

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
Fisheries and Federal Aid



FISHERY AND AQUATIC MANAGEMENT PROGRAM
in
YELLOWSTONE NATIONAL PARK
Technical Report for Calendar Year 1990
May 1991

ANNUAL PROJECT TECHNICAL REPORT FOR 1990

Fishery and Aquatic Management Program

Yellowstone National Park

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May 1991

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Cover photo: Turn-of-the-century fishing at Fish Pot geyser, on the shore of Yellowstone Lake near West Thumb. Visitors to early Yellowstone sometimes amused themselves by catching Yellowstone cutthroat trout from the lake and cooking the fish on the hook in the boiling, geothermally heated waters of Fish Pot. This practice was outlawed in 1929.

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INTRODUCTION

In 1872, the United States Congress established Yellowstone National Park, the Nation's first national park, "...for the benefit and enjoyment of the people and for the preservation, from injury and spoliation of all timber, mineral deposits, natural curiosities and wonders..., and their retention in their natural condition." The Park occupies an area of almost 890,000 hectares (3,500 mi²) in the northwest corner of Wyoming and adjacent areas of Montana and Idaho. Astride the Continental Divide, Yellowstone National Park is bordered on the north and east by mountains that rise to 3,400 m (11,000 ft). The Park is characterized by several broad, forested volcanic plateaus that contain the world's largest caldera and thousands of geysers and other geothermal features.

Yellowstone National Park includes one of the few largely pristine aquatic ecosystems that remain in the contiguous United States. Slightly over 5% of the surface area of Yellowstone National Park is water. Over 150 lakes comprise an area of about 43,000 hectares (108,000 acres) and occur at elevations between 1,700 and 3,000 m (5,500 and 9,700 ft) above mean sea level. Yellowstone, Shoshone, Lewis, and Heart lakes make up 94% of the total lake area. In addition, over 220 named and hundreds of unnamed streams make up over 4,300 km (2,650 mi) or about 2,000 hectares (5,000 acres) of flowing water. The aquatic ecosystems of Yellowstone National Park contain, sustain, and protect a great diversity of aquatic organisms.

Yellowstone National Park is managed for the perpetuation of natural processes within the Yellowstone ecosystem, including interactions among native animals, plants, geology, and scenic landscapes (Houston 1971). Federal legislation and National Park Service policies have evolved to prohibit hunting and to closely regulate fishing in Yellowstone National Park. Yellowstone has always been recognized as a park with exceptional opportunities for recreationists, particularly those who seek a quality angling experience.

Since 1889, the U.S. Fish and Wildlife Service (USFWS) and its predecessor agencies have provided technical assistance in the management of the aquatic resources of the Park. Although an average of 2.5 million people visit the Park each year and an estimated 400,000 angler days were spent fishing Park waters in 1990, restrictive angling regulations promulgated by the USFWS have led to exceptionally low creel rates and large, self-sustaining fish populations with characteristics like those from environments unaffected by humans. In Yellowstone National Park, quality angling has been defined and successfully promoted as consisting of the opportunity to fish wild, self-sustaining populations of trout in a pristine environment. Harvesting fish by anglers, though allowed on a limited basis on specified waters, is reserved for grizzly bears, river otters, ospreys, pelicans, and other natural members of the Park ecosystem.

Objectives of the aquatic management program of Yellowstone National Park are to:

(1) Manage aquatic systems as an integral part of the Park ecosystem.

(2) Preserve and restore native species and aquatic habitats.

(3) Provide the visitor with the opportunity to fish for wild fish in a natural setting.

The U.S. Fish and Wildlife Service conducts investigations to evaluate the response of the fishery and aquatic ecosystem of Yellowstone National Park to the management program, and to assure program adherence to National Park Service policies. This report describes results of our efforts during 1990.

PARKWIDE ANGLING

Nearly 2.9 million people (the highest level of visitation on record) visited Yellowstone National Park in 1990. Approximately 171,700 non-fee fishing permits were issued this year; however, exit-gate survey data indicated that 15% of permit holders did not fish. Therefore, the estimated number of Park anglers in 1990 was about 150,400 (Table 1). Exit-gate survey data also indicated that in 1990 the average angler in the Park spent 2.2 d fishing, fished for 2.5 h/d, and fished 1.3 different waters/d.

Using the method of Jones et al. (1977), estimated parkwide angler use (number of fishing trips) was nearly 422,100 angler days, and estimated parkwide angler effort (hours spent fishing) totaled over 1.04 million hours in 1990. Parkwide angler use and effort estimates in 1990 increased 32 and 30%, respectively, compared to 1989 estimates, and both 1990 estimates are the highest on record (Table 2).

The Volunteer Angler Report (VAR) system estimated that in 1990 anglers landed just over 1 million fish and creeled about 61,700 fish (i.e., approximately 94% of all fish landed were released). The VAR system also estimated that the average angler landed 1.0 fish/h (2.5 fish/angler-day) and creeled 0.1 fish/h (0.2 fish/angler-day; Table 2).

Species composition of fish landed in 1990 as reported by anglers through the VAR system was 71% cutthroat trout *Oncorhynchus clarki*, 11% rainbow trout *O. mykiss*, 7% brown trout *Salmo trutta*, 7% brook trout *Salvelinus fontinalis*, and 1% mountain whitefish *Prosopium williamsoni*. Lake trout *S. namaycush*, Arctic grayling *Thymallus arcticus*, and unidentified fishes made up the remaining 3% of angler-landed fish.

Mean length of 50,140 angler-landed fish in 1990 as reported through the VAR system was 338 mm (13.3 in); about 67% of these fish were ≥ 305 mm (12 in) long, and nearly 52% were ≥ 356 mm (14 in) in length. Lake trout were the largest fish landed (mean length, 443 mm or 17.5 in), and were followed in descending order by cutthroat trout (mean length, 367 mm or 14.4 in), mountain whitefish (mean length, 312 mm or 12.3 in), unidentified fishes (mean length, 306 mm or 12.0 in), brown trout (mean length, 300 mm or 11.8 in), rainbow trout (mean length, 279 mm or 11.0 in), Arctic grayling (mean length, 222 mm or 8.7 in), and brook trout (mean length, 179 mm or 7.1 in).

Based on returns from the VAR system, nearly 80% of all anglers who fished in Yellowstone National Park in 1990 were satisfied with their overall fishing experience. About 73 and 71% of all anglers were also satisfied with sizes and numbers of fish landed, respectively. Anglers that were satisfied with their Park fishing experience in 1990 landed an average of 2.9 fish that had a mean length of 343 mm (13.5 in). Anglers that were unsatisfied with their 1990 fishing experience landed

TABLE 1.-Estimates of Park visitors, fishing permits issued, total parkwide anglers, and total parkwide angler days, Yellowstone National Park, 1973 to 1990.

Year	Total Park visitors	Park fishing permits issued	Total parkwide anglers	Total parkwide angler days	95% confidence limits
1973	2,061,537	169,103	121,888	230,100	225,500 - 234,700
1974	1,928,915	164,600	116,518	220,000	215,500 - 224,300
1975	2,239,483	191,550	136,332	257,300	248,400 - 266,300
1976	2,519,224	213,200	151,730	284,200	278,500 - 298,900
1977	2,481,933	217,000	154,581	311,300	304,000 - 318,500
1978	2,618,380	218,000	155,700	333,800	326,200 - 341,300
1979	1,892,908	195,100	139,100	291,300	274,500 - 308,200
1980	2,000,273	184,200 ^a	130,800	311,300	287,000 - 334,600
1981	2,521,831	172,300	160,000	383,400	363,400 - 403,300
1982	2,368,897	205,000	152,000	332,500	314,700 - 350,300
1983	2,347,242	166,800	120,500	275,900	261,800 - 289,900
1984	2,222,027	176,800	135,000	329,200	305,400 - 341,000
1985	2,226,159	166,700	123,800	279,000	260,800 - 297,200
1986	2,363,756	163,300	124,900	294,800	269,300 - 320,400
1987	2,573,194	183,900	151,500	370,900	349,062 - 392,804
1988	2,182,113	165,700	134,600	293,800	272,716 - 314,917
1989	2,644,442	159,200	124,360	320,900	301,100 - 340,700
1990	2,857,096	171,724	150,389	422,097	386,708 - 457,486

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

TABLE 2.-Angler use, effort, success, and harvest for Yellowstone National Park, 1973-1990.

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			Average length of fish landed (in)	Mean expertise ^a
								Overall experience	Numbers caught	Sizes caught		
1973	230,100	2.45	564,400	0.86	485,400	0.16	90,300	--	--	--	--	--
1974	220,000	2.42	531,300	0.86	456,900	0.19	101,000	--	--	--	--	--
1975	257,300	2.31	594,400	1.09	647,900	0.23	136,700	77	74	75	13.3	--
1976	284,200	2.36	670,700	1.02	684,100	0.20	134,100	74	69	69	13.2	1.90
1977	311,300	2.33	725,300	0.98	710,800	0.20	145,100	75	68	70	13.4	1.83
1978	333,800	2.23	744,400	0.99	736,900	0.17	126,500	73	66	68	13.4	1.86
1979 ^b	291,300	2.49	725,300	1.01	731,100	0.15	107,300	73	67	68	13.6	1.88
1980	311,300	2.44	758,000	0.96	725,300	0.13	101,000	73	66	68	13.4	1.87
1981	383,400	2.41	923,000	0.93	844,700	0.12	110,800	73	65	66	13.4	1.88
1982	332,500	2.34	777,600	0.95	740,200	0.14	107,500	74	67	68	13.5	1.88
1983	275,900	2.36	652,100	0.95	622,400	0.11	71,600	76	69	68	13.6	1.89
1984	329,200	2.40	790,100	0.93	732,700	0.12	92,100	76	68	69	13.5	1.91
1985	279,000	2.47	688,500	0.92	629,700	0.10	69,800	76	68	71	13.3	1.90
1986	294,800	2.49	734,700	1.01	740,900	0.10	73,400	79	72	72	13.3	1.93
1987	370,900	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	422,097	2.47	1,042,937	0.97	1,009,914	0.06	61,740	80	71	73	13.3	1.88

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

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

an average of 1.2 fish that had an average size of 285 mm (11.2 in). Mean angling-expertise level for Park anglers in 1990 was 1.9, indicating that most anglers in Yellowstone National Park in 1990 classified themselves as either inexperienced (1.0) or experienced (2.0). Few Park anglers classified themselves as experts (3.0).

Sport-fishery statistics for 21 lakes and streams (as estimated through the VAR system) that collectively constituted over 95% of parkwide angler use in 1990 are listed in Table 3.

TABLE 3.-Fishery statistics for Yellowstone National Park waters with 40 or more angler days and which collectively comprise over 95% of the estimated parkwide angler use in 1990.

	% of total parkwide angler days	Total reported angler days (1989)	Estimates for the season							Mean length fish landed (inches)	Mean length fish creeled (inches)	% anglers landing 1 or more fish	Average expertise	% anglers satisfied with:			
			Anglers	Mean length of angler day (h)	Angler days (trips)	Angler hours (effort)	Landing rate	Creel rate	Total fish landed					Total fish creeled	Overall experience	Numbers caught	Fish sizes caught
Parkwide fishery	100.00	11,487	150,309	2.47	422,097	1,042,937	0.97	0.06	1,009,914	61,740	13.30	12.21	69	1.88	80	71	73
Yellowstone Lake	39.37	4,522	53,934	2.55	166,150	422,881	1.01	0.09	427,080	36,271	15.35	12.54	72	1.75	82	75	79
Yellowstone River	15.69	1,802	22,871	2.63	66,197	174,351	0.91	0.02	158,409	2,893	14.89	13.29	66	1.94	85	76	83
Madison River	7.51	863	9,836	2.45	31,691	77,513	0.50	0.02	38,707	1,155	13.15	11.00	50	1.97	63	50	58
Firehole River	6.87	789	10,830	2.41	28,972	69,938	0.85	0.02	59,649	1,387	10.18	8.07	65	1.97	80	67	60
Slough Creek	4.34	499	7,393	2.85	18,315	52,147	1.29	0.01	67,214	635	13.59	--	87	2.03	91	82	89
Gibbon River	4.31	495	8,366	1.65	18,168	29,972	0.88	0.06	26,397	1,767	7.36	8.59	55	1.91	66	57	44
Lewis Lake	2.84	326	3,848	3.10	11,958	37,123	0.47	0.11	17,370	4,238	14.71	15.11	51	1.92	67	55	69
Lamar River	2.10	241	3,588	2.46	8,834	21,713	0.94	0.03	20,310	656	11.49	12.40	76	2.02	82	69	76
Shoshone Lake	2.07	238	2,010	3.11	8,724	27,160	0.58	0.15	15,667	4,061	18.11	17.92	68	1.73	69	62	88
Gardner River	2.05	236	3,545	2.08	8,651	18,001	1.48	0.12	26,691	2,189	8.63	9.48	75	1.92	92	81	67
Soda Butte Creek	1.51	175	2,616	2.00	6,336	12,639	1.23	0.07	15,568	865	10.36	13.82	71	1.99	79	69	70
Gallatin River	1.35	155	2,075	2.42	5,674	13,708	0.99	0.41	13,502	562	11.40	11.50	76	2.03	77	62	73
Lewis River	1.15	132	2,270	1.88	4,829	9,063	0.64	0.04	5,771	354	9.54	10.33	48	1.85	64	55	45
Grabe Lake	0.74	85	1,405	2.57	3,102	7,983	1.46	0.04	11,670	292	9.38	10.40	98	1.92	92	81	74
Indian Creek	0.58	64	1,232	1.68	2,330	3,902	2.04	0.34	7,948	1,319	6.48	7.39	76	1.87	70	64	45
Trout Lake	0.55	63	1,081	2.08	2,293	4,769	0.84	0.01	4,008	56	14.14	--	70	1.73	89	91	95
Obsidian Creek	0.51	59	1,038	1.70	2,146	3,650	1.27	0.23	4,636	854	6.08	7.26	85	1.83	83	78	38
Bechler River	0.46	53	865	2.52	1,926	4,848	1.09	0.01	5,293	57	10.35	--	87	2.23	71	76	56
Tower Creek	0.42	48	692	2.16	1,742	3,762	2.01	0.29	7,576	1,089	8.92	8.27	96	1.90	90	83	72
Nez Perce Creek	0.40	46	778	1.72	1,669	2,871	0.99	0.13	2,834	365	8.68	9.25	40	1.80	74	70	52
Lava Creek	0.35	40	649	1.33	1,448	1,922	1.43	0.24	2,753	456	8.28	7.20	88	1.89	83	91	70

YELLOWSTONE LAKE

Yellowstone Lake has the largest inland population of Yellowstone cutthroat trout *Oncorhynchus clarki bouvieri* in the world. During the past 100 years, the historic abundance and structure of this population have been altered by human activity (Gresswell and Varley 1988). A commercial fishery supplied cutthroat trout to the hotels and restaurants in Yellowstone National Park in the late 1800s and early 1900s, millions of cutthroat trout eggs were shipped out of the Park as part of large-scale hatchery operations between the early 1900s and 1953, and sport anglers have annually harvested thousands of cutthroat trout from the lake.

Angling regulations on Yellowstone Lake date back to the late 1800s. Although creel limits were periodically reduced between 1900 and 1968, the abundance of trout stocks in the lake declined (Gresswell 1980). In 1970, a 356-mm minimum-size restriction and three-fish-per-day creel limit were implemented, and in 1973 the creel limit was reduced to two fish per day. Despite these changes in regulations, the proportion of larger trout (≥ 356 mm) in the population failed to increase (Gresswell 1980). Consequently, a 330-mm maximum-size restriction and two-fish-per-day creel limit were instituted on Yellowstone Lake in 1975 and on all tributaries of the lake in 1978. Fishery managers hypothesized that this regulation would reduce angler harvest, allow increased survival of older and larger trout, and eventually return the trout population structure to one resembling that which existed a century ago.

The goals of this report are to describe and evaluate long-term trends in the Yellowstone Lake cutthroat trout fishery in relation to changes in angling regulations.

Study Areas

Yellowstone Lake

Yellowstone Lake (Figure 1) is located in east-central Yellowstone National Park. The lake lies at an elevation of 2,357 m above mean sea level, and 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 this oligotrophic lake from mid-December through May or early June, and summer surface temperatures rarely exceed 18°C.

The Yellowstone cutthroat trout and the longnose dace *Rhinichthys cataractae* are the endemic fishes of Yellowstone Lake. Introduced fishes of Yellowstone Lake include the longnose sucker *Catostomus catostomus*, reidside shiner *Richardsonius balteatus*, and lake chub *Couesius plumbeus*.

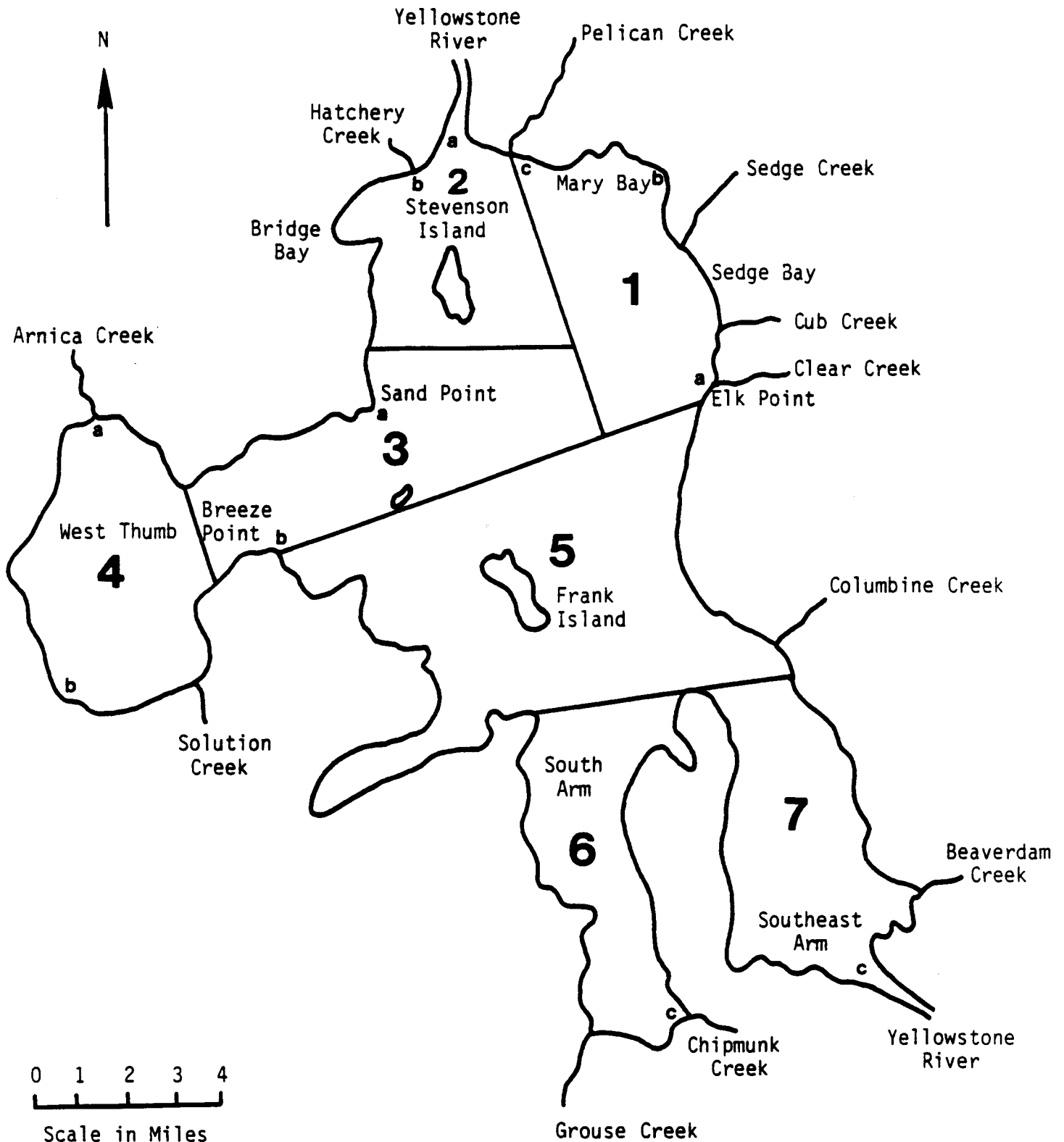


FIGURE 1.-Creel survey, gillnetting, and spawning trap sites, Yellowstone Lake, 1990.

Clear Creek

Clear Creek originates 2,585 m above mean sea level on the western slope of the Absaroka Mountains and flows west for nearly 20 km before reaching the northeast shore of Yellowstone Lake (Figure 1). Peak discharge of Clear Creek may reach 6.7 m³/s during spring runoff, but flow drops to about 0.5 m³/s by August.

Suitable spawning sites for trout are distributed throughout Clear Creek and its 18 km of tributaries. From late April through July, cutthroat trout from Yellowstone Lake enter Clear Creek to spawn. Most spawners return to the lake after spawning.

Methods

Data sources and field procedures.—Data from three independent sources are used to monitor trends in the cutthroat trout sport fishery and fish populations of Yellowstone Lake.

Manned creel surveys and the Volunteer Angler Report (VAR) system provide information on the cutthroat trout sport fishery. These sport-fishery data have been compiled almost annually during the 22-year period between 1969 and 1990. Sport-fishery parameters included in this report are estimates of annual angler effort (total hours of fishing), mean-annual landing rate (average number of trout landed per hour of fishing), annual angler-caused mortality (number of trout creeled per year plus an estimated 10% hooking mortality of released fish), and selected length-structure characteristics of angler-landed trout (mean total length, Proportional Stock Density [PSD], and Relative Stock Density [RSD]).

Operation of the fish trap at Clear Creek provides information on adfluvial cutthroat trout spawners from Yellowstone Lake. Although these data were first collected at Clear Creek in 1945, trap operation has not been continuous. Thus, only 28 years of data are available for the period 1945 to 1990.

Field methods have varied over the years; however, the trap has usually been operated daily from late April or early May through July or early August. Prior to 1989, the upstream trap was open between 0800 and 2000 hours and the downstream trap was open between 0800 and 2400 hours. Electronic counters (Pulsar Electronics Model 550) were tested in 1989 and 1990 and have, on occasion, allowed both traps to remain open 24 h per day.

Counts of cutthroat trout moving through the upstream and downstream traps are made daily during the spawning season. Each day, a maximum of 75 trout from the upstream trap are identified to sex, evaluated for spawning condition, and measured to the nearest 5 mm total length. Each week, an additional 100 trout from the upstream trap are identified to sex, evaluated for spawning condition, measured to the nearest 1 mm total length, and weighed to the nearest 2 g; scales from a subsample of these trout are collected for age-growth analyses. Similar daily and

weekly sampling procedures for trout moving through the downstream trap have been followed in most years.

Data resulting from operation of the trap and included in this report are the number of upstream migrants, selected length-structure characteristics of upstream migrants, and mean age of upstream migrants. Ages were estimated by the scale method (Bagenal and Tesch 1978) and mean age was estimated by expanding results with an age-length key (Westrheim and Ricker 1978).

The largemouth gillnetting study provides data on cutthroat trout and longnose sucker populations from several areas of Yellowstone Lake for 19 of the 22 years between 1969 and 1990. Field methods have varied over the years; however, sampling has usually been conducted during a 5-d period in the third week of September. Eleven sites (Figure 1) are sampled annually.

At each site, five Swedish experimental gill nets are set between 1300 and 1500 hours and retrieved the following day between 0800 and 0900 hours. The nets are constructed of monofilament nylon, are 38 m long and 1.5 m deep, and have five 7.6-m-long graduated-mesh panels of 19, 25, 32, 38, and 51 mm (bar measure). Nets are set perpendicular to the shoreline (smallest mesh closest to shore) in water depths of about 1.5 m at the nearshore end of the net to 4.6 m at the offshore end. Spacing between nets is about 100 m.

Captured fish are separated by site, net, and species. Individuals of each species are then sorted from largest to smallest in length. Each fish is measured to the nearest 1 mm total length and weighed to the nearest 2 g. On the basis of gonadal examination, each fish is sexed and assigned a stage of maturity according to the terminology of Jones et al. (1979). Scales for age-growth analysis are collected from every third cutthroat trout. The presence of the tapeworm, *Ligula intestinalis*, and the eyefluke, *Diplostomum spathaceum*, is noted for longnose suckers.

Gillnetting data on cutthroat trout and longnose suckers include an annual index of abundance (mean number of fish captured per net) and selected length-structure characteristics. These analyses were also applied to gill-net captured cutthroat trout and longnose suckers classified as "prespawners" (i.e., fish captured in fall that, based on visual inspection of the gonads, apparently will spawn the following spring).

Data analysis.-Correlation analysis (Zar 1984; Hintze 1991) was used to detect significant ($P < 0.05$) trends in the sport fishery and fish population characteristics.

Proportional Stock Density and Relative Stock Density are length-frequency indices (Gabelhouse 1984) that eliminate the influence of smaller fish in data analysis. "Stock", "quality", and "preferred" lengths are often selected from length ranges that are based on percentages of world-record lengths for a species (Gabelhouse 1984); however, the growth potential of

individual fish of a species in a particular stream or lake must also be considered.

Stock, quality, and preferred lengths for cutthroat trout in this study were set at 254, 356, and 406 mm, respectively. Although a preferred length of 406 mm is less than that recommended by Gabelhouse (1984), the growth potential of cutthroat trout in Yellowstone Lake was an overriding consideration. Stock, quality, and preferred lengths for longnose suckers in this study were set at 254, 406, and 457 mm, respectively. Gabelhouse (1984) does not provide recommended lengths for the longnose sucker, and the lengths used here are based on a subjective estimate of the growth potential of this species in Yellowstone Lake.

Results

Cutthroat Trout

Sport fishery (1969-1990).—Between 1969 and 1990, estimated annual angler effort on Yellowstone Lake has ranged from 268,000 to 423,000 h. Although no significant trend ($r = -0.19$; $P = 0.39$) was detected for this 22-year period, over the past 6 years, angler effort has risen from a low of 279,000 h to a record high of 423,000 h (Figure 2).

Mean-annual landing rate has increased significantly ($r = 0.50$; $P = 0.02$) over the past 22 years. Landing rate rose from 0.5 to 1.1 trout/h between 1969 and 1975 and has fluctuated between 0.8 and 1.1 trout/h since then (Figure 2).

The estimated annual angler-caused mortality of cutthroat trout in Yellowstone Lake has dropped significantly ($r = -0.89$; $P < 0.01$) between 1969 and 1990. Estimated angler-caused mortality was highest in 1969 (155,000 trout) and lowest (57,000 trout) in 1987 (Figure 2).

Length-structure data from angler-landed trout were available for the years 1973 through 1990. During this 18-year period, mean length of angler-landed trout has increased significantly ($r = 0.93$; $P < 0.01$) from about 350 mm between 1973 and 1976 to 390 mm in 1990 (Figure 3). Concurrently, PSD and RSD estimates for angler-landed trout have increased significantly ($r = 0.90$ and 0.94 respectively; $P < 0.01$). Proportional Stock Density estimates ranged between 47 and 54% between 1973 and 1976 but have increased to a record high of 82% in 1990. Similarly, RSD estimates have increased from about 8% between 1973 and 1976 to a record high of 40% in 1990 (Figure 3).

Clear Creek spawning run (1945-1990).—The number of cutthroat trout that annually migrate from Yellowstone Lake into Clear Creek to spawn has risen significantly ($r = 0.78$; $P < 0.01$) between 1945 and 1990. Prior to 1961, the number of upstream migrants was often less than 11,000 and never exceeded 23,300.

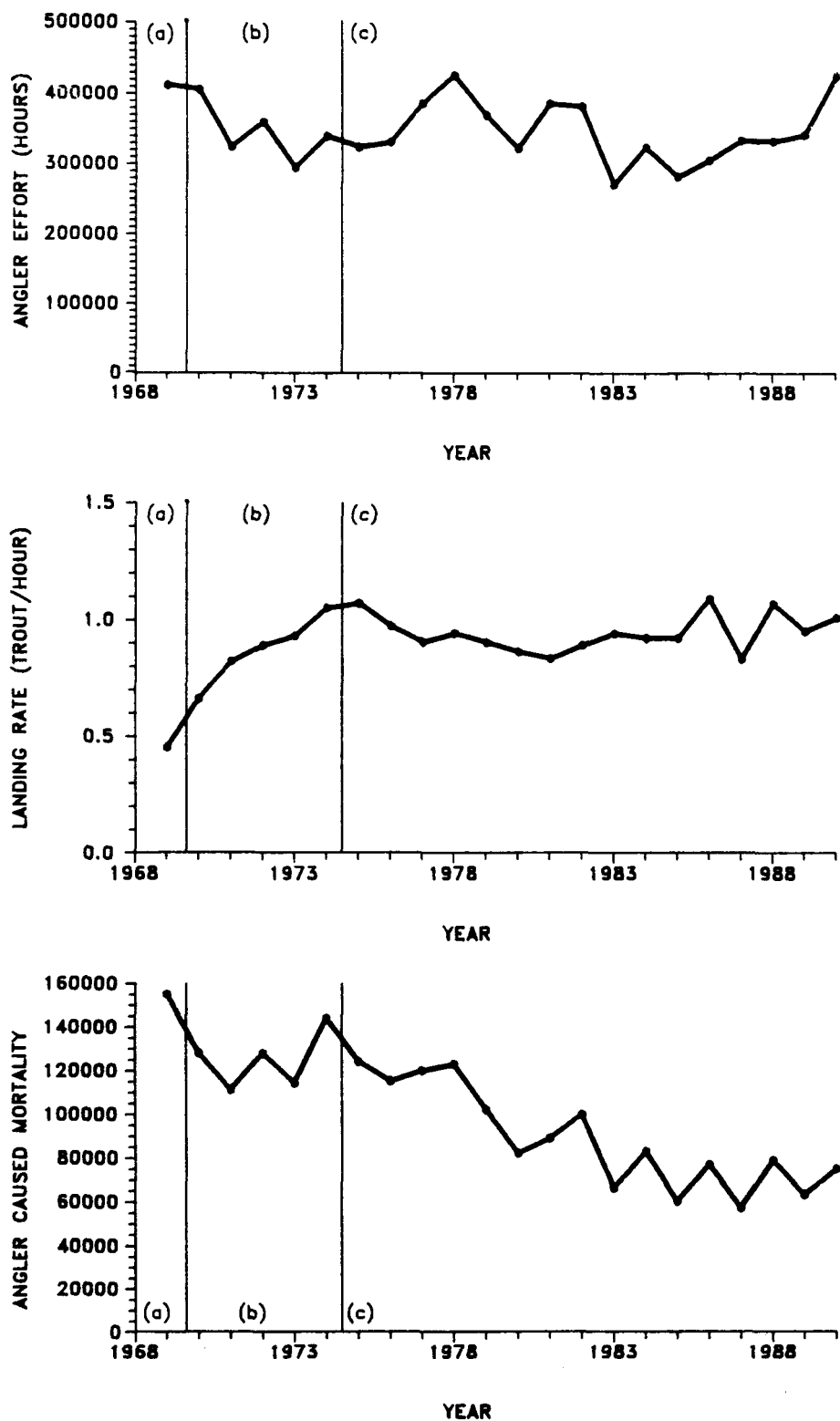


FIGURE 2.-Estimates of angler effort, mean landing rate, and angler-caused mortality for cutthroat trout from Yellowstone Lake, 1969 to 1990. Angling regulations: (a) 1969, no size limit and three-trout-per-day creel limit; (b) 1970 to 1974, 356-mm minimum-size limit and two- or three-trout-per-day creel limit; and (c) 1975 to 1990, 330-mm maximum-size limit and two-trout-day creel limit.

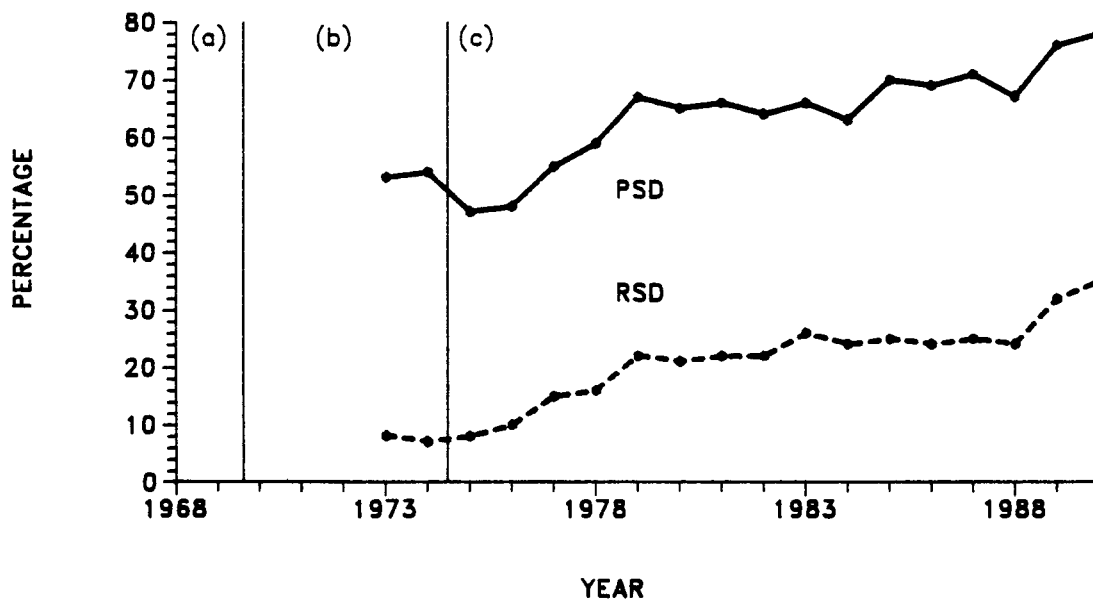
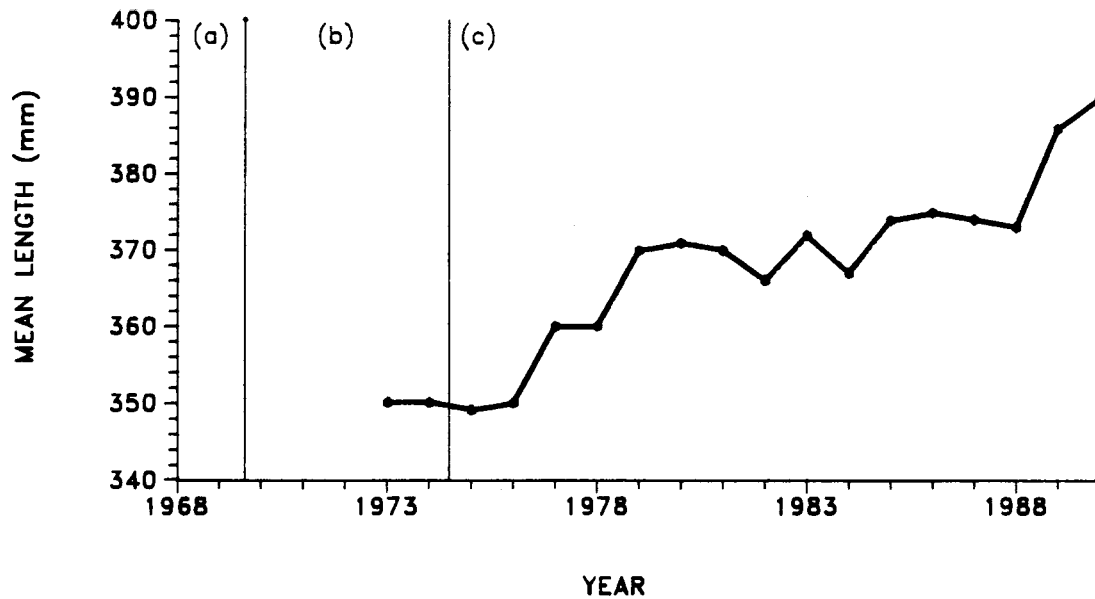


FIGURE 3.-Estimates of mean length, Proportional Stock Density (PSD), and Relative Stock Density (RSD) for angler-landed cutthroat trout from Yellowstone Lake, 1973 to 1990. Angling regulations: (a) 1969, no size limit and three-trout-per-day creel limit; (b) 1970 to 1974, 356-mm minimum-size limit and two- or three-trout-per-day creel limit; and (c) 1975 to 1990, 330-mm maximum-size limit and two-trout-per-day creel limit.

Since 1965, however, the number of upstream migrants has always been between 32,100 and 70,100 (Figure 4).

Mean length of cutthroat trout migrating from Yellowstone Lake into Clear Creek has increased significantly ($r = 0.59$; $P < 0.01$) between 1953 and 1990. Mean length rose from about 370 to 390 mm during the 1950s, but dropped to 365 mm in the mid-1960s. Since the early 1970s, however, mean length has increased almost annually to a record high of 400 mm in 1990 (Figure 5).

Proportional Stock Density estimates and RSD estimates have increased significantly ($r = 0.62$ and 0.67 , respectively; $P < 0.01$) between 1961 and 1990. Proportional Stock Density and RSD estimates were lowest in the mid-1960s (66 and 4%, respectively) and increased during the 1970s and 1980s. The PSD estimate of 96% in 1990 was one of the highest observed, and the 1990 RSD estimate of 38% is the highest on record (Figure 5).

Estimated mean age of upstream migrants has increased significantly ($r = 0.82$; $P < 0.01$) between 1945 and 1990. Between 1945 and 1966, estimated mean age fluctuated between 3.9 and 4.5 years. Since 1967, however, mean age has risen from 4.5 years in 1973 to a record high of 6.1 years in 1990 (Figure 5).

Largemouth gillnetting (1969-1990).—Between 1969 and 1990, mean number of cutthroat trout captured per gill net has ranged between 10.6 and 19.5, although no significant trend ($r = 0.34$; $P = 0.16$) was detected (Figure 6). During this 22-year period, the mean length of gill-net captured cutthroat trout has varied between 281 and 330 mm, PSD estimates have fluctuated between 32 and 68%, and RSD estimates have ranged between 1 and 24%. Although no significant trend ($r = 0.07$; $P = 0.78$) was evident in mean length, PSD and RSD estimates have risen significantly ($r = 0.71$ and 0.93 , respectively; $P < 0.01$) (Figure 6).

Mean number of cutthroat trout prespawners captured per net has ranged between 3.2 and 5.6 between 1969 and 1990, but there was no significant trend ($r = -0.19$; $P = 0.44$; Figure 7). Mean length of cutthroat trout prespawners has increased significantly ($r = 0.96$; $P < 0.01$) since 1969. Mean length of prespawners was shortest (350 mm) in 1969 and longest (400 mm) in 1990 (Figure 7).

Longnose Sucker (1969 to 1990)

Between 1969 and 1990 the mean number of longnose suckers captured per net has ranged between 2.6 and 16.3, although no significant trend ($r = -0.35$; $P = 0.15$) was evident (Figure 8). During this 22-year period, the mean length of gill-net captured longnose suckers has fluctuated between 316 and 401 mm, PSD estimates have ranged between 24 and 65%, and RSD estimates have

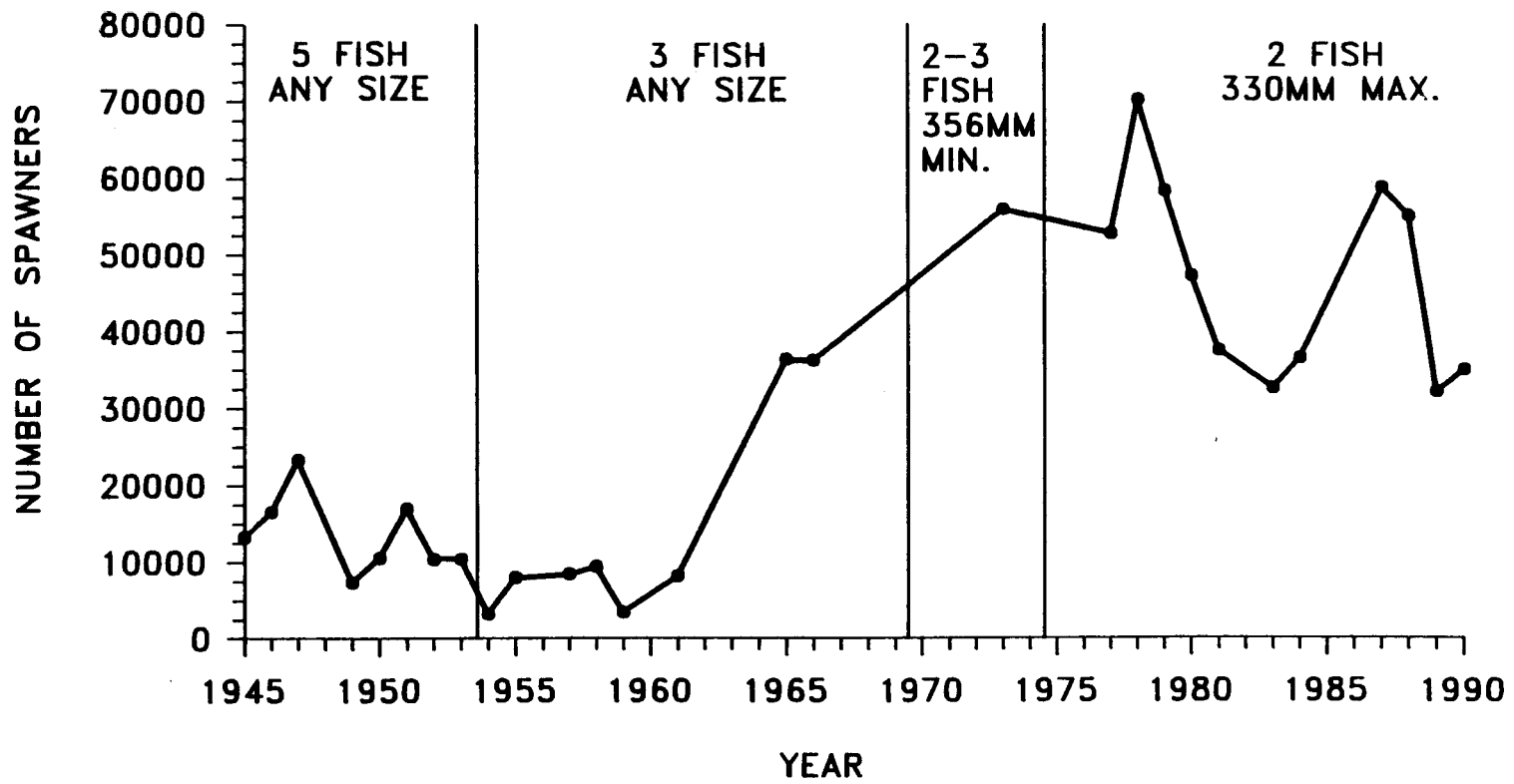


FIGURE 4.-Number of cutthroat trout spawners counted through the upstream trap at Clear Creek, 1945 to 1990.

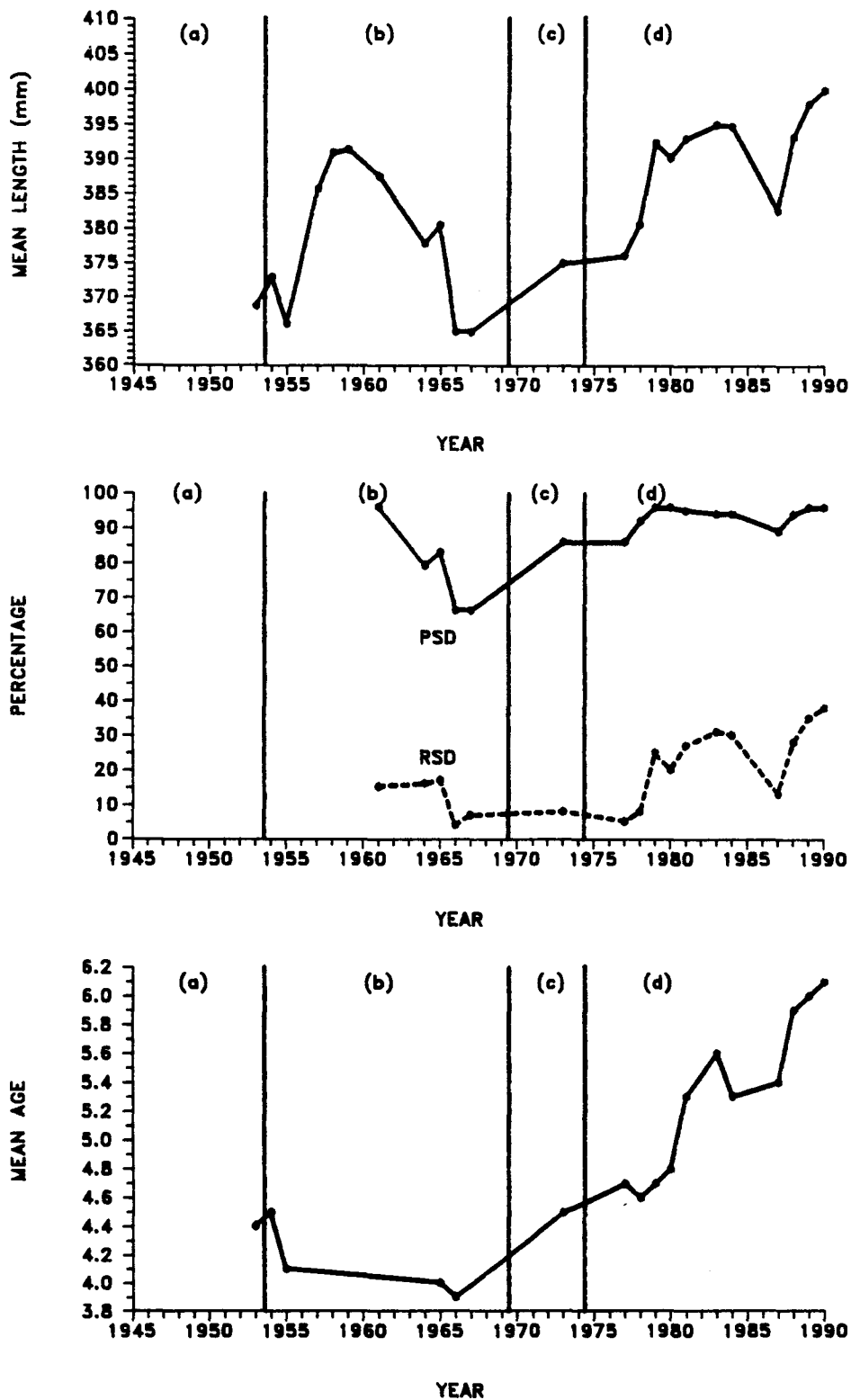


FIGURE 5.-Estimates of mean length, Proportional Stock Density (PSD), Relative Stock Density (RSD), and mean age for cutthroat trout sampled from the upstream trap at Clear Creek, 1953 to 1990. Angling regulations: (a) 1953, no size limit and five-trout-per-day creel limit; (b) 1954 to 1969, no size limit and three-trout-per-day creel limit; (c) 1970 to 1974, 356-mm minimum-size limit and two- or three-trout-per-day creel limit; (d) 1975 to 1990, 330-mm maximum-size limit and two-trout-per-day creel limit.

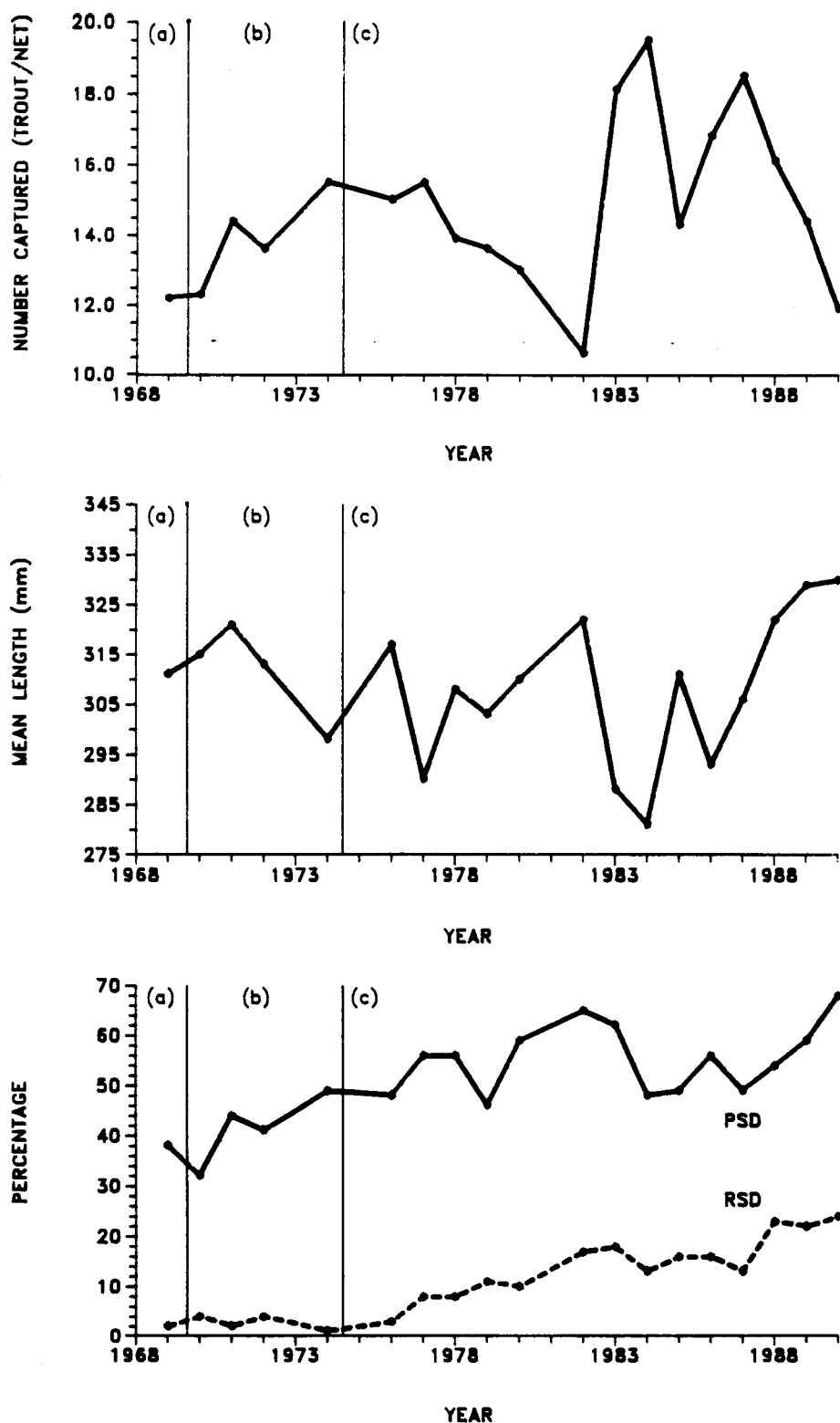


FIGURE 6.-Relative abundance index, mean length, Proportional Stock Density (PSD) estimates, and Relative Stock Density (RSD) estimates for cutthroat trout captured in experimental largemouth gill nets, Yellowstone Lake, 1969 to 1990. Angling regulations: (a) 1969, no size limit and three-trout-per-day creel limit; (b) 1970 to 1974, 356-mm minimum-size limit and two- or three-trout-per-day creel limit; and (c) 1975 to 1990, 330-mm maximum-size limit and two-trout-per-day creel limit.

