THESIS

MORTALITY OF CUTTHROAT TROUT FRY, *Salmo clarki*,

IN YELLOWSTONE PARK, WYOMING

Submitted by

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In partial fulfillment of the requirements

for the Degree of Master of Science

Colorado State University

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WE HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER OUR SUPERVISION BY Wayne O. Deason

ENTITLED Mortality of Cutthroat Trout Fry, *Salmo clarki*, in Yellowstone Park, Wyoming

BE ACCEPTED AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE.

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Permission to publish this thesis or any part of it must be obtained from the Dean of the Graduate School.

ABSTRACT OF THESIS

A field study to determine mortality of cutthroat trout fry was conducted in Yellowstone Park, Wyoming. The total adult run upstream was counted in order to predict numbers of downstream migrating fry. A total of 36,098 trout were counted migrating upstream. Of these, 11,997 were males and 24,101 were females. Average fecundity was 1000 eggs per female. Allowing 21.0 percent for death in redds, 19,039,790 fry were expected in the downstream migration. A trap was set across Clear Creek to determine numbers of downstream migrating fry. Total fry count was 116,895. Excessively high water runoff hampered further trapping.

One hundred adults were collected from Clear and Cub Creeks at their outlets into Yellowstone Lake to determine if predation was a major factor in fry mortality. Adults were collected during daylight and dark. Results showed that adult predation was insignificant in both creeks and outlets.

A total of 50 moribund fry kidney smears were made on blood agar plates. Twenty-five healthy fry kidneys were used as controls. All plates were incubated from 45° to 60°F. None of the plates had growth, therefore fry mortality due to bacterial invasion was considered to be insignificant.

A sampling device used for counting downstream migrating fry was tested for accuracy. Five lots of 4000 fry each were poured from the trap through the sampling device. The range of inaccuracy was from 57.5 percent below the actual count to 42.0 percent over the actual count.

A library study analyzing various fry trapping operations and methods was included.

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Special thanks are extended to my wife, Kathy, who spent many long hours typing the manuscript.

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INTRODUCTION

Management of any good sport fishery requires a knowledge of the life history of the species in the fishery. Recently, much study has been based on optimum annual yield which is essentially the number and size of fishes which may be removed from the lake without having deleterious effects on the population (Ball and Cope, 1961). This safe removal has been defined as "equilibrium yield" (Ricker, 1958).

A thorough knowledge of fry mortality is essential in order to better predict equilibrium yield. Fry mortality is of major importance in fisheries management. On one stream, Arnica Creek, entering Yellowstone Lake, Yellowstone National Park, Wyoming, an average mortality has been reported to be 99.6 percent from egg deposition to migration of fry into the lake fishery (Benson, 1960). Cope (1957) stated that less than one percent of eggs deposited reach the lake as fry.

The author undertook the task of determining fry mortality in Clear and Cub Creeks which are two of the major spawning streams of Yellowstone Lake. The first phase of the study was undertaken during the summer of 1966 in order to refine various methods and techniques for the second phase which was to commence during the summer of 1967. Exceedingly high water runoff in the summer of 1967 caused a change to be made in the second phase from attempting to discover total fry mortality to factors contributing to fry mortality.

Problem Analysis

The problem was divided into two parts:

(1) Do adult cutthroat trout (*Salmo clarki*) utilize cutthroat trout fry as a major food supply?

(2) Do parasitic bacteria cause an appreciable mortality to downstream migrating cutthroat trout fry?

A study was undertaken to determine the soundness of the sampler used to count fry during the first phase of the study.

Included in the thesis is a review of recent and some older literature on trapping and sampling devices. This literature review should aid any biologist who is planning fry trapping operations on large rivers or small streams.

Delimitations

This thesis deals with two of forty streams entering Yellowstone Lake. Therefore the mortality found at Clear and Cub Creeks does not necessarily hold true for all forty streams or in the lake proper.

No attempt was made to determine mortality caused by fishermen or animals wading in creeks, fish-eating birds and animals, nor was an attempt made to discover the effect of high water.

REVIEW OF THE LITERATURE

Traps

Tait and Kirkwood Trap

Tait and Kirkwood (1962) undertook a large scale fry sampling operation in order to predict future adult salmon runs in the Prince William Sound, Alaska. Eight streams were studied. Traps were set across the stream, beginning at the bank-water interface and running to mid-stream, in such a way as to cover 10 percent of the stream channel. Each stream used traps made specifically for that stream. An example of the trap can be seen in Figure 1. Marked fry were released upstream from the traps in units of 500 and were distributed across the stream. The recovery figure aided in determining total migration for that stream

> "The percent of fry migration that the traps captured was estimated by (1) measuring the volume of water strained by the traps and (2) determining the average percentage of marked fry captured by the traps after release in each stream."

The formula used for estimating total fry migration from above trap installation for each stream was as follows:

$$T = \left(\frac{a}{b} 100 \right) \left(\frac{100}{c} \right) \left(\frac{100}{100-d} \right)$$

where a = number of fry captured by traps at a station

b = percent of fry captured by traps

c = percent of fry migration between original installation date and dismantling date

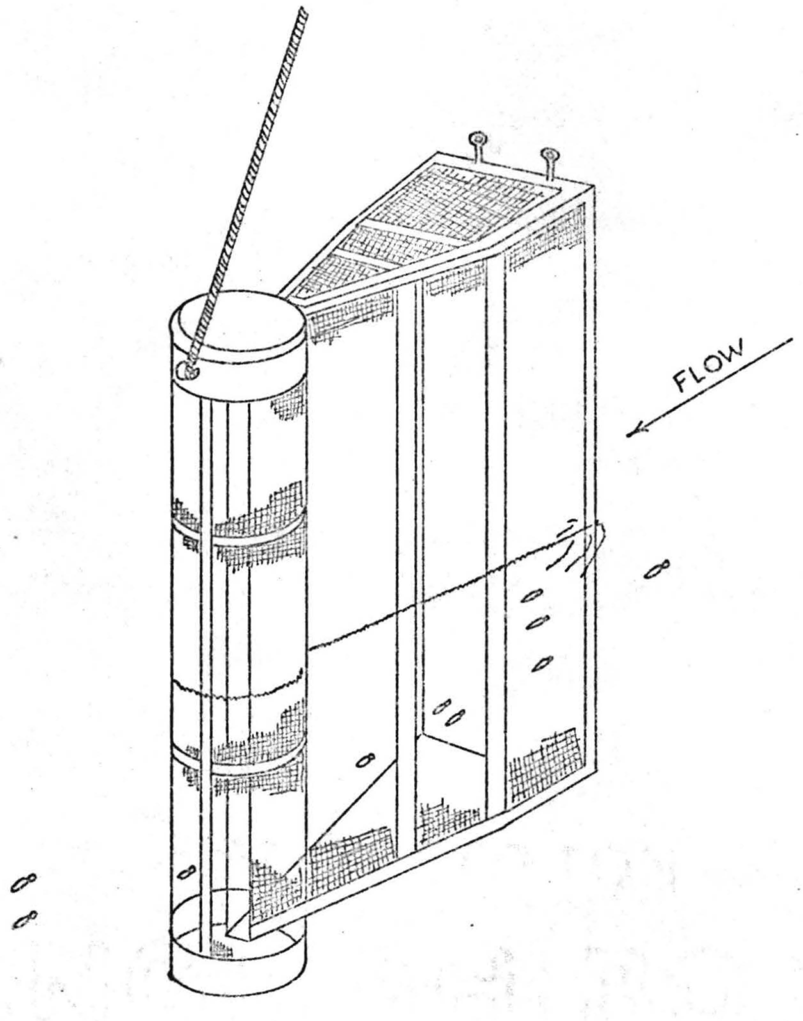


Figure 1. Metal fry trap used in enumerating pink and chum salmon fry in Prince William Sound streams (Tait and Kirkwood, 1962).

d = percent of time traps were not fished while being cleared, repaired, or moved to a better location

