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Subproject 1. South Fork Snake River Canal Investigations

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ABSTRACT

I estimated trout exploitation rates for salmonids intercepted by irrigation diversions on Burns and Palisades creeks, tributaries to the South Fork Snake River, during the 1996 irrigation season. These tributaries are high gradient streams with little rearing or holding habitat, consequently trout populations in each tributary are extremely migrant. Adult cutthroat trout *Oncorhynchus clarki,* rainbow trout O. *mykiss,* and rainbow x cutthroat trout hybrids enter these tributaries in the spring to spawn, with most returning to the mainstem by late July to early August. Juvenile fish emigrate to the mainstem shortly after emergence. The Burns Creek diversion is an unregulated ditch (no headgate) with a maximum capacity of about 20 cubic feet per second (cfs), and the Palisades Creek diversion is a regulated canal (2 headgates) with a 189 cfs decreed water right. The intake of each canal is situated on the outside of a river bend in association with a diversion dam. Each diversion is screened. To estimate exploitation, I marked and released trout upstream of the canal intakes, and then recaptured them in screen bypass traps. The validity of the exploitation estimates rested on the fate and behavior of the fish that were marked and released. Mortality, migration delays, and trap avoidance could bias results. I estimated that 69% of trout <80 mm were exploited by the Burns Creek diversion and 44% by the Palisades Creek diversion. Trout z80 mm were exploited at rates of 26% and 62% in the Burns and Palisades diversions, respectively. Although these rates are high, the migratory nature of these fish may have increased their vulnerability to exploitation. A variety of canals will need to be sampled before I can determine whether these exploitation rates are typical.

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INTRODUCTION

Idaho fishery managers and anglers have long suspected that significant numbers of resident salmonids are lost to irrigation diversions. However, there is little quantitative data available to assess the effects of such losses on stream populations, or to even determine whether a widespread problem exists. The conditions for potentially harmful repercussions on trout populations are certainly present. Hundreds of streams are diverted for agricultural purposes statewide, with irrigation diversions ranging in size from a few cubic feet per second (cfs) to 4,500 cfs. Although the majority of diversions in the Salmon River drainage and a few diversions in southeastern Idaho are screened to protect against fish loss, most irrigation diversions in the state are not.

The goal of this research project is to determine under what circumstances and to what degree sport fishing opportunities could be enhanced by minimizing losses of resident salmonids to irrigation diversions. The impact of these losses on the availability of harvestable fish will be evaluated by estimating exploitation of stream trout populations by irrigation diversions for a variety of canals, and then modeling the effect of this source of exploitation using population parameters from trout stocks in Idaho. If exploitation by irrigation diversions is shown to have a significant impact on representative trout fisheries, then the canal characteristics associated with the highest exploitation rates will be used to classify diversions and identify potential problem sites. The cost-benefit for managing fish loss will be evaluated and solutions for minimizing losses will be recommended.

This was the second year of a five-year study. Field operations during 1996 focused on estimating canal exploitation rates. This report presents results from sampling efforts conducted in two canals located on tributaries to the South Fork Snake River. Previous research in Idaho (Gebhards 1959) has indicated that the movement of fish down irrigation diversions can best be monitored with fish screen bypass traps. With this in mind, the canals I sampled in 1996 were screened.

RESEARCH GOAL

The goal of this research project is to determine under what circumstances and to what degree sport fishing opportunities could be enhanced by minimizing losses of resident salmonids to irrigation diversions.

OBJECTIVES

1. To assess the population effects of resident salmonid losses to irrigation diversions in terms of trends in the abundance of harvestable fish.

2. To identify diversion system characteristics that adversely affect resident salmonid stocks.

3. To evaluate the cost-benefit of loss management.

4. To recommend cost-effective methods for minimizing losses of resident salmonids to irrigation diversions.

Task

1. To estimate exploitation rates on salmonids by irrigation diversions on Burns and Palisades creeks, South Fork Snake River, during the 1996 irrigation season.

DESCRIPTION OF STUDY AREA

Burns and Palisades creeks are tributaries to the South Fork Snake River (Figure 1). These tributaries are high gradient streams that have adequate spawning areas but little rearing or holding habitat. Consequently, trout populations in each tributary are extremely migrant. Cutthroat trout *Oncorhynchus clarki,* rainbow trout O. *mykiss,* and rainbow x cutthroat trout hybrids enter these tributaries in the spring to spawn, with most returning to the mainstem by late July to early August. Juvenile fish emigrate to the mainstem shortly after emergence.

One diversion is located on each tributary. The Burns Creek diversion is an unregulated ditch (no headgate) with a maximum capacity of about 20 cfs. This ditch is screened with a paddle wheel-driven rotary drum located about 90 m below the canal intake. The diversion intake is approximately 0.4 km upstream of the creek mouth and is situated on the outside of a river bend. A 0.3-m high gravel diversion dam extends across the creek during much of the irrigation season, although it is probably not a migration barrier. This ditch can be used for irrigation anytime between May and October. During the 1996 season (mid-June through late September), I estimated this canal captured approximately 25% of the stream flow in Burns Creek. The Palisades Creek diversion is a regulated canal (2 headgates) with a 189 cfs decreed water right. This diversion is screened with three electric-powered rotary drums located about 15 m below the headgates. The canal intake is located approximately 0.8 km upstream of the creek mouth and is also situated on the outside of a river bend. A 0.8 m high diversion dam, constructed out of concrete abutments and wood slats, extends across the creek during most of the irrigation season. This dam could be a migration barrier during low water years and at certain flows. For example, the dam was not installed until July 2 in 1996 due to high flows, so it did not interfere with the immigration of spawning adults. However, during low water years, the dam may be installed earlier in the season when adults are actively immigrating. This dam may also be a barrier to emigrating adults and fry during low water years, although young fish may be able to pass through openings between the wood slats. During high water years, an intermittent side channel that skirts the canal intake may provide passage around the dam. Withdrawals for stock watering purposes can sometimes begin as early as April and continue through early November, but the primary irrigation season generally occurs between May and October. During the 1996 season (late May through mid-October), I estimated this ditch captured about 26% of the stream flow in Palisades Creek. Physical characteristics of each canal are presented in Appendix A.

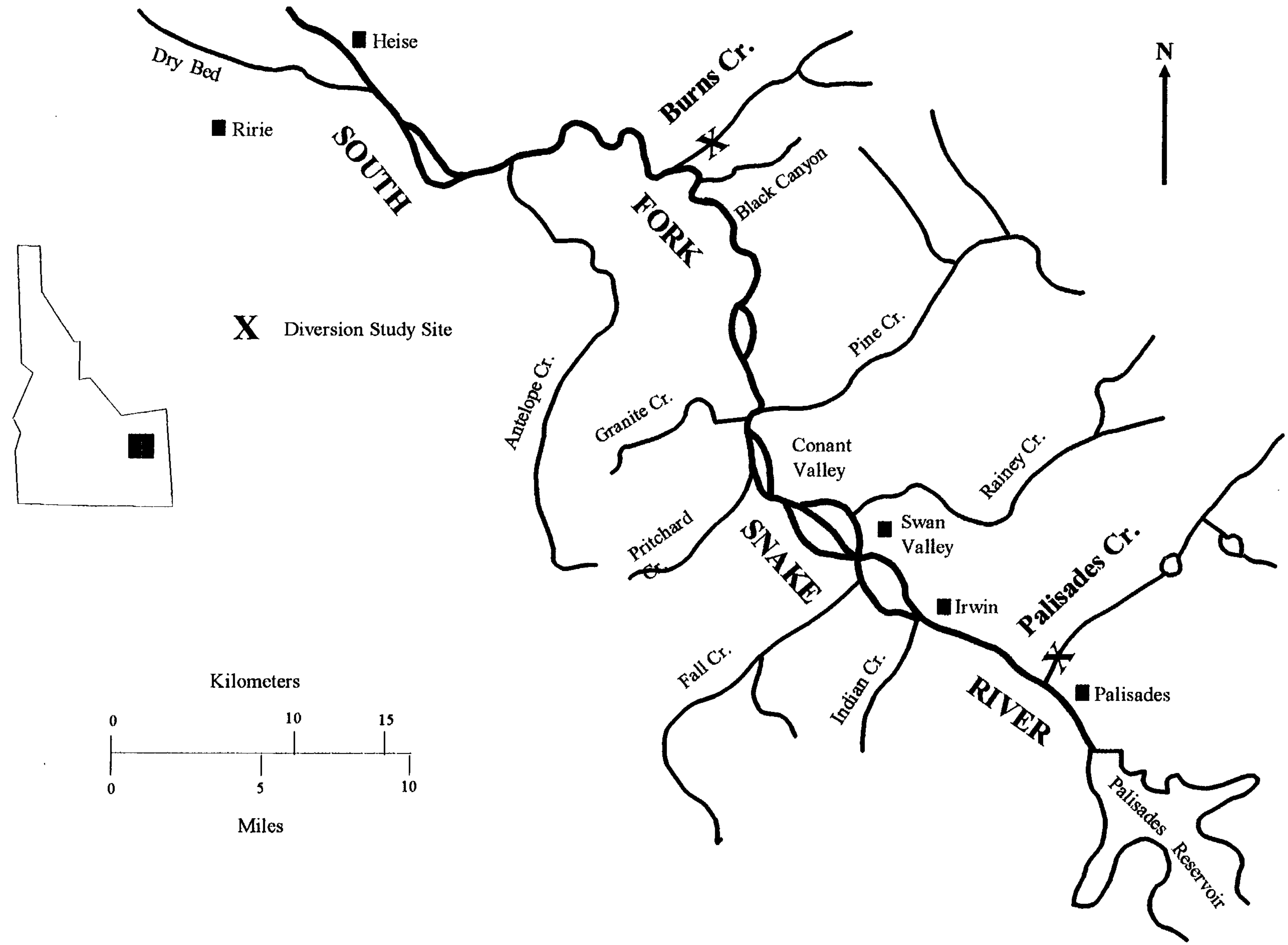

Figure 1. Map of the South Fork Snake River with irrigation diversion study sites.

