

UNITED STATES DEPARTMENT OF THE INTERIOR

U.S. Fish and Wildlife Service

Division of Planning and Assistance



Annual Project Report

YELLOWSTONE FISHERY INVESTIGATIONS

Yellowstone National Park

Calendar Year 1973

June 10, 1974

UNITED STATES GOVERNMENT

Memorandum

TO : Sub-District Ranger

DATE: December 5, 1974

FROM : Biological Aid, Yellowstone Fishery Investigations, Fish and
Wildlife Service

SUBJECT: Annual Project Reports - 1973

Enclosed is a copy of our most recent Annual Project Report - calendar year 1973. We would like you to read it to find out what we are doing and why - for your own information and others. We are getting pretty low on our supply of these reports; therefore, if you do not wish to read your copy or keep it for future reference, please return it to us.

Jandy Hoskins

TABLE OF CONTENTS

"Old" U.S. Bureau of Fisheries Boat on Yellowstone Lake (about 1915)	Cover
	<u>Page</u>
Abstract	1
Introduction	3
Parkwide Estimates of Angler Use, Success and Harvest	5
Yellowstone Lake	14
Yellowstone River	37
Native Species Restoration Program	43
Gibbon River	45
Heart Lake	64
Aquatic Survey Program	77
Tanager Lake	77
Mallard Lake	87
Joffe Lake	93
Hering Lake	99
Beula Lake	104
Unnamed Lakes (near Snake Hot Springs)	109
Lake Survey Reconnaissance	114
Aster Lake, Forest Lake, Lake of the Woods, South Boundary Lake and Lake Abundance	
Lewis Lake	117

	<u>Page</u>
Acknowledgements	119
Literature Cited	120
Appendix	122
A. The Predation of Cutthroat Trout on Redside Shiners in Pelican Creek - by Rachael R. Brown	124
B. Piscivorous Avifauna on Yellowstone Lake - by Margaret B. Davenport	132
C. Life History of the Longnose Sucker (<u>Catostomus</u> <u>Catostomus</u> Forster): A Literature Review by Margaret B. Davenport	138
D. Species Composition and Relative Abundance of the Planktonic and Benthic Organisms of Yellowstone Lake - by Thom H. Johnson	147
E. Culverts and Fish Migration from Yellowstone Lake - by Robert Ruediger	156
F. Creel Census Worksheet for the Shoreline Fishery, Yellowstone Lake	169

ABSTRACT

Major project activities included the first parkwide angler and use estimates, creel studies on Yellowstone Lake and the Yellowstone River, operation of the Cub and Clear Creek fish traps, aquatic surveys of six "back country" lakes, a gill netting survey of Heart Lake, and first year efforts at locating and restoring the native Arctic grayling in the Gibbon River watershed.

PARKWIDE ANGLER USE ESTIMATES

A "Volunteer Fisherman Report" card was given out with the new non-fee fishing permit. Returns from the card and statistics gathered on the regular contact creel census programs indicated that 365,000 ($\pm$ 80,900) angler-days of use occurred in the park in 1973. The native cutthroat trout made up nearly 82% of all fish landed.

YELLOWSTONE LAKE

Creel studies on the five major segments of the fishery indicated that 114,187 anglers fished 268,321 hours and landed 243,090 cutthroat trout for an overall landing rate of 0.91 trout per hour. Anglers retained 87,813 cutthroats or only 36% of those landed.

An estimated 65,215 cutthroat spawners ascended Clear Creek while 15,164 utilized Cub Creek. The spawning run into Clear Creek was nearly twice the previous record. At Cub Creek the number of spawners equalled the peak established in 1966. Although record numbers of cutthroats were available, few fish used the excellent spawning gravels near the headwaters of either stream.

YELLOWSTONE RIVER

A creel survey was conducted on this popular stream to measure angler use and angling quality changes resulting from the new "catch and release" angling regulation. The new regulations had a substantial effect on the fishery. During a six week period the river was fished by 15,603 anglers who caught 63,916 cutthroats in 36,731 hours for a landing rate of 1.74 trout per hour. This is considered excellent fishing by national standards. The new regulations caused a decline

of 57% in angler-days, 47% in effort, and an increase of 16% in the number of trout landed compared to 1972 when a three fish, 14-inch size limit was in effect. Overall angler response to this new management program was considered favorable.

GIBBON RIVER

Five sections of the river were sampled with electrofishing gear to determine species composition and to locate stream dwelling Arctic grayling. Of the 1,280 fish of seven species that were sampled only two were grayling. They were transplanted to a "fishless" stretch of Castle Creek, a Gibbon River tributary. Substantial changes have occurred in the river's fish populations. Brown trout have completely replaced rainbow trout in the Gibbon Meadows area and grayling numbers have decreased throughout the entire stream.

HEART LAKE

A gill netting study of Heart Lake was carried out in 1973 as were observations on several important spawning streams. A search of historical records was also made to detect trends in the fishery. A total of 293 fish were netted of which 25% were the exotic salmonid lake trout. Of the native species, cutthroat trout made up 4% of the gill net catches, mountain whitefish 22%, Utah chubs 19%, Utah suckers 29%, and the mountain sucker 1%. Analysis of all pertinent data indicated a sizeable decline in the native cutthroat population believed due to competition and predation by lake trout and angling pressure. Catch-and-release regulation and closure of streams during spawning periods was proposed as a first step to help protect the cutthroat.

AQUATIC SURVEY PROGRAM

Basic surveys were completed on 6 "back country" lakes. These were Tanager Lake (32 acres) Mallard Lake (32 acres), Joffe Lake (1.6 acres), Hering Lake (60 acres), Beula Lake (107 acres), and the unnamed lakes near Snake Hot Springs (1.6 acres). Tanager lake is populated by redbside shiners. Both Hering and Beula Lakes contain cutthroat trout and Joffe Lake supports a "healthy" brook trout population. Mallard Lake was found to be barren of fish life or nearly so. The Snake Hot Springs middle lake was found to contain all of the original native fish species of the Snake River drainage and it was recommended that it be closed to fishing and camping to preserve its unique scientific value. Details of each survey along with management recommendations are presented for each lake.

ANNUAL PROJECT REPORT - 1973
Fishery Management Program
Yellowstone National Park, Wyoming

by
Jack L. Dean
and
John D. Varley

INTRODUCTION

This is the eleventh annual report to be issued since technical assistance to Yellowstone National Park was initiated in 1962 by the old Division of Fishery services (now included in the Division of Planning and Assistance). This is the fifth report to include all project accomplishments under one cover.

The objectives of this fishery program are:

1. To preserve and restore native species and aquatic habitats.
2. To provide anglers with a high quality angling experience with wild fish under natural settings.
3. To manage the fishery program as an integral part of the park ecosystem.

A number of major changes were made to the park fishing regulations in 1973. These were as follows:

1. A free fishing permit was required for all anglers over 12 years of age.
2. One mile of the Yellowstone River at Fishing Bridge was closed to angling to protect the native resident river cutthroats and to provide non-anglers a readily accessible place to see and appreciate wild native trout.

3. Four "catch and release" waters were established to reduce man's impact on the fishery and to improve angling quality. These were the Yellowstone River above the Upper Falls, Slough Creek, the Lower Lamar River, and the Lewis River below Lewis Lake.
4. A reduction was made in the possession limit to reduce the consumptive use of fish. On Yellowstone Lake the limit was reduced from 3 fish to 2 fish over 14 inches in length. Throughout most of the remainder of the Park the limit was reduced from 5 fish to 2 fish.

PARKWIDE ESTIMATES OF ANGLER USE, SUCCESS, AND HARVEST

A new law that requires all potential anglers in Yellowstone Park to obtain a free fishing permit prior to fishing was implemented in 1973. This new requirement provided the basis for the first reliable estimates of the total number of parkwide anglers in several decades. It was thought that if fisheries statistics could be obtained in conjunction with the total angler estimates that such figures could be used to aid in the management of the many waters of Yellowstone. In the Park there may be as many as 60 lakes and 170 rivers and streams which receive fishing exploitation. Exploitation information exists for very few of these waters.

With the above objective set, a series of trial experiments were designed to determine if a program based upon voluntary angler responses could be used in place of or in addition to, costly manned creel surveys.

From a base figure furnished by the Ranger Division on the number of permits issued, the total parkwide number of angler days was estimated. The information and details of how this total was derived is shown in Table 1. Data needed for the expansion was collected from anglers interviewed during normal creel surveys on Yellowstone Lake and River.

Results (Table 1) indicated that Yellowstone Park sustained some 365,000 ($\pm 80,900$) angler days use in 1973. The wide confidence limits are the result of wide variability by month, and probably by different waters in the Park, of the average fishing stay in the Park. This statistic (1.78 ± 0.4 days) is presently the weakest link in the calculation of the total angler days and needs much refinement.

Beginning on July 31, 1973, each angler requesting a fishing permit was given a "Volunteer Fisherman Report" (Figure 1). This card requested pertinent use, effort and harvest information and asked that it be dropped in any mailbox.

Cards were issued with the free fishing permits at all ranger and visitor stations in the Park. A total of 1,730 cards were marked and were randomly distributed to fishermen with unmarked cards. A mark-recapture formula using the return of marked cards was used to estimate the total number issued. One hundred and eight marked cards returned giving an estimate of 17,946 issued, thus the percentage of anglers returning the card was approximately 6.2%.

The design of the volunteer card is important in the percentage of cards that will ultimately be returned. It was expected that a lower percentage of cards would be returned than in many fishery studies because of the lengthy and technical nature of the questionnaire. The 6.2% return was fairly predictable and is considered acceptable.

Table 1 .—first parkwide estimates of angler day use, 1973, Yellowstone National Park

Park permits issued: ¹⁾	169,103
Invalid permits issued: ²⁾	3,467
Total valid permits issued:	165,636
Adult anglers without permits: ³⁾	10,610
Adult anglers with permits but did not fish: ⁴⁾	1,057
Total adult anglers in the Park:	175,189
Juvenile anglers (with & without permits): ⁵⁾	29,624
Total parkwide anglers:	204,813
Average fishing stay in 1973: ⁶⁾	1.78 $\pm$ 0.40 days
Total parkwide angler days:	365,000 $\pm$ 80,900

- 1) Figure furnished from Ranger Division, Yellowstone National Park.
- 2) Juveniles (under 12 years) which were issued a permit (2.05%).
- 3) 6.02% of 1320 anglers contacted on Yellowstone Lake and River did not obtain a permit.
- 4) 0.006% of 1105 anglers contacted obtained a permit but did not fish.
- 5) 14.39% of 1320 anglers contacted on Yellowstone Lake and River were juveniles.
- 6) If any portion of a day is spent in the pursuit of fishing it is considered a "fishing day".

Table 2 .—"Volunteer Fisherman Report" cars returned and unusable

Reason unusable	Number	Percent
Incomplete or no statistics	37	26
Information furnished on multiple waters	16	11
Crank response	2	1
Did not fish	16	11
Could not determine specific water fished	67	47
Water reported not in the Park	5	4
Total	143*	100

* The 143 unusable cards represents 12.9% of the cards returned.

OFFICIAL BUSINESS

POSTAGE AND FEES PAID
U.S. DEPT. OF THE INTERIOR
INT. 417

SUPERINTENDENT, NATIONAL PARK SERVICE

P.O. BOX 184

YELLOWSTONE NATIONAL PARK, WYOMING 82190

FISHERMEN:

**WE
NEED
VOLUNTEERS!**

SEE REVERSE

OMB Approval 42-R-1664
Approval Expires April 30, 1974

TEAR OFF THIS STUB BEFORE MAILING

VOLUNTEER FISHERMAN REPORT YELLOWSTONE NATIONAL PARK

PLEASE USE ONE CARD ONLY PER LAKE OR STREAM FISHED

LAKE OR STREAM FISHED _____ DATE _____

HOW MANY DAYS DID YOUR PARTY FISH ON THIS LAKE/STREAM? _____

AVERAGE NUMBER OF FISHERMEN? _____ AVERAGE HOURS FISHED PER DAY? _____

DID YOU FISH FROM A RAFT OR BOAT? YES _____ NO _____

WERE YOU CHECKED BY CREEL SURVEY PERSONNEL? YES _____ NO _____

WERE YOU SATISFIED WITH THE NUMBERS AND SIZES OF FISH CAUGHT? YES _____ NO _____

COMMENTS:

Species Caught: (Number)	Fish Species Caught or Kept by Sizes (Lengths)		
	Length Classes	Number Caught	Number Kept
Cutthroat _____	Under 10 Inches		
Rainbow _____	10.1 to 12 In.		
Brook _____	12.1 to 14 In.		
Brown _____	14.1 to 16 In.		
Lake (Mac.) _____	16.1 to 18 In.		
Grayling _____	18.1 to 20 In.		
Whitefish _____	Over 20 Inches		
Hybrid _____			
Unknown _____			
Other (Specify) _____			

If You Caught Two or More Species Indicate Which Species the Length Measurements are for: _____

FISHERMEN:

The National Park Service and Bureau of Sport Fisheries and Wildlife need your help in the management of the Yellowstone Park fisheries. With your help in keeping accurate information we can determine the "health" of the fish population on the lake or stream you fished. Information from unsuccessful anglers is just as important as that from anglers catching a limit. These forms are self-addressed and postage paid. Drop them in any mailbox. For the results of this survey, please send a stamped, self-addressed envelope to the address on the reverse side. Thank you for assisting us!

Please use only one card per lake or stream fished. Additional cards are available at any Ranger Station.

TEAR OFF THIS STUB BEFORE MAILING

TEAR OFF THIS STUB BEFORE MAILING

Slightly over 1,100 cards were returned of the 17,946 estimated to have been issued. A fairly high percentage (12.9%) of cards returned were unusable due to various reasons (Table 2). The most common reason the card could not be used was that the specific water fished could not be determined. Some anglers genuinely did not know where they were fishing, however, these were a minority. The most common situation were those anglers who wrote down "Yellowstone" meaning either the Park, the river, or the lake. These type of problem responses can be reduced through a simple change in the question on the card.

Using the assumption that the return of the cards was random and proportional to the distribution of effort in the Park, Table 3 was prepared. This table used 365,000 angler days as the base from which distribution was made. Allowances were made for lakes and streams known to sustain fishing pressure, but for which there were no cards returned.

Table 4 details the estimates of the total fish landed and creeled in the Park by species. The native cutthroat is shown to have made up nearly 82% of all of the fish landed. The cutthroat is followed by four exotic trouts which combined totaled 15.7% and by the endemic whitefish and grayling which totaled 1.3%.

Twelve waters in the Park were shown to have made up over 85% of the total angling pressure (Table 5). The effort on the waters comprising the "top" twelve were largely expected except, perhaps, for the ranking of Soda Butte Creek and the Bechler River. Previously, these were not thought to sustain that much angling pressure.

Waters sustaining less than one percent of the angling pressure are shown in Table 6. Despite the fact that effort on each water is less than 1%, a number of them rank very high when effort/unit area is considered. The small lakes such as Cascade, Squaw, Ribbon, Grebe, Trout and Sylvan Lakes (Table 6) sustain a great deal more exploitation by anglers than do the large lakes (Yellowstone, Shoshone, Lewis and Heart Lakes). A number of rivers and streams (Clear Creek, Hellroaring Creek, Lewis-Shoshone Channel, Nez Perce Creek-Table 6) show a similar high exploitation per unit area.

Estimates of use based on the volunteer report - angling permit expansion, where comparisons could be made, ranged from a 14.5% underestimate (Lewis Lake) to a 32.5% overestimate (Yellowstone Lake) and averaged a plus 16.6% (Table 7). Two factors should be taken in consideration when comparing the independent estimates with estimates from the expansion:

1. The volunteer report-permit estimate is based on use over the entire fishing season whereas each of the independent estimates are for the three-month summer season. This would account for some of the overestimate variability.

2. The independent estimates generally range from a plus or minus 16 to 23% accuracy.

Theoretically, with vastly increased sample size and good distribution throughout the angling season, the amount of variability would be reduced to the point that the expansion technique would be well within the range of the costly manned survey estimates.

Because the 1973 expansion and calculation of use, effort, and harvest was a "trial run" and the confidence limits were quite high, conclusions must be guarded although the 1973 data proved the practicality and value of the system. The weak points were discovered and provisions were made to correct them in 1974. During 1974, a revised card will be issued with each permit throughout the entire fishing season. A minimum of 5,000 usable cards should be returned yielding enough information to make valid estimates for most of the waters in the Park.

Table 3.—Angler use, effort, fish landing, and harvest estimates for Yellowstone National Park, 1973*

Water	% total use	Angler days	Angler hours	Total fish landed	Total fish creeled
Yellowstone River drainage					
Lakes					
Yellowstone Lake	46.317	169,057	437,857	227,686	91,950
Squaw Lake	0.349	1,274	3,300	0	0
Cascade Lake	0.325	1,186	3,072	1,413	0
Riddle Lake	0.139	507	1,313	1,576	328
Trail Lake	0.139	507	1,313	6,040	1,050
Sylvan Lake	0.116	423	1,096	548	0
Ribbon Falls Lake	0.093	339	878	992	334
Trout Lake	0.093	339	878	0	0
Grizzly Lake	0.046	168	435	218	0
Fern Lake	0.023	84	218	0	0
15 other lakes	0.697	2,544	6,589	3,769	1,028
Drainage subtotal- lakes	48.338	176,428	456,949	242,242	94,690
Streams					
Yellowstone River	15.361	56,068	145,216	296,241	10,165
Soda Butte Creek	1.975	7,209	18,671	12,136	4,668
Gardner River	1.441	5,260	13,623	13,214	3,678
Slough Creek	1.232	4,497	11,647	30,399	582
Clear Creek	0.930	3,395	8,793	7,562	1,583
Pelican Creek	0.744	2,716	7,034	6,049	1,266
Hellroaring Creek	0.697	2,544	6,589	6,391	198
Lamar River	0.627	2,289	5,929	9,012	1,482
Cache Creek	0.349	1,274	3,300	3,729	1,155
Lava Creek	0.349	1,274	3,300	1,320	1,089
Indian Creek	0.302	1,102	2,854	1,570	885
Cascade Creek	0.302	1,102	2,854	1,027	29
Obsidian Creek	0.256	934	2,419	1,645	339
Raven Creek	0.209	763	1,976	2,351	119
Tower Creek	0.163	595	1,541	2,003	154
Beaverdam Creek	0.139	507	1,313	4,819	3,283
Arnica Creek	0.139	507	1,313	1,221	92
Straight Creek	0.093	339	878	1,651	1,045
Glen Creek	0.070	256	663	0	0
Chipmunk Creek	0.046	168	435	291	291
Otter Creek	0.046	168	435	0	0
32 other streams	1.487	5,428	14,059	8,042	2,193
Drainage subtotal-streams	26.958	98,395	254,842	410,673	34,296
Drainage total-all waters	75.296	274,823	711,791	652,935	128,986
Gallatin River drainage					
Lakes					
3 lakes	0.139	507	1,313	751	205
Drainage subtotal-lakes	0.139	507	1,313	751	205
Streams					
Gallatin River	0.232	847	2,194	1,426	505
Bacon Rind Creek	0.046	168	435	3,263	218
4 other streams	0.186	679	1,759	1,006	274
Drainage subtotal-streams	0.465	1,694	4,388	5,695	997
Drainage total-all waters	0.604	2,201	5,701	6,446	1,202

* All estimates $\pm$ 23%

Water	% total use	Angler days	Angler hours	Total fish landed	Total fish creeled
Madison River drainage					
Lakes					
Grebe Lake	0.720	2,628	6,807	3,880	408
Ice Lake	0.093	339	878	0	0
Goose Lake	0.070	256	663	113	113
Feather Lake	0.023	84	218	0	0
2 other lakes	0.093	339	878	502	137
Drainage subtotal-lakes	0.999	3,646	9,444	4,495	658
Streams					
Madison River	5.206	19,002	49,215	21,655	492
Firehole River	3.579	13,063	33,833	10,827	304
Gibbon River	2.951	10,771	27,897	30,408	2,511
Nez Perce Creek	0.465	1,697	4,395	1,187	88
Little Firehole River	0.232	847	2,194	4,125	132
Grayling Creek	0.232	847	2,194	2,918	2,567
Iron Creek	0.023	84	218	0	0
10 other streams	0.465	1,697	4,395	2,514	686
Drainage subtotal-streams	13.154	48,008	124,341	73,634	6,780
Drainage total-all waters	14.153	51,654	133,785	78,129	7,438
Snake River drainage					
Lakes					
Shoshone Lake	2.185	7,975	20,655	14,872	2,479
Lewis Lake	1.813	6,617	17,138	12,168	4,970
Heart Lake	0.418	1,526	3,952	3,952	2,292
2 other lakes	0.093	339	878	502	137
Drainage subtotal-lakes	4.509	16,457	42,623	31,494	9,878
Streams					
Lewis River	1.673	6,106	15,815	16,606	2,847
Lewis-Shoshone Channel	0.325	1,186	3,072	1,628	430
Snake River	0.139	507	1,313	473	79
Delacy Creek	0.093	339	878	2,985	1,054
Crawfish Creek	0.093	339	878	4,021	509
Moose Creek	0.046	168	435	609	174
15 other streams	0.697	2,544	6,589	37,689	1,028
Drainage subtotal-streams	3.066	11,189	28,980	64,011	6,121
Drainage total-all waters	7.575	27,646	71,603	95,505	15,999
Falls River drainage					
Lakes					
3 lakes	0.139	507	1,313	751	205
Drainage subtotal-lakes	0.139	507	1,313	751	205
Streams					
Bechler River	1.859	6,785	17,573	5,448	1,054
Falls River	0.093	339	878	439	290
Boundary Creek	0.046	168	435	744	0
3 other streams	0.139	507	1,313	751	205
Drainage subtotal-streams	2.137	7,799	20,199	7,382	1,549
Drainage total-all waters	2.276	8,306	21,512	8,133	1,754
Shoshone River drainage					
Lakes-none					
Streams					
Middle Creek	0.093	339	878	220	114
Drainage total-all waters	0.093	339	878	220	114
Subtotal parkwide-lakes	54.124	197,545	511,642	279,733	105,636
Subtotal parkwide-streams	45.873	167,455	433,628	561,615	49,857
Parkwide total-all waters	100.000	365,000	945,270	841,348	155,493

Table 4.—Estimates of total fish landed and creeled in Yellowstone Park, 1973

	Number landed	Number creeled	%
Cutthroat trout	688,223	127,193	81.8
Rainbow trout	41,226	7,619	4.9
Brown trout	37,019	6,842	4.4
Brook trout	36,178	6,686	4.3
Lake trout	17,668	3,265	2.1
Mt. Whitefish	10,096	1,866	1.2
Grayling	3,365	622	0.4
Hybrids & others	7,573	1,400	0.9
Park-wide total	841,348	155,493	100.0

Table 5.—Pertinent fishery statistics on Yellowstone Park waters sustaining over one percent of the 1973 park-wide angler use

Rank	Water	% of total use	Angler day	Angler days/mile or acre	Landing rate fish/hr.	Creel rate fish/hr.	% anglers satisfied	% fish landed >12"
1	Yellowstone Lake	46.32	169,057	1.9	0.52	0.21	67	98
2	Yellowstone River	15.36	56,068	904	2.04	0.07	72	79
3	Madison River	5.21	19,002	1188	0.44	0.01	31	55
4	Firehole River	3.56	13,063	467	0.32	0.009	20	14
5	Gibbon River	2.95	10,771	449	1.09	0.03	41	9
6	Shoshone Lake	2.19	7,975	0.9	0.72	0.12	54	94
7	Soda Butte Creek	1.98	7,209	555	0.65	0.25	73	9
8	Bechler River	1.86	6,785	377	0.31	0.06	75	59
9	Lewis Lake	1.81	6,617	2.3	0.71	0.29	54	73
10	Lewis River	1.67	6,106	555	1.05	0.18	40	12
11	Gardner River	1.44	5,260	405	0.97	0.27	50	13
12	Slough Creek	1.23	4,497	281	2.61	0.05	80	49
Total or mean		85.58	312,410	1.7/ac. 576 /mi.	0.95	0.13	54.8	47.0

Table 6 .—Pertinent fishery statistics on Yellowstone Park waters each sustaining less than one percent of the 1973 parkwide angler use (arranged alphabetically)

Water	Est. angler days	Angler days/mile or acre	Landing rate fish/hr.	Creel rate fish/hr.	% satisfied anglers	% fish landed >12"
Streams						
Arnica Creek	507	101	0.93	0.07	100	7
Bacon Rind Creek	168	56	7.50	0.50	100	0
Beaverdam Creek	507	85	3.67	2.50	100	100
Boundary Creek	168	12	1.71	0.0	100	21
Cache Creek	1274	91	1.13	0.35	100	16
Cascade Creek	1102	110	0.36	0.01	20	11
Chipmunk Creek	168	21	0.67	0.67	100	100
Clear Creek	3395	340	0.86	0.18	100	57
Crawfish Creek	339	34	4.58	0.58	0	0
Delacy Creek	339	57	3.40	1.20	0	4
Falls River	339	23	0.50	0.33	50	0
Gallatin River	847	42	0.65	0.23	80	35
Glen Creek	256	18	0	0	0	0
Grayling Creek	847	47	1.33	1.17	50	0
Hellroaring Creek	2544	363	0.97	0.03	75	17
Indian Creek	1102	61	0.55	0.31	33	0
Iron Creek	84	14	0	0	0	0
Lamar River	2289	55	1.52	0.25	90	43
Lava Creek	1274	80	0.40	0.33	33	0
Lewis-Shoshone Ch.	1186	395	0.53	0.14	33	5
Little Firehole Riv.	847	47	1.88	0.06	0	0
Middle Creek	339	136	0.25	0.13	0	0
Moose Creek	186	17	1.40	0.40	0	0
Nez Perce Creek	1697	212	0.27	0.02	37	32
Obsidian Creek	934	156	0.68	0.14	33	0
Otter Creek	168	56	0	0	0	0
Pelican Creek	2716	136	1.19	0.25	86	71
Raven Creek	763	95	1.19	0.06	100	73
Snake River	507	14	0.36	0.06	50	33
Straight Creek	339	113	1.88	1.19	100	0
Tower Creek	595	50	1.30	0.10	50	0
Lakes						
Cascade Lake	1186	69.0	0.46	0.0	0	0
Feather Lake	84	5.3	0	0	0	0
Fern Lake	84	0.8	0	0	0	0
Goose Lake	256	8.0	0.17	0.17	0	0
Grebe Lake	2628	29.2	0.57	0.06	63	40
Grizzly Lake	168	1.2	0.50	0.0	0	0
Heart Lake	1526	0.6	1.00	0.58	75	87
Ice Lake	256	2.9	0	0	0	0
Ribbon Lake	339	31.0	1.13	0.38	100	0
Riddle Lake	507	1.9	1.20	0.25	75	100
Squaw Lake	1274	53.0	0	0	0	0
Sylvan Lake	423	19.0	0.50	0	100	0
Trail Lake	507	9.0	4.60	0.80	100	45
Trout Lake	339	19.0	0	0	0	0

Table 7.—Comparison of the 1973 "Volunteer Fisherman Report" use estimates with independent 1973 (or recent) estimates.

Location	Angler-day use		% difference
	1973 Vol. Fish. Report	Independent estimate ⁵⁾	
Yellowstone Lake	169,057	114,187 ¹⁾	+ 32.5
Madison River	19,002	13,079 ²⁾	+ 31.2
Firehole River	13,063	10,572 ²⁾	+ 19.1
Lewis Lake	6,617	7,742 ³⁾	- 14.5
Grebe Lake	2,628	2,355 ⁴⁾	+ 10.4
Heart Lake	1,526	1,184 ⁴⁾	+ 22.4
Riddle Lake	507	576 ⁴⁾	+ 12.0
Ribbon Lake	339	317 ⁴⁾	+ 6.5
Grizzly Lake	168	197 ⁴⁾	- 14.7
Ice Lake	256	263 ⁴⁾	- 3.0
Simple mean:			+ 16.6

1) This report.

2) 1972 figures, Dean and Varley 1973.

3) Average use estimate for 1971 through 1973, this report.

4) Estimates made in 1973 based on registrations at the trailheads.

5) Most estimates are ± 16 to 23% accuracy.

YELLOWSTONE LAKE

Procedures

A creel survey was carried out on the five major segments of the lake fishery. These are the shoreline, private boats, rental boats, guide boats, and private cruisers. Fishing Bridge was not censused in 1973 because it was closed to fishing.

The shoreline angler count and census program has modified in 1973 to further reduce variability. The 72-day period from opening day (June 15) to August 25 was divided into six-12 day periods. In 1972, we used six-14 day periods. Since few anglers are present during the last week of August and the first week of September, we elected to forego censusing these two weeks and to concentrate our efforts during the period of greatest use. Except for the shortened periods, the same methods were used and same man-days of effort were expended as in 1972.

Five biological programs were conducted in 1973 in an effort to further our knowledge of selected aspects of the lake's biology. These included the operation of the Cub and Clear Creek fish traps to enumerate the cutthroat spawning runs. A sampling effort was carried out on upper Cub Creek to measure the sizes of cutthroats ascending the headwaters to spawn. A small mesh gill netting study was conducted to measure the abundance of yearling cutthroat, yearling suckers, and adult shiners. Four "special projects" were carried out on Yellowstone Lake by our seasonal employees. These are reported in the Appendices.

Catch - Effort

Expansion of the creel data from the five major segments of the Yellowstone Lake fishery show that 114,187 anglers fished 268,321 hours and landed 243,000 cutthroat trout. These were decreases of 22% in number of anglers, 20% in angler effort, and 19% in trout landed compared to the previous year (Table 8). Anglers harvested 87,813 cutthroats, a decrease of 12% from 1972. The overall landing rate of 0.91 cutthroats per hour of effort was the highest on record since intensive harvest surveys were initiated in 1950. The fishing was not as good, however, in 1973 as compared to 1972. The closure of Fishing Bridge, which historically has been the least successful segment, helped raise the overall landing rate to a new high.

A portion of the decrease in angler use could be attributed to the closing of Fishing Bridge which in 1972 accounted for 16% of the anglers, 11% of the hours, and 4% of the cutthroats landed. Another factor which would have influenced angling pressure was the 8.6% decline in park visitation in 1973. A third and also important factor is the decline in angler use which usually occurs after fishing regulation changes. Since the daily and possession limit on Yellowstone Lake was reduced from three fish to two fish over 14 inches, a decrease could have been expected on this basis alone.

A more detailed listing by segments of the results of the 1973 creel census on Yellowstone Lake are shown in Table 9. The shoreline fishery is the most popular followed by private boat anglers and those renting boats. The most successful fisheries in terms of landing and creel rates are the guide boats and the private cruisers.

Table 10 shows pertinent catch-effort results by areas for the lake (Figure 2). The poorest fishing (0.65 trout per hour) occurred in West Thumb (Area 4) (Figure 2). In recent years Area 2 has repeatedly held this dubious honor. Without the depressing effect of Fishing Bridge, Area 2 now provides the second poorest fishing. Area 2 (Lake - Bridge Bay) is also the most heavily fished area of the lake because of easy access and the presence of two major campgrounds and Bridge Bay Marina. The remote portions of the lake (Areas 5, 6 and 7) provide excellent fishing by national standards.

The average cutthroat trout removed from Yellowstone Lake in 1973 was 14.8 inches in total length (Table 11). Only 10.4% of the trout creel were smaller (illegal) than the 14 inch size limit. This is the lowest percentage of size limit violations in recent years. Comparable figures were 18.6% in 1970, 19.3% in 1971 and 13.2% in 1972.

Table 8.—Catch-effort data, Yellowstone Lake, 1968-1973

	Number of anglers					
	1968	1969	1970	1971	1972	1973
Shoreline	80,027	104,590	99,977	85,783	77,011	70,805
Private boats	39,164	30,564	26,413	16,844	25,611	17,900
Rental boats	16,466	18,659	18,322	14,978	15,272	17,207
Guide boats	8,736	6,944	3,442	4,387	3,667	4,856
Private cruisers	5,043	4,652	3,481	2,364	2,797	3,419
Fishing Bridge	40,153	40,153	25,699	25,699	22,824	0
Totals	198,589	205,562	177,334	150,055	147,182	114,187

	Total hours of fishing					
	1968	1969	1970	1971	1972	1973
Shoreline	194,054	160,693	169,044	143,198	151,910	137,785
Private boats	133,248	115,981	107,488	73,561	88,359	67,953
Rental boats	46,293	47,229	53,296	41,125	42,076	41,744
Guide boats	16,151	12,205	7,327	5,270	7,000	10,583
Private cruisers	10,582	9,577	10,319	8,069	8,324	10,256
Fishing Bridge	40,262	40,262	31,664	31,664	38,079	0
Totals	440,590	385,947	379,138	302,887	335,748	268,321

	Trout landed					
	1968	1969	1970	1971	1972	1973
Shoreline	83,250	42,908	68,154	100,705	109,009	84,549
Private boats	86,785	65,740	86,129	60,379	88,249	57,110
Rental boats	36,466	30,162	57,610	49,180	49,703	46,873
Guide boats	27,846	15,532	12,055	11,976	17,990	30,907
Private cruisers	13,502	16,348	20,176	18,116	21,700	23,651
Fishing Bridge	4,234	4,234	7,316	7,316	12,651	0
Totals	252,083	174,924	251,440	247,672	299,302	243,090

	Trout landed per hour					
	1968	1969	1970	1971	1972	1973
Shoreline	0.43	0.27	0.40	0.70	0.72	0.61
Private boats	0.65	0.57	0.80	0.82	1.00	0.84
Rental boats	0.79	0.64	1.08	1.20	1.18	1.12
Guide boats	1.72	1.27	1.65	2.27	2.57	2.92
Private cruisers	1.28	1.71	1.96	2.25	2.61	2.31
Fishing Bridge	0.13	0.13	0.23	0.23	0.33	0
Averages	0.57	0.45	0.66	0.82	0.89	0.91

Table 9.—Catch-effort summary by fishing method, Yellowstone Lake, 1973

Fishing method	Angler days	Hours fished	Trout landed	Trout creeled	Landing rate (trout per hour)	Creeld rate (trout per hour)	Length of trip (hours)
Shoreline	70,805	137,785	84,549	39,274	0.61	0.29	1.95
Private boats	17,900	67,953	57,110	20,068	0.84	0.30	3.80
Rental boats	17,207	41,744	46,873	16,580	1.12	0.40	2.43
Guide boats	4,856	10,583	30,907	5,839	2.92	0.55	2.18
Private cruisers	3,419	10,256	23,651	6,052	2.31	0.59	3.00
Totals and averages	114,187	268,321	243,090	87,813	0.91	0.33	2.35

Table 10.—Catch-effort summary by areas, Yellowstone Lake, 1973

Areas	Angler days	Hours fished	Trout landed	Trout creeled	Landing rate (trout per hour)	Creeld rate (trout per hour)	Length of trip (hours)
1	12,535	27,037	22,689	9,308	0.84	0.34	2.16
2	40,623	90,651	63,980	23,184	0.71	0.26	2.23
3	17,121	48,185	42,220	15,773	0.88	0.33	2.81
4	27,169	54,392	35,384	19,025	0.65	0.35	2.00
5	11,695	32,506	49,931	12,964	1.54	0.40	2.78
6	2,180	6,891	13,545	3,640	1.97	0.53	3.16
7	2,864	8,659	15,341	3,919	1.77	0.45	3.02
Totals and averages	114,187	268,321	243,090	87,813	0.91	0.33	2.35

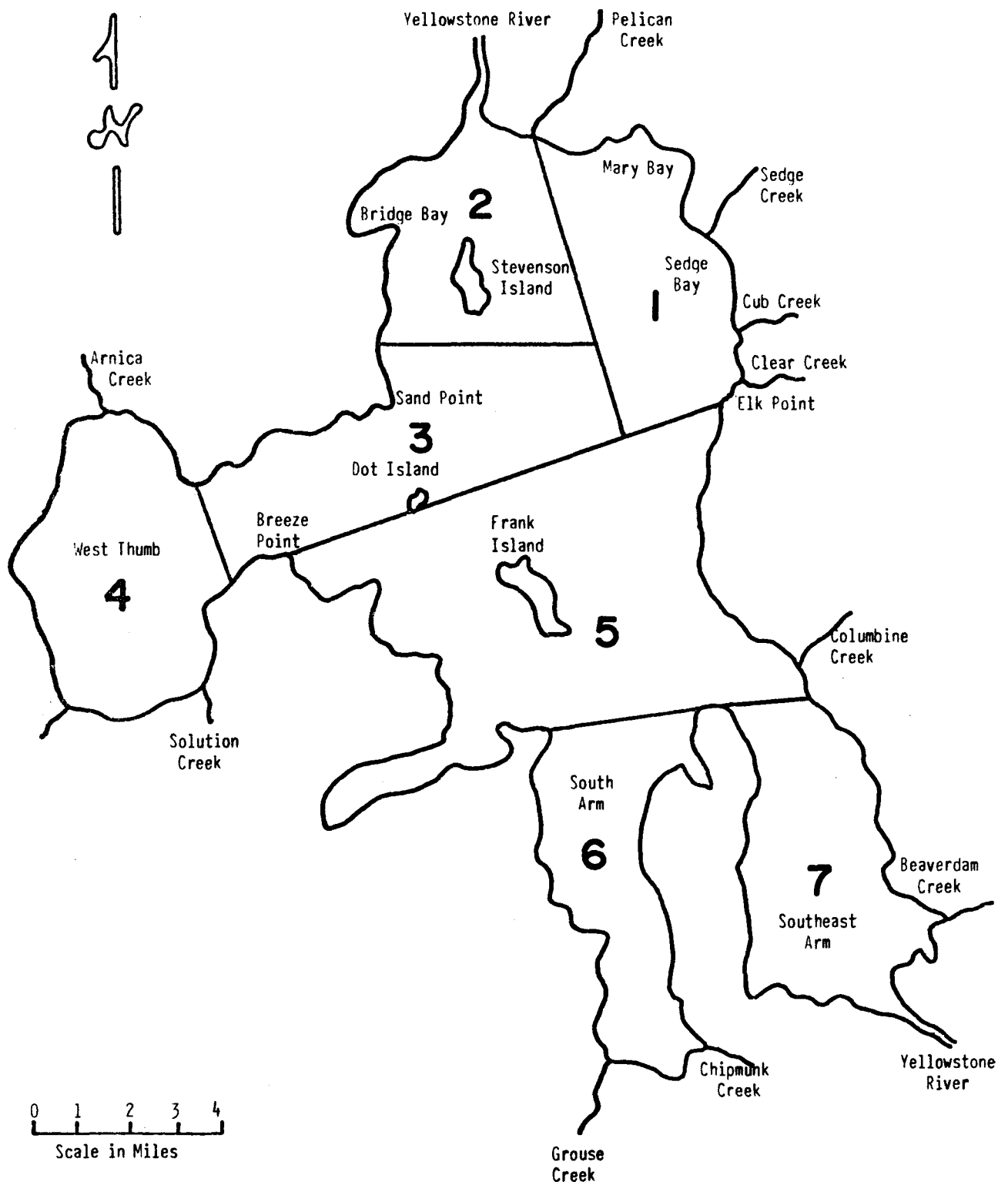


Figure 2. Yellowstone Lake Showing Gill Netting and Creel Census Areas.