T = estimated total fry migration from above traps

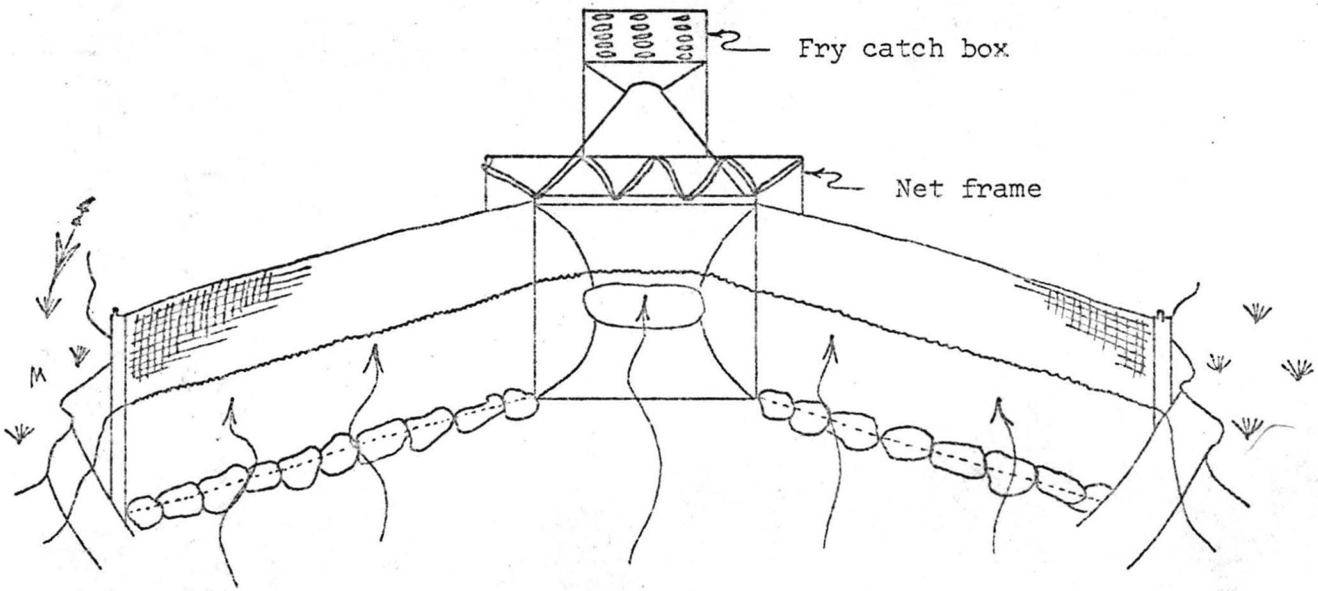
Craddock, Drummond, Snyder and Tanner Trap

Biologists interested in trapping fry on small streams should study the trap designed by Craddock (1959). Drummond (1966) and Snyder and Tanner (1960) trapped cutthroat trout fry at Trappers Lake, Colorado. A modified version of Craddock's trap was used. Excellent results were obtained. Snyder and Tanner noticed that occasionally small numbers of fry were found dead within the trap box. To eliminate the artificial mortality factor, a water deflector was constructed and placed within the trap. The deflector created a resting area for the fry and eliminated mortality due to fatigue. The assembled fry trap with wings used by Drummond, Snyder and Tanner is shown in Figure 2. A diagram of the individual parts is shown in Figure 3.

Snyder and Tanner tested fry-net efficiency by placing another trapping system of the same design directly below the first trap. The efficiency was 99.9 percent for eight nights of testing. Overflow was the apparent cause of fry loss around the first trap. Small holes at the bottom of the wings did not appear to reduce efficiency of the net. Fry would not go out holes at the bottom of the wings since migration takes place near the surface of the water.

Everhart, Hallock, Fry and LaFaunce Trap

Everhart (personnel communication) used a modified wire fyke trap patterned after Hallock, Fry and LaFaunce (1957) to catch salmon smolts in Maine. The trap was quite large. It measured 10 feet in diameter by 19 1/2 feet in length and weighed between 500 and 600 pounds



Front View

Figure 2. Diagram of fry net and catch box (Snyder and Tanner, 1960).

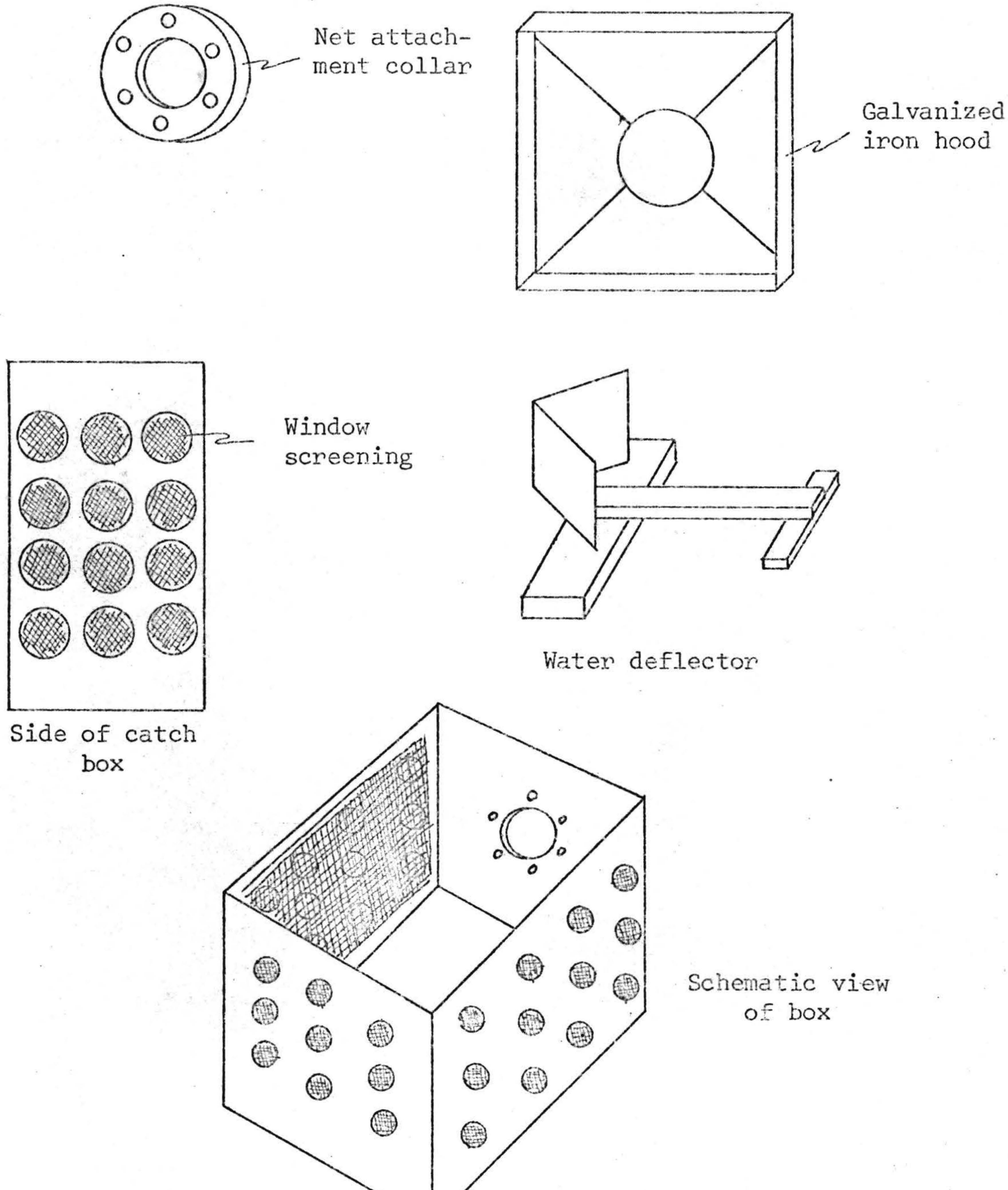


Figure 3. Parts of fry catch box (Snyder and Tanner, 1960).

