest millimeter TL, and salmonids longer than 70 mm TL were weighed to the nearest 2 g. Scale samples were collected from a stratified

(25-mm TL groups) subsample for use in estimating age-and-growth characteristics. Mean-annual growth rates were defined as differences among back-calculated lengths at annuli determined by the direct proportion method (Bagenal and Tesch 1978). Fish from 1991 were excluded from multi-year growth comparisons because scales from age-1 individuals only were readable. Trout were classified as nonspawners (includes immature fish), spawners (ripe or nearly-ripe fish which may or may not have been observed spawning), or postspawners.

1992.-In 1992 six study sections of similar length were delimited between the mouth of Reese Creek and Diversion 3. Sections 1-3 were downstream from Diversion 1, the reach between Diversions 1 and 2 was subdivided into sections 4 and 5, and section 6 encompassed the area between Diversions 2 and 3 (Figure 10). Each section was electrofished weekly from early June through mid-August; however, equipment failure prevented sampling in all sections on July 15 and 24 and August 20.

Length and weight measurements and scales were collected as in previous years. Captured fish were fin-clipped with a section-specific mark and released. Different clips were used to distinguish capture locations bounded by diversion and fish passage structures; however, the same clip was used for fish captured in contiguous sections not separated by structures. Section-specific fin clips and unique (in comparison to the total sample) total lengths of some fish were combined with mark-recapture data to detect movement patterns and estimate length-of-stay of individual trout.

Results

Streamflow

Previous studies.-Streamflow patterns in Reese Creek between 1984 and 1989 have been reported (Jones et al. 1985, 1988, 1989, 1990; Lentsch 1986; Mahony 1987). In years of average precipitation (1984, 1986, 1989), late summer (August and September) undiverted streamflow varied between 0.1 and 0.2 m^3/s (Figure 11). Sequential water withdrawals resulted in increased severity of dewatering in a downstream direction. The reach between Diversions 2 and 3 was only partially dewatered, but the other four sections were often dry by late summer. Furthermore, flows at the lower staff gauge did not always reflect flow conditions further downstream. At very low flows, Sections 1 and 2 were dry despite measurable flows at the lower staff gage.

1992.-In 1992 annual precipitation at Mammoth Hot Springs (40.64 cm) was the highest since 1982 (USGS; unpublished SNOTEL data). Reese Creek discharge peaked in the latter part of June, and estimated streamflow at the upper Parshall flume ranged from a high of 0.227 m^3/s on June 30 to a base flow of about 0.110 m^3/s (Figure 11). Except for July 6, estimated streamflow at the lower Parshall flume was smaller than the upstream discharge and decreased to less than 0.030 m^3/s for most of August. A Gardiner, Montana, resident observed

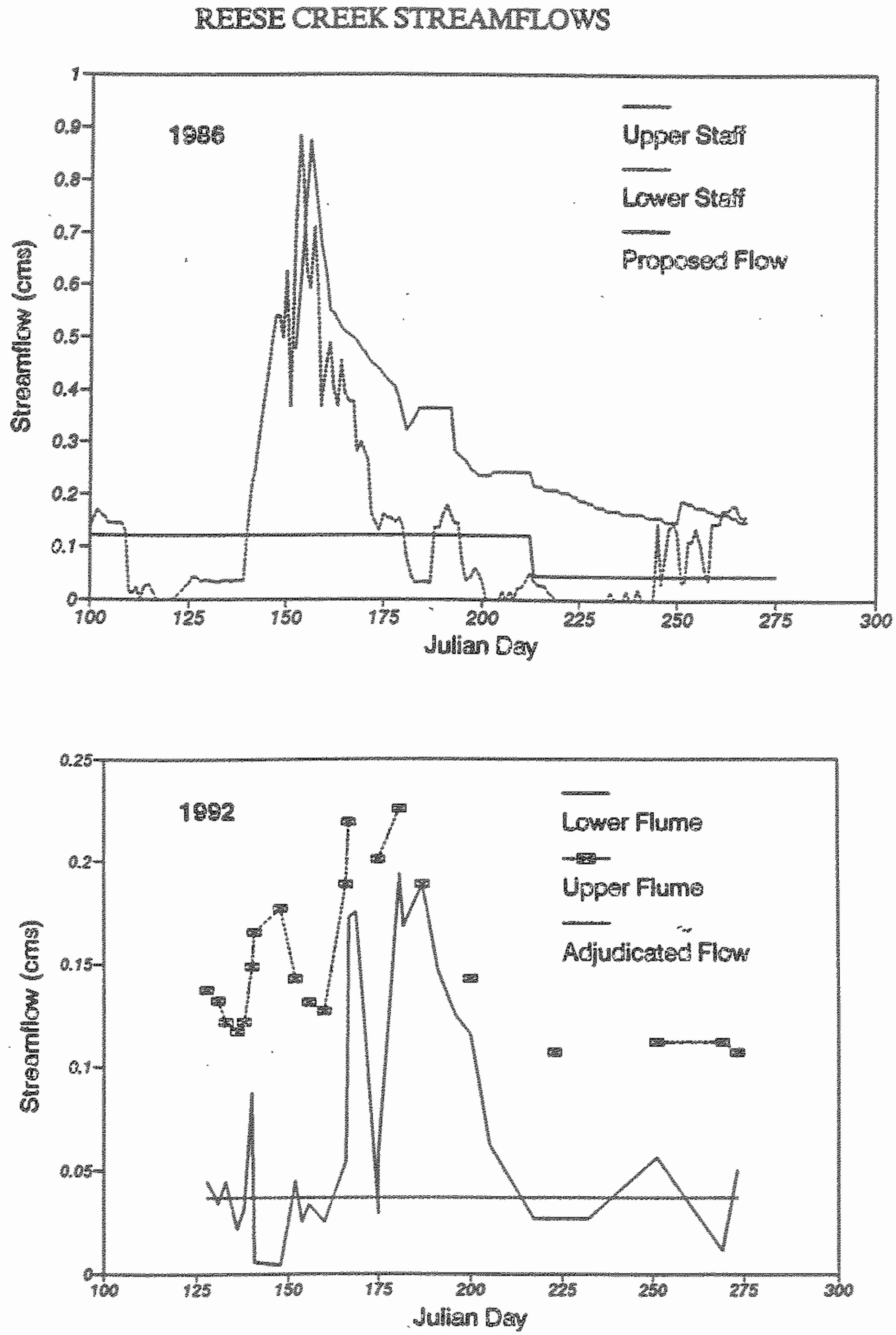

FIGURE 11.-Estimated streamflows at the upper and lower staff gauge sites in 1986. "Proposed flows" of 0.122 m^3/s from April 1 through July 31 and 0.045 m^3/s for the remainder of the year are recommended flows derived from wetted perimeter method. Bottom figure shows estimated flows at the Parshall flumes in 1992. "Adjudicated flow" is negotiated instream flow of 0.037 m^3/s (1.3 cfs). Note differences in vertical scale between years.

complete dewatering of Section 1 in mid-September 1992 (R. Parks, personal communication).

Sediment accumulation at the upstream portion of each diversion structure in 1992 precluded accurate staff gauge readings at the main channel sites and resulted in nonfunctional fish screens. The amount of water diverted from Reese Creek varied throughout the irrigation season. The period of greatest water withdrawal at Diversion 3 (late May and early August) coincided with minimum discharge at the lower Parshall flume site. In contrast, when dewatering at Diversion 3 was minimal (late June through mid-July), discharge in the lower section of Reese Creek was near maximum.

Fish Populations

Previous studies.-At least one rainbow trout was captured in the lower reaches of Reese Creek each year between 1984 and 1986, but cutthroat trout were captured in only 1984 and 1986 (Table 8). Although trout captured in 1986 were usually larger than those captured in 1984, unequal sampling effort and small sample sizes in 1984 and 1985 limit comparisons of trout populations among years. Brown trout *Salmo trutta*, brook trout *Salvelinus fontinalis,* and mottled sculpin *Cottus bairdi* were also caught. Drought conditions and low discharge prevailed in 1987 and 1988; by mid-June, Reese Creek was dry between the road bridge and the Yellowstone River. Consequently, spawning surveys were canceled in these years.