Table 11.—Projected numbers and sizes of trout removed by anglers from Yellowstone Lake in 1973

Size class (inches)	Number measured		Total	Percentage	Number creel
	Shoreline	Boat docks			
9	1	...	1	0.1	88
10	...	...	...	...	...
11	...	1	1	0.1	88
12	9	10	19	1.4	1,229
13	41	80	121	8.9	7,815
14	256	391	647	47.5	41,712
15	159	334	493	36.2	31,788
16	25	45	70	5.1	4,478
17	3	6	9	0.6	527
18	1	...	1	0.1	88
Totals	495	867	1,362	100.0	87,813
Average total length in inches	14.7"	14.8"	14.8"		
Percentage smaller than the 14-inch size limit	10.3%	10.5%	10.4%		

The closure of Fishing Bridge went much smoother than anyone associated with the fishery program predicted. Few complaints were heard and the general public responded favorably. The success of this change was due primarily to the efforts of the Rangers and Naturalists. The Naturalists deserve special praise for their untiring efforts (50 hours a week) to contact visitors on the Bridge, answer questions, and explain the reasons for the new program. The resident river cutthroat trout also helped by putting on impressive surface feeding flurries and spawning shows and by attracting ospreys and pelicans to a popular area they formally avoided.

Small-Mesh Gill Netting Studies

Small-mesh gillnets are effective in capturing immature cutthroat trout, adult redbside shiners, and immature longnose suckers. They have been used annually since 1969 (except 1972) to obtain measures of relative abundance and depth distributions of the three major species found in Yellowstone Lake. Each small-mesh sinking gillnet is 100 feet long, 6 feet deep, and consists of four 25-foot panels of 3/8, 1/2, 5/8 and 3/4 inch bar-mesh monofilament webbing.

Results of the late August-early September small-mesh gill netting study are shown in Table 12. Each overnight set was made in water 15 feet or less in depth.

The nets captured 272 cutthroats, 213 shiners, 58 suckers, and 1 lake chub (Couesius plumbeus). There were 1.28 cutthroats per shiner and 4.69 cutthroats per sucker. In each net there were an average of 18 cutthroats, 14 shiners, and 4 suckers. On the basis of the number of fish taken per unit of effort, there appeared to be a reduction in the numbers of young trout, young suckers, and adult shiners.

Table 12.—Small-mesh gill netting results, August-September, 1973

Date	Location	Fish caught			
		Cutthroat	Shiner	Sucker	Chub
9/9	Off West Thumb	11	8	...	...
9/7	Near Alder Lake	12	1	...	...
9/9	Off Solution Creek	5	...	...	...
9/6	Off Beaverdam Creek	18	3	1	...
9/9	Off Arnica Creek	18	2	6	...
9/6	Off Columbine Creek	17	3	...	...
9/7	Eagle Bay	7	...	...	...
9/6	Off Clear Creek	21	4	1	...
9/7	Flat Mountain Arm	19	47	1	...
8/31	North of Sand Point	37	...	2	...
8/31	Bridge Bay	28	...	...	...
8/29	Mary Bay	15	58	31	...
8/29	Sedge Bay	18	16	3	...
8/30	Off Hatchery Creek	30	59	9	...
8/30	Yellowstone River Outlet	16	12	4	1
Totals	15 net sets	272	213	58	1

Clear and Cub Creek Fish Traps

Following the massive spawn-taking and hatchery operations on Yellowstone Lake that were concluded in the early 1950's, all tributary traps were removed except those located on Clear, Cub and Pelican Creeks. The original intent for leaving these traps in an operational condition was to monitor the spawning runs over time giving an additional indice of the impact of sport-fishing on the Yellowstone Lake cutthroat population, and to measure the status of the exotic non-game fishes. The Clear and Cub Creek traps were operated in 1973 for the first time since 1966.

Lake ice conditions prevented the installation of the Clear and Cub Creek traps until the 28th and 29th of May. The spawning runs were already in progress at this time and had probably been so for approximately several weeks. Grates had to be removed after one week due to high water. The traps were reinstalled by the third week in June and were worked daily until the 13th of July. After this date the traps were operated 24 hours each week until the spawning runs were completely finished.

The duration of the Clear Creek run was estimated to be approximately 70 days long and the trap was fully operational for 27 days. During the 27 trap-days approximately 89% of the estimated total run was enumerated.

The Cub Creek trap was installed on the 29th of May. The trap was fully operational for 34 out of an estimated 67 possible trap days. As with the Clear Creek trap, the Cub Creek installation was removed for 12 days during spring flood waters and was operated for 24 hours a week subsequent to the peak spawning period. Approximately 88% of the estimated total run was enumerated.

Data were collected weekly from 1.5% (841 spawners) of the counted run from Clear Creek and 5.9% (835) trout from Cub Creek. Upstream migrants were randomly selected from the trap, anesthetized and released upstream apparently unharmed following pertinent measurements.

During the operation of the two traps some fish loss was sustained that would otherwise not have occurred without the traps. In 1973, approximately 357 spawners (0.004%) were killed as a result of trapping.

In addition to the operation of the Clear and Cub Creek traps, a temporary weir was built on Cub Creek about 7.4 miles upstream from the stream mouth.

Clear Creek Trap

During the first week in June the number running averaged about 119 per day. This number increased to a single day maximum of 9,813 spawners on the 27th of June and then decreased to about 5 spawners per day during the last week in July (Figure 3). Eighty-two percent of the total escapement occurred between the 15th of June and the 5th of July.

Numbers of fish ascending during high water periods and other non-trap days were estimated from the weekly average escapement curve (Figure 3). The actual number of spawners counted through the trap was 55,818 which, extrapolated for non-trap days, gives an estimate for the total run at 71,902. Subtracting the immature runners and postspawners that passed through the trap more than one time yields an effective total estimated run of 65,215. This escapement was nearly twice the maximum number in any trap-year counted since 1945 (Table 13).

The overall male to female relationship was 1:1.68 although the weekly average varied from 1:1 to 1:2.55. No consistent pattern in this ratio was observed over time. With 40,889 females ascending and assuming an average fecundity of 900 eggs/female it is probable that over 42 million cutthroat eggs were deposited in Clear Creek and its tributaries.

The overall average length and weight of Clear Creek spawners was 14.8 inches (375 mm) and 0.97 pounds (442 g.), respectively. Males were slightly longer and heavier than females: 15.0 inches (381 mm) and 0.98 pounds (446 g.) vs 14.6 inches (372 mm) and 0.97 pounds (440 g.).

Larger spawners entered the stream earlier and subsequent fish were progressively shorter in length and lighter in weight (Figure 4). Combined sexes averaged 15.0 inches (380 mm) and 1.04 pounds (473 g.) the first week of trapping and declined to 14.6 inches (370 mm) and 0.8 pounds (361 g.) by the end of the migration. Computed condition factors showed a similar negative trend with time (Figure 5).

Females entering the stream at the beginning of the spawning run were typically "green." The percentage of "ripe" females in the population increased very quickly during the peak of the run and peaked to near 100% by the second week of July (Figure 6).

Weekly visual surveys of the left fork of Clear Creek north of Sylvan Lake implied that this fork did not receive any spawners. The lack of any fry in the stream later in the summer substantiated this observation.

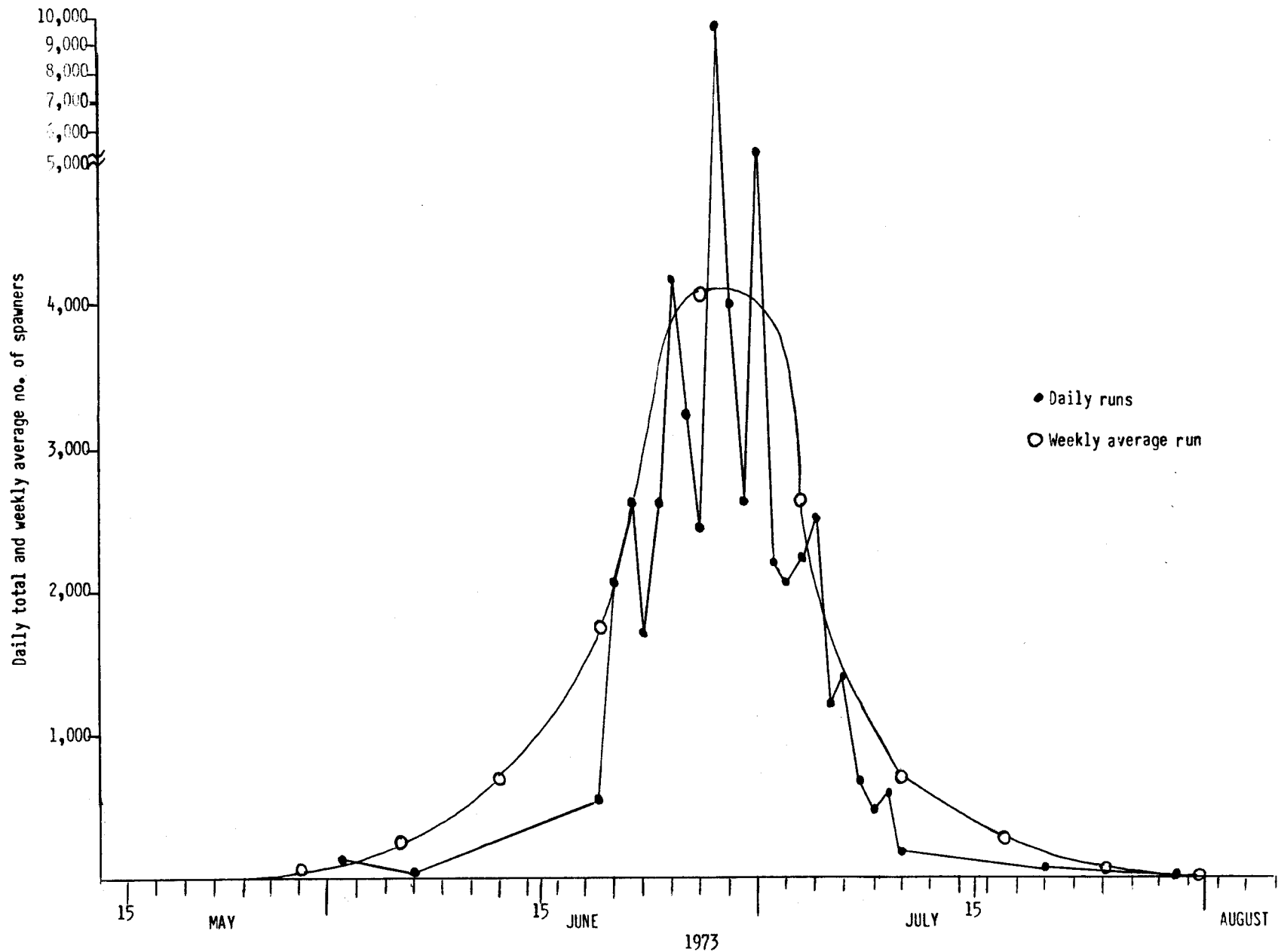


Fig. 3 . Daily total and weekly average escapement of cutthroat spawners, Clear Creek spawning trap, May through August, 1973.

Table 13—Chronology of cutthroat spawner escapement in Clear and Cub Creeks, Yellowstone Lake, 1945-1973

	Clear Creek	Cub Creek
1945	13,123	6,864
1946	16,429	11,027
1947	23,211	11,344
1948	12,389	975
1949	7,274	.....
1950	10,459	2,179
1951	16,879	2,676
1952	10,269	2,056
1953	10,323	3,848
1954	3,161	3,446
1955	7,929	2,558
1956	.....	.....
1957	8,398	2,976
1958	9,355	1,747
1959	3,353	7,257
1960	.....	.....
1961	8,119	5,087
1962-64	.....	.....
1965	34,948	9,286
1966	36,078	15,162
1967-72	.....	.....
1973	65,215	15,164

..... Escapement not measured

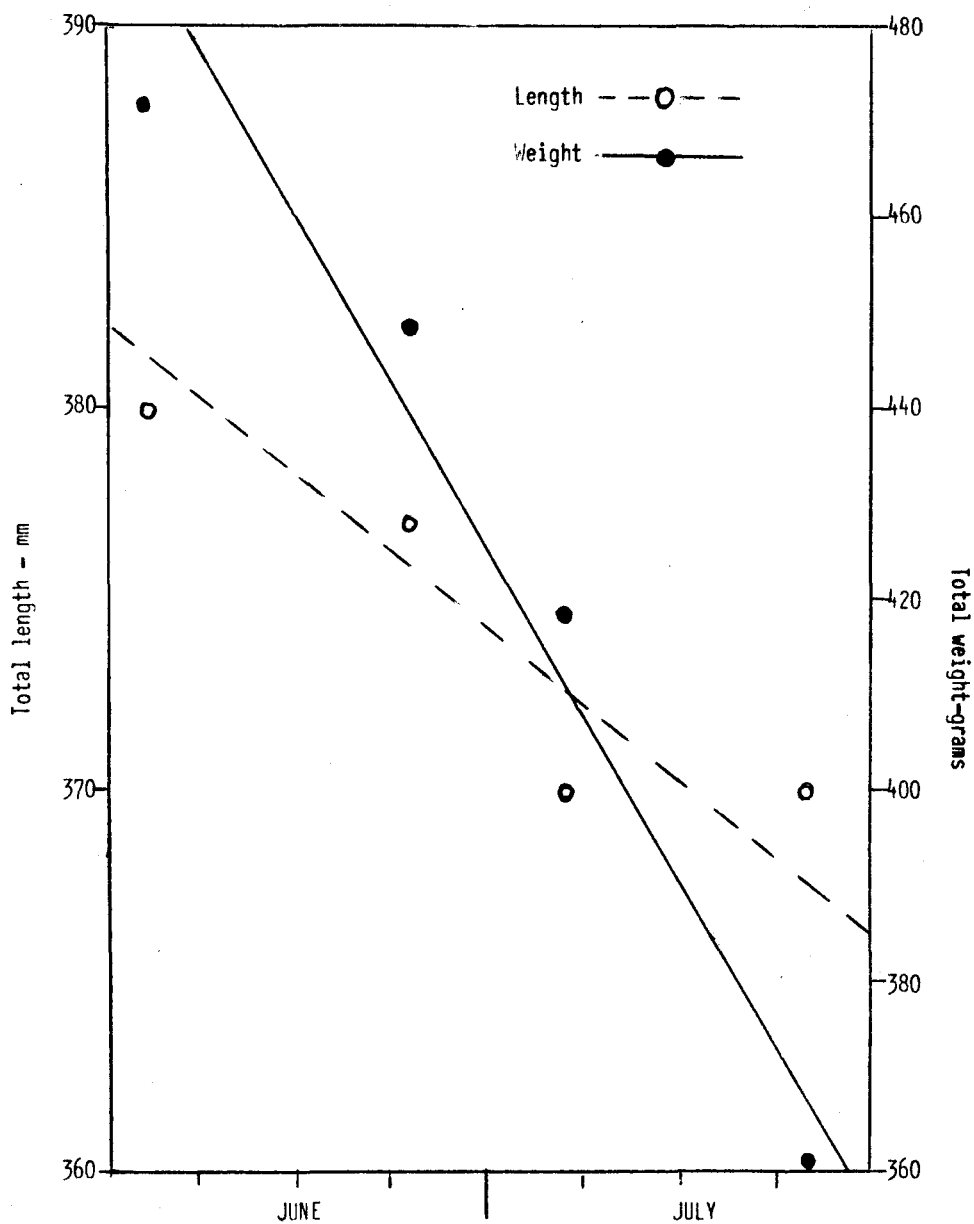


Fig. 4. Average lengths and weights of Clear Creek prespawners throughout the duration of the run, 1973.

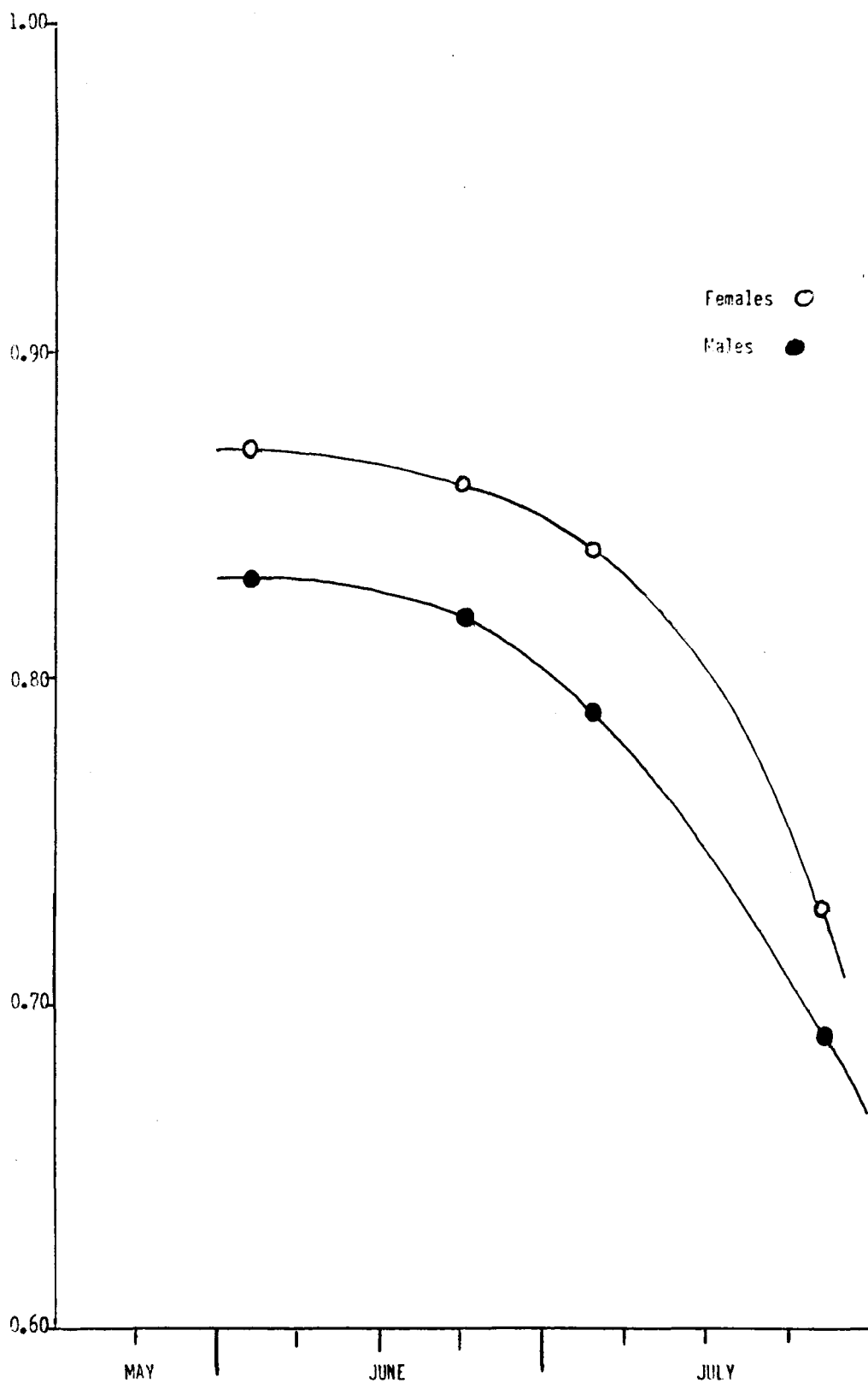


Fig. 5 . Average condition factors (metric-K) of Clear Creek male and female spawners throughout the duration of the spawning run, 1973.

The weekly observations of the right fork of Clear Creek southeast of Sylvan Lake indicated that few spawners ascended to this prime spawning habitat. Fry were present in this section by the third week of August but were very sparse.

Cutthroat fry were first observed near the trap site in the third week of July and by the second week in August were very numerous.

A group of spawning longnose suckers was observed spawning in the mouth of Clear Creek though none passed through the trap.

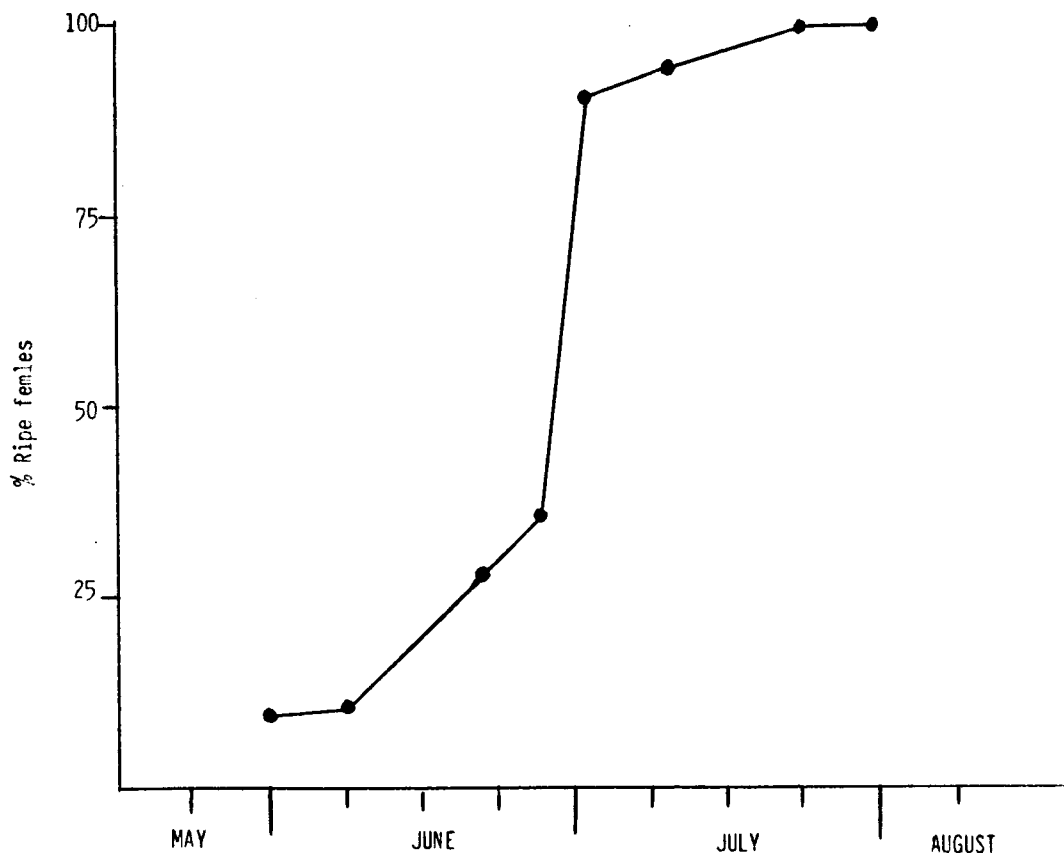


Fig. 6. The percentage of ripe females entering the Clear Creek trap through the spawning season, 1973.

Daily total and weekly average no. of spawners

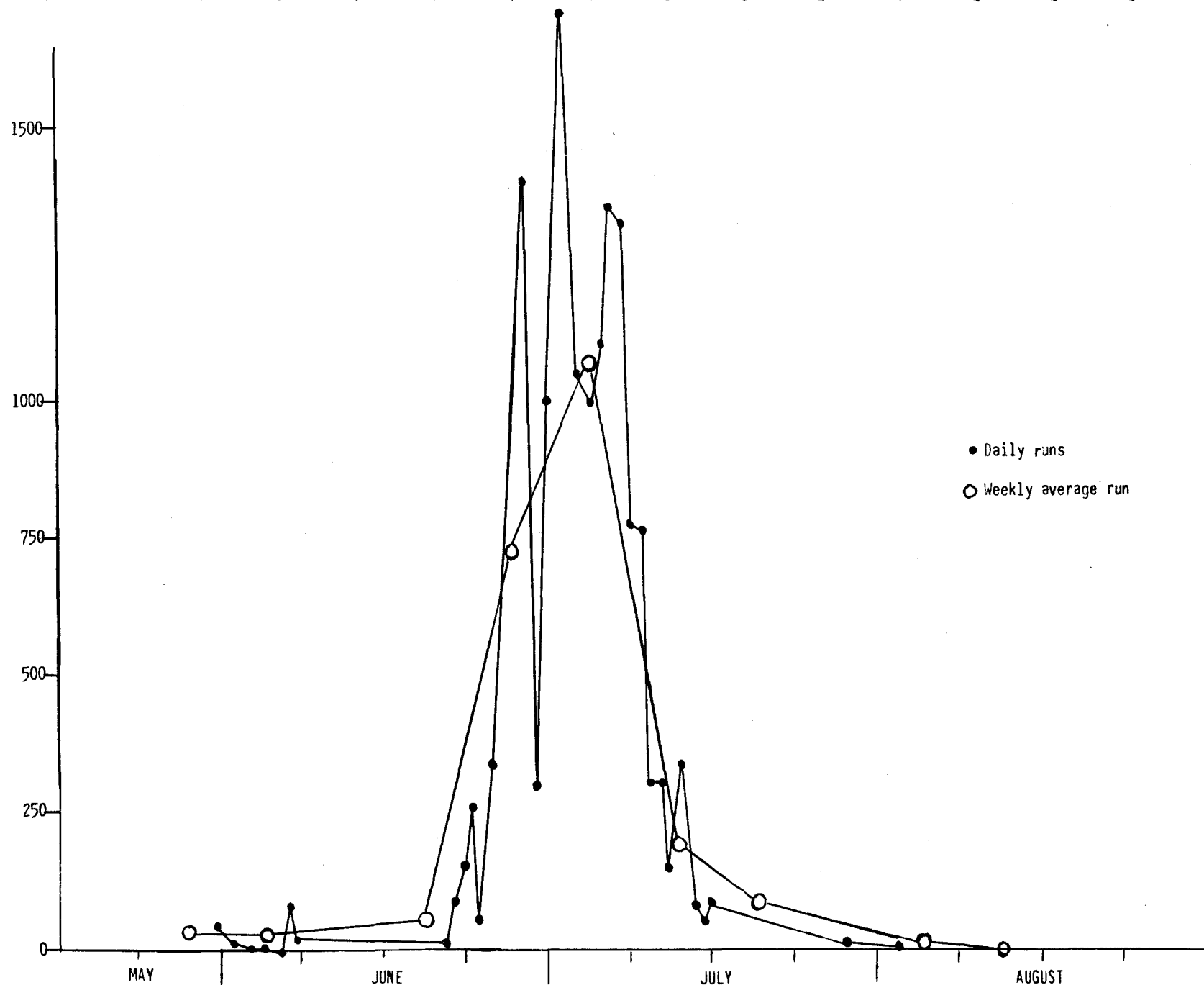


Fig. 7 . Daily total and weekly average escapement of cutthroat spawners, Cub Creek spawning trap, May through August, 1973.

Cub Creek Trap

From the date of trap installation through the 21st of June the average daily run was estimated at 45 spawners. The number in the run then increased to a peak on June 28th of 1,763 and remained high through the first week of July tapering off gradually until completion in the first week of August (Figure 7). Approximately 86% of the total escapement ascended between the 22nd of June and the 12th of July.

As with the Clear Creek run, numbers of fish running during high water periods and other non-trap days were estimated from the weekly average escapement curve (Figure 7). The actual number of spawners counted through the trap was 14,092 or 88% of the total estimated run of 16,017. Removal of immatures and rerunning postspawners (469 and 384, respectively) yields a net total effective run of 15,164.

Similarly to Clear Creek, the total escapement at Cub Creek was the highest recorded since 1945 although it is probably the same number as ran in 1966 (Table 13).

Data showed an overall male to female ratio of 1:1.37 which varied weekly from 0.81:1 to 1:3.06. No consistent pattern was observed although at the peak of the run (June 28) the ratio was 1:1. The total potential egg deposition in Cub Creek (assuming 8,765 females and 900 eggs per female) would be approximately 7.9 million.

The overall average length and weight of Cub Creek spawners was 14.7 inches (373 mm) and 1.0 pounds (456 g.), respectively. Males were significantly (99% probability level: length, $t=5.084$, $df\ 121$; weight $t=2.544$, $df\ 121$) longer and heavier than females: 14.9 inches (379 mm) 1.03 pounds (467 g.) vs 14.5 inches (369 mm) and 0.99 pounds (449 g.).

Combined data on sexes showed that longer and heavier spawners entered the stream earlier in the run and measurements progressively decreased with time. The average length and weight of ascending prespawners was 15.6 inches (395 mm) and 1.16 pounds (527 g.) at the beginning of the season and was 14.3 inches (364 mm) and 0.88 pounds (400 g.) in the last two weeks of the run. Computed condition factors showed a similar negative trend with time.

Data on the percentage of ripe females entering the stream is not shown but represented a trend very similar to Clear Creek (Figure 6).

One longnose sucker was observed in Cub Creek below the trap but neither suckers nor reidside shiners passed through the trap.

Cutthroat fry first appeared in Cub Creek near the mouth the first week in August. Fry were never as numerous in Cub as in Clear Creek. Fry were visible in the headwaters section by the third week of August. Weekly observations in the headwater reach indicated a sparse population.

Cub Creek Weir

The operation of a weir on Cub Creek at the East Entrance Highway bridge was attempted during the spawning season. The purpose was to measure the numbers of fish and to obtain population and life history data on those spawners reaching "headwater" areas to spawn. In this report, waters above the highway bridge (4.4 miles or 37% of the total available) were considered "headwaters" and the Creek and its tributaries below the bridge (7.4 miles or 63% of the total) were considered middle and lower sections for spawning purposes. Cope (1957) also surveyed Cub Creek and reported it to be 10 miles in length (vs. our surveyed potential spawning length of 11.9 miles) and that all spawning above the fifth mile was prevented by a log-jam barrier (this barrier no longer exists).

For spawners to reach the weir at the highway bridge, they would have to travel 7.4 stream miles, ascend 737 vertical feet (99.1 feet per mile) and surmount 38 obstacles: 34 log jams each up to 3 vertical feet, 2 areas of thermal influence and 2 rock falls each with a vertical drop of approximately 3 to 5 feet.

The Upper Cub Creek weir was installed on June 1 and was temporarily removed due to high water on June 7. No trout were observed during this 7-day period. Visual surveys of this section on June 12, 20 and 26 did not reveal the presence of spawners. The weir was reinstalled on July 6 and operated 10 days during which time 62 downstream post-spawners and 27 upstream prespawners were enumerated. By July 26 no spawning activity was evident in the headwater section.

A total of 89 pre and postspawning cutthroats were caught, measured and marked at the Cub Creek weir. Based upon our trapping data and visual surveys, it is estimated that fewer than 200 spawners reached the headwaters spawning area during the summer. It should be pointed out, however, that high water conditions during mid-June prevented optimum visual observation of the stream.

If the assumption were made that our estimate of fish passing the bridge were reasonably correct it would indicate that only 1.3% of those fish entering Cub Creek were spawning in 37% of the potentially available spawning area (headwater section).

The spawning population reaching the headwater area had some characteristics distinctively different from the population trapped at the mouth of the stream. It has previously been shown that the male to female ratio entering Cub Creek was 1:1.37. At the weir the reverse situation occurred and males outnumbered females 1:0.85. In addition

to more males than females reaching the headwater area the males were significantly larger than the females (99.9% probability level: $t=4.65$, $df=39$). Males reaching the weir were also significantly larger than the population of males measured at the trap (99.0% probability level: $t=2.67$, $df=39$). Males reaching the weir averaged 15.3 inches (388 mm) vs 14.9 inches (379 mm) at the trap. Large males (here defined as trout over 15.7 inches (400 mm) made up 21% of the males entering the trap and 28% of the males passing the weir. The length of females reaching the weir was not significantly different than those entering the stream, however large females over 15.7 inches (400 mm) entered the stream at a frequency of 3.3% as opposed to a frequency of 5.4% at the highway weir.

Spawning females that were potentially consecutive year spawners (females with two ripe egg rows plus two "new" and much smaller egg rows) entered the trap at a frequency of about 40% versus a 77% frequency at the weir. Consecutive year spawning females are a minority in the lake population. In the past there has been various speculations as to whether this phenomena has a physiological or a genetic basis.

Discussion

Perhaps the most difficult feature of the 1973 escapement in Clear and Cub Creeks was the large size of the runs as compared to escapement in the previous twenty-seven years. Comparisons of the 1973 escapement with past year's runs to determine "normal" or comparative "average" migrations is difficult: the stream's escapement for a number of decades prior to 1946 were either wholly or partially blocked by spawn-takers. From 1947 through 1951, some migrants were passed over the trap to naturally spawn but specific data on numbers are lacking. Since 1952, essentially all spawners were left to naturally spawn but after five decades of intensive spawn-taking and random mixture of racial groups the vitality of the cutthroat population (as measured by numerical escapement) did not readily respond. Following 13 to 20 years of natural reproduction the numerical escapement has vastly increased but there remains no way of knowing if it is "normal." During the period of readjustment to natural reproduction, management measures (maximum sustained yield, size limits, trophy fishing) were drastically altering the historical population structure.

The escapement in 1973 may have been too large, too small or close to the historical size. Despite the large numbers of fish, however, the evidence of a lack of adequate distribution of spawners throughout the length of the streams is significant.

The presence and competition of the majority of spawners for a lower elevation and limited spawning area has the definite potential for being counter-productive from a recruitment standpoint. There is an increasing amount of data that indicates that man-caused modifications in the historical age-size population structure may be the vehicle by which the spawners no longer distribute themselves throughout the length of the tributary streams.

Discussion (Yellowstone Lake)

Since the 14-inch size limit was enacted on Yellowstone Lake in 1970, the sport fishery has stabilized with a mean annual harvest of 95,876 cutthroat trout (range 87,813 - 106,570). The native fish population is in no danger of being overexploited at these harvest levels. There is, however, increasing evidence that numerous departures from the historic age, size, density structure exist and that these changes have been accentuated by the 14-inch size limit. If the National Park Service is serious about restoring the native cutthroat population to some approximation of its former abundance and diversity, then further changes in angling regulations will be required.

Hopefully a detailed report will be completed within the next year detailing the population changes that have occurred in the lake in the past 100 years. The report will also include a number of options for consideration and the anticipated results of each one.

YELLOWSTONE RIVER

The 9-mile stretch of the Yellowstone River, 0.7 miles downstream from Fishing Bridge to the Upper Falls (excluding a 6.4 mile closed section), is undoubtedly the most heavily fished cutthroat stream in North America. This fishery is maintained solely by wild, naturally-reared Yellowstone cutthroat trout. Because of the unique character and quality of this river section, it was selected by the National Park Service as one of four Yellowstone Park streams for "catch and release" fishing in 1973. A creel survey was conducted to measure the impact of these new angling regulations on the level of use, angler response, and quality of fishing.

Creel surveys have been conducted on the river in 5 of the past 7 years. The method used in 1973 was essentially the same as that described in our 1970 report. In order to reduce variability and concentrate more survey effort during the period of heaviest use, the procedure was modified slightly in 1973 by reducing the survey period from 7 to 6 weeks. The interval from opening day on July 15 to August 25 was divided into four sampling periods. The first 6 days, which receive the heaviest use, were selected as the first period. It was sampled 2 days. The remaining 36 days were divided into three-12 day periods. Three sampling days were selected at random during each of these periods. In all other respects, except for the shortened sampling intervals, the same methods were employed and the same days of census effort expended as in 1970 and 1972.

Another change which influenced the fishery and this survey was the closure of Fishing Bridge and the first mile of the Yellowstone River downstream from the outlet of Yellowstone Lake. This closure reduced the area open to fishing by 0.7 miles. As a result, we were able to concentrate all of our sampling efforts to the remaining 9 miles open to fishing.

Results

Expansion of the data indicated that 15,603 anglers fished 36,731 hours between July 15 and August 25, 1973. They landed and returned 63,916 Yellowstone cutthroat trout for a landing rate (catch rate) of 1.74 trout per hour which is considered excellent fishing (Table 14). The average angler fished 2.35 hours which is a longer average trip than in previous years. There were declines of 57% in angler days, 47% in angler effort, and an increase of 16% in the number of trout landed compared to the previous year when the 14-inch size limit was in effect. The landing rate increased 245% compared to 1972.