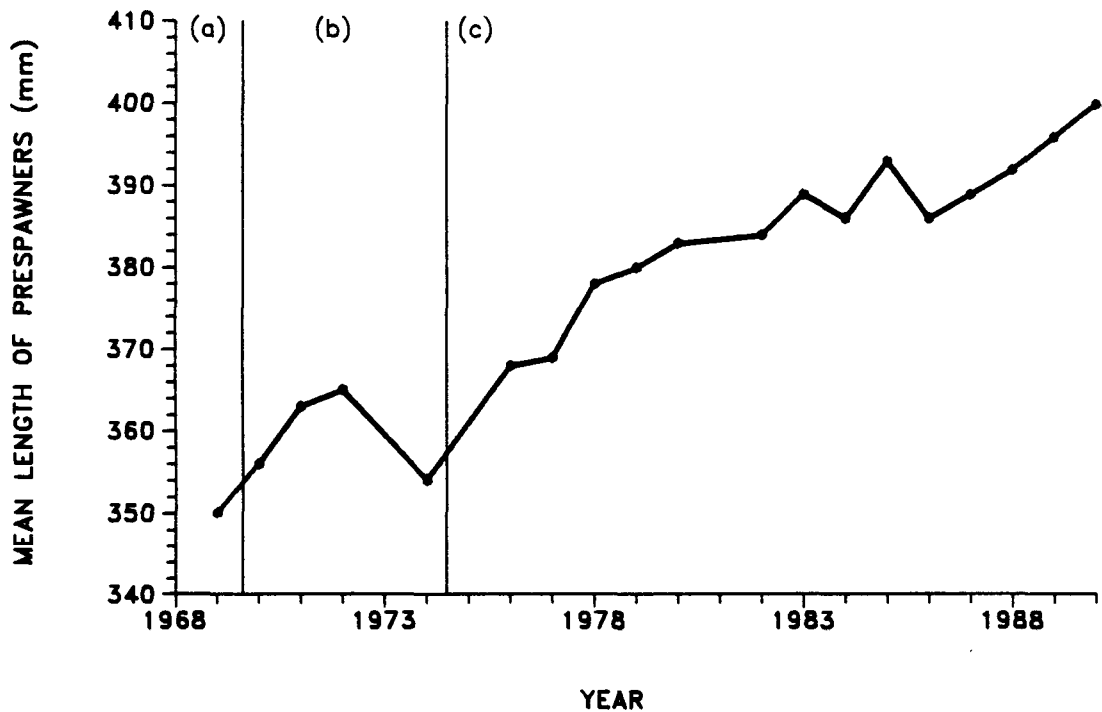


FIGURE 7.-Relative abundance index and mean length for cutthroat trout prespawners captured in experimental largemouth gill nets, Yellowstone Lake, 1969 to 1990. Angling regulations: (a) 1969, no size limit and three-trout-per-day creel limit; (b) 1970 to 1974, 356-mm minimum-size limit and two- or three-trout-per-day creel limit; and (c) 1975 to 1990, 330-mm maximum-size limit and two-trout-per-day creel limit.

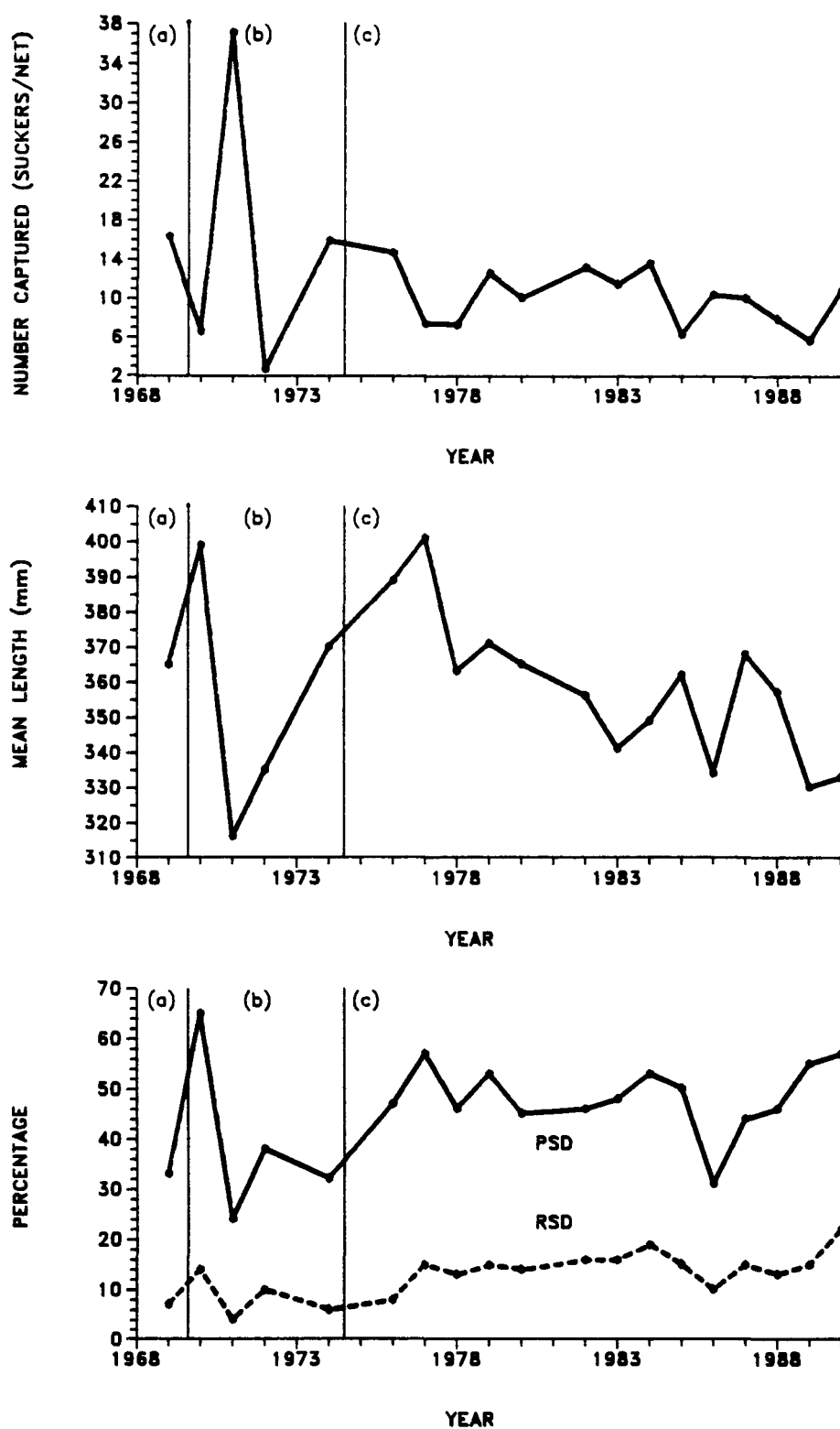


FIGURE 8.-Relative abundance index, mean length, Proportional Stock Density (PSD) estimates, and Relative Stock Density (RSD) estimates of longnose suckers captured in experimental largemouth gill nets, Yellowstone Lake, 1969 to 1990. Angling regulations: (a), (b), and (c) 1969 to 1990, five fish of any size.

varied between 6 and 22%. Although no significant trends were evident in mean length ($r = -0.33$; $P = 0.17$) or PSD estimates ($r = 0.31$; $P = 0.19$), RSD estimates have risen significantly ($r = 0.67$; $P < 0.01$) (Figure 8).

Mean number of longnose sucker prespawners captured per net has varied between 1.4 and 20.4 between 1969 and 1990, but no significant trend ($r = -0.46$; $P = 0.05$) was detected (Figure 9). During this same period the mean length of longnose sucker prespawners has fluctuated between 377 and 420 mm, but no significant trend ($r = 0.40$; $P = 0.09$) was evident (Figure 9).

Discussion and Conclusions

Cutthroat Trout

Gresswell and Varley (1988) summarized the effects of human activity on the Yellowstone cutthroat trout stocks of Yellowstone Lake between the late 1800s and the mid-1980s. They concluded that the commercial fishery and hatchery operations had serious negative effects on the trout stocks and that sport-fishery regulations in effect between the early 1900s and 1974 led to excessive harvest of large and old fish. Gresswell and Varley (1988) also documented positive changes in the cutthroat trout stocks between 1975 and the mid-1980s. These changes apparently resulted from the implementation in 1975 of the 330-mm maximum-size restriction and two-trout-per-day creel limit.

Based on the data presented in this report, it is evident that the positive changes in the cutthroat trout stocks reported by Gresswell and Varley (1988) are continuing. Length-structure data from the sport fishery, Clear Creek spawning run, and largemouth gillnetting reveal that the proportion of larger trout continues to increase. Data from the Clear Creek trap reveal that the proportion of older trout in the spawning run continues to increase.

The 330-mm maximum-size restriction and two-fish-per-day creel limit are benefitting the cutthroat trout stocks of Yellowstone Lake. By directing angler harvest toward smaller fish and taking advantage of compensatory survivorship, the proportion of larger and older cutthroat trout in the population is increasing. How long these positive trends will continue may in part depend on future trends in angler-caused mortality. If angler-caused mortality increases substantially, the current regulation may have to be adjusted to ensure adequate protection for the cutthroat trout stocks of Yellowstone Lake.

Longnose Sucker

Data from the largemouth gillnetting study suggest that since 1969 the proportion of longnose suckers ≥ 457 mm long has increased. Reasons for the shift in the longnose sucker

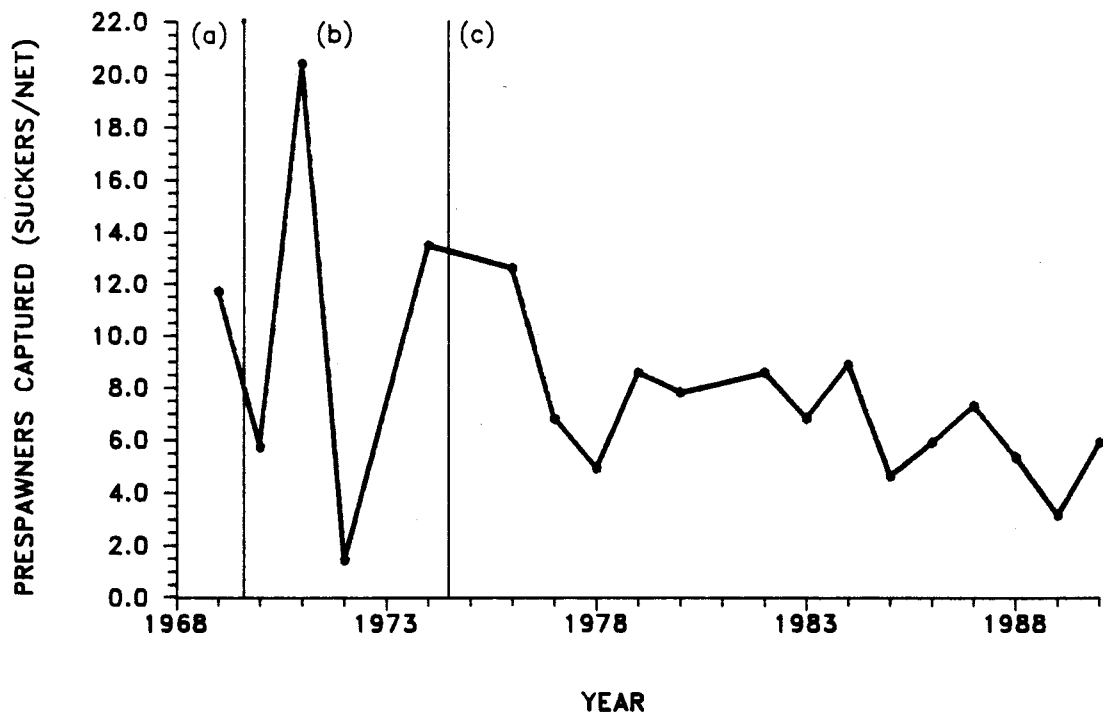


FIGURE 9.-Relative abundance index and mean length of longnose sucker prespawners captured in experimental largemouth gill nets, Yellowstone Lake, 1969 to 1990. Angling regulations: (a), (b), and (c) 1969 to 1990, five fish of any size.

population, if real, are poorly understood. Because longnose suckers are rarely caught in Yellowstone Lake by anglers, it is probable that the change has occurred in response to factors independent of the sport fishery. It is also possible that the observed change is independent of interactions with cutthroat trout, because longnose suckers and cutthroat trout probably do not compete spatially or temporally in Yellowstone Lake (Gresswell and Varley 1988).

GRANT VILLAGE SPAWNING AND ASSOCIATED BEAR USE SURVEY: 1986 to 1990

Grizzly bears *Ursus arctos horribilis* and black bears *U. americanus* prey on spawning Yellowstone cutthroat trout *Oncorhynchus clarki bouvieri* in tributary streams of Yellowstone Lake (Hoskins 1974, 1975; Mealy 1975; Reinhart and Mattson 1986; Jones et al. 1989). Bear predation on spawning trout in streams in Grant Village has created concerns about potential bear-human conflicts. To address these concerns, monitoring techniques developed by the U.S. Fish and Wildlife Service and the Interagency Grizzly Bear Study Team have been used annually since 1986 by the National Park Service (NPS) to detect the onset, peak, and end of the spring spawning run and to estimate associated bear use.

Stream monitoring results are used to help minimize bear-human conflicts in Grant Village (e.g., setting an opening date for the Grant Village Campground). This arrangement was first introduced by the NPS in 1986 and extended in 1988 when Grant Village was designated as a special Bear Management Area (NPS 1986, 1988).

Study Area

Grant Village occupies an area of approximately 3.75 km² adjacent to the West Thumb of Yellowstone Lake. Visitor services include a ranger station, visitor center, gas station, general store, restaurants, motel lodging, and a 418-site campground. Employee housing, a maintenance shop, and sewage and water treatment plants provide support for the visitor services. Camping, boating, sightseeing, picnicking, day hiking, bicycling, and angling are popular recreational activities.

Five streams flow through Grant Village to Yellowstone Lake (Figure 10). Big Thumb Creek, bordering Grant Village on the north, is the largest stream and the only perennial stream in the area. Stream 1167 and Sandy Creek flow through the campground. Stream 1165 enters the lake east of the visitor lodging area. Sewer Creek borders Grant Village on the southeast and passes near a concessionaire trailer court.

Methods

Grant Village Resource Management and Visitor Protection staff monitored spawning streams from May through July 1990. Sampling was concentrated on Stream 1167, Sandy Creek, and Sewer Creek. Big Thumb Creek was not sampled because spawning occurs in areas not used extensively by humans. Stream 1165 was not sampled because previous studies (Jones et al. 1986, 1987, 1988) indicated that spawners usually do not enter this stream.

To detect the onset of spawning, daily visual observations of Stream 1167, Sandy Creek, and Sewer Creek began on 1 May. After spawning began, observers conducted weekly visual counts to

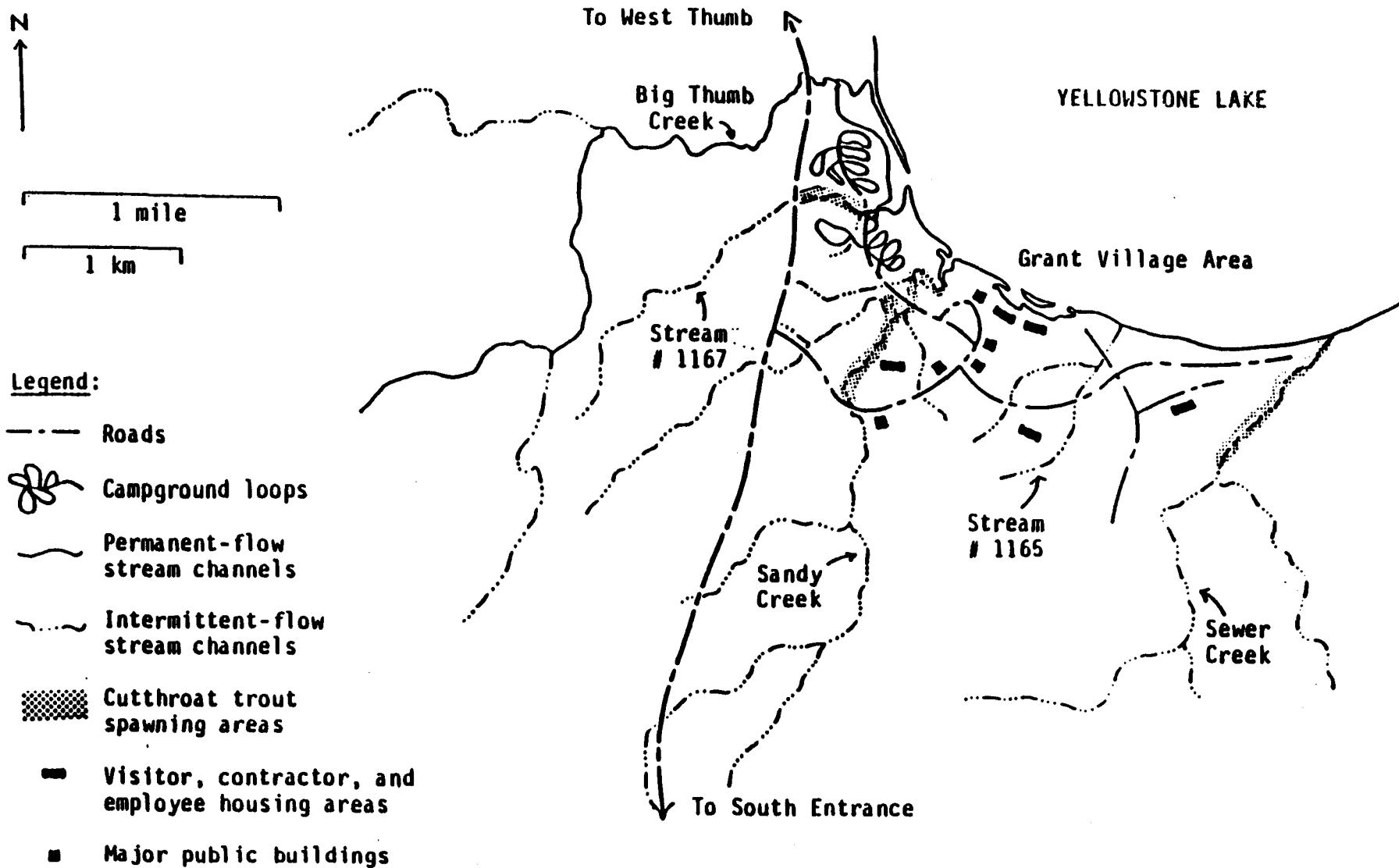


FIGURE 10.-Grant Village area showing major roads, stream channels, buildings, campground loops, housing areas, and cutthroat trout spawning areas.

monitor numbers and distribution of spawners. On each sample date, observers walked from the stream mouth upstream as far as spawners were found and counted spawners in each stream. Sampling continued weekly until most spawners had returned to the lake. All counts were made between 1035 and 1800 hours to maximize comparability among streams. Spawner counts on Sewer Creek were not completed on 13 and 20 June because observers encountered black bears along the stream channel.

While conducting fish counts, observers also recorded bear sign (e.g., sightings, fish parts, scat, and tracks). Tracks and track measurements were used to determine bear species and estimate the number of individual bears using the streams. Overlapping track sizes (less than 1 cm difference) were considered to be the same bear. Bear use was classified as light, moderate, or heavy on the basis of indices developed by Reinhart (1988).

Results

Cutthroat Trout Spawning 1990

Cutthroat trout began spawning in Stream 1167, Sandy Creek, and Sewer Creek on 11 May, 14 May, and 18 May, respectively (Figure 11). Peak spawner counts occurred on 30 May in all three streams. Weekly counts indicated that the number of spawners in Sewer Creek and Sandy Creek was similar, followed by Stream 1167. Fish were last observed in Sewer Creek on 11 July and in Stream 1167 and Sandy Creek on 18 July (Figure 11).

Bear Use 1990

Between four and six grizzly bears used Grant Village spawning streams in 1990. This group included two lone subadults, one female with a cub of the year, and one lone adult. Two adult black bears and one or two subadult black bears also used Grant Village streams in 1990.

Bear sign on Stream 1167 was greatest on 6 June and bear sign on Sewer Creek was greatest from 6 to 20 June. Bear sign on Sandy Creek was greatest (classified as moderate) on 23 and 30 May and 6 June. Bear sign was last observed on 20 June on Stream 1167, 4 July on Sandy Creek, and 18 July on Sewer Creek (Table 4).

One grizzly bear that had become habituated to humans was removed by the NPS from Grant Village during the spawning season. Bear 173, a subadult male grizzly bear, was trapped in Grant Village on 19 May and relocated to the northern part of Yellowstone National Park. This bear did not return to Grant Village in 1990. Another subadult male grizzly bear, 3 years of age, was hit and killed by an automobile near Little Thumb Creek on 2 July.

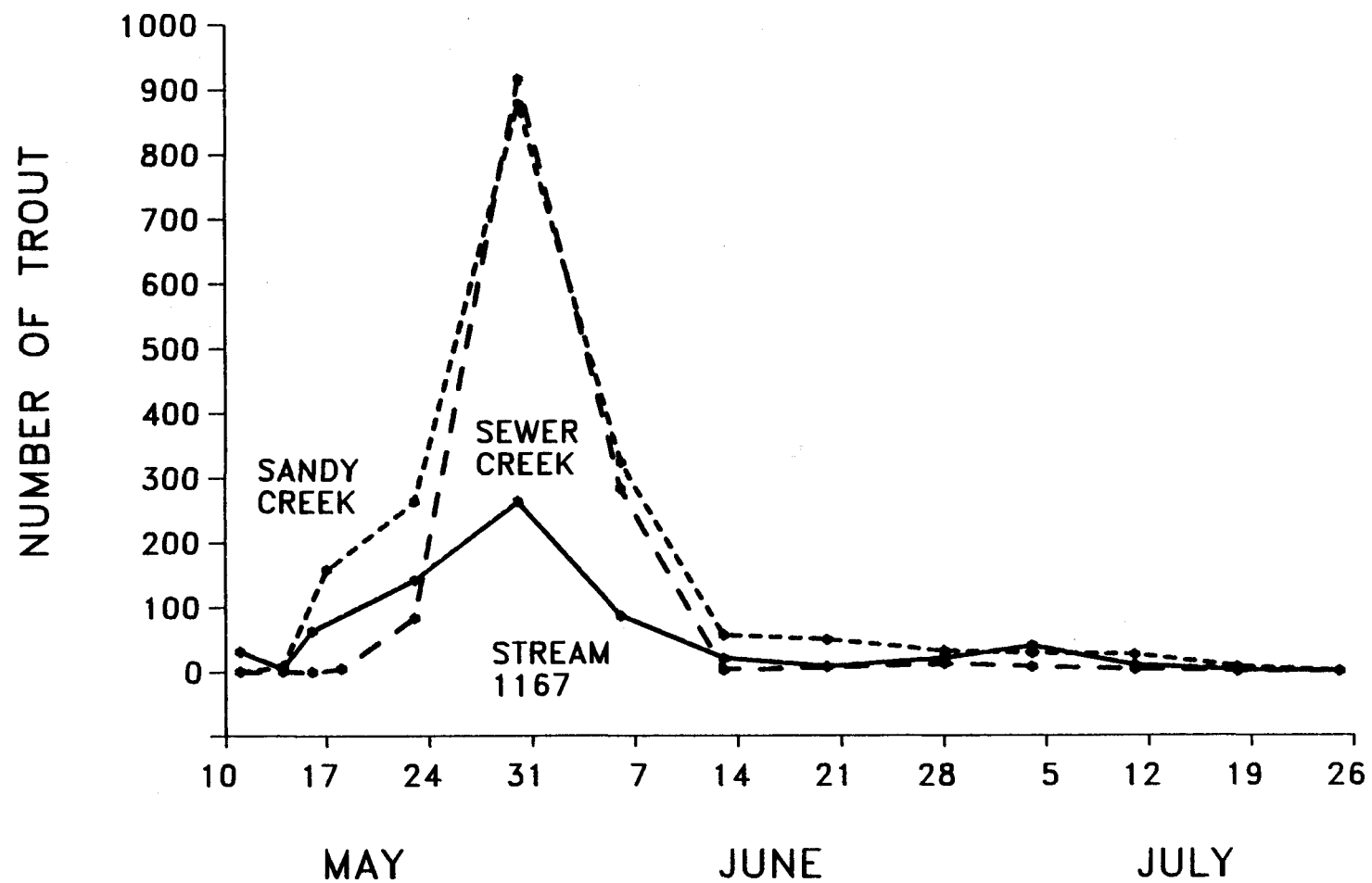


FIGURE 11.-Counts of cutthroat trout spawners in three streams at Grant Village, 1990.

TABLE 4.-Observed bear use of Grant Village spawning tributaries, 1990.

Date	Stream 1167	Sandy Creek	Sewer Creek
16 May	63 fish LIGHT Bear Use	158 fish LIGHT Bear Use	No Monitoring
23 May	142 fish MODERATE Bear Use	263 fish MODERATE Bear Use	83 fish LIGHT Bear Use
30 May	263 fish LIGHT Bear Use	877 fish MODERATE Bear Use	915 fish MODERATE Bear Use
6 June	86 fish HEAVY Bear Use	323 fish MODERATE Bear Use	283 fish HEAVY Bear Use
13 June	20 fish MODERATE-HEAVY Bear Use	56 fish No Bear Sign	2 fish HEAVY Bear Use
20 June	7 fish LIGHT Bear Use	49 fish No Bear Sign	Count Aborted 2 Bears Observed
28 June	21 fish No Bear Sign	31 fish No Bear Sign	12 fish MODERATE-HEAVY Bear Use
4 July	40 fish No Bear Sign	28 fish LIGHT Bear Use	7 fish MODERATE Bear Use
11 July	7 fish No Bear Sign	26 fish No Bear Sign	3 fish LIGHT Bear Use
18 July	1 fish No Bear Sign	7 fish No Bear Sign	0 fish MODERATE Bear Use
25 July	Not Monitored	Not Monitored	No fish No Bear Sign

Grant Village Area Management 1990

The Grant Village Campground was opened on 20 June (loops F through K) and 21 June (loops A through E), on the basis of declining amounts of bear sign associated with spawning trout. The Sandy Creek Picnic Area was opened on 28 June and the Grant Village employee fire ring near Sewer Creek was opened on 5 July.

Stream 1167 and Sandy Creek were opened to the public on 18 July and Sewer Creek was opened on 25 July. The delayed openings were not completely effective, however, because human tracks were observed on all three streams in early June, and two people were cited for illegally entering Sandy Creek on 7 June.

Discussion

Annual Variation in Spawning Migrations 1986 to 1990

During the past 5 years, spawning in Stream 1167, Sandy Creek, and Sewer Creek has begun as early as the first week of May and as late as the second week of June (Figure 12). Annual variation in the onset of spawning is probably influenced by annual variation in climatic conditions and thus is difficult to predict. In Stream 1167, Sandy Creek, and Sewer Creek (Jones et al. 1988), as in many other Yellowstone Lake tributaries (Cope 1957; Jones et al. 1978 to 1981), cutthroat trout spawners begin entering streams as streamflows decline from peak spring runoff and water temperatures increase to 8-10°C.

As in the previous 4 years, the 1990 spawning run in Sewer Creek began later than in Stream 1167 and Sandy Creek (Figure 11). Sandy Creek and Sewer Creek apparently had spawning runs of similar magnitude in 1990; in contrast, Sandy Creek had the largest spawning run in the previous 3 years. Greater runoff in Sewer Creek in 1990 may have increased available spawning habitat compared to previous years. Stream 1167 again had the lowest number of spawners in 1990 (Figure 11).

Bear-Use Trends 1986 to 1990

Bear predation on spawning fish in tributary streams of Yellowstone Lake is apparently increasing. Reinhart and Mattson (1990) observed that 61% of Yellowstone Lake tributary streams with spawning runs had evidence of bear fishing compared to 19% from a similar study 10 years earlier (Hoskins 1975).

Bear use of Grant Village streams may also be increasing. Data from 1989 suggest Grant Village streams were used by three grizzly bears and one black bear. In 1990, Grant Village streams were used by at least four grizzly bears and three black bears.

Reinhart and Mattson (1990) suggested that in Yellowstone National Park, bears increased their use of spawning streams as part of their transition from substantial use of human foods (e.g., garbage) to natural foods. If this trend continues, more

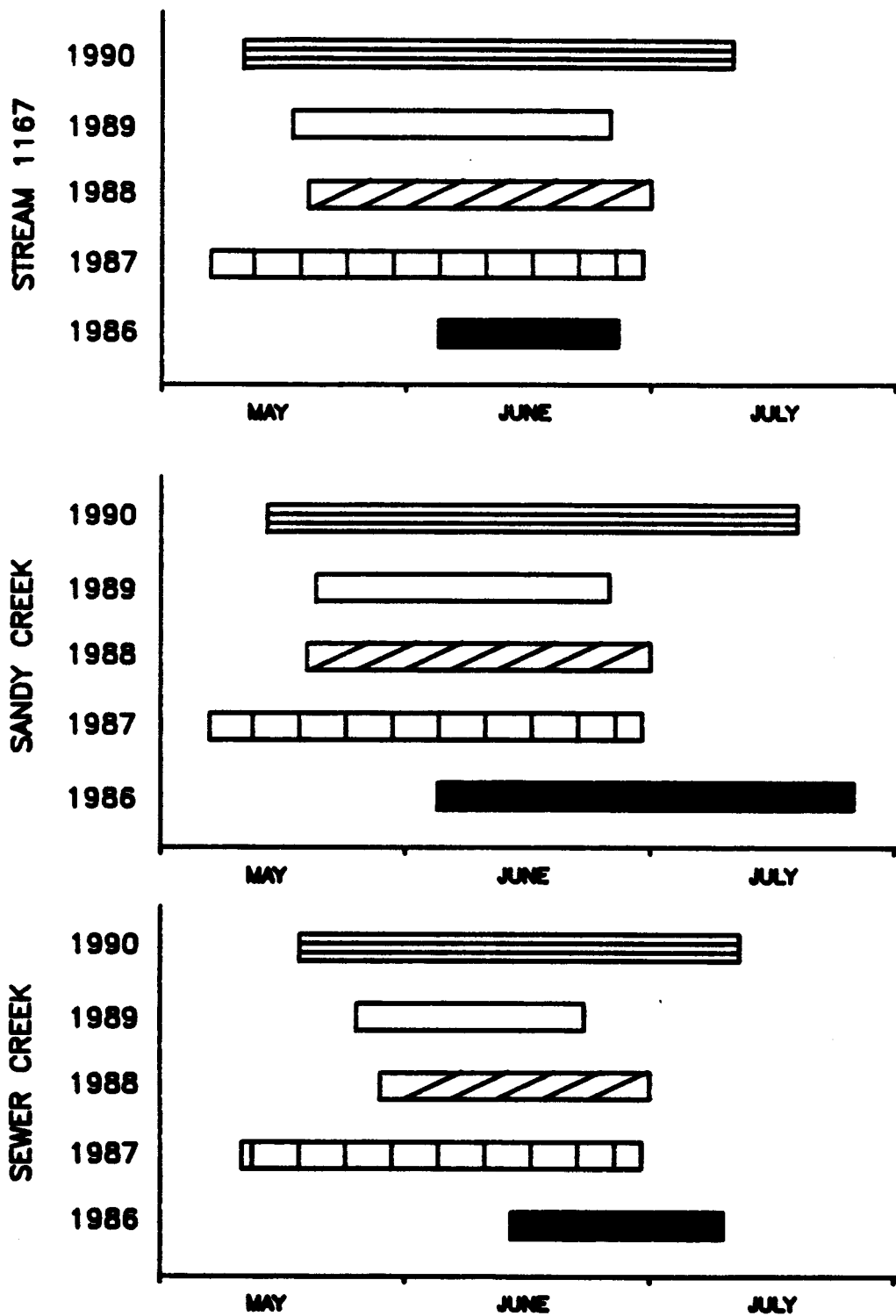


FIGURE 12.-Duration of cutthroat trout spawning runs in three streams at Grant Village, 1986 to 1990.

bears can be expected to use Yellowstone Lake spawning streams in the future.

Greatest bear use generally occurs after the spawning run peaks. Reinhart and Mattson (1987) found that bear use of Yellowstone Lake tributaries began at the peak of spawning, was greatest after the peak of spawning, and declined after that. Stream 1167 and Sewer Creek followed this general pattern in 1990. All three streams monitored in Grant Village in 1989 followed this pattern.

Grant Village streams are intermittent and by late June (in most years), spawners become trapped in pools. These fish may attract bears later than would be expected on the basis of spawning-run patterns in streams with permanent flows.

Human developments in areas adjacent to spawning streams may interfere with bear foraging strategies. Reinhart and Mattson (1990) found that spawning streams within 1 km of Park developments had 90% less bear use in 1986 and 30% less use in 1987 than comparable backcountry streams. They also observed that 61% of backcountry streams were fished by bears compared to 24% of streams near human developments.

Mattson et al. (1987) found that subordinate bears (subadults and females with young) were displaced into habitats near developments by more dominant bears, and the data from Grant Village in both 1989 and 1990 support this conclusion. Of a minimum seven grizzly bears using the Grant Village streams during these 2 years, all but one appeared to be lone subadults or sows with cubs.

Bears using spawning streams near developments have an increased probability of contact with humans, and continued contact with humans may lead to bear habituation. Habituated bears have caused injury to humans (Herrero 1985), and some habituated bears have been removed from the Yellowstone National Park population (Meagher and Fowler 1989).

Management Implications

Management at Grant Village should continue to focus on regulating human use to minimize the potential for bear-human conflicts. Timing of the annual spawning run and associated bear use is difficult to predict; therefore, it is important to continue to monitor spawning streams and open the Grant Village Campground on the basis of resulting data. The current low-cost monitoring technique provides a useful means of determining when the Grant Village Campground can be safely opened.

LAKE AREA-BRIDGE BAY SPAWNING SURVEY: 1989 to 1990

Conflicts between humans and wildlife are major concerns in Yellowstone National Park. From May through July, adfluvial Yellowstone cutthroat trout *Oncorhynchus clarki bouvieri* from Yellowstone Lake spawn in tributaries (Hoskins 1974, 1975; Jones et al. 1986, 1987) and are preyed on by grizzly bears *Ursus arctos horribilis* and black bears *U. americanus* (Hoskins 1974, 1975; Jones et al. 1990; Reinhart 1990). The cutthroat trout spawning season coincides with the opening of visitor facilities in the Lake Area and Bridge Bay (LA-BB). The National Park Service is attempting to minimize the potential for human-bear conflicts in the LA-BB area during the spawning season by managing human use. Effective human-use management requires accurate information on cutthroat trout spawning and bear activity patterns.

Yellowstone Lake tributaries used by Yellowstone cutthroat trout for spawning in the LA-BB area have been identified (Hoskins 1974, 1975; Jones et al. 1986, 1987; Reinhart and Mattson 1986, 1987; Reinhart 1990), and limited data on the timing of spawning migrations have been collected (Jones et al. 1986, 1987; Reinhart 1990). Based on recommendations by the U.S. Fish and Wildlife Service, the Interagency Grizzly Bear Study Team, and the National Park Service, cutthroat trout spawning and bear activity patterns in the LA-BB area were monitored in 1989 (Jones et al. 1990) and 1990. The objectives of this study are to determine the timing (onset, peak periods, and duration) and relative magnitude of spawning runs and to document bear activity along spawning streams.

Study Area

The LA-BB area is on the north shore of Yellowstone Lake (Figure 13). Major visitor services in the Lake Area include a ranger station, general store, restaurants, lodging, hospital, and U.S. Fish and Wildlife Service field station. Housing for National Park Service, U.S. Fish and Wildlife Service, and concessioner employees is in the Lake Area. Major visitor services in Bridge Bay are a ranger station, seasonal ranger residence, marina, general store, and campground. Sightseeing, picnicking, day hiking, bicycling, boating, and angling are popular recreational activities in the LA-BB area.

There are 15 tributaries of Yellowstone Lake in the LA-BB area (Figure 13). Cutthroat trout spawn annually in Lodge Creek, Hatchery Creek, Streams 1199, 1200, and 1204, Wells Creek, and Bridge Creek. In Hotel Creek, a culvert prevents trout from ascending the stream, but trout spawn in the stream mouth. Spawning also occurs in Weasel Creek in years when lake levels are high enough to allow access through the culvert under the Grand Loop Road. Stream 1191 also had a spawning run in 1990. The remaining five streams are not known to support spawning runs (Jones et al. 1986, 1987; Reinhart 1990).

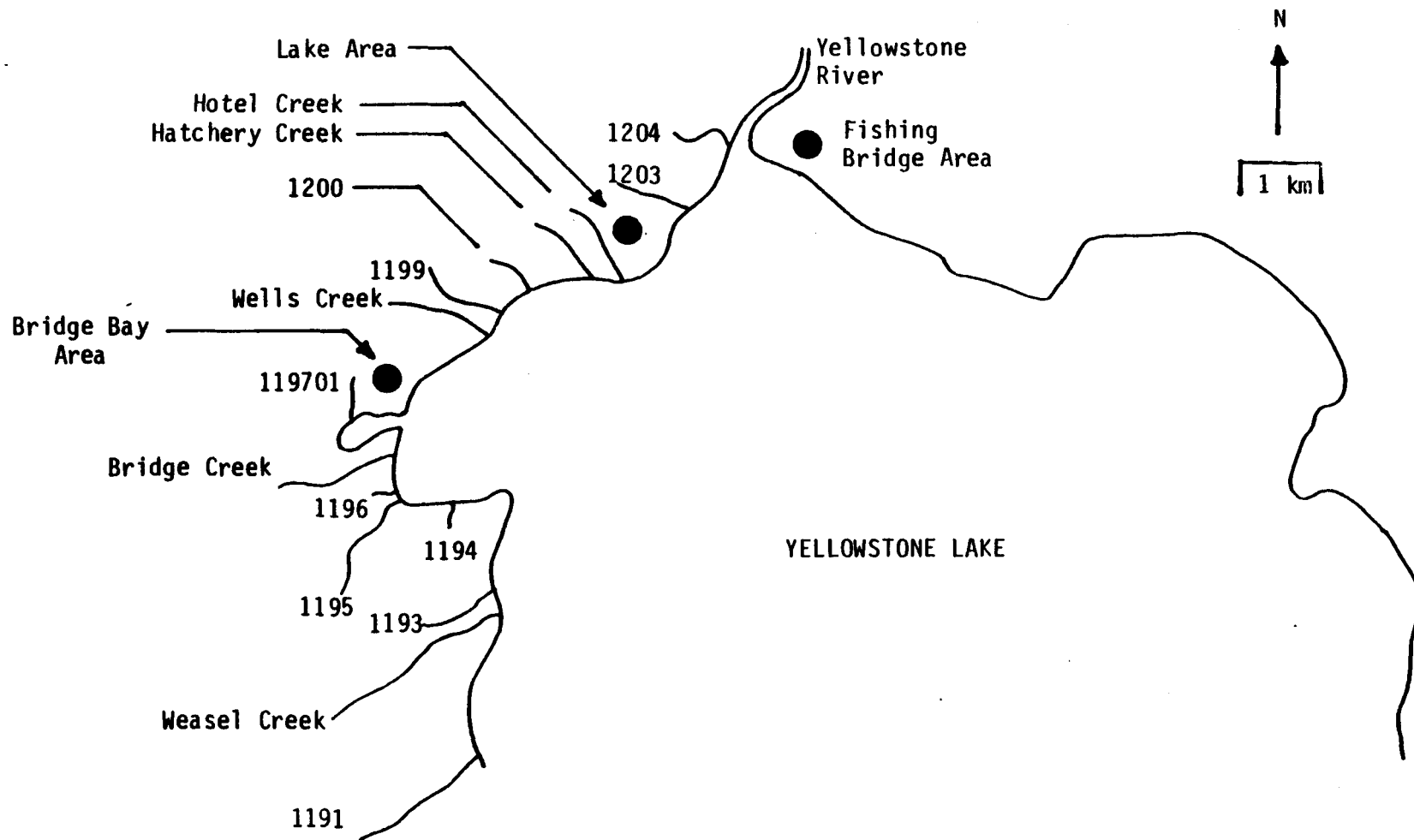


FIGURE 13.-Yellowstone Lake tributaries in the Lake Area and Bridge Bay area, Yellowstone National Park.

Methods

In 1990, cutthroat trout spawning in the LA-BB area was monitored from May through July. Sampling was concentrated on spawning streams near areas of high human use. Weasel Creek was also sampled because a new campground has been proposed nearby.

Streams in the LA-BB area were checked daily beginning 1 May to detect the onset of spawning. Once spawning began, weekly visual counts of fish were used to monitor spawning runs. Each stream was longitudinally stratified into 100- to 200-m-long sampling sections. On each sample date, two observers walked from the stream mouth upstream as far as spawners were found and counted the number of spawners in each stream. Sampling continued weekly until most spawners had returned to the lake. Bear sign (e.g., sightings, fish parts, hair, scats, and tracks) was also recorded weekly. Bear tracks were measured to determine the number, species, and association of family groups for all spawning streams. All observations were made between 0900 and 1800 hours.

Results

Cutthroat Trout Spawning (1990)

The earliest date on which spawners were observed in streams in the LA-BB area was 8 May (two streams), and the last date spawners were found was on 3 July (four streams) (Figure 14). Weekly counts indicated that the largest spawning run occurred in Bridge Creek, followed by Wells Creek, Lodge Creek, Stream 1199, Weasel Creek, Hatchery Creek, and Hotel Creek, respectively (Figure 14).

A sand spit that usually blocks the mouth of Stream 1191 was opened periodically in 1990 by wave action and stream current. On 20 June, 50 spawners were observed in this stream within a 100-m section, and 40 fish carcasses or fish parts were observed on the streambank. Some spawners were stranded in this stream in late June when streamflow became intermittent and the mouth was again blocked off by the sand spit. The spawning run in Stream 1191 lasted about 2 weeks.

Bear Activity (1990)

Bear sign and evidence of bear predation on spawning trout were found along most LA-BB spawning streams in 1990. Grizzly bear tracks were first found along Hatchery Creek and Bridge Creek on 22 May, Lodge Creek and Stream 1199 on 5 June, Stream 1191 on 20 June, and Wells Creek on 26 June. No tracks were observed along Hotel Creek or Weasel Creek; however, a grizzly bear sow and cub were seen at the mouth of Hotel Creek on 26 June. Grizzly bear tracks and sightings, as well as bear predation on spawning trout, have been observed in previous years

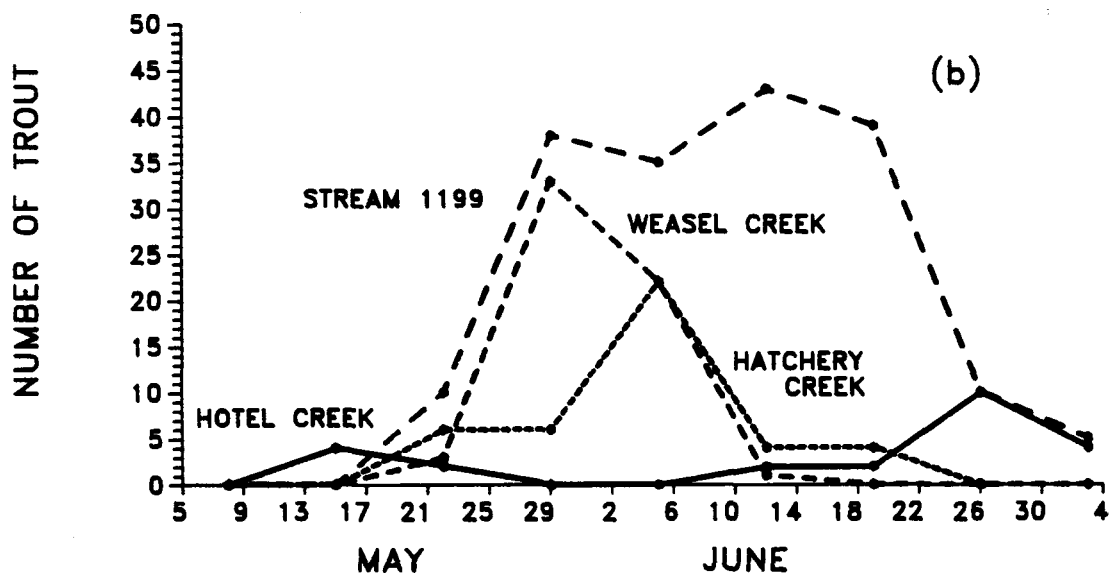
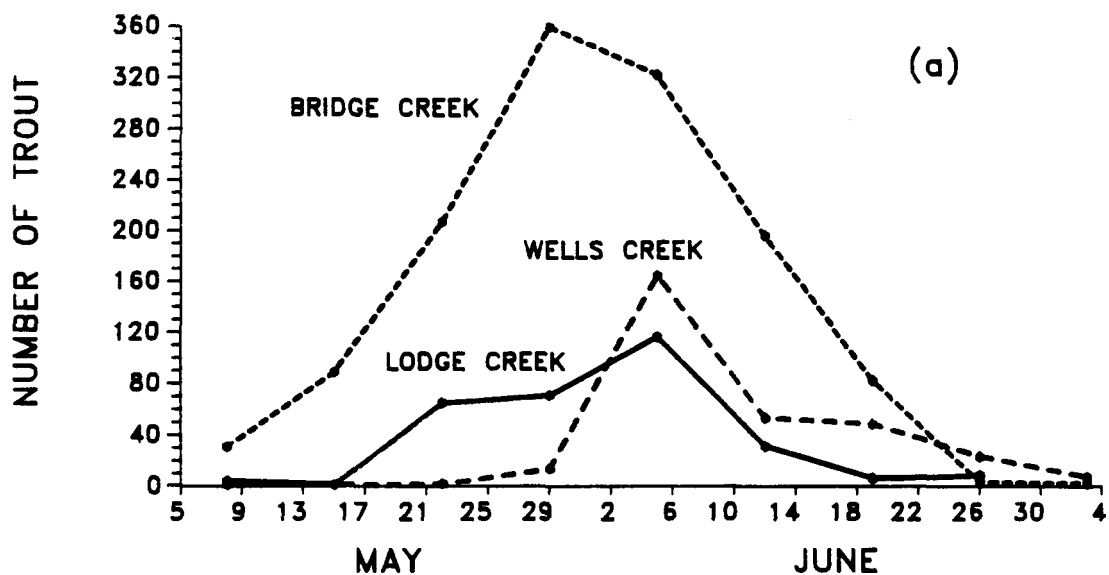


FIGURE 14.-Counts of cutthroat trout spawners in seven streams in the LA-BB area, 1990 ((a) streams in which maximum spawner counts exceeded 100, and (b) streams in which maximum spawner counts were less than 100).

along Hotel Creek and Weasel Creek (French and French 1990; Reinhart 1990).

Track measurements made during fish surveys indicated that seven or eight bears used the streams; six or seven were grizzly bears and one could not be identified. Two of the grizzly bears were with young, one with a cub-of-the-year and the other with a yearling.

Discussion

Variation in Spawning Runs (1989 to 1990)

Annual variation in onset of spawning is probably influenced by annual variation in climatic conditions. In Yellowstone Lake tributaries, cutthroat trout usually enter spawning streams as peak spring flows decline and water temperatures approach 8 to 10°C (Cope 1957; Jones et al. 1978, 1979, 1980, 1981). Duration of spawning runs in streams may be limited by streamflow, natural blockage of the stream mouth by sand spits, or road culverts. Magnitude of spawning runs may be a function of access and the availability of suitable spawning habitat.

In 1990, spawning in LA-BB area streams began about 1 to 2 weeks earlier than in 1989 and for most streams ended about 1 week later than in 1989 (Figure 15). Highest spawner counts in 1990 were in Bridge Creek, followed by Wells Creek, Lodge Creek, Stream 1199, Weasel Creek, Hatchery Creek, and Hotel Creek, respectively. In 1989, highest spawner counts were in Bridge Creek, followed by Lodge Creek, Wells Creek, Hatchery Creek, Stream 1199, and Weasel Creek, respectively. No spawning was observed in Hotel Creek during 1989.

Bear Activity Trends (1989 to 1990)

Bear predation on spawning cutthroat trout has apparently increased since the 1970s. Reinhart (1990) found 56 spawning streams with associated bear activity during the 1980s as opposed to 17 during the 1970s (Hoskins 1975). During the 1970s, bears were switching from a substantial use of solid-waste disposal areas within the Park to a more natural food base (Reinhart and Mattson 1990).