METHODS

Traps and Sampling Periods

I placed trap boxes at the bypass terminus in each diversion to monitor the movement of fish into the canals (Figure 2). At the Burns Creek screen bypass, a box was positioned in the creek and connected to the bypass pipe via a 9 cm diameter flex hose. At the Palisades site, a box was set in the bypass bay below a ramp that regulated water flow through the bypass structure. The Burns Creek box measured 0.9 m wide x 1.2 m long x 0.6 m high and was constructed with 3.75 cm aluminum angle and 3 mm diameter aluminum perforated plate. The Palisades Creek trap measured 0.8 m wide x 0.9 m long x 1.1 m high and was constructed with 3.75 cm aluminum angle, 6.25 mm aluminum plate, and #8 wire mesh.

I operated the Burns trap from June 15 through September 23, and the Palisades trap from May 21 through October 14. Trapping operations at the Burns site encompassed the entire irrigation season, except for a five-day test period by the canal owner in late May and a short period in October when the canal owner took water to soak his field before freeze-up. The Palisades trap was operated from the time the fish screens were activated until the time when only a few cfs were being withdrawn to water stock. Prior to activation of the fish screens, a few cfs were also being taken by the Palisades diversion to water stock.

Trap Efficiency

I estimated trap efficiency in each canal because: 1) changing canal flows can affect efficiency rates; 2) screens may not completely block the passage of fish into any given canal; and 3) fish may be able to move out of a canal before entering the bypass traps. (This was particularly true at the Burns site because this ditch did not have a headgate, and because water height on the rotary drum was adjusted by shunting water back to the stream via a "blow off" channel located upstream of the bypass pipe). I estimated trap efficiency by releasing marked trout upstream of the bypass in each canal. Because trout of different sizes may have been unequally vulnerable to capture, I estimated trap efficiency by length group (<80 and ≤80 mm). Trout <80 mm total length (TL) were assumed to be young-of-the-year (Bill Schrader, Idaho Department of Fish and Game, personal communication). Newly captured trout <80 mm TL were removed from the traps and either anaesthetized with MS-222 and given a left ventral fin clip, or marked with Bismarck brown Y dye at a concentration of 0.5 g/15 L water for 20 min (to facilitate quick detection of recoveries when catch numbers were high). I held dye-marked fish overnight to adjust for short-term mortality. Newly captured trout ≤80 mm TL were removed from the trap, anaesthetized with MS-222, and given a left ventral fin clip. I released marked fish 20 m to 45 m upstream of the bypass in each canal, and checked the traps daily for recoveries. Recaptured fish were released in the stream below the canal intake. Although the availability of fish largely governed the frequency of the trap efficiency tests, I generally released marked groups of fish whenever canal staff gage readings changed by 5 cm, or on a weekly basis when staff gage readings were relatively stable.

I combined release (D) and recovery (d) data over consecutive time periods with similar canal staff gage measurements (Figure 3) and calculated efficiency for each length group as

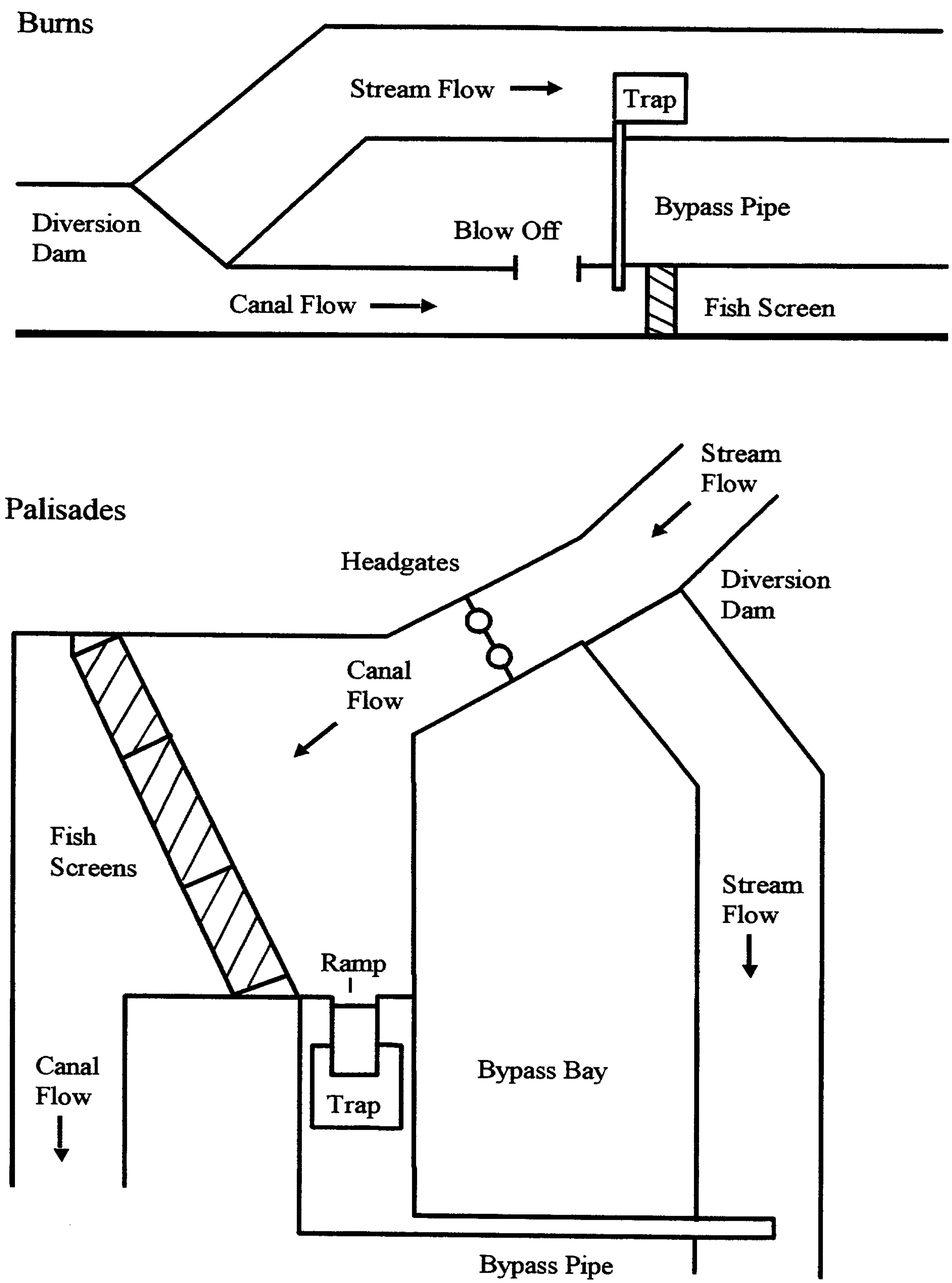

Figure 2. Bird's-eye view of fish bypass configurations on the Burns Creek and Palisades Creek diversions.

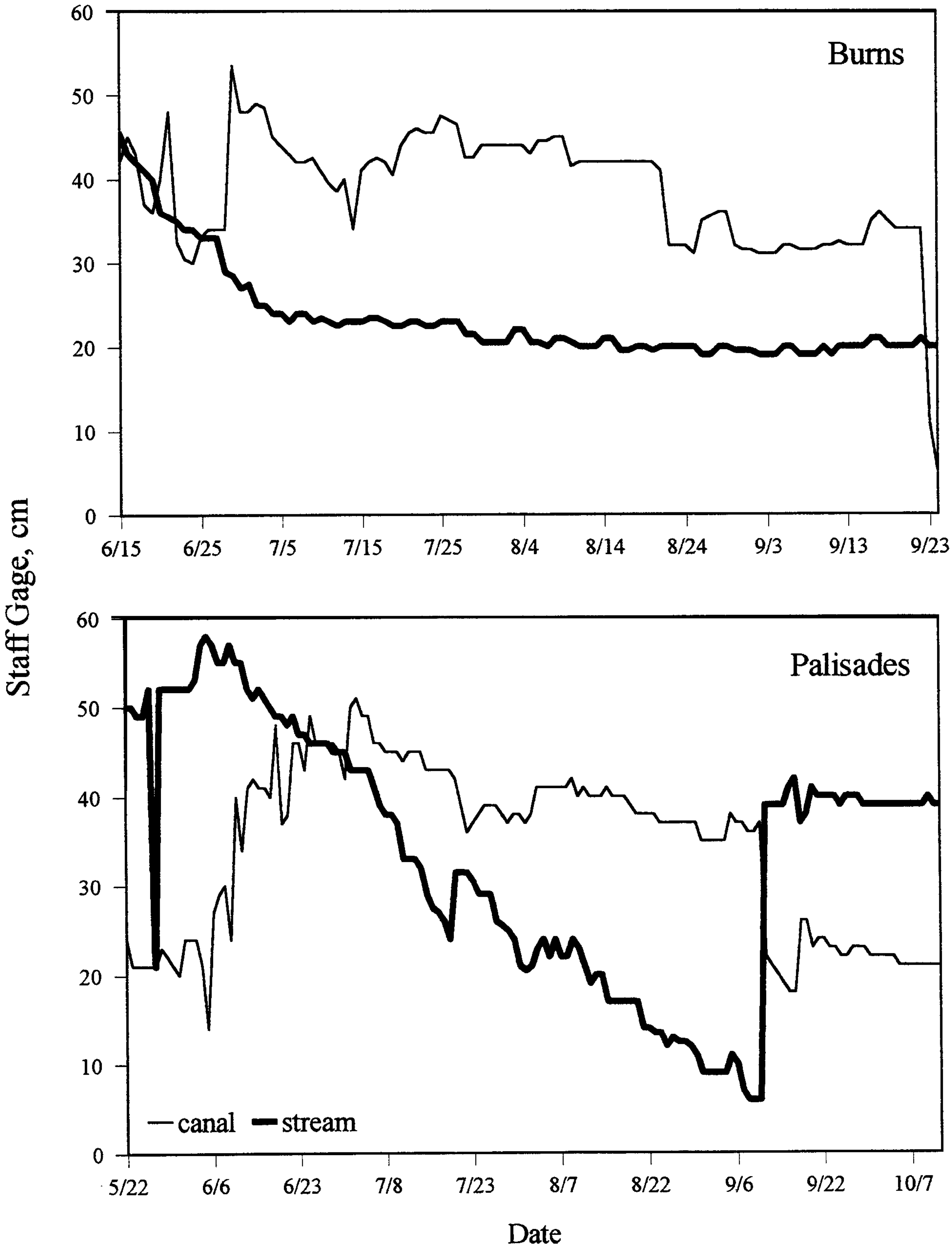

Figure 3. Canal and stream staff gage measurements, Burns and Palisades sampling sites, 1996 irrigation season.

d/D. To increase sample sizes, I did not segregate fish by species for these estimates. Confidence intervals were obtained using a relationship between the F and binomial distributions (Zar 1984). Efficiency estimates were then compared by time period with a X^2 test. If the X^2 test indicated that the estimates were not significantly different over time, the data were pooled and used to calculate an overall trap efficiency estimate. If the X^2 test was significant, the data were stratified and used to calculate estimates for each time period.