Table 14. —Creel census summary, Yellowstone River, 1967, 1968, 1970, 1972, and 1973

	Year				
	1967	1968	1970	1972	1973
Number of anglers	40,808	39,755	39,260	36,436	15,603
Hours fished	72,261	88,607	62,500	78,172	36,731
Trout landed	29,692	39,180	49,193	55,199	63,916
Trout creeled	.....	.....	9,864	15,195	0
Landing rate (trout/hour)	0.41	0.44	0.79	0.71	1.74
Creeled rate (trout/hour)	....	....	0.16	0.19	0.00
Average length of angler trip (hours)	1.77	2.23	1.59	2.15	2.35
Percentage of trout landed that were released	....	....	79.9	72.5	100.0
Average length of trout creeled (inches)	13.3"	13.7"	14.9"	14.5"	.....
Angling regulations:					
Season July 15–October 31					
3 fish—no size limit, bait fishing permitted	X	X			
3 fish—14 inch size limit, lures and flies			X	X	
"Catch and release" fishing only, lures and flies					X

Table 15—Creel census worksheet for the Yellowstone River, 1973

1	2	3	4	5	6	7	8	9	10	11	12
Period	Day length (hours)	(1)(2) Total daylight hours	Anglers counted in 12 passes	(4) 12 Average angler count	(3)(5) Total hours	Landing rate	(6)(7) Trout landed	Creel rate	(6)(9) Trout creeled	Length of trip (hours)	(6) (11) Total anglers
7/15-7/20	15	90	716*	89.5	8,055	2.42	19,493	0.00	0	2.72	2,961
7/21-8/1	15	180	822	68.5	12,330	1.42	17,509	0.00	0	2.08	5,928
8/2-8/13	14	168	759	63.3	10,634	2.30	24,458	0.00	0	2.35	4,525
8/14-8/25	14	168	408	34.0	5,712	0.43	2,456	0.00	0	2.61	2,189
Totals and averages		606	2,705	61.5	36,731**	1.74	63,916	0.00	0	2.35	15,603

* Anglers counted in 8 passes

** 95% confidence probability $\pm$ 7,502 hours

The first six days of the season produced the best fishing and highest angler density (Table 15). Fishing quality dipped during late July, improved substantially in early August, and then dropped off rapidly in late August.

In order to measure response to the new regulations, anglers were asked for their impression of their fishing experience on the river and also asked to describe a high quality angling trip. We had 292 usable responses to the first question and 182 to the second. We tried to group the diverse responses into 9-10 categories that essentially covered the range of opinions. The results are shown in Table 16. Nearly 70% of the anglers indicated a favorable response to the "catch and release" regulations on the Yellowstone River.

The residence of Yellowstone River anglers is shown in Table 17. California anglers ranked first each year. There was little change in the relative percentage of anglers from the various states the first year of "catch and release" fishing. In the past, whenever a more restrictive park fishing regulation became effective, there has been a noticeable decline in the percentage of local anglers (Idaho Montana, Utah and Wyoming) the first year or two and then a return towards previous levels. It appears that "local anglers" responded in this manner again in 1973 to these new fishing regulations.

Table 16.—Anglers responses on the Yellowstone River, 1973

Question: In a few words describe the anglers reaction to his overall fishing experience on this water today.

Question: In a few words, how does the angler describe a high quality angling experience.

Response	Percentage	Response	Percentage
1. Great, terrific, wonderful	28	1. Yellowstone River—this is it	27
2. Fine, good	28	2. Lots of fish	22
3. Okay, alright	11	3. Catch a few fish	11
4. Dumb, stupid, poor	18	4. Big fish	7
5. Used to be better	3	5. Where there is a challenge	4
6. Would like to keep a big trout	3	6. Other places, Canada, Salt Water, etc.	3
7. Good, but....	2	7. Lots of fish, few people, good scenery	4
8. Concerned about hooking mortality	1	8. Fly fishing	2
9. Other—miscellaneous	6	9. Keeping fish	2
Total	100	10. Miscellaneous and don't know	18
Favorable responses	69	Total	100
Unfavorable responses	25		
Other responses	6		
Total	100		

Table 17.—Residence of anglers on the Yellowstone River, 1967-1970-1972-1973

Year	Percentage by state						Other states and foreign countries
	Calif.	Idaho-Wyo. and Mont.	Pa.	Colo.	Ill.	Utah	
1967	16.5	14.4	1.0	4.2	9.0	11.3	43.6
1970	19.3	4.9	1.7	3.7	5.1	7.8	57.5
1972	14.7	8.5	4.2	5.9	4.8	7.1	54.8
1973	20.2	7.8	6.8	6.0	5.5	4.2	49.5

Discussion

Results indicate that the "catch and release" regulations did have a dramatic effect on fishing pressure and fishing success on the river. When the season opened we expected to encounter a considerable number of irate fishermen. Much to our surprise there were few stressful encounters. We surmised and our contacts with anglers on Yellowstone Lake led us to conclude that anglers unhappy with "catch and release" regulations were fishing elsewhere. We interviewed more anglers unhappy about the Yellowstone River situation on Yellowstone Lake than we did on the river.

Overall, we were highly pleased with the human response to "catch and release" fishing on the Yellowstone River in 1973. Over two-thirds of the anglers interviewed indicated support for the program and many of these were highly enthusiastic and wanted to know why this hadn't been done years ago. The anglers who were unfavorable were far less negative than expected. Most anglers had never experienced "catch and release" regulations before and apparently many hadn't given much thought to this method of trout management. Considering the newness of this approach in America and the lack of exposure anglers have had to it, acceptance was far better than expected. Probably a major factor in the first year success of this project was the cutthroat trout itself. This native fish is easily captured by anglers. We suspect that many individual fish were caught and released two or more times during the season. This was probably the case since the landing rate increased 220% over the previous record which was recorded in 1970.

This program should result in a shift of the trout population towards older and larger fish. Such a shift would be towards the historic age-size structure which now exists in the closed portions of the river in Hayden Valley. Fish population studies should be carried out periodically to determine if the "catch and release" regulations do result in a changed age-size class structure. Creel studies should also be continued to further measure public acceptance and response to this method of fishery management. This approach appears to be more in keeping in National Park Service management directives for natural areas than the present "catch and keep" regulations in effect on most native Park fish populations.

NATIVE SPECIES RESTORATION PROGRAM

The native fish fauna of Yellowstone Park consisted of eleven species. The native species of interest to anglers were the Arctic grayling, the mountain whitefish, and several varieties or subspecies of cut-throat trout. The remaining natives are three species of suckers, four species of minnows, and the mottled sculpin.

Man's activities during the past 100 years have had considerable influence on the native fishes. Sport species such as brown, brook, rainbow and lake trout have been stocked in many park watersheds. In many cases these exotics have essentially replaced the natives. During the period when exotic sport fishes were being introduced, there was also an ever increasing amount of fishing. In most waters the native species were easily taken by anglers while the warier and more sophisticated exotics remained and became dominant.

Among the native species, the Arctic grayling has suffered most from man's activities. In the park it was originally found in the Gallatin River, Grayling Creek, and the Madison River system below the lower falls on the Gibbon and Firehole Rivers. It is no longer present in the Gallatin River or in Grayling Creek and is rare in the Madison River system. The original grayling could all be described as stream-dwelling, stream-spawning populations rather than a lacustrine form. Concern for the parks dwindling grayling populations led to the introduction of stock originating from Red Rock Lakes, Montana in 1921. These lake-dwelling, stream-spawning grayling were stocked in Grebe Lake and represent the predominant and possibly only grayling stock in the park today.

Grayling Creek was investigated in 1970 (Dean and Mills, 1971) as the most likely watershed for stream grayling restoration. The middle section appeared especially promising although portions of the watershed were outside the park boundaries. A barrier was reported to be present below the park which would have prevented the upstream invasion of exotic fish following their removal. Reconnaissance of this area in 1973 revealed that the reported barrier was the 12 foot fault scarp of the 1959 Hebgen Lake earthquake. Since then Grayling Creek has cut through the scarp and rendered it useless as a fish barrier. With this barrier no longer effective, Grayling Creek showed little promise as a grayling refuge and the program of restoration planned for this stream has been held in abeyance.

Since grayling were native to the lower Gibbon River and since they have been reported there in recent years, our efforts were shifted to that watershed. This watershed has several other advantages that

Grayling Creek does not possess--the entire watershed is within the park boundaries and several sizeable tributaries exist which could serve as "enclaves" for grayling or the Madison River cutthroat which has also suffered greatly from man's activities. This project received \$3,843 for rare and endangered species work in FY '74. All of this funding was spent on studies of the Gibbon River system which are reported in the following section.

GIBBON RIVER

Fishery investigations were initiated on the Gibbon River watershed in 1973 as part of a "rare and endangered" species program to restore the native stream dwelling Arctic grayling. The results of our study plus the work of previous researchers are presented below.

Physical

The Gibbon River originates as the outlet of Grebe Lake (156 acres) at an elevation of 8,028 feet (Figure 8). Approximately 1.5 miles downstream the river passes through Wolf Lake (51 acres). It then flows about 25 miles to Madison Junction where it joins the Firehole River at 6,800 feet to form the Madison River. The stream drops 1,228 feet for an average gradient of 47 feet per mile. The watershed covers 117 square miles with Observation Peak (9,397 ft) the highest point.

Melting snow and cold springs are the river's primary water sources, although the stream does receive effluents from several thermal areas. Vincent (1967) reported maximum stream temperatures of 75°F in the lower river and 64°F at Virginia Meadows. The Environmental Protection Agency reported a maximum temperature of 73°F near Norris Junction on August 2, 1970. Vincent (1967) reported minimum temperatures of 32°F on the upper and lower river. He also reported that no appreciable amount of surface ice formed, but anchor ice appeared in the Virginia Meadows area in December 1964. He reported the lowest temperatures in December with the highest occurring in July and August. During low flows, geyser and hot spring discharges contribute about 6% of the flow in the lower reaches of the Gibbon River.

May and June are the months of peak discharge. During peak runoffs, the river exceeds its banks and floods adjacent meadows. The remainder of the year, water levels remain stable based on flow records for the Madison River within the park.

The Gibbon River can be divided into five sections for fishery purposes. Each section is separated by barriers to upstream fish movement. The upper section is about 5.8 miles long and extends from Grebe Lake to the Upper Gibbon Falls (25 ft). During most of this distance, the river flows through a lodgepole forest. Smith and Kendall (1921) reported a hot springs below Wolf Lake: "About a

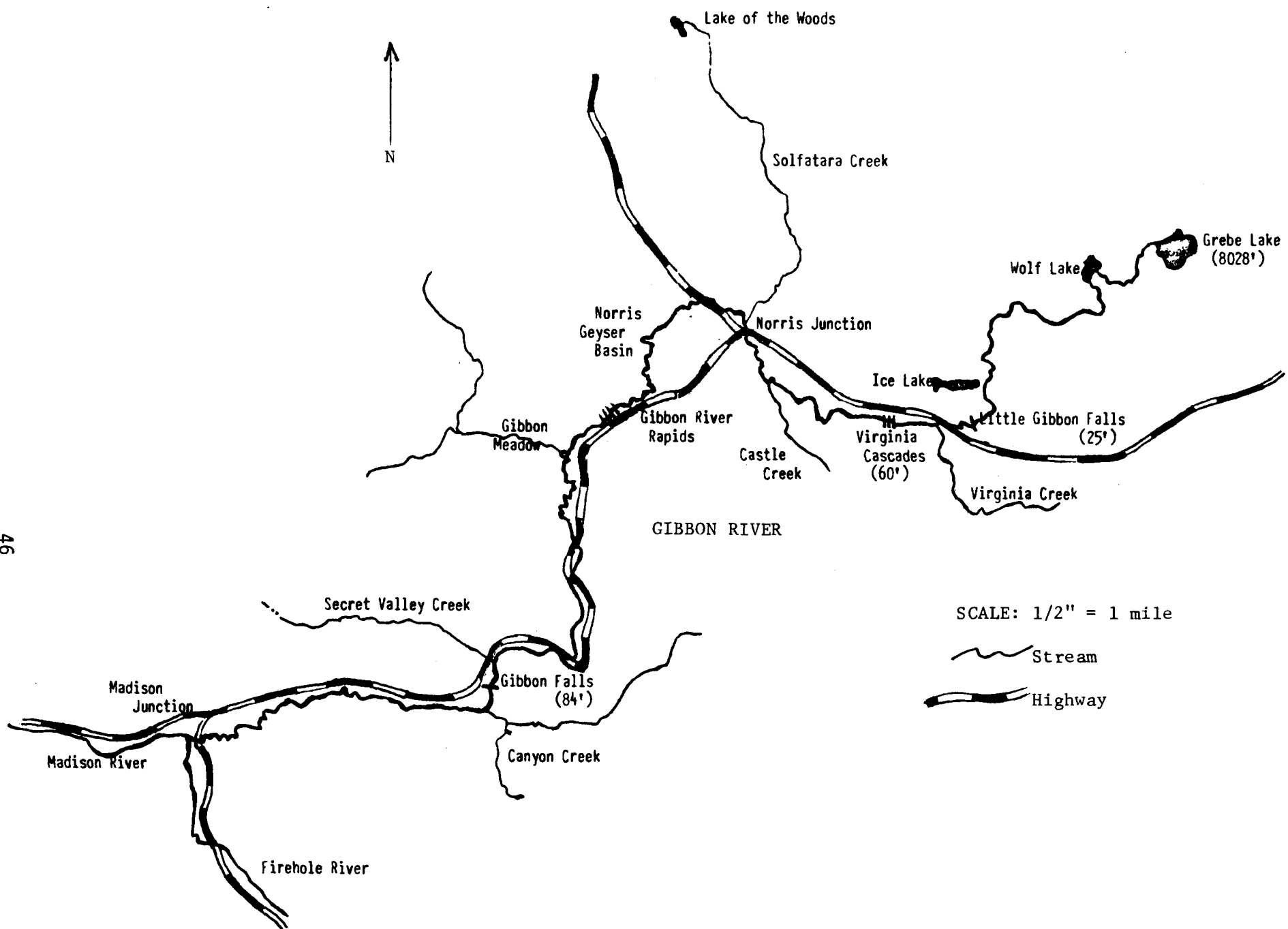


Figure 8.—Gibbon River, Yellowstone National Park, Wyoming

mile below the lake a hot springs which discharges into the river and for a mile or more the water is warm, distinctly impregnated and fishless. Then cold springs entering the river from the hillsides render the stream again inhabitable by trout, which occur all the way to the Upper Falls of the Gibbon." The next section is the 1.5 mile reach which meanders through Virginia Meadows. It is separated from the upper section by Little Gibbon Falls and from below by Virginia Cascades (60 ft). The Norris Junction section is approximately 7.3 miles long and meanders through Norris Geyser Basin and Elk Park. It is bounded by Virginia Cascades and the Gibbon River rapids which appears to be at least a partial barrier to upstream fish movements, especially during low water periods. The Gibbon Meadows section is 6.2 miles in length and extends downstream from the rapids to Gibbon Falls (84 ft). The upper part in the meadow has a low gradient and deep pools (over 5 feet) on most bends. The lower half of the section flows through a canyon and is primarily riffles. The lower section is 5.5 miles long and extends from Gibbon Falls to the confluence with the Firehole River. The upper half of this section flows through a canyon while the remainder meanders through the mountain meadows near Madison Junction. Numerous pools occur in this meadow section.

Aquatic Invertebrates

Vincent (1967) reported a slightly greater biomass of aquatic insects below the thermal areas on the Gibbon River by a factor of 0.36 ml per square foot to 0.32. He also found differences in the number of taxa and abundance of the various orders. Above the thermal influences there were 50 taxa with Ephemeroptera and Coleoptera predominating. Below the thermal areas, in the lower river, there were 45 taxa with Trichoptera and Diptera the major orders. Plecoptera were about the same numbers and biomass in both areas.

Seamans (1940) studied 7 streams in the park and reported that the Gibbon River was the least productive. He found only 0.5 ml of fish food per square foot in the lower Gibbon, 0.6 ml in the section above Gibbon Falls, and 0.56 ml in the Virginia Meadows area. The average food volume of the other park streams sampled was 1.46 ml or nearly 3 times greater. A food supply of between 1 to 2 ml per square foot is considered average and values above and below this good and poor respectively. By this rating method the Gibbon River must be considered a poor food producer.

Chemical Characteristics

Water quality of the Gibbon River changes substantially from the thermal effluents (Table 18). The major changes occur from discharges at Norris Geyser Basin. Most anions (Ca, Mg, Na and K) and cations (SO and CL) increase by factors of 2 to 4 from Norris to the river's mouth. The Gibbon River is the only major stream within the park that consistently maintains an acid pH (below 7.0).

A comparison was made of the 29 water quality parameters in the lower Gibbon River with three of the most productive park streams, namely the Madison, Firehole and lower Gardner Rivers. This was done in an effort to discover the reasons for its reportedly poor invertebrate production. The Gibbon River was lowest in water temperature, pH, conductivity, total alkalinity, and total organic carbon of the four streams. It was highest in potassium and manganese, the latter being a trace element. The differences in water quality were not great but the combined effects of colder water, acid pH, and reduced electrolytes should account for much of the reduced invertebrate production in the Gibbon River.

Table 18.—Mean water quality measurements, Gibbon River May 7 to August 19, 1973

Determination	Gibbon River below Norris campground (7,480')	Gibbon River at Gibbon River Rapids (7,460')	Gibbon River near Firehole River Junction (6,800')
Water temperature °F	49.4	51.4	52.5
Stream flow c.f.s.	71.00		146.00
Dissolved oxygen mg/l	8.02	8.10	8.02
pH	6.72	6.72	6.95
Conductivity—micromhos	90.25	247.74	263.75
Turbidity—Jackson units	1.50	2.10	2.35
Total alkalinity CaCO_3 mg/l	30.40	50.00	75.00
Chloride mg/l	7.75	38.50	30.00
Sulfate mg/l	11.60	24.50	21.50
NO^2 and NO^3 nitrogen mg/l	0.02	0.03	0.04
Other phosphate mg/l	0.01	0.05	0.04
Calcium mg/l	5.00	6.25	6.90
Sodium mg/l	11.02	37.50	44.00
Potassium mg/l	3.55	7.87	8.02
Total iron ug/l	292.50	579.99	562.49
Manganese ug/l	30.00	40.00	55.00
Magnesium mg/l	0.77	1.20	1.17
Silica mg/l	39.50	70.00	75.50
Total organic carbon mg/l	8.75	11.00	19.50

Most of these values are based on 4 water samples collected and analyzed by the Environmental Protection Agency at each sampling location. The water temperatures are based on 15–18 measurements.

Fish Stocking

Fish stocking activities began on the Gibbon River in 1889 when 1,000 rainbow trout were stocked above Virginia Cascades.

Fish stocking continued to be the major management activity for many years. Bass were planted at Norris Geyser Basin in December of 1893 but were never seen again. Brook trout were first stocked above Virginia Cascades in 1905. By 1955, when stocking on the river ceased, over 6 million fish had been planted during the 67 year period since 1889 (Table 19). Additional stocking had also been carried out in the headwater lakes.

Grebe Lake was barren of fishlife until rainbow trout were stocked in 1907. Cutthroat trout were added to the lake in 1912 and grayling established there in 1921.

Fishing Pressure

The first intensive study on the Gibbon River was reported by Benson et al in 1959. They conducted a 4-year creel census from 1953 to 1956 to determine characteristics of the catch and to measure the return of stocked fingerling and catchable sized rainbow trout. They found an average of 4,773 anglers who fished 9,277 hours and creeled 2,850 fish for a creeled rate of 0.31 trout per hour. The mean angler day was 1.94 hours and pressure on the river averaged 199 anglers per stream mile. The catch of wild fish consisted of 44% brown trout, 31% brook trout, 23% rainbow trout, and 2% Arctic grayling. Catchable-sized rainbow trout contributed significantly to the catch only during the season of stocking and increased the harvest by 30%. The creeled rate on wild fish was 0.24 fish per hour. They found that the stocking of fingerling rainbow trout contributed little to the fishing.

Table 19.—Fish stocking record, Gibbon River, Yellowstone National Park

Years	Species	Number	Size (inches)	Location*	Source
1889	Rainbow trout	1,000		3	Northville, Michigan National Fish Hatchery
1893	Black bass	250		2	
1905	Brook trout	17,000		3	Spearfish, S.D. National Fish Hatchery
1906-1910	Brook trout	10,000		2	Spearfish
1906-1910	Rainbow trout	17,000			Spearfish
1916-1920	Brook trout	40,000			
1921-1925	Rainbow trout	80,000			Bozeman, Montana National Fish Hatchery
1926-1930	Rainbow trout	37,000	4 - 5"	1 & 2	Bozeman and Mammoth Pools
1931-1935	Arctic grayling	1,552,000	Fry - 1"	1, 2, & 3	Grebe Lake Hatchery
1931-1935	Brook trout	16,000	4.5 - 5"	2	Mammoth Pools
1931-1935	Rainbow trout	332,487	1 - 6"	1 & 2	Bozeman, Mammoth, Grebe Lake
1936-1940	Arctic grayling	2,395,675	Fry	2 & 3	Grebe Lake
1936-1940	Rainbow trout	743,877	Fry - 3"	1 & 2	Bozeman, Emigrant, Ennis, and Big Timber
1941-1945	Arctic grayling	1,252,979	Eyed eggs - fry	1 & 2	Grebe Lake
1941-1945	Brown trout	81,975	Fry - 2"	1	Bozeman, Emigrant, and Big Timber
1941-1945	Rainbow trout	46,890	1 - 5"		Ennis, Montana National Fish Hatchery
1946-1950	Brown trout	30,000	1.5 - 4"	1	Bozeman
1946-1950	Rainbow trout	25,180	4 - 6"	1	Ennis
1951-1955	Brown trout	28,000	2"	1	Bozeman
1951-1955	Rainbow trout	15,000	3 - 10"	1	Bozeman and Ennis
Totals		6,722,313			

* Location 1 is below Gibbon Falls; location 2 is above Gibbon Falls; and location 3 is Virginia Meadows.

Fish Species Composition

Fishery work on the Gibbon River began in 1889 with David Starr Jordan's investigation. He found that sculpins were abundant above Gibbon Falls (84 ft) but was at a loss to explain how this species had surmounted the nearly vertical barrier. He reported cutthroat trout to be abundant in the 5.5 mile reach of the river below Gibbon Falls.

Evermann (1893) made a reconnaissance of the river and also reported sculpins to be abundant on Canyon Creek. At the mouth of the Gibbon River he reported that grayling, whitefish, dace, sculpins and suckers were abundant.

Each of the five sections of the Gibbon River were electrofished in 1973 in a search for stream dwelling grayling and to determine overall fish species abundance and distribution (Table 20). This was the first electrofishing sampling to be conducted on this stream. No prior studies of a similar nature are available for comparison. Seamans (1940) reported on the fish species composition but his efforts were confined to visual observations. Limited as his observations were, they indicate that a substantial change in the fish species composition has occurred since 1940.

Seamans (1940) reported brook trout and grayling with an average size of 5 inches in the Virginia Meadows section. We found this section to be dominated by small brook trout and a few rainbow trout.

In the river reach below Virginia Cascades (our Norris Junction section should be reasonably comparable), Seamans (1940) again reported grayling, brook trout, and sculpins. We found brook trout, sculpins and one brown trout.

In the Gibbon Meadows area, Seamans (1940) reported rainbow trout, grayling and brook trout. He reported the few larger fish observed were grayling. We found this stretch to be inhabited primarily by brown trout which comprised 84% of the fish taken. Brook trout were the second most numerous species and made up 10% of the samples. We did not collect a grayling. Sculpins and longnose dace were reported by Seamans and also collected in 1973.

In the lower Gibbon River (below Gibbon Falls), Seamans (1940) reported rainbow trout of an average size of 7 inches, plus dace and sculpin. Again we found a different situation: brown trout are now dominant followed by rainbow trout and sculpins. We also found adult mountain whitefish and two Arctic grayling (Table 20).

Table 20.—Electrofishing results, Gibbon River, 1973

Location and elevation (feet m.s.l.)	Date	Species	Number	Average length (inches)	Length range (inches)	Condition factor* "C"
Above Little Gibbon Falls (7,850')	9/17/73	Rainbow trout	52	2.8"	1.1"-7.8"	37.5
Virginia Meadows (7,790')	9/13/73	Brook trout	115	4.4"	1.9"-8.3"	33.6
		Rainbow trout	3	5.9"	5.6"-6.4"	31.4
Norris Junction (7,475')	9/17/73	Brook trout	41	4.0"	2.4"-8.3"	37.1
		Mottled sculpin	23	3.5"	2.2"-4.6"	....
		Brown trout	1	6.3"	6.3"	35.9
Gibbon Meadows (7,340')	10/10 and 10/11/73	Brown trout	660	8.8"	2.9"-21.3"	31.7
		Brook trout	77	5.2"	2.9"-9.6"	34.8
		Mottled sculpin	51	3.1"	1.5"-4.1"	....
		Longnose dace	1	1.0"	1.0"	....
Madison Junction Meadows (6,820')	9/12, 9/18 and 10/12/73	Brown trout	166	8.1"	3.1"-17.3"	30.6
		Rainbow trout	41	6.1"	1.4"-15.5"	28.9
		Mottled sculpin	40	2.3"	1.1"-3.9"	....
		Longnose dace	5	2.6"	1.4"-3.6"	....
		Mountain whitefish	2	17.0"	16.7"-17.3"	34.1
		Arctic grayling	2**	7.8"	7.8"	29.5

* Condition factor = $100,000 \text{ wt. (lbs.)} / \text{total length}^3 \text{ (inches)}$

** Only one grayling measured

Total = 1,280 fish sampled

Ranger Guy McCarty in 1933 reported rainbow trout up to 3 pounds from the meadow (presumably Gibbon Meadow). Rainbow trout, which were reported to be common to Gibbon Meadow in 1940, are no longer present there. They have been replaced by brown trout (Table 20). Brown trout are known to have been present above Gibbon Falls at least since the early 1950's. In 1952 the Superintendent reported a 9 pound 6 ounce specimen caught at Norris Junction. A trout of this size must have been at least 5 years old.

How and when brown trout gained access to the river above Gibbon Falls remains a mystery. There are no official records of brown trout stocking above the falls. It is possible that an "unofficial" plant was made and it's also possible that a few brown trout were accidentally stocked with the 6,700,000 fish planted in the river prior to 1956 (Table 19).

Brown trout are now the dominant species in the Gibbon Meadow. At least 5 and possibly 6 year classes, based on length frequency distribution, appear to be present with young-of-the-year well represented (Figure 9). These young brown trout averaged 4.2 inches in total length when captured in early October 1973. Trout considered to be yearlings had an average total length of approximately 8.1 inches. Brown trout judged to be age group II had an average total length of about 11.1 inches.

There were not over 3 age groups of brook trout captured in the Gibbon Meadows area. Young-of-the-year were common and comprised 62% of the brook trout collections. They averaged 4.0 inches in total length. The older brook trout were in better condition (Table 20) than brown trout of the same length but are growing slower.

How and when the longnose dace became established above Gibbon Falls is also a mystery. They were originally found below the falls but not above. Seamans (1940) was the first to report their presence above the falls. They are now common in sheltered areas next to the bank in the Gibbon Meadow and lower sections of the river.

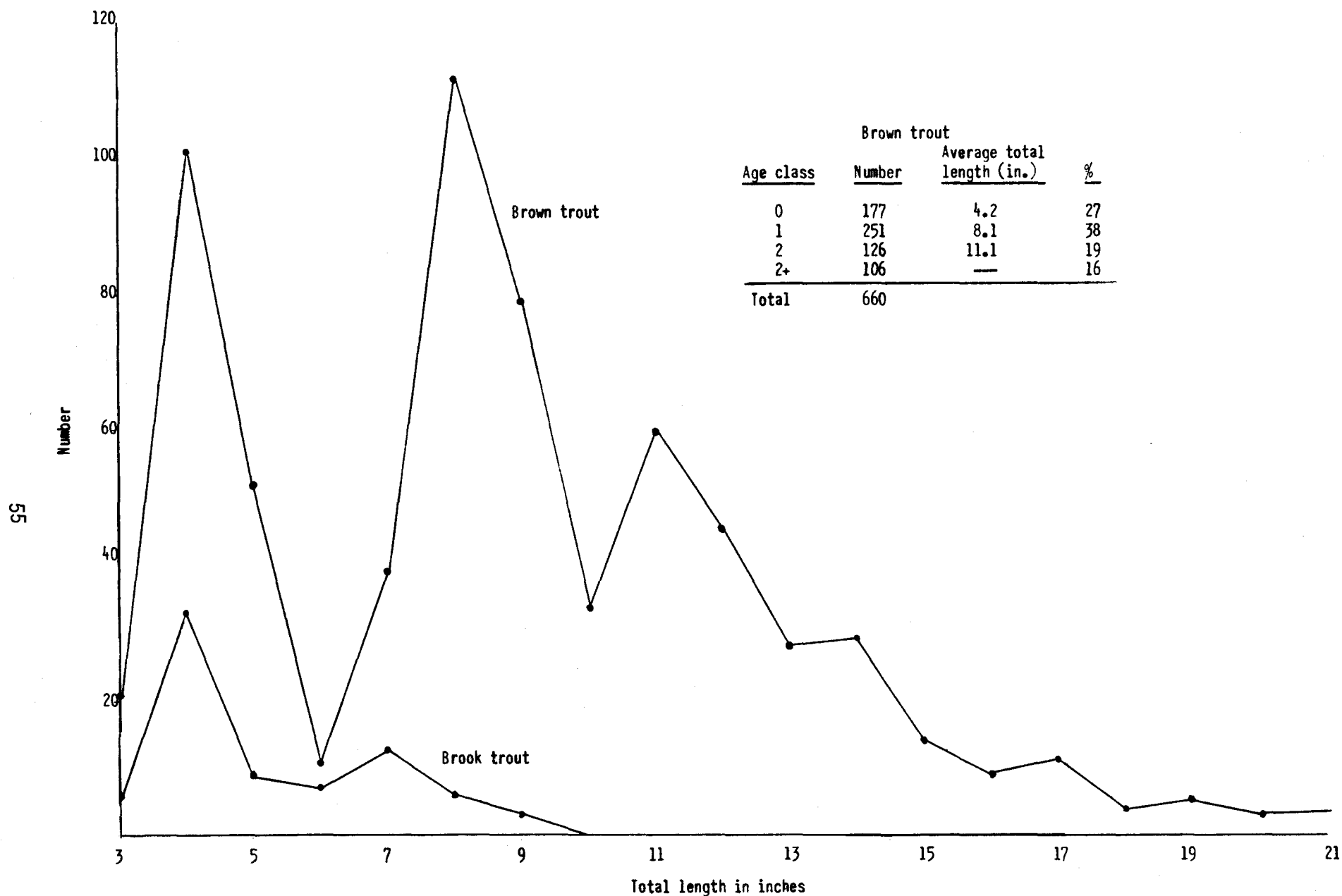


Figure 9 .—Length frequency distribution of brook and brown trout captured by electrofishing in the Gibbon Meadows area of the Gibbon River, October 10-11, 1973

Tributaries

The major cool tributaries are Canyon, Secret Valley, Gibbon Meadows, Solfatara, Castle and Virginia Creeks. Major thermal effluents are received from the Monument, Gibbon and Norris Geyser Basins and Terrace, Iron and Beryl hot springs.

Solfatara Creek, the largest tributary, is 7.4 miles long. One intermittent fork of the creek drains Lake of the Woods, a shallow lilly pad lake. Solfatara Creek is nearly as large as the Gibbon River where they join. Small brook trout were the principle fish species observed in this creek at Norris campground. A water sample collected on August 31, 1971 and reported in the "Master Domestic Systems Study" (1972) showed the following chemical profile in ppm: Sodium 12, potassium 3, calcium 3, magnesium 1, sulfate 6, chloride 4, biocarbonate 37, total dissolved solids 47 and conductivity 98 micromhos.

Virginia Creek enters the Gibbon River in Virginia Meadows. Not much is known about this stream which is 3.4 miles in length. It originates from a small unnamed lake on the Central Plateau. Seamans (1940) reported that it contained brook trout.

Canyon Creek is an important tributary and enters the Gibbon River about 5 miles above its mouth and 0.5 miles below Gibbon Falls.

Canyon (Cañon) Creek

During his 1889 collecting trip to Yellowstone Park, David Starr Jordan (1891) wrote "Cañon Creek, a small clear stream, very cold and with grassy bottom, joins the Gibbon River below the falls. This stream flows through steep pastures, without falls except near its source. It is 6 to 8 feet wide and 1 to 3 feet deep and is well stocked with (cutthroat) trout. In this stream the blob (sculpin) is very abundant, absolutely swarming in the grass."

Our collecting trip in 1973 may be the first survey of this stream since Jordan's descriptive visit 84 years ago. Our purpose was also similar to Jordan's: to ascertain the species inhabiting the watershed.

From a physical standpoint, it would appear that Canyon Creek has changed little from Jordan's (1891) description. Canyon Creek remains clear, cold and with a "grassy bottom." The stream appears to be very stable with no scoured banks or other evidences of high erosive water. At the mouth, the stream averaged 8.5 inches deep and was 7 feet wide. The water temperature was 56°F at noon (April 26) and was 58°F at 1630 hours on June 14, 1973. The estimated volume flow was 10 cubic feet per second (cfs) (April 26). The lower 1500 feet of stream is fairly high gradient with abundant spawning gravel. Further on, (Figure 10) the gradient becomes less and the stream becomes placid with numerous

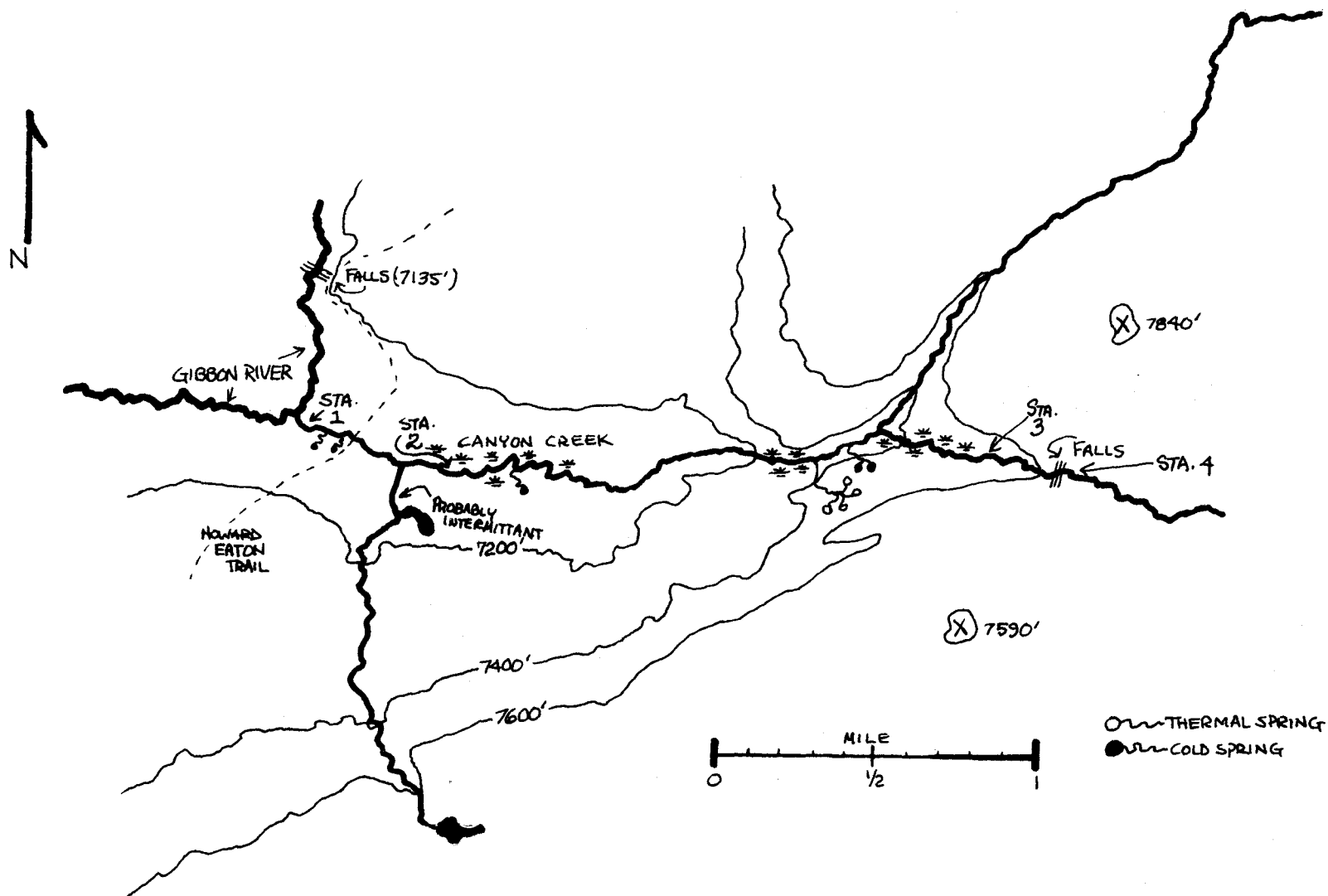


Figure 10.—Canyon (Cañon) Creek, Yellowstone National Park, Wyoming

glassy pools (up to 6 feet deep) and smooth runs. About 1/3 of the stream meanders through open meadows with the remainder traversing through thick lodgepole pine. Between the mouth and the falls there are at least six cold springs and one thermal area with substantial water input. Total distance from the Gibbon River-Canyon Creek confluence to the falls is approximately 3 miles. The falls which Jordan (1891) originally described appear to be 30 to 50 feet high.