Based on track-measurement data, the number of bears using spawning streams in the LA-BB area increased between 1989 and 1990. In 1989, tracks of three or four grizzly bears and one black bear were found along LA-BB area spawning streams. The track data also indicated that one of the grizzly bears was a sow with two cubs-of-the-year. In 1990, tracks of seven or eight bears were found along spawning streams in the LA-BB area; six or seven of these bears were grizzly bears, and one bear was not identified. The track data also indicated that two or three of the grizzly bears were sows with young. One sow grizzly bear

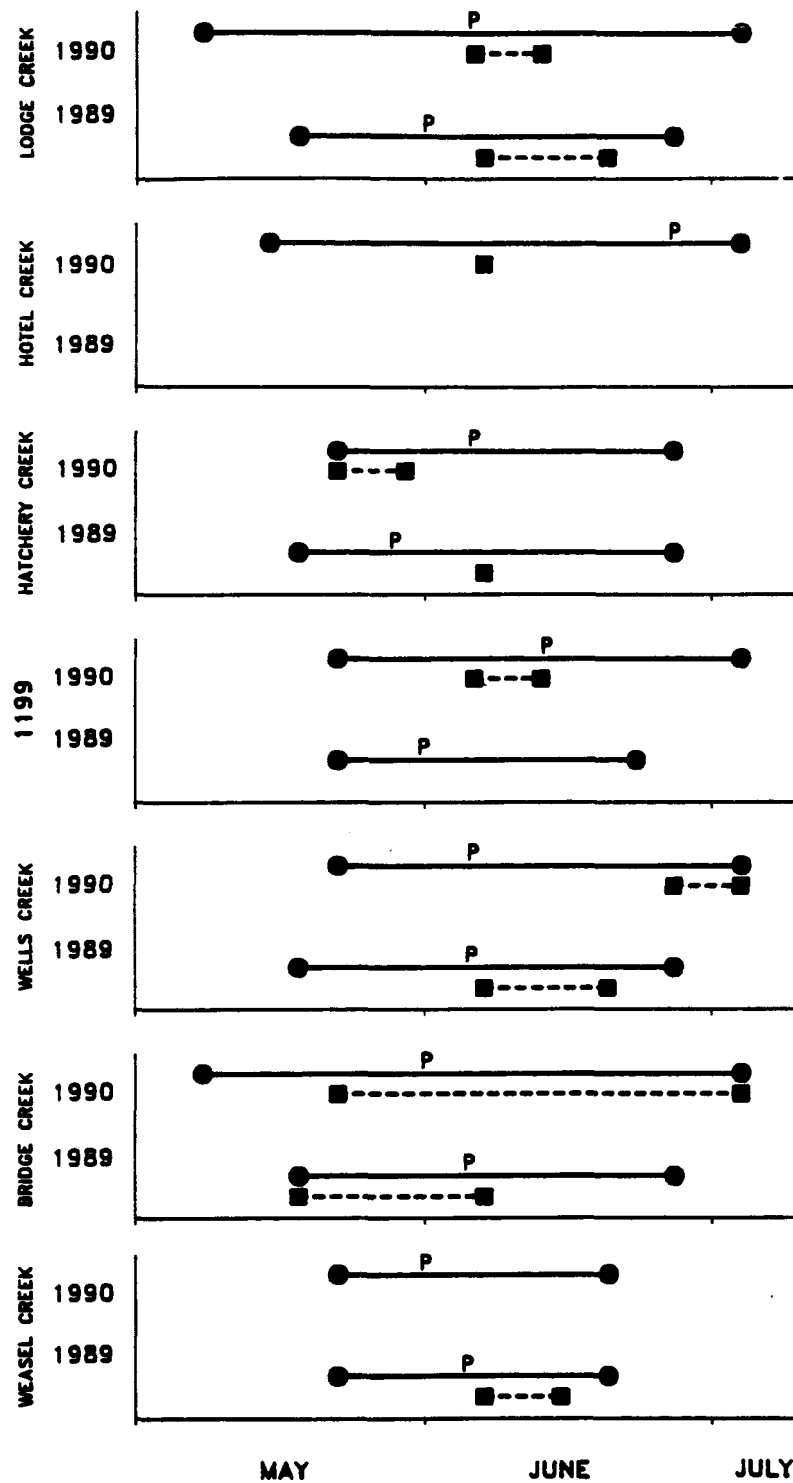


FIGURE 15.-Duration of cutthroat trout spawning runs (●—●) and bear activity (■-----■) in seven streams in the LA-BB area, 1989 to 1990 (P refers to approximate date of peak spawning).

apparently was with a cub-of-the-year, and the other was with a yearling.

Analysis of 1990 track data also suggested that the number of bears using a single spawning stream at any one time in LA-BB area ranged between one and five. For example, tracks of five bears (including two sows with cubs) were found along Bridge Creek. These results are similar to those of Reinhart (1990), who estimated that a maximum of four to six bears used a single spawning stream at any one time.

It is probable that not all bears using spawning streams in the LA-BB area in 1989 and 1990 were tallied by track analysis because trackable substrate was not always ideal. French and French (in press) observed that bears preying on fish often walked in the stream, thus reducing the presence of tracks. Reinhart (1990) stated that the track census method probably underestimated the number of bears using a stream.

Bear predation on spawning trout appears strongly related to fish density. Reinhart and Mattson (1990), Jones et al. (1990), and results from the LA-BB area in 1990 indicated that bear activity began at the peak of the spawning run, was highest after peak spawning, and declined thereafter. One reason for this pattern may be that trout returning to the lake after spawning are often in poor condition and thus more vulnerable to predators. Also, as stream flows decline during summer, vulnerability of trout to predation increases.

Mattson et al. (1987) found that subordinate bears (subadults and females with young) were often displaced into habitats near developments by more dominant bears, and the data from the LA-BB area show a similar pattern. It is hypothesized that less-dominant bears take advantage of feeding opportunities when other bears prefer to bed down or stay under cover.

Bears using streams in areas close to Park developments may be negatively affected by the presence of humans. Reinhart and Mattson (1990) found that bear use of spawning streams less than 1 km from Park developments was less than expected despite high spawner densities. Although some bears are likely displaced away from streams near developed areas, others may be attracted to the area and become habituated to the presence of humans and human activity. This may occur because natural food attractants, such as spawning cutthroat trout, outweigh the effects that human presence might otherwise have or because other bears may dominate more secure habitats. Adult female and subadult grizzly bears are more likely to forage closer to humans and become habituated. Habituation entails greater risk of injury to humans (Herrero 1985); therefore, these bears may be more likely to become involved in management actions and potential removals (Mattson 1990).

Management Options

In an effort to reduce the potential for human-bear conflicts in the LA-BB area during the cutthroat trout spawning

season, several management actions have been implemented:

(1) closing spawning streams to human access during the spawning season; (2) temporarily restricting human access and use of portions of the LA-BB developed areas that bears frequent; (3) phasing in campground and lodging unit loops near spawning streams and bear travel corridors; and (4) public education through brochures, signs, and visitor contacts. These management actions should be reviewed and updated annually.

Because of concession operations and annual variation in timing and duration of spawning runs, it has been difficult to establish a predetermined date for opening the visitor facilities in the LA-BB area. However, it is also not practical to allow unregulated human access to spawning areas. Data collected in 1989 and 1990 can help minimize potential human-bear conflicts in the LA-BB area during the cutthroat trout spawning season, and it is recommended that monitoring cutthroat trout spawning and bear activity be continued in 1991.

YELLOWSTONE RIVER:
YELLOWSTONE LAKE OUTLET TO UPPER FALLS

Fishing for Yellowstone cutthroat trout *Oncorhynchus clarki bouvieri* in the Yellowstone River between the Yellowstone Lake outlet and the Upper Falls has probably been popular since Jordan (1891) described the abundance of trout in this reach as "remarkable" and Evermann (1892) stated that both large and small trout were very abundant. Today, this section of river is the second-most-popular fishery in Yellowstone National Park, ranking only behind the Yellowstone cutthroat trout fishery of Yellowstone Lake. Moreover, this river reach may be one of the most intensively fished wild trout fisheries in North America (Jones et al. 1990).

Increasingly restrictive angling regulations have been implemented over the years to protect the native cutthroat trout population in this section of the Yellowstone River. The creel limit was 20 trout of any size per day during the 1920s, 10 trout of any size per day during the 1930s, and five trout of any size per day between 1949 and 1953 (Dean and Mills 1971). The creel limit was reduced to three trout of any size per day in 1953 (Dean and Mills 1971), despite the conclusion of Moore et al. (1952) that angling was not negatively affecting the cutthroat trout population. Subsequently, Benson and Bulkley (1963) concluded that the resident river trout population was being overexploited by anglers, recommended that the daily creel limit be reduced, and stated that a minimum-length limit be established. However, no further changes in angling regulations were made until 1973, when catch-and-release-only angling was instituted.

The length of the fishing season has also been adjusted over the years to protect this native cutthroat trout population. The fishing season lasted from 23 May to 20 October prior to 1938, did not open until 1 July between 1938 and 1964, and has not opened earlier than 15 July since 1965 (Dean and Mills 1971). Currently, the fishing season ends on the first Sunday in November.

Although all 26 km of the Yellowstone River between the Yellowstone Lake outlet and the Upper Falls were once open to angling, three sections have been closed to protect cutthroat trout or to provide Park visitors with the opportunity to watch fish and wildlife. The LeHardy Rapids area has been closed to angling since 1949. A 10-km section of the river in Hayden Valley has been closed since 1965, and the section of river from the Yellowstone Lake outlet to 1.6 km downstream from Fishing Bridge has been closed to angling since 1973.

The goal of this report is to describe and evaluate long-term trends in the sport fishery and Yellowstone cutthroat trout population of the Yellowstone River between the Yellowstone Lake outlet and the Upper Falls.

Study Areas

Catch-and-Release Areas

Two sections of the Yellowstone River between the Yellowstone Lake outlet and the Upper Falls are open to angling. The upper section, nearly 10 km long, begins about 1.6 km below Fishing Bridge and extends downstream to Sulphur Caldron. The lower section starts at the confluence of Alum Creek and the Yellowstone River and extends downstream for 5 km to Chittenden Bridge (Figure 16).

LeHardy Rapids

LeHardy Rapids is a series of small cascades about 6 km downstream from the Yellowstone Lake outlet and within the boundaries of the upper catch-and-release area (Figure 16). During spawning season (May through July), cutthroat trout congregate in pools on the west bank of the river immediately below the rapids. A boardwalk and viewing platform allow Park visitors to watch trout ascend the rapids.

Methods

Data sources and field procedures.—Manned creel surveys and the Volunteer Angler Report (VAR) system provide information on the cutthroat trout sport fishery. Manned creel survey results have been converted from "summer" to "season-long" estimates and averaged for the periods 1951 through 1955, 1967 through 1968, and 1970 through 1972 to maximize comparability with season-long VAR estimates for the years 1973 through 1990 (Jones et al. 1990). Estimates of sport-fishery parameters reported for 1990 include the number of anglers, angler use (number of fishing trips), angler effort (number of hours fished), number of trout landed, mean landing rate (average number of trout landed per hour), mean length of landed trout, number of trout illegally harvested, percentage of anglers satisfied with their fishing experience, and mean expertise level of anglers. Long-term analyses, however, are restricted to angler effort, mean-annual landing rate, and length structure of trout landed (mean length, Proportional Stock Density estimates, and Relative Stock Density estimates).

The LeHardy Rapids study has provided information on the cutthroat trout spawning population since 1974. Cutthroat trout spawners are sampled weekly throughout the spawning season. On each sample day, a maximum of 100 trout are collected by dipnetting from pools along the west bank of the river just downstream of the rapids. Captured trout are classified by sex and spawning condition, measured to the nearest 1 mm total length, and weighed to the nearest 2 g. Scales are collected from a subsample of captured trout for age-growth analysis. Ages

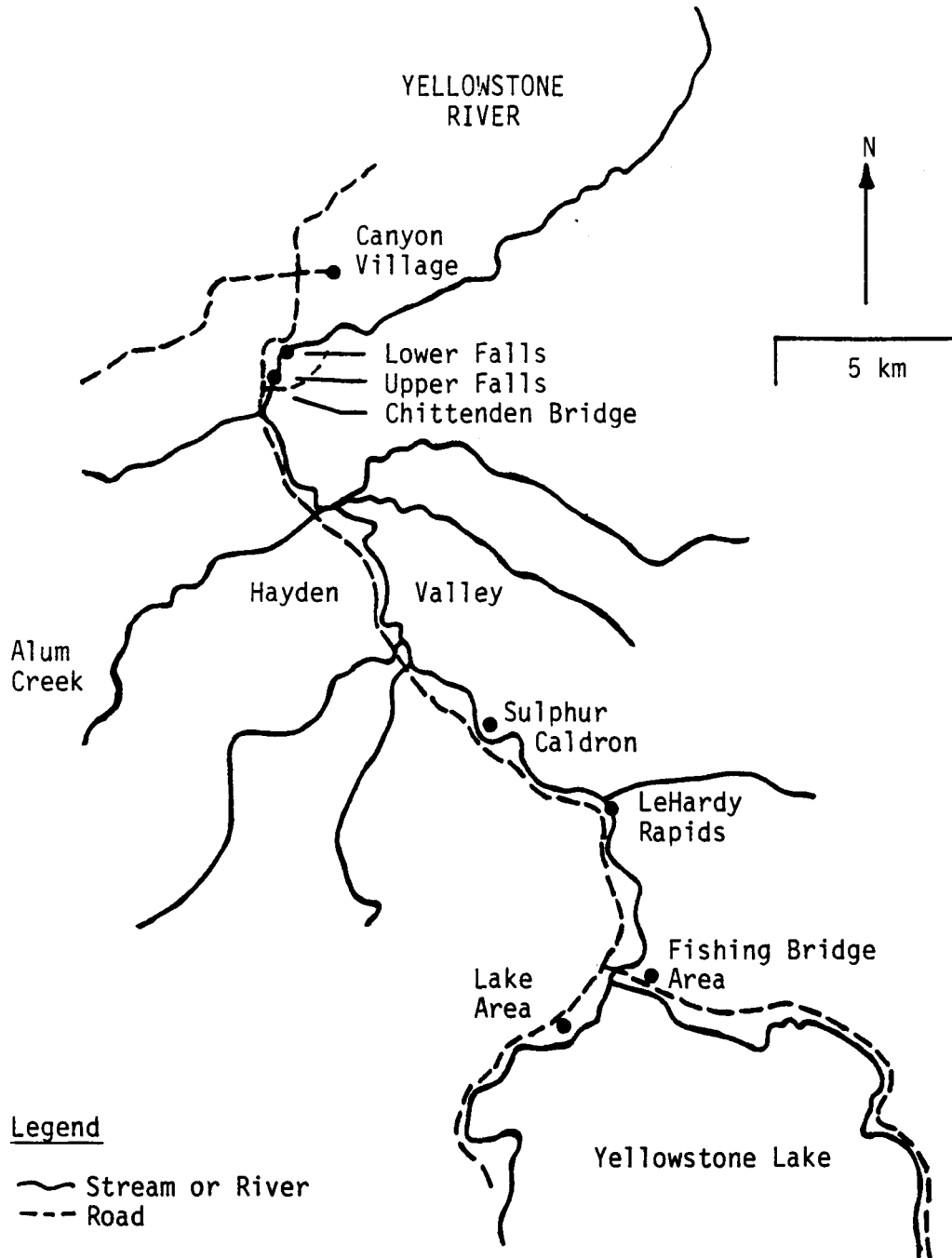


FIGURE 16.-Yellowstone River, Yellowstone National Park, from Yellowstone Lake outlet to the Upper Falls.

are estimated by the scale method (Bagenal and Tesch 1978) and results expanded with an age-length key (Westrheim and Wicker 1978) to obtain an estimate of mean age. In 1990, cutthroat trout were sampled at LeHardy Rapids for 8 consecutive weeks between late May and mid-July. Long-term analyses of data obtained from the LeHardy Rapids study are restricted to length structure and mean age.

Data analysis.—Correlation analysis (Zar 1984; Hintze 1991) was used to detect significant ($P < 0.05$) trends in sport-fishery parameters and characteristics of the spawning population.

Proportional Stock Density (PSD) and Relative Stock Density (RSD) are length-frequency indices (Gabelhouse 1984) that eliminate the influence of smaller fish in data analysis. "Stock", "quality", and "preferred" lengths for cutthroat trout in this study were set at 254, 356, and 406 mm, respectively. Although a preferred length of 406 mm is less than that recommended by Gabelhouse (1984), the growth potential of cutthroat trout in the Yellowstone River was an overriding consideration.

Results

Sport Fishery

Current year.—In 1990, an estimated 16,700 anglers made 50,900 fishing trips and spent 137,400 h fishing the catch-and-release-only sections of the Yellowstone River. In these two sections, anglers landed just over 107,000 Yellowstone cutthroat trout. Average landing rate was 0.8 trout/h, and mean length of landed fish was 412 mm. Approximately 130 of the trout landed were illegally creeled. Nearly 85% of the anglers were satisfied with their overall fishing experience, 77% were satisfied with numbers of trout landed, and 85% were satisfied with sizes of trout landed. About 63% of single-day anglers landed one or more trout. Average angler expertise was 1.96, suggesting that most people who fish these two areas rate themselves as experienced anglers.

Long-term trends (1950s to 1990).—Estimated annual angler effort has increased significantly ($r = 0.54$; $P = 0.01$) between the 1950s and 1990. From the 1950s through 1972, effort averaged about 87,600 h, but in 1973 and 1974 (the first 2 years of the catch-and-release-only regulation), effort dropped to about 57,200 h. Since 1974, however, effort has risen and has averaged about 121,500 h over the past 5 years (Figure 17).

Mean-annual landing rate has decreased significantly ($r = -0.46$; $P = 0.04$) since the late 1960s (landing rates were not estimated in the 1950s). Relatively low mean-annual landing rates of about 0.7 trout/h were recorded between the late 1960s and 1972. Mean-annual landing rate rose sharply after implementation of catch-and-release-only angling to a record high

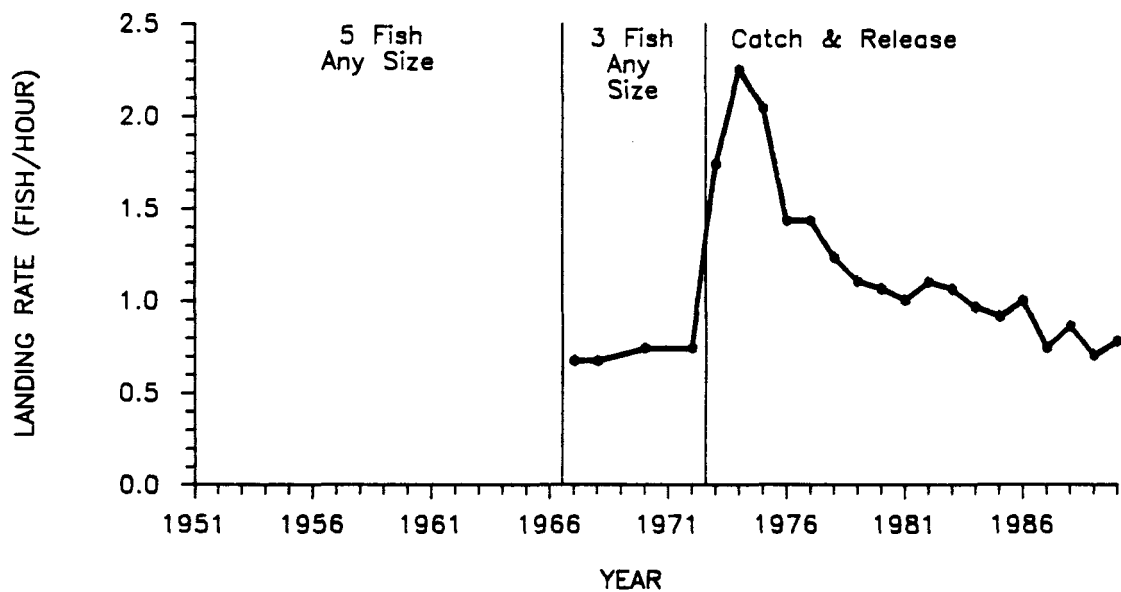
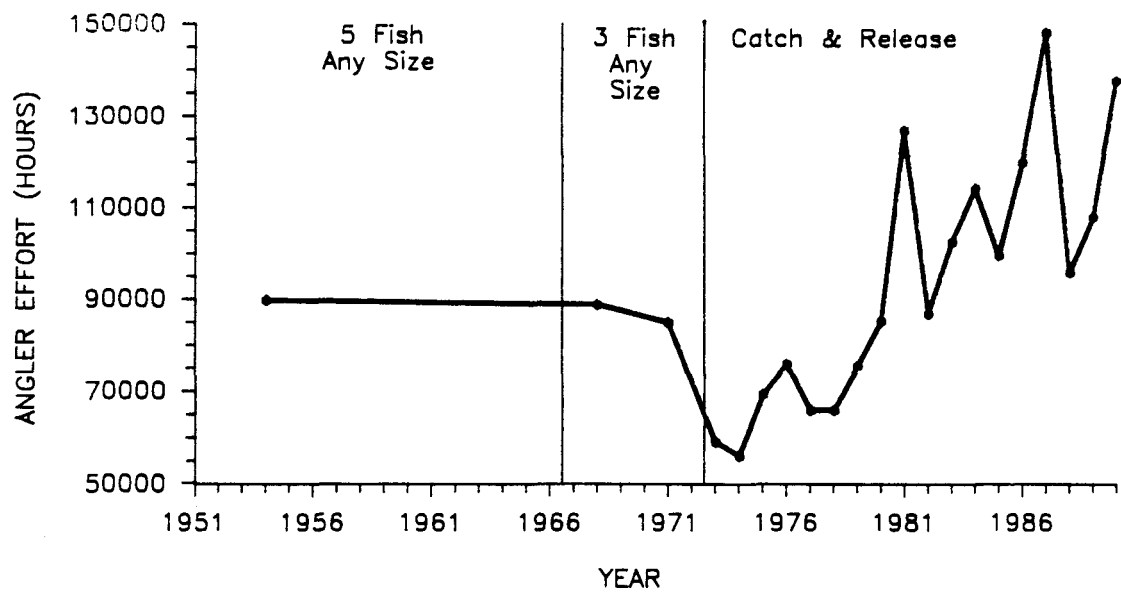


FIGURE 17.-Angler effort (1954 to 1990) and mean-annual landing rate (1967 to 1990) in the Yellowstone River between the Yellowstone Lake outlet and the Upper Falls.

of 2.3 trout/h in 1974, but dropped to 1.2 trout/h by 1978. Since 1978, mean-annual landing rate has continued to decline and has averaged about 0.8 trout/h over the past 5 years (Figure 17).

Mean length of landed trout has increased significantly ($r = 0.93$; $P < 0.01$) since the early 1950s. Shortest mean length (330 mm) occurred in the 1950s. Since then, mean length of landed trout has increased almost annually and reached a record high of 412 mm in 1990 (Figure 18).

Proportional Stock Density and RSD estimates have also increased significantly ($r = 0.82$ and 0.94 , respectively; $P < 0.01$), although data are only available for the 18-year period between 1973 and 1990. Proportional Stock Density estimates have ranged between 62% in 1975 and 89% in 1990, and RSD estimates have fluctuated between 16% in 1975 and 57% in 1990 (Figure 18).

LeHardy Rapids

Current year.—In 1990, 411 adult cutthroat trout were collected. Mean total length, weight, and condition factor (K) of these fish were 397 mm, 546 g, and 0.87, respectively (Table 5). Mean total length of males (407 mm) was significantly ($P < 0.05$) greater than that of females (385 mm), and average weight of males was also significantly ($P < 0.05$) greater than that of females. Scale analysis revealed five age groups (ranging between age 4 and age 8) in the 1990 sample. The estimated mean age of 5.9 years in 1990 is a near-record high and has been exceeded in only 1986 and 1989.

Long-term trends (1974 to 1990).—Mean length of cutthroat trout spawners captured by dipnetting at LeHardy Rapids has increased significantly ($r = 0.92$; $P < 0.01$) between 1974 and 1990. Mean length was lowest (362 mm) in 1974 and rose to a record high of 402 mm in 1985. Since 1985, mean length has varied between 394 and 400 mm (Figure 19).

Proportional Stock Density and RSD estimates have also increased significantly ($r = 0.85$ and 0.88 ; respectively; $P < 0.01$) over the past 17 years. Proportional Stock Density estimates rose from 51% in 1974 to a record high of 97% in 1985. Since 1985, PSD estimates have been stable at about 95% (Figure 19). Relative Stock Density estimates increased from 8% in 1974 to a record high of 38% in 1984. Since 1984, RSD estimates have ranged between 25 and 37% (Figure 19).

Estimated mean age of cutthroat trout spawners has increased significantly ($r = 0.93$, $P < 0.01$) since 1974. Youngest mean age (3.7 years) was observed in 1974 and 1975 and oldest mean age (6.1 years) was observed in 1986 and 1989 (Figure 19).

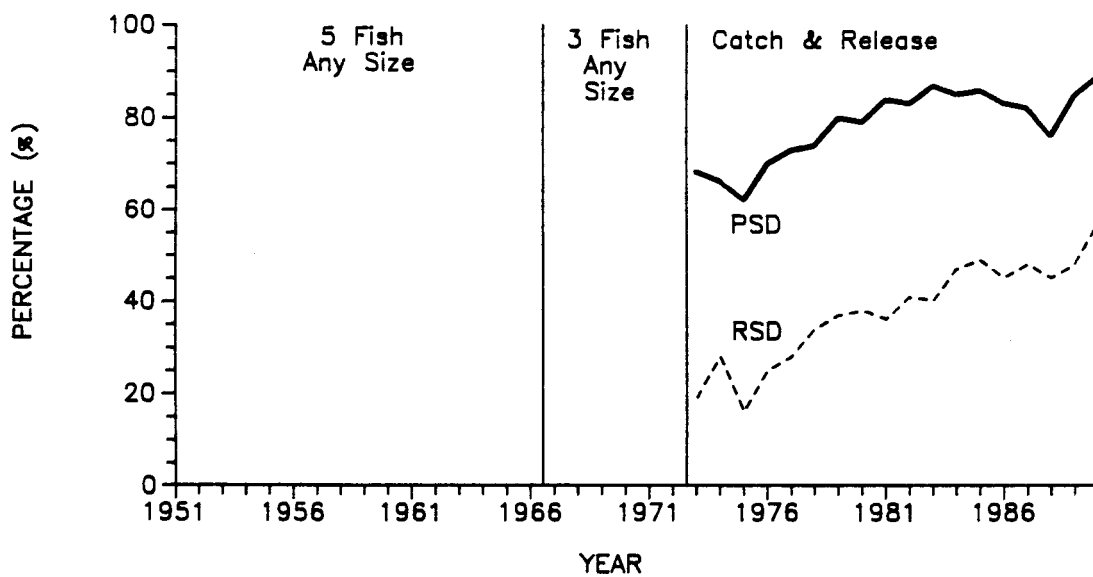
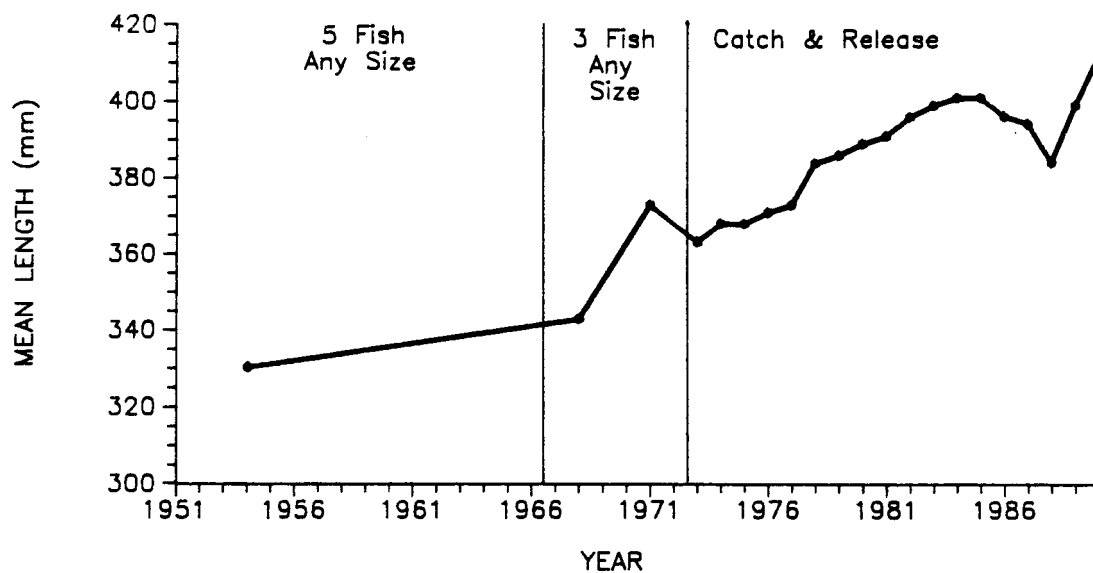


FIGURE 18.-Mean length (1954 to 1990) and length structure (1973 to 1990) of angler-landed cutthroat trout from the Yellowstone River between the Yellowstone Lake outlet and the Upper Falls.

TABLE 5.-Mean length, weight, and condition of cutthroat trout captured by dip net at LeHardy Rapids, Yellowstone River, 1974 to 1990.

Year	Adult males				Adult females				All adults			
	Number captured	Average length (mm)	Average weight (g)	Average K factor	Number captured	Average length (mm)	Average weight (g)	Average K factor	Number captured	Average length (mm)	Average weight (g)	Average K factor
1974 ^a	177	375	394	0.75	244	352	339	0.78	453	362	363	0.76
1975	338	385	451	0.78	426	359	363	0.78	775	370	401	0.78
1976 ^a	531	384	431	0.75	423	362	360	0.75	964	375	399	0.75
1977 ^a	133	382	429	0.77	111	362	370	0.78	245	373	402	0.77
1978	399	386	458	0.78	358	364	413	0.85	759	376	437	0.81
1979	334	394	514	0.83	237	371	431	0.84	571	385	480	0.83
1980	293	391	488	0.81	190	372	418	0.80	483	384	460	0.81
1981	383	394	496	0.80	188	373	440	0.84	571	387	478	0.82
1982	327	401	517	0.80	367	380	474	0.86	694	389	494	0.83
1983	338	402	546	0.83	232	380	276	0.86	570	394	517	0.84
1984 ^b	321	408	539	0.79	199	386	477	0.82	526	399	515	0.80
1985 ^b	269	408	554	0.82	161	391	513	0.85	431	402	539	0.83
1986 ^b	279	405	565	0.84	316	388	503	0.85	596	396	532	0.85
1987	21	407	586	0.84	12	389	520	0.88	33	400	562	0.86
1988 ^a	60	400	559	0.88	46	385	508	0.88	106	394	537	0.88
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

^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.

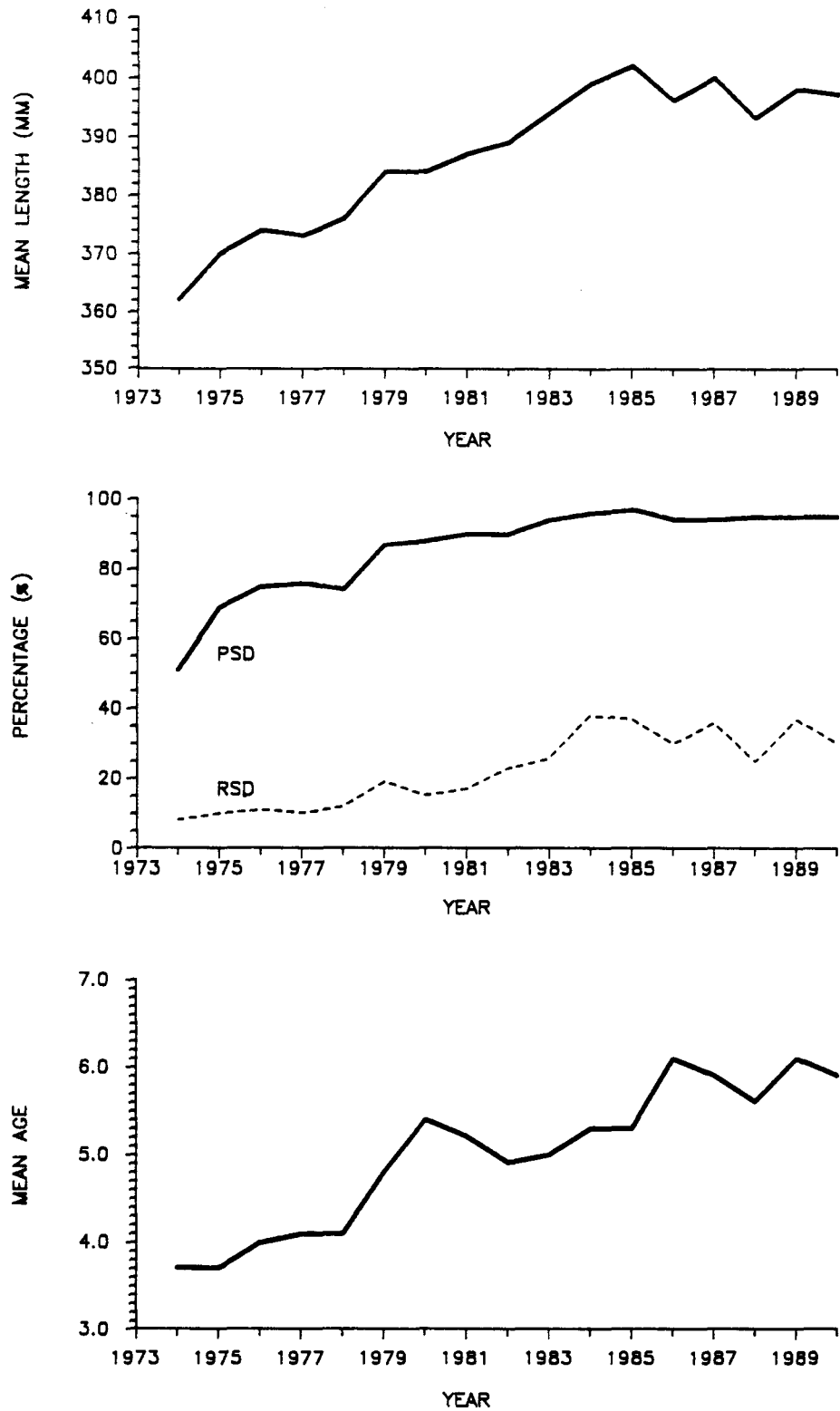


FIGURE 19.-Mean length, length structure, and mean age of cutthroat trout captured by dipnetting at LeHardy Rapids, 1974 to 1990.

Discussion and Conclusions

From the data presented, it is clear that positive changes have occurred in this cutthroat trout population since the implementation of catch-and-release-only angling in 1973. Length-structure and mean-age data from the sport fishery and the LeHardy Rapids study reveal that the proportion of larger and older trout increased almost annually between 1974 and the mid-1980s. Relatively little change in length structure and mean age since the mid-1980s suggests that the cutthroat trout population in this section of the Yellowstone River may be approaching equilibrium under current levels of angler-caused mortality. If angler-caused mortality increases substantially in the future, however, the catch-and-release-only regulation may need to be amended to ensure compliance with current fishery management goals in Yellowstone National Park.

POTENTIAL INFLUENCE OF ANGLER USE ON CUTTHROAT TROUT REPRODUCTION IN THE YELLOWSTONE RIVER

There is concern that wading by anglers on trout redds may reduce egg incubation and fry emergence success. Wading on redds caused up to 83% mortality of Yellowstone cutthroat trout *Oncorhynchus clarki bouvieri* embryos and pre-emergent fry in a laboratory study, and the amount of mortality depended on wading frequency and the stage of embryo or fry development (Roberts 1988). In 1990, the U.S. Fish and Wildlife Service and Montana State University initiated a study to assess potential effects of angler wading on Yellowstone cutthroat trout embryos and pre-emergent fry in the Yellowstone River between Yellowstone Lake and the Upper Falls in Yellowstone National Park, WY. In 1990, an estimated 137,392 angler hours of fishing occurred in the 14-km-long river reach open for catch-and-release angling between 15 July and the first Sunday in November.

The overall goal of the study is to learn more about the reproductive ecology of Yellowstone cutthroat trout in the Yellowstone River. Study objectives are: (1) document the timing and distribution of cutthroat trout spawning; (2) document the timing of hatching and pre-emergent stages and the timing and distribution of fry emergence; (3) document the amount of angler wading in the Buffalo Ford area; (4) estimate the amount of pre-emergent mortality due to angler wading; and (5) examine movements of adult cutthroat trout.

Methods

To estimate the timing of spawning, stage of sexual maturity was visually estimated for adult trout collected by electrofishing during May and June and by weekly dip-net sampling at LeHardy Rapids during May, June, and July.

Locations of suitable cutthroat trout spawning gravels were mapped from the Yellowstone Lake outlet to 2 km above the Upper Falls, in the lower 3.3 km of Elk Antler Creek, and in the lower 1.6 km of Trout Creek.

To document the timing of emergence, fry were counted while walking along the river bank in 12 sections of the Buffalo Ford area. Counts were made on 15 d between 15 July and 27 August. Samples averaging 55 fry were hand-netted on 11 d and measured to the nearest millimeter total length.

The distribution of fry between the Yellowstone Lake outlet and the Upper Falls was documented by estimating relative abundances of fry while rowing a boat near shore. Also, fry were counted from the river bank along 25-m longitudinal transects at 36 locations.

The frequency of angler trampling was documented by using three Minolta 35-mm movie cameras mounted in streamside trees. Two cameras were in the Buffalo Ford area, and one was approximately 2 km upstream from Buffalo Ford. Each camera took

a single photograph every 3 min during daylight hours. Redds were mapped in the areas photographed. Photographs were analyzed by placing angler locations on a stream map. Angler use at the Buffalo Ford access was estimated using data from a car counter and by conducting an on-site creel survey.

Mean daily water temperatures (monitored with computer-programmable Ryan Tempmentor) for the Buffalo Ford area were used to calculate degree-days (sum of mean daily temperatures above 0°C), which were then used to backcalculate the stage of fry development on the opening of the fishing season (15 July). I assumed 158 degree-days to eye-up, 294 degree-days to hatch, and 478 degree-days to emergence (Roberts 1988).

To document trout movement patterns, 1,478 trout were tagged with colored and numbered floy tags in May and June 1990. Fish were collected by electrofishing and released within 1 km of their capture site. Length to the nearest millimeter, weight to the nearest 2 g, sex, and stage of maturity were recorded for each fish. Different tag colors were used for each of three river sections: (area 2) Yellowstone Lake to above LeHardy Rapids; (area 4) below LeHardy Rapids to Sulphur Caldron; and (area 6) below Sulphur Caldron to Upper Falls. Tag return information was obtained from anglers, weekly dip-net sampling at LeHardy Rapids, electrofishing, and observations from 6 d of snorkeling.

Results

In 1990, spawning began around mid-May and was mostly complete by late June. Suitable spawning sites were most abundant in the Buffalo Ford area and in a several-hundred-meter-long section below Fishing Bridge. Small areas of spawning gravels were present throughout the study area. In Elk Antler and Trout creeks, suitable spawning sites were common. Fry were most abundant in the Buffalo Ford area, rare to common in the Fishing Bridge and Hayden Valley areas, and common through most of the creek areas surveyed.

Based on the fry counts and length measurements, it appeared that relatively few fry emerged prior to 15 July. Abundance of cutthroat trout fry peaked between 17 and 27 July (Table 6). The average size of fry in hand-net samples increased from less than 25 mm on 16 and 18 July to greater than 29 mm on 2, 3, 7, and 8 August. Also, the proportion of recently hatched fry (≤ 26 mm) decreased from 98% on 16 and 18 July to 25% (average) for 2, 3, 7, and 8 August (Table 7). Recently hatched fry were rarely observed after 8 August.

Three-hundred-fifty-seven automobiles were surveyed at Buffalo Ford. There was an average of 1.4 anglers/automobile, and each angler had fished an average of 3.0 h. From this and car counter information, angler hours for the Buffalo Ford area were estimated (Table 8).

TABLE 6.-Bankside counts of cutthroat trout fry, Buffalo Ford area, Yellowstone River, 1990.

Date	Number of fry	Distance (m)	Fry/10 m
7/15	396	845	4.7
7/16	172	627	5.3
7/17	132	616	21.4
7/18	574	412	13.9
7/19	2,265	502	45.1
7/23	4,050	1,071	37.8
7/24	2,388	953	25.1
7/27	2,402	659	36.7
7/30	556	441	12.6
8/2	1,556	1,071	14.5
8/7	958	1,071	8.9
8/13	532	890	6.0
8/20	252	919	2.7
8/22	37	205	1.8
8/27	186	853	2.2

TABLE 7.-Mean total length of cutthroat trout fry and percent of fry ≤ 26 mm total length, July and August 1990.

Date	N	Average length (mm)	N ≤ 26 mm	% ≤ 26 mm
7/16	67	24.6	56	98
7/18	51	24.6	50	98
7/20	61	25.9	42	69
7/21	60	26.8	29	48
7/23	60	27.5	23	38
7/24	60	26.7	25	42
7/27	69	26.6	43	62
8/2	68	29.8	18	26
8/3	67	32.2	4	7
8/7	12	29.6	3	26
8/8	46	29.9	20	43

TABLE 8.-Estimated angler effort in hours for the Buffalo Ford access area, 1990.

Dates	Number of automobiles	Estimated angler hours
15 to 31 July	3,610	15,000
1 to 14 August	2,364	9,900
15 to 31 August	2,160	9,100
1 to 14 September	1,311	5,500
15 to 30 September	910	3,800
Total	10,355	43,000

There were 71 tag returns (Table 9), but clear movement patterns were not evident.

TABLE 9.-Numbers and location of tagged adult cutthroat trout recaptured, Yellowstone River, 1990.

Area recaptured	Area tagged		
	(2)	(4)	(6)
(1) Yellowstone Lake	1	1	0
(2) Yellowstone Lake to above LeHardy Rapids	1	1	0
(3) LeHardy Rapids	1	12	2
(4) Below LeHardy Rapids to Sulphur Caldron	4	35	10
(5) Below Sulphur Caldron to Upper Falls	0	1	2

Discussion

On the basis of the data collected in 1990, anglers appeared to be wading on redds before most fry had emerged. On 15 July, most fry would be in the pre-emergent stage of development. Roberts (1988) measured 35% mortality of pre-emergent Yellowstone cutthroat trout fry waded on twice daily, and mortality from one wading event during this period ranged from 4 to 26% (mean, 13.7%; $N = 4$).

In 1991, additional fieldwork will be conducted to meet the study goal and objectives.

DUCK LAKE

Duck Lake, historically barren of fish (Jordan 1891), was stocked between 1903 and 1938 with several native and nonnative salmonid species (Varley 1981). These introductions resulted in the establishment of a self-sustaining population of nonnative brown trout *Salmo trutta* (Arnold and Sharpe 1967). Because Duck Lake lies near Yellowstone Lake, Arnold and Sharpe (1967) recommended that brown trout be eliminated from Duck Lake to prevent any unofficial introductions of this species into Yellowstone Lake. Based on that recommendation, Duck Lake was treated with rotenone in 1967 (Mills and Sharpe 1968). No brown trout were captured during three subsequent gillnetting surveys (Mills 1969; Dean 1972; Jones et al. 1979), indicating that the Duck Lake renovation project had been successful.

In 1990, National Park Service rangers observed fish in Duck Lake. In response, the U.S. Fish and Wildlife Service conducted a gillnetting survey of Duck Lake in July 1990. The objective of this survey was to determine the species of fish that presently occur in Duck Lake.

Study Area

Duck Lake is a 15-hectare lake that lies at an elevation of 2,374 m about 0.3 km west of the West Thumb of Yellowstone Lake (Figure 20). Mean and maximum depths are 7 and 18 m, respectively. There are two small inlet streams on the northwest side of the lake, but there is no outlet stream. Reaches considered suitable for spawning in each inlet stream are less than 30 m long (Arnold and Sharpe 1967).

Methods

Six gill nets were set overnight in Duck Lake between 6 and 7 July. These monofilament nets were 38 m long, 1.5 m deep, and composed of five 7.6-m-long panels of 19, 25, 32, 38, and 51 mm mesh (bar measure). Depending on bottom contour, each net was set as perpendicular to shore as possible.

Captured fish were identified to species, measured to the nearest 1 mm total length, and weighed to the nearest 100 g. Scale samples were taken from each fish for aging, and gonads were checked to determine sex. Stomach contents were examined to provide information on food habits.

Results

Seven Yellowstone cutthroat trout *Oncorhynchus clarki bouvieri* were captured in the gill nets. Mean length and weight were 523 mm (range, 477-557 mm) and 2,000 g (range, 1,300-2,600 g), respectively. All seven trout were estimated to be 5 years old. The two male trout appeared ready to spawn, but only one of the

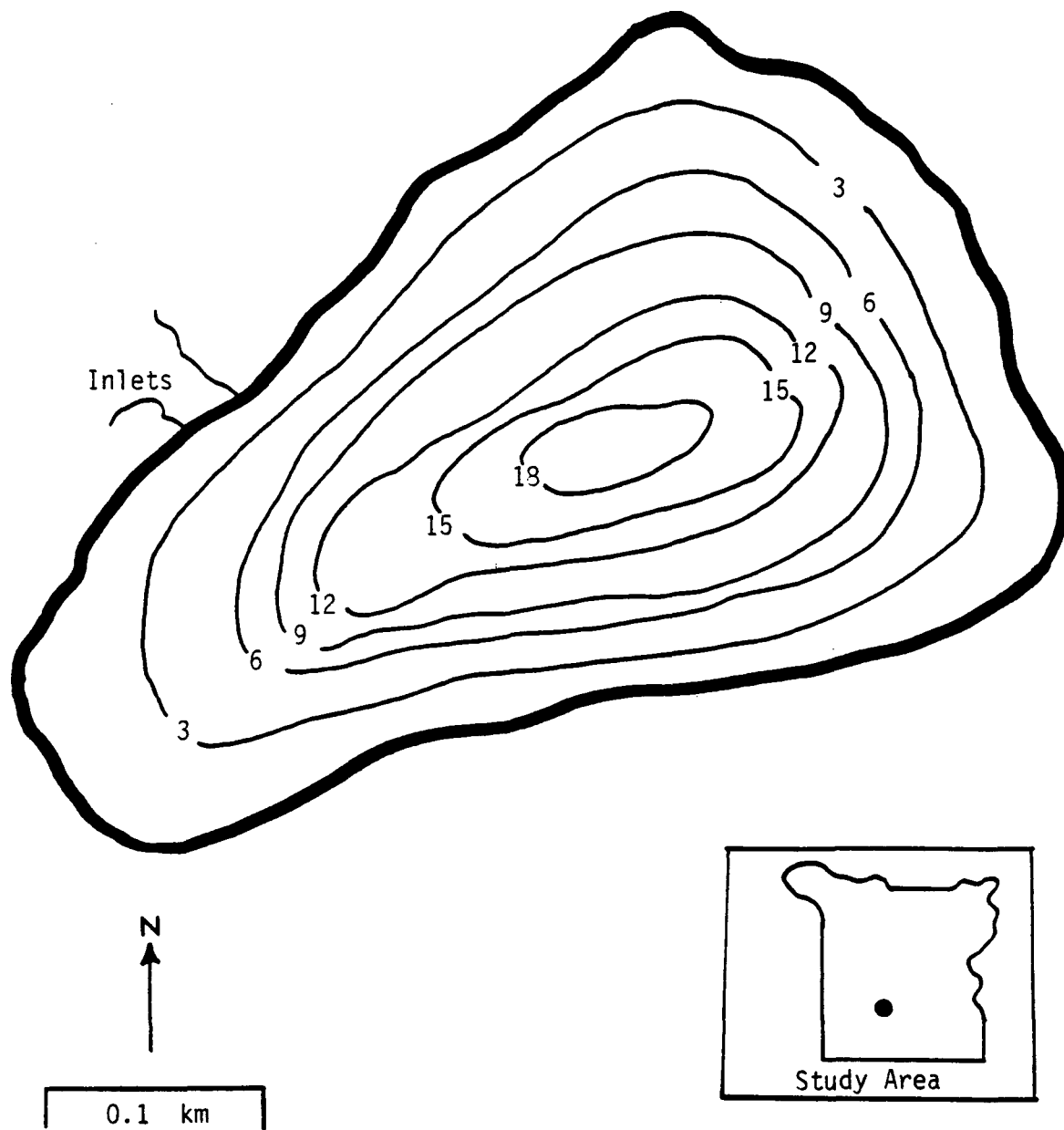


FIGURE 20.-Duck Lake, Yellowstone National Park, showing inlet streams and 3-m depth intervals.

five female trout had fully developed eggs. Examination of stomach contents revealed *Gammarus* sp. and *Hyallolella* sp.

Discussion

Based on data from gillnetting surveys in 1968, 1969, 1979, and 1990, it is apparent that an unauthorized introduction of Yellowstone cutthroat trout into Duck Lake occurred sometime during the past 11 years. Results from the current survey suggest that the number of cutthroat trout in Duck Lake is relatively low. Although no small fish were observed in the lake during the current survey, it is not known whether the existing cutthroat trout population is reproducing successfully. The cutthroat trout in Duck Lake are not considered to be a threat to the genetic integrity of cutthroat trout populations in Yellowstone Lake because the cutthroat trout in Duck Lake are assumed to be of Yellowstone Lake origin; however, the historically fishless condition of Duck Lake has once again been altered by human activity.

Recommendations

It is recommended that a study be conducted in 1991 to determine if the cutthroat trout in Duck Lake are reproducing successfully.

GIBBON RIVER

The Gibbon River watershed encompasses 31,300 hectares in west-central Yellowstone National Park. Observation Peak and Solfatara Plateau lie at the eastern boundary of the watershed. The small hills and ridges surrounding Nymph Lake separate portions of the northern Gibbon River drainage basin from the southernmost area of the Gardner River watershed. From the headwaters at Grebe Lake, the Gibbon River flows west and south for nearly 43 km before joining the Firehole River at Madison Junction to form the Madison River (Figure 21).

Prior to the beginning of stocking activities in the Park, fish were found only downstream from Gibbon Falls. Native fish species included westslope cutthroat trout *Oncorhynchus clarki lewisi*, fluvial Arctic grayling *Thymallus arcticus*, mountain whitefish *Prosopium williamsoni*, and mottled sculpin *Cottus bairdi*. During the 55-year period from 1898 to 1943, many fish species were stocked throughout the Gibbon River watershed (Varley 1981). Stocked species included rainbow trout *O. mykiss*, brown trout *Salmo trutta*, brook trout *Salvelinus fontinalis*, cutthroat trout and Arctic grayling. An introduction of 250 black bass *Micropterus* sp. to the Gibbon River in 1893 was unsuccessful. Because of stocking activities, introduced salmonid species became well established throughout the Gibbon River drainage.

Scientific interest in the Gibbon River fishery has spanned nearly a century. In the 1890s, Jordan (1891) and Evermann (1892) described historic fish species composition and distribution. Seamans (1940) gave a qualitative description of fish species composition of the Gibbon River watershed and noted that, despite its popularity, the Gibbon River was an "unproductive stream," particularly in the upper reaches. A comprehensive survey of the Gibbon River was conducted several decades later by Dean and Varley (1974). They described stream habitat, water chemistry, fish species composition, and historical investigations of the Gibbon River.

Jones et al. (1986) examined fish populations in a reach of the Gibbon River between Gibbon Rapids and Virginia Cascades and noted changes in species composition as streamflow decreased from spring to fall. They conducted an additional survey in the lower section (Madison Junction to Gibbon Falls) in response to angler reports of numerous catches of Arctic grayling (Jones et al. 1988). The present study in this lower section involves monitoring of a site selected for investigation of post-fire effects (Jones et al. 1989). In 1990, an additional study was initiated in the upper reaches of the Gibbon River as a cooperative research project with the Young Scholars Program, which gives college-age students experience in scientific techniques used in a field or research project.

