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Ronald D. Jones, Project Leader

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Authors (alphabetical):

Daniel G. Carty, Fishery Biologist: Yellowstone Lake -
Largemouth gillnetting; Cutthroat trout spawning
activity in tributaries of Yellowstone Lake.

Robert E. Gresswell, Fishery Biologist: Parkwide
fishery management evaluation; Yellowstone Lake -
Creel survey, Clear Creek cutthroat trout spawning
run, conclusion; Arnica Creek restoration program;
Lake survey program; Lake trout spawn-taking
operation; Nonconsumptive use of aquatic areas;
Technical reports; and general subjects.

Crystal J. Hudson, Biological Technician: Yellowstone
River - LeHardy Rapids; Stream survey program -
Cursory surveys.

Ronald D. Jones, Project Leader: Introduction; Other
project activities.

Leo D. Lentsch, Fishery Biologist: co-authored Sonyew
revised; Stream survey program - Ecological
performance surveys; Technical reports.

Daniel L. Mahony, Biological Aid: co-authored Sonyew
revised.

Cover photo: Fish and Wildlife egg-collection boats.

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INTRODUCTION

Yellowstone National Park is located in the northwest corner of the State of Wyoming and small adjacent areas of the states of Montana and Idaho. It occupies an area of almost 9,000,000 ha (3,500 sq. mi) astride the continental divide and is bordered by mountains on the north and east sides which rise to 3400 m (11,000 ft). The Park is characterized by several broad, forested volcanic plateaus, containing the world's largest caldera and thousands of thermal features.

Slightly over five percent of the landmass of Yellowstone Park is covered with water. Specifically, over 150 lakes comprise an area of approximately 43,000 ha (107,000 acres). Yellowstone, Shoshone, Lewis and Heart Lakes make up 94% of the total lake area. The elevations of park lakes range from 1,700 to 3,000 m (5,500 to 9,700 ft) above sea level. Additionally, over 220 named and hundreds of unnamed streams make up over 4300 km (2,650 miles) or approximately 2,000 ha (5,000 acres) of running water.

In 1872, the United States Congress established Yellowstone National Park "... for the benefit and enjoyment of the people and for the preservation, from injury and spoilation of all timber, mineral deposits, natural curiosities or wonders..., and their retention in their natural condition." From this beginning, federal legislation and policies have evolved to prohibit hunting of all birds and mammals and to regulate fishing. The park is currently managed for the perpetuation of natural processes within the Yellowstone ecosystem, including interactions between and among native fauna, flora, geology, and scenic landscapes (Houston 1971).

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

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

1. Manage aquatic systems as an integral part of the park ecosystem.
2. Preserve and restore native species and aquatic habitats.

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

Protective policies of the National Park Service that have prevented significant degradation of the aquatic habitat have also restricted the use of maintenance stocking in park waters. Special regulations have become the primary means to accomplish park fishery objectives. Regulations used to protect the fishery have included manipulating season dates, bait and terminal gear restrictions, and the use of creel and size limits (including catch and release). Additionally, some waters have been closed to angling in order to protect threatened species, nesting birds, or provide scenic vistas with undisturbed wildlife and fish.

Yellowstone has one fish species (Montana grayling) and over a dozen waters restricted to catch and release fishing. Several other waters, including Yellowstone Lake, require the release of some fish as a result of maximum or minimum size limits. The implementation of these regulations has improved the angling experience despite substantial fishing pressure, and population structure more closely resembles historic levels.

In 1985, approximately 167,800 non-fee permits were issued to potential park anglers. Permittees came from all 50 states, all Canadian provinces, and several other foreign countries (Table 1). The largest single group resided in the west coast states (California, Oregon, and Washington); however, an almost equal number were from local states of Montana, Wyoming, Idaho, and Utah. On an individual state basis, the number of permittees from each of the local states was exceeded only by California and Colorado.

The 1980 National Survey of Fishing, Hunting, and Wildlife Associated Recreation (USDI 1982) indicated that Yellowstone Park supports approximately 1.3% of the nation's trout anglers. Of 120 lakes and streams which are annually utilized by park anglers, 30 support most of the fishing pressure. The quality of at least six of these fisheries has gained national recognition, and several articles, usually complimentary, are published about Yellowstone fishing each year.

Table 1. Residency of anglers¹⁾ interviewed when leaving Yellowstone Park, 1976 and 1978-1985.

States by geographical groups	Number interviewed at entrance stations									Percentage of total interviewed								
	1976	1978	1979	1980	1981	1982	1983	1984	1985	1976	1978	1979	1980	1981	1982	1983	1984	1985
"Local states"																		
Idaho	37	47	61	23	71	55	86	52	50	2.79	3.91	4.96	3.38	4.64	4.42	5.09	3.64	4.69
Montana	68	46	62	49	79	79	78	70	57	5.14	3.83	5.04	7.20	5.17	6.35	4.62	4.90	5.35
Utah	71	97	112	50	141	103	128	131	107	5.36	8.07	9.10	7.34	9.23	8.28	7.58	9.17	10.04
Wyoming	67	56	58	23	89	62	100	63	63	5.06	4.82	4.71	3.38	5.82	4.96	5.92	4.41	5.91
Total	243	248	293	145	380	299	392	316	277	18.35	25.48	23.80	21.29	24.87	24.04	23.22	22.11	25.96
West coast states																		
California	225	158	222	102	228	198	270	225	165	16.99	13.15	18.03	14.98	14.92	15.92	16.00	15.75	15.48
Oregon	24	34	24	23	40	36	56	50	24	1.81	2.83	1.95	3.38	2.62	2.89	3.32	3.50	2.25
Washington	56	49	48	21	54	64	69	73	34	4.23	4.07	3.90	3.08	3.53	5.14	4.09	5.11	3.19
Total	305	241	294	146	322	298	395	348	223	23.03	20.05	23.88	21.44	21.07	23.95	23.40	24.35	20.92
Southwest states																		
Arizona	18	28	26	22	41	23	42	28	20	1.36	2.33	2.11	3.23	2.68	1.85	2.49	1.96	1.88
Colorado	65	65	80	47	118	111	163	130	89	4.91	5.41	6.50	6.90	7.72	8.92	9.66	9.10	8.35
Nevada	7	4	10	4	12	7	14	15	11	0.53	0.33	0.81	0.59	0.79	0.56	0.83	1.05	1.03
New Mexico	9	8	9	6	16	18	15	21	10	0.68	0.67	0.73	0.68	1.05	1.45	0.89	1.47	0.94
Total	99	105	125	79	187	159	234	194	130	7.48	8.74	10.15	11.60	12.23	12.78	13.66	13.58	12.20
Central plains states																		
Iowa	15	25	17	13	28	21	33	21	14	1.13	2.08	1.38	1.90	1.83	1.69	1.95	1.47	1.31
Kansas	14	12	8	7	26	14	21	21	17	1.06	1.00	0.65	1.03	1.70	1.13	1.24	1.47	1.59
Nebraska	18	15	21	10	22	19	19	16	17	1.36	1.24	1.71	1.47	1.44	1.53	1.13	0.70	1.59
North Dakota	10	12	2	8	10	8	20	7	5	0.76	1.00	0.16	1.17	0.65	0.64	1.16	0.49	0.47
Oklahoma	14	7	10	11	28	18	20	23	13	1.06	0.58	0.81	1.62	1.83	1.45	1.18	1.61	1.22
South Dakota	9	14	8	5	5	11	12	4	11	0.68	1.16	0.65	0.73	0.32	0.88	0.71	0.28	1.03
Texas	42	52	43	30	57	46	68	59	64	3.17	4.32	3.49	4.41	3.73	3.70	4.03	4.13	6.00
Total	122	137	109	84	176	137	193	145	141	9.22	11.38	8.89	12.33	11.52	11.01	11.43	10.15	13.23
North central states																		
Illinois	70	48	40	26	56	32	47	53	25	5.29	4.00	3.25	3.82	3.66	2.57	2.78	3.71	2.35
Indiana	20	23	11	3	10	7	15	20	12	1.51	1.91	0.89	0.84	0.65	0.56	0.89	1.40	1.13
Michigan	58	61	47	13	42	27	39	33	25	4.38	5.07	3.82	1.91	2.75	2.17	2.31	2.31	2.35
Minnesota	64	44	31	17	44	39	63	32	29	4.83	3.66	2.52	2.50	2.88	3.14	3.73	2.24	2.72
Ohio	49	40	22	19	32	32	33	32	21	3.70	3.33	1.79	2.79	2.09	2.57	1.95	2.24	1.97
Wisconsin	40	37	31	23	44	25	35	35	26	3.02	3.08	2.52	3.38	2.88	2.00	2.47	2.45	2.44
Total	301	253	182	101	228	162	232	205	138	22.73	21.05	14.78	14.83	14.92	13.62	13.74	14.35	12.95
Southern states																		
Alabama	3	3	1	2	2	6	3	4	2	0.23	0.24	0.08	0.29	0.13	0.48	0.18	0.28	0.19
Arkansas	1	4	6	3	5	4	5	7	6	0.08	0.33	0.49	0.44	0.33	0.32	0.30	0.49	0.56
Florida	22	14	20	12	23	13	42	32	20	1.66	1.16	1.62	1.76	1.50	1.05	2.49	2.24	1.88
Georgia	7	10	7	5	7	7	10	9	5	0.53	0.83	0.57	0.73	0.46	0.56	0.59	0.63	0.47
Kentucky	7	2	4	3	7	4	6	4	4	0.53	0.16	0.32	0.44	0.46	0.32	0.36	0.28	0.38
Louisiana	5	4	5	1	6	4	4	5	4	0.38	0.33	0.41	0.15	0.39	0.32	0.24	0.35	0.38
Mississippi	5	8	3	3	5	7	5	3	7	0.38	0.66	0.24	0.44	0.33	0.56	0.30	0.21	0.66
Missouri	19	19	23	12	11	13	24	26	23	1.44	1.58	1.87	1.76	0.72	1.05	1.42	1.82	2.16
North Carolina	9	9	6	2	3	9	3	3	4	0.68	0.79	0.49	0.29	0.20	0.72	0.18	0.21	0.38
South Carolina	5	4	3	1	3	2	2	2	1	0.38	0.33	0.24	0.15	0.20	0.16	0.12	0.14	0.09
Tennessee	7	1	4	0	4	7	11	4	3	0.53	0.08	0.32	0.00	0.26	0.32	0.65	0.28	0.26
Virginia	11	4	7	6	10	9	12	10	8	0.83	0.33	0.57	0.88	0.65	0.72	0.71	0.70	0.75
Washington, D.C.	4	0	0	0	0	0	0	0	0	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
West Virginia	4	4	1	2	3	3	1	4	1	0.30	0.33	0.08	0.29	0.20	0.24	0.06	0.28	0.09
Total	106	86	90	52	89	85	128	113	88	8.03	7.15	7.31	7.64	5.82	6.63	7.58	7.91	8.26
Northeast states																		
Connecticut	10	11	13	7	3	7	8	10	2	0.76	0.95	1.06	1.03	0.20	0.56	0.47	0.70	0.19
Delaware	1	0	0	1	1	3	0	0	1	0.08	0.00	0.00	0.15	0.07	0.24	0.00	0.00	0.09
Maine	2	1	0	1	4	2	1	1	3	0.15	0.08	0.00	0.15	0.26	0.16	0.06	0.07	0.26
Maryland	14	9	9	7	8	7	4	5	2	1.06	0.74	0.73	1.03	0.52	0.56	0.24	0.35	0.19
Massachusetts	10	6	9	7	8	4	6	9	5	0.76	0.49	0.73	1.03	0.52	0.32	0.36	0.63	0.47
New Hampshire	3	2	2	2	2	2	0	2	1	0.23	0.16	0.16	0.29	0.13	0.16	0.00	0.14	0.09
New Jersey	14	12	17	10	17	12	18	12	14	1.06	1.00	1.38	1.47	1.11	0.96	1.07	0.84	1.31
New York	28	27	31	12	27	11	17	15	14	2.11	2.24	2.51	1.76	1.77	0.88	1.01	1.05	1.31
Pennsylvania	26	41	25	10	34	29	33	29	20	1.96	3.41	2.03	1.47	2.23	2.33	1.95	2.03	1.88
Rhode Island	1	0	1	0	3	1	1	0	0	0.08	0.00	0.08	0.00	0.20	0.68	0.06	0.00	0.00
Vermont	1	1	3	0	1	2	2	3	2	0.08	0.08	0.24	0.00	0.07	0.16	0.12	0.21	0.19
Total	110	110	110	57	108	80	91	86	64	8.33	9.15	8.94	8.37	7.07	6.43	5.39	6.02	6.00
Isolated states																		
Alaska	3	1	1	1	2	1	0	2	0	0.23	0.08	0.08	0.15	0.13	0.08	0.06	0.14	0.06
Hawaii	2	1	1	2	0	2	0	2	1	0.15	0.08	0.08	0.29	0.00	0.16	0.00	0.14	0.09
Total	5	2	2	3	2	3	0	4	1	0.38	0.16	0.16	0.44	0.13	0.24	0.06	0.28	0.09
Canada	33	19	12	11	31	16	22	17	3	2.49	1.58	0.97	1.62	2.03	1.26	1.30	1.19	0.28
Foreign countries	0	0	14	3	5	5	1	1	1	0.00	0.00	1.14	0.44	0.33	0.40	0.06	0.07	0.09
GRAND TOTAL w/o Canada	1291	1182	1205	667	1492	1223	1685	1411	1062									
GRAND TOTAL w/ Canada	1324	1201	1217	678	1523	1239	1687	1428	1065									
GRAND TOTAL w/ Canada and foreign countries	1324	1201	1231	681	1528	1244	1688	1429	1066									

1) Persons who obtained fishing permits.

In order to manage the diverse and complex aquatic resources of Yellowstone National Park, this project conducts annual investigations which provide information necessary to evaluate the fishery management program and monitor its adherence to park objectives. The following report details results of our efforts during 1985.

SONYEW REVISED: RENUMBERING YELLOWSTONE WATERS

In 1985, a revised system for numbering streams and lakes in Yellowstone National Park was developed. This system not only contains a precise geographical reference to the particular water being discussed, but it also allows for the addition of new numbers without changing the entire numbering system. By using maps, historical records, and information collected on surveys, new numbers were assigned to all previously numbered park waters. In addition, procedures were outlined for the assignment of numbers to unnumbered waters.

The first attempt at numbering all of Yellowstone waters (SONYEW) was developed in 1975 (Varley et al. 1976) to avoid confusion of unnamed waters and facilitate data compilation. In the subsequent decade, several problems and inadequacies of the SONYEW system became apparent. Although the four digit system was ordered so that a particular set of numbers related to a particular drainage basin, the numbers contained no specific reference to the location of streams and lakes. Recent surveys revealed many unreported streams. These were customarily assigned the next consecutive SONYEW number. In several instances, consecutive SONYEW numbers were already assigned and the next available number had to be used. This led to confusion in the relationship between SONYEW number and proximity of waters. One final problem with the old SONYEW system was a lack of consistency in the assignment of numbers. Some tributary streams were numbered upstream from the mainstem confluence, while others were numbered downstream.

ASSIGNMENT OF NUMBERS

The revised system for numbering streams and lakes in Yellowstone National Park was based on Shera's (1981) hierarchical stream coding system for British Columbia waters. The new numbering system is based on a 15-digit number which is subdivided into 9 sections (0 000 00 00 00 00 00 0 00). From 4 to 15 digits are required to identify streams or stream segments and 6 digits are required to identify lakes. Only the necessary numbers are reported and a dash replaces the unused digits. Under this procedure, 2017- identifies the Gibbon River, 2017-05 denotes the 5th water chemistry site on the Gibbon River, and 2017-60 represents Wolf Lake. Streams higher in the hierarchical order require more numbers, for example, Pebble Creek is reported as 10331713-.

A large percentage of park streams remain unnumbered. These streams will be given a number after United States Geological Survey (USGS) 15-minute quadrangle maps have been ground-truthed through surveys. Differences in these maps and actual stream basin morphometry can be significant, and assignment of numbers prior to ground-truthing could cause problems.

Digit 1

The first digit (X 000 00 00 00 00 0 00) identifies the major drainage basin in which the particular lake or stream is contained. In order of decreasing size, the major drainage basins were numbered as follows:

- 1 - Yellowstone River
- 2 - Madison River
- 3 - Snake River
- 4 - Falls River
- 5 - Gallatin River
- 6 - Shoshone River

The assigned number for the mainstem river in a drainage was given the drainage number followed by zeros, e.g., the Madison River was designated 2000--.

Digits 2-4

The next three digits (0 XXX 00 00 00 00 0 00) of the numerical sequence represent tributary drainage basins to the mainstem river. Six rules were established for the assignment of these digits.

Numbering of Drainage Basins

Assignment of numbers generally proceeded sequentially upstream from the park boundary. The first tributary was assigned 001, second numbered 002, and so forth. The number relates to the location of the tributary, not its size. Drainages with defined channels less than 100 m long were considered seeps and unnumbered. All other tributaries, perennial, intermittent, named, or unnamed were assigned a number.

Confluences Downstream of Park Boundary

In several instances, a tributary stream exited the park prior to its confluence with the major river. In this case, the tributary was still numbered sequentially based on the location of its confluence with the river; e.g., Mol Heron Creek was numbered as tributary 001 since its confluence with the Yellowstone River was furthest downstream of any park water. Likewise, Duck Creek was considered the second tributary (002) to the Madison River, even though Duck Creek flows into Hebgen Reservoir.

One exception to this numbering procedure occurred. Tributaries along the southwest park boundary were considered to flow directly into the Falls River and numbered sequentially beginning (001) with tributaries at the Continental Divide and proceeding south. It was assumed that streams with the furthest northern

location would have the furthest downstream confluence. While several of these tributaries probably do not have a direct confluence with the Falls River, assignment of numbers in this manner provided consistency in the numbering system.

Tributaries to Lakes

A special situation also occurred while numbering tributary streams entering lakes. For purposes of the revised numbering system, these tributaries were considered tributaries of the stream on which the lake was located. Tributaries to Yellowstone Lake were considered as Yellowstone River tributaries since the lake occurs on the mainstem of the river, but tributaries were not numbered sequentially from downstream to upstream locations. To eliminate the possible confusion of going back and forth between both sides of the lake looking for tributaries, these streams were numbered consecutively around the lake in a clockwise direction beginning at the outlet; and the tributary numbering sequence continued upstream from the mainstem inlet.

Main Channel Determination

In many streams, headwater tributaries are unnamed. For the purpose of this numbering system, the longest fork was considered to be the mainstem. Any other tributaries in the headwater area were assigned numbers that indicate they are tributaries to that mainstem stream.

Named Forks

Some named streams in the park originate at the confluence of two or more named tributaries. In this situation, the mainstem stream was assumed to start at the junction of the feeder streams and the tributary streams were assigned subdrainage numbers. This was the case with the Madison River (2000-). The Gibbon and Firehole Rivers were assigned numbers 2017- and 2018-, respectively.

Lakes Without Outlets

Some lakes in the park have no outlet stream. When this situation arose, the lake was treated as a tributary of the nearest stream, and its drainage basin was assigned the next sequential number. For example, three lakes near Snake River Hot Springs did not have outlets. These lakes were assumed to be in the same drainage and were assigned numbers (3008-51, 3008-52, and 3008-53) that identified them as being contained in a tributary drainage (3008-) of the Snake River.

Digits 5-13

Digits 5-13 (0 000 XX XX XX XX X 00) were reserved for tributary streams. Assignment of these numbers follows the same rules for designating tributaries of the six major rivers. An unnamed stream flows into Cache Creek from the east at Cache Creek Cabin. The number of this stream is 10332220-. The first digit (1) indicates Yellowstone River. The next three digits (033) identify the tributary to the Yellowstone River, Lamar River. The next two digits (22) identify the tributary to the Lamar River, Cache Creek. Finally, the following two digits (20) indicate the twentieth tributary to Cache Creek.

Digits 14-15

Streams

The last 2 digits (0 000 00 00 00 00 0 XX) of the 15-digit sequence refer to segments of the particular stream under investigation. Water chemistry sites were assigned numbers 01-20. Site numbers were based on the date of the sample. Oldest sites were assigned the smallest number. Therefore, the first water chemistry site established on a stream was given number 01. Habitat inventory reaches and/or Volunteer Angler Report (VAR) subsections were numbered sequentially upstream from the confluence starting with -21 and -36, respectively.

Lakes, Ponds, and Reservoirs

Lakes are numbered sequentially upstream throughout the mainstem tributary drainage basin beginning with 51. For example, Ice Lake and Wolf Lake were assigned numbers 2017-59 and 2017-60. The number indicates the ninth (59) and tenth (60) lakes on the Gibbon River (2017-). Grebe Lake is 2017-62. The unnamed lake at the headwaters of the tributary between Wolf Lake and Grebe Lake receives 2017-61.

Several unusual situations became apparent in the numbering of lakes and ponds. Clusters of lakes sometimes have no apparent upstream or downstream orientation with respect to the nearest major tributary stream. In this case, the lakes were numbered clockwise, beginning with the lake nearest to a tributary stream. Crater Lakes at the Twin Buttes in the Lower Geyser Basin were numbered in this manner.

Due to the wide variety of data collected on Yellowstone Lake, it was necessary to assign numbers in a different method than other lakes. Number 1000-51 refers to the lake in general terms. Since Yellowstone Lake is the only mainstem lake on the Yellowstone River, the remaining digits (52-99) were available to subdivide the lake for purposes of gillnetting, VAR, and water

chemistry data. Data from water chemistry analysis were recorded under numbers 1000-52 through 1000-86. One number was assigned to each of the lake's seven subsections. This method of numbering large lakes can be applied to other major bodies of water in the park which the investigator may wish to subdivide, e.g., Lewis, Shoshone, or Heart Lakes.

DISCUSSION

In addition to providing an accurate geographical location of streams and having the capacity to accumulate additional data, the revised system contains other advantages. Examination of the reference number of a stream high in the watershed reveals a quick and accurate estimate of the number of tributaries downstream of that point. Relative major and minor watershed sizes can also be determined. the number for the Little Lamar River is 103347-; thus, the investigator knows that there are 46 tributaries to the Lamar River (the 33rd tributary of Yellowstone River) downstream from the Little Lamar River.

The same type of estimate can be used for lakes and ponds. If the investigator desires to know how many lakes and ponds are cataloged in the Firehole drainage, he merely refers to the number of the uppermost lake, in this case, Madison Lake, 2018-81. Since lakes are numbered sequentially from 51, this lets the investigator know that there are 331 lakes and ponds in this particular drainage.

If he desires to know the total number of tributaries for a particular river, reference to the uppermost tributary will reveal this information. Falcon Creek is the uppermost tributary to Yellowstone River. The revised number 1224- tells the investigator that there are 224 tributaries to Yellowstone River and Yellowstone Lake that are contained wholly or partially within park boundaries.

PARKWIDE ANGLING

Although park recreational visitation (2.2 million visitors) increased slightly (0.2% more than 1984) in 1985, issuance of non-fee fishing permits decreased 6.1% (Table 2). Approximately 166,700 permits were issued; however, gate survey data indicated that 29.8% of the permit holders did not fish. After adjustments were made for nonanglers, the number of park anglers was estimated at 123,800. This represents a 9.0% decrease in the number of anglers since 1984.

The exit gate survey indicated that anglers spent an average of 1.89 days fishing in the park and fished approximately 1.19 different waters/day. Computations utilizing these data (Jones et al. 1977) yielded estimates of total use (279,200 angler days) and effort (688,500 angler hours). Both figures are among the lowest estimates since 1976 (Table 2).

The Volunteer Angler Report (VAR) system estimated that 629,700 fish were landed and 69,800 creeled at a rate of 0.91 and 0.10 fish/hour, respectively (Table 3). Of the fish landed, 91% were released and 8.8% creeled. The number of fish landed per average angler trip (2.47 hours) was 2.26, and the number creeled was 0.25 (Table 4).

Species composition was indicated by anglers for 42,172 landed fish; 70.5% were reported as cutthroat trout, followed by rainbow trout (10.3%), brown trout (8.5%), brook trout (6.2%), and lake trout (1.8%). Small numbers of grayling, mountain whitefish, and unidentified fish were also caught.

Average size of landed fish (337 mm or 13.3 in) decreased slightly from 1984. Of 41,461 fish, about 68% were greater than 305 mm (12 in), and 51% exceeded 356 mm (14 in). Average length of creeled fish was 314 mm (12.4 in). Lake trout were the largest fish landed (435 mm or 17.1 in) followed by cutthroat trout (361 mm or 14.2 in), unknown species (328 mm or 12.9 in), brown trout (311 mm or 12.2 in), whitefish (307 mm or 12.1 in), grayling (277 mm or 10.9 in), and rainbow trout (274 mm or 10.8 in).

Prior to 1985, positive bias in mean length was suspected in VAR parkwide estimates because 229 mm (9 in) represented the minimum size which could be reported. In order to improve the sensitivity and accuracy of the VAR system, three new length categories were initiated in 1985; minimum size was reduced to

Table 2. Estimates of park recreational visitation, fishing permits issued, total parkwide anglers, and total parkwide angler days, Yellowstone National Park, 1972-1985.

Year	Total Park Recreational Visitation	Park Fishing Permits Issued	Total Parkwide Anglers	Total Parkwide Angler Days	95% Confidence Limits
1972	2,246,827 --	----- --	----- --	----- --	----- --
1973	2,061,537 -8.2% ¹⁾	169,103 --	121,888 --	230,100 --	225,500- 234,700
1974	1,928,915 -6.4%	164,600 -2.7%	116,518 -4.4%	220,000 -4.4%	215,500- 224,300
1975	2,239,483 +13.9%	191,550 +16.4%	136,322 +17.0%	257,300 +17.0%	248,400- 266,300
1976	2,519,224 +12.5%	213,200 +11.3%	151,730 +9.7%	284,200 +10.5%	278,500- 289,900
1977	2,481,933 -1.5%	217,000 +1.8%	154,581 +1.9%	311,300 +9.5%	304,000- 318,500
1978	2,618,380 +5.5%	218,000 +0.5%	155,700 +0.7%	333,800 +7.2%	326,200- 341,300
1979	1,892,908 -27.7%	195,100 -10.5%	139,100 -10.7%	291,300 -12.7%	274,500- 308,200
1980	2,000,273 +5.7%	184,200 ²⁾ -5.6%	130,800 -6.0%	311,300 +6.9%	287,000 334,600
1981	2,521,831 +26.1%	172,300 -6.5%	160,000 +22.3%	383,400 +23.2%	363,400- 403,300
1982	2,368,897 -5.9%	205,000 +19.0%	152,000 -5.0%	332,500 -13.3%	314,700- 350,300
1983	2,347,242 -0.9%	166,800 -18.6%	120,500 -20.7%	275,900 -17.0%	261,800- 289,900
1984	2,222,027 -5.6%	176,800 +5.7%	135,000 +10.7%	329,200 +16.2%	305,400- 341,000
1985	2,226,159 +0.2%	166,700 -6.1%	123,800 -9.0%	279,000 -18.0%	260,800- 297,200

1) Percent change from previous year.

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

Table 3. Fisherman use, effort, success, and harvest for Yellowstone National Park, 1973-1985.

Year	Angler days	X length angler day	Total hours fished	Landing rate	Total fish landed	Creel rate	Total fish creeled	% of anglers satisfied with			Average length of landed fish (in.)	Mean expertise level (95% C.I.) ¹⁾
								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 ²⁾	291,300	2.49	725,300	1.01	731,100	0.15	107,300	73	67	68	13.6	1.86 (1.87-1.90)
1980	311,300	2.44	758,000	0.96	725,300	0.13	101,000	73	66	68	13.4	1.87 (1.86-1.88)
1981	383,400	2.41	923,000	0.93	844,700	0.12	110,800	73	65	66	13.4	1.88 (1.87-1.89)
1982	332,500	2.34	777,600	0.95	740,200	0.14	107,500	74	67	68	13.5	1.88 (1.86-1.89)
1983	275,900	2.36	652,100	0.95	622,400	0.11	71,600	76	69	68	13.6	1.89 (1.88-1.90)
1984	329,200	2.40	790,100	0.93	732,700	0.12	92,100	76	68	69	13.5	1.91 (1.89-1.92)
1985	279,000	2.47	688,500	0.92	629,700	0.10	69,800	76	68	71	13.3	1.90 (1.88-1.92)

1) Based on: 1.0 = inexperienced angler, 2.0 = experienced, 3.0 = expert. 95% confidence interval in parenthesis.

2) Revised from that reported in Jones et al 1980.

Table 4. Characteristics of satisfied and unsatisfied anglers, and the influence of the relative expertise of anglers to sportfishing success in Yellowstone National Park, 1985.

	Mean number days fishing	Mean number hours fished per day	Landing rate	Creel rate	Fish landed per angler day	Fish creeled per angler day	Average length fish landed (in)	Average expertise ¹⁾	Sample anglers (n)
Satisfied anglers		2.60	1.08	0.12	2.81	0.31	13.47	1.02	3,385
Unsatisfied anglers		2.30	0.50	0.06	1.15	0.14	11.29	1.86	1,331
sum or x	1.79	2.47	0.92	0.10	2.26	0.25	13.26	1.90	5,606 ²⁾
Inexperienced anglers	1.60	2.15	0.58	0.12	1.25	0.26	12.63	1.00	1,172
Experienced anglers	1.80	2.50	0.92	0.10	2.30	0.25	13.29	2.00	3,590
Expert anglers	1.84	2.78	1.41	0.10	3.91	0.28	13.35	3.00	647
sum or x	1.79	2.47	0.92	0.10	2.26	0.25	13.26	1.90	5,606 ²⁾

Satisfaction Matrix

	Satisfied Anglers			Unsatisfied Anglers		
	Overall satisfaction	Satisfaction with numbers landed	Satisfaction with sizes landed	Overall satisfaction	Satisfaction with numbers landed	Satisfaction with sizes landed
Landing Rate (Fish/hr)						
Inexperienced anglers	0.67	0.71	0.63	0.23	0.27	0.47
Experienced anglers	1.05	1.12	1.01	0.38	0.39	0.64
Expert anglers	1.56	1.63	1.46	0.69	0.60	1.23
Creel Rate (Fish/hr)						
Inexperienced anglers	0.14	0.15	0.13	0.03	0.05	0.08
Experienced anglers	0.12	0.12	0.11	0.05	0.05	0.08
Expert anglers	0.11	0.12	0.12	0.06	0.06	0.06
Fish Size (Inches)						
Inexperienced anglers	12.70	12.69	13.14	10.37	11.80	10.60
Experienced anglers	13.40	13.36	13.73	11.46	12.42	10.87
Expert anglers	13.55	13.46	13.94	10.75	11.97	10.97

1) Based on 1.0 = inexperienced angler; 2.0 experienced; 3.0 expert.

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

127 mm (5 in). Since the mean of all landed fish only declined 7 mm (0.3 in) from 1984 figures, it appears that overall effect of the change was not great. Mean length of brook trout, however, declined 23% (55 mm or 2.2 in), suggesting the added length categories have greatly improved the ability of the system to provide accurate statistics for a variety of species in widely differing habitats.

The percentage of anglers that reported satisfaction with their overall fishing experience was 76% in 1985. Satisfaction rates with numbers and sizes of fish landed were 68% and 71%, respectively (Table 4). Anglers indicating satisfaction with their fishing trip landed 2.8 fish, but unsatisfied anglers landed only 1.2 fish. Average length of fish landed was also higher for satisfied anglers (342 mm or 13.5 in) than for unsatisfied anglers (287 mm or 11.3 in).

On the VAR card, anglers are asked to judge their own angling expertise level, and expertise is then estimated for each water by a mean index value as follows: 1.0 is an inexperienced angler, 2.0 is experienced, and 3.0 is an expert. In 1985, mean expertise for 5,606 park anglers was 1.90, indicating that most fishermen fall into the inexperienced to experienced category (Table 4).

Comprehensive analyses of several fisheries including Yellowstone Lake, the catch and release section of the Yellowstone River, Sylvan Lake, Gibbon River, Madison River, Slough Creek, and Soda Butte Creek were completed in 1985. Although it was not possible to expand these analyses to additional waters, data for 26 lakes and streams that made up over 95% of the total park angler use are given in tabular form (Tables 5 and 6).

Table 5. Fishery statistics from Yellowstone Park waters with over 40 angler days in the sample and which comprise over 94% of the parkwide angler day use in 1985.

	% of total parkwide angler days	Total reported angler days (VAN)	Estimates for the season						Total fish landed	Total fish creeled	$\bar{x}$ length fish landed (inches)	$\bar{x}$ length fish creeled (inches)	% anglers landing 1 or more fish	Average expertise	% anglers satisfied with:		
			Anglers	$\bar{x}$ length angler day (hours)	Angler days (trips)	Angler hours (effort)	Landing rate	Creel rate							Overall experience	Numbers caught	Fish sizes caught
Parkwide fishery	100.00	10,052	123,819	2.47	278,998	688,504	0.92	0.10	629,684	69,774	13.3	12.4	68	1.90	76	68	71
Yellowstone Lake	39.96	4,017	42,208	2.50	111,486	278,794	0.92	0.14	250,625	36,439	14.7	12.2	70	1.78	80	73	77
Yellowstone River	16.62	1,617	21,358	2.66	46,369	123,257	0.94	0.06	115,952	7,088	15.0	12.8	72	1.98	82	72	84
Madison River	7.22	726	8,437	2.39	20,139	48,156	0.50	0.03	24,083	1,524	13.1	15.6	47	1.97	58	45	54
Gibbon River	5.31	534	8,437	1.88	14,809	27,886	0.82	0.09	22,747	2,485	8.2	10.2	57	1.96	63	52	44
Firehole River	5.23	526	7,465	2.20	14,587	32,056	0.71	0.03	22,778	884	10.4	13.2	56	1.97	69	55	50
Slough Creek	4.21	423	6,162	2.92	11,728	34,227	1.27	0.01	43,527	419	13.7	15.0	82	2.06	85	80	86
Shoshone Lake	2.72	274	2,209	3.38	7,593	25,623	0.49	0.13	12,531	3,300	17.4	17.9	55	1.79	71	66	79
Lewis Lake	2.71	272	3,446	2.98	7,537	22,431	0.61	0.20	13,766	4,375	14.2	14.9	48	1.87	75	68	69
Gardner River	1.53	154	2,518	1.87	4,262	7,987	1.46	0.27	11,672	2,153	8.8	9.7	84	1.96	87	84	67
Lamar River	1.41	142	2,341	2.13	3,929	8,362	1.02	0.04	8,544	298	11.6	9.2	82	2.04	73	63	72
Lewis River	1.39	140	2,253	2.08	3,873	8,044	0.96	0.05	7,761	387	9.2	13.7	71	1.94	70	67	48
Bechler River	1.29	130	707	2.54	3,596	9,124	0.88	0.03	7,985	288	8.6	11.5	85	1.97	89	81	37
Soda Butte Creek	1.25	126	1,171	2.37	3,485	8,248	1.31	0.17	10,833	1,370	9.8	11.2	91	1.98	75	66	68
Gallatin River	0.88	88	1,193	2.59	2,430	6,293	0.95	0.11	5,952	704	12.4	13.7	76	1.98	69	61	76
Indian Creek	0.72	72	1,104	1.83	1,986	3,640	1.39	0.22	5,067	792	6.8	7.6	78	1.88	64	55	14
Nez Perce Creek	0.66	66	1,391	1.74	1,819	3,169	0.57	0.09	1,802	273	9.1	10.9	40	1.90	44	40	40
Falls River	0.60	60	773	2.73	1,653	4,516	1.17	0.15	5,302	693	9.3	12.4	100	2.03	87	71	58
Snake River	0.56	56	883	2.22	1,542	3,419	0.71	0.10	2,431	344	9.1	11.7	72	1.84	63	47	57
Lewis Channel	0.40	40	641	2.44	1,098	2,678	1.21	0.08	3,003	226	16.6	19.0	48	1.92	60	52	76

Table 6. Fishery statistics from Yellowstone Park waters with less than 40 angler days per year represented in the sample, 1985.

	% of total parkwide angler days	Total reported angler days (VPS)	Estimates for the season								X length fish landed (inches)	X length fish creel (inches)	X anglers landing 1 or more fish	Average expertise	% anglers satisfied with:		
			Anglers	X length angler day (hours)	Angler days (trips)	Angler hours (effort)	Landing rate	Creel rate	Total fish landed	Total fish creel					Overall experience	Numbers caught	Fish sizes caught
Sylvan Lake	0.36	36	707	1.94	986	1,910	1.24	0.04	2,364	84	9.1	8.0	90	1.96	89	89	93
Heart Lake	0.35	35	331	3.01	959	2,885	0.91	0.07	2,630	202	17.3	18.6	100	1.93	67	60	67
Middle Creek	0.32	32	707	1.57	875	1,371	2.67	0.49	3,664	666	9.1	10.4	81	1.78	92	92	81
Pelican Creek	0.32	32	618	2.70	875	2,362	1.56	0.02	3,695	43	14.4	17.0	88	2.18	77	73	88
Hellroaring Creek	0.30	30	442	1.82	820	1,494	2.12	0.24	3,176	358	9.5	10.4	93	1.75	95	95	79
Grebe Lake	0.27	27	552	1.90	737	1,398	1.12	0.07	1,560	93	11.3	14.6	83	1.86	80	80	75
Obsidian Creek	0.22	22	464	1.81	598	1,083	1.13	0.11	1,227	121	6.2	8.1	80	1.81	65	65	15

YELLOWSTONE LAKE

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

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

Beginning in 1975, regulations allowed the daily harvest of two trout under 330 mm (13 in) total length (TL). Theoretically, this regulation would take advantage of compensatory survival in younger age groups and improve the population age structure. With an increase of older and larger trout, the stability and productivity of multiple age spawning stocks would ideally resemble historic levels. This regulation has remained unchanged since 1975; however, it was 1978 before it was extended to lake tributaries.

In 1985, efforts to assess the response of the Yellowstone Lake cutthroat trout to the 330 mm maximum size limit continued. Studies included a creel survey utilizing the VAR system (Jones et al. 1977), the operation of the spawning trap at Clear Creek, a monthly sampling of limnological parameters, and an experimental gillnetting program.

ANGLER USE

During 1985, angler use on Yellowstone Lake comprised 40% of the total parkwide angler use. An estimated 42,208 anglers spent 111,486 angler days and 278,794 angler hours fishing in the lake (Table 7). Use and effort estimates remained below the 11-year average

Table 7. Fishing statistics from Yellowstone Lake, 1985.

Table 1. Fishing Statistics from Yellowstone Lake, 1957.															
Yellowstone Lake area:		% of lake total	Total VFR use reported	Predicted totals for season								% Anglers satisfied with:			
				Anglers	F length angler day (hours)	Angler days (trips)	Angler hours	Landing rate	Creel rate	tal fish landed	Total fish creeled	Overall experience	Fish numbers	Fish sizes	Mean expertise
1	Shore	2.44	98	1,546	1.99	2,707	5,390	0.65	0.11	3,520	604	79	75	77	1.93
	Boat	0.42	17	135	2.76	459	1,269	0.84	0.34	1,061	426	83	100	83	1.43
2	Shore	27.01	1,085	11,441	1.95	30,103	58,806	0.64	0.09	37,527	5,188	70	62	70	1.79
	Boat	15.31	615	8,150	2.91	17,058	49,641	0.94	0.22	46,629	10,778	88	81	61	1.71
3	Shore	6.47	260	2,319	2.33	7,204	16,763	1.22	0.13	20,398	2,129	80	75	79	1.90
	Boat	2.39	96	817	2.16	2,652	5,739	1.21	0.21	6,950	1,203	88	88	91	1.81
4	Shore	13.77	553	6,471	2.01	15,337	30,790	0.73	0.12	22,512	3,554	73	65	74	1.78
	Boat	7.92	318	2,783	3.36	8,814	29,608	1.12	0.21	33,117	6,106	92	86	90	1.76
5	Shore	0.17	7	66	1.53	182	278	1.05	0.18	292	49	100	100	100	2.50
	Boat	3.21	129	1,325	3.15	3,568	11,243	1.13	0.13	12,676	1,479	93	80	86	1.74
6	Shore	0.02	1	22	4.13	15	62	0.35	0.01	22	1	0	0	0	1.00
	Boat	1.34	54	530	4.76	1,486	7,073	2.12	0.07	14,969	523	95	89	74	2.00
7	Shore	0.45	18	44	2.50	487	1,220	1.79	0.29	2,185	353	100	100	100	2.00
	Boat	1.72	69	442	3.01	1,902	5,721	1.13	0.11	6,471	634	83	83	94	1.79
Unknown shore		7.44	299	2,717	2.04	8,286	16,928	0.72	0.10	12,273	1,775	70	63	61	1.76
Unknown boat		9.91	396	3,379	3.42	11,034	37,733	1.14	0.14	42,879	5,107	91	81	82	1.82
All shore		57.78	2,321	24,627	2.02	64,411	130,447	0.76	0.10	99,099	13,692	72	65	72	1.80
All boat		42.22	1,696	17,561	3.15	47,063	148,313	1.11	0.18	165,122	26,303	90	83	83	1.76
Entire lake		100.00	4,017	42,208	2.50	111,486	278,794	0.92	0.14	256,625	38,439	80	73	77	1.78

since 1975 (142,800 angler days and 342,930 angler hours, respectively). These figures represent 17% and 13% decreases, respectively, from 1984 (Figure 1).

Angler use continued to be most heavily concentrated in the accessible areas including the northwest portion of the lake, the West Thumb segment, western shoreline and eastern shoreline. The central and southern areas sustained the lowest proportion of use (Table 7). Success continues to be inversely related to angling pressure; the more remote areas sustain higher landing rates than the more heavily fished accessible areas.

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

Yellowstone Lake anglers landed an estimated 256,600 trout and released 218,200. Total angler-caused mortality was estimated at 60,200 (38,400 creeled plus an estimated 21,800 which may have died of hooking wounds following release). Overall landing and creel rates were 0.92 and 0.14 trout/hour, respectively. Landing and creel rates from the boat segment (1.11 and 0.18 trout/hour, respectively) were substantially above those from the shoreline segment (0.76 and 0.10 trout/hour, respectively) (Table 7). Seventy percent of one-day anglers landed one or more trout from the lake, and 27% creeled one or more.

Based on length measurements of 15,471 trout reported from Yellowstone Lake, it is apparent that the size structure of the cutthroat population continued to improve (Table 8). Average size of landed trout in 1985 was 372 mm. Length frequencies displayed a general improvement indicating survival of proportionately more fish to older and larger size groups (Table 8). The percentage of landed trout exceeding 406 mm TL (24.1%) was substantially higher than before the regulation change. The percentage of landed trout measuring over 475 mm and 508 mm were among the highest yet reported.

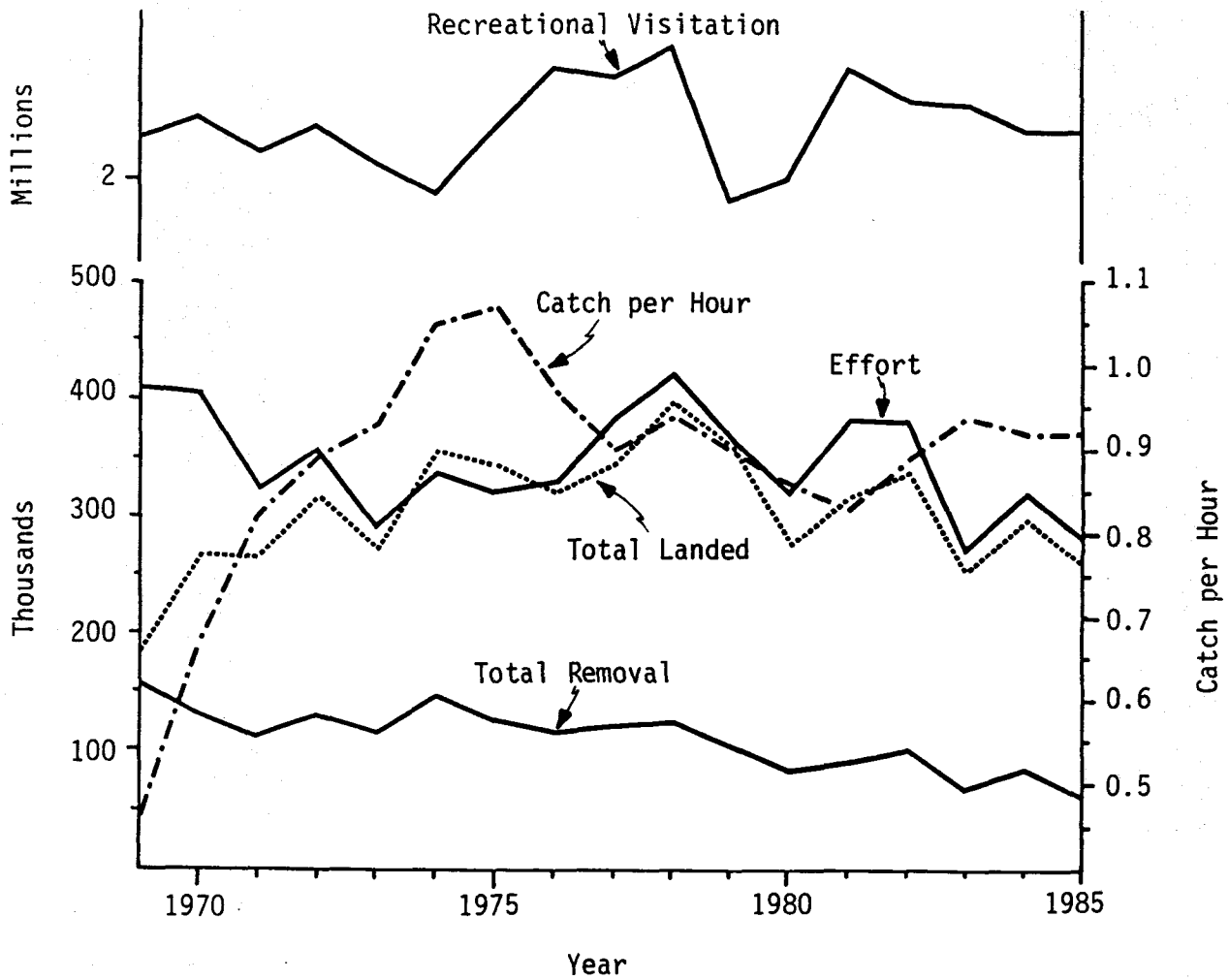


Figure 1. Recreational visitation, catch per hour, total effort, total trout landed, and total trout removed from Yellowstone Lake, 1969-1985.

Table 8 . Average length and length frequencies of cutthroat trout landed and creeled from Yellowstone Lake, 1973-1985.

Number and percentage of trout in length groups (inches):										
		<10	10-12	12-14	14-16	16-18	18-20	>20	N	
Number of trout reported landed:										
14"	1973	131	364	1,204	1,521	268	9	0	3,497	
min.	1974	823	1,861	6,276	8,296	1,097	90	4	18,447	
size										
13"	1975	686	2,634	8,654	8,366	1,571	155	44	22,110	
max.	1976	816	3,415	10,160	10,123	2,295	349	94	27,252	
size	1977	645	3,029	10,068	11,778	3,619	613	228	29,980	
	1978	1,174	3,878	10,322	14,794	4,523	728	188	35,607	
	1979	781	2,463	7,042	13,193	5,308	912	237	29,936	
	1980	295	1,500	5,418	8,855	3,268	699	212	20,217	
	1981	356	1,646	5,112	8,670	3,570	569	131	20,054	
	1982	771	2,702	9,909	9,965	4,186	736	226	24,495	
	1983	543	1,760	4,446	7,362	3,632	891	308	18,942	
	1984	552	1,955	4,536	6,666	3,367	655	213	17,944	
	1985	491	1,001	3,520	6,723	2,885	669	182	15,471	
Percentage of trout reported landed:										
14"	1973	3.7	10.4	34.4	43.5	7.7	0.3	0.0	3,497	
min.	1974	4.5	10.1	34.0	45.0	5.9	0.5	0.02	18,447	
size										
13"	1975	3.1	11.9	39.1	37.8	7.1	0.7	0.2	22,133	
max.	1976	3.0	12.5	37.3	37.1	8.4	1.3	0.3	27,252	
size	1977	2.2	10.1	33.6	39.3	12.1	2.0	0.8	29,980	
	1978	3.3	10.9	29.0	41.5	12.7	2.0	0.5	35,607	
	1979	2.6	8.2	23.5	44.1	17.7	3.0	0.8	29,936	
	1980	1.5	7.4	26.8	43.8	16.2	3.3	1.0	20,217	
	1981	1.8	8.2	25.5	43.2	17.8	2.8	0.7	20,054	
	1982	3.1	11.0	24.1	40.7	17.1	3.0	0.9	24,495	
	1983	2.9	9.3	23.5	38.9	19.2	4.7	1.6	18,942	
	1984	3.1	10.9	25.3	37.1	18.8	3.7	1.2	17,944	
	1985	3.2	6.5	22.8	43.5	18.6	4.3	1.2	15,471	

Percentage of trout landed measuring over:							Mean length landed		Mean length creeled	
		>12 in	>14 in	>16 in	>18 in	>20 in	in	mm	in	mm
14"	1973	85.8	51.4	7.9	0.3	0.0	13.8	350	--	--
min.	1974	85.5	51.4	6.5	0.5	0.02	13.8	350	--	--
size										
13"	1975	84.9	45.8	8.0	0.9	0.2	13.7	349	12.4	316
max.	1976	84.8	47.5	14.1	2.0	0.3	13.8	350	12.4	314
size	1977	87.8	54.2	14.9	2.8	0.8	14.2	360	12.6	319
	1978	85.8	56.8	15.3	2.6	0.5	14.2	360	12.4	314
	1979	89.2	65.6	21.6	3.8	0.8	14.6	370	12.4	316
	1980	91.9	64.3	20.5	4.4	1.0	14.6	371	12.6	320
	1981	90.0	64.5	21.3	3.5	0.7	14.6	370	12.5	316
	1982	85.8	61.7	21.0	3.9	0.9	14.4	366	12.2	311
	1983	87.8	64.4	25.5	6.3	1.6	14.7	372	12.2	309
	1984	86.0	60.8	23.6	4.8	1.2	14.5	367	12.3	313
	1985	90.4	67.6	24.1	5.5	1.2	14.7	372	12.2	311

Like other fishing violations, the illegal harvest of trout over 330 mm is a continuing problem. An estimated 12,700 trout over 330 mm, including 1,230 over 356 mm, were creelied in 1985. The combination of strict law enforcement, increased public awareness, and acceptance of the 330 mm maximum size regulation have caused significant declines in the percentage of illegal trout harvested; however, the level of violations is still a major concern.

During 1985, the percentage of anglers satisfied with their overall angling experience on Yellowstone Lake was 80%; satisfaction with numbers and sizes landed was 73% and 71%, respectively (Table 7). Average expertise was 1.78.

CLEAR CREEK CUTTHROAT SPAWNING RUN

From its source (2,585 m above MSL) in the Absaroka Mountains, Clear Creek flows westward approximately 20.3 km before entering Yellowstone Lake along the east shore (Figure 2). This stream was utilized for spawn-taking activities almost annually from 1913 to 1950. Since 1951, the fish trap has been used to monitor cutthroat trout spawning migrations in Clear Creek (Jones et al. 1979).

Methods

Personnel and monetary shortages required a reduction in trapping effort in 1985. It was necessary, therefore, to develop a sampling design which would not only reduce effort but also provide results which would be comparable with previous data collected at Clear Creek.

Initial planning included the description of fish movement patterns during the annual cutthroat trout migration. Since the distributional pattern for all years combined suggested distinct bimodal peaks, the time necessary for 75% or more of the run to enter the trap was compared between years. Runs which peaked prior to 1 July were designated as "early" runs (1977, 1979, 1980, and 1981) and those peaking after 1 July were assigned the "late" designation (1978, 1983, and 1984).

When it became evident that snowmelt in 1985 was progressing at a rate which would result in an early spawning migration, the early run pattern was utilized to construct the final sampling design. Eighteen sample days within a 30-day period between 14 June and 13 July were chosen at random, and the resulting mean daily count was expanded to estimate the total number of

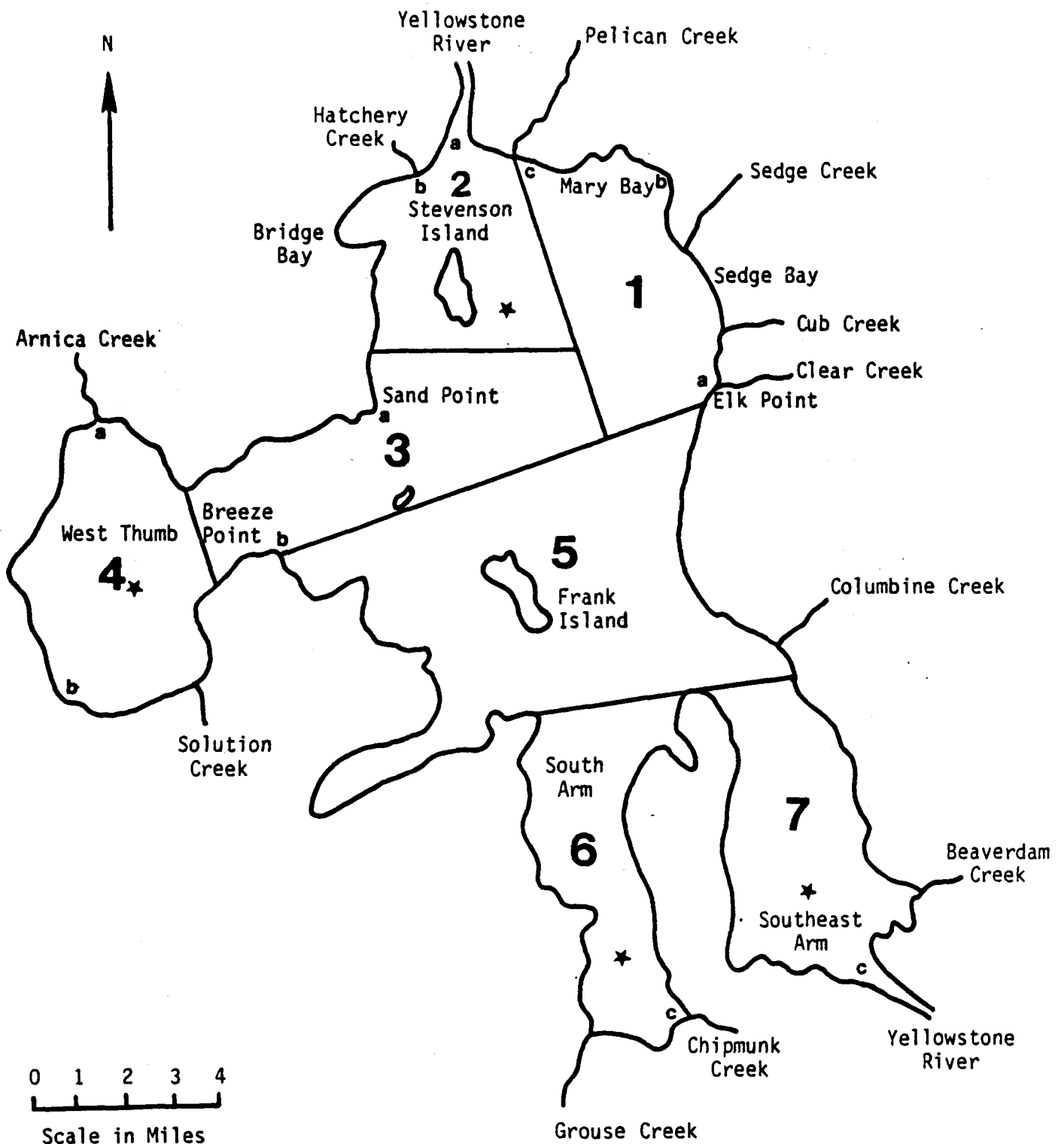


Figure 2. Creel survey, gillnetting, plankton sampling (☆), and spawning trap sites, Yellowstone Lake, 1985.

migrants during the period. In order to reduce variation between years, each year was divided into three strata (14 June through 21 June, 22 June through 1 July, and 2 July through 13 July). Six sample days were drawn randomly from each strata, and the estimates for each strata were combined to yield the final estimate.