Trout Exploitation by Canals

I estimated exploitation by releasing marked trout in the stream above the intakes of each diversion. Since these fish were actively emigrating to the mainstem, I assumed they would eventually pass by the diversion intakes. Fish for the stream release samples were obtained from the bypass traps. Because trout of different sizes may have been unequally vulnerable to interception by the canals, I estimated exploitation by the same length groups used to estimate trap efficiency. Trout <80 mm TL were either marked with an adipose fin clip or with Bismarck brown Y dye, as described above, and an adipose fin clip. Dye-marked fish were again held overnight to adjust for short-term mortality. Trout z80 mm TL were given an upper caudal fin clip. I released marked fish about 180 m upstream of the intake of each canal, which required them to negotiate a path through several riffles before they encountered the diversion intakes. The traps were then checked daily for recoveries. Although these fish were actively emigrating, I marked all recaptured fish, except for fry, with a secondary mark to prevent the possibility of repeat sampling. All recaptured fish were released in the stream below the canal intake. Fish availability largely determined the frequency of the stream releases, but I attempted to release marked groups of fish throughout periods of active migration.

Since fish that entered the canals were not necessarily captured in the bypass traps, I used the trap efficiency data to expand the counts of recovered stream release fish. To increase sample sizes, I did not segregate the counts by species. If the trap efficiency estimates were not significantly different over time, the stream release data were pooled and used to calculate overall expanded recovery and error estimates by length (Rawson 1984):

$$\hat{N} = \frac{nD}{d}\left[1 + \frac{D-d}{Dd}\right], \qquad \textbf{(1)}$$

where *N* = the overall expanded estimate of stream release fish in a length group that were recovered; n = the total number of stream release fish in a length group that were recovered; *D* = the total number of fish in a length group that were marked and released in a canal to estimate trap efficiency; and d = the total number of fish recovered from release *D.* Error estimates and confidence intervals (assuming a normal distribution for *N)* were calculated as (Rawson 1984):

$$\mathrm{V}[\hat{N}] = n(n+d)\,D\,\frac{(D-d)}{d^3}, \qquad \textbf{(2)}$$

$$\text{SE}\,[\hat{N}] = \sqrt{\text{V}\,[\hat{N}]}, \quad \textbf{(3)}$$

$$(1-\alpha)\ \text{C.I.} = \hat{N} \pm z_{\alpha}\,(\text{SE}\,[\hat{N}]). \quad \textbf{(4)}$$

If the trap efficiency estimates were significantly different over time, the stream release data were stratified and used to calculate expanded recovery and error estimates by time period for each length group. The strata estimates were then summed to obtain overall expanded recovery *N* and variance *V[N]* estimates. Standard errors and confidence intervals were then calculated by Equations 3 and 4.

I calculated exploitation by length group as N/M , where M = the total number of fish in a length group that were marked and released in a stream. Error and approximate confidence intervals (Zar 1984); assuming an approximately normal distribution for N/M) were calculated by treating 1/M as a constant (Lehman 1975):

$$\text{V}\left[\frac{\hat{N}}{\text{M}}\right] = \left(\frac{1}{\text{M}}\right)^2 \text{V}[\hat{N}], \quad \textbf{(5)}$$

$$\text{SE} = \sqrt{\text{V}\left[\frac{\hat{N}}{\text{M}}\right]}, \quad \textbf{(6)}$$

$$(1-\alpha)\ \text{C.I.} = \frac{\hat{N}}{\text{M}} \pm z_{\alpha}\left(\text{SE}\left[\frac{\hat{N}}{\text{M}}\right] + \frac{1}{2\text{M}}\right). \quad \textbf{(7)}$$

Trap Catch Counts

I counted all fish captured in the bypass traps and recorded them by length group and species. The only exception to this occurred at the Palisades site in early August when the catch of fish <80 mm TL was estimated by counting dip net scoops *n* of fish. The number of fish in a dip net scoop were periodically counted to derive a mean number of fish per scoop x. Daily catches were estimated by multiplying the number of scoops counted by x. The variance of these estimates were calculated as n^2 V[x] by treating the number of daily net scoops as a constant (Lehman 1975); standard errors were calculated as the square root of the variance estimates.

Outmigration

Outmigration estimates were generated for adults and fry that emigrated from Burns and Palisades creeks. Estimation methods are outlined in Appendix B.

RESULTS

Trap Efficiency

At the Burns site, trap efficiencies by time period for trout <80 mm were not significantly different (x2 = 0.66, 3 df, 0.75<P<0.90), so I pooled the data to obtain an overall estimate of 39% (Table 1). Trap efficiencies by time period for trout <80 mm at the Palisades site were significantly different (x^2 = 8.48, 3 df, P<0.05). I stratified these data and calculated estimates that ranged from 32% to 53% (Table 2).

Table 1. Trap efficiency estimates by length group for trout captured in the Burns Creek irrigation diversion screen bypass trap, 1996 irrigation season.

	Number of Marked Canal Releases			95% Confidence Interval, %	
Date	Released *(D)*	Recovered *(d)*	Efficiency, %	Lower	Upper
<80 mm					
8/26-9/1	210	78	37.1 [a]	30.6	44.1
9/2-9/8	360	144	40.0	34.9	45.3
9/9-9/13	298	122	40.9	35.3	46.8
9/14-9/23	264	97	36.7	30.9	42.9
Overall	1,132	441	39.0	36.1	41.9
≥80 mm					
6/21-7/1	62	15	24.2 [b]	14.2	36.7
7/2-7/18	52	45	86.5	74.2	94.4

[a] Since trap efficiency estimates by time period were not significantly different (x^2 = 0.66, 3 df, 0.75<P<0.90), the data were pooled and used to calculate an overall estimate.

[b] Since trap efficiency estimates by time period were significantly different (x^2 = 13.76, 1 df, P<0.001), the data were stratified and used to calculate estimates for each time period.

Table 2. Trap efficiency estimates by length group for trout captured in the Palisades Creek irrigation diversion screen bypass trap, 1996 irrigation season.

Date	Number of Marked Fish			95% Confidence Interval, %	
	Released (D)	Recovered (d)	Efficiency, %	Lower	Upper
<80 mm					
5/21-6/11	19	10	[illegible] [a]	28.9	75.6
6/12-7/21	27	9	33.3	16.5	53.9
7/22-9/8	149	47	31.5	24.2	39.7
9/9-10/14	340	181	53.2	47.8	58.6
≥80 mm					
5/21-6/11	40	29	72.5 [b]	56.1	85.4
6/12-7/16	136	62	45.6	37.0	54.3
7/17-9/7	24	'16	66.7	44.7	84.4
Overall	200	107	53.5	46.3	60.6

[a] Since trap efficiency estimates by time period were significantly different (x^2 = 8.48, 3 df, P<0.05), the data were stratified and used to calculate estimates for each time period.

[b] Since trap efficiency estimates by time period were not significantly different (x^2 = 3.12, 2 df, 0.10<P<0.25), the data pooled and used to calculate an overall estimate.

Trap efficiencies by time period for fish z80 mm at the Burns site were significantly different (x^2 = 13.76, 1 df, P<0.001) and ranged from 24% to 87% (Table 1). Trap efficiencies were similar (x^2 = 3.12, 2 df, 0.10<P<0.25) for fish 80 mm at the Palisades site, so I pooled the data and calculated an overall estimate of 54% (Table 2).

Trout Exploitation by Canals

Trap efficiency and exploitation data for trout <80 mm were only available at the Burns site from August 26 through the time the canal was closed on September 23, because fish were not marked and released in the canal or stream at the onset of the fry outmigration. However, 93% (26,236/28,153) (Appendix C) of newly captured trout <80 mm were caught in the bypass trap during this period, so my exploitation estimate is germane to most of the fish that were intercepted by this ditch over the course of the irrigation season. Since the trap efficiency estimates I used to expand the stream release recovery counts were not significantly different over time, I pooled the trap efficiency and stream release data and estimated an overall exploitation rate of 69% for fish <80 mm that emigrated between August 26 and September 23 (Table 3; Appendix D).

Table 3. Trout exploitation estimates by length group for the Burns Creek irrigation diversion, 1996 irrigation season.