Fishery managers have attempted to regulate the Gibbon River fishery by changing angling regulations in response to increased angler use. Generally, the Gibbon River has been subdivided into

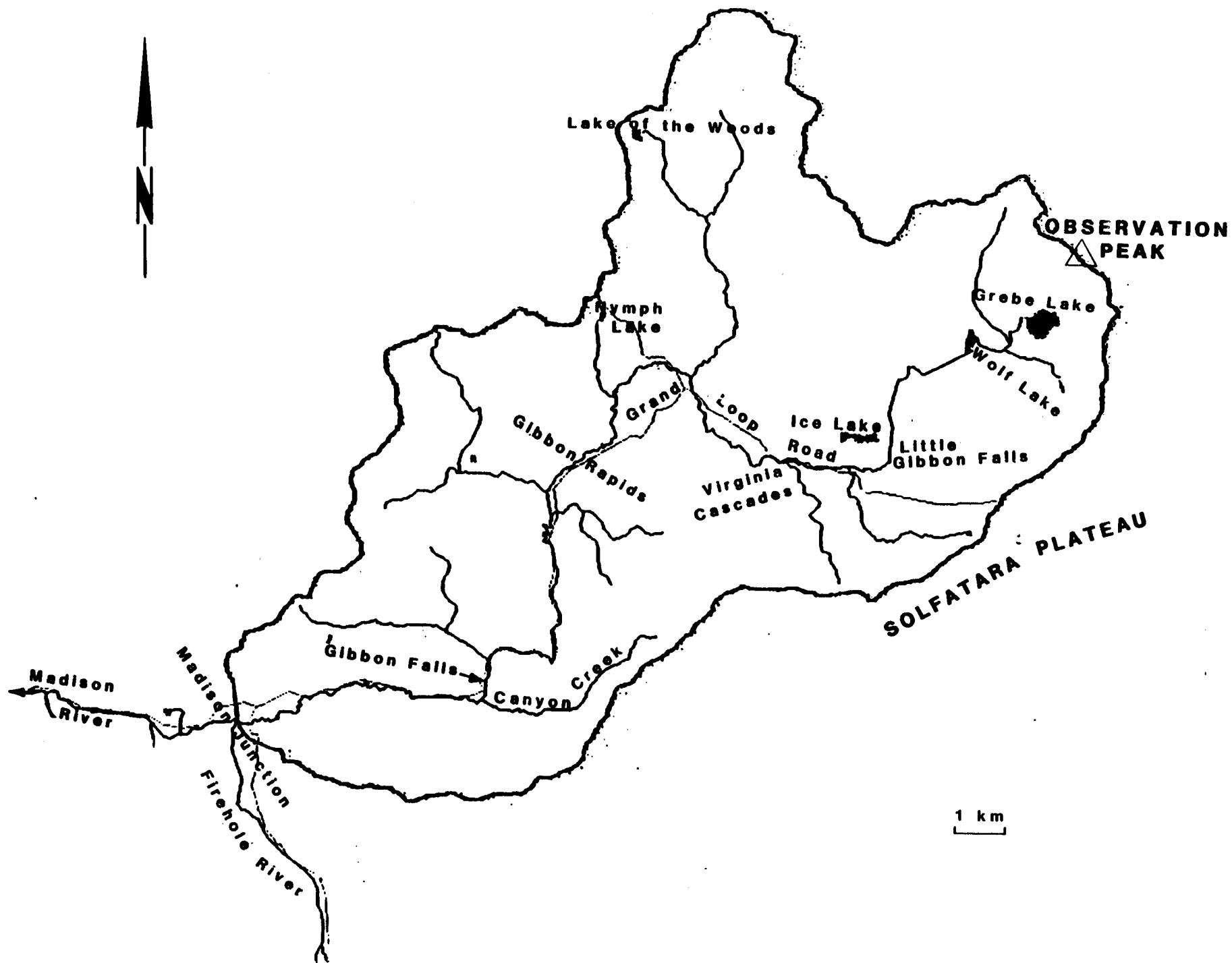


FIGURE 21 Gibbon River watershed, Yellowstone National Park.

two sections (downstream from Gibbon Falls and upstream from Gibbon Falls) for purposes of fishery management. Below Gibbon Falls, fishery regulations have been the same as those for the Madison River. Since 1950, this river reach has been restricted to fly fishing only. In 1970, the five-fish, any-size harvest limit was replaced with a two-fish harvest limit. In addition, brown trout and rainbow trout were placed under a 406-mm total length minimum-size creel limit. No size limits were in effect for mountain whitefish or brook trout. In 1987, more restrictive regulations were implemented. Rainbow trout were restricted to catch-and-release only. Brown trout and brook trout were placed under a 254-mm maximum-size creel limit, but the regulation for mountain whitefish was unchanged.

Upstream from Gibbon Falls, the fly-fishing-only regulation is not in effect. With the exception of brook trout, the five-fish, any-size creel limit was not reduced to a two-fish, any-size limit until 1973. In 1987, rainbow trout were placed under catch-and-release restrictions. Brook trout harvest limits remained at five fish, but a 254-mm maximum-length harvest limit was imposed. No size limits were instituted for brown trout. Grayling have received catch-and-release protection throughout Yellowstone National Park since 1970.

This report describes fish populations in selected reaches of the Gibbon River on the basis of recent (1988 to 1990) surveys and makes general comparisons with historical descriptions of fish populations in these reaches. Effects of anglers on the fish populations during the current year and among previous years are also examined.

Study Area

The Gibbon River is located on the approximate northwestern rim of the Yellowstone Caldera (USGS 1972). The southern part of the watershed is composed primarily of Pleistocene rhyolite flows, and the northern area is underlain with Lava Creek tuff (Christiansen 1975). Upstream from Gibbon Falls, the uplands adjacent to Gibbon Canyon contain substantial amounts of unconsolidated glacial deposits (Christiansen and Blank 1974). Surficial geology of the Gibbon River watershed has been influenced primarily by the Pinedale glaciation. Areas underlain with rhyolite are covered with glacial till, but the areas of Lava Creek tuff generally are covered with rubble veneer glacial deposits (Richmond and Waldrop 1975; Waldrop and Pierce 1975).

Several natural barriers separate the Gibbon River into five distinct reaches, Madison Junction to 25.6-m-high Gibbon Falls, Gibbon Falls to Gibbon Rapids, Gibbon Rapids to 18.3-m-high Virginia Cascades, Virginia Cascades to 7.6-m-high Little Gibbon Falls, and from Little Gibbon Falls to the headwater area at Grebe Lake (Figure 21).

Methods

Aquatic habitat parameters were measured at transects during a reconnaissance-level stream survey (Jones et al. 1990) of each study area. In the lower section (downstream from Gibbon Falls), permanent habitat transects were established near the confluence with Canyon Creek in the fall of 1988 (Figure 22). These transects were subsequently surveyed in conjunction with each electrofishing sample. In the upper study reaches (Virginia Meadows, Ice Lake Meadows, and Wolf Lake Springs), reconnaissance-level surveys were conducted in 1990 only.

The lower Gibbon River electrofishing reach extended from the confluence with Canyon Creek downstream for 1.5 km to the U.S. Geological Survey gaging station (Figure 22). Electrofishing equipment consisted of hand-held positive electrodes connected to a DC shocking system carried in a 2-m-long plastic boat. Captured fish were measured to the nearest 1 mm total length (TL), weighed (to the nearest 2 g), and scales were collected from each fish in a stratified subsample (based on 25-mm length groups) of the total catch. Length structure of the population was described by Proportional Stock Density (PSD) and Relative Stock Density (RSD) indices developed by Gabelhouse (1984). The lengths used for PSD and RSD analyses in this study are: brown trout, 203, 381, and 457 mm; rainbow trout, 229, 406, and 508 mm; brook trout, 178, 305, 382 mm; and mountain whitefish, 127, 178, and 254 mm total length. Fish populations in the lower study reach of the Gibbon River were sampled by electrofishing in July 1989, October 1989, and August 1990. Population estimates were made only on the first and third sample occasions. Population size was estimated by applying the adjusted Peterson formula (Ricker 1975) to mark-and-recapture data.

A multiple-pass removal method (Zippin 1958) was used to estimate population size in the three upper reaches. Each electrofishing reach encompassed the habitat transect site and was between 130 to 140 m in length (Figure 23). Block nets were placed at the upstream and downstream boundaries of each electrofishing section and fish were captured with Coffelt BP-1 backpack electroshockers. Data from captured fish were collected in the same manner that was used in the lower section.

Angler effects on the Gibbon River fishery are estimated on the basis of data derived from the Volunteer Angler Report (VAR) system for the period from 1977 to 1990. Estimated parameters include annual effort (hours spent fishing), annual mean landing rate (number of fish caught per hour), mean total length of landed fish, and length composition of the total catch. Significant changes in long-term trends were detected by linear correlation.

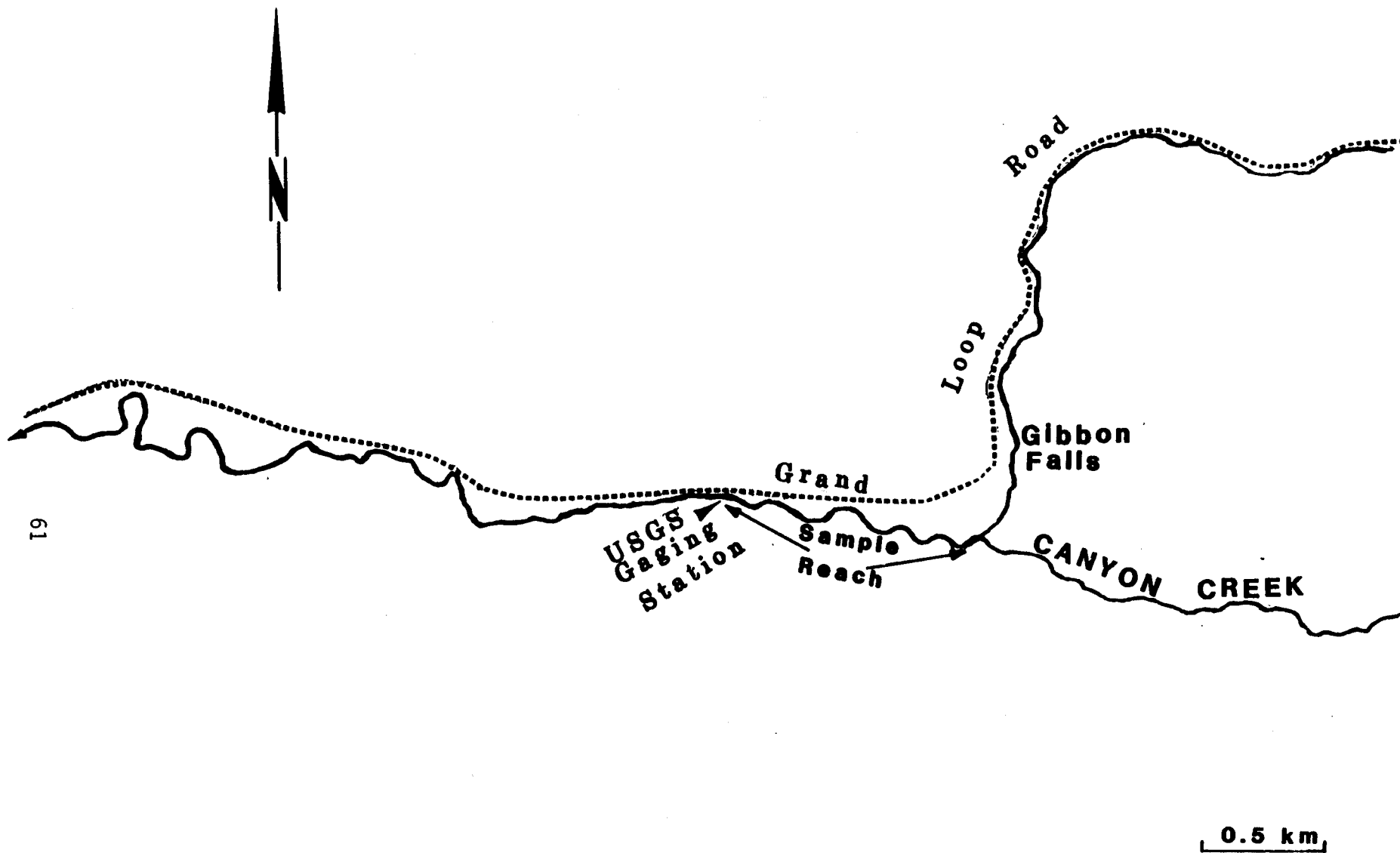


FIGURE 22.-Gibbon River showing location of lower electrofishing and habitat study site, 1988 to 1990.

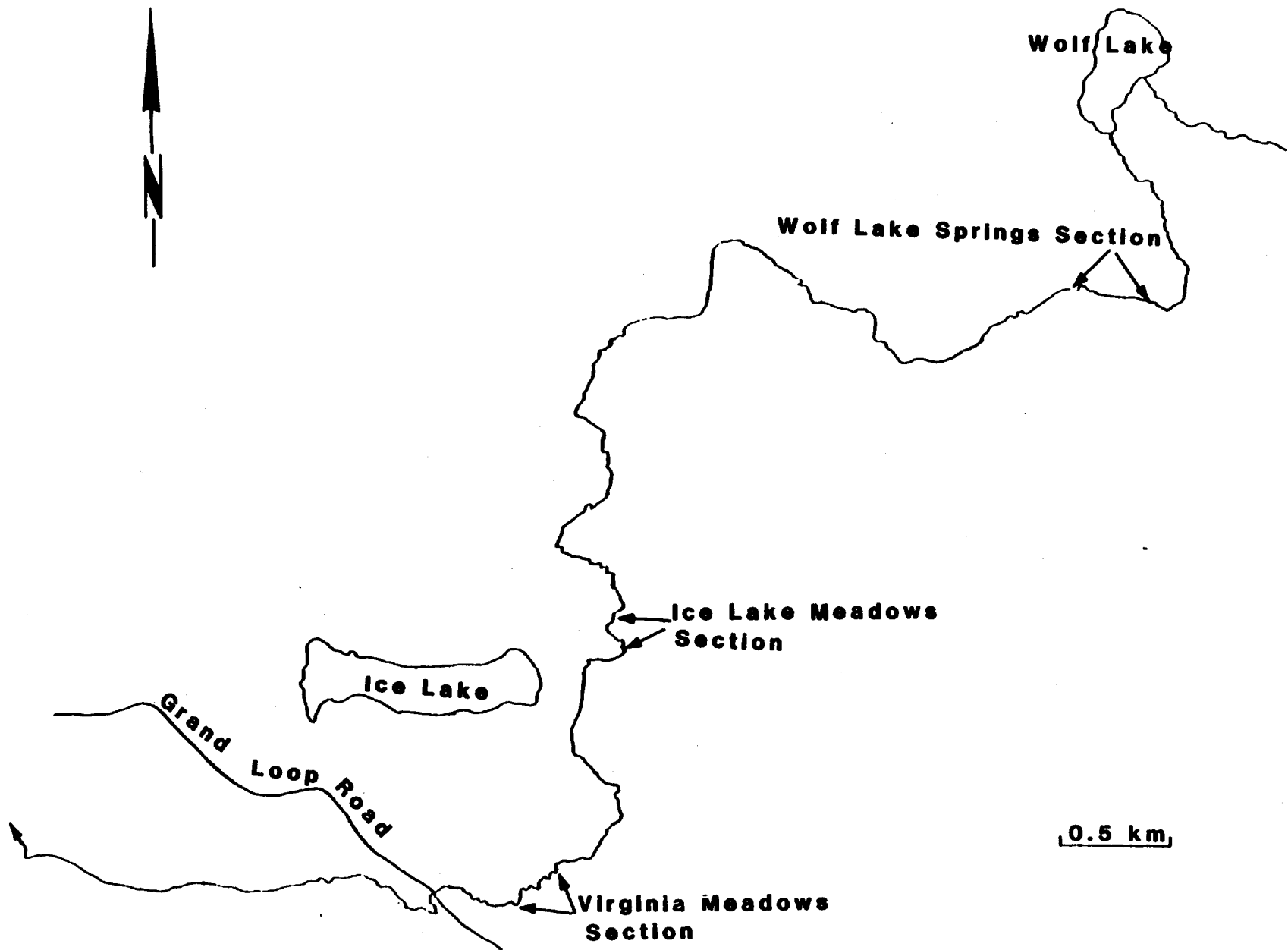


FIGURE 23.-Map of upper Gibbon River showing location of electrofishing sample sections, 1990.

Results

Physical Characteristics

In the lower reach of the Gibbon River near Canyon Creek, an area that experienced intense canopy and understory burn, habitat transects were initially surveyed shortly after the 1988 fires. During this initial survey, channel stability was rated good because only one-fourth of the streambanks exhibited evidence of erosion. Average width of undercut banks (7 cm) appeared to provide suitable cover for trout. Approximately half of the stream bottom was bedrock, whereas the remaining substrate was boulder, cobble, and sand in similar proportions (Table 10). Pools at the transects were rated average quality and were formed by logs or boulders. The abundant channel vegetative cover observed in the 1988 survey consisted of downed timber and instream vegetation.

In the post-fire period, streambank stability rating suggested little change from the initial survey. Stream width and stream depth in 1989 and 1990 changed only to the degree expected with varied streamflows (Table 10). Average pool size fluctuated, but appeared to provide adequate cover for trout in all 3 years. Solar angle increased consistently in the years following the fires, suggesting that the forest canopy adjacent to the stream channel is becoming less dense as fire-killed trees fall. The most evident changes during the study period occurred in composition of the stream substrate. Although bedrock formed more than 50% of the stream bottom in all samples, proportions of cobble, sand, and silt varied considerably after the initial survey (Table 10). In August 1989, a major landslide occurred in a section of Gibbon Canyon approximately 3.5 km upstream from the habitat transects. The high percentage of coarse sand in October 1989 could be a result of the large amount of sediment introduced into the channel by the landslide. Channel vegetative cover was least abundant during the fall 1989 survey, possibly because fine sediments limited the amount of suitable attachment sites for instream vegetation. Only small amounts of gravel occurred in all samples (Table 10).

Numerous habitat characteristics (including stream width, stream depth, and amount of channel vegetative cover) in the 1990 survey were similar to those measured in fall 1988. Although the amount of bare ground on the streambanks increased slightly (decrease in stream cover type rating) between 1988 and 1990, streambank vegetation overhang increased by an order of magnitude during this period. This illustrates the extensive regrowth of vegetation in the riparian zones of this intensively burned area following the 1988 fires.

Habitat study reaches in the upper Gibbon River were selected on the basis of natural barriers and differences in stream discharge and gradient. The Virginia Meadows study reach was the deepest of the three reaches and contained the highest

TABLE 10.-Drainage basin characteristics and habitat features of the Gibbon River near Canyon Creek, 1988-1990.

Stream order	V			
Length (km)	1.52			
Elevation:				
Maximum (m)	2,124			
Minimum (m)	2,111			
Drainage Size (hectares)	26,805			
Stream type ^a	B1			
Habitat features				
Sample date	10/24/88	7/20/89	10/3/89	8/2/90
Time	1045	945	1400	1400
Water column:				
Flow (m ³ /s)	2.158	2.928	2.997	3.202
Channel width (m)	19.3	22.5	18.4	18.7
Stream width (m)	17.1	17.3	16.9	17.2
Stream depth (cm)	20.4	25.0	22.6	26.5
Stream shore water depth (cm)	5.8	0.0	0.0	5.2
Riffle width (m)	10.2	10.9	12.0	13.2
Pools:				
Width (m)	2.3	1.9	2.1	1.2
Quality	2.2	2.2	2.2	2.3
Feature ^b	1,4	4,1	4,1	1,4
Solar angle (°)	63.3	74.0	75.3	76.0
Channel morphology				
Streambank alteration (%)	23.3	26.7	20.8	25.8
Vegetative stability	3.5	3.3	3.5	3.5
Undercut (cm)	6.7	1.5	4.0	4.0
Channel-bank angle (°)	112.5	98.3	118.3	119.2
Stream bottom:				
Gradient (%)	3.9	1.4	2.1	3.2
Sinuosity	1.33	1.28	1.30	1.19
Substrate:				
Bedrock	56.0	58.8	55.3	60.7
Boulder (>305 mm)	10.2	8.9	4.0	8.0
Cobble (64-305 mm)	13.1	17.9	7.6	13.8
Gravel (2-64 mm)	2.4	2.6	1.6	4.4
Sand (0.6-2 mm)	13.6	9.5	24.0	7.2
Silt (<0.6 mm)	4.2	2.4	7.8	6.0
Embeddedness (%)	70.0	21.7	21.7	20.0
Channel vegetative cover (cm)	131.1	91.4	48.2	138.1
Riparian zone:				
Streamside cover type	2.0	1.8	1.8	1.8
Vegetative use (%)	9.2	6.7	16.7	6.7
Vegetation overhang (cm)	0.6	7.0	18.9	15.2
Habitat type	18,9	12,13	12,9	12,14

^a After Rosgen (1985).

^b 1 = log, tree, root, stump, brush, or debris; 2 = channel meander; 3 = rubble or gravel; 4 = boulder or bedrock; 5 = stream channel; 6 = fine sediments; 7 = streambank.

quality pools and greatest amount of overhanging streambank vegetation (Table 11). This reach exhibited the highest amount of channel meander (sinuosity, 1.42) and streambank alteration. In addition, the largest undercut banks (mean shore depth, 24 cm) occurred in this stream reach. Instream vegetation covered approximately 10% of each transect in the Virginia Meadows study reach (Table 11).

Several habitat characteristics including stream width, riffle width, pool width, and stream gradient were nearly identical between Ice Lake Meadows and Virginia Meadows. Pool quality and streambank alteration in the Ice Lake Meadows reach were rated the lowest of any of the upper Gibbon River study reaches (Table 11). Boulders were present in the stream bottom but cobble-size materials were sparse. An abundance of gravel and low embeddedness of substrate suggest that this stream reach contains extensive areas of suitable spawning habitat.

The Wolf Lake Springs site was the widest and shallowest of the three habitat study reaches. A small solar angle (49°) indicates that the dense forest canopy adjacent to the stream restricts the amount of sunlight that reaches the stream channel. Pools in this reach were rated fair in quality. In contrast to the downstream reaches, the primary pool-forming features at the Wolf Lake Springs transects were logs (Table 11). Besides forming plunge pools, downed trees in the channel made up a substantial portion of abundant channel vegetative cover in this reach. Bottom substrate appeared to be more heterogeneous at Wolf Lake Springs than in the other two study reaches (Table 11).

Fish

Lower section.—In July 1989, 101 brown trout were captured from the lower Gibbon River electrofishing reach. Estimated population abundance was 409 trout (95% confidence limits, 203 to 894). In August 1990, 196 brown trout were captured from this reach and estimated population size was 548 (95% confidence limits, 321 to 1,005). In October 1989, 203 brown trout were captured but no population estimate was made.

Mean total length of brown trout did not change significantly ($t = 0.08$, $P > 0.05$) between the two 1989 samples (July, 240 mm; October, 241 mm), but declined in August 1990 to 227 mm ($t = 1.42$, $P > 0.05$).

Examination of length-frequency distributions of brown trout captured by electrofishing indicated that about 40% of the fish in each population were longer than 254 mm (Figure 24). The PSD and RSD indices were 12 and 0, respectively, in the July 1989 sample. These indices increased to 27 and 4 in the October sample but declined to 10 and 1, respectively, in 1990. Mean weight of brown trout increased from 194 g in July 1989 to 395 g in fall 1989, then decreased to 219 g in August 1990. Condition factor followed a pattern similar to that for mean weight.

TABLE 11.-Drainage basin characteristics and habitat features of study reaches in upper Gibbon River, 1990.

Habitat features	Virginia Meadows	Ice Lake Meadow	Wolf Lake Springs
Sample date	8/3/90	7/23/90	7/23/90
Time	1010	1645	1215
Stream order	IV	IV	IV
Length (km)	1.82	2.67	3.30
Elevation:			
Maximum (m)	2,379.0	2,414.1	2,435.4
Minimum (m)	2,365.2	2,395.7	2,414.1
Drainage Size (hectares)	6,800.8	4,963.5	3,306.5
Stream type ^a	C3	C3	B4
Water column:			
Flow (m ³ /s)	0.311	0.286	0.163
Channel width (m)	4.1	4.4	6.2
Stream width (m)	3.9	3.9	5.2
Stream depth (cm)	30.5	24.4	17.2
Stream shore water depth (cm)	23.9	16.5	11.9
Riffle width (m)	1.0	0.8	1.9
Pools:			
Width (m)	1.5	1.5	1.0
Quality	3.4	2.5	2.6
Feature ^b	7,2	7,3	1,3
Solar angle (°)	106.7	81.3	49.0
Channel morphology			
Streambank alteration (%)	32.5	27.5	30.8
Vegetative stability	4.0	4.0	4.0
Undercut (cm)	25.4	20.3	14.5
Channel-bank angle (°)	50.0	59.2	75.8
Stream bottom:			
Gradient (%)	0.5	0.5	1.5
Sinuosity	1.42	1.23	1.15
Substrate:			
Bedrock			
Boulder (>305 mm)		8.1	6.0
Cobble (64-305 mm)	13.8	2.7	9.3
Gravel (2-64 mm)	49.8	57.0	41.7
Sand (0.6-2 mm)	21.0	21.7	34.5
Silt (<0.6 mm)	15.5	10.6	8.6
Embeddedness (%)	23.3	13.3	13.3
Channel vegetative cover (cm)	42.7	6.6	128.5
Riparian zone:			
Streamside cover type	2.0	2.0	2.0
Vegetative use (%)	13.3	5.0	5.0
Vegetation overhang (cm)	46.7	15.2	13.0
Habitat type	12	13,12	12,17

^a After Rosgen (1985).

^b 1 = log, tree, root, stump, brush, or debris; 2 = channel meander; 3 = rubble or gravel; 4 = boulder or bedrock; 5 = stream channel; 6 = fine sediments; 7 = streambank.

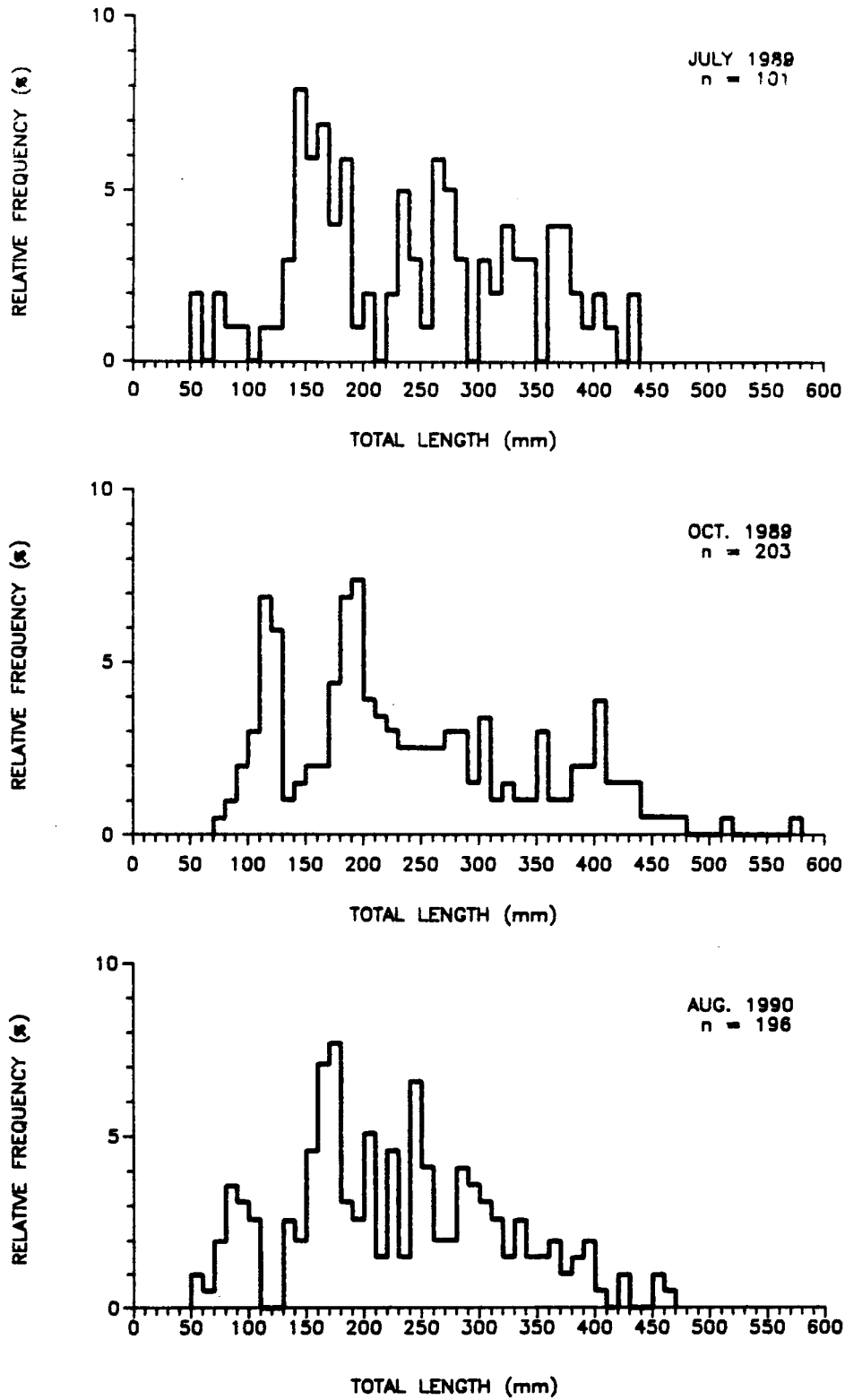


FIGURE 24.-Length-frequency distributions of brown trout captured by electrofishing, lower Gibbon River (near Canyon Creek), 1989 and 1990.

Analyses of scales from the brown trout indicated that at least five year classes were present in each sample, and the fall 1989 sample included one age-6 brown trout. Backcalculated lengths at annulus formation were similar in all three samples; however, brown trout from the October 1989 sample grew faster for the first four growing seasons than did the brown trout in the other two samples.

Rainbow trout were also collected during each electrofishing survey of the lower Gibbon River site. Mean total length of nine rainbow trout captured in July 1989 was 232 mm. Mean weight and condition factor of these fish were 134 g and 1.02, respectively. Both PSD and RSD were 0 for this small sample. In the fall 1989 sample, number of rainbow trout captured by electrofishing increased by an order of magnitude ($N = 93$). Mean weight decreased to 159 g, but condition factor was relatively unchanged (mean, 1.00) from that of the summer sample. The presence of several large rainbow trout in the October sample resulted in a PSD of 47; RSD, however, remained 0.

In August 1990, 153 rainbow trout were captured from this lower section. Estimated population was 2,052 rainbow trout (95% confidence limits, 751 to 5,130). Mean total length of rainbow trout in this sample (85 mm) reflects the predominance (83%) of rainbow trout shorter than 100 mm (Figure 25). Mean weight and condition factor were 88 g and 1.05, respectively. Although the 1990 PSD value (14) was greater than that of July 1989, it was only one-third that of fall 1989.

Scale analyses revealed that two age classes of rainbow trout were present in the July 1989 sample. Age-6 rainbow trout were captured in October of that year and four age groups were found in 1990. Estimated mean age has declined from 1.8 years in July 1989 to 1.4 years in 1990 and illustrates the large proportion of small (and presumably younger) rainbow trout. Growth patterns have revealed few distinct trends, but rainbow trout in August 1990 exhibited slower mean annual growth than the rainbow trout in the previous two samples.

Preliminary evidence suggests a year class of rainbow trout was either missing or not sampled. In October 1989, no rainbow trout were classified as 3-year-old fish and only one rainbow trout was classified as 4 years old in 1990. Length-frequency distributions clearly show the absence of these fish within the range of captured fish (Figure 25).

In July 1989, eight mountain whitefish were captured by electrofishing in the lower Gibbon River reach. Mean total length, mean weight, and mean condition factor were 342 mm, 380 g, and 0.93, respectively. Comparable values for the six whitefish captured in the fall 1989 sample were 273 mm, 270 g, and 0.95, respectively. In August 1990, three whitefish were collected during the "mark" electrofishing pass. Although one of these whitefish was subsequently recaptured, this sample size is too small to make a reliable population estimate. Mean length (374 mm) and mean weight (476 g) of the whitefish in August 1990

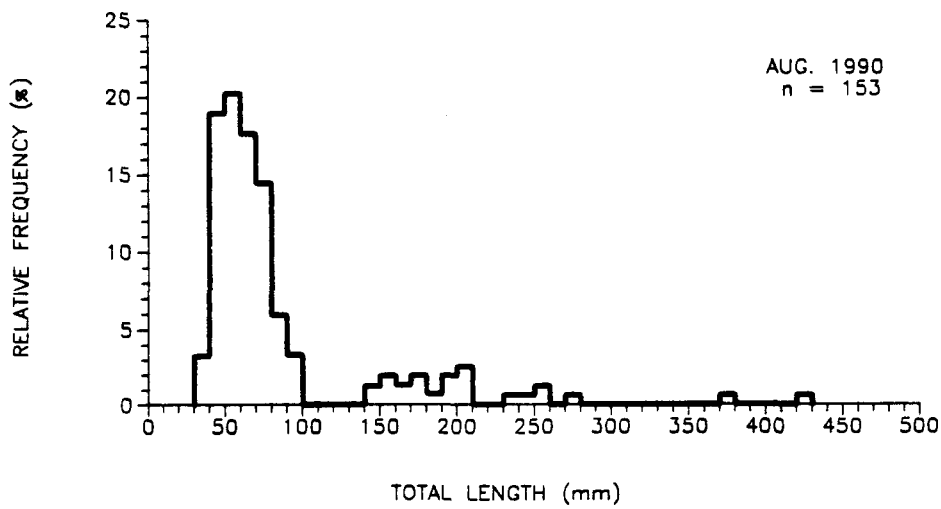
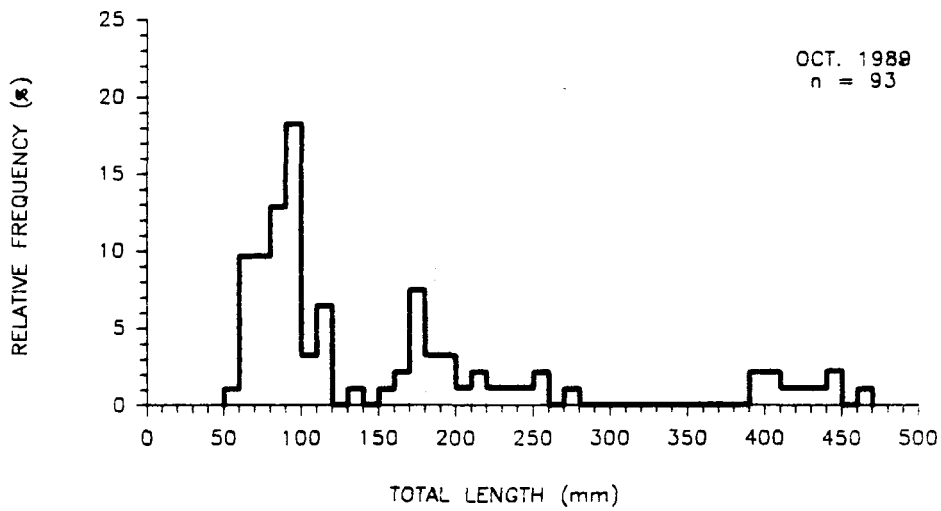
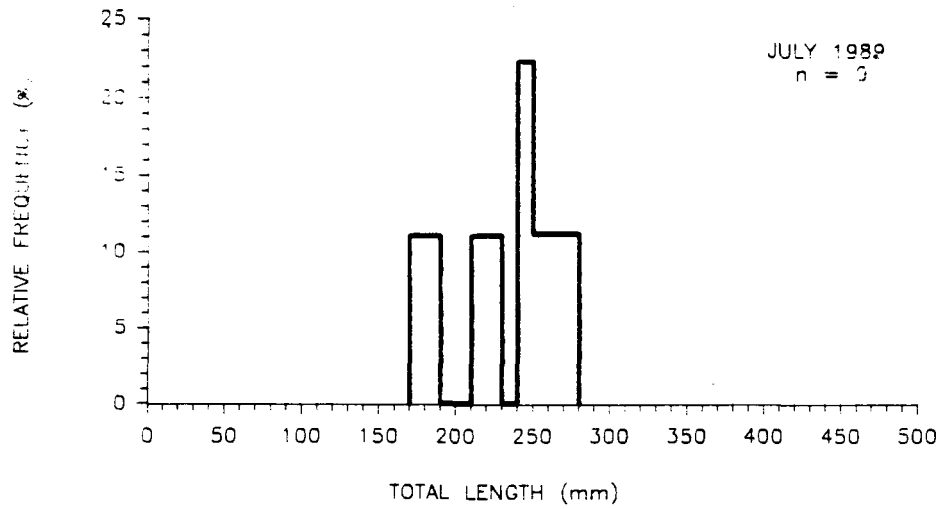


FIGURE 25.-Length-frequency distributions of rainbow trout captured by electrofishing, lower Gibbon River (near Canyon Creek), 1989 and 1990.

were the highest of three samples. In contrast, condition factor (0.91) was lower than the previous two samples.

The PSD value for whitefish was 100 in all three samples and RSD values ranged from 67 to 100. By adjusting the stock, quality, and preferred lengths upward to recommended trophy-size categories of 254, 305, and 381 mm TL (Gabelhouse 1984), PSD ranged between 67 in July 1989 and 100 in August 1990, and RSD ranged from 25 in July 1989 to 67 in the summer 1990 sample. These results indicate that the lower Gibbon River contains "world-class" mountain whitefish.

In July 1989, four brook trout were captured in the lower Gibbon River electrofishing sample area. Mean total length of these fish was 184 mm, mean weight was 72 g, and condition factor (K) was 1.10. Estimated mean age was 1.3 years. The PSD value for the July 1989 sample was 0. In October 1989, the largest brook trout from the July sample was recaptured but no other brook trout were collected. In the summer 1990 electrofishing effort, only one brook trout (221 mm TL) was caught. This trout was caught again during the recapture pass of the population estimate. These results suggest that, despite a high recapture efficiency, there is a very small population of brook trout in the lower reach of the Gibbon River.

In August 1990, one Arctic grayling was captured in the lower Gibbon River reach. Length, weight, and condition factor for this fish were 201 mm, 64 g, and 0.79, respectively. Length structure indices are not applicable to an individual fish; however, using length criteria recommended by Gabelhouse (1984), this grayling would be classified as a "stock" length fish. Based on scale analysis, the grayling was 2 years old.

Virginia Meadows section.—In July 1990, a three-pass removal method yielded seven rainbow trout and 262 brook trout in this 0.15-km-long reach. Estimated population size was eight rainbow trout (95% confidence limits, 7 to 10) or 57 rainbow trout/km. An accurate estimate could not be made for brook trout because the most brook trout were captured on the last pass.

Rainbow trout averaged 122 mm TL, and mean total length of brook trout was 95 mm. Brook trout generally weighed more (mean weight, 37 g) than rainbow trout (mean weight, 28 g), but the rainbow trout had slightly higher mean condition factors than did brook trout. The PSD and RSD indices were 0 for both species. Length-frequency distributions reveal the predominance of small fish in both populations (Figure 26).

Estimated mean age of the rainbow trout in the Virginia Meadows section was 1.4 years and only age-1 and age-2 trout were present in the sample. Approximately half of the captured brook trout were classified as young-of-the-year fish; estimated mean age for the remainder of the sample ($N = 139$) was 1.3 years. Brook trout had a greater average annual growth rate (68 mm/year) than rainbow trout (57 mm/year).

Ice Lake Meadows section.—In the Ice Lake Meadows sample area, rainbow trout was the only species captured ($N = 61$). A

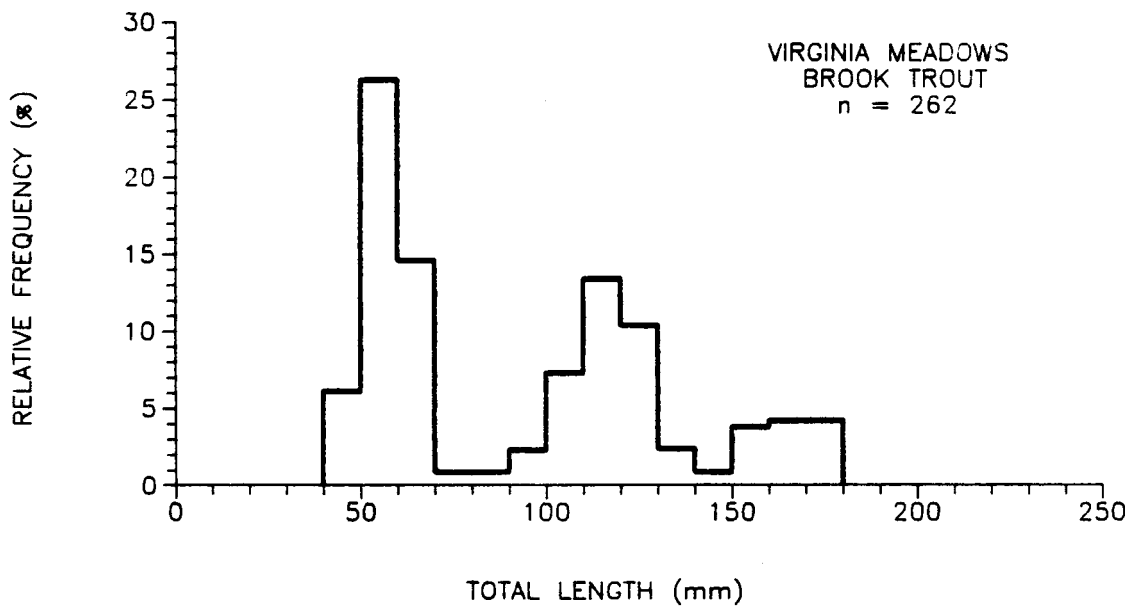
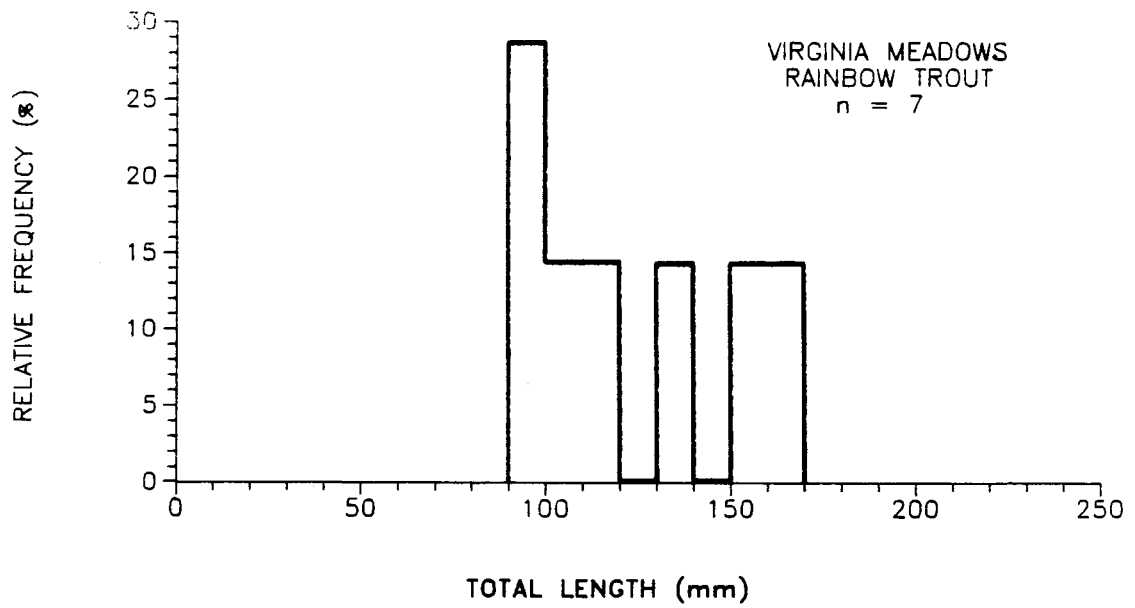


FIGURE 26.-Length-frequency distributions of rainbow trout and brook trout captured by electrofishing in the Virginia Meadows section of the Gibbon River, 1990.

three-pass removal yielded an estimated population of 72 rainbow trout (95% confidence limits, 61 to 88) or an estimated 566 trout/km of stream. Mean length, weight, and condition factor were 114 mm, 24 g, and 1.32, respectively. Because all captured rainbow trout in this section were shorter than 229 mm (Figure 27), PSD and RSD were 0 for the sample. Scale analyses indicated that three age groups were present. Estimated mean age of rainbow trout from Ice Lake Meadows was 1.2 years.

Wolf Lake Springs.-At the Wolf Lake Springs site, 121 rainbow trout were captured. Estimated population size was 131 rainbow trout (95% confidence limits, 121 to 142) or 930 rainbow trout/km of stream. Mean total length, weight, and condition factor were 119 mm, 28 g, and 1.39, respectively. As in the two downstream reaches, PSD and RSD were 0. Two year classes were represented in the sample and estimated mean age was 1.1 years. Average annual growth rate (62 mm) was similar to that of rainbow trout in the Ice Lake Meadows section.

Anglers

Lower section.-In 1990, an estimated 4,000 anglers spent over 6,700 h fishing in the Gibbon River between Madison Junction and Gibbon Falls. This level of effort was only slightly below the mean-annual angler effort of 7,100 h for the period between 1977 and 1990 (Figure 28). Landing rate in 1990 declined from the record highs of 1988 and 1989 to match the low rates observed in 1978 and 1979 (0.4 fish/h). Consequently, estimated total number of fish landed (2,992) in the lower section of the Gibbon River in 1990 was the third-lowest total catch since 1977. Mean total length of landed fish (all species combined) was relatively unchanged from 1989 (Figure 28). No significant ($P > 0.05$) long-term trends were observed for angler effort ($r = -0.13$), landing rate ($r = 0.31$), or mean length of landed fish ($r = -0.29$) between 1977 and 1990 in the lower section of the Gibbon River.

Prior to the regulation change in 1987, an estimated 281 fish were harvested annually between Gibbon Falls and Madison Junction. Since 1987, estimated harvest in this section of the river has declined by approximately 25%. The 1990 estimated total harvest of 100 fish was the second lowest since 1977.

Brown trout have consistently been the most frequently caught species from the lower Gibbon River (Figure 29); however, in 1990, anglers landed more rainbow trout than brown trout. Mean total lengths of these species have exhibited substantial variation, but brown trout generally are longer than rainbow trout (Figure 29). Since 1977, there have been no significant changes in mean length of either species. Mean total lengths of the two species are positively correlated with one another ($r = 0.51$, $P < 0.05$).

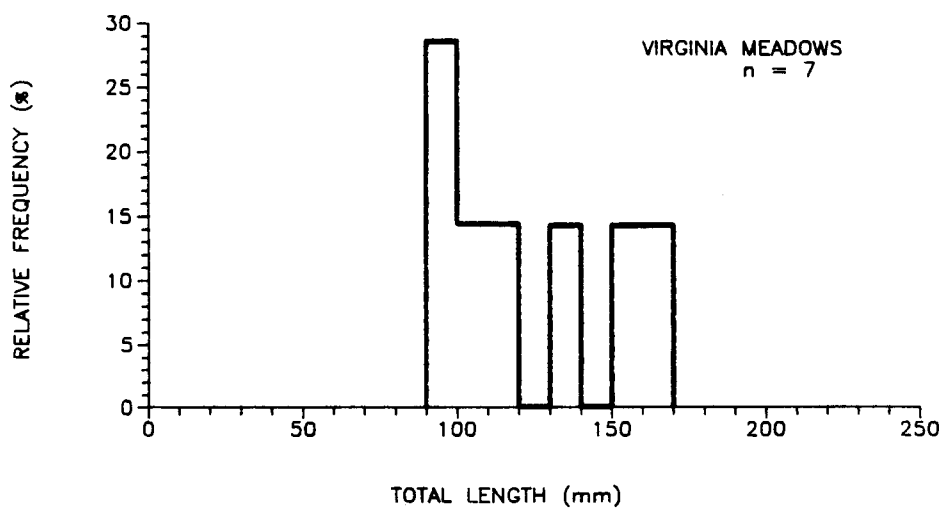
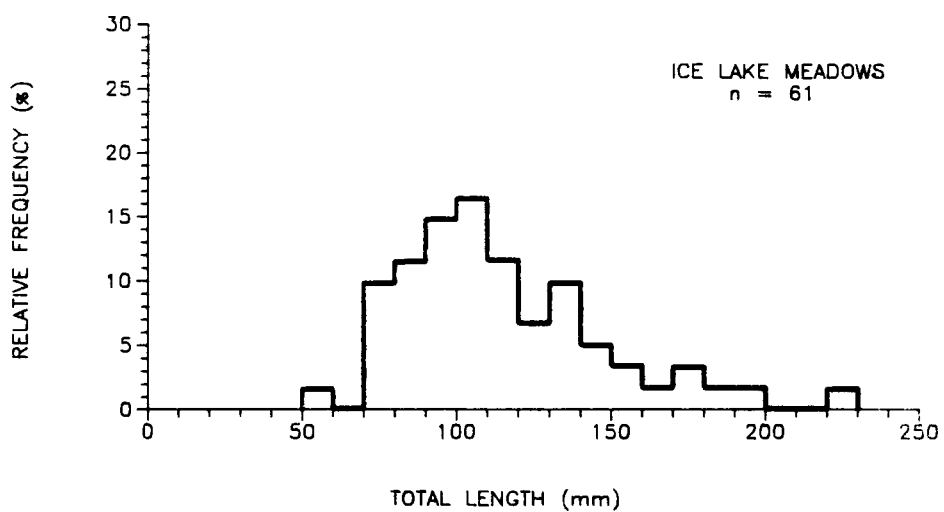
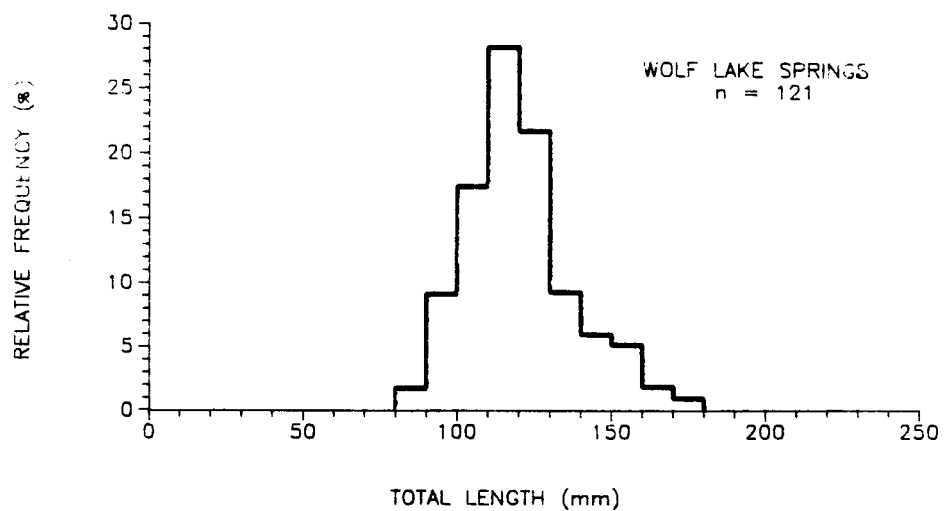


FIGURE 27.-Length-frequency distributions of rainbow trout captured by electrofishing at three different sample sites in the upper Gibbon River, 1990.