Sample days utilized in 1985 were 14, 16, 17, 19, 20, 21, 22, 25, 26, 28, and 29 June, and, 1, 3, 6, 8, 9, 12, and 13 July. Upstream and downstream migrations were monitored between 0800 and 2000 hours on each sample day. Weir gates were removed on nonsample days in order to allow free movement of spawners into and out of Clear Creek.

Each sample day, 75 upstream migrants were separated according to sex and measured to the nearest 5 mm total length (TL). Additionally, scales from a minimum of 10 trout were collected for age determination. A stratified sample of 10 male and 10 female trout was sought in each 10 mm length group for the entire run; therefore, additional scales were taken as needed to complete the sample. Sampling of the downstream migration began on 28 June and was limited to length frequency data. All sampled trout were inspected for fin clips.

Stream discharge was monitored using a staff gauge located approximately 400 m upstream of the weir. Daily flows were estimated from a level-flow prediction equation based on 31 flow measurements collected near the gauge in 1984 (Jones et al. 1985). Water temperatures were obtained daily with a hand-held thermometer.

Results

Upstream

A total of 16,762 cutthroat trout were counted through the upstream trap. Daily counts ranged from 29 (21 July) to 2,352 (19 June) but generally decreased through time. Over 48% of the trout were counted during the first six sample days; mean daily counts dropped from 1,342 in the first period to 1,116 and 336 in the second and third periods, respectively (Table 9).

Expansion of mean daily counts within each sampling period yielded an estimate of 25,925 upstream migrants between 14 June and 13 July. Estimates from the four early years suggest that from 81% to 98% of the total number of migrants counted through the upstream trap

Table 9. Counts and expanded estimates of cutthroat trout spawners during three sample periods, Clear Creek, 1985.

Period	Upstream				Downstream	
	Sum	Mean	Expanded ¹⁾ Estimate	Confidence Interval (+/-)	Sum	Mean
June 14-June 21 ²⁾	8050	1342	10733	5577	1864	311
June 22-July 1 ³⁾	6697	1116	11162	8741	5694	949
July 2-July 3 ⁴⁾	2015	336	4030	4956	5736	956
Total	16762		25925		13294	

- 1) Estimate expanded from 6 sample days per period.
2) Sample days 14, 16, 17, 19, 20, 21 June.
3) Sample days 22, 25, 26, 28, 29 June, 1 July.
4) Sample days 3, 6, 8, 9, 12, 13 July.

were sampled during this 30 day period (Table 10). Since the peak of the run was extremely early in 1985, a value similar to the earliest of the other years (81%) might provide the most comparable answer. Assuming the expanded sample estimate was 81% of the total run, an upstream migration of 32,006 was predicted for 1985. Upper and lower confidence limits were 54,335 and 9,677, respectively.

Daily mean water temperature generally increased through the sample period and ranged from 4 C (25 June) to 13.5 C (20 July) (Figure 3). Discharge declined steadily from 14 June (2.36 m³/s) to 13 July (1.05 m³/s) (Figure 3).

During the downstream migration in 1979, the adipose fin was removed from 42,229 cutthroat trout at Clear Creek (Jones et al. 1980). In 1985, 1,413 trout in the upstream run were inspected for clips, and only one clipped trout was observed. This result suggests that 0.07% of the trout entering Clear Creek were clipped, yielding a 0.05% return of 1979 spawners.

Mean total length of upstream cutthroat trout was 382 mm (n=1,195). The male:female ratio was 0.64:1. Average length of males (391 mm) was significantly greater than that of females (375 mm). Weekly averages of length for both sexes varied only slightly until the final week.

Average age for an expanded sample of 1,408 cutthroat trout was 4.4 years. Mean age of males (4.6 years) was greater than that estimated for females (4.2 years). Approximately 3% of the upstream migrants were age VII+ and older.

Downstream

A total of 13,294 cutthroat trout were counted through the downstream trap. Numbers increased sharply after the first sample period but displayed little variation between the last two periods (Table 9). Expanded estimates suggest 23,450 trout descended from 14 June-13 July; estimates for the entire downstream migration were not calculated. Mean length of downstream trout was 380 mm (n=718), and the male:female ratio was 0.98:1.

Fingerling trout were first observed near the fish trap on 13 June; however, young-of-the-year cutthroat were not observed in 1985 prior to cessation of trap operations.

Table 10 . Annual estimates of the number of cutthroat trout spawners ascending Clear Creek between 14 June and 13 July, 1977, 1979, 1980, and 1981.

Year	Upstream Sample				% Total Run	Total Count	
	Sum	Mean	Estimate ¹⁾	95% Confidence Interval (+/-)		Sample	Total Run
1977	28862	1603	42456	18337	0.81	49437	52641
1979	32776	1821	57198	15617	0.98	51024	58244
1980	26375	1465	41839	20515	0.89	41649	47115
1981	20623	1146	32194	16071	0.86	32462	37439
Mean	27159		43424			43643	48860

¹⁾ Estimates expanded from three strata with six sample days per stratum; 14, 16, 17, 19, 20, 21 June; 22, 25, 26, 28, 29 June, 1 July; 3, 6, 8, 9, 12, 13 July.

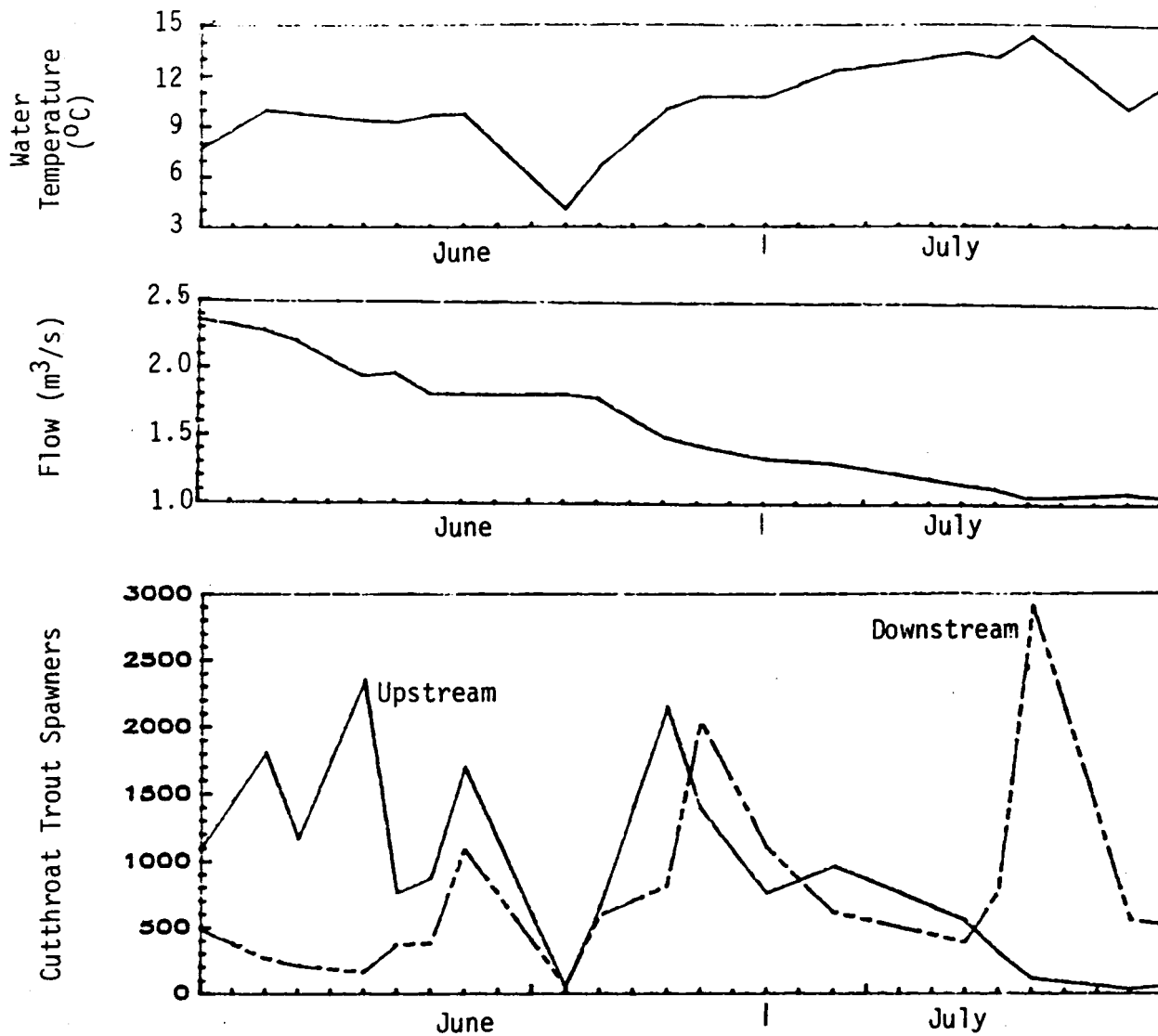


Figure 3 . Pattern of daily water temperature, flow, and cutthroat trout spawning migration, Clear Creek, 1985.

Wildlife Use of Spawning Cutthroat Trout

Evidence of bears feeding on fish at the weir was first noted on 3 July. Bears continued to visit the trap occasionally, usually at night, until trap operations ended on 15 July. Other wildlife commonly associated with the spawning run include mink, common loons, common mergansers, California gulls, as well as several osprey, golden and bald eagles, great blue heron, and white pelicans.

Discussion

The daily counts of upstream cutthroat trout migrants strongly suggest that the current sampling design failed to encompass the peak of the run in 1985 (Figure 3). Aside from below average counts, declining streamflows and increasing water temperatures during the sample period support this assumption. Normally peak flows in Clear Creek range between 4.5 and 5.0 m³/s. The majority of spawners generally enter the stream soon after peak flow (Jones et al. 1984); however, current data suggest the trap was not installed until water flows were well below the mean peak discharge and were already declining steadily. Water temperatures were also above the level normally associated with run maxima.

A significant decrease in the mean length of cutthroat trout was observed in 1985. It appears, however, that the smaller mean length was also strongly affected by the sample design. Previous studies at Clear Creek indicate that mean length of both male and female cutthroat trout declines significantly throughout the spawning season (Jones et al. 1984, 1985). Since weekly means were relatively constant, it is apparent that larger, earlier spawning trout did not appear in the sample.

The spawning migration in 1981 was the earliest run for which data were available, and although it was not as early as the 1985 run, it can be used for comparative purposes. Mean length of all spawners was 394 mm in 1981 (Jones et al. 1982), and there was no significant difference between the mean length of spawners in 1981 and 1984 (395 mm) (Jones et al. 1985). When mean length was calculated for 18 sample days similar to those in 1985, however, mean length of 1981 spawners dropped to 387 mm, only 5 mm greater than 1985. These data apparently support the assumption that sampling did not begin until after the peak of the run in 1985.

Mean length of angler-captured cutthroat trout actually increased in 1985 (see Yellowstone Lake Angler Use; this report) as did mean length of prespawners in largemouth gillnets (see Largemouth Gillnetting; this report). Since changes in mean length of Clear Creek spawners generally coincide with changes observed utilizing these other methods, it appears that mean length of cutthroat trout spawners did not decline in Clear Creek during 1985.

Mean age also displayed an abrupt decline in 1985. Although current estimates represent the lowest mean age observed at Clear Creek since 1973, the direct relationship between length and age indicates that the current estimate of mean age was probably affected by sampling bias also. Comparison with mean age from prespawners captured in largemouth gillnets strongly support this assumption.

Although current results indicate that the estimates of spawner numbers, mean length, and age were confounded due to the failure to sample a greater proportion of the run, it is difficult to properly evaluate the sampling design. It is possible that given a run more typical of either the early or late migration, representative data may have been collected using the chosen design; however, the difficulty of predicting the timing of the annual migration is certainly evident.

Given continued funding and manpower shortages, it is apparent that some type of modified operation at the Clear Creek trap will be necessary. Any future modification should encompass enough of the entire run to insure comparability with previous length and age data while providing a reasonable estimate of the total number of spawners. These data are not only critical to monitoring of the Yellowstone Lake fishery but are essential to understanding the dynamics of other cutthroat trout spawning streams around the lake.

LARGEMESH GILLNETTING

Largemouth gillnetting has been conducted annually on Yellowstone Lake since 1969 (excluding 1973 and 1975) (Dean et al. 1970-1975; Varley et al. 1976; Jones et al. 1977-1985). The primary objective has been to monitor relative abundance, distribution, and population structure of cutthroat trout and longnose suckers. Each year current methods and results are presented and long-term trends are discussed.

Methods

In 1985, largemouth gillnetting was conducted from 16 to 21 September. Eleven sites (Figure 2) were sampled during the six-day period. Field and laboratory sampling techniques used in 1985 were identical to those employed in 1984 (Jones et al. 1985).

Results

Cutthroat Trout 1985

A total of 784 cutthroat trout were captured in largemouth gillnets in 1985. Average number of trout caught per net was 14.3. Overall mean length, weight, and condition were 311 mm, 332 g, and 0.93 K, respectively (Table 11). No clipped or tagged trout were captured.

Average number of trout caught per net differed significantly among the 11 sample sites (Appendix Table 1). Highest numbers were captured at sites 3a and 4a (23 and 22 trout/net, respectively). Intermediate numbers were caught at sites 1c, 6c, 1b, 1a, 2b, 3b, and 4b (19, 16, 15, 14, 13, 13, and 12 trout/net, respectively). Catches were lowest at sites 7c and 2a (9 and 1 trout/net, respectively).

There were no significant differences in average number of trout caught per net between the four lake zones (North: 1a, 1b, 1c, 2a, 2b; Central: 3a, 3b; West Thumb: 4a, 4b; South: 6c, 7c) (Appendix Table 2). Numbers of trout caught in Central and West Thumb (17.8 and 17.1 trout/net, respectively) were slightly greater than numbers captured in North and South (12.4 and 12.4 trout/net, respectively).

Mean lengths of captured trout differed significantly among the 11 sample sites (Appendix Table 1). Average lengths were greatest at sites 6c, 7c, and 3b (362, 355, and 353 mm, respectively), and intermediate at sites 4b, 2a, and 1c (331, 327, and 323 mm, respectively). Mean lengths at sites 2b, 1a, 1b, 3a, and 4a ranged from 297 to 274 mm. Mean lengths of trout were not significantly correlated to average number of trout caught per net.

Significant differences also occurred in the mean lengths of trout captured in the four lake zones (Appendix Table 2). Average length was greatest in South (360 mm). Mean lengths were smaller in North, Central, and West Thumb (305, 303, and 294 mm, respectively).

Table 11. Length-frequency distribution, average lengths, weights, and condition factors of nonspawning and prespawning cutthroat trout and longnose suckers captured in largemouth gillnets, 1.5-4.6 m depth interval, Yellowstone Lake, 1985.

Species	Maturity category ¹⁾	Size-group (lower length of interval - mm)								Total number	Average total length (mm)	Average weight (g)	Average condition factor (K)
		100	150	200	250	300	350	400	450	500			
Cutthroat Trout	Nonspawners	1	94	103	137	135	100	36	2	608	287	257	0.92
	Prespawning males		1	1	1	7	36	50	7	103	399	625	0.95
	Prespawning females					9	42	22		73	384	544	0.94
	TOTALS AND AVERAGES	1	95	104	138	151	178	108	9	784	311	332	0.93
Longnose Sucker	Nonspawners		6	41	29	14			1	91	253	214	1.16
	Prespawning males				26	20	35	62	3	146	373	723	1.29
	Prespawning females					6	10	37	49	3	105	1050	1.19
	TOTALS AND AVERAGES		6	41	55	40	45	99	53	342	362	688	1.23

¹⁾ Prespawning fish defined as those judged to have sufficient gonadal development to spawn in 1986; nonspawners include immature, and mature fish which were judged to lack sufficient gonadal development to spawn in 1986.

About 22% of all cutthroat trout captured were categorized as prespawners (prespawners were defined as those fish judged to have sufficient gonadal development to spawn in 1986). Mean length, weight, and condition factor (K) of prespawners (n=173) were 393 mm, 591 g, and 0.95, respectively. The prespawner male:female ratio was 1.41:1. Ninety percent of male prespawners and over 100% of female prespawners were between 300 and 400 mm in length.

Longnose Suckers

A total of 342 longnose suckers were captured in largemesh gillnets in 1985 (Appendix Table 3). Average number of longnose suckers caught per net was 6.2. Overall mean length, weight, and condition of captured longnose suckers were 362 mm, 688 g, and 1.23 K, respectively (Table 11). Ligula intestinalis was found in 3.6% of all captured suckers. No clipped or tagged suckers were caught.

Approximately 73% of all longnose suckers captured were categorized as prespawners. Overall prespawner mean length, weight, and condition factor (K) were 401 mm, 860 g, and 1.25, respectively. The prespawner male:female ratio was 1.39:1. Eighty-two percent of male prespawners were between 300 and 400 mm total length, and 91% of female prespawners were between 350 and 450 mm total length.

Discussion

Although the experimental design of the largemesh gillnetting program has been modified since the program began in 1969, data are comparable for 14 of 15 years in which studies have been conducted. Significant differences in efficiency were found between nets used in 1981 and those used in all other years (Jones et al. 1982); therefore, data from 1981 have been deleted to prevent confounding comparisons between years.

Cutthroat Trout 1969-1985

Relative abundance and distribution. The average number of trout caught per net has varied significantly since 1969 (Table 12). A significant correlation ($r=0.61$) was found between the percentage of trout less than 203 mm total length (TL) annually caught in gillnets and the average number of trout caught per net per year. It appears that the total number of trout caught in gillnets each year is substantially influenced by the relative abundance of age-1 and age-2 trout, and

therefore, the usefulness of relative-density comparisons is reduced.

Combining 14 years of gillnetting data, the average number of trout caught per net was significantly different among the 11 sample sites. Mean number caught per net ranged from 16 to 17 at sites 1b, 1c, 2b, 3a, and 4b, and from 11 to 14 at sites 1a, 2a, 3b, 4a, 6c, and 7c. Average number of trout caught per net did not differ significantly between the four lake zones. Catches in North and West Thumb averaged 15 trout/net, respectively. Mean catches at Central and South were 14 and 13 trout/net, respectively. Interpretation of these data is confounded by lack of observable trends.

Population structure. Mean length of trout captured in largemouth gillnets has varied significantly since 1969 (Table 12). Similar results were obtained when data were combined over years and compared by site and zone (Appendix Tables 1 and 2). A significant correlation ($r=-0.88$) between the percentage of trout less than 203 mm TL and the mean length of all trout captured in gillnets probably reflects year-class fluctuations of age-1 and age-2 trout.

Mean length of prespawners is not affected by the proportion of smaller trout in the gillnet catch; hence, yearly comparisons of prespawners may be used to detect length changes in mature trout. Mean length of prespawners has risen almost every year since 1974 (Figure 4). In 1985, mean lengths of male prespawners (399 mm) and female prespawners (384 mm) were the highest yet recorded. Increases for both sexes are viewed as a positive response to the 330 mm maximum size limit (2 fish creel) instituted on Yellowstone Lake in 1975.

Changes in length-distribution patterns of the gillnetting catch have also occurred since the 330 mm maximum size limit was instituted in 1975 (Figure 5). The shift towards larger trout in the 330 to 400 mm and 400 to 500 mm length groups suggests a greater survival of older age groups. The decline in relative abundance of trout between 206 and 330 mm may be related to the fact that approximately 91% of all trout creel from Yellowstone Lake are between 230 and 360 mm (Jones et al. 1984); however, other unknown factors may also be involved. Future gillnetting operations, in conjunction with other Yellowstone Lake investigations, should address whether the observed decline in the relative abundance of trout between 260 and 330 mm in the gillnetting catch represents a real decrease and, if so,

Table 12. Comparative largemouth gillnetting results, cutthroat trout, 1.52-4.57 m depth interval, Yellowstone Lake, 1969-1972, 1974, 1976-1980, and 1982-1985.

Year	Number of gillnet sets ¹⁾	Average number trout per net	95% confidence interval of number trout/net	Mean length (mm)	% of trout over 356 mm (TL)	% of trout over 406 mm (TL)	% of trout over 457 mm (TL)	Percent of prespawning trout over 304 mm TL	Prespawning male:female ratio	Average length of prespawning males (mm)	Average length of prespawning females (mm)	Condition factor (K)
1969	9	12.22	+6.71	311	29.1	1.8	0.0	53.6	1.06:1	353	346	0.924
1970	11	12.27	+5.90	315	26.7	3.0	0.0	46.6	1.73:1	359	351	0.917
1971	5	14.40	+9.76	321	37.5	1.4	0.0	54.3	1.50:1	360	368	0.853
1972	11	13.63	+3.57	313	32.7	3.3	0.0	39.8	0.52:1	358	369	0.937
1974	11	15.45	+4.75	298	34.7	0.6	0.0	56.4	1.00:1	349	359	0.859
1976	11	15.00	+3.06	317	37.6	2.4	0.0	48.6	1.43:1	370	365	0.877
1977	44	15.55	+1.98	290	33.0	4.7	0.2	75.6	0.98:1	376	362	0.892
1978	55	13.93	+1.06	308	37.5	5.4	0.3	65.7	1.06:1	383	372	0.923
1979	55	13.60	+1.27	303	32.3	7.4	0.1	59.0	0.91:1	387	374	0.915
1980	55	13.00	+1.53	309	40.6	7.1	0.3	50.1	1.05:1	389	376	0.884
1982	55	10.60	+1.05	322	47.1	12.7	0.7	61.7	1.10:1	389	379	0.909
1983	55	18.05	+1.67	288	32.5	9.6	0.8	52.2	1.12:1	396	380	0.901
1984	54	19.50	+1.88	281	26.1	7.6	0.5	52.6	1.09:1	389	382	0.921
1985	55	14.30	+1.90	311	34.8	11.6	0.5	98.3	1.41:1	399	384	0.927

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

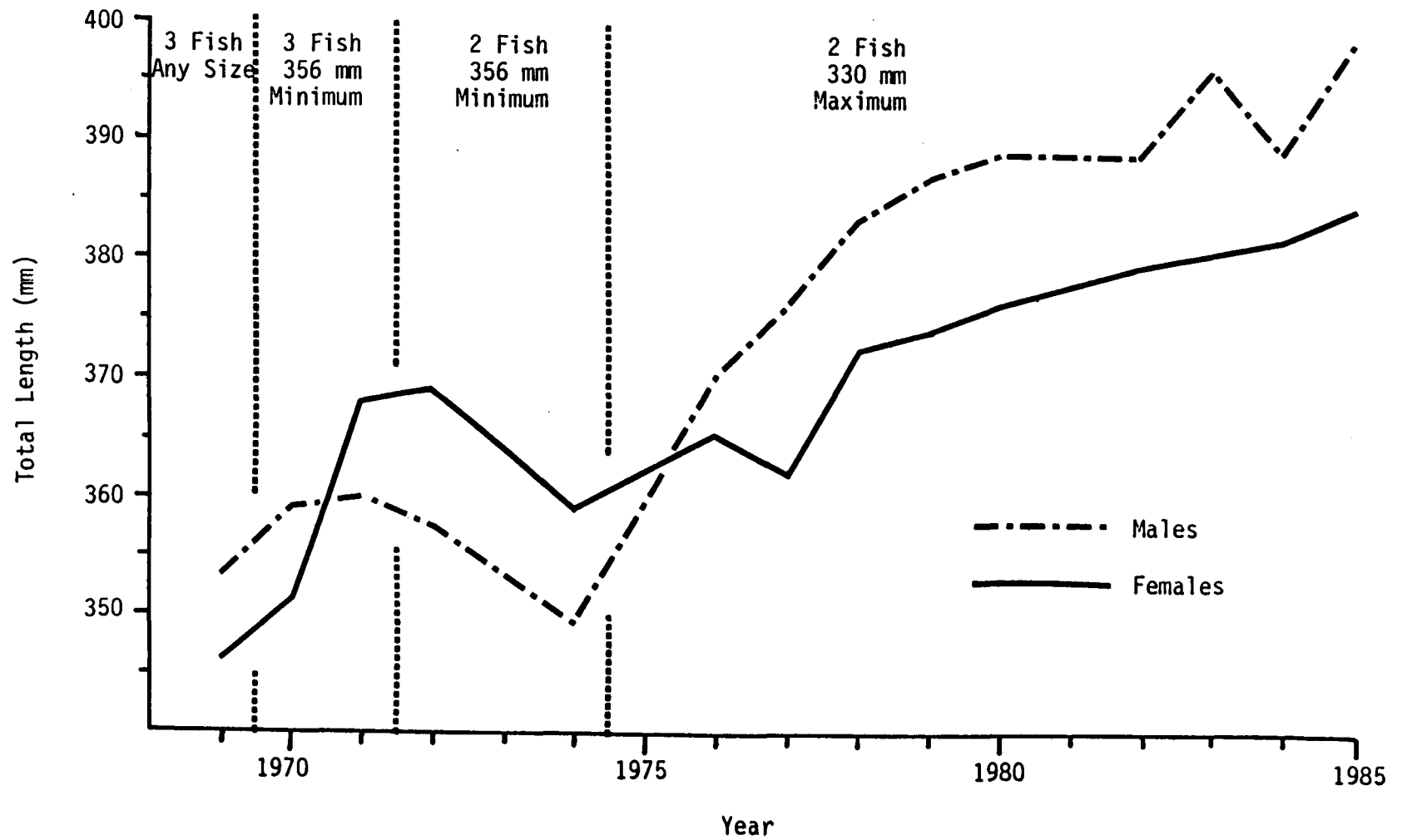


Figure 4 . Mean total length of prespawning cutthroat trout captured in largemesh gillnets, Yellowstone Lake, 1969-1985.

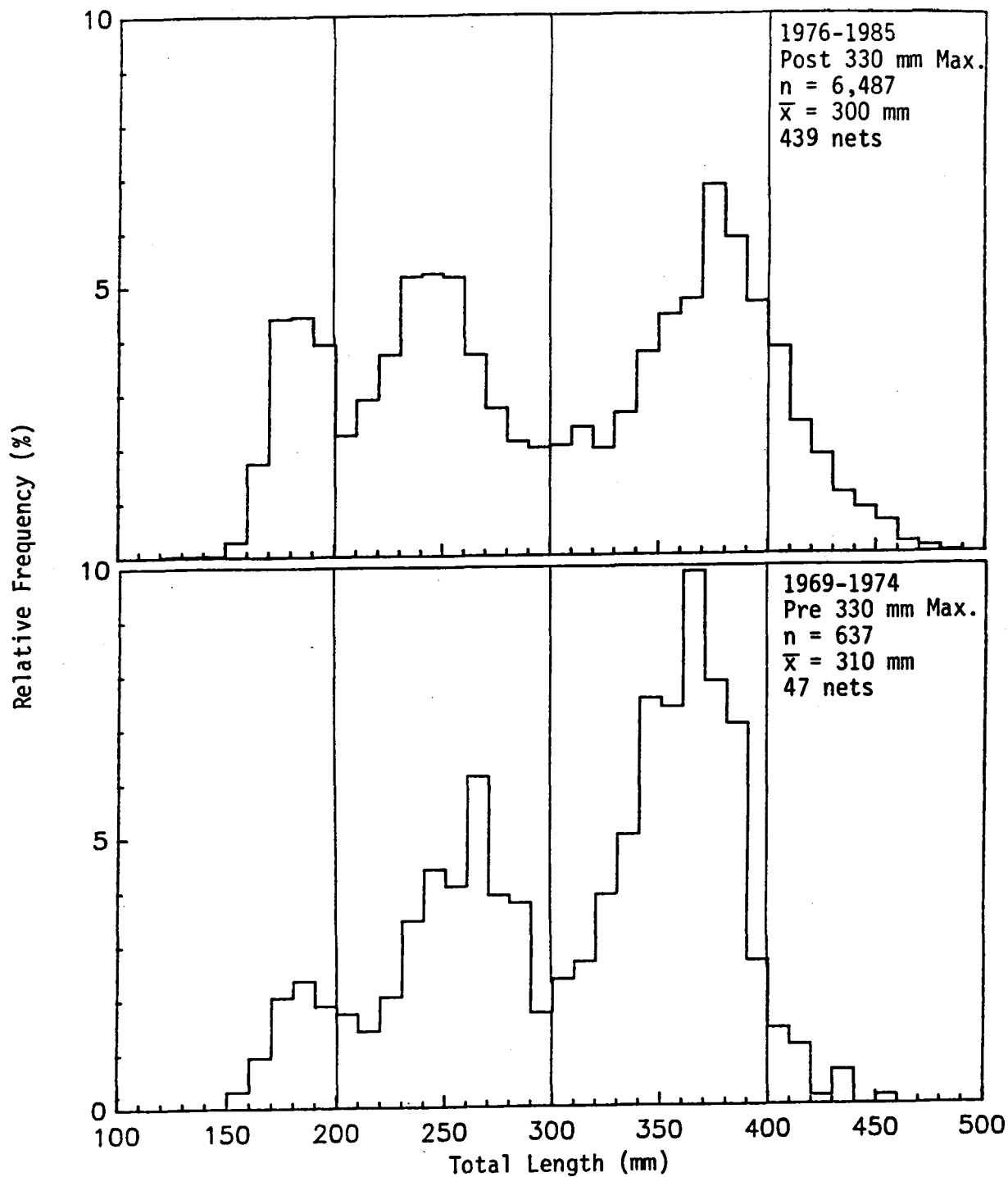


Figure 5 . Length frequencies of cutthroat trout captured in largemouth gillnets at the 1.5-4.6 m depth interval in Yellowstone Lake, 1969-1985 (excluding 1981).

whether this decrease is severe enough to negatively affect the cutthroat trout population as a whole.

Longnose Suckers 1969-1985

Average number per net. Although differences between years in the average number of suckers captured per net are significant (Table 13), reasons for these changes remain unidentified. It is doubtful these differences are due to population fluctuations since the longnose sucker is believed to be long-lived in Yellowstone Lake (Jones et al. 1977). These fluctuations may be partially due to schooling behavior; such behavior would intensify variation in the gillnet catch.

Average size. Comparisons between years (Table 13) yield significant differences in mean length. Mean length of suckers has been inversely correlated to the male:female ratio ($r=-0.78$) and directly correlated to the percentage of suckers over 310 mm ($r=0.94$) (Jones et al. 1981). Since the latter two factors are probably related to distribution, annual variations affecting numbers captured may also affect variations in mean length.

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

CONCLUSIONS

It appears that the 330 mm maximum size limit is accomplishing the objective of increasing the proportion of older and larger cutthroat trout in Yellowstone Lake. Scattered historic size data and current estimates utilizing the Walford line (Ricker 1975) suggest a maximum of 11 age groups prior to modern angler exploitation. Since Ricker (1963) has stated that exploitation as low as 5% annually may significantly alter a pristine population, the cutthroat trout population may never reach historic levels under current regulations.

It is apparent, however, that the 330 mm maximum size limit has been more successful at approaching historic

Table 13. Comparative largemouth gillnetting results, longnose sucker, 1.52-4.57 m depth interval, Yellowstone Lake, 1969-1972, 1974, 1976-1980, and 1982-1985.

Year	Number of gillnet sets ¹⁾	Average number suckers per net	95% confidence interval of number suckers/net	Mean length (mm)	% of suckers over 356 mm (TL)	% of suckers over 406 mm (TL)	% of suckers over 457 mm (TL)	Percent of prespawning suckers over 310 mm TL	Prespawning male:female ratio	Average length of prespawning males (mm)	Average length of prespawning females (mm)	Condition factor (K)
1969	9	16.33	+10.65	365	66.0	29.2	6.1	92.1	1.28:1	382	419	1.207
1970	11	6.45	+5.01	393	83.1	59.2	12.7	100.0	0.08:1	386	440	1.235
1971	5	37.00	+42.17	316	34.0	17.8	2.7	100.0	2.00:1	357	417	1.207
1972	11	2.54	+1.29	335	42.9	28.6	7.1	88.2	2.00:1	378	428	1.205
1974	11	15.91	+5.92	370	69.7	29.1	5.7	100.0	1.28:1	372	415	1.215
1976	11	14.55	+5.36	389	80.6	44.4	7.5	95.2	1.07:1	387	425	1.227
1977	44	7.25	+1.83	401	80.9	55.5	14.7	100.0	1.48:1	390	441	1.229
1978	55	7.25	+1.99	363	58.3	38.9	11.1	92.5	1.13:1	385	435	1.187
1979	55	12.64	+2.07	371	62.6	45.2	13.0	87.8	0.99:1	399	440	1.197
1980	55	9.98	+1.82	365	59.3	39.4	12.6	78.1	1.12:1	370	432	1.171
1982	55	8.64	+2.13	356	51.1	37.2	12.5	65.2	0.95:1	373	438	1.209
1983	55	11.36	+1.87	341	50.1	36.5	12.8	57.3	1.21:1	381	442	1.183
1984	54	13.65	+2.29	349	55.2	39.3	14.0	98.6	0.92:1	386	439	1.059
1985	55	6.20	+1.61	362	57.6	43.3	13.5	86.9	1.39:1	373	441	1.228

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

levels than any regulations utilized thus far. Average lengths of trout landed in the fishery and prespawners in fall-set gillnets are among the greatest yet recorded (Figures 4 and 5). Fecundity estimates suggest that current reproductive potential in Clear Creek is five times greater than it was during the 1950's (Jones et al. 1985).

What may be as important as the shift in population structure is that these changes are occurring while use (in the range of 150,000 angler days annually) and effort (over 350,000 angler hours) remain high. Despite these levels of pressure, the landing rate has been excellent, averaging 0.94 trout/hour since 1975. The continued decrease in creel rate during this period is indeed curious, but data indicate that it is not related to a depletion of legal size trout. Increased popularity of catch and release fishing may be responsible for the decline in harvested trout.

The biological response to altered harvests patterns associated with the 330 mm maximum size regulation are not completely understood at present, but harvesting trout prior to maturity shifts fishing mortality to life stages which may better be able to withstand high levels of exploitation. The relatively short period that trout are vulnerable to harvest in Yellowstone Lake may also influence results. Most trout do not enter the fishery until approximately 300 mm (11.8 in) and are beyond the legal limit within one growing season.

As angler use and effort steadily increased, creel limits as low as three trout per day failed to protect the structure of this cutthroat population. Fishing closure or "no kill" (catch and release) regulations would undoubtedly provide maximum protection. The 330 mm maximum size limit, however, not only provides substantial protection, but allows a daily creel limit which satisfies most anglers. Currently five large trout (356-457 mm) are captured and released for each trout under 330 mm creeled. Over two-thirds of all anglers catch one or more trout, and over one-third creel one or more. Excellent landing rates, often associated with "no kill" regulations, have been sustained while anglers have retained the privilege of harvesting trout for a campfire meal.

Results from the Yellowstone Lake fishery during the first 11 years of the 330 mm maximum size limit are indeed encouraging; however, it should be emphasized that these results may not describe an equilibrium condition. Future increases in angler use may affect

the cutthroat trout population despite the protection afforded under the current regulation. Continued research is essential to the evaluation of the 330 mm maximum size limit, especially under higher levels of use.

CUTTHROAT TROUT SPAWNING ACTIVITY IN TRIBUTARIES OF YELLOWSTONE LAKE

INTRODUCTION

Cutthroat trout (Salmo clarki bouvieri) in Yellowstone Lake are adfluvial, and spawning in lake tributaries generally extends from May through July. Prior to 1974, investigations of spawning in lake tributaries were largely limited to eight streams: Pelican Creek, Cub Creek, Clear Creek, Columbine Creek, Chipmunk Creek, Grouse Creek, Arnica Creek, and Hatchery Creek (Figure 2). These studies, and most since then, have dealt with spawner counts, diel and seasonal patterns of upstream and downstream spawning migrations, instream mortality, and population structure of spawning runs (Welsh 1952; Cope 1953, 1956, 1957a, 1975b; Ball and Cope 1961; Bulkley 1961; Bulkley and Benson 1962; Benson and Bulkley 1963; Jones et al. 1980; Jones et al. 1983; Jones et al. 1985). Fecundity (Cope 1957a, Jones et al. 1985), homing (Ball 1955; Cope 1957a; McCleave 1967; Labar 1971; Jones et al. 1981, 1982), distribution of spawners in streams (Welsh 1952; Cope 1957b), and factors influencing young-of-the-year (YOY) production (Benson 1960; Bulkley and Benson 1962; Jones et al. 1979) have also been investigated. Dean and Varley (1974) and Dean et al. (1975) reported on road culverts that hindered or blocked spawning migrations.

Hoskins (1974, 1975) investigated the relationship between spawning cutthroat trout and grizzly bear (Ursus arctos horribilis) feeding activity in tributaries of Yellowstone Lake. He identified streams where spawning occurred, and streams which were actively "fished" by bears. Data collected included the presence/absence of spawning cutthroat trout, visual estimates of spawner densities, and physical and chemical characteristics of selected streams.

In 1985, a cooperative study was conducted by the U.S. Fish and Wildlife Service (USFWS) and Interagency Grizzly Bear Study Team (IGBST) to obtain a greater understanding of cutthroat trout spawning activity and bear-fish relationships in tributaries of Yellowstone Lake. Sampling efforts by both groups were concentrated in streams along the lakeshore from just south of Sedge Creek through Southeast Arm, South Arm, and Flat Mountain Arm, and west from Flat Mountain Arm to Solution Creek (Figure 6a-b). Most bear predation on fish observed by Hoskins (1974, 1975) was found in these areas, and the IGBST was interested in determining if bear-fish relationships in these areas had changed since

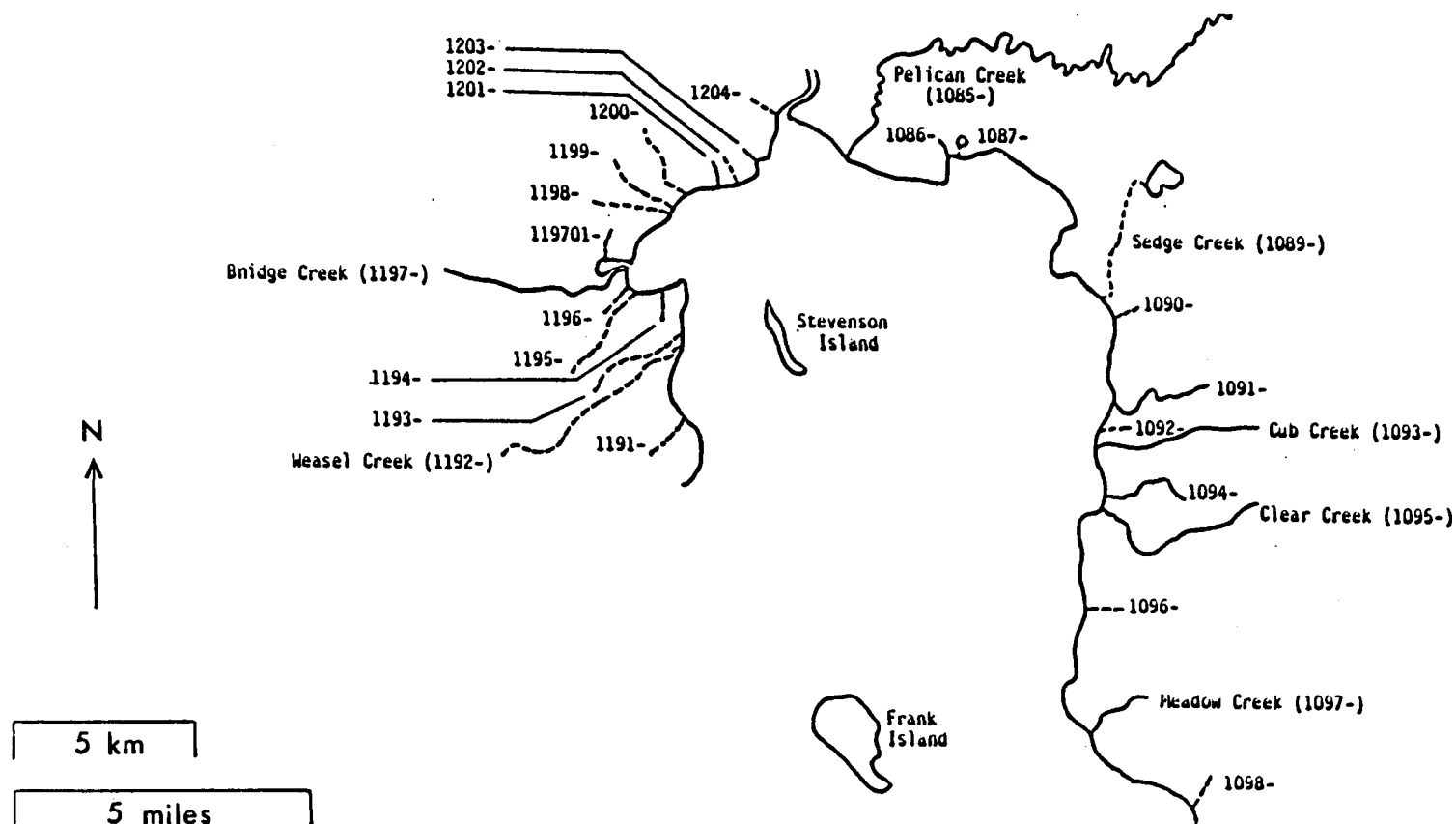


Figure 6a . Yellowstone Lake tributaries - northern area
 (——— denotes tributaries where spawning was observed in 1935)
 (---- denotes tributaries where no spawning was observed in 1985)
 (-.-.- denotes tributaries not found in 1985).

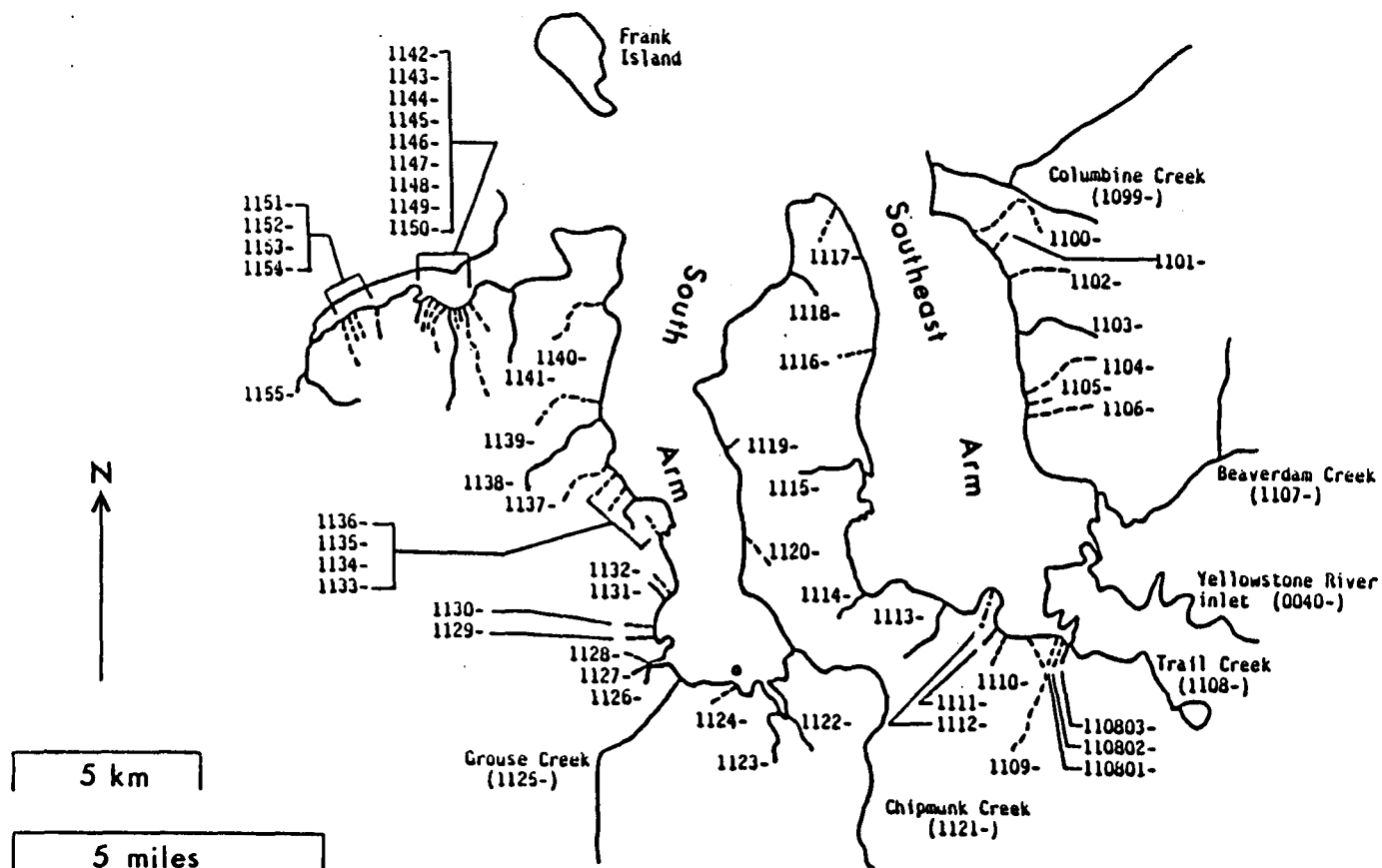


Figure 6b. (continued) Yellowstone Lake tributaries - southern area
 (—— denotes tributaries where spawning was observed in 1985)
 (--- denotes tributaries where no spawning was observed in 1985)
 (.... denotes tributaries not found in 1985).

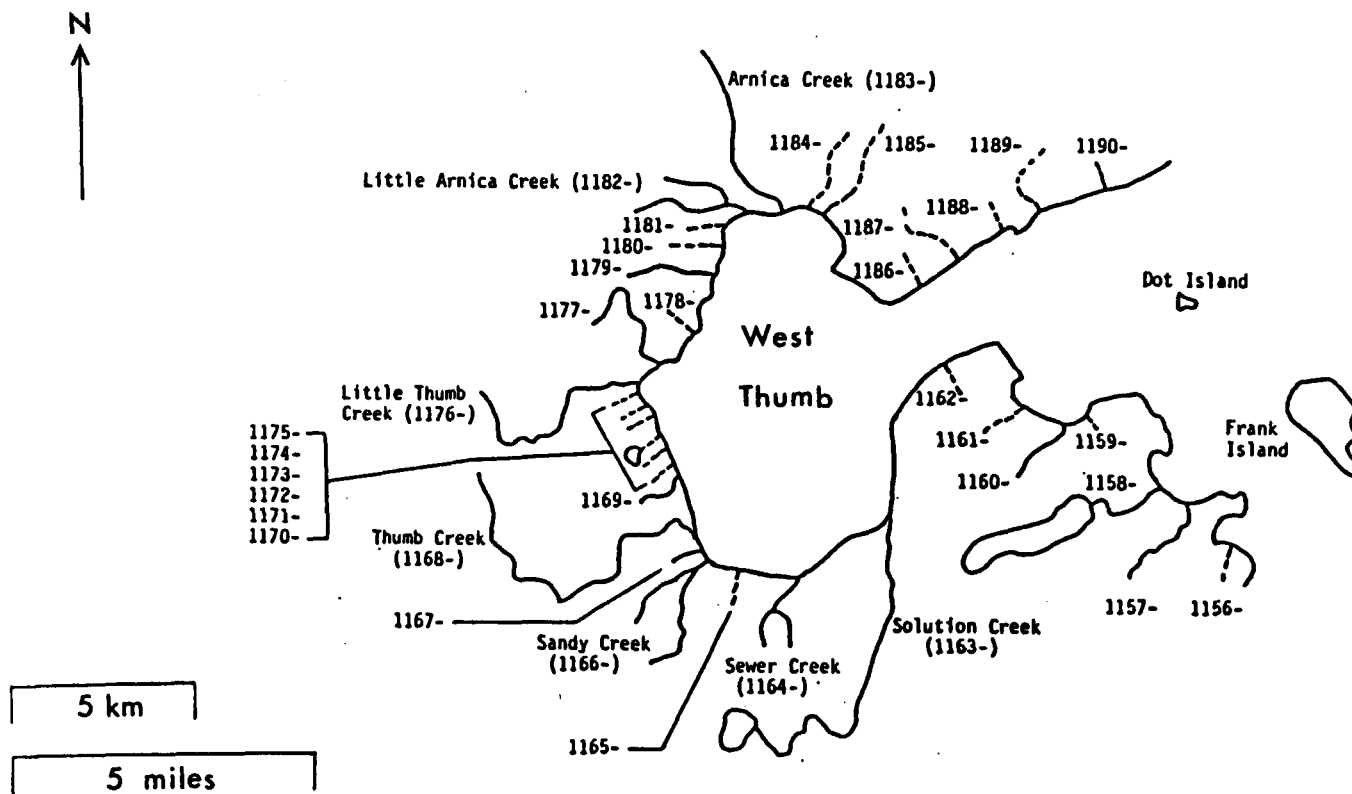


Figure 6c. (continued) Yellowstone Lake tributaries - West Thumb area
 (—— denotes tributaries where spawning was observed in 1985)
 (--- denotes tributaries where no spawning was observed in 1985)
 (.... denotes tributaries not found in 1985).

since 1974-1975. Limited sampling was also conducted by the USFWS in lake tributaries from Sedge Creek to the Yellowstone Lake outlet, and from the outlet to Sewer Creek in West Thumb (Figure 6c).

U.S. Fish and Wildlife Service personnel collected data related to spawning while IGBST biologists collected information related to bear activity in and along tributary streams. Objectives established by the USFWS in 1985 were to: (1) verify the location of Yellowstone Lake tributaries as mapped by Hoskins (1974) and USFWS (unpublished data) and determine which of these streams were used by adfluvial cutthroat trout; (2) monitor seasonal patterns of spawning migrations within tributaries; (3) measure the relative magnitude of spawning runs within tributaries; (4) investigate the population structure of spawning runs, and; (5) relate objectives 2, 3, and 4 to physical stream characteristics. Results of USFWS investigations are reported here. Reinhart and Mattson (1985) summarize information obtained by the IGBST.

DESCRIPTION OF STUDY AREA

Yellowstone Lake is an oligotrophic lake located in the east-central portion of Yellowstone National Park, Wyoming. It has an elevation of 2,357 m above MSL, surface area of 35,391 ha, mean depth of 42 m, and basin capacity of $14 \times 10^9 \text{ m}^3$ (Benson 1961). Summer surface temperatures rarely exceed 18 C, and ice covers the lake from late December until late May or early June. Gresswell and Varley (manuscript in preparation) provide a general description of the lake and fishery.

There are 124 named and/or numbered direct tributaries to Yellowstone Lake, including the Yellowstone River inlet (Figure 6a-c, Appendix Table 4) (Hoskins 1974; Varley et al. 1976). With few exceptions, tributaries south of Sedge Creek to Solution Creek are accessible only by foot, horse, or boat. In recent years, large areas surrounding these streams have been closed to visitor use during all or part of the spawning season. Tributaries between Sedge Creek and Sewer Creek flow under the main park highway before reaching the lake, and are accessible by motor vehicle; thus, human activity in these areas is generally much greater than in other lakeshore areas. Tributaries of Yellowstone Lake are closed to angling during most of the spawning season.

METHODS

Cutthroat trout spawning activity in tributaries of Yellowstone Lake was investigated from 16 May to 5 August 1985. Since many Yellowstone Lake tributaries do not appear on U.S. Geological Survey maps, maps developed by Hoskins (1974) and USFWS (unpublished data) were used to help locate streams. Verification of tributary locations along park roads (Sedge Creek to Sewer Creek) began on 16 May, and verification of backcountry stream locations (south of Sedge Creek to Solution Creek) commenced on 29 May, 1 week after ice-out on Yellowstone Lake. Backcountry streams were reached by traveling the lake perimeter in a 14-ft aluminum boat powered by a 40-hp outboard motor.

Once a tributary location was verified, possible use by adfluvial cutthroat trout was evaluated. Streams were categorized as unusable if natural or man-made barriers at the stream mouth prevented upstream migration; these streams were excluded from further sampling. Potential spawning streams were visited periodically until the presence or absence of spawning was confirmed.

When spawning in a tributary was confirmed, a 100-m long sample section was established within 1 km of the stream mouth. Sections were periodically sampled with a backpack electrofishing system; a Coffelt rectifying unit was used to output direct current. Electrofishing began at the downstream boundary of the sample section and proceeded to the upstream boundary. The total number of cutthroat trout spawners observed (number captured plus number escaped) was recorded. Captured spawners were sexed, evaluated for stage of maturity, and measured to the nearest 1 mm total length. Captured fish were released within the boundaries of the sample section.

Physical habitat measurements were made in each sample section at three cross-sectional transects. Transects were located at upstream and downstream boundaries and at the section mid-point. Stream width and a series of water depths were measured along each transect. Visual observations of dominant substrate type and physical structures which could be used as cover by spawning trout were also recorded. Discharge estimates were made at the downstream boundary of each sample section using a modification of the midsection method (Buchanan and Somers 1969). A Teledyne Pygmy Gurley meter was used to measure mean water velocities. Water temperatures were recorded with a hand-held thermometer.

RESULTS

In 1985, 116 of 124 known tributaries to Yellowstone Lake were examined for evidence of cutthroat trout spawning activity. Seven tributaries were not found by the study team (Figure 6a-b, Appendix Table 5); however, Hoskins (1974, 1975) located these seven streams. The Yellowstone River inlet was omitted from sampling due to its large size.