In 1991 Sections 1 and 2 were completely dry by August 1, but cutthroat trout, brown trout, and brook trout were captured in the other study sections. Most cutthroat trout (i.e., all but one >200 mm TL) were collected in Section 6. Brown trout were restricted to pools in Section 3, and brook trout were equally distributed between Section 6 and the pools in Section 3.

Reese Creek was sampled upstream from Diversion 3 on three occasions in 1986 and 1987 and once in 1990. Maximum length of cutthroat trout captured in this area was usually smaller than from downstream areas; however, the smallest trout in Reese Creek were captured in the lower sections (Tables 9-10). Comparison of estimated annual growth revealed that cutthroat trout captured at the upstream site grew significantly slower in 1987 than in 1990 (Table 11). With the exception of trout in the 1990 sample, cutthroat trout in the downstream study sections grew faster than the upstream fish in all years (ANOVA; $F = 3.00$, $P = 0.043$).

1992.-With few exceptions, cutthroat trout were captured in all study sections on all 1992 sample dates (Figure 12). Number of trout captured weekly during this 10-week study exhibited a bimodal peak. Most of the captured cutthroat trout were <100 mm TL (Figure 13). Mean weight and condition factor (K) of a subsample of 197 cutthroat trout were 128 g and 1.03 (Table 10). More than half of the cutthroat trout longer than 100 mm were classified as male ($N = 41$) or female ($N = 25$) spawners. Most cutthroat trout captured in Sections 1-3

TABLE 8.-Characteristics of fish captured by electrofishing downstream from Diversion 3 in Reese Creek, 1984 - 1991.

Species	Number captured	Mean total length (mm)	Total length range	Mean weight (g)	Mean condition (K)
		1984			
Cutthroat trout	6	167	75-231	74	1.11
Rainbow trout	1	211	~ ~	92	0.98
Brown trout	1	62	~ ~	~ ~	~ ~
Mottled sculpin	2	74	64-84	~ ~	~ ~
		1985			
Rainbow trout	2	164	161-167	~ ~	~ ~
Brown trout	5	52	46-64	~ ~	~ ~
		1986			
Cutthroat trout	73	257	74-382	278	1.32
Rainbow trout	13	196	60-383	220	1.38
Brown trout	7	84	58-166	40	0.87
Brook trout	3	180	175-182	52	0.91
Mottled sculpin	17	65	48-100	~ ~	~ ~
		1991			
Cutthroat trout	18	168	56-345	~ ~	~ ~
Brown trout	8	96	82-127	~ ~	~ ~
Brook trout	6	193	147-230	~ ~	~ ~

TABLE 9.-Characteristics of cutthroat trout captured upstream from the diversion structures in Reese Creek, 1986 - 1990.

Year	Number captured	Mean total length (mm)	Total length range	Mean weight (g)	Mean condition (K)
1986	7	294	219-284	182	1.15
1987	50	170	64-290	177	1.39
1990	25	198	107-335	111	1.21

TABLE 10.-Characteristics of fish captured by electrofishing in Reese Creek, 1992.

Species	Number captured	Mean total length (mm)	Total length range	Mean weight (g)	Mean condition (K)
Cutthroat trout	343	121	27-400	128	1.03
Rainbow trout	10	202	136-331	101	1.07
Brown trout	34	91	54-211	13	0.94
Brook trout	11	202	125-273	106	1.06
Mountain whitefish	2	314	314	261	0.84
Mottled sculpin	76	72	54-100	5	1.14

TABLE 11.-Estimated mean annual growth rates (increase in total length) of cutthroat trout from Reese Creek, 1986-1992. Annual growth rate derived from differences in back-calculated length at annuli formation. Area denotes study sections (downstream from Diversion 3) where fish were captured; fish in the "upper" area were collected upstream from Diversion 3.

Year	Area	*N*	I	II	III	IV	V	VI
1986	1-6	40	74	71	71	68	61	52
1986	Upper	5	57	55	70	45	~ ~	~ ~
1987	Upper	33	59	55	60	42	27	22
1990	Upper	21	80	76	47	53	~ ~	~ ~
1991	3-6	5	71	~ ~	~ ~	~ ~	~ ~	~ ~
1992	1-6	79	70	75	86	60	50	~ ~

~ ~ No fish in this age-group.

REESE CREEK
CUTTHROAT TROUT

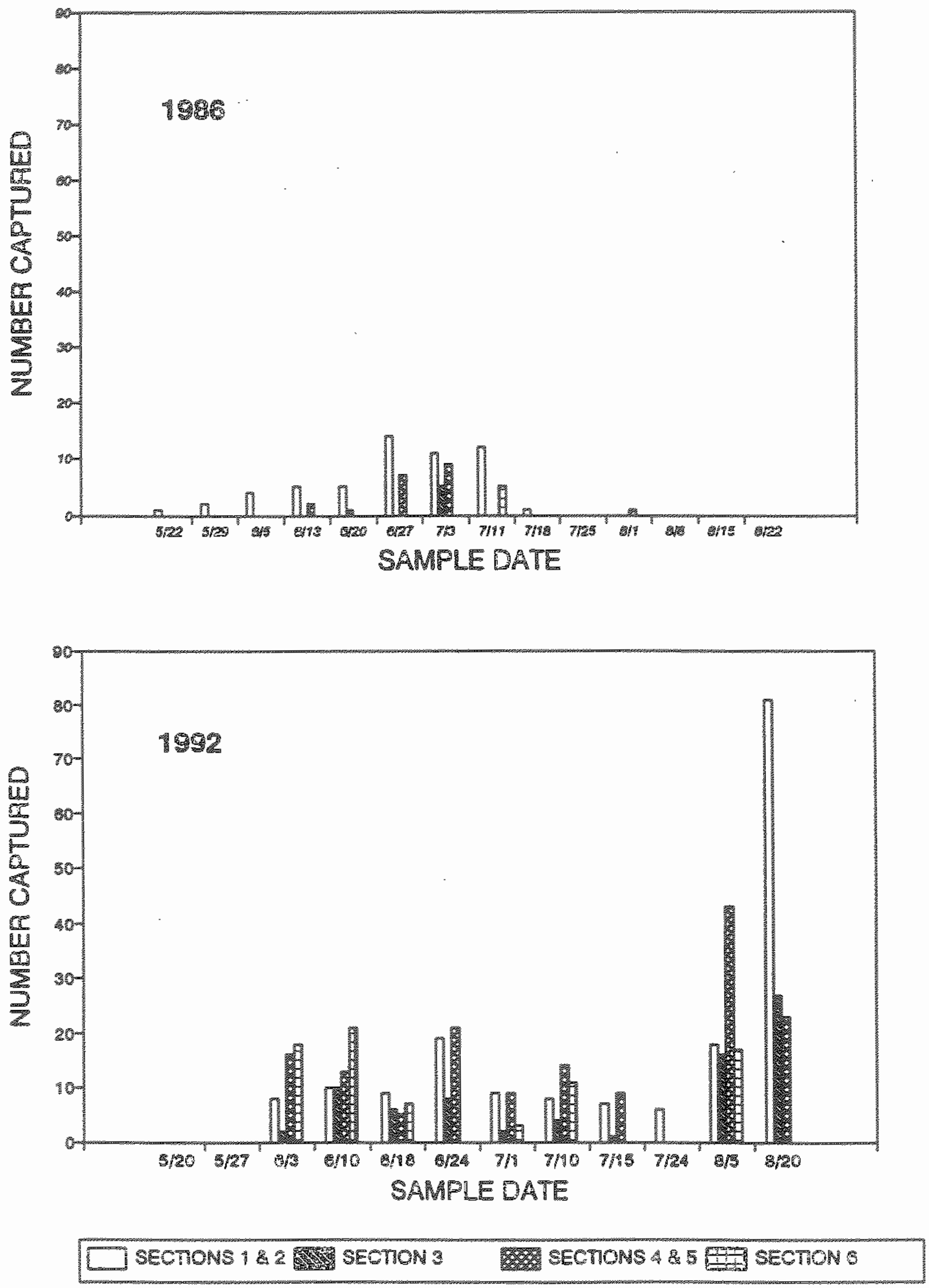

FIGURE 12.-Total number of cutthroat trout captured in Reese Creek, 1986 and 1992 (by week and section).