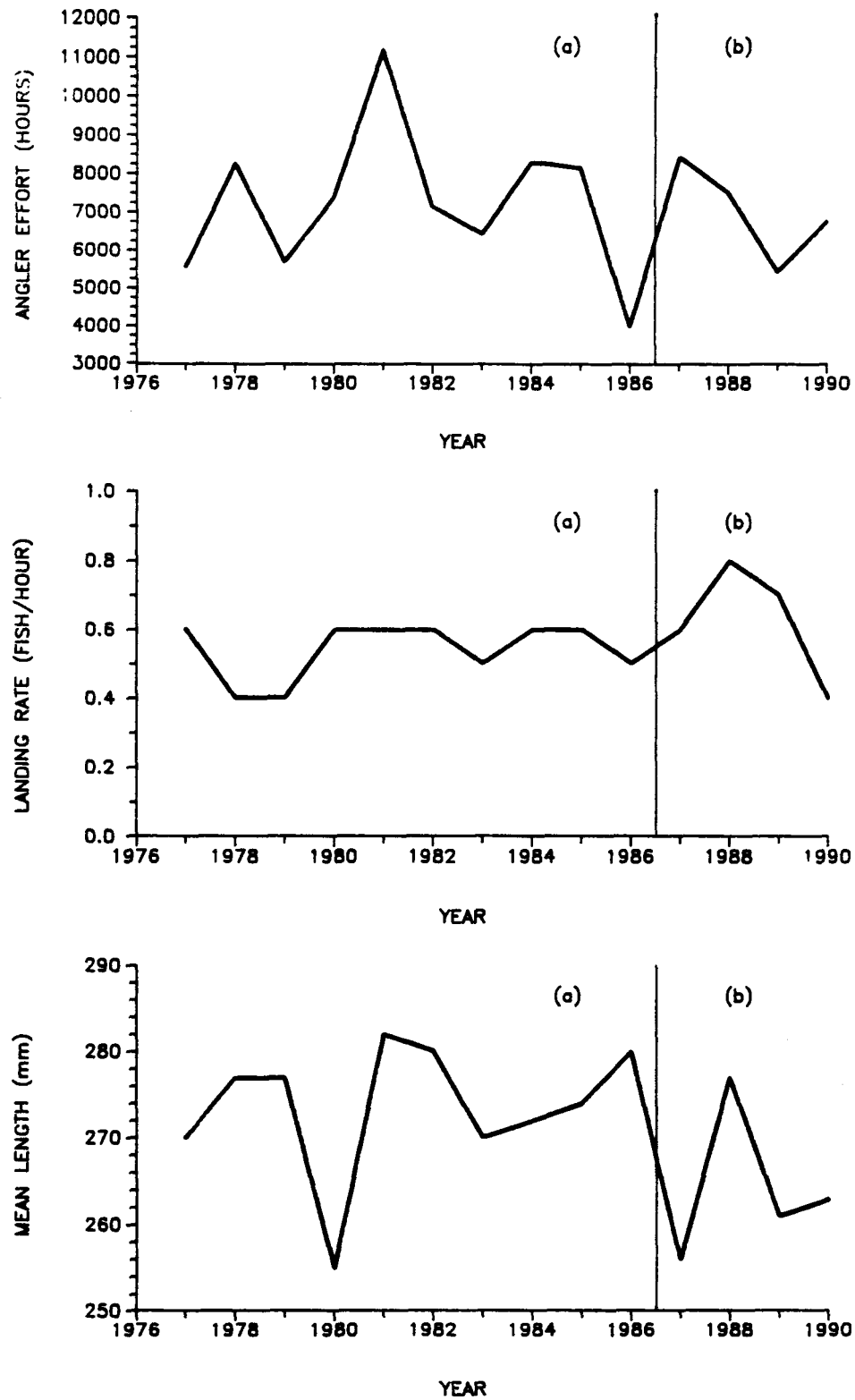


FIGURE 28.-Angler effort, mean annual landing rate, and mean length of landed fish (all species combined) in the Gibbon River from Madison Junction to Gibbon Falls, 1977 to 1990. See text for regulations in (a) and (b).

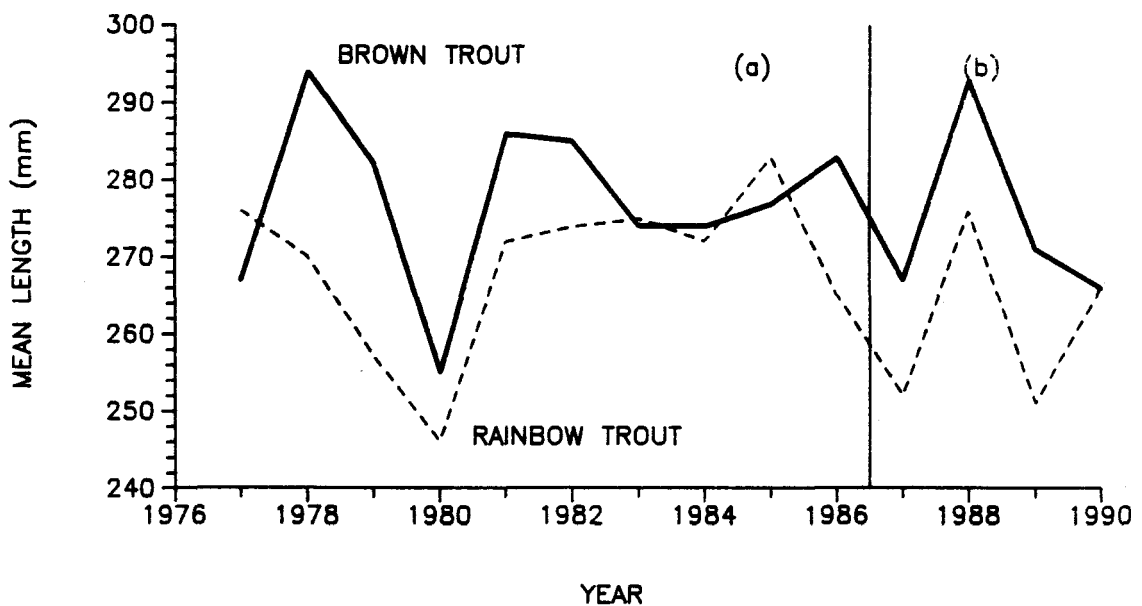
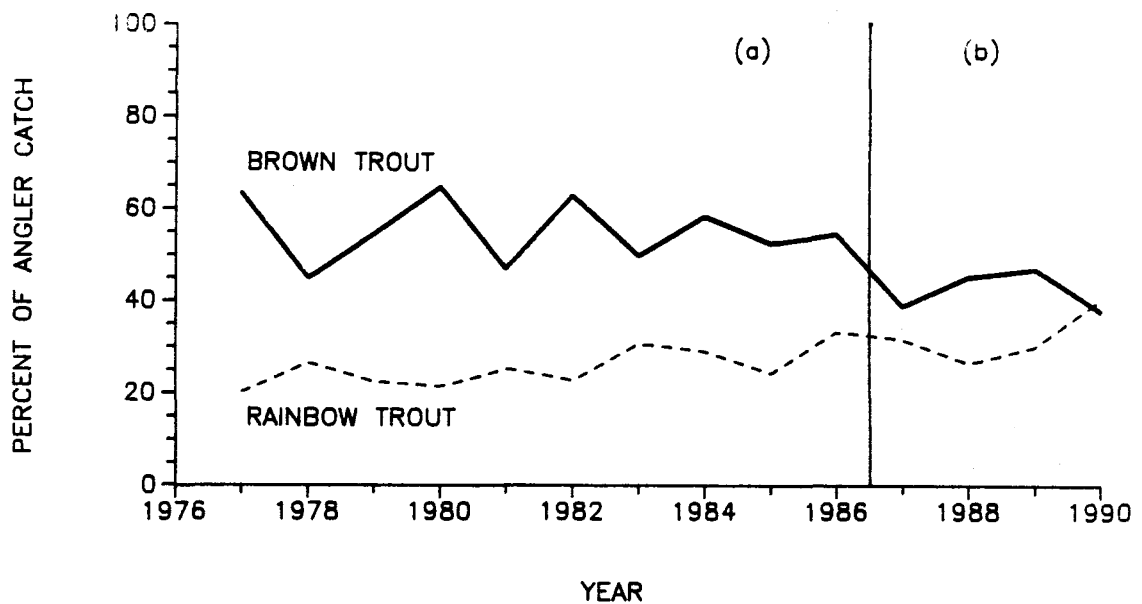


FIGURE 29.-Proportion of total catch and mean total length of brown trout and rainbow trout landed in the Gibbon River from Madison Junction to Gibbon Falls, 1977 to 1990. See text for regulations in (a) and (b).

Virginia Cascades section.-Anglers spent an estimated 1,740 h fishing in the Gibbon River between Virginia Cascades and Little Gibbon Falls in 1990 and landed an estimated 3,135 fish, of which 93% were brook trout. Mean landing rate in 1990 (1.8 fish/h) was 0.4 fish/h less than the average annual landing rate for the period between 1977 and 1990 (Figure 30). Mean length of landed fish in 1990 (230 mm) was equal to the average for the period 1987 to 1990, during which regulations have remained unchanged. Although the low number of VAR returns from this stream section may substantially bias estimates, there appear to be no detectable trends ($P > 0.05$) in angler effort ($r = 0.14$), landing rate ($r = 0.20$), or mean length of trout landed ($r = 0.31$) in this section of the Gibbon River. In addition, there were no significant differences in these parameters between the two periods of different angling regulations (1979 to 1986 versus 1987 to 1990).

Little Gibbon Falls to headwaters section.-Limited VAR data are available from the uppermost reach of the Gibbon River and no data are available for 1986 and 1987. Angler effort in this reach has averaged slightly over 300 h annually since 1979. In 1990, an estimated 275 h of fishing effort were expended in this section. Average annual effort in the post-regulation-change period (1988 to 1990) was about half that noted prior to 1986, but the reduction has not been significant ($t = 1.97$, $P > 0.05$). Estimated landing rate has fluctuated considerably from a record high of 3.6 fish/h in 1981 to a record low of 0.6 fish/h in 1988 (Figure 31). The 1990 landing rate (3.2 fish/h) was the second highest observed since 1979. Estimated mean length of landed fish has also exhibited considerable variation among years, but the 1990 mean length was the highest reported to date. Although average mean length in the post-regulation-change period has increased slightly (2 mm) from the average noted prior to 1987, the increase has not been significant ($t = 0.29$, $P > 0.05$). There have not been any significant trends in angler effort ($r = -0.16$), landing rate ($r = -0.01$), or mean length of trout caught ($r = 0.11$) in this headwater section of the Gibbon River, nor have there been significant changes in these parameters during the two periods of differing angling regulations.

Discussion

The Gibbon River has traditionally been a popular fishery in Yellowstone National Park. In 1990, this river was the fifth-most-popular stream fishery in terms of percent of total estimated parkwide use (Table 3). Numerous factors including fire activity, past introductions of nonnative fish species, and effects of angler harvest may have influenced the current species composition and distribution of fishes in the Gibbon River. Physical barriers to fish passage and longitudinal changes in habitats have spatially segregated the Gibbon River fishery into

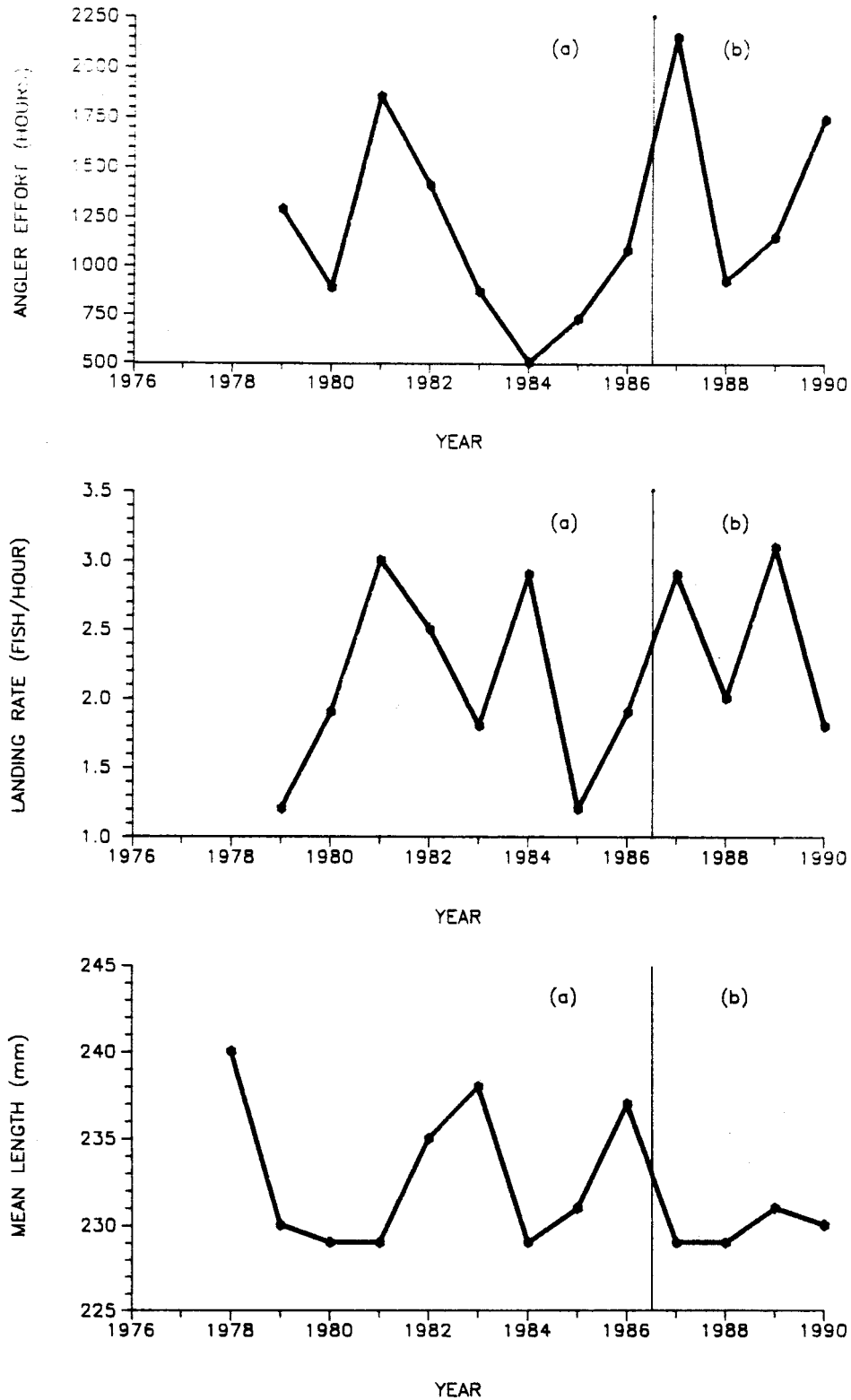


FIGURE 30.-Angler effort, mean annual landing rate, and mean total length of landed fish in the Gibbon River between Virginia Cascades and Little Gibbon Falls, 1978 to 1990. See text for regulations in (a) and (b).

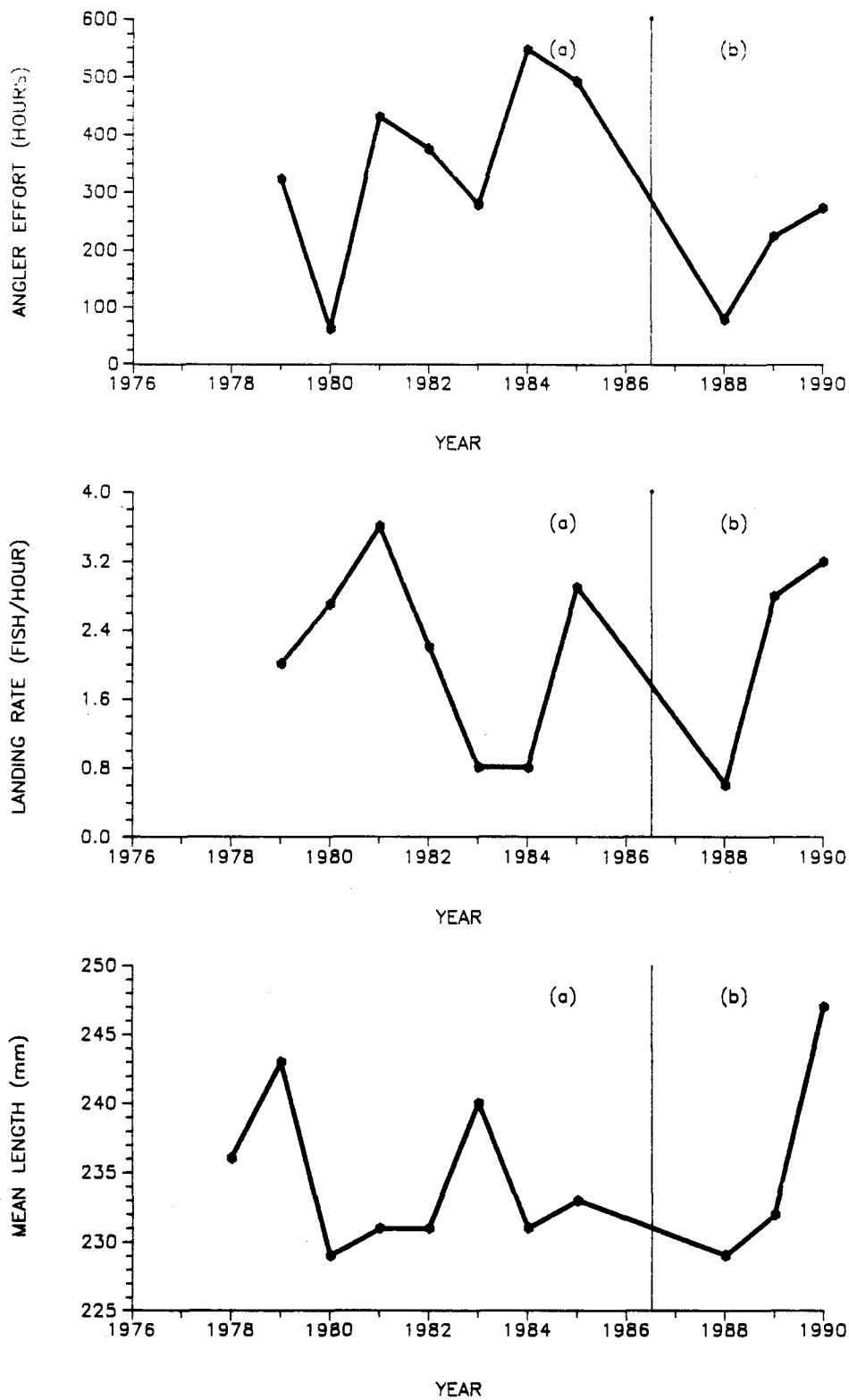


FIGURE 31.-Angler effort, mean landing rate, and mean total length of landed fish in the Gibbon River between Little Gibbon Falls and Grebe Lake, 1978 to 1990. See text for regulations in (a) and (b).

several distinct reaches that have been utilized as separate study areas.

In the lower Gibbon River habitat study section, channel stability and cover for trout appeared to be adequate during the post-fire study (1989 and 1990). Although this stream reach was exposed to intense burn activity, recovery of riparian vegetation has been rapid (Table 10). A concern in this reach has been the introduction of large amounts of sediment into the stream channel after the landslide in August 1989. Concentration of fine sediment increased at the study site by fall of that year. Negative impacts on trout spawning are not evident in current data, however. The collection of numerous young-of-the-year brown trout and rainbow trout at the lower site the following summer (Figures 24 and 25) indicate that successful spawning and emergence of young fish occurred despite the increased sedimentation. The primary effect of the increased sediments may have been a dramatic reduction (90%) in macroinvertebrate abundance (Mangum 1990).

As a result of past stocking activities, the current fish species composition and distribution in the Gibbon River bears little resemblance to historical accounts. Almost 25,000 Arctic grayling from Red Rocks Lake, MT, were stocked in the lower section of the Gibbon River in the fall of 1988. The fact that only one grayling was captured in the lower section during four electrofishing samples between 1987 and 1990 illustrates the difficulty of reestablishing a displaced population. In contrast, electrofishing results from the current study are in agreement with those of Dean and Varley (1974) with respect to species composition and relative abundance. This suggests that, in terms of these parameters, the populations have remained relatively stable for the past 25 years. However, few definitive comparisons can be made with the current study because of variability in the electrofishing results. In addition, several of the fish captured in October 1989 appeared to be in spawning condition. Some of these fish may have migrated into the study area from downstream reaches.

Data from VAR returns have revealed no significant trends in mean annual effort, landing rate, or mean length of fish caught from the Gibbon River between Gibbon Falls and Madison Junction. This suggests that current regulations may be providing sufficient protection to the population because negative trends are not apparent. The catch-and-release regulation for rainbow trout in the lower reach may be exhibiting positive benefits. Although not statistically significant ($r = 0.65$, $P > 0.05$), the estimated proportion of rainbow trout in the catch since 1987 has increased to nearly one-third of all fish landed (Figure 29). Prior to 1987, rainbow trout were an estimated 25% of the total catch. The no-harvest regulation for rainbow trout may be contributing to the increased proportion of rainbow trout in the catch.

In the upper three study reaches (Virginia Meadows, Ice Lake Meadows, and Wolf Lake Springs), few differences (except relative abundance) in rainbow trout populations were detected. The low abundance of rainbow trout in the Virginia Meadows section may be affected by the relatively high abundance of brook trout. Scarcity of large rainbow trout in the Ice Lake Meadows and Wolf Lake Springs sections is puzzling. Seamans (1940) described the macroinvertebrate productivity of the upper reaches of the Gibbon River as "poor." Preliminary data from the current study, however, indicate that macroinvertebrate abundance in the two upper study sites is above average for the Gibbon River. The habitat at these two sites may be unsuitable for adult trout, particularly during winter when the shallow pools may freeze.

The limited data available from VAR returns is also quite variable. Few negative trends are apparent and VAR data and electrofishing results (species composition and abundance) are generally comparable in these upper sections. Angler use is light in this portion of the river and angler effects on the trout populations appear to be minimal.

Lamar River

The Lamar River is the largest tributary of the Yellowstone River within Yellowstone National Park. The 129,500-hectare Lamar River watershed drains the northeastern portion of the Park and encompasses almost 15% of the entire Park area. From its headwaters in the Absaroka Mountains, the Lamar River flows to the west and north for nearly 70 km before joining the Yellowstone River near Tower Junction. Primary tributaries of the Lamar River include Slough Creek, Soda Butte Creek, Cache Creek, Calfee Creek, Cold Creek, and the Little Lamar River (Figure 32).

From the headwaters downstream to Cache Creek, the Lamar River is bordered by steep mountains formed by Eocene volcanic flows and the subsequent Pinedale glaciation. Upland slopes are generally covered with dense stands of lodgepole pine *Pinus contorta*. Whitebark pine *Pinus albicaulis* occur at higher elevations (>2,680 m) of upland areas, and subalpine fir *Abies lasiocarpa*/Engelmann spruce *Picea engelmanni* communities commonly occupy the moister soils. Downstream from Cache Creek, the Lamar River meanders for 15 km through a valley composed of loose, unconsolidated alluvial deposits, up to 30.5 m thick (Pierce 1974), that cover an undivided layer of rock of upper-Mississippian to middle-Cambrian age (Protska et al. 1975). Downstream from the valley and upstream from the confluence with Slough Creek, a 3-km-long outcrop of Precambrian gneiss forms the Lamar Canyon, which separates the lowermost 4 km of the Lamar River from the large valley area upstream. The valley portion of the watershed, as well as the area downstream from Lamar Canyon, are extensively utilized by elk *Cervus elaphus* and bison *Bison bison*, and includes the winter range of these animals (Figure 33). Pronghorn antelope *Antilocapra americana*, whitetail deer *Odocoileus virginianus*, coyote *Canis latrans*, and peregrine falcon *Falco peregrinus* may also be observed in this area.

Native fish species of the Lamar River include Yellowstone cutthroat trout *Oncorhynchus clarki bouvieri*, mountain sucker *Catostomus platyrhynchus*, longnose sucker *Catostomus catostomus*, and longnose dace *Rhinichthys cataractae*. In 1938, 70,600 rainbow trout *O. mykiss* were stocked into the Lamar River (Varley 1981). The subsequent establishment of a rainbow trout population has jeopardized the genetic integrity of the native cutthroat trout population of the Lamar River. Arnold and Sharpe (1967) and Dean and Mills (1970) reported that trout populations downstream from Lamar Canyon consisted of cutthroat trout, rainbow trout, and cutthroat trout X rainbow trout hybrids. On the basis of a recent field examination, the current trout population in the Lamar River valley appears to be composed primarily of rainbow trout X cutthroat trout hybrids (D. Shiozawa, personal communication).

The Lamar River has traditionally supported one of the most

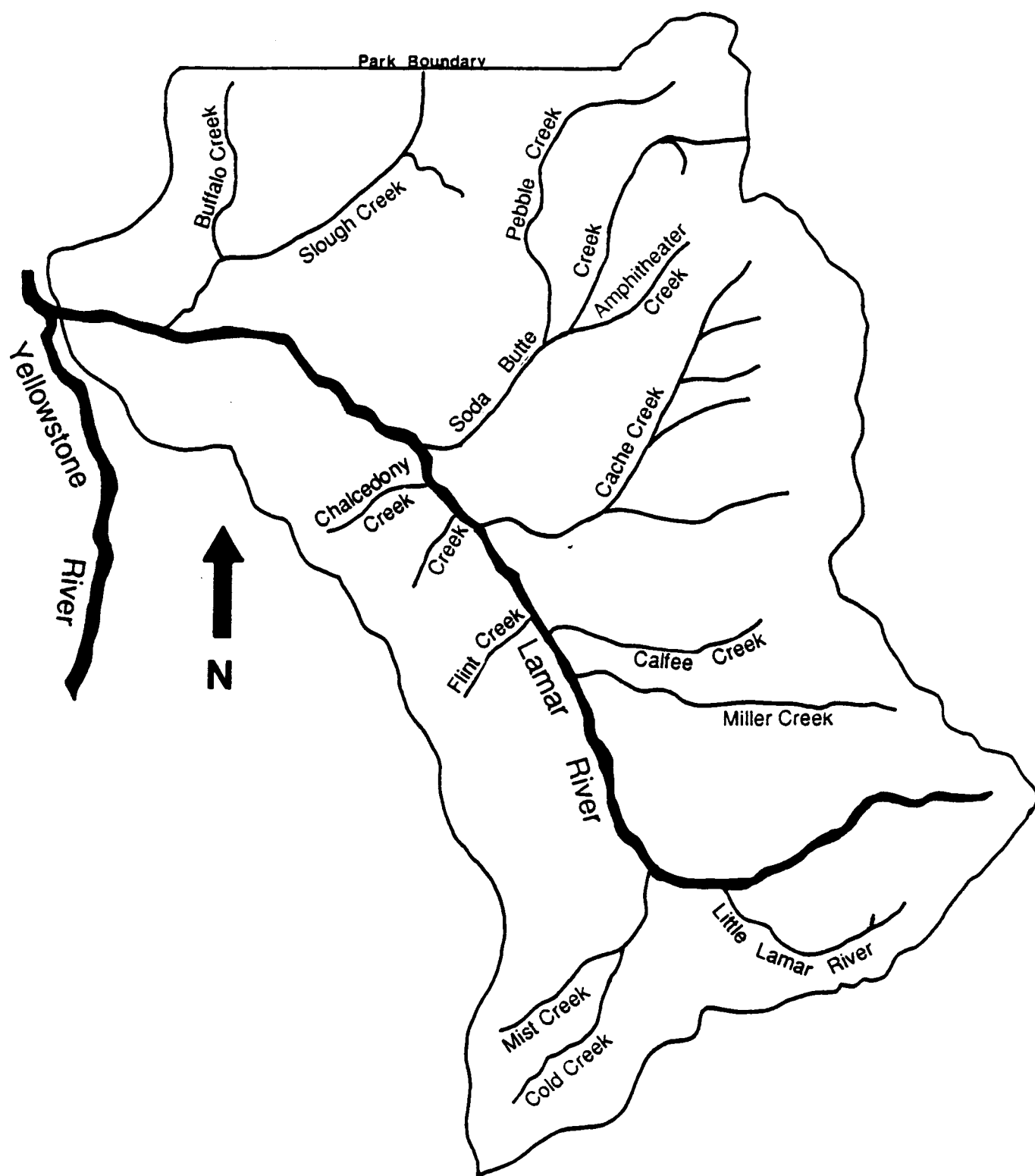


Fig. 32. Named streams in the Lamar River drainage, Yellowstone National Park.

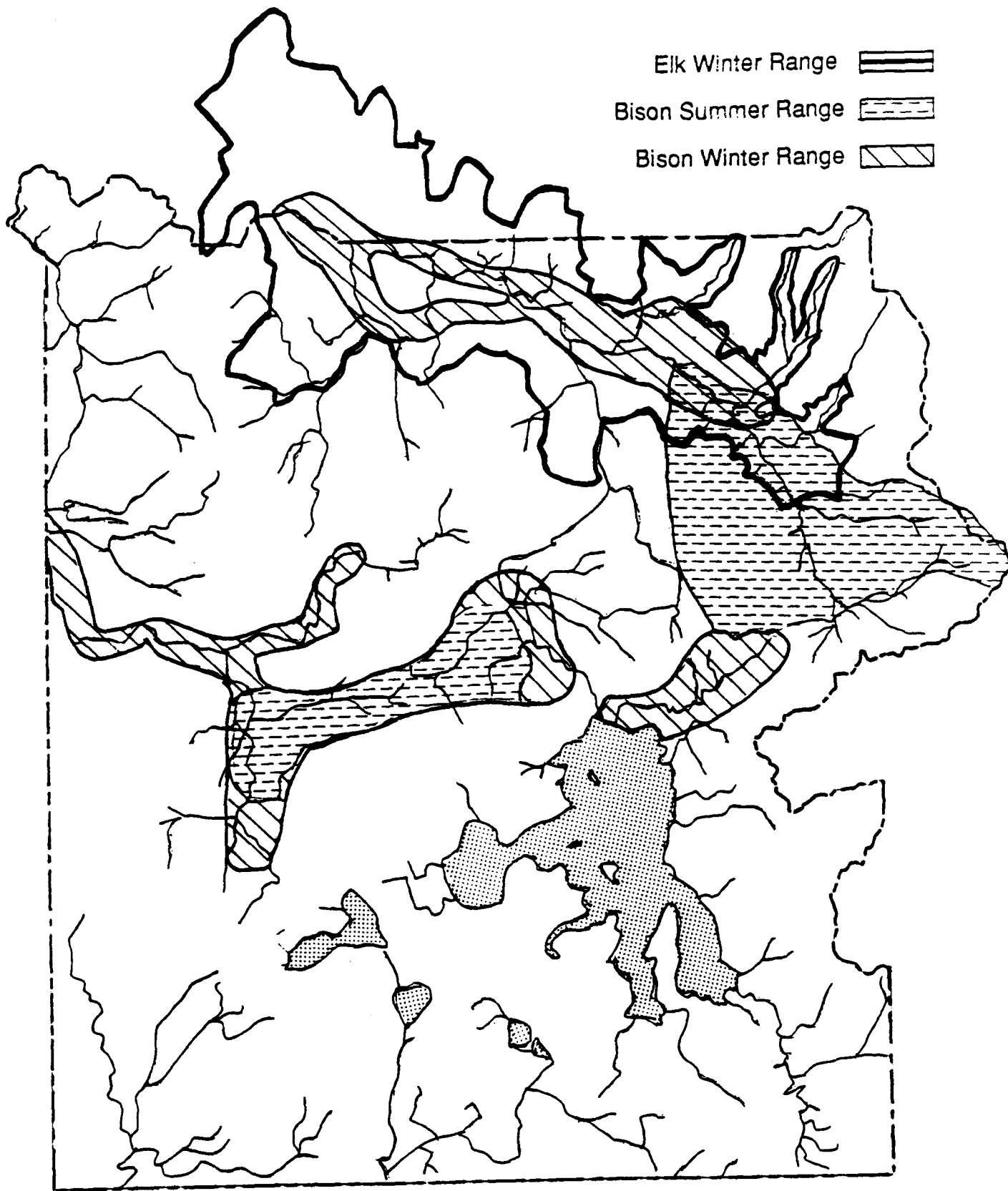


Fig. 33. Winter range of elk and summer and winter bison ranges.

popular stream fisheries in the Park. The wide, picturesque valley and convenient highway access heighten the appeal of the river to anglers. In 1990, the Lamar River was the eighth-most-popular fishery in Yellowstone National Park and sustained slightly over 2% of the estimated total parkwide angler use (Table 3). Since 1973, the reach of the Lamar River between Cache Creek and the confluence with the Yellowstone River (Figure 32) has been managed under a catch-and-release-only regulation. In 1987, the catch-and-release area was extended upstream to Calfee Creek. Current angling regulations restrict harvest from the Lamar River to two fish of any size, but fish can be creel (kept) only in the mainstem Lamar River and tributaries upstream from and including Calfee Creek.

Information obtained from the Volunteer Angler Report (VAR) system (Dean and Varley 1974) indicates that the majority of angler use in the Lamar River occurs between Cache Creek and Lamar Canyon. Fishery management studies of the Lamar River have also been concentrated within this area. Arnold and Sharpe (1967) provided a habitat description, sampled the fish population, and rated fish abundance as "poor to fair" in this portion of the Lamar River. Subsequently, Jones et al. (1977 to 1980) used VAR data to evaluate responses of the fishery to catch-and-release regulations and concluded that the Lamar River contained a healthy trout population. Since 1984, additional studies of population structure and population size have been conducted in a section of the catch-and-release area of the Lamar River valley (Jones et al. 1985, 1987, 1989).

Studies of the Lamar River fishery were continued in 1990. Study objectives included: (1) an assessment of the current status of the trout populations in the Lamar River valley catch-and-release area, (2) a synthesis of data from previous studies, (3) an analysis of long-term trends in important fishery parameters, and (4) an examination of fishing and other factors that may influence the Lamar River fishery.

Methods

Habitat, water chemistry, and aquatic macroinvertebrate collection sites were located near the Lamar River picnic area. These sites were within the electrofishing sample reach, which extended from the confluence with Soda Butte Creek downstream for a distance of 2.2 km (Figure 34).

For the third consecutive year, a reconnaissance-level survey (Jones et al. 1989) was conducted at the three permanent aquatic habitat transects. In addition to the parameters usually measured, water depths at the second and third transects were used to obtain a channel profile. Habitat data from the transect sites was also analyzed in terms of indices derived from the General Aquatic Wildlife System (GAWS) program of the U.S. Forest Service (USFS 1988). Program outputs include the Habitat Condition Index (based on substrate, pool area and quality, and streambank vegetation stability), which compares current stream

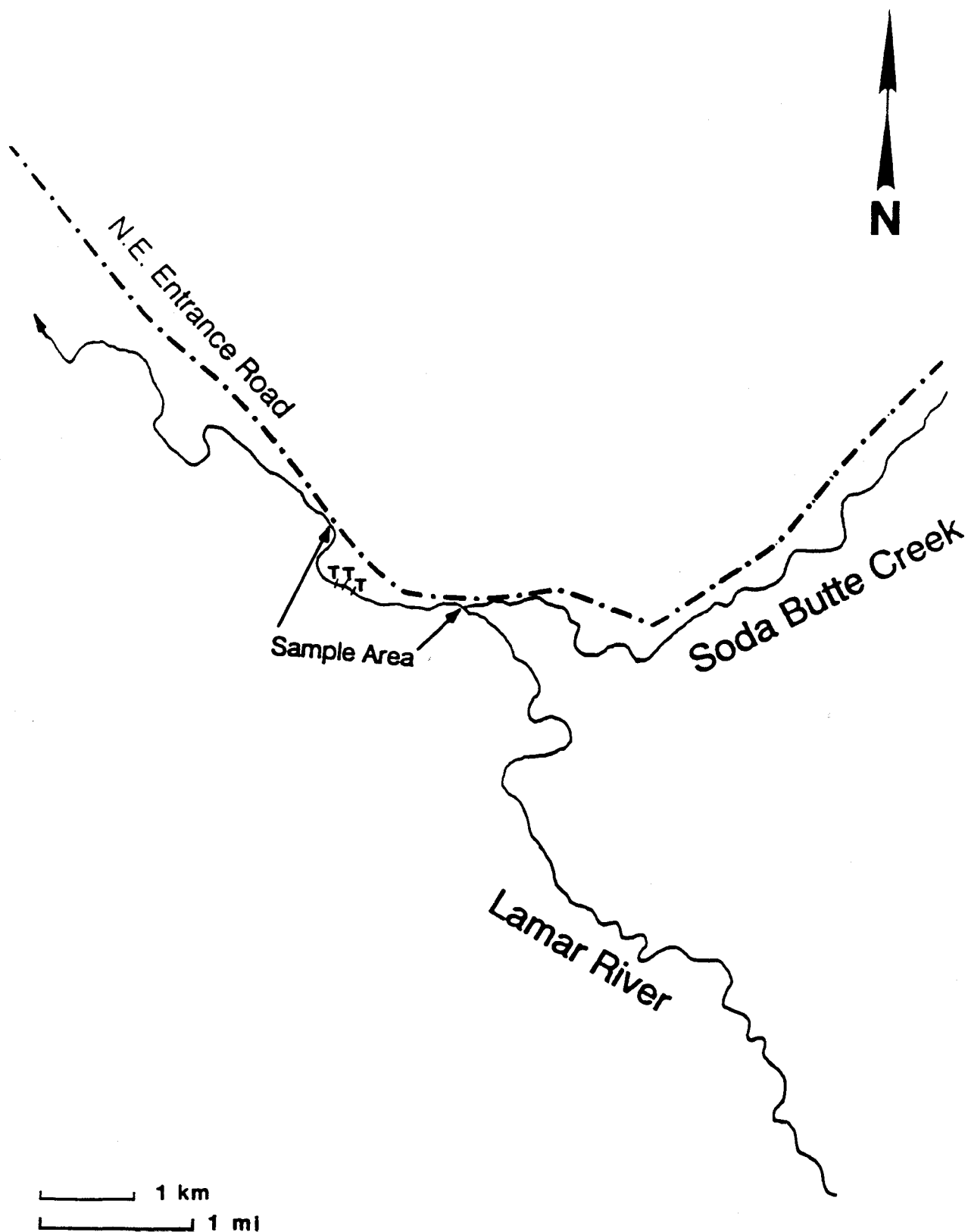


FIGURE 34.-Map of Lamar River valley catch and release section showing electrofishing sample area and habitat transect sites (T).

condition to a theoretical optimum condition, and the Habitat Vulnerability Index, a measure of the susceptibility of the stream channel (based on gradient, streambank stability, and geological features) to erosive forces.

A water sample was collected and then analyzed by a commercial laboratory. Specific conductance and water temperature were measured prior to each electrofishing pass.

Three macroinvertebrate samples were collected from a riffle area with a Surber sampler (0.09 m^2), preserved, and analyzed by an independent investigator. The Biotic Condition Index (Winget and Mangum 1979) and biomass estimates were among the products of the macroinvertebrate analyses.

Data from mark-and-recapture electrofishing were used to make an adjusted Peterson estimate of population size (Ricker 1975). Fish were collected from a 4.2-m-long raft equipped with boom-mounted electrodes. All captured fish were measured to the nearest millimeter in total length (TL). Fish from a stratified subsample (based on 25-mm length groups) from the total catch were individually weighed to the nearest 2 g. Scales were collected from these fish for age-and-growth analyses.

Proportional Stock Density (PSD) and Relative Stock Density (RSD) indices were used to examine the length structure of the trout populations sampled by electrofishing. Following guidelines recommended by Gabelhouse (1984), 203, 381, and 457 mm TL were used as stock, quality, and preferred lengths, respectively, for cutthroat trout.

The influence of anglers on the Lamar River fishery was examined by using VAR data compiled since 1973. Analyses of VAR data (Jones et al. 1977) yielded estimates of total angler use and effort, landing rate, mean total length of fish landed, length composition of the angler-caught trout, and total number of fish landed. Lengths of landed fish are reported on VAR cards in 51-mm increments of fish length. When a particular length of importance to our analyses (e.g., 330 mm) occurred within a 51-mm interval, fish lengths were assumed to be uniformly distributed (Zar 1984) within the interval and only fish longer than the length of interest were used in the analysis. Linear correlation was used to test for significant ($P < 0.05$) trends in VAR data.

Results

Physical characteristics

In 1990, high solar angle (amount of sunlight reaching the stream channel) and lack of undercut banks and instream channel vegetative cover were characteristics of the Lamar River similar to those of the previous two surveys (Table 12). Relatively high discharge in 1990 increased mean channel width, stream depth, and size and quality of the pools at the transect sites. Conversely, in 1990, average riffle width was only one-third that of the previous two surveys.

Although streambank vegetation stability has shown a moderate decline since 1988, the amount of streambank erosion has remained essentially unchanged. An increase in the frequency of

TABLE 12.-Drainage basin characteristics and habitat features of Lamar River near the Lamar River picnic area, 1988 to 1990.

Stream order	V		
Length (km)	2.277		
Elevation:			
Maximum (m)	2,002.5		
Minimum (m)	1,988.8		
Drainage Size (hectares)	99,816.1		
Stream type ^a	C1		
Habitat features	1988	1989	1990
Sample date	11/6	9/7	9/6
Time	0945	1100	1530
Water column:			
Flow (m ³ /s)	1.599	3.860	6.198
Channel width (m)	41.7	38.0	44.6
Stream width (m)	24.9	26.8	26.8
Stream depth (cm)	27.7	38.4	41.8
Stream shore water depth (cm)	0.0	0.0	0.0
Riffle width (m)	2.1	2.9	0.8
Pools:			
Width (m)	17.1	17.9	18.7
Quality	3.8	2.8	3.3
Feature ^b	4,2	2,4	2,4
Solar angle (°)	152.3	151.3	153.3
Channel morphology			
Streambank alteration (%)	52.5	52.5	50.0
Vegetative stability	3.2	3.0	2.8
Undercut (cm)	0.0	0.3	0.0
Channel-bank angle (°)	156.7	137.5	160.0
Stream bottom:			
Gradient (%)	1.1	0.6	1.0
Sinuosity	1.03	1.03	1.04
Substrate: (%)			
Bedrock			
Boulder (>305 mm)	9.6	3.2	4.2
Cobble (64-305 mm)	54.8	54.6	61.1
Gravel (2-64 mm)	9.6	12.0	14.9
Sand (0.6-2 mm)	10.9	20.9	10.3
Silt (<0.6 mm)	17.4	9.3	9.5
Embeddedness (%)	22	62	32
Channel vegetative cover (cm)	0.0	0.0	0.0
Riparian zone:			
Streamside cover type	2.5	1.7	1.5
Vegetative use (%)	26	17	14
Vegetation overhang (cm)	0.0	0.0	6.1
Habitat type	8,12	8,3	9,13

^a After Rosgen (1985).

^b 1 = log, tree, root, stump, brush, or debris; 2 = channel meander; 3 = rubble or gravel; 4 = boulder or bedrock; 5 = stream channel; 6 = fine sediments; 7 = streambank.

slumped banks in 1990 resulted in greater channel bank angles and more bare ground (i.e., low value for streamside cover type) than in previous years (Table 12). Substrate embeddedness in 1990 was half that observed in 1989 and large particles (cobble and gravel) composed over 75% of the bottom material. This suggests that runoff flows effectively transport fine sediments (sand and silt) through this stream reach.

Results from the GAWS program (USFS 1988) indicated that Habitat Condition Index of the Lamar River has varied little since 1988 and was highest in 1990. Habitat Vulnerability Index has followed a similar pattern and indicates the Lamar River study site is moderately susceptible to erosion.

Water Chemistry

Chemical analyses indicate that the Lamar River is a moderately dilute calcium-bicarbonate stream. Concentrations of major ionic components from the Lamar River are within the ranges of other calcium-bicarbonate streams in Yellowstone National Park, although values for total dissolved solids, alkalinity, and hardness are slightly above the average for 48 other calcium-bicarbonate streams in the Park.

Available water chemistry data for the Lamar River are not extensive and long-term trends in these data are not evident. Analyses of samples collected in September 1984, 1989, and 1990, however, reveal that primary chemical characteristics have been relatively stable (Table 13). The 1984 sample was collected near the mouth of the river, and elevated concentrations of some chemical components in this sample may be influenced by waters from Slough Creek, a tributary upstream.

Macroinvertebrates

Several investigators have sampled benthic aquatic macroinvertebrates from the Lamar River. Muttkowski (1929) included macroinvertebrates from the Lamar River in his discussion of stream ecology in Yellowstone National Park. Arnold and Sharpe (1967) collected a diverse group of aquatic macroinvertebrates from the Lamar River watershed. Dipterans and mayflies were found at each of the five mainstem collection sites and the aquatic invertebrate population was rated "good" at the sample site a short distance downstream from the picnic area transect sites of the current study.

In recent studies, aquatic macroinvertebrates have generally been identified to the taxonomic level of genera or species. In summer of 1988, 12 macroinvertebrate taxa were collected from the habitat study area. Seven ephemeropteran species, three trichopteran species, and two dipteran genera were represented. In subsequent collections (fall of 1988 and 1989), species richness (number of taxa) more than doubled in comparison to the July 1988 sample (Table 14). All but three taxa (*Prosimulium* sp. and two species of *Cheumatopsyche* sp.) from the summer 1988 sample were found in the September 1989 collection; however, different genera within the same families (Simuliidae and Hydropsychidae, respectively) were found in the 1989 sample.

TABLE 13.-Chemical characteristics of the Lamar River, 1984, 1989, and 1990. Turbidity expressed in NTUs, other values (except pH) expressed in mg/L.

	1984	1989	1990
Total Dissolved Solid	120	110	130
Total Alkalinity	93	55	90
Phenolphthalein Alkalinity	0	<2.0	<2.0
Carbonate Alkalinity	0	<4.0	<0.5
Bicarbonate Alkalinity	93	55	90
Total Hardness	95.9	76.1	77
Magnesium Hardness	40.5	28.2	28
Calcium Hardness	55.4	47.9	49
Carbonates	0	<2.4	<0.5
Bicarbonates	113	67	90
Hydroxides	0	0	<2.0
Carbon Dioxide	0.3	<1.0	2.4
Chloride	<1	<1	<1
Sulfate	11.6	12	6.1
Fluoride	8	0.1	0.5
Silica	10.4	2.7	21
Hydrogen Sulfide	<0.01	<0.1	<0.1
Sodium	11.3	11.6	12
Potassium	1.52	<1.0	<1.0
Calcium	55.4	19.2	19
Magnesium	9.85	6.85	6.90
Iron	0.79	0.22	0.38
Manganese	<0.05	<0.05	<0.05
Copper	<0.01	0.02	<0.01
pH	8.0	8.1	7.9
Turbidity	7.9	1.7	0.86

TABLE 14.-Macroinvertebrate community characteristics in Lamar River, 1988 and 1989.

	July 1988	November 1988	September 1989
Total # of taxa	12	28	32
BCI	85	98	94
% Collectors	74.6	78.7	78.0
% Scrapers	0.8	1.6	2.6
% Shredders	13.3	7.6	8.1
% Predators	11.2	12.1	10.9

Plecopterans and chironomids (which were absent from the summer 1988 sample) comprised nearly half of the increase in species richness in the fall samples.

Estimated macroinvertebrate biomass at the sample site in November 1988 and September 1989 was 2.9 and 6.0 g/m², respectively. This biomass is considered excellent in view of the low alkalinity of the Lamar River (Mangum 1990). The estimated high macroinvertebrate biomass in the Lamar River results from the estimated abundance of almost 40,000 organisms/m² in November 1988, nearly 75% of which were chironomids.

Aquatic habitat, as measured by the Biotic Condition Index (Winget and Mangum 1979), was rated as good to excellent (i.e., >85) in all three samples (Table 14). Although approximately 40% of the macroinvertebrate species in each collection can be classified as sediment-tolerant, the presence of cleanwater species such as *Drunella doddsi* and *Rhithrogena* sp. indicates good water quality and aquatic macroinvertebrate habitat (Mangum 1990).

Classification of the macroinvertebrate samples according to trophic groups (Cummins 1977) showed few differences among samples (Table 14). Collectors were the majority of each sample and predators comprised an average of 11% of the total community. Scrapers constituted a minor group in all samples. This result was not totally unexpected because instream vegetation (such as attached algae) that scrapers depend upon for food (Vannote et al. 1980) was scarce in the study area (Table 12). The relatively high proportion of shredders compared to scrapers in the community (Table 14) was an unexpected result, however. Community structure similar to that of these samples commonly occurs in headwater streams that receive extensive input of riparian vegetation.

Fish

In 1990, 199 rainbow trout X cutthroat trout hybrids were captured in the Lamar River electrofishing study area. Estimated population size for trout longer than 120 mm was 1,063 trout (95% confidence limits, 474-2,657 fish), or approximately 180 fish/hectare. Mean total length of trout in the 1990 sample (287 mm) represented a significant ($P < 0.05$) increase over the 1988 sample (267 mm); however, the increase over the 1989 sample (mean TL = 280 mm) was not significant. The PSD and RSD values for the 1990 sample were 8 and 1, respectively. Although PSD has declined since 1984, RSD values have been relatively stable. Examination of length frequencies shows that nearly 40% of the hybrid trout captured in 1990 were longer than 300 mm TL (Figure 35). This population structure was similar to that observed in 1989 and suggests a reversal in the declining proportion of large fish noted since 1984.