No spawning was observed in 68 tributaries (Figure 6a-c, Appendix Table 6). Thirty-one of these were found to have unsuitable discharge, substrate, and/or gradient. Natural physical and/or chemical barriers were apparent in an additional 15 streams, and man-made barriers that completely blocked upstream migration were found at the mouths of 2 other streams. Twenty tributaries which appeared suitable for spawning did not have spawning runs; the reasons that no spawning occurred in these 20 streams were not determined.

Spawning by adfluvial cutthroat trout was found in 48 streams (Figure 6a-c, Appendix Table 7). Nineteen of these 48 streams were not sampled; 9 had discharges too large to be effectively sampled with a backpack electrofishing unit, and 10 others had spawning runs of such short duration that spawning was completed before the streams could be sampled. The remaining 29 tributaries were periodically examined for spawning cutthroat trout and physical stream characteristics.

Distribution of spawning streams around Yellowstone Lake was evaluated by partitioning the lakeshore into six geographical zones: North, Central, Southeast Arm, South Arm, Flat Mountain Arm, and West Thumb (Figure 7). The greatest number of spawning streams was found in West Thumb, followed by South Arm, Southeast Arm and North, and Flat Mountain Arm. The least number of spawning streams was observed in Central (Table 14).

The 27 spawning streams sampled for width and depth had mean widths narrower than 4 m and mean depths shallower than 0.6 m (Table 15). Discharge data obtained from 21 streams revealed that most (90%) streams had discharges less than 0.14 m³/s; sample-section gradients in these 21 streams ranged from 1% to 8%. Limited temperature data collected from 29 creeks showed that mean water temperatures varied from 6.1 to 15.0 C. Sample-section substrates appeared to be dominated by gravel and cobble. Physical structures which were used as cover by spawning trout included undercut banks, deadfall, and overhanging vegetation; stream pools also seemed to serve as cover in some instances.

Table 14. Total number of streams known to exist and number of spawning streams found in 1985 in six geographical areas of Yellowstone Lake.

Lake area	Total number of streams known to exist in area	Number of spawning streams found in area in 1985
North	25	9
Central	14	4
Southeast Arm	24	9
South Arm	23	10
Flat Mountain Arm	15	5
West Thumb	23	11
Totals	124	48

Limited data were obtained regarding seasonal patterns of spawning migrations in Yellowstone Lake tributaries (Table 16). Spawning was in progress in 22 of the 48 spawning streams when initial visual inspections were made from 15 May to 5 June. Of the remaining streams, spawning began in 17 streams in June and in 2 streams in July; onset of spawning was not determined in 7 tributaries. Peak periods of spawning, based on electrofishing results for creeks that were sampled at least three times (n=9), occurred in June. Spawning activity presumably peaked in July in the two streams in which spawning commenced in July. Observed durations of spawning runs in the 11 streams for which complete run duration data are available were 1-5 weeks. The latest date spawning was observed in any lake tributary was 17 July; however, lack of extensive, systematic sampling after this time undoubtedly precluded determining the latest date of spawning in 1985.

Between the six lake areas, onset of spawning can be compared under the assumption that spawning began in May in those streams in which spawning was in progress when initial visual inspections were made from 15 May-5 June. In all spawning streams in North and West Thumb and in all but one spawning stream in Central, spawning began in May. In streams in Southeast Arm, onset of spawning was about equally divided between May and June. Nearly all spawning activity in South Arm and Flat Mountain Arm commenced in June (Table 16). Data were too limited to make comparisons between lake areas with regard to peak periods of spawning or duration of spawning runs.

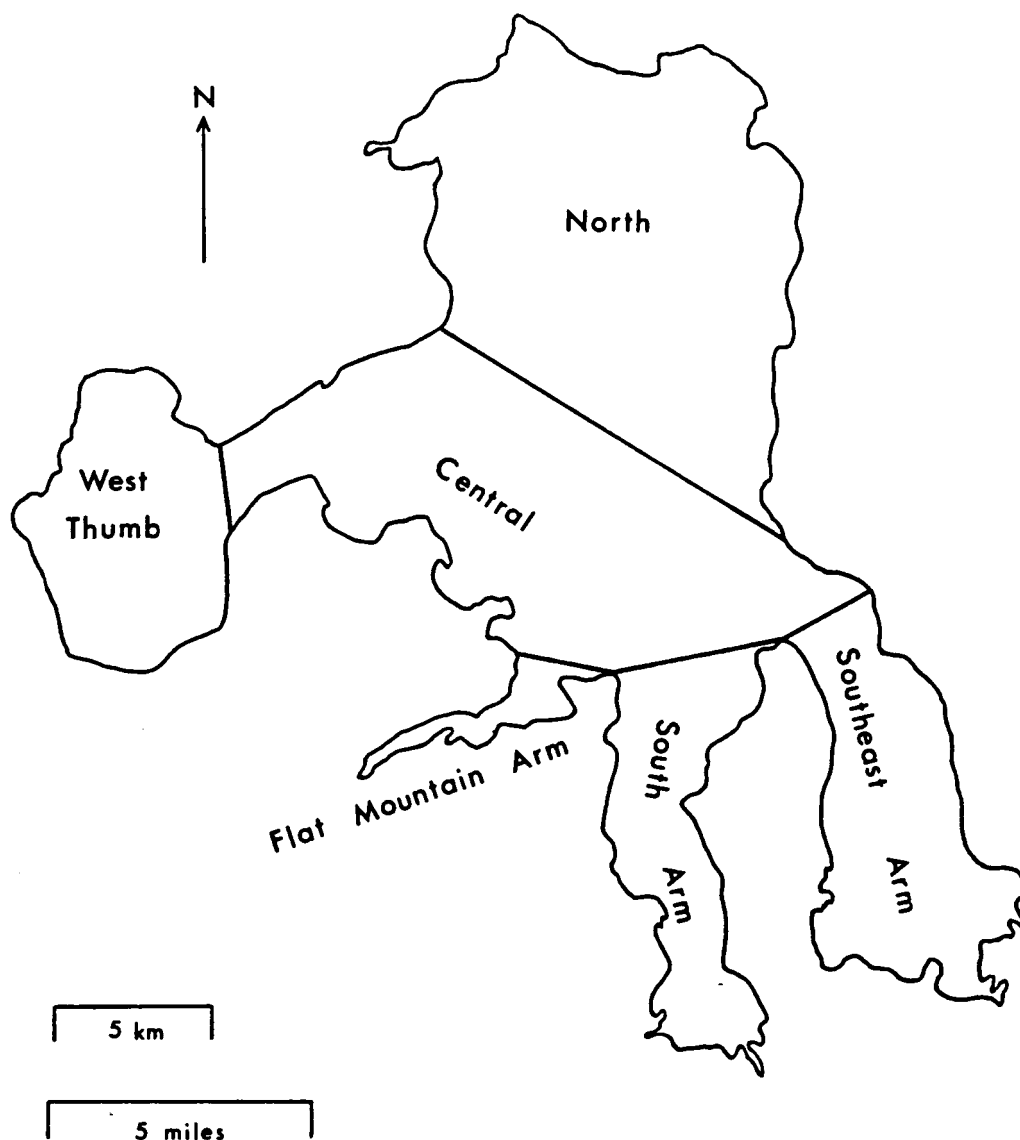


Figure 7 . Geographical zones in Yellowstone Lake, 1985.

Table 15. Physical stream characteristics measured in 29 Yellowstone Lake spawning tributaries, 1985.

Lake Area ¹⁾	Stream Number	Stream Name	Dates Sampled	Mean Width ²⁾ (m)	Mean Depth ²⁾ (m)	Mean Discharge ²⁾ (m ³ /s)	Mean Temperature ²⁾ (C)	Mean Gradient ²⁾ (%)	Dominant Substrate Type ³⁾	Cover Types Present ⁴⁾
N	1091-		6/11,18,28	1.7	0.09	0.041	6.5	4.5	G/C	UB/P/D/O
N	1094-		6/11,18,28	1.3	0.10	0.029	7.0	1.5	G	UB/D
C	1097-	Meadow Creek	6/11,18	1.6	0.59	0.458	7.0	1.0	G	UB/P
C	1158-		6/6,26	1.3	0.20	0.064	9.8	3.0	F/G	UB/P/D
SEA	1103-		6/18; 7/1,9,16	1.4	0.07	0.039	6.3	3.0	G	UB/P/D
SEA	110803-		7/1,9	1.2	0.07	0.031	8.1	2.0	G/C	UB/P/D/O
SEA	1111-		6/12,19; 7/1,9,16	1.9	0.08	0.051	12.9	5.5	G/C	D
SEA	1113-		6/12,19; 7/1,9	1.2	0.07	0.023	13.3	3.5	G/C	UB/P
SA	1118-		6/28	1.1	0.08	0.014	6.1	2.0	F	UB/P/D
SA	1122-		6/13,19	1.1	0.15	0.019	13.1	5.0	G/C	UB/P
SA	1123-		6/13,19,28; 7/2	1.0	0.10	0.024	8.6	3.0	G	UB/P
SA	1126-		6/5,19,27; 7/2	0.9	0.12	0.033	10.2	2.5	G	UB/P/D
SA	1127-		6/5,19	1.2	0.11	0.043	9.7	2.0	G	UB/P/D
SA	1131-		6/13,19,27	0.7	0.06	0.017	11.5	3.5	G	UB/D
SA	1134-		6/27	1.4	0.05	0.013	9.4	3.0	G	UB/P/D
SA	1138-		6/13,19,27; 7/2,10	1.2	0.10	0.039	9.3	4.0	G/C	UB/P/D
FMA	1141-		6/14,27	1.4	0.13	0.039	6.1	6.0	G/C	UB/P/D
FMA	1144-		7/3	1.2	0.05	0.018	11.7	8.0	C	UB/D/O
FMA	1146-		6/27; 7/3,10	1.7	0.05	0.035	10.9	6.0	G/C	UB/P/D
FMA	1150-		6/14,26	2.2	0.10	0.086	10.6	8.0	G/C	UB/P/D
FMA	1155-		6/6,26; 7/3,10	2.0	0.17	0.181	8.9	3.0	G	UB/P/D
WT	1164-	Sewer Creek	6/11	1.6	0.08		12.2			
WT	1166-	Sandy Creek	6/11	2.4	0.09		15.0			
WT	1168-	Thumb Creek	6/12	3.9	0.15		7.2			
WT	1169-		6/12	3.5	0.15		7.2			
WT	1176-	Little Thumb Creek	6/12,25; 7/1	1.7	0.13		8.2			
WT	1177-		6/12	1.5	0.24		7.8			
WT	1182-	Little Arnica Creek	6/11				12.8			
WT	1183-	Arnica Creek	6/11				11.1			

1) Lake Area Codes: N = North, C = Central, SEA = Southeast Arm, SA = South Arm, FMA = Flat Mountain Arm, WT = West Thumb.

2) Widths, depths, discharges, temperatures, and gradients listed for streams which were sampled only on one date are based on single observations and are not true arithmetic averages.

3) Substrate Codes: F = Fines (<2 mm diameter), G = Gravel (2-65 mm diameter), C = Cobble (65-256 mm diameter).

4) Cover Codes: UB = Undercut Bank, P = Pools, D = Deadfall, O = Overhanging vegetation.

Table 16. Observed dates of first and last spawning, duration of spawning run, and estimated peak period of spawning in 48 Yellowstone Lake tributaries, 1985.

Lake area ¹⁾	Stream number	Stream name	Date spawning first observed	Date spawning last observed	Approximate duration of spawning run (weeks)	Estimated peak period of spawning
N	1085-	Pelican Creek	-	-	-	-
N	1086-		6-3*	6-25	-	-
N	1091-		6-4*	6-28	-	-
N	1093-	Cub Creek	6-4*	-	-	-
N	1094-		6-4*	6-28	-	-
N	1095-	Clear Creek	5-22*	-	-	-
N	1197-		5-16*	6-18	-	-
N	1201-	Hatchery Creek	5-16*	-	-	-
N	1203-		-	6-25	-	-
C	1097-	Meadow Creek	6-11	6-28	3	-
C	1157-		5-29*	6-14	-	-
C	1158-		5-29*	6-26	-	-
C	1160-		5-29*	6-14	-	-
SEA	1099-	Columbine Creek	6-11	-	-	-
SEA	1103-		6-18	7-16	4	6/16-22
SEA	1107-	Beaverdam Creek	6-11	-	-	-
SEA	1108-	Trail Creek	6-12	-	-	-
SEA	110803-		7-1	7-9	1	-
SEA	1111-		6-12	7-16	5	6/16-22
SEA	1113-		6-5*	7-9	-	6/9-15
SEA	1114-		6-5*	6-12	-	-
SEA	1115-		6-5*	6-12	-	-
SA	1118-		6-12	-	-	-
SA	1121-	Chipmunk Creek	6-12	-	-	-
SA	1122-		6-13	6-20	1	-
SA	1123-		6-13	7-2	3	6/16-22
SA	1125-	Grouse Creek	6-13	-	-	-
SA	1126-		5-30*	7-2	-	6/2-8
SA	1127-		5-30*	6-20	-	-
SA	1131-		6-13	6-27	2	-
SA	1134-		6-20*	6-27	-	-

Table 16. continued.

Lake area ¹⁾	Stream number	Stream name	Date spawning first observed	Date spawning last observed	Approximate duration of spawning run (weeks)	Estimated peak period of spawning
SA	1138-		6-13	7-10	4	6/9-15
FMA	1141-		6-14	6-27	2	-
FMA	1144-		7-3	-	-	-
FMA	1146-		6-27	7-10	2	6/23-29
FMA	1150-		6-14	6-26	2	-
FMA	1155-		5-31*	7-10	-	6/2-8
WT	1163-	Solution Creek	5-29*	6-26	-	-
WT	1164-	Sewer Creek	5-29*	6-18	-	-
WT	1166-	Sandy Creek	5-17*	6-25	-	-
WT	1167-		5-17*	6-25	-	-
WT	1168-	Thumb Creek	-	6-25	-	-
WT	1169-		-	6-18	-	-
WT	1176-	Little Thumb Creek	-	7-17	-	6/9-15
WT	1177-		-	7-1	-	-
WT	1179-		-	7-11	-	-
WT	1182-	Little Arnica Creek	5-17*	7-1	-	-
WT	1183-	Arnica Creek	5-16*	6-18	-	-

* Denotes spawning already in progress when stream was first visited.

1) Lake Area Codes: N = North, C = Central, SEA = Southeast Arm, SA = South Arm, FMA = Flat Mountain Arm, WT = West Thumb

Maximum spawner densities observed in the 29 spawning tributaries ranged from 0 to 163 fish per 100-m sample section (Table 16). Densities tended to be highest in West Thumb, followed by Flat Mountain Arm, Southeast Arm, and South Arm. Lowest densities were recorded in North and Central (Table 17).

Table 17. Average maximum spawner densities measured in six areas of Yellowstone Lake, 1985.

	Number of spawning streams sampled	Average maximum spawner density (#fish/100 m)
North	2	4
Central	2	3
Southeast Arm	4	15
South Arm	8	13
Flat Mountain Arm	5	29
West Thumb	8	63

A total of 737 cutthroat trout spawners were captured by electrofishing in 1985 (Table 18). Mean length of captured spawners was 348 mm. Mean length of males (345 mm, n=453) was significantly less than that of females (353 mm, n=284) ($P < 0.05$). The overall male:female ratio was 1.6:1.

Mean length of captured spawners differed significantly among the six lake areas ($P < 0.001$). Mean length of spawners was largest in North and South Arm (367 and 362 mm, respectively), followed by Flat Mountain Arm (352 mm), and West Thumb and Southeast Arm (343 and 339 mm, respectively). Mean spawner length was least in Central (289 mm).

Correlations of spawning data with measured physical stream characteristics were not significant (Table 19). As a consequence, attempts to accurately predict spawning run duration, spawner densities, or mean length of spawners by linear regression analysis based on these physical characteristics were not successful.

DISCUSSION

The number of Yellowstone Lake tributaries which support spawning runs of adfluvial cutthroat trout and the distribution of spawning streams around the lake can be determined by combining the results of the current investigation with the data of Hoskins (1974, 1975). Between the two studies, all 124 known lake tributaries

Table 18. Catch statistics for 29 Yellowstone Lake spawning tributaries sampled by electrofishing, 1985.

Lake Area ¹⁾	Stream Number	Stream Name	Dates Sampled	Maximum Spawner Density ²⁾ (# fish/100 m)	Number of Spawners Captured	Mean Length ³⁾ (mm)	Number of Males	Mean Length ³⁾ (mm)	Number of Females	Mean Length ³⁾ (mm)	Male:Female Ratio
N	1091-	Meadow Creek	6/11,18,28	4	8	386	5	383	3	391	1.7:1
N	1094-		6/11,18,28	3	4	328	4	328	0	-	-
C	1097-		6/11,18	1	1	345	1	345	0	-	-
C	1158-		6/11	4	7	289	5	264	2	353	2.5:1
SEA	1103-		7/1,9	19	28	376	15	375	13	376	1.2:1
SEA	110803-		6/12,19; 7/1,9,16	3	3	341	2	327	1	370	2.0:1
SEA	1111-		6/12,19; 7/1,9	21	31	305	16	274	15	337	1.1:1
SEA	1113-		6/28	16	27	342	16	335	11	350	1.5:1
SA	1118-		6/13,19	0	0	-	0	-	0	-	-
SA	1122-		6/13,19,28; 7/2	6	3	381	2	381	1	38	.0:1
SA	1123-	Sewer Creek	6/5,19,27; 7/2	26	33	363	20	365	13	360	1.5:1
SA	1126-		6/5,19	46	58	374	34	378	24	368	1.4:1
SA	1127-		6/13,19,27	11	11	368	7	368	4	369	1.8:1
SA	1131-		6/27	4	8	354	4	330	4	377	1.0:1
SA	1134-		6/13,19,27; 7/2,10	0	0	-	0	-	0	-	-
SA	1138-		6/14,27	14	23	331	15	328	8	336	1.9:1
FMA	1141-		7/3	4	4	353	3	354	1	350	8.0:1
FMA	1144-		6/27; 7/3,10	0	0	-	0	-	0	-	-
FMA	1146-		6/14,26	12	18	316	11	307	7	331	1.6:1
FMA	1150-		6/6,26; 7/3,10	13	9	330	8	325	1	378	3.0:1
FMA	1155-	Sandy Creek	6/6,26	118	122	359	79	357	43	363	1.8:1
WT	1164-		6/11	72	47	351	30	353	17	347	1.8:1
WT	1166-		6/12	43	43	342	34	337	9	359	3.8:1
WT	1168-		6/12	33	33	342	20	336	13	351	1.5:1
WT	1169-	Thumb Creek	6/12,25; 7/1	31	24	344	16	346	8	341	2.0:1
WT	1176-		6/12	163	138	339	78	337	60	342	1.3:1
WT	1177-	Little Thumb Creek	6/11	159	49	350	25	350	24	350	1.0:1
WT	1182-		6/11	5	5	337	3	326	2	355	1.5:1
WT	1183-	Arnica Creek	6/11	0	0	-	0	-	0	-	-
Totals/Averages					737	348	453	345	284	353	1.6:1

1) Lake Area Code: N = North, C = Central, SEA = Southeast Arm, SA = South Arm, FMA = Flat Mountain Arm, WT = West Thumb

2) Maximum spawner densities listed for streams which were sampled only on one date are based on single observations and are not true arithmetic means.

3) Mean lengths listed which are based only on the measurement of one fish are not true arithmetic averages.

Table 19. Correlations (r) between spawning run duration, spawner densities, and mean length of spawners and selected physical stream characteristics for Yellowstone Lake tributaries, 1985.¹⁾

Spawning Data	Physical Stream Characteristics Measured in Sample Sections ²⁾							
	Mean Discharge (m ³ /s)		Mean Temperature (C)		Mean Gradient (%)		Number of Cover Components	
Spawning Run Duration (weeks)	0.13	(11)	-0.07	(11)	-0.09	(11)	-0.46	(11)
Average Spawner Density (# fish/100 m)	-0.01	(18)	-0.25	(18)	-0.21	(18)	0.11	(18)
Maximum Spawner Density (# fish/100 m)	0.07	(18)	0.10	(18)	0.00	(18)	0.12	(18)
Mean Length of Spawners (mm)	0.10	(18)	0.05	(18)	-0.08	(18)	0.05	(18)

1) Correlations tested at $\alpha=0.05$

2) Number of streams on which correlations are based are in parentheses.

have been examined for the presence of spawning trout, and spawners have been observed in 68 streams. The greatest number of spawning streams was found in South Arm (14), followed by West Thumb and North (13 and 13, respectively), Southeast Arm (12), Flat Mountain Arm (9), and Central (7).

In any year, however, the number of lake tributaries in which spawning occurs and/or in which young trout hatch successfully and migrate to the lake is probably less than 68. Sand spits and beaches built up by wave action may block the mouths of relatively small streams (Benson and Bulkely 1963). Spawners may be prevented from entering a creek or, if blockage does not occur until after spawning has taken place, YOY trout may be prevented from migrating downstream to the lake. Field observations in 1985 revealed that tributaries with discharges less than about $0.14 \text{ m}^3/\text{s}$ which were located on the eastern shores (windward) of North, Central, Southeast Arm, and South Arm were particularly susceptible to this phenomenon. In low-water years, some small tributaries may also dry up before eggs hatch or YOY trout migrate to the lake. Production of YOY trout from a tributary may be completely lost or severely reduced if the stream mouth becomes blocked or the stream dries up during any part of the "spawning" season.

Generally, spawning activity occurs in Yellowstone Lake tributaries from May through July. From year to year, onset and peak periods of spawning may vary 1-2 weeks (Cope 1957a) depending on water temperature and discharge patterns (Jones et al. 1985). Within a year, seasonal patterns of spawning migrations also vary among individual streams. In 1985, onset of spawning ranged from May to July, peak periods of spawning occurred in June or July, and observed duration of spawning runs was 1-5 weeks. However, data collected in 1985 were limited, so seasonal patterns of spawning migration observed are not entirely representative of patterns that occur in all lake tributaries. In some lake tributaries, spawning may commence as early as April (Jones et al. 1982), peak periods of spawning may occur in May (Welsh 1952; Benson 1960), and spawning run duration may last up to 12 weeks (Cope 1957a; Benson 1960; Ball and Cope 1961; Jones et al. 1985).

There also appears to be variation between the six lake areas in seasonal patterns of spawning migration. In 1985, spawning activity in tributaries to North, West Thumb, and Central tended to begin and peak before streams in Southeast Arm, South Arm, and Flat Mountain

Arm. Hoskins (1974) observed that many spawning runs in tributaries in the northern part of the lake and West Thumb area peaked in June, whereas spawning runs in tributaries of Southeast Arm, South Arm, and Flat Mountain Arm peaked in July.

Spawner densities measured in sample sections were used as an index of the relative magnitude of spawning runs in Yellowstone Lake tributaries, but not all spawning tributaries around Yellowstone Lake were sampled. Therefore, relationships observed in 1985 with regard to the relative magnitude of spawning runs between stream and lake areas may change when spawner-density data are collected from all lake tributaries.

In 1985, overall mean length of males was significantly less than that of females, and the overall male:female ratio (1.6:1) strongly favored males. These results are in direct contrast to male-female relationships observed at spawning traps operated in six Yellowstone Lake tributaries from 1945 to 1953 and in three lake tributaries between 1977 and 1984. From 1945 to 1953, the overall sex ratio was 0.68 males:1 female (Ball and Cope 1961), and mean length of males always exceeded that of females (Jones et al. 1978-85). Between 1977 and 1984, sex ratios ranged from 0.52 males:1 female to 0.79 males:1 female. Since data at the spawning traps were collected systematically throughout the spawning season, male-female relationships observed at the spawning traps are probably more representative of those that actually occur in spawning runs in tributaries of Yellowstone Lake.

In 1985, mean length of spawners differed significantly among some of the six lake areas. Cope (1953) found significant differences in the mean length of spawners entering Grouse Creek compared to mean lengths of spawners ascending Pelican Creek and Arnica Creek, and later Cope (1957a) speculated that significant differences in length might be used as a criterion to delineate races of cutthroat trout within Yellowstone Lake. Bulkley (1963), however, combined spawners from Grouse Creek, Chipmunk Creek, Pelican Creek, and Arnica Creek into one population based on spot counts and hyoid teeth counts. Liebelt (1968), on the other hand, identified five populations of Yellowstone Lake cutthroat trout based on serological analyses of spawners taken from the Yellowstone River outlet, Cub Creek, Clear Creek, Columbine Creek, Pelican Creek, Yellowstone River inlet, Chipmunk Creek, and Grouse Creek. Results from these studies are influenced by the fact that, prior to 1953, fish stocks in Yellowstone

Lake were mixed on an annual basis by hatchery operations (Benson and Bulkley 1963). Obviously, mean length comparisons in 1985 cannot be used alone to evaluate the hypothesis that cutthroat trout from the six lake areas constitute different races of this species.

Observations of spawning run duration, and measurements of spawner densities and mean length of spawners were not significantly correlated with mean discharge, mean water temperature, sample-section gradient, and/or the number of cover components found in a sample section. These results are not surprising since data were limited to streams where discharge during the spawning season was less than about $0.57 \text{ m}^3/\text{s}$ or where spawning run duration lasted only 1-3 weeks. Data must be collected from all Yellowstone Lake tributaries used for spawning if relationships between spawning activity and physical stream characteristics are to be accurately determined.

ARNICA CREEK RESTORATION PROJECT

Arnica Creek is a tributary to Yellowstone Lake in the northern portion of West Thumb (Figure 8). With over 44 km of flowing water, the creek lies within the largest stream drainage (5,471 ha) in this region of Yellowstone Lake. Arnica Creek empties into a 23.6 ha lagoon; the Arnica Creek lagoon is generally open to the lake except for prolonged dry periods during late summer (Welsh 1952).

Yellowstone Lake supports what may be the largest remaining population of native inland cutthroat trout (Salmo clarki bouvieri) in the world. From May through July, cutthroat trout spawners ascend approximately 68 tributaries to Yellowstone Lake (See Yellowstone Tributaries; this report). Arnica Creek sustains one of the larger spawning migrations (Ball and Cope 1961), and Benson (1961) reported that an average of 4,400 cutthroat trout entered the stream annually between 1951 and 1958. Arnica Creek was studied intensively from 1950 to 1961 (Welsh 1952; Cope 1956, 1957; Benson 1960; Ball and Cope 1961; Bulkley 1961; Benson and Bulkley 1963).

One other native fish (longnose dace Rhinichthys cataractae) and three introduced fishes (redside shiner Richardsonius balteatus, lake chub Couesius plumbeus, and longnose sucker Catostomus catostomus) also occur in Yellowstone Lake, and all five fish species have been collected in the Arnica Creek Lagoon since the late 1950's (Biesinger 1961). With the exception of the lake chub, these fishes have been collected from Arnica Creek. Since lake chub are tributary spawners (Brown 1971), this species probably utilizes portions of the creek during the spring.

On 16 May 1985, an electrofishing survey of Yellowstone Lake tributaries revealed the presence of an introduced population of brook trout (Salvelinus fontinalis) in Arnica Creek. Subsequent investigation indicated that the nonnative brook trout could not have entered Arnica Creek by natural means; they were apparently introduced by humans. Although nonnative salmonids have been stocked in the Yellowstone Lake drainage (Jones et al. 1980; Varley 1981), the brook trout in Arnica Creek represented the first established nonnative salmonid population with direct access to Yellowstone Lake and the upper Yellowstone River drainage.

The significance of the discovery of brook trout in the Yellowstone Lake drainage is related to potential harm

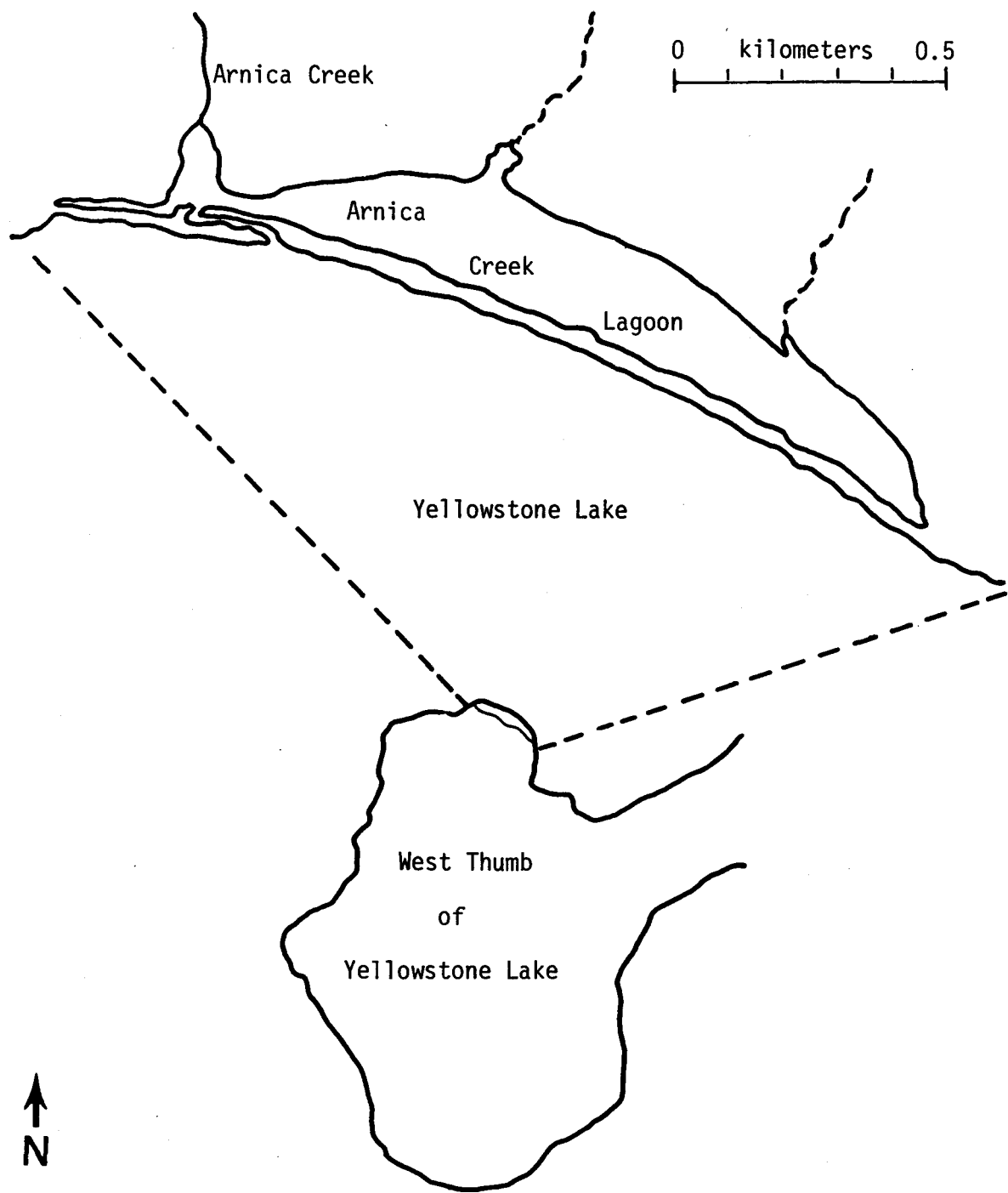


Figure 8. Arnica Creek and Arnica Creek Lagoon in relation to West Thumb of Yellowstone Lake.

to the native cutthroat trout. In many cases when brook trout have been introduced into cutthroat trout waters, brook trout have replaced native cutthroat trout (Griffith 1972; Hickman and Duff 1978). Within Yellowstone Park, brook trout have always been the dominant species in waters where brook trout and cutthroat trout coexist; in some waters, cutthroat trout have disappeared almost completely (Varley 1981). The chance of removing brook trout from the Yellowstone Lake drainage would greatly increase if they were restricted to Arnica Creek. Expansion of their range within the Yellowstone Lake drainage would greatly reduce chances of complete renovation, and the potential for a negative impact would increase abruptly.

Beyond the possible loss of the endemic cutthroat trout, the establishment of brook trout in Yellowstone Lake would have other severe ecological consequences. There are a vast number of mammals and birds, including several threatened or endangered species, which depend on the native trout as a vital food resource (Ball and Cope 1961, Davenport 1974, Mealey 1975, Swenson 1978). Large cutthroat trout are readily available throughout the spring spawning season to grizzly bears, bald eagles, osprey, and pelicans; however, the smaller, fall spawning brook trout would not be accessible during the critical spring period when some animals are raising young and others are recovering from a long winter with limited food. Additionally, native cutthroat trout support the largest fishery in the park, and there is little doubt that the quality of the fishery would diminish substantially if the larger cutthroat trout were replaced by smaller brook trout.

Initial response to the discovery of brook trout in Arnica Creek included attempts to prevent fish movement from the creek into Yellowstone Lake. A dike constructed of sandbags was initially installed on 20 May at the mouth of the lagoon, but high streamflows limited the effectiveness until 1 July. Sampling in the lagoon with gillnets (23-24 May) and electrofishing (19 June) failed to yield brook trout, suggesting that the potential for movement out of the lagoon was probably minimal.

Electrofishing surveys conducted on 28 other tributaries to Yellowstone Lake (see Yellowstone Tributaries; this report), including most major spawning streams in the West Thumb region, indicated that brook trout were limited to the Arnica Creek drainage. Within Arnica Creek, most brook trout were located in sections above the main road. Brook trout collected during these

surveys varied from age I+ to age III+; however, it appeared that most age III+ brook trout would spawn in the fall of 1985.

Since brook trout posed a significant threat to a unique natural and recreational resource, a rapid response was needed in order to curtail possible expansion of brook trout in the Yellowstone Lake drainage. An environmental assessment addressing the brook trout introduction was completed in July, and the selected alternative required the elimination of all fish in Arnica Creek and the Arnica Creek lagoon using a fish toxicant. The primary objective of this paper is to describe the resulting renovation project on Arnica Creek.

Methods

Antimycin, sold under the commercial name of Fintrol, was the selected fish toxicant. This poison has been widely used in renovation projects since the early 1960's (Lennon et al. 1970). It has been applied in several national parks (including Yellowstone) and wilderness areas in conjunction with programs designed to protect or reintroduce native fishes (Varley et al. 1976; USFWS 1985; Coman undated).

Antimycin has several qualities which were desirable for the Arnica Creek project. The specificity of this toxin is quite narrow. Walker et al. (1964) reported that at concentrations of up to 50 ppb, antimycin affected Daphnia and bullfrog tadpoles, but other invertebrates and vertebrates were unaffected. In a comprehensive literature review, Schneck (1974a) found that antimycin did affect some invertebrates; however, in most cases recovery was rapid, and it appears to do less damage to invertebrate populations than rotenone (Schneck 1974a, 1974b). Most importantly, antimycin is not hazardous to humans or other vertebrates which might drink treated water or eat poisoned fish (Herr et al. 1967).

Another important advantage of antimycin is that it does not repel target species. Repellency is especially important in areas where spring activity is great or distribution of the toxin is poor; if fish are repelled by the toxin, they will seek those areas where the toxin is absent or in lowest concentration (Lennon et al. 1970). Since rotenone is highly repellent, antimycin would probably be much more effective in Arnica Creek.

Two interrelated qualities of antimycin are a low exposure time and a rapid biodegradation. Gilderhaus

(1972) reported that the effective contact time (ECT) for rainbow trout was only 2 hours at a concentration of 5 ppb. Effectiveness increases rapidly at higher temperatures (Herr et al. 1967), and effects are irreversible after fish display the first signs of distress (Gilderhaus 1972). Natural degradation of antimycin ranges from 1 to 14 days, but it usually occurs between 4 and 7 days (Walker et al. 1964). Marking and Dawson (1972) reported that rate of degradation was directly related to temperature and pH. Low exposure time, therefore, would be especially important in cases where high temperature and pH accelerated the degradation of antimycin.

Arnica Creek

A comprehensive stream survey of Arnica Creek began on 26 June. The distribution of brook trout within the drainage was determined, and the physical attributes of the stream were mapped (Figure 9). Stream discharge was estimated periodically using the midsection method (Buchanan and Somers 1969). Flow and stream length estimates were essential for locating drip stations and estimating the amount of poison necessary to accomplish an application rate of 8 ppb.

Daily maximum water temperature in Arnica Creek generally ranged between 10 C and 16 C from May through August 1985. Given this temperature regime, a concentration of 5 ppb antimycin would have an ECT of 2 hours (Gilderhaus 1972); however, Rosenlund (personal communication) found that 8 ppb antimycin was effective for brook trout in streams in Rocky Mountain National Park. He noted that a higher concentration was often necessary in a fluvial environment.

By 15 August, much of Arnica Creek had become dry, and several sections of stream were no longer connected to the mainstem. For example, portions of tributary stream 118306- still held water, but the lower section was dry. Fish were never collected in the upper portions of the stream, and it was not treated. Final estimates for toxin were based upon approximately 16 km in the Arnica Creek drainage (Figure 9).

A total of 13 drip stations were placed within the drainage. Stations were positioned at the head of major tributaries and at several points along the mainstem. Originally each drip station consisted of a plastic carboy (either 10 l or 20 l) with a nozzle inserted on one side near the bottom. A 50 cm piece of Tygon tubing was attached to the nozzle with hose clamps, and a 1 ml

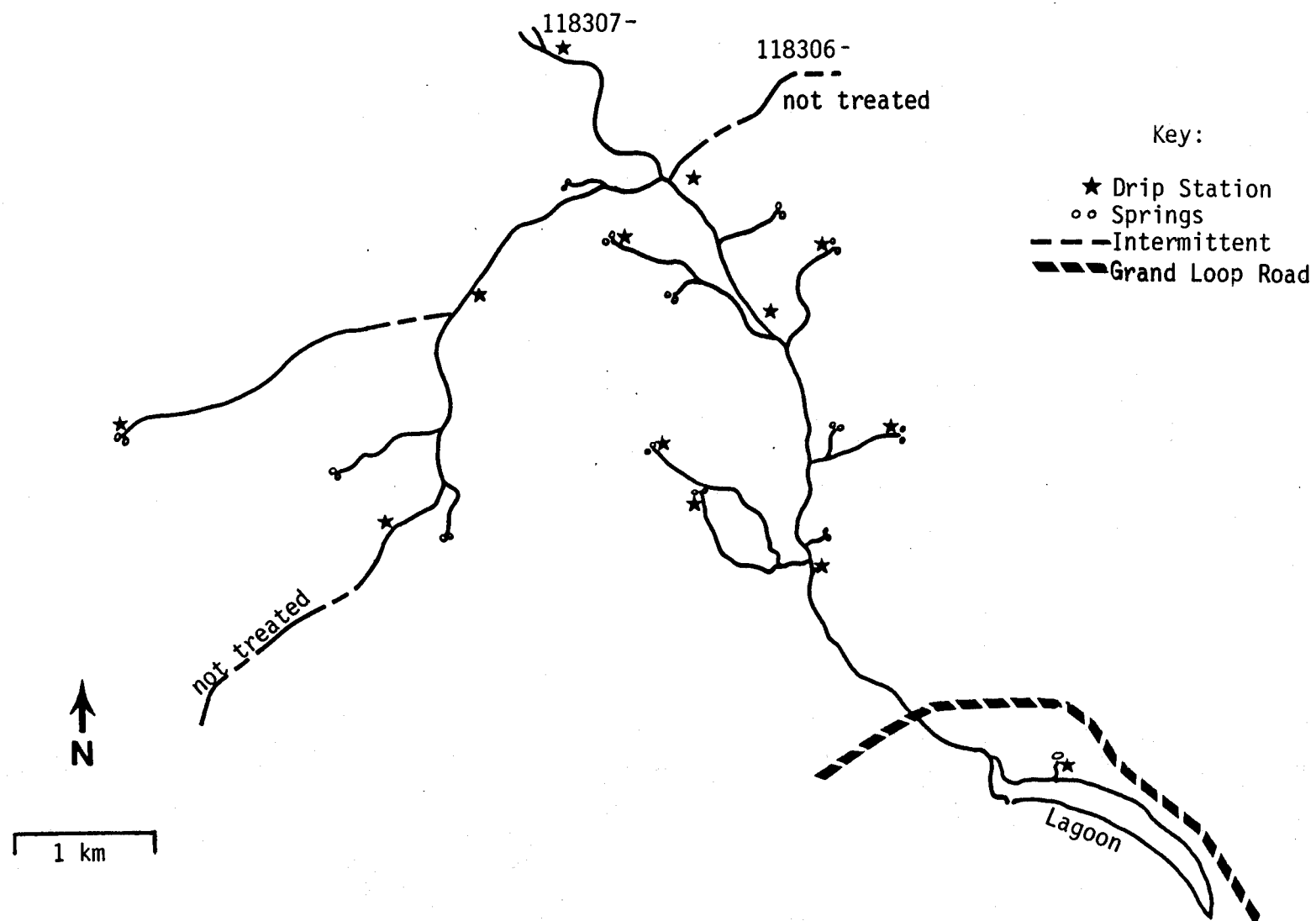


Figure 9 . Antimycin drip stations, Arnica Creek, 1985.

plastic pipette was inserted into the other end of the tubing. An adjustable metal clamp was placed on the hose to regulate flow.

In order to insure delivery of the required amount of toxin for a given streamflow, each drip station was calibrated to deliver a set rate over time. Water was placed in the carboy, and flow was adjusted until the required delivery rate was accomplished. Delivery rates changed somewhat as head pressure decreased, but in most cases, changes were negligible during initial tests.

A second type of drip station was used at three locations during the renovation project. These stations were simply "chicken waterers" available at farm supply stores. A small hole was drilled in the pan portion of each waterer, and the flow rate was estimated by measuring volume discharged in a given time period. Since head pressure is almost constant in these waterers, there was virtually no change in delivery rate. The necessary amount of toxin was calculated according to delivery rate, streamflow, and target concentration (8 ppb).

In order to estimate the amount of antimycin required to accomplish the desired concentration in Arnica Creek, discharge estimates at each station were converted to cubic meters per hour. The volume was then expanded by the amount necessary to treat approximately 1,234 m³ at 8 ppb (98.4 ml) for the required time period.

In many areas, streamflow was insufficient to provide adequate distribution of toxin, and backpack sprayers were used to apply the antimycin. All tributaries and the upper portions of the mainstem were treated in this manner.

Drip stations were started at 0630 hours on 27 August, and most remained in operation for 24 hours. Additional spraying was conducted on 28 August. Personnel attempted to collect all dead fish from Arnica Creek. Biomass estimates were made for study areas in seven stream reaches (see Stream Survey; this report), and values were expanded for the entire stream. As fish were netted, they were placed in plastic bags. Periodically, bags were relayed to vehicles, and later emptied into Yellowstone Lake. Clean-up operations continued through 28 August.

Arnica Creek Lagoon

On 27 August, flow from the lagoon outlet was blocked completely to prevent effluent from the stream or lagoon

from entering Yellowstone Lake. Retention of water within the lagoon not only made detoxification unnecessary, but effective contact time was increased in the lagoon. Since contact time was longer, target concentration was reduced to 4 ppb.

Detailed bathymetric surveys were conducted on 23 May and 14 August (Figure 10). Mean depth (1.7 m) was estimated from the resulting maps and subsequently multiplied by the surface area to calculate total volume. The amount of antimycin required to achieve the desired concentration was expanded from the amount needed to treat approximately 1,234 m³ at 4 ppb (49.2 ml).

Initial application began at approximately 0730 hours on 27 August and was completed by 1200 hours. Toxin was applied to Arnica Lagoon using venturi pumps, and antimycin was pumped into the propellar wash to enhance mixing. Two boats were used for the application. In one boat, antimycin was dispensed from a sealed 210 l metal drum fitted with a faucet. An open 130 l galvanized garbage can was utilized on the second boat, and the intake hose from the venturi was simply submerged in the can. After all of the toxin had been dispensed, the boats continued to move around the lagoon to improve mixing.

A second application began at approximately 0730 hours on 28 August. Target concentration of this application was 2 ppb. The toxin had been applied by 1030 hours; fish collection continued until 1500 hours.

In an effort to assess the success of the lagoon treatment, three largemouth gillnets were set overnight on 28-29 August, 3-4 September, and 11-12 September. Nets were set at depths from 0.5 to 3 m in open water and heavily vegetated areas.

Results

Arnica Creek

Plastic carboy drip stations did not operate as expected; tubes often became clogged, and flow was blocked completely. Although small particles in the stream water used to dilute the toxin were not always filtered effectively, in most cases an unexplained increase in viscosity reduced the flow to a negligible level.

The metal "chicken waterers" worked almost flawlessly. These stations required only occasional monitoring to

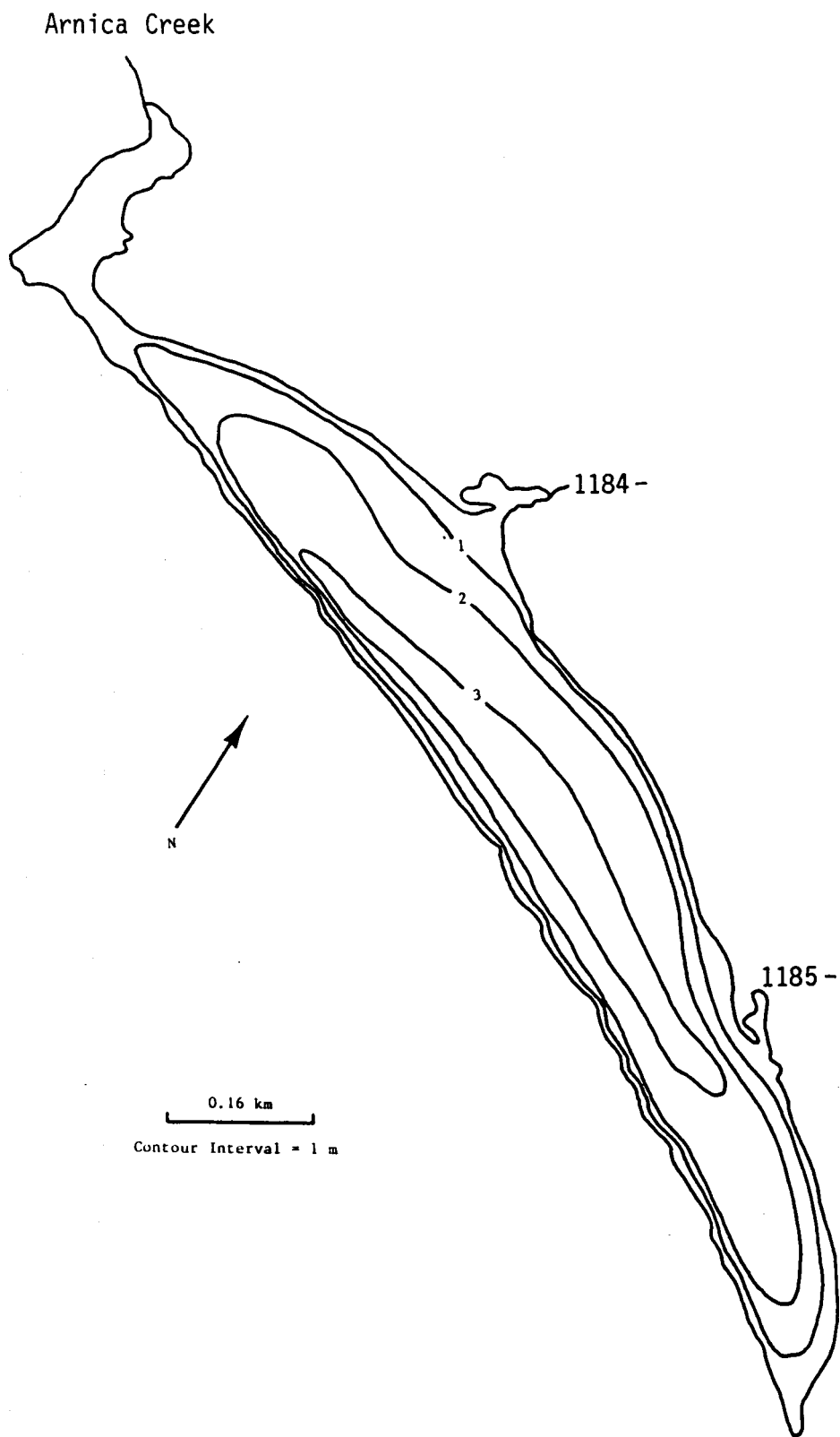


Figure 10. Arnica Lagoon, Yellowstone National Park, 1985.

prevent plugging from debris. In the event the drain hole was clogged, however, removing the problem debris was simple and took only seconds. The chicken waterers generally had a greater delivery rate and therefore, required more frequent filling.

In some areas, streamflows were so low that antimycin from the drip stations was not being distributed either downstream or within the stream channel. These areas were treated by spraying, but manpower and the amount of required toxin increased.

Expanded estimates from stream reach samples suggested approximately 12,500 cutthroat trout and 4,000 brook trout were removed from Arnica Creek (see Stream Surveys; this report). Sampled cutthroat trout (n=1,840) ranged between 27 and 261 mm (TL) with a mean of 57 mm; 90% of the cutthroat trout were less than 80 mm. A total of 577 brook trout were sampled, and mean length was 108 mm. Lengths ranged from 45 mm to 275 mm. Length frequency indicated a cluster of brook trout from 40 to 90 mm and a second group between 100 and 160 mm; only 11% of the brook trout were over 170 mm. Approximately, 850 reidside shiners and 800 longnose dace were also killed. No fish were observed during visual surveys of Arnica Creek on 29 August and 3 September.

Arnica Creek Lagoon

Substantial numbers of distressed fish first appeared at about 1500 hours in the lagoon. It became apparent, however, that the success of the lagoon operation was questionable. The second application completed on 28 August appeared to have a significant effect, and by mid-afternoon on 28 August chances of success had improved immensely.

Over 4,000 fish including longnose suckers, reidside shiners, lake chub, longnose dace, and cutthroat trout were removed from the lagoon. Shiners and small suckers were the most abundant; less than 10% of the total were cutthroat trout. Most significantly, not one brook trout was recovered from the lagoon.

Gillnets pulled on 29 August, yielded approximately 20 cutthroat trout and 10 suckers; however, only 4 cutthroat trout were captured on 3 September. No fish were captured on 13 September. These results suggest that despite a slow reaction, the renovation was also successful in the lagoon.

Discussion

Arnica Creek

Although results indicate that the renovation project in Arnica Creek was successful, the project will be repeated in 1986 in order to insure the complete removal of brook trout from the drainage. The total production of cutthroat trout from Arnica Creek will be lost for two years as an unavoidable consequence of the renovation; however, there are at least five year-classes of cutthroat trout in the lake which will be available to reestablish the spawning run. Other non-target species should redistribute when the project is completed.

It appears that the chicken waterer was the better of the two drip stations. The waterer was much simpler to calibrate, and in the field, maintaining the desired flow was easier. The fact that toxin flow is unaffected by changes in head pressure is an additional benefit of this unit. The use of a fine mesh filter when mixing desired antimycin concentrations should reduce incidence of drain plugging.

Lack of sufficient streamflow was a major problem in some areas during 1985. Rosenlund (personal communication) recommends the use of fluorescein dye prior to toxin application in order to better understand the hydrological properties of the target stream. Marking (1969) reported that antimycin is compatible with fluorescein, and therefore, the dye can also be used to monitor the movement of toxin downstream. Unless flows are significantly higher in 1986, additional backpack sprayers will be needed to treat those areas of low flow identified in dye tests.

Arnica Creek Lagoon

Dense plant growth in Arnica Lagoon appeared to have direct and indirect effects on the renovation. The physical presence of thick vegetative mats greatly impaired efforts to distribute the toxin throughout the lagoon. Although the non-repellent quality of antimycin greatly reduces the need for a complete mix, efforts to improve the distribution would probably increase effectiveness. Utilization of submerged pipes and electric pumps would allow application at a greater depth in the areas of dense vegetation.

Indirect effects of the dense vegetation including elevated pH and oxygen levels combine with increased temperature to reduce the effectiveness of the antimycin

(Marking and Dawson 1972; INHS 1975). Abundance of plants also greatly increase the surface area for toxicant adsorption, thereby reducing the effective concentration of antimycin (Lennon et al. 1970, INHS 1975).

Although the addition of the extra 2 ppb of antimycin appeared to bring the effective concentration to an adequate level, increasing the concentration to 8 ppb is recommended for the 1986 project. Bioassay experiments consisting of submerged cages with adult cutthroat trout and longnose suckers would provide an accurate measure of renovation success in the lagoon. Adult fish exhibit a greater tolerance to antimycin than juveniles (Walker et al. 1964), and suckers are less affected than trout (Gilderhaus 1972); use of both species in the bioassay would provide some measure of effectiveness over a range of target susceptibilities.

YELLOWSTONE RIVER (CATCH AND RELEASE AREA)

Approximately 14 km (8.8 mi) of the Yellowstone River between Yellowstone Lake and Upper Falls have been managed under a catch and release regulation since 1973. This area annually supports over 80% of the total angler use on the Yellowstone River (114 km or 71 mi in the park) and is the second most popular park fishery. Although there may be some interaction with cutthroat trout from Yellowstone Lake, this area is treated as a discrete fishery.

Fishery research on the Yellowstone River between the lake and the falls dates back to 1950 (Moore et al. 1952). Since that time, various studies have been conducted to monitor angler impact on this important cutthroat trout fishery. Research since 1973 has been concentrated on the evaluation of the catch and release regulation. In 1985, studies included a creel survey utilizing the VAR system (Jones et al. 1977) and continued sampling of spawning trout at LeHardy Rapids.

ANGLER USE

In 1985, angler use on the catch and release segment of the Yellowstone River (36,600 angler days) declined 18% from 1984. An estimated 16,200 anglers spent 99,400 hours and captured 90,500 cutthroat trout. Approximately 1,400 of these trout were illegally creeled. Landing rate (0.91 trout/hour) dropped to the lowest level since the catch and release regulation was implemented in 1973 (Table 20).

When the upper and lower portions of the catch and release area were examined separately, the upper section (9.8 km) sustained 93% of the angler use for the entire area (34,000 angler days or 3,500 angler days/km). A total of 14,700 anglers captured 87,200 trout while expending 94,800 hours of effort. Landing rate was 0.92 trout/hour.

The number of angler days in the lower section (2,600 angler days or 600 angler days/km) decreased almost 13% from 1984. Approximately 1,550 anglers expended 4,600 angler hours. Although effort is much lower in this section, landing rate was only 0.72 trout/hour. Expanded results indicate that of 3,300 trout landed, about 100 were illegally creeled.