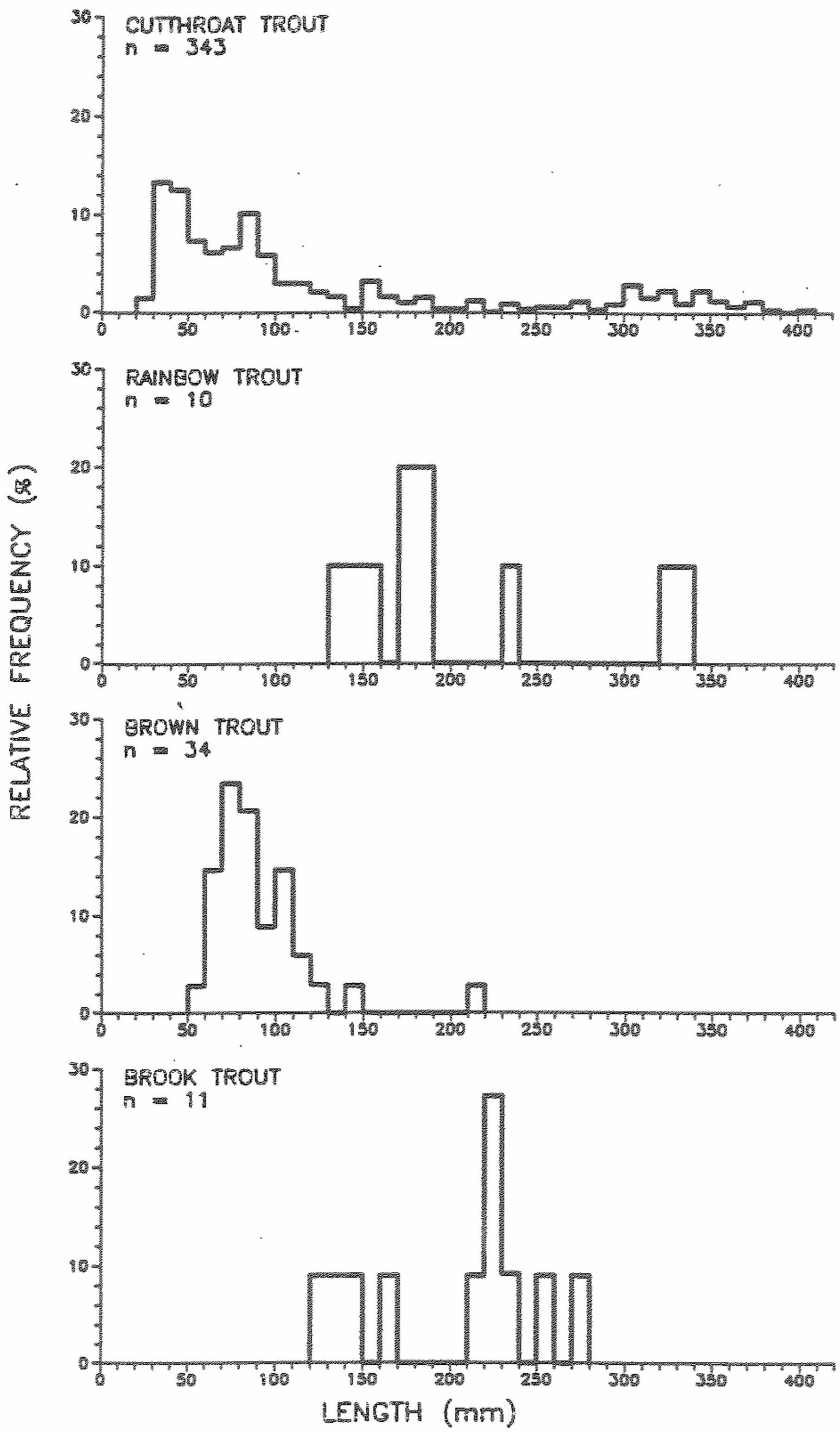

FIGURE 13.-Length-frequency distribution of cutthroat trout, rainbow trout, brown trout, and brook trout captured by electrofishing in Reese Creek, 1992.

prior to July 15 were spawners longer than 250 mm TL. In contrast, most cutthroat trout in Sections 4-6 were nonspawners between 50 and 150 mm TL.

Scale analyses of cutthroat trout suggested that at least five age groups were present in 1992. All male spawners were estimated to be ≥2 years old; female spawners were ≥3 years old. Estimated mean-annual growth varied from 70 mm in the first year to 84 mm in the third year; annual growth declined in older fish (Table 11).

Ten rainbow trout from 136 to 330 mm TL (Figure 13) were caught in Reese Creek during June 1992. All but the shortest of these were estimated to be ≥2 years old, and the eight largest fish were in spawning condition. Estimated first-year growth (86 mm) of rainbow trout was about 20% greater than that estimated for cutthroat trout.

Brown trout, brook trout, mottled sculpin, and mountain whitefish *Prosopium williamsoni* were also captured in Reese Creek in 1992. Scale analyses indicated that 80% of the brown trout were ≤1 year old and all but three of the brook trout were ≥2 years old. The one whitefish that could be aged was estimated to be 4 years old; the other whitefish of identical length may have been the same age.

Cutthroat Trout Spawning

1986-1991.-During the 11 weeks between May 29 and July 11, 1986, all cutthroat trout >225 mm TL were in spawning or post-spawning condition. Most spawners were captured in Sections 1-3 in the last 2 weeks of June and the first week of July (Figure 14); however, the longest fish captured (390 mm TL) moved upstream from Section 1 and was recaptured 1 week later in Section 4. Most adult trout captured on July 11 were postspawners, and no trout >225 mm TL were captured after this date. The stream channel was dry at the lower staff gauge by the first week of August, and sampling was discontinued.

All cutthroat trout captured upstream from the diversions in 1986 were in spawning condition; only female postspawners (N = 2) were caught in the last (July 11) sample. In contrast, male and female spawners were present in the July 24, 1991, sample.

1992.-In the lower three study sections, peak numbers of cutthroat trout spawners occurred in the latter half of June. Similar to results from 1986, most of the cutthroat trout had ceased spawning in Reese Creek by early July (Figure 14). In the sections between the diversion structures, fewer spawners were captured than in the downstream sections (X^2 = 55.78, P = 0.0498). Section 4 was used infrequently by spawners, and abundance of cutthroat spawners in Sections 5 and 6 was highest in the first week of the study. After July 15, no spawning trout were captured from the lower three sections, and fry emergence commenced in the next 2 to 3 weeks (Figure 12).