Beyond the physical features, similarities between Jordan's (1891) description and that found in 1973 end.

Whereas the stream was described as being "well stocked" with cutthroat trout and "swarming" with sculpin, we found the stream to be totally dominated by the brown trout with very few sculpin (Table 21). The change in species composition and abundance has apparently come about through natural emigration from the Gibbon River as there is no record of the stream ever having been stocked. Because of its remoteness and small size, it is unlikely that angling exploitation had much to do with the demise of the endemic cutthroat. Therefore, based upon the limited evidence available, it would appear that the cutthroat was replaced by a superior competitor and that the sculpin may have also been negatively affected.

Based upon the size range of brown trout captured, it would also indicate that the stream is presently and primarily a spawning and nursery area for trout running out of the Gibbon-Madison system and/or possibly Hebgen Lake.

Based upon the limited data thus far available, it would appear that Canyon Creek would offer the type of habitat suitable for an enclave for an endemic endangered species. Prior to becoming an enclave, however, the brown trout would have to be removed and an artificial barrier constructed to prevent recontamination.

Table 21.—Electrofishing results on Canyon Creek, June 1973 (stations located on map, Figure)

Station	Brown trout			Mottled sculpin		
	No.	$\bar{x}$ TL (in.)	TL range (in.)	No.	$\bar{x}$ TL (in.)	TL range (in.)
1	14	2.6	1.5-4.3	1	2.5	—
2	14	3.9	1.3-7.5	3	2.5	0.5-3.7
3	5	3.5	1.7-7.4	0	—	—
4	0	—	—	0	—	—
Total	33	3.3	1.3-7.5	4	2.5	0.5-3.7

Castle Creek (Norris Water Supply Creek)

The stream from which the Norris area receives its water supply was given a cursory survey during the spring and summer 1973. The stream has been called Castle Creek but a library search failed to substantiate any sound basis for the name. It will be called Castle Creek here for purposes of convenience.

The creek was surveyed as a possible site or enclave for one of the Park's endangered fish species (or races). Two Gibbon River grayling presently are the only inhabitants above the falls (Figure 11).

Figure 11 gives the basic topography of the stream detailing pertinent features. Below the falls, the stream meanders without barriers to a confluence with the Gibbon River. This section is approximately 3/4 miles long. Electrofishing below the falls (an approximate 200 foot section) produced 10 brook trout ranging 4 to 6 inches in length and 2 rainbow trout 6.5 and 7.5 inches. There were no fish captured above the falls. There is no record of this stream ever having been planted with fish. The resident fish below the falls are undoubtedly emigrants from the Gibbon River.

Aquatic insects were abundant in both the barren and fishery sections of the stream. Mayfly and dragonfly nymphs were especially common. At least five species of aquatic vascular plants and numerous algae species were common in the stream. The banks were stable and heavily vegetated with grasses and emergent aquatic plants.

The watershed is thickly vegetated with lodgepole forest with some meadow along the stream and in seep areas. Water input is primarily from the central plateau (some thermal activity) and from a thermal area north of Gibbon Hill. The cooler water input as measured at the water supply diversion dam (Figure 11) was about 2 cfs. After passing the dam, the stream travels through an area of extensive cold and thermal spring activity. Several stream-side hot springs had temperatures exceeding 190°F. The thermal brooklet issuing from the Gibbon Hill area had a flow of 0.5 cfs and a temperature of 76°F during the latter part of May.

Near the falls, the flow was measured at 4 cfs and the temperature was 68°F (late May). The water temperature in the same area on June 13th was 72°F. An early fall measurement yielded 75°F.

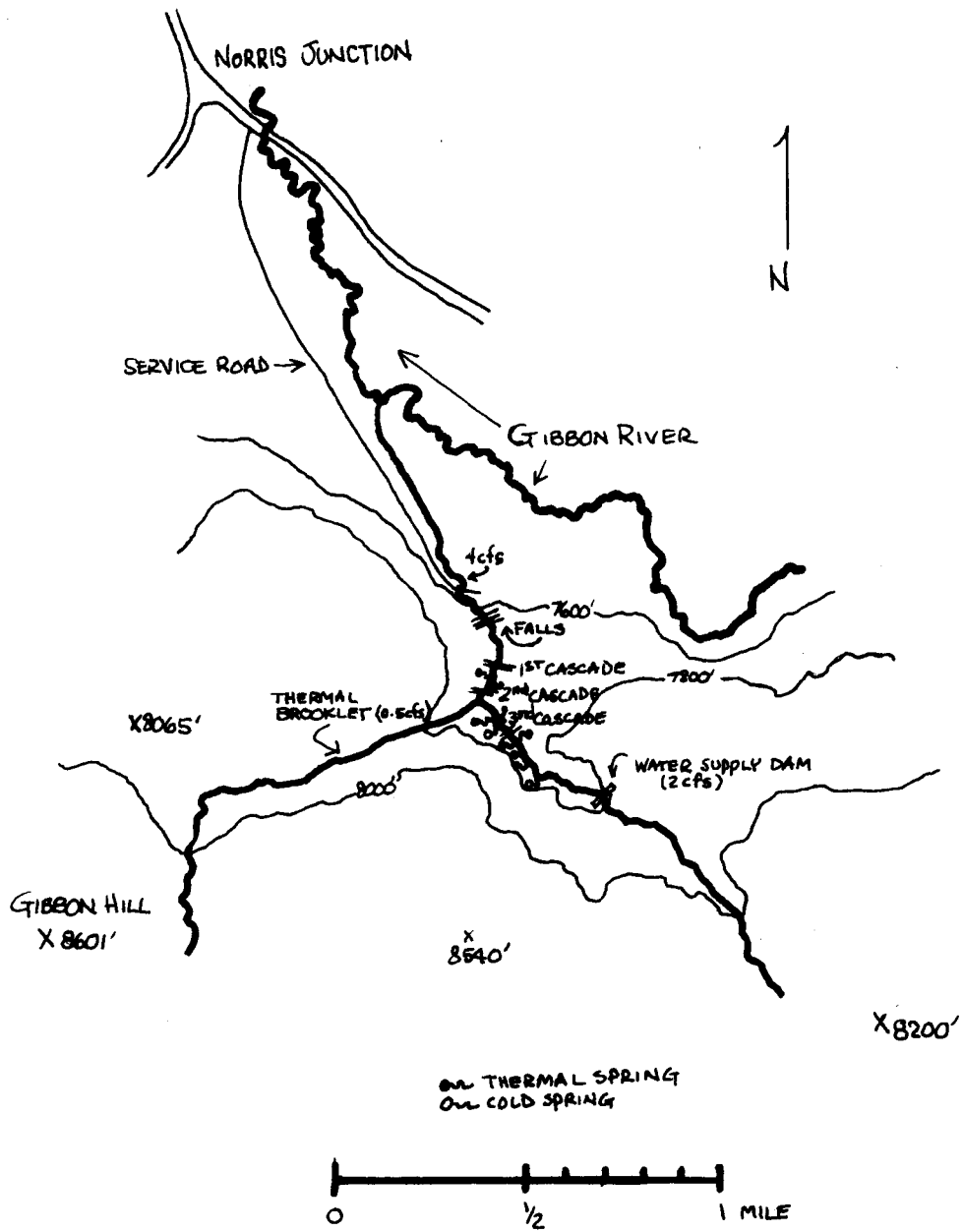


Figure 11.—Castle (Norris Water Supply) Creek, Yellowstone National Park, Wyoming

Water quality data reported for Castle Creek at the culinary intake and below the falls indicate the following:

	Water intake*	Below falls*
Temperature (summer)	68°F	73°F
Iron (ppm)	0	0
Sulphate (ppm)	Trace	5
Chloride (ppm)	5	15
Carbonates (ppm)	0	0
Bicarbonates (ppm)	50	80
pH	7.0	8.3
Total hardness (ppm)	20	25
Specific cond. (micromhos)	118	---

*data from "Master Domestic Water Systems Study" 1972.

These data indicate a thermally influenced water quality somewhat more alkaline and enriched than that normally found in the Gibbon River drainage above Norris Geyser Basin. The alkaline reaction is partially different from the Gibbon River (data elsewhere in this report).

Considering the small size of the stream and its gradient (400 feet per mile) the quality of the pools was excellent, the riffles somewhat less so. Potential spawning habitat was fairly limited but that which was present is of excellent quality. The substrate was mostly volcanic rubble; followed by mud and silt (vegetated), and pea-size gravel.

It was concluded that the section of Castle Creek between the falls and the intake (approximately 0.7 miles) is a suitable enclave for a native species (such as the endemic Madison River cutthroat or grayling) particularly one which historically was adapted to thermally influenced waters.

Conclusions and Recommendations

Grayling, which were present in 1940 throughout most of the river above Gibbon Falls, were only found as a few scattered individuals below Gibbon Falls in 1973. The near demise of the grayling is of special concern since this species has suffered more from man's activities than any other fish in Yellowstone Park. Seamans (1940) thought that downstream migrants from Grebe and Wolf lakes helped maintain the grayling population in the upper Gibbon. Benson et al (1959) thought that downstream migrants from the upper Gibbon were the source of the few grayling found in the Madison and Firehole Rivers. The presence or absence of a downstream drift of grayling is not definitely known. Young-of-the-year grayling have not been collected or reported from the Gibbon River or its lower tributaries to substantiate the presence of a reproducing resident stream grayling population. The two grayling captured in the lower Gibbon in 1973 were considered to be yearlings. If downstream drift from Grebe and Wolf lakes were the only source of grayling for the lower Gibbon River and the Madison River, it seems strange that no grayling were captured during the electrofishing operations at intermediate locations at Norris Junction and Gibbon Meadows. It is possible, of course, that a downstream drift does not occur every year. It is known that the grayling population in Grebe Lake has experienced wide fluctuations in population abundance over the years. The population is presently reduced in numbers based on limited observations and reports from anglers. Downstream drift may be a function of population density and thus not have been of significance in 1973. If the chemical-thermal barrier below Wolf Lake is still effective, it may be difficult for grayling to move downstream except during high water periods.

Grayling are also known to be highly susceptible to angling pressure. Heavy fishing pressure over the past 25 years may have been a contributing factor to their decline. They have been given complete legal protection from angling in the park since 1969. Grayling are also known to be poor competitors in the presence of salmonids such as brook and brown trout.

Efforts to collect stream grayling should continue as should work to determine if they are reproducing in the Gibbon River. Aquatic surveys should also continue on Gibbon River tributaries in an effort to find suitable "enclaves" for grayling. If additional funding becomes available, university studies of morphological and genetic characteristics of lake-dwelling and stream-dwelling populations should be initiated to determine if any differences do in fact exist.

HEART LAKE

A complete aquatic survey of Heart Lake has never been attempted, although two surveys to measure fish population status and the preparation of a cursory ecological profile have been accomplished in recent years (Sharpe and Babcock 1964, Dean and Mills 1970).

Investigations in 1973 addressed three principle objectives: 1. To prepare a historical picture of the lake's fishery prior to man's influence, 2. To learn more of the status of the endemic cutthroat trout (especially spawning information), and 3. Add to the existing information on the ecology of Heart Lake.

Two trips were made to the lake on the 10th and the 28th through the 30th of June, and a second effort was accomplished from the 24th through the 27th of September.

Stream Survey - Heart Lake System

Several tributaries to Heart Lake and the Heart River were visited by project members on June 10, 1973 and again on June 29-30, 1973.

Beaver Creek

On June 10th, Beaver Creek was populated by an abundance of spawning Utah suckers and some cutthroat trout. Actual spawning activities by the suckers were observed, but this was not seen in the cutthroat population. Cutthroats (3) were caught by hook and line and measured 13.5", 18" and 21 inches. Spawning suckers were typically one to three pounds each. Electrofishing results (Table 22) on the 29th of June proved that all spawning was completed by the two species. Large dead suckers remained in the creek. One juvenile cutthroat, 3 sculpin, 3 speckled dace and 18 redbreast shiners were apparently the only fish in the stream (the cutthroat and sucker spawn had not yet emerged). The shiners were large, ripe and very colorful indicating that they probably were in the creek to spawn.

Beaver Creek had a flow of 11 cfs during the June visit (Table 23). The stream appears to be excellent spawning habitat with vast areas of pea-sized spawning gravel. The temperature on the 29th of June was 60°F (1600 hrs) and the pH and specific conductivity was 7.2 and 60 micromhos respectively.

Table 22.—Summary of electrofishing data collected from four streams tributary to Heart Lake and the Heart River, June 29-30, 1973

	Stream			
	Heart River	Outlet Creek	Beaver Creek	Witch Creek
Cutthroat trout				
Number	5		1	
$\bar{x}$ T.L. (mm)	55		185	
T.L. range (mm)	28 - 99			
$\bar{x}$ Wgt. (gr)	5		87	
Mt. Whitefish				
Number	1			
$\bar{x}$ T.L. (mm)	162			
T.L. range (mm)				
$\bar{x}$ Wgt. (gr)	36			
Redside shiner				
Number	97		18	35
$\bar{x}$ T.L. (mm)	65		75	62
T.L. range (mm)	44 - 87		67 - 92	42 - 84
$\bar{x}$ Wgt. (gr)	5		6	4
Utah chub				
Number	1			4*
$\bar{x}$ T.L. (mm)	65			99
T.L. range (mm)				81 - 117
$\bar{x}$ Wgt. (gr)	3			19
Speckled dace				
Number	1		3	
$\bar{x}$ T.L. (mm)	55		64	
T.L. range (mm)			52 - 78	
$\bar{x}$ Wgt. (gr)	2		3	
Mottled sculpin				
Number		4	3	
$\bar{x}$ T.L. (mm)		44	50	
T.L. range (mm)		21 - 78	35 - 65	
$\bar{x}$ Wgt. (gr)		3	4	
Utah sucker				
Number	7			
$\bar{x}$ T.L. (mm)	113			
T.L. range (mm)	77 - 141			
$\bar{x}$ Wgt. (gr)	18			

* The Utah chubs were collected from a slough adjacent to Witch Creek but with a connection to the stream.

Table 23—Some physical and chemical characteristics of inlet streams and the outlet of Heart Lake - data collected June 29-30, 1973

Stream	Est. flow cfs	Stream width (ft.)	Average depth (ft.)	Temp. F°	pH	Specific cond. (µmhos)	ppm Hardness		ppm Alkalinity	
							Ca	total	Ph.	M.O.
Outlet Creek	14.0	30	1.2	56° (pm)	7.4	90	30	50	5	50
Witch Creek	8.5	22	0.8	56° (am)	7.4	280	trace	10	2	50
Heart River	31.4	44	1.5	62° (noon)	7.4	200	10	20	2	40
Beaver Creek	11.1	15	0.9	60° (pm)	7.2	60	*	*	*	*

* Missing

Table 24.—Heart Lake fishery statistics based upon entries to the station logs 1930 through 1973

Period	Trophy trout - reported catch		Lake trout x trophy size (lbs)		Cutthroat trout x trophy size (lbs)		Average angler stay (days)	Average trout catch per person	Responses to fishing (%)	
	% lake	% cutt.	mean	max.	mean	max.			pos.	neg.
1930 - 1950	92	8	11	26	4.0	5.0	—	5.6	56	44
1951 - 1973	57	43	6	11	2.6	3.9	1.98	3.3	48	52

Table 25.—Heart Lake angler use and trout harvest estimates based on ranger and fire control aide entries to the station log 1930-1973 - estimates are "rough" and are probably only reliable to indicate trends

Period	Angler day use: av. per year	Trout harvest		
		x no./year	x lbs./year	x lbs./acre/yr.
1930-40	1,250	3,525	10,575	3.9
1941-50	400	975	2,430	0.9
1951-60	775	1,160	2,325	0.9
1961-70	1,625	2,770	4,160	1.5
1971-73	1,525	2,595	5,120	1.9

Little aquatic vegetation was found in the stream, but aquatic insects were numerous.

Outlet Creek

Outlet Creek enters the Heart River approximately 1/4 mile below the outlet of Heart Lake. It is formed by the joining of Outlet and Surprise Creeks and carried a flow of 14 cfs near its confluence with the Heart River. Unsubstantiated reports in past years have indicated that a run of Heart Lake cutthroats use Outlet Creek for spawning. We observed no evidence of spawning during our brief survey.

Only the mottled sculpin was captured with electrofishing gear (Table 22). If lake cutthroat do in fact spawn in the stream, it would be a very unique genotype as it would have to possess mechanisms to get it down Outlet Creek and up the Heart River to the lake--a very complex task genetically.

Outlet Creek is light to moderately hard water (Table 23) with low conductivity and a pH of 7.4. The water temperature was 56°F at 1400 hours.

Aquatic insects appeared to be abundant in the stream. The only aquatic vegetation observed was an occasional tuft of Cladophora attached to the rocks.

Witch Creek

Witch Creek has been mentioned by numerous authors ever since Jordan described the stream in 1890. It arises in the Heart Lake Geyser Basin. In its headwaters, water temperatures exceed 80°F. On the morning of June 30th, the temperature was 56°F near the mouth. Jordan (1890) found Utah suckers, Utah chubs and redbside shiners in Witch Creek and noted that the chubs were found in water 88°F far up the stream. Jordan (1890) measured the temperature at the mouth of the creek in early October and found it to be 75°F.

During our survey only the redbside shiner was electrofished from Witch Creek proper. Utah chubs appeared to be restricted to the slough-like oxbows adjacent to the creek (Table 22). The fact that no suckers were collected was probably due to the current year's spawn not having emerged by the end of June. Juvenile cutthroat trout and dace were observed though not collected in several of the cool tributaries to Witch Creek.

The stream had a flow on June 30th of about 8.5 cfs and is wide and shallow (Table 23). It had a pH of 7.4, high conductivity for the drainage, but was relatively low in hardness and alkalinity (Table 23).

Heart River

The Heart River at the outlet of Heart Lake is a major tributary of the Snake River. On June 29th it had a flow of approximately 31 cfs and averaged about 1.5 feet deep. The water temperature was 62°F at noon. The stream had a pH of 7.2, specific conductivity of 200 micromhos, and was low in hardness and alkalinity (Table 23). Judging from the insects and vegetation, it would appear that the river is productive. Excellent spawning gravel exists in the first 1/4 to 1/2 mile downstream. The river supports a rich fish fauna (Table 22). Besides the smaller individuals of the six species collected by electrofishing, three species were spawning in the outlet gravel. Two species of suckers were clearly observed spawning and were, presumably, Utah suckers and mountain suckers. In addition, an outlet spawning race of cutthroats were evident. An outlet genotype has not been previously described from Heart Lake. These fish, according to an angler having "good luck" on the stream, ranged in size from 10 inches to about 4 pounds, averaging 2 pounds each. Fishing this group of spawners, it was estimated that he had a catch rate of 8 to 9 trout/angler hour. It is thought that trout in this size range would be more likely from a lake system rather than spawners associated with the Heart River resident group.

As inlet-tributary spawning for the cutthroat was complete as of the time of our survey, it would appear that the outlet group may be reproductively isolated from the remainder of the lake population.

Five cutthroat were electrofished from the Heart River, two were yearlings and three were young-of-the-year. The 0+ trout were unexpected (as spawning was going on during our sampling), and one can only speculate from which spawning group they came.

Judging from the diversity of species and the small sizes (Table 22), it would appear that the Heart Lake outlet (Heart River) is a major spawning and nursery area.

Historical

Little on the historical nature of fish and fishing was found for Heart Lake.

Jordan (1890) visited the lake in 1889 and reported that cutthroat trout were numerous around the mouth of Witch Creek. Although his comments were primarily of taxonomic interest, he detailed the first description of the lake's endemic species (cutthroat trout, Utah chub, suckers, shiners, sculpin and dace).

Forbes (1892) visited the lake one year later (1890) and described the following: "The abundance of fishes in the lake was shown by the fact that our trammel net, simply stretched in the open water in the evening and lifted at noon the following day, contained 87 fishes, 12 of them trout, the remainder suckers and chubs, the latter most numerous. At another setting of this net, near the mouth of Witch Creek, in 8 to 10 feet of water, 10 trout, 2 chubs, and 65 suckers were taken in six hours."

In a letter to W. T. Thompson, Superintendent of the U.S. Fish Hatchery at Bozeman dated April 30, 1915, Col. L. M. Brett, Acting Superintendent of the Park noted in reference to the proposed stocking of Heart Lake: "...fishing is already most excellent in Hart (sic) Lake... Some of the best fishing for native trout in the park is found in Hart Lake..." (Yellowstone National Park Archives, Mammoth).

A void exists in the historical literature until the early 1930's. District Ranger Dale Nuss (personal communication 1969) reported the Park record lake trout, a 42 pound fish, was taken in 1931 from the lake. This is the earliest known record of the presence of lake trout in Heart Lake. Kendall (1915) and Smith and Kendall (1921) do not record the lake trout as being present in the lake. They do mention that the species had spread from Lewis lake downstream and throughout the Lewis River system. Mention of lake trout being taken from the lake first occurs in the Heart Lake Ranger Station logs in an entry for 1933 when numerous lake trout ranging from 2 to 32 pounds were reported.

The decade from 1931 to 1941 was truly the "big fish" era for the lake. According to the station logs (Yellowstone National Park Archives, Mammoth), lake trout from 3 to 17 pounds were common in the catch with a few individuals reaching 38 pounds. During this same period, the logs report good catches of cutthroat trout from 3 to 5 pounds. The largest reported cutthroat from the logs was a 5.5 pound fish taken in 1961. It should be noted that the majority of

length and/or weight measurements in the logs are for "trout" rather than for a given species; therefore, the maximum historical size and a modal size based on information from the logs is probably not precisely accurate.

Extraction of all pertinent fishery information for the period from 1930 through 1973 yielded enough information to divide into two periods of approximately 20 years each. The information presented (Table 24) is based upon the reports of fishermen as interpreted by numerous rangers and fire control aides stationed at Heart Lake over the years. In the form presented, these data are unique and cannot be compared to any standardized fishery statistic normally used. Rather, they are of some value in comparing trends at Heart Lake.

Table 24 details the considerable decline in the mean reported size and the average maximum size (mean of the largest trout recorded over a series of years) of both lake trout and cutthroat trout. The mean reported size figures are biased somewhat by a tendency by anglers in early years not to report "medium" trophy fish, i.e., a five pound trout is more of a trophy in 1973 than it was in 1935. The average maximum size figures cannot be influenced in that same manner. Because the same trend is shown in both categories, the figures are thought to be valid.

The average trout catch per person also shows a marked decline. This figure is undoubtedly influenced by different creel limits (20 fish per person, 1930's, 5 fish 1950's and 60's, 2 fish 1970's) but may also be partially reflective of species abundance.

The assumedly voluntary responses in the "quality" of angling has dropped from 56% positive response in the earlier period to 48% positive in the past 23 years.

The percentage of lake and cutthroat trout in the catch is biased in the earlier period by the failure of anglers to think of 2 to 5 pounds as "trophies." The data from 1951-1973 includes trout as small as eleven inches and is, therefore, thought to be a fairly accurate representation of the species composition of the catch for the recent period.

Table 25 details the estimated use and harvest in Heart Lake from 1930 to the present. The estimates are rough and are thought to be more descriptive of trends than actual use and harvest. The 1930's is the decade of greatest exploitation. It is not the period of highest angler-day use, but the longer average stay at the lake and the liberal limits (20 trout per day) undoubtedly had an impact. Use drastically declined through the war years and has generally been increasing since that time.

The road to Heart Lake was closed in 1948. This closure decreased the number of anglers exploiting the lake.

Fish Populations

Tables 26 and 27 detail the results of the 1973 gill netting on Heart Lake and compares current life history and population data with that of past years.

The eight nets set in a variety of habitats over the entire lake is the most comprehensive netting done thus far in Heart Lake.

Four nets were set in essentially similar areas that were used in 1969 so that comparisons (equivalent nets) between those years could be made (Table 27). The remaining four nets were set in the western, southwestern, and extreme eastern portions of the lake. These are areas not heretofore sampled.

Despite occasional reports of rainbow and brown trout being present in the lake none were sampled in 1973. The station logs 1930-73 have four entries specifying catches of brown trout. While arguments on the validity of brown trout reports could be made both ways, the brownish hue of the cutthroat often "fools" anglers. This is frequently shown on Yellowstone Lake where volunteer angler responses would show a considerable "brown trout" harvest from a lake where no brown trout exist.

The brown trout is not apparently impeded from entry from the Snake River via the Heart River to Heart Lake. The senior author has inspected a true brown trout reportedly caught from the lake.

The netting of 4 mountain suckers was the first time these fish have been captured from the lake. They are a common endemic species in the drainage.

Most of the differences in length and weight data shown in Table 27 are probably attributable to the large increase in sample size in 1973 and to normal fluctuations in year-class strengths. Data on the Utah chub and the Utah sucker, however, may be indicative of trends. The Utah chub average lengths, maximum and minimum lengths show a trend towards a smaller and younger population. Conversely, data on the Utah sucker show the reverse--a trend towards a larger population with more mature individuals.

The comparative statistics on the number and pounds of fish caught per net are presented in Table 27. Though each of the nets are not strictly comparable with each other, it is clear that the expansion of the lake

Table 26.—Results of 1973 gillnetting at Heart Lake including life history data and comparative statistics with past sampling 1)

Species/ year	Sample size	Average total length (in.)	Length range (in.)	Average weight (lbs.)	Weight range (lbs.)	Total weight (lbs.)	Condition factor "C"
Cutthroat							
1964	32	14.3	8.5 - 26.5	*	*	*	*
1969	8	10.2	7.1 - 16.5	0.45	0.09 - 1.66	3.6	31.1
1973	12	13.3	8.5 - 20.0	1.07	0.2 - 2.77	12.8	35.1
Lake trout							
1964	5	15.7	8.0 - 22.0	*	*	*	*
1969	19	18.9	15.6 - 21.5	1.95	1.6 - 2.96	37.0	27.0
1973	72	17.8	8.0 - 26.1	1.75	0.1 - 7.50	126.0	27.3
Mt. whitefish							
1964	12	8.3	7.0 - 11.5	*	*	*	*
1969	2	7.4	7.1 - 7.7	0.10	0.09- 0.11	0.2	24.7
1973	65	11.1	7.2 - 16.4	0.53	0.07- 1.59	34.2	30.1
Utah chub							
1964	169	13.5	8.0 - 18.0	*	*	*	*
1969	160	10.3	4.9 - 16.3	0.58	0.07- 1.91	93.3	45.2
1973	54	9.4	3.2 - 15.4	0.55	0.02- 1.85	29.5	48.0
Utah sucker							
1964	48	11.1	5.0 - 18.0	*	*	*	*
1969	108	13.9	6.9 - 21.1	1.16	0.10- 4.16	125.1	36.8
1973	86	16.6	6.5 - 23.6	0.90	0.15- 5.12	171.1	39.3
Mt. sucker							
1964	0		None sampled				
1969	0		None sampled				
1973	4	7.2	6.1 - 8.8	0.14	0.07- 0.26	0.55	37.5

1) In 1964 2 experimental nets were set, 4 experimental nets in 1969, and 8 experimental nets in 1973. The 1964 net data includes an unknown number of angler-caught lake and cutthroat trout and is, therefore, not comparable (for those species) to the 1969 and 1973 net data.

Table 27.—Comparative gillnet catch statistics for Heart Lake from 1890 to the present

Species	Number of fish (lbs.) captured per net									
	1890 ¹⁾		1964 ²⁾		Equivalent nets				All nets	
	no.	lbs.	no.	lbs.	1969 ³⁾		1973 ⁴⁾		1973 ⁴⁾	
					no.	lbs.	no.	lbs.	no.	lbs.
Cutthroat	11.0		16.0 ⁵⁾		3.8	0.9	2.5	1.8	1.5	1.6
Lake trout	0		2.5 ⁵⁾		1.6	9.3	6.8	11.0	9.0	15.8
Mt. whitefish	0		6.0		0.4	0.05	2.0	0.5	8.1	4.3
Utah sucker			24.0		21.6	31.3	16.3	33.8	10.8	21.4
Utah chub	71.0		84.5		32.0	23.3	9.5	6.3	6.8	3.7
Mt. sucker			0		0	0	0.8	0.1	0.5	0.7
Totals	82.0		133.0		59.4	64.9	37.9	53.5	36.7	47.5

1) 150' trammel net, Forbes 1892.

2) Sharpe and Babcock 1964.

3) Dean and Mills 1969.

4) Present study.

5) These figures include an unknown number of angler-caught trout and are, therefore, not comparable.

trout population has been coincident to the decline of native cutthroat trout and probably also the Utah chub. The Utah sucker (lbs/net) may be a beneficiary species.

In 1973, the cutthroat made up only 4% of the population (as measured by the gill net catch) compared to Forbes (1892) trammel net catch indicating a contribution of 13% to the total population. Granting the difficulty of making such comparisons between different nets, locations, etc., these data would nevertheless indicate a reduction of nearly 70% in the cutthroat population. A reduction of this magnitude agrees with descriptions before and after the introduction of the lake trout.

Another factor also must be considered. It is clear that the cutthroat has always been a minority species in the total lake population and more recent minority with respect to the lake trout. Despite its small numbers, the cutthroat makes up from 25% (Vol. Ang. Report, 1973) to 43% (Heart Lake Cabin logs 1951-1973) of the angler catch. Clearly the species is being harvested disproportionately to its strength in the population.

Jordan (1891), Forbes (1893), Smith and Kendall (1921), nor Simon (1939) indicated that the mountain whitefish was present in the lake. Sharpe and Babcock's (1964) net catch was apparently the first record of the species from Heart Lake. That the whitefish is a recent and new species in the lake is unlikely. The fish has been in the upper Snake River drainage for (probably) thousands of years. Despite the high average number caught/net reported in Table 26 (8 fish per net lake wide), the catch was concentrated in only three of the eight nets set. It would appear, therefore, that the absence of the species as reported in early years was a function of small sample sizes and, apparently, the absence of the species in the angler catch.

Between 1935 and 1940, 762,692 Yellowstone cutthroats were reported as having been stocked in the lake. One of the plants (July 1937, as reported in the cabin logs) comprised 200,000 eyed eggs which were buried in Beaver and Outlet Creeks. The introduction of Yellowstone cutthroat genes into the Heart Lake stock has apparently been unsuccessful or at least minimal. Dr. Robert Behnke (pers. comm. 1969) examined some Heart Lake cutthroats and reported there was considerable evidence to indicate these trout were the pure endemic strain and appeared to be different from both the Yellowstone Lake form and the finespotted Snake River genotype. This would indicate that the Heart Lake cutthroat is a genotype unique to the lake and drainage and a form worthy of preservation, not only because of its uniqueness, but also for its potential for varied management purposes outside of the Park.

Conclusions - Recommendations

Based upon all evidence thus far obtained, the following preliminary conclusions can be advanced:

1. The Heart Lake cutthroat population is declining and is endangered.

The primary force contributing to the demise appears to inter-specific competition with the non-native lake trout. The evidence indicates that lake trout biomass and numbers continue to increase. The reported presence and possible expansion of brown trout in the lake is further cause for concern. The disproportionate pressure put on the cutthroat by angler exploitation appears to be a contributing force and may have been greater in the first half of this century than in the last twenty-five or so years.

2. The Heart Lake genotype is found in no other (known) water and is threatened with extinction.

The genotype could be diluted from rainbow input although the presence of rainbows is thus far unsubstantiated. More critical perhaps, but only a point of speculation is how far the population can dwindle before minimum population size is reached and the population essentially collapses. The loss of this genotype would not only be a great loss to the pristine concept of natural areas in the National Park Service and the loss of another unique cutthroat genotype from the West but would also be a loss to fishery management potential because of its angling qualities, its large size, and its affinity for utilizing littoral and pelagic forage fishes.

3. The endemic Utah chub population may also be declining.

Though considered a "trash" fish almost everywhere else it occurs, this species evolved and coexisted with the endemic cutthroat in Heart Lake for thousands of years. This association alone makes the population of chubs (along with the cutthroat) of unique scientific interest. The reasons for the apparent decline in chubs is not well understood but may be related to the increase in lake trout and/or a possible environmental change in the spawning-nursery areas.

4. The Utah sucker population may be increasing to the point of being deleterious to the cutthroat population.

The species runs and utilizes the same spawning beds at the same time as the cutthroat trout. It is postulated that a balance existed between the species in historic times and that present

conditions may be currently favoring the sucker in the spawning and nursery areas.

The following recommendations are proposed for Heart Lake:

1. It is recommended that the angling regulations be amended to include "catch and release" fishing only for Heart Lake cutthroat trout.
2. It is recommended that the spawning streams tributary to Heart Lake and the Heart River downstream to Outlet Creek be closed to fishing between October 30 and July 15th.
3. It is recommended that a survey be undertaken to select a lake within the Snake River drainage to expand the range of the Heart Lake cutthroat genotype for preservation purposes.
4. Further aquatic work is recommended for Heart Lake. Needs include bathymetric and limnological surveys and further ecological work on the lake proper. Projected efforts should be aimed towards enhancement of the cutthroat population at the expense of or giving injury to the lake trout population.

AQUATIC SURVEY PROGRAM

Introduction

The program of investigating the aquatic resources of the Park was initiated in 1965. During the 1973 field season, six lakes were surveyed. In addition, three streams and Heart Lake received survey-type attention and are covered in another section of this report.

Since 1965, over 50 Park lakes have been surveyed of the 60 or so that are thought to have fish-life. Barren lakes are surveyed because of the distinctive non-fish fauna and flora they contain and also to assess them as possible enclaves for the Park's rare or threatened fishes.

In addition to the six lakes surveyed, preliminary observations were made on four lakes to be surveyed in the future. Lake Abundance was visited in an attempt to determine whether the lake chub survived the 1969 rehabilitation work.

Surveys were carried out during the summer and fall months. From one to four days were spent on each individual water. Methods used were essentially the same as those used in the past and reported by Dean and Mills (1970).

Tanager Lake

Tanager Lake is a fairly large lake on the south boundary of Yellowstone Park. Access to the lake is gained by the South Boundary Trail from Snake River Ranger Station, a distance of approximately one mile. The survey was conducted on the 1st and 2nd of August 1973. Despite its close proximity to the South Entrance the lake has very few signs of human visitation and the area is, in fact, in a very pristine state.

Physical

Tanager Lake has an area of 32 surface acres and a maximum depth of approximately 11 feet (Table 28). At an elevation of 6,970 feet, it is fairly low lake by Park standards but it is in an area of high annual precipitation and has a damp and lush topographical setting.

Table 28.—Physical characteristics of lakes surveyed in 1973

Lake	Location ¹⁾	Elevation (ft.)	Approximate drainage area (acres)	Surface acreage ²⁾	Maximum depth (ft.)	Average depth (ft.)	Acre feet	Tributary to:	Major drainage
Beula Lake	S3,48N,116W	7377	4600	107	35	11.5	1231	Falls River	Falls River
Hering Lake	S3,48N,116W	7381	860	60	44	11.3	678	Beula Lake	Falls River
Joffe Lake (Reservoir)	S6,57N,114W	6500	NA	1.56	10	3.7	5.8	Glen Creek	Yellowstone River
Mallard Lake	S13,52N,116W	8026	630	32	29	9.7	310	Firehole River	Madison River
Tanager Lake	S8,48N,115W	6970	300	31	11	2.4	74	Polecat Creek	Snake River
Unnamed Lake ³⁾	S34,49N,114W	6954	20	1.13	73	28.6	32	Snake River	Snake River

1) Based upon USGS map of Yellowstone National Park, N4408-W10948/59x82, 1962, theoretical township and section lines

2) As calculated from aerial photos, ETZ series, 1969, scale 1:15840

3) Data for largest lake only—upstream lake is approximately 0.1 acres, downstream lake is approximately 0.2 acres

The lake is surrounded on three sides by a flat, wet meadow and on one side by conifers and low shrubs. Besides the South Boundary Trail which passes near the outlet of the lake, a good game trail parallels the lake along the east shore.

The water supply to the lake is comprised of a series of seeps on the north shore that originates in a wet meadow to the northeast and a small spring close to the east shore. The total inflow was not measurable but appeared to equal the outflow which was measured at 0.24 cfs.

Normal water fluctuation appeared to be about 18 inches. In high water years the lake could increase its surface area immensely.

The secchi disc was visible in the deepest portion of the lake (11 ft).

Vertical water temperature varied from 70°F at the surface to 62°F at 11 feet. The surface water temperature ranged up to 78°F in the shallower portions of the lake and the outlet stream was measured at 72°.

Over 90% of the lake bottom is composed of organic muck which in some areas is up to 3 feet thick. Two areas of rock and rubble occur along the eastern shore and around the island (Figure 12).

The drainage area contributing water to the lake is about 300 acres most of which is forested and relatively flat to rolling hills terrain.

Chemical Characteristics

Tanager Lake is an alkaline lake with low conductivity and hardness (Table 29). The pH was 8.0, dissolved oxygen was 7.5 ppm, and specific conductance was measured at 40 micromhos. There was a trace of phenothalein alkalinity and Methyl orange alkalinity was 25 ppm. Total hardness was found to be 5 ppm.

A water sample collected from the spring on the east shore showed a pH value of 6.8 but was otherwise very similar to the chemical profile of the lake.