Date	Number of Marked Stream Releases: Released (M)	Number of Marked Stream Releases: Recovered *(n)*	Expanded Stream Release Recoveries *(N* ▸	SE *[1V]*	95% Confidence Interval: Lower	95% Confidence Interval: Upper	Trout Exploitation Rate (R/M)	SE [N/M)	95% Confidence Interval: Lower	95% Confidence Interval: Upper
<80 mm										
8/26-9/23 [a,b]	1,312	354	910	51	811	1,009	0.694	0.039	0.618	0.770
≥80mm										
6/21-7/18 [c,d]	188	37	49	6	37	62	0.262	0.034	0.198	0.331

[a] Trap efficiency and exploitation data were only available for August 26 through September 23. However, 93% (26,236/28,153) of newly captured trout <80 mm were caught during this period.

[b] Since the trap efficiency estimates used to expand the number of stream release recoveries were not significantly different over time, the data were pooled and used to calculate overall expanded recovery and error estimates.

[c] Trap efficiency and exploitation data were only available for June 21 through July 18. However, 76% (293/384) of newly captured trout z80 mm were caught during this period.

[d] Since the trap efficiency estimates used to expand the number of stream release recoveries were significantly different over time, the data were stratified and used to calculate expanded recovery estimates by time period. The expanded recovery estimate presented here is the sum of those strata estimates, and its standard error is the square root of the sum of the associated variance estimates.

Trap efficiency and exploitation data for trout <80 mm were available at the Palisades site from May 21 through the time I pulled the trap on October 14. Since the trap efficiency estimates were significantly different over time at the Palisades site, I stratified the trap efficiency and stream release data by time period. Stratum estimates were calculated and summed to yield an exploitation estimate of 44% for fish <80 mm that emigrated between May 21 and October 14 (Table 4; Appendix E).

Trap efficiency and exploitation data for trout Z80 mm were only available at the Burns site from June 21 through July 18 because fish that emigrated after this period were not marked and released in the canal or stream. However, 76% (293/384) (Appendix C) of newly captured trout z80 mm were caught in the bypass trap during this period. The trap efficiency estimates were significantly different over time, so I stratified the data to obtain an exploitation estimate of 26% for trout z80 mm that emigrated between June 21 and July 18 (Table 3; Appendix D).

At the Palisades site, trap efficiency and exploitation data were only available May 21 through September 7 because fish that emigrated after this period were not marked and released in the canal or stream, but 89% (362/409) (Appendix F) of newly captured trout ≥80 mm were caught in the bypass trap during this time. The trap efficiency estimates were not significantly different, so I calculated an overall exploitation rate of 62% for trout ≥80 mm that emigrated between May 21 and September 7 (Table 4; Appendix E).

The fish I used to estimate the exploitation of trout <80 mm at the Burns and Palisades sites were predominately fry. Fish of this size could not be identified beyond a general "rainbow/cutthroat" designation. The mean lengths of the stream release and recapture groups appeared to be nearly identical, as did the length distributions of these groups (Table 5; Figure 4). The majority of the fish I released and recaptured to estimate the exploitation of trout ≥80 mm were cutthroat trout spawners >300 mm TL (Table 5; Figure 5). Although I marked and released some trout between 120 mm and 300 mm in the streams, these fish were generally not recaptured in the bypass traps.

Trap Catch Counts

I began catching trout z80 mm at each site immediately following installation of the bypass traps. Cutthroat trout predominated the catch at both sites (Figures 6 and 7; Appendices C and F). Catches of rainbow trout and rainbow x cutthroat trout hybrids were mostly confined to the Palisades trap. Most of the trout ≥80 mm I captured were spawners - only a few yearlings were caught at either site. The emigration of trout z80 mm was largely over at each site by the end of July, although fish continued to leave the creeks throughout the study periods.

I began catching a few trout <80 mm at the Palisades site immediately following installation of the bypass trap, but these fish were few in number and larger (60 mm to 80 mm) than fish caught later in the season. I did not catch any fish <80 mm at the Burns site until late summer. Emigrations of fry began at each site between early and mid-August (Figure 8). The fry emigration at Burns Creek appeared to peak just before the canal was closed in late September, but past research (Moore and Schill 1984) has shown that the peak can occur later.

Table 4. Trout exploitation estimates by length group for the Palisades Creek irrigation diversion, 1996 irrigation season.

Date	Number of Marked Stream Releases		Expanded Stream Release Recoveries		95% Confidence Interval		Trout Exploitation Rate		95% Confidence Interval	
	Released (M)	Recovered *(n)*	*(N)*	SE *[1V]*	Lower	Upper	(RIM)	SE [R/M]	Lower	Upper
<80 mm										
5/21-10/14 [a]	687	142	301	24	255	347	0.438	0.034	0.371	0.506
≥80 mm										
5/21-9/7 [b,c]	131	43	81	10	61	100	0.616	0.076	0.472	0.768

[a] Since the trap efficiency estimates used to expand the number of stream release recoveries were significantly different over time, the data were stratified and used to calculate expanded recovery estimates by time period. The expanded recovery estimate presented here is the sum of those strata estimates, and its standard error is the square root of the sum of the associated variance estimates.

[b] Trap efficiency and exploitation data were only available for May 21 through September 7. However, 89% (362/409) of newly captured trout Z 80 mm were caught during this period.

[c] Since the trap efficiency estimates used to expand the number of stream release recoveries were not significantly different over time, the data were pooled and used to calculate overall expanded recovery and error estimates.

Table 5. Length statistics for trout marked and released in the streams and recaptured in the irrigation diversion screen bypass traps, Burns and Palisades sampling sites, 1996 irrigation season.

Site	Species	n	Range, mm TL	Mean Length, mm TL	SE
			<80 mm		
Burns [a]	rainbow/cutthroat (released)	100	22-55	39	6
	rainbow/cutthroat (recaptured)	215	25-57	39	6
Palisades	rainbow/cutthroat (released)	242	22-77	47	11
	rainbow/cutthroat (recaptured)	139	26-76	46	9
			≥80 mm		
Burns [b]	cutthroat (released)	186	130-495	376	67
	cutthroat (recaptured)	35	225-440	382	38
Palisades [c]	cutthroat (released)	110	80-493	339	117
	cutthroat (recaptured)	34	81-495	386	88

[a] One hundred (100) of 1,312 fish released and 215 of 354 recaptured were measured.

[b] Only one rainbow trout and brown trout were marked and released; one rainbow trout was recaptured.

[c] Five rainbow x cutthroat trout hybrids and 14 rainbow trout were marked and released; 2 rainbow x cutthroat trout hybrids and 3 rainbow trout were recaptured.

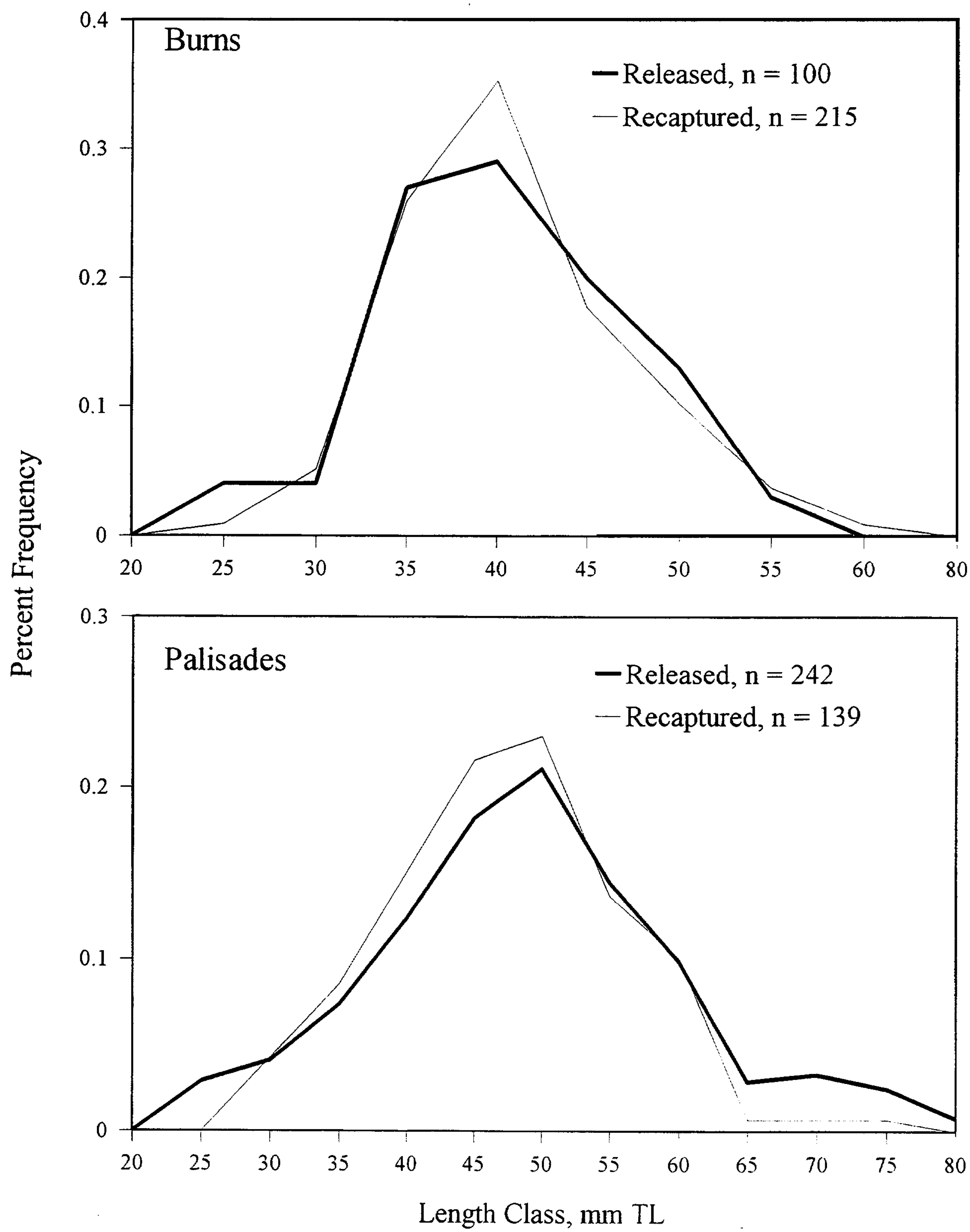

Figure 4. Length frequency distributions of rainbow/cutthroat trout <80 mm TL released upstream of the diversions and recaptured in the irrigation diversion screen bypass traps, Burns and Palisades sampling sites, 1996 irrigation season.