Mean weight of fish from a subsample of rainbow trout X cutthroat trout hybrids collected in 1990 was 293 g. This yielded an estimated biomass of 24 kg/hectare in the study section. In 1989, estimated biomass for this reach was about 17 kg/hectare. Although estimated biomass and population size in

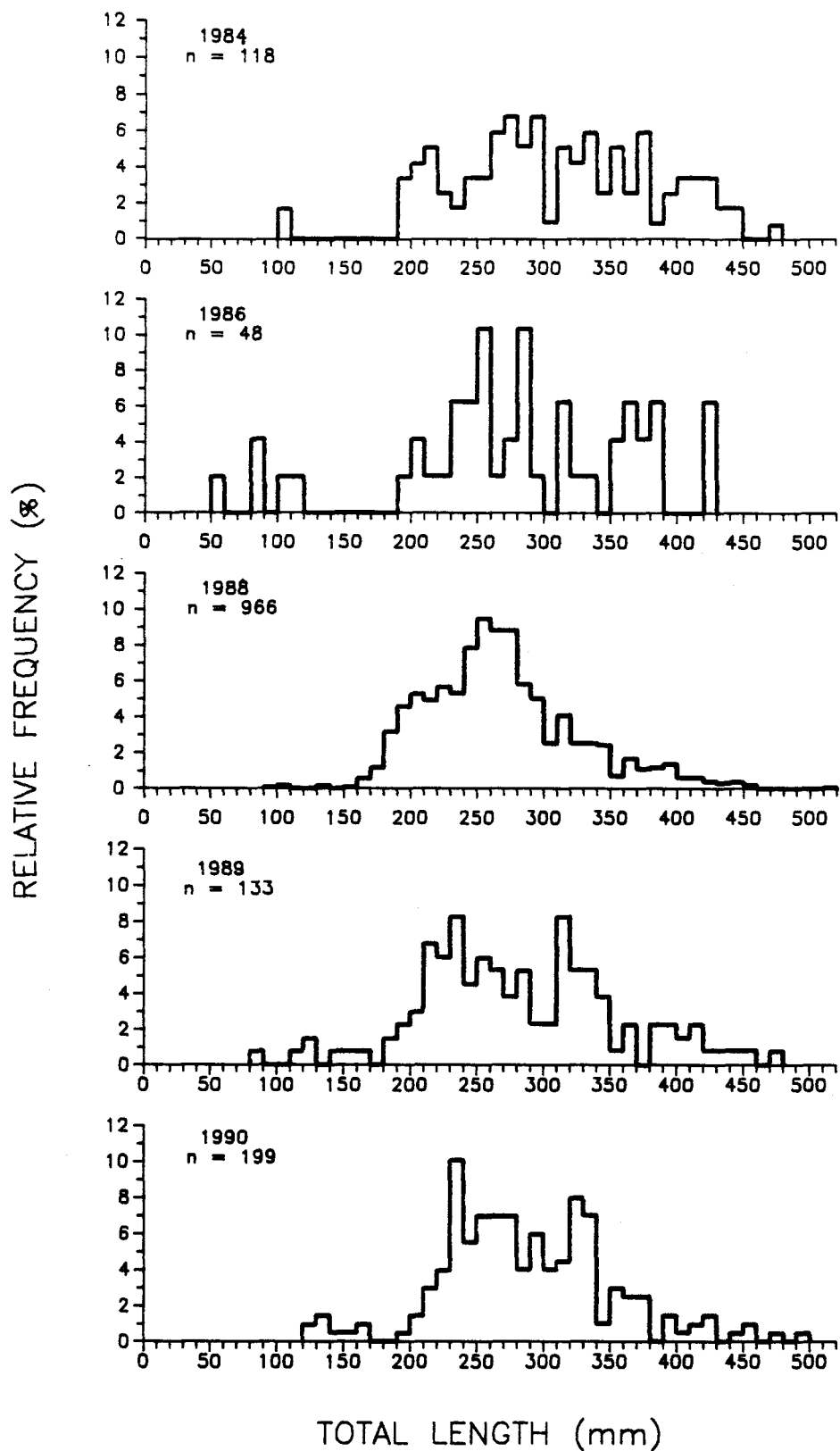


FIGURE 35 .-Length-frequency distributions of rainbow trout x cutthroat trout hybrids captured by electrofishing, Lamar River, 1984 to 1990.

1990 were the second-highest to date, they were only one-fourth the values observed in 1988 (Jones et al. 1989).

Analyses of scales from 82 of the hybrid trout yielded seven age classes in the 1990 electrofishing catch. Estimated mean age for the entire catch was 3.2 years, which was the youngest estimated mean age in 5 years of sampling by electrofishing. In all 5 sample years, rainbow trout X cutthroat trout hybrids >330 mm TL have generally been classified as 5-year-old or older fish.

In contrast to the decrease observed in mean age of captured fish, estimated growth rates have increased from a mean-annual growth of 59 mm in the 1988 sample to 65 mm/year in the 1990 catch. The growth pattern of fish from 1990 (fastest growth in age-3 and age-4 fish) was similar to that observed in previous electrofishing catches from the Lamar River (Jones et al. 1985).

In each of the past 3 years, a few putative rainbow trout have been part of the electrofishing sample. In 1990, 15 rainbow trout were captured (mean total length, 299 mm). Mean weight and condition factor (K) of a subsample ($N = 14$) of the rainbow trout were 272 g and 0.99, respectively. As in 1988 and 1989, PSD in 1990 was 0 because no rainbow trout longer than the suggested quality length (Gabelhouse 1984) of 406 mm TL were captured.

Examination of scales from a subsample of seven rainbow trout revealed that four age classes were present in the 1990 electrofishing sample. Almost half of the rainbow trout were classified as age 4 or older. Estimated mean age for all of the rainbow trout ($N = 15$) in the electrofishing catch was 3.7 years. Mean-annual growth in length of these fish was estimated to be 68 mm. Growth of rainbow trout was greatest in their third and fourth years. Although this growth pattern is similar to that observed in the hybrid trout, rainbow trout growth appears slower than that of rainbow trout X cutthroat trout hybrids in the first two growing seasons. This disparity continued into later years. Thus, despite similar growth rates in their fourth year, mean back-calculated length of rainbow trout at annulus IV averaged 242 mm for the period from 1988 to 1990. Comparable length for the rainbow trout X cutthroat trout hybrids was 270 mm TL.

Angler Use

In 1990, an estimated 1,665 anglers spent 10,000 h fishing the Lamar River between Lamar Canyon and the confluence with Calfee Creek. Returns from VAR cards indicated that the estimated landing rate in this portion of the Lamar River (1.1 fish/h) increased slightly over the 1989 catch rate of 1.0 fish/h. Despite this increase, the 1990 landing rate was nearly 0.5 fish/h less than the mean landing rate (1.55 fish/h) for the period from 1976 to 1990 (Figure 36), and reflects the significant decrease ($P < 0.05$) in landing rate since 1976.

Estimated mean total length of landed trout in this section of the Lamar River has exhibited a trend similar to that for landing rate (Figure 36). Mean total length of landed trout in 1990 (297 mm) was unchanged from data for 1989; however, the mean total length in 1990 was the fourth-smallest observed since 1976.

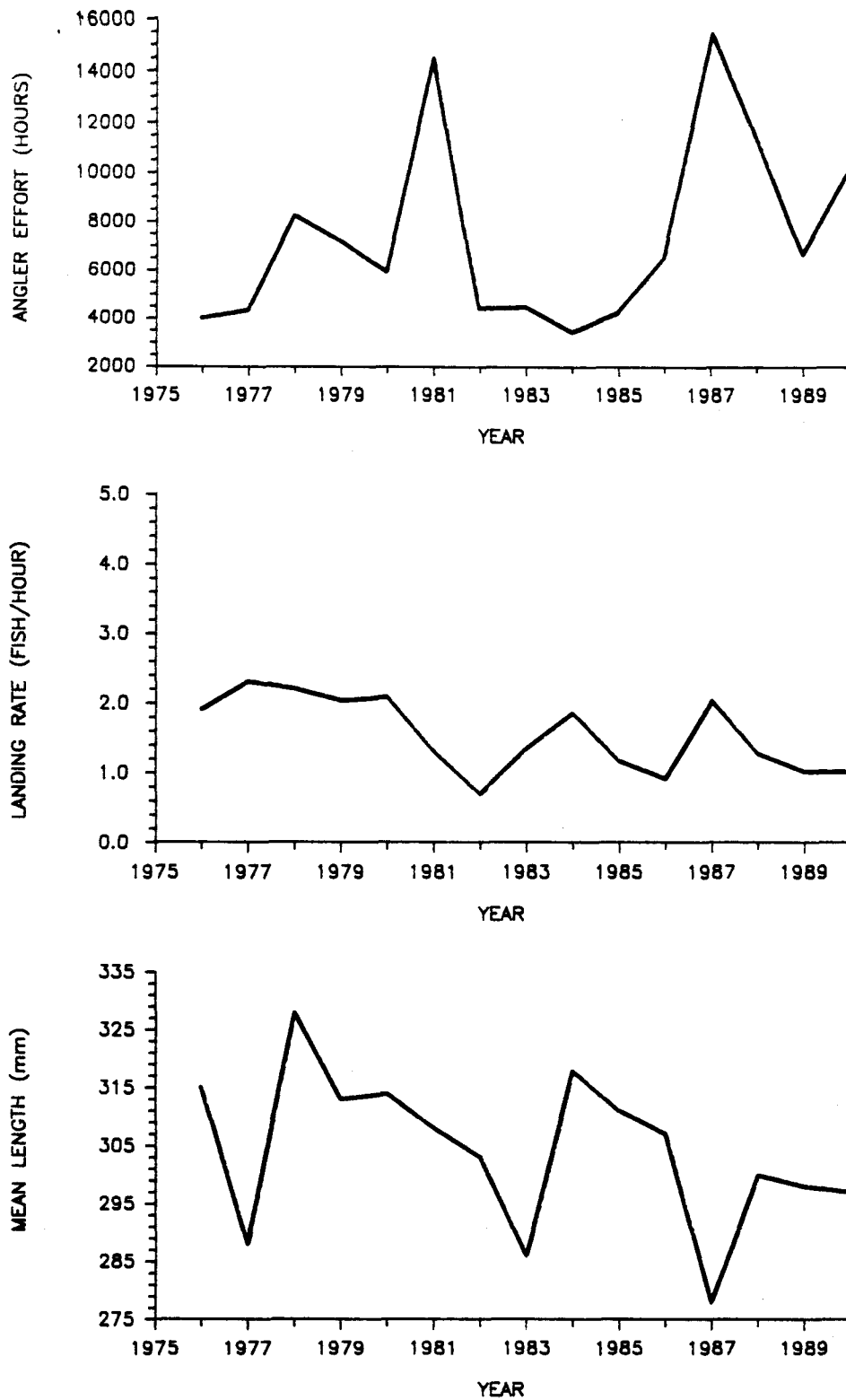


FIGURE 36 -Angler statistics from Lamar River valley catch and release area, 1976 to 1990.

Despite the variability in average length of landed trout during the past 13 years, almost one-third of the fish landed were ≥ 330 mm TL.

The estimated 11,000 trout landed in the Lamar Valley in 1990 was 66% greater than the number landed in 1989 and only slightly less than the average-annual catch for the period 1976 to 1990 (11,349 trout landed). As in the trends for angler hours, landing rate, and mean total length of fish landed, total annual catch in the Lamar River has exhibited much variability. Because landing rate was relatively low in 1990, the increased total number of trout landed resulted primarily from the higher-than-average angler effort in 1990.

Discussion

Numerous studies of the Lamar River have examined the physical characteristics and hydrological processes of the watershed. Historical descriptions have emphasized the unstable condition of the streambed and the large amounts of sediment in the system. Muttkowski (1929) classified the Lamar River as a "flood" type stream characterized by dramatic changes in streamflow, pool scouring, and deposition of silt following the spring runoff period. Annual variation in streamflow is considered one of the primary physical forces affecting trout production in streams (Binns and Eiserman 1979; Binns 1982).

Several decades after Muttkowski's description of the Lamar River, Arnold and Sharpe (1967) reported extensive eroding of streambanks and a lack of ground cover along the sagebrush and grassy slopes of the lower valley. Severe bank cutting and slumping were common in the alluvial flood plains, and the investigators speculated that erosion and siltation were major factors limiting trout reproduction and survival in the Lamar River. Results of the habitat surveys conducted between 1988 and 1990 indicated that about one-half of the streambanks within the study section were subject to some erosion (Table 12) and that composition of small substrate (<64-mm diameter) in the streambed varied considerably on an annual basis. As a result, suitable cover for trout was restricted to the large pools within the reach.

Several investigations of the sediment dynamics of the Lamar River watershed have been initiated in recent years, in response to the suggestion that the drainage is producing more sediment than it did a decade ago. Studies by Mohrman et al. (1988) and Ewing and Mohrman (1990) have shown that the Lamar River transports large amounts of sediment. Moreover, examination of the surficial geology of the watershed (Shovic et al. 1988) indicated that the watershed is highly erosive, and eroded materials contribute to elevated sediment concentrations in the river following storm events. Christensen et al. (1989) suggested that large amounts of sediment could be introduced into stream channels following the major wildfires of 1988, when about half of the Lamar River watershed upstream from the electrofishing study area was burned. During the post-fire period, fine-sediment deposition was noted in pools throughout the study reach and available trout habitat may have been

temporarily reduced. Preliminary data (Ewing and Mohrman 1990) revealed that post-fire sediment concentrations in the Lamar River were within the range encountered in the pre-fire period.

High levels of turbidity could have negative effects on a cutthroat trout population. In a review of turbidity effects on salmonids, Lloyd (1987) stated that feeding by cutthroat trout may be reduced when turbidity reaches 35 ppm. Turbidity concentrations in the Lamar River are often higher than this, although such events are normally of short duration (Mohrman et al. 1988). Specific effects of elevated turbidity on cutthroat trout in the Lamar River are unknown.

Chemical components of flowing water are inherently variable in concentration (Hem 1985). The few water-chemistry data from the Lamar River reflect this variability and show no definitive trends. Although concentrations of total dissolved solids, total alkalinity, and total hardness are higher in the samples from 1984, 1989, and 1990 than in the samples of Arnold and Sharpe (1967), values for these samples are within the range of other calcium-bicarbonate streams in Yellowstone National Park (e.g., Cache Creek, Slough Creek, and Yellowstone River) that support cutthroat trout populations. The available water-chemistry data do not indicate factors that would be detrimental to resident trout.

Composition of aquatic macroinvertebrate communities can be highly variable (Needham and Usinger 1956; Pollard and McKinney 1979; Keup 1988), and intensive sampling is often required to detect long-term changes in the resident community. The macroinvertebrate community of the Lamar River has not been sampled intensively, but limited comparisons of data can be made. Although quantitative macroinvertebrate data were not provided by either Muttkowski (1929) or Arnold and Sharpe (1967), their qualitative descriptions (e.g., macroinvertebrate orders represented) are in agreement with the current study. Although he did not mention specific collection sites, Muttkowski collected *Brachycentrus* sp., *Atherix* sp., and simuliids from the Lamar River in 1921. These taxa also occurred in the samples from 1988 and 1989. This suggests that, on this broad taxonomic level, at least a portion of the macroinvertebrate community of the Lamar River has remained unchanged for nearly 70 years.

Macroinvertebrate abundance described in early investigations of the Lamar River was adequate to sustain resident trout. The macroinvertebrate biomass estimated in the current study could support a good fishery, and the large stoneflies in the benthic community could be an especially important food source for large trout (Mangum 1990).

Many of the macroinvertebrate taxa in recent collections are tolerant of some environmental fluctuations, particularly changes in sediment concentrations (Mangum 1990), and they appear ideally suited to the dynamic habitat conditions of the Lamar River. Nonetheless, elevated river turbidities could affect the benthic macroinvertebrate communities. Reduction in water clarity during periods of high turbidity could reduce production of instream aquatic vegetation. As a result, invertebrate species (e.g., scrapers) that depend on attached algae for food could be limited in abundance. Recent collections reveal a scarcity of scrapers

within the macroinvertebrate community of the study area (Table 14). In contrast, the high proportion of shredders in the Lamar River samples is indicative of excellent riparian habitat conditions (Mangum 1990).

Electrofishing data on the cutthroat trout populations in the Lamar River do not reveal definitive trends and some data appear contradictory. For example, while PSD values have generally declined since 1984, the mean length of trout caught by electrofishing has generally increased since 1986. Mean total length and PSD are not necessarily correlated with each other, however, because they are measures of somewhat different data sets. The PSD data set has a minimum-fish-length criterion, whereas the data set used to calculate mean length does not. If young fish are abundant, they will reduce the mean length of trout but may have no effect on PSD because the fish are shorter than the minimum-length criterion. This explains why PSD declined between 1984 and 1990 while the abundance of trout longer than 330 mm in the 1990 sample was the same as that in 1984.

Comparisons of the present Lamar River fishery with historical descriptions can be made only at a broad level because available data are limited. Jordan (1891) described the Lamar River as "well stocked with fish" and noted that trout over 16 inches (406 mm) long were caught. Trout captured by Arnold and Sharpe (1967) were 165 to 345 mm long and trout captured by Dean and Mills (1970) were 210 to 361 mm long. Length-frequency distributions of trout captured during the recent study generally were broader and included larger fish than did the distributions of the earlier investigations.

Estimated trout biomass in the Lamar River is low compared to recent estimates from other Yellowstone Park streams (Table 15). In addition, when compared to biomass-frequency relations for streams in the Rocky Mountain region (Platts and McHenry 1988), trout biomass is low to moderate for most Yellowstone Park streams for which data are available. This suggests that productivity of the Lamar River is relatively low.

Some of the variability in the data on trout populations in the Lamar River may result from interactions with trout populations in Soda Butte Creek. There are no barriers to fish movement between these contiguous stream sections (Figure 34). Fish longer than 330 mm are susceptible to harvest in Soda Butte Creek and large trout from the Lamar River would be harvestable if they migrated into Soda Butte Creek. Although the proximity of the current sampling reach to the confluence with Soda Butte Creek could obscure detection of interactions between the two populations, preliminary electrofishing data suggest that the number of fish that move between the two streams is small.

Despite a general decline in landing rate and mean length of landed fish, the Lamar River continues to be a popular fishery. In 1990, more than three-fourths of the anglers in the catch-and-release area of the Lamar River landed at least one trout. Reported angler satisfaction with the overall angling experience on the Lamar River was at the same high level as that reported for Yellowstone Lake (Table 3). The Lamar River ranked third in angler satisfaction with size of fish landed in a stream fishery. Comparison of estimated trout population size with

TABLE 15.-Estimated biomass (kg/hectare) of trout captured by electrofishing from selected Yellowstone National Park streams.

	Year	Biomass	Source
Cache Creek	1989	48	Jones et al. (1990)
Firehole River	1988	40	Jones et al. (1989)
Lamar River	1990	25	Current study
Slough Creek	1989	67	Jones et al. (1990)
Soda Butte Creek	1989	138	Jones et al. (1990)
Yellowstone River near LeHardy Rapids	1981	650	Griffith and Schill (1982)

total number of trout landed in the Lamar River between Lamar Canyon and the confluence with Calfee Creek suggested that approximately 85% of the trout were caught at least once during the 1990 angling season. This level of angling success underscores the importance of the catch-and-release regulation in maintaining a robust trout population in the Lamar River.

The ecosystem-level management concept requires that activities in the upland and riparian areas of a watershed be examined to determine their effects on aquatic communities downstream. Numerous studies have documented the importance of riparian areas to trout production (Boussu 1954; Barton et al. 1985; Wesche et al. 1987; Platts and Nelson 1989). Although precise measurements of ecosystem-level habitat dynamics are difficult to obtain (Platts et al. 1987), many studies have attempted to determine the effects of domestic livestock grazing on riparian systems and associated salmonid populations (Platts and Rinne 1985; Clary and Webster 1989; Chaney et al. 1990). Negative influences of livestock grazing that may reduce resident fish populations include a decrease in streamside cover for trout, increased instability of streambanks, and increased bank erosion. Little is known about the effects of elk, bison, or other wild ungulates on aquatic ecosystems.

Few quantitative data on the riparian areas of the Lamar River have been collected during fishery investigations at the catch-and-release area, and the available data are primarily qualitative. For example, although Arnold and Sharpe (1967) reported evidence of "heavy use by big game animals" throughout the Lamar drainage, they provided no quantitative data on the riparian area that could be compared to those of recent studies. Although recent habitat studies have indirectly monitored riparian conditions through estimates of streambank alteration and vegetation stability, no relations are evident between these data and the fishery. Ungulate effects on fish, if they occur, are most likely indirect effects that involve sedimentation in the stream and subsequent effects of sediments on spawning success and survival of young fish.

Conclusions

Although data from the Lamar River are limited, they suggest that the habitat, macroinvertebrate communities, and fish populations there are similar to those that occurred historically. Although relative abundance and biomass of trout in the Lamar River is low compared to other Yellowstone Park streams, length structure of the population suggests that large trout are as abundant or more abundant now than in the 1960s and early 1970s. Despite declines in landing rate and mean length of caught trout, reported angler satisfaction with the Lamar River remains high.

Although available data are limited and definitive conclusions regarding sedimentation in the Lamar River watershed and the effects of ungulates on the fishery cannot be reached, useful generalizations can be made from the data. For example, the electrofishing data on the fish populations in 1990 are

similar to those from 1984, which suggests stability in the fish populations. These data were collected during the period of record-high ungulate numbers in the Park, when the negative effects of ungulates on the fishery, if they occur, would probably be greatest. In contrast, the unfavorable assessment of the fishery was provided by Sharpe and Arnold (1967) when ungulate populations were at low levels of abundance. If ungulates are negatively affecting the fishery, it is not evident in these data.

Definitive investigations of possible ungulate effects on the trout populations of the Lamar River would require an intensive field effort using approaches different from those of past studies. Such investigations should examine spawning behavior and related movements of adult fish, population dynamics and recruitment to the adult stocks, and perhaps behavioral responses of the cutthroat trout to high river turbidities.

Although a variety of factors influences the dynamics of the Lamar River fish populations, the data indicate the river has a viable fishery. Continued monitoring of fish populations, macroinvertebrates, and angler use, and implementation of an investigation of fish-ungulate interactions, should lead to a clearer understanding of the ecology of this important Yellowstone National Park stream.

SODA BUTTE CREEK

Soda Butte Creek, located in the northeastern corner of Yellowstone National Park, is a primary tributary of the Lamar River. Although Soda Butte Creek originates outside of the Park near Cooke City, MT, a major portion of the watershed (19,500 hectares) is located within Park boundaries. The Northeast Entrance highway parallels the stream and provides convenient access for anglers to fish in wide, picturesque meadows and forested valleys surrounded by steep mountains.

Historically, native species in Soda Butte Creek included Yellowstone cutthroat trout *Oncorhynchus clarki bouvieri*, mountain sucker *Catostomus platyrhynchus*, longnose dace *Rhinichthys cataractae*, and longnose sucker *Catostomus catostomus* (Varley and Schullery 1983). Between 1920 and 1943, more than 4.5 million cutthroat trout were stocked into Soda Butte Creek to supplement resident stocks. In addition, rainbow trout *Oncorhynchus mykiss* were stocked into Soda Butte Creek in 1937 (Varley 1981), and apparently hybridized with the cutthroat trout. Consequently, the current salmonid population is composed of cutthroat trout introgressed with rainbow trout genes (Loudenslager and Gall 1981). Since 1982, there have been angler reports of brook trout *Salvelinus fontinalis* from the upper portions of Soda Butte Creek, but the occurrence of this nonnative species has not been verified.

Because Soda Butte Creek is one of the few Yellowstone National Park streams that originates outside of the Park, it has a long history of investigations relating to environmental changes. Seamans (1940), Sharpe and Arnold (1966), and Jones et al. (1982) examined aquatic habitat at several mainstem sites and commented that shifting stream channels and lack of pools may be important influences on the fish communities of Soda Butte Creek. Later studies (Decker-Hess and White 1987; Jones et al. 1989, 1990) reexamined habitat in relation to changing streamflow patterns or effects associated with forest fires.

Most studies of aquatic communities in Soda Butte Creek have examined potential impacts resulting from mining activities in the Cooke City area. Degraded habitat conditions were initially described in a "pollution study" by Mills and Sharpe (1968) and have been reexamined periodically (Dean and Mills 1970, 1971; Dean 1972; Duff 1972; Jones et al. 1982). Extensive water chemistry analyses (Dean and Mills 1971; Dean 1972; Pickett and Chadwick 1973; Hill 1977) and macroinvertebrate collections (Mills and Sharpe 1968; Pickett and Chadwick 1973) were performed during the same time period. Jones et al. (1977 to 1982, 1985 to 1990) conducted subsequent studies and stressed the need for continued monitoring of the Soda Butte Creek fishery. Water samples have continued to be collected and analyzed on an annual basis, and a macroinvertebrate monitoring program begun in 1984 continues to the present (Mangum 1986, 1988, 1990).

Soda Butte Creek has traditionally been a popular stream fishery in Yellowstone National Park. The popularity of Soda

Butte Creek may be due in part to angling regulations that are less restrictive than those of most other cutthroat trout fisheries in the Park. Prior to 1987, the creel limit in Soda Butte Creek was two fish, any size. Concern about potentially excessive harvest levels was expressed in the late 1970s, and a catch-and-release regulation was recommended for Soda Butte Creek (Jones et al. 1979). Although this recommendation was not implemented, a more restrictive harvest regulation of two fish longer than 330 mm was implemented in 1987.

In addition to monitoring effects of anglers on the fish populations in Soda Butte Creek, fishery studies have examined fish population size and structure in relation to human activities inside and outside the Park. In the past 3 decades, fish populations from six different areas of Soda Butte Creek have been surveyed (Sharpe and Arnold 1966; Jones et al. 1982, 1984 to 1990). Four areas have been sampled several times and provide an opportunity for long-term examination of the fishery. Fish populations at these four study sites were sampled again in 1990, in order to estimate the relative abundance of trout. This report examines current and historic fishery data from Soda Butte Creek. In addition, effects of aquatic habitat, water chemistry, and macroinvertebrates on the fishery are considered.

Study Area

The Soda Butte Creek watershed is a product of Eocene Absaroka volcanic flows followed by extensive Pleistocene glaciation. Isolated outcrops of the underlying Madison limestone formation occur throughout the drainage (Parsons 1978), and massive landslides from Druid Peak and The Thunderer have had a major influence on local topography near the confluence of Soda Butte Creek and Pebble Creek. Within the Park, the 26-km-long mainstem of Soda Butte Creek is separated into two sections of similar length by Icebox Canyon (Figure 37). The canyon may be a barrier to upstream movement of fish (Sharpe and Arnold 1966; Jones et al. 1982). Upstream from Icebox Canyon, Soda Butte Creek flows through a narrow, V-shaped, densely forested valley that is bordered on the east by Abiathar Peak and on the west by Barronette Peak. Downstream from Icebox Canyon, major tributaries (Pebble Creek and Amphitheater Creek) increase mainstem discharge substantially. The section of Soda Butte Creek downstream from Icebox Canyon meanders through large meadows enclosed in a wide, U-shaped valley.

In 1990, the four electrofishing sample reaches were located in the Soda Butte Creek mainstem. The 2.3-km-long Footbridge study section, which extends from the Lamar River trail footbridge downstream to the confluence with the Lamar River (Figure 37), has been electrofished on six previous occasions. The Round Prairie sample area extends from the base of Icebox Canyon downstream for approximately 2 km, and the third electrofishing study area encompasses a 1-km-long section of Soda Butte Creek just upstream from Icebox Canyon (Figure 37). These

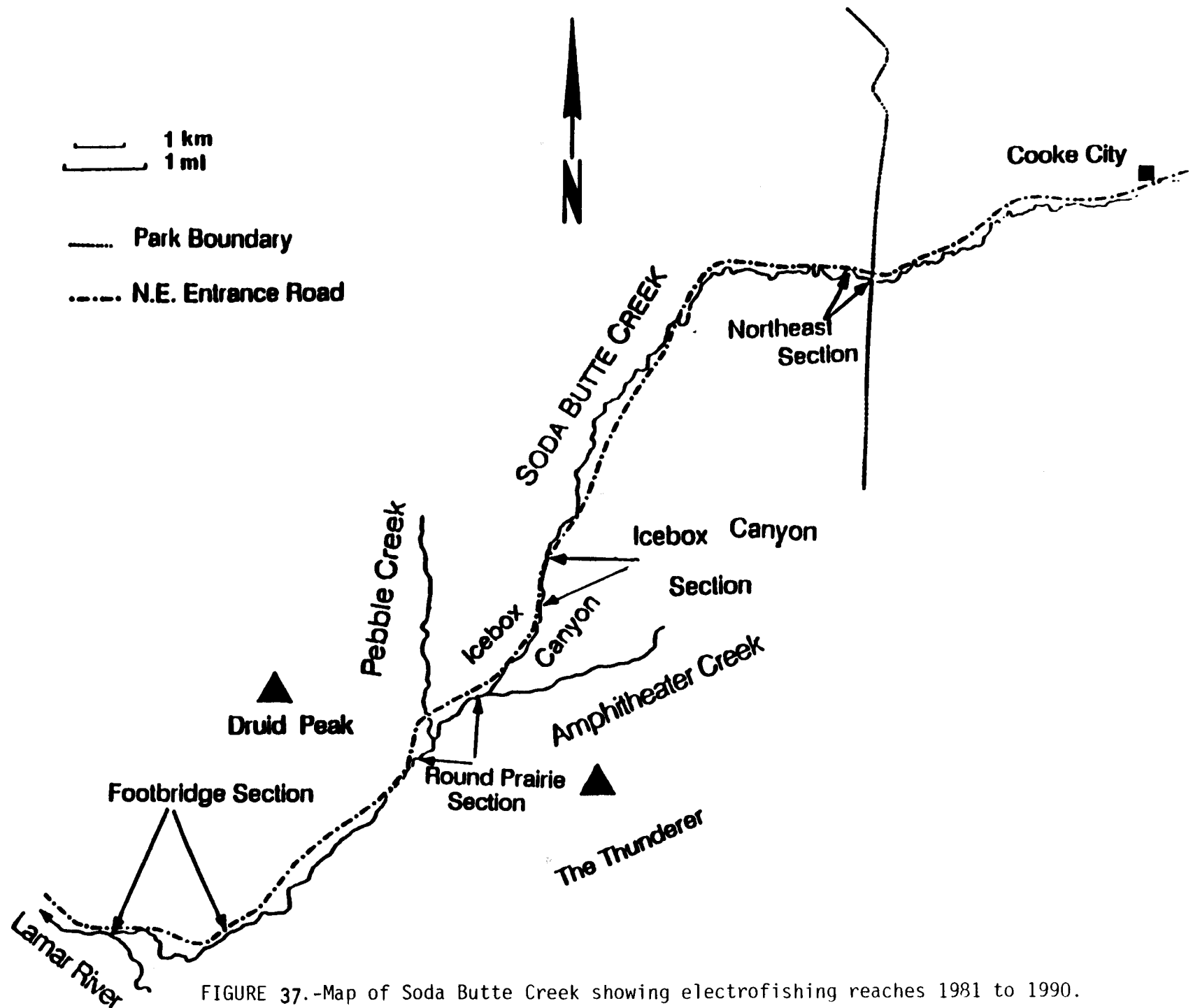


FIGURE 37.-Map of Soda Butte Creek showing electrofishing reaches 1981 to 1990.

latter two study sites have been surveyed on at least three occasions prior to 1990. The Northeast Boundary sample area begins near the Northeast boundary of the Park and extends downstream for 305 m. This study reach was sampled in 1981 and annually since 1984.

Methods

To describe aquatic habitat of Soda Butte Creek, the three transects established at the Footbridge section in 1988 (Jones et al. 1989) were resurveyed at the reconnaissance level in 1990. Techniques used to measure habitat parameters generally are those described in Platts et al. (1983) and modified by Jones et al. (1990). A water sample was collected for extensive analyses by a commercial laboratory. Three macroinvertebrate samples were obtained in this study area with a 0.09 m² Surber sampler. The macroinvertebrate community is described in terms of abundance, diversity, functional feeding groups (Merritt and Cummins 1984) and Biotic Condition Index (BCI; Winget and Mangum 1979).

In 1990, electrofishing in the Footbridge and Round Prairie sections was conducted from a 4.3-m rubber raft that contained boom-mounted electrodes, a portable generator, and a pulsed DC shocking system. All captured salmonids were measured to the nearest 1 mm total length (TL) and marked with a fin clip. Collected fish were stratified into 25-mm length groups. Five fish from each length group were individually weighed to the nearest 2 g and had scales collected for age and growth analyses.

Because discharge was low in the Icebox Canyon and Northeast sections, alternate electrofishing equipment was required. In the Icebox Canyon section, two Coffelt BP-1 backpack electroshockers were used to capture fish. All trout were measured to the nearest 1 mm TL, weighed to the nearest 2 g, and marked with a fin clip. Scale samples were collected from each fish for age and growth analyses. Equipment and techniques used in the Northeast section were similar to those used in the Footbridge section, except a 2-m plastic boat was used to carry shocking equipment and the electrodes were hand-held rather than boom-mounted.

In 1990, trout population size in the Footbridge section and Northeast section was estimated by the adjusted Petersen formula (Ricker 1975). In the Northeast Boundary section, a removal method (Zippin 1958) was used to estimate fish populations in 1981. Since 1984, however, the cutthroat trout population in this sample area has been examined annually through mark-and-recapture electrofishing. In the middle sections of Soda Butte Creek (Round Prairie and Icebox Canyon sites), because only a single electrofishing pass was made in 1990 to examine cutthroat trout population structure and to compare relative abundance in these two sections with that of previous years, population size could not be estimated. Proportional Stock Density (PSD) and Relative Stock Density (RSD) indices (Gabelhouse 1984) were used to examine length structure of the

cutthroat trout population in each study section of Soda Butte Creek. For cutthroat trout, PSD is the proportion of fish in the population longer than 203 mm TL (stock length) that are also longer than 381 mm TL (quality length), and RSD is the proportion of fish in the population longer than 203 mm TL that are also longer than 457 mm (preferred length). However, because length categories recommended by Gabelhouse for cutthroat trout are generally greater than those found in the cutthroat trout in Soda Butte Creek, stock, quality, and preferred lengths were reduced to 153, 254, and 330 mm, respectively. These lengths more realistically reflected the size composition of trout caught by anglers than did the recommended length values.

The influence of anglers on the Soda Butte Creek fishery was examined by using Volunteer Angler Report (VAR) data compiled since 1977. Analyses of VAR data yielded estimates of total angler use and effort, landing rate, mean total length of fish landed, length composition of the angler-caught trout, and total number of fish landed.

Fishery data from VAR returns from Soda Butte Creek have been divided into two stream sections: from the confluence with the Lamar River upstream to Icebox Canyon (below Icebox Canyon) and from Icebox Canyon upstream to the Park's Northeast boundary (above Icebox Canyon). Mean lengths of landed fish are reported in 51-mm increments on VAR cards. Lengths of landed fish were assumed to be uniformly distributed (Snedecor and Cochran 1967) within each interval, and if a particular mean length of interest (e.g., 330 mm) occurred within a 51 mm interval, only fish longer than the length of interest were used in the analysis.

Linear correlation was used to test for significant ($P < 0.05$) long-term trends in estimated parameters derived from electrofishing and VAR data. Significant ($P < 0.05$) differences in growth rates of trout captured by electrofishing or differences in VAR statistics between the period 1977 to 1986 and the period 1987 to 1990 were determined by a *t*-test.

Results

Physical Characteristics

At the Footbridge habitat study site, stream discharge and average stream depth were considerably greater in 1989 and 1990 than in 1988; however, several habitat features (including channel width, stream width, and percentage of riffle at each transect) were relatively unchanged over the period from 1988 to 1990 (Table 16). In 1990, as in previous years, pools were rated poor in quality because they were small and lacked cover for trout; however, several deep pools with extensive undercut banks that provide suitable refuges for numerous fish are located within the electrofishing study area adjacent to the transect sites.

TABLE 16.-Drainage basin characteristics and habitat features of Soda Butte Creek, 1988 to 1990.

Stream order	IV		
Length (km)	3.26		
Elevation:			
Maximum (m)	2,016.3		
Minimum (m)	2,002.5		
Drainage Size (hectares)	20,938.2		
Stream type ^a	C1		
Habitat features	1988	1989	1990
Sample date	11/3	8/31	9/27
Time	1030	1015	1030
Water column:			
Flow (m ³ /s)	0.684	1.618	1.587
Channel width (m)	24.4	23.1	22.9
Stream width (m)	13.3	14.6	13.7
Stream depth (cm)	16.8	24.7	21.3
Stream shore water depth (cm)	0.0	0.0	0.9
Riffle width (m)	10.7	11.9	10.9
Pools:			
Width (m)	1.2	1.1	1.1
Quality	1.2	1.0	1.0
Feature ^b	3,4	3	3
Solar angle (°)	155.7	156.2	157.7
Channel morphology			
Streambank alteration (%)	38.3	50.8	61.7
Vegetative stability	2.5	2.83	2.5
Undercut (cm)	0.0	0.1	0.1
Channel-bank angle (°)	149.2	148.3	160.8
Stream bottom:			
Gradient (%)	0.6	0.7	0.6
Sinuosity	1.18	1.08	1.09
Substrate:			
Bedrock			
Boulder (> 305 mm)	2.3	2.8	2.4
Cobble (64-305 mm)	70.4	91.6	76.4
Gravel (2-64 mm)	18.4	3.5	10.0
Sand (0.6-2 mm)	2.3	0.7	5.2
Silt (< 0.6 mm)	6.8	1.4	6.0
Embeddedness (%)	50.0	40.0	40.0
Channel vegetative cover (cm)	13.1	9.8	14.3
Riparian zone:			
Streamside cover type	2.2	2.0	2.2
Vegetative use (%)	13.3	8.3	5.8
Vegetation overhang (cm)	0.0	0.0	0.0
Habitat type	12,6	8,4	12,8

^a After Rosgen (1985).

^b 1 = log, tree, root, stump, brush, or debris; 2 = channel meander; 3 = rubble or gravel; 4 = boulder or bedrock; 5 = stream channel; 6 = fine sediments; 7 = streambank.

Variation in solar angle has been minimal since 1988. The high values indicate that a large amount of sunlight reaches the stream channel in this wide valley area of Soda Butte Creek.

Comparison of substrate composition for the past 3 years reveals a consistent predominance of small cobble and gravel and a minor proportion (<12%) of fine sediments (sand and silt) in all years (Table 16). These results show a substrate composition similar to that reported by Jones et al. (1982), but differ from other studies that indicated a predominance of gravel (Sharpe and Arnold 1966) or equal proportions of gravel and cobble (Decker-Hess and White 1987) in this study reach.

Substrate particles were moderately embedded during each of the past 3 study years (Table 16). Because increased embeddedness may limit biological productivity (Minshall et al. 1990), these observations suggest less-than-optimum production in this study section of Soda Butte Creek. Alternatively, the embedded substrate in this area could remain in place during variable streamflows and provide attachment sites for instream vegetation.

In common with results from previous studies, one of the more noticeable habitat features was the condition of streambanks in this portion of Soda Butte Creek. Over half of the streambank had been eroded at the transect sites in 1990 and vegetative stability had decreased slightly from the previous year (Table 16). Overhanging bank vegetation was lacking and channel bank angles increased over prior years. These habitat features suggest extensive channel alteration within this stream reach.

Examination of the Footbridge stream habitat site by using alternative indices resulted in a Habitat Condition Index rating (USDA 1988) of approximately 50% of optimum condition for each of the 3 years of study. About 10% of the reach may contain suitable spawning substrate; however, the stream appears highly vulnerable to erosion during periods of high streamflow.

Water Chemistry

Chemical analyses revealed that Soda Butte Creek is a calcium-bicarbonate stream. Concentrations of the principal chemical components in Soda Butte Creek have generally been within the ranges observed in other calcium-bicarbonate streams in Yellowstone National Park. With the exception of the late-summer sample from 1988, concentrations of major anions and cations have been similar for the past 10 years (Table 17). Small concentrations of most chemical elements in 1988 may be a result of the extremely low streamflows that occurred that year. An additional interesting feature of the 1988 analyses is the presence of a measurable concentration (7.7 mg/L) of phenolphthalein alkalinity. This result may be a function of the high pH associated with this sample, because phenolphthalein alkalinity does not occur below pH 8.3 (Hem 1985).

TABLE 17.-Chemical characteristics of the Footbridge Section of Soda Butte Creek. Turbidity expressed in NTUs, other values (except pH) expressed in mg/L.

	Year					
	1981	1984	1986	1988	1989	1990
Total Dissolved Solids	87	149	150	40	130	150
Total Alkalinity	60	124	135	42	100	130
Phenolphthalein Alkalinity	0	0	0	7.7	0	<2.0
Carbonate Alkalinity	0	0	0	15	0	<0.5
Bicarbonate Alkalinity	60	124	135	27	100	130
Total Hardness	54	139	123	85.7	112	139
Magnesium Hardness	12	52.3	44.27	26.8	40.1	48
Calcium Hardness	42	86.4	78.86	58.9	71.9	91
Carbonates	0	0	0	9.2	0	<0.5
Bicarbonates	73	151	165	51	120	130
Hydroxides	0	0	0	0	0	<2.0
Carbon Dioxide	1.5	1.3	21.0	<1.0	<1.0	5.7
Chloride	3.0	<1	<1.0	<1.0	<1.0	<1.0
Sulfate	10	8.8	20.1	3	5.5	5.9
Fluoride	0.18	0.08	0.07	<0.1	<0.1	<0.1
Silica	4.2	9.4	8.9	11	35	17
Hydrogen Sulfide		<0.01	<0.1	<0.1	<0.1	<0.1
Sodium	3.3	4.66	5.0	2.43	3.9	4.3
Potassium	0.35	1.91	1.0	1.79	1.73	2.1
Calcium	17	34.6	31.58	23.6	28.8	35.0
Magnesium	2.9	12.7	10.75	6.5	9.74	12.0
Iron	0.33	0.38	0.23	<0.10	0.143	0.20
Manganese	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Copper	<0.3	<0.01	<0.01	<0.01	<0.01	<0.01
pH	7.9	8.0	7.1	8.9	8.4	7.62
Turbidity	10	3.1	1.0	3.3	1.1	0.31

In several of the studies on Soda Butte Creek, concentrations of ionic iron have been used to monitor the effects of mine drainage near Cooke City (Jones et al. 1988). Concentration of iron at the Footbridge section appears to have decreased since 1981 (Table 17). There has been a substantial reduction in the concentration of iron from a high of 49 mg/L reported in the 1970s to the current low values. These results suggest that present negative effects of iron on the aquatic system may be reduced from those that occurred historically.

Macroinvertebrates

Aquatic macroinvertebrate communities have been extensively monitored in Soda Butte Creek as a means of assessing habitat quality. Most studies have been concentrated near mining sites outside of Yellowstone National Park. In order to monitor the extent of recovery within the system, investigators have selected additional collection sites for macroinvertebrates far downstream from the pollution sources and within the Park. Three of the earlier studies (Mills and Sharpe 1967; Pickett and Chadwick 1973; Hill 1977) sampled macroinvertebrates from the Round Prairie section of Soda Butte Creek. Examination of results from the first two of these studies reveals few differences in community structure except for higher abundance of macroinvertebrates in 1973 (Table 18). Because results from Hill's study (1977) were reported at the taxonomic level of Order, analyses of trophic groups or BCI could not be conducted; however, Hill noted that 88% of the macroinvertebrate species collected were pollution sensitive (i.e., cannot survive in polluted water). These results indicate that between 1966 and 1977, high-quality macroinvertebrate habitat was available in the Round Prairie section of Soda Butte Creek.

Recent macroinvertebrate samples (Jones et al. 1982; Minshall et al. 1990; Mangum 1990) have been collected from the Footbridge study area. The initial sample (Jones et al. 1982) was qualitative only, but the BCI was indicative of high-quality aquatic habitat. Nine of the 10 taxa collected in this sample were also found in earlier collections from the Round Prairie area (Mills and Sharpe 1967). The similarity in species composition among these samples suggests a widespread distribution of some of the taxa in Soda Butte Creek. Minshall et al. (1990) reported data on only the five most abundant taxa from their 1988 collection. Consequently, trophic-group analyses and BCI determinations could not be made for that sample; however, all five taxa collected in 1988 were again collected in 1989. Although macroinvertebrate abundance was very high in 1989 (Table 18), Chironomids accounted for almost 80% of the total number of organisms sampled. A minority of shredders in the 1989 sample is indicative of a riparian area in only fair condition (Mangum 1990) and a BCI value less than 85 suggests that habitat is less than optimum (Winget and Mangum 1979). Although

TABLE 18.-Macroinvertebrate community characteristics from two sections of Soda Butte Creek. Total taxa collected is a pooled result from all samples, except Hill (1977). Other values are means of the indicated number of samples for each site and year.

	Round Prairie			Footbridge		
Year	1967	1973	1977	1981	1988	1989
Source	Mills & Sharpe	Pickett & Chadwick	Hill	Jones et al.	Minshall et al.	Mangum
Total number taxa collected	18	19	5 ^a	10	>5	28
Number m ²	652	1,284	414	N/A	>16,837	33,715
Functional feeding groups						
% Collectors	68.6	73.6	-	-	-	85.0
% Scrapers	13.4	10.0	-	-	-	2.0
% Shredders	11.1	12.1	-	-	-	0.6
% Predators	6.8	4.4	-	-	-	12.3
Biotic Condition Index (BCI)	85	124	N/A	191	N/A	83
Number samples	7	12	6	2	5	3

^a samples were classified by Order.

cleanwater species including *Rhithrogena*, *Arctopsyche*, and *Apatania* were collected at the Footbridge section in 1989, 96% of the sample was sediment-tolerant macroinvertebrates. The aquatic community appears to be well adapted to high sediment loads and the unstable channel characteristic of the Footbridge section of Soda Butte Creek.

Fish

Footbridge section.-In 1990, 669 cutthroat trout were captured from the Footbridge electrofishing reach. The estimated population of 1,766 cutthroat trout (95% confidence limits, 1,362-2,339) in 1990 was the second-highest abundance of trout in this section in 6 years of electrofishing. Mean total length of the cutthroat trout was 254 mm, and the proportion of the fish ≥ 330 mm declined slightly from the previous 2 years (Table 19).

Length-frequency distribution for the cutthroat trout in the Footbridge section in 1990 was similar to that observed in 1986, 1987, and 1989 (Figure 38). Adjusted PSD and RSD values (58 and 11, respectively) declined from the peak values noted in 1988.

Mean weight and condition factor (K) for 138 cutthroat trout were 197 g and 0.95, respectively. Multiplying this mean weight by the estimated 1990 population yielded an estimated biomass of 151 kg/km (108.8 kg/hectare), which is nearly identical to the mean biomass for the period from 1984 to 1990.

Scale analyses of 126 cutthroat trout revealed five age classes. Although this result represents a decrease from 1989 (seven age classes) and 1987 (six age classes), electrofishing samples from all other years in the Footbridge section also were limited to five year classes. Mean age for the entire 1990 sample ($N = 669$) was estimated as 2.4 years. In common with previous samples, 3-year-old trout were the most abundant age group. In 1990, 47% of the population was classified as age 3 or older. Backcalculated growth rates of cutthroat trout in the 1990 sample were some of the highest to date in this sample section and indicated an average annual growth of 76 mm.

In 1990, nine trout that visually appeared to be pure rainbow trout were caught by electrofishing in the Footbridge section. Estimated total number of rainbow trout for the entire section was 13 (95% confidence limits, 13-33); however, this estimate is probably negatively biased due to a small number of recaptures. Mean total length, mean weight, and mean condition factor (K) were 303 mm, 308 g, and 1.05, respectively. Comparable values from rainbow trout in the 1989 sample ($N = 12$) were 274 mm, 224 g, and 1.07, respectively (Jones et al. 1990). The increased mean length in 1990 was also reflected in length-structure indices. Adjusted PSD declined from 83 in 1989 to 78 in 1990; however, RSD values increased from 8 in 1989 to 33 in 1990. Analyses of scales from the rainbow trout indicated growth rates similar to those observed in the cutthroat trout from this electrofishing reach.

TABLE 19.-Sample size and length data for cutthroat trout from the Footbridge electrofishing section, Soda Butte Creek, 1984 to 1990.

Year	N	Mean total length (mm)	Percent ≥ 330 mm
1984	511	243	7.4
1986	331	234	6.0
1987	1,276	238	3.1
1988	319	236	14.1
1989	508	258	12.4
1990	669	254	10.3

TABLE 20.-Sample size and length data for cutthroat trout from the Northeast electrofishing section, Soda Butte Creek, 1981 to 1990.

Year	N	Mean total length (mm)	Percent ≥ 330 mm
1981	22	201	4.5
1984	163	205	0.6
1985	88	222	1.1
1986	23	250	4.3
1987	26	256	0.0
1988	23	223	4.3
1989	51	208	4.0
1990	156	177	0.6

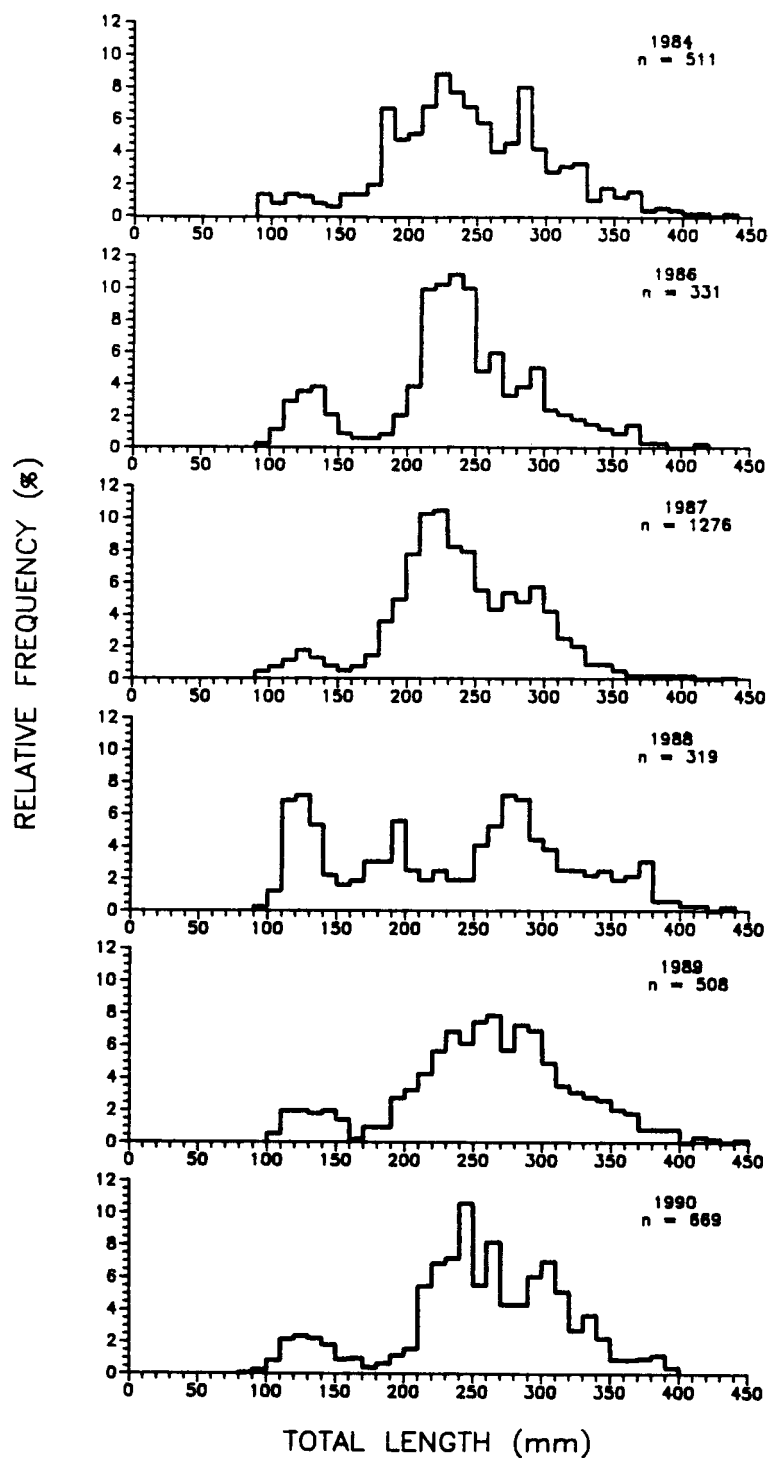


FIGURE 38.-Length-frequency distributions of cutthroat trout captured by electrofishing in the Footbridge Section of Soda Butte Creek, 1984 to 1990.