Average size of cutthroat trout landed for the entire catch and release area remained at the record high of 401 mm (15.8 in). Trout from the upper portion were

Table 20. Creel survey summary, Yellowstone River between Fishing Bridge and Chittenden Bridge, 1951-1955, 1967, 1968, 1970, 1972, 1973 through 1985¹⁾.

Regulation		Angler Days (trips)	Mean Length Angler Trip (hours)	Total Hours Fished	Landing Rate	Total Trout Landed	Creel Rate	Total Trout Creel	Angler Days Per mile ²	Angler Days Per Acre ²	Angler Hours Per Acre ²	Mean Angler Expertise ³⁾	Percent Trout Landed And Released	Average Length Trout Creel ⁴⁾	Average Length Trout Landed
4.2 Fish creel limit ⁵⁾ No size limit Bait fishing permitted	1951-1955 Average	45,430	1.97	89,500	6)	6)	0.41	36,700	2,800	99	195	-	6)	6)	6)
3 Fish creel limit No size limit Bait fishing permitted	1967-1968 Average	44,300	2.00	88,625	6)	6)	0.43	38,100	4,600	167	334	-	6)	13.5"	6)
3 Fish creel limit 14" Minimum size limit Bait fishing prohibited	1970-1972 Average	45,120	1.87	84,700	0.74	62,500	0.18	14,825	4,700	170	318	-	76.2	14.7"	6)
Catch and release	1973	25,000	2.35	58,750	1.74	102,200	0.01	590	2,900	106	250	-	99.4	6)	14.3"
Lures and flies only	1974	23,900	2.31	55,700	2.25	124,200	0.01	550	2,700	102	235	-	99.9	6)	14.4"
Bait fishing prohibited	1975	27,900	2.48	69,200	2.04	141,100	0.01	690	3,200	119	295	-	99.5	6)	14.5"
	1976	30,900	2.45	75,700	1.43	108,200	0.01	980	3,600	132	322	2.00	99.8	6)	14.7"
	1977 ⁷⁾	26,900	2.44	65,600	1.43	93,900	0.02	1,300	3,100	114	279	1.98	99.6	14.3"	14.7"
	1978	26,300	2.50	65,700	1.23	80,800	0.02	1,100	3,000	112	280	1.99	99.6	13.3"	15.1"
	1979	28,900	2.60	75,300	1.10	82,800	0.02	1,500	3,300	123	320	2.02	99.3	13.2"	15.3"
	1980	34,900	2.44	85,100	1.06	88,700	0.02	2,000	4,000	148	362	2.04	99.0	13.5"	15.3"
	1981	48,800	2.60	126,800	1.00	127,100	0.01	1,800	5,600	208	540	2.01	98.6	13.1"	15.4"
	1982	35,200	2.46	86,600	1.10	95,400	0.02	1,400	4,000	150	369	2.00	98.5	12.4"	15.6"
	1983	39,300	2.61	102,400	1.06	109,000	0.01	1,400	4,500	167	436	1.98	99.8	12.5"	15.6"
	1984	44,500	2.56	114,000	0.96	109,000	0.02	2,500	5,100	189	485	2.00	97.7	11.8"	15.8"
	1985	36,600	2.72	99,400	0.91	90,500	0.02	1,443	4,200	156	423	2.02	98.4	12.7"	15.8"

- 1) Statistics for 1951 through 1972 have been converted from summer to season-long estimates.
- 2) Yellowstone River between Fishing Bridge and Chittenden Bridge is 16 miles long and averages 458 acres. Area open to fishing was 9.7 miles and 265 acres between 1965 and 1972. Beginning in 1973, the area open was 8.7 miles and 235 acres.
- 3) Based on formula: 1.0 = inexperienced, 2.0 = experienced, 3.0 = expert.
- 4) Illegal beginning in 1973.
- 5) 3 years of 5 fish creel limit plus 2 years of 3 fish creel limit.
- 6) Revised upward 6% from that reported (Jones et al 1978).
- 7) Not measured.

significantly larger than those in the lower section (402 and 362 mm, respectively). Mean length of creel-trout for the entire catch and release area was 322 mm, and mean length was greater in the upper section (381 mm and 310 mm for the upper and lower sections, respectively).

Approximately 83% of the anglers were satisfied by their overall experience, 73% were satisfied with numbers landed, and 87% were satisfied with size of fish landed. Levels of satisfaction decreased from 1984; however, estimates remain well above the park mean. The proportion of single day anglers landing one or more trout was 72%; average expertise remained high at 2.01.

LEHARDY RAPIDS

In 1973, a catch and release regulation was implemented on the Yellowstone River between Fishing Bridge and the Upper Falls (Dean et al 1974). Cutthroat trout migrating through LeHardy Rapids have been monitored annually since 1974 to evaluate the effects of this regulation on the spawning population structure. This data collection provides an alternate means of evaluating the cutthroat trout population, independent of the VAR system.

Results and Discussion

In 1985, 431 adult cutthroat trout were captured during weekly sampling between 6 June and 11 July. One subadult was captured. Visual observation indicated that the spawning run began much earlier than the start of the sampling period. This may be associated with an early spring and a 22 May ice-off date from Yellowstone Lake. Sampling was more difficult and time consuming than past years due to low run-off caused by a low snow pack (82% of normal) (Phil Farnes, Snotel, pers. comm., 1985).

Mean length of all adults was 401 mm. Mean length of males and females was 407 mm and 391 mm, respectively. Mean length for males was the same as 1984, which was the largest since sampling began in 1974. Mean length for females was the highest reported for all years. Mean length for all adults was also the longest reported length to date (Table 21 and Figure 11). The percentage of trout larger than 406 mm total length (TL) was 38%, just slightly less than 1984, but significantly higher than previous years (Figure 12).

Table 21. Total number and average length, weight and condition factor of cutthroat trout for each year sampled at LeHardy Rapids, Yellowstone River, 1974-1985.

Year	Adult Males				Adult Females				All Adults				Immatures and Subadults			
	Number captured	Average length (mm)	Average weight (g)	Average K factor	Number captured	Average length (mm)	Average weight (g)	Average K factor	Number captured	Average length (mm)	Average weight (g)	Average K factor	Number captured	Average length (mm)	Average weight (g)	Average K factor
1974 ¹⁾	177	375	394	0.75	244	352	339	0.78	453	362	363	0.76	43	177	60	0.84
1975	338	385	451	0.78	426	359	363	0.78	775	370	401	0.78	40	205	118	1.04
1976 ¹⁾	531	384	431	0.75	423	362	360	0.75	964	375	399	0.75	29	173	71	1.04
1977 ¹⁾	133	382	429	0.77	111	362	370	0.78	245	373	402	0.77	2	250	139	0.87
1978	399	386	458	0.78	358	364	413	0.85	759	376	437	0.81	68	169	62	0.96
1979	334	394	514	0.83	237	371	431	0.84	571	385	480	0.83	5	225	122	0.91
1980	293	391	488	0.81	190	372	418	0.80	483	384	460	0.81	2	247	184	0.94
1981	383	394	496	0.80	188	373	440	0.84	571	387	478	0.82	7	308	286	0.89
1982	327	401	517	0.80	367	380	474	0.86	694	389	494	0.83	26	281	218	0.90
1983	338	402	546	0.83	232	380	276	0.86	570	394	517	0.84	1	225	100	0.88
1984 ²⁾	321	408	539	0.79	199	386	477	0.82	526	399	515	0.80	0	---	---	---
1985 ²⁾	269	408	554	0.82	161	391	513	0.85	431	402	539	0.83	1	199	70	0.89

1) Due to erroneous measurements, fish were deleted from average weight and K factor calculations only, as follows: 6 males and 2 females from 1974, 1 male and 2 females from 1976, and 1 male and 1 female from 1977.

2) Six adults in 1984 and one adult in 1985 were not identified to sex.

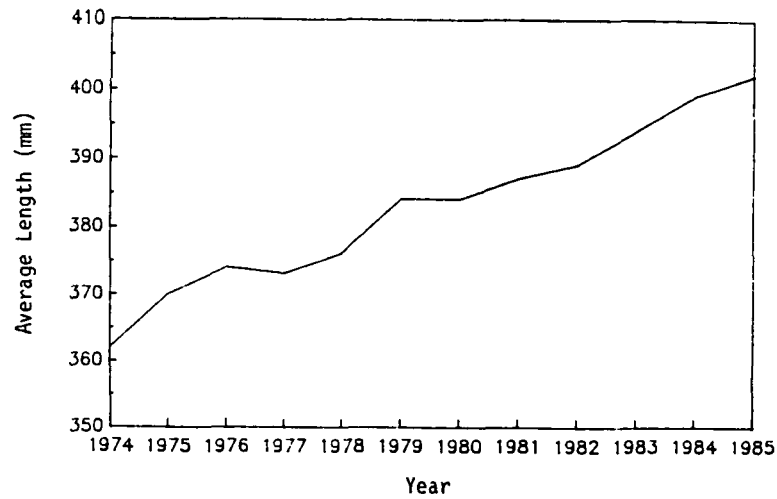


Figure 11. Average length for the entire season for all adults, LeHardy Rapids, 1974-1985.

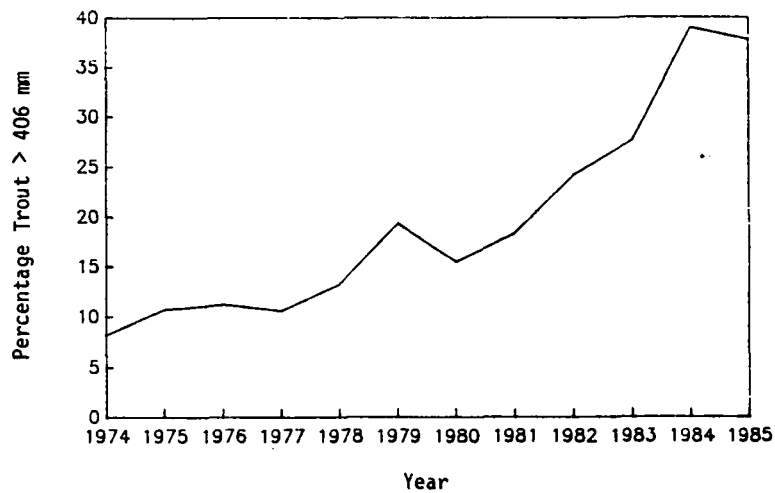


Figure 12. Percentage of adult trout greater than 406 mm captured at LeHardy Rapids, 1974-1985.

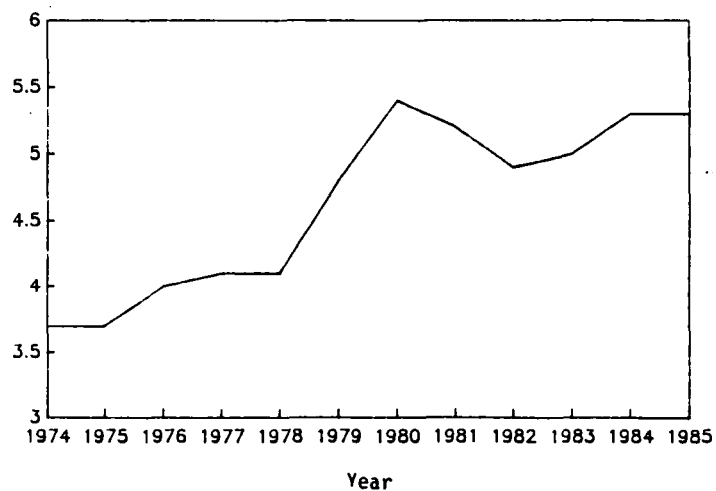


Figure 13. Average age of all adult trout captured at LeHardy Rapids, 1974-1985.

Mean weight of all adults was 539 g. Mean weight of males and females was 554 g and 513 g, respectively. These figures are the highest mean weights reported to date.

Mean condition factor for the spawning population was 0.83. Mean K for males and females was 0.82 and 0.85, respectively. Mean K for all adults was higher than the 12 year average of 0.80.

In 1985, the male:female ratio of 430 adults was 1.67:1. Since 1977, male:female ratios at LeHardy Rapids have ranged from 0.89 to 2.04:1.

Average age of an expanded sample of 423 fish (5.3 years) was the same as 1984 and the highest since 1980 (Figure 13). Average age of males and females was 5.4 and 4.9 years, respectively.

The increase in mean length and weight of all adults, and the general trend of increased mean age over the past 12 years (Figures 11, 12, and 13) suggest that the catch and release regulation has had a positive impact on cutthroat trout migrating through this portion of the Yellowstone River. By substantially reducing angling mortality, the population has exhibited a trend towards larger and older fish.

During 1984 and 1985, the largest weekly numbers of trout captured occurred before peak flow was achieved in the the Yellowstone River at Fishing Bridge (Figure 14). This pattern differs from that observed in Clear Creek, a spawning tributary to Yellowstone Lake. In 1984, discharge at Clear Creek peaked at approximately 26 June. The greatest numbers of upstream fish observed occurred after peak water flow (4 July-13 July). Downstream numbers peaked during the period of 17 July-24 July.

Efforts to understand the timing and pattern of the cutthroat trout spawning migration at LeHardy Rapids have continued since 1974. Water temperature has been obtained on each sample date and each year the date of ice-out on Yellowstone Lake has been recorded. Preliminary analysis suggested that both temperature and the number of days elapsed since ice-out were positively correlated to the number of trout captured ($r=0.93$) and $r=0.86$, respectively). Additionally, a distinct interaction between temperature and days was suggested by a positive correlation between the two variables ($r=0.89$). Temperature, days since ice-out, and an interaction term (temperature x days) were subsequently

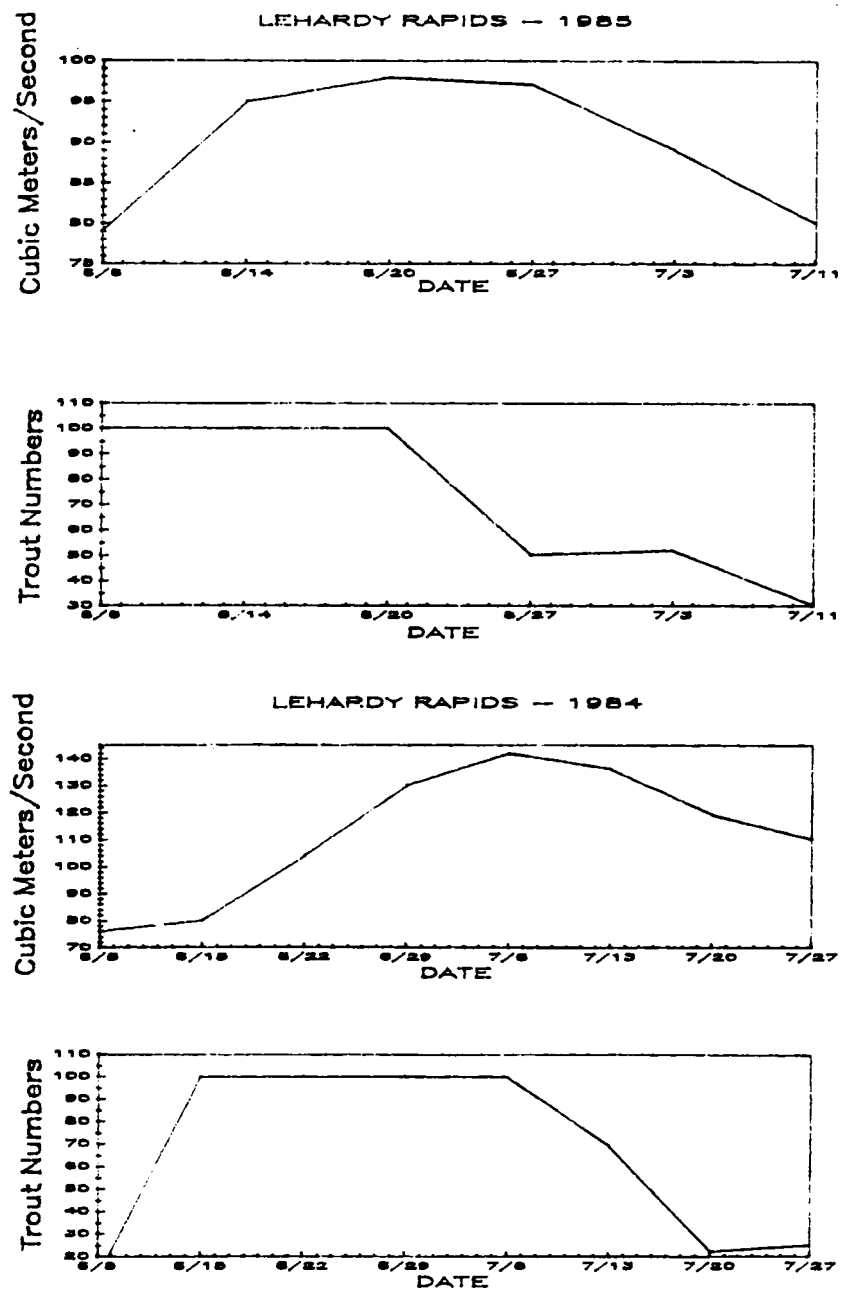


Figure 14. Comparison of discharge pattern in the Yellowstone River (USGS 1935) and trout numbers captured at LeHardy Rapids, 1984-1985.

tested as independent variables in a multiple regression analysis with the number of trout captured as the dependent variable. The resulting equation suggested that the independent variables may account for 95% of the observed variability in the number of cutthroat trout captured annually at LeHardy Rapids.

CONCLUSION

Angler use and effort have increased steadily since the catch and release regulation was implemented in 1973. Despite a precipitous decline in use after this regulation was initiated, current levels remain high (Table 20). These figures equated to 2,600 angler days/km (4,200 angler days/mi), or 385 angler days/ha (156 angler days/acre) in 1985. According to these data, the catch and release portion of the Yellowstone River sustains the highest level of use in the park and is probably one of the most intensively fished wild trout fisheries in North America. Angler effort per unit area on this section of the river (1,000 angler hours/ha or 423 angler hours/acre) remains extremely high (Table 20).

Increasing use and effort have affected the landing rate. As effort declined after implementation of catch and release, landing rate more than doubled and rose to a high of 2.25 trout/hour in 1974 (Table 20). As effort increased, landing rates gradually declined. The sharp drop in landing rate during 1985 is significant, and monitoring activities may need to be increased if this indicator continues to decline. Despite record levels of effort, however, landing rate remains over 0.90 trout/hour.

Regardless of increases in effort and concomitant decreases in landing rate, size structure of the population appears to be moving toward historic proportions. Length-frequency analysis of cutthroat trout captured in the spawning run at LeHardy Rapids reveals a definite shift towards larger trout (Figures 11 and 12, Table 21, and Appendix Table 8). Length frequency and mean length of cutthroat trout landed by anglers also indicates a substantial increase in larger trout (Tables 20 and 22). A general rise in average age has accompanied the increase in size at LeHardy Rapids.

Although there is an inverse relationship between effort and landing rate, changes in population structure have also influenced landing rate. As biomass shifts toward older and larger trout, the number of trout will

probably decrease (Nikolskii 1969). The interaction of these two factors (increases in effort and shifts in structure) may continue to lower landing rates in the future.

Table 22. Percentage of trout in various length categories, catch and release section, Yellowstone River, 1973-1985.

Year	305 mm	356 mm	406 mm	457 mm	508 mm
1973	86.3	62.5	17.3	3.1	0.7
1974	89.5	63.3	26.6	6.6	1.2
1975	92.7	60.4	15.4	2.6	0.3
1976	90.0	67.7	24.3	4.4	0.7
1977	89.2	68.7	26.2	5.3	0.9
1978	91.1	71.6	33.2	9.0	1.8
1979	92.5	77.5	35.9	8.7	1.0
1980	93.8	77.8	37.6	9.2	1.2
1981	95.4	82.6	35.8	7.6	1.1
1982	96.4	82.3	40.7	8.6	1.5
1983	96.7	85.9	39.9	10.7	2.3
1984	95.9	84.3	46.6	12.3	1.9
1985	95.7	84.5	47.8	12.7	2.6

Hooking mortality and recatchability are critical to the success of the catch and release regulation. Schill et al. (In press) report hooking mortality of 0.3% on a per capture basis, or 3% of the total population for a portion of the upper catch and release section. The recatchability of the cutthroat trout is evidenced in these estimates. Comparison of total landings for the upper portion of the catch and release section (123,800 cutthroat trout) and population estimates for the 9.8 km segment (1,750 trout/km) suggests that trout may be captured an average of seven times during the 108 day season. This figure emphasizes the value of the catch and release regulation and illustrates how such a regulation can support high levels of effort on a cutthroat trout fishery.

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

and excellent habitat conditions in this portion of the Yellowstone River undoubtedly contribute to the continued success of the catch and release regulation.

LAKE SURVEY PROGRAM

INTRODUCTION

Since 1963, data describing physical, chemical, and biological parameters of 112 park lakes have been collected in conjunction with the lake survey program. The objective of this program is the fundamental inventory of lacustrine systems which provide baseline data necessary to assess changes through time. Analysis of angler impact is an integral part of this program and has been utilized to monitor the effects of various angling regulations. In 1985, an aquatic survey was conducted on one lake.

METHODS

Although sampling techniques have varied during the past 22 years, data are reasonably comparable. With few exceptions, current methods are those described by Dean and Mills (1970). Since 1974, one water sample from each lake has been comprehensively analyzed by a commercial laboratory. In order to enhance comparability, additional samples have been collected for many of the lakes surveyed prior to 1974.

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

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

A methodology for utilizing electrofishing for monitoring fish populations in roadside lakes was developed and tested in 1985. Electrofishing from a boat with boom-mounted dropper electrodes (Novotny and Priegel 1974) was used to collect fish in mark and recapture runs. Pulsed direct current (80 pulses/s) was utilized with a voltage between 100 and 200 volts. Electrofishing was conducted at night, and sampling was

limited to shallow water sections (<1.2 m) of the littoral zone.

During the marking run, captured fish were measured to the nearest 5 mm total length (TL) and fin-clipped prior to release. The recapture run was conducted approximately 48 hours later. Length (nearest 1 mm TL) and weight (nearest 2 g) measurements were obtained from a sample of all fish species; scales were collected from a subsample of these fish for age determination. Remaining fish were measured to the nearest 5 mm (TL). All fish were checked for fin-clips prior to release.

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

SYLVAN LAKE

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

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

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

Arnold and Sharpe (1967) conducted the initial survey of Sylvan Lake in 1966. In 1978, the lake was resurveyed to provide baseline data necessary for evaluation of the

catch and release regulation. A third survey, conducted in 1981, revealed a significant increase in the density of longnose suckers and a decline in cutthroat trout numbers despite the catch and release regulation. Trout size structure appeared stable, however, and VAR data indicated a significantly improved landing rate despite increases in angler use.

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

In accordance with these recommendations, an abbreviated survey was conducted on Sylvan Lake from 6 to 8 July 1985. In addition to the continued evaluation of the cutthroat trout and longnose sucker populations within the lake, an attempt was made to develop a method of population monitoring utilizing electrofishing.

Physical

Jones et al. (1979) provided a detailed description of physical characteristics of Sylvan Lake and the surrounding drainage. During the current survey, secchi disc visibility was 6.4 m through dark-green waters on a calm, partly cloudy day. Water temperature ranged from 14.7 C at the surface to 11.1 C at the bottom (7.3 m), but stratification had not occurred.

Chemical

Nutrient concentration (TDS=32.5 ppm) was the lowest yet reported for Sylvan Lake (Table 23); however, observed variation in TDS is probably related to annual fluctuations in total lake volume. Sylvan Lake can be classified as a dilute water (TDS<50 ppm) on the basis of the mean of four water samples collected since 1978. Although levels of most chemical constituents have been above the mean for dilute park waters, they are well below average for more concentrated (TDS>50 ppm) waters. Predominant ions were calcium and bicarbonate. Nitrate and phosphate were again below levels detectable by current analytical techniques (<0.01 and <0.03 ppm, respectively); silica levels were well below the park mean for dilute waters.

Table 23. Sylvan Lake water chemistry, 1978-1985.

	1978	1981	1984	1985
Water Temperature C*	12.8	16.9	16.9	14.7
Spec. Cond. mhos*	79	80	72	-
pH*	7.6	7.4	7.3	7.7
Dissolved Oxygen*	7.2	7.4	7.8	7.6
Secchi (m)*	5.8	6.1	6.7	6.4
Pheno. Alkalinity	0	0	0	0
Total Alkalinity	30	48	33.4	35.9
Ca Hardness	16	48	24.8	24.2
Total Hardness	20	66	32.0	30.5
Total Diss. Solids	50	66	48	32.5
Carbonate Alk.	0	0	0	0
Bicarbonate Alk.	30	48	33.4	35.9
Carbonates	0	0	0	0
Bicarbonates	37	59	40.7	43.8
Hydroxides	0	0	0	0
Carbon Dioxide	2.5	3.9	1.72	2.0
Chloride	1.1	<3.0	<1.0	<1.0
Sulfate	4.0	4.0	2.4	1.8
Fluoride	<0.1	0.12	0.046	0.044
Phosphate	<0.06	0.09	<0.03	<0.03
Potassium	0.3	<1.0	0.29	<1.00
Mg Hardness	4	18	7.27	6.29
Calcium	6.4	19	9.91	9.68
Magnesium	1.0	4.4	1.77	1.53
Sodium	2.2	2.7	2.69	3.62
Iron	0.02	0.01	<0.10	<0.10
Manganese	<0.05	<0.05	<0.05	<0.05
Copper	<0.1	<0.3	0.01	<0.01
Silica	3.0	1.8	3.74	2.9
Color (PCU)	0	0	0	5
Turbidity (NTU)	0.38	0.69	0.2	0.9
Total Organic Carbon	3.7	4.9	6.6	-
Ortho-phosphate	<0.06	0.09	<0.03	-
Kjeldahl N	0.05	0.12	-	-
Nitrate N	0.12	<0.02	<0.1	-

* Field measurements, all others made by commercial laboratory.

Aquatic Vertebrates

Approximately 4 hours of electrofishing effort were expended on each sample night (6 and 8 August). Combined marking and recapture runs yielded 933 cutthroat trout and 263 longnose suckers; no other aquatic vertebrates were captured.

Cutthroat Trout

Total length of cutthroat trout ranged from 80 to 310 mm with a mean of 204 mm (Table 24). Mean length of 275 marked trout (218 mm) was significantly greater than mean length of 658 trout in the recapture sample. Mean weight and condition factor (K) were 98 g and 1.14, respectively, for 100 trout in the recapture sample; average length in this subsample was 201 mm. The length-weight equation was: $\log W = 2.3127 (\log L) - 7.8078$ (GM equation: $\log W = 2.3348 (\log L) - 7.9237$).

Age was determined for 45 cutthroat trout using the scale method (Lagler 1956); 9 of these trout failed to form an annulus at the end of the first growing season (Laakso and Cope 1956). Ages were expanded for 753 trout using an age-length key (Westerheim and Ricker 1978). Mean age was 2.7 years with ages ranging from I+ to VI+ (Table 25). Back-calculated lengths at annulus formation were 67, 130, 193, 225, and 234 mm for ages I-V, respectively (Table 26).

Although differences in sample methods used to collect trout from Sylvan Lake may confound comparisons, similarity in mean length of trout sampled in 1984 and 1985 suggests that length estimates remain comparable. Current results indicate that the increases in mean length since 1978 (Jones et al. 1985) continued during 1985. Length-frequency analysis supports this conclusion; the proportion of trout greater than 254 mm is greater than in any year since 1966 (Figure 15). Length-frequency data do differ greatly from 1984, however, and the influence of sampling technique cannot be ignored. Greatly increased sample size obtained with electrofishing should enhance precision, however, and improve monitoring capabilities.

Mean age also increased during the current study, but back-calculated lengths suggest that growth has remained fairly stable (Tables 25 and 26). The number of age groups returned to five in 1985. Increases in mean age suggest a possible shift towards older trout as a result of reduced harvest under the catch and release only regulation.

Table 24. Results from fishery surveys, Sylvan Lake, 1964 through 1985.

Species	Year	Number of Nets ¹⁾		Total Number Captured	Length (mm)			Weight (g)			Mean K Factor
		Largemesh	Smallmesh		mean	n	range	mean	n	range	
Cutthroat Trout	1964 ²⁾	-	-	59	239	59	185-300	-	-	-	-
	1966 ³⁾	2	0	76	242	76	110-365	-	-	-	-
	1978 ⁴⁾	2	2	590	177	590	75-330	125	92	16-338	0.96
	1981 ⁵⁾	2	1	200	167	190	75-307	81	96	6-216	0.83
	1984 ⁶⁾	2	1	132	198	132	88-272	81	132	8-234	0.92
	1985	electrofishing		933	204	933	80-310	98	100	16-258	1.14
Longnose Sucker	1978 ⁴⁾	2	2	46	194	40	173-212	96	15	70-118	1.17
	1981 ⁵⁾	2	1	123	253	112	125-360	321	77	40-572	1.12
	1984 ⁶⁾	2	1	50	294	50	122-387	317	50	22-608	1.12
	1985	electrofishing		263	162	263	75-435	48	24	22-120	1.36

- 1) Largemesh: monofilament experimental gillnets 38.7 m long x 1.5 m deep with 7.6 panels of 19, 25, 32, 38, and 51 mm bar mesh; smallmesh: monofilament experimental gillnets 30 m long x 1.8 m deep with 7.6 m panels of 10, 13, 16, and 19 mm bar mesh.
- 2) Unpublished data collected in 1964; 50 trout captured by electrofishing and 9 trout captured in a single largemesh gillnet.
- 3) Arnold and Sharpe 1967.
- 4) Jones et al. 1979.
- 5) Jones et al. 1982.
- 6) Jones et al. 1985.

Table 25. Age frequency (by percentage) of fish captured in Sylvan Lake, 1966-1985.

Species	Year	Sample size	Percentages in each age						Mean age (years)
			I	II	III	IV	V	VI	
Cutthroat Trout	1967 ¹⁾	9	11	78	11				2.0
	1978 ²⁾	349	32	47	17	3	<1	<1	1.9
	1981 ³⁾	161	44	28	25	2	1		1.9
	1984 ⁴⁾	132	21	53	26				2.1
	1985	753	16	28	30	24	2		2.7

1) Arnold and Sharpe 1967.

2) Jones et al. 1979.

3) Jones et al. 1982.

4) Jones et al. 1985.

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Table 26. Back-calculated total length at annulus formation of fish captured in Sylvan Lake, 1966-1985.

Species	Year	Sample Size	Annulus					
			I	II	III	IV	V	VI
Cutthroat Trout	1966 ¹⁾	9	96	198	283			
	1978 ²⁾	67	71	142	202	264	289	290
	1981 ³⁾	42	58	144	201	229	283	
	1984 ⁴⁾	79	64	151	214			
	1985	45	67	130	193	225	234	

1) Arnold and Sharpe 1967.

2) Jones et al. 1979.

3) Jones et al. 1982.

4) Jones et al. 1985.

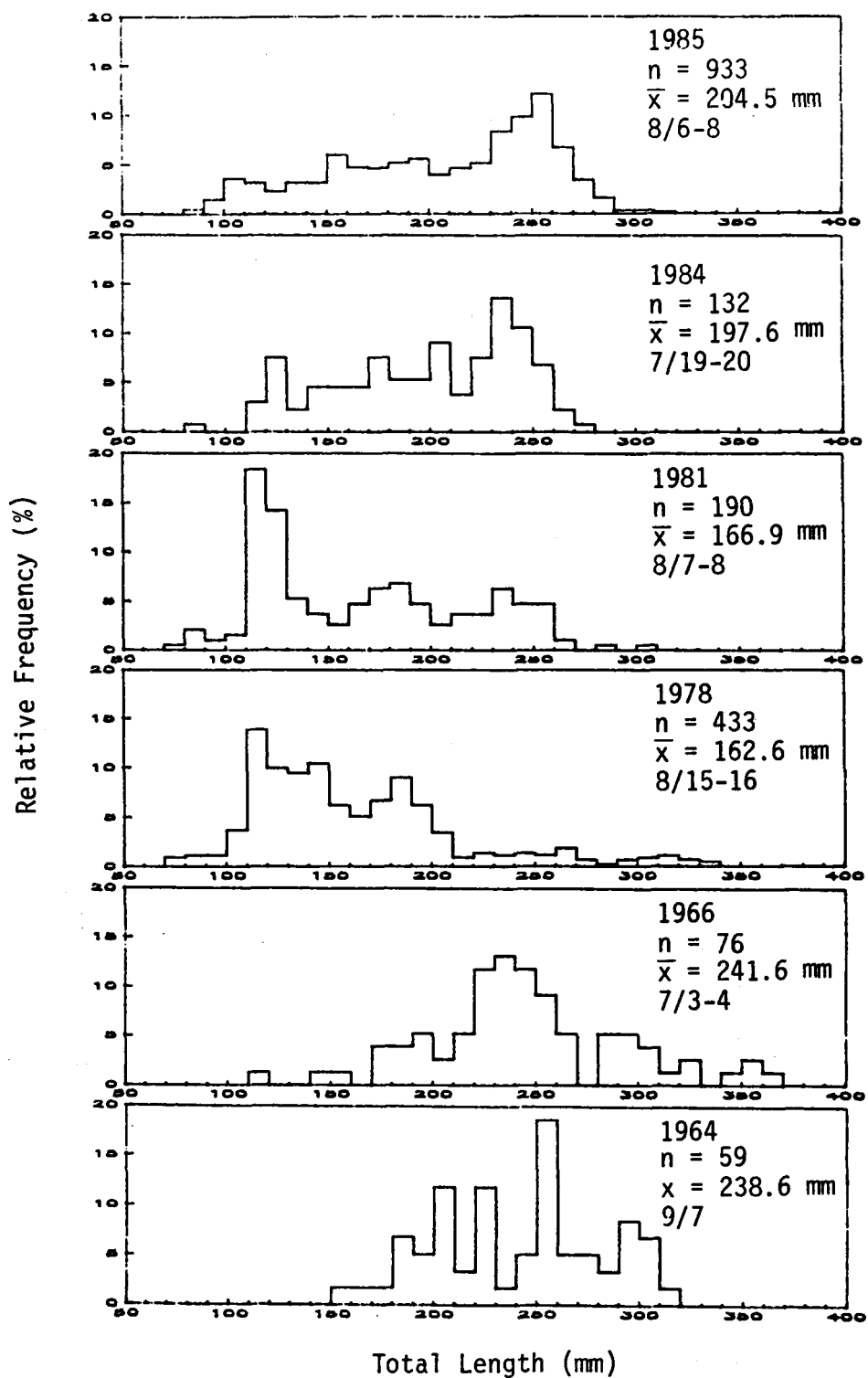


Figure 15. Length frequency of cutthroat trout captured in experimental gillnets (1964, 1965, 1978, 1981, and 1984) and by electrofishing (1964 and 1985), Sylvan Lake.

Previous relative density comparisons using gillnetting data have been hampered by extreme variation associated with the number of trout captured per net (Jones et al. 1977). Most backcountry lake surveys include overnight gillnet sets composed of 1 largemouth and 2 smallmouth gillnets; current sample size estimates (Snedecor and Cochran 1969), based on data from gillnets set in Sylvan Lake (1981 and 1984), suggest that the minimum detectable difference between samples would be approximately 200 to 300% of the mean number per net. In order to detect a difference of 30% of the mean, from 145 to 295 sets would be required annually. Data indicate that limiting comparisons to largemouth nets alone might reduce variation, but estimates based on the largemouth gillnetting on Yellowstone Lake (see Largemouth Gillnetting; this report) reveal that 58 gillnet sets would be necessary annually in Sylvan Lake to detect a difference of 30% of the mean.

The number of gillnet sets necessary to obtain statistical comparability of catch per net data greatly reduces the usefulness of this sampling technique as a monitoring tool for backcountry lakes. Although mean length data from trout captured in gillnets may provide some meaningful comparisons between years, results from Yellowstone Lake suggest that year-class strength may confound these results also (Jones et al. 1984).

Gillnets are still a necessary component of the lake survey program. They provide important information on species composition, and because gillnets sample areas not accessible to electrofishing, they are useful for describing fish distribution. Additionally, number per net comparisons have some utility when relative density differences are great; however, gillnet estimates of relative density apparently lack sensitivity necessary for annual monitoring.

Population estimates from shallow portions of the littoral zone may provide density values with the precision required for monitoring purposes. Such approximations would not produce accurate estimates of a total lake population but should yield a valuable index of density which is directly comparable between years.

In 1985, population estimates were calculated separately for 40-mm length groups in order to enhance comparability with future samples (Table 27). Estimates were statistically biased (Robson and Regier 1964) for the 80 to 120 mm size groups, but all other estimates were statistically unbiased. The total population estimate for the sample area (4,240 cutthroat trout) was derived by

Table 27. Population estimates¹⁾ for cutthroat trout captured by electrofishing shallow (<3 m depth) littoral areas, Sylvan Lake, 1985.

Size Class (mm)	Mean Length (mm)	Number Marked (M)	Number Sampled (N)	Number Recaptured (R)	Population Estimate	Confidence Limits		Efficiency ²⁾ (%)
						Upper	Lower	
80	106	9	73	1	370 ³⁾	7400	132	11
120	144	30	108	8	375	994	214	27
160	180	53	134	6	1041	3314	556	11
200	223	66	140	8	1050	2779	598	12
240	256	111	187	14	1404	2735	896	13
Total	201				4240			

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

2) R/M (Ricker 1975).

3) Estimate is statistically biased (Robson and Regier 1964).

summing estimates for the various length intervals. A separate estimate calculated from pooled mark and recapture samples yielded 4,769 trout; upper and lower confidence limits were 6,990 and 3,553, respectively.

The sample area in Sylvan Lake covered approximately 27% (3.1 ha) of the entire surface area. Total biomass of cutthroat trout (420.7 kg) was calculated by multiplying the population estimate for each size interval by the mean weight of fish in the interval. Biomass of trout inhabiting the sample area, therefore, equated to 136 kg/ha.

In 1978, 140 trout were captured by electrofishing, marked, and returned to Sylvan Lake. Seven days later, 433 trout were collected in gillnets for the recapture sample (Jones et al. 1979). The resulting estimate was 13,987 cutthroat trout over 90 mm long; upper and lower confidence limits were 69,936 and 6,856, respectively. Calculated biomass of trout over age I+ (90 mm) was 93.7 kg/ha.

Differences in sample methods confound direct comparison of estimates obtained in 1978 and 1985, but it is apparent that precision (as measured by confidence intervals) is substantially greater using current techniques. Although the estimates obtained in 1985 are limited to the shallow portions of the lake, a high degree of precision greatly enhances the comparative value of this index of density.

Longnose Suckers

Mean total length of captured suckers was 162 mm with a range of 75 to 435 mm. Mean weight of 24 suckers in the recapture sample was 48 g, and mean K factor was 1.36 (Table 23). The length-weight equation was $\text{Log } W = 2.4734 (\text{Log } L) - 8.5794$ (GM equation was $\text{Log } W = 2.7218 (\text{Log } L) - 9.8226$).

It appears that mark-recapture estimates did not provide a suitable index of relative density of longnose suckers in Sylvan Lake. Only 1 of 226 marked suckers was recaptured, and the resulting population estimate (4,427) was statistically biased (Robson and Regier 1964). Very few suckers (38) were collected during the recapture run.

Comparisons using number of suckers per net from gillnets set in Yellowstone Lake have been unsuccessful due to the variability between nets (Jones et al. 1984). It is doubtful, therefore, that gillnets provide useful

estimates of relative density for smaller samples in backcountry lakes. Although mean lengths and size distribution data may be more comparable, past attempts to utilize this type of data for suckers has also been unreliable (Jones et al. 1984). Size structure and the appearance of sexually mature suckers do indicate that longnose suckers have become permanently established in Sylvan Lake, however, and this species appears to be reproducing successfully.

Angler Use

The Volunteer Angler Report (VAR) provides angler use and creel data for Sylvan Lake dating back to 1974. Arnold and Sharpe (1967) had no creel survey records but estimated annual use ranging from 500 to 1,000 angler days. Current data indicate that use levels averaged about 960 angler days during the 4 years prior to the catch and release regulation and then dropped to 560 angler days in 1978 (the first year of the new regulation). Angler use rose to a record high of 1,451 angler days in 1982; use had declined to a mean of 940 angler days during the past two years. Angler effort (hours) also declined in 1978; however, effort has remained high (mean=1,921 hours) since 1980 (Figure 16).

Landing rate appeared fairly stable (mean=0.59 trout/hour) during the 4 years preceeding the catch and release restriction (Figure 16). After the no harvest regulation was implemented, rates rose to a record 1.84 trout/hour in 1982. Landing rate has declined since then, but it has only dropped below 1.0 trout/hour once since 1980. Mean annual landing rate has remained significantly higher (1.29 trout/hour) under the catch and release regulation.

Despite some variation, mean length of angler captured trout has not changed significantly from pre-regulation estimates. Gillnetting and electrofishing data do suggest a steady increase in mean length since 1978, however (Table 23). The apparent anomaly may be related to the lack of length intervals below 254 mm on the VAK cards prior to 1985.

Discussion

Jones et al. (1985) suggested an apparent decline in cutthroat trout densities in Sylvan Lake since catch and release regulations were implemented in 1978; however, reexamination of previous surveys, in conjunction with additional data collected in 1985, do not support this hypothesis. A decrease in density is often associated

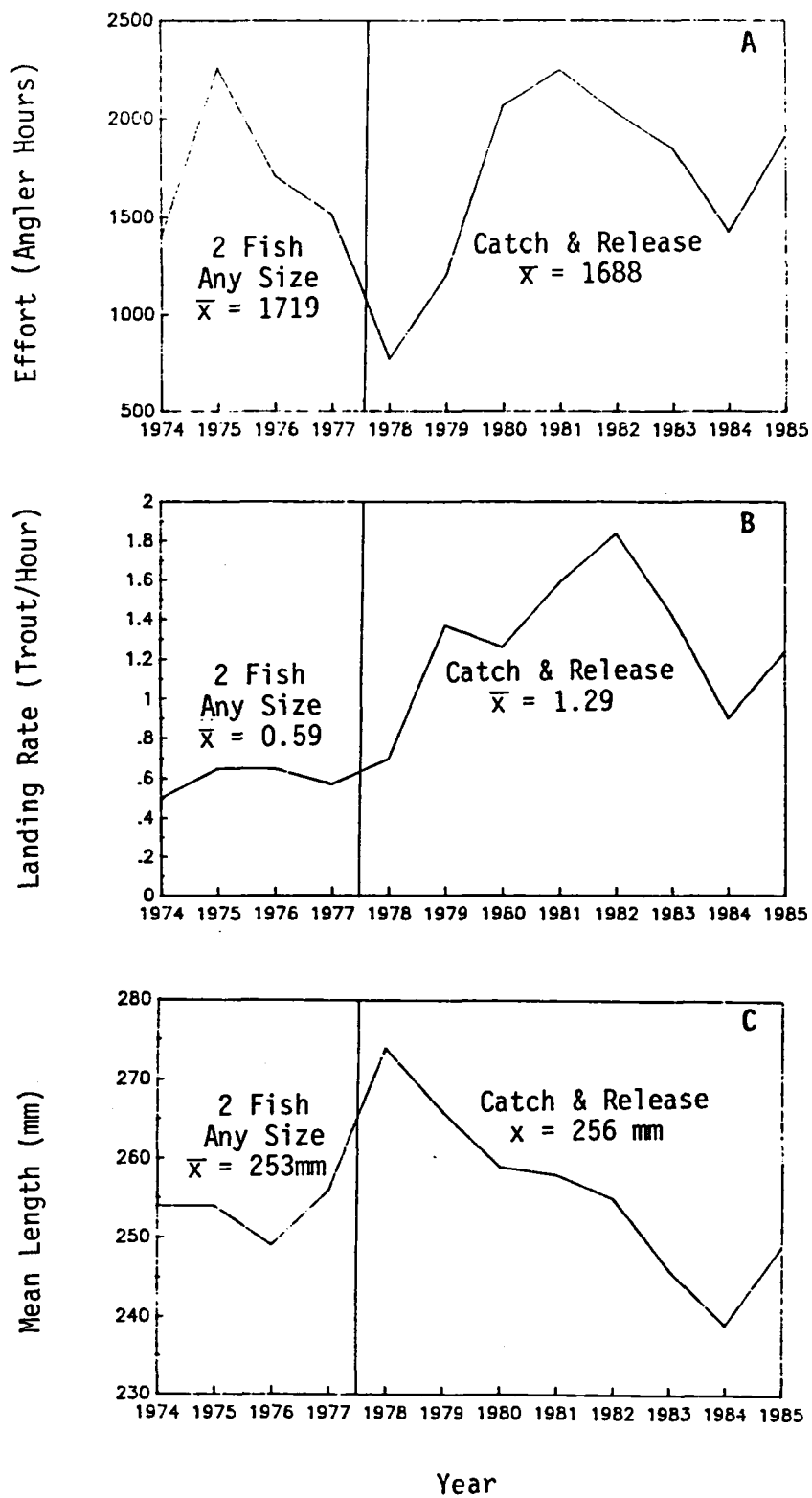


Figure 16 . Angler effort (A), landing rate (B), and mean length of landed trout (C), Sylvan Lake, 1974-1985.

with a biomass shift towards older and larger fish (Nikolskii 1969), but gillnetting data apparently lack the precision necessary to detect subtle changes in mean number per net. It is apparent, however, that major declines in density have not occurred. Angler landing rates reported by the VAR have actually risen since 1978. Although high recatchability may influence the increase in landing rates under catch and release regulations, success would decline if there had been substantial decreases in density.

The effect of no harvest regulations on the population structure of cutthroat trout in Sylvan Lake is poorly understood. Despite conflicting evidence, however, the mean length of trout does not appear to be decreasing. Apparently anomalous data, such as the average size of angler-captured trout, may be influenced by the entry of larger Yellowstone Lake cutthroat trout into Sylvan Lake from Clear Creek. Electrofishing should provide an efficient means of increasing sample sizes for trout length comparisons without affecting the population by the permanent removal of sample fish. The inclusion of three smaller size-categories on VAR cards should greatly enhance the future comparability of these samples also.

It appears that in Sylvan Lake, electrofishing is an effective and efficient means of collecting samples for monitoring purposes. In addition to increased sample size, this method allows fish to be returned to the lake with very little mortality; this factor is especially important as the intensity of the sampling program on this 11.4 ha lake increases. Population estimates calculated from samples collected by electrofishing have much greater precision than similar estimates which use gillnets for the recapture sample; successful utilization of the population estimates as density indices is dependent on a high degree of precision.

Monitoring the longnose sucker population remains difficult. This introduced species has become established in Sylvan Lake, but effective monitoring may require the development of more precise sampling techniques.

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

of this species may be low. Since the longnose sucker is more fecund (Carlander 1969) and has less stringent spawning requirements (Brown 1971), it may have a reproductive advantage in Sylvan Lake. Food may also be limiting in this subalpine lake, especially for larger trout which require larger food organisms such as benthic invertebrates. With a distinct adaptation for benthic feeding, suckers may have an additional competitive advantage for a limited food resource. Even if this species is not a more efficient feeder, numbers alone could cause additional stress in this unproductive environment.

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

STREAM SURVEY PROGRAM

The goal of the stream survey program is to identify and document the biological, physical, and chemical processes regulating stream ecosystems within Yellowstone National Park (YNP). Muttkowski (1929) developed the first classification system for YNP streams. In this system, streams were categorized based on visual estimates of flow patterns, gradients, and fish carrying capacity. Until 1963, however, no systematic attempt was made to measure physical, chemical, or biological attributes of YNP stream systems. From 1963 through 1975, baseline information (water flow, chemistry, and presence or absence of fish) on streams was collected, but little quantitative evidence concerning the influence of habitat parameters on stream systems was obtained. In 1976, investigation of the relationship between fish standing crops and attributes of stream systems was initiated (Jones et al. 1977). Habitat evaluation techniques that rated fish carrying capacity of streams (stream reach inventory, channel stability rating, habitat quality index, habitat suitability index, and weighted usable area) were employed to study this relationship through 1981. No meaningful conclusions concerning fish biomass and stream habitat, however, were drawn from that investigation.

We are currently working on a procedure to classify YNP streams based on three attributes: (1) Species value, (2) Habitat value, and (3) Sport Fishery value. All stream reaches will be assessed based on each of these values. The final classification, an aquatic resource value, will be the highest value given for the three categories.

A species value will be derived for each stream or stream segment based on the species composition of the aquatic community. Communities with native species will be given higher ratings than those with nonnative species. Areas that contain native species that have been extirpated from most of their indigenous range in the park will be given the highest ratings. Habitat values will be derived for streams based on fish carrying capacities and special habitat attributes (e.g., a spawning tributary). Those areas that contain the best fish habitat will receive the highest ratings. Finally, a sport fishery value can be derived for streams based on use by anglers. Those areas receiving or potentially receiving the highest use would receive the highest ratings.

This procedure is a modification of the method of assessing the significance of river segments and systems for fisheries resources used by Montana Department of Fish, Wildlife and Parks (G. Holton, Senior Resource Specialist, personal communication, 1985). The aquatic resource value of stream segments may be assigned as follows:

<u>Value Class</u>	<u>Class Definition</u>
1	Outstanding aquatic resource
2	High value aquatic resource
3	Substantial aquatic resource
4	Moderate aquatic resource
5	Limited aquatic resource
6	Insufficient information

METHODS

To provide the baseline information necessary to rate each stream segment for the three attributes, three types of surveys (cursory, reconnaissance, and ecological performance) are performed on streams within each of the six major drainage systems in YNP (Table 28). Cursory surveys are designed to collect the initial data required to evaluate streams. Usually, cursory surveys are performed on a group of tributary streams in a drainage. Once this initial survey is completed, the information gathered is used to prioritize which streams will be more intensively surveyed. A cursory survey is completed before reconnaissance or ecological performance surveys are performed on a stream.

During reconnaissance surveys, streams are subdivided into regions (reaches) that are relatively uniform with respect to discharge, water depth, riparian vegetation, and slope. Within each reach, 29 stream features are measured, and a cursory survey is performed on all tributaries (Table 28). Measurement of stream features has generally followed procedures outlined by Platts et al. (1983).

During ecological performance surveys an estimate of the number and size (length to nearest 1 mm and/or weight to nearest 1 g) of fish is generally made in conjunction with measurement of the same stream features taken during reconnaissance surveys (Table 28). In this way, the ecological performance of the stream (fish biomass and/or size distribution) is compared to stream habitat features. To provide a means of further evaluating the length distribution of populations, the length-categorization system outlined by Gabelhouse (1984) was included in this analysis. The influence of angling on the fish community is also considered.

Table 28. Type of information collected during cursory, reconnaissance, and ecological performance surveys in Yellowstone National Park, 1985.

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

CURSORY SURVEYS

In 1985, stream investigations centered on cursory surveys. These surveys were performed on 145 streams in the Falls and Yellowstone River drainages. To date, cursory survey information has been collected on approximately 69% of YNP streams.

Yellowstone River Drainage

The Yellowstone River drainage is the largest drainage system in the park. Approximately 114 km (71 mi) of the Yellowstone River flow through the park. It is the second most heavily fished water in the park and sustained almost 17% of total parkwide angler days (1,617) in 1985. An estimated 21,358 anglers spent 46,369 angler days (trips) and 123,257 angler hours fishing the river in 1985 (Table 5). Discussion of cursory surveys was divided into the upper and lower drainages of the river separated by Yellowstone Lake (Figures 17 and 18).

Upper Yellowstone River Drainage

Nineteen eighty-five was the first year cursory surveys were performed on the upper portion of the Yellowstone River drainage system. Jones et al. (1985) estimated the total drainage size of the Upper Yellowstone to be 43,296 ha. In 1985, cursory information was collected on 21 streams in the upper portion of the drainage (Figure 17); 11 are named and 10 are unnamed. These streams comprise 28,494 ha or 66% of the total drainage size of the upper Yellowstone drainage system. Sampled streams equalled 172 total km.

Physical attributes. The Upper Yellowstone River drainage is characterized by V-shaped valleys and detrital deposits. Geologic information classifies the drainage as part of the Absaroka region (Parsons 1978). It is predominantly andesitic lava flows and breccia with basalt and some occurrence of sandstone and limestone.

Upper Yellowstone drainage forest types include: lodgepole pine (Pinus contorta), Engelmann spruce-subalpine fir complex (Picea engelmanni-Abies lasiocarpa), Douglas fir (Pseudotsuga menziesii), and whitebark pine (Pinus albicaulis) (Despain 1985).

Streams sampled in the upper portion of the Yellowstone River drainage included: one fourth order stream; three

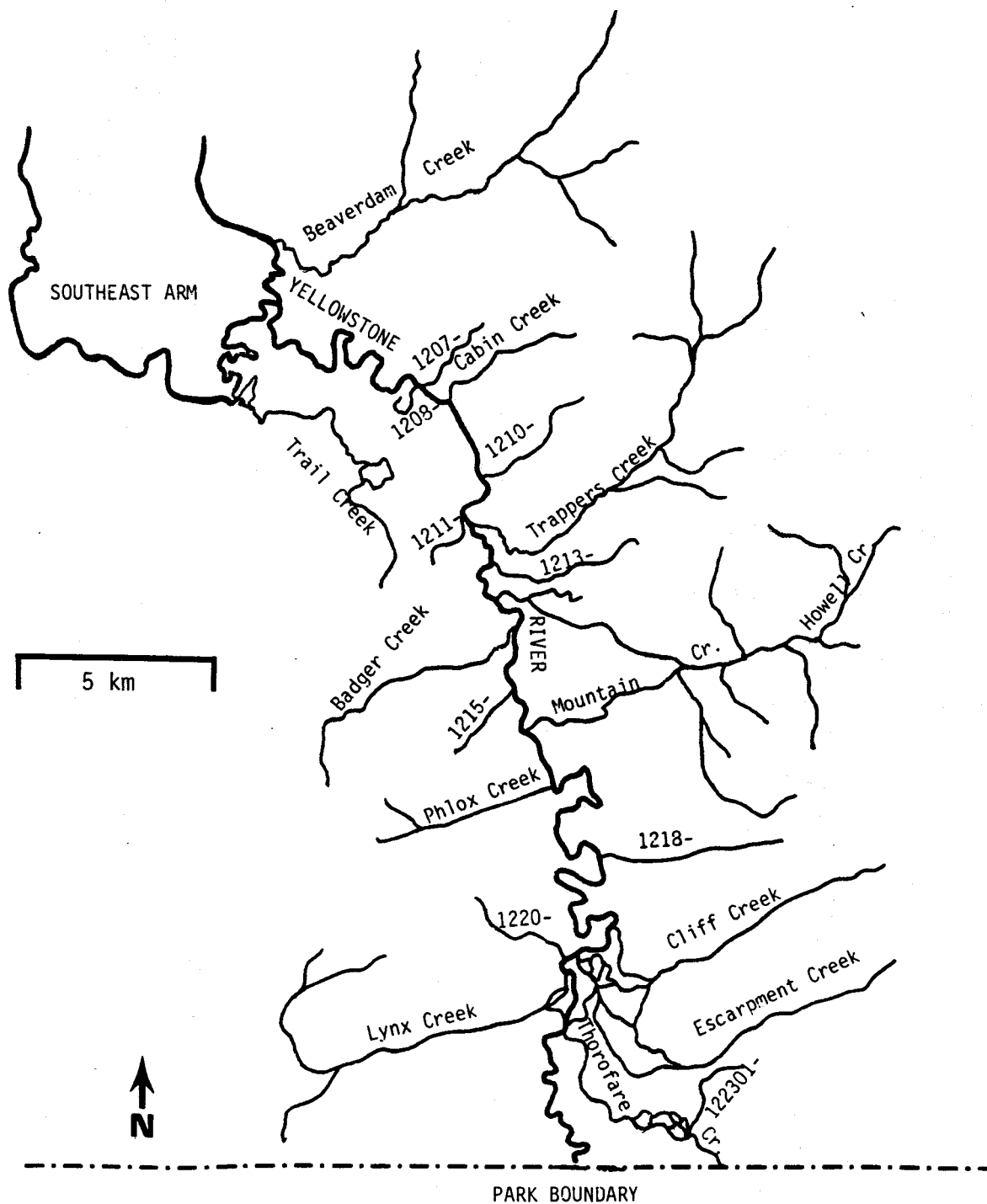


Figure 17 . Upper Yellowstone River drainage, south from Yellowstone Lake to Park boundary.