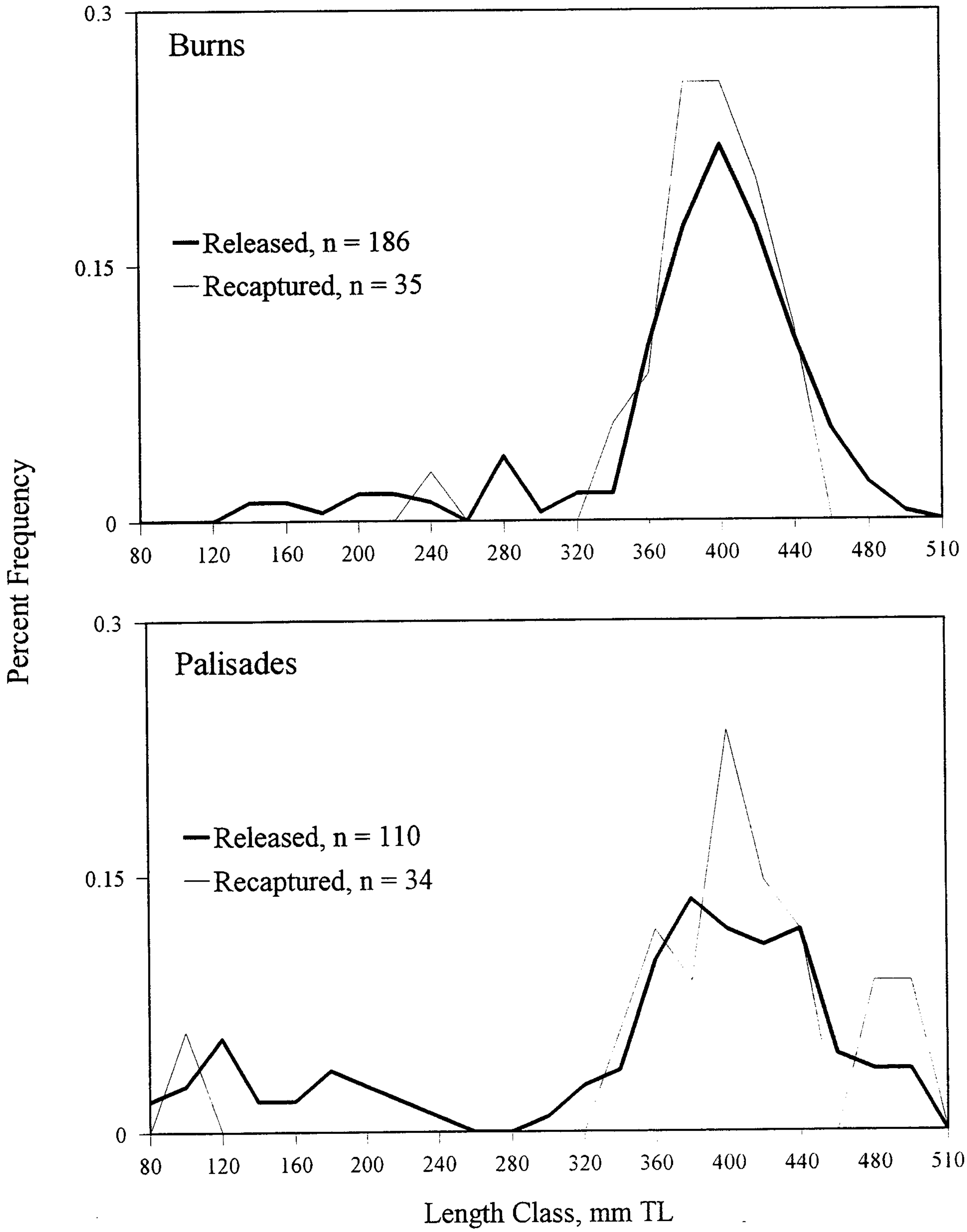

Figure 5. Length frequency distributions of cutthroat trout ≥80 mm TL released upstream of the diversions and recaptured in the irrigation diversion screen bypass traps, Burns and Palisades sampling sites, 1996 irrigation season.

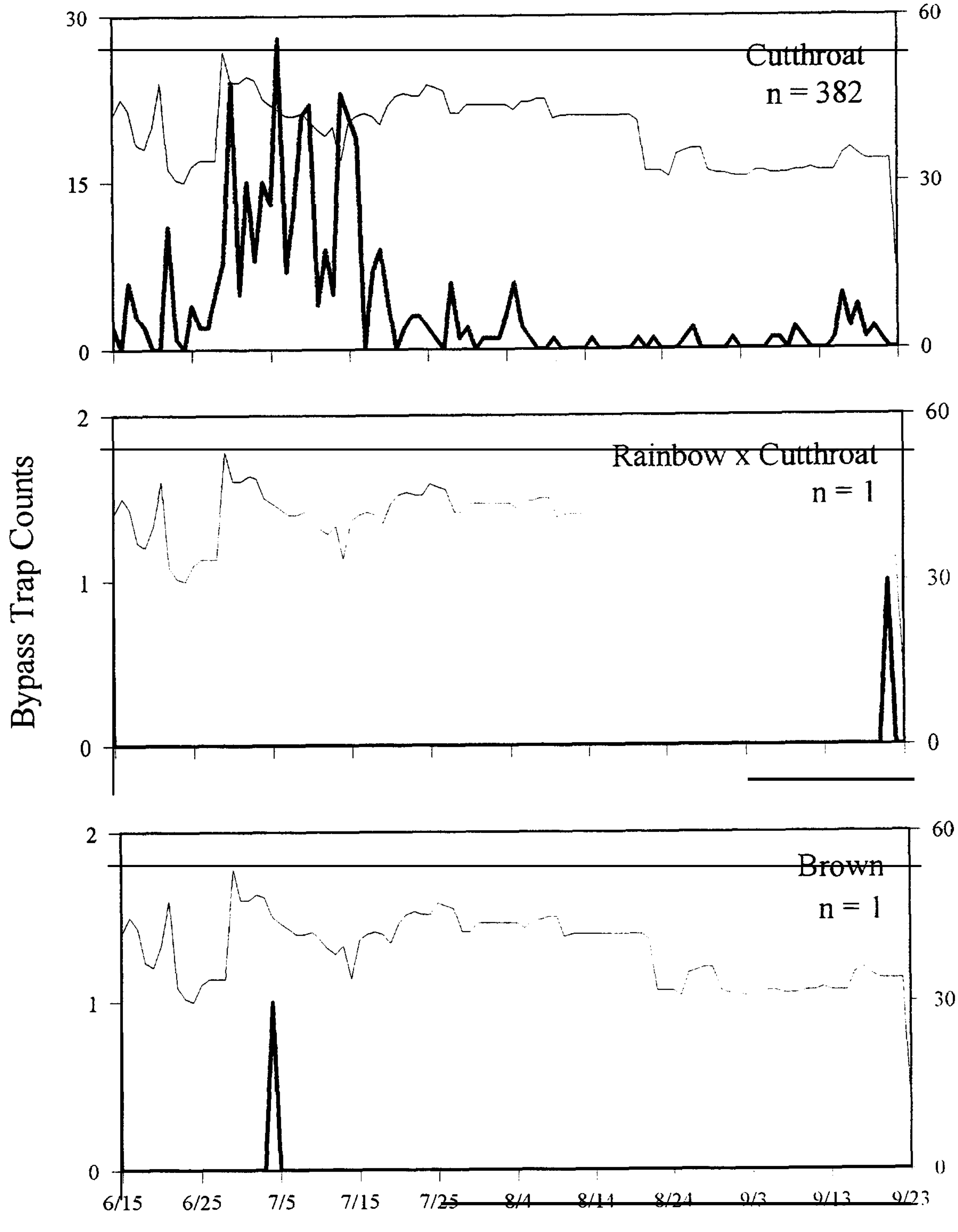

Figure 6. Unexpanded counts of emigrant cutthroat trout, rainbow x cutthroat trout hybrids, and brown trout ≥80 mm TL captured in the Burns Creek irrigation diversion screen bypass trap, 1996 irrigation season. Hairline represents canal staff gage measurements.