Round Prairie.-In 1990, 209 cutthroat trout were captured by electrofishing within the Round Prairie study reach. Mean total length of all captured fish was 206 mm. Only five of the trout were longer than or equal to 330 mm TL; however, the length-frequency distribution indicates that over half of the population in 1990 exceeded 200 mm TL. In contrast, fewer than 10% of the trout in the 1981 electrofishing catch were longer than 200 mm (Figure 39). Adjusted PSD has also increased from a low value of 7 in 1981 to a high of 29 in 1990.

Mean weight and condition factor (K) for 110 captured trout was 130 g and 0.95, respectively. Multiplication of this mean weight to the entire sample yielded an estimated trout biomass of approximately 13 kg/km in the electrofishing catch.

Estimated average age of captured trout in 1990 was 2.3 years, slightly above the mean age of 2.2 years for 5 years of sampling combined. The 1990 sample encompassed four age classes that exhibited above-average growth. The estimated annual growth rate of fish in the 1990 sample was nearly 77 mm/year. This represents a 15% increase over the rates from 1989.

Icebox Canyon section.-Mean total length of 67 cutthroat trout captured from the Icebox Canyon section in 1990 was 162 mm and represented a significant ($r = -0.94$, $P < 0.01$) decrease in average length since 1987. Adjusted PSD values have declined from 41 in 1987 to 24 in 1990.

Mean weight (68 g) of 65 cutthroat trout captured in 1990 continued the significant ($r = -0.98$, $P < 0.01$) decreasing trend observed since 1987. When this mean weight was applied to the entire 1990 electrofishing catch, there was an estimated biomass of approximately 4 kg/km in the study section, slightly less than half of the estimated biomass in 1987 (8.4 kg/km). Condition factor (K) has shown a variable ($P > 0.05$) trend in the Icebox Canyon section among the 4 years of sampling.

Scale analyses indicated that the 1990 sample encompassed four age classes. More than 75% of the captured trout were classified as 1- or 2-year-old fish. Estimated annual growth in 1990 (73 mm/year) was 20% higher than that estimated for the 1987 sample (61 mm/year); however, the increase in growth rates was not significant ($P > 0.05$).

Northeast Boundary section.-Because it may be most affected by pollution from the mine tailings, the Northeast Boundary section has been the most frequently sampled area of Soda Butte Creek. In 1990, an estimated 521 (95% confidence limits, 240-1,256) cutthroat trout inhabited the study reach. This estimated trout abundance was the highest in 8 years of sampling. Conversely, mean total length (177 mm) of 156 captured trout was the smallest to date. Few fish were longer than 330 mm TL (Table 20). The predominance of small fish in the 1990 sample is evident from the large proportion (56%) of cutthroat trout between 100 and 200 mm

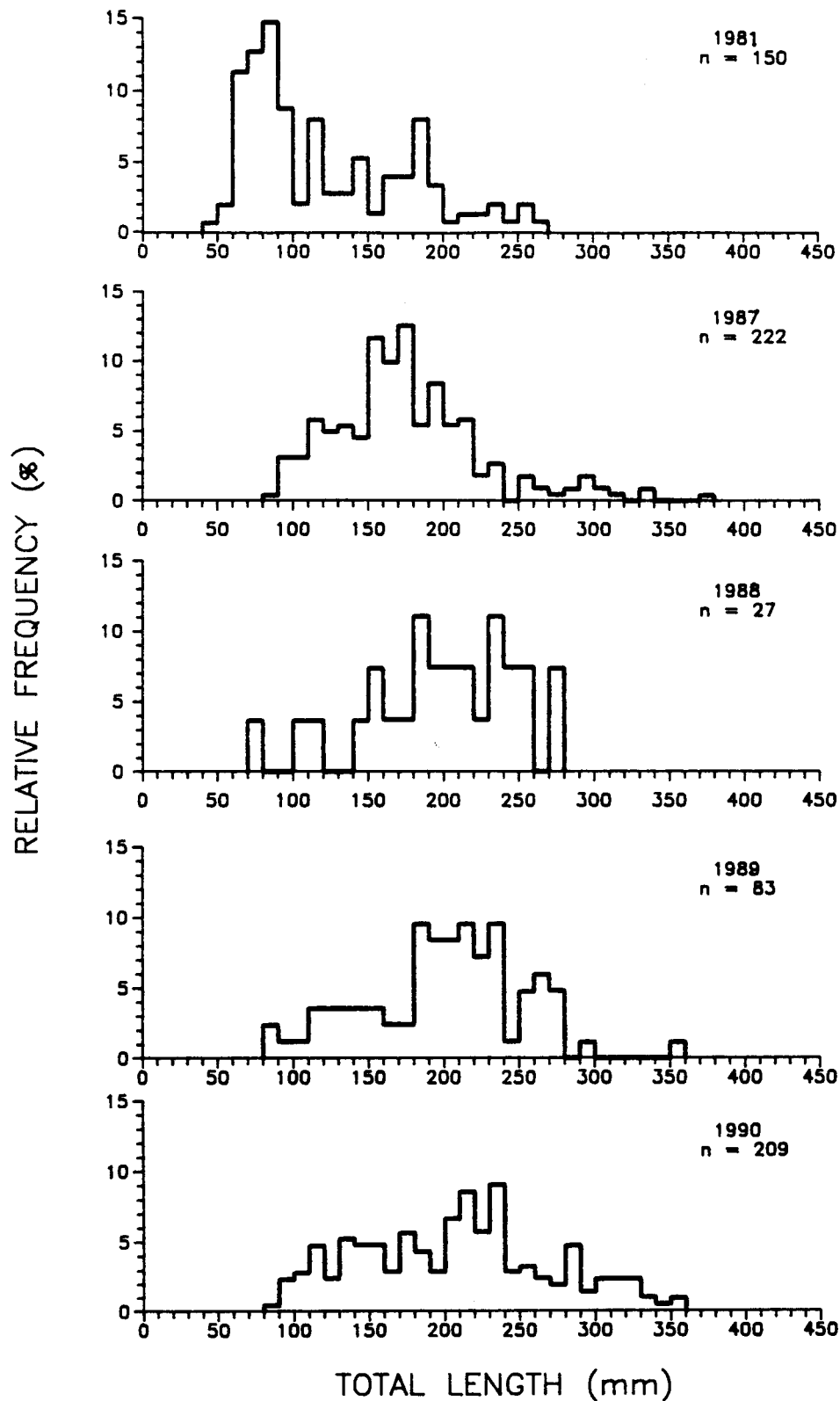


FIGURE 39.-Length-frequency distributions of cutthroat trout captured by electrofishing in the Round Prairie section of Soda Butte Creek, 1981 to 1990.

long (Figure 40). Length-frequency distribution for the 1990 sample was similar to that for the 1984 sample.

Modified PSD values have been highly variable and exhibit a negative correlation ($r = -0.65$, $P < 0.05$) with sample size. In the Northeast Boundary section, PSD in 1990 was 34, slightly less than the average PSD of 37 for all eight samples combined.

Mean weight and condition factor (K) of 108 cutthroat trout were 108 g and 0.99, respectively. This average weight was the second smallest to date. Estimated biomass in the Northeast Boundary section in 1990 was 105 kg/hectare. A slightly higher biomass was estimated for the Footbridge sample area in 1990.

Age-and-growth analyses from 47 cutthroat trout from the Northeast Boundary section revealed four age classes in 1990. Estimated mean age for the total electrofishing catch was 1.9 years. This record-low average age provides an additional illustration of the predominance of small (presumably young) fish in this sample. In contrast to the low mean age, estimated annual growth in 1990 (72 mm/year) was the highest of any sample from the Northeast Boundary section. Estimated annual growth rate was similar among the first three growing seasons and declined in the fourth year. A similar growth pattern was observed in cutthroat trout sampled in this section in 1987 and 1988. Growth patterns were highly variable in the other samples from the Northeast Boundary section.

Anglers

In 1990, Soda Butte Creek was the eighth-most-heavily-fished stream in Yellowstone National Park and sustained 1.5% of the total parkwide angler use (Table 3). Angler effort has been consistently higher below Icebox Canyon than above Icebox Canyon (Figure 41). In 1990, both areas exhibited a substantial increase in effort when compared to 1989, possibly reflecting the record-high angler use that occurred parkwide in 1990 (Table 1). Below Icebox Canyon, angler effort in 1990 (6,872 h) was nearly double that of 1989 (Figure 41). Above Icebox Canyon, angler effort increased by 50% above 1989 levels of use.

In contrast, landing rate below Icebox Canyon in 1990 was identical to the record-low rate of 1977 (1.04 fish/h). An estimated 7,144 trout were landed below Icebox Canyon in 1990. Although this is less than the estimated average annual catch of 8,000 fish for the period from 1987 to 1990, the 1990 catch was the fifth highest since 1977 (Figure 42).

Mean length of fish landed below Icebox Canyon in 1990 (273 mm) was the third highest for any angling season between 1977 and 1990 (Figure 41). More than 17% of the fish caught in 1990 were ≥ 330 mm TL, and an estimated 387 trout were creelied in the lower section of Soda Butte Creek. This harvest was slightly above the post-1986 average annual harvest of 344 trout longer than 330 mm.

Above Icebox Canyon, landing rates have generally been higher than those below Icebox Canyon. Prior to 1986, landing

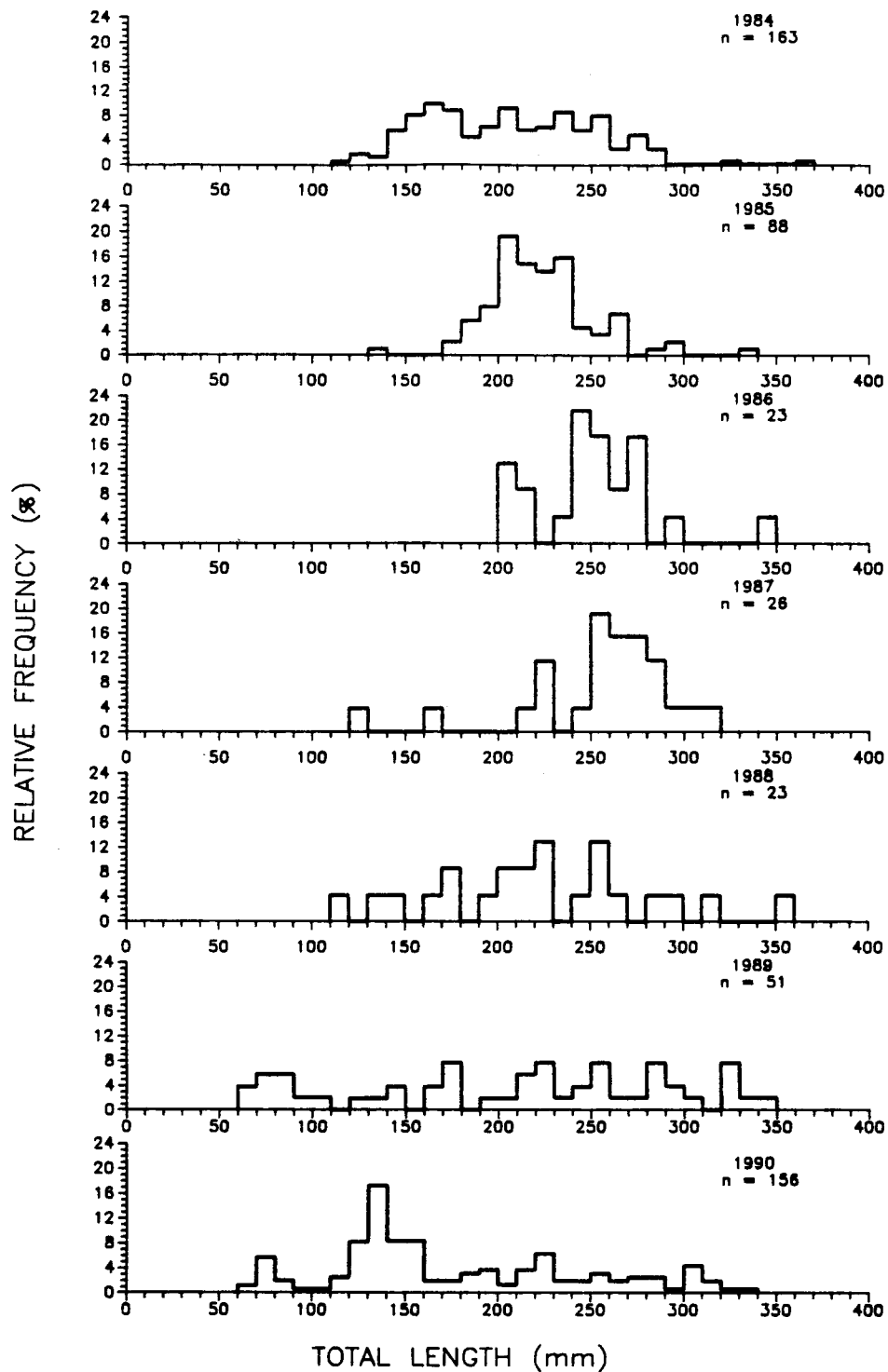


FIGURE 40.-Length-frequency distributions of cutthroat trout captured by electrofishing in the Northeast Boundary section of Soda Butte Creek, 1984 to 1990.

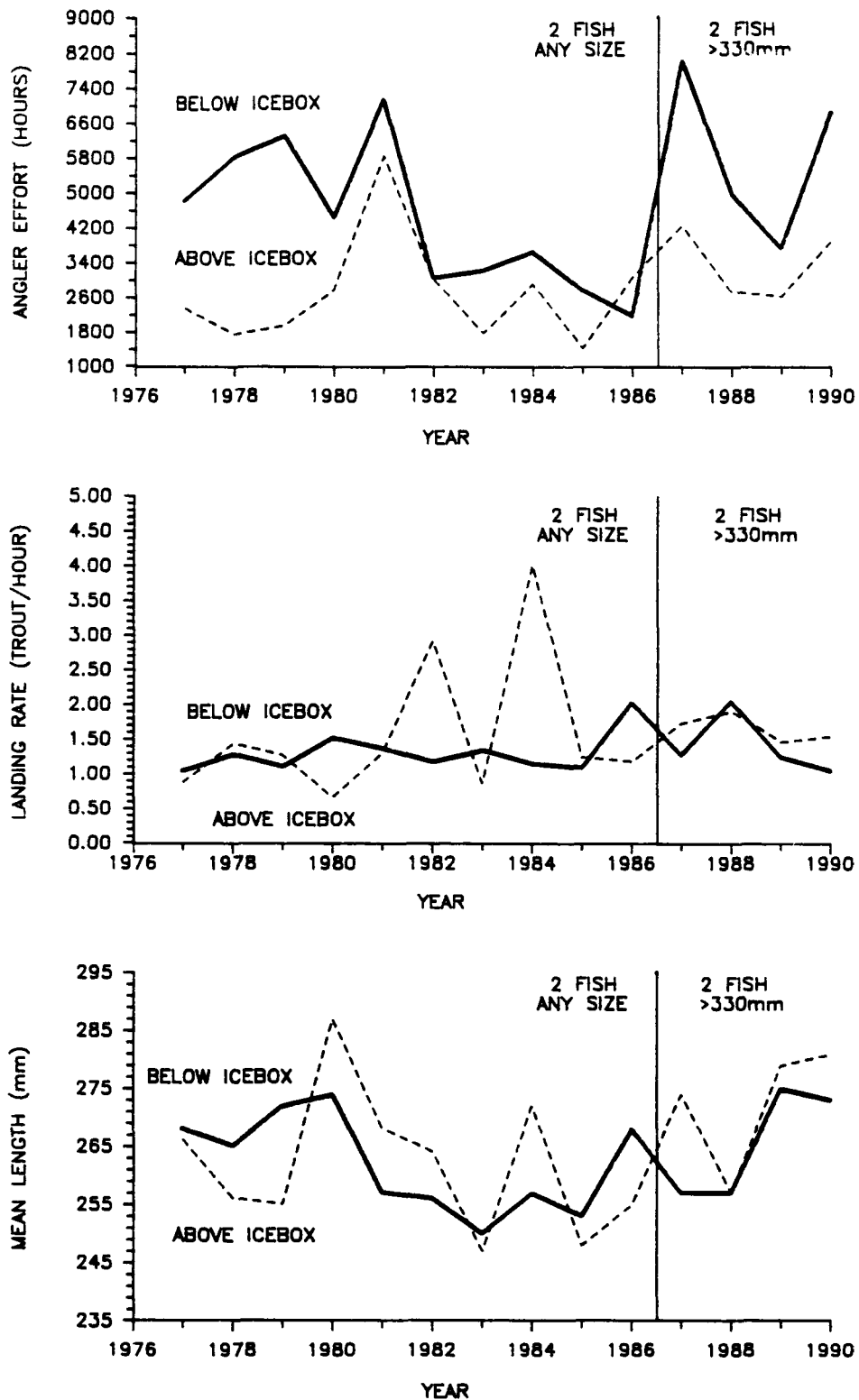


FIGURE 41.-Angler effort, mean annual landing rate, and mean length of landed fish, Soda Butte Creek, 1977 to 1990.

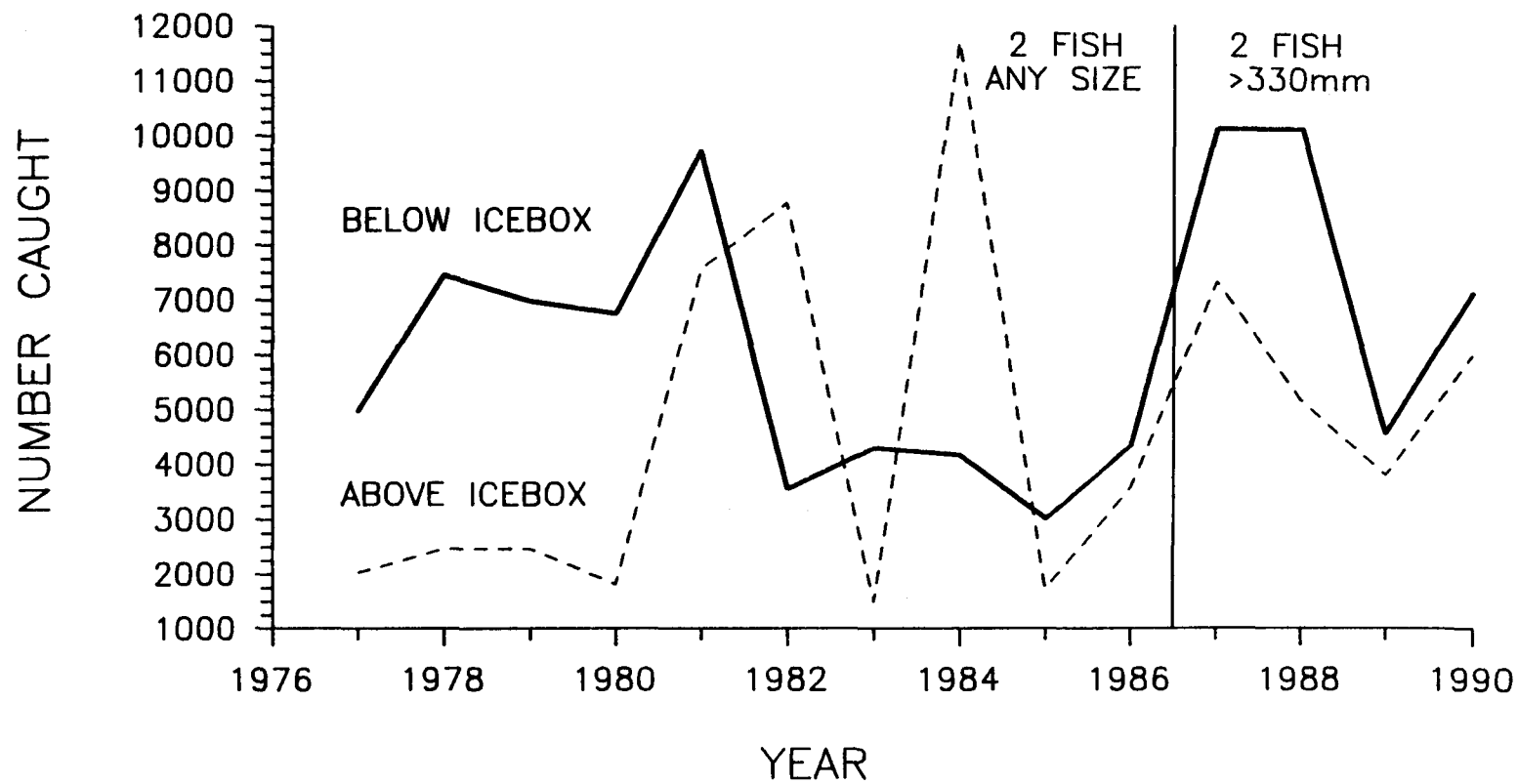


FIGURE 42.-Estimated annual total catch by anglers in Soda Butte Creek, 1977 to 1990.

rates ranged from a low of 0.65 fish/h in 1980 to a record high of 4 fish/h in 1984 (Figure 41). Landing rates have been relatively stable since 1987, and the 1990 landing rate (1.5 fish/h) was nearly identical to the average annual landing rate for the period from 1977 to 1990 (1.6 fish/h). Total number of fish landed above Icebox Canyon has shown a pattern similar to that of landing rates. Total catch appears to be more strongly influenced by landing rate ($r = 0.87$, $P < 0.01$) than angler effort ($r = 0.60$, $P < 0.05$). Estimated total number of trout landed above Icebox Canyon in 1990 was the fifth highest since 1977 (Figure 42).

Average length of landed fish above Icebox Canyon has varied considerably among years; however, mean total length of landed fish has generally increased ($r = 0.67$, $P < 0.05$) since 1983 (Figure 41). Mean total length of angler-caught trout in 1990 (281 mm) was the second highest to date. Since the implementation of the 330-mm minimum-size regulation, average length of landed fish above Icebox Canyon has been greater (except in 1988) than the average mean length estimated under the no-size-limit regulation. In 1990, approximately 21% of the landed fish above Icebox Canyon exceeded 330 mm TL. Since 1987, an average of 16% of the landed trout have been in this size group. In contrast, a significantly smaller ($t = 2.83$, $P < 0.05$) percentage (mean, 7.9%) of fish landed between 1977 and 1986 were longer than 330 mm TL.

In 1990, an estimated 387 trout were creeled above Icebox Canyon. This was an increase of 40% over the average annual harvest between 1987 and 1990.

Discussion

Historical accounts, as well as recent studies, illustrate that many factors affect the Soda Butte Creek fishery. Habitat quality has been cited as a major influence in this stream. Sharpe and Arnold (1966) suggested that "frequent flooding and shifting channels" in Soda Butte Creek could be limiting production in the stream. In 1981, channel stability was rated "fair" (Pfankuch 1977) at study transects upstream from the Footbridge section. Decker-Hess and White (1987) emphasized the unstable and unvegetated condition of the streambanks at the habitat transects within the Footbridge section. Results from the recent (1988 to 1990) habitat survey generally agree with previous studies. Common elements in these studies include a scarcity of high-quality pools and a stream channel exhibiting a high degree of instability. Dramatic evidence of channel instability was noted within the Footbridge electrofishing section. During runoff in 1990, deposition of new gravel bars resulted in lateral displacement (up to 15 m) of the stream channel in several portions of the electrofishing sample reach.

Sedimentation within the Soda Butte Creek watershed has also been suggested as a factor that limits trout productivity. Many

C-type channels are erosive, sediment-producing systems (Rosgen 1985), and Soda Butte Creek appears to be no exception. Studies in the 1980s indicated that Soda Butte Creek is susceptible to rapid increases in turbidity following precipitation events (Mohrman et al. 1988). A similar result was reported by Seamans (1940) nearly 50 years earlier. This suggests that varying turbidity levels are the normal condition for Soda Butte Creek. Additional studies (Christensen et al. 1989) suggested that sedimentation could increase significantly in streams affected by fire activity in 1988. However, increases in suspended sediment in Soda Butte Creek did not occur and preliminary results showed little difference between pre-fire and post-fire suspended-sediment concentrations (Ewing and Mohrman 1990).

Effects of mining activity near Cooke City have been the primary factors affecting fish populations in Soda Butte Creek. Sedimentation and mine-tailing effluents were termed "pollution" in some of the early investigations of Soda Butte Creek (Mills and Sharpe 1968b). Following the cessation of mining activity, construction of a dam at the tailings pond resulted in a noticeable "reduction in silt loads below the mine" (Dean and Mills 1971). Recovery of the aquatic system was not complete, however, and Jones et al. (1980) suggested that mine pollution effects occurred downstream as far as the confluence with Pebble Creek. Additional mine-reclamation projects will attempt to remove tailings and restore the stream to its original channel at the tailings site. These activities should greatly enhance water quality and aquatic habitat in Soda Butte Creek.

Recent collections of numerous aquatic macroinvertebrates (e.g., *Zapada* sp., *Arctopsyche* sp., and *Apatania* sp.) that are intolerant of pollution suggest an improvement in water quality in Soda Butte Creek (Mangum 1990). In addition, although no fish were found outside the Park boundary in the late 1970s (Hill 1977), a small number were sampled at the Northeast Boundary section in 1981 (Jones et al. 1982) and recent electrofishing results indicate an increase in population abundance. These results indicate improvement in water quality and reduction in mine tailings impacts in recent years. However, Hill (1977) recommended that the concentration of dissolved iron for safe long-term exposure of juvenile cutthroat trout should not exceed 0.2 mg/L. The concentrations of dissolved iron observed since 1981 (range, 0.1 to 0.38 mg/L) indicate that potential deleterious effects on aquatic populations may remain in some reaches of Soda Butte Creek.

Trends in fish population characteristics have differed among study areas of Soda Butte Creek. Within the Footbridge electrofishing reach, estimated population sizes and mean length of captured fish have generally increased since 1984 (Table 19). Mean age in 1990, however, was the lowest to date. This may reflect successful recruitment and a large percentage of small fish in the catch. Mean length of trout caught by anglers from below Icebox Canyon has paralleled the increasing trends observed

in electrofishing samples since the regulation changed in 1987 (Figure 41). Since the implementation of the 330-mm minimum-length regulation in 1987, harvest has been concentrated on the larger fish in the population. When compared to estimated population sizes derived from electrofishing data, recent results suggest an average annual creel since 1987 of nearly one-third of the fish available for harvest below Icebox Canyon. Comparable rates of annual harvest under the unrestricted size limit in effect between 1977 and 1986 was 218 trout ≥ 330 mm in length, which suggests that approximately half of the estimated population in this larger size group was harvested. Despite these harvest levels, other data (population abundance and length structures) do not indicate negative impacts on this fishery.

Jones et al. (1979) suggested that movement of trout from the catch-and-release population in adjacent areas of the Lamar River helped to maintain the Soda Butte Creek fishery. Preliminary electrofishing data have revealed some movement between the fish populations in these two streams; thus, fish ≥ 330 mm TL from Lamar River could be harvested if they moved into Soda Butte Creek. Conversely, large fish from Soda Butte Creek would be protected from harvest if they moved downstream into the Lamar River.

At the Northeast Boundary sample reach, trends in fish population characteristics are less clear. Population size appears to be increasing and PSD values for trout caught by electrofishing have averaged 50% higher under the 330-mm minimum-size regulation. Mean age and the length-frequency distribution in 1990 (Figure 40) indicate a large percentage of young fish in this population, and successful spawning and recruitment during the past 2 years suggests that water quality has improved substantially in this section of Soda Butte Creek. The scarcity of large (≥ 330 mm) trout in the electrofishing samples (Table 20) remains a concern, however. Although preliminary estimates indicate that there are more large trout being produced in Soda Butte Creek, the estimated high level of exploitation may result in most of the large fish being harvested. Approximately one-third of the landed trout ≥ 330 mm were creeled annually prior to 1987. Overall harvest of trout above Icebox Canyon decreased by more than 50% after the regulation changed in 1987. Current estimated harvest suggests that approximately two-thirds of the fish available for harvest (derived from electrofishing estimates) are currently being creeled. Current harvest levels above Icebox Canyon suggest a doubled exploitation rate of cutthroat trout longer than 330 mm since the more restrictive regulation was instituted.

The two middle study sections of Soda Butte Creek (Round Prairie and Icebox Canyon) were accidentally treated with an excess amount of rotenone in 1988 (Jones et al. 1989). The Round Prairie section showed substantial repopulation within a year, but recovery in the Icebox Canyon section was modest (Jones et al. 1990). By 1990, however, number of trout captured by electrofishing, length-frequency distribution, and mean age in

the Round Prairie section were very similar to those of the pretreatment sample in 1987. Furthermore, mean total length of trout captured by electrofishing, adjusted PSD value, and mean weight in the 1990 sample were the largest of any sample from this section. These results suggest a return of the population to pretreatment conditions within 2 years. In addition, the age structure of the sample from 1990 was very similar to that of the 1987 populations. Workman (1981) considered a reestablishment of the original age structure as evidence of recovery of the affected population.

In the electrofishing reach above Icebox Canyon, the rotenone treatment eliminated almost all of the trout in 1988 (Jones et al. 1989) and recovery has been slower than in the Round Prairie section. Number of cutthroat trout captured by electrofishing, mean total length of captured fish, and estimated mean age of trout in the 1990 sample were considerably smaller than values for these parameters in the pretreatment sample from 1987. Small trout appear to be the predominant size group within the recovering population (Figure 43). Percentages of age-2 and age-3 trout in the 1990 sample were similar to those within the 1987 sample; however, age-4 and older fish were scarce in the 1990 sample. Jones et al. (1988) indicated that the sample from 1987 may have underestimated the abundance of the resident population because turbid water reduced capture efficiency. These findings suggest that the cutthroat trout population in the Icebox Canyon sample reach has not reestablished itself to pretreatment levels. Several additional years may be required before this population is fully recovered; however, rapid growth rates observed in the past 2 years suggest that the recovered population should be robust.

Historic as well as recent studies of Soda Butte Creek illustrate that a complex variety of factors affects the trout populations in this stream. Although the genetic status of some portions of the population is unknown, this stream has been managed as a native cutthroat trout fishery. Consequently, monitoring of angler effects (including estimated harvest) is critical to this important fishery. Continued examination of long-term fish population dynamics will assist in making the proper decisions to assure the viability of this self-sustaining population of wild trout.

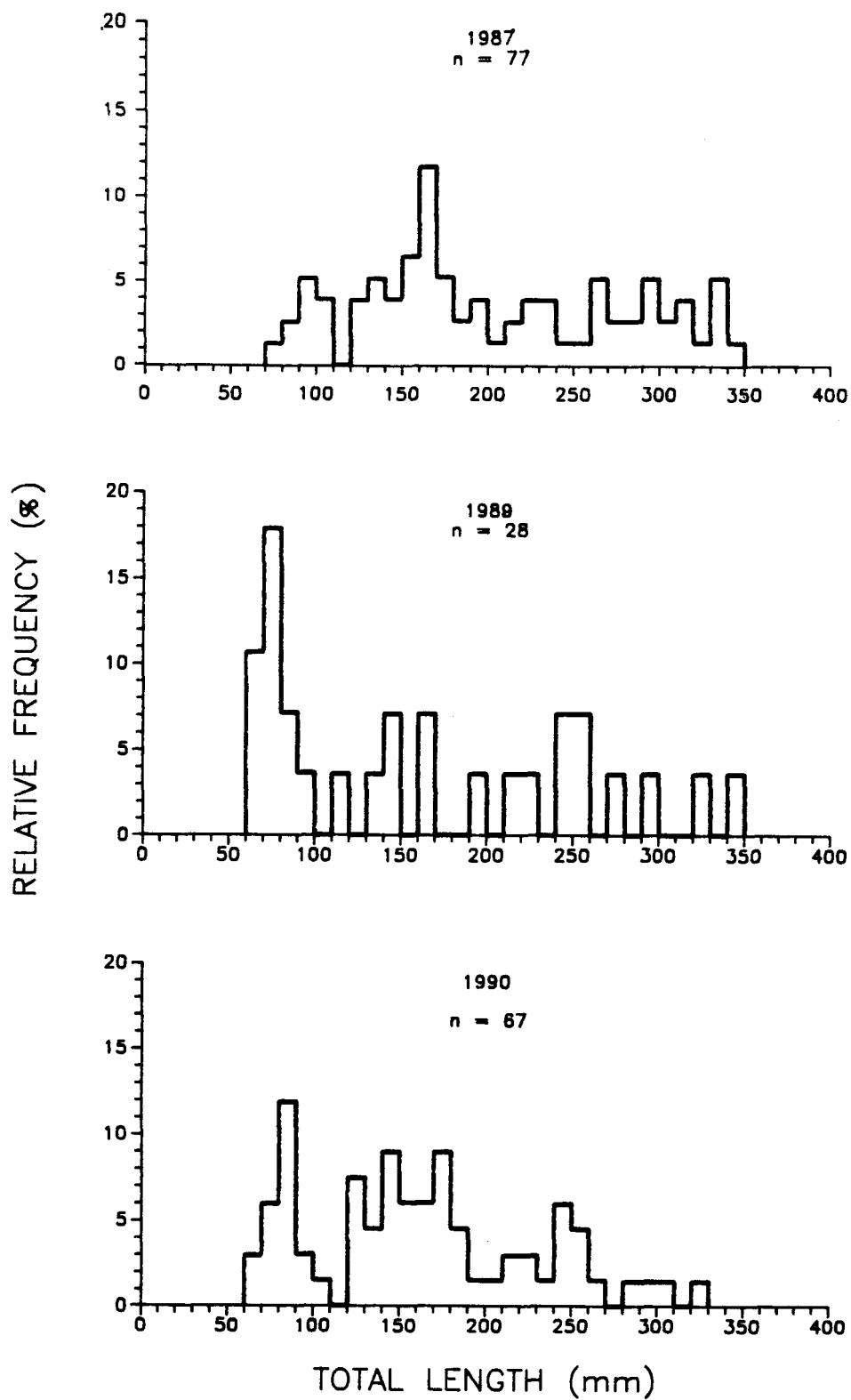


FIGURE 43.-Length-frequency distributions of cutthroat trout captured by electrofishing above Icebox Canyon, Soda Butte Creek, 1987 to 1990.

LEWIS LAKE SPAWNING OPERATION

Lewis Lake, located in south-central Yellowstone National Park, was historically fishless (Jordan 1891). In 1890, lake trout *Salvelinus namaycush* were collected from spawning reefs near the Beaver Islands in Lake Michigan and introduced into Lewis Lake (Varley 1981; Visscher 1984). The only other introduction of lake trout into Lewis Lake occurred in 1941, when about 6,000 fingerlings of unknown genetic origin from a federal fisheries station in Bozeman, MT, were released (Visscher 1984).

During the past century, lake trout stocks in Lake Michigan have severely declined because of overfishing, parasitism by sea lamprey *Petromyzon marinus*, and pollution. Because the genetic integrity of the Beaver Island stock has probably been maintained in Lewis Lake, the lake trout stock of Lewis Lake is a good candidate for reestablishment efforts in Lake Michigan.

U.S. Fish and Wildlife Service personnel have captured and artificially spawned lake trout from Lewis Lake almost annually since 1982. Fertilized eggs are reared to maturity in federal hatcheries outside the Park. Mature lake trout are then used as broodstock in the lake trout restoration program in Lake Michigan.

Methods

In 1990, lake trout were collected by electrofishing at night from two boats with boom-mounted dropper electrodes (Novotny and Priegel 1974) on 24 September and 2 October. Trout were captured at several sites along the east shore of Lewis Lake (Figure 44). Stunned fish were netted, placed in a boat-mounted livewell to recuperate, and subsequently transferred to a 9-m-long barge for processing. On 24 September, captured females were injected with gonadotropin, and all fish captured on this date were retained in holding nets for 8 d prior to being artificially spawned on 2 October by personnel from Jackson National Fish Hatchery (NFH), WY, and Saratoga NFH, WY. Females captured on 2 October were also injected with gonadotropin, and all fish captured on this date were held for 8 d before being artificially spawned on 10 October.

Fish health samples were collected from a subsample of electrofishing-captured Lewis Lake lake trout in 1990. Samples were tested for specific bacterial, viral, and parasitic pathogens at the U.S. Fish and Wildlife Service Fish Health Center, Fort Morgan, CO. Tests were made for bacteria that cause enteric redmouth disease ($N = 155$), furunculosis ($N = 155$), and bacterial kidney disease ($N = 82$); for viruses that cause infectious hematopoietic necrosis ($N = 135$), infectious pancreatic necrosis ($N = 65$), and viral hemorrhagic septicemia ($N = 65$); and for the internal parasite that causes whirling disease ($N = 50$).

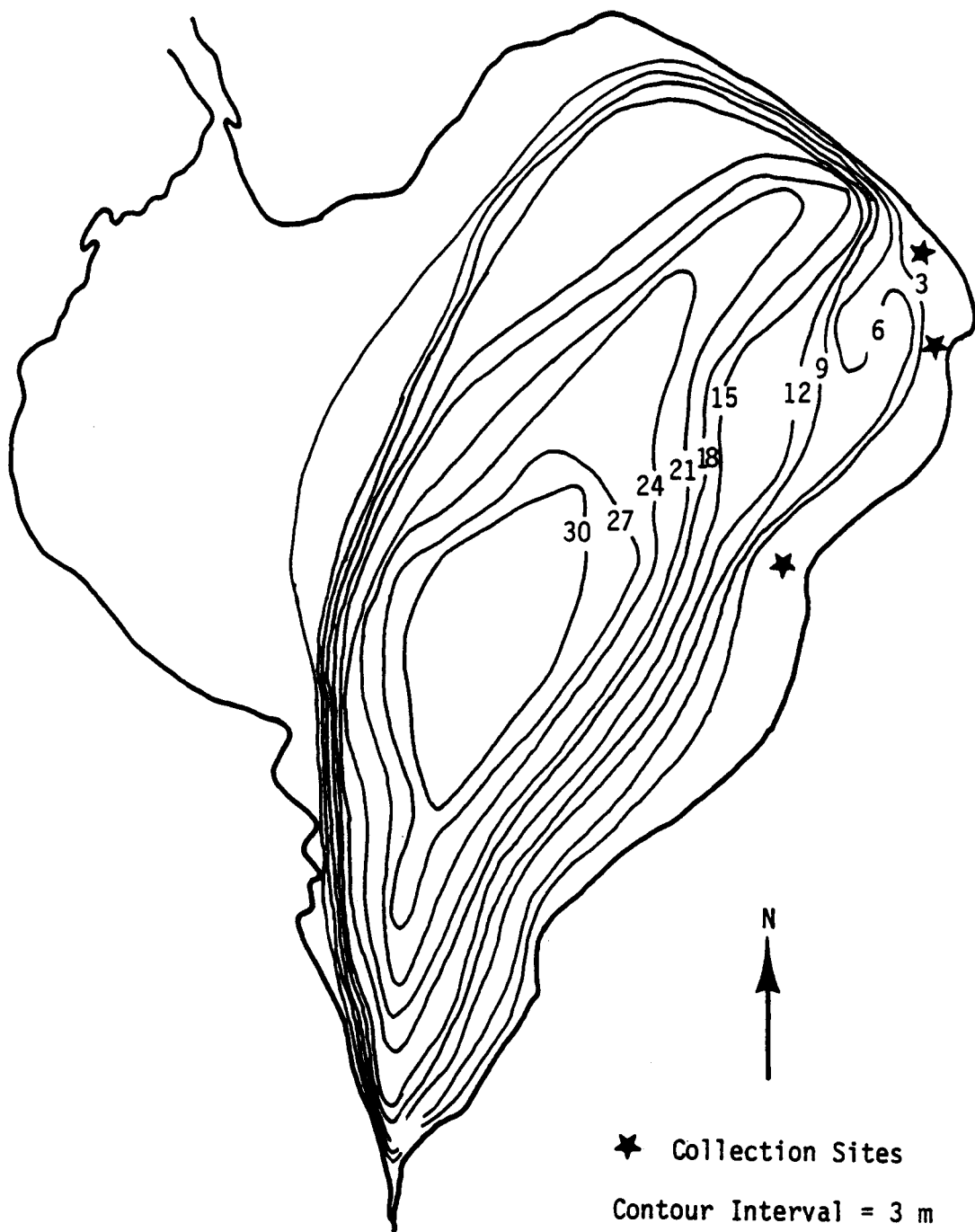


FIGURE 44.-Collection sites for spawn-taking operations, Lewis Lake, 1990.

Results

Three hundred twenty lake trout were captured in 1990, but 74 (23%) of these trout died from what appeared to be electrofishing-induced injuries. Eggs were collected from 52 ripe females, milt was taken from 66 ripe males, and eggs were fertilized on-site. All live trout were released after spawning operations were completed.

Of the nearly 43,300 fertilized lake trout eggs obtained from Lewis Lake in 1990, about 24,600 (57%) survived to the eyed-egg stage. Equal portions of eyed eggs were shipped to Creston NFH, MT, and Saratoga NFH to be hatched, reared, and eventually used as brood stock. All of the fish-health samples tested negative, resulting in a "specific pathogen-free" classification for the Lewis Lake lake trout population (C.J. Hudson, personal communication).

Discussion

Although 1990 was the first year in which a quantitative estimate of electrofishing-induced mortality was made during the Lewis Lake lake trout spawning operation, biologists who have participated in the project since 1982 speculated that the amount of electrofishing-induced mortality in 1990 was higher than in previous years. Relatively high water temperatures during the electrofishing operation in 1990 may have contributed to the observed increase in mortality. At Lewis Lake, as in most electrofishing operations, electrode shape, type of direct current (straight or pulsed), pulse width and frequency, and voltage can be controlled. Also, the amount of electric current in the water and water temperature, conductivity, and depth can be measured or estimated. However, despite our ability to measure these variables that affect the efficacy of electrofishing, it is always difficult to predict, even in highly controlled laboratory situations, how an individual fish will be affected by an electric field (Shreck et al. 1976). Clearly, systematic field experimentation is needed to minimize electrofishing-induced mortality of lake trout during the Lewis Lake spawning operation.

In 1988, disease problems at Jackson NFH resulted in the loss of all of the Lewis Lake lake trout broodstock at this facility. Since then, Lewis Lake lake trout broodstocks have been established at Saratoga NFH and Creston NFH. Maintaining healthy broodstocks at these two facilities will require periodic collection of eggs and milt from wild lake trout in Lewis Lake.

ARNICA CREEK

During a survey of tributary streams of Yellowstone Lake in 1985, brook trout *Salvelinus fontinalis* were collected from Arnica Creek. Because brook trout are not native to the Yellowstone Lake watershed, concern about potential negative impacts of brook trout on the native Yellowstone Lake cutthroat trout *Oncorhynchus clarki bouvieri* prompted Park managers to chemically treat the Arnica Creek watershed to remove brook trout in 1985 (Jones et al. 1986). An additional treatment was applied in 1986 to assure complete eradication of the brook trout. Subsequent electrofishing surveys in 1987, 1988, and 1989 (Jones et al. 1988 to 1990) failed to find any brook trout.

Methods

In September 1990, five sites in the Arnica Creek drainage were sampled with a Coffelt BP-1 backpack electroshocker (Figure 45). Fish were captured with smallmesh dip nets and visually identified to species. Total lengths of cutthroat trout and relative abundance of each species sampled were estimated visually.

Results and Discussion

In 1990, no brook trout were found in Arnica Creek. Cutthroat trout fry (50-75 mm estimated total length) were found at all sample sites. Juvenile cutthroat trout (>100 mm total length) were restricted primarily to the mainstem of Arnica Creek. Several cutthroat trout up to 200 mm total length were collected at the uppermost sample site (downstream from the confluence of tributary Streams 118307 and 118308) and one cutthroat trout approximately 300 mm total length was caught at the lower site near the highway (Figure 45). Redside shiners *Richardsonius balteatus* were captured at all locations, except in Stream 118304. Distribution of the lake chub *Couesius plumbeus* was similar to that observed in 1989 (Jones et al. 1990); lake chub were collected only at the two lower sites. Relative abundance of nonsalmonids (in comparison to cutthroat trout abundance) appeared to decrease in an upstream direction.

The 1990 sample was the fourth-consecutive year in which no brook trout were collected from Arnica Creek. This provides strong evidence that the treatment objectives of elimination of brook trout from Arnica Creek and continued successful cutthroat trout spawning there have been accomplished.

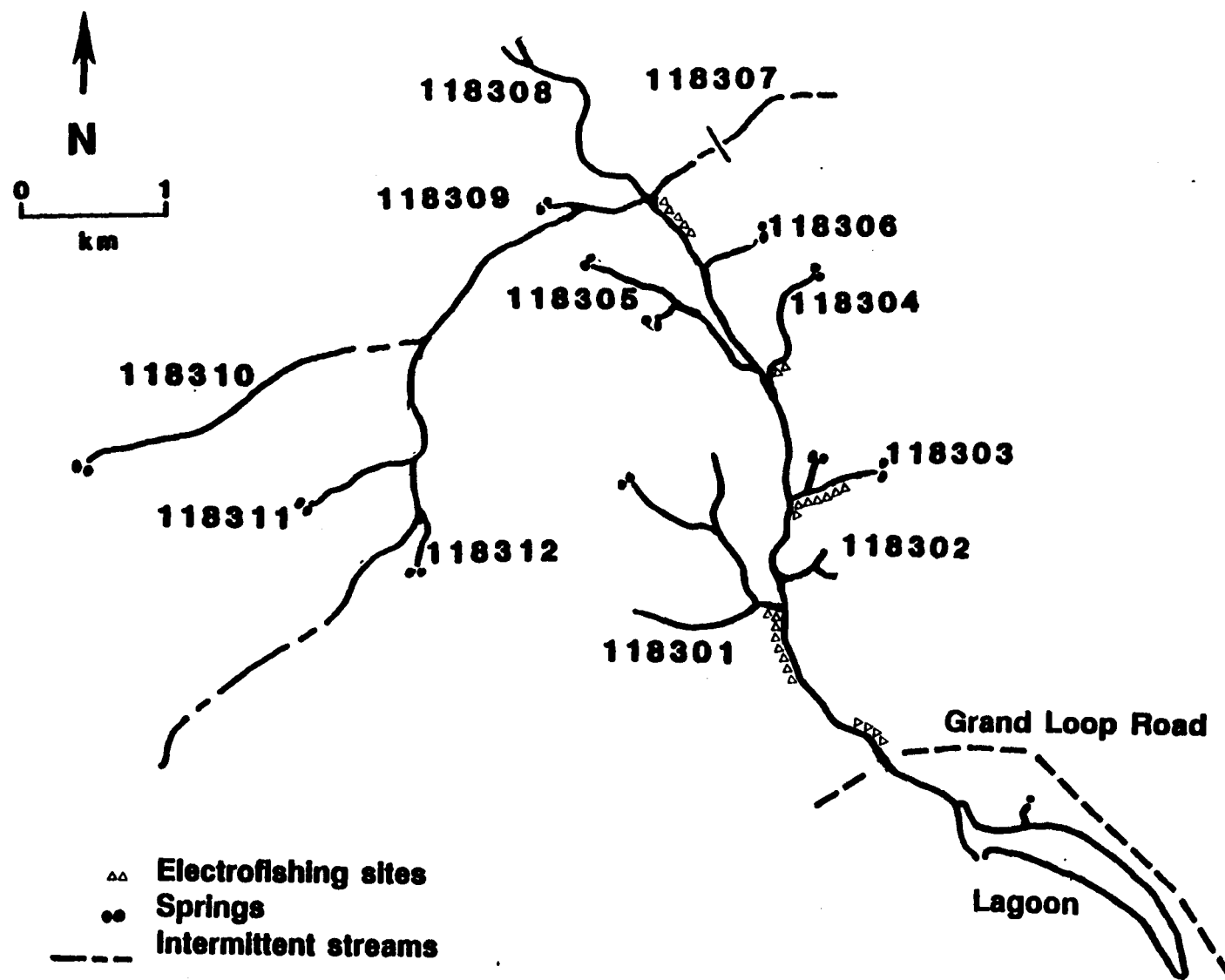


FIGURE 45.-Electrofishing sites on Arnica Creek, 1990.

YELLOWSTONE RIVER SEDIMENT STUDY PROGRESS REPORT

Sediment study staff worked on two projects in 1990:

- (1) post-fire stream suspended sediment and turbidity, and
- (2) riparian fluvial landform and deposit mapping of Soda Butte Creek.

Post-fire Suspended Sediment and Turbidity

Stream suspended sediment samples were taken in 1990 at most of the same stream sites in Yellowstone National Park that were sampled during the pre-fire years 1985 to 1987 (Mohrman et al. 1988). In 1989, a continuous stage recorder was added to the Lamar River cableway site near Tower Junction. Gaging stations with continuous stage recorders were added to Soda Butte and Blacktail Deer creeks. Blacktail Deer Creek was not monitored in the pre-fire sediment study but was severely burned during the 1988 wildfires and streamflow information was available for the stream from the late 1930s and early 1940s.