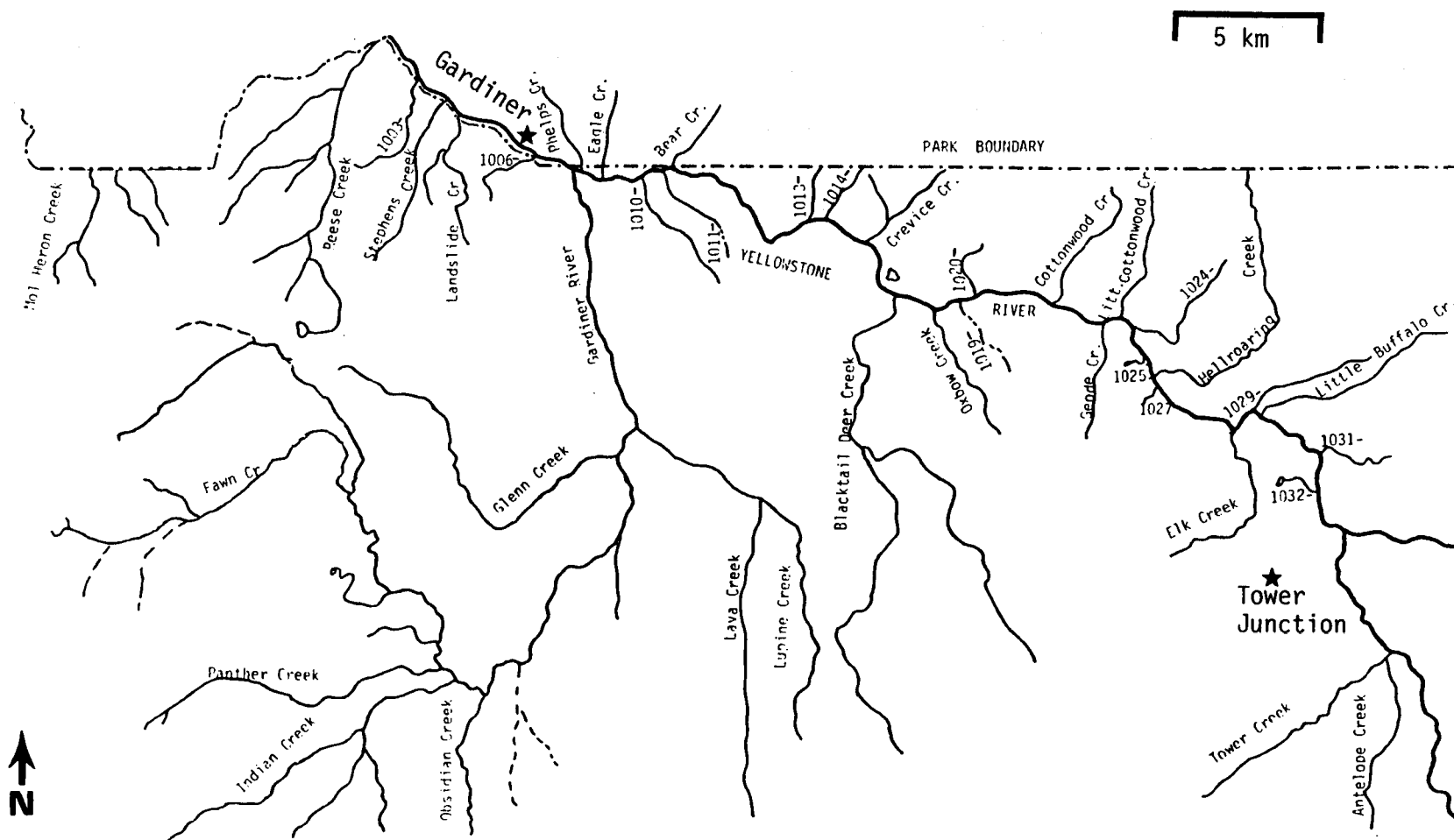


Figure 18. Lower Yellowstone River drainage system, from Tower Jct. to North Entrance, YNP.

third order streams; nine second order streams; and eight first order streams. Physical characteristics of the streams (length of channel, discharge, depth, area, and slope) were broadly correlated with their position in the hierarchy of tributaries (stream order) (Table 29).

Linear equations were developed which described the relationship between watershed size and streamflow ($r^2=0.95$), maximum channel width ($r^2=0.91$), and channel depth ($r^2=0.77$). All three parameters were positively correlated with watershed size. Generally, streams with high stream orders had large watershed, high water flows, and deep and wide channels (Table 29).

The average watershed size of tributaries in the Upper Yellowstone River drainage was 1,415 ha. Yellowstone River and stream 1215- had the largest and smallest watersheds, respectively. Mean elevation of sampled streams was 2,612 m (range 2,359-3,194 m) above MSL. Stream gradients ranged from 0.13% (stream 1206-) to 26.4% (stream 122302-). The range in gradients was fairly large and may be attributed to the substantial number of second order streams sampled. Generally, streams with lower gradients had higher flows. Mean flow of these measured streams was 0.43 m³/s. A positive correlation was evident between stream discharge and watershed size ($r=0.97$). Mean water temperature was 10.6 C.

Chemical attributes. Comprehensive water chemistry analysis was performed on nine streams in the Upper Yellowstone River drainage (Table 30). This evaluation indicated eight streams were calcium-bicarbonate and one stream (Cliff Creek) was sodium-potassium-bicarbonate type water. The average total dissolved solids (TDS) was 18 ppm, indicating a dilute condition (<50 ppm) in most streams measured compared to the parkwide mean of 107 ppm. Cliff and Escarpment Creeks were the most dilute streams sampled with a TDS of 16 ppm. Total hardness of the Upper Yellowstone drainage is below the parkwide mean of 61 ppm, with an average of 21 ppm. Calcium was also below the parkwide mean (16 ppm) at 1.2 ppm. The average pH value was 7.2.

Biological attributes. Over 23 different species of macroinvertebrates were collected from streams in the Upper Yellowstone River drainage (Table 31). Insects dominated the sample. Mayflies (Ephemeroptera) were the most frequently found order and most diverse group of insects sampled (14 species). Caddisflies (Trichoptera)

Table 29 Results of cursory surveys performed on tributaries to the Yellowstone River, 1985.

	Stream Order	Watershed Size (ha)	Stream Length (km)	Elevation		Gradient	Stream Flow (m3/s)	Mean Width (m)	Mean Depth (cm)	Mean Velocity (cm/s)	Temperature (C)
				Maximum (m)	Minimum (m)						
UPPER YELLOWSTONE RIVER DRAINAGE											
Stream #1208	I	126.00	0.80	2362.30	2362.00	0.01					
Stream #1207	I	220.52	2.41	2651.80	2362.20	12.20	0.08	1.70	6.61	68.58	8
Stream #1210	I	467.30	3.56	2889.50	2365.20	14.70	0.04	2.18	6.10	30.18	11
Stream #1211	I	220.50	1.61	2429.00	2366.00	3.93					
Stream #1213	I	535.50	4.27	2600.00	2368.00	5.43	0.05	1.32	10.82	32.31	13
Stream #1218	I	493.50	4.86	3115.00	2386.00	14.90	0.19	3.79	10.06	48.46	6
Stream #122301	I	278.30	2.95	2572.50	2398.80	5.89					
Stream #1215	I	178.50	2.14	2828.50	2374.40	21.20					
Cabin Creek	II	598.55	4.08	2890.00	2363.70	12.90	0.15	2.42	13.72	43.59	8
Trappers Creek	II	2387.00	5.52	2920.00	2367.00	4.50	1.93	9.97	20.73	93.57	13
Howell Creek	II	3323.50	10.43	2779.80	2447.50	3.19					
Cliff Creek	II	1890.20	9.22	3133.30	2386.90	8.09					13
Escarpment Creek	II	1989.90	14.39	3212.60	2386.90	5.73	0.58	4.33	18.67	71.93	6
Stream #122302	II	288.70	4.22	3145.50	2400.30	17.65					
Stream #1220	II	740.30	3.32	2625.30	2386.90	7.18					
Phlox Creek	II	1097.40	5.60	2822.50	2383.50	7.84					
Badger Creek	II	1575.20	7.68	2950.50	2371.30	7.50					
Mountain Creek	III	8558.32	21.50	3185.20	2377.40	3.76					12
Falcon Creek	III	514.54	9.49	2950.50	2389.60	5.91					
Lynx Creek	III	2294.47	11.63	3005.30	2387.00	5.52					12
Thorofare Creek	VI	2299.70	44.60	3462.50	2387.50	2.41					15
LOWER YELLOWSTONE RIVER DRAINAGE											
Stream #1003	I	551.30	4.00	2121.40	1560.60	14.00					
Stream #1006	I	382.80	2.80	1804.40	1585.00	7.80					
Stream #1010	I	587.60	4.60	2072.60	1609.30	10.10					
Stream #1011	I	409.60	3.60	1950.70	1663.70	8.80					
Stream #1013	I	141.80	1.60	2316.50	1694.60	38.90					
Stream #1014	I	357.10	3.60	2572.50	1694.60	2.40					
Stream #1019	I	677.30	5.20	1999.50	1706.90	5.60					
Stream #1020	I	215.80	2.00	2316.50	1688.60	31.40					
Little Cottonwood Creek	I	393.80	5.60	2022.40	1706.90	19.90	0.01	3.33	2.62	10.06	11
Stream #1024	I	467.90	4.60	2362.20	1719.00	14.00					
Stream #1025	I	63.00	1.40	1938.50	1755.60	13.10					
Stream #1027	I	582.80	3.00	1877.60	1767.80	3.70					
Stream #1031	I	299.30	4.60	2081.40	1804.40	23.40					
Stream #1032	I	52.00	0.80	1926.30	1828.80	12.20					
Stephens Creek	II	1050.60	6.20	2499.40	1560.60	15.10	0.04	0.98	7.37	56.99	8
Landslide Creek	II	582.80	5.00	2023.90	1585.00	8.80	0.01	0.45	9.27	35.36	12
Phelps Creek	II	661.50	6.20	2438.40	1609.30	13.40					
Eagle Creek	II	1310.10	8.10	2560.30	1585.00	12.00					8
Cravice Creek	II	2083.00	11.10	2926.10	1706.90	11.00	0.32	4.93	15.48	42.37	13
Oxbow Creek	II	1829.20	13.30	2638.70	1706.90	7.00	0.08	1.97	10.06	41.76	10
Geode Creek	II	556.00	5.60	2194.60	1706.90	8.70					
Stream #1029	II	264.80	3.80	2340.80	1767.80	15.10					
Little Buffalo Creek	II	751.40	8.30	2670.00	1780.00	10.70					
Bear Creek	III	12293.40	17.30	2974.80	1609.30	7.90					8
Blacktail Deer Creek	III	9198.80	17.50	2657.90	1664.20	5.70	0.50	4.04	19.05	64.31	13
Cottonwood Creek	III	1890.20	6.20	2755.40	1694.70	17.10	0.01	3.02	6.86	5.79	16
Elk Creek	III	4588.40	15.70	2755.40	1719.10	6.60	0.05	2.75	8.84	21.03	14
Antelope Creek	III	3323.60	12.50	2884.30	1901.90	7.90	0.09	3.62	11.43	20.63	10
Mol Heron Creek	IV	13293.60	17.90	2840.70	1554.50	7.20					
Gardner River	IV	51665.00	39.00	2956.60	1609.30	3.00					
Tower Creek	IV	11861.00	21.90	2956.90	1926.30	3.10		12.19	40.23		10

Table 30 Chemical characteristics of the Upper Yellowstone River drainage, Yellowstone National Park, 1985.

	Cabin Creek	Cliff Creek	Escarpment Creek	Lynx Creek	Mountain Creek	Thorofare Creek	Trappers Creek	Yellowstone River (Cabin)	Yellowstone River (Boundary)	Unnamed Stream #0044	Average	Drainage Standard Error	Maximum	Minimum
Total Dissolved Solids	19.000	15.500	15.500	21.500	18.000	19.500	16.000	19.000	16.000	20.000	18.000	0.675	21.500	15.500
Pheno. Alkalinity	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total Alkalinity	20.700	17.800	18.800	26.700	19.700	12.800	13.800	20.700	17.800	21.700	19.050	1.253	26.700	12.800
Carbonate Alkalinity	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Bicarbonate Alkalinity	20.700	17.800	18.800	26.700	19.700	12.800	13.800	20.700	17.800	21.700	19.050	1.253	26.700	12.800
Carbonate	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Bicarbonate	25.300	21.700	22.900	32.600	24.000	15.600	16.800	25.300	21.700	26.500	23.240	1.535	32.600	15.600
Hydroxides	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Carbon dioxide	2.700	2.100	2.000	3.100	2.500	1.200	2.100	4.000	3.500	2.800	2.600	0.256	4.000	1.200
Chloride	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.000	0.900	0.900
Sulfate	0.036	0.035	0.048	0.048	0.073	0.039	0.052	0.037	0.039	0.042	0.045	0.004	0.073	0.035
Fluoride	7.200	7.200	7.300	7.200	7.200	7.300	7.100	7.000	7.000	7.200	7.170	0.033	7.300	7.000
pH	9.110	10.030	9.270	8.860	9.250	9.440	9.400	9.160	9.230	9.090	9.204	0.098	10.030	8.860
pHs	11.010	12.070	11.240	10.520	11.300	11.560	11.710	11.330	11.460	10.970	11.397	0.195	12.070	10.520
Stability Index	-1.910	-2.830	-1.970	-1.660	-2.050	-2.140	-2.300	-2.160	-2.230	-1.690	-2.114	0.099	-1.660	-2.830
Saturation Index	0.000	0.000	0.000	0.000	5.000	5.000	0.000	5.000	5.000	10.000	3.000	1.106	10.000	0.000
Color (PCU)	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.000	1.000	1.000
Odor Threshold	1.200	0.400	0.300	0.300	1.400	1.000	0.400	2.600	1.700	3.400	1.270	0.333	3.400	0.300
Turbidity (NTU)	0.700	9.200	8.200	15.500	9.500	9.400	13.800	9.900	8.700	9.600	10.250	0.761	15.500	0.200
Silica	0.090	0.090	0.090	0.090	0.090	0.090	0.090	0.090	0.090	0.090	0.100	0.005	0.090	0.090
Hydrogen Sulfide	3.750	2.380	3.070	2.760	4.320	4.020	4.260	3.100	2.560	3.180	3.344	0.223	4.320	2.380
Sodium	0.900	1.000	0.900	1.290	0.900	0.900	1.100	0.900	1.000	1.230	1.012	0.047	1.290	0.900
Potassium	22.390	8.219	19.000	31.000	17.900	19.100	17.900	23.200	21.000	25.200	20.491	1.062	31.000	8.219
Total Hardness	18.250	2.490	13.750	25.000	13.750	13.750	13.750	16.000	16.000	18.250	15.099	1.782	25.000	2.490
Calcium Hardness	4.119	5.720	5.230	5.930	4.119	5.350	4.119	7.200	4.900	7.000	5.377	0.354	7.200	4.119
Magnesium Hardness	7.300	0.900	5.500	10.000	5.500	5.500	5.500	6.400	6.400	7.300	6.030	0.720	10.000	0.900
Calcium	0.900	0.390	1.270	1.440	0.300	1.300	0.900	1.750	1.210	1.700	1.176	0.131	1.750	0.390
Magnesium	0.100	0.090	0.230	0.100	0.120	0.650	0.130	0.210	0.320	0.380	0.241	0.054	0.650	0.090
Iron	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.000	0.049	0.049
Manganese	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.000	0.009	0.009
Copper	1.000	0.900	0.900	1.600	0.900	0.900	0.900	3.100	1.600	5.600	1.740	0.481	5.600	0.900
Total Organic Carbon	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.000	0.029	0.029
Total Ortho Phosphorous	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.000	0.029	0.029
Total Suspended Phosphorous	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.000	0.029	0.029
Total Dissolved Phosphorous	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.000	0.029	0.029

(5 species), true flies, (Diptera) (4 species), and stoneflies (Plecoptera) (1 species), were also present.

Two species of mayflies dominated the invertebrate samples. Baetis bicaudatus was the most numerous and found at seven sample sites. Baetis inhabits lotic-erosional, depositional, and lentic-littoral areas (Merritt and Cummins 1978). They are characterized as swimmers, climbers, and clingers. Their trophic relationships are described as gatherers, collectors, and scrapers. The genus Cingymula was less numerous but sampled in nine streams. These mayflies inhabit lotic and erosional areas. They are also characterized as clingers, collectors, gatherers, and scrapers. Generally, the greatest mayfly species diversity can be found in rocky-bottomed second and third order streams (Merritt and Cummins 1978). Mountain Creek (third order) exhibited the greatest diversity of mayflies (7 species).

Diptera (true flies) genera were found in four streams and Trichoptera in six streams. Plecoptera were represented by the family Nemouridae and found in only one stream.

Generally, macroinvertebrate densities were not high in the Upper Yellowstone River drainage. Escarpment Creek exhibited the greatest density of macroinvertebrates. Cliff Creek, Escarpment Creek, Trappers Creek, and streams 1210- and 1218- had almost equally diverse communities. Stream 1207- had only two species. Mayflies comprised over 60% of the diversity of all stream communities.

Lower Yellowstone River Drainage

The 1985 cursory survey of the lower Yellowstone drainage encompassed streams starting near the Tower area to the Mol Heron Creek drainage at the northern boundary of the park (Figure 18). Information was collected on 31 streams; 17 streams were named and 14 were unnamed. Total length of streams sampled was 263 km. Total combined watershed size for sampled streams was 111,357 ha.

Physical attributes. The lower Yellowstone River drainage is characterized by V-shaped valleys and steep ridges. The southern portion of the drainage lies in the Absaroka region with predominantly andesitic lava flows and breccia with basalt; sandstone and limestone occurs sporadically. The northern portion of the

Table 31. Occurrence and densities of macroinvertebrates found in Upper Yellowstone River drainage, 1985.

	Cabin Creek	Cliff Creek	Escarpment Creek	Lynx Creek	Mountain Creek	Thorofare Creek	Trappers Creek	Yellowstone River	Tributaries:			
									# 42	# 44	# 47	# 51

Insecta												
Diptera (true flies)												
Athericidae												
Atherix pachypus						1						
Blephariceridae												
Bibiocephala sp.	3								3			
Chironomidae				4								
Simuliidae												
Prosimulium sp.				1								
Ephemeroptera (mayflies)												
Baetidae												
Baetis bicaudatus	14	12	21	14	3					10		9
Baetis hageni										3		
Ephemerellidae												
Drunella coloradensis			1		1	1					1	1
Drunella doddsi			4		2	4	4	1			7	
Drunella grandis								2				
Drunella spinifera		2										
Serratella mitchneri					5						6	
Heptageniidae												
Cinygmula sp.	4	5	2		4	7	4			5	4	4
Epeorus albertae			6						2			
Epeorus grandis		3										
Epeorus longimanus		1			4	4						
Epeorus sp.										2		
Rithrogena sp.	3				4		1	4		4		4
Siphonuridae												
Ameletus sp.											3	
Plecoptera (stoneflies)												
Nemouridae												1
Trichoptera (caddisflies)												
Glossosomatidae												
Glossosoma sp.							2	2				
Hydropsychidae												
Arctopsyche grandis			1				2			1		
Parapsyche elsis		1										
Limnephilidae												
Apatania sp.				1			6					
Rhyacophilidae												
Rhyacophila sp.				1								1

TOTAL NUMBER OF SPECIES:	24	24	35	21	23	17	19	9	5	25	21	20

drainage lies in the Beartooth Region and is a mix of Precambrian gneiss and schist, Paleozoic and Mesozoic sandstones and shales, and Tertiary-Quaternary volcanics (Parsons 1978).

Lower Yellowstone drainage forest types include a predominantly Douglas fir (Pseudotsuga menziesii), Englemann spruce (Picea engelmannii) association. Douglas fir/ninebark (Pseudotsuga menziesii/Physocarpus malvaceus) is a forest habitat type common to the Yellowstone drainage. It occurs on moist protected slopes from 1,646 to 2,286 m. Englemann spruce/common horesetail (Picea engelmannii/Equisetum arvense) type occurs in the lower Yellowstone River valley where cold air drainage allows Picea to grow. It ranges from 1,889 to 2,652 m and occupies the saturated soils of stream terraces, benches, or seeps (Despain 1985).

Streams sampled in the lower Yellowstone River drainage included 3 fourth order streams; 5 third order streams; 9 second order streams; and 14 first order streams. Linear regressions were used to describe the relationship between watershed size and streamflow ($r^2=0.58$), maximum channel width ($r^2=0.67$), and mean channel depth ($r^2=0.80$). Coefficient of determination values were generally lower than those in the upper Yellowstone. This may indicate several factors influencing these relationships such as precipitation patterns, surface geology, elevation, or channel morphology. These factors may explain some of the differences between the upper and lower Yellowstone. Positive correlations existed between watershed size and flow ($r=0.76$), channel width ($r=0.82$), and channel depth ($r=0.89$).

Generally, streams with high stream orders had large watersheds, high water flows, deep and wide channels and low gradients (Table 29). Mean watershed size for first and second order streams closely paralleled first and second order streams sampled in the upper Yellowstone. Mean watershed sizes were slightly larger in the lower Yellowstone River drainage.

Mean watershed size in the lower Yellowstone drainage was 3,592 ha. Yellowstone River and stream 1032- were the largest and smallest watersheds, respectively. Mean maximum elevation of streams sampled was 2,073 m (range 1,804-2,974 m) above MSL. Stream gradients ranged from 2.4% (stream 1014-) to 38.9% (stream 1013-). A large gradient range was related to the number of first and fourth order streams in the sample. Mean flow of these

streams was $0.12 \text{ m}^3/\text{s}$. A positive correlation existed between stream discharge and depth ($r=0.90$). Average water temperature was 11°C .

Chemical attributes. Water chemistry analysis was performed on 10 streams in the lower Yellowstone drainage (Table 32). Only two streams (Landslide Creek and Antelope Creek) were found to be sodium-bicarbonate type waters. The remaining eight streams were classified as calcium-bicarbonate type waters. Mean total dissolved solids (TDS) of these streams (90 ppm) was approximately 16% lower than the parkwide mean (107 ppm). Landslide and Oxbow Creeks had the highest TDS (140 ppm) and Crevice Creek had the lowest TDS reading (24 ppm). Mean total hardness (TH) in the lower drainage was 53 ppm, which was slightly below the parkwide mean of 61 ppm. Oxbow Creek had the highest TH value of 98 ppm and Crevice Creek had the lowest TH value (18 ppm). The most turbid stream was Landslide Creek at 24 NTU. Mean turbidity for all streams (2.9 NTU) was 1.2 times the parkwide mean (2.4 NTU). Mean pH value was 7.8.

Biological attributes. Macroinvertebrates were collected from 12 streams, and over 42 species were sampled (Table 33). Insects dominated the sample with over 96% of the species representing this class. Mayflies (Ephemeroptera) were the most frequently sampled aquatic insects (13 species) and comprised 39% of all macroinvertebrates collected. True Flies (Diptera) (8 species), Caddisflies (Trichoptera) (6 species), Stoneflies (Plecoptera) (5 species), and Beetles (Coleoptera) (4 species) were also present.

Three species of mayflies were found in five streams, (*Baetis bicaudatus*, *Baetis tricaudatus*, and *Cinygmula* sp.). One species (*Serratella mitcheneri*) was found in six streams. True flies accounted for 22% of the diversity of all aquatic insects. They were sampled in 10 streams. The family Chironomidae was found in five streams. Caddisflies were found in six streams. Rhyacophila was sampled in four streams. This order comprised over 19% of macroinvertebrate samples. Stoneflies were sampled in 10 streams. The family Chloroperlidae was found in six streams. This order represented 12% of aquatic insects sampled. Beetles were the least common aquatic insect sampled. They comprised only 8% of all species found. They were found in only four streams in relatively low numbers. Planarians were found in three streams and Amphidpoda (scuds) appeared in one stream (Landslide Creek).

Table 32 Chemical characteristics of tributaries surveyed, Lower Yellowstone River, Yellowstone National Park, 1985.

	Drainage													Parkwide								
	Agate Creek	Antelope Creek	Bear Creek	Blacktail Deer Creek	Cottonwood Creek	Crevice Creek	Deep Creek	Eagle Creek	Elk Creek	Landslide Creek	Oxbow Creek	Quartz Creek	Stephens Creek	Average	Standard Error	Maximum	Minimum	Average	Standard Error	Maximum	Minimum	
Total Dissolved Solids	85.00	70.00	85.00	110.00	35.00	24.00	36.00	100.00	120.00	140.00	140.00	145.00	80.00	90.00	11.40	145.00	24.00	107.02	11.74	690.00	15.50	
Pheno. Alkalinity	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Total Alkalinity	68.70	59.00	53.00	91.60	32.90	35.90	41.00	97.10	93.60	96.20	107.00	125.00	63.70	74.39	0.14	125.00	32.90	67.13	5.34	246.00	0.90	
Carbonate Alkalinity	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Bicarbonate Alkalinity	68.70	59.00	53.00	91.60	32.90	35.90	41.00	97.10	93.60	96.20	107.00	125.00	63.70	74.39	0.14	125.00	32.90	67.13	5.34	246.00	0.90	
Carbonate	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Bicarbonate	83.00	73.00	65.00	112.00	40.10	43.00	51.00	118.00	114.00	117.00	131.00	153.00	77.70	90.77	9.95	153.00	40.10	81.43	6.50	300.00	1.22	
Hydroxides	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Carbon dioxide	4.00	2.50	1.50	1.50	1.20	3.50	4.00	3.00	1.60	3.00	1.50	5.00	2.00	2.64	0.34	5.00	1.20					
Chloride	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.00	0.90	0.90	6.19	1.67	104.00	0.90	
Sulfate	3.10	0.90	12.00	4.30	4.40	0.90	1.50	6.50	0.90	20.00	9.20	9.60	5.10	6.07	1.53	20.00	0.90	14.20	3.43	165.00	0.60	
Fluoride	0.70	0.30	0.13	0.54	0.31	0.05	0.90	0.13	0.42	0.22	0.24	0.65	0.11	0.37	0.00	0.90	0.05	0.04	0.10	0.20	0.04	
pH	7.00	7.70	7.90	8.10	7.91	7.30	7.30	7.00	8.10	7.00	8.20	7.70	7.00	7.70	0.07	8.20	7.30	7.71	0.07	8.75	4.50	
Stability Index	8.40	8.55	8.45	8.11	8.91	9.02	9.20	8.13	8.10	8.20	7.80	7.91	8.45	8.42	0.12	9.20	7.80					
Saturation Index	9.45	9.41	9.00	8.11	10.12	10.74	11.11	8.47	8.10	8.75	7.56	8.13	9.10	9.00	0.30	11.11	7.56					
Color (PCU)	-0.90	-0.85	-0.55	-0.01	-1.21	-1.72	-1.90	-0.33	-0.01	-0.40	0.32	-0.21	-0.65	-0.66	0.18	0.32	-1.90					
Odor Threshold	5.00	10.00	0.00	10.00	15.00	5.00	0.00	30.00	10.00	70.00	0.00	5.00	0.00	12.31	5.33	70.00	0.00					
Turbidity (NTU)	1.00	1.00	0.30	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	1.00	0.00					
Silica	1.40	1.00	0.30	1.20	0.20	0.70	1.10	3.30	1.00	24.00	1.90	0.50	1.30	2.92	1.77	24.00	0.20	2.36	0.35	24.00	0.20	
Hydrogen Sulfide	9.00	7.60	7.30	9.40	4.90	5.90	15.60	5.50	9.30	11.40	6.03	8.40	11.20	6.64	0.02	15.60	4.90	11.62	1.49	90.00	1.30	
Sodium	0.09	0.90	0.90	0.90	0.09	0.09	0.09	0.09	0.01	0.09	0.09	0.09	0.09	0.09	0.27	10.90	0.01					
Potassium	12.50	10.30	6.03	7.26	4.27	2.97	14.70	4.09	10.20	35.40	11.30	14.10	0.64	10.97	2.20	35.40	2.97	13.39	2.63	106.00	0.50	
Total Hardness	2.04	1.03	1.63	1.63	1.00	1.12	1.35	1.03	1.60	1.53	1.16	1.64	1.22	1.50	0.00	1.60	1.12	3.14	0.71	39.00	0.16	
Calcium Hardness	44.30	36.50	52.10	74.90	20.60	17.40	11.00	67.40	74.00	45.30	57.30	52.00	45.70	52.07	7.44	97.30	11.00	60.25	5.02	201.00	4.00	
Magnesium Hardness	26.20	24.60	35.30	47.60	10.50	12.00	7.40	41.30	47.00	32.00	71.90	57.50	29.30	34.01	5.05	71.90	7.40	39.70	4.52	193.00	2.00	
Calcium	10.50	9.63	14.10	19.00	7.39	5.10	2.99	16.50	19.10	12.00	25.40	34.50	16.30	18.09	2.50	34.50	4.36					
Magnesium	4.41	2.91	4.09	6.64	2.46	1.13	1.06	6.33	6.35	3.22	6.10	8.30	3.95	4.39	0.63	8.30	1.06	5.01	0.61	26.50	0.90	
Iron	0.27	0.32	0.10	0.60	0.09	0.16	1.09	0.05	0.60	0.24	0.43	0.62	0.24	0.39	0.41	0.00	1.09	0.09	0.05	0.03	1.09	0.01
Manganese	0.05	0.05	0.01	0.01	0.01	0.01	0.05	0.05	0.01	0.05	0.05	0.05	0.05	0.05	0.01	0.00	0.01	0.05	0.00	0.17	0.01	
Copper	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.02	0.01	0.29	0.01	
Total Organic Carbon	5.40	4.60	2.60	4.00	7.60	2.20	1.60	7.50	5.70	7.00	7.50	6.00	3.90	5.11	0.57	7.60	1.60	3.79	0.30	11.60	0.30	
Total Ortho Phosphorous	0.02	0.03	0.02	0.02	0.04	0.02	0.03	0.03	0.02	0.03	0.04	0.02	0.05	0.03	0.00	0.05	0.02	0.09	0.02	0.93	0.01	
Total Suspended Phosphorous	0.03	0.00	0.02	0.02	0.04	0.02	0.03	0.03	0.02	0.03	0.02	0.03	0.06	0.03	0.01	0.00	0.02	0.06	0.01	0.65	0.01	
Total Dissolved Phosphorous	0.03	0.00	0.02	0.02	0.02	0.02	0.03	0.03	0.04	0.03	0.04	0.03	0.15	0.04	0.01	0.15	0.02	0.09	0.01	0.40	0.01	

Table 33. Occurrence and densities of macroinvertebrates found in the Lower Yellowstone River drainage, 1985.

	Antelope Creek	Bear Cr.	Cotton- Wood Creek	Eagle Creek	Elk Cr.	Hell- Roaring Creek	Land- Slide Creek	Little Cotton- Wood Creek	Stephens Creek	Tower Creek	# 3802-	# 3803-
Platyhelminthes												
Turbellaria (planarians)			3					6			1	
Arthropoda												
Crustacea												
Amphipoda (scuds)												
Gammaridae												
Gammarus lacustris								5				
Hyalella azteca								3				
Insecta												
Coleoptera (beetles)												
Elmidae												
Cleptelmis sp.					2							
Rhizelmis sp.					1							
Stenelmis sp.			5		11	1	2					
Sphaeriidae					1							
Sphaerium sp.												
Diptera (true flies)												
Chironomidae		3		12					2	1		4
Ephydriidae			1									
Pelecorhynchidae												
Glutopis sp.	8											
Ptychopteridae				1								
Ptychoptera sp.												
Simuliidae												
Prosimulium sp.											1	
Simulium sp.				9	1		17					
Tipulidae												
Erioptera sp.	1											
Hexatoma sp.		2										
Tipula sp.										1		
Ephemeroptera (mayflies)												
Baetidae												
Baetis bicaudatus	2					3			11	2	5	
Baetis hageni						4						
Baetis tricaudatus				1			2	8		2	3	
Ephemerellidae												
Drumella coloradensis		1										
Drumella spinifera												1
Drumella doddsi												
Serratella mitchneri	3		9		7			4	1			1
Heptageniidae												
Cinygmula sp.	4			1	5		3				4	
Epeorus deceptivus									2			
Epeorus longimanus											1	
Rithrogena sp.		7										
Leptophlebiidae												
Paraleptophlebia sp.												
Siphonuridae												
Ameletus sp.								2		1		3
Plecoptera (stoneflies)												
Capniidae												
Isocapnia sp.												
Chloroperlidae		3	3	2				2		2	1	
Nemouridae												
Amphinemura sp.							1					
Visoka Cataractae											7	
Zapada sp.												
Perlidae												
Doroneuria theodora					1			7				3
Perlodidae												
Metagerys sp.			1									
Trichoptera (caddisflies)												
Hydropsychidae												
Arctopsycha grandis												5
Limnephilidae												
Apatania sp.					17	2						
Neothremma alicia											1	5
Onocosmoecus sp.			1									
Rhyacophiliidae												
Rhyacophila sp.	2		1		2							4
TOTAL NUMBER OF SPECIES:	20	20	24	25	43	16	30	32	16	9	24	26

The diversity of the macroinvertebrate communities in the lower Yellowstone River drainage was generally higher than the upper Yellowstone. Elk Creek exhibited the highest density (numbers) and Tower Creek the lowest. Nine species were sampled in both Elk Creek and stream 103348702-. The remaining streams were almost as equally diverse. Insects were sampled exclusively in eight streams. Mayflies were the dominant order, similar to that observed in the upper Yellowstone drainage.

Bechler and Falls River Drainages

The Bechler River is a subdrainage system of the Falls River drainage. It is located in the southwestern corner of the park. It flows for 33 km (20 mi) in the park, joins the Falls River, and then flows to Henry's Fork of the Snake River. The Bechler River sustained 1.29% of total parkwide angler days and a reported 707 anglers in 1985. On the Falls River, 773 anglers expended approximately 60 angler days (Table 5). In 1978, stream survey work was performed in the Bechler drainage including water chemistry sampling, flow estimates, and habitat measurements. In 1985, cursory surveys were performed on eight streams in the Bechler River drainage and three streams in the Falls River drainage (Figure 29). Seven streams were named and four were unnamed. Macroinvertebrate samples were taken on 11 streams, and flow estimates were taken on the Falls River and stream 4012- in the Bechler drainage.

Physical attributes. Topography is dominated by high forested plateaus containing headwaters of the Bechler drainage basin. Geologic events of the Pleistocene have strongly influenced the nature of the Bechler Region (Jones et al. 1978). The high plateaus have been blanketed and built-up at least three times by volcanic flows leaving formations of rhyolite, an extrusive rock high in quartz and feldspathic minerals. Evidence is present for at least three periods of major Pleistocene glaciation covering the area: the Pre-Bell Lake, Bell Lake, and Pinedale glaciations. Surficial deposits of glacial and stream colluvium occur in scattered areas through the region.

Rhyolite bedrock often forms substrate of the streams flowing on the high plateaus. The Bechler River carves through lacustrine sediments in the upper Bechler Meadows. Basalt deposits are encountered along the course of the Falls River in its lower sections.

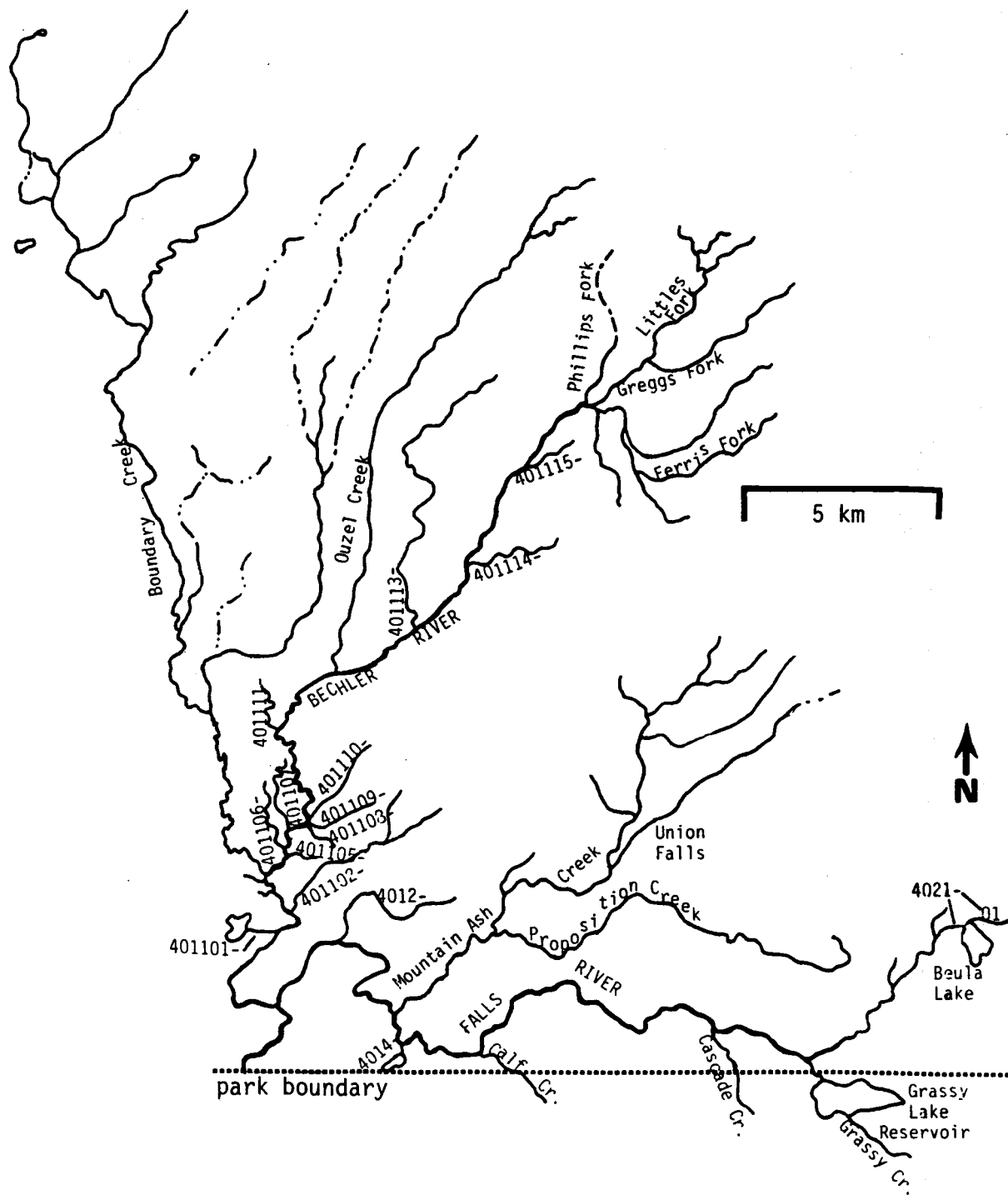


Figure 19. Falls and Bechler River drainages, YNP.

Streams flow over rhyolite plateaus and bedrock outcrops forming numerous cascades and waterfalls. These geologic features are predominant influences on the chemical and physical characteristics of streams in this region.

The headwaters of the Bechler River are comprised of Phillips Fork, Gregg Fork, Littles Fork, and Ferris Fork which unite at the Three Rivers Junction to form the mainstem of the Bechler River. These headwaters drain the slopes surrounding the rim of the Bechler Canyon. The watershed is forested with lodgepole pine (Pinus contorta), whitebark pine (Pinus albicaulus), Engelmann spruce (Picea engelmanni), and subalpine fir (Abies lasiocarpa).

Sampled streams in these drainages included one fifth, one fourth, three third, one second, and five first order streams. Cursory surveys began at Three Rivers Junction. The most apparent feature of the headwaters is the extensive thermal springs activity. Below this junction, the Bechler River mainstem is fed by large hot springs and seeps. The systematic numbering of Bechler streams includes these flow sources.

Mean elevation of Bechler streams was 2,170 m (range 1,947-2,664 m) above MSL (Table 34). Stream gradients ranged from 0.24% (stream 401106-) to 30.2% (Phillips Fork). Total watershed size of the Bechler and Falls Rivers was 39,651 and 65,888 ha, respectively. Average watershed size of sampled tributaries to both rivers was 475 ha. Falls River and stream 401116- were the largest and smallest watersheds, respectively.

Linear equations were used to describe the relationship between watershed size and streamflow ($r^2=0.58$), water velocity ($r^2=0.77$), and maximum channel depth ($r^2=0.53$). Average watershed size of streams in the Bechler and Falls River drainages was much lower than that found in the upper and lower Yellowstone River drainages. A positive correlation existed between stream order and watershed size ($r=0.77$).

Flow was estimated on two streams 401116- and 4012- (tributaries to the Falls River). Average flow for these streams was 0.273 m³/s, and mean velocity was 46.79 cm/s. Average water temperature was 12.5 C.

Chemical attributes. Lithological features determine the water chemistry of the drainage. Waters flowing over rhyolite deposits are commonly dilute and poorly

Table 34. Results of cursory surveys performed on tributaries to the Falls and Bechler Rivers, 1985.

Stream Order	Watershed Size (ha)	Stream Length (km)	Elevation Maximum (m)	Elevation Minimum (m)	Gradient	Stream Flow (m3/s)	Mean Width (m)	Mean Depth (cm)	Mean Velocity (cm/s)	Temperature (C)
Falls River	V	65888.6	41.4	2633.5	1885.5	1.8				
Stream 401101	I	252.0	1.3	1961.4	1932.4	2.2				
Stream 401102	II	2535.9	19.8	2664.0	1944.6	3.6				
Boundary Creek	III	21794.8	36.0	2570.0	1947.7	1.7				16
Stream 401106	I	147.0	2.0	1949.2	1948.0	0.05				
Stream 401107	I	189.0	2.6	1949.5	1948.3	0.04				
Stream 401110	I	404.3	3.1	2045.2	1948.7	3.2				
Stream 401111	I	141.8	1.6	1959.9	1949.2	0.6				
Ouzel Creek	II	2436.2	16.5	2545.8	1927.9	3.8				
Stream 401113	I	908.3	10.7	2508.5	1969.0	5.0				
Stream 401114	I	362.3	3.0	2522.2	2107.7	13.8				
Stream 401115	I	94.5	1.2	2286.0	2154.9	10.9				9
Phillips Fork	II	1197.0	5.0	2548.0	2217.4	6.7				
Stream 401116	I	7.9	0.3	2206.7	2199.2	2.6	0.244	5.05	15.09	32.00
Ferris Fork	II	2535.9	9.3	2638.0	2217.4	4.5				7
Gregg Fork	II	2089.7	7.3	2546.6	2218.9	4.6				16
Stream 4012	I	887.3	4.8	1999.0	1942.2	1.2	0.303	2.87	17.14	61.57
Mountain Ash Creek	III	10369.7	16.8	2583.2	1956.8	3.7				14
Stream 4014	I	74.8	0.4	1962.6	1959.5	0.8				18
Calf Creek	I	973.2	7.2	2286.0	1965.3	4.5				10
Cascade Creek	II	2291.7	8.9	2607.5	2125.6	5.4				
Grassy Creek	I	964.7	3.2	2340.8	2158.0	6.0				
Stream 4021	II	1638.2	10.6	2526.2	2217.4	2.9				

buffered. The influence of hydrothermal activity on water chemistry is considerable in these dilute waters (Jones et al. 1978). Streams have been classified as dilute and sodium-bicarbonate waters. The dilute chemistries are generally found in the headwater streams, and those classified as sodium-bicarbonate waters are found downstream and near hydrothermal sources.

Biological attributes. Bechler Meadows, Rocky Ford, and six tributaries to the Bechler River were sampled for macroinvertebrates. Mountain Ash Creek, Proposition Creek and Falls River were sampled in the Falls River drainage. There were over 30 different species of macroinvertebrates sampled in the combined drainages (Table 35). Insects were the dominant group. Mayflies (Ephemeroptera) were the most diverse order of aquatic insects sampled (13 species). Caddisflies (Trichoptera) were second in diversity (8 species). Stoneflies (Plecoptera) were represented by six species. Beetles (Coleoptera), true flies (Diptera), and dragonflies (Odonata) each had only one species present. Distribution of macroinvertebrates in the Bechler and Falls River drainages followed the same general trend as diversity. Two species of mayflies were sampled in four streams. Baetis tricaudatus was sampled in five streams and was the most widely distributed macroinvertebrate in the two drainages. Cinygmula sp. and Ameletus sp. were the second and third most widely distributed macroinvertebrates, respectively. Seven mayfly genera were found in only one stream each.

Genera (Brachycentrus and Neothremma) were the only caddisflies found in more than one stream. In general, caddisflies were sampled in the lower Bechler River drainage near the confluence with the Falls River and in the Falls River and its tributaries.

Stoneflies were sampled in five streams. Four genera were found in two streams each. Beetles, true flies, and dragonflies were present but not widely distributed. Both true flies and beetles were limited exclusively to Boundary Creek. Dragonfly genus Ophipgomphe was found in Boundary Creek and the Bechler River at Rocky Ford. Ferris Fork and Bechler Meadows yielded one species of scuds (Hyalolella azteca).

The diversity of macroinvertebrate communities in the Bechler and Falls River drainages was generally lower than that observed in the upper and lower Yellowstone River drainages. Mountain Ash Creek (tributary to the

Table 35 Occurrence and densities of macroinvertebrates found in the Bechler and Falls River drainages, 1985.

	Boundary Creek	Ferris Fork	Greggs Fork	Bechler Meadow	Mountain Ash Cr.	Proposition Creek	Rocky Ford	# 401116	# 401115	# 4012	Falls River
Arthropoda											
Crustacea											
Amphipoda											
Talitridae											
<i>Hyalella azteca</i>		3		1							
Insecta											
Coleoptera (beetles)											
Elmidae											
<i>Stenelmis</i> sp.	1										
Diptera (true flies)											
Chironomidae											
Simuliidae											
<i>Prosimulium</i> sp.											
Tipulidae											
<i>Hexatoma</i> sp.	1										
Ephemeroptera (mayflies)											
Baetidae											
<i>Baetis bicaudatus</i>		7	4		1		5		1	2	2
<i>Baetis tricaudatus</i>											
<i>Tricorythodes minutus</i>						5					
Ephemereillidae											
<i>Drunella coloradensis</i>				3							
<i>Drunella grandis</i>						1					
<i>Drunella spinifera</i>			1								
<i>Ephemerella simulans</i>						1					
<i>Ephemerella alleni</i>						5					
<i>Serratella mitchneri</i>					1					4	
Heptageniidae											
<i>Cinygmula</i> sp.	1			3	12		4				
<i>Epeorus longimanus</i>											13
<i>Rithrogena</i> sp.											1
Siphonuridae											
<i>Ameletus</i> sp.			2	2			3	5			
Odonata (dragonflies)											
Gomphidae											
<i>Gomphogomphus</i> sp.	4						2				
Plecoptera (stoneflies)											
Capniidae											
<i>Isocapnia</i> sp.						1					
Chloroperlidae						1			3		
Nemouridae											
<i>Zapada</i> sp.										1	
Perlidae											
<i>Doroneuria theodora</i>						1					1
<i>Hesperoperla pacificum</i>				1							
Perlodidae											
<i>Kogotus</i> sp.	1							1			
Trichoptera (caddisflies)											
Brachycentridae											
<i>Brachycentrus</i> sp.	1				7						
<i>Micrasema</i> sp.							1				
Helicopsychidae											
<i>Helicopsyche borealis</i>					1						
Hydropsychidae											
<i>Arctopsyche grandis</i>						1					
Limnephilidae											
<i>Neothremma alicia</i>					2			1			
<i>Onocosmoecus</i> sp.							1				
Rhyacophilidae											
<i>Rhyacophila</i> sp.											1
TOTAL NUMBER OF SPECIES:	9	10	7	10	24	4	16	17	10	6	17

Falls River) exhibited the greatest density of macroinvertebrates. Stream 401116- (tributary to the Bechler River) had the greatest diversity of any stream sampled (8 species). Only four species were sampled at Proposition Creek. Mayflies comprised over 43% of the diversity in all sampled streams.

Lamar River Drainage

The Lamar River is the largest tributary to the Yellowstone River. This subdrainage contains 20% (1,241 km) of the total stream distance in YNP. Nineteen of the tributaries to the Lamar River are named, and 38 are unnamed. Streams range in elevation from 1,880 to 2,972 m above MSL. In 1985, cursory surveys were performed on 71 streams in the Lamar River drainage (Figures 20 and 21). Six streams were second order and 65 streams were first order.

The Lamar River is characterized by high peaks, steep ridges, and broad U-shaped valleys. Absaroka volcanic rocks dominate the drainage (Keefer 1971). Precambrian gneiss and schist occur in the Slough Creek drainage, and Yellowstone tuff and related lava flows are found on the Mirror Plateau.

Lamar drainage forest types include lodgepole pine (Pinus contorta), whitebark pine (Pinus albicaulis), Douglas fir (Pseudotsuga menziesii), and Engelmann spruce-subalpine fir complex (Picea engelmanni-Abies lasiocarpa) (Despain 1985). Despain (1985) found that lodgepole pine dominate the drainage and occur mainly in lower elevations. The spruce-fir complex occurred in the upper reaches of the drainage. Whitebark pine and Douglas fir are interspersed throughout the Lamar area.

Streams in the Lamar drainage receive over 10% of the angler stream use in YNP. The Lamar River was the 10th most popular fishery parkwide in 1985. It received 142 angler days or 1.4% of the parkwide use. Slough Creek (a tributary to the Lamar River) was the sixth most popular stream fishery in YNP in 1985. This stream received approximately 4.2% of parkwide angler use days (423 angler days) in 1985 (Table 5).

Upper Lamar River Tributaries

Cursory survey work was performed on 16 tributaries to the upper Lamar River, 1 tributary to Mist Creek, and 5 tributaries to the Little Lamar River. Sampled streams were comprised of 4 second, and 19 first order streams. The same general patterns between stream order and physical

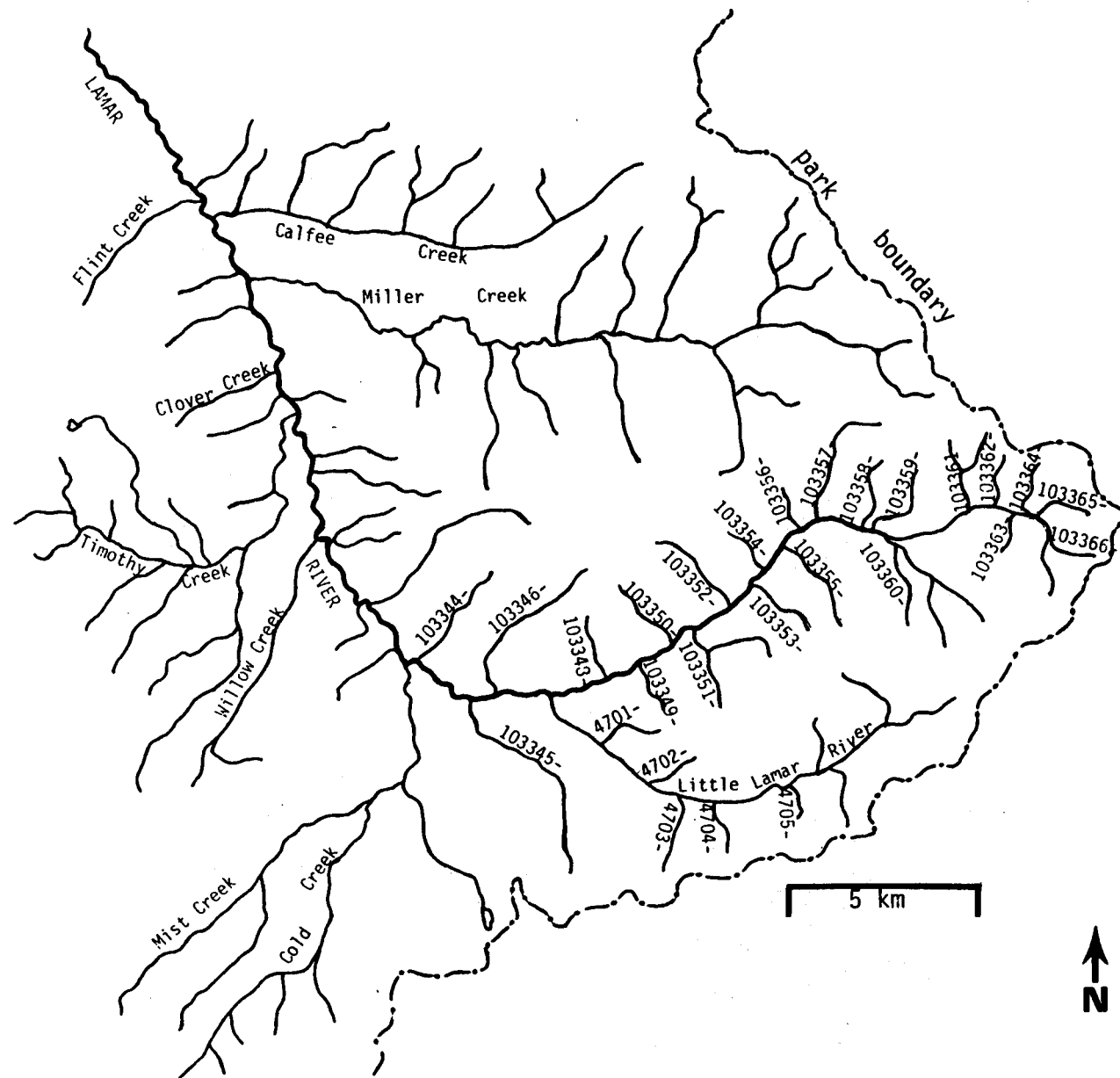


Figure 20. Upper Lamar River drainage system, YNP.