Estimated residence time for male spawners and nonspawners in Sections 1-3 varied from 1 to at least 3 weeks. Cutthroat trout spent more time in Sections 4-

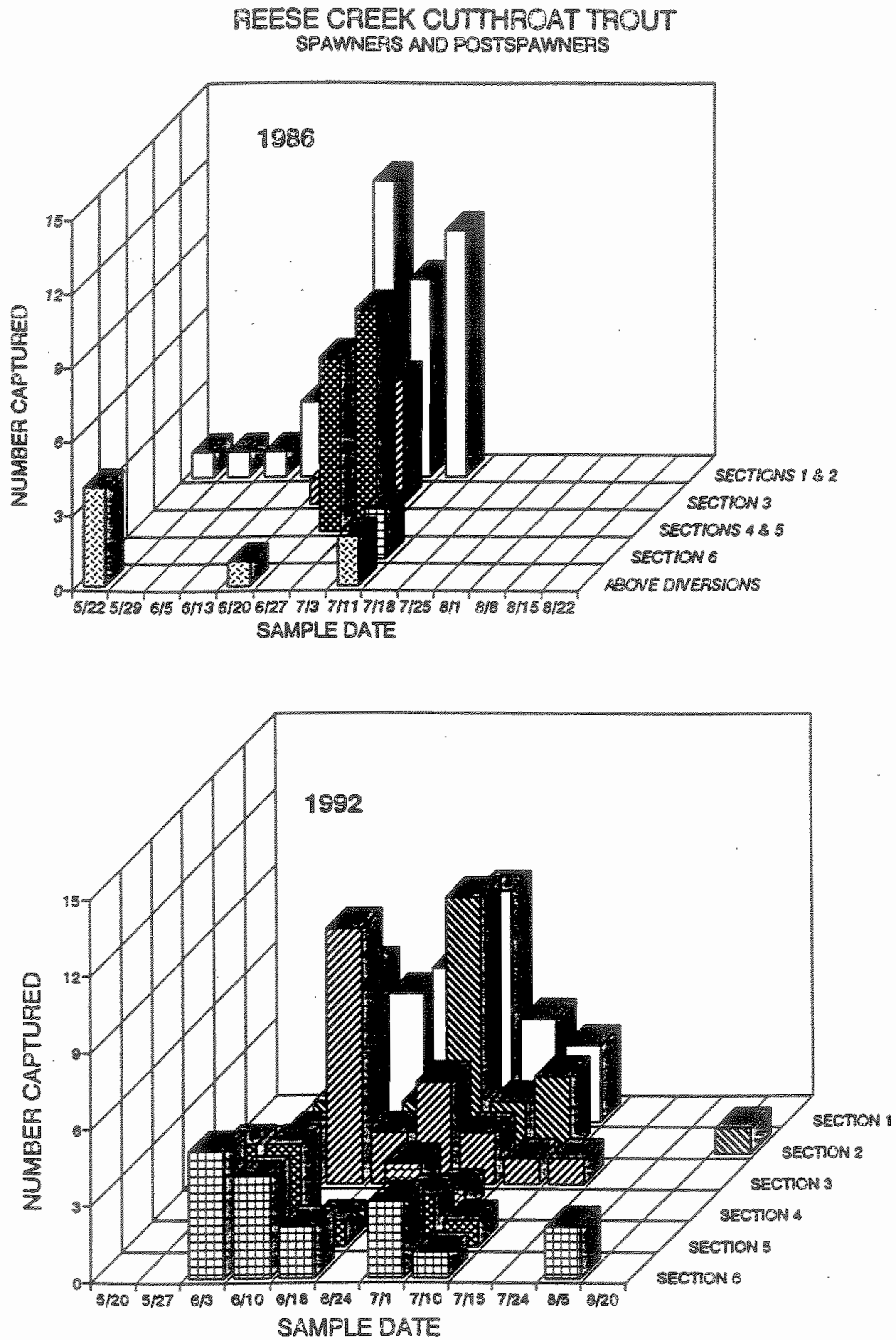

FIGURE 14.-Number of cutthroat trout classified as spawners or postspawners in Reese Creek, 1986 and 1992 (by week and section).

6 than in the downstream sections. In these upper sections, recapture intervals of 2-3 weeks were common for both spawners and nonspawners. The two largest spawners in Section 6 were recaptured on each sample occasion, which suggests that these fish resided in this section of Reese Creek for a minimum of 8 weeks.

Mark-recapture data also suggested that cutthroat trout had a strong fidelity for the stream section where they were initially captured. Unlike 1986, there was no documented upstream movement of spawners through the fish passage facilities in 1992; in contrast, several trout moved downstream after spawning. The downstream movement was detected not only past fish passage facilities (e.g., from Section 4 or 5 to Section 3), but also within sections not separated by barriers (e.g., from Section 3 to Section 1). Cutthroat trout originally captured in Section 6 were recaptured only in Section 6. Cutthroat trout that had presumedly resided upstream from Diversion 3 were observed in Diversion ditch 3 on at least two occasions.

Rainbow Trout Spawning

Because only three rainbow trout spawners (all females) were captured in Reese Creek in 1986, no spawning trends could be determined. All three fish were caught in Section 1 between June 20 and June 27, and two were in post-spawning condition.

In 1992 spawning rainbow trout were captured in all but the two middle study sections (3 and 4) of Reese Creek . Spawning females were captured only in Section 1, but male spawners were found in all four sections. Most male rainbow trout were recaptured at least once; estimated length-of-stay ranged from a minimum of 2 weeks in Section 1 to the entire 10-week study period in Section 6. Mark-recapture data indicated section fidelity of male rainbow trout similar to that observed for cutthroat trout. Some downstream movement among sections occurred, but no rainbow trout were detected moving upstream past fish passage facilities. Females were not recaptured in either year, suggesting a short residence period in Reese Creek or post-spawning mortality.

Distribution of Other Fish Species

In all years most brown trout and brook trout were captured downstream from the first irrigation diversion structure; however, the largest individuals were caught in the upper portion of Section 6. Except for one brown trout (127 mm TL) marked in Section 1 on July 10 that was recaptured upstream in Section 4 on August 20, little movement of brown trout or brook trout among sections was detected in 1992. Mark-recapture data indicated that some brown trout and brook trout resided in Reese Creek for at least 9 weeks (through the end of the study) in 1992.

Mountain whitefish and mottled sculpins were captured only in Sections 1 and 2. After extensive water withdrawal commenced in mid-July 1986, sculpin catch declined to zero. For the first 5 weeks of the 1992 study, electrofishing yielded a maximum of three sculpins per sample date. In response to high streamflows of the next couple weeks, the stream channel of Reese Creek downcut approximately 1 m at the confluence with the Yellowstone River. Subsequent to this channel alteration, sculpin abundance in the lower sections of Reese Creek increased dramatically (Figure 15). These results suggest that mottled sculpin distribution is influenced by access at the mouth of Reese Creek.

Discussion

In contrast to the extensive dewatering observed in Reese Creek from 1984 to 1991 (Jones et al. 1985, 1988, 1989, 1990; Lentsch 1986; Mahony 1987), in 1992 streamflows higher than the recently negotiated baseflow of 0.037 m/s^3 were maintained through the end of July (Figure 11). For the first time since monitoring began, we documented emergence of cutthroat trout fry with higher streamflows in the historically dewatered sections of Reese Creek. Although long-term data on fish populations in Reese Creek are limited, similarities in timing of salmonid spawning among study years (Figure 14) suggest that emergence of fry in Reese Creek usually coincides with mid-summer dewatering of the lower sections of the stream. Other investigators have observed that complete dewatering of redds for periods of less than 1 d can result in high mortality of recently emerged salmonid fry (Becker et al. 1982; Reiser and White 1983).

The age structure of cutthroat trout in Reese Creek suggests that at least some fry have survived each year. Trout fry may emigrate downstream in response to declining streamflows in intermittent streams (Erman and Leidy 1972); however, the magnitude, timing, and rapidity of dewatering in Reese Creek has probably severely limited fry survival. In addition, cutthroat trout fry that emerge but do not emigrate downstream to the Yellowstone River prior to dewatering could be stranded in isolated pools (as in 1991) and be vulnerable to predation by brook trout (Griffith 1988; Gresswell 1991) and avian or other predators. Timing of fry emergence in the sections upstream from Diversion 3 cannot be determined with the limited amount of available data; however, capture of numerous age-1 trout in downstream study areas following high streamflows (e.g., Section 4, between June 18 and June 24; Figure 12) suggests that some of these fish originated upstream.

The relative proportions of fluvial-adfluvial and resident cutthroat trout in Reese Creek are unknown. Based on location of capture, size distribution, estimated time of spawning, and estimated age, trout in the upstream sections may be residents distinct from the fluvial-adfluvial Yellowstone River population (Jones et al. 1985, 1988, 1992; Lentsch 1986; Mahony 1987). Unlike the downstream sections, each sample above the diversions contained adult cutthroat trout. In most years, postspawners were usually captured earliest in Section 6 or above the diversions, which suggests some behavioral differences between the fluvial-adfluvial and resident populations. Also, trout marked in 1991 were recaptured in 1992 in Section 6, which implies year-round residence. Because sampling in Reese Creek has been temporally and spatially fragmented, the possibility exists that these recaptured trout are consecutive-year spawners from the Yellowstone River.