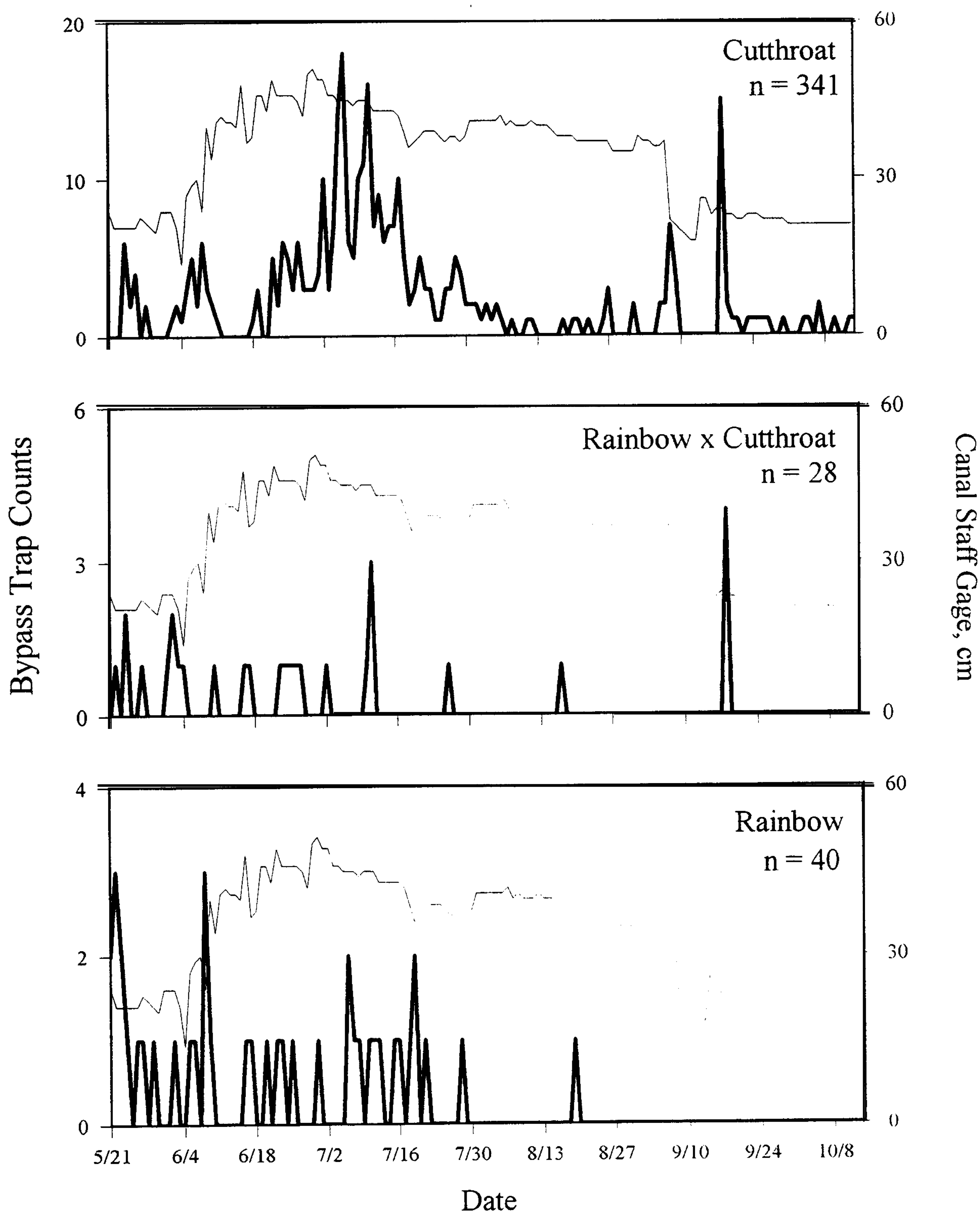

Figure 7. Unexpanded counts of emigrant cutthroat trout, rainbow x cutthroat trout hybrids, and rainbow trout ≥80 mm TL captured in the Palisades Creek irrigation diversion screen bypass trap, 1996 irrigation season. Hairline represents canal staff gage measurements.

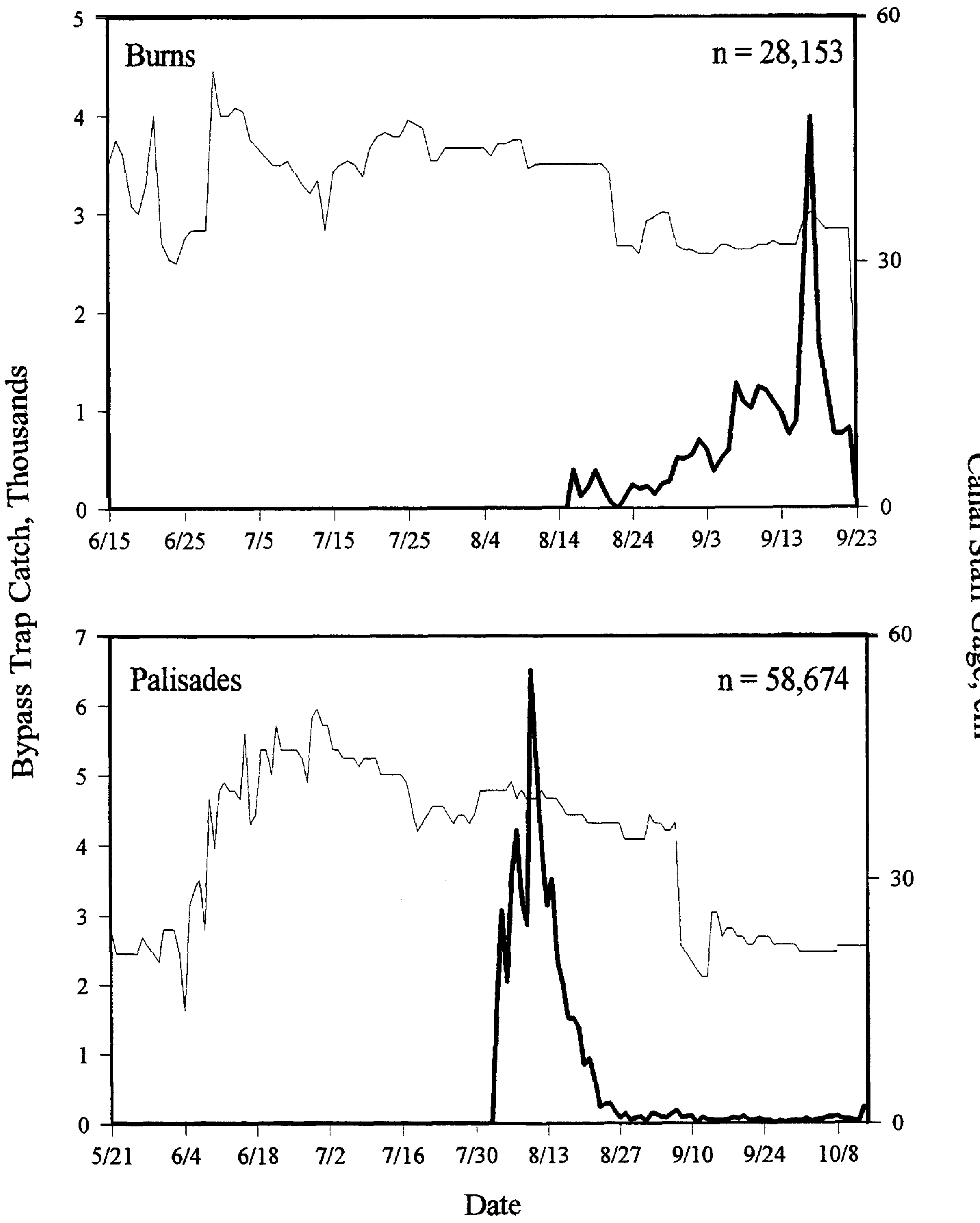

Figure 8. Unexpanded counts of emigrant rainbow/cutthroat trout <80 mm TL captured in the irrigation diversion screen bypass traps, Burns and Palisades sampling sites, 1996 irrigation season. Daily catches at the Palisades site during the period of August 3-22 are the sum of actual counts and dip net scoop estimates. Hairline represents canal staff gage measurements.

The emigration of fry from Palisades Creek appeared to peak in late August, more than a month earlier than reported in past studies (Moore and Schill 1984). The actual peak of the migration may have been masked by a sudden drop in withdrawals by the Palisades diversion beginning in early September (Figure 8).

Outmigration

Outmigrations of fish <80 mm (rainbow/cutthroat fry) from Burns and Palisades creeks were estimated at about 97,000 and 181,000, respectively (Appendix B). The Palisades Creek estimate is low because it was based on expanded (by trap efficiency estimates) trap catch counts and unexpanded dip net counts. Cutthroat trout predominated the outmigration of fish ≥80 mm from each location and ranged from 2,045 fish at Burns Creek to 908 at Palisades (Appendix B). These estimates only represent a portion of the outmigration since emigrating fish ≥80 mm were not marked for release in the canals or streams after July 17 at Burns Creek and September 7 at Palisades.

DISCUSSION

The exploitation rates I calculated for the Burns and Palisades diversions were quite high (Tables 3 and 4). However, the migratory nature of the fish involved may have increased their vulnerability to exploitation. A variety of canals will need to be sampled before I can determine whether these rates are typical, particularly canals in systems where relatively non-migratory trout stocks occur.

The validity of the exploitation estimates derived in this study rests on the fate and behavior of the fish that were marked and released. Mortality of the fish released to estimate trap efficiency (decrease D) would positively bias (overestimate) the exploitation estimates, while mortality of the fish released to estimate exploitation (decrease M) would yield negatively biased (underestimated) estimates. The two sources of mortality working together would also tend to promote negatively-biased estimates. I attempted to reduce the impacts of mortality-dependent bias by only marking and releasing fish that were in good condition and, in the case of the fish that were dye-marked, holding fish overnight to adjust for short-term mortality.

In the instances when the trap efficiency and exploitation data needed to be stratified by time period, recoveries could have been erroneously included in time strata other than the one of release if fish failed to immediately move down a canal or stream, particularly since the fish were not uniquely marked. If the fish that were released to estimate trap efficiency failed to immediately move down a canal, but were recaptured in subsequent time strata (increase *d* in subsequent strata), the exploitation estimates would be negatively biased. If the fish that were released in a stream to estimate exploitation did not continue to emigrate, but were recaptured in subsequent strata (increase n in subsequent strata), exploitation would be positively biased. Likewise, a combination of the two sources of error would result in positively biased exploitation estimates. Although I had no means of determining when a recaptured fish was released, I used the pattern of releases and recoveries in a stratum to assign recoveries to the appropriate stratum. Releases were generally followed by a short, intense period of recovery, after which recoveries dropped off to zero until another group of fish was released.

For the most part, fish <80 and Z80 mm were actively emigrating and appeared to resume their migrations after release. However, the general absence of fish 120 mm to 300 mm among the recoveries of stream released fish (Figure 5) suggests they either died, were not actively emigrating, did not continue to emigrate, learned to avoid the canals and/or screen bypasses, etc.