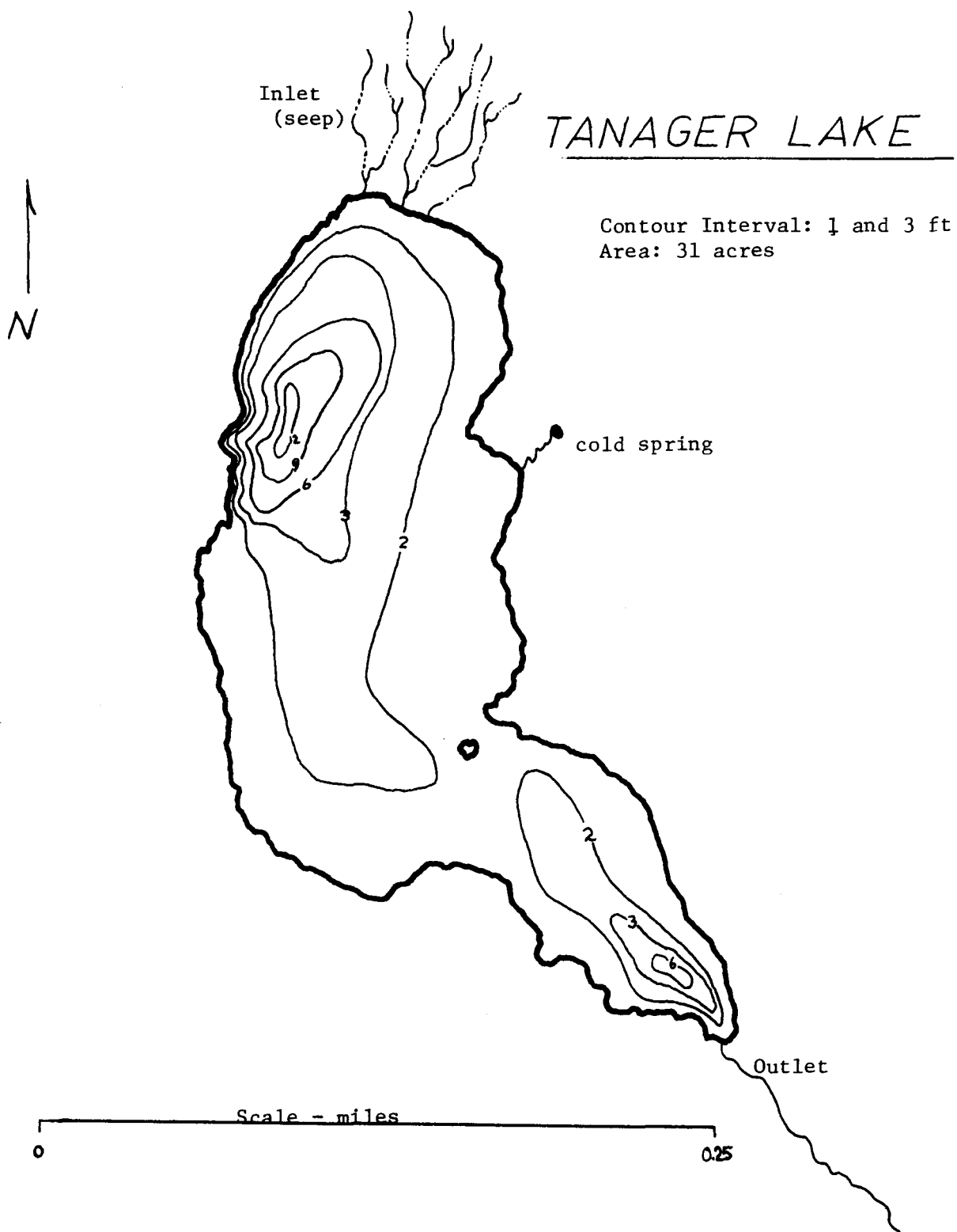


Figure 12. Tanager Lake, Yellowstone National Park, Wyoming.

Table 29. — Chemical characteristics of Yellowstone lakes surveyed in 1973 as measured in the field

Lake	Date sampled	Sample depths (ft.)	Temperature °F	pH	Specific cond. mhos	D.O. mg/l	phth. alk.	M.O. alk.	Ca hard.	Total hard.	Secchi vis. (ft.)
Beula Lake	8/29/73	6	60°	7.2	120	7.0	0	40	ND ²⁾	10	15
		30	57°	7.2	120	6.7	0	40	ND	10	—
Hering Lake	8/29/73	6	60°	7.1	40-	6.7	0	20	ND	5	20
		35	41°	6.6	20	1.2	0	25	ND	5	—
Joffe Lake	9/13/73	3	55°	8.4	220	10.5	0	120	85	110	10
		6	54°	8.4	220	9.5	0	120	85	110	—
Mallard Lake	9/6/73	6	58°	6.8	—	4.8	0	10	ND	3	16
		25	44°	6.8	—	1.4	0	20	ND	5	—
Tanager Lake	8/1/73	6	66°	8.0	40	7.5	TR	25	ND	5	11
Unnamed Lake	8/17/73	10	65°	7.6	210	8.6	0	90	65	90	41
		60	41°	7.0	260	2.8	0	105	80	105	—

1) Measurements from the middle, 1.1 acre lake

2) ND=present, not measurable

Table 30.—Checklist of aquatic vascular plants collected in Yellowstone Park from lakes surveyed in 1973

Location	Common name	Species
Tanager Lake	Water smartweed	<u>Polygonum amphibium</u>
	Little burreed	<u>Sparganium minimum</u>
	Floating-leaf pondweed	<u>Potamogeton natans</u>
	Pondweed	<u>Potamogeton sp. (prob. nodosus)</u>
	Yellow pond lily	<u>Nuphar polysepalum</u>
Joffe Lake	Muskgrass ¹⁾	<u>Chara sp.</u>
	Water milfoil	<u>Myriophyllum spicatum</u>
Hering Lake	Water smartweed	<u>Polygonum amphibium</u>
	Unidentified plant	
Beula Lake	Water smartweed	<u>Polygonum amphibium</u>
	Pondweed	<u>Potamogeton sp. (prob. nodosus)</u>
	Pondweed	<u>Potamogeton sp.</u>
	Yellow pond lily	<u>Nuphar polysepalum</u>
Mallard Lake	Water smartweed	<u>Polygonum amphibium</u>
	Pondweed	<u>Potamogeton sp. (prob. nodosus)</u>
	Green felt ¹⁾	<u>Vaucheria sp.</u>
	Unidentified plant	
Unnamed Lake ²⁾	Water milfoil	<u>Myriophyllum spicatum</u>
	Pondweed	<u>Potamogeton sp.</u>
	Water moss ³⁾	<u>Fontinalis sp.</u>

1) An alga (chlorophyta).

2) Near Snake Hot Springs, Snake River drainage.

3) A true moss (Musci).

Limnoplankton

The desmid Staurastrum was the most common phytoplankton observed (Table 36). Desmids are often used as indicators of alpine waters that are poor in productivity. The flagellated brown algae Ceratium was the only other common phytoplankton observed.

Tanager Lake's zooplankton was reasonably abundant but was represented by small species. The small species of Diaptomus and Cyclops undoubtedly are a response to the intense predation of larger forms by the redbreasted sunfish.

Aquatic Vegetation

The yellow water lily, Nuphar peltatum, was the most common plant in Tanager Lake flourishing in 60 to 70% of the area of the lake. Water smartweed (Polygonum amphibium) and little burreed (Sparganium minimum) were also readily observed (Table 30). An unidentified filamentous green algae was also common in some areas of the lake.

Littoral and Benthic Organisms

Tanager Lake had the fewest (8) taxa of aquatic organisms collected from any of the lakes surveyed in 1973. It is thought that three factors are principally responsible for this scarcity and lack of diversity:

- 1) The intense level of predation that the redbreasted sunfish must exert in the lake;
- 2) The very weak productivity potential as shown by water quality data; and
- 3) The lack of diversity in habitat, i.e., the homogeneity in depth and substrate type.

Dragon and damselflies were the most abundant organism collected (Table 32). Very large and bright red-orange dragon fly adults were common around the lake. The species (unknown) had not been observed before in the Park by survey personnel.

Large, free-swimming leeches were also commonly observed throughout the lake.

Fish Species Composition

Fish were collected from Tanager Lake with gillnets, dipnets, and electro-fishing gear. The redbside shiner, Richardsonius balteatus, was the only species found.

The presence of shiners in the lake presents an interesting distribution problem. There is no record to indicate that Tanager Lake has ever been stocked with fish. Indeed, it is poor trout habitat and personnel stocking fish in past years probably recognized that fact. The redbside shiner is native to the Snake River and Polecat Creek drainages, but the outlet creek from Tanager Lake enters Huckleberry Hot Springs thence to Polecat Creek. The hot springs provide a thermal (100°F) barrier between Polecat Creek and the Tanager outlet creek. Presently, the hot spring is thought to be inhabited by dace (Rhinichthys sp.) only. The presence of shiners in the Tanager Lake system (why not the dace?), therefore, is not readily explainable in terms of current physical features.

The existence of redbside shiners in the lake and surrounding area perpetuates a unique ecosystem in the Park. These fish along with abundant water snakes, leopard frogs, and aquatic invertebrates forms the trophic basis for the numerous belted kingfishers, blue herons, gulls, goldeneyes, and sandhill cranes observed at the lake during the survey.

Seventy-nine shiners were collected from the lake (Table 33). These fish averaged 2.6 inches (66 mm) in total length and 0.009 pounds (4 g.) each. The range in length was from 1.5 to 3.9 inches (38-100 mm). Generally, females 60 mm or less were immature and those exceeding 60 mm were in ripe, spawning condition. The high (51.2) condition factor is thought to reflect the plump condition of the pre-spawning females.

According to the literature (Carlander 1959), redbside shiners are usually finished with spawning by mid-July. If Tanager Lake shiners did not spawn until mid-to late August, as was indicated, it would be very unusual population behavior for the species.

Three age groups (I+, II+, III+) were represented in the sample. A few very large shiners (125-150 mm) were observed in the lake but were not collected. These fish were probably 4 to 5 years of age.

In many lakes where the shiner is preyed upon by salmonids or other species, it is often thought that the shiner's penchant for the eulittoral is a function of that predation. In Tanager Lake it was observed that even in the absence of piscine predation shiners stayed very close to the shoreline and avoided the pelagic epilimnion.

Table 33.—Lengths, weights, and condition factors ("C") for fish taken from five Yellowstone lakes, 1973*

Location	Species	No. nets	No. sampled	$\bar{x}$ T.L. mm (in.)	T.L. range mm (in.)	Average wt. gr. (lbs.)	Total wt. kg. (lbs.)	Weighted "C" **
Joffe Lake (res.)	Brook	1	46	228 (9.0)	156-381 (6.1-15.0)	150 (0.33)	6.9 (15.2)	46.1
Hering Lake	Cutthroat	2	56	325 (12.8)	144-468 (5.7-18.4)	404 (0.89)	22.6 (49.8)	36.7
Beula Lake	Cutthroat	2	117	239 (9.4)	73-376 (2.9-14.8)	130 (0.29)	15.3 (33.6)	30.6
Unnamed Lake @	Cutthroat	2	1	314 (12.4)	— —	312 (0.68)	0.31 (0.7)	35.7
	Mt. Whitefish	2	2	326 (12.8)	315-337 (12.4-13.3)	356 (0.78)	0.71 (1.6)	37.2
	Utah Chub	2	10	123 (4.8)	93-153 (3.7-6.0)	27 (0.06)	0.28 (0.62)	54.3
	Utah Sucker	2	10	182 (7.2)	101-275 (4.0-10.8)	79 (0.17)	0.79 (1.7)	45.5
	Mt. Sucker	2	1	178 (7.0)	— —	58 (0.13)	0.06 (0.1)	37.9
	Redside Shiner	2	34	81 (3.2)	68-109 (2.7-4.3)	5 (0.01)	0.17 (0.4)	30.5
	Entire net catch		58	120 (4.7)	68-337 (2.7-13.3)	40 (0.09)	2.32 (5.1)	—
Tanager Lake	Redside Shiner	2	79	66 (2.6)	38-100 (1.5-3.9)	4 (0.009)	0.29 (0.64)	51.2

* No fish caught at Mallard Lake.

**Weighted by the numbers of fish in each inch group.

@1.1 acre lake near Snake Hot Springs.

Conclusions and Recommendations

Tanager Lake is a unique ecosystem in Yellowstone. The presence of the presumably endemic redbside shiner has formed the basis for an expansive ecosystem involving principally avian predators but encompassing many more wildlife forms.

The redbside shiner population apparently has some unusual characteristics (i.e., spawning time) which gives them a certain "uniqueness." The population is interesting too because of the lack of interspecific competition or predation by other fish species.

We have no management recommendations other than to suggest that this area should have a high priority with regard to preservation and protection from undue human intrusion or impact.

Mallard Lake

Mallard Lake is a sizable and heavily visited lake near Old Faithful. Surveys were conducted on this water on the 24th of August, and the 5th and 6th of September 1973. Access to Mallard Lake is gained via a well-used path from the trailhead near Old Faithful Lodge. The trail is about 3 miles long and terminates at the lake.

Physical

The elevation of Mallard Lake is 8,026 feet and the surface area is approximately 32 acres. The area draining into the lake is less than one square mile. Both the inlet and outlet streams were dry during our visits. Two seemingly deep ponds occur a short distance to the west of the lake and together comprise an area of approximately 1.9 acres (Figure 13).

The shoreline is bounded by a thick lodgepole pine forest except for a talus slope near the outlet and a narrow grass-sedge meadow along the northeast shore and up the inlet stream for a short distance (Figure 13). The lake itself has good shoreline development, good protection from prevailing winds and a large littoral area. Over 1/2 of the lake is less than 9 feet deep. A peculiar mound exists in the upper center of the lake and is probably an island during extreme low water years.

The water supply to the lake appears to be primarily snow melt with some seepage. The inlet stream has no channel bed and the spring flood waters enter flowing over vegetation. The outlet stream has gravel and would be a fair spawning stream if it were not intermittent.

The maximum depth of the lake was measured at about 30 feet. Secchi visibility was 16 feet and water temperatures varied from 58°F at the surface to 44°F at the bottom. A weak thermocline was evident between the 20 and 27 foot depth.

The bottom type was predominantly organic muck although some rock and gravel was present around the shoreline.

Chemical Characteristics

Mallard Lake was the most acidic lake surveyed in 1973. Samples taken at 6 feet and 25 feet in the general area of the deepest portion of the lake revealed pH values of 6.8. Dissolved oxygen was low having values of 4.8 ppm and 1.4 ppm at 6 feet and 25 feet respectively. These lower

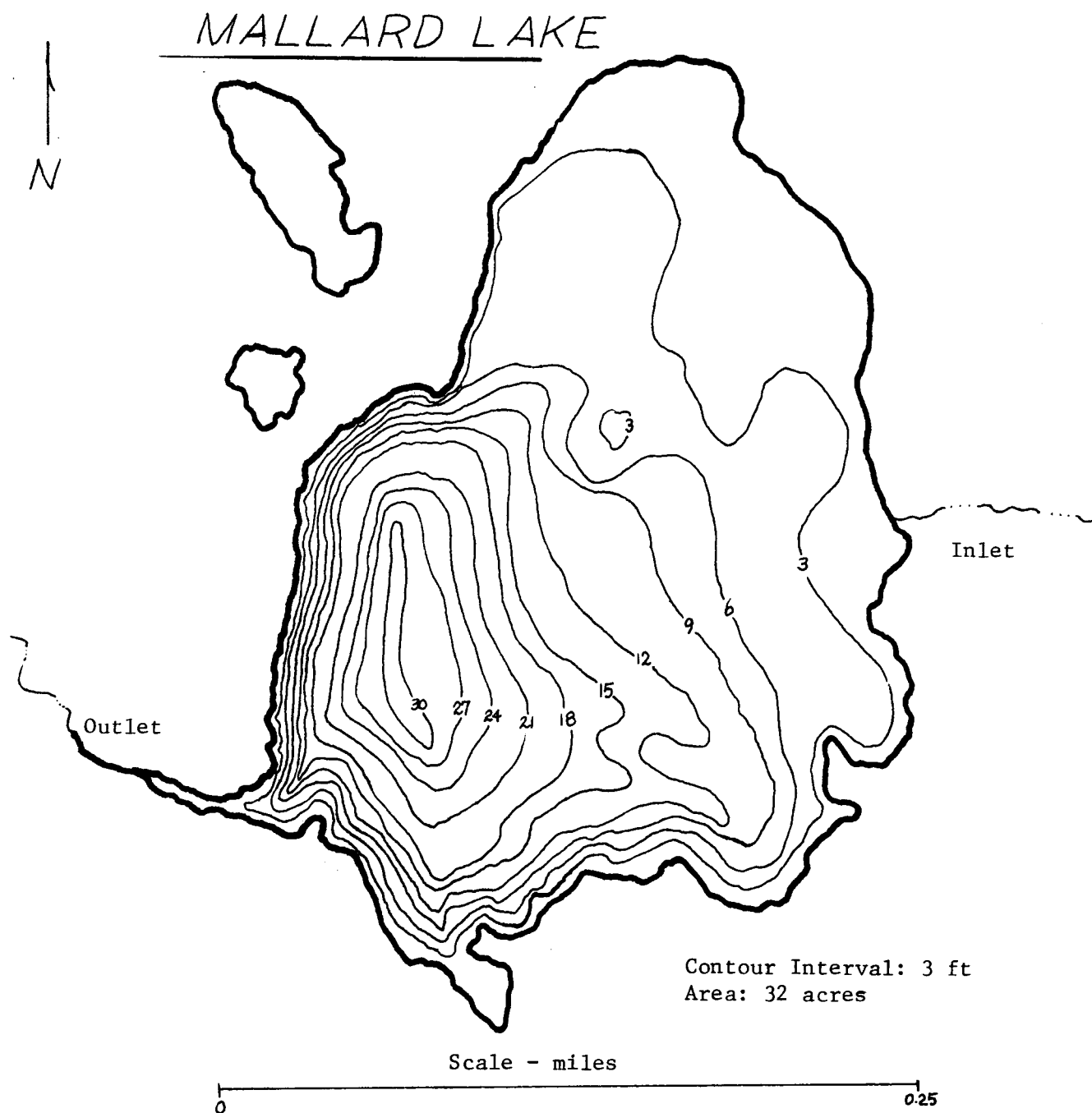


Figure 13. Mallard Lake, Yellowstone National Park, Wyoming.

than normal readings could have been the result of technique or that the fall overturn had begun increasing the B.O.D. in the epilimnion. Low readings of alkalinity and hardness coincide with the pH values in indicating the lake has a low productivity potential.

Aquatic Vegetation

Several species of sedge Carex form the principle vegetation around the shoreline although the butrush, Scirpus, is common around 50% of the shore. Water smartweed, Polygonum, is present in two extensive stands in the north and east portions of the lake. The green alga, Vaucheria, is fairly common around submerged fallen trees. A Potamogeton species and an unidentified vascular plant were somewhat less common throughout the lake.

Limnoplankton

Mallard Lake had the fewest plankters and number of genera of any of the lakes surveyed in 1973 (Table 31). This may be reflective of either low productivity or it may be suggestive of a water barren of fish life, i.e., the presence of the two larger zooplankters Chaoborus and Holopedium suggests that they are at the top of the food pyramid rather than fish. In Park waters it has been generally found that Chaoborus is only present in lakes barren of fish or waters where fish densities are very low. In these situations it appears that Chaoborus assumes the role of terminal plankton predator.

Another factor that may have explained the simplistic and meager limnoplankton was that the sampling was done at the beginning of the fall season rather than during the peak of the growing season.

The presence of diatoms in a mildly acidic water such as Mallard Lake was unexpected and is further evidence that the acidity found was a function of the season rather than an innate phenomena.

Table 31.---Checklist of common net plankton examined from lakes surveyed in 1973. Numbers are theoretical densities per liter computed following a method modified from McNabb (1960).

Classification	Common name	Joffe Lake	Beula Lake	Hering Lake	Mallard Lake	Tanager Lake	Unnamed Lake ¹⁾
Division: Pyrrophyta	Brown algae						
<u>Ceratium</u>						260	1778
Division: Chrysophyta	Yellow-green algae						
<u>Asterionella</u>			741		44		2992
<u>Fragilaria</u>		3700	143			p2)	44
<u>Synedra</u>		161					
<u>Cymbella</u>		22					
<u>Navicula</u>		52					
<u>Gyrosigma</u>					148		
<u>Dinobryon</u>				4014			208
Division: Chlorophyta	Green algae						
<u>Pandorina</u>			149	754			
<u>Closterium</u>			464				
<u>Ulothrix</u>		22					
<u>Rhizoclonium</u>		161					
<u>Spirogyra</u>		467				P	
<u>Volvox</u>		52					
<u>Staurastrum</u>				110		384	
<u>Sphaerocystis</u>				110			
<u>Westella</u>				932			
Unident. filamentous				44		44	
Class: Rotatoria	Rotifers						
<u>Keratella</u>			242	754	384		44
<u>Kellicottia</u>				44			
Order: Cladocera	Water fleas						
<u>Holopedium</u>				260	208		
<u>Macrothrix</u>		P					
<u>Daphnia</u>			143	384		44	104
<u>Bosmina</u>			242				P
Order: Copepoda	Copepods						
<u>Diaptomus</u>					44	660	44
<u>Cyclops</u>		22				260	324
nauplii		22	242	1022	44		44
Order: Diptera	Flies						
<u>Chaoborus</u>					P		
Total phytoplankton		4637	1497	5964	192	688	5022
Total zooplankton		44	869	2464	680	964	560
Total plankton		4681	2366	8428	872	1652	5582
No. genera		11	8	11	7	8	10

1) In Snake River drainage near Snake Hot Springs.

2) P=present in small numbers.

Fish Species Composition

One large and one small mesh gillnet were set overnight in water 3 to 20 feet deep. No fish were captured during these sets although one larval salamander (Ambystoma sp.) was caught. Interviews with six anglers, angling by ourselves, and the lack of any evening feeding activity during insect hatches support the premise that fish were not present. Throughout the Park survey program lakes which have limnetic salamanders and phantom midges (Chaoborus) have nearly always found to be nearly or completely barren of fish life.

From 1934 through 1943, 120,240 eyed eggs and 197,655 fry and fingerling of Yellowstone Lake cutthroat were planted in Mallard Lake. Sharpe (1970) either assumed they were still present in the lake or knew it for a fact when he reported the lake as having a cutthroat population. During our survey, grebes and belted kingfishers were active around the lake. Their presence is usually indicative of a fish population although the kingfishers could have been preying on salamanders. The greater portion of evidence suggests that Mallard Lake has restored itself to its original barren condition. There is some chance, however, that a small remnant trout population still exists. The likelihood that a small population could survive in the future without man's mass aid is dim.

Fishing Pressure

Six anglers were observed fishing on Mallard Lake on the 24th of August. None were observed during our visit in September. The lake did not show up as a part of the Volunteer Fisherman Report which would indicate that angling pressure is probably something less than 100 angling days/year.

The lake nevertheless receives heavy use. The designated camp sites are well-worn and even have a central outhouse. Campfire scars and litter are common along the well-worn trail around the lake. Several log rafts were beached on the windward side of the lake.

Personnel at the Old Faithful Ranger Station indicate that the lake receives much tourist use and also a lot of use from the army of seasonal workers at Old Faithful.

Conclusions and Recommendations

Mallard Lake is poor trout habitat primarily due to its low productivity potential and the lack of suitable spawning streams. Because of its close proximity to Old Faithful the lake receives heavy use. The added burden of fishermen if fish were present would add to this heavy use and probably create more problems.

As the lake was originally barren, it is suggested that no attempts should be made to alter its present barren or soon-to-be barren condition.

Joffe Lake

Joffe Lake is actually a small reservoir several miles due south of the town of Mammoth. The reason for the creation of the reservoir is obscure but is believed to be part of an old water system created for Mammoth's culinary and hydroelectric needs. Access is from the Mammoth-Norris Grand Loop road 1.3 miles south of Mammoth thence 0.9 miles via dirt road southerly to the lake.

One portion of the survey was accomplished on May 9 and 10 and the job was completed September 13, 1973.

At one time the reservoir was known as "Hoodoo Lake" and also "Demonstration Pond" (W.S. Chapman, Personal Communication 1974).

Physical

Joffe Lake lies at an elevation of 6,500 feet, has a total area of 1.56 acres, and a maximum depth of about 9 feet (Figure 14). This shallow basin is in a hilly setting of mixed conifers, sagebrush, shrubs, and grasses.

The lake's inlet stream had a flow of 0.8 cfs in May and 0.76 cfs in September. Outflow measurements were similar. With an average depth of 3.7 feet and a storage volume of 5.8 acre-feet the lake's volume is exchanged every several days, thus, the lake is limnologically more like a beaver pond than a true lake. Water level fluctuations appears to be insignificant.

The inlet stream to Joffe Lake comes from the Mammoth Water Supply Reservoir 1/4 mile to the northwest. The water in the upper reservoir is diverted from Glen Creek and part of the year from the Gardener River and Indian Creek. The outlet is a 50-foot pipe through the earthen fill dam. The water then cascades over rock about 25 feet, slows and reenters Glen Creek a short distance downstream.

In the inlet stream barriers to upstream fish movement begin approximately 100 yards above the lake. It is unlikely that fish could move upstream beyond about 175 yards. The total spawning area in the stream does not appear to exceed 50 to 60 square feet.

The secchi disc was visable throughout the lake.

Water temperatures were taken during the May sampling and were a uniform 40°F throughout the lake. During September, temperatures ranged from 54-55° throughout.

JOFFE LAKE

Contour Interval: 3 ft
Area: 1.56 acres



Inlet

Outlet
(pipe)

0 Scale - miles 0.1

Figure 14. Joffe Lake, Yellowstone National Park, Wyoming.

The bottom type ranges from rock to silt and sand and some organic substrate in the more heavily vegetated portions of the lake.

Chemical

Water chemistry data was collected at 3 feet and 6 feet. There were no appreciable differences between depths. The pH was 8.4 and conductivity was 220 micromhos. The total hardness and alkalinity of the water was 110 and 120 ppm, respectively. Dissolved oxygen concentration indicated saturation.

Aquatic Vegetation

Joffe Lake by mid-to-late summer is almost totally dominated by muskgrass, Chara sp. (Table 30). This species flourishes by virtue of a high concentration of carbonate-bicarbonate ions in the water supply. Water milfoil, Myriophyllum spicatum, is common as are numerous species of green filamentous algae (see Limnoplankton).

Limnoplankton

The near total absence of zooplankton and the abundance of green filamentous algae give credence to the premise that the lake is limnologically more of a "beaver pond" than a true lake (Table 31). The abundance and diversity of diatoms in a lake with a high water exchange was unexpected but probably reflects the productive water quality and the protective nature of the vascular plant beds (where the sample was taken).

Benthic Organisms

The 14 taxa of aquatic organisms collected from Joffe Lake represent the impressive diversity and productivity of the environment. All organisms were present in abundance. The four species of molluscs, numerous amphipods, mayflies, true bugs, beetles, and caddis flies (Table 32) form a broad and varied food base for brook trout.

The species collected together with the absence of dragon and damselflies probably represent the "beaver pond" nature of the impoundment.

Table 32.---Qualitative checklist of littoral and benthic invertebrates commonly found in six back-country lakes surveyed in 1973

Taxon	Common name	Beula Lake	Hering Lake	Joffe Lake	Mallard Lake	Tanager Lake	Unnamed Lake 1)
Oligochaeta	Aquatic earthworms	X	X	X	X	X	X
Hirundinea	Leeches		X	X	X	X	X
Gastropoda	Snails						
<u>Physa</u>				X			X
<u>Lymnea</u>				X			
<u>Gyraulus</u>		X		X		X	
Pelecypoda	Clams						
<u>Pisidium</u>		X	X	X	X		
<u>Sphaerium</u>					X		
Crustacea							
Amphipoda							
<u>Gammarus</u>	Scuds	X		X			
<u>Hyalella</u>	Scuds	X	X		X		X
Araneae	Spiders						X
Insecta							
Ephemeroptera	Mayflies						
<u>Paraleptophlebia</u>			X	X			
<u>Callibaetis</u>		X	X				
<u>Centroptilum</u>					X		
<u>Caenis</u>					X		
Odonata	Dragon/damsel flies						
Anisoptera							
Libellulidae		X			X	X	
Gomphidae			X				
Aeschnidae							X
Zygoptera							
<u>Ischnura</u>		X				X	
<u>Agrion</u>					X		
Hemiptera	True bugs						
Gerridae							X
Corixidae		X	X	X	X		X
Coleoptera	Aquatic beetles						
Dytiscidae		X	X	X	X		X
Hydrophilidae			X	X			X
Trichoptera	Caddisflies						
Limnephilidae				X	X	X	X
Molannidae			X			X	
Phryganeidae			X		X		
Leptoceridae					X		
Diptera	Aquatic flies						
Culicidae							
<u>Chaoborus</u>	Phantom midges				X		
Tendipedidae	Midges	X		X	X	X	
Ceratopogonidae	Biting midges			X			X
Tipulidae	Crane flies						X

1) Snake River drainage near Snake Hot Springs

Fish Species Composition

From 1945 through 1952, 34,000 fingerling brook trout were planted in Joffe (Hoodoo) Lake. All fish came from the Emigrant, Montana hatchery.

An overnight gillnet set in May produced 46 brook trout ranging in length from 6.1 to 15.0 inches (156-381 mm). The average length and weight was 9.0 inches (228 mm) and 0.33 pounds (152 g) (Table 33).

Of the trout netted 52% were aged as II+, 45% were III+, and 3% were IV+. Young-of-the-year and yearling trout were observed but not captured. The five year classes observed together with the 6 to 15 inch range in size represents a healthy brook trout population by Yellowstone (alpine) standards. The weighted condition factor, "C", of 46.1 is the highest ever recorded from a Park trout population (Table 33). As condition factors in this range generally are indicative of brook trout in hatcheries or otherwise ideal conditions, it may be concluded that Joffe Lake is an extremely productive environment.

Fishing Pressure

Although Joffe Lake did not appear on the Park-wide distribution of angler use and pressure, it is known that the lake is popular with Park residents and fishermen from nearby Gardiner, Montana. It is said by locals that the fishing in the early summer is excellent for brook trout but slows later on due to the density of aquatic vegetation and the subsequent reduction in gear efficiency. That the lake does receive fairly heavy use is shown by the well-worn trails around the shoreline. The convenience of being able to drive by auto to the lake and yet being removed from tourist pressure undoubtedly adds to its popularity. A Park lake having "large" brook trout has a special attraction in its own right.

Conclusions and Recommendations

Joffe Lake has an excellent productivity potential largely because of its water quality. The fact that it maintains a good brook trout population with an excellent size and age class structure despite fairly heavy angling pressure indicates several forces must influence population size and integrity. Emigration from the unfished water supply reservoir upstream and the lack of emigration from Glen Creek downstream may play an important role. The small size of the available spawning area may also be a significant factor.

Whatever factors are influencing the population, it is of interest that it is one of the few Park brook trout populations maintaining integrity in the face of angling pressure. Though it may be termed a quality

fishery, it is nonetheless, there at the expense of the cutthroat native to the drainage. At this time restoration of the cutthroat is not feasible largely because of the complications caused by having a culinary water supply in the drainage. In light of this and the fact that it is a "healthy" fishery, we offer no recommendations at this time.

Hering Lake

Hering Lake was surveyed from the 28th through the 30th of August, 1973. The lake is reached by trail either from Beula Lake, which is about 1/4 mile to the north or from the South Boundary trail at South Boundary Lake thence along an abandoned trail north for approximately 3/4 of a mile. Total distance by trail from the Beula Lake trailhead on the Reclamation Road is about 3 miles.

The origin of the piscine name for the lake is unknown.

Physical Characteristics

Hering Lake is found in a setting of low hills and is surrounded by a thick lodgepole pine forest. The surface area as calculated from a 1969 aerial photo is 60 surface acres. An unpublished N.P.S. report dated 1941 estimated the lake to be 14.4 acres. Maps published in that era also indicated a lake very much smaller than the present day lake. The lake level fluctuation in 1973 was estimated to be about five feet. The size of Hering Lake is quite obviously very sensitive to variations in annual precipitation, e.g. the 1930's was a decade of below normal water years whereas the 1969 aerial photograph was preceded by at least two years of above normal annual precipitation.

The map prepared in Figure 15 is drawn on the high water line although depth contours are actual soundings, therefore maximum depths would be some 5 feet deeper than those reported herein. During our survey, the maximum depth was 44 feet and the average depth was calculated at 11.3 feet. The storage was thus calculated at 678 acre-feet of water.

Twelve intermittent tributary streams drain an area of about 860 acres and furnish Hering Lake with water. Several of these tributaries have rock and gravel bottoms including the largest stream located in the south-eastern corner. It is possible that during a year of high snow pack and gradual runoff this stream could produce some trout fry.

Water temperatures taken in the deepest portion of the lake ranged from 61°F at the surface to 40° at 44 feet. A well developed thermocline was evident between 21.5 feet and 27 feet. Secchi visibility was 20 feet at the same location.

The bottom of Hering Lake is predominately composed of rock, gravel, and sand except for the deepest portion of the lake which is a thick organic muck.

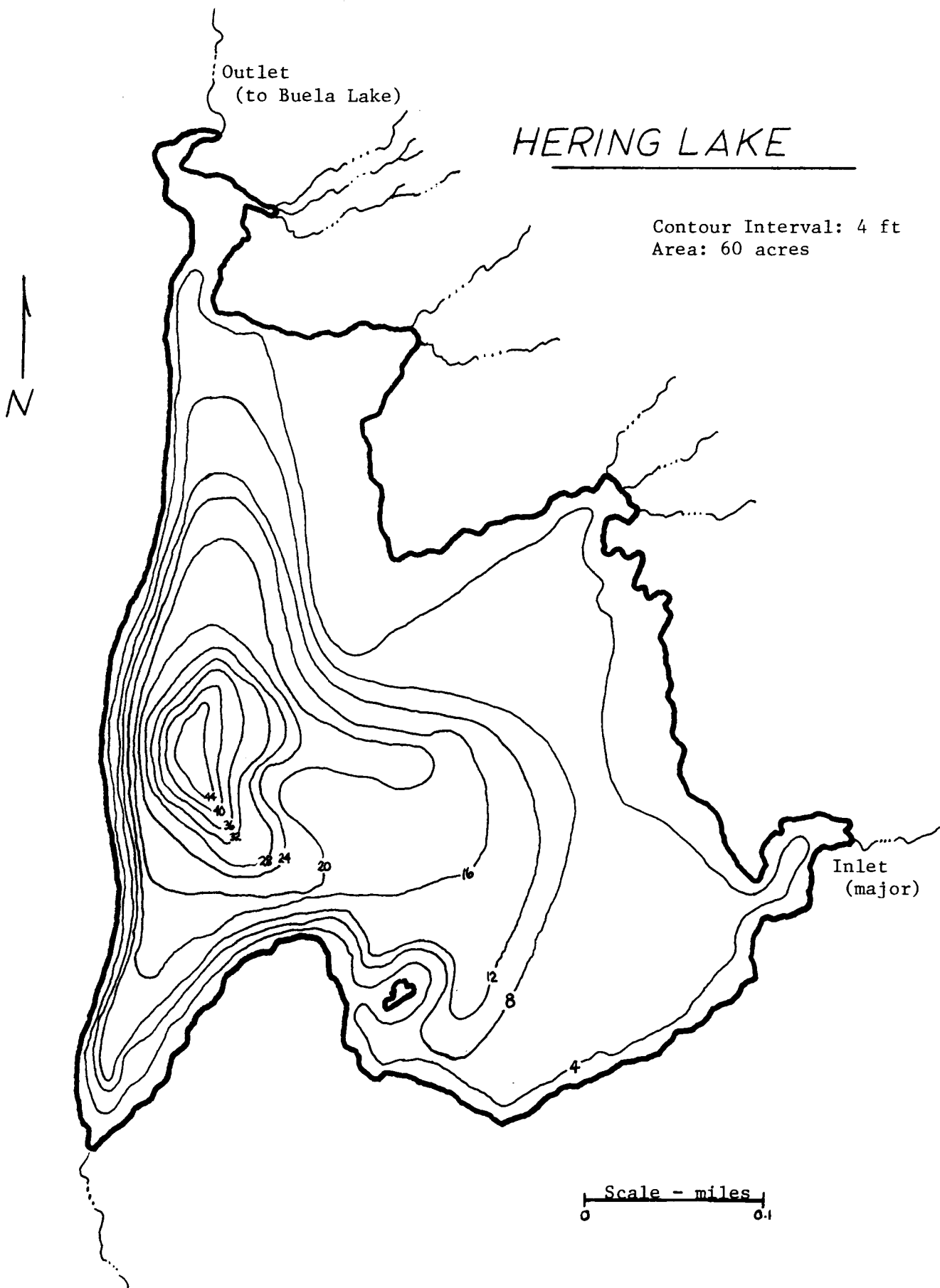


Figure 15 Hering Lake, Yellowstone National Park, Wyoming.

Chemical Characteristics

Samples were collected from 6 and 35 feet. The pH value was near neutral in the upper strata and declined to 6.6 near the bottom. Dissolved oxygen was adequate in the epilimnion but declined considerably in the hypolimnion. Specific conductance, alkalinity, and hardness values were lower than values considered normal for Yellowstone back country waters (Table 29).

The lack of an oxygenated hypolimnion is thought to be a function of the deepest portion of the lake being in a position of protection from the prevailing winds.

Aquatic Vegetation

Hering Lake supports a meager aquatic flora (Table 30). Water smartweed, Polygonum, is present in three small patches in the lake. Besides smartweed, a few specimens of an unidentified vascular plant were collected.