REESE CREEK

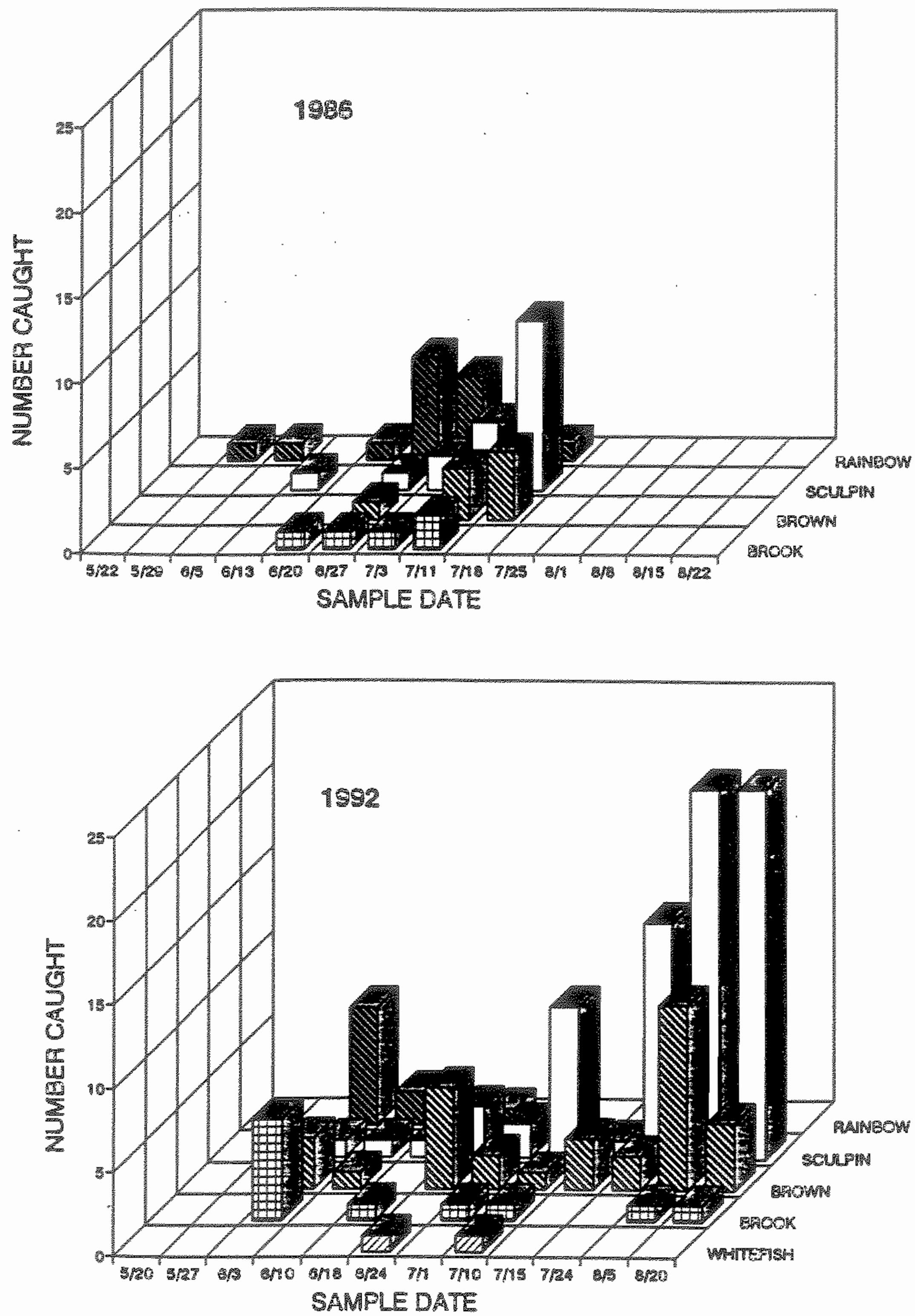

FIGURE 15.-Number of whitefish, rainbow trout, brook trout, brown trout, and sculpin captured in Reese Creek, 1986 and 1992 (by week and section).

Based on genetic analyses, Leary (1990) concluded that cutthroat trout above Diversion 3 have only recently hybridized with rainbow trout. Stocking of rainbow trout in the Yellowstone River began in the 1940s (Varley 1981). Similarities in timing of spawning between rainbow trout and cutthroat trout suggest that fluvial-adfluvial cutthroat trout have also had access to areas upstream from the diversions.

Our preliminary data revealed that trout $\geq$125 mm TL could ascend upstream through the fish passage structures at Diversions 1 and 2. Uncertainty regarding the effectiveness of the barrier at Diversion 3 precludes determination of the amount of interaction between the fluvial-adfluvial and resident populations. Although the largest brook trout and brown trout were recaptured several times near Diversion 3, neither of these species nor marked trout from downstream sections have been collected upstream from this diversion. More extensive sampling would clarify distribution of these species. Modifications of the headgates or their operation may be necessary to assure functioning fish screens.

Despite uncertainties regarding genetic and life history characteristics of cutthroat trout in Reese Creek, inadequate streamflow has limited the magnitude of the trout population in the lower sections of the stream. Lack of data limits description of a population not subjected to dewatering in the lower portions of this stream; however, abundance of spawners in Reese Creek in 1986 and 1992 was similar to that observed in other small tributaries of the Yellowstone River (e.g., Cedar Creek, Mol Heron Creek; Clancy 1987; Vincent et al 1989). Capture of a tagged fish that had migrated more than 100 km from Springfield, Montana, to Reese Creek in 1986 indicates the importance of the remaining spawning habitat to Yellowstone cutthroat trout populations in the Yellowstone River drainage.

Above-average precipitation in 1992 probably lessened irrigation demands from Reese Creek and facilitated adherence to the instream flow agreement through the end of July. The primary fisheries benefit in 1992 may have been the postponement of severe dewatering until early September, which may have allowed fry time to emigrate to the Yellowstone River. Other benefits associated with uninterrupted season-long streamflow included extensive riparian vegetation growth and increased macroinvertebrate abundance.

Mid-summer termination of our surveys has precluded assessment of long-term fry survival. Studies that encompass the spawning season, emergence, and post-emergence periods would reveal benefits of perennial flow. Also, increases in fry survival and recruitment might be detected through monitoring trends in spawner abundance. It is recommended that (1) streamflows in Reese Creek be closely monitored, particularly downstream from the road bridge, to ensure adherence to agreed-on minimum flows and (2) spawner surveys be conducted several years after reestablishment of minimum flows to evaluate long-term effects of enhanced streamflows.

NONANGLING USES OF AQUATIC RESOURCES ON THE YELLOWSTONE RIVER

Bishop et al. (1987) classified human uses of environmental resources as consumptive, nonconsumptive, or indirect. Consumptive uses (e.g., mining and hunting) permanently remove resources from their natural settings; however, nonconsumptive uses (e.g., watching wildlife and photography) do not. Indirect uses encompass activities (e.g., reading about animals and visiting aquaria) in which people do not come into contact with environmental resources in their natural settings.

In Yellowstone National Park (YNP) the U.S. Fish and Wildlife Service (FWS) recently adopted the phrase "nonangling uses" to avoid confusion in classifying catch-and-release fishing as a consumptive or nonconsumptive use under the definitions of Bishop et al. (1987). Although catch-and-release fishing is theoretically a nonconsumptive use, in practice a few fish are permanently removed through hooking mortality. Under the FWS definition, nonangling uses are nonconsumptive uses that exclude fishing.

In 1978 the National Park Service (NPS) and FWS began to identify and quantify nonangling uses of aquatic resources in YNP. Since then, the FWS has annually monitored visitor use at two sites on the Yellowstone River that are closed to angling. The NPS closed a third area of the Yellowstone River to angling in 1992, and the FWS began monitoring visitor use at this site in 1993. At all three sites, visitors can watch and photograph native Yellowstone cutthroat trout *Oncorhynchus clarki bouvieri* and other wildlife.