There was some disparity between the exploitation rates I calculated at each site for the different length groups. While the Burns Creek diversion exploited fish <80 mm at a much higher rate (69%) than the Palisades diversion (44%), the Burns diversion exploited fish ≥80 mm at a much lower rate (26%) than the Palisades diversion (62%). Since the canals essentially captured the same percentage of streamflow over the course of the irrigation season (25% at Burns versus 26% at Palisades), I expected similar rates for the two length groups at each site. I suspect this departure from expectation is related to differences in canal operations and the physical characteristics of the diversions. The Burns Creek diversion apparently exploited fish <80 mm at a higher rate than the Palisades diversion, but withdrawals by the Palisades diversion were significantly reduced beginning in early September (Figure 3). This could have influenced the degree of exploitation on small fish by this canal. Conversely, the Burns diversion exploited fish Z 80 mm at a lower rate than the Palisades diversion. This may have been due to the nature of the diversion dams at these sites. The Burns Creek diversion had a short boulder dam that could have been easily traversed by emigrating adult trout. On the other hand, the Palisades diversion dam was a complete barrier to emigrating adults, so fish were either forced to continue down the ditch, return upstream, or jump over the dam.

RECOMMENDATIONS

1. Continue to estimate trout exploitation rates for a variety of canals.

2. Expand short-term mortality evaluations to include fish of all sizes that are marked and released.

3. Uniquely mark all fish released for trap efficiency and trout exploitation estimation.

ACKNOWLEDGMENTS

Donnie Wicker and Tom Alworth were invaluable in the field. Their perseverance and dedication to detail helped to insure that the data they collected were complete and accurate. Mark Gamblin and Bill Schrader provided critical logistical support and equipment. Their interest and concern regarding the impact of irrigation diversions on resident fish have helped direct the course of this project. Steve Elie also helped with equipment needs and supplied some interesting historical perspectives on the study canals. Tom Curet, Doug Nemeth, and Dan Schill provided thoughtful reviews of this manuscript. Their comments and suggestions were indispensable. Thanks to all.

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A P P E N D I C E S

Appendix A. Physical characteristics of the Burns Creek and Palisades Creek irrigation diversions, August 1996.

Diversion	River [a] Dewatered	Headgate Location/ Kind	Diversion Dam	Drop Structure, m	Relation to River	Decreed cfs	Velocity, m/s	Gradient, %	Width, m	Depth, m	Canal Angle
Burns	N	none	Y	N	outside bend	none	0.66	-1.0	3.1	0.25	40
Palisades	N	canal/ vertical	Y	N	outside bend	189	0.97	-1.0	9.2	0.64	80

[a] See Der Hovanisian 1997 for methods and definitions.

Appendix B. Estimates of the outmigration of adults and fry from Burns and Palisades creeks, 1996.

To: BILL SCHRADER@FISHERY@IDFGREG6
From: JOHN DER HOVANISIAN
Cc: DAN SCHILL@FISHERY@IDFGHQ
Bcc:
Subject: Burns/Palisades outmigrant estimates
Attachment: c:\irrdiver\9697rep\outmig.mem,c:\irrdiver\9697rep\outmig.wk4
Date: 2/24/97 2:43 PM

Bill - attached are some outmigration and associated variance estimates for Burns and Palisades creeks. The're not worth much as far as spawner-recruit functions are concerned because they only represent a portion of the runs in each stream, but they may provide you with some idea of relative production. If you have any questions or if these files don't arrive intact, give me a shout.

24 Feb 97

Bill:

Here are outmigration and variance estimates for YOY and spawners captured during trapping operations at the Burns and Palisades creek diversions. Outmigration was estimated by:

$$O = \textbf{Outmigration} = \frac{\textbf{Expanded Trap Catch}}{\textbf{Canal Exploitation Rate}} = \frac{C}{E} = C\left[\frac{1}{E}\right].$$

It's variance was estimated according to Goodman (1960):

$$V[O] = \left(V[C]\left[\frac{1}{E}\right]^2 + V\left[\frac{1}{E}\right]C^2 - V[C]\,V\left[\frac{1}{E}\right]\right).$$

$V\left[\frac{1}{E}\right]$ was derived accordingly:

1. a bootstrap procedure was used to generate 5,000 binomially distributed values of E based on the number of fish that were marked and released in the stream (M) and the expanded number of recaptures (n);

2. the variance of the reciprocals of the 5,000 values of E was calculated.

Approximate 95% confidence intervals for 0 were calculated by normal approximation ignoring the continuity term.

Literature

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Appendix B. Continued

Species	Dates	C	V[C]	E	1/E	V[1/E]	0	V[O]	95% CI Lower	95% CI Upper
Burns										
RB-CT [a]	8/26-9/23	67,438	6,383,272	0.69	1.44	0.0007	97,236	16,424,459	89,293	105,180
CT	6/21-7/18	536	4,375	0.26	3.82	0.2508	2,045	134,656	1,326	2,764
Palisades										
RB-CT [a,b]	5/21-10/14	79,462	17,176,721	0.44	2.28	0.0099	181,424	151,669,813	157,286	205,562
CT [c]	5/21-9/7	559	1,832	0.62	1.62	0.0130	908	8,870	723	1,092
RB [c]	5/21-9/7	75	89	0.62	1.62	0.0130	122	307	88	156
RBxCT [c]	5/21-9/7	45	48	0.62	1.62	0.0130	73	151	49	97

[a] Fish <80 mm.

[b] The outmigration for RB-CT is underestimated since the expanded trap catch is the sum of expanded actual counts and unexpanded dip net counts.

[c] Fish ≥80 mm.

Appendix C. Unexpanded counts of emigrant trout captured in the Burns Creek irrigation diversion screen bypass trap, 1996 irrigation season.

	<80 mm	≥80mm		
Date	Rainbow/Cutthroat	Cutthroat	Rainbow x Cutthroat	Brown
06/15/96	0	0	0	0
06/16/96	0	0	0	0
06/17/96	0	0	0	0
06/18/96	0	0	0	0
06/19/96	0	0	0	0
06/20/96	0	0	0	0
06/21/96	0	0	0	0
06/22/96	0	0	0	0
06/23/96	0	0	0	0
06/24/96	0	0	0	0
06/25/96	0	0	0	0
06/26/96	0	0	0	0
06/27/96	0	0	0	0
06/28/96	0	0	0	0
06/29/96	0	0	0	0
06/30/96	0	0	0	0
07/01/96	0	0	0	0
07/02/96	0	0	0	0
07/03/96	0	0	0	0
07/04/96	0	0	0	1
07/05/96	0	0	0	0
07/06/96	0	0	0	0
07/07/96	0	0	0	0
07/08/96	0	0	0	0
07/09/96	0	0	0	0
07/10/96	0	0	0	0
07/11/96	0	0	0	0
07/12/96	0	0	0	0
07/13/96	0	0	0	0
07/14/96	0	0	0	0
07/15/96	0	0	0	0
07/16/96	0	0	0	0
07/17/96	0	0	0	0
07/18/96	0	0	0	0
07/19/96	0	0	0	0
07/20/96	0	0	0	0
07/21/96	0	0	0	0
07/22/96	0	0	0	0
07/23/96	0	0	0	0
07/24/96	0	0	0	0
07/25/96	0	0	0	0
07/26/96	0	0	0	0

Appendix C. Continued.

	<80 mm	≥80 mm		
Date	Rainbow/Cutthroat	Cutthroat	Rainbow x Cutthroat	Brown
07/27/96	0	0	0	0
07/28/96	0	0	0	0
07/29/96	0	0	0	0
07/30/96	0	0	0	0
07/31/96	0	0	0	0
08/01/96	0	0	0	0
08/02/96	0	0	0	0
08/03/96	0	0	0	0
08/04/96	0	0	0	0
08/05/96	0	0	0	0
08/06/96	0	0	0	0
08/07/96	0	0	0	0
08/08/96	0	0	0	0
08/09/96	0	0	0	0
08/10/96	0	0	0	0
08/11/96	0	0	0	0
08/12/96	0	0	0	0
08/13/96	0	0	0	0
08/14/96	0	0	0	0
08/15/96	0	0	0	0
08/16/96	0	0	0	0
08/17/96	0	0	0	0
08/18/96	0	0	0	0
08/19/96	0	0	0	0
08/20/96	0	0	0	0
08/21/96	0	0	0	0
08/22/96	0	0	0	0
08/23/96	0	0	0	0
08/24/96	0	0	0	0
08/25/96	0	0	0	0
08/26/96	0	0	0	0
08/27/96	0	0	0	0
08/28/96	0	0	0	0
08/29/96	0	0	0	0
08/30/96	0	0	0	0
08/31/96	0	0	0	0
09/01/96	0	0	0	0
09/02/96	0	0	0	0
09/03/96	0	0	0	0
09/04/96	0	0	0	0
09/05/96	0	0	0	0
09/06/96	0	0	0	0
09/07/96	0	0	0	0

Appendix C. Continued.

	<80 mm	≥80 mm		
Date	Rainbow/Cutthroat	Cutthroat	Rainbow x Cutthroat	Brown
09/08/96	1,079	0	0	0
09/09/96	1,010	0	0	0
09/10/96	1,224	0	0	0
09/11/96	1,195	0	0	0
09/12/96	1,075	0	0	0
09/13/96	0	0	0	0
09/14/96	0	0	0	0
09/15/96	0	0	0	0
09/16/96	2,415	0	0	0
09/17/96	3,977	0	0	0
09/18/96	1,668	0	0	0
09/19/96	1,216	0	0	0
09/20/96	0	0	0	0
09/21/96	0	0	1	0
09/22/96	0	0	0	0
09/23/96	0	0	0	0
Total	28,153	382	1	1

Appendix D. Trout exploitation data by length group collected at the Burns Creek irrigation diversion, 1996 irrigation season.