Limnoplankton

Hering Lake had the highest plankton counts of any of the six lakes surveyed in 1973 (Table 31). It is of no small interest that a lake with such a poor productivity potential (as measured by water quality data-Table 29) can produce such a rich and varied limnoplankton. The lack of a permanent inlet and outlet, hence a zero water exchange rate may partially explain this productivity. The fact that over 50% of the lake is less than 10 feet deep should also contribute to plankton abundance.

During our survey, the chrysophyte Dinobryon, chlorophytes Pandorina, Westella and Sphaerocystis, and the desmid Staurastrum were in bloom. The colonies of Dinobryon, estimated to number over 4,000/liter, was the densest bloom observed in the 1973 lake survey program (Table 31).

The rotifer Keratella, and the nauplii of Copepoda formed the dominant feature of the zooplankton although Daphnia and Holopedium were also present in abundance.

Littoral and Benthic Organisms

The lake possessed a diverse abundance of aquatic organisms as shown by littoral and deep water dredge collections (Table 32).

Totally, 12 taxa were represented. Two genera were collected from each of the following families: mayflies, beetles and caddis flies. Corixids, dragon flies, and scuds were also abundant.

There were several notable absences from Hering Lake. No aquatic flies (Diptera) nor snails (Gastropoda) were collected.

These collections further indicated that Hering Lake is more productive than would normally be expected.

Angler Use and Pressure

Judging from shoreline evidence it is doubtful that more than a few anglers visit Hering Lake in any given year. As the lake has heretofore been considered barren of fishlife by Park employees would also tend to minimize travel to this water. Owing to the difficulty of fishing deep water from the shoreline, the relatively sparse population, and their obviously well-fed condition, it is also unlikely that the few people who would stop and "try their luck" would have a very good chance at catching fish.

Fish Species Composition

There is no record of fish ever having been planted in Hering Lake. For many years it has been generally considered that the lake was barren of fish life. Following the element of surprise at finding a cutthroat population, speculations were made on the means of entry into the lake. It is possible that the lake was in fact planted officially but never recorded and that the population "hangs on" through limited spawning during wet years. It is also possible that it has been and/or is presently stocked unofficially. Perhaps more likely, there is reason to suspect that movement between Beula and Hering Lakes takes place during spring runoff. The channel connecting the two lakes is only 1,300 feet long with a four foot difference in elevation. During very high runoff the channel may contain a stream some 60 feet wide and 20 inches deep. While most mature Beula Lake cutthroats would "home" to their birth stream to spawn, a one to 10 percent straying rate would insure that Hering Lake would be replenished, at least during high water years.

One large mesh and one small mesh gillnet were set overnight yielding 56 cutthroat trout (Table 33). The average total length of trout caught was 12.8 inches (323 mm) with a range from 5.7 to 18.4 inches (144 - 468 mm). The average weight was 0.89 pounds (404 g).

The condition factor, "C", was calculated at 36.7 which is higher than average for Yellowstone Park cutthroat trout. This condition factor probably reflects a near optimal trout biomass as it relates to the lake's basic productivity.

Age groups I+ through V+ were represented in the Hering Lake population. The existence of I+ and II+ fish in the population could support the premise that there is natural reproduction in the lake.

Conclusions and Recommendations

Hering Lake is a remarkably productive lake considering its small drainage area and meager chemical makeup. The cutthroat trout population is robust, healthy, and relatively unexploited. The very fact that the population is for the first time reported here will add to the angling pressure on the lake. There are several potential buffers against overexploitation: the population has a well-fed condition; the lake basin has a gently sloping contour which limits the effectiveness of fishing gear; and of course, the lake will still be a relative "unknown." On the other hand, if the lake received the fishing pressure that its neighbor Beula Lake receives (together with its lacking or limited natural reproduction) it could be easily overexploited.

Hering Lake should be visited again in three to five years to ascertain whether angling pressure is substantially increased and is affecting the integrity of the population.

Beula Lake

Beula Lake is a popular and sizable lake located near Yellowstone's south boundary in the Falls River drainage. The trailhead to the lake is located in the Teton National Forest on the Reclamation Road approximately 10 miles from Flagg Ranch. Distance from the trailhead to Beula Lake is about 2.5 miles over a good and well-used trail. The lake can also be reached from an offshoot trail, now abandoned, that leaves the South Boundary Trail near South Boundary Lake thence to Hering Lake and to Beula Lake.

Beula Lake was surveyed August 28 through 30, 1973. The lake is the ultimate lake source of the Falls River.

Physical

Located at an elevation of 7,381 feet, Beula Lake has a large surface acreage (107 acres) but is fairly shallow. The maximum depth is calculated at 36 feet. The lake obviously has an expansive and productive littoral as over one-half of the lake has a depth less than the August secchi depth reading of 15 feet. Due to its size and exposure to wind the lake is also well mixed.

Water temperature taken in the deepest portion of the lake ranged from 60°F at the surface to 57°F at the bottom. There was no thermocline. Beula Lake drains an area exceeding 4,600 acres but during the survey period there was only one permanent stream entering the lake. This unnamed tributary entering the lake from the southeast is a low gradient stream flowing approximately 22 cfs. It is one of the finest trout spawning and nursery streams in the Park for (at least) a distance of three miles.

Other than some minor spring activity along the northern shore all other streams entering the lake appeared to be intermittent (Figure 16). The largest intermittent stream is the outlet stream from Hering Lake, the channel of which was about 60 feet wide and appeared to have a depth of about 20 inches. The difference in elevation between the two lakes is only four feet.

Beula Lake does not appear to have a very large annual fluctuation although it is apparent from the dead conifers along the southern shore that the lake has had above normal water levels in recent years.

The theoretical August water exchange rate for the lake was calculated at between 20 and 30 days.

The lake has a variety of bottom types including rock, sand and organic muck and were estimated to be present in approximately equal percentages.

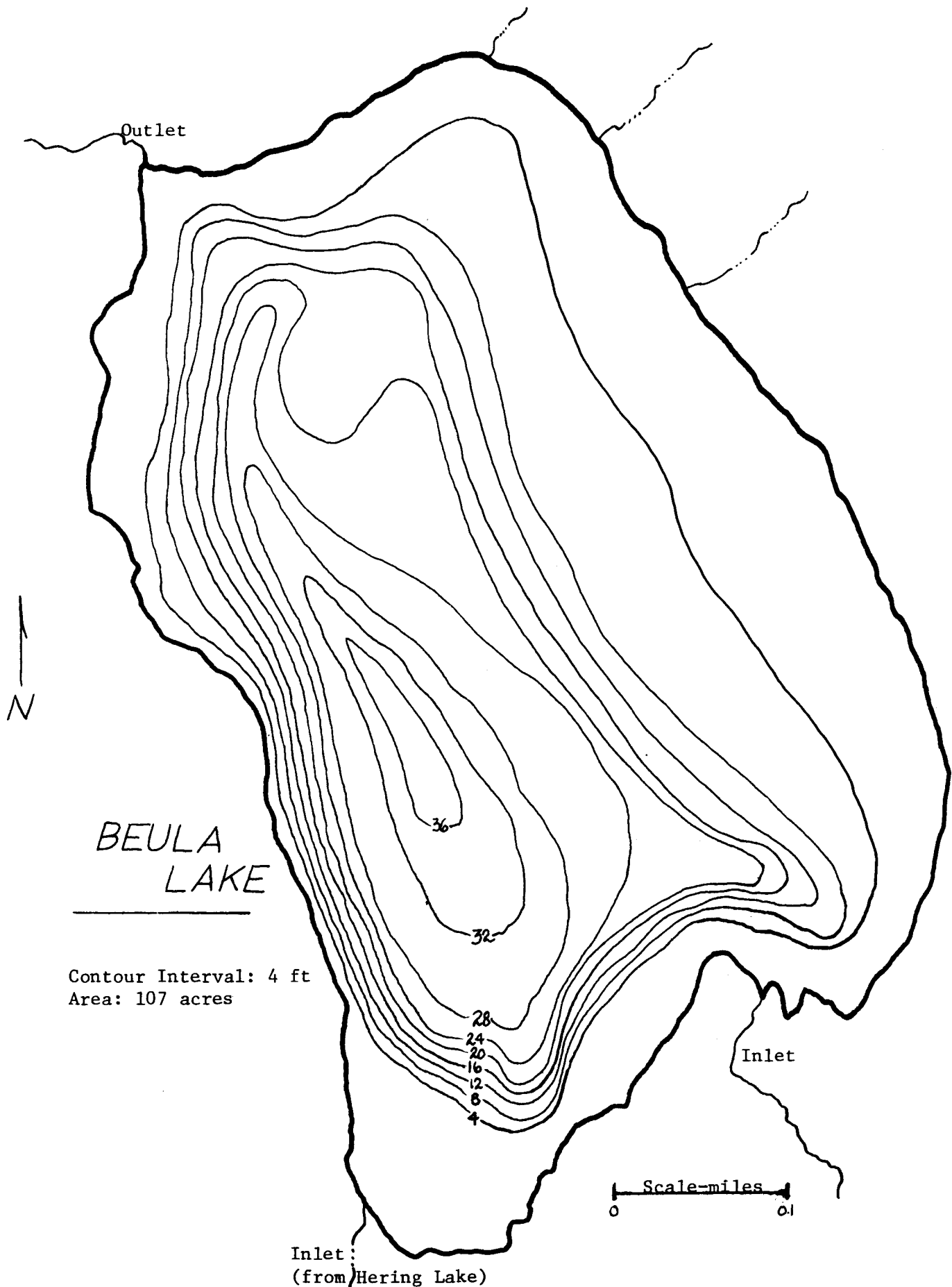


Figure 16. Buela Lake, Yellowstone National Park, Wyoming.

Chemical Characteristics

Beula Lake is a mildly alkaline lake with low conductivity and mineralization. Water samples collected from 6 to 30 foot depths showed a pH of 7.2 and high dissolved oxygen concentrations. M.O. alkalinity and total hardness values of 40 ppm and 10 ppm, respectively, were among the lowest measured in 1973 but are "normal" for Yellowstone Park.

Aquatic Vegetation

Beula Lake supports a rich aquatic plant flora. Yellow pond lilies, Nuphar, and bulrushes, Scirpus, form extensive stands near the outlet of Beula Lake, the Hering Lake outlet, and the principle inlet (Figure 16). Additionally, two pondweed species and water smartweed are common around the shoreline margin (Table 30).

Limnoplankton

Limnoplankton abundance was only fair in Beula Lake. Only eight taxa were examined which is fewer than would be considered "normal" (Table 31).

Small diatoms (Asterionella, Fragilaria) and chlorophytes (Pandorina, Closterium) dominated the phytoplankton. The zooplankton was also dominated by diminutive species (Copepod nauplii, Keratella).

It is suggested that the prevalence of small zooplankton species and lack of abundance in the lake may be a function of intense cropping by the abundant small trout, and by the high water exchange rate in the lake which would limit the full development of the plankton community.

Littoral and Benthic Organisms

The number of taxa and abundance of littoral and benthic organisms observed in Beula Lake was about normal for Yellowstone's back-country waters (Table 32).

Beula Lake was the only lake surveyed in 1973 where two genera of amphipods (Gammarus, Hyaella) were observed living sympatrically in the same water. This relationship is observed in about 50% of Yellowstone's back-country waters. Snails, dragonflies, mayflies, midges, and beetles form the remainder of the predominant food base for cutthroat trout.

The absence of free-swimming leeches (Hirundinea) may also be a function of intense fish predation.

Most of the species observed in the lake are forms well adapted for escaping fish predation by one or more means.

Angler Pressure and Use

Beula Lake did not show up on the random Volunteer Angler Report Park-wide distribution. A separate estimate, based upon registrations at the trailhead register, would indicate that the lake received approximately 1,900 angler days use in 1973. Given about 18 angler days per surface acre, this would indicate that by Park standards, Beula Lake would fall into the category of moderate or "average" use for back-country lakes. An inspection of the campgrounds and shoreline would lead one to believe that the lake was more heavily utilized than the statistics indicate. Cans and bottles are common around the entire shoreline and at least five log rafts are evident along the windward shore. The campgrounds were well-worn with numerous camp tables and shelters constructed of native materials. From the trail register it would appear that the lake is popular with boy scout troops.

Exploitation of the fishery is limited somewhat by the extensive shallow water littoral zone that surrounds the shoreline. Without chest waders or a raft, much of the deeper portion of the lake is not accessible to angling.

Fish Species Composition

Beula Lake was historically barren of fishes due to the many falls and cascades in the Falls River system. Between 1935 and 1944, 50,000 cutthroat fry and 1,095,678 eyed eggs were stocked in the lake and tributaries. All fry and eggs originated from the Yellowstone Lake Hatchery.

Due to the suitability of the lake habitat and the excellent spawning and nursery stream it is not at all surprising that the cutthroat has done so well.

One large and one small mesh gillnet were set overnight in the lake. One hundred seventeen cutthroats were captured (Table 33). They averaged 9.4 inches (239 mm) in total length and 0.29 pounds (130 g.). Age groups 0+ through V+ were represented in the net and ranged in size from 2.9 to 14.8 inches (73-376 mm). The calculated condition factor of 30.6 is lower than average by Park standards. It is biased downward by the large number of 2 to 6 inch fish in the sample and does not truly represent the empirical condition of the fishable stock. Young-of-the-year fish were

common in the littoral and age I+, III+ and IV+ were abundant in the gillnets. Age II+ and V+ trout were rare. Only two of 117 fish netted exceeded one pound. The number of two-year old trout comprising the 1971 year class were very sparse (6% of those fish netted). 1971 had the highest runoff ever measured in the Park.

Conclusions and Recommendations

Beula Lake is a large productive back-country lake that appears to fall in the category of moderate exploitation from a fishery standpoint. A significant increase in exploitation may seriously reduce the populations capacity for self-replacement. The paucity of five-year old trout and the apparent lack of VI+ and VII+ cutthroats suggests that the transition from light to moderate exploitation has taken place. Any future trend back towards light exploitation would significantly improve the population.

It is unfortunate that the Beula Lake system does not have the native Snake River (i.e., Falls River) cutthroat genotype. As it is not known if this native genotype still exists in nature and any plans or speculations on restoring the original genotype would be premature. Because of its headwater isolation, the lake would be a prime area for such a restoration.

It is recommended that the lake be revisited in three to five years to reassess the rate of exploitation.

Unnamed Lakes (Near Snake Hot Springs)

Three unnamed lakes approximately 1/4 mile north of the thermal area known as Snake Hot Springs were surveyed on July 16 and 17, 1973. Access to these lakes is via the South Boundary trail about 5.5 miles northeast of the trailhead at South Entrance.

These lakes have various names locally. Forest Lake has been used, but that name is probably a confusion with the Forest Lake located about 2.75 miles to the southwest. The lakes are also in close proximity to Forest Creek (3/4 miles, SW) although there is no physical connection. Snake Hot Springs Lakes has been used because of proximity to a named area, but again there is no connection. The only known written reference to the lake is Chapman's (1964) trail guide, but he did not mention a name.

Perhaps an appropriate name would be "Little Heart Lake" because of its near-perfect heart shape and because of its similar aquatic ecology with Heart Lake. The latter feature will be developed in a later paragraph of this report.

Physical

The three unnamed lakes lie at an elevation of 6,954 feet and altogether make up only about 1.57 acres (Figure 17). They exist on the Snake River floodplain between Red and Forest Creeks in a mixed conifer and grassland setting.

The upstream and smallest (0.13 acres) of the three lakes is about 15 feet deep and is populated by larval salamanders. The middle and largest lake is 1.13 acres, 73 feet deep, and has a rich diversity of fish fauna. The lower, downstream lake is about 18 feet deep and is populated with redbreast shiners.

The three lakes are interconnected by streams during spring runoff periods and probably have a running outlet to the Snake River through a complicated maze of channels during high water. During our visit all channels were dry except for an occasional water pocket. Water for these lakes currently originates from snow-melt from the small (20 acres) watershed to the north. Water is not collected in a central stream but rather enters at numerous places at each lake and along the connecting channel.

UNNAMED LAKES

(NEAR SNAKE HOT SPRINGS)



Contour Interval: 5 and 10 ft
Area: Middle Lake, 1.1 acres

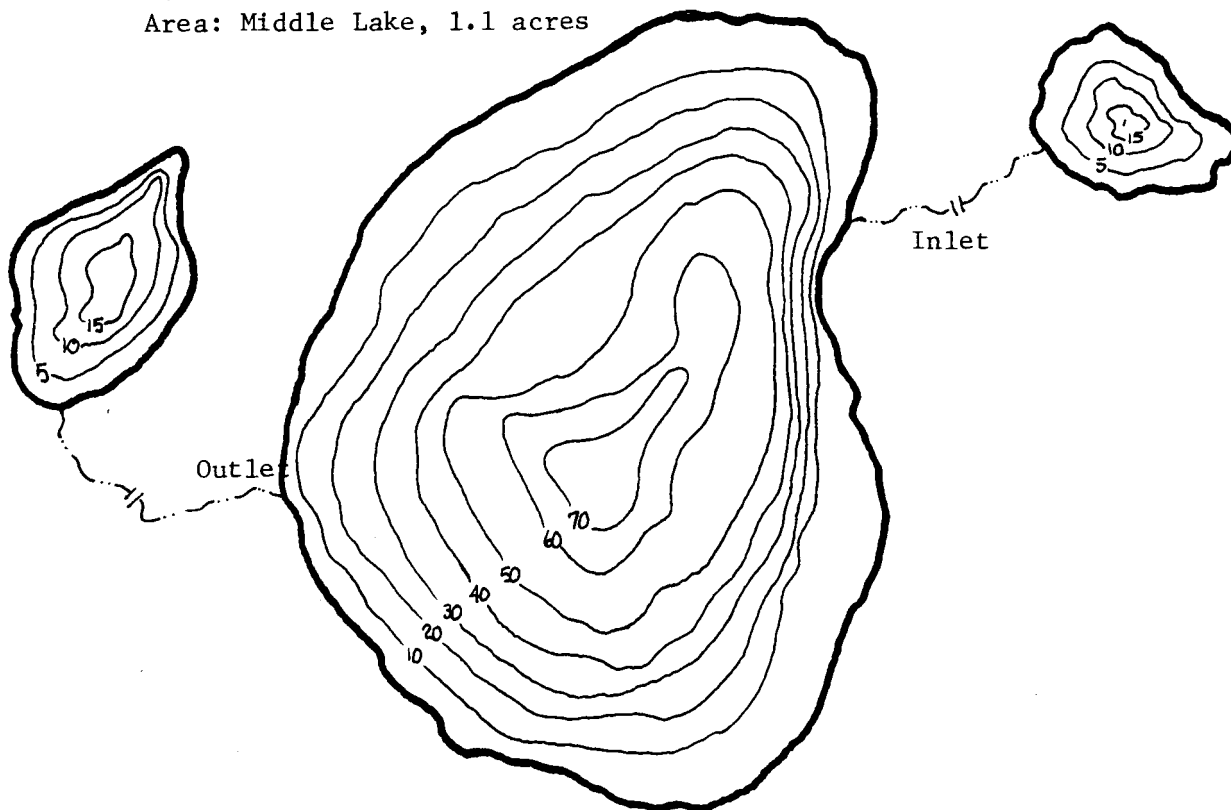


Figure 17. Unnamed Lakes (near Snake Hot Springs), Yellowstone National Park, Wyoming.

Tributaries leading into these lakes are all mud and are choked with grasses and sedges. There are some areas of gravel in the outlet from the lower lake. It is possible that spawning could occur in the middle lake at the point of the inlet while the inlet stream is running.

Data presented henceforth centers on the middle and largest lake.

The middle lake is a deep, azure pool with a uniform bottom type of typical alluvial rock. Annual water fluctuation appears to be as much as 3 feet; and during our visit the lake level appeared to be some 18 inches below the high water level for the year.

The littoral zone is extremely limited. The water is 3 to 4 feet deep approximately 4 feet from shore but then drops off precipitously.

Water temperatures ranged from 65°F at the surface to 41° at 50 feet and thence to the bottom. A well-developed thermocline was present between the 17 and 21 foot depth which was not unexpected in light of the depth of the lake, its small size, and the wind protection offered the lake by the surrounding forest.

The presence of three lakes of considerable depth in an active floodplain is an anomaly. "Holes" of this depth are not found in the Snake River proper. An inspection of the aerial photos of the lakes indicate that at some time in recent geological history they were a part of a meander of the Snake River. Judging from the direction of present bank cutting, they will be a part of the Snake River again in the future. It is also possible that they receive a part of their maintenance supply of water from river water perculating through the porous alluvial strata. This point is contradicted, however, by water chemistry data.

Chemical Characteristics

Chemical profiles were taken in the middle lake at the 10 foot and 60 foot depths. Dissolved oxygen was 8.6 ppm and 2.8 ppm at the upper and lower depths, respectively. The pH value was 7.6 at 10 feet and declined to neutrality (7.0) at 60 feet. Total hardness was 90 ppm and 105 ppm at the upper and lower strata. Calcium hardness made up about 75% of the total at both depths. No phenothalein alkalinity was found. Methyl-orange alkalinity values were exactly the same at each depth as the total hardness values. Specific conductance was 210 micromhos at 10 feet and 260 micromhos at 60 feet.

The chemical profile from the lake was different than the EPA measurements of the Heart River and the Snake River. This may be a further indication of cold-spring activity in the lake.

Aquatic Vegetation

The middle lake had the sparsest aquatic plant flora of any of the lakes surveyed in 1973. One stalk of water milfoil, Myriophyllum, was collected along with a few sprigs of a Potamogeton species and true water moss, Fontinalis (Table 30). The remainder of the benthic and littoral flora is made up of periphyton. The presence of water moss is usually indicative of cold-spring activity.

Limnoplankton

The phytoplankton of the lake was dominated by the brown algae Ceratium and the diatom Asterionella (Table 31). Ceratium is a common Park form, as in the diatom species. Five species of zooplankton was observed of which Cyclops and Daphnia were most abundant.

Ten genera were collected which indicates a diversity about normal for Park waters.

Littoral and Benthic Organisms

Dredge samples could not be obtained in the lake due to the rocky substrate, therefore, the following is a synopsis of littoral forms only.

Thirteen genera representing ten orders were represented in the collections. There were no genera that appeared to dominate the fauna but rather many forms seemed to share codominance.

The lake was the only lake surveyed in 1973 where aquatic spiders, crane-fly larvae, and a species of Gerridae were collected (Table 32). Overall, the lake has a rather rich diversity and a good abundance of aquatic organisms.

Angling Pressure

Angling pressure seems to be very high for a lake of this size. Six to eight campfire scars were in evidence as was litter. A well-worn (fisherman) trail was apparent around the lake.

The presence of gamefish in the middle lake was probably little known until the publication of Chapman's (1964) pamphlet entitled Yellowstone Back-Country. In this publication he details the location of the lake and adds that fishermen passing through the area should "give it a try". It is possible that only recently pack strings departed from the main (South Boundary) trail and created a well-used trail by these lakes. The trail would appear to be a popular bypass that ultimately connects up with the Heart Lake trail near the mouth of Red Creek.

Fish Species Composition

Two large mesh gillnets were set overnight in the middle lake. Fifty-eight fish comprising six species were collected (Table 33). All species were endemic Snake River forms. One cutthroat and two mountain whitefish were the only sport fish caught, the remainder being Utah chubs, Utah suckers, mountain suckers, and redbreasted shiners. Dace (Rhinichthys sp.) were observed in a thermal pool several hundred yards to the east of the lake and may also be present in the middle and lower lakes.

Considering the small size of the lake and the lack of any apparent lotic spawning areas, a very interesting and delicate balance must exist between all species.

Conclusions and Recommendations

As a result of evidence gathered in 1973, it is apparent that this chain of small lakes may be of unique scientific value due to the following physical, chemical, and biological features:

1. All three lakes have very deep, cup-shaped basins that are geological anomalies in a young river floodplain.
2. There is evidence that the chemistry of these lakes may be significantly different from the waters of the Snake River and surrounding watershed.
3. The middle and largest lake is the only known water in the Park's Snake River watershed that has not been invaded by exotic fish species.

As the last known preserve of the original Snake River fauna, these lakes should be totally protected for preservation and research purposes. Accordingly, it is recommended that they be closed to angling and that camping in the vicinity be discouraged.

Lake Survey Reconnaissance

Preliminary reconnaissance visits are made to each lake prior to full scale survey venture. In 1973, five lakes were visited to study the feasibility of carrying out an aquatic survey. A brief synopsis of these visits follows.

Aster Lake

Aster Lake is located about 4 miles from the South Entrance road, up Aster Creek, near the base of Factory Hill (S14, 50N, R114W). The lake was visited on August 8, 1973. There is no trail to the lake and the overland route through wet meadows and downed timber is tough. Perhaps a better route (it is about the same total distance) is to travel up the Heart Lake trail approximately 2.5 miles thence due south through a draw about 1.5 miles to Aster Lake. A portion of the unnamed draw has an old abandoned trail. Either route is difficult going for trail stock.

Aster Creek receives most of its water from the two tributaries (on the map) issuing from the Red Mountains and from accretion flows from bogs and wet meadows. The tributary from Aster Lake was dry. No fish were observed in Aster Creek. The abundance and species of aquatic moss observed in the stream indicate high carbon dioxide concentrations. No physical barriers to fish movement were observed but not all of the stream was observed.

The lake covers about 14 acres and is located in a minute basin reminiscent of the Squaw Lake basin near Yellowstone Lake. There were no visible inlets nor even channels to collect the limited snowmelt. Spring activity is indicated underwater along the east shore. The outlet was small and dry.

Water lilies ring the entire margin of the lake and outwardly some 10 to 30 feet. Thereafter, the lakebed appears to drop off. The lake gives the appearance of being very deep.

Aster Lake was planted with 5,150 fingerling cutthroats in 1940. Recent reports (rumors) have indicated a brook trout population. Limited angling and observation at the lake produced no sign of fishlife. The apparent complete absence of lotic spawning grounds probably precludes salmonid reproduction.

Forest Lake

Forest Lake is reached via the South Entrance trail from South Entrance about 2.3 miles northeast thence 1/4 mile due east through heavy timber (S31, 49N,

R114W). The lake was visited on July 27, 1973.

Forest Lake covers about 9 acres and lies in a heavily timbered setting. The lake has no permanent inlets nor outlet. As no spring activity was observed, the lake is probably supplied with water from snowmelt. Lake level fluctuation appeared large, perhaps 4 to 6 feet. Most of the shoreline is sandy - very little organic substrate was seen. The basin appeared to be fairly shallow although some deep portions may exist. No aquatic plants were seen. No signs of any fish-life were observed. The lake has no record of ever having been planted with fish. The high water outlet appears to go directly down (south) and over cliffs overlooking the Snake River which would preclude fish emigration.

Lake of the Woods

Lake of the Woods is reached from a trailhead at Lemonade Creek on the Mammoth-Norris road. The lake is approximately 1.5 miles from the trailhead although it lies in heavy forest and requires "bushwhacking" for about 1/8 mile northeast of the trail (S27, 48N, R116W). It is not marked. The lake is large (29 acres) but has no visible inlets or spring activity. There may be some thermal influence from the north although no running water was observed.

The outlet (tributary to Solfatara Creek) was dry on the day visited (August 7, 1973) although some stagnant water pockets existed downstream. The lake does not appear to have changed since visited by Forbes in 1889. He described a dry outlet and the total lack of permanent inlets.

The lake is ringed with water lilies but appears to have some depth towards the center. The water gives the appearance of being very productive.

Lake of the Woods was planted with 5,000 rainbow trout in 1937. Both cut-throat and brook trout were rumored to have been stocked, but no record of these plants exists. There were no signs of fish-life observed during our visit. It is not known if there are barriers to fish migration between the lake's outlet and Solfatara Creek, 2 to 3 miles to the southeast.

South Boundary Lake

South Boundary Lake is a 10 acre lake located on the South Boundary of the Park in the headwaters of Glade Creek (S10,11,48N,R116W). It is about 2/3 mile southeast of Hering Lake, but a low divide separates the Falls River drainage (Hering Lake) from the Snake River drainage (Glade Creek). The lake can be reached via the South Boundary trail or from Hering Lake along an abandoned but marked trail.

The lake is totally a "lily pad" lake indicating little depth and subsequently severe freezing conditions. There are no permanent inlet or outlet streams. It is highly unlikely that it has ever or now supports a fish population. There is no record of it ever having been planted with fish.

Lake Abundance

Lake Abundance is located in the Absaroka National Forest, Montana approximately seven miles northwest of Cooke City (S32,84N, R109W). The lake is in the headwaters of Slough Creek and in 1969, was chemically treated to remove lake chubs, Couesius plumbeus. The lake was subsequently replanted with McBride Lake (Slough Creek) cutthroats.

The lake was visited in the fall of 1973. No signs of the lake chub were observed in the lake. Numerous cutthroat fry were seen in the lake's inlet stream and somewhat fewer were noted in the lake's littoral zone.

LEWIS LAKE

A voluntary creel census of private boat anglers using Lewis Lake (2,716 acres) was conducted in 1973. Only one creel stand was used and was placed at the boat launching ramp near the campground.

Boat fishermen expended 8,844 angler days, fished 35,596 hours, and landed 9,981 trout for a landing (catch) rate of 0.28 trout per hour. Brown trout predominated and made up 75% of the catch. Lake trout were the second most common species. A few brook trout were also reported. Lewis Lake contains a substantial population of Utah chubs but this species is rarely caught.

Results of the 1971, 1972 and 1973 census are shown in Table 34. The major changes noted in 1973 were decreases in the number of trout caught and the landing rate.

Table 34.—Results of the voluntary creel census on private boats, Lewis Lake, 1971-1973

	Year		
	1971	1972	1973
Angler days	6,026	8,357	8,844
Angler hours	26,756	41,078	35,596
Trout landed	9,470	15,182	9,981
Trout creeled	7,756	10,748	5,212
Landing rate (trout per hour)	0.35	0.38	0.28
Creeled rate (trout per hour)	0.29	0.27	0.15
Average length of trip (hours)	4.44	4.92	4.02
Average number of anglers per boat	2.66	2.73	2.85
Average length of trip (days)	1.60	1.76	1.80
Boat permits issued for Lewis Lake	1,398	1,668	1,511
Species composition of catch (percentage)			
Brown trout	74%	63%	75%
Lake trout	26%	37%	23%
Brook trout	...	...	1%
Unknown species	...	...	1%
Residence of boat anglers by state (percentage)			
Wyoming	15.0%	17.0%	16.0%
Utah	18.4%	10.5%	17.0%
Idaho	5.0%	10.4%	0.2%
California	7.2%	9.1%	13.8%
Colorado	13.3%	4.6%	12.4%
Other states	41.1%	48.4%	40.6%

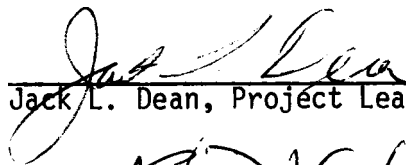
ACKNOWLEDGEMENTS

This report is the collective efforts of numerous individuals who deserve mention for their contributions.

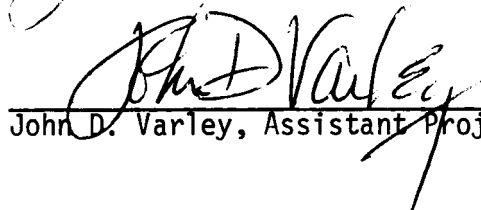
Ms. Sandy Rubrecht compiled much of the data, typed the tables, and assisted with the creel census and biological collections. Mr. Thom Johnson, Mr. Robert Ruediger, Ms. Rae Brown, and Ms. Peggy Davenport assisted with the collections of most of the data appearing in this report.

Messrs. Mike Cohen and Mike Robinson provided assistance as unpaid volunteers through the National Park Services "Volunteers in Parks" (VIP) program. National Park Service biologists Pete Hayden and Kelly Rubrecht from Grand Teton National Park provided equipment and assisted with some of the electro-fishing studies on the Gibbon River.

Prepared by:

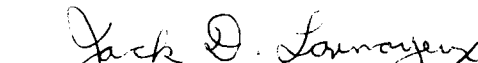


Jack L. Dean, Project Leader



John D. Varley, Assistant Project Leader

Reviewed by:



Jack D. Larmoyeux, Area Supervisor
Fish Hatcheries, Billings Area Office

LITERATURE CITED

- Benson, N.G.; Cope, and Bulkley, R.V. 1959. Fishery Management Studies on the Madison River System in Yellowstone National Park. U.S. Fish and Wildlife Service, Spe. Sci. Report, Fish. No. 307. 29 p.
- Carlander, K.D. 1969. Handbook of Freshwater Fishery Biology, Vol 1. Iowa St. Univ. Press, Ames, Iowa. 752 p.
- Chapman, W.S. 1964. Yellowstone Backcountry. Yell. Libr. and Mus. Asso. Yellowstone National Park
- Cope, O.B. 1957. The Choice of Spawning Sites by Cutthroat Trout. Ut. Acad. Proc. 34: pp.73-79.
- Dean, J.L. and Mills, L.E. 1970. Annual Project Report - Fishery Management Investigations - Yellowstone National Park. Calendar year 1969. Unpubl. mimeo. Bur. Sport Fisheries and Wildlife. 100 p.
- Evermann, B. W. 1893. A Reconnaissance of the Streams and Lakes of Western Montana and Northwestern Wyoming. Bull. U.S. Fish Comm. 11: p. 60
- Forbes, S. A. 1893. A Preliminary Report on the Aquatic Invertebrate Fauna of the Yellowstone National Park, Wyoming and the Flathead Region of Montana. Bull. U.S. Fish Comm. for 1891, 11: pp.207-256.
- Jordan, D.S. 1891. A Reconnaissance of the Streams and Lakes of the Yellowstone National Park, Wyoming in the Interest of the U.S. Fish Commission. Bull. for 1889, Vol. 9: pp.41-63.
- Kendall, W.C. 1915. Fishes of the Yellowstone National Park. Bur. Fish Doc. No. 818. 28 p.
- Seamans, J.E. 1940. A Report on a Survey of some of the Trout Streams of Yellowstone National Park. National Park Service. Unpublished type-written. 28 p.
- Sharpe, F. P. 1970. Yellowstone Fish and Fishing. Yellowstone Libr. and Mus. Assoc., Yellowstone National Park. 49 p.
- Sharpe, F.P. and Babcock, W.H. 1964. Reconnaissance Report - Fishery Management Program - Yellowstone National Park. Unpubl. mimeo. Bur. Sport Fish and Wildlife. 18 p.
- Simon, J.R. 1939. Yellowstone Fishes. Yellowstone Libr. and Mus. Assoc., Yellowstone National Park. First ed. 40 p.

Smith, H.M. and Kendall, W.C. 1921. Fishes of the Yellowstone National Park. Bur. Fish. Doc. No. 904. 30 p.

Vincent, E. R. 1967. A Comparison of Riffle Insect Populations in the Gibbon River above and below the Geyser Basins, Yellowstone National Park. Limnology and Oceanography, 12:1, pp. 18-26.

Preface to the Appendices

A new element was added to the project activities during the 1973 field season in the form of "Special Projects" for seasonal personnel. During project activities numerous questions often arise for which there is little or no information available to aid in making a given management decision. While these needs are consistently present, there often is too little time available to the permanent project staff to seek the answers required. "Special Projects" were initiated to answer specific management needs. Such projects are limited scope research tasks that are added to a master list as needs become apparent. Seasonals are asked if they wish to participate in the volunteer program and they select a project in which they may have a specific interest. They are given time (in 1973 averaging 4 days/month), equipment, and a relatively free hand to design and carry out the research. Each of the individuals additionally gave a significant portion of their own personal time in completing their projects prior to fall departure.

The results presented (Appendix A through E) prove the success of the program in terms of answering management needs. Further, the individuals participating unanimously agreed that the "Special Project" approach was both enjoyable and instructive.

Appendix A is a study entitled "The Predation of Cutthroat Trout on Redside Shiners in Pelican Creek" by Rachael R. Brown. This study arose from past references to the fact that the Yellowstone cutthroat is not and has never been a piscivore. Ms. Brown refines that statement.

For at least six decades the white pelican on Yellowstone Lake has been maligned and even destroyed because of the large numbers of trout required to sustain the population. Past estimates of pelican consumption has ranged as high as 400,000 pounds/year. This figure is close to the maximum sustained yield for the lake calculated for human anglers. Ms. Margaret D. Davenport (Appendix B, "The Piscivorous Avifauna on Yellowstone Lake") addressed this problem and attempted to refine estimates of bird predation on the cutthroat trout. The report presented here is an interim report as the subject has been expanded and further work will be carried out in 1974.

Appendix C was also prepared by Ms. Davenport in response to a need for a definitive review of the literature on the longnose sucker. This species is an exotic in Yellowstone Lake and has undergone a substantial population increase in the past decade.

A revaluation of whether or not Yellowstone Lake has undergone any major ecological changes since white man first visited the area is a continuing subject of interest for project biologists. Mr. Thom H. Johnson (Appendix D, "The Species Composition and Relative Abundance

of the Planktonic and Benthic Organisms of Yellowstone Lake") sought to answer this question with regard to planktonic and benthic organisms.

It has been noted by several biologists in recent years that certain road culverts on tributaries to Yellowstone Lake may partially or wholly block runs of migrating cutthroats from the lake. Mr. Robert Ruediger (Appendix E, "Culverts and Fish Migration from Yellowstone Lake") inventoried and analyzed every road culvert in the lake drainage and reports on problem areas.