The goal of this study was to evaluate the relative importance of nonangling uses of aquatic resources on the Yellowstone River in YNP. Objectives included presenting current estimates of and evaluating long-term trends in (1) parkwide visitation (number of park visitors), (2) visitor numbers and hours at the three viewing sites (Fishing Bridge, LeHardy Rapids, and Buffalo Ford), and (3) number of park anglers and parkwide angler effort (hours fished).

Study Areas

Fishing Bridge spans the Yellowstone River at the outlet of Yellowstone Lake (Figure 16), and the 1.6-km river section downstream from the lake outlet has been closed to angling since 1973. The bridge, which is marked with a location sign, is 0.5 km east of Fishing Bridge Junction. Parking near and walkways on the bridge provide access for visitors. An interpretive display on the bridge explains the life history of Yellowstone cutthroat trout.

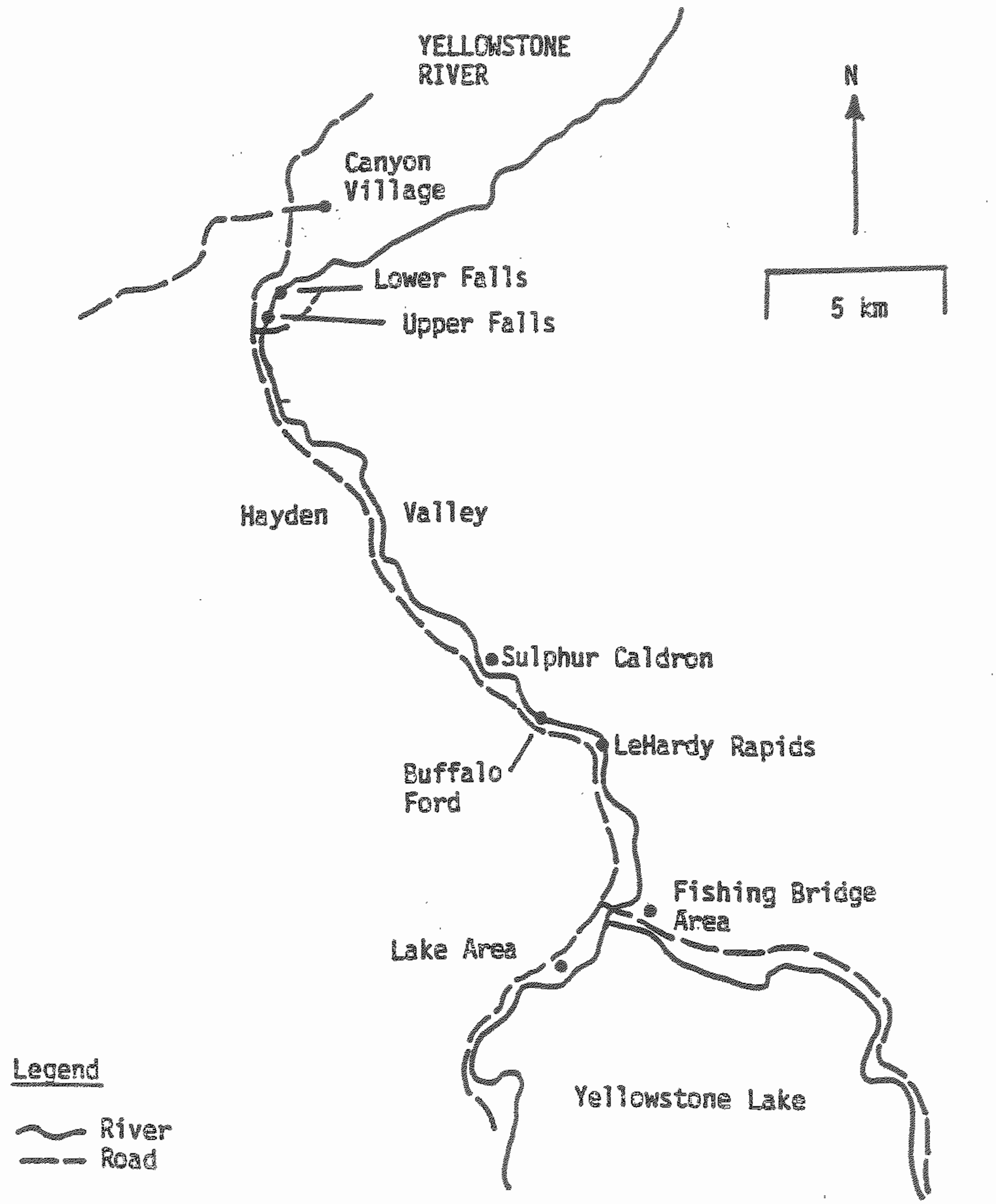

FIGURE 16.-Yellowstone River, Yellowstone National Park, from the Yellowstone Lake outlet to the Lower Falls, 1993.

LeHardy Rapids, 6 km downstream from the Yellowstone Lake outlet (Figure 16), has been closed to angling since 1949. In 1984 the NPS built walkways between the rapids and nearby vehicle pullouts and constructed a viewing platform and interpretive display overlooking the rapids. The NPS placed a location sign at the upper vehicle pullout in 1985. From 1991 through 1993 LeHardy Rapids has been closed to visitors through the first week of June to reduce disturbance to harlequin ducks *Histrionicus histrionicus*, an uncommon bird in the park that uses the rapids in May and early June.

Buffalo Ford is 3 km downstream from LeHardy Rapids (Figure 16). In 1992 the NPS closed a side channel of the river in this area to angling and built a viewing platform (as yet without an interpretive display) that overlooks the channel. Parking near the viewing platform provides access for visitors.

Methods

Annual estimates of visitor numbers and visitor hours.-The NPS estimates the number of park visitors each year.

A "time-available" methodology (Mathisen 1949; Bulkley 1966; Geiger 1972; Brown 1978) is used to annually estimate visitor numbers and hours at Fishing Bridge, LeHardy Rapids, and Buffalo Ford. Daily visitor-use patterns at each site are determined from instantaneous counts made between May and early October by FWS and NPS employees on their way to and from work sites. Mean length of visit at each site is estimated from timed counts of individuals and groups made by FWS employees on four or five randomly selected weekdays between June and August.

A daily visitor-use curve for each site is developed, and total visitor hours for each 15-min interval are calculated by:

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

where I is the interval, and t_i is the mean number of visitors counted in interval i. To estimate a daily total for visitor hours, instantaneous counts are expanded by the proportion of daily use represented by each time interval. On days when more than one count is made, the mean number of visitor hours is used. Total visitor numbers for each day are then estimated by dividing visitor hours by mean length of visit. Annual estimates of visitor numbers and visitor hours are calculated by summing daily totals and then expanding the results by the proportion of days counted.

Long-term trends and correlations.-A two-tailed, Mann-Kendall test for $N < 40$ (Hollander and Wolfe 1973; Gilbert 1987) was used to examine trends in parkwide visitation and visitor numbers and hours at Fishing Bridge and LeHardy Rapids from 1978 through 1993. This nonparametric test allows missing data, is distribution-free, and is preferred to a standard *t*-test for zero slope when the data may be serially correlated (Hirsch et al. 1982; Gilbert 1987; Norris and Georges

1993). Linear correlation (Zar 1984) was used to relate annual estimates of parkwide visitation to annual estimates of visitor numbers at Fishing Bridge and LeHardy Rapids between 1978 and 1993. Statistical tests were performed at $\alpha=0.05$.

Results

Current Year (1993)

Approximately 2.9 million people visited Yellowstone National Park in 1993, a 7% decrease compared to 1992.

Nearly 364,000 visitors spent about 48,800 h at Fishing Bridge in 1993; the average visit lasted 8.1 min. The 1993 estimate for visitor numbers increased 24% compared to 1992; however, because the mean length of visit dropped 21%, the 1993 estimate for visitor hours decreased 3% compared to 1992.