Date	Trap Efficiency Releases *(D)*	Trap Efficiency Recoveries *(d)*	Marked Stream Releases (M)	Marked Stream Recoveries *(n)*
<80 mm				
8/26-9/1 [a]	210	78	428	124
9/2-9/8	360	144	292	67
9/9-9/13	298	122	296	91
9/14-9/23	264	97	296	72
Overall	1,132	441	1,312	354
≥80 mm				
6/21-7/01 [b]	62	15	35	2
7/2-7/18	52	45	153	35

[a] Since the trap efficiency estimates used to expand the number of marked stream release recoveries were not significantly different over time, the data were pooled and used to calculate overall expanded recovery and error estimates.

[b] Since the trap efficiency estimates used to expand the number of marked stream release recoveries were significantly different over time, the data were stratified and used to calculate expanded recovery and associated variance estimates by time period.

Appendix E. Trout exploitation data by length group collected at the Palisades Creek irrigation diversion, 1996 irrigation season.

Date	Trap Efficiency Releases *(D)*	Trap Efficiency Recoveries *(d)*	Marked Stream Releases (M)	Marked Stream Recoveries *(n)*
<80 mm				
5/21-6/11 [a]	19	10	18	1
6/12-7/21	27	9	25	6
7/22-9/8	148	47	105	19
9/9-10/14	340	181	539	116
≥80 mm				
5/21-6/11 [b]	40	29	27	2
6/12-7/16	136	62	67	27
7/17-9/7	24	16	37	14
Overall	200	107	131	43

[a] Since the trap efficiency estimates used to expand the number of marked stream release recoveries were significantly different over time, the data were stratified and used to calculate expanded recovery and associated variance estimates by time period.

[b] Since the trap efficiency estimates used to expand the number of marked stream release recoveries were not significantly different over time, the data were pooled and used to calculate overall expanded recovery and error estimates.

Appendix F. Unexpanded counts of emigrant trout captured in the Palisades Creek irrigation diversion screen bypass trap, 1996 irrigation season.

	<80mm[a]					
	Rainbow/Cutthroat			≥80 mm		
Date	Actual	Dip Net (Ĉ)	SE [Ĉ]	Cutthroat	Rainbow x Cutthroat	Rainbow
05/21/96	7	0		0	0	2
05/22/96	3	0		0	1	3
05/23/96	2	0		0	0	2
05/24/96	2	0		6	2	1
05/25/96	1	0		2	0	0
05/26/96	1	0		4	0	1
05/27/96	0	0		0	1	1
05/28/96	3	0		2	0	0
05/29/96	0	0		0	0	1
05/30/96	0	0		0	0	0
05/31/96	0	0		0	0	0
06/01/96	0	0		0	1	0
06/02/96	1	0		1	2	1
06/03/96	1	0		2	1	0
06/04/96	4	0		1	1	0
06/05/96	1	0		3	0	1
06/06/96	4	0		5	0	1
06/07/96	3	0		2	0	0
06/08/96	3	0		6	0	3
06/09/96	0	0		3	0	1
06/10/96	0	0		2	1	0
06/11/96	1	0		1	0	0
06/12/96	0	0		0	0	0
06/13/96	0	0		0	0	0
06/14/96	0	0		0	0	0
06/15/96	2	0		0	0	0
06/16/96	2	0		0	1	1
06/17/96	1	0		0	1	1
06/18/96	1	0		1	0	0
06/19/96	6	0		3	0	0
06/20/96	1	0		0	0	1
06/21/96	2	0		0	0	0
06/22/96	2	0		5	0	1
06/23/96	3	0		2	1	1
06/24/96	3	0		6	1	0
06/25/96	6	0		5	1	1
06/26/96	1	0		3	1	0
06/27/96	5	0		6	1	0
06/28/96	5	0		3	0	0

Appendix F. Continued.

	<80 mm [a]					
	Rainbow/Cutthroat			≥80 mm		
Date	Actual	Dip Net (Ĉ)	SE [Ĉ]	Cutthroat	Rainbow x Cutthroat	Rainbow
06/29/96	3	0	--	3	0	0
06/30/96	3	0	--	3	0	1
07/01/96	1	0	--	4	0	0
07/02/96	2	0	--	10	1	0
07/03/96	0	0	--	3	0	0
07/04/96	1	0	--	7	0	0
07/05/96	2	0	--	14	0	0
07/06/96	0	0	--	18	0	2
07/07/96	1	0	--	6	0	1
07/08/96	2	0	--	5	0	1
07/09/96	0	0	--	10	0	0
07/10/96	0	0	--	11	1	1
07/11/96	0	0	--	16	3	1
07/12/96	1	0	--	7	0	1
07/13/96	1	0	--	9	0	0
07/14/96	0	0	--	6	0	0
07/15/96	1	0	--	7	0	1
07/16/96	2	0	--	7	0	1
07/17/96	3	0	--	10	0	0
07/18/96	0	0	--	5	0	1
07/19/96	1	0	--	2	0	2
07/20/96	0	0	--	3	0	0
07/21/96	1	0	--	5	0	1
07/22/96	0	0	--	3	0	0
07/23/96	0	0	--	3	0	0
07/24/96	0	0	--	1	0	0
07/25/96	1	0	--	1	0	0
07/26/96	0	0	--	3	1	0
07/27/96	1	0	--	3	0	0
07/28/96	0	0	--	5	0	1
07/29/96	1	0	--	4	0	0
07/30/96	0	0	--	2	0	0
07/31/96	0	0	--	2	0	0
08/01/96	0	0	--	2	0	0
08/02/96	1	0	--	1	0	0
08/03/96	213	1,486.8	38.5	2	0	0
08/04/96	266	2,808.4	52.9	1	0	0
08/05/96	410	1,628.4	40.3	2	0	0
08/06/96	343	3,209.6	56.5	1	0	0
08/07/96	291	3,917.6	62.5	0	0	0

Appendix F. Continued.

	<80 mm [a]			≥80 mm		
	Rainbow/Cutthroat					
Date	Actual	Dip Net (Ĉ)	SE [Ĉ]	Cutthroat	Rainbow x Cutthroat	Rainbow
08/08/96	250	2,950.0	54.2	1	0	0
08/09/96	70	2,784.8	52.7	0	0	0
08/10/96	456	6,053.4	77.6	0	0	0
08/11/96	289	4,885.2	69.7	1	0	0
08/12/96	346	3,658.0	60.4	1	0	0
08/13/96	414	2,714.0	52.0	0	0	0
08/14/96	302	3,209.6	56.5	0	0	0
08/15/96	317	1,982.4	44.4	0	0	0
08/16/96	374	1,628.4	40.3	0	0	0
08/17/96	37	1,463.2	38.2	0	1	0
08/18/96	243	1,262.6	35.5	1	0	0
08/19/96	380	991.2	31.4	0	0	1
08/20/96	272	566.4	23.7	1	0	0
08/21/96	382	542.8	23.2	1	0	0
08/22/96	429	212.4	14.5	0	0	0
08/23/96	239	0	--	1	0	0
08/24/96	281	0	--	0	0	0
08/25/96	286	0	--	0	0	0
08/26/96	170	0	--	1	0	0
08/27/96	79	0	--	3	0	0
08/28/96	148	0	--	0	0	0
08/29/96	50	0	--	0	0	0
08/30/96	79	0	--	0	0	0
08/31/96	101	0	--	0	0	0
09/01/96	27	0	--	2	0	0
09/02/96	141	0	--	0	0	0
09/03/96	141	0	--	0	0	0
09/04/96	96	0	--	0	0	0
09/05/96	82	0	--	0	0	0
09/06/96	139	0	--	2	0	0
09/07/96	188	0	--	2	0	0
09/08/96	88	0	--	7	0	0
09/09/96	99	0	--	4	0	0
09/10/96	108	0	--	0	0	0
09/11/96	0	0	--	0	0	0
09/12/96	93	0	--	0	0	0
09/13/96	52	0	--	0	0	0
09/14/96	47	0	--	0	0	0
09/15/96	40	0	--	0	0	0
09/16/96	38	0	--	0	0	0

Appendix F. Continued.

	<80mm[a]			≥80 mm		
	Rainbow/Cutthroat					
Date	Actual	Dip Net (Ĉ)	SE [Ĉ]	Cutthroat	Rainbow x Cutthroat	Rainbow
09/17/96	49	0	--	0	0	0
09/18/96	78	0	--	15	4	0
09/19/96	58	0	--	2	0	0
09/20/96	107	0	--	1	0	0
09/21/96	46	0	--	1	0	0
09/22/96	36	0	--	0	0	0
09/23/96	68	0	--	1	0	0
09/24/96	38	0	--	1	0	0
09/25/96	41	0	--	1	0	0
09/26/96	9	0	--	1	0	0
09/27/96	27	0	--	1	0	0
09/28/96	14	0	--	0	0	0
09/29/96	27	0	--	0	0	0
09/30/96	37	0	--	1	0	0
10/01/96	30	0	--	0	0	0
10/02/96	64	0	--	0	0	0
10/03/96	18	0	--	0	0	0
10/04/96	49	0	--	1	0	0
10/05/96	55	0	--	1	0	0
10/06/96	84	0	--	0	0	0
10/07/96	94	0	--	2	0	0
10/08/96	96	0	--	0	0	0
10/09/96	54	0	--	0	0	0
10/10/96	59	0	--	1	0	0
10/11/96	46	0	--	0	0	0
10/12/96	23	0	--	0	0	0
10/13/96	233	0	--	1	0	0
10/14/96	177	0	--	1	0	0
Total	10,719	47,955		341	28	40

[a] Trap catch was the sum of actual counts and dip net estimates 08/03-08/22. Daily dip net estimates C were calculated by multiplying the mean number of fish per dip net scoop ($\bar{x}$= 23.6, var[x] = 23.5) by the number of net scoops n. The standard errors of the daily estimates were calculated as the square root of n^2var[x].

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Project Costs

April 1, 1996 - June 30, 1997:

Sport Fish Restoration Funds	$ 99,843.76
State Funds	33,281.25
Total	$ 133,125.01