Benefits of Increased Minimum Instream Flows on Chinook Salmon and Steelhead in Clear Creek, Shasta County, California 1995-6.

Final Report

Prepared by Matthew R. Brown

U.S. Fish and Wildlife Service
Northern Central Valley Fishery Resource Office
10950 Tyler Road
Red Bluff, California 96080

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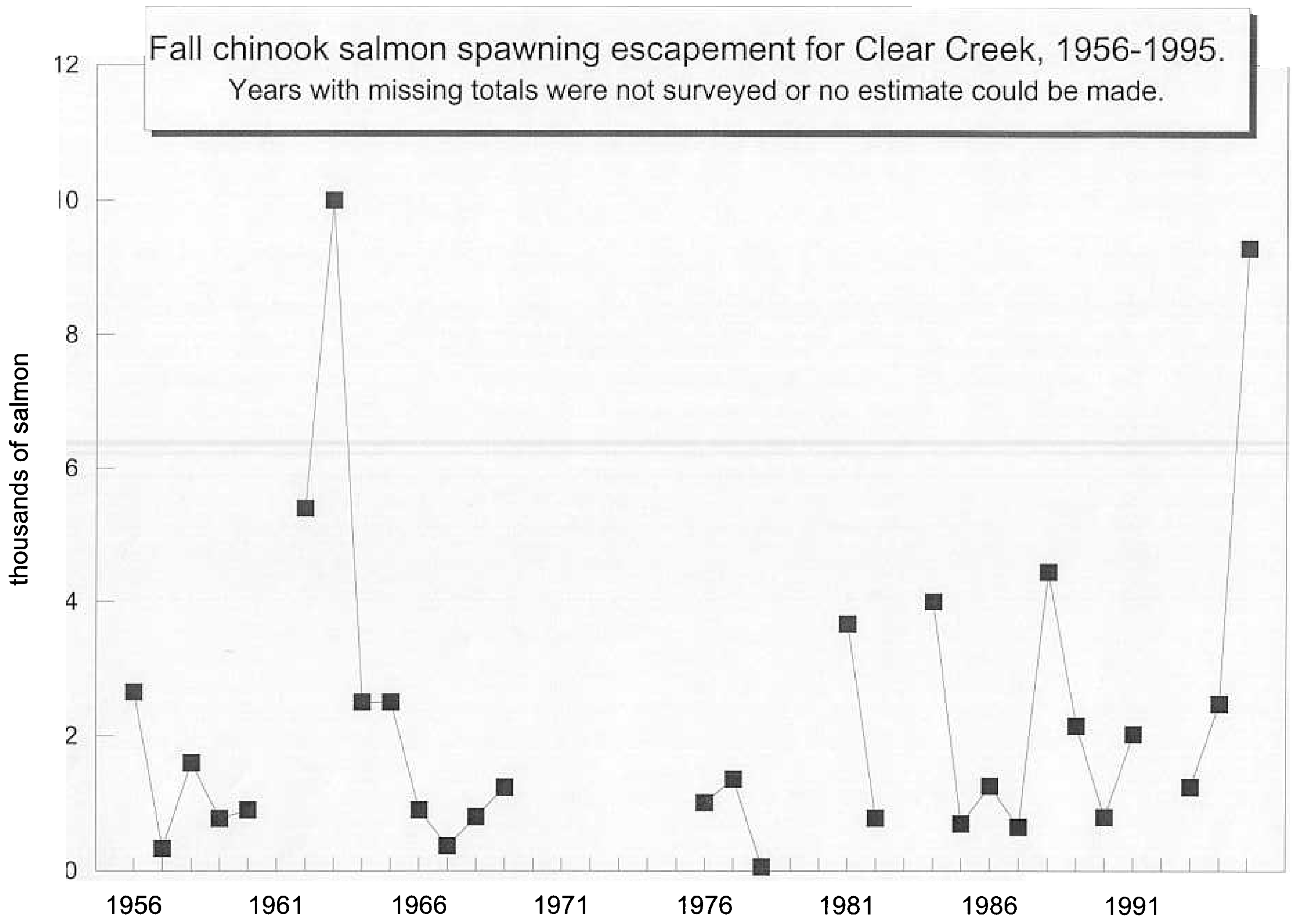
Introduction