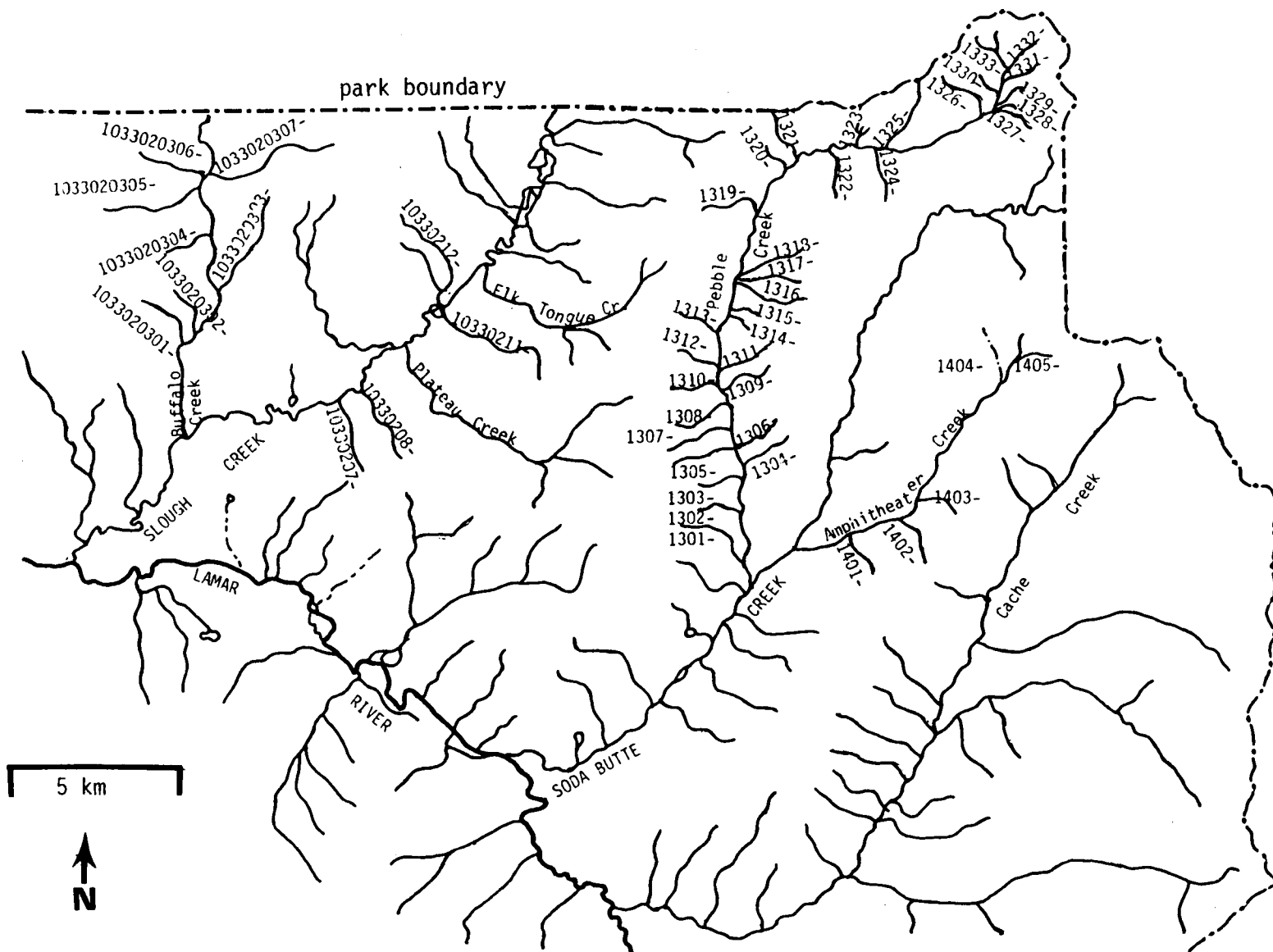


Figure 21. Slough, Soda Butte, and Cache Creeks, Lamar River tributaries, YNP.

characteristics that occurred in Bechler and Yellowstone tributaries were observed in the Lamar streams. Linear regressions were used to describe the relationships between watershed size and flow ($r^2=0.81$) and channel width ($r^2=0.83$).

The average size of watershed in the upper Lamar was 468 ha. The Little Lamar River and stream 103349- had the largest and smallest watersheds, respectively. Mean elevation of sampled streams was 2,607 m (range 2,609-3,011 m) above MSL (Table 36). Stream gradients ranged from 8.04% (stream 103345-) to 34.74% (stream 10334703-). Generally, streams with lower gradients had higher flows. Mean water temperature was 11 C.

Mean flow of sampled streams was 0.06 m³/s. Mean velocity was 20.5 cm/s. Both flow and velocity were lower than those observed in the Yellowstone and Bechler streams. This difference may be related to the higher percentage of large (greater than second order) stream systems sampled the Yellowstone and Bechler drainages.

Chemical attributes. No water chemistry samples were obtained from Lamar streams in 1985. In 1984 water chemistry analysis was performed at 17 locations on Lamar River tributaries. The upper Lamar was documented as sodium-bicarbonate type water. The Lamar River changes to a calcium-bicarbonate type water closer to the outlet. Average pH value was 7.4.

Biological attributes. Macroinvertebrate samples were collected on 19 streams in the Upper Lamar drainage. Over 23 different species of aquatic insects were collected (Table 37). Mayflies (Ephemeroptera) were the most diverse group of insects sampled (over 9 species). Stoneflies (Plecoptera) were the second most diverse order (6 species). True flies (Diptera) and caddisflies (Trichoptera) were represented by five and three species, respectively. Only one species of beetle (Coleoptera) was sampled (Cleptelmis sp.).

Macroinvertebrate distribution in the upper Lamar followed the same general trend as diversity (Table 37). One genus of mayfly (Cinygmula) was found in 15 streams and was the most widely distributed aquatic insect sampled. Baetis bicaudatus was sampled in 13 streams. Epeorus deceptivus was sampled in eight streams.

Three genera of stoneflies were sampled in three different streams. Insects from the families Chloroperlidae and Perlodidae were found in the greatest

Table 36. Results of cursory surveys performed on tributaries to the Lamar River, 1985.

	Stream Order	Watershed Size (ha)	Stream Length (km)	Elevation		Gradient	Stream Flow (m3/s)	Mean Width (m)	Mean Depth (cm)	Mean Velocity (cm/s)	Temperature (C)
				Maximum (m)	Minimum (m)						
Stream #1033430211	I	-	-	-	-	-	0.011	1.36	7.62	10.36	9
Stream #103344	I	236.3	3.4	2909.7	2210.9	20.5	0.019	1.19	10.06	15.54	8
Stream #103345	II	1386.0	6.3	2737.0	2228.0	8.0	0.195	4.62	12.00	32.92	11
Stream #103346	I	598.6	4.6	2950.5	2241.8	15.3	0.049	1.93	14.33	17.68	16
Little Lamar River	II	3743.6	13.4	2964.0	2262.8	5.2					
Stream #10334701	I	94.5	1.8	2743.2	2336.3	22.5	0.009	0.74	6.40	20.12	9
Stream #10334702	I	110.3	1.6	2837.7	2395.7	27.5					
Stream #10334703	I	47.3	0.8	2682.3	2404.3	34.7	0.027	1.32	11.43	17.98	10
Stream #10334704	I	315.0	2.4	2822.4	2426.2	16.4	0.115	2.24	17.68	28.96	10
Stream #10334705	I	141.7	1.5	2836.2	2483.8	23.5	0.056	2.12	10.06	25.91	7
Stream #103348	I	110.3	1.8	2816.4	2289.0	29.1	0.002	0.68	4.57	7.92	15
Stream #103349	I	78.8	1.2	2706.0	2304.3	32.4	0.014	1.63	3.96	21.03	9
Stream #103350	I	315.0	2.3	2871.3	2322.6	23.8	0.025	1.65	10.06	15.24	14
Stream #103351	II	724.6	4.2	2877.3	2343.9	12.6	0.157	2.57	18.29	33.53	13
Stream #103352	I	262.5	3.2	3011.4	2367.7	20.1	0.022	1.54	10.36	13.72	16
Stream #103353	I	225.8	2.6	2834.6	2382.3	17.3	0.025	1.30	9.75	19.81	15
Stream #103354	I	141.8	1.7	2791.9	2393.3	23.5	0.008	1.60	9.14	5.79	14
Stream #103355	I	267.7	3.1	2889.5	2414.0	15.3	0.025	1.56	10.97	14.63	8
Stream #103356	I	94.5	0.8	2609.0	2434.3	21.8	0.007	0.86	2.29	36.58	8
Stream #103357	I	483.0	4.0	29944.4	2448.4	12.3	0.095	3.01	12.00	24.69	9
Stream #103358	I	136.5	2.2	2916.9	2472.2	20.1					
Stream #103359	I	126.0	2.6	2968.8	2475.9	18.9					
Stream #103360	II	1113.1	4.4	2885.4	2489.1	8.9	0.195	4.87	14.63	27.43	15

Table 37. Occurrence and densities of macroinvertebrates in the Lamar River drainage, 1985.

	Mist Creek Trib. 1033440202-	Lamar River Trib. 1033-- 35- 44- 45- 46- 48- 49- 50- 51- 52- 53- 55- 56- 57- 60- 701- 703- 704- 705-	Little Lamar Trib. 103347- 703- 704- 705-
Platyhelminthes			
Turbellaria (planarians)			3
Arthropoda			
Insecta			
Coleoptera (beetles)			
Elmidae			
<i>Cleptelmis</i> sp.		1	
Diptera (true flies)			
Chironomidae	1	1 2	7 3
Ephydriidae			1
Pelecorhynchidae			
<i>Glutops</i> sp.			1
Tipulidae			
<i>Tipula</i> sp.			2
<i>Rhabdomastix</i> sp.		1	
Ephemeroptera (mayflies)			
Baetidae			
<i>Baetis bicaudatus</i>	5	2	15 2 3 2 4 4 7 5 1 5 8 7
<i>Pseudocloeon</i> sp.			2
Ephemerellidae			
<i>Drunella coloradensis</i>	1	11	6 2 4
<i>Drunella doddsi</i>		1	
Heptageniidae			
<i>Cinygmula</i> sp.	1	1 7 3 1	10 5 4 4 4 9 3 6 4 12
<i>Epeorus deceptivus</i>		2 5	10 3 9 10 4 4 11
<i>Epeorus longimanus</i>	3		
<i>Rithrogena</i> sp.		1 1	6 3 3
Siphonuridae			
<i>Ameletus</i> sp.	1	1 2 1	3 1 1 1
Plecoptera (stoneflies)			
Capniidae			
<i>Isocapnia</i> sp.			1
Chloroperlidae		1 2	3
Nemouridae			
<i>Zapada</i> sp.			1 1 2
<i>Yoraperla brevis</i>			2
Perlidae			
Perlodidae			1 3 2
<i>Isoperla</i> sp.			
Trichoptera (caddisflies)			
Limnephilidae			
<i>Imania</i> sp.			1
<i>Neothremma alicia</i>	3		
<i>Neothremma</i> sp.			
Rhyacophilidae			
<i>Rhyacophila</i> sp.		1 4	2 1 1
TOTAL NUMBER OF SPECIES:	9	6 11 33 7 7 36 10 26 4 11 11 15 30 26 4 19 15 31	

numbers. An additional three genera were found at single sample locations.

Caddisflies were sampled in six streams. Members of Rhyacophila were the most widely distributed (5 streams). Merritt and Cummins (1978) described Rhyacophila as lotic erosional inhabitants, clingers, and generally engulfers.

Dipterans were found in nine streams. Five streams contained members of the family Chironomidae. Tributaries to the Little Lamar did not contain insects from this family. Tipula sp. and Glutops sp. were the only Dipterans limited to one stream (103349-).

Beetles were absent from all but one sample site. Stream 103345- contained the genus Cleptelmis and only a single insect from this genus was sampled. Stream 103356- was the only tributary where planarians were sampled.

Diversity of macroinvertebrates was slightly lower than that found in the Bechler and Yellowstone drainage. Stream 103344- exhibited the greatest diversity (9 species). Streams 103345-, 103356-, and 103357- had almost equally diverse communities. Only one species of macroinvertebrate was sampled in stream 103352-. In all but one stream insects were sampled exclusively. An average of 82% of the diversity of all stream communities was contributed by mayflies.

Amphitheater Creek

Cursory survey information was gathered on six streams in the Amphitheater Creek drainage. Amphitheater Creek is classified as a second order stream and is a tributary to Soda Butte Creek. It arises from glacial and spring flows at 2,682 m elevation. Flow is southwesterly for 10 km to the confluence at approximately 2,094 m elevation.

The drainage is narrow with few open meadows present. Conifer-aspen types predominate the lower reaches. Pure conifer stands dominate the upper part of the drainage. Grasses and forbs are mixed among sagebrush slopes at lower elevations.

Generally, streams with higher watershed size had lower gradients (Table 38). The average size of tributary watershed in the Amphitheater drainage was 123.4 ha. The first tributary to Amphitheater (1033171401-) had

Table 38. Results of cursory surveys performed on tributaries to Amphitheater Creek, 1985.

	Stream Order	Watershed Size (ha)	Stream Length (km)	Elevation		Gradient	Stream Flow (m ³ /s)	Mean Width (m)	Mean Depth (cm)	Mean Velocity (cm/s)	Temperature (C)
				Maximum (m)	Minimum (m)						
Amphitheater Creek	II	2693.3	9.9	2804.0	2094.0	7.2					
Stream 1033171401	I	138.3	1.2	2512.0	2210.0	24.9					
Stream 1033171402	I	133.0	1.5	2615.0	2289.0	22.0					
Stream 1033171403	I	133.0	1.0	2573.0	2320.0	25.0	0.236	1.37	8.23	21.03	7
Stream 1033171404	I	111.7	1.2	2804.0	2451.0	29.1					
Stream 1033171405	I	101.1	0.9	2658.0	2505.0	17.6					

the largest watershed (138.3 ha). The fifth tributary (1033171405-) had the smallest watershed (101.1 ha). Average elevation of sampled streams 2,486 m (range 2,094-2,505 m) above MSL. Stream gradients ranged from 7% (Amphitheater Creek) to 29% (tributary 1033171404-).

A flow estimate was taken on stream 10333171403-. Streamflow was 0.24 m³/s and velocity was 21.03 cm/s. Stream width and depth were 1.4 m and 8.2 cm, respectively.

Biological attributes. Eleven species of macroinvertebrates were sampled in the Amphitheater drainage. Stoneflies (Plecoptera) had the greatest diversity (4 species). Mayflies were almost as equally diverse with three species. Caddisflies (Trichoptera) were represented by two species. Although, only three species of mayflies were sampled, they were present in greater numbers than stoneflies (Table 39). Mayfly species (Epeorus deceptivus) and stonefly species (Visoka cataractae) were present in the greatest numbers of all insects sampled.

Mayflies are characterized as erosional and depositional inhabitants, swimmers, clingers, collectors, gatherers, and scrapers (Merritt and Cummins 1978). Mayfly nymphs occur wherever there is an abundance of oxygen. Depending on temperature, 2-5 ppm of dissolved oxygen seem to be the lethal limits (Pennack 1978). They are most characteristic of shallow waters. Amphitheater Creek appears to provide adequately oxygenated conditions and water depth to facilitate mayfly growth. Stoneflies are primarily associated with clean and cool running water with rocky substrate as found in Amphitheater Creek. Extreme gradients may have contributed to the low species diversity of stoneflies sampled.

The remaining macroinvertebrate species sampled were less numerous. Turbellaria (planarians) were present in the Amphitheater drainage in low numbers. Approximately 46% of the macroinvertebrate sample was comprised of mayflies and 40% were stoneflies.

Pebble Creek

Pebble Creek is a major tributary to Soda Butte Creek. It originates in the extreme northeast corner of Yellowstone Park. Flow is southwesterly 29 km to the confluence with Soda Butte Creek. The drainage is steep but well vegetated up to 2,590 m. Several peaks over

Table 39. Occurrence and densities of macroinvertebrates found during cursory survey on Pebble and Amphitheater Creeks, 1985.

Pebble Creek Tributaries: 10331713-								
	01-	03-	10-	15-	20-	23-	29-	Amphitheater Cr.
Platyhelminthes								
Turbellaria (planarians)				2	1			3
Arthropoda								
Insecta								
Diptera (true flies)								
Chironomidae			1	15	4	3	10	
Empididae							1	
Ephemeroptera (mayflies)								
Baetidae								
Baetis bicaudatus						7		7
Pseudocloeon sp.						2		
Ephemerellidae								
Drunella coloradensis		2	1		8	4		
Seratella mitchineri						3		
Heptageniidae								
Cinygmula sp.		1		7	23	21	3	
Epeorus deceptivus		5	1					15
Rithrogena sp.			1	2				
Siphonuridae								
Ameletus sp.				1				2
Plecoptera (stoneflies)								
Chloroperlidae				4			1	
Nemouridae								
Amphinemura sp.						2		
Visoka cataractae			1					14
Peltoperlidae								
Yoro-perla brevis					2			2
Zapada sp.		1		10			1	2
Perlodidae					2			
Isoperla sp.					1			3
Trichoptera (caddisflies)								
Hydropsychidae								
Arctopsyche grandis								1
Lepidostomatidae								
Lepidostoma sp.					1			
Limnephilidae								
Apatania sp.					2			
Neothremma alicia								3
Rhyacophilidae								
Rhyacophila sp.	2			10				3
TOTAL NUMBER OF SPECIES:	2	9	5	51	44	42	16	52

3,048 m surround the area. the drainage is forested with lodgepole pine (Pinus contorta), Engelmann spruce (Picea engelmanni), and some Douglas fir (Pseudotsuga menziesii). Willows and cottonwood are also present.

Geologically, Pebble Creek consists mainly of alluvium and glaciofluvial deposits of the Holocene and Pleistocene eras. The area is influenced by alluvial-facies, volcanic conglomerate, sandstone, tuff and well sorted breccia (Christiansen et al. 1975).

Pebble Creek is a third order stream. cursory surveys were performed on 28 streams in the Pebble Creek drainage. All streams surveyed were first order. Total watershed size of Pebble Creek and its tributaries was 6,260 ha. Total stream length was 22 km. Generally, streams with larger watershed sizes had lower gradients. The average watershed size of sampled streams was 151 ha (Table 40). Streams 1033171301- and 1033171318- had the largest watershed size (224 ha). Pebble Creek and stream 1033171304- had the smallest watersheds (96 ha). Positive correlations existed between streamflow and channel depth ($r=0.88$) and channel width ($r=0.80$).

Mean elevation of sampled streams was 2,545 m (range 2,353-2,752 m) above MSL. Pebble Creek had the lowest elevation, (2,071 m), and stream 1033171329- had the highest (2972 m). Stream gradients ranged from 3.6% (Pebble Creek) to 34% (stream 1033171312-). Mean gradient was 21.5%. Generally higher gradients were associated with shallow depths (Table 40).

Mean flow of sampled streams was $0.017 \text{ m}^3/\text{s}$. Mean velocity was 15.2 cm/s. Stream 1033171332- had the highest flow ($0.64 \text{ m}^3/\text{s}$). Streams 1033171301-, 1033171303-, 1033171306-, and 1033171315- had the same flow estimate ($0.003 \text{ m}^3/\text{sec}$), which was the lowest value in the drainage. Average flow was lower than tributaries sampled in the Upper Lamar drainage. This difference can be explained by the dominance of first order streams with smaller channel width and depth in the Pebble Creek survey. The average water temperature was 7 C. Average pH was 7.6.

Biological attributes. Macroinvertebrate samples were collected from six streams. Over 18 species of aquatic invertebrates were sampled in the Pebble Creek drainage (Table 39). Insects dominated with over 94% of the species from this group. Mayflies (Ephemeroptera) was the most diverse order (8 species). Stoneflies (Plecoptera) were the second most diverse group

Table 40. Results of cursory surveys performed on tributaries to Pebble Creek, 1985.

	Stream Order	Watershed Size (ha)	Stream Length (km)	Elevation		Gradient	Stream Flow (m ³ /s)	Mean Width (m)	Mean Depth (cm)	Mean Velocity (cm/s)	Temperature (C)
				Maximum (m)	Minimum (m)						
Pebble Creek	III	6259.6	21.6	2849.8	2071.1	3.6					
Pebble Creek	I	95.8	1.1	2804.0	2633.0	15.5	0.035	2.16	9.14	17.68	4
Stream #1033171301	I	223.6	2.5	2658.0	2091.0	22.8	0.003	1.20	2.67	7.92	10
Stream #1033171302	I	175.7	2.2	2755.0	2188.0	26.0					
Stream #1033171303	I	143.7	2.1	2877.0	2210.0	31.7	0.003	0.62	7.01	7.01	11
Stream #1033171304	I	95.8	1.2	2487.0	2220.0	22.1					
Stream #1033171305	I	175.7	2.3	2877.0	2240.0	27.1					
Stream #1033171306	I	111.8	1.4	2585.0	2242.0	24.3	0.003	0.68	7.32	7.32	8
Stream #1033171307	I	127.7	1.9	2780.0	2256.0	26.9	0.009	0.66	7.01	19.51	6
Stream #1033171308	I	127.7	1.7	2707.0	2268.0	25.1	0.008	0.56	7.01	20.12	6
Stream #1033171309	I	207.6	2.6	2853.0	2277.0	21.7					
Stream #1033171310	I	127.7	1.2	2682.0	2283.0	33.0	0.010	0.94	9.14	12.19	11
Stream #1033171311	I	127.7	2.0	2780.0	2286.0	24.5					
Stream #1033171312	I	111.8	1.4	2755.0	2289.0	34.0					
Stream #1033171315	I	23.6	0.6	2438.4	2322.5	19.3	0.003	0.94	3.05	9.75	10
Stream #1033171316	I	207.6	2.3	2877.0	2329.0	24.0					
Stream #1033171317	I	31.5	1.2	2506.3	2337.8	18.5	0.004	0.55	5.49	15.24	7
Stream #1033171318	I	223.6	2.4	2853.0	2355.0	21.5					
Stream #1033171319	I	159.7	1.8	2789.0	2367.0	23.4					
Stream #1033171320	I	106.3	0.6	2453.6	2387.6	11.0	0.007	0.94	6.71	10.97	7
Stream #1033171321	I	127.7	1.4	2667.0	2393.0	19.6	0.009	0.76	5.49	23.47	7
Stream #1033171322	I	159.7	1.8	2652.0	2403.0	13.8					
Stream #1033171323	II	31.5	0.4	2438.4	2419.3	4.5	0.041	2.14	12.19	15.54	6
Stream #1033171324	I	127.7	1.2	2591.0	2435.0	13.0					
Stream #1033171325	I	175.7	1.7	2743.0	2454.0	17.0					
Stream #1033171326	I	143.7	1.7	2743.0	2513.0	13.5					
Stream #1033171327	I	143.7	1.4	2789.0	2527.0	18.7					
Stream #1033171329	I	127.7	1.9	2972.0	2533.0	23.1	0.037	1.75	9.75	21.34	4
Stream #1033171332	I	175.7	1.2	2728.0	2579.0	12.4	0.064	1.60	15.54	25.30	3

(7 species). True flies, (Diptera) were the least diverse order with two species.

Distribution of macroinvertebrates in the Pebble Creek drainage was similar to the trend in diversity.

Mayflies were sampled in five streams. Cinygmula was found in the greatest numbers of any macroinvertebrate and was the most widely distributed (five streams).

Drunella coloradensis was found in four streams.

One stonefly genus (Zapada) was sampled in three streams. The genus (Amphinemura) from the family Nemouridae was present in two streams. An additional five stonefly genera were each found in a single sample location.

Dipterans were represented by only two species. Species from the family Chironomidae were sampled in five streams. Stream 1033171315- contained the largest number of Dipterans in the drainage. Turbellaria (planarians) were sampled in two streams (1033171315- and 1033171320-).

Diversity of macroinvertebrates was generally lower than that observed in the Upper Lamar tributaries and the Slough Creek drainage. Three streams (1033171315-, 1033171320-, and 1033171323-) had the same number of species sampled (seven). Stream 1033171303- had the lowest diversity (four species). Five species each were sampled in both streams 1033171310- and 1033171329-. Four streams contained insects exclusively. Stream 1033171323- had the highest density of macroinvertebrates. An average of 44% of the diversity of all stream communities was contributed by mayflies. Approximately 56% of the density of the collective samples was comprised of mayflies.

Slough Creek

Slough Creek originates in Gallatin National Forest at an elevation of 2,972 m at the base of Pinnacle Mountain. Water supply is from snow, glaciers, springs and lakes. Slough Creek has a large drainage area of 56,941 ha, of which only 19,953 (35%) are within park boundaries.

The upper slopes are generally big sagebrush/Idaho fescue and Englemann spruce/northern twinflower interspersed with aspen and occasional patches of subalpine fir/northern twinflower. In the canyon area, wet sedges, tufted hargrass, Englemann spruce (Picea

engelmannii) and Douglas fir (Pseudotsuga menziesii) are found. Below the canyon to the mouth, Slough Creek meanders through wet sedge/tufted hairgrass meadow surrounded by big sagebrush/Idaho fescue and infrequent stands of aspen and Douglas fir/snowberry (Jones et al. 1979).

Geologically, the main course of the river meanders through alluvium and glaciofluvial deposits of Pleistocene and Holocene eras. Below Slough Creek patrol cabin, the upper slopes are heavily influenced by Precambrian schist and gneiss. Above the cabin, the area is glacial till and landslide deposits made up of volcanic conglomerate, sandstone, tuff and well-sorted breccia (Jones et al. 1979).

Total watershed size of Slough Creek was 19,490 ha. Seven streams were sampled in the Slough Creek drainage. One second order stream occurs as a tributary to Elk Tongue Creek. The average size of sampled watershed in the Slough Creek drainage was 276 ha. Streams of comparable order in the Upper Lamar had slightly smaller watershed size than those in the Slough Creek drainage. Streams 10330211- and 10330207- had the largest and smallest watershed size, respectively. Linear regression equations described the relationship between watershed size and flow ($r^2=0.94$), channel width ($r^2=0.67$), channel depth ($r^2=0.64$), and channel velocity ($r^2=0.86$). Positive correlations existed between streamflow and channel depth ($r=0.78$) and channel width ($r=0.88$). Average pH value was 7.9 and mean water temperature was 6.3 C (Table 41).

Mean elevation of sampled streams was 2,463 m (range 2,276-2,603 m) above MSL. Stream gradients ranged from 14.3% (stream 10330211-) to 27.8% (stream 1033021004-). Generally, streams with lower gradients had higher flows.

Mean flow of sampled streams was 0.012 m³/s. Mean velocity was 15.32 cm/s. These averages were lower than those observed in the Upper Lamar tributaries. This can be attributed to the higher percentage of large (greater than first order) streams sampled in the Upper Lamar.

Chemical attributes. Water chemistry analysis was not performed on Slough Creek in 1985. However, the Slough Creek system has been classified as a calcium-bicarbonate type water (Jones et al. 1979). Most of the measured chemical parameters were average for park

Table 41. Results of cursory surveys performed on tributaries to Slough Creek, 1985.

	Stream Order	Watershed Size (ha)	Stream Length (km)	Elevation		Gradient	Stream Flow (m3/s)	Mean Width (m)	Mean Depth (cm)	Mean Velocity (cm/s)	Temperature (C)
				Maximum (m)	Minimum (m)						
Stream 10330207	I	82.7	2.0	2511.0	1978.0	26.5	0.002	0.43	3.05	16.15	7
Stream 10330208	I	382.7	2.6	2575.6	1978.0	23.0	0.010	0.72	9.45	15.54	8
Stream 1033021004	I	120.8	1.4	2682.2	2293.6	27.8	0.005	0.58	6.10	14.02	4
Stream 1033021006	I	346.5	2.5	2822.4	2385.0	17.5	0.017	1.03	11.58	14.33	7
Stream 10330211	I	687.8	4.7	2657.9	1984.0	14.3	0.031	1.55	7.92	24.69	7
Stream 1033021201	I	83.5	1.1	2665.5	2374.4	26.5	0.005	1.15	5.49	8.53	5
Stream 1033021302	II	231.0	1.7	2755.4	2374.4	22.4	0.014	1.29	7.62	14.02	6

waters except for higher than average concentrations of magnesium and calcium near the mouth and on the mainstem near Elk Tongue Creek. Surveys in 1978 provided evidence that Slough Creek may become a magnesium-bicarbonate water in late winter. Magnesium has a much longer residence time than calcium which cycles through the aquatic system much more rapidly. Spring run-off recharges the river with calcium and dilutes concentrations of magnesium (Jones et al. 1978).

Water quality approached the standard considered excellent for trout streams. Hardness was moderate, dissolved oxygen nearly always at saturation levels, pH varied from 7.5 to 8.3, and alkalinity ranged from 92 to 120 ppm (Jones et al. 1978).

Biological attributes. Macroinvertebrate samples were collected on six streams in the Slough Creek drainage. Over 24 species of macroinvertebrates were found. Insects dominated the sample with over 96% of species from this group (Table 42). Mayflies (Ephemeroptera) were the most diverse group of insects sampled (7 species). Caddisflies (Trichoptera) were the second most diverse group (6 species). Beetles (Coleoptera) and true flies, (Diptera) were almost as equally diverse with three and four species, respectively.

Density differed from the pattern of diversity observed. Mayflies were the most diverse, but caddisflies were present in approximately 10 times the density observed in mayflies. Two mayflies Baetis bicaudatus and Cinygmula sp. were found in four streams. Tributary 10330211- contained the greatest diversity of mayflies (4 species). Tributaries 10330207- and 10330208- contained only one species each.

The caddisfly (Neothremma alicia) was found in the greatest numbers of any macroinvertebrate sampled in the drainage and was found in four streams. Tributary 10330208- contained the greatest diversity of caddisflies (5 species).

Plecopteran (Zapada) was found in five streams sampled. Yoraperla brevis was sampled in three streams. Two additional genera were found in single sample locations.

Only four Dipterans were found in the Slough Creek drainage. They were sampled in tributaries 10330207- and 10330208- and 1033021006-. Two species were from the family Chironomidae.

Table 42 Occurrence and densities of macroinvertebrates found in cursory survey of Slough Creek drainage, 1985.

103302-	Buffalo Creek:03- Tributaries: 02- 04-		Elk Tongue Creek:13- Tributaries: 01- 02-		Plateau Creek:10- Trib 06-	Slough Creek Tributaries: 07- 08- 11-		
Platyhelminthes								
Turbellaria (planarians)			7		5		4	3
Arthropoda								
Insecta								
Coleoptera (beetles)								
Dytiscidae								
Dytiscus sp.							1	
Elmidae								
Cleptelmis sp.							12	
Stenelmis sp.	5							
Sphaeriidae								
Sphaerium sp.							7	
Diptera (true flies)								
Chironomidae							1	
Pelecorhynchidae								
Glutops sp.							1	2
Stratiomyidae								
Odontomyia sp.							1	
Tipulidae								
Hexatoma sp.					1			
Ephemeroptera (mayflies)								
Baetidae								
Baetis bicaudatus		1			9		2	3
Baetis tricaudatus	4							
Ephemerellidae								
Drumella coloradensis	1							1
Seratella mitchineri	2						17	
Heptageniidae								
Cinygmula sp.	6	7	3					5
Epeorus deceptivus	5			11	4			
Rithrogena sp.				2				
Siphonuridae								
Ameletus sp.			8					1
Plecoptera (stoneflies)								
Chloroperlidae	3	1						
Nemouridae								
Amphinemura sp.	5							
Visoka cataractae				3				
Yoroperla brevis			7	1				1
Zapada sp.			4	1	12	7	9	
Perlodidae								1
Isoperla sp.	3							
Trichoptera (caddisflies)								
Brachycentridae								
Microsema sp.	17							
Glossosomatidae								
Glossosoma sp.	3							
Limnephilidae								
Agatania sp.	8						3	
Limnephilus sp.							3	
Neothremma alicia					48	3	368	8
Neothremma sp.			1					
Rhyacophilidae								
Rhyacophila sp.	3		2				5	4
TOTAL NUMBER OF SPECIES:	65	9	22	28	79	15	434	27

Three species of beetles were found exclusively in the tributary 10330208-. Turbellaria (planarians) were present in four streams.

Tributary 10330208- exhibited the greatest diversity of all streams sampled (12 species). This stream contained the greatest density of macroinvertebrates of all sites. Nine species were collected from tributary 10330211-. The first tributary to Elk Tongue Creek 1033021201- had the lowest diversity (4 species). An average of 29% of the diversity of all stream communities was contributed by mayflies. Approximately 72% of the density of macroinvertebrates was made up of caddisflies.

Buffalo Creek

Buffalo Creek is the largest tributary to Slough Creek in the park. Its total stream length was 29 km. Total watershed size was 15,870 ha. The stream forks approximately 1.5 km before entering Slough Creek.

Alders, conifers, aspens, and grasses are found along the stream channel. Specific forest types include: Douglas fir (Pseudotsuga menzeisii), and Engelmann spruce (Picea engelmanni) (Despain 1985).

Cursory surveys were performed on seven tributaries to Buffalo Creek. All streams were classified as first order. Mean watershed size of sampled streams was 459 ha. Stream 1033020307- had the largest watershed (898. ha), and stream 1033020301- had the smallest (325 ha). A linear regression equation was used to describe the relationship between watershed size and water velocity ($r^2=0.63$). Generally, streams with large watersheds had higher water flows, deeper and wider stream channels, and lower gradients (Table 43). Average water temperature was 5.3 C. Average pH value was 7.6.

Mean elevation of sampled streams was 2,354 m (range 2212.8-2504.5 m) above MSL. Stream gradients ranged from 8.7% (stream 1033020303-) to 19.0% (stream 1033020301-). Average gradient was 13%. Generally, streams with lower gradients had higher water flows.

Mean flow of sampled streams was 0.035 m³/s. Mean velocity was 13.2 cm/s. Average streamflow was almost twice the mean flow observed in the Pebble Creek drainage. Positive correlations existed between streamflow and channel width ($r=0.91$) and channel depth ($r=0.70$).

Table 43 Results of cursory surveys performed on tributaries to Buffalo Creek, 1985.

	Stream Order	Watershed Size (ha)	Stream Length (km)	Elevation		Gradient	Stream Flow (m ³ /s)	Mean Width (m)	Mean Depth (cm)	Mean Velocity (cm/s)	Temperature (C)
				Maximum (m)	Minimum (m)						
Stream 1033020301	I	325.5	1.8	2426.2	2087.9	19.0	0.002	0.72	7.01	4.88	5
Stream 1033020302	I	750.8	1.8	2353.1	2072.6	15.6	0.024	2.01	11.28	10.67	5
Stream 1033020303	I	571.8	4.5	2506.7	2116.5	8.7	0.012	1.33	13.11	7.32	7
Stream 1033020304	I	719.8	4.1	2667.0	2222.0	10.9	0.010	0.84	12.19	9.75	5
Stream 1033020305	I	388.5	2.3	2554.2	2228.0	14.2	0.054	2.16	11.89	21.03	5
Stream 1033020306	I	678.6	2.6	2529.8	2229.5	11.5	0.073	2.89	12.19	20.73	7
Stream 1033020307	I	897.8	5.3	2769.1	2240.0	10.0	0.072	2.50	15.85	17.98	3

Biological attributes. Macroinvertebrate samples were collected on two tributaries to Buffalo Creek, (1033020302- and 1033020304-). A total of seven species were sampled. Mayflies (Ephemeroptera) were the most diverse (6 species). Beetles (Coleoptera) were represented by only one species.

The mayfly genus (Cinygmula) was the only aquatic insect found in both streams. It also was found in the greatest density of any macroinvertebrate. One beetle genus Stenelmis was sampled exclusively in the tributary 1033020302-.

Tributary 1033020302- had the greatest diversity of macroinvertebrates (6 species). Only two genera were collected in tributary 1033020304-, both were Ephemeropterans. No beetles were collected in this tributary.

An average of 86% of the diversity of aquatic insects was comprised of mayflies. Approximately 74% of the density of macroinvertebrates was contributed also by mayflies.

RECONNAISSANCE SURVEYS

During 1985, reconnaissance surveys were initiated on 10 streams. These streams included Agate Creek, Amphitheater Creek, Buffalo Creek, Cold Creek, Elk Antler Creek, Lamar River, Little Lamar River, Mist Creek, Pebble Creek, and Quartz Creek. Because of logistics, these surveys were not completed. They will be completed in 1986 and results will be forthcoming.

ECOLOGICAL PERFORMANCE SURVEYS

During 1985, ecological performance surveys were performed on the Gibbon River, Madison River, Slough Creek, and Soda Butte Creek. In addition, a special project was performed on Arnica Creek relating fish habitat parameters to fish standing crop in seven separate reaches.

Gibbon River

The Gibbon River supports the fourth most popular stream fishery in Yellowstone Park. Approximately 12,000 days of angler use are spent each year fishing this stream (Figure 22). Anglers generally catch 5 brown trout (Salmo trutta) for every 2 hours of effort on the Gibbon River (Figure 22). During each fishing season about 11,500 brown trout are caught. Almost 4% of these

1. Wolf Lake-Little Falls
2. Little Falls-Virginia Cascades
3. Virginia Cascades-Gibbon Rapids
4. Gibbon Rapids-Gibbon Falls
5. Gibbon Falls-Madison Junction

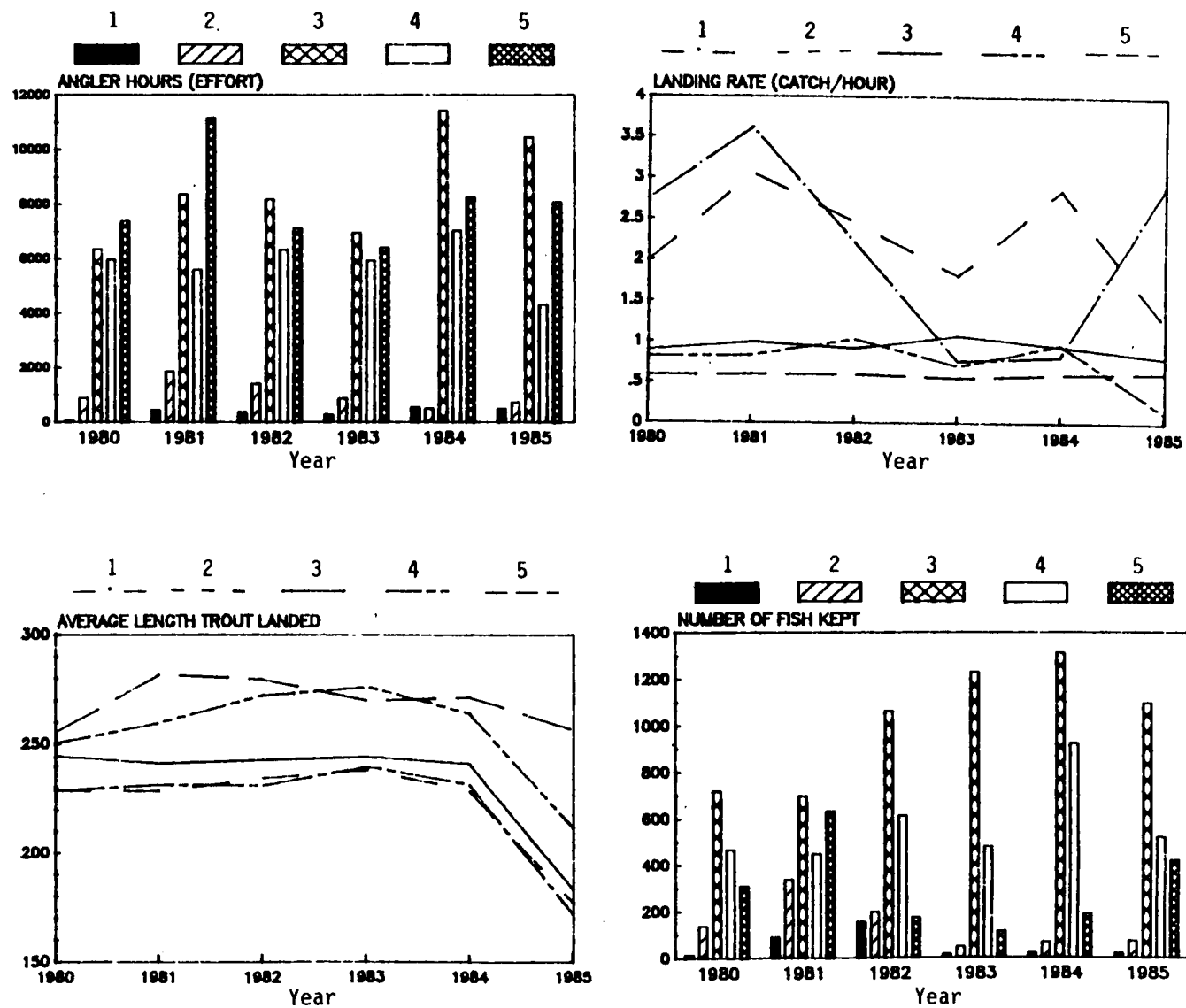


Figure 22 Angler statistics on the Gibbon River, Yellowstone National Park, 1980-1985.

fish are longer than 400 mm. Further, anglers tend to keep a higher percentage of larger than smaller fish.

Since 1970, the lower Gibbon River has been managed with a 406 mm minimum length, 2-fish creel limit. The upper Gibbon River (above Gibbon Falls) has had a harvest restriction of two fish of any size since 1973.

Mottled sculpin (Cottus bairdi) was the only fish species native to the Gibbon River above Gibbon Falls. Rainbow trout (Salmo gairdneri) were introduced in 1889 and brook trout (Salvelinus fontinalis) were first stocked in 1905. Brown trout were introduced in the Gibbon River in 1928 when 43,000 Loch Leven browns were stocked. It is feasible that brown trout inhabited the section of the Gibbon River below Gibbon Falls (Lower Gibbon River) earlier than this date since brown trout were stocked in the Firehole River in 1889.

Ecological performance surveys were performed on the section of the Gibbon River for the Norris picnic area to the Norris campground (Norris Section) on 30 May and 5 September 1985. Fish populations in this area were sampled on one previous occasion. In 1973, a 276 m section was sampled (Dean and Varley 1974).

Four species of fish were captured in the Norris section of the Gibbon River on 30 May: brook trout, brown trout, rainbow trout, and mottled sculpin. Total number of fish captured was 225. Approximately 47% were brook trout, 29% were brown trout, 22% were mottled sculpin, and 2% were rainbow trout. An estimated 1,938 (+1,167) brook trout and 613 (+401) brown trout inhabited this section (Table 44). Efficiency rates for these estimates were 4.9% and 9.5%, respectively. Total number of sport fish in this area was estimated at 1962.2 fish/km.

Brook trout averaged 156 mm, brown trout averaged 283 mm, and rainbow trout averaged 229 mm TL (Table 44 and Figure 23). Proportional stock density (PSD) was 59.5% for brown trout, 1.8% for brook trout, and 0.0% for rainbow trout. Mean weight for these fish was 203, 42, and 134 g, respectively. Total biomass of all sport fish was estimated at 158.3 kg/km. Brown trout biomass totaled an estimated 95.7 kg/km and brook trout biomass totaled 62.6 kg/km.

The same four species of fish were captured on 5 September. Total number of captured fish was 649. Approximately 73% were brook trout, 19% were brown trout, 8% were mottled sculpin, and less than 1% were

rainbow trout. An estimated 2,988 (+711) brook trout and 372 (+81) brown trout inhabited this section of the Gibbon River (Table 44). Efficiency rates of these estimates were 15.6% and 32.9%, respectively. Density of sport fish in this section was estimated at 2584.7 fish/km.

Mean TL of brook trout was 120 mm, brown trout was 147 mm, and rainbow trout was 229 mm (Table 44 and Figure 23). PSD was 0.0% for brook trout, 15.4% for brown trout, and 0.0% for rainbow trout. Mean weight of these fish was 21, 38, and 134 g, respectively. Total biomass of all sport fish was estimated at 59.2 kg/km. Brook trout comprised over 80% (48.3 kg/km) of the total sport fish biomass. Mean age of brown and brook trout was 1.4 and 1.5 years, respectively (Table 45).

The most obvious differences between the spring and fall samples was the reduction in size and number of brown trout and the reduction in size but increase in number of brook trout. The number of brown trout in the sample section from May to September decreased by 39% and the average size decreased by 48%. As a result of these two factors, the total biomass of brown trout in this area was reduced by 89%. Total biomass of brook trout, between spring and fall samples, was reduced by 23%. Total number of brook trout increased by 54% from May to September.

Madison River

The Madison River supports the second most popular stream fishery in YNP (Table 5). This fishery is supported by five fish species: brown trout, rainbow trout, cutthroat trout (Salmo clarki bouvieri), mountain whitefish (Prosopium williamsoni), and Montana grayling (Thymallus arcticus). Since 1951, fishing gear has been restricted to artificial flies with a single hook. Since 1970, the fishery has been managed with a 406 mm minimum size limit (2 fish creel) and grayling have been protected with a catch and release regulation.

Angler use on the Madison River may be divided into two segments: downstream (below Seven-Mile Bridge) and upstream (above Seven-Mile Bridge) (Figure 24). Angler use, landing rate, average length of fish landed, and creel rate have been higher downstream of Seven-Mile Bridge than upstream of it. Since 1980, total number of fish harvested has averaged almost 2.6 times greater in the lower section. Approximately 100 fish/km and 65 fish/km are harvested in the lower and upper sections, respectively. In the lower section, an

Table 44. Results of fish population size estimations performed on Yellowstone National Park streams, 1985.

Stream	Species	Date	Length (km)	Area (ha)	Population Estimate						Mean length (mm)	Mean weight (g)	PSD
					N	95% CI	Fish/km	Fish/ha	kg/km	kg/ha			
Gibbon River	Brook trout	05/30/85	1.3	0.9	1938	+1167	1490.7	2153.3	62.6	90.4	156	42	1.8
		09/05/85			2988	+711	2298.5	3320.0	48.3	69.7	120	21	0.0
	Brown trout	05/30/85	1.3	0.9	613	+401	471.5	681.1	95.7	138.3	283	203	59.5
		09/05/85			372	+81	286.2	413.3	10.9	15.7	147	38	15.4
	Rainbow trout	05/30/85	1.3	0.9	-	-	-	-	-	-	229	134	0.0
		09/05/85			-	-	-	-	-	-	229	134	0.0
Madison River Barns	Brown trout	09/23/85	6.0	22.6	4395	+3787	732.5	194.5	865.1	229.7	494	1181	59.6
	Rainbow trout	09/23/85	6.0	22.6	1799	+2003	299.8	79.6	188.6	50.1	400	629	64.3
	Mountain whitefish	09/23/85	6.0	22.6	7693	+3801	1282.2	340.4	309.0	82.0	302	241	94.7
Slough Creek	Rainbow-cutthroat hybrid	05/24/85	4.3	16.4	181	+107	42.1	11.0	20.9	5.5	369	498	21.4
		09/03/85			532	+243	123.7	32.4	57.2	14.9	359	462	33.3
Soda Butte Creek	Rainbow-cutthroat hybrid	09/04/85	0.3	0.4	214	+123	713.3	535.0	70.6	52.9	221	99	0.0

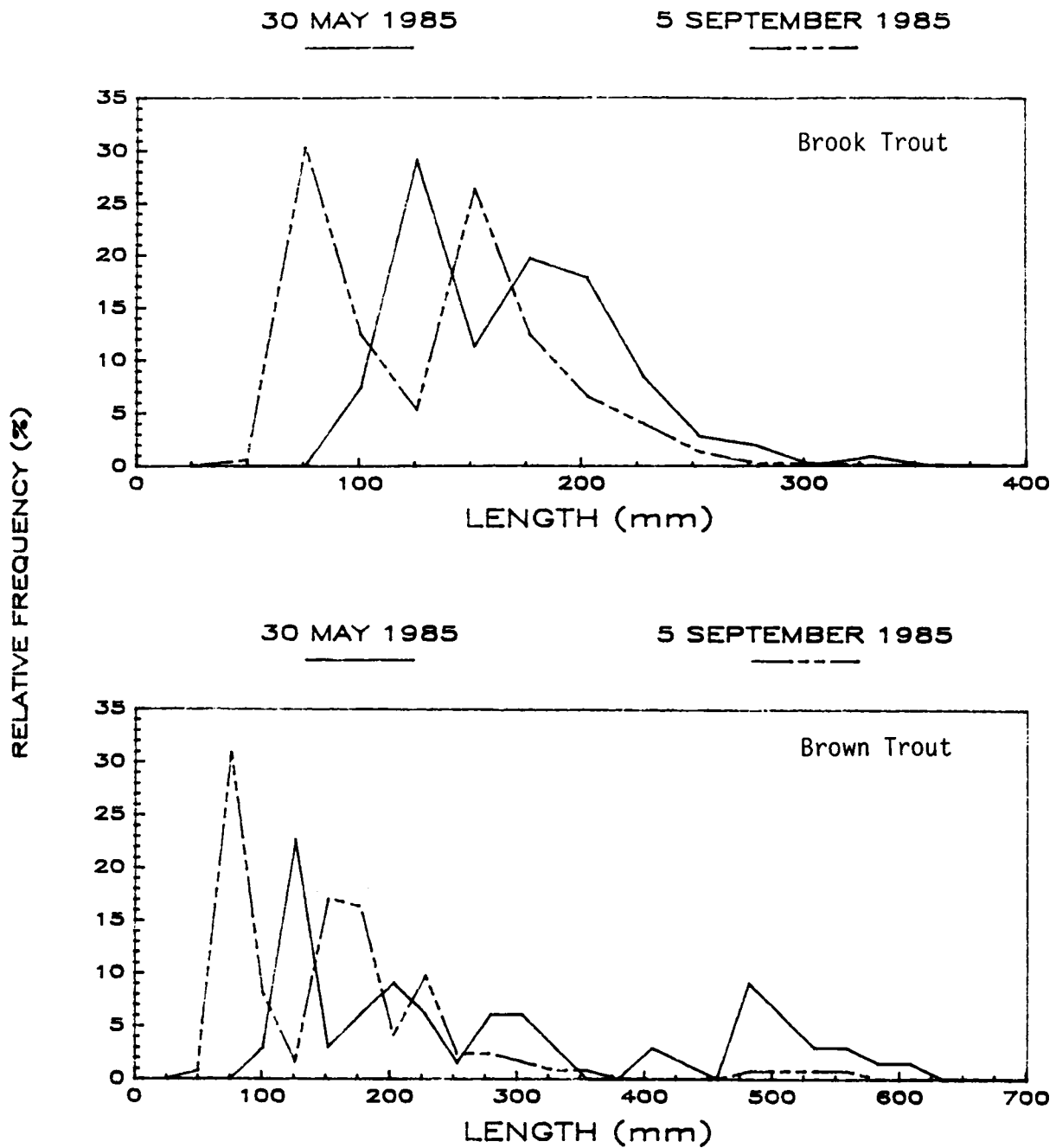


Figure 23. Length frequency of brook and brown trout captured in the Gibbon River, Yellowstone National Park, 1985.

Table 45. Empirical length, by age group, of fish captured during stream surveys in Yellowstone National Park, 1985.

Stream	Species	Sample Size	Length at Age ¹⁾							
			I+	II+	III+	IV+	V+	VI+	VII+	VIII+
Arnica Creek	Brook trout	81	139 (45)	197 (34)	225 (2)	-	-	-	-	-
	Cutthroat trout	33	118 (29)	178 (3)	261 (1)	-	-	-	-	-
Gibbon River	Brook trout	37	137 (19)	185 (17)	230 (1)	-	-	-	-	-
	Brown trout	22	164 (16)	197 (5)	-	447 (1)	-	-	-	-
	Rainbow trout	3	-	206 (3)	-	-	-	-	-	-
Madison River	Brown trout	33	205 (4)	182 (2)	338 (4)	419 (6)	537 (3)	477 (1)	-	-
	Rainbow trout	22	177 (3)	235 (1)	135 (2)	380 (9)	427 (6)	430 (1)	-	-
	Mountain whitefish	13	132 (2)	207 (3)	276 (1)	271 (5)	-	-	386 (1)	410 (1)
Slough Creek	Rainbow-cutthroat hybrid	43	141 (1)	200 (2)	354 (11)	395 (14)	441 (8)	445 (5)	465 (1)	462 (1)
Soda Butte Creek	Rainbow-cutthroat hybrid	23	-	206 (9)	236 (12)	300 (2)	-	-	-	-

1) Values given as means with sample size in parentheses.

average of 40 rainbow trout, 38 brown trout, and 20 mountain whitefish per kilometer are harvested each year. In the upper section, approximately 30 brown trout, 20 rainbow trout, and 2 mountain whitefish per kilometer have been creelied each year.

The most noticeable change in angler statistics for the Madison River fishery has been a shift in the species composition of fish caught since 1954 (Jones et al. 1985). The main shift occurred from 1976 through 1981 when the percentage of brown trout caught decreased and the percentage of whitefish caught increased. Since 1982, however, the percentage of brown trout has increased in the catch as the percentage of mountain whitefish has decreased.

An ecological performance survey was performed on the section of the Madison River from the Barns to a point 6.0 km downstream (Barns Section) on 23 September 1985. Fish populations in this area have been evaluated in three previous years; 1957, 1978 and 1984.

Five species of fish were captured in the Barns section on 23 September: brown trout, rainbow trout, mountain whitefish, longnose dace, and mottled sculpin. Total number of fish captured was 585. Approximately 61% were mountain whitefish, 25% were brown trout, and 10% were rainbow trout. An estimated 7,693 (+3,801) mountain whitefish, 4,395 (+3,787) brown trout, and 1,799 (+2,003) rainbow trout inhabited this section (Table 44). Efficiency rates for these estimates were 4.3%, 2.6%, and 1.7%, respectively. Total number of sport fish in this area was estimated at 2,314 fish/km.