About 195,000 visitors spent nearly 26,600 h at LeHardy Rapids in 1993; the average visit lasted 8.2 min. The 1993 estimates for visitor numbers and visitor hours at LeHardy Rapids increased 42% and 25% compared to 1992.

An estimated 8,200 visitors spent 625 h at Buffalo Ford this year, and the average visit lasted 4.6 min.

Long-term Trends and Correlations (1978-1993)

Parkwide visitation.-Parkwide visitation has increased significantly between 1978 and 1993, and the increase has been especially evident during the past 5 years. From 1978 through 1988 visitor numbers never exceeded 2.63 million per year and showed no obvious trends. Parkwide visitation has since increased to nearly 3 million per year between 1991 and 1993 (Figure 17).

Fishing Bridge.-Visitor numbers and visitor hours at Fishing Bridge have increased significantly between 1978 and 1993, and long-term trends in visitor numbers and hours at Fishing Bridge have closely paralleled the long-term trend in parkwide visitation. At Fishing Bridge between 1978 and 1987 visitor numbers never exceeded 210,000, and visitor hours never rose above 36,000; no trends were evident in visitor numbers or hours at Fishing Bridge during this 10-year period (Figure 17). Substantial increases in visitor numbers and hours at Fishing Bridge began in 1988 and have continued through 1993 (Figure 17). During the past 6 years annual estimates of visitor numbers have ranged from 256,000 to 383,000, and annual estimates of visitor hours have fluctuated between 46,000 and 67,000. Visitor numbers at Fishing Bridge and parkwide visitation were significantly correlated (r = 0.69) for the period 1978-1993, suggesting that the number of park visitors affects the number of visitors to Fishing Bridge each year.

LeHardy Rapids.-At LeHardy Rapids visitor numbers and hours have increased significantly between 1978 and 1993. Long-term trends in visitation at

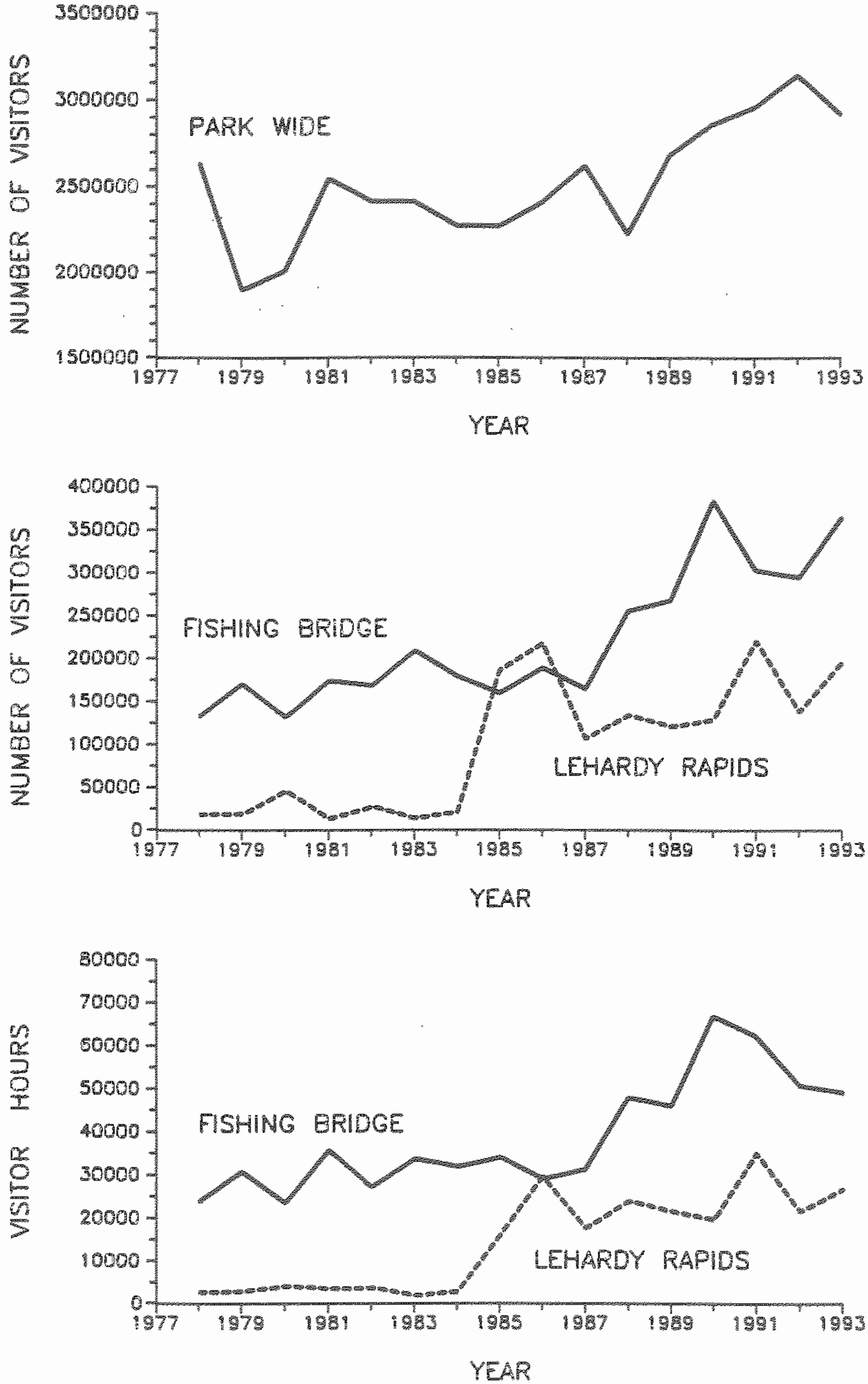

FIGURE 17.-Parkwide visitation (upper graph) and estimates of visitor numbers (middle graph) and hours (lower graph) at Fishing Bridge and LeHardy Rapids, 1978-1993.

LeHardy Rapids have been similar to those observed parkwide and at Fishing Bridge, with the exception that substantial increases in visitation at LeHardy Rapids began in 1985. From 1978 through 1984 at LeHardy Rapids annual estimates of visitor numbers were below 46,000, and annual estimates of visitor hours were less than 4,100; no trends were evident in vistor numbers or hours at LeHardy Rapids during this 7-year period (Figure 17). No increase in visitor numbers or hours was observed at LeHardy Rapids when the walkways were constructed in 1984; however, visitor numbers and hours increased substantially after the location sign was erected in 1985 (Figure 17). During the past 9 years, annual estimates of visitor numbers have ranged from 106,000 to 220,000, and annual estimates of visitor hours have fluctuated between 16,000 and 35,000. Visitor numbers at LeHardy Rapids and parkwide visitation were not significantly correlated (r = 0.46) between 1978 and 1993; however, visitor numbers at LeHardy Rapids and Fishing Bridge were significantly correlated (r = 0.56) during the same 16-year period.

Nonangling Uses versus Parkwide Angling (1978-1993)

Comparisons of visitor numbers at Fishing Bridge, LeHardy Rapids, and Buffalo Ford with annual estimates of the number of park anglers revealed that for 14 of the past 16 years more people have stopped at Fishing Bridge than have fished in the park (Table 12). In 1993 the number of visitors at LeHardy Rapids was greater than the number of park anglers for the fifth time in 16 years (Table 12).

Because average length of the angler day (2.5 h for the period 1978-1993) is greater than mean length of visit at Fishing Bridge, LeHardy Rapids, or Buffalo Ford (9.7 min for the period 1978-1993), annual estimates of parkwide angler effort have always been greater than annual estimates of visitor hours at the three viewing sites (Table 12). Nevertheless, Fishing Bridge and LeHardy Rapids rank among the top 10 areas when compared to individual park fisheries in terms of visitor hours (Tables 1 and 12).

Discussion

Estimates of visitor numbers and hours at Fishing Bridge and LeHardy Rapids during the past 16 years suggest that nonangling uses of aquatic resources on the Yellowstone River are important to park visitors. It is probable that the amount of nonangling use of aquatic resources will remain high if the number of park visitors stays at current levels or increases. The site at Buffalo Ford now provides additional nonangling-use opportunities.