Measurement of turbidity of ash/carbon-rich suspended sediment was improved in 1990 through the acquisition of a Ratio/XR Turbidimeter, which is not influenced by the color of the solution or the light absorption due to carbon particles.

Some preliminary conclusions of the 1990 post-fire study follow. More detailed results will be published as a U.S. Fish and Wildlife Service technical report in the Aquatic Ecology Studies series.

Preliminary Conclusions:

Precipitation and Streamflow

(1) Despite greater October through June post-fire precipitation, October through June post-fire streamflow on the Yellowstone at Corwin Springs was less than the pre-fire average for all but one month (April).

(2) Post-fire summer (July through September) precipitation was less than the pre-fire at all four weather stations in the study area. Post-fire streamflow was less than pre-fire on the Yellowstone River at Corwin Springs for August and September, but greater for July. July post-fire streamflow may have been influenced by cool, gradual snowmelts during the post-fire years.

(3) The Yellowstone River at Corwin Springs and the Lamar River did not achieve peak snowmelt flows prior to unburned streams of similar elevation in the greater Yellowstone area in 1990. In 1989, the Lamar River, a high-elevation watershed with substantial burned areas, had peak snowmelt runoff at the same time as did some lower elevation watersheds. This may have been related to the 1988 wildfires.

(4) Post-fire Lamar River average mean-daily discharge, the mean of 1990 and 1989 monthly values, exceeded that of

mean-monthly pre-fire discharge for every month of the May through September sampling period save September. This possible fire effect was not observed on the Yellowstone River at Corwin Springs.

(5) Post-fire streamflow on the Lamar River was greater than pre-fire flows for July and August, despite generally lower precipitation for the period.

Sediment and Turbidity

(1) For the Yellowstone River at Corwin Springs, sediment concentration and discharge averages for the sample period followed the trend of average streamflow for the sampling period, with 1986 values exceeding those of 1989, 1990, 1985, and 1987, respectively.

(2) During the snowmelt period, 1990 average sediment concentration and discharge in the Yellowstone River at Corwin Springs was less than 1986 and 1989 values but greater than that of 1985, despite having less streamflow in 1985.

(3) Apparently, flushing of suspended sediment stored in the Lamar River and Yellowstone River channels during the 1990 snowmelt did not cause any great increase in sediment transport.

(4) Snowmelt pre-fire average sediment concentration and discharge was greater than post-fire averages for May and June. The April post-fire average was greater than the pre-fire value by a considerable amount.

(5) The 1990 summer sediment concentration average on the Yellowstone River surpassed that of previous years. Summer streamflow was higher than other years, with the exception of 1986. Summer sediment discharge, combining the effects of streamflow and concentration, was greater for 1986 than other years. The 1990 discharge was the second highest.

(6) Turbidity on the Yellowstone River at Corwin Springs in 1990 exceeded that of all previous years for snowmelt, summer, and overall averages.

(7) On the Lamar River, average sediment concentration and discharge for the entire sample period did not follow the rankings of streamflow as they did on the Yellowstone River, i.e., high streamflow years having high sediment values. The entire sample period of 1990 had the highest concentrations but the next to the lowest streamflow.

(8) The highest sediment transport on the Lamar River during the May through September period of the years of the sediment study was in 1986.

(9) Pre-fire snowmelt sediment concentration in the Lamar River was greater than post-fire values. Both 1990 and 1989 had less average snowmelt concentrations and discharge than in 1986.

(10) Summer suspended sediment concentration and discharge for 1990 were much greater than in any other year of the study period. This was the result of summer storms in the upper Lamar

River drainages during August. August post-fire values were an order of magnitude larger than the pre-fire average.

(11) The 1990 average Lamar River turbidity for all seasons surpassed that of previous years. Summer turbidity was especially high.

Soda Butte Creek Fluvial Landform/Deposit Mapping

Sediment Study staff collected riparian landform and deposit information during the 1990 field season to investigate willow-landform relationships and produce a landform/deposit map of Soda Butte Creek. Willow-landform relationships will be determined from data collected on willow species, landform, and soil depth along leveled cross-sections across major willow plots delineated on Soda Butte Creek by the Yellowstone National Park Research Division's Willow Study. Field data will be entered in a database to discover willow species relations to landform and soil depth.

Landforms of the riparian and valley bottom areas of Soda Butte Creek were determined by stereoscopic examination of large scale black and white aerial photos (1:6000 scale), 1:20000 color photos, and 1:24000 color infrared photos. Landforms and associated spot soil samples will also be entered into a data base to establish map units for the drainage. Landform map units will be delineated in the Yellowstone National Park Geographic Information System (GIS) for final map production. This map will be used as a basis for further willow or other riparian vegetation studies.

RECREATIONAL USE AND WILDLIFE RESOURCES
IN THE LEWIS RIVER CHANNEL DURING THE
BROWN TROUT SPAWNING SEASON: 1990 ANNUAL REPORT

The Lewis River Channel is a 5-km long river reach that connects Shoshone and Lewis lakes. In fall and early winter, brown trout *Salmo trutta* from Lewis Lake (and possibly Shoshone Lake) migrate into the channel to spawn (Dean 1972). During this time, resident and migratory waterfowl, including ducks, trumpeter swans *Cygnus buccinator*, and tundra swans *C. columbianus*, also use the channel. Apparently, waterfowl are attracted to the area by the open water and beds of the aquatic macrophyte, *Elodea* sp. (T. McEneaney, personal communication). Bald eagles *Haliaeetus leucocephalus* frequent the channel area in fall and early winter, and probably prey on brown trout and ducks. Grizzly bear *Ursus arctos horribilis*, black bear *U. americanus*, mule deer *Odocoileus hemionus*, elk *Cervus elaphus*, and moose *Alces alces* have been observed in the channel area in the fall.

Recreational activities in the Lewis River Channel in fall and early winter include fishing for brown trout, backpacking, and boating. Resource managers are interested in the effects that recreational activities might have on wildlife resources. There is concern that trumpeter swans and bald eagles may be temporarily or permanently displaced by human activity. Also, angling and boating might disrupt brown trout spawning or cause direct mortality (through wading on or dragging boats over spawning beds) of brown trout eggs in the gravel.

The goal of this study is to evaluate the effects of recreational activities on wildlife resources in the Lewis River Channel area during the brown trout spawning season. Specific objectives established cooperatively by the National Park Service (NPS) and U.S. Fish and Wildlife Service (USFWS) are:

- (1) determine levels and patterns of angler use;
- (2) determine the onset, peak, and end of the brown trout spawning run;
- (3) determine abundance and distribution of ducks, swans, and eagles in the channel area during the brown trout spawning run; and
- (4) determine the level of bear activity in the channel area during the brown trout spawning run.

Study Area

The Lewis River Channel lies in south-central Yellowstone National Park. The channel is the outlet of Shoshone Lake and flows south to Lewis Lake (Figure 46). Average channel gradient is 0.05%.

The Lewis River Channel has three river reaches that differ greatly in morphology. Reach 1 extends from Lewis Lake upstream

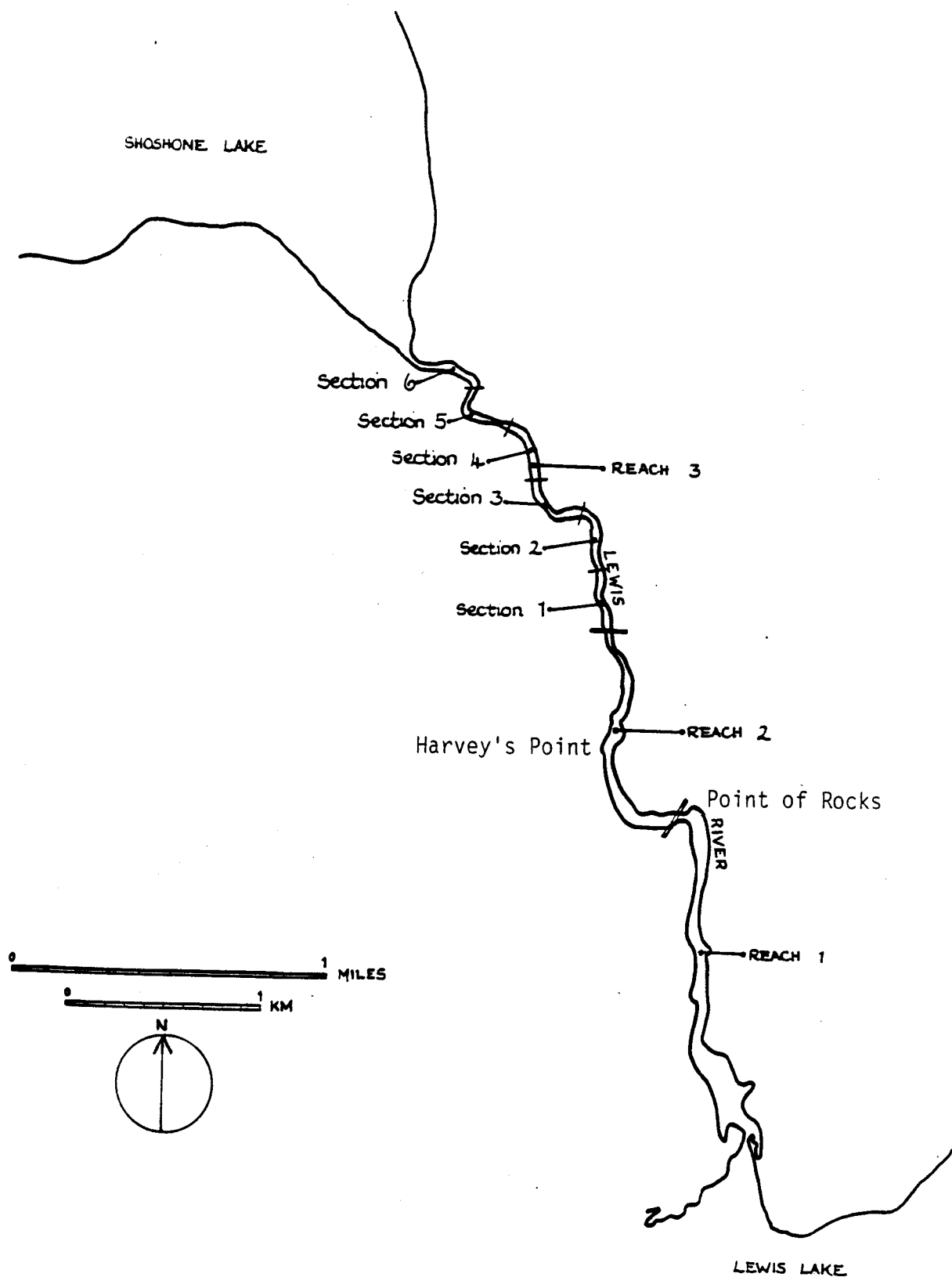


FIGURE 46 .-Detail of the Lewis River Channel, showing Reaches and Sections.

1.7 km to a landmark known as Point of Rocks (Figure 46). This reach is characterized by relatively deep, slow-moving water. Reach 2 begins at Point of Rocks and extends upstream for 1.4 km (Figure 46). Water depth and velocity in Reach 2 are slightly shallower and faster than in Reach 1. *Elodea* sp. beds are abundant in Reach 2 near a landmark known locally as Harvey's Point (Figure 46). Reach 3, the upper 1.8-km river reach (Figure 46), is characterized by shallow, rapidly moving water and a gravel substrate. Most of the 3.3-m drop in elevation between Shoshone and Lewis lakes and most of the brown trout spawning occur in Reach 3.

Visitors access the channel by boat, foot, or horseback. Boaters motor or paddle across Lewis Lake and then paddle up the channel (a total distance of about 8 km). Visitors paddling up the channel to Shoshone Lake must drag their boats through most of Reach 3 because of the shallow, rapid water. Hikers and horse parties can access the channel via a 19-km loop trail that starts and ends at the Shoshone Lake trailhead. Camping is available near the outlet of Shoshone Lake for hikers and boaters.

Methods

Study duration (1990 to 1993).—The study began in 1990 and will extend through 1993. During the first 2 years (1990 and 1991), visitor use will not be restricted, and the length of the fishing season will remain unchanged. During the last 2 years (1992 and 1993), the channel will be closed to all visitor use, including angling, on 15 October (the fishing season currently closes on the first Sunday in November). Data collection during all 4 years will extend from September through November.

Angler Use (1990).—Manned creel surveys were used to estimate angler use and sample creel fish. The current creel survey was similar to those conducted in the Lewis River Channel by the USFWS in both 1971 and 1976 (Jones et al. 1977).

Creel surveys were conducted twice each week, beginning the last week of September and ending the first week of November, and survey dates were established in the following manner. Each week was stratified by weekday and weekend. Weekday survey dates were chosen randomly. Weekend dates were chosen using a random start then alternating between Saturday and Sunday. The 1990 creel surveys were conducted on 26 and 29 September; 2, 7, 10, 13, 19, 21, 22, and 27 October; and 2 and 4 November.

On each survey date, counts of anglers were made in the morning and afternoon, alternating between upstream and downstream starts. Morning counts began at approximately 1100 hours, and afternoon counts at approximately 1400 hours. Between counts, anglers were interviewed to determine the length of time that they spent fishing and the species and number of fish that they landed and creel. Creel fish were weighed and measured, and scale samples were collected for age-growth analysis.

Brown trout spawning (1990).-Visual counts were used to determine the onset, peak, and end of the brown trout spawning run. A twice-weekly visual check, beginning in mid September, determined the onset of the spawning run. Once spawning began, visual counts were conducted once each week until the end of the spawning run. To determine distribution of spawners, Reach 3 was divided into six sections, each approximately 300-m long (Figure 46). The 1990 counts were conducted on 26 September; 3, 10, 17, 25, and 31 October; and 7, 14, and 28 November. All counts were conducted between 1000 and 1500 hours.

A thermograph was installed in the channel on 14 September and will be removed in the spring of 1991. Water temperature data will be correlated to the timing of brown trout spawning and will be used to estimate hatching and emergence dates for brown trout eggs and fry, respectively.

Bird use (1990).-Bird surveys were conducted weekly during October and November. Data collected during these surveys included the number, species, and distribution of ducks, swans, and eagles. The 1990 surveys were conducted on 4, 11, and 25 October and 1, 8, 14, and 28 November.

Bear activity (1990).-While observers counted fish, signs of bear activity were recorded according to methods in Reinhart (1988).

Results

Recreational Use 1990

Estimated total angler effort and landing rate were 833 h and 1.1 fish/h, respectively. Of an estimated 1,067 trout landed, 93% were released (Table 21). Highest angler use occurred during the first and fourth weeks of October (Figure 47).

Highest boat use in the channel was during the last week of September with the numbers declining thereafter (Figure 47). Each boat counted represented one trip up and down the channel.

Brown Trout Spawning 1990

Brown trout spawners were first observed in the channel on 20 September, and the highest spawner count occurred on 31 October (Figure 48). Spawning ended about the fourth week of November, indicating that the duration of the spawning run was approximately 10 weeks. Spawner counts were highest in Section 5, followed by Section 6 and Section 3 (Figure 49).

Bird Use 1990

The number of unduplicated bald eagle sightings was highest on 1 November (Figure 48). Except for data from 8 November, bald eagle trends closely followed fish trends. Trumpeter swans were

TABLE 21.-Lewis River Channel creel survey results, 1971, 1976, and 1990.

Year	Angler days (# trips)	Average length of angler day (hours)	Total effort (hours)	Trout landed	Landing rate (fish/h)	Trout kept	Creel rate (fish/h)	Fish released (%)
1971 ^a	413	3.8	1,568	1,537	0.98	643	0.41	58
1976 ^a	689	2.7	1,847	2,992	1.62	388	0.21	87
1990	305	2.9	833	1,067	1.13	67	0.08	93

^a Jones et al. (1977).

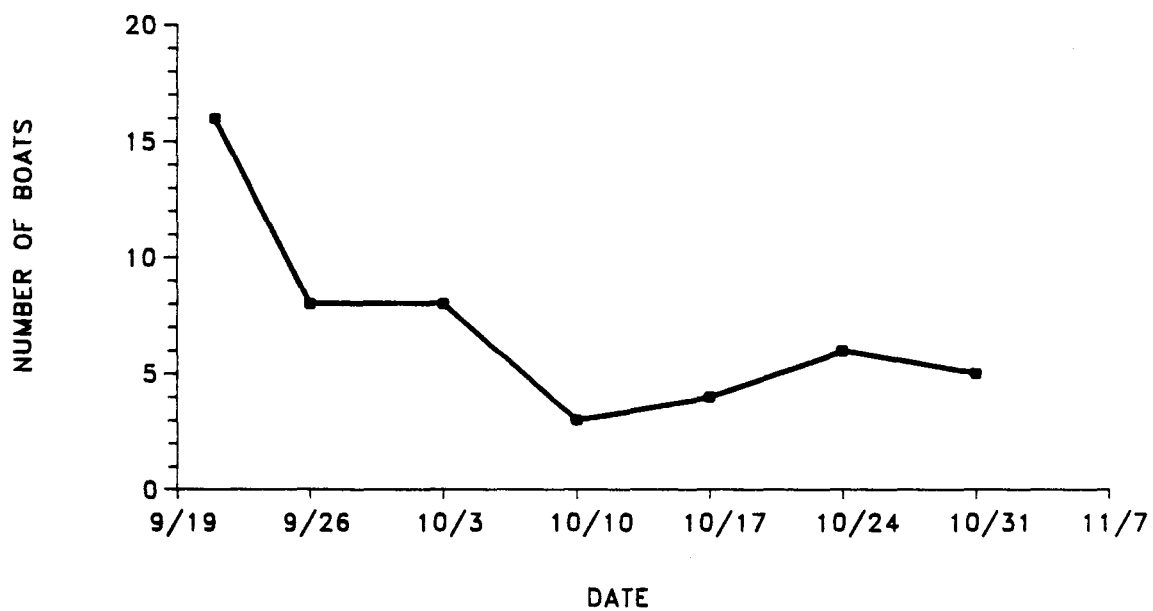
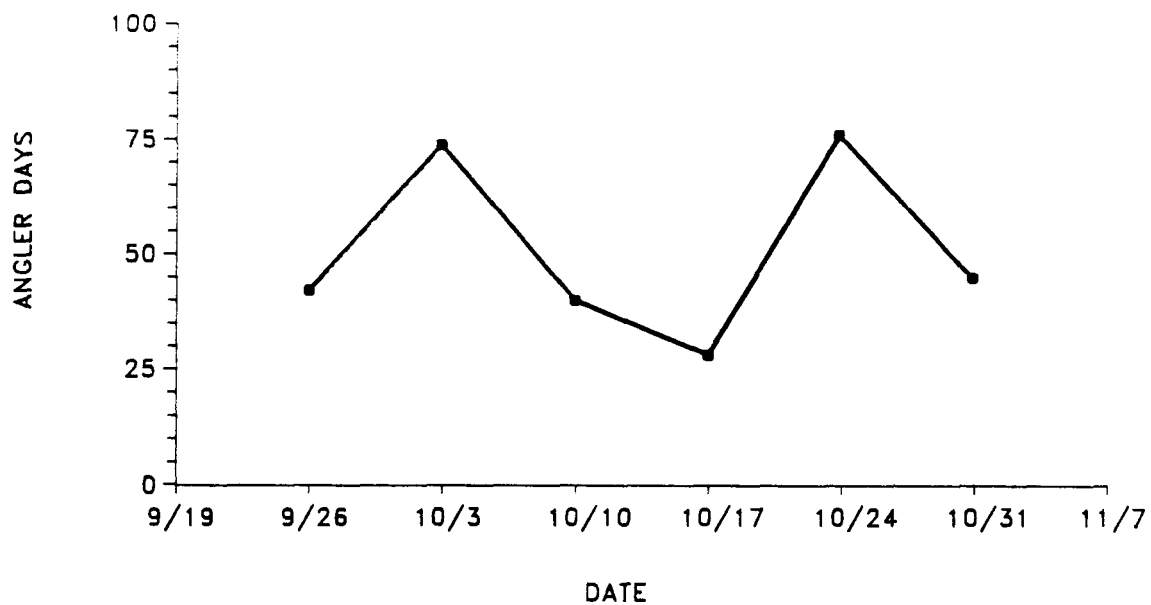


FIGURE 47.-Estimates of angler use and boat use in the Lewis River Channel, 1990.

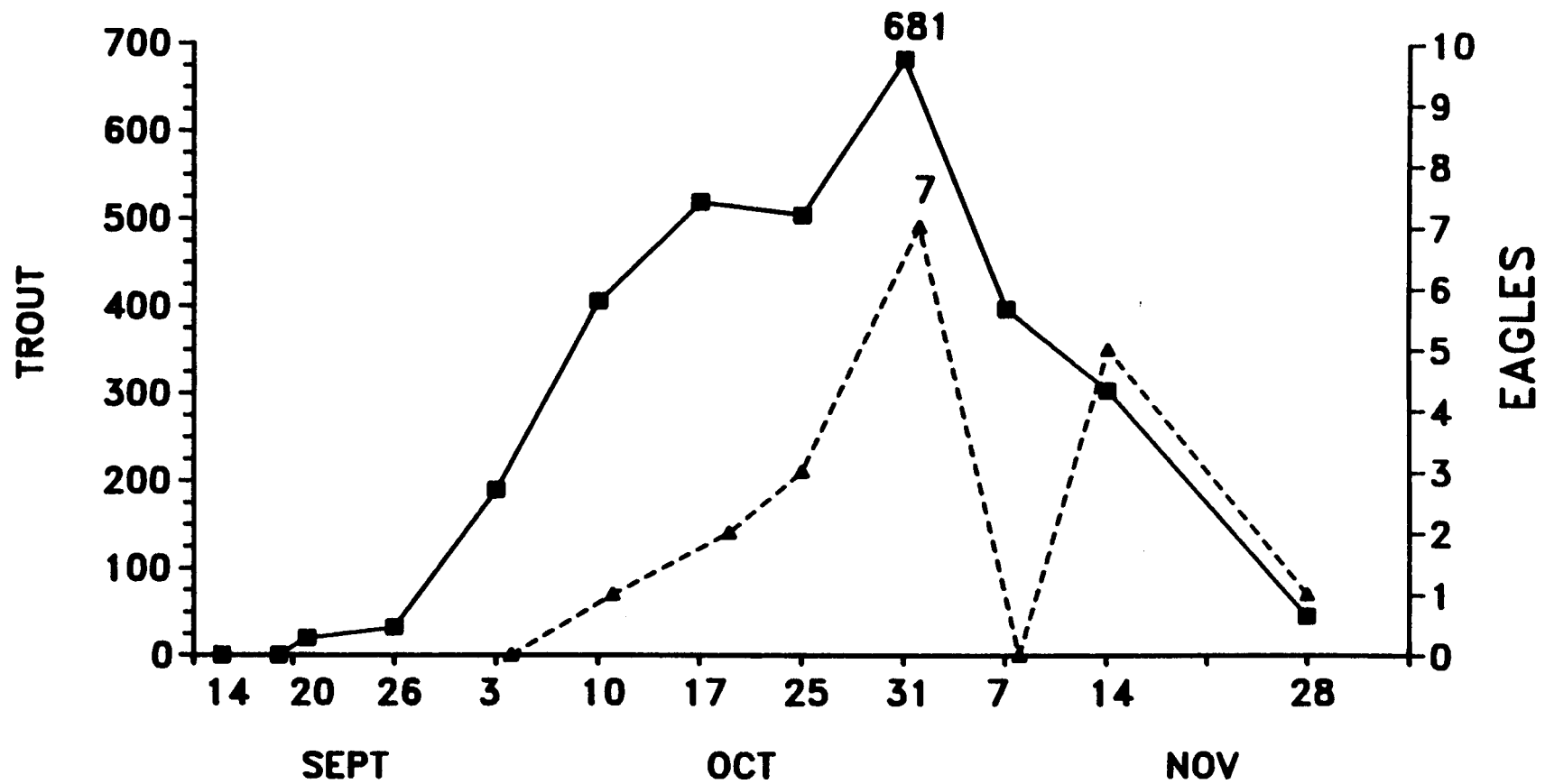


FIGURE 48.-Counts of brown trout spawners and bald eagles in the Lewis River Channel, 1990.

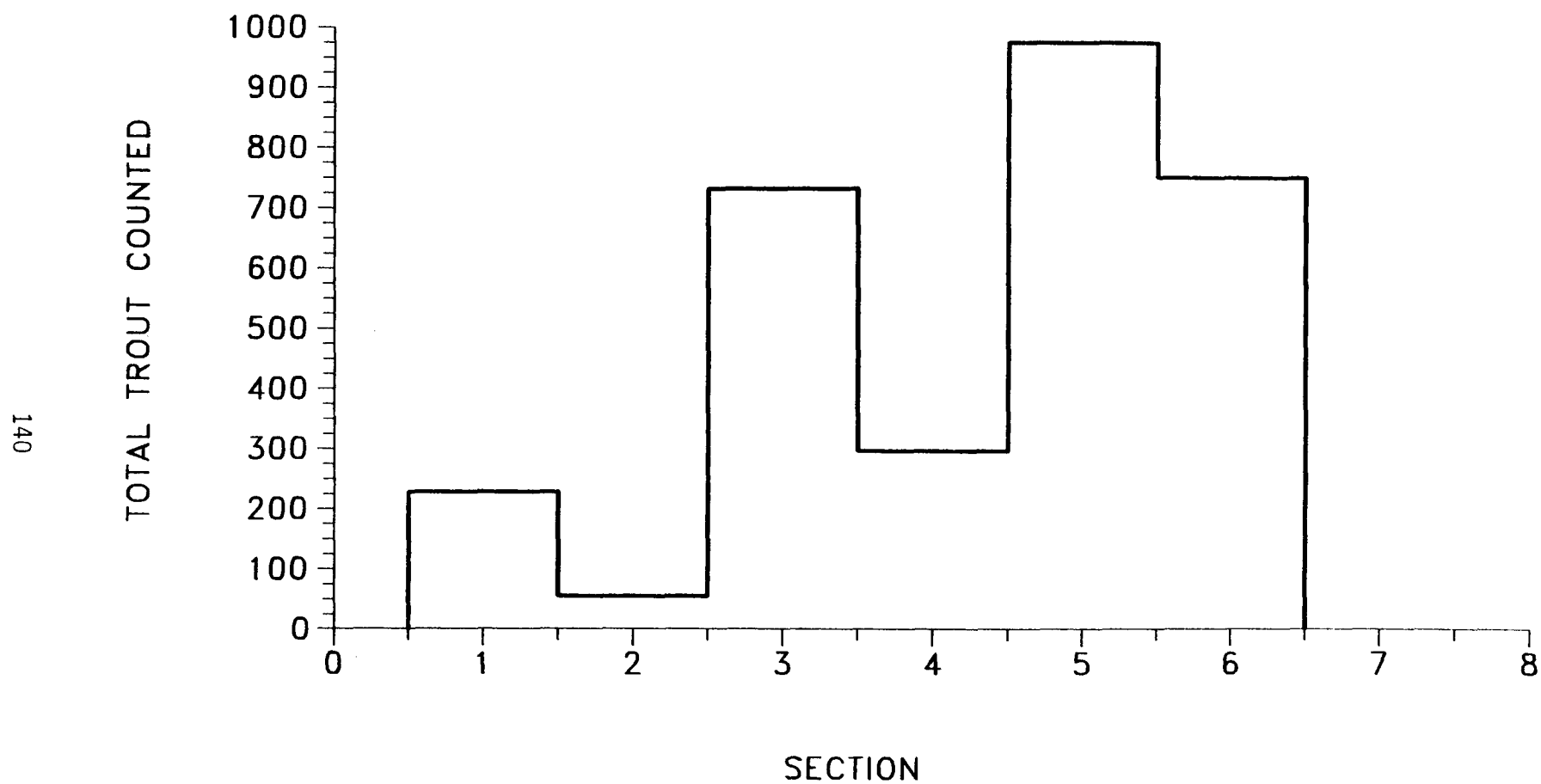


FIGURE 49.-Distribution of brown trout spawners in the Lewis River Channel, 1990.

first observed on Shoshone Lake near the channel on 24 October, and were first observed at the channel outlet on 2 November. Numbers of swans remained relatively constant throughout the monitoring period (Figure 50).

Bear Activity 1990

There was no documented bear use of the channel during the 1990 brown trout spawning run. Black bear tracks were observed near the Shoshone Lake trailhead on 14 November.

Discussion

Angler Use 1971, 1976, and 1990

Creel surveys conducted by the USFWS in 1971 and 1976 are directly comparable to the 1990 survey (Table 21). Estimated total angler effort (hours) dropped 55% between 1976 and 1990. Estimated angler days (number of trips) also dropped 55% between 1976 and 1990. Landing rate did not change substantially during the period 1971 to 1990; however, the percent of fish released rose from 58% in 1971 to 87% in 1976 and 93% in 1990.

Brown Trout Spawning

Jones et al. (1977) speculated that anglers fished only the beginning of the brown trout spawning run because weather conditions were usually favorable and the fishing season closed in late October. Data from 1990 indicated, however, that the spawning run peaks during fishing season and begins to decline before fishing season ends. It is unlikely that angling is harming the brown trout population because 93% of the trout landed are released.

In both the 1971 and 1976 creel surveys, creeled fish were measured, weighed, and aged to obtain population structure information. In 1990, only four fish were sampled due to the low creel rate, and this sample was not sufficient to provide reliable data on population structure.

Although results suggest that brown trout are not being overharvested by anglers, walking on redds while fishing or dragging boats through spawning grounds may increase the mortality of developing eggs and embryos above natural levels. Increased mortality of cutthroat trout *Oncorhynchus clarki* eggs and pre-emergent fry from trampling by anglers has been documented in laboratory studies (Roberts 1988). Temperature data that will be available when the thermograph is retrieved in the spring should provide estimates of hatching and emergence dates in the Lewis River Channel. These estimates will help us to better understand the degree to which trampling may be affecting brown trout reproduction in the Lewis River Channel.

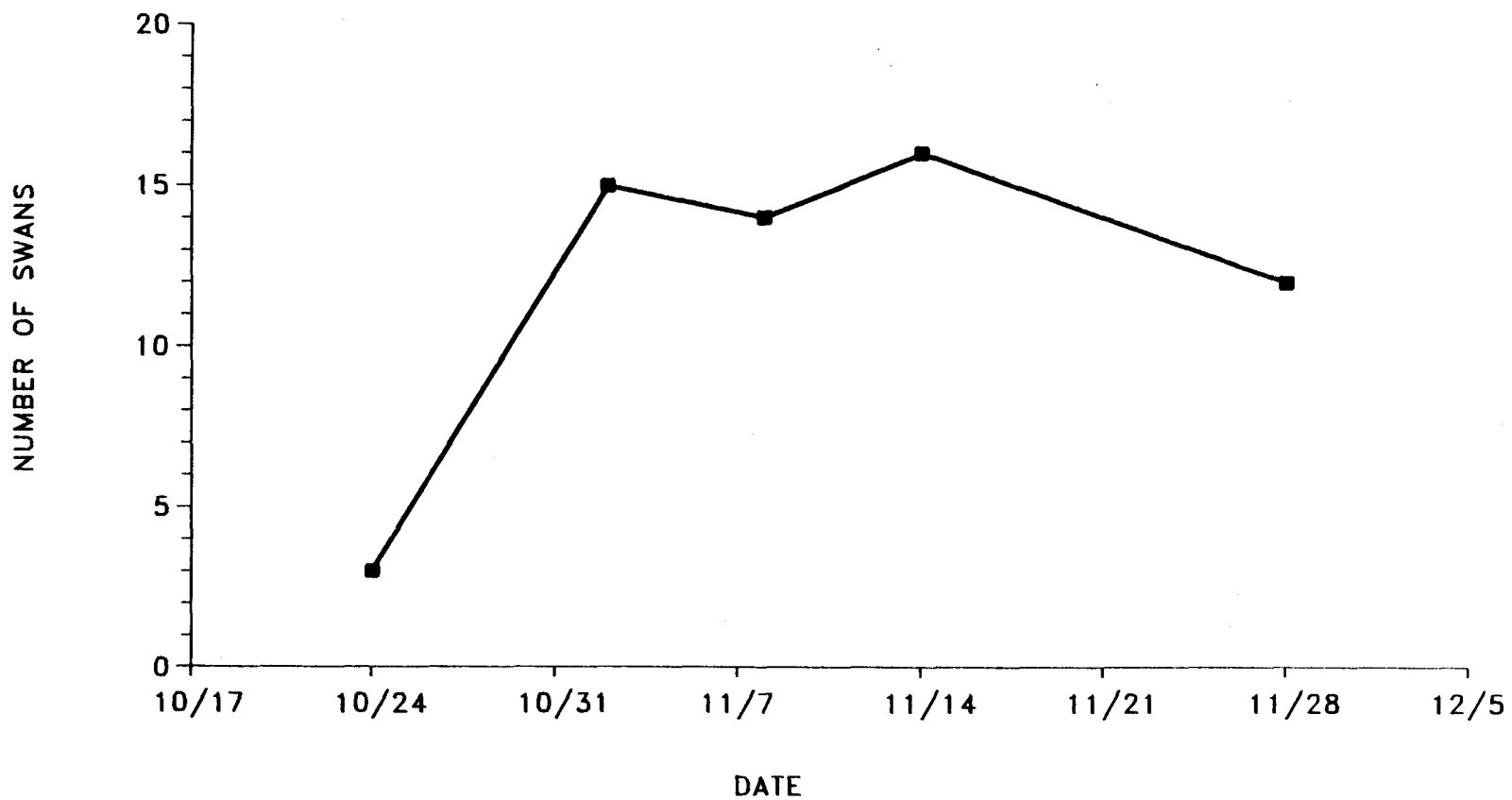


FIGURE 50.-Counts of swans in the Lewis River Channel, 1990.

Recreational Impacts on Trumpeter Swans and Bald Eagles

Trumpeter swans may be particularly sensitive to human activity (Banko 1960), and sections of Red Rock Lakes Refuge, MT, are closed to human use to prevent disturbance of swans (T. McEneaney, personal communication). Trumpeter swans using the Lewis River Channel are primarily concentrated in the stretch of water upstream of Harvey's Point (in the upper stretch of Reach 2) until this area ices over (late November in 1990). Observers in this study noted short-term disturbance of swans whenever paddlers or hikers passed through or near this area; however, possible negative effects on swans could not be determined from the limited number of observations.

Stalmaster (1987) found that high levels of human activity adversely affected bald eagles by disrupting normal behavior and displacing eagles to nonpreferred, marginal habitat. Observers in this study noted short-term disturbance of bald eagles by both boaters and hikers, although no conclusions regarding negative effects on eagles can presently be drawn from these observations.

Management Implications and Recommendations

The information gathered in 1990 will serve as baseline data for comparison with data gathered in subsequent years. Methods will not significantly change in 1991; however, observers will concentrate on collecting more data from creel fish. Data analysis will also try to quantify nonangling recreational use in addition to the angling use now estimated.

NONCONSUMPTIVE USE OF THE AQUATIC RESOURCE

Two sections of the Yellowstone River in Yellowstone National Park are closed to angling to protect Yellowstone cutthroat trout *Oncorhynchus clarki bouvieri* during the spawning season. These areas provide an excellent opportunity to evaluate public use of aquatic habitats that are suitable for nonangling uses, such as photography or viewing.

Fishing Bridge spans the Yellowstone River at the outlet of Yellowstone Lake, and the 1.6-km river reach immediately below the lake outlet has been closed to fishing since 1973. The river immediately upstream and downstream from Fishing Bridge provides visitors with an outstanding opportunity to view spawning cutthroat trout and the interactions of trout and other wildlife (e.g., pelicans, ospreys, eagles, coyotes).

LeHardy Rapids, which is located approximately 5.7 km downstream from the Yellowstone Lake outlet, has been closed to angling since 1949. During spring runoff (May through July), Yellowstone cutthroat trout congregate near the west bank of the river in pools immediately below the rapids. From these pools the fish jump the rapids and provide an extraordinary sight for the visitor. In 1984, a new boardwalk and viewing platform were constructed at LeHardy Rapids to enhance visitor access and prevent continued erosion of the trail to the rapids. A sign identifying LeHardy Rapids was placed at the vehicle pullout in 1985.

Visitor use was monitored at Fishing Bridge and LeHardy Rapids for the 13th consecutive year in 1990, and the number of visitors and mean length of stay were estimated at both areas.

Methods

Because personnel available to make counts were few, a "time-available" method (Mathisen 1949; Bulkley 1966; Geiger 1972; Brown 1978) of data collection was employed. Instantaneous counts of visitors at Fishing Bridge and LeHardy Rapids were made by U.S. Fish and Wildlife Service personnel whenever possible, usually while employees were en route to a work site. Additional counts were made by ranger and naturalist employees of the National Park Service.

Important components of the time-available method are accurate estimates of daily visitation patterns at each site and the average time spent per person at each site. Although accuracy of estimates increases as the visitor day is partitioned into shorter time intervals, when time intervals become too short, the increasing proportion of intervals without visitor counts causes negative bias in the resulting estimate. With these considerations in mind, a 15-min time interval was used for Fishing Bridge and LeHardy Rapids visitor-use estimates.

A daily visitor-use curve was determined for each site by averaging all counts for each interval. Total visitor hours

(i.e., use) for each interval were then calculated using the formula:

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

where I is the time interval and t_i is the mean number of visitors counted in interval i .

To obtain a daily total for visitor hours, instantaneous counts were expanded by the proportion of daily use represented by each time interval. On days when more than one count was made, the mean number of visitor hours was used. Total number of visitors for each day was obtained by dividing visitor hours by the mean length of stay. Season totals were calculated by summing daily totals and then expanding by the proportion of days actually counted.

Results

At Fishing Bridge in 1990, the total number of visitors and total visitor hours reached record highs of 383,492 people and 66,728 h (Table 22). Visitors stayed at the bridge an average of 10.4 min ($N = 2,029$). This is the third-consecutive year that nonangler use at Fishing Bridge has reached record levels. Compared to 1989, the number of visitors at this site in 1990 increased 43% and visitor hours increased 46% in 1990.

An estimated 128,494 people spent 19,403 viewing hours at LeHardy Rapids in 1990 (Table 22). Mean length of stay at the rapids was 9.1 min ($N = 1,695$). The number of visitors in 1990 increased 7% compared to 1989, but total visitor use in 1990 decreased 9% from 1989. The drop in visitor use in 1990 reflects the decline in the mean length of stay between 1989 and 1990.

Discussion

Creel census data for the last 8 years (1965 to 1972) of angling on Fishing Bridge averaged 33,275 anglers/year and 36,714 angler hours/year (Table 23). The 1990 nonconsumptive use figures represent greater total hours on Fishing Bridge, and the total number of people (anglers and nonanglers) enjoying this area has increased considerably since the bridge was closed to fishing.

The number of visitors at Fishing Bridge in 1990 was the highest yet reported. Although the reasons for this increase are not known, a concomitant increase in total Park recreational visitation may have influenced the observed change. Visitor use at LeHardy Rapids remains above the mean prior to the placement of signs in 1985 (Table 22).

Jones et al. (1985) suggested that the boardwalk, completed late in 1984, might attract more visitors to LeHardy Rapids in future years. The boardwalk has undoubtedly contributed to current levels of visitation in the area; however, the addition

TABLE 22.-Nonconsumptive use of the aquatic resource, 1978 to 1990.

Year	Number of counts	Total number of visitors	Mean minutes per person	Total visitor hours
Fishing Bridge				
1978	582	132,966	10.8	23,934
1979	670	170,383		30,669
1980	551	130,305	10.7	23,238
1981	1,015	173,679	12.3	35,604
1982	425	167,333	9.7	26,941
1983	421	208,672		33,580
1984	430	178,009	10.7	31,686
1985	253	158,360	12.8	33,915
1986	587	188,674	9.2	28,773
1987	206	163,570	11.4	31,187
1988	683	255,928		47,773
1989	585	268,602	10.2	45,707
1990	453	383,492	10.4	66,728
LeHardy Rapids				
1978	222	17,287	8.4	2,420
1979	206	17,627		2,798
1980	94	45,610	5.3	4,029
1981	155	12,056	16.2	3,255
1982	154	26,768	8.1	3,600
1983	93	12,245		1,647
1984	131	26,768	8.1	3,600
1985	212	185,467	5.1	15,827
1986	286	217,371	8.2	29,454
1987	140	105,907	9.8	17,369
1988	260	133,487	10.7	23,805
1989	232	119,756	10.7	21,297
1990	188	128,494	9.1	19,403

TABLE 23.-Fishing Bridge creel census data, 1965 to 1972.

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

of the location sign may have had a greater effect on visitor use. Although access was improved by the boardwalk, the rapids are difficult to see from passing cars. The sign identifies the location as an area of interest to the Park visitor.

Comparing nonangler use at these two locations to angler use of Park fisheries, more people use Fishing Bridge than any single fishery in the Park (Tables 3 and 22). LeHardy Rapids ranks seventh and Fishing Bridge fourth when compared, in terms of total hours, to angler effort among Park fisheries.

Estimates of nonangler use during the past 13 years emphasize the value of these viewing sites and the demand for this type of visitor activity. Observing the behavior of fish in their natural habitat is an important educational experience for all visitors to Yellowstone National Park.

OTHER PROJECT ACTIVITIES

Reese Creek: An agreement has been reached with Church Universal and Triumphant over water rights in Reese Creek and project personnel have been involved with designing new control structures for measuring and controlling irrigation diversions. The diversions will be screened and fish passage will be provided over the diversions. Project personnel will be involved with the installation and operation of these structures.

Mol Heron Creek oil spill: Project personnel assisted the State of Montana and Environmental Protection Agency in monitoring the oil spill caused by the rupture of several fuel storage tanks at the Church Universal and Triumphant's bomb shelter site on Mol Heron Creek. The State of Montana has monitored the clean-up and it will continue for at least 1 year.

Genetics studies: Project personnel collected cutthroat trout from three locations in the Park (Chipmunk, Reese, and Grayling creeks) for electrophoresis analysis and a check of population purity.

Environmental education: Contact was made with the Science Department of the Gardiner High School concerning field projects for high school science classes. Project personnel made a presentation on project activities and conducted a field trip to demonstrate invertebrate collection on two streams in the Park. The Gardiner High School has applied for a grant to support a aquatic monitoring study on the Gardner River in the Park. Project personnel would assist in developing the study and act as technical advisors. If the school is successful in obtaining the grant, the study will begin in the fall of 1991.

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

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

The project provided laboratory space, boats, and 10 man-days of assistance to J.V. Klump of the University of Wisconsin-Milwaukee Center for Great Lakes Studies. This research, "ROV studies of Unique Aquatic Environments in Yellowstone National Park," was conducted with a Deep Sea Mini-Rover MK1 under contract with Eastern Oceanics, Inc. The Rover is designed to dive to depths of 152 m and collect several types of data, including video pictures.

The upper reach of Soda Butte Creek from Cooke City, MT, downstream to the northeast corner of Yellowstone National Park is polluted by heavy metals (particularly iron) that are leached into the stream from the tailings of a long-abandoned gold mine. Since 1984, the project has collected macroinvertebrate samples from five locations in Soda Butte Creek that represent a high-to-low pollution gradient. Samples are collected quarterly and sent to Dr. Fred Mangum of the U.S. Forest Service for analysis. Dr. Mangum has prepared two reports discussing impacts of the pollution on aquatic macroinvertebrates in Soda Butte Creek.

The project provided equipment and 10 man-days of assistance to the Bear Creek Council for collecting macroinvertebrate samples from the Yellowstone River and Bear Creek. The study is designed to monitor water quality in these streams above and below the Mineral Hill gold mine at Jardine, MT, and the town of Gardiner, MT.

The project provided Fred Binkowski of the University of Wisconsin-Milwaukee Center for Great Lakes Studies with laboratory space, boats, equipment, and 6 man-days of assistance. Mr. Binkowski is studying the life history of lake trout in Lewis Lake.

The project provided Dr. Wayne Minshall, Idaho State University, with 10 man-days of assistance in collecting post-fire data on 22 study sites to monitor the effects of the 1988 fires on the aquatic system of Yellowstone National Park. These collections were made in April and August.

Office space and vehicles were provided to the National Park Service Research Division in support of various studies in the Park.

Project personnel provided 20 man-days of assistance to the Western Division and Montana Chapter of the American Fisheries Society. The effort included editing papers and organizing sessions at meetings.

U.S. Fish and Wildlife Service personnel spent approximately 15 man-days coordinating the project's sedimentation study on the Yellowstone River. David Rosgen, a wildland hydrology

consultant, has been contracted with to do a river classification study on the Lamar River system. The field work is being done by the Park hydrologist staff under the U.S. Fish and Wildlife Service project supervisor. The study is funded by the National Park Service and several other state and federal agencies, plus Trout Unlimited in Livingston, MT.

The project provided housing, equipment, and 20 days of personnel assistance to Cathy W. Whitlock, Assistant Curator of Paleobotany at Carnegie Institute, Museum of Natural History, Pittsburgh, PA. Dr. Whitlock is looking at post-glacial fire frequency and its relation to long-term vegetational and climatic changes in Yellowstone National Park. She is examining core samples taken from lakes in the Park and studying the pollen records.

Project personnel provided Dr. Jim Brass of the National Aeronautics and Space Administration with equipment and 40 man-days of assistance in collecting water samples from Yellowstone and Lewis lakes. Dr. Brass was coordinating water samples with high altitude photography from a satellite passing over the lakes. The photographs were used to track nutrient flow from burn areas into the aquatic systems.

The project provided a boat and 2 man-days of assistance to Dr. Edward Theriot of the Academy of Natural Sciences, in support of his study of the diatoms in Yellowstone National Park.

Project personnel assisted U.S. Geological Survey personnel with equipment and 2 man-days of assistance in installing a streamflow gage under the Yellowstone River bridge at Tower Junction, Yellowstone National Park.

The project is cooperating in a Master's study on the Yellowstone River with Dr. Bob White and student Barbara M. Kelly. The study is titled "The potential effects of angler wading on cutthroat trout embryo and pre-emergent fry in the upper Yellowstone River." One year of the 2-year study has been completed.

Publications:

Fishery and aquatic management program in Yellowstone National Park, technical report for calendar year 1989.

Volunteer program: Volunteer programs of the U.S. Fish and Wildlife Service, National Park Service, and Student Conservation Association have been utilized for many years. The programs provide a needed manpower source for the project and a valuable training experience for the volunteer. In 1990, the project utilized 158 man-days of volunteer work and 170 man-days of Student Conservation Association work. These volunteers were involved in all phases of project work including angler interviews, gillnetting, electrofishing, backcountry stream and

lake surveys,, and a variety of clerical and maintenance jobs. The effort and dedication of these volunteers is very important to the Yellowstone Fishery Assistance program.

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

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

The following talks and presentations were given:

Presentations were made to Gardiner Fly Fishers, Gardiner, MT; Butte Trout Unlimited, Butte, MT; and to the Federation of Fly Fishers National Conclave in Eugene, OR.

Presentations were given to the student forum and student forum banquet at Montana State University, Bozeman, MT.

Presentations were made to the National Meeting of Public Affairs Offices of the U.S. Fish and Wildlife Service at Jackson, WY, and the U.S. Fish and Wildlife Service Project Leader's meeting in Denver, CO, and the U.S. Fish and Wildlife Service Research Laboratory in Ann Arbor, MI.

Two presentations and field trips were given to science classes at the Gardiner High School, Gardiner, MT.

Presentations were made at the National Park Service resource management and naturalist trainings, outfitters meeting, and concessions meeting in Yellowstone National Park.

Two presentations were given to classes at the Carnegie Institute in Pennsylvania.

Numerous newspaper, radio, television, and personal interviews were made to the press in 1990.

ACKNOWLEDGMENTS

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

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

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

During the 1990 field season, Scott Relyea and Mike Kiehn (Biological Aides) and John Byrne, Paul Doenier, and Peter Browne (Student Conservation Association) were the core of our summer field crew. Barb Kelly, a M.S. student in Fish and Wildlife Management at Montana State University, began a 2-year study of the Yellowstone cutthroat trout in the Yellowstone River and assisted with various other summer field projects. Sheral Patel (Volunteer in Parks program [VIP]) participated in several early season projects before moving on to her summer job at the Woods Hole Oceanographic Institute, and Simon Lewis (visiting resource manager from Argentina) spent several days assisting with the Clear Creek fish trap operation. Mark Delaray (Montana State University), Christy Stalder (National Park Service), and Imes Vaughn (VIP) helped out during spring electrofishing; Imes enjoyed the work so much that he returned to volunteer for the entire month of September. Jack Brooks and Wade Miller were here once again for fall gillnetting, and special additions for fall gillnetting included Janet Lewis (National Park Service) and Laurie Owens (Lake Hospital staff). Lewis Lake lake trout spawning was expedited by U.S. Fish and Wildlife Service personnel from Jackson National Fish Hatchery, Bozeman Fish Technology Center, and Ft. Morgan Fish Health Center. Marion Jones helped bring our new boat, the SeaArk, back from Arkansas, and volunteered her time whenever possible during the summer field season.

The National Park Service also provided manpower and assistance during the 1990 field season. District Rangers Steve Frye, Joe Evans, John Lounsbury, and Jerry Mernin and their staffs provided logistical support. Resource Management Coordinators Craig McClure, Jim Sweaney, Roger Andrascik, and Tom Olliff provided logistical support, ensured that the exit-gate surveys of anglers were completed on schedule, and participated in several field projects.

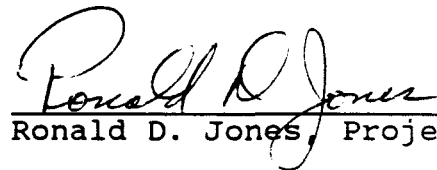
During the winter of 1990-1991, Kim West was responsible for data entry and analysis, computerizing VAR cards, and typing this report; we could not have completed the report without her help. George McKay (National Park Service) continued to assist us with

applications of the Geographic Information Service to fisheries-related data. Dave LaConte (VIP) compiled a computerized list of all known aquatic macroinvertebrates that have been collected from Yellowstone National Park streams and was involved in several other office projects before moving on to a job with the National Park Service Research office here in Yellowstone. Dr. George Roemhild (professor emeritus at Montana State University) graciously lent us his Yellowstone National Park aquatic macroinvertebrate files for use in compiling our master list, and he and Dr. Fred Mangum (U.S. Forest Service) analyzed aquatic macroinvertebrate samples collected in 1990.

Bob Gresswell (Fishery Biologist) headed "back to school" in the fall of 1990 to begin a Ph.D. program. For the next several years, Bob will attend Oregon State University in the winter and work in Yellowstone during the summer field season.

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

This report was submitted by:


Ronald D. Jones, Project Leader

Reviewed by:


Larry Visscher, Associate Manager - Fisheries
Fisheries and Federal Aid, Denver Regional Office

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