(Figure 4). The trap used by Hallock, Fry, and LaFaunce (1957) in California was effective in catching adult steelhead trout, king salmon, silver salmon, striped bass, and shad. Everhart removed the large mesh used by California and replaced it with fine mesh which proved to be very effective in trapping the smaller smolts.

The trap was designed to be used in large rivers in very slow moving or standing water. Installation required from two to five men to roll it in and out of the water. The trap was transported on a two-wheeled flat bed trailer. A sled was used when the trap was moved a short distance up or down river.

This trap appeared to be especially adaptable for trapping large rivers.

Incline Plane Trap

The incline plane screen (Rounsefell and Everhart, 1953) was found to be useful for collecting small fish in a considerable volume of water containing large quantities of debris. The screen was most useful for estimating numbers of downstream migrating fish. Water was directed a short distance onto a sloping fine mesh screen. The water passed through the screen while fish and debris slid down the screen into a trough at the bottom.

> "The height of the drop and the angle of the screen vary with the size of the screen mesh and the volume of water. The screen should be adjustable so that the angle can be regulated."

The trapping system worked well with small or large fish but was originally designed to catch small fish.

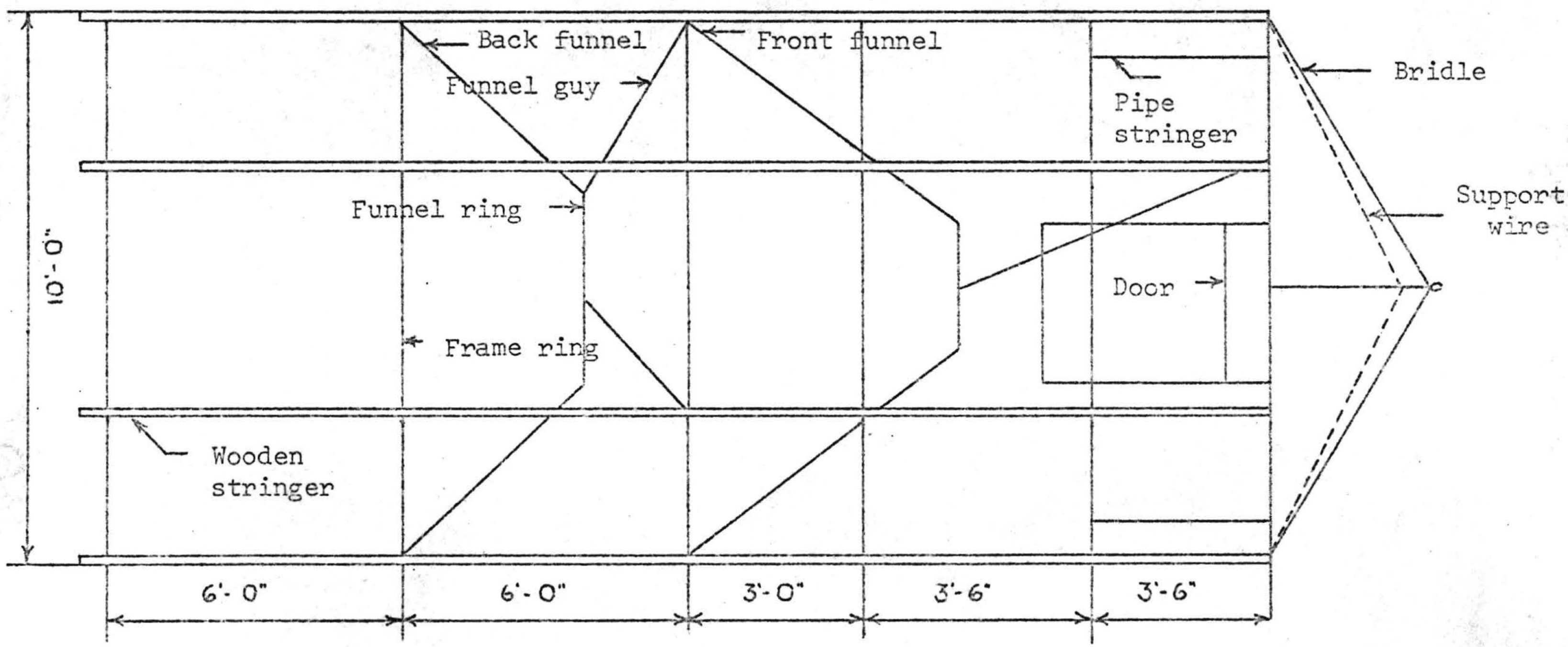


Figure 4. Diagram of wire fyke trap construction (Hallock, Fry and LaFaunce, 1957).

Wolf Trap

Wolf (1951) developed a trap which would catch all solid objects moving downstream. It was rather simple in design but extremely efficient. The trap was designed to meet the following qualifications:

> "(1) It should trap all fish, moving downstream, regardless of size; (2) it should not injure the fish even if the trap were not attended very frequently; (3) it should be able to accommodate flows varying from a mere trickle to 1 cubic meter per second (approximately 35 cfs) or more, since the brooks in which the planting was done were mountain streams subject to very heavy floods; (4) it should be so constructed that even in times of heavy floods laden with debris it would not clog; and (5) it should be possible to leave the trap without any attention for rather long periods, at least 3 weeks."

A diagram of the trap is given in Figure 5.

Humphreys Trap

Humphreys (unpublished report) recently designed a floating, self-cleaning trap which was used on the Grande Ronde River in Oregon. During high water runoff, the river carries moderate to heavy debris loads. The trap was designed so as to be operable during these heavy debris loads. The trap was essentially a floating, inclined-plane, self-cleaning design (Figures 6, 7, 8, 9). The traveling inclined screen was powered by a paddle wheel. The screen was raised or lowered into the water by hand winches which were attached to the flotation system. Debris was carried by the moving screen and dropped into the live box. Another moving, rotary screen removed the debris from the live box. Trap construction prevented fish removal from the live box by the rotary screen. The rotary screen was powered by the same paddle wheel which powered the inclined plane screen.

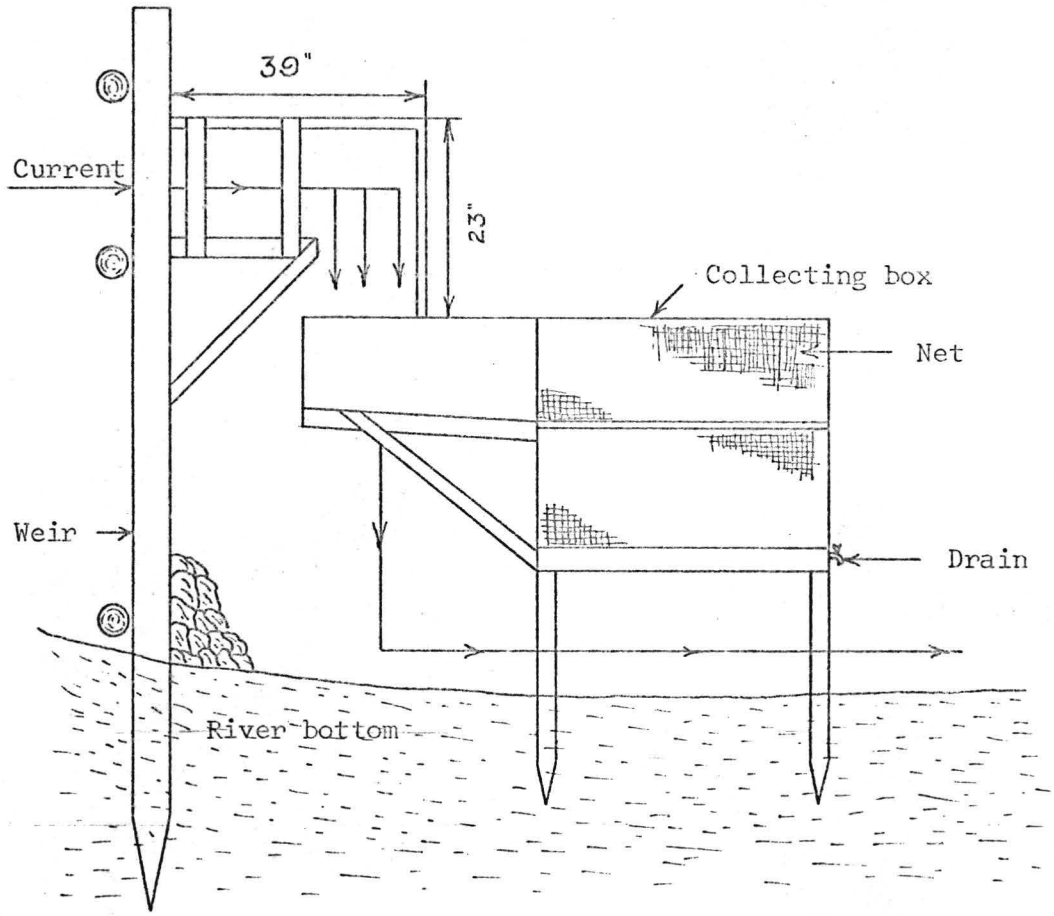


Figure 5. Diagram of installed Wolf trap (Wolf, 1951).

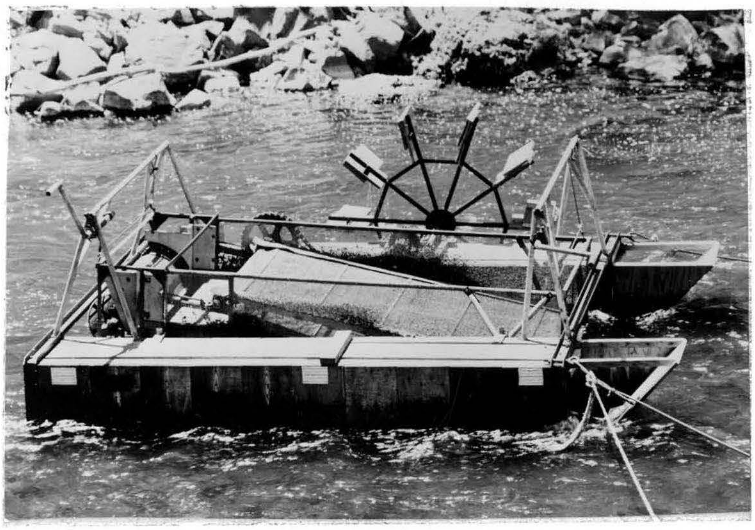


Figure 6. Self-cleaning scoop trap in operation
(courtesy of W. R. Humphreys)

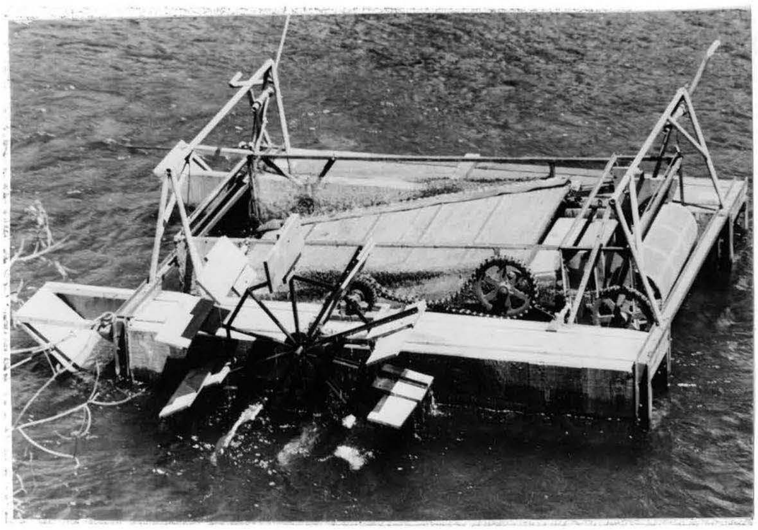


Figure 7. Self-cleaning scoop trap in operation
(courtesy of W. R. Humphreys)

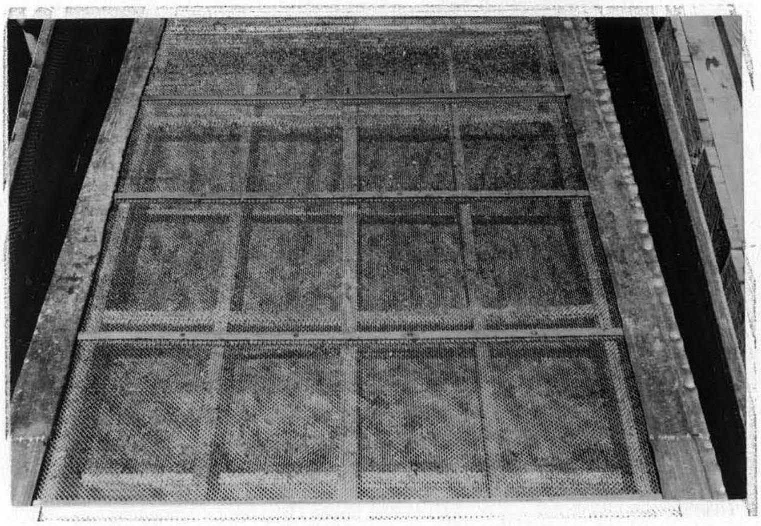


Figure 8. Traveling screen
(courtesy of W. R. Humphreys).

Figure 9. Rotary screen for debris removal
(courtesy of W. R. Humphreys

Humphreys placed the trap in a constricted section of the river. This caused an increase in velocity and a concentration of the downward migrating fish. A velocity of 4 to 6 feet per second was necessary to prevent fish from swimming back out of the trap before entering the live box. The trap was held in place by cables which were attached to trees on each side of the stream channel.

Humphreys determined trapping efficiency by releasing branded fish two miles above the trap. Efficiency tests were conducted when stream flow was 300 cfs. Efficiencies of 9.9 percent and 13.7 percent were reported.

Big Qualicum Trap

An efficient trapping system was used on the Big Qualicum project in Vancouver, B. C. (Lister, personal correspondence). The traps were designed to enumerate chum salmon fry (0.4 gm) to steelhead trout smolts (50 gm) by straining a portion of the stream. The downstream end of the trap was raised or lowered by a hand winch. Each individual one-foot-wide trap screened up to 8 cfs. Each trap led into an attached live box, Figure 10, or into a common trough which directed the fish into a series of live boxes at the edge of the stream. Figures 11 and 12 show the traps in operation.

Fulton River Trap

Another trap used in Vancouver was designed after the Wolf-type trap (Lister, personal correspondence). It was modified to provide a greater water screening area. The trap was used to enumerate total numbers of sockeye salmon fry migrating in an artificial spawning channel. The trap was designed to screen up to 25 cfs. Debris was directed into the live box with the fish. The trap was of good design and was

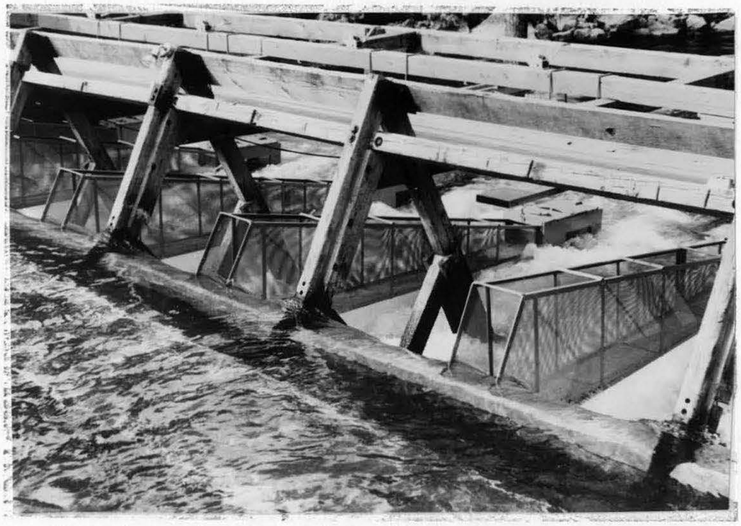


Figure 10. Series of traps in operation
(courtesy of D. B. Lister)

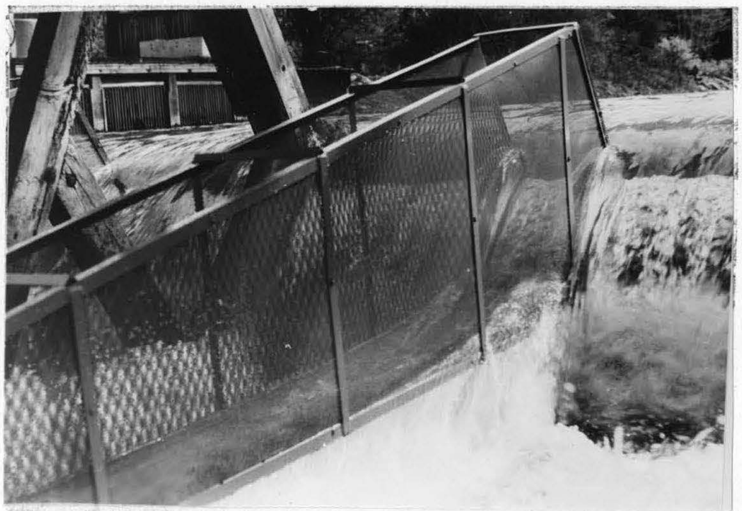


Figure 11. Entrance of trap
(courtesy of D. B. Lister)

Figure 12. Fry removal from trap
(courtesy of D. B. Lister)

efficient in trapping fry. The trap Lister used was approximately 5 feet wide and 12 feet long. The live box was lifted out of the water when enumerating fry. Lister recommended that the size of the trapping system be reduced to increase its portability and ease of installation.

Fry Sampling Methods

Snyder and Tanner (1960) used the following method of sampling fry in Cabin Creek, one of three major streams entering Trappers Lake, Colorado.

> "When the fry became too numerous for total counts, a sampling pattern was established. During the first part of the run of Cabin Creek samples of five and twenty-minute periods were compared with the hourly counts in order to establish an adequate sampling schedule. Counts were also taken each five minutes for one hour in order to determine the best sampling period in the hour. The twenty-minute counts most closely approximated the actual count but were biased downwardly (7 percent). Throughout the sampling period and after the sampling period terminated, samples were compared with hourly counts more or less as a pilot sampling study for 1959. The twenty-minute samples taken on the downward slope of the daily migration peak were upwardly biased (35 percent).

Drummond (1966) used a special dip net which would just fit inside the trap. Fry were counted and released each hour beginning at 9:00 p.m. and continuing until 12:00 p.m. All fry captured after 12:00 p.m. were counted and released at 8:00 a.m. the following morning. No mention of the sampling method could be found. The assumption was made that total fry sampled was a function of dip net size to trap size.

Tait and Kirkwood (1962) sampled fry in relation to water screened by each trap at a given location. They would place traps across a stream in such a way as to cover 10 percent of the stream. By measuring the volume of water strained by the traps and determining the average percentage of marked fry captured by the traps, an estimation of total fry migration could be obtained. Refer to Pages 3 and 4 for a more detailed discussion of the subject.

The sampling method used by Tait and Kirkwood was similar to the one used on the Big Qualicum project by Lister (personal communication). One-foot-wide traps were set across the stream. Each trap would strain up to 8 cfs depending on water velocity. Marked fry were released upstream from the traps. Knowing percent recaptured fry and amount of water strained by the screens would give an estimate of fry abundance.

Predation by Adults

Very little has been written concerning the feeding behavior of adult cutthroat trout under natural conditions. During 1958, Snyder and Tanner (1960) collected 23 stomach samples from cutthroat trout in Trappers Lake, Colorado. Trout fry made up a significant part of the diet during migration. Again in 1959, 6 trout were collected and the stomachs analyzed. An average of 61 fry per stomach was counted. Although this is a high number of fry per stomach it would be necessary to collect a larger sample of fish before stating that fry make up a significant part of the adults' diet.

Calhoun (1944) stated that the only evidence of cannibalism in two Sierra Nevada lakes was in late summer following the propagation of 50,000 fry. Calhoun found 7.7 percent of total stomach content to be composed of fry. Calhoun insinuated that if fry are available, adult trout will eat them. Hazzard and Madsen (1933) also stated that where small fish are available adult cutthroats will eat them. The authors showed that cutthroat trout from the Teton Park area of

Wyoming utilized fry as a major source of nutrient and that as adults became older and grew in size they consumed more fry. Fleener (1952) found only two occurrences where adult cutthroats had fish in stomach samples. Fleener showed that fry do not make up the normal adult diet in the Logan River, Utah. Irving (1954) reported that cutthroat trout fingerling occasionally feed on one another in hatchery rearing ponds. Since hatchery rearing ponds are far removed from natural conditions, this has no significance with relation to fingerlings in the wild. Muttkowski (1925) states that fish are cannibals and will eat fry and fingerling trout when the opportunity arises. Cutthroat adults are no exception for they will eat other fish just as greedily as will bass. Muttkowski studied lakes and streams throughout Yellowstone Park but gave no data to prove his statements correct.

DESCRIPTION OF AREA

Yellowstone Lake, located in Yellowstone National Park, Wyoming, is situated approximately in the center of the Park at an elevation of 7731 feet. It contains about 100 miles of shoreline and approximately 90,000 surface acres (Ball, 1955). The lake has a surface area of 135.77 square miles with an average depth of 139 feet. The basin has an estimated capacity of 12,095,264 acre feet of water with an annual outflow of 1,100,000 acre feet. The lake becomes thermally stratified during August of each year with surface temperatures rarely exceeding 66°F (Benson, 1958).

The lake is fed by 40 streams; 14 are considered major spawning tributaries and 26 are minor. These streams drain approximately 1,006 square miles of watershed (Farnes and Bulkley, 1964).

Adult spawning cutthroat trout begin their upstream migration in late spring and early summer (Mills, 1966). The fish spend approximately three weeks in the stream before they move back downstream (Ball and Cope, 1961).

Clear Creek

Clear Creek is one of the major spawning tributaries of the lake. Headwaters of Clear Creek, the Sylvan Lake area, are approximately 13 miles from Yellowstone Lake. Sylvan Lake is located on the western slope of the Absaroka Range and drains westward into Yellowstone Lake. Sylvan Lake is approximately 8510 feet in elevation; therefore the average gradient from Yellowstone Lake to Sylvan Lake is 59 feet per mile. During spring runoff water flow exceeds 1000 cfs while August flow may be as low as 20 cfs (Mills, 1966).

Cub Creek

Cub Creek flows into Yellowstone Lake approximately one mile north of Clear Creek. Like Clear Creek, it originates on the west slope of the Absaroka Mountain Range but is considerably smaller in size. Water flow ranges from 400 cfs during high runoff to 5 cfs through August (Mills, 1966). The stream channel is approximately 10 miles long with an average gradient of 76 feet per mile.

METHODS AND MATERIALS

Trapping Operation

The trapping operation instituted on Clear Creek, Yellowstone National Park, was similar to the operation of Drummond (1966) and Snyder and Tanner (1960). The wings of the trap measured 30' x 3'. Wings were made from 1" x 4" pine lumber frames with screen wire (8 mesh/inch) nailed to the frames so as to direct the fry into the trap as well as letting excess water flow through the wings. A metal frame, measuring 24" x 32", was driven into the streambed and used to hold the flume which directed the fry into the trap. The trap was a large plywood box which measured 24" wide, 36" long, and 24" deep. Holes, cut in the sides to allow water passage, were covered with screen wire to prevent passage of fry.

The trap frame was set one-third the distance across the stream and about 15 feet above where the stream enters the lake. This position was chosen because of the narrow width of the stream at that location and because the water flowed mainly down the one side of the stream. This resulted in a majority of the fry migrating downstream from the stream's deep water side to approximately two-thirds the distance across the stream.

The fry trapping operation began shortly after the adult migration terminated. Each night from 7 August until 24 August, the trap was attached to the frame at 7:00 p.m. and removed from the frame the following morning at 8:00 a.m. The trap was operated 24 hours per day from 24 August to 10 September. The trap was observed once every three hours at the beginning of the trapping study. Because there were so few fry, a count was not made until the trap removal at 8:00 a.m. the following morning. Not until 11 August did the fry migrate heavily enough to warrant counting at three-hour intervals.

Snyder and Tanner (1960) found a significant effect on migration with changes in temperature of the water. To obtain an accurate temperature correlation a thermograph was set close by the trap location and stream temperature was recorded throughout each 24-hour period.

Sampling

Once the trap was in operation, a major problem was encountered in counting fry. Since many of the larger streams with a large adult migration will produce numbers of fry in the hundreds of thousands and higher, it is obvious that the worker cannot count each fry. Some method of sampling the fry in the trap must be devised. The author used a ten-gallon milk can which had the bottom removed. Within the can, a cylinder was inserted which measured one foot in length and was just wide enough to fit inside the can snuggly. The cylinder had ten pie-shaped sections, only one of which was closed. Theoretically, one-tenth of the fry would be trapped in the closed section when poured through the sampler. By counting this sample and multiplying by ten, the total number trapped for a given time period should be obtained, (Figures 13 and 14).

The sampling device appeared to give an inaccurate count during the summer of 1966. During the summer of 1967, an experiment was performed to check the soundness of the statistical device. The device was modified by placing a cylinder in the mouth of the sampler so the

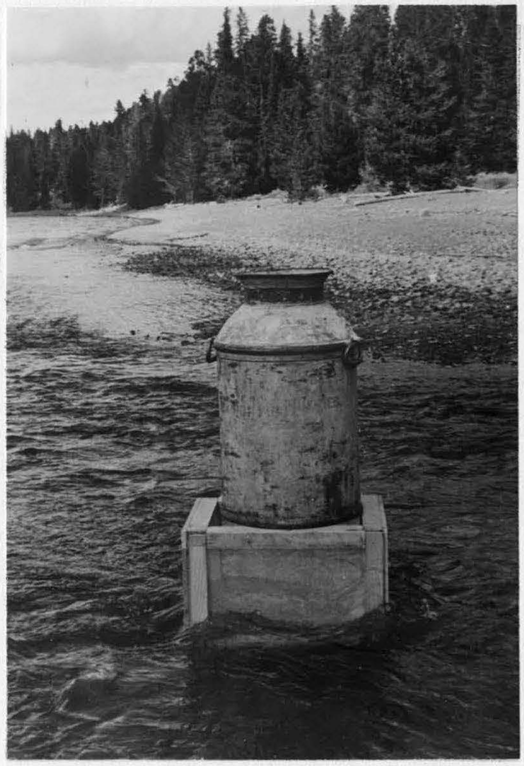


Figure 13. Sampling device

Figure 14. Bottom view of sampling device showing sampler installed

fry would fall in a random mass which would give better results. A metal sleeve was inserted inside the mouth of the device and set on top of the cylinder (Figure 15).

Determining Bacterial Parasites

During the first phase of the study, many of the fry which were collected each night were noticed to be moribund or dead. Possibly a bacterial parasite could be causing death of many of these fry. A sample of moribund fry were removed each night and kidney smears made on blood agar plates the following morning. A total of 50 moribund fry kidneys were used. Kidney smears from 25 apparently healthy fry were used as controls.

The plates were incubated by placing a five-gallon glass jar containing the plates in a notch in the stream bank. This method of incubation was thought to be best because the temperature of the incubator would fluctuate nearly the same as the stream.

Figure 15. Metal sleeve used to constrict mouth of sampling device

RESULTS

Trapping and Enumeration

A total of 36,098 adult trout were counted migrating upstream in Clear Creek. Of these, 11,997 were males and 24,101 were females, a ratio of 1:2. A predicted 24,101,000 eggs were expected to be deposited in the streambed. This assumes a fecundity rate of 1000 eggs per female.

No migration patterns could be established until 20 August (Table 1). Heavy rain periodically created freshets during which water temperature fluctuated noticeably and fry movement was altered significantly (Tables 2 and 3).

Upon termination of the trapping operation, 116,895 fry had been counted. Calculations indicated total fry mortality was 99.5 percent.

Predation

A total of 36 adult fish were collected from Clear Creek during the summer of 1967. One fry was found in one stomach sample. Adult fish collections could not be made in Cub Creek in late August because nearly all fish had returned to the lake. The one fish collected did not contain fry in the stomach.

One hundred fish were taken in the lake near the mouths of Clear and Cub Creeks and their stomachs analyzed. Fifty of these fish were taken during the day and 50 at night. Two fish were found with fry in their stomachs. One fish contained four fry while the other contained five (Table 4).

TABLE 1

Total Number of Cutthroat Trout Fry Trapped Per Day in August 1966 from Clear Creek, Yellowstone Park, Wyoming

Date	Number Trapped
7	400
8	220
9	140
10	---
11	2,535
12	1,428
13	-----
14	-----
15	-----
16	8,878
17	-----
18	-----
19	-----
20	860
21	3,351
22	5,930
23	11,395
24	16,290
25	17,270
26	22,520
27	9,100
28	2,403
29	5,220
30	4,100
31	1,430
TOTAL	113,270

TABLE 1 (Continued)

Total Number of Cutthroat Trout Fry Trapped Per Day in September 1966 from Clear Creek, Yellowstone Park, Wyoming

Date	Number Trapped
1	Trap not set
2	Trap not set
3	100 (estimated)
4	2,200
5	1,350
6	50 (estimated)
7	25 (estimated)
8	0
9	0
10	0
TOTAL	3,625

TOTAL FRY MOVING DOWNSTREAM 116,895

TABLE 2

Maximum and Minimum Water Temperatures
From August 21 to September 8, 1966
in Clear Creek, Yellowstone Park, Wyoming

Date	High °F	Time	Low °F	Time
8/21	58°	4:00 p.m.	Installed at noon	
8/22	60°	4:30 p.m.	45°	8:00 a.m.
8/23	61°	4:30 p.m.	47°	8:00 a.m.
8/24	62°	4:30 p.m.	47°	8:00 a.m.
8/25	62°	4:30 p.m.	48°	8:30 a.m.
8/26	59°*	3:30 p.m.	49°	8:30 a.m.
8/27	57°*	5:00 p.m.	49°	9:00 a.m.
8/28	58°	4:00 p.m.	46°	8:30 a.m.
8/29	60°	4:00 p.m.	47°	7:30 a.m.
8/30	59°	3:30 p.m.	51°	8:00 a.m.
8/31	57°*	4:30 p.m.	48°*	8:00 a.m.
9/1	55°	5:00 p.m.	51°*	8:00 a.m.
9/2	53°*	5:00 p.m.	50°	7:30 a.m.
9/3	59°	5:00 p.m.	47°	8:30 a.m.
9/4	60°	4:30 p.m.	47°	9:00 a.m.
9/5	57°	4:00 p.m.	48°	8:00 a.m.
9/6	59°	5:00 p.m.	48°	9:00 a.m.
9/7	59°	5:00 p.m.	48°	8:30 a.m.
9/8	58°	6:00 p.m.	48°	8:00 a.m.

* Periods of rain

TABLE 3

Effect of Water Temperature on Fry Movement
in Clear Creek, Yellowstone Park, Wyoming

Temp (F°)	Date	Time (First Run - Second Run)	Number of Fry
51	8/21	12:00 midnight	855
45		7:00 a.m.	1,580
51	8/22	12:00 midnight	2,885
51		3:00 a.m.	1,725
53	8/23	1:00 a.m.	2,004
49		6:00 a.m.	1,660
54	8/24	1:00 a.m.	2,490
49		6:00 a.m.	2,000
55	8/25	1:00 a.m.	7,310
52		4:00 a.m.	4,960
53	8/26	1:00 a.m.	2,150
51		4:00 a.m.	12,930
49	8/27	4:00 a.m.	4,180
46	8/28	8:00 a.m.	2,403
47	8/29	8:00 a.m.	5,220
51	8/30	8:00 a.m.	4,100
48	8/31	8:00 a.m.	1,430
46	9/3	8:00 a.m.	100
47	9/4	8:00 a.m.	2,200
48	9/5	8:00 a.m.	1,350

TABLE 4

Adult Predation

Creek Sampled	Sampling Period	# Sampled in Stream	# With Fry in Stomachs	% of Adults With Fry
Clear Creek	Daylight	36	1	2.7
Cub Creek*	Daylight	1	0	0.0

Outlet Sampled	Sampling Period	# Sampled in Outlet	# With Fry in Stomachs	% of Adults With Fry
Clear Creek	Daylight	27	2	7.4
Clear Creek	Night time	26	0	0.0
Cub Creek	Daylight	25	0	0.0
Cub Creek	Night time	25	0	0.0

*By the time fish collection had begun on Cub Creek, the adults had already migrated back into the lake fishery.

Sampling Device

The results obtained from five groups of 4000 fry placed in the trap and poured through the sampling device are given in Table 5. The conclusion was made from these data that the sampling device gives an inaccurate count.

Bacterial Cultures

Fry kidney cultures were observed for growth on the third, sixth, and seventh days. A total of 50 kidney cultures were made on blood agar plates. Three of the plates produced mixed colonies and were therefore assumed contaminated. It is also possible, though unlikely, that these positive cultures indicated infections. In the absence of additional bacteriological studies, one may not be justified in assuming no etiological significance for the "mixed colonies". The 25 control plates had no growth. The plates were removed from incubation and stored in the refrigerator at 37°F for two weeks whereupon they were incubated at 60°F in a laboratory incubator for another week. Results remained unchanged.

TABLE 5

Soundness of Sampling Device

# Fry (Actual)	# Fry (Sampler)	% Inaccuracy
4000	2700	32.5 (under)*
4000	1700	57.5 (under)*
4000	2700	32.5 (under)*
4000	5400	35.0 (over) *
4000	5680	42.0 (over) *

*Designates percentages counted over and under the actual count of 4000.

DISCUSSION

Trapping and Enumeration

Fry trapping operations were terminated on September 10 for 1966. Calculations showed that an estimated 0.5 percent of the fry had migrated downstream by that time. This figure was based on two assumptions: (1) no egg retention and (2) no egg mortality in the redd. Several of the females whose stomachs were analyzed for fry showed signs of egg retention; therefore, this factor should be investigated further to determine the percent of egg retention. Mills (1966) obtained an egg mortality of 29.3 and 12.7 percent for 1964 and 1965 respectively in Clear Creek for an average of 21.0 percent. Assuming the average of 21.0 percent is correct, then 21.0 percent of the 24,101,000 are lost in redds. The expected figure for migrating fry would then be 19,039,790. Therefore the estimated mortality of emerged fry was 99.39 percent. However, only 0.61 percent of the expected fry successfully returned to the lake fishery. Possibly 0.61 percent is an inaccurate figure because of the following six points:

(1) Downstream fry migration had commenced before the trap was installed;

(2) Wings washed out on occasion allowing fry to bypass trap;

(3) No attempt was made to determine the high net mortality;

(4) The sampling device gave biased results;

(5) No attempt was made to determine mortality by other factors such as predatory animals and birds or fishermen wading in stream;

(6) The trap was dismantled early.

Water flow during the summer of 1966 was above normal. Even though certain modifications were made on the trapping system, the trap could not withstand the greater water flow during the summer of 1967. Fry were not trapped during the second summer of the research because of such a large flow of water.

Traps

A modified form of the Tait and Kirkwood (1962) trap could possibly have been used successfully on Clear Creek during the summer of 1967 because it was designed to be used on large rivers where considerable water volumes are encountered.

These traps were of good design and with minor additions could prove efficient for use with large volumes of water. Tait and Kirkwood witnessed high mortality within the traps during periods of increased water flows which resulted from melting snow and ice. Mortality was attributed to water pressure and the large amount of debris which was carried into the trap by the high water. Fry were forced against the screen at the back of the trap and either became too weak to pull themselves from the screen or were crushed by debris. Death rapidly ensued when fry lost the energy necessary to pull themselves from the screen. To prevent such unnecessary mortality a water deflector (such as the one used by Snyder and Tanner, 1960) could have been attached where the trap flume enters the trap proper. The deflector would create a pool behind the deflector where fry could escape the force of the current. Tait and Kirkwood stated that the traps were not entirely satisfactory for estimating fry abundance. One point in proof of this statement was

> "Predators such as Dolly Varden trout and sculpins introduce unknown errors by entering the traps and devouring large numbers of fry."

Such a mortality factor could have been alleviated by attaching a large mesh net or chicken wire over the trap flume entrance which would allow small fry to go into the trap while closing the entrance to predators and larger debris.

The trap used on Clear Creek was more efficient in that it trapped all fry moving downstream whereas the Tait and Kirkwood trap sampled only a part of the total downstream migration. More water could be strained before the fry reach the trap if the angle at which the wings leave the trap were decreased and the wing length increased. This could decrease the pressure exerted on the wings and guide fry into the trap.

The paper by Tait and Kirkwood should be studied by all those undertaking a fry trapping study where large volumes of water will be encountered. However, streams of low velocity can be trapped with small, more efficient traps such as the one used by Craddock (1959), Drummond (1966) and Snyder and Tanner (1960).

The trap used by Craddock (1959), Drummond (1966) and Snyder and Tanner (1960) is very efficient when trapping waters under 10 cfs. The wings of the trap used by Drummond (1966) and Snyder and Tanner (1960) were made of nylon netting. Nylon netting was used for the first summer in Yellowstone but was found inadequate. The force of the water stretched the nylon netting and tore it in several places where it was attached to the wooden frame. Pockets were created which trapped fry in the nylon netting by continued water pressure. The fry were unable to pull themselves upstream out of the pockets and into the trap flume, subsequently many fry died in the pockets. Research on Clear Creek showed that replacing the nylon netting with wire screen made the wings capable of withstanding stream pressure and allowed the cleaning of the wings with a stiff-bristled brush. This trap can be used on small streams if one wishes to enumerate all fry migrating downstream.

The trap used by Everhart (personal communication), and Hallock, Fry and LaFaunce (1957) would be very difficult to use in high mountain streams because of size and weight. It was designed to be used in large slow-moving rivers with deep holes. It was effective in trapping fish when placed in slow, deep waters. Two to five men are required to move the trap and would therefore require the employment of additional men to operate the trap. A trailer was needed to transport the trap from location to location. The trailer would add more expense to an already expensive trap.

This trap could not have been used in Clear Creek because of the size of the trap and the remoteness of Clear Creek. The trap used on Clear Creek was more suitable because it was designed to trap all fry whereas the trap used by Everhart, Hallock, Fry and LaFaunce only sampled a portion of the total downstream migration.

The incline plane trap of Rounsefell and Everhart (1953) was designed to catch small fish. It was effective in trapping fish in waters that contained large volumes of debris. Such a trap could be used successfully in high mountain streams with frequent high water runoff. Debris would not be a problem because it seldom enters the trap box. Debris was collected by the screen and could be removed from the screen quite easily.

Such a trap could have been used on Clear Creek because it traps all fry migrating downstream. Clear Creek often carried heavy loads of trash and debris. The pressure associated with the buildup of debris eventually destroyed the nylon-covered wings.

The Wolf trap was found to be effective in trapping all fish moving downstream (Wolf, 1951). It was designed to be used in small streams with water flows up to 35 cfs. Debris and fish are held in the same compartment. The compartment can be baffled so as to offer holding pools where fish can escape the force of the current. The Wolf trap could have been used in Clear Creek at the base of a small, natural falls. Debris collectors of some kind could be placed above the trap to stop large, more destructive material such as logs, while allowing grass, twigs, etc. to enter the trap.

The Humphreys trap was designed to be used in fast streams which may carry large volumes of water but it does not trap the entire stream. The trap incorporates a traveling screen, powered by a paddle wheel, which carries fish to the rear of the screen and drops them into the trap. One merely pulls the trap to the bank and counts the fish in the trap. Humphreys placed the trap in a constricted part of the stream where fish moving downstream were concentrated. To determine accuracy of the trap, Humphreys released two groups of branded fish two miles upstream from the trap. Only 9.9 percent and 13.7 percent of the fish were recaptured. By counting the trapped fish and multiplying by a percentage factor of fish trapped, the number of fish migrating downstream was obtained. Such a trap could be considered useful on Clear Creek during heavy runoff.

The Big Qualicum trap operates similarly to the Tait and Kirkwood trap (Tait and Kirkwood, 1962), in that several of the traps are set across a stream. The traps strain a sample of the creek. The trap requires only one man for operation. It was designed to be used on streams up to 8 cfs, but with additional support could be used on larger streams. This trapping system was found to be effective during high and low water velocity. Debris could be a problem because it was directed into the live box. Since only a portion of the total stream was trapped, most of the debris would bypass the trap openings. A deadman could be installed upstream from the trap to catch large debris such as trees or branches. Lister (personal correspondence) stated that smolts avoid the traps to some degree depending on approach velocity. The Big Qualicum trap would be satisfactory for Clear Creek during high runoff but unsatisfactory during low runoff. During low runoff, the fry can choose the route of downstream movement and may avoid the trap opening.

The Fulton River trap was designed after a Wolf-type trap. The trap can be used to sample a portion of the stream or the entire stream. It is provided with a greater surface screening area than the Wolf trap so larger volumes of water can be screened. This trap could be used on any stream adaptable to the Wolf trap. It could have been used on Clear Creek. Debris would have been a problem since it is directed into the trap.

Predation

Fishermen and knowledgeable fishery personnel have reported adult fish lying near the outlets of several streams entering Yellowstone Lake preying on downstream migrating fry. The possibility that adult fish were moving in from deeper water and consuming fry as they moved into the lake was considered. One hundred fish were collected to determine the validity of this consideration. In addition, an attempt was made to collect fish from within Clear and Cub Creeks to determine if adults in the stream prey on fry. Unfortunately, most of the adults had returned to the lake fishery before the collecting began. Thirty-six fish were collected from Clear Creek by electrofishing. Only one adult trout contained fry. According to these figures, 2.7 percent of adults contained fry. One must realize, however, that a sample size of 36 adults is quite small. In order to definitely state that 2.7 percent of all adults in Clear Creek prey on fry a larger sample size would be needed. Relating 2.7 percent to the total adult run of 36,098 fish would mean that 974 adults consumed fry. By the time fry appear in the stream, most adults have returned to the lake.

Twenty-five fish from the outlets of the two streams were collected by hook and line during the day and twenty-five by an electrofishing boat at night. Fish were taken from the outlets during both day and night to determine at what time adults might prey on fry. Since fry migrate at night, adults may move in from deeper water and wait for them to enter the lake. Analysis of night-sampled trout stomachs revealed that adults did not utilize fry at that time. No fry were found in the stomach of any of these fish.

Many fry remain along the lake's edge during the day. For this reason, 50 adult fish were collected at the outlets during daylight. Analysis of stomachs revealed only two with fry. The conclusion was made that adults probably do not utilize fry to any appreciable extent for food along Clear and Cub Creek outlets.

The adult population living around Clear and Cub Creek outlets is large, therefore a sample of 100 may be insignificant. One would have to collect many more adults to state emphatically that these fish do not prey on fry. One must also consider that Clear and Cub Creeks are only two of forty streams entering Yellowstone Lake. What holds true for Clear and Cub Creeks may not necessarily hold true for the remainder of the streams. Welsh (1952) found predation on cutthroat trout fry by age groups I and II in Arnica Creek to be a major factor in fry mortality. The size of the sample of adult fish examined was not given. The outlet of Arnica Creek is into a bay while the outlets of Clear and Cub Creeks are directly into the lake. The difference in the topography of the outlets of these streams and different stocks of fish may account for some of the cannibalistic behavior of the fish in Arnica Creek outlet.

Sampling

The sampling device was used to make all fry counts during the summer of 1966. The study conducted during the summer of 1967 proved the device to be quite inaccurate. The number of fry obtained in 1966 is considered to be invalid in predicting future adult migration up Clear Creek.

The sampling device used for fry enumeration was thought to be a basically sound idea. Certain refinements might enable a biologist to obtain accurate counts. The most noteworthy refinement would be to change the manner in which the fry are poured through the device. The method of using the device for the research reported here was to rest the entrance lip of the trap on the neck of the device until the fry were distributed uniformly. The fry were then poured through the sampling device quickly when uniformity had been attained such as pouring water from a pail. A better way would be to install a sliding door in the trap entrance. The trap can then be tipped completely vertical, holding the fry and water in the trap by the sliding door. Once the fry gained uniformity in distribution, the door could be opened quickly and the fry would fall in a uniform pattern. Another possible refinement would be to have the device uniform in diameter. As it is, there is a constricted neck and a larger base. A more accurate count could have been made had the neck and base been the same dimensions and a sliding door used.

Tait and Kirkwood (1962) took samples from portions of the stream with a series of traps. Calculation of the volume of water strained by each trap and determination of the percentage of marked fry captured by the traps yielded a fry migration estimation. Such a figure was still somewhat biased because of uncounted dead fry trapped against the screens as well as fry lost to predation.

The Big Qualicum and Humphreys' traps worked on the same principle as the Tait and Kirkwood trap in that only a portion of the stream flowed through the trap. An average figure of recaptured fry had to be known in order to estimate the entire fry migration.

Humphreys' report (unpublished) gave no information on statistical formulas used in calculating trapping efficiency. The assumption was made that sampling methods for total downstream migration bould be established similar to those of Tait and Kirkwood. Humphrey's data could then be entered into a formula similar to the one used by Tait and Kirkwood (refer to Trapping Devices, pages 3 and 4).

Bacterial Cultures

The fry kidney cultures were primarily without bacterial growth. Three of the 50 plates had growth. Colonies consisted of fungi and bacteria. Bacteria considered to be fish pathogens were not observed. Active fish infection normally produce pure cultures if care is taken to withdraw tissue for culture. The three plates showing mixed growth had been marked "possibly contaminated" before incubation. Therefore the assumption was made that growth on these plates was attributed to contamination rather than active infection in the fish.

SUMMARY AND CONCLUSIONS

Total upstream migration of adult cutthroat trout in Clear Creek, 1966, was 36,098. Of these, 11,997 were males and 24,101 were females. A fecundity study revealed 1000 eggs per female. Assuming 21.0 percent mortality in the redds, 19,039,790 fry were expected to migrate downstream. Fry trapping netted 116,905 fry. This gives a 0.61 percent survival rate.

The fry sampling device used to count fry was tested for accuracy. Known numbers of fry were poured through the sampling device. Inaccuracy ranged from 57.5 percent below to 42.0 percent over the actual count.

Adult fish were collected in the streams and outlets of Clear and Cub Creeks to determine if adults were preying on fry. Results showed that predation by adults was insignificant in creeks and outlets.

Kidneys of suspected parasitized fry were streaked on blood agar plates and incubated at stream temperatures. Three plates had growth. Mortality due to bacterial invasion was considered to be insignificant.

A library study analyzing other trapping methods was undertaken. Two traps were used on large rivers where heavy runoff was encountered. As many as ten trapping devices were installed at certain intervals across the river. The traps sampled only a segment of the downstream migration.

Other investigators used a trap similar to the Yellowstone trap. It was effective in waters up to 10 cfs. The trap was not designed to be used in streams carrying large amounts of debris.

A modified fyke trap was used to trap adult fish in California It was used successfully in Maine for trapping salmon smolts.

The incline plane screen was used in sampling water of considerable volume containing large amounts of debris.

The Wolf and Fulton River traps were designed to catch all objects moving downstream. The Wolf trap is used in streams with water velocity up to 35 cfs. The Fulton River trap can be used in streams up to 25 cfs.

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