Mountain whitefish averaged 302 mm, brown trout averaged 494 mm, and rainbow trout averaged 400 mm TL (Table 44 and Figures 25-27). PSD was 94.7% for mountain whitefish, 59.6% for brown trout, and 64.3% for rainbow trout. Mean weight for these fish was 241, 1181, and 629 g, respectively. Total biomass of sport fish was estimated at 1362.7 kg/km. Brown trout comprised almost 64% of the total sportfish biomass.

In the Madison River, the exploitation rate of fish longer than 406 mm has been highest in the Barns section. Approximately 44% of the standing crop of fish longer than 406 mm/km has been harvested each year. Over 80% of the harvested fish have been brown and rainbow trout.

Jones et al. (1981) recommended that brown trout and mountain whitefish in the Madison River be managed under

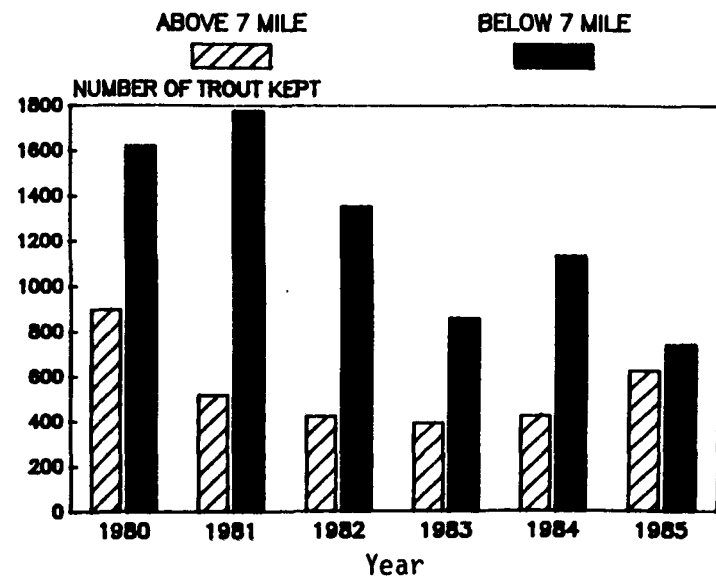
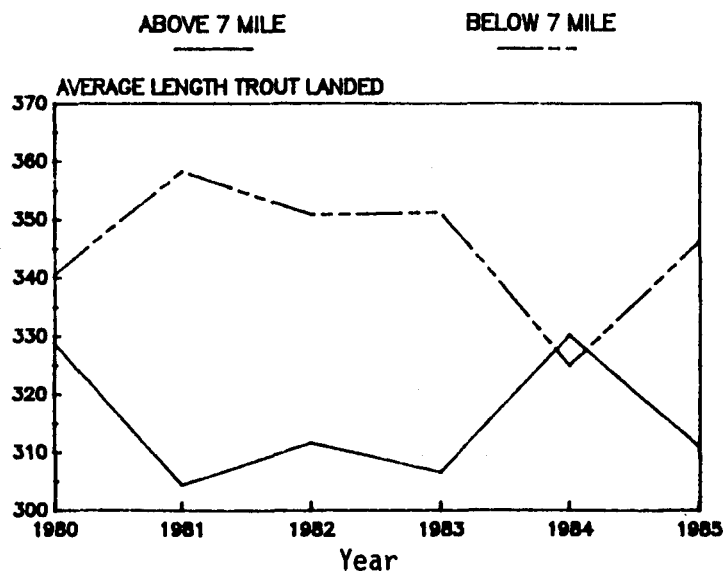
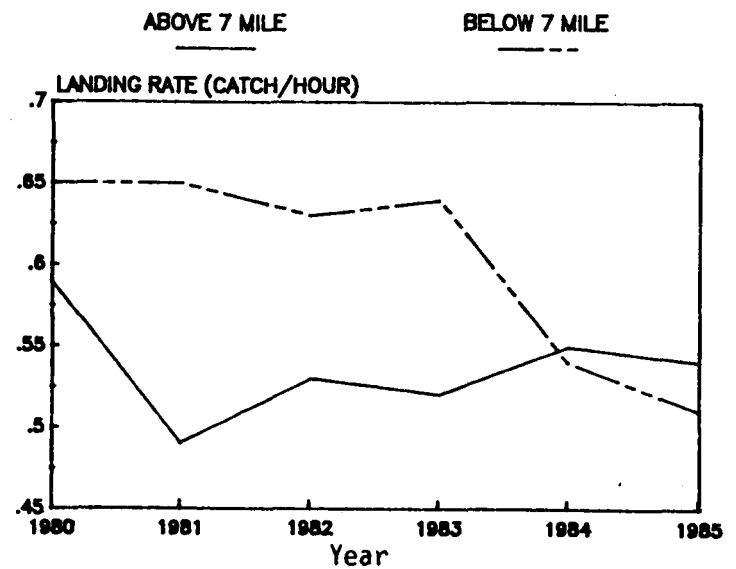
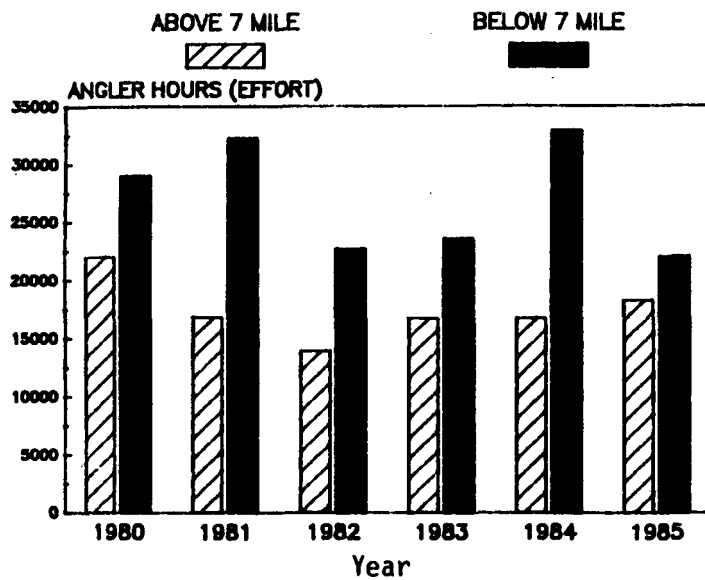


Figure 24. Angler statistics on the Madison River, Yellowstone National Park, 1980-1985.

RELATIVE FREQUENCY (%)

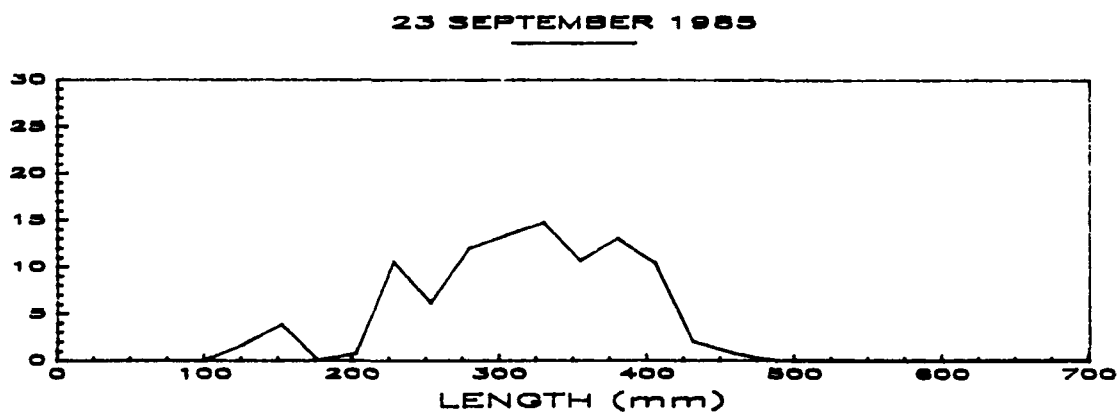
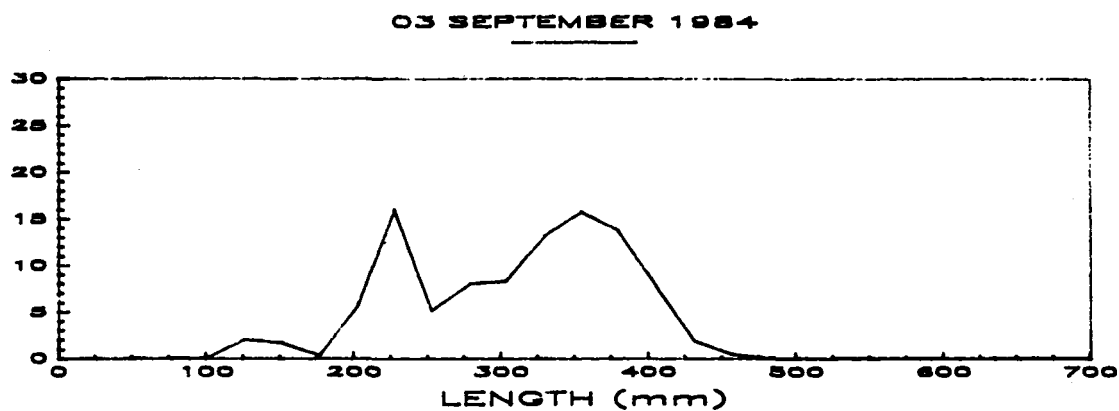
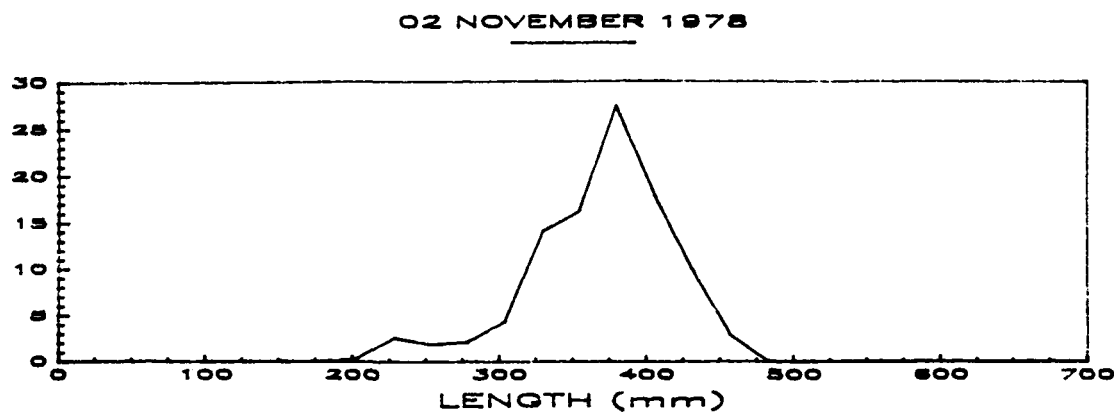


Figure 25. Length frequency of mountain whitefish captured in the Madison River, 1978-1985.

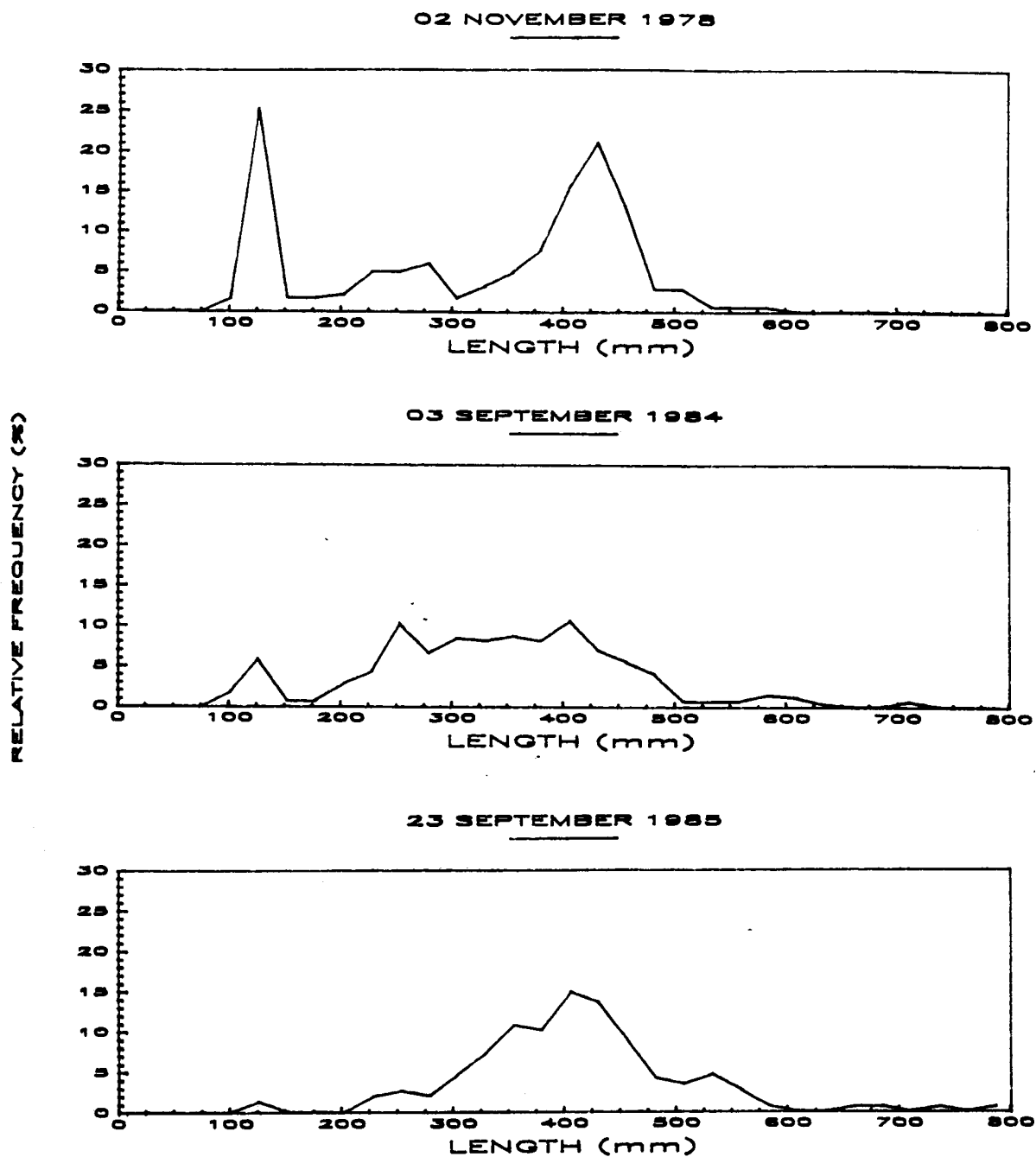


Figure 26. Length frequency of brown trout captured in the Madison River, 1978-1985.

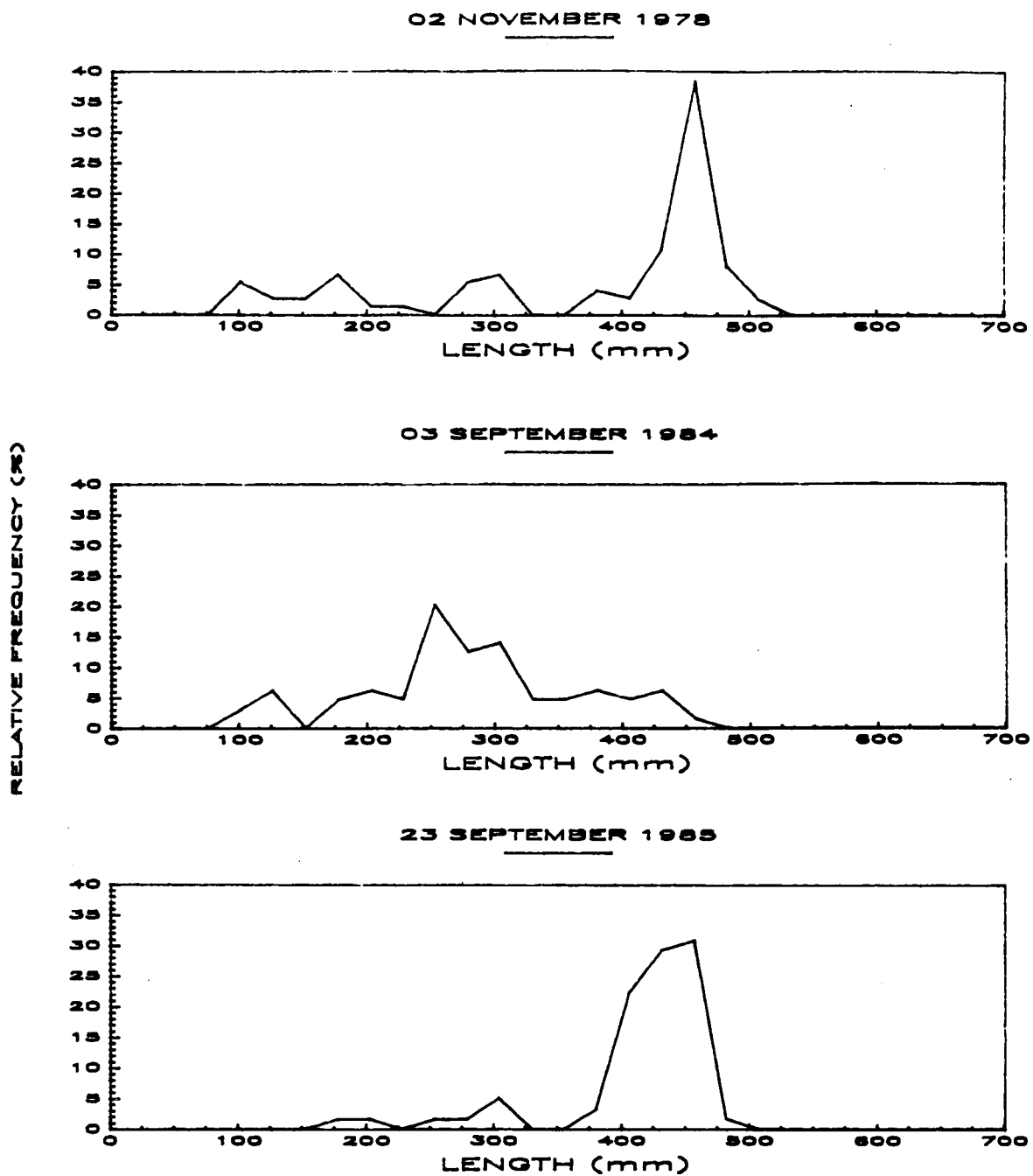


Figure 27. Length frequency of rainbow trout captured in the Madison River, 1978-1985.

a maximum size restriction and rainbow trout be managed under a catch and release regulation; however, these regulations have never been implemented. Since the percentage of large brown and rainbow trout is small in the National Park Meadows section, this fishery might benefit under such a management scheme. It is doubtful, however, that a significant change in the size structure of fish populations in the Barns section would occur. With the extension of the angling season on the Madison River in 1984, further analysis is needed before definitive recommendations can be made.

Slough Creek

Slough Creek supports the fifth most popular stream fishery in YNP (Jones et al. 1985). Further, this is the most popular stream fishery in the Lamar River drainage. It is supported by a cutthroat trout population, introgressed with rainbow trout genes, which has been managed under a catch and release regulation since 1973. Since 1980, the popularity of this fishery has increased (Figure 28), while angler use on many of the park streams has decreased (Jones et al. 1985).

Angler use on Slough Creek may be divided into two segments: upstream and downstream of the cascades at Slough Creek campground. Over the past six years, the lower section has received approximately 54% of the angler effort. Since 1980, landing rate has declined while the average size of fish landed has increased in both sections (Figure 28). An average of 36,000 (1,459 fish/km) trout are caught each year in Slough Creek. Of these, approximately 1.1% have been illegally creelied each year.

Historically, the fishery resources of Slough Creek have received much attention by aquatic investigators (Jordan 1891; Lanier 1927; Fromm 1941; Hanzel 1960; Arnold and Sharpe 1968; Mills 1969; Dean and Mills 1970; Dean and Mills 1971; Dean 1972; Pickett and Chadwick 1973; Dean et al. 1975; Jones et al. 1979, 1980). From 1980 to 1985, the only information collected on the status of the Slough Creek fishery has been volunteer angler statistics. In 1985, ecological performance surveys were conducted in Slough Creek below the Slough Creek campground on 24 May and 3 September.

Four species of fish were captured in Slough Creek on 24 May: rainbow-cutthroat hybrid trout, mottled sculpin, longnose dace, and mountain sucker. Slough Creek is the only stream in the Lamar River drainage where mottled sculpin have been captured. Total number of fish

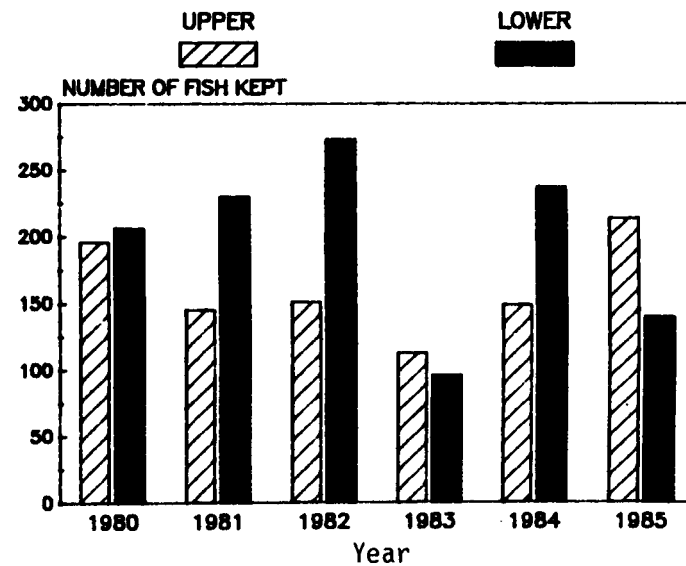
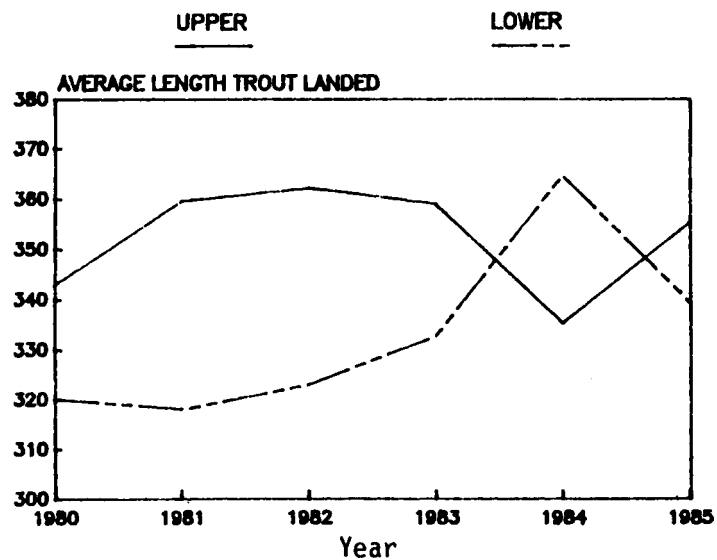
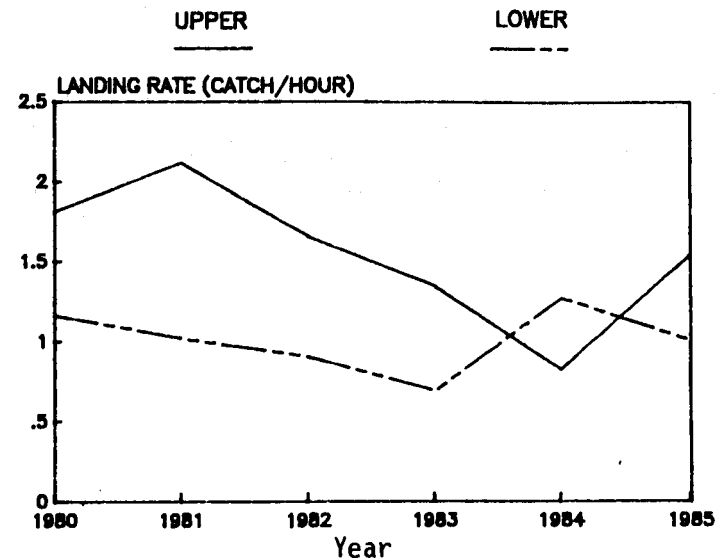
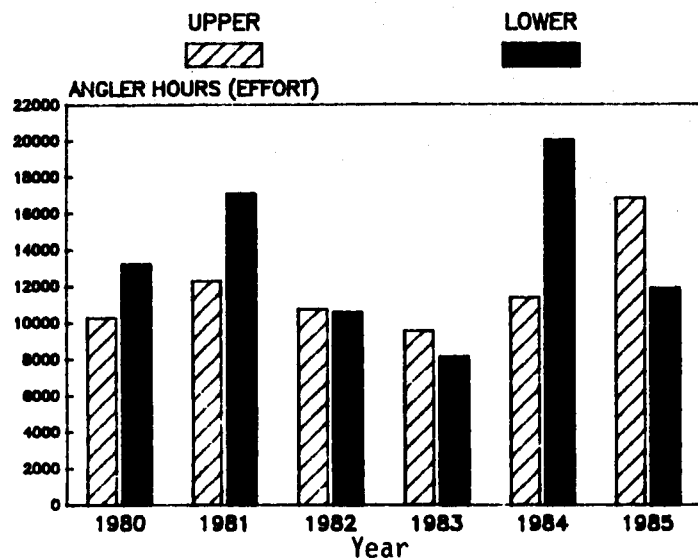


Figure 28. Angler statistics on Slough Creek, Yellowstone National Park, 1980-1985.

captured on the recapture run on 28 May was 129. Approximately 72% of these fish were rainbow-cutthroat hybrid trout. An estimated 181 (+107) trout inhabited this section (Table 44). Efficiency rate for this estimate was 7.9%. The density of trout in this area was approximately 42.1 fish/km. Mean TL of rainbow-cutthroat trout was 369 mm, PSD was 21.4%, mean weight was 498 g (Figure 29). Total biomass of trout was approximately 20.9 kg/km.

The same four fish species were also captured on 3 September. Total number of captured fish was 172. Approximately 38% were rainbow-cutthroat hybrid trout. An estimated 532 (+243) trout inhabited this section (Table 44). Efficiency rate for this estimate was 11.8%. Density of trout in this area was estimated at 123.7 fish/km. Mean TL of these fish was 359 mm, mean weight was 462 mm, and PSD was 33.3% (Figure 29). Total trout biomass was approximately 57.2 kg/km.

Soda Butte Creek

Soda Butte Creek contains the ninth most popular stream fishery in YNP (Table 5). This fishery, supported by a cutthroat trout population introgressed with rainbow trout genes, has been managed under a two fish creel limit since 1973. Angler use of this stream may be divided into two segments: upstream and downstream of Icebox Canyon (Figure 30). Over the past 8 years, the lower section has received 71% more use than the upper section. Highest recorded use for both sections was in 1981. Since 1977, landing rate and average length of trout landed has been variable, and no trends are apparent.

Approximately 80% of the fish landed in Soda Butte Creek are released; however, this fishery sustains the third highest exploitation rate of all stream fisheries in YNP. The number of trout creeled averages 2,000/year. Highest number creeled occurred in 1981, when an estimated 4,500 fish were removed. An average of 313 fish/ha (813 fish/km) have been landed and 60 fish/ha (157 fish/km) are kept each year (Figure 30). Anglers generally creeled the largest fish. Since 1977, average size of fish kept (287 mm) has averaged 25 mm longer than average size of fish landed (262 mm).

On 4 September 1985, an estimate was made on the number and size of fish in a 305 m section of Soda Butte Creek from the Northeast Entrance downstream (Northeast Section). This site has been sampled for fish population analysis on two previous occasions (Jones et al. 1982, 1985).

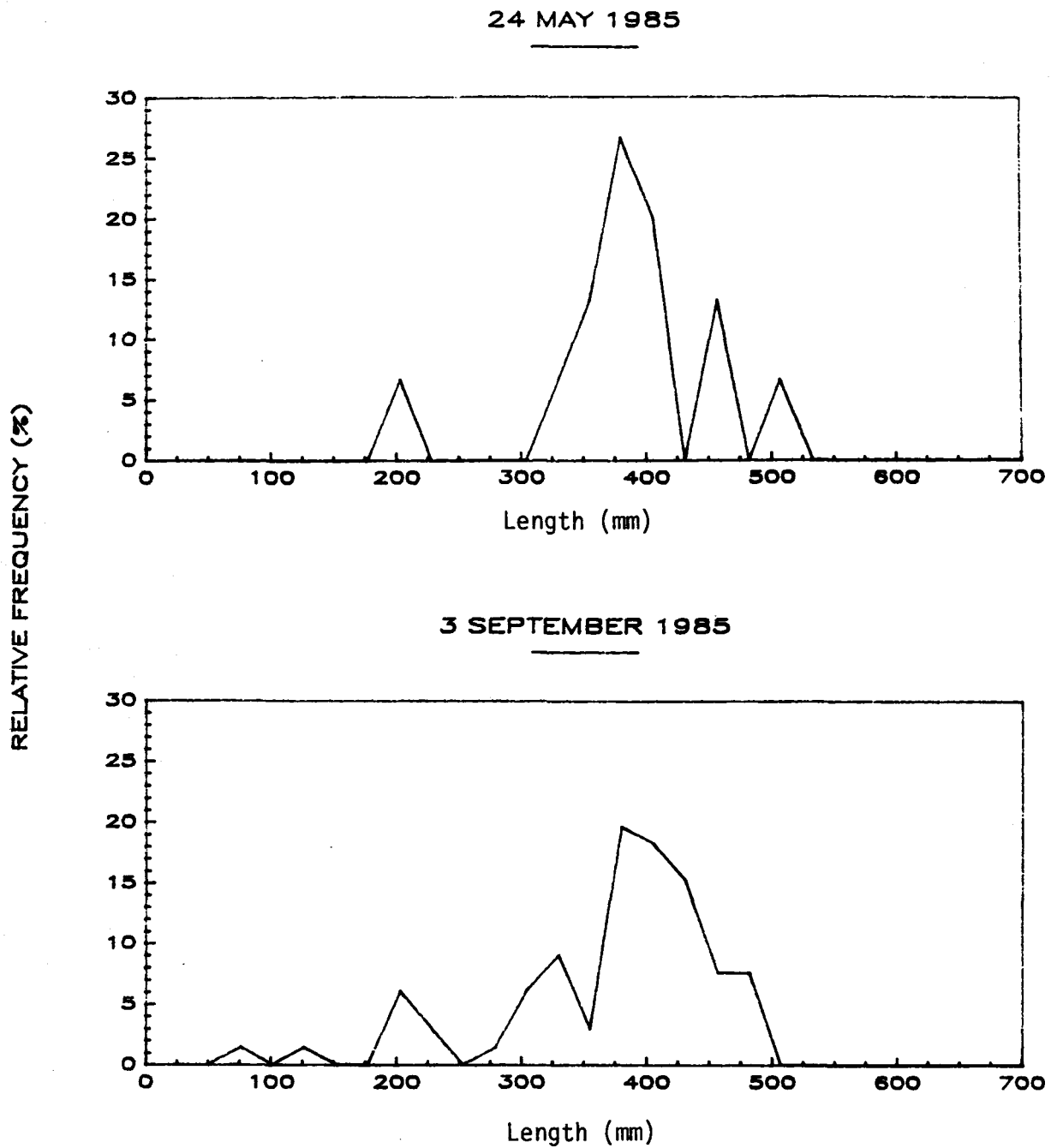


Figure 29. Length frequency of rainbow-cutthroat hybrid trout captured in Slough Creek, Yellowstone National Park, 1985.

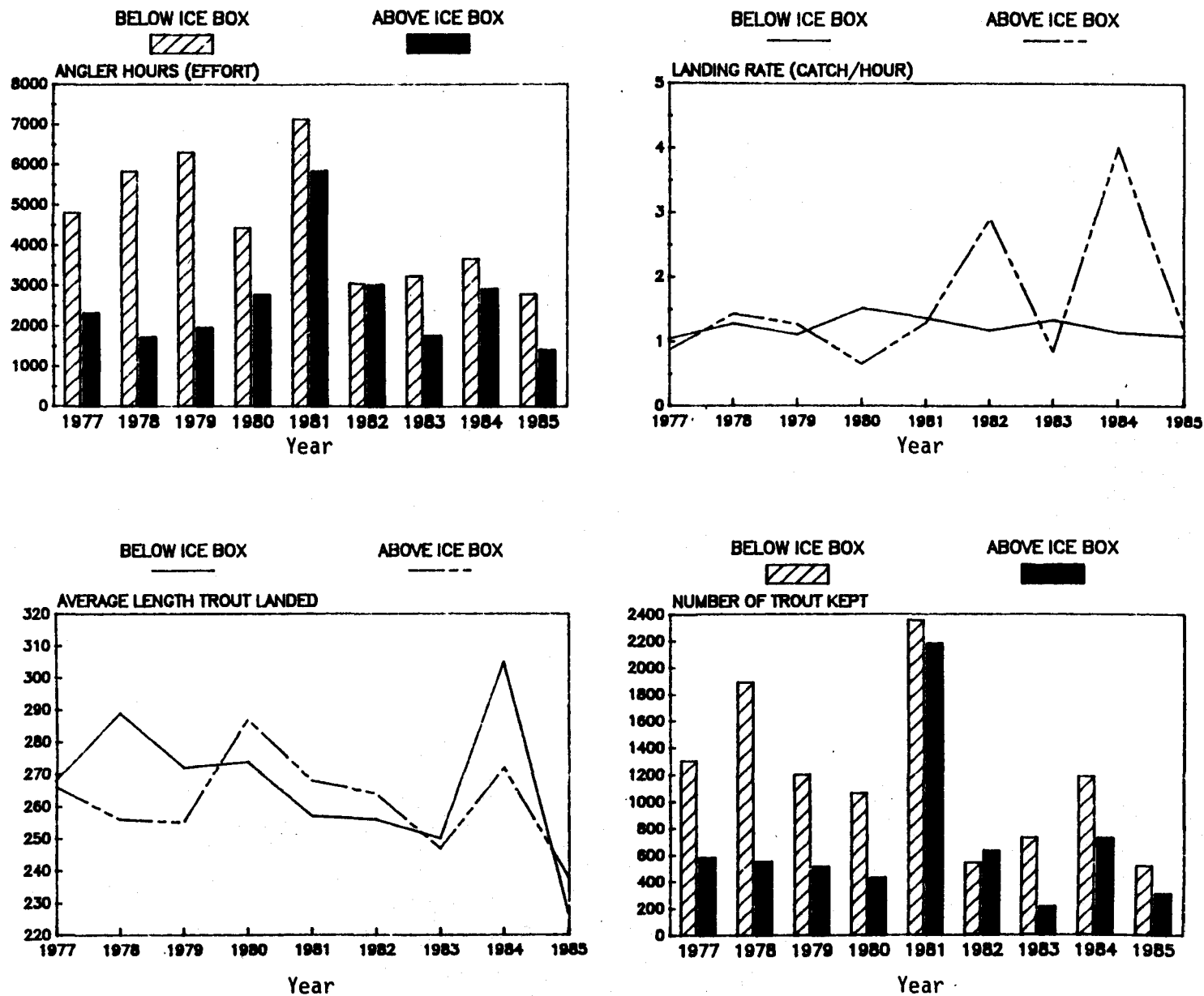


Figure 30. Angler statistics on Soda Butte Creek, Yellowstone National Park, 1977-1985.

Introgressed cutthroat trout was the only fish captured. An estimated 214 (+123) trout inhabited this 0.305 km (0.356 ha) area (Table 44). Efficiency rate of this estimate was 27.3%. In 1984, approximately 295 (+87) trout were estimated to inhabit this section of stream. The number of fish estimated in this section of Soda Butte Creek in 1984 and 1985 was over 5 times the number estimated in 1981.

Mean TL, mean weight, and PSD were 221 mm, 99 g, and 0.0%, respectively (Figure 31). Approximately 93.3% of the fish were longer than 203 mm and 14.6% were longer than 330 mm. Mean TL and weight of trout in 1981 was 201 mm and 129 g, respectively, and the percentage of fish longer than 203 and 330 mm TL was 55% and 5%, respectively. Mean TL and weight of trout in 1984 was 183 mm and 60 g, respectively, and the percentage of fish longer than 203 and 330 mm TL was 42% and 1%, respectively. Age III+ was the most frequently sampled age group in all three years. Average empirical growth rate for all age groups combined has averaged 74 mm/year for all sample years. Total biomass of trout was estimated at 70.6 kg/km in 1985 and 76.6 kg/km in 1984.

A decrease in angler use has been the most obvious change in the Soda Butte fishery since 1981. An increase in fish numbers in the upper section signifies improving conditions for the trout population. However, since this stream has the third highest exploitation rate of all streams in YNP and harvest is concentrated on the largest fish, further monitoring is necessary.

HABITAT FEATURES AND FISH BIOMASS IN ARNICA CREEK

Documenting the relationships between numbers and biomass of fish species and stream habitat parameters has been an objective of Yellowstone's stream survey program since 1976. With the complete removal of all fish from Arnica Creek (see Arnica Creek Restoration; this report) a unique opportunity to closely examine these relationships was available.

Methods

The main channel of Arnica Creek was divided into nine stream habitat reaches and stream 118307- was divided into two stream habitat reaches (Figure 32). Three study transects were established in each of these 11 reaches. The first transect location in each reach was selected to best represent the habitat parameters in that area. Two additional transects for each reach were selected by measuring upstream approximately 10 and 20

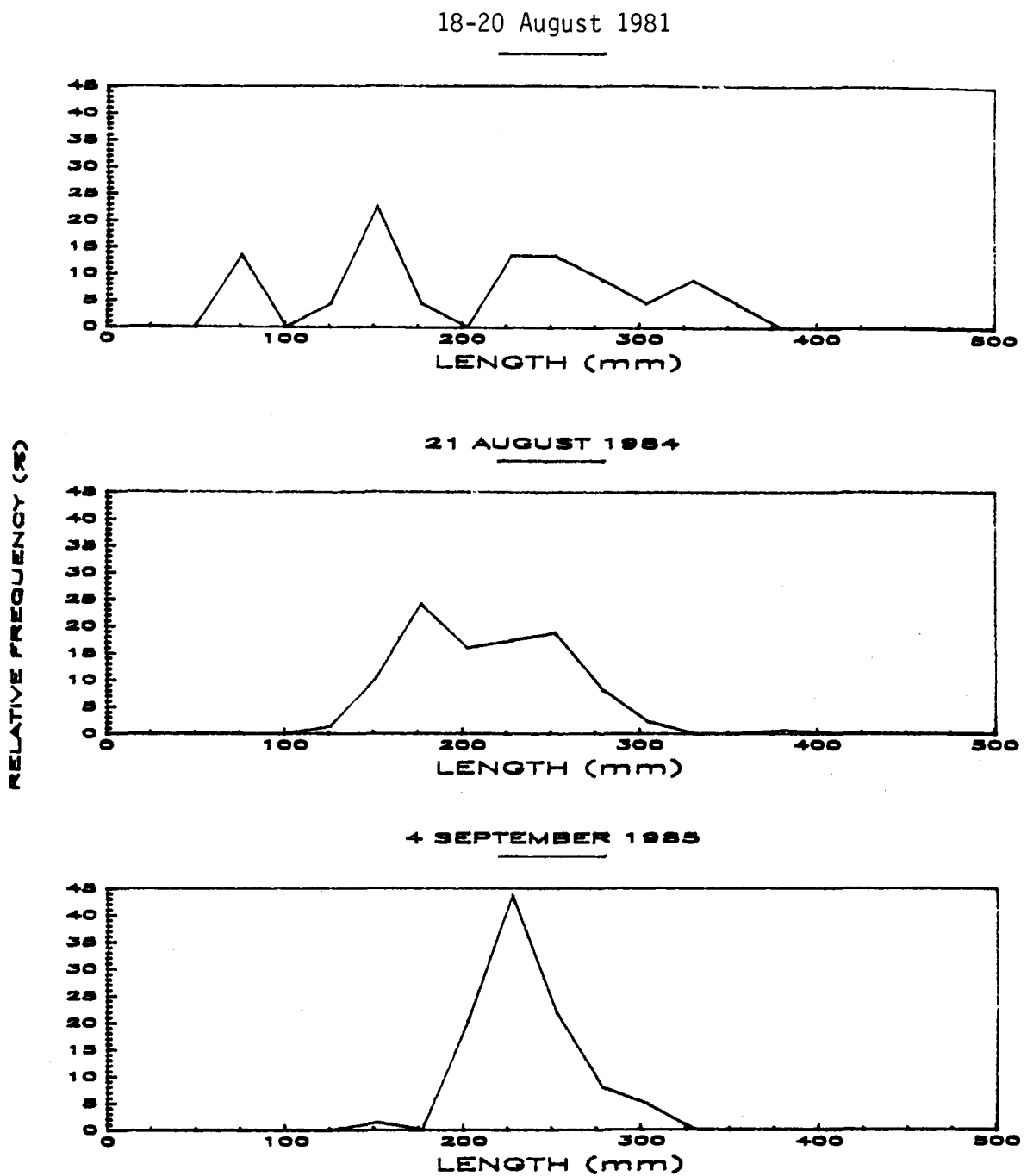


Figure 31. Length frequency of introgressed cutthroat trout captured in Soda Butte Creek, Yellowstone National Park, 1981-1985.

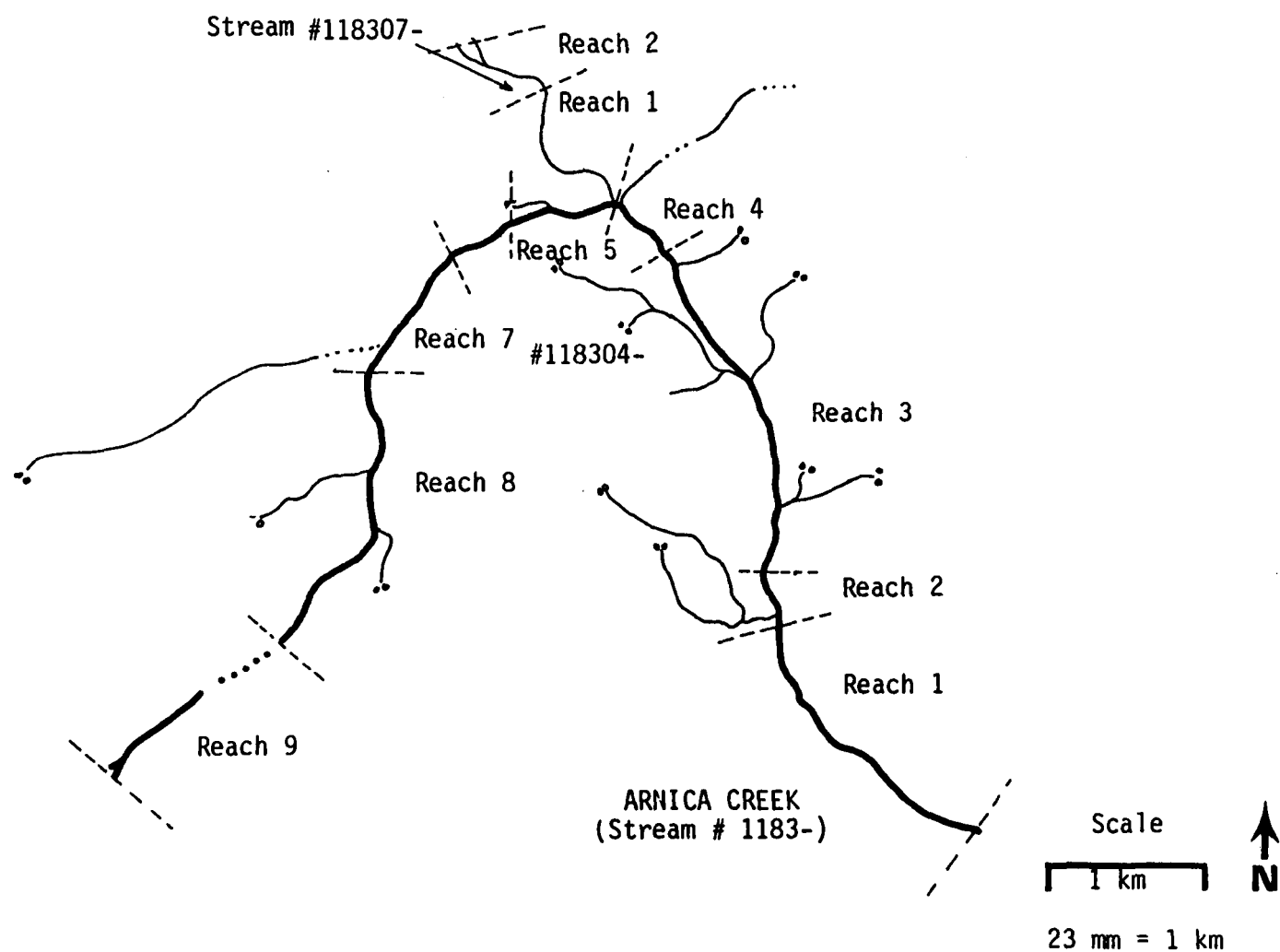


Figure 32. Habitat reaches established on Arnica Creek and stream #118307- in Yellowstone National Park, 1985.

times the average channel width of the first transect. A total of 21 stream features were measured at each transect (Table 46). Measurements of these features followed procedures outlined in Platts et al. (1983).

Estimates of the numbers and biomass of fish species were made within 7 of the 11 stream reaches (Table 47). For reach 1 and reaches 3 through 5 of Arnica Creek as well as reach 1 of stream 118307-, approximately 330 m of stream were sampled; whereas, in reaches 7 and 8 of Arnica Creek, 200 m of stream were sampled. Block nets were placed in the stream at the upstream and downstream edge of sample sections. All fish within each sample section were identified to species, measured to the nearest 5 mm total length (TL), and counted. Fish within each species were then divided into 25 mm size groups. Length was measured to the nearest 1 mm TL, and weight was taken to the nearest 1 g for 20 fish, if available, from each 25 mm size group. In addition, scale samples were collected from 5 fish, if available, from each 25 mm size group.

Results and Discussion

Habitat Parameters

Arnica Creek drains approximately 5458 ha. The 11 habitat reaches evaluated in this drainage had a combined average channel width of 1.4 m (range 0.3-4.2 m) stream width of 1.4 m (range 0.4-3.8 m), and stream depth of 13.0 cm (range 3.0-24.4 cm) (Table 46). The combined total length of stream channel for Arnica Creek and stream 118307- was 12.3 km. Streamside habitat that was the most common for all reaches was trees, roots, and sod. Approximately 34% (47.1 cm) of the stream width of each reach was overhung with vegetation. The amount of channel vegetative cover was also significant. About 13% (18.6 cm) of the average stream width of the reaches was covered with instream vegetation, mainly in the form of logs. Pools were common throughout both channels. An average of 50% (69.8 cm) of the stream width of each reach was a pool, whereas 35% (49.0 cm) of the stream width of each reach was a riffle. The amount of undercut banks appeared to be low in each reach and most instream cover was probably provided by overhanging and instream vegetation. Approximately 9% (13.3 cm) of the stream width of each reach was under the bank. The most dominant substrate size in all reaches was gravel. About 50% (60.2 cm) of the stream width of each reach was composed of particles 2-64 mm in diameter.

Table 46. Results of measurements made on stream habitat parameters in the Arnica Creek drainage, Yellowstone National Park, 1985.

Habitat Features:	Arnica Creek									Stream 113897-					
	Reach #1	Reach #2	Reach #3	Reach #4	Reach #5	Reach #6	Reach #7	Reach #8	Reach #9	Reach #1	Reach #2	Mean	Standard Error	Minimum	Maximum
Stream Reach:															
Stream Order	3.0	3.0	3.0	3.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.4	0.2	2.0	3.0
Elevation															
High (m)	2379.0	2387.0	2405.0	2411.0	2421.0	2432.0	2478.0	2511.0	2548.0	2438.0	2512.0	2447.5	17.0	2379.0	2548.0
Low (m)	2358.0	2379.0	2387.0	2405.0	2411.0	2421.0	2432.0	2478.0	2511.0	2411.0	2438.0	2421.0	13.2	2358.0	2511.0
Gradient (%)	1.2	2.2	0.9	1.5	1.7	2.2	5.8	1.6	2.2	2.3	9.3	2.0	0.8	0.9	9.3
Length (km)	1.0	0.4	2.1	0.4	0.6	0.5	0.8	2.0	1.7	1.2	0.8	1.1	0.2	0.4	2.1
Drainage basin (ha)	5457.6	4638.1	4800.0	3878.6	2445.3	2390.2	2350.8	724.5	101.1	1550.1	212.6	2620.0	571.6	101.1	5457.6
Water Column:															
Channel Width (m)	4.2	1.6	1.4	1.7	1.2	1.0	1.6	1.3	0.3	0.7	0.5	1.4	0.3	0.3	4.2
Stream Width (m)	3.0	1.9	1.7	1.2	1.3	0.8	1.3	1.3	0.5	0.7	0.4	1.4	0.3	0.4	3.0
Stream Depth (cm)	12.2	24.4	21.3	9.1	12.2	18.3	9.1	18.3	3.0	12.2	3.0	13.0	2.1	3.0	24.4
Stream Shore Water Depth (cm)	6.1	27.4	21.3	6.1	6.1	3.0	3.0	9.1	3.0	15.2	6.1	9.7	2.5	3.0	27.4
Riffle Width (cm)	301.8	48.8	33.5	51.8	0.0	30.5	0.0	21.3	27.4	9.1	15.2	49.0	25.8	0.0	301.8
Pools:															
Width (cm)	73.2	109.7	88.4	51.8	103.6	15.2	125.0	112.8	18.3	36.6	33.5	69.8	12.2	15.2	125.0
Quality	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	0.0	4.0	4.0
Feature	1.0	2.0	2.0	2.0	2.0	2.0	3.0	5.0	5.0	2.0	1.0	2.5	0.4	1.0	5.0
Solar Incidence	26.7	48.3	75.0	43.3	26.7	30.0	36.7	68.3	16.7	36.7	43.3	41.1	5.3	16.7	75.0
Solar Angle	115.7	53.3	24.0	81.7	84.7	124.7	85.0	42.3	132.0	64.3	90.0	81.6	10.3	24.0	132.0
Channel Morphology:															
Streambank Alteration	11.7	36.7	48.3	35.0	21.7	15.0	10.0	40.0	21.7	36.7	26.7	27.6	3.0	10.0	48.3
Vegetative Stability	4.0	3.7	4.0	3.3	4.0	4.0	3.3	4.0	4.0	3.7	4.0	3.8	0.1	3.3	4.0
Undercut (cm)	12.2	24.4	24.4	6.1	18.3	6.1	6.1	9.1	18.3	12.2	9.1	13.3	2.1	6.1	24.4
Channel-Bank Angle	91.7	75.0	79.2	90.0	97.5	89.2	96.7	105.0	30.0	104.2	98.3	87.0	6.4	30.0	105.0
Stream Bottom:															
Gradient	1.0	1.0	0.5	0.8	1.0	2.0	3.0	1.0	1.2	0.8	3.3	1.4	0.3	0.5	3.3
Sinuosity	1.1	1.1	1.7	1.5	1.2	1.0	1.1	1.9	1.2	1.0	1.2	1.3	0.1	1.0	1.9
Substrate (cm)															
Boulder > 256 mm	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.1	0.1	0.0	0.5
Cobble 64-256 mm	4.0	1.3	0.0	0.0	0.0	0.6	2.0	0.0	0.1	0.0	0.1	0.7	0.4	0.0	4.0
Gravel 2-64 mm	6.4	2.1	4.3	2.3	2.0	1.2	1.7	0.9	1.3	0.7	0.0	2.1	0.5	0.0	6.4
Sand 0.6-2 mm	2.2	1.8	1.0	0.7	1.6	0.9	0.7	0.4	0.0	0.2	0.0	0.9	0.2	0.0	2.2
Silt < 0.6 mm	0.0	1.1	0.3	0.7	0.7	0.0	0.0	3.1	0.3	1.5	0.8	0.0	0.3	0.0	3.1
Embeddedness	2.7	3.7	3.0	3.0	2.3	3.0	3.7	2.7	3.7	2.0	1.7	2.9	0.2	1.7	3.7
Channel Vegetative Cover (cm)	51.8	30.5	21.3	36.6	51.8	0.0	3.0	9.1	0.0	0.0	0.0	10.6	6.3	0.0	51.8
Riparian Zone:															
Streamside Cover	2.0	2.0	2.0	2.0	2.0	2.0	1.7	2.0	2.0	2.0	2.0	2.0	0.0	1.7	2.0
Vegetative Use	6.7	5.0	5.0	5.0	6.7	8.3	5.0	16.7	5.0	10.0	10.0	7.6	1.1	5.0	16.7
Vegetation Overhang (cm)	79.2	54.9	36.6	36.6	79.2	45.7	36.6	36.6	21.3	51.8	39.6	47.1	5.5	21.3	79.2
Habitat Type	13.0	14.0	17.0	13.0	10.0	14.0	13.0	14.0	14.0	17.0	14.0	14.6	0.5	13.0	10.0

Table 47. Density and biomass, by sample reach, of fish captured in the Arnica Creek drainage, Yellowstone National Park, 1985.

Number	Reach			Species	Number/km	Number/ha	Total Number	kg/km	kg/ha	Total Biomass
	Length (km)	Width (m)	Area (ha)							
1	1.8	3.8	0.7	Cutthroat trout	2437.7	6414.9	4387.8	4.9	12.8	8.8
				Longnose dace	439.6	1156.9	791.3	1.3	3.5	2.4
				Redside shiner	475.7	1251.9	856.3	2.4	6.3	4.3
2	0.4	1.9	0.1							
3	2.2	1.7	0.4	Brook trout	180.4	1061.4	397.0	2.5	14.9	5.6
				Cutthroat trout	1030.2	6055.9	2266.4	2.1	12.1	4.5
				Longnose dace	3.3	19.3	7.2	0.0	0.3	0.1
4	0.5	1.2	0.1	Brook trout	813.6	6780.4	406.8	12.2	101.7	6.1
				Cutthroat trout	383.9	3198.8	191.9	0.8	6.4	0.4
5	0.7	1.3	0.1	Brook trout	767.7	5905.5	537.4	13.1	100.4	9.1
				Cutthroat trout	1066.3	8202.1	746.4	2.1	16.4	1.5
6	0.4	0.8	0.0							
7	0.8	1.3	0.1	Cutthroat trout	1328.4	10218.1	1062.7	2.7	20.4	2.1
8	1.9	1.3	0.2	Brook trout	14.9	114.8	28.4	1.6	12.5	3.1
				Cutthroat trout	343.3	2640.6	652.2	0.7	5.3	1.3
9	1.7	0.3	0.1							
1	1.2	0.7	0.1	Brook trout	240.0	1734.2	288.0	4.1	29.5	4.9
				Cutthroat trout	16.4	234.3	19.7	0.04	0.5	0.0
2	0.8	0.4	0.0							

Fish Biomass

Four species of fish were captured in the seven habitat reaches sampled in Arnica Creek and stream 118307- (Table 48). These fish included brook trout (Salvelinus fontinalis), cutthroat trout (Salmo clarki bouvieri), longnose dace (Rhinichthys cataractae), and redbside shiners (Richardsonius balteatus). Over 68% of all fish sampled (n=2,697) were cutthroat trout, 21% were brook trout, 6% were redbside shiners, and 5% longnose dace.