APPENDIX A

The Predation of Cutthroat Trout on
Redside Shiners in Pelican Creek

by

Rachael R. Brown, Biological Aid (Fisheries)
Fish and Wildlife Service
Yellowstone Fishery Investigations
Yellowstone National Park, Wyoming

INTRODUCTION

The exotic redbside shiner, Richardsonius balteatus, was first observed in Yellowstone Lake and its tributaries by the U.S. Fish and Wildlife Service in 1957. It appears that this species has since increased in number and therefore warrants study concerning its population and inter-relationships with the native Yellowstone cutthroat trout. It is known that Pelican Creek, the second largest tributary to Yellowstone Lake, is an important spawning stream for cutthroat trout and redbside shiners thus making it a suitable location for studying trout-shiner interactions. This Bureau has operated a fish trap on Pelican Creek to study the spawning runs of cutthroats and shiners. In 1970 and 1972 Bureau workers observed cutthroat trout preying on redbside shiners as the shiners, after being weighed and measured, were returned to the stream. Although this situation was an artificial one since the trap was in operation and the shiners were distressed from being handled, it was intriguing since previous food habits studies (Benson, 1961) showed that cutthroat trout seldom preyed on small fish.

On July 8, 1972, 27 trout were caught near the Pelican Creek fish trap by hook and line and by dip net for stomach analysis to help determine the extent of predation of cutthroats on shiners. The results of the analysis showed three possible correlations between the two species. The first indication was that the trout sampled were feeding predominantly on the smaller shiners or the males in the spawning run. Secondly, there appeared to be a correlation between increased cutthroat length and frequency of shiner consumption. Finally, the study suggested that shiner frequency in the stomachs was lower in ripe females than it was in post-spawning males and females. (Dean and Varley, 1973)

In 1973 this study was conducted to elucidate the above possibilities. Because the trap was not operated in 1973, the unnatural situation involving the trap and distressed shiners was eliminated.

METHODS

The collecting was done in early July after observing shiners going upstream to spawn and after observing trout already in the stream. Sixty-nine cutthroats were taken by hook and line between July 4 and July 17, 1973 (Table 1). Of the 69 trout caught, 62 were caught on lures, 5 on flies, and 2 on a lure-bait combination. The cutthroats were preserved immediately in 10% formalin. Before the stomach analyses were performed, the trout were placed in a water-formalin neutralizer mixture and soaked. Information obtained on each trout was length, weight, sex (including ripe or spent female, alternate or consecutive year female spawner), volume of fish food in stomach (volumetric measurements obtained by measuring volumetric displacement in water), and when possible number, species, length, and sex of each stomach fish.

Table 1.—Cutthroat trout stomach analysis, Pelican Creek, 1973

Collecting date	Time & Water temperature	Contents of cutthroat trout stomachs		
		Empty	Food other than fish	Fish food
7/5/73	10:30 am 55°F	6	6	11
	2:30 pm 65°F	6	8	6
7/9/73	1:30 pm 62°F	3	2	2
7/11/73	1:30 pm 64°F	5	4	
7/13/73	10:00 am 54°F	3		
7/16/73	2:00 pm 64°F	1	2	4
Totals		24	22	23

Table 2.—A comparative analysis of 27 stomachs taken from mature cutthroat trout, Pelican Creek, July 1972 and of 69 stomachs taken from mature cutthroat trout, Pelican Creek, July 1973

Year	Empty		With foods other than fish		With fish	
	No.	Percent	No.	Percent	No.	Percent
1972	8	29.7	10	37.0	9	33.3
1973	24	34.8	22	31.9	23	33.3
Mean no. of fish per stomach ¹						
Range						
				1972 ² 2.9 ⁿ		1973 ³ 1.7 ⁿ
				1 to 7 per stomach		1 to 6 per stomach
Mean size of fish per stomach				3.6 ⁿ		3.8 ⁿ
Range				3.0-4.3 ⁿ		2.6-4.5 ⁿ
Mean size of cutthroat sampled				14.1 ⁿ		14.5 ⁿ
Range				11.3-17.8 ⁿ		9.8-16.5 ⁿ

¹ Mean number of fish in stomachs containing at least one fish per stomach.

² Fifteen out of 26 fish taken from stomachs were identifiable and were all redbside shiners.

³ Fifteen out of 39 fish taken from stomachs were identifiable. Fourteen were redbside shiners and one a longnose dace.

Table 3.---Cutthroat trout stomach analysis, Pelican Creek, 1973

	Female alternate*	Female consecutive	Male
7/5/73			
Empty	2	4	6
Other food	1	3	10
Fish food	4 { 1 trout-6 minnows 1 trout-1 minnow 1 trout-2 minnows 1 trout-3 minnows	3 { 1 trout-3 minnows 1 trout-1 minnow 1 trout-1 minnow	10 { 1 trout-1 minnow 1 trout-1 minnow 1 trout-3 minnows 1 trout-1 minnow 1 trout-2 minnows 1 trout-1 minnow 1 trout-1 minnow 1 trout-1 minnow 1 trout-1 minnow
7/9/73			
Empty	---	---	3
Other food	---	---	2
Fish food	1 trout-1 minnow		1 trout-2 minnows
7/11/73			
Empty	2	---	3
Other food	1	---	3
Fish food	---	---	---
7/13/73			
Empty	---	2	1
Other food	---	---	---
Fish food	---	---	---
7/16/73			
Empty	1**	---	---
Other food	---	---	2
Fish food	2 { 1 trout-2 minnows 1 trout-1 minnow	---	2 { 1 trout-2 minnows 1 trout-1 minnow

* A female was an alternate spawner if she had only small eggs and no large ones.
A female was a consecutive spawner if she had large and small eggs.

** One female had no small eggs and was labeled "spent".

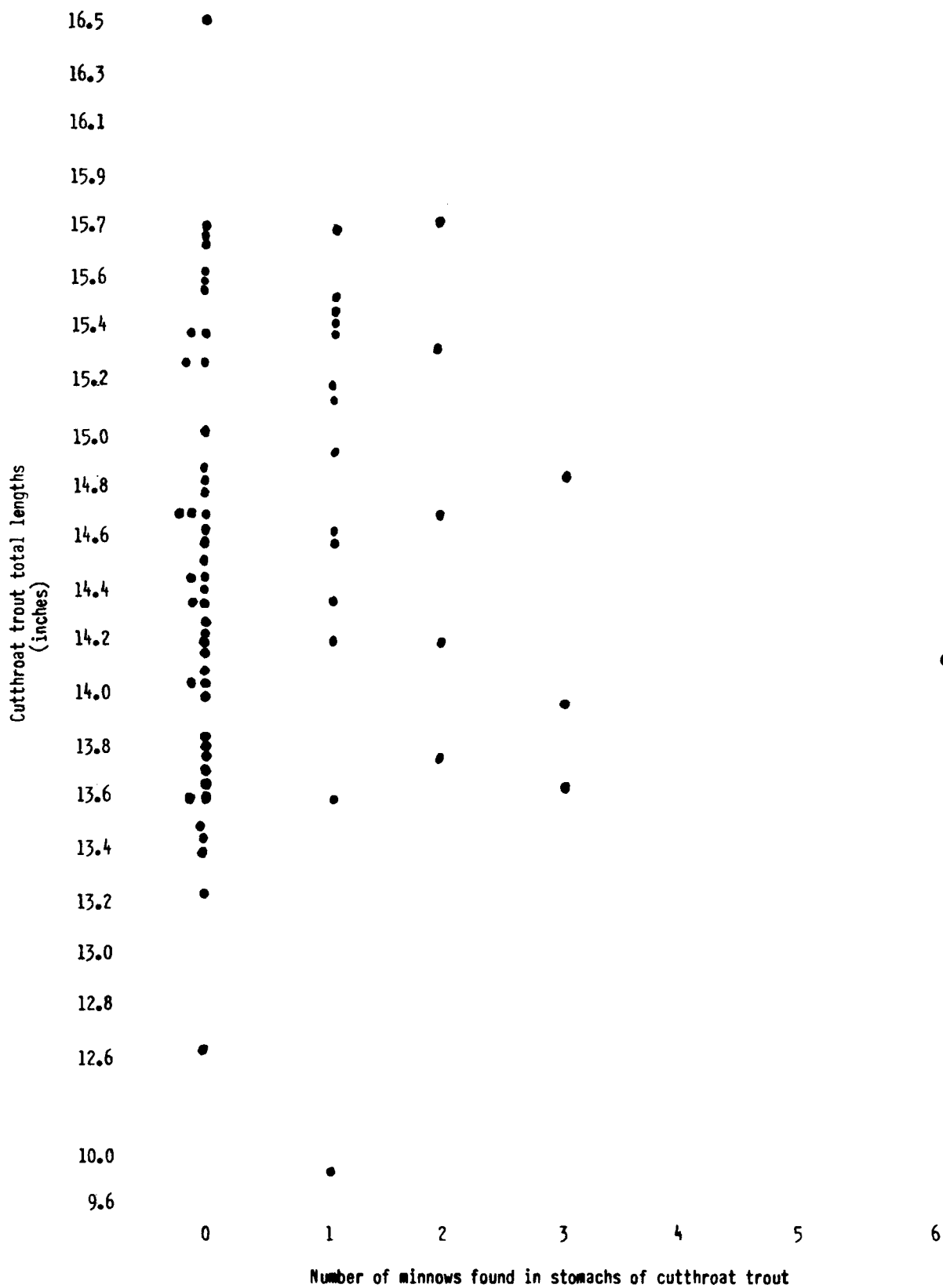


Figure 1.—Correlation between lengths of cutthroat trout and numbers of minnows found in cutthroats stomachs, Pelican Creek, 1973

RESULTS AND DISCUSSION

Of the 69 cutthroats caught, 22 had food other than fish in their stomachs, 24 had empty stomachs and 23 had fish in their stomachs. Of the 23 trout having fish in their stomachs, 15 of these fish were identifiable: 14 were redbase shiners and one was a longnose dace. These same 23 cutthroats averaged 1.7 fish per stomach with a range of 1 to 6 fish per stomach. The average total length of measurable fish in cutthroat stomachs was 3.8 inches with a range of 2.6 to 4.5 inches. This information was similar to that obtained in 1972 (Tables 2 & 3).

The 1972 data on the redbase shiner spawning run indicated two possibilities: the average length of fish in the run decreased as the run progressed and the average size of females was larger than the average size of males. From the stomach analysis of the 27 cutthroats sampled in 1972, it appeared that the trout were either feeding predominantly on smaller fish in the run or on males. The 1973 study supported that conclusion. The average total length of measurable stomach minnows in 1972 was 3.6 inches, and the average total length of measurable stomach minnows in 1973 was 3.8 inches. In 1972, the average size of males and females in the spawning run was 3.9 and 4.4 inches, respectively. Of the 15 measurable stomach minnows only four, which were ripe female shiners, could be accurately sexed. Therefore it could be that the cutthroat trout sampled in 1973 were preying primarily on small minnows in the run and/or on males.

However, the other indications from the 1972 data were not corroborated by the 1973 findings. From the information collected, there was no correlation between increased length in cutthroats and increased frequency of shiner consumption (Figure 1).

Whether the shiner frequency in the stomachs was lower in ripe females as opposed to post-spawning males and females could not be determined because of the 26 females collected, all were spent.

The Bureau was also interested in determining possible relationships between lengths of cutthroats and lengths of small fish in their stomachs. No relationships were suggested (Figure 2).

Obviously more information is needed on cutthroat-shiner relationships. If a similar study is made in the future, it is suggested that more emphasis be given the organization and execution of the project. For instance, observing Pelican Creek more frequently for the first of the shiner spawning run, and hopefully obtaining the necessary minimum number of cutthroats with stomach fish for a statistical sample; electrofishing, if possible, and generally eliminating factors which might create a biased sample.

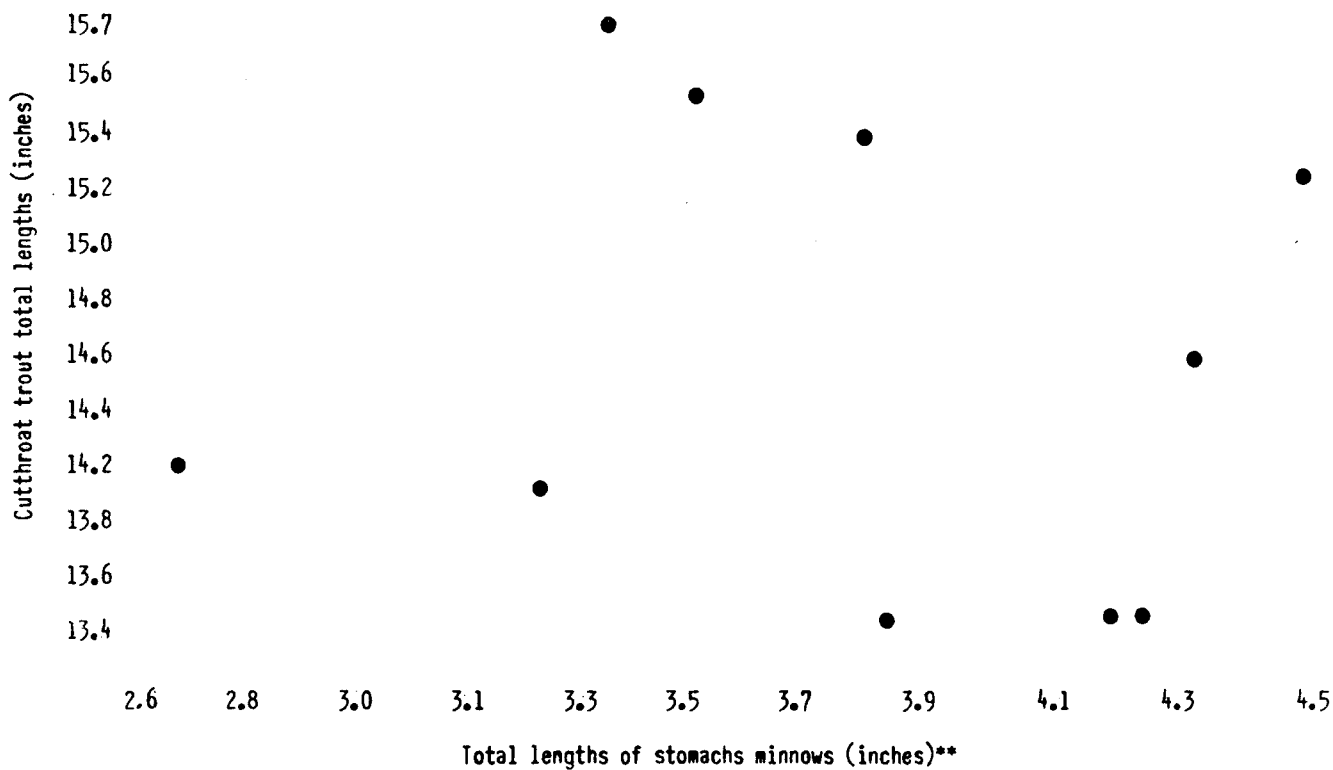


Figure 2.—Correlations between lengths of cutthroat trout and lengths of minnows found in cutthroat stomachs, Pelican Creek, 1973*

* Ten of the minnows were redbside shiners; one was a longnose dace.

** All lengths of the shiners were standard. Each standard length was multiplied by 1.2 for the total length.

Literature Cited

- Benson, Norman G., 1961 - Limnology of Yellowstone Lake in Relation to the Cutthroat Trout. U.S. Fish and Wildlife Service. Res. Report 56 33 pp.
- Dean, Jack L. and Varley, John D., 1973. Annual Project Report-1972, Fishery Management Program, Yellowstone National Park, Wyoming. Unpub. mimeo, rpt. U.S. Fish and Wildlife Service, 84 pp.

APPENDIX B

PISCIVOROUS AVIFAUNA ON YELLOWSTONE LAKE

by

Margaret B. Davenport, Biological Aid (Fisheries)
National Park Service
Yellowstone Fishery Investigations
Yellowstone National Park, Wyoming

Piscivorous Avifauna on Yellowstone Lake

The objective of this study was to attempt to estimate the biomass of cutthroat trout required to support the piscivorous avifauna of Yellowstone Lake.

Methods

During the summer of 1973, the objective was addressed by determining population numbers of various species on the lake, and determining consumption rates of fish by these birds.

Population numbers were obtained by a census. Birds were counted during two periods: 24 July-19 August and 28 September-7 October. The earlier count was for determining the numbers of summer residents, the latter for purposes of comparing numbers and species of migrating birds with those of summer residents.

Both general dietary information and consumption rates were obtained from a survey of the literature.

Results

Data from the summer census (residents) gave the following population sizes: eared grebe (Podiceps auritus) 2,580; California gull (Larus californicus) 1,664; barrow's goldeneye (Bucephala islandica) 1,452; common merganser (Mergus merganser) 658; white pelican (Pelecanus erythrorhynchos) 380; unidentified ducks 268; spotted sandpiper (Actitis macularia) 229; bufflehead (Bucephala albeola) 104; lesser scaup (Aythya affinis) 86; raven (Corvus corax) 54; mallard (Anas platyrhynchos) 30; osprey (Pandion haliaetus) 26; great blue heron (Ardea herodias) 15; common loon (Gavia immer) 14; bald eagle (Haliaeetus leucocephalus) 12; belted kingfisher (Megasceryle alcyon) 9; teal (Anas sp.) 8; Caspian tern (Hydroprogne caspia) 6; double-crested cormorant (Phalacrocorax auritus) 5; sandhill crane (Grus canadensis) 2; and willet (Catoptrophorus semipalmatus) 2. The total number was estimated at 7,500.

Several of the species were counted by other researchers in the park. A comparison of their data and the numbers obtained in this study is presented in Table I. My study numbers were fairly accurate, but were consistently low.

Table I. Comparison of the number of birds estimated from this study with species counted by independent researchers.

Species	Numbers from this study (A)	Numbers from other researchers (B)	Ratio of A/B
pelican	380	400 adults (Diem)	0.95
cormorant	5	5 (Diem)	1.00
eagle	12	17 (Swenson)	0.71
osprey	26	44 ad. (Swenson)	0.59
gull	1664	2000 (Diem)	0.83
tern	6	26 (Diem)	0.23

The second census, while not being as complete, indicated that the total number of birds during the fall migration period was approximately twice that of the number of residents. Also, species composition changed, the pelicans, cormorants, terns and spotted sandpipers disappearing from the counts, and species such as the western grebe (Aechmophorus occidentalis), pied-billed grebe (Podilymbus podiceps), gadwall (Anas strepera), ruddy duck (Oxyura jamaicensis), red-breasted merganser (Mergus serrator), coot (Fulica americana), and snowy plover (Charadrius alexandrinus) appearing in the counts.

Most of the literature reported what the diet consisted of, some sources dividing the composition into proportionate parts so that the percentage (by volume) of the diet consisting of fish was determined. This kind of data from many authors results in the following generalizations. Loons, cormorants, pelicans, mergansers, osprey, kingfishers, terns, and herons eat mainly fish (White 1936, Kortright 1953, Cornwell 1963, Bent 1940, 1921, 1919, Sayler and Laqler 1946, Hall 1922, Schaller 1962, Garber 1972, McAtee 1919, Palmer 1962, Olson and Marshall 1952). The percentage of gull and goldeneye diets that consists of fish varies from zero to 100% (Rothweiler 1960, Vermeer 1970, Bent 1921, Cottam 1945, Greenhalgh 1952, Kortright 1953, Munro 1918, Mendall and Gashwiler 1940, Olney 1963). The bald eagle's diet also varied greatly with respect to fish consumption, but Swenson (pers. comm.) has found that on Yellowstone tone Lake their diet consists mostly of waterfowl. Bufflehead, eared grebe and pied-billed grebe will take fish but the fish make up a very small percentage of the diet (Weston 1963, Munro 1941, Dawn 1959, Bent 1919, Cottam 1939, Mendall and Gashwiler 1940). Indications are that blue-winged teal, green-winged teal, cinnamon teal, lesser scaup, redhead, mallard, horned grebe, sandhill crane, raven, and ruddy duck do not eat fish (Kortright 1953, Bennett 1938, Bartoneck and Hickey 1969, Cottam 1939, Cronan 1957, Mendall and Gashwiler 1940, Bell 1973, Swarth 1919, Pawley, pers. comm.). No information on the willet, spotted sandpiper, western grebe or snowy plover was found.

Some literature dealt with specific consumption rates of fish by these birds. The species for which information was found are the eagle, osprey, merganser, kingfisher and pelican.

Best estimates for the bald eagle put adult consumption at about 0.75 pounds per bird per day under normal conditions (Stewart 1970, Chura and Stewart 1967, Rossman, Rossman and Rossman 1971). There were 15 adult eagles on the lake during the summer of 1973 (Swenson 1973) and these could have consumed at least 1,350 pounds of fish except that in Yellowstone their diet is mostly waterfowl.

Based on figures from Koplin, et. al. (1970) and Garber (1972), I calculated that it takes roughly 125 pounds to raise a young osprey. For adults, indications are that one requires 1-2 pounds of fish per day. Based on the above and on Swenson's population numbers of 44 adults and 12 young, the osprey consumed approximately 8,800 pounds of fish during the 1973 summer season.

Merganser adults consume 6-8 ounces of fish per day (White 1936, Latta & Sharkey 1966). A population of 650 birds would consume approximately 37,000 pounds of fish during a summer season.

Kingfishers, both adult and young, consume approximately 0.2-0.4 pounds of fish per day (White 1936). Assuming that the nine kingfishers observed on the lake were both male and female adults, it can be concluded that there were at least five pairs of this species. White (1936) reports that a nest of kingfishers averages six young. Thus there were perhaps as many as 40 birds of this species on the lake during the summer of 1973. They would have consumed 1,550 pounds of fish.

Schaller (1962) felt that Hall's (1922) estimates of 150 pounds of fish to raise a young pelican and 2-3 pounds of fish per adult per day were the most accurate rate figures. Diem counted 400 adults and 203 young. Thus pelican consumption of fish for the 1973 summer season was approximately 160,500 pounds.

The total number of pounds of fish consumed by osprey, mergansers, kingfishers, and pelicans during the summer of 1973 was approximately 207,850 pounds. Of this, 38,550 pounds--that eaten by the mergansers and kingfishers -- consisted of fish averaging 3-5 inches in length.

Conclusion

The study represents a starting point for further research. Some useful dietary information was found in the literature, but field studies to enlarge on and substantiate this data are certainly needed.

Literature Cited

- Bennett, L.J. 1938. The blue-winged teal, its ecology and management. Collegiate Press, Inc., Ames, Iowa, 144 p.
- Bent, A.C. 1940. Life histories of North American cuckoos, goatsuckers, hummingbirds and their allies. U.S. Natural Museum Bulletin 176.
1921. Life histories of North American gulls and terns. U.S. National Museum Bulletin 113.
1919. Life histories of North American diving birds. U.S. National Museum Bulletin 107.
- Chura, N.J. and Stewart, P.A. 1967. Care, food consumption, and behavior of bald eagles used DDT tests. The Wilson Bulletin 79:441-448.
- Cornwell, G.W. 1963. Observations on the breeding biology and behavior of a nesting population of belted kingfishers. Condor 65:426-431.
- Cottam, C. 1939. Food habits of North American diving ducks. U.S. Dept. of Agriculture Tech. Bulletin 643, 140 p.
- Cronan, J.M., Jr. 1957. Food and feeding habits of the scaups in Connecticut waters. Auk 74:459-468.
- Dawn, W. 1959. Eared grebe in South Carolina. Auk 76:521.
- Garber, D.P. 1972. Osprey study. Lassen and Plumas counties, California 1970-1971. State of California. The Resources Agency. Department of Fish and Game.
- Greenhalgh, C.M. 1952. Food habits of the California gull in Utah. Condor 54:302-308.
- Hall, E.R. 1922. Pelicans versus fishes in Pyramid Lake. Condor 27:147-160.
- Hickey, J.J. and Bartonek, J.C. 1969. Food habits of canvasbacks, redheads and lesser scaups in Manitoba. Candor 71:267-279.
- Koplin, J.R., MacCarter, D.L., and MacCarter, D.S., 1970. Flathead Lake osprey study (final report).
- Kortright, F.H. 1953. The ducks, geese and swans of North America. Harrisburg: The Stackpole Company, 476 p.
- Latta, W.C., and Sharkey, R.F. 1966. Feeding behavior of the American merganser in captivity. J. Wildl. Mgmt. 30:17-23.

- McAtee, W.L. 1919. Further notes on the "fishy" flavor of birds. Auk 36: 100-101.
- Mendall, H.L. and Gashwiler, J.S. 1940. Water bulrush as a food of waterfowl. Auk. 57:245-246.
- Munro, J.A. 1941. The grebes. Studies of waterfowl in British Columbia. Occasional Papers of the British Columbia Provincial Museum No. 3.
1918. The barrow golden-eye in the Okanagan Valley, British Columbia. Condor 20:3-5.
- Olney, P.J.S. 1963. The food and feeding habits of teal (Anas crecca crecca). Proc. Zool. Soc. Dons. 140:169-210.
- Olson, S.T. and Marshall, W.H. 1952. The common loon in Minnesota. Minn. Mus. Nat. Hist. (Univ. Minn.) Occas. Papers No. 5.
- Palmer, R.S. ed. 1962. Handbook of North American birds. Vol. 1. New Haven: Yale University Press, 567 p.
- Rothweiler, R.A. 1960. Food habits, movements and nesting of gulls, Freeze-out Lake, Teaton County, Montana. Project No. MS 844, Paper No. 494. Mimeo. Montana Fish and Game Department, 26 p.
- Rossman, G., Rossman, A. and Rossman, B. 1971. Bald eagles of the Chippewa Forest. Grand Rapids Herald-Review. Grand Rapids, Minnesota, pamphlet.
- Sayler, J.C. and Lagler, K.F. 1949. The eastern belted kingfisher, Megaceryle alcyon alcyon, in relation to fish management. Trans. Amer. Fisheries Soc. 1946, 76:97-117.
- Schaller, G.B. 1962. The conservation of the white pelican in Yellowstone Park. YNP library. xerox.
- Stewart, P.A. 1970. Weight changes and feeding behavior of a captive-reared bald eagle. Bird-Banding 41:103-110.
- Swarth, H.S. 1919. A California specimen of the sandhill crane Condor 21:213-214.
- Swenson, J. 1973. Yellowstone National Park bald eagle-osprey study, 1973 progress report.
- Vermeer, K. 1970. Breeding biology of California and ring-billed gulls. A study of ecological adaptation to the inland habitat. Canadian Wildlife Service Report Series, No. 12.
- Weston, H.G. 1963. Dead fish as a source of food for various birds. Auk 80:550-551.
- White, H.C. 1936. The food of kingfishers and mergansers on the Margaree River, Nova Scotia. J. Biol. Board Canada 2:299-309.

APPENDIX C

The Life History of the Longnose Sucker
(*Catostomus catostomus* Forster)

A Literature Review

by

Margaret B. Davenport, Biological Aid (Fisheries)

National Park Service

Yellowstone Fishery Investigations

Yellowstone National Park, Wyoming

Description

The longnose sucker, Catostomus catostomus Forster has a slender, elongated body, almost cylindrical in section. Its head is flattened on top. The elongated snout has an inferior mouth with thick, tuberculated lips that have a median notch, but no lateral notches. Scales are small and much crowded toward the head, there being 95-120 along the lateral line. Dorsal rays number 9-12, anal rays number 7. Breeding males have tubercles on their head and anal fin, occasionally on the caudal fin. Color varies from gray above and white or yellow below to almost jet black above, males having a broad rosy band on each side when spawning. Average length is 14 to 18 inches, some getting as long as 24 inches (Carl and Clemens 1953, Baxter and Simon 1970).

Range

This species, adapted to cold waters, is found in Siberia and in the western hemisphere, from the Arctic Circle south to Colorado, and east across the United States to New England. In Wyoming it is found in Yellowstone Lake, Yellowstone River and Pelican Creek in Yellowstone National Park; in Sand Creek and Redwater Creek in the Belle Fourche River drainage; in the North and South Platte River systems; in Big Sandy Creek in the Green River drainage; and in lakes of the Snowy Range in Albany and Carbon counties (Baxter and Simon 1970).

Food Habits

Food habits of the longnose sucker vary among locations. It seems that in more northerly latitudes, i.e., in Canada, the sucker feeds mostly on animal material. Carl and Clemens (1953) generalized that in British Columbia food consists of bottom organisms such as snails, crustaceans, insect larvae and worms. In average percent by volume of foods taken, amphipods (63%), sphaeriids (11%), chironomid larvae (15%), and other aquatic insects (9%) made up 98% of sucker food in Great Slave Lake (Rawson 1951). Rawson and Elsey (1948) found that in Pyramid Lake, Alberta, food taken by fish larger than 2 inches consisted of amphipods (72%), chironomid pupae and larvae (19%), mayfly nymphs (5%), cladocera (1.5%), sphaeriids (1.2%), and snails (0.6%). Young suckers, less than 2 inches, in this same location ate mostly zooplankton, their diet consisting of cladocera of 8 species (66%), Cyclops (4%), chironomid larvae and pupae (6%), Gammarus (1%), and terrestrial insects (23%). Stenton (1951) found that eastern brook trout eggs, after being exposed by later spawning trout, were consumed by longnose suckers. Rawson and Elsey (1948) found, however, no trout eggs in stomachs of suckers taken near the spawning area of Pyramid Lake.

In contrast to this, suckers in more southerly latitudes, i.e., Wyoming, feed almost entirely on plant materials (Simon 1951). Food habits of suckers in Yellowstone National Park, ascertained by stomach analysis of specimens from the mouths of Pelican Creek and an unnamed stream which enters the West Thumb, revealed that approximately two-thirds of the stomachs contained algae and higher aquatic plants. Animal material included crustaceans and aquatic insects (Brown and Graham 1954). Stomach examinations of specimens from Towner Lake in the Snowy Range found that animal material--midge larvae, gastropods, cladocerans, and caddisflies--made up 25% of the diet while the majority of the contents were algae, Elodea, and miscellaneous detritus.

Other statements about food habits and feeding behavior include: (1) no important seasonal differences in the kinds of food eaten were found during the period of May to September in Pyramid Lake (Rawson and Elsey 1948); (2) Catostomus catostomus lacustris Bajkov feeds entirely at the bottom, mainly at night, and usually in the shallow waters near shore (Neave and Bajkov 1929).

Age Classes

The following are average lengths for the different age classes as determined by various researchers:

Age	Length in Inches				
	female	male	1/	2/	3/
1				2.0	4.0
2				3.3	6.0
3				4.2	7.6
4				5.2	9.0
5				6.0	10.8
6				7.0	13.4
7	13.5	15.0		8.0	14.5
8	15.0	16.4		8.8	15.6
9	17.5	17.8		9.6	16.7
10	18.6	18.7		10.4	17.2
11	19.3	18.4		11.4	18.2
12	20.0	19.8		12.4	
13	20.8	19.9			
14	20.8	20.6			
15	22.0	20.5			
16	22.2	21.9			
17	22.7				
18	23.5				
19	25.0				

- 1/ Harris (1962); Great Slave Lake
- 2/ Rawson and Elsey (1948); Pyramid Lake
- 3/ Bailey (1969); western Lake Superior
- 4/ Kathrein (1951); Missouri River between Holter Dam and Cascade, Montana
- 5/ Brown and Graham (1954); Yellowstone Lake

Kathrein (1951) found that growth rate was greatest during the first year and progressively decreased as fish grew older. In general, it was found that females live longer and attained larger sizes than did males (Rawson and Elsey 1948, Brown and Graham 1954, Geen 1958).

Spawning Timing

On a daily basis Geen (1958) found that a great majority of fish moved upstream between 1800 and 0600 hours, suggesting strongly nocturnal migration.

Seasonally longnose suckers generally spawn in spring and early summer, there being annual variation in the start, peak and end of migration (Wynne-Edwards 1952, Geen 1958, Geen, et. al. 1966, Bailey 1969). More specifically: in Great Slave Lake suckers spawn from after the ice breaks up to June 15 (Harris 1962); in Lake Nipigon, Ontario, spawning usually occurs in late May or early June (Dymond 1926); in Pyramid Lake, Alberta, spawning runs from June 10 to July 1 (Rawson and Elsey 1948); in Lac la Jache, B.C., spawning is in April (Carl and Clemens 1953); in the Quesnel area, B.C., spawning occurs from May 1 to June 1 (Geen 1958); in Sixteen Mile Lake, B.C., over an eight-year period, the start of the migration varied from April 20 to as late as well into May (Geen, et. al. 1966); in western Lake Superior spawning is from mid-April to mid-June (Bailey 1969); in Montana spawning is generally in May (Weisel 1957); and in Yellowstone Lake, Wyoming the spawning run begins in late June and continues through most of July (Brown and Graham 1954).

Several theories have been proposed to explain why suckers begin migrations when they do. Migration is not affected by water levels (Geen 1958, Geen, et. al. 1966), but rather by stream temperatures (Rawson and Elsey 1948, Brown and Graham 1954, Wescoatt 1955, Geen, et. al. 1966, Bailey 1969), critical temperatures being 52-54°F in Pyramid Lake (Rawson and Elsey 1948), 54-55°F in western Lake Superior (Bailey 1969), and 41°F in Sixteen Mile Lake (Geen, et. al. 1966). Geen (1958) suggests two other possibilities: (1) Runs started soon after the ice left the lake thus the "instability of the lake which had not yet stratified, or some associated condition may possibly have influenced migration of fish into the stream" (2) "Complex currents resulting from the effects of discharge into the lake and wind driven currents may determine the numbers of fish which arrive at the mouth of the stream in any one day" and thus the numbers available to move upstream.

Spawning Areas

Geen (1958) found most spawning occurred in inlet streams, only a few fish spawning in outlet streams. Suckers in Yellowstone Lake spawn mostly in Pelican Creek, an inlet stream (Brown and Graham 1954). Both Rawson and Elsey (1948) and Scott (1954) found spawning took place on gravelly stream bottoms in shallow rocky parts of lakes. In streams suckers have been found to be selective about areas utilized for spawning, choosing riffle areas of streams where gravel size varied from pea gravel to stones about four inches in diameter, and water depth was less than a foot (Geen 1958).

Spawning Behavior

Geen, et. al. (1966) describes spawning behavior:

During the day the males remained on the bottom of the creek the female along the banks in still water. During spawning, the female left the still water and moved into the midst of the males. Two to four males escorted the female a short distance and crowded beside her. During egg deposition the group thrashed about for three to four seconds, the males apparently clasping the female with their pelvic fins or vibrating against her with the anal fin. Following the act the female returned to still water, the males to their original positions. No aggressive behavior or area defense was noted.

Sexual Maturity Among Spawning Suckers

Geen (1958) found that female suckers in the Quesnel area spawned primarily in their sixth year, some in the fifth, seventh and eighth years. Spawning suckers in Sixteen Mile Lake ranged from 5 to 9 years (Geen, et. al. 1966). Ages of suckers in the spawning run from Great Slave Lake ranged from 9 to 15 years, with 38% in the 11 year group (Harris 1962). Rawson and Elsey (1948), in their study of Pyramid Lake, found that 40% of 4 year old males and 12% of 4 year old females were sexually mature; 65% of males and 20% of females were mature at 5 years; and all males and females were mature at 6 years. Males in western Lake Superior were first mature at 4 years, females at 5 years. By 8 years all males were mature and by 9 years all females were mature (Bailey 1969).

Geen (1958) made several observations concerning the sexual maturity of fish entering the spawning area. He found that males were mature upon entering. Females were generally green, but the ratio of green to ripe changed through the run, there being more green females at the first of the run, more ripe at the latter stages. Harris (1962) noted that females in

spawning runs had ovaries in three states: latent, spawning, spent. Eggs from latent ovaries appeared to be in a state of early maturation, but not likely to be spawned during the season being studied. He states that this suggests that suckers in Great Slave Lake do not spawn every year. However, in their study of Sixteen Mile Lake, Geen et. al. (1966) found that a few marked adults returned as many as five successive years to spawn.

Both Bailey (1969) and Geen (1958) note that suckers spawn more than one year.

Downstream Movement of Adults at End of Spawning Run

Geen, et. al (1966) found that the main downstream movement of spent longnose suckers started about five days after the spawning migration began. Maximum downstream movement occurred each day during or shortly after the period of highest water temperature. The majority of females returned to the lake during the first half of the migration, most males returned in the latter half.

Eggs - Numbers

Bailey (1969) found the numbers of eggs per female ranged from 14,000 to 35,000 with an average of 24,000 eggs for fish 13.9 to 17.7 inches. Harris (1962) collected the following data:

Egg counts from eight longnose suckers			
Age	Fork length (inches)	Weight (pounds)	Egg numbers
9	17.7	2.40	17,525
10	19.3	3.50	38,104
10	20.7	4.30	60,307
11	18.3	3.39	38,746
11	19.9	3.59	20,817
12	19.9	3.50	24,795
13	22.4	4.49	42,432
14	20.6	3.39	37,312

Incubation Period

Under field conditions, Geen, et. al. (1966) found the incubation period to be 11 days to two weeks. Under controlled conditions eggs were found to hatch in 11 days at 50°F, eight days at 59°F and at 68°F took 5 days to reach the eyed stage (Geen 1958).

Young

In western Lake Superior larval suckers spend little time in the stream used for spawning, instead drifting to the lake soon after hatching (Bailey 1969). In the Quesnel area fry which hatched in inlet streams moved into the lake almost immediately after emergence from the gravel, i.e., after 7 to 10 days (Geen 1958). However, Harris (1962) found that in Great Slave Lake, fry and fingerling spend at least their first summer in the river where they hatched.