Comparisons between nonangling uses and angling are currently limited to numbers of people and hours spent participating in each activity. It has not been possible to identify all the factors that attract visitors to Fishing Bridge, LeHardy Rapids, and Buffalo Ford because visitors are not interviewed as part of the study. In addition to fish-watching, visitors undoubtedly stop to watch and photograph birds, mammals, and scenic views. Understanding the differences between

TABLE 12.-Estimates of parkwide visitation, parkwide angling, and nonangling use at Fishing Bridge, Lehardy Rapids, and Buffalo Ford, Yellowstone National Park, 1978-1993.

		Parkwide angling		Fishing Bridge		LeHardy Rapids		Buffalo Ford	
Year	Parkwide visitors[a]	Number of anglers	Angler effort (hours)	Number of visitors	Visitor hours	Number of visitors	Visitor hours	Number of visitors	Visitor hours
1978	2,623,100	155,700	744,400	133,000	23,900	17,300	2,400	-	-
1979	1,891,900	139,100	725,300	170,400	30,700	17,600	2,800	-	-
1980	2,009,600	130,800	758,000	130,300	23,200	45,600	4,000	-	-
1981	2,544,200	160,000	923,000	173,700	35,600	12,100	3,300	-	-
1982	2,404,900	152,000	777,600	167,300	26,900	26,800	3,600	-	-
1983	2,405,700	120,500	652,100	208,700	33,600	12,200	1,600	-	-
1984	2,263,000	135,000	790,100	178,000	31,700	20,700	2,800	-	-
1985	2,262,500	123,800	688,500	158,400	33,900	185,500	15,800	-	-
1986	2,405,100	124,900	734,700	188,700	28,800	217,400	29,500	-	-
1987	2,618,200	151,500	917,800	163,600	31,200	105,900	17,400	-	-
1988	2,219,100	134,600	753,400	255,900	47,800	133,500	23,800	-	-
1989	2,680,400	124,400	801,300	268,600	45,700	119,800	21,300	-	-
1990	2,857,100	150,400	1,042,900	383,500	66,700	128,500	19,400	-	-
1991	2,957,900	161,100	1,072,200	302,000	61,900	220,400	34,900	-	-
1992	3,142,300	130,800	877,100	293,700	50,400	136,900	21,300	-	-
1993	2,912,200	141,100	1,026,100	364,000	48,800	195,000	26,600	8,200	600

[a]Annual estimates of parkwide visitation are from the National Park Service, Visitor Service's Office, Yellowstone National Park.

nonangling and angling experiences will require addressing sociological issues of nonangling uses of aquatic resources in YNP.

OTHER PROJECT ACTIVITIES

Management Activities

Global climate change investigation.-In 1993 the project completed a 3-year investigation of the possible effects of global warming on the rainbow trout and brown trout populations of the Firehole River. The Firehole River receives substantial amounts of geothermally heated water from three geyser basins in the drainage.

Objectives were to (1) monitor the frequency, duration, and magnitude of use of coolwater tributaries by fish from the Firehole River during summer, and (2) determine relations between coolwater tributary use and water temperatures in geothermally heated areas of the Firehole River. In addition, relations between coolwater tributary use and long-term trends in the Firehole River fishery were investigated. A final report will appear in 1994.

Movements of radiotagged cutthroat trout.-In 1993 the project began a 3-year investigation of the movements of radiotagged Yellowstone cutthroat trout in the Yellowstone River between Yellowstone Lake and the Upper Falls of the Yellowstone River. Objectives are to determine (1) the spatial relations between spawning trout from the lake and the river, (2) the time that lake fish occupy the river, and (3) the effect that angling has on trout movement.

Restoration of fluvial Arctic grayling.-In 1993 the project performed the first of three experimental introductions of fluvial Arctic grayling to Cougar Creek, a small stream in the Madison River drainage of the park. Eight hundred age-0 and yearling grayling, the progeny of fluvial grayling from the Big Hole River of Montana, were stocked in the creek in August. Results will be provided in future annual reports.

Assistance to Visiting Researchers

In 1993 the project provided assistance to Dr. Edward Theriot (Academy of Natural Sciences, Philadelphia) and his colleagues. Their research involves the evolution of an endemic species of diatom in Yellowstone Lake.

The project assisted Dr. Cathy Whitlock and Ms. Sarah Milspaugh, both with the University of Oregon (Eugene). They are studying the frequency of wildfires during the post-glacial period and its relation to long-term vegetational and climatic changes in Yellowstone National Park.

Project personnel assisted Dr. Steve Hostetler, U.S. Geological Survey, Lakewood, Colorado, with the collection of data needed to develop a temperature model for Yellowstone Lake.

Volunteer Program

The volunteer programs of the U.S. Fish and Wildlife Service, National Park Service, and Student Conservation Association (SCA) have been important to the success of the Yellowstone Fishery Assistance Office for many years. In addition to being major sources of manpower for our project, these volunteer programs provide valuable on-the-job training for volunteers. In 1993 volunteers provided 280 person-days of assistance to the project (240 person-days of which were by SCA personnel).

Reports

Fishery and aquatic management program in Yellowstone National Park: Technical Report for Calendar Year 1992.
(Annual report for the project.)

Oral Presentations

Gardiner Fly Fishers, Gardiner, Montana; Visiting field zoology class from The Colorado College, Colorado Springs, Colorado; Public Education Program of the Yellowstone Institute, Yellowstone National Park; Madison-Gallatin Chapter of Trout Unlimited; National Park Service resource management and naturalist training sessions, Yellowstone National Park; Montana Chapter of the American Fisheries Society; National Park Service symposium on fires in the Yellowstone ecosystem; International group of visiting environmental educators.

ACKNOWLEDGMENTS

We thank the people who helped accomplish the activities of the Yellowstone Fishery Assistance Office during the past year.

In January 1993 Melissa Schultz (a Student Conservation Association [SCA] volunteer during the 1992 field season) returned to the project as a volunteer for the winter season. During the 1993 field season, Melissa (then a NPS Biological Aide), and Sarah MacMillan, Scott Mimnaugh, Diane Simodynes, and Brendan Bowler (all with the SCA) were our summer field crew. Marc Hanna (NPS Volunteer in Parks) also helped during the summer, when his time allowed. Renee Thompson computerized data during the summer and fall and occasionally helped with field activities.

National Park Service District Rangers Mona Devine, Jerry Mernin, John Lounsbury, Bob Seibert, and their staffs provided logistical support for project activities. Resource Management Coordinators Craig McClure, Tom Olliff, Dan Reinhart, and Jim Sweaney ensured that the exit gate surveys of anglers were completed on schedule. Resource Management Specialists Karl Cordova and Sally Sprouse assisted on several of our field activities. Ken Walters helped us collect fish from Sentinel Creek as part of our global warming study. George McKay, John Hamilton, and Bill Whitmore performed work using the park's Geographic Information System.

George Roemhild (professor emeritus, Montana State University) and Dr. Fred Mangum (U.S. Forest Service) analyzed aquatic macroinvertebrate samples. Dr. Roemhild continued his voluntary effort to build a collection of macroinvertebrates from park waters for curation in the Yellowstone Museum.

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EDITORIAL NOTES

1. Format and abbreviations were modified from the American Fisheries Society's North American Journal of Fisheries Management.

2. Editorial references that proved useful included:

Berube, M. S., and coauthors. 1982. American Heritage dictionary: second college edition. Houghton Mifflin Company, Boston, Massachusetts.

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3. Text and tables were produced with Word Perfect 6.0 software (MS-DOS) using Univers fonts. The report was printed on a Hewlett Packard Laser Jet III printer. Graphs were produced on a Hewlett Packard 7475A, six-pen plotter with Grapher 1.79 software and on the laser printer with Quatro Pro 4.0 software. Several of the study area figures were produced by the National Park Service GIS Lab, Yellowstone National Park.