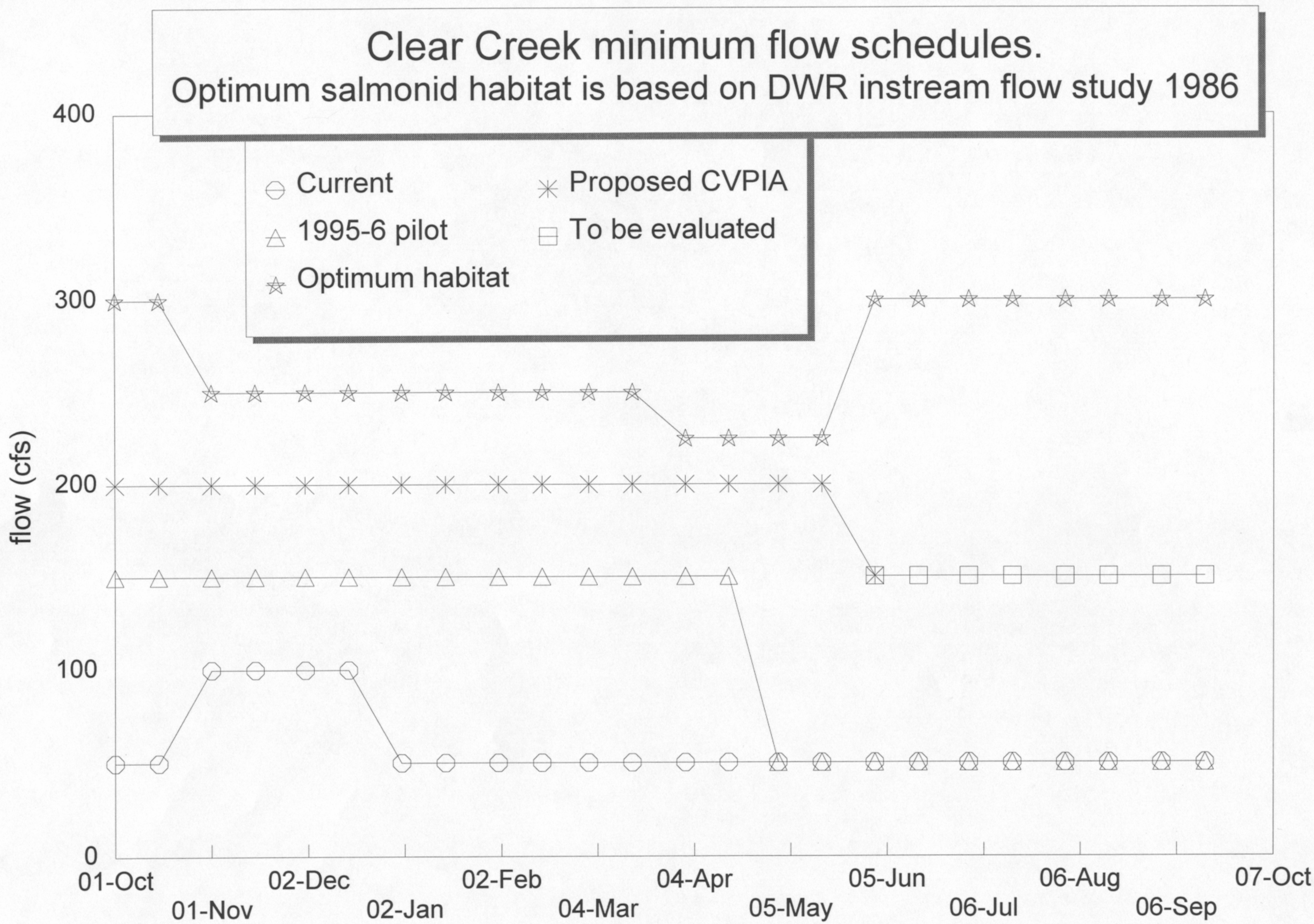
The Central Valley Project Improvement Act (CVPIA) directs the Secretary of the Interior to "develop and implement a comprehensive program to provide flows to allow sufficient spawning, incubation, rearing and outmigration for salmon and steelhead from Whiskeytown Dam as determined by instream flow studies conducted by the California Department of Fish and Game." Increased minimum flows were provided in Clear Creek from October 1, 1995 to May 3, 1996 to increase and improve fish passage, and spawning, incubation and rearing habitat for fall chinook. This paper presents some of the fishery impacts of these flows.

Clear Creek currently supports fall and late-fall chinook salmon, and can potentially support spring chinook salmon and steelhead. Annual adult escapement of fall chinook averaged 1,200 adults between 1967 and 1991 (Figure 1). Late-fall chinook escapement is difficult to estimate because of high turbidity and flows during spawning in January, February and March. Clear Creek is well suited for restoration of spring chinook and steelhead because Whiskeytown Reservoir can provide cold water required by these fish during the summer months. Closing the fish ladder at the Saeltzer Dam could be used to isolate fall chinook from spring chinook during spawning, thereby limiting hybridization. Hybridization has contributed to the decline of the spring chinook in the Sacramento River. Dams have restricted the range of spring chinook in the Sacramento River and tributaries, in many cases forcing spring chinook to spawn in the same areas as fall chinook, resulting in hybridization. In order to re-establish the spring chinook, 200,000 juveniles from the Feather River Hatchery were planted in Clear Creek annually in 1991, 1992 and 1993. Surveys for steelhead have not been conducted recently in Clear Creek.

Salmon and steelhead can benefit from increased minimum flows in many ways, including some discussed in this report: 1) improving upstream fish passage; 2) increasing flows to attract fish into Clear Creek; 3) lowering high water temperatures in the fall; 4) increasing low temperatures in the winter; 5) increasing the amount of available spawning gravels; and 6) increasing amount of rearing habitat for juvenile fish.

Previous studies have identified increased minimum instream flows as a restoration action necessary to improve anadromous fish populations in Clear Creek. The current minimum flow schedule provides 50 cfs from January 1 to October 31 and 100 cfs during November and December below Whiskeytown Dam (Figure 2). Minimum instream flows of 200 cfs from October 1 to June 1 and the evaluation of flows from June 1 to November 1 for spring chinook and steelhead, were proposed in the CVPIA "Draft Anadromous Fish Restoration Plan" by the Fish and Wildlife Service (Figure 2). In 1986, a California Department of Water Resources (DWR) study entitled "Clear Creek Fishery Study" identified optimal flows for salmon and steelhead of 250 cfs from October 16 to April 1, 225 cfs from April 1 to May 15, and 300 cfs from May 15 to October 15 (Figure 2). Optimal refers to flows that create the most salmonid habitat based on water depth and velocity . The study suggested a compromise flow schedule of 200 cfs from October through April and flows of 150 cfs from April through October. It was suggested that this flow release schedule "would be 'fine-tuned' as its fishery impacts are determined." Later in 1986, a Bureau of Reclamation study entitled "Evaluation of the Benefits and Costs of Improving the Anadromous Fishery of Clear Creek, California" recommended


Fall chinook salmon spawning escapement for Clear Creek, 1956-1995.
Years with missing totals were not surveyed or no estimate could be made.
thousands of salmon
12
10
8
6
4
2
0
1956
1961
1966
1971
1976
1981
1986
1991


Clear Creek minimum flow schedules.
Optimum salmonid habitat is based on DWR instream flow study 1986
Current
1995-6 pilot
Optimum habitat
Proposed CVPIA
To be evaluated
flow (cfs)
400
300
200
100
0
01-Oct
01-Nov
02-Dec
02-Jan
02-Feb
04-Mar
04-Apr
05-May
05-Jun
06-Jul
06-Aug
06-Sep
07-Oct

flows of 250 cfs from May 15 to April 1, 225 cfs from April 1 to May 1 and 150 cfs from May 1 to May 15. These flows would be measured at the Saeltzer Dam. Tributary inflow would provide much of the instream flow during winter.

Increased minimum flows were provided during water year 1996 to increase and improve fish passage and habitat for fall chinook. These releases may have also benefited late-fall chinook and spring chinook from the Feather River Hatchery fish, which were planted in Clear Creek from 1991 through 1993. Minimum flows were not provided for spring chinook and steelhead which require higher flows during the summer months.

Rapid decreases in flow can strand fish in shallow water habitats such as side channels and intermittent pools. More gradual flow decreases allow fish to move out of shallow water areas and avoid stranding. One pattern that gradually decreases flow is a "ramp down" in which flow is decreased in stepwise increments over time, simulating natural decreases in flow. Surveys to detect fish stranding were conducted in May 1996 during such a flow ramp down at the end of the increased water releases to Clear Creek.

Methods

Temperature measurement. Temperature measuring devices were located at four locations on lower Clear Creek in the fall of 1995: 1) Placer Road at river mile 10.4; 2) below Saeltzer Dam at river mile 6; 3) the Anderson Cottonwood Irrigation District (ACID) siphon at river mile 1.2; and 4) near the City of Redding Waste Water Treatment Plant at river mile 0.3. DWR has measured temperatures near the treatment plant since 1993. DWR installed additional devices at Saeltzer Dam and the ACID siphon on October 6, 1995. CDFG installed a device near the Placer Road Crossing (near the Igo gage) on October 6, 1995. From September 1991 through May 1995, CDFG maintained seasonal temperature devices near both the Placer Road Crossing (near the Igo gage) and at the National Environmental Education Camp.

Stream width surveys. Portions of Clear Creek that include the primary spawning areas for salmon were surveyed on foot three times: September 29, 1995, before the flow increases; October 5, 1995, during 100 cfs release; and November 6, 1995 during the 150 cfs release. Flows at Igo were 72, 99 and 144 cfs, respectively. Stream width measurements were made, photographs were taken and the number and condition of salmon were visually estimated.

Spawning escapement surveys. The number of salmon spawning in Clear Creek was estimated by CDFG. Escapement surveys since 1988 have been supervised by Colleen Harvey (Fishery Biologist, CDFG) and have been consistent enough in technique to allow comparison with data collected this year. Many of the CDFG crew members who performed this survey in past years were interviewed. The author assisted in this years survey. The surveys were conducted every one to two weeks depending on weather and stream conditions, during fall chinook spawning. Two crews of two simultaneously waded two reaches of the creek, where most of the fall chinook spawning takes place. A total of 4.2 miles of stream were surveyed, all below Saeltzer Dam. Salmon carcasses were tagged for recapture on subsequent surveys for population size estimation using the Schaefer calculation. Records of salmon spawning upstream of Red Bluff

Diversion Dam in the Sacramento River and tributaries was provided by CDFG (Frank Fisher, personal communication)

Fish stranding surveys. Field surveys to detect fish stranding were made on May 1 and 3, 1996 when releases from Whiskeytown Reservoir were 75 cfs, before the final decrease in flow to 50 cfs. A crew of two visually inspected side channels and isolated pools in areas of Clear Creek with the most side channels. In addition, Backpack electrofishing was conducted on May 3 in the side channel with the most potential for stranding and in an adjacent portion of the Clear Creek main channel.

Results and Discussion

Hydrology

Releases from Whiskeytown Reservoir to Clear Creek were increased in 1995 from 70 to 100 cfs on October 1, and then to 150 cfs on October 5. Whiskeytown releases were reflected in stream flow as measured 10 miles downstream at the Clear Creek near Igo gage (Figure 3). The 150 cfs release was maintained until the evening of April 28, 1996 when it was decreased to 125 (Figure 4). Whiskeytown releases decreased to 100 cfs on April 29 and to 75 cfs on April 30. The 75 cfs release was maintained until May 3 when the release was dropped to 50 cfs. The final decrease to 50 cfs had been scheduled for May 1, however, fish surveys on May 1 indicated that the likelihood of fish stranding would be reduced by delaying the final flow decrease.

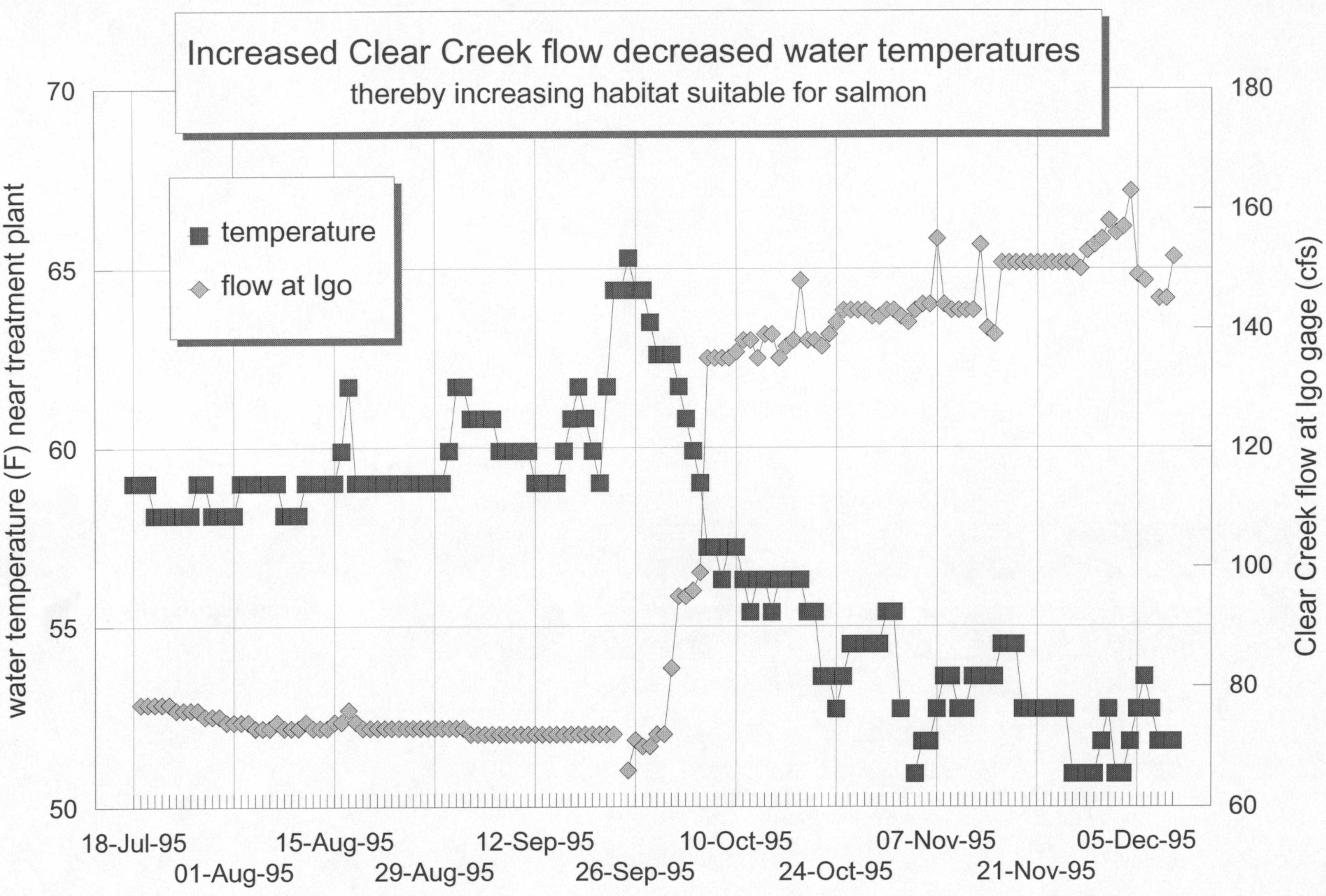
Attraction or Passage Flows

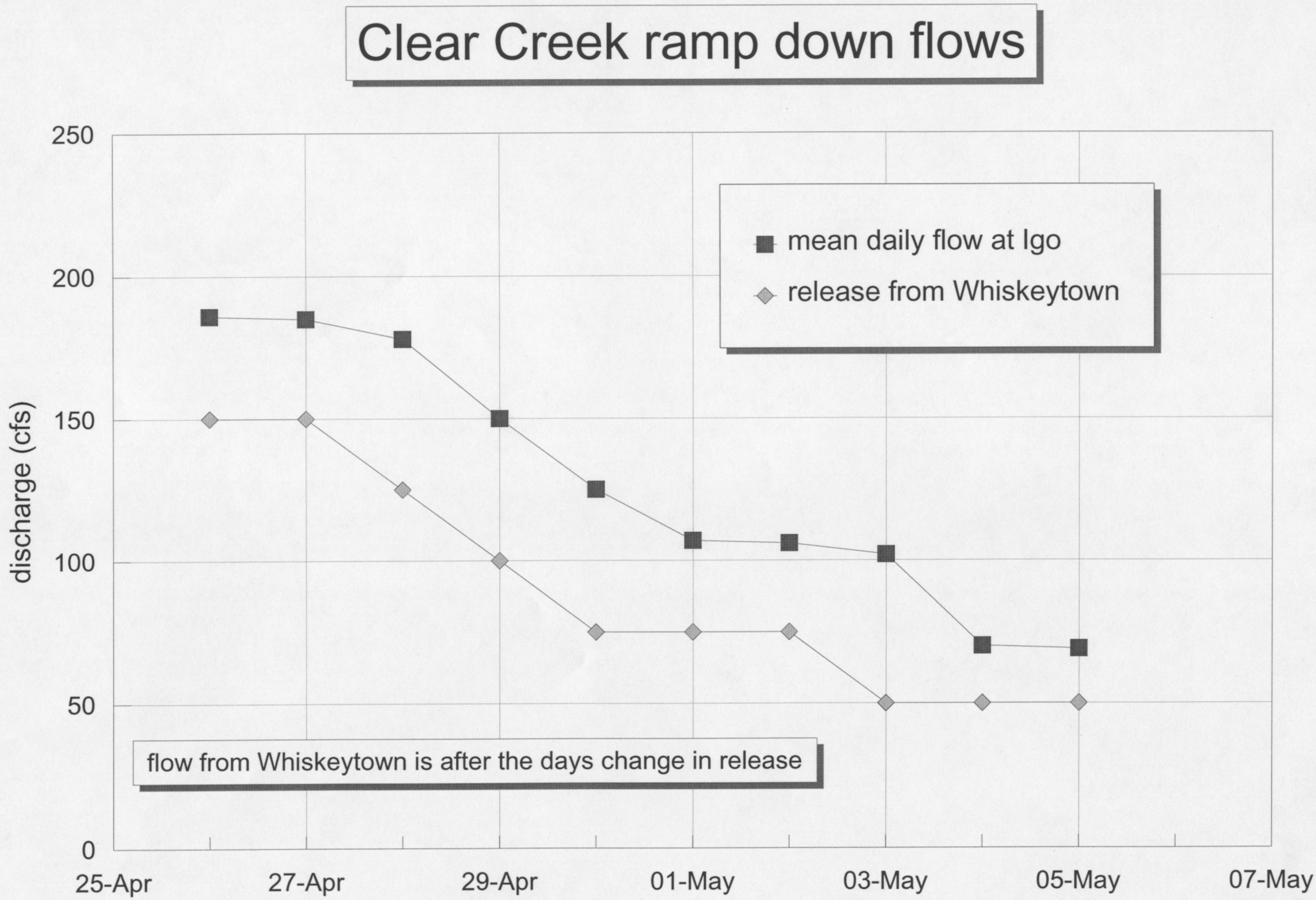
Increased minimum flows appeared to be instrumental in attracting salmon or improving salmon passage into Clear Creek in 1995. Visual observations made during stream measurement surveys were used as an approximation of the general density of salmon. Based on these visual observations, salmon numbers were low prior to the flow increase. Within 5 days of the flow increase, salmon numbers increased approximately 10-fold. This suggests that the increased flow and / or the decrease in temperatures caused by the flow, may have increased the number of fish in Clear Creek.