In Yellowstone Lake, Brown and Graham (1954) found that small, young suckers may go through their first winter without scales.

Mortality

Longnose suckers are long lived fish (Geen, et. al. 1966, female suckers living as long as 19 years (Harris 1962). There is a differential rate of mortality between the two sexes, males having higher mortality rates after the first spawning run (Geen 1958).

The high adult survival rate is attributed to two factors. The first is that the suckers are in better condition when returning to the lake due to the fact that they do not migrate as far upstream as do other fish such as rainbow trout (Geen 1958). The second factor is that spawning animals show little or no aggressive behavior leading to the fish being in good condition when they return to the lake (Geen, et. al. 1966).

Mortality of young fish in the lake is substantial as suggested by the low annual recruitment rate--10 to 20% in Sixteen Mile Lake. The mortality is attributed to predation (Geen, et. al. 1966).

Literature Cited

- Bailey, M. M. 1969. Age, growth and maturity of the longnose sucker Catostomus catostomus of western Lake Superior. J. Fish. Res. Bd. Can., 26: 1289-1299.
- Baxter, G. T. and Simon, J. R. 1970. Wyoming Fishes. Bull. Wyoming Game and Fish Dept., 4. 168 pp.
- Brown, C. J. D. and Graham, R. J. 1954. Observations on the longnose sucker in Yellowstone Lake. Trans. Amer. Fish. Soc., 83:38-46.
- Carl, G. C. and Clemens, W. A. 1953. The freshwater fishes of British Columbia. British Columbia Prov. Mus., Handbook No. 5, second ed., 136 pp.
- Dymond, J. R. 1926. The fishes of Lake Nipigon, Univ. Toronto Stud., Biol. Ser., No. 27; Publ. Ontario Fish. Res. Lab., No. 27, 108 pp.
- Geen, G. H. 1958. Reproduction of three species of suckers (Catostomidae) in British Columbia. M. A. thesis, Dept. of Zool., Univ. British Columbia, 117 pp.
- Geen, G. H. Northcote, T. G., Hartman, G. F. and Lindsey, C. C. 1966. Life histories of two species of catostomid fishes in Sixteen Mile Lake, B.C. with particular reference to inlet stream spawning. J. Fish. Res. Bd. Can., 23:1761-1788.
- Harris, R. H. D. 1962. Growth and reproduction of the longnose sucker, Catostomus catostomus (Forster) in Great Slave Lake. J. Fish. Res. Bd. Can., 19:113-126.
- Hepworth, W. G. 1959. A study of the population dynamics of brook trout in two sub-alpine lakes in southeastern Wyoming. M. S. thesis (unpublished) Univ. of Wyoming. 155pp.
- Kathrein, J. W. 1951. Growth rate of four species of fish in a section of the Missouri River between Holter Dam and Cascade, Montana. Trans. Am. Fish. Soc., 80:93-98.
- Neave, F. and Bajkov, A. 1929. Reports of the Jasper Park Lake investigations. 1925-26. V-Food and growth of Jasper Park fishes. Contrib. Can. Biol and Fish., 4:199-217.
- Rawson, D. S. 1951. Studies of the fish of Great Slave Lake. J. Fish. Res. Bd. Can. 8:207-240.
- Rawson, D. S. and Elsey, C. A. 1948. Reduction in the longnose sucker population of Pyramid Lake, Alberta, in an attempt to improve angling. Trans. Amer. Fish. Soc., 78:13-31.

- Scott, W. B. 1954. Freshwater fishes of eastern Canada. Univ. Toronto Press. in Cooperation with Royal Ontario Museum. Zool. and Pal., 128 pp.
In Geen, G. H. 1958. Reproduction of three species of suckers (Catostomidae) in British Columbia, M.A. thesis, Dept. Zool. Univ. British Columbia, 117 pp.
- Simon, J. R. 1951. Wyoming Fishes. (revised). Bull. Wyoming Game and Fish Commission. 129 pp. In Baxter, G. T. and Simon, J. R. 1970. Wyoming Fishes. Bull. Wyoming Game and Fish Dept., 4. 168 pp.
- Stenton, J. E. 1951. Eastern brook trout eggs taken by longnose suckers in Banff National Park, Canada, Copeia, 1951:171-172.
- Weisel, G. F. 1957. Fish guide for intermountain Montana. Publ. by Montana St. Univ. Press. 88 pp. In Geen, G. H. 1958. Reproduction of three species of suckers (Catostomidae) in British Columbia. M. A. thesis, Dept. Zool. Univ. British Columbia, 117 pp.
- Wescoatt, I. I. 1955. Stream migration studies. Job Completion Reports. State of Colorado Dept. of Game and Fish. Mimeo. Rept. 3 pp. In Geen, G. H. 1958. Reproduction of three species of suckers (Catostomidae) in British Columbia. M. A. thesis, Dept. Zool. Univ. British Columbia, 117 pp.
- Wynne-Edwards, V. C. 1952. Freshwater vertebrates of the arctic and sub-arctic. Bull. Fish. Res. Bd. Can., 94:1-28.

APPENDIX D

THE SPECIES COMPOSITION AND RELATIVE ABUNDANCE OF THE
PLANKTONIC AND BENTHIC ORGANISMS OF YELLOWSTONE LAKE

BY

Thom H. Johnson, Biological Aid (Fisheries)
U.S. Fish and Wildlife Service
Yellowstone Fishery Investigations
Yellowstone National Park, Wyoming

INTRODUCTION

A brief and searching study of the planktonic and benthic organisms of Yellowstone Lake was undertaken by the author between August 4 and August 26, 1973 to observe the species composition, relative abundance and general vertical and/or horizontal distributions of the organisms present. It was also purposed to compare these findings with those of S. A. Forbes (1893) who, in 1890 and 1891, did a study of the zooplankton and bottom organisms in Yellowstone Lake; and with those of Norman G. Benson (1961), who studied the plankton of Yellowstone Lake between 1956 and 1958.

It is realized that to have a statistically valid sampling of the plankton population present in Yellowstone Lake, much effort would be necessary. This was, however, beyond the limits of available time as the scope of this study was of a much narrower nature. Hence, samples were systematically taken in an attempt to represent the plankton population at various depths and at various distances from shore. All observations in this paper are obviously based solely upon consistencies in the data collected. Expanded sampling efforts may yield different results.

METHODS

Sampling areas. Three areas of Yellowstone Lake were selected as sites for sampling. These areas were 1) the waters off the settlement known as Lake, 2) the lee side of Stevenson Island, and 3) representative waters of the West Thumb area of the lake. These sites were chosen due to the varied water conditions and habitats present and their accessibility. The waters near Lake represented an area having a limnetic zone of moderate depth and a semi-protected littoral zone. The lee side of Stevenson Island provided a shallow limnetic zone and a protected littoral zone, while the areas of West Thumb sampled were representative of a deep limnetic zone and an open, unprotected littoral zone.

Plankton. Surface net plankton were collected with the use of a Wisconsin plankton net with No. 25 bolting cloth. The Wisconsin plankton net was pulled through the water for a distance of 15 feet, sampling the top 3 feet of the water. Three such hauls were made per sample. The plankton concentrates were then washed into 125 ml. bottles and later analyzed at the laboratory under magnifications to 60x. Several inherent errors in this method are recognized (Welch 1948).

Net plankton were also collected at various depths with the aid of a 3 liter Kemmerer water sampler. Each sample consisted of 12 liters of water and was strained through a plankton net with No. 25 bolting cloth. The plankton concentrates were then washed into 125 ml. bottles and later analyzed at the laboratory under magnifications to 60x.

Abundant zooplankters were identified to species and the major phytoplankton forms to genus. The reader should note that difficulty with the taxonomics of two zooplankton species was encountered. The references in this report to Daphnia pulex may be, in fact, the species Daphnia schoedleri and/or a mixture of the two species. Similarly, the copepod species referred to here as Diaptomus sicilis may actually be Diaptomus minutus.

Bottom organisms. Bottom samples were collected with a 6 x 6 inch (231 sq. cm.) Ekman dredge and organisms were separated from bottom soils by sieving through a No. 30 (0.589 mm.) Tyler screen. Two samples were collected at each depth sampled in each area. The samples were identified using Ward and Whipple (1963) and Pennak (1953).

Temperatures. Air and water temperatures were measured with the use of an electronic thermometer with a depth range of 100 feet.

RESULTS AND DISCUSSION

Plankton

Only general statements can be made concerning the abundance, distribution, and genera of the phytoplankton collected since collections were aimed primarily at sampling zooplankton. This study was also primarily qualitative in nature, although relative abundance of the organisms will be noted.

Phytoplankton. The major phytoplankton collected were Anabaena, Asterionella and Melosira. Stephanodiscus and desmids also appeared in the samples periodically.

Anabaena was abundant throughout the sampling period, falling off somewhat in late August. The heaviest concentration of Anabaena was found in West Thumb where the bloom extended to a depth of 30 feet in places. Asterionella and Melosira were also quite abundant throughout the sampling period, although to a lesser degree than Anabaena. The two diatoms were found in greatest abundance on the lee side of Stevenson Island and in the waters near Lake.

Zooplankton. The zooplankton fauna consisted principally of Conochilus unicornis, Daphnia pulex, Diaptomus sicilis, Diaptomus shoshone, and the nauplii and copepodids of Diaptomus. Due to similarities and differences, the zooplankton collected from the lee side of Stevenson Island and those collected in the waters off of Lake will be discussed together and those zooplankton collected in West Thumb will be discussed separately.

STEVENSON-LAKE

The species composition in the collections off of Lake in order of abundance was consistently 1) nauplii and copepodids of Diaptomus, 2) Conochilus unicornis, 3) Diaptomus sicilis, 4) Daphnia pulex, and 5) Diaptomus shoshone. The order of abundance of the zooplankton collected on the lee side of Stevenson Island was much the same as that at Lake, except that Diaptomus shoshone was consistently more abundant than Daphnia pulex.

The nauplii and copepodids of Diaptomus were most abundant in the littoral zone collections and in the surface water collections to distances of 500+ yards from shore (furthest sampled). The nauplii and copepodids were also taken in abundance to depths of 30 feet, decreasing in abundance with increased depths. The copepodids invariably outnumbered the nauplii.

The distribution and relative abundance of Conochilus unicornis, a colonial rotifer, are much the same as those of the nauplii and copepodids of Diaptomus, except that several colonies of Conochilus were collected from depths to 75 feet. These rotifers were generally collected in greater abundance from the waters off of Lake than from those near Stevenson Island.

Two species of Diaptomus, namely D. shoshone and D. sicilis were also taken in the collections. D. sicilis, usually taken in association with and in greater numbers than D. shoshone, was collected from both the littoral and limnetic zones of the two sampling areas. D. shoshone was absent from the littoral collections off of Lake, but present in all other collections. Both species were collected in abundance as far offshore as 500+ yards (furthest sampled). D. sicilis and D. shoshone were collected at depths to 75 feet although their concentrations were highest in the waters to 30 feet.

Daphnia pulex was abundant in the surface collections up to approximately 400 yards off shore as well as in the littoral collections. A few Daphnia were collected at depths to 75 feet, but most were collected at depths to 15 feet.

Forbes (1893) found that Daphnia was by far the most common crustacean in Yellowstone Lake away from the shore. The present study consistently found a greater abundance of D. sicilis in the offshore waters. This could be a result of the extreme negative phototoxis exhibited by D. pulex, as eluded to by Forbes (1893), although the presence of a great abundance of Daphnia at the surface on clear, sunny days, (as on August 25 and 26, 1973) would seem to be contradictory.

In the littoral zone, the numbers of Daphnia and Diaptomus sicilis collected were consistently nearly equal, the number of Daphnia often surpassing that of D. sicilis. Forbes (1893) found that D. pulex was generally less abundant in the shallow water collections than D. sicilis.

A notable consistency in all of the collections was that the relative abundance of one of the species at any one sampling site was directly related to the abundance of the other species at that sampling station. That is, if Diaptomus sicilis was found to be scarce in one collection, the other species were also scarce and if D. sicilis were abundant, the other organisms were abundant. Avoidance, a common problem encountered in the sampling of mobile organisms like D. shoshone (National Academy of Sciences 1969) is probably not the cause for the absence of D. shoshone from the littoral collections off of Lake since the other organisms were all found to be relatively abundant in the littoral collections. D. shoshone was probably not present in the areas of the littoral zone sampled.

The phenomena described above also demonstrates the "patchiness" that occurs in the horizontal distribution of zooplankton in the lake.

WEST THUMB

The species composition of the zooplankton collections taken in the West Thumb area, in order of overall abundance, was 1) Conochilus unicornis 2) nauplii and copepodids of Diaptomus, 3) Daphnia pulex, 4) Diaptomus sicilis, and 5) Diaptomus shoshone. This generalized order of abundance was not, however, consistent throughout the samplings as Daphnia and the nauplii and copepodids of Diaptomus were frequently the most abundant organisms collected and Diaptomus shoshone was often found in greater numbers than both D. sicilis and Daphnia pulex.

Colonies of Conochilus unicornis were collected in abundance in the littoral area. In the limnetic zone, Conochilus was collected at levels ranging from the surface to 100 feet (deepest sampled) but was most abundant at depths of 30 to 50 feet.

The nauplii and copepodids of Diaptomus were abundant in the littoral zone to depths of 15 feet. Copepodids consistently outnumbered the nauplii. In the limnetic zone, the nauplii and copepodids were abundant in the surface waters to approximately 400 yards offshore (furthest sampled). These organisms were also abundant at depths of 30 to 50 feet in waters approximately 100 feet deep and 150 yards offshore, but were relatively scarce at those same levels in waters approximately 200 feet deep and 250 yards offshore. Nauplii and copepodids were numerous, scarce, and rare at depths of 10-15 feet, 15-30 feet, and 75-100 feet, respectively.

Daphnia pulex was rather scarce in the littoral collections in West Thumb but was the dominant species and very abundant in surface water collections to distances of 400 yards offshore (furthest sampled). Daphnia was also abundant at depths between 10 and 30 feet and was rare at depths ranging from 45-100 feet.

The scarcity of Daphnia in the West Thumb littoral zone is in direct contrast with the abundance of the same cladoceran in the littoral zones around Stevenson Island and near Lake. The unprotected nature of the littoral zone in West Thumb may have been a factor in the scarcity of the species. The more pelagic and limnetic type of existence is more in keeping with the general habits of the species as a whole (Pennak 1953).

Diaptomus sicilis was abundant in the littoral collections. It was found in great abundance in the surface waters to approximately 200 yards offshore as well as at depths of 30-50 feet at the same distance from shore. Samples taken at distances to approximately 400 yards offshore and depths to 100 feet found no D. sicilis at any of the levels sampled.

Diaptomus shoshone was generally scarce in all of the collections in West Thumb, and were taken only in samples from the limnetic zone.

The overall abundance of the zooplankton in West Thumb is generally less than that found near Lake and Stevenson Island. Benson (1961) had similar findings and concluded that this was probably due to upwelling and the transport of surface water easterly from the West Thumb area due to wind action. These currents probably resulted in the transportation of plankton out of West Thumb and into other areas of the lake. The species notably effected by these currents are Diaptomus shoshone and the nauplii and copepodids of Diaptomus.

BENTHOS

The common benthic organisms collected, the depth of the samples, the number of samples at each depth, and the bottom types of the samples appear in Table 1. The figures presented are the actual numbers of organisms collected rather than numbers per unit area.

Benson (1961) found that the standing crop of benthic organisms of Yellowstone Lake was greatest in the 6-11 meter (20-36 feet) range. The available data from the present study would lead toward the same conclusion but voids in the collections at depths between 20-50 feet make any firm conclusion unfeasible.

Based on my limited findings it would appear that the species composition of the benthic organisms of Yellowstone Lake has changed very little since 1890 when S. A. Forbes did a preliminary study of Yellowstone Lake.

Table 1. The species composition and number of bottom organisms collected at various depth ranges in Yellowstone Lake, August 4 - 26, 1973

Organism	Number of Organism Collected at Depths of:					
	0-5' * 2 samples	5-10' * 2 samples	10-20' * 8 samples	50-70' ** 2 samples	95-104' ** 4 samples	190-240' ** 4 samples
Porifera :	--	12	32	--	--	--
Spongilla	--	--	--	1	--	--
Turbellaria	--	--	--	--	--	--
Oligochaeta:	--	--	--	--	--	--
Tubifex tubifex	4	--	10	2	1	6
Limnodrilus sp.	3	--	--	--	1	--
Hirudinea:	--	--	--	--	--	--
Helobdella stagnalis	7	1 w/young	7	--	1	--
Glossiphonia complanata	1	--	--	--	--	--
G. heteroclita	--	1	--	--	--	--
Unidentified	1	--	1	--	--	--
Amphipoda:	--	--	--	--	--	--
Gammarus	26	13	72	--	--	--
Hyalolella aztec	8	5	18	--	--	--
Hydracarina	2	--	1	--	--	--
Insecta:	--	--	--	--	--	--
Tendipes larvae	3	--	4	7	11	5
Caddisfly larvae	1	4	1	--	--	--
Culex larvae	--	--	--	--	1	--
Prodiamesa larvae	--	--	--	--	--	15
Gastropoda	--	--	1	--	--	--
Pelecypoda:	--	--	--	--	--	--
Pisidium	3	--	--	--	--	--
Sphaerium	--	--	--	2	1	--

* Bottom type: Sand, rock, aquatic plant beds

** Bottom type: Silt - sand

TEMPERATURES

Temperature readings of Yellowstone Lake were first taken on August 13. At 10:00 a.m. the air temperature was 59°F, the surface water temperature was 59°F, and the water temperature at the bottom at 95 feet was 43.5°F. Surface water temperatures had dropped to 56.5°F by August 25. These temperatures compare somewhat similarly with those collected by S. A. Forbes on August 4, 1890, when a surface water temperature of 62°F and a temperature of 46°F on the bottom at 100 feet were recorded.

SUMMARY

A study of the plankton and benthic organisms of Yellowstone Lake was undertaken between August 4 and August 26, 1973. Three representative sampling areas, namely one each on the waters near Lake, on the waters off the lee side of Stevenson Island, and on the waters in West Thumb were chosen.

The major zooplankton collected in order of abundance were Conochilus unicornis in colonies, nauplii and copepodids of Diaptomus, Diaptomus sicilis, Daphnia pulex and Diaptomus shoshone. The major phytoplankton collected included Anabaena, Asterionella, Melosira and Stephanodiscus.

Benthic organisms were sampled from depths up to 240 feet with the following organisms being the common species collected: Gammarus, Hyallolella azteca, Spongilla, several oligochaetes, several leeches, including Helobdella stagnalis in fair numbers, insect larvae, with Tendipes larvae being the most common, and a few pelecypods.

Based on my observations it would appear that the overall species composition of the plankton and benthic organisms of Yellowstone Lake have changed remarkably little since studies were done in 1890 by S. A. Forbes and between 1956-1958 by Norman G. Benson. The abundance of Daphnia pulex and Diaptomus sicilis appear to have changed somewhat, but larger sampling efforts should be undertaken to determine any definite changes.

LITERATURE CITED

- Benson, Norman G. 1961. Limnology of Yellowstone Lake in Relation to the Cutthroat Trout. U.S. Fish and Wildlife Service. Research Report 56. 33 pp.
- Forbes, S. A. 1893. A Preliminary Report on Aquatic Invertebrate Fauna of the Yellowstone National Park, Wyoming and the Flathead Region of Montana. U.S. Fish Commission, Bulletin for 1891, Vol. II, pp. 207-256.
- National Academy of Sciences. 1969. Recommended Procedures for Measuring the Productivity of Plankton Standing Stock and Related Oceanic Properties. National Academy of Sciences. Washington, DC 59 pp.
- Pennak, Robert W. 1953. Freshwater Invertebrates of the United States. The Ronald Press Co., New York. 769 pp.
- Ward, Henry Baldwin and Whipple, George Cahndler. Edmondson, W.T., ed. Freshwater Biology, 2nd ed. John Wiley & Sons, Inc., New York. 1248 pp.
- Welch, Paul S. 1948. Limnological Methods. McGraw-Hill Book Co., Inc. New York. 381 pp.

APPENDIX E

CULVERTS AND FISH MIGRATION FROM YELLOWSTONE LAKE

BY

Robert Ruediger, Biological Aid (Fisheries)

U.S. Fish and Wildlife Service

Yellowstone Fishery Investigations

Yellowstone National Park, Wyoming

INTRODUCTION

It is the policy of the National Park Service that all natural areas and phenomena will be managed so as to retain their natural qualities. It follows that in the event that the natural qualities of an area or phenomenon are adversely affected to any degree by a structure or management policy, that the effects of the structure or policy will be corrected.

This study dealt with the possible effects of road culvert construction on the spawning migration of the Yellowstone cutthroat trout (Salmo clarki lewisi). The major task was to identify which culverts, if any, blocked, in part or whole, the spawning migration of the cutthroat trout as they moved upstream from the lake. According to the strictest interpretation of the Park's policy, if the construction of a culvert is such that the passage of one fish is obstructed, then the culvert should be modified or replaced in such a manner as to allow all fish to pass.

Due to the low water conditions and the breakdown of a key sampling instrument this study was not completed. Suggestions as to the continuation of the study are made.

METHODS

An attempt was made to find and classify all road culverts west of Sylvan Pass on the east entrance road to Fishing Bridge then south to the continental divide on the south entrance road. Eleanor Lake, just west of Sylvan Pass, is one of the headwaters of Clear Creek and represents the eastern-most point where fish migrating up from Yellowstone Lake can come into contact with a culvert. The continental divide on the south entrance road is the southern-most point where a road may cross a migration route. At least 55 miles of principle and secondary roadways, including residential areas and campgrounds were surveyed.

An important part of this study, that of measuring water velocity in the culverts, was not done due to the breakdown of the Pygmy Gurley meter halfway through the summer. Without this instrument the study had to take on a more qualitative aspect.

Culverts were classified under one of five categories:

1. Drainage - for surface water runoff due to rain or snow, no spawning;
2. Type 1 - constant flow, passage by all fish likely;
3. Type 2 - constant flow, passage by only some fish likely;

4. Type 3 - constant flow, no fish passage likely;
5. Type 4 - constant flow, not used for spawning due to the physical or chemical nature of stream. This refers mainly to culverts draining hot spring activity or bog areas.

The following criteria were used to classify the culvert:

1. Name and/or location of stream;
2. Location of culvert on stream (if more than one is present);
3. Length of culvert;
4. Velocity of water through culvert;
5. Culvert type: box, round, elliptical; concrete or metal;
6. Water depth at head, tail & flu;
7. If present, height of water outfall.

The culvert head is considered to be the downstream end of the culvert. A pace of 21 inches was used to estimate culvert lengths.

The field work for this project was done during the period from mid-July to mid-September, 1973.

RESULTS

A total of 327 culverts were located and classified. The majority of them, 281, would probably not be used by fish. A breakdown of the culverts shows:

Drainage - 236

Type 1	-	31
Type 2	-	11
Type 3	-	4
Type 4	-	45

There were 45 culverts that appeared likely to interfere with the migration of fish.

The appendix includes all the information obtained on these 15 culverts and also gives representative examples of culvert types 1 through 4.

The locations of the 15 problem culverts are:

1. Left Fork of Clear Creek on East Entrance road (Type 3);
2. North of parking area at west end of Fishing Bridge (Type 3);
3. Approx. 0.25 mile south of Fishing Bridge Junction (Type 2);
4. Hotel Creek, 1st culvert above Yellowstone Lake (Type 3);
5. Hotel Creek, mainstream, at Lake Area entrance road (Type 2);
6. Hotel Creek, Grand Loop Road (Type 3)
7. Hotel Creek, Grand Loop Road, 15 ft. south of #6 (Type 2);
8. Hatchery Creek, at boat house (Type 2);
9. Hatchery Creek, Lake Area entrance road (Type 2);
10. Hatchery Creek, Grand Loop Road (Type 2);
11. Approx. 0.25 mile south of Lake Area (Type 2);
12. 1st paved pullout south of Lake Area (Type 2);
13. Incinerator Creek (south of incinerator near Lake) (Type 2);
14. Approx. 0.15 mile south of Gull Point Drive, Grand Loop Road (Type 2);
15. Approx. 0.35 mile north of Spruce Forest Picnic Area (Type 2);

Hereafter these culverts will be referred to by their respective numbers, i.e., culvert (1) will refer to the culvert on the Left Fork of Clear Creek.

The classification of these culverts should be considered to be tentative until further information on seasonal (spring) water depths and velocities can be obtained.

DISCUSSION

Metsker (1970) lists three criteria for locations that are best suited for the placement of a culvert in a stream; these are (1) where there is no sudden increase in the stream velocity above, below, or at the culvert site; (2) the channel gradient of the stream should be near zero percent; and (3)

the stream reach should be of similar alignment for a 100 foot reach above and below the culvert site. Examples can be found among the 115 problem culverts where each of the above criteria were not considered. Culverts (2) and (4) can be cited as culverts that were placed where the stream velocity increases at the culvert site. Culverts (1), (2), (4), and (11) were placed where the stream gradient is greater than zero percent. Changes in the reach of the stream can be found just upstream of culverts (9) and (13).

Culvert sites where these location criteria were considered would be Arnica Creek and several culverts on Clear Creek above Sylvan Lake. These culverts were classified as Type 1 culverts. The local topography at these sites is much more favorable to culvert construction than many of the problem culvert sites.

Wherever possible it is always better to install a bridge instead of a culvert. When it is not economical to build a bridge, the next best alternative is to use an open-bottomed culvert, cement or metal. Open-bottomed culverts allow for the retention of a natural stream bed through the culvert and therefore affect the aquatic environment the least (Metsker 1970). McClellan (1970) states, however, that open-bottomed culverts are not always the best from the hydraulic, structural or foundations point of view. No open-bottomed culverts were seen in this study, except at the Cub Creek Picnic Area.

Of the prefabricated culverts, the elliptical or arch type are preferred where stream velocity is low and the gradient is flat (Metsker 1970). The culvert on Arnica Creek is a good example of this culvert type. Metsker (1970) also points out that debris catchers should be avoided. Culvert outfalls often provide a barrier to fish movement. Whenever possible, outfalls greater than one foot should be avoided. If an outfall of greater than one foot is unavoidable, then one or more of the following modifications will have to be employed in the downstream channel;

1. "One or a series of downstream weirs, orificed weirs, cribs, orificed low head dams" or a raise in the stream gradient by step increases of less than one foot;
2. With the desired pool-riffle ratio, fill the downstream channel to decrease the gradient;
3. Provide entrance approach with a fishway structure, i.e., Denil, Steepass, Vertical slot;
4. Provide an outfall pool that is deep enough to allow for a swim up situation (Metsker 1970).

Culverts on the Left Fork of Clear Creek (1) and Hotel Creek (4) are adversely affected by outfall problems. Modifications are possible for the Left Fork of Clear Creek but would be difficult on Hotel Creek. Culvert (3) has a 15 inch outfall but some fry were seen above and below the culvert but modifications could and should be made here. Culvert (14) also has a high outfall, but a water-mark on the culvert indicates that the culvert is partly submerged when the Lake is at higher levels. The high water may or may not occur during the spawning period.

"The sustained swimming speed in feet per second for a salmoid is four times the length of the fish in feet." A fish can maintain this speed for about 20 seconds. With this in mind one can consider the relationship between the velocity of a stream, fish size, and the horizontal distance a fish can swim between resting pools. The magnitude of the water velocity through a culvert should be less than the sustained swimming speed of the smallest fish that must pass through that culvert (Metsker 1970). The minimum size of the fish that spawn from Yellowstone Lake is about 12 inches. With the rule of thumb stated above, one could figure that these 12 inch fish would likely be able to pass through a culvert that is 80 feet long with a water velocity of 4.0 feet per second. It was not possible to check the water velocities of the 15 problem culverts, but the lengths of nine of these culverts was over 80 feet. If any of these nine "long" culverts has a velocity over 4.0 feet per second, then it would serve as a barrier to migration unless it were modified with some fish passage structures. Metsker (1970) suggests that a maximum velocity of 6 feet per second be allowed for a 15 inch fish, but that a fish this size could handle velocities of up to 8 feet per second. The average size of spawning fish in Yellowstone Lake is just under 15 inches.

One possible method to reduce stream velocity is backflooding. This also reduces the distance that a fish has to travel up a culvert. This can be accomplished by constructing a small overflow dam or weir at the entrance of the culvert (Metsker 1970).

Constructing baffles or a ladder system in the culvert also helps to provide for fish passage. These systems are modeled after the Denil or Steepass fishway facilities. McClellan (1970) found that most any baffle or ladder system will be effective. The height and spacing of these baffles is dependent on the slope of the culvert. These fishway facilities not only slow the velocity of the water through the culvert, they also provide resting areas for the fish.

McClellan (1970) also found that culverts using a reduced invert gradient to slow velocity not only worked well, but were less expensive initially and more effective hydraulically than culverts with baffle systems.

Fish biologists that McClellan (1970) contacted rated as "good" those culverts where the invert gradient did not exceed 5% and the length was less than 50 feet. They rated as "poor" those culverts where the invert gradient exceeded 5% and had no fish passage facilities, regardless of length.

CONCLUSIONS

A total of 327 culverts were located and classified along roadways in Yellowstone Park which crossed areas with streams that may be used by spawning cutthroat trout from Yellowstone Lake. Of these culverts 15 may, to some extent, block the passage of fish.

If the Left Fork of Clear Creek is used by spawning fish, then culvert (1) should be provided with a baffle system and an adequate swim up pool. Culvert (8) on Hatchery Creek should also be provided with a baffle system.

Culverts (2) and (11) block most fish passage, but it would be expensive to correct these. Culvert (2) is too long and both culverts have waterfall barriers just upstream.

Culvert (3) has an outfall barrier, but this stream should be rechecked for spawning activity as no fry were seen below the culvert.

Culvert (4) on Hotel Creek blocks all fish passage due to a high outfall and should be replaced with a new culvert, preferably of the open-bottomed type.

The conditions surrounding culvert (6) on Hotel Creek should be looked into; it seems possible that this may only be an outlet for a spring.

Culverts (5), (7), (9), (10), (12), (13), (14) and (15) should be checked again in mid-June for water depths in the culverts and for water velocity. Due to the time in the year that these were surveyed, it was not possible to adequately assess them. They should all be rechecked again in early August for the presence of fry. These new checks should allow for a more accurate classification of these culverts.

LITERATURE CITED

- McClellan, T. J. 1970. Fish Passage Through Highway Culverts: A Field Evaluation. U.S. Department of Transportation, Federal Highway Admin.
- Metsker, H. E. 1970. Fish Versus Culverts (Some Considerations for Resource Managers.) Engineering Technical Report ETR-7700-5, U.S. Forest Service, U.S. Department of Agriculture, July.

APPENDIX

Examples of Culvert Types 1,2,3,4

- Type 1: Cement box = on Clear Creek above Sylvan Lake
Metal pipe = Arnica Creek (Grand Loop Road)
- Type 2: Cement box = Hatchery Creek, 1st culvert above Lake
Metal pipe = 1st paved pullout south of Lake area
- Type 3: Cement box = Left fork of Clear Creek
Metal pipe = Hotel Creek; at west end of Fishing Bridge
- Type 4: Metal pipe = Beach Springs Area (Mary Bay)

15 Problem Culverts

1. Left Fork of Clear Creek and East Entrance Road
Date Checked - July 27, 1973
Cement box
Velocity - 156 rpm, 2.46 fps
Length - 32 ft.
Depth of water at: head 1 1/2 in.
tail 2 1/2 in.
Outfall - 10 in.; swim up pool depth - 11"
Type 3
No fry seen above or below culvert.
2. North of parking area at west end of Fishing Bridge
Date checked - September 11, 1973
Metal pipe
Length - Approx. 380 ft.
Type 3
Fry below culvert, none above

3. Approximately 1/4 mile south of Fishing Bridge Junction

Date checked - September 11, 1973

Metal pipe

Length - Approx. 75 ft.

Depth of water at: head - 1/2 in.
tail - 3/4 in.
flu - 1/4 in.

Outfall - 15 in.

Type 2

No fry above or below culvert

4. Hotel Creek, 1st culvert above Yellowstone Lake

Date checked - September 18, 1973

Metal pipe

Length - Approx. 65 ft.

Depth of water at: head - 1 3/4 in.
tail - 2 1/2 in.

Outfall - 3 ft. 2 in.

Type 3

No fry above culvert

5. Hotel Creek, main stream, at Lake area entrance road

Date checked - September 18, 1973

Metal pipe

Length - Approx. 49 ft.

Depth of water at: head - 1 1/4 in.
tail - 1 1/2 in.
flu - 3/4 in.

Outfall - 4 1/2 in.

Type 2

6. Hotel Creek, Grand Loop Road

Date checked - September 18, 1973

Metal pipe

Type 3

Could not find upstream end of culvert; downstream end has only a 2 inch opening which is 5 inches below the water surface.

7. Hotel Creek, Grand Loop Road, 15 ft. south of #6

Date checked - September 18, 1973

Metal pipe

Length - Approx. 145 ft.

Depth of water at: head - 1/2 in.
tail - 1/2 in.

Type 2

8. Hatchery Creek, at boat house

Date checked - September 18, 1973

Cement Box

Length - Approx. 25 ft.

Depth of water at: head - 3/4 in.
tail - 1 1/2 in.

Outfall - 2 in.

Type 2

Fry above culvert

9. Hatchery Creek, Lake Area entrance road

Date checked - September 18, 1973

Metal pipe

Length - Approx. 93 ft.

Depth of water at: head - 2 in.
tail - 2 1/2 in.
flu - 1 in.

Outfall - 6 in.

Type 2

Fry above culvert

10. Hatchery Creek, Grand Loop Road

Date checked - September 18, 1973

Metal pipe

Length - Approx. 150 ft.

Depth of water at: head - 2 in.
tail - 3 1/2 in.
flu - 2 in.

Type 2

Fry above culvert

11. Approximately 1/4 mile south of Lake Area

Date checked - September 14, 1973

Metal pipe

Length - Approx. 97 ft.

Depth of water at: head - 1 1/4 in.
tail - 1 in.

Type 2

Fry below culvert, none above, about 30 ft. above culvert is a waterfall barrier.

12. 1st paved pullout south of Lake Area

Date checked - September 14, 1973

Metal pipe - cement box combined

Length - Approx. 115 ft.

Depth of water at: head - 1 in.
tail - 1 1/2 in.

Type 2

Fry above culvert

13. Incinerator Creek (south of incinerator near Lake)

Date checked - September 14, 1973

Double metal pipe

Length - Approx. 90 ft.

Depth of water at: head - 1/2 in.
tail - 1/2 in.

Type 2

Fry above. South pipe filled with sand.

14. Approximately 0.15 miles south of Gull Point Drive, Grand Loop Road

Date checked - September 14, 1973

Metal pipe

Length - Approx. 110 ft.

Depth of water at: head - 1/2 in.
tail - 2 in.

Outfall - 17 in.

Type 2

Fry above culvert, water mark on culvert indicates that the outfall is not present when water in Lake is high.

15. Approximately 0.35 miles north of Spruce Forest Picnic Area,
Grand Loop Road

Date checked - September 11, 1973

Metal pipe

Length - Approx. 85 ft.

Depth of water at: head - 1/2 in.
tail - 1/2 in.

Outfall - 3 in.

Type 2

Fry above culvert

APPENDIX F

Table .—Creel census worksheet for the shoreline fishery, Yellowstone Lake, 1973

	1	2	3	4	5	6	7	8	9	10	11	12
Area	Period	Day length (hours)	(1)(2) Total daylight hours	Anglers counted in 24 passes	(4) 24 Average angler count	(3)(5) Total hours	Landing rate	(6)(7) Trout landed	Creeled rate	(6)(9) Trout creeled	Length of trip (hours)	(6) (11) Total anglers
1	6/15-7/8	16	384	371	15.5	5,952	1.07	6,369	0.56	3,333	1.79	3,325
	7/9-8/1	15	360	469	19.5	7,020	0.32	2,246	0.13	913	1.71	4,105
	8/2-8/25	14	336	129	5.4	1,814	0.49	889	0.34	617	1.37	1,324
2	6/15-7/8	16	384	1,806	75.3	28,915	0.76	21,975	0.28	8,096	2.23	12,966
	7/9-8/1	15	360	1,445	60.2	21,672	0.31	6,718	0.11	2,384	1.82	11,908
	8/2-8/25	14	336	814	33.9	11,390	0.57	6,492	0.20	2,278	2.01	5,667
3	6/15-7/8	16	384	755	31.5	12,096	1.02	12,338	0.37	4,476	2.59	4,670
	7/9-8/1	15	360	710	29.6	10,656	0.76	8,099	0.32	3,410	2.59	4,114
	8/2-8/25	14	336	565	23.5	7,896	0.37	2,922	0.17	1,342	3.42	2,309
4	6/15-7/8	16	384	626	26.1	10,022	0.77	7,717	0.66	6,614	1.71	5,861
	7/9-8/1	15	360	932	38.8	13,968	0.51	7,124	0.32	4,470	1.31	10,663
	8/2-8/25	14	336	456	19.0	6,384	0.26	1,660	0.21	1,341	1.64	3,893
Totals and averages				9,078		137,785*	0.61	84,549	0.29	39,274	1.95	70,805

* 95% confidence probability $\pm$ 16,351 hours

DISTRIBUTION:

Washington USFWS	6
Denver Regional Office USFWS	5
Billings Area Office USFWS	5
Fishery Services Field Offices, Region 6	5
Yellowstone Fishery Investigations	60
Superintendent, Yellowstone National Park	25
National Park Service, Washington	5
National Park Service, Denver RO	5