Cutthroat trout were found in all reaches sampled (Tables 47 and 48). These fish averaged 57 mm TL and had an estimated mean weight of 2 g (Table 48). Approximately 90% of all cutthroat trout examined were smaller than 80 mm TL, and 65% were between 40 and 60 mm TL (Figure 33). The length distribution of cutthroat trout was not significantly different between reaches. Fish from reach 7 had the smallest mean TL (43 mm), and fish in reach 1 of Arnica Creek and stream 118307- had the largest mean TL (64 and 68 mm, respectively). Reach 8 contained the largest cutthroat trout captured (261 mm TL).

Total number of cutthroat trout captured in the 7 study sections was 1,840. Density of cutthroat trout averaged 944 fish/km or 528 fish/ha. Biomass of cutthroat trout averaged 6.7 kg/km or 51.8 kg/ha. Total number of cutthroat trout inhabiting the Arnica Creek drainage was estimated at 12,500. Total cutthroat trout biomass was approximately 27.8 kg.

Generally, reaches low in the drainage had a greater number of cutthroat trout than those reaches higher in the drainage (Table 48). Reach 1 of Arnica Creek had almost 2 times more fish than reach 3 and almost 8 times more fish than reach 8. The number and density of cutthroat trout in reach 4 was noticeably low. Compared to reach 3 and reach 5, this section of Arnica Creek had 12 and 4 times fewer fish, respectively. The low number and density of cutthroat trout in reach 4 could have been a result of the high number and density of brook trout in that section of stream. Reach 4 contained the highest total number (537) and density (5,905 fish/ha) of brook trout in all study sections.

Brook trout were distributed throughout the drainage, but were sampled in only five of the seven study sections (Table 47). Total length of brook trout ranged from 45-275 mm. The length distribution of brook trout was noticeably different from that of cutthroat trout (Figure 33). Brook trout were well represented in most

Table 48. Mean length, weight, and number of fish captured in sample sections within each habitat reach established on Arnica Creek drainage, Yellowstone National Park, 1985.

Drainage, Yellowstone National Park, 1955.																		
Reach ¹⁾	Sample section length (m)	Cutthroat trout				Brook trout				Longnose dace				Redside shiners				
		Length (mm)			Mean weight ¹⁾ (g)	Length (mm)			Mean weight ¹⁾ (g)	Length (mm)			Mean weight ¹⁾ (g)	Length (mm)			Mean weight ¹⁾ (g)	
		n	mean	range		n	Mean	Range		n	Mean	Range		n	Mean	Range		
<u>Arnica Creek</u>																		
1	305	743	64	30-182	2	-	-	-	-	134	65	45-90	3	145	79	55-117	5	
2	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	
3	305	314	58	30-152	2	55	100	45-241	14	1	107	-	15	-	-	-	-	
4	305	117	53	30-110	2	248	102	50-200	15	-	-	-	-	-	-	-	-	
5	305	325	54	30-173	2	234	107	45-263	17	-	-	-	-	-	-	-	-	
6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
7	201	267	43	27-50	2	-	-	-	-	-	-	-	-	-	-	-	-	
8	201	69	48	30-261	2	3	226	215-232	109	-	-	-	-	-	-	-	-	
9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<u>Stream #118307-</u>																		
1	305	5	69	40-122	2	37	107	45-189	17	-	-	-	-	-	-	-	-	
2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
All Reaches	1927	1840	57	27-261	2	577	108	45-275	18	135	66	45-107		145	79	55-117		

1) Reach #2, 6, 9 of Arnica Creek and Reach #2 of Stream #118307- were not sampled.

2) Mean weight estimated from length-weight equation derived from fish sampled in all sections.

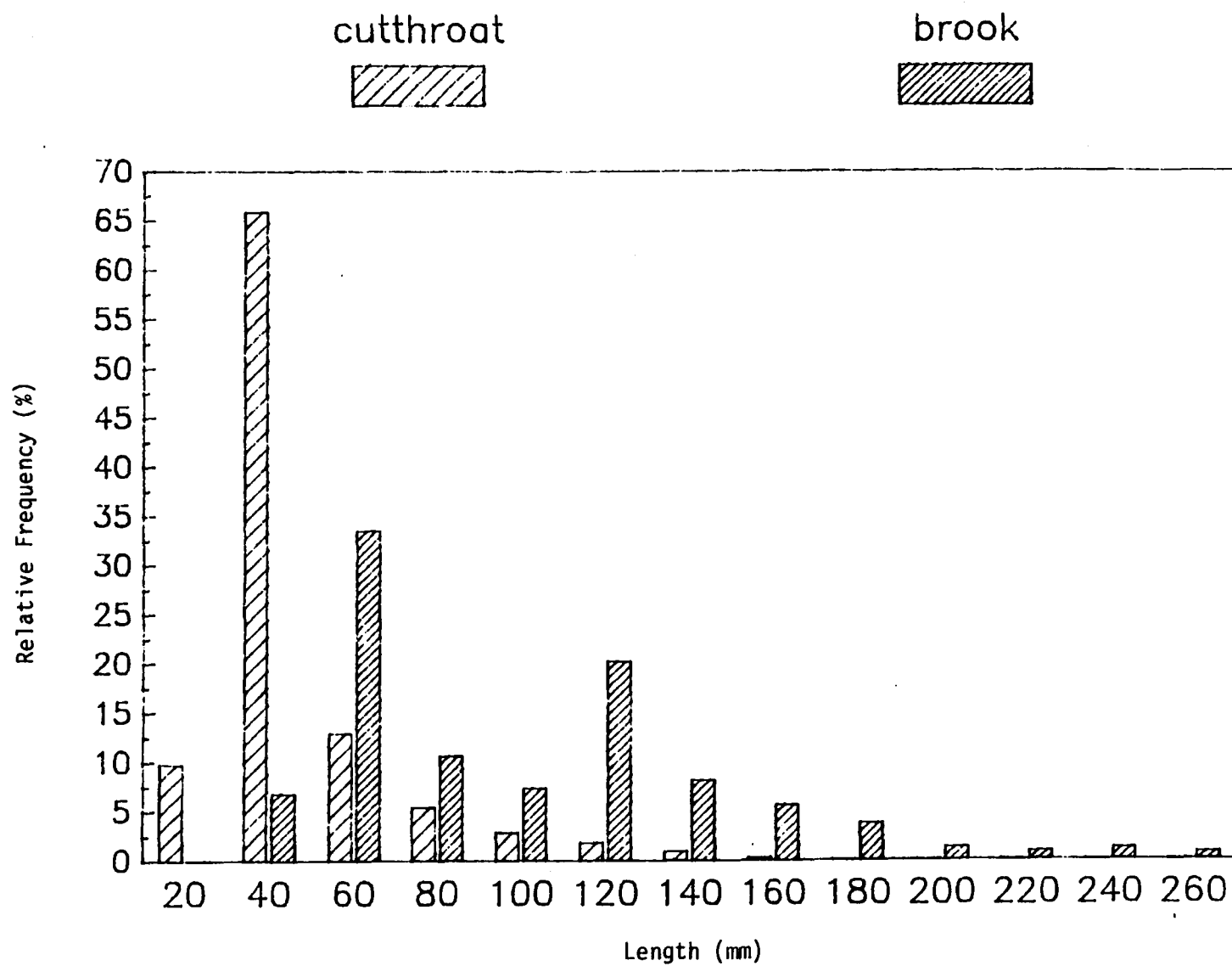


Figure 33. Length distribution of cutthroat trout and brook trout captured in the Arnica Creek drainage, Yellowstone National Park, 27 August 1985.

size groups sampled, while the majority of cutthroat trout was concentrated in the smaller size categories. Generally, no trend was apparent in the length distribution of brook trout between sample sections. Fish from reach 8 had the longest mean TL; however, only three fish were sampled in this area. Reach 5 contained the largest brook trout sampled (263 mm TL).

Total number of brook trout captured in the 7 study sections was 577. Density of these fish averaged 403 brook trout/km or 3,119 brook trout/ha, and brook trout biomass averaged 6.7 kg/km or 51.8 kg/ha (Table 47). Total number of brook trout in the Arnica Creek drainage was estimated at 4,000 fish. Total biomass of brook trout in the drainage was approximately 63.0 kg.

Reaches 4 and 5 contained the highest densities of brook trout in the drainage. The density (fish per hectare) of brook trout in Reach 4 was 1.1, 3.9, 6.4, 59.0 times higher than the density of brook trout in reach 5 of Arnica Creek, reach 1 of stream 118307-, reach 3 of Arnica Creek, and reach 8 of Arnica Creek, respectively. Reach 8, which contained the lowest density of brook trout also contained the largest brook trout. The largest biomass of brook trout occurred in reach 5.

Longnose dace were distributed through reach 3 and redbside shiners were restricted to reach 1 of Arnica Creek. Mean TL ranged from 45 to 107 mm (mean 66 mm) for longnose dace and 55 to 117 mm (mean 79 mm) for redbside shiners. The total number of longnose dace and redbside shiners in the drainage was estimated at 800 and 850, respectively. Longnose dace averaged 1,157/ha and redbside shiners averaged 1,252/ha in reach 1 of Arnica Creek. Total biomass of longnose dace and redbside shiners was 2.5 kg and 4.3 kg, respectively.

Interrelationship: Biomass and Habitat

Substantial evidence suggests that cutthroat trout utilize the Arnica Creek drainage only as a spawning area; whereas, brook trout established a stream resident population in the drainage. The most significant correlations between density and/or biomass of cutthroat trout and stream habitat features generally occurred with those features associated with trout spawning habitat, large stream width, wide riffle areas, and substrate with diameters from 0.6 to 64 mm (Table 49). Significant correlations were also evident between number of cutthroat trout per kilometer and channel vegetative cover. Those areas with more logs in the

Table 49. Relationships between selected habitat parameters, density, and biomass of brook and cutthroat trout in the Arnica Creek drainage, Yellowstone National Park, 27 August 1985.

Habitat Parameter	Correlation Coefficient (r)							
	Brook Trout (n=5)				Cutthroat Trout (n=7)			
	Fish/km	Fish/ha	kg/km	kg/ha	fish/km	fish/ha	kg/km	kg/ha
Stream width	0.07	0.11	0.05	0.14	0.93	0.38	0.94	0.38
Stream depth	0.68	0.80	0.68	0.80	0.06	0.19	0.06	0.19
Stream shore water depth	0.61	0.63	0.68	0.69	0.23	0.34	0.23	0.33
Riffle width	0.10	0.06	0.00	0.05	0.84	0.21	0.85	0.21
Pool width								
Undercut	0.06	0.15	0.07	0.16	0.25	0.29	0.24	0.29
Substrate diameter								
0.6-2 mm	0.69	0.58	0.72	0.61	0.95	0.72	0.95	0.72
2-64 mm	0.21	0.08	0.13	0.00	0.93	0.53	0.93	0.53
Channel Vegetative Cover	0.92	0.84	0.93	0.85	0.72	0.70	0.71	0.70
Vegetative Overhang	0.52	0.52	0.60	0.63	0.63	0.36	0.63	0.37

channel generally had more cutthroat trout. Factors other than habitat parameters could also have been responsible for the distribution of cutthroat trout throughout the drainage. Stream features do not explain the low density of cutthroat trout in reach 4. Possibly the high density of brook trout in this reach was responsible for the low density of cutthroat trout.

The distribution, density, and biomass of brook trout in the Arnica Creek drainage appeared to be associated with those stream features associated with providing instream cover. Significant correlations existed between stream depth, amount of substrate with a diameter between 0.6 and 2 mm, channel vegetative cover, vegetative overhang, and fish density or fish biomass. Those areas that provided the largest amount of cover had the greatest densities of brook trout. Stream depth has probably been an important factor in providing over winter habitat.

LAKE TROUT SPAWN-TAKING OPERATION

Lewis Lake was historically fishless (Jordan 1891), and initial plants of lake trout (Salvelinus namaycush) and brown trout (Salmo trutta) occurred in 1890 (Varley 1981; Visscher 1984). Lake trout for this introduction were collected from spawning reefs near the Beaver Islands in Lake Michigan (Visscher 1983). Since Lewis Lake is only 4.8 km downstream from Shoshone Lake, rainbow trout (Salmo gairdneri) and brook trout (Salvelinus fontinalis) probably gained access to Lewis Lake soon after they were stocked into tributaries of Shoshone Lake (1893 and 1895, respectively) (Varley 1981). The only other occasion when fish were planted into either lake occurred in 1941; 5,890 lake trout fingerlings were obtained from Bozeman Montana Fisheries Station and released into Lewis Lake (Visscher 1984).

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

To this end, annual collection of sex products from Lewis Lake lake trout was initiated in 1982 (Jones et al. 1983). Both eggs and sperm were collected in 1982 and 1983, but 1984 collections were limited to sperm alone. In 1985, both eggs and sperm were collected.

Methods

All lake trout were collected by electrofishing from boats with boom mounted dropper electrodes (Novotny and Priegel 1974). Pulsed direct current (80 pulses/s) was utilized with a voltage between 100 and 200 volts. Stunned fish were netted and placed into a boat-mounted livewell to recuperate. Periodically, trout from the electrofishing boats were transferred to a 9 m barge for processing.

Disease samples were obtained from 150 lake trout on 23 September 1985. Thirty of these trout were sacrificed for liver and kidney samples; sampling was limited to fecal matter from the remaining trout. Samples were

shipped to the USFWS Disease Control Center (Ft. Morgan, Colorado) for analysis. Tests were made for the following pathogens: Aeromonas salmonicida, enteric redmouth bacterium, salmonid kidney disease bacterium, viral hemorrhagic septicemia virus, infectious hematopoietic necrosis virus, and infectious pancreatic necrosis virus.

Sperm and egg collections were conducted by personnel from the Jackson National Fish Hatchery (NFH) on 25 September and 3 October. Trout were captured at four sites along the east shore of Lewis Lake (Figure 34). Eggs from Lewis Lake females were fertilized at Lewis Lake and returned to Jackson NFH. Additional sperm was transported to the hatchery to fertilize females of the Jackson NFH broodstock.

Sex determination, total length measurements (to the nearest 1 mm), and weight (to the nearest 2 g) were recorded for 40 trout in the disease sample. Total length (5 mm intervals) was collected from an additional 49 trout in the disease sample and 295 of the trout used for spawning on 25 September.

Results

All trout in the disease sample tested negative for the selected pathogens. Mean lengths of 44 males and 45 females from the disease sample were 447 and 452 mm, respectively, and the male:female ratio was 0.98:1. Mean length for the combined sample was 449 mm. Difference in mean weight between males (1,251 g) and females (929 g) was not statistically significant ($\alpha=0.05$).

Eggs were collected from 37 females in 1985; the majority of ripe females were obtained on 25 September, but 2 were captured on 23 September and a single female was caught on 3 October. Mean length of 95 females measured on 25 September was 441 mm; individual lengths ranged from 400 to 515 mm.

On 25 September, sperm was collected from 113 males in addition to those used to fertilize the eggs taken at Lewis Lake. Mean length of 189 males was 431 mm, ranging from 290 to 630 mm. A total of 47 more males were stripped on 3 October.

An approximate 90% eye-up of almost 20,000 lake trout eggs from Lewis Lake yielded 17,413 eyed eggs. These eggs were divided among Jackson NFH, Saratoga NFH, and Wyoming Game and Fish for use in brood stock programs.

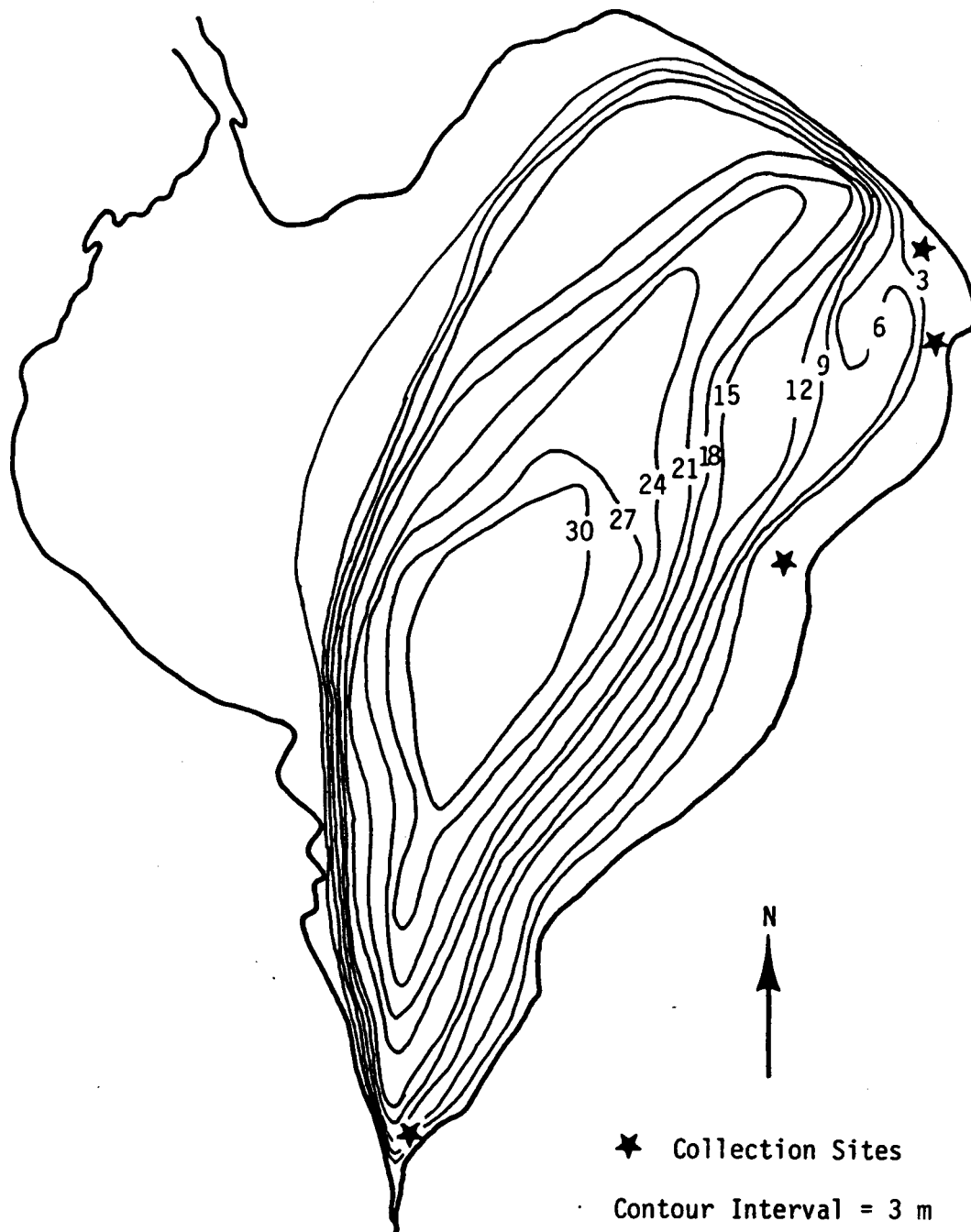


Figure 34. Collection sites for spawn-taking operations, Lewis Lake, 1985.

Hatchery out-crosses with Lewis Lake males yielded 1,109,606 eyed eggs; eye-up was about 70%, significantly higher than 1984 (54.4%). All of these eggs were shipped for eventual stocking in Lake Michigan.

Discussion

Collection of a sufficient number of ripe females is still the most difficult part of the lake trout spawn-taking operation on Lewis Lake. Limiting collections to ripe males greatly reduces field time necessary to complete the operation. Since females in the Jackson NFH came from Jenny Lake (the result of another planting of fry from Lewis Lake), the resulting fry should enhance restoration attempts in Lake Michigan. Broodstocks from Lewis Lake fish will be available for production in the next several years, and results from initial plants of the Lewis Lake strain should be forthcoming.

NONCONSUMPTIVE USE OF THE AQUATIC RESOURCE

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

Fishing Bridge spans the Yellowstone River at the outlet of Yellowstone Lake; the area from the lake to a point 1.6 km downstream of the bridge has been closed to fishing since 1973. Although once very popular with anglers, Fishing Bridge was not considered a high quality fishery. Average landing rate for 1963 (Sharpe 1964) was 0.20 trout/hour, varying from a high of 0.48 during the first week of July to a low of 0.00 trout/hour during the first week of September. In 1966, Sharpe and Arnold (1967) reported that the catch per unit effort was lower than most park waters. Dean and Varley (1973) concluded that few anglers returned to the bridge after an initial experience because of crowding and low success rates.

LeHardy Rapids, located approximately 5.7 km downstream from the lake on Yellowstone River, has been closed to fishing for 90 m upstream and downstream from the rapids since 1949. During high water (May through July) fish congregate near the west bank in pools immediately below the rapids. From here the fish jump the rapids, often having to make several attempts, providing an extraordinary sight for the visitor. In 1984, a new boardwalk and viewing platform were constructed at LeHardy Rapids to facilitate visitor access and prevent continued erosion of the trail to the rapids. A sign identifying LeHardy Rapids was placed at the vehicle pullout in 1985.

Effects of angling closures were monitored at Fishing Bridge and LeHardy Rapids for the eighth consecutive year in 1985. Visitor use and mean length of stay were estimated at both areas.

Methods

Since effort available for counts was limited, a "time available" method (Mathisen 1949; Bulkley 1966; Geiger 1972; and Brown 1978) of data collection was employed. Instantaneous counts of visitors were made whenever possible at both Fishing Bridge and LeHardy Rapids, usually while en route to a work site. The location of

project activities affects sampling effort at each site; therefore, sample size varies between years.

Critical aspects of this method are accurate estimates of average time spent per person and daily use pattern. Accuracy increases as the number of time intervals increase; however, if interval sizes become too small, the increase in time periods without counts causes a decrease in the resulting estimate. Using these criteria, a 15 minute time interval appears to be optimum for Fishing Bridge and LeHardy Rapids use estimates.

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

Effort (visitor hours) = $1/2 I(t_i + t_{i+1})$, where I is the time interval, and t_i is the mean number counted at interval i .

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

Results

In 1985, mean length of stay at Fishing Bridge for 1,242 people was 12.8 minutes/person. Total number of visitors decreased from 1984 (approximately 11%) to 158,360 visitors. Total visitor hours actually increased (approximately 7%) from 1984 to 33,915 hours (Table 50).

Mean length of stay at LeHardy Rapids was 5.1 minutes/person in 1985 ($n=1,141$). Total number of visitors was estimated to be 185,467 people, and total time spent at the rapids was 15,827 hours. Both values are the highest ever reported for LeHardy Rapids nonangler use.

Discussion

Creel census data for the last 8 years (1965-1972) of angling on Fishing Bridge yielded an average of 33,275

Table 50. Nonconsumptive use of the aquatic resource, 1978-1985.

	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
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	20,718	-	2,787
	1985	212	185,467	5.1	15,827

Table 51. Fishing Bridge creel census data, 1965-1972.

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

total anglers and 36,714 total angler hours/year (Table 51). While the 1985 figures represent slightly lower total hours on Fishing Bridge, the number of people enjoying this area has increased almost 400% since the bridge was closed to fishing; concomitantly, park visitation has only risen approximately 16%.

Visitor use at LeHardy Rapids increased phenomenally in 1985. Current levels of use are over 400% greater than the previous record use (45,610 visitors) reported in 1981 and almost 9 times greater than the 7-year average. Although total visitor hours remain much higher at Fishing Bridge, the number of visitors at LeHardy Rapids in 1985 exceeded Fishing Bridge estimates for all years except 1980 (Table 50).

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

It is difficult to explain the difference in the number of visitors at LeHardy Rapids and Fishing Bridge. If the number of people traveling past LeHardy Rapids is greater, then the addition of the location sign may account for the inequality. Actual time expended remained about twice as high at Fishing Bridge; the greater diversity of the Fishing Bridge area probably encourages a longer stay on the bridge.

Comparing nonangler use to park fisheries, more people utilize either Fishing Bridge or LeHardy Rapids than any single fishery in the park (Tables 5 and 50). In terms of total man hours, Fishing Bridge ranks fifth and LeHardy Rapids eighth when compared to angler effort among park fisheries.

Estimates of nonangler use during the past 8 years emphasize the value of these viewing sites and the demand for this type of visitor activity. Observing the interactions of fish with their natural habitat, including reproduction, feeding, and as prey, is truly an educational experience for anglers and nonanglers alike.

TECHNICAL PAPERS

The need arose during 1985 for this office to produce technical reports that were separate publications from this annual progress report. Additionally, several papers are generally published each year which appear in other reference sources. As a result, this section of the annual report was established to summarize papers that were completed during the current year.

Carty, D.G., E.L. Ewing, Jr., L.D. Lentsch, and J.L. Mohrman. 1986. Sources and quantities of suspended sediment in the Upper Yellowstone River and its tributaries: 1985 annual progress report. United States Fish and Wildlife Service. Yellowstone Fisheries Office. Aquatic Ecology Studies. Technical Report Number 2. In print.

The production of suspended sediment in the Upper Yellowstone River and its tributaries is regulated by a highly complex combination of geological, hydrological, chemical, meteorological, and biological factors. In 1984, anglers who regularly fish on the Yellowstone River between Yellowstone National Park (YNP) and Livingston, Montana, raised concerns to the National Park Service and two Montana state agencies (Department of Fish, Wildlife and Parks and Water Quality Bureau) that the amount of suspended sediment in the Yellowstone River had drastically increased since 1980. As a result of that increase, the river was much more turbid and remained turbid for longer periods of time during July and August. As a result of these concerns, a cooperative study was initiated by this office in 1985. The objectives of the study include:

1. Determination of amounts and mode of occurrence of suspended sediment carried in the Upper Yellowstone River, and
2. Estimation of relative contributions of suspended sediment produced by the major tributaries of the Yellowstone River from Tower Junction, YNP, to Livingston, Montana.

Gresswell, R.E. 1985. Saving the dumb gene in Yellowstone: there is more to preservation than granola. Proceedings of the 65th Annual Conference of the Western Association of Fish and Wildlife Agencies 65.

Fishery management objectives in Yellowstone National Park include managing the fishery as an integral part of

the total park ecosystem, protecting and restoring native fish fauna, and maintaining high quality angling. The use of maintenance stocking to support angling activities has not been utilized for 30 years; alternatively, special regulations in conjunction with habitat preservation appear to be a successful means of accomplishing management objectives.

Angling quality in park lakes and streams is judged by anglers to be high. Inherent susceptibility to angling appears to be one of the factors which make the native cutthroat trout and grayling such popular sport species. Special regulations have protected these highly vulnerable fish and, perhaps through preservation of the "dumb gene", helped to insure the perpetuation of angler satisfaction.

Effects of the management program, however, reach far beyond this measure of human satisfaction. Protection of these fishes is not only significant for the preservation of a native faunal diversity; it is vital for perpetuation of many of the nonaquatic life forms within the park ecosystem.

Lentsch, L.D. 1986. Fisheries inventory and instream flow requirements for Reese Creek, Yellowstone National Park. United States Fish and Wildlife Service. Yellowstone Fisheries Office. Aquatic Ecology Studies. Technical Report Number 1. 29 p.

Reese Creek, located along the northern boundary of the park, is the only stream within Yellowstone National Park that has all of its water periodically removed for irrigation purposes. Three active irrigation ditches divert water from the stream in a northerly direction. These ditches are located approximately 0.5, 0.9, and 1.2 miles upstream from the confluence with the Yellowstone River. The upper two ditches, either solely or in combination, are capable of diverting the entire flow of Reese Creek away from the main channel during periods of low streamflow.

Although water has been diverted from Reese Creek for about 100 years, the National Park Service has observed with concern that the severity of water depletions has increased in recent years. In response to this observation and initiation of a water rights adjudication process by the State of Montana, a study was established in 1984 to evaluate the aquatic resources of Reese Creek effected by water depletions. The objectives of this study were to (1) inventory the fishery resources of Reese Creek, (2) document the

amount of water flowing in Reese Creek, (3) determine quantities of streamflow necessary to sustain Reese Creek's fishery resource (establish a minimum streamflow requirement).

The following is a summary of recommendations made as a result of the Reese Creek study.

1. Maintain instream flow of 4.3 cfs from 15 May to 30 July for spawning cutthroat trout migrating from Yellowstone River.
2. Maintain instream flow of 4.3 cfs from 1 October to 1 December for spawning brown trout migrating from Yellowstone River.
3. Maintain instream flow of 1.6 cfs for the remaining time period.
4. Alter road culvert and irrigation diversions to allow upstream migration of fish.
5. Place grates across irrigation diversions to prevent fish migration into ditches.

Lentsch, L.D., and J.S. Griffith. 1986. Lack of first-year annuli on scales: frequency of occurrence and predictability in trout of the western United States. In R.C. Summerfelt and G.E. Hall, editors. Age and growth of fish. Iowa State University Press, Ames, Iowa, USA.

Lack of first-year annuli on scales is a common occurrence for salmonids in the Intermountain West. We examined 24 salmonid populations divided among 2 forms (cutthroat trout Salmo clarki and rainbow-cutthroat hybrid trout Salmo gairdneri x S. clarki); of these, 21 contained individual fish that failed to form a first-year annulus. These fish were identified by determining the maximum number of circuli formed by young fish during the first growing season and counting the number of circuli to the first annual mark on the scales of older fish. Number of circuli formed and percentage of fish not forming an annulus at the conclusion of the first growing season varied among populations from 0 to 15 and 0 to 100, respectively. This variability was largely explained by the number of degree-days to which fish were exposed: when this number was less than 720, no fish formed a first-year annulus; when it exceeded 1,500 all fish formed the annulus.

Schill, D.J, J.S. Griffith, and R.E. Gresswell. In Press. Hooking mortality of cutthroat trout in a catch-and-release segment of the Yellowstone River, Yellowstone National Park. North American Journal of Fisheries Management.

Hooking mortality was examined in a population of wild cutthroat trout (Salmo clarki bouvieri) in a portion of the Yellowstone River, Yellowstone National Park, which is managed under catch-and release regulations. The number of trout dying from capture and release in the 4.5 km study area was assessed by searching for trout carcasses in established snorkeling routes. We divided our estimate of angler-induced mortalities by cutthroat trout abundance and creel survey data to estimate single capture hooking mortality and exploitation rates resulting from catch-and-release angling in the study area. The average number of times cutthroat trout were recaptured during the study period was estimated using the results of the creel survey and cutthroat trout abundance data. The hooking mortality rate per single capture was 0.3%. In 1981, 3% of the estimated cutthroat trout population died after capture and release by anglers. Cutthroat trout in the study area were captured an average of 9.7 times during the study period in 1981.

OTHER PROJECT ACTIVITIES

Assistance to Independent Researchers

The Yellowstone fishery project functions as an administrative liason 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 an economical and timely completion of research in the park. Project equipment, manpower, and facilities are provided without compensation for small studies, and on a reimbursable basis for larger ones.

In 1985, the project provided assistance to Stephen Klein, a Ph. D. candidate of the Civil and Environmental Engineering School at the University of Colorado. Steve is performing a study entitled "Environmental Assessment of Heavy Metal Contamination in Yellowstone National Park". The objective of the research is to define the level of metal contamination in aquatic habitats within the park through a combined analyses of environmental transport, bioaccumulation, and environmental chemistry. This study will provide a detailed analysis and assessment of contamination and its significance to the health of aquatic environments and park visitors.

The project provided laboratory space, boats, and 4 man-days of assistance to Jerry Kaster of the University of Wisconsin-Milwaukee Center for Great Lake Studies. This research, "The Study of Substrate Characterization of Retrogressive Oligotrophy in Yellowstone Lake", will attempt to determine if Yellowstone Lake is becoming more oligotrophic, by investigating the bottom sediments.

Assistance was provided to Dave Blackwell of Southern Methodist University in Dallas, Texas. The project provided a 30 foot research vessel (Cutthroat), laboratory and shop space, and 10 man-days of personnel assistance in support of his 6 week project. Dr. Blackwell's research involves temperature measurements of the bottom of Yellowstone Lake. The project was reimbursed for the use of the boat on personnel cost.

The project assisted Richard Heckman of Brigham Young University in Provo, Utah with a study of fish parasites. Fish collections were made by project personnel, and fish holding facilities were provided by the project. The project also assisted Newton Kingston of the University of Wyoming in providing Rolf Vik of Norway with a collection of fish parasites from Yellowstone Lake.

Information Distribution

Information on the Yellowstone Fishery and Aquatic Management Program is made available to the scientific field and the general public in several ways. The annual Fishery and Aquatic Management Program Technical Report has a distribution of approximately 130 copies per year. The project receives 50 to 75 information requests each year by phone or mail. Response time on these requests requires from 10 minutes on the phone, to several days on a research request. Project personnel also make several presentations each year to clubs, societies, and organizations. In 1985, papers were presented at the National Meeting of the American Fishery Society in Sun Valley, Idaho; the Western Division of the American Fishery Society in Aspen, Colorado; and the International Age and Growth Symposium in Des Moines, Iowa. Presentations were also made at the Montana Chapter of the American Fishery Society, the Gardiner, Montana Chapter of Federation of Fly Fishermen, the Bozeman and Livingston, Montana Chapters of Trout Unlimited, and the Yellowstone Park naturalist seasonal training program.

Volunteer Program

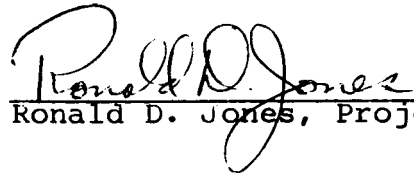
Volunteer programs of the Fish and Wildlife Service and the National Park Service have been utilized for many years. The program provides a needed manpower source for the project and a valuable training experience for the volunteer. In 1985, the project utilized 160 man-days of volunteer time and 80 man-days of Student Conservation enrollee time. They were involved in angler interviews, fish trap operations, gillnetting, electrofishing, backcountry stream and lake surveys, and a variety of clerical and maintenance jobs. The effort and dedication of these volunteers is very important to the Yellowstone fishery program.

ACKNOWLEDGMENTS

Once again, we find ourselves indebted to a group of dedicated individuals who enable the fishery program in Yellowstone Park to remain successful. Therefore, we would like to thank the following persons: Karl Biastoch, Bill Conner, Vicki Hamer, Dan Mahony, and Jeff Shenot were critical to our field work as paid seasonals. Tony Wasowicz, a member of the VIP program, and Ted Koch, a SCA, worked as full-time volunteers during the intense field season. Karl returned in the winter and worked as a full-time volunteer; he aged fish collected during the field season and compiled much of the data derived from maps for cursory stream surveys. In addition to his other duties, Dan aided in the development of the revised SONYEW system and coauthored that section of the report. Although they did not participate on a full-time basis, Anne Hall, Marion Jones, Anne Nichols, and Tina Schlaile volunteered their time whenever possible; each provided significant input to several crucial projects. Crystal Hudson, a permanent staff member, served as the project administrative assistant and an experienced member of the field crew. Crystal also participated in the preparation of this report and authored two sections of the report. Karrie West, the unsung heroine of this project, returned for the sixth winter season; she was responsible for manuscript typing, table and figure preparation, and data punching. Additionally, Karrie magically converted the VAR cards to data on computer tapes. Roy Ewing and Jana Mohrman, NPS employees, provided the backbone for the Upper Yellowstone River Sediment Study, and participated in the Reese Creek sampling. George Koemhild provided needed expertise for identification of macroinvertebrate samples. Ann Marie Chytra, the intrepid Heart Lake Ranger, again served as "resident limnologist" in addition to her general duties at Heart Lake. Jack Brooks and Wade Miller returned for the annual fall gillnetting; while Wade helped with the nets, Jack provided another edition of his famous epicurean delights. Once again the crew from Jackson NFH efficiently expedited the lake trout spawning at Lewis Lake.

Our special thanks to all of the above and also those who contributed but have not been specifically cited.

This report was submitted by:


Ronald D. Jones, Project Leader

Reviewed by:


Larry Visscher, Area Supervisor
Fishery Resources, Denver Regional Office

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APPENDIX A

Appendix Table 1. Gillnet catches of cutthroat trout by site, Yellowstone Lake, 1969-1972, 1974, 1976-1980, and 1982-1985¹⁾.

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

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

	Average weight (g)											Average
	1a	1b	1c	2a	2b	3a	3b	4a	4b	6c	7c	
1969	213	272	317	359	527	3)	3)	411	261	403	249	312
1970	311	279	348	450	223	382	390	320	349	488	108	320
1971	249	363	267	318	452	3)	3)	3)	3)	3)	3)	305
1972	269	276	231	350	352	262	410	405	358	459	349	320
1974	167	341	267	269	200	253	290	265	285	361	309	266
1976	322	337	280	363	267	285	322	331	306	353	358	314
1977	273	214	292	268	258	219	399	256	215	430	270	271
1978	254	360	235	336	292	283	337	260	290	416	497	316
1979	222	245	316	339	300	239	304	255	280	517	400	301
1980	357	302	316	418	314	309	410	217	255	430	414	329
1982	233	240	403	406	319	239	470	369	455	471	360	359
1983	188	226	216	294	272	168	375	248	347	455	378	271
1984	199	399	250	244	165	191	318	250	354	375	227	259
1985	281	280	344	343	279	234	470	237	365	524	458	332

- 1) Experimental gillnets (38.1 m long) set overnight (7.6 m graduated mesh panels 19, 25, 32, 38, and 51 mm) in the 1.5-4.6 m depth interval.
- 2) From 1969-1974, only 1 set was made in each area at the specified depth interval; for 1977, the number represents an average of 4 sets, and 1978-1985 represents an average of 5 sets.
- 3) Areas not sampled.

Appendix Table 2. Gillnet catches of cutthroat trout by general area, Yellowstone Lake, 1969-1972, 1974, 1976-1980, and 1982-1985¹⁾.

Year	Number/net				Average total length (mm)				Percentage under 210 mm				
	North	Central	W. Thumb	South	North	Central	W. Thumb	South	North	Central	W. Thumb	South	Total
1969	10	--	16	15	316	--	296	319	12.2	--	9.7	10.0	10.9
1970	13	14	17	4	311	352	285	346	7.8	0.0	17.6	0.0	8.1
1971	14	--	--	--	321	--	--	--	1.4	--	--	--	1.4
1972	15	10	14	12	297	307	342	336	11.7	0.0	0.0	4.0	6.7
1974	19	9	16	13	289	302	294	329	14.7	16.7	25.8	0.0	14.7
1976	16	17	13	13	310	311	328	333	11.0	5.9	4.3	7.7	8.5
1977	17	15	11	17	284	293	273	309	28.2	23.1	30.3	13.3	24.6
1978	13	15	17	13	298	305	294	353	13.2	8.6	5.4	0.8	8.5
1979	12	15	17	11	297	290	291	356	18.1	21.0	14.5	6.1	16.0
1980	13	12	15	12	307	325	278	341	14.0	11.0	16.0	11.0	13.4
1982	10	11	10	11	307	316	341	342	15.7	15.0	6.9	4.5	11.9
1983	21	18	16	14	275	278	297	339	26.4	21.6	13.7	8.0	20.9
1984	22	19	15	18	272	286	304	286	30.3	18.0	12.4	24.2	24.8
1985	12	18	17	12	305	303	294	360	11.3	20.8	16.4	5.7	13.7
Averages	15	14	15	13	299	306	301	335	15.4	13.5	13.3	7.3	13.2

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

Appendix Table 3. Gillnet catches of longnose sucker by site, Yellowstone Lake 1969-1972, 1974, 1976-1980, and 1982-1985¹⁾.

	Number per net ²⁾											Total
	1a	1b	1c	2a	2b	3a	3b	4a	4b	6c	7c	
1969	7	28	39	13	31	3)	3)	5	1	1	22	147
1970	13	3	4	23	16	3	1	4	3	0	1	71
1971	17	75	7	13	73	3)	3)	3)	3)	3)	3)	185
1972	4	4	0	3	2	0	0	3	2	5	5	28
1974	27	26	15	9	26	6	18	5	17	4	22	175
1976	13	30	13	26	13	8	14	13	14	0	16	160
1977	9	3	8	14	13	4	8	4	8	0	10	319
1978	4	18	7	11	13	6	3	5	5	1	2	398
1979	18	21	11	18	23	5	13	6	12	5	7	695
1980	5	12	9	15	13	2	15	5	17	6	11	548
1982	15	21	8	12	15	17	19	7	20	8	3	726
1983	14	24	8	11	16	11	8	7	13	7	4	625
1984	17	11	11	21	26	12	6	13	12	11	11	737
1985	8	6	4	5	18	4	6	8	5	0	4	342

	Average total length (mm)											Average
	1a	1b	1c	2a	2b	3a	3b	4a	4b	6c	7c	
1969	431	319	411	394	323	3)	3)	368	425	360	358	365
1970	444	392	427	380	415	425	306	376	317	---	214	393
1971	432	267	433	410	312	3)	3)	3)	3)	3)	3)	316
1972	446	291	---	242	318	---	---	422	358	330	290	335
1974	401	340	428	401	345	392	355	385	358	369	356	370
1976	427	334	414	408	394	396	373	411	385	---	398	389
1977	440	408	434	407	413	380	361	400	431	---	409	401
1978	437	353	424	412	307	354	329	409	321	285	338	363
1979	435	342	429	413	334	396	325	397	345	285	362	371
1980	422	330	428	410	360	402	322	416	312	300	414	365
1982	438	363	432	400	323	374	316	414	289	261	401	356
1983	416	298	436	410	300	382	337	377	298	254	236	341
1984	407	311	410	339	283	382	385	340	361	266	443	349
1985	420	407	421	414	299	319	327	395	325	---	417	362

	Average weight (g)											Average
	1a	1b	1c	2a	2b	3a	3b	4a	4b	6c	7c	
1969	938	415	855	825	434	3)	3)	621	860	614	592	635
1970	1076	971	970	773	883	1003	366	692	367	---	112	838
1971	963	273	935	869	413	3)	3)	3)	3)	3)	3)	459
1972	1012	260	---	167	575	---	---	961	600	457	286	519
1974	804	561	952	774	574	775	546	790	367	646	577	668
1976	930	527	951	834	560	765	651	876	720	---	806	759
1977	995	847	1047	840	898	716	656	810	529	---	889	833
1978	992	594	913	899	423	593	478	859	467	304	595	654
1979	986	567	964	864	563	791	484	810	552	339	689	699
1980	929	502	957	848	657	777	468	855	429	346	885	660
1982	970	662	931	852	478	701	451	911	324	249	928	631
1983	935	442	1042	898	415	743	524	759	361	211	234	596
1984	331	397	385	574	265	753	580	701	574	263	1077	500
1985	947	870	990	932	393	493	504	888	480	---	997	688

- 1) Experimental gillnets (38.1 m long) set overnight (7.6 graduated mesh panels 19, 25, 32, 38, and 51 mm) in the 1.5-4.6 m depth interval.
- 2) From 1969-1976, only 1 set was made in each area at the specified depth interval; for 1977, the number represents an average of 4 sets, and 1978-1985 represents an average of 5 sets.
- 3) Areas not sampled.

Appendix Table 4 . Stream names/numbers used to identify
Yellowstone Lake tributaries,
1974-86.

Revised SONYEW Number (1986)	Original SONYEW Number (1976-85)	Name or Hoskin's number (1974-75)
1085-	0070	Pelican Creek
1086-	0088	10
1087-	0089	Squaw Lake outlet
1089-	0092	Sedge Creek
1090-	0097	1
1091-	0098	2
1092-	0099	5
1093-	0100	Cub Creek
1094-	0103	6
1095-	0104	Clear Creek
1096-	0112	9
1097-	0113	Meadow Creek
1098-	0114	8
1099-	0115	Columbine Creek
1100-	0118	Alluvium Creek
1101-	0119	53
1102-	0120	54
1103-	0121	55
1104-	0122	56
1105-	0123	57
1106-	0124	58
1107-	0125	Beaverdam Creek
1000-	0040	Yellowstone River inlet
1108-	0129	Trail Creek
110803-	0131	59
110802-	0132	60
110801-	0133	61
1109-	0134	62
1110-	0135	63
1111-	0136	64
1112-	0137	70
1113-	0138	65
1114-	0141	66
1115-	0142	67
1116-	0143	68
1117-	0144	69
1118-	0145	71 or 112
1119-	0146	Alder Lake outlet
1120-	0152	72
1121-	0153	Chipmunk Creek
1122-	0160	73
1123-	0161	74

Appendix Table 4 . continued.

Revised SONYEW Number (1986)	Original SONYEW Number (1976-85)	Name or Hoskin's number (1974-75)
1124-	0162	75
1125-	0165	Grouse Creek
1126-	0168	76
1127-	0169	77
1128-	0170	78
1129-	0171	79
1130-	0172	80
1131-	0173	81
1132-	0174	82
1133-	0175	83
1134-	0176	84
1135-	0177	85
1136-	0178	86
1137-	0179	87
1138-	0180	88
1139-	0181	89
1140-	0182	91
1141-	0186	92
1142-	0187	93
1143-	0188	94
1144-	0189	96
1145-	0190	95
1146-	0191	97
1147-	0192	98
1148-	0193	99
1149-	0194	100
1150-	0195	101
1151-	0196	102
1152-	0197	103
1153-	0198	104
1154-	0199	105
1155-	0200	106
1156-	0201	-
1157-	0202	107
1158-	0203	108
1159-	0204	-
1160-	0205	109
1161-	0206	-
1162-	0211	41
1163-	0212	Solution Creek
1164-	0214	Sewer Creek (40)
1165-	0215	39
1166-	0216	Sandy Creek (38)
1167-	0217	37

Appendix Table 4. continued.

Revised SONYEW Number (1986)	Original SONYEW Number (1976-85)	Name or Hoskin's number (1974-75)
1168-	0218	Thumb Creek
1169-	0219	36
1170-	0220	35
1171-	0221	-
1172-	0222	-
1173-	0225	34
1174-	0226	33
1175-	0227	-
1176-	0228	Little Thumb Creek
1177-	0229	32
1178-	0230	31
1179-	0231	30
1180-	0232	29
1181-	0233	28
1182-	0234	Little Arnica Creek (27)
1183-	0235	Arnica Creek
1184-	0238	25
1185-	0239	26
1186-	0247	24
1187-	0248	23
1188-	0249	22
1189-	0250	21
1190-	0251	20
1191-	0252	42
1192-	0255	Weasel Creek
1193-	0256	19
1194-	0257	18
1195-	0258	16
1196-	0259	17
1197-	0260	Bridge Creek
119701-	0265	15
1198-	0266	Wells Creek (14)
1199-	0267	13
1200-	0268	12
1201-	0269	Hatchery Creek (11)
1202-	0270	Hotel Creek (110)
1203-	0271	111
1204-	0272	-

Appendix Table 5. Yellowstone Lake tributaries not
found by the study team in 1985
(Revised SONYEW numbers and/or names
only).

Stream Number	Stream Name
1112-	-
1116-	-
1117-	-
1133-	-
1139-	-
1149-	-
1191-	-

Appendix Table 6. Yellowstone Lake tributaries where no spawning was observed in 1985
(Revised SONYEW numbers and/or names only).

Stream Number	Stream Name	Reason for no Spawning ¹⁾
1087-	Squaw Lake outlet	A
1089-	Sedge Creek	C
1090-	-	A
1092-	-	B
1096-	-	A
1098-	-	B
1100-	Alluvium Creek	C
1101-	-	U
1102-	-	C
1104-	-	C
1105-	-	A
1106-	-	U
110802-	-	U
110601-	-	U
1109-	-	U
1110-	-	A
1119-	Alder Lake outlet	A
1120-	-	A
1124-	-	A
1128-	-	A
1129-	-	A
1130-	-	U
1132-	-	U
1135-	-	A
1136-	-	A
1137-	-	U
1140-	-	A
1142-	-	A
1143-	-	U
1145-	-	A
1147-	-	U
1148-	-	U
1151-	-	U
1152-	-	A
1153-	-	A
1154-	-	A
1156-	-	A
1159-	-	A
1161-	-	B
1162-	-	U
1165-	-	U
1170-	-	B,C

Appendix Table 6. continued.

Stream Number	Stream Name	Reason for no Spawning ¹⁾
1171-	-	B,C
1172-	-	B,C
1173-	-	B,C
1174-	-	B,C
1175-	-	B,C
1178-	-	A
1180-	-	U
1181-	-	A
1184-	-	C
1185-	-	A
1186-	-	A
1187-	-	U
1188-	-	B
1189-	-	U
1190-	-	A
1192-	Weasel Creek	U
1193-	-	A
1194-	-	A
1195-	-	A
1196-	-	A
119701-	-	A
1198-	Wells Creek	U
1199-	-	D
1200-	-	U
1202-	Hotel Creek	D
1204-	-	A

1) Reason for no spawning: A = Judged unsuitable by study team (n=31); B = Natural physical barrier at stream mouth (n=10); C = Apparent chemical barrier (n=11); D = Man-made physical barrier (n=2); and U = Unknown (n=20).

Appendix Table 7. Yellowstone Lake tributaries where spawning was observed in 1985
(Revised SONYEW numbers and/or names only).

Stream Number	Stream Name	Was stream sampled? (Y=yes, N=no)	If not sampled, why not? ¹⁾
1085-	Pelican Creek	N	A
1086-	-	N	B
1091-	-	Y	
1093-	Cub Creek	N	A
1094-	-	Y	
1095-	Clear Creek	N	A
1097-	Meadow Creek	Y	
1099-	Columbine Creek	N	A
1103-	-	Y	
1107-	Beaverdam Creek	N	A
1108-	Trail Creek	N	A
110803-	-	Y	
1111-	-	Y	
1113-	-	Y	
1114-	-	N	B
1115-	-	N	B
1118-	-	Y	
1121-	Chipmunk Creek	N	A
1122-	-	Y	
1123-	-	Y	
1125-	Grouse Creek	N	A
1126-	-	Y	
1127-	-	Y	
1131-	-	Y	
1134-	-	Y	
1138-	-	Y	
1141-	-	Y	
1144-	-	Y	
1146-	-	Y	
1150-	-	Y	
1155-	-	Y	
1157-	-	N	B
1158-	-	Y	
1160-	-	N	B
1163-	Solution Creek	N	A
1164-	Sewer Creek	Y	
1166-	Sandy Creek	Y	
1167-	-	N	B
1168-	Thumb Creek	Y	
1169-	-	Y	
1176-	Little Thumb Creek	Y	
1177-	-	Y	

Appendix Table 7. continued.

Stream Number	Stream Name	Was stream sampled? (Y=yes, N=no)	If not sampled, why not? ¹⁾
1179-	-	N	B
1182-	Little Arnica Creek	Y	
1183-	Arnica Creek	Y	
1197-	Bridge Creek	N	B
1201-	Hatchery Creek	N	B
1203-	-	N	B

1) If not sampled, why not? A = Stream too large to be sampled with backpack electrofishing gear;
B = Spawning was completed before the stream could be adequately sampled.

Appendix Table 8. Mean total lengths of cutthroat trout captured in the Yellowstone River, 1952-1985.

Regulations	Year	Mean total length in mm (inches)				Sample size	Area	Source
		Dip net	Electrofishing	Hook and line	Creel			
5 fish bag limit, no size limit	1952	368 (14.5) ¹⁾			330 (13.0)	382 107	LeHardy Rapids Above Upper Falls	Cope 1953 Cope 1953
3 fish bag limit, no size limit	1967		345 (13.6)		338 (13.3)	346 127	Excluding Hayden Valley Excluding Hayden Valley	Unpublished data Dean and Varley 1973
	1968		351 (13.8)		348 (13.7)	351 487	Excluding Hayden Valley Excluding Hayden Valley	Unpublished data Dean and Varley 1973
	1970			424 (16.7)	378 (14.9)	43 17	Excluding Hayden Valley Hayden Valley	Dean and Mills 1971 Dean 1972
	1971		447 (17.6) 361 (14.2)			309 378	Hayden Valley Fishing Bridge	Dean 1972 Dean 1972
	1972				368 (14.5)	125	Excluding Hayden Valley	Dean and Varley 1973
	1973				363 (14.3)	2798	Above falls, excluding Hayden Valley	Jones et al. 1976
Catch and release	1974	362 (14.3) ¹⁾			372 (14.6)	463 3926	LeHardy Rapids Excluding Hayden Valley	Dean et al. 1975 Dean et al. 1975
	1975	370 (14.6) ¹⁾			366 (14.4)	775 10540	LeHardy Rapids Above falls, excluding Hayden Valley	Varley et al. 1976 Varley et al. 1976
	1976	375 (14.8) ¹⁾			373 (14.7)	964 11062	LeHardy Rapids Above falls, excluding Hayden Valley	Jones et al. 1977 Jones et al. 1980
	1977	373 (14.7) ¹⁾			373 (14.7)	245 10239	LeHardy Rapids Above falls, excluding Hayden Valley	Jones et al. 1978 Jones et al. 1980
	1978	376 (14.8) ¹⁾			382 (15.1)	759 8950	LeHardy Rapids Above falls, excluding Hayden Valley	Jones et al. 1979 Jones et al. 1980
	1979	385 (15.2) ¹⁾			387 (15.2)	571 8495	LeHardy Rapids Above falls, excluding Hayden Valley	Jones et al. 1980 Jones et al. 1980
	1980	384 (15.1) ¹⁾			390 (15.3)	483 7789	LeHardy Rapids Above falls, excluding Hayden Valley	Jones et al. 1981 Jones et al. 1981
	1981	387 (15.2) ¹⁾	397 (15.6)		392 (15.4)	571 148 9904	LeHardy Rapids Cable Car Area Above falls, excluding Hayden Valley	Jones et al. 1982 Jones et al. 1982 Jones et al. 1982
	1982	389 (15.3) ¹⁾			395 (15.6)	694 8746	LeHardy Rapids Above falls, excluding Hayden Valley	Jones et al. 1983 Jones et al. 1983
	1983	394 (15.5) ¹⁾			398 (15.7)	570 9983	LeHardy Rapids Above falls, excluding Hayden Valley	Jones et al. 1984 Jones et al. 1984
	1984	399 (15.7) ¹⁾			401 (15.8)	526 7567	LeHardy Rapids Above falls, excluding Hayden Valley	Jones et al. 1985 Jones et al. 1985
	1985	401 (15.8) ¹⁾			401 (15.8)	431 6626	LeHardy Rapids Above falls, excluding Hayden Valley	Current Report Current Report

¹⁾ All adults only.