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SOUTH FORK OF THE MADISON RIVER SALMONID ESCAPEMENT STUDY

INTERIM REPORT

SUBMITTED TO

The Federation of Fly Fishers
Grants Committee
1956 Ives Road
Leslie, MI 49251

and

The Montana Trout Foundation
PO Box 3165
Bozeman, Montana 59772

PREPARED BY

Nicholas J. Hetrick
Cooperative Fisheries Biologist
Montana Department of Fish, Wildlife and Parks
&
U.S.D.A. Forest Service

Hebgen Lake Ranger District
P.O. Box 520
West Yellowstone, Montana 59758

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Project Background

The current management objective for the fishery of Hebgen Lake, initiated by the Montana Department of Fish, Wildlife and Parks in 1979, is to establish self-sustaining populations of wild trout. To obtain this goal, the Department began stocking wild-strain trout in Hebgen Lake with the intent of establishing successful spawning runs that would, under natural conditions, exceed recruitment into the fishery previously maintained by stocking of domesticated fish. This change developed in response to the short life span of the domesticated strain of rainbow trout (*Oncorhynchus mykiss*) planted in Hebgen Lake prior to 1979 coupled with the lake's limited growth season. The poor survival and growth of the domesticated rainbow trout resulted in low angler catch rates (0.24 - 0.41 fish/hr) of fish having an average maximum total length of only 12.0 in. In addition, the domesticated rainbow trout did not establish significant spawning runs in any of the numerous tributaries of Hebgen Lake. During this period, however, runs of brown trout (*Salmo trutta*) in tributaries such as Black Sands Spring, South Fork of the Madison, mainstem Madison, Duck Creek, etc., were very successful, reflecting the high quality of spawning conditions in these streams and the potential for establishing a self-sustaining population of wild rainbow trout. In addition, it was anticipated that wild-strain rainbow trout would have a higher survival rate than the domesticated rainbows, resulting in increased angler catch rates of fish having a greater average maximum total length.

The wild trout management goal established in 1979 lead to the cessation of stocking domesticated hatchery rainbow trout (Figure 1). The Department then switched to planting wild-strain Lake McBride Cutthroat trout (*O. clarki)*. The McBride cutthroat exhibited high survival and growth rates but did not effectively reproduce in tributaries of Hebgen Lake, as was the case with the domesticated rainbows. As a result, in the late 1980's the Department initiated a stocking program of Eagle Lake and DeSmet rainbow trout in Hebgen Lake, both of which are also genetically wild fish. The original stock of Eagle Lake rainbow is a piscivore obtained from Eagle Lake, California where it feeds primarily on lake chubs. The DeSmet rainbow stock is primarily a plankton feeder and was obtained from Lake DeSmet, Wyoming. The DeSmet strain has since been established in Willow Creek Reservoir located near Harrison, Montana which serves as the egg source for stocking in Hebgen Lake. From 1986 to present, several hundred thousand young-of-the-year Eagle Lake and DeSmet rainbows were stocked in Hebgen Lake with the intent of building wild populations that would reproduce naturally, thereby providing ample recruitment to sustain a productive fishery without the dependence and expense associated with annual stocking.

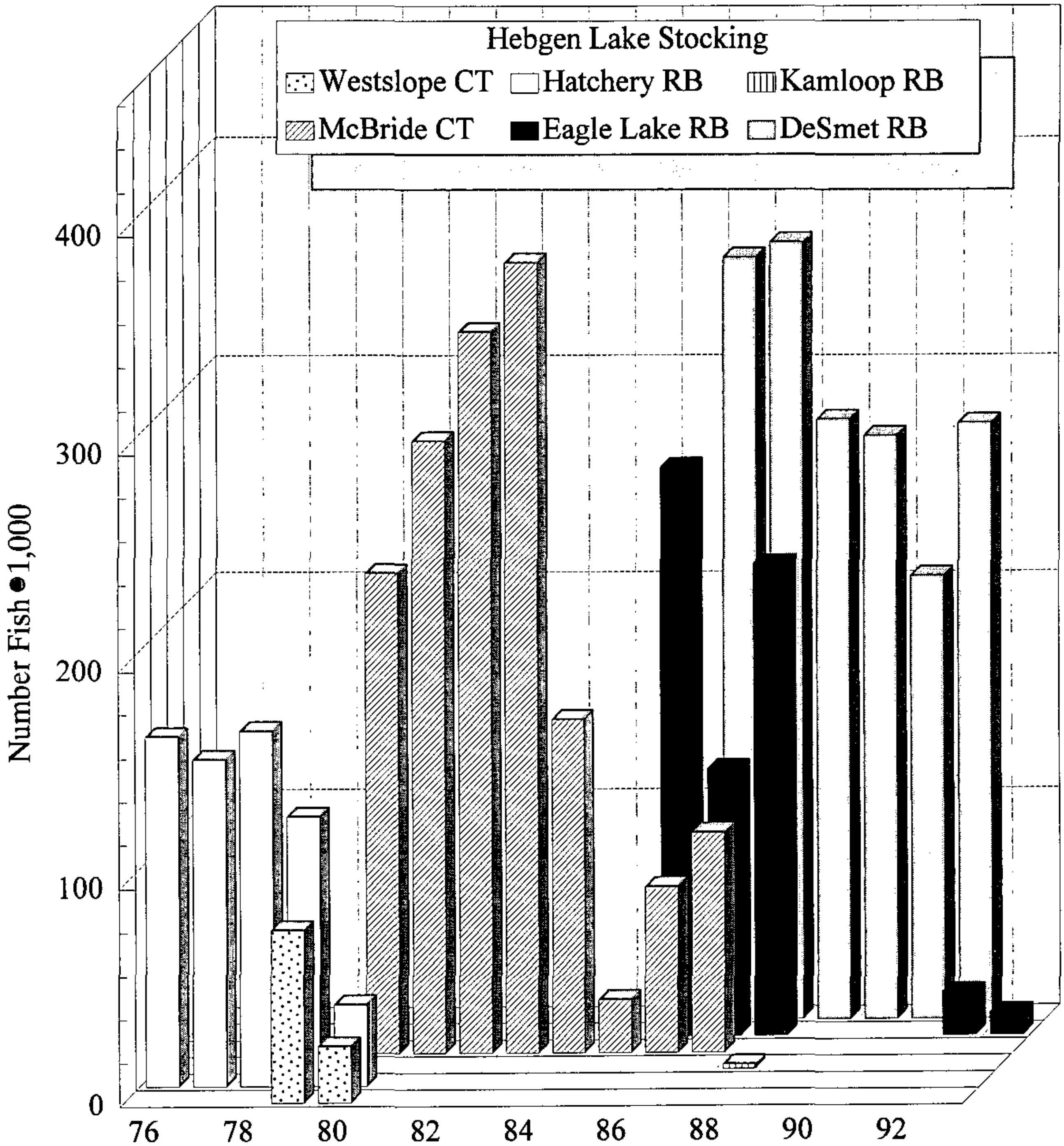


Figure 1. Quantities and strains of salmonids stocked in Hebgen Lake between 1976 and 1994.

In 1994, Hebgen Lake is scheduled for stocking of approximately 50,0000 Eagle Lake and 50,000 DeSmet rainbow trout. The rationale behind the equal split of stocking these two wild stains of rainbow trout is that little information exists on which strain, if either, is reproducing naturally and to what extent natural reproduction contributes to recruitment of the Hebgen Lake fishery. The South Fork of the Madison River Salmonid Escapement Study developed in response to this lack of data regarding natural reproduction of wild rainbow trout populations of Hebgen Lake.

The South Fork of the Madison River Salmonid Escapement Study utilized methods that were established for estimating smolt outmigration in large rivers. Seelbach et al. (1985) were largely responsible for developing a modified-inclined screen trap initially described by Wolf (1950) that could be used to capture fish in rivers with flows greater than 100 cfs and depths exceeding 3 ft, providing a low-head dam could be built. Seelbach's modified inclined screen trap was designed to subsample populations of outmigrant steelhead trout (*O. mykiss*) and chinook (*O. tshawytscha*) and coho (*O. kisutch*) salmon smolts. A percentage of the captured smolts were marked, transported upstream, then released where they would migrate back downstream and potentially be recaptured in the trap. The total estimate was made for each species by dividing the number of recaptures by the total number of marked fish to determine a trap efficiency. This trap efficiency value could then be used to extrapolate the trap catch to estimate the total population of outmigrant smolts. Variance for the population estimate was calculated using the variance of the proportion as described by Remington and Schork 1970.

Dempson and Stansbury (1991) modified this partial counting technique to conduct a mark-recapture experiment using a two-sample stratified design to calculate a maximum-likelihood estimate of Atlantic salmon smolts (*Salmo salar*) migrating out of the Conne River, Newfoundland. Smolts were captured and marked at a partial counting fence located approximately 10 km upstream from the recapture site. In this study, the outmigrant smolt estimate ranged from 64,676 to 68,130 smolts with confidence intervals less than ± 8% of the population estimate.

The South Fork of the Madison River Salmonid Escapement Study proposed to use the sampling and statistical concepts used in the above mentioned studies to estimate adult escapement of rainbow trout into the South Fork system. Our study differed from these smolt studies in that instead of capturing smolts migrating downstream, we focused on capturing reproductive adults migrating upstream.

Description of Study Site

The South Fork of the Madison River is a cold, clear-flowing third to fourth order stream with an abundance of high quality spawning habitat. The South Fork originates at the base of the Continental Divide near Reas Pass on the Idaho-Montana border. From its source, the South Fork flows due north for approximately 19 mi before it enters into the southern end of Hebgen Lake (Figure 2). Historically, the South Fork of the Madison River was the source for millions of brown trout eggs collected from a spawning trap located near its mouth between 1935 and 1964. Observations and electrofishing from 1985-1989, however, failed to disclose any significant numbers of spawning rainbow trout.

Black Sands Spring is a pristine spring creek approximately 0.75 mi long that enters the South Fork of the Madison about 6 mi upstream from Hebgen Lake (Figure 2). Black Sands Spring has a stable base flow of approximately 20 cfs and has extremely high water quality and spawning habitat. The value of Black Sands Spring as a spawning stream was documented in a trapping study conducted in the fall and winter 1993-94. In that trapping study, approximately 1,500 adult brown trout were passed through the trap to spawn in Black Sands Spring.

Project Objectives

We set several objectives for the South Fork of the Madison River Salmonid Escapement Study. These objectives were to:

- estimate escapement for the South Fork of the Madison River and for Black Sands Spring
- determine, through gel electophoretic analyses, the genetic composition of spawning runs in the South Fork of the Madison River and in Black Sands Spring
- develop a sampling methodology that could be used to estimate escapement on large river systems such as the mainstem Madison
- mark individual fish that could be captured at a later date to determine growth rates and the South Fork system's contribution the overall fishery of Hebgen Lake.

Project Methods

Fish Trapping

Four fish traps were used to conduct the investigation. Two traps subsampled a portion of the lower reach of the South Fork of the Madison River and were located approximately 0.5 mi upstream from Hebgen Lake (Figure 2). The subsampling traps consisted of a 4 ft square box constructed of a ½ in steel square stock frame used to support a

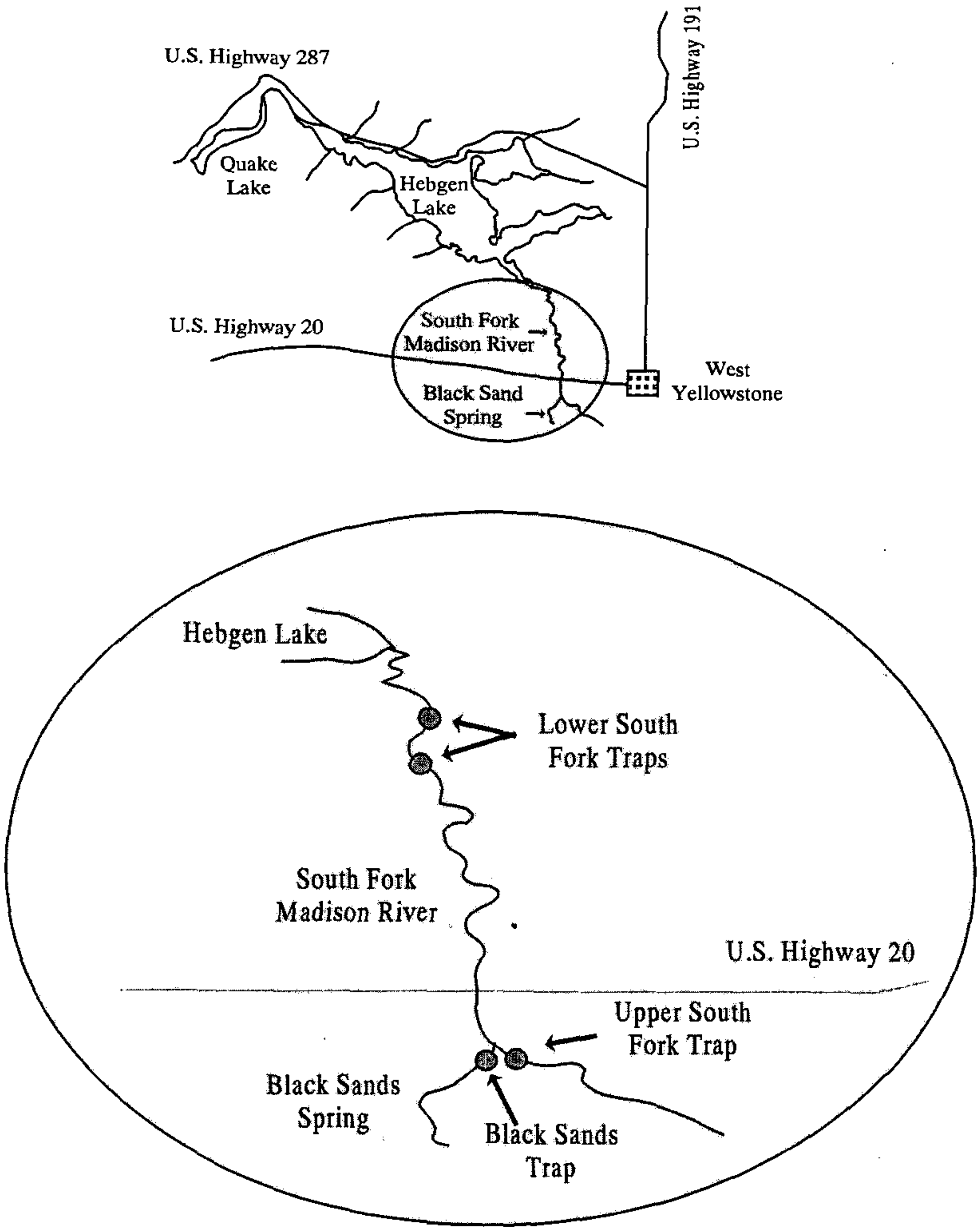


Figure 2. General location of the South Fork of the Madison Salmonid Escapement Study and specific locations of fish traps used in the study.

fence of 0.5 in electrical metal tubing (EMT) with a 2 ft long fyke entering the box (Figure 3). Fish were funneled into the fyke that entered the retaining box using 20 ft fences constructed of 0.5 in EMT with 0.5 in sections of PVC pipe used as spacers between the sections of EMT. Three-eighths in aircraft cable was used to string the sections of EMT and PVC spacers together. Fences were tilted downstream relevant to the streambed to shunt debris to the water surface, thus allowing free-flow of water through the fence (Figure 4a). The subsampling traps blocked approximately 20% of the channel width at both sites.

In addition to the subsampling traps, traps were installed in the South Fork of the Madison River and in Black Sands Spring (Figure 4b), just upstream from their confluence (Figure 2). These traps blocked the entire channel, thereby capturing all fish migrating above the trap locations.

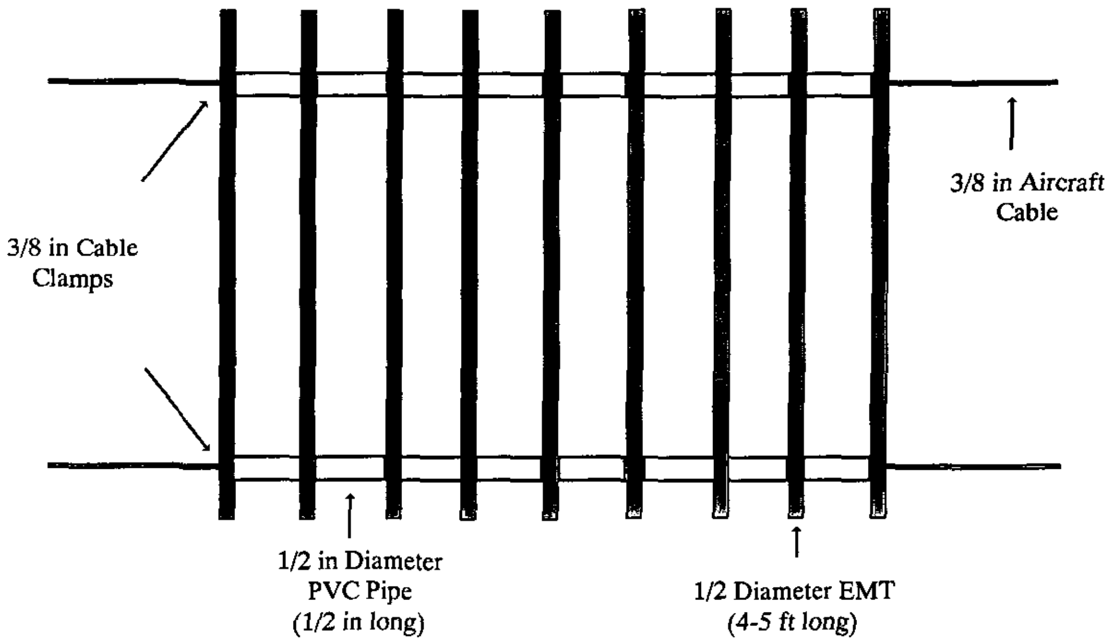
Traps were built during the first 2 weeks in April 1994 and installed and operational by 22 April 1994 with the exception of the Black Sands Spring Trap. The Black Sands trap was installed in the fall of 1993 and has been operated continuously since. All traps were checked daily during the peak of upstream migration and every second or third day thereafter depending upon the intensity of the run. Fish captured in the traps were anesthetized using tricaine methanesulphonate, allowing collection of the following information without damaging the fish:

- weight
- maximum total length
- sex
- sexual maturity
- presence of external marks (tags, hook scars, hatchery deformities, etc.)
- scale sample to determine age.

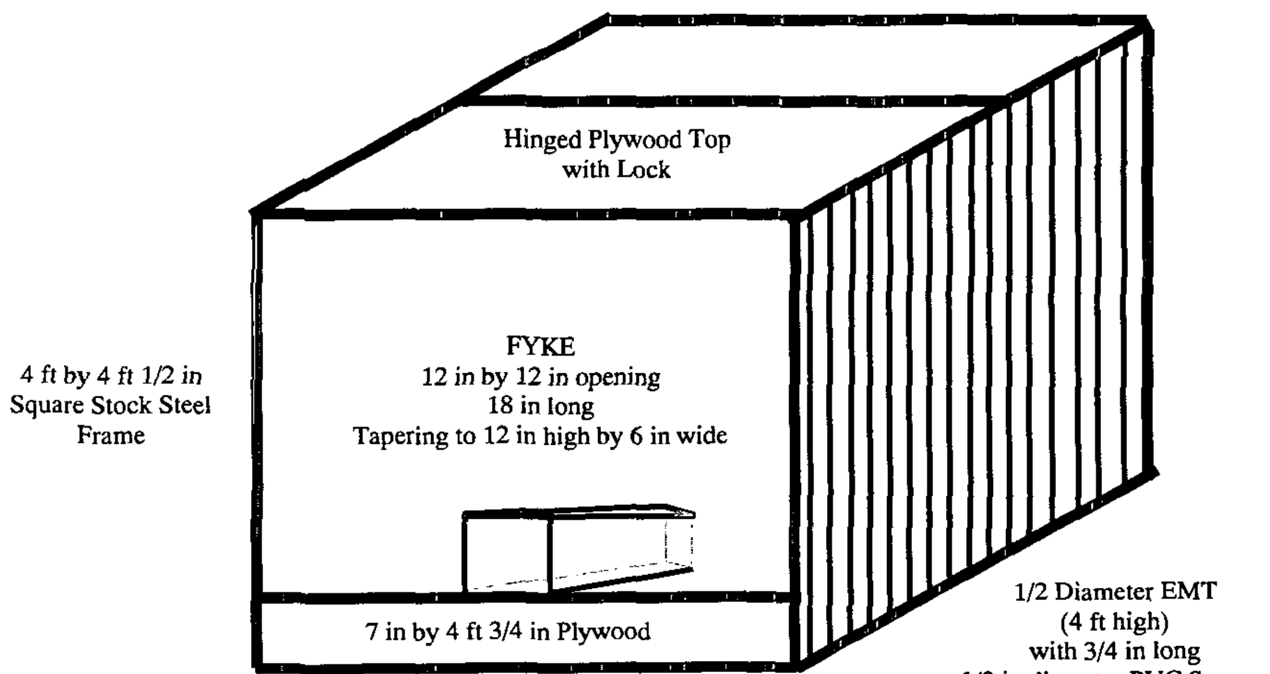
In addition, each fish was injected with a visual implant tag behind the left eye and given an adipose fin clip. Fish were then placed in a live car in the channel and allowed ample time to recuperate prior to their release. Fish were released at various locations across the width of the channel to evenly disperse them with unmarked fish. Fish data were entered, summarized, and analyzed using dBase IV relational database and appropriate statistical software.

Genetic Analysis

Samples were collected from the Black Sands Spring and Upper South Fork traps for horizontal starch gel electrophoretic analysis by the Population Genetics Laboratory of the University of Montana. Electrophoretic analysis will follow the procedures detailed by Allendorf and Utter (1979). Fish collected for genetic analysis were first photographed, then



EMT FENCE



TRAP BOX

Figure 3. Trap design used to capture adult salmonids in the South Fork of the Madison Salmonid Escapement Study.

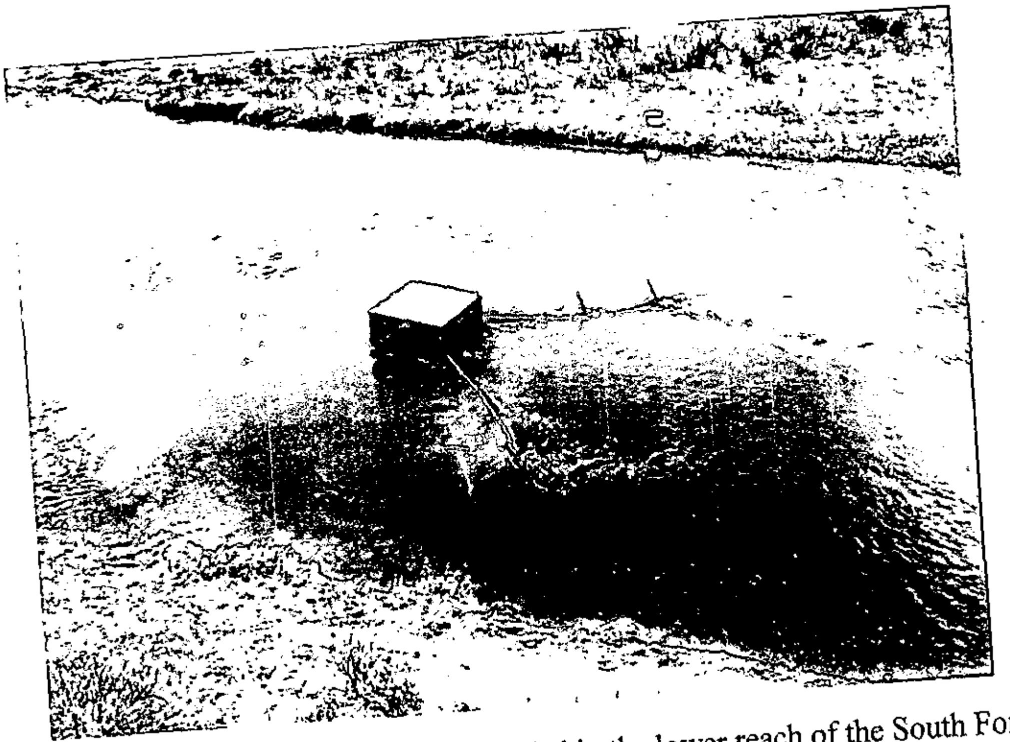


Figure 4a. Subsampling adult fish trap installed in the lower reach of the South Fork of the Madison River.

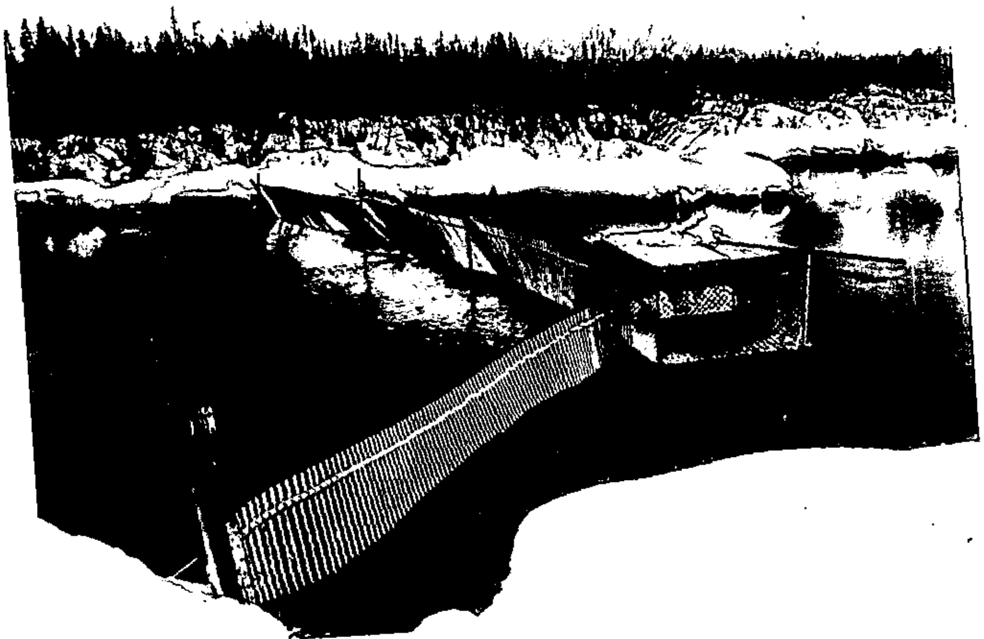


Figure 4b. Full spanning channel trap operated on Black Sands Spring, a tributary to the South Fork of the Madison River.

dissected to remove a sample of muscle tissue, an eye, and the liver. Tissue samples were placed in a labeled plastic bag, returned to the office, and placed in a freezer. Collection of fish tissue samples was dispersed throughout the run to account for temporal variability. In addition, adipose fins were collected from other fish captured in each of the two traps that were used to run a less sensitive electrophoretic test. Collection of adipose fin samples was also dispersed throughout the run. We choose to run the adipose fin genetic test to limit the number of reproductive adult fish that needed to be sacrificed to run the more sensitive electrophoretic analysis.

Population Estimates

Due to the unique characteristics of the South Fork system and placement of the traps, several options existed for calculating estimates of the South Fork run of rainbow trout.

Method One

The first estimate planned was to use the lowermost of the South Fork traps to mark fish with the trap located 0.25 mi upstream to recapture fish. A Peterson mark-recapture estimate could then be made for the overall run as follows:

$$\hat{N} = \frac{(m+1)(c+1)}{(r+1)}$$

Where

$\hat{N}$ = population estimate
m = number of fish marked
c = number fish caught
r = number of recaptures

95 % confidence intervals with the number of recaptures from a Poisson distribution as:

$$\hat{N} = \frac{(m+1)(c+1)}{\text{(Upper and Lower Limits at } \alpha = 0.05)}$$

This estimate could also be stratified by time periods established to minimize the occurrence of zero cells in the data matrix as described by and Stansbury (1991).

Method Two

The second estimate planned was to be made in a manner similar to the first estimate with the following changes:

- the two traps located on the lower South Fork would be considered as a single sampling unit used to mark fish
- the upper trap on the South Fork and Black Sands Spring would be used to recapture marked fish

Method Three

The final estimate planned for the South Fork escapement study was to be made by calculating the percentage of marked to unmarked fish captured in the Black Sands Spring and Upper South Fork traps to determine the efficiency of the lower South Fork traps (considered as a single sampling unit) as detailed by Seelbach et al. (1985). The trap efficiency value was then used to extrapolate the trap catch to estimate the total run size with the variance of the proportion calculated as described by Remington and Schork (1970).

Trap Efficiency (E) $E = r/c\ (100\%)$

with trap efficiency variance (V) as:

$$V = pq/N$$

and

p = the proportion in question
q = 1-p
N = sample size

and 95 % confidence intervals as:

$$(\sqrt{V})\ (\alpha \text{ at } 0.05)\ (100\%)$$

Assumptions

Assumptions associated with the use of mark recapture investigations used to estimate population size have been discussed in a number of publications, including those by Cousens et al. (1982), Seber (1982), and Bowen and Sargeant (1983), among others. Assumptions that will be made in this study are as follows:

1. fish will not lose their marks
2. fish will be correctly identified as being marked or unmarked
3. marked and unmarked fish are randomly distributed in the population
4. marking or capturing fish will not affect their catchability at recapture sites
5. marked and unmarked fish have equal mortality
6. the population is closed.

The first two assumptions were adequately met by marking fish with visual implant (VI) tags accompanied by an adipose fin clip. Use of two marks allowed marked fish to be recognized even in the event of individual tag loss. The third assumption, that is, marked and unmarked fish are randomly distributed in the population, should have been met under each estimate technique by placing the traps far enough from each other to allow mixing with unmarked individuals. In addition, each marked batch of fish, after recuperating from anesthesia, was released at various locations across the width of the channel to facilitate mixing of marked and unmarked fish.

The forth assumption was difficult to make as little information is available on rainbow trout's ability to avoid a trap due to its previous capture. In the brown trout escapement study on Black Sands Spring conducted in 1993-94, however, several individuals were captured in the trap, marked, and released that were subsequently recaptured in the same trap on a later date. In fact, one individual was captured in the trap on five different occasions. Based on these findings, we speculate that this assumption was met.

The fifth assumption regarding equal mortality between marked and unmarked fish should have also been met. In the Black Sands brown trout escapement study, we observed no mortality associated with trapping or marking fish. Although some delayed mortality may have occurred from handling fish, we speculate that this loss was insignificant compared with natural mortality associated with predation and angling which were considered equal between marked and unmarked fish.

The final assumption that the population is closed, should have been adequately met under the first estimation method. Little if any suitable spawning habitat exists between the two subsampling traps located on the lower reach of the South Fork of the Madison so it was assumed that fish passing by the first trap also passed by the next trap. Using the second and third estimation methods, however, this assumption may not have been adequately met. Between the lower two traps and the upper trap on the South Fork, Black Sands Spring is the only tributary and therefor the only source of immigration or emigration into the South Fork spawner population. This should not have been a problem as the entrance or exodus of fish into the South Fork spawner population could be corrected for using Black Sands trap data. However, some fish may have spawned between the lower South Fork traps and the confluence of Black Sands Spring with the upper South Fork.

Temperature Monitoring

Water temperatures were monitored throughout the duration of the study using Omnidata continuous temperature recorders. One recorder was placed near the lower two fish traps on the South Fork, in Black Sands Spring, and at the upper fish trap on South Fork. Recorders were set to monitor daily average, maximum and minimum water temperatures. These data will be plotted against cumulative escapement for each site to determine the potential influence of water temperature on spawning activity.

Project Results

Fish Trapping

The following is a summary of the total catch of reproductive rainbow trout from each of the four traps:

Lower South Fork	34
Middle South Fork	27
Upper South Fork	68
Black Sands Spring	133

No distinct patterns in the timing of upstream migration were observed in the lower and middle traps on the South Fork of the Madison, presumably due to their low catch rates of what appears to be a very small population (Figure 5). It looked like we captured the peak of the run but may have missed some fish near its start. The run of rainbow trout into Black Sands Spring was very concentrated from 1 May to 15 May - only a few individuals were captured outside this time period (Figure 6). In contrast, fish on the Upper South Fork, particularly males, were captured well into June. This may reflect the occurrence of genetic isolation between the Black Sands and upper South Fork populations. Comparison of length frequency of the catch for these traps also supports a distinction between the two populations (Figure 7). The catch of the Black Sands Spring trap showed a greater range and variability than did that of the Upper South Fork trap. Results of the pending electrophoretic analyses should be able to distinguish any genetic differences between these populations.

Population Estimates

As the traps on the Upper South Fork and Black Sands Spring blocked the entire channel, we were able to document the actual spawning runs. Escapement of spring spawning rainbow trout in Black Sands Spring was 84 females; 49 males were passed above the trap (Figure 6). Escapement for the upper reach of South Fork of the Madison River upstream from its confluence with Black Sands Spring was 35 females; 33 males were passed above the South Fork trap (Figure 6).

None of the 34 fish captured in the lowermost South Fork trap were recaptured in the trap located just upstream. Of the 201 rainbow trout captured in the upper South Fork and Black Sands Spring traps, only 5 had been captured in the lower traps and marked. Based on these data and procedures outlined under method three:

efficiency of the lower trapping unit 2.49%

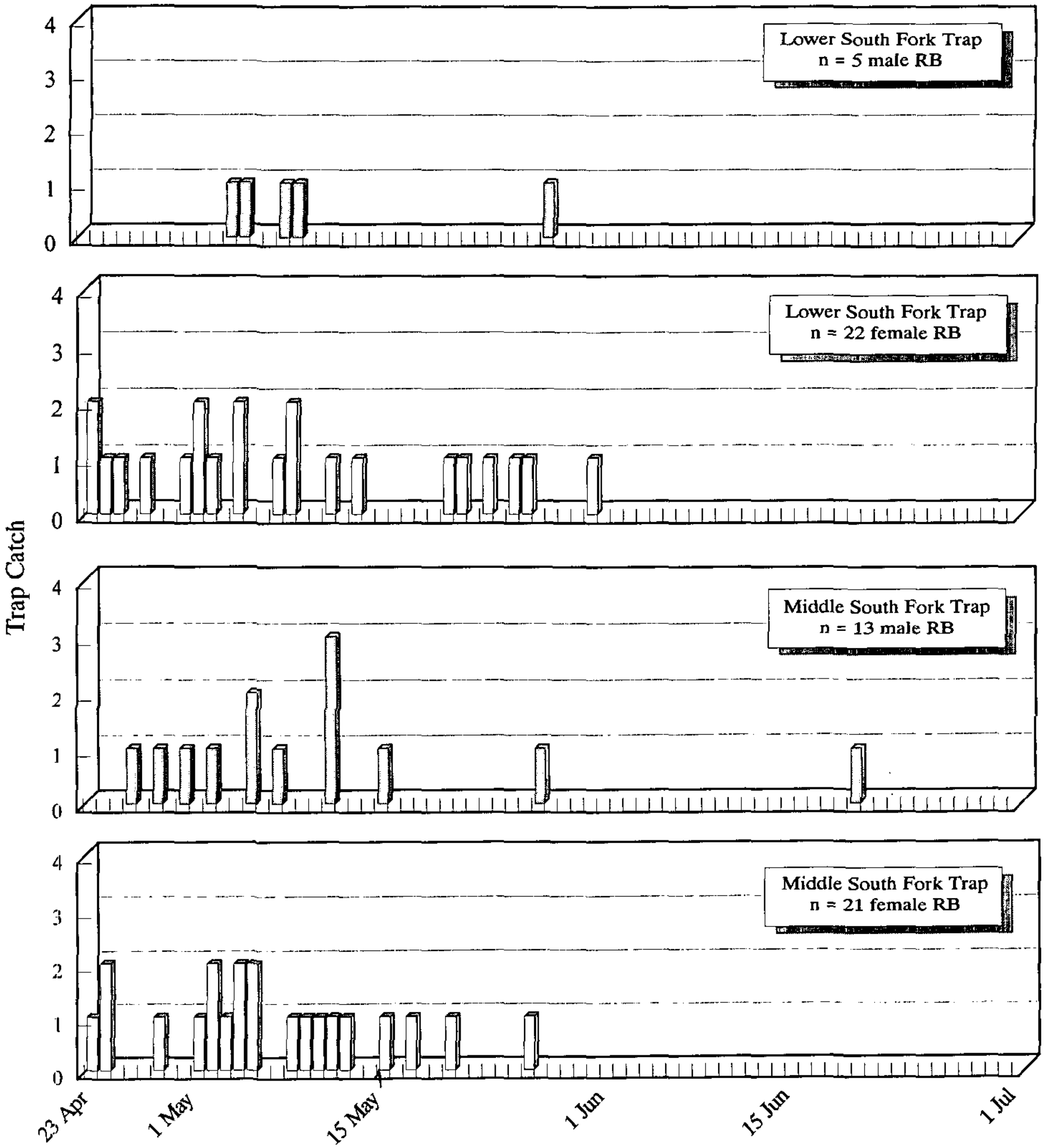


Figure 5. Catch of adult rainbow trout in the lowermost upstream migrant traps on the South Fork of the Madison River during spring 1994.

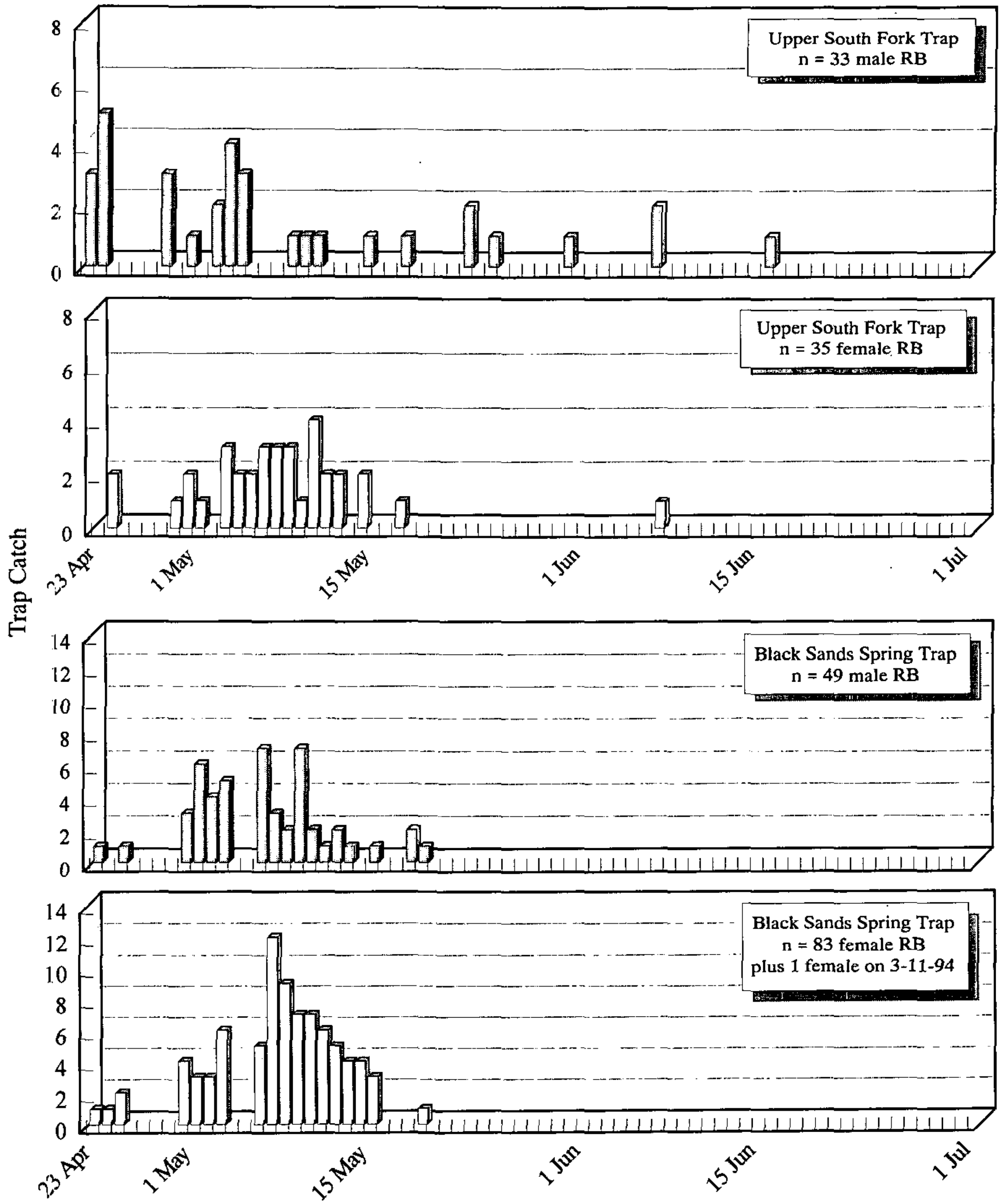


Figure 6. Upstream migrant catch of adult rainbow trout in fish traps located in the upper South Fork of the Madison River and in Black Sands Spring during spring 1994.

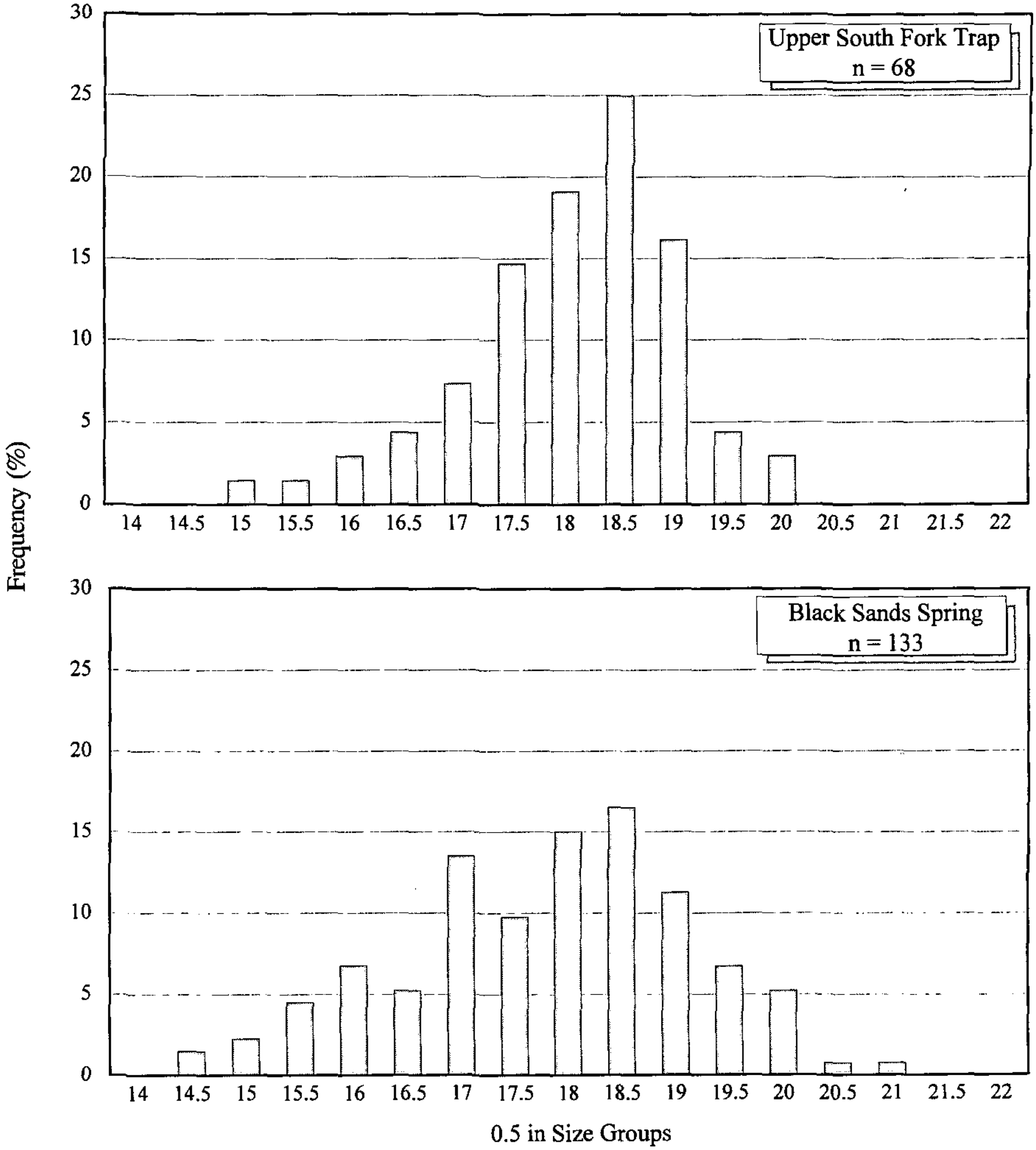


Figure 7. Comparison of length-frequencies of adult rainbow trout captured in fish traps located on the upper South Fork of the Madison River (top) and Black Sands Spring (bottom) during spring 1994.

with 95% confidence intervals of the estimate

$$5{,}710 \leq \text{population estimate} \leq 6{,}186$$

However, we are fairly certain that this is a gross overestimation of the run size. This overestimation is probably due to an avoidance of the subsampling traps which was not possible with the full channel spanning traps located on the upper South Fork and Black Sands Spring. In addition, some fish may have spawned between the lower two traps on the South Fork and the traps located on the upper South Fork and Black Sands Spring.

Genetic Analyses

As of 6 July 1994, we collected 18 tissue and 10 adipose fin samples from the Upper South Fork of the Madison River and 14 tissue and 13 adipose fin samples from Black Sands Spring. We also collected 50 hatchery DeSmet and 50 Eagle Lake rainbow trout from the fish plant that occurred in late June 1994. Genetic analyses of these fish will provide updated background information on the genetic composition of these two stocks which may increase the sensitivity of the tissue and adipose fin tests.

Results of the electrophoretic analyses may provide some valuable insight on the success of establishing runs of wild trout in Hebgen Lake tributaries. If, for example, the analyses show that the spawning runs are comprised primarily of Eagle Lake strain rainbows, future stocking should be adjusted to build the Eagle Lake population and should not emphasize stocking of DeSmet rainbows. Note that genetic analyses should also be collected on runs of rainbow trout in other tributaries of Hebgen Lake prior to making any final alterations in the Hebgen Lake stocking program. The bottom line is, if genetic analyses show that one of the wild strains of rainbow trout planted in Hebgen Lake account for a significant proportion of the spawning runs and therefor, natural recruitment to the fishery of Hebgen Lake, future stocking should focus on that strain.

Work in Progress

As this is an interim report of an ongoing biological study, results presented should be considered preliminary. The following tasks are currently in progress:

- Scale analysis to determine age structure
- Electrophoretic analyses
- Water temperatures and backcalculated fry emergence
- Analyses of physical attribute data (i.e., hook scars, deformities, etc.)

Results of these analyses will be presented in a final report later this year. We are planning to operate the traps again starting in August after some modifications have been made to the subsamplers. We are anticipating to capture a limited number of fall-run rainbow trout as well as brown trout. Funding provided by the participants in this study should be adequate to cover the additional costs of continuing the study. As such, all of the cooperating groups will be included as participants in the ongoing study.

Cost-Share Description

The South Fork of the Madison Salmonid Escapement Study was made possible through a cost-share agreement between the Montana department of Fish, Wildlife and Parks, the USDA Forest Service, the Montana Trout Foundation, and the Federation of Flyfishers. This type of agreement is beneficial as it combines the expertise of all the participants and allows implementation of the "best" alternative that could not be funded solely by any of the participating groups. As this project was a cooperative effort, all news releases, publications and/or presentations regarding the South Fork of the Madison Spawning Escapement Study will acknowledge all participating entities. Special mention will be made recognizing the financial assistance provided by the Montana Trout Foundation and the Federation of Flyfishers.

The overall cost of the project was estimated to be $17,100.57. This estimate does not include some of the low-cost items necessary to construct the traps such as welding rod, plywood, etc. that are readily available at the Hebgen Lake Ranger District of the USFS. We initially requested that the total cost of the project be covered as follows:

FUNDING SOURCE	AMOUNT	% of TOTAL
Montana Department of Fish, Wildlife and Parks	$5,035.53	29.4%
Hebgen Lake Ranger District, USFS	$4,765.02	27.9%
Gallatin Nation Forest Supervisor's Office	$1,800.00	10.5%
Federation of Fly Fishers	$2,000.00	11.7%
Montana Trout Foundation	$3,500.00	20.5%
TOTAL	$17,100.57	100.0%

A detailed listing of all costs of the project are provided in Table 1.

Table 1. Costs associated with completing the South Fork of the Madison River Salmonid Escapement Study.

Component	Unit Cost	Number Required	Total Cost	Cost Covered
Personnel				
Grade 8 Technician - Construct & Operate Traps				
FY 1994	$9.93/hr*	7 days @ 8 hr/days	$556.08	MDFWP
LCA Position	$9.93/hr*	22 days @ 8 hr/day	$1,747.68	Cost-Share
USFS GS-5	$9.76/hr*	35 days @ 8 hr/day	$2,732.80	USFS
Grade 8 Technician - Data Entry & Scale Analysis				
FY 1995	$9.93/hr*	15 days @ 8 hr/days	$1,191.60	MDFWP
Grade 14 Biologist - Construct & Operate Traps				
FY 1994	$14.11/hr**	32 days @ 8 hr/day	$3,612.16	MDFWP-USFS
Grade 14 Biologist - Data Analysis & Final Report				
FY 1994	$14.11/hr**	15 days @ 8 hr/day	$1,693.20	MDFWP-USFS
Subtotal			**$11,533.52**	
Equipment				
Visual Implant Tags	$50.00/100 tags	3,000	$1,500.00	Cost-Share
6 - 20 ft Trap Fence Sections				
1/2 in EMT	$15.58/100 ft	6 • 1,200 ft = 7,200 ft	$1,121.76	USFS
3/8 in aircraft cable	$0.50/ft	6 • 30 ft = 180 ft	$90.00	MDFWP
1/2 in PVC pipe	$2.00/10 ft	6 • 20 ft = 120 ft	$24.00	MDFWP
3/8 in cable clamps	$0.20 each	6 • 4 clamps = 24	$4.80	MDFWP
3 Trap Boxes				
1/2 in EMT	$15.58/100 ft	3 • 960 ft = 2,880 ft	$448.71	MDFWP
1/2 PVC pipe	$2.00/10 ft	3 • 16 ft = 48 ft	$10.00	MDFWP
3/8 in aircraft cable	$0.50/ft	3 • 40 ft = 120 ft	$60.00	MDFWP
1/2 in square stock	$6.42/20 ft	3 • 56 ft = 168 ft	$57.78	USFS
Subtotal			**$3,317.05**	
Electrophoretic sampling				
Sacrificed fish	$17.50/fish	50	$875.00	Cost-Share
Hatchery DeSmet	$17.50/fish	50	$875.00	Cost-Share
Adipose Fins	$10.00/fin	50	$500.00	Cost-Share
Subtotal			**$2,250.00**	
Travel	$0.30/mile	1,350 miles	**$405.00**	MDFWP
TOTAL COST			**$17,100.57**	

* Includes benefits.

** Salary split between MDFWP and USFS under a cooperative agreement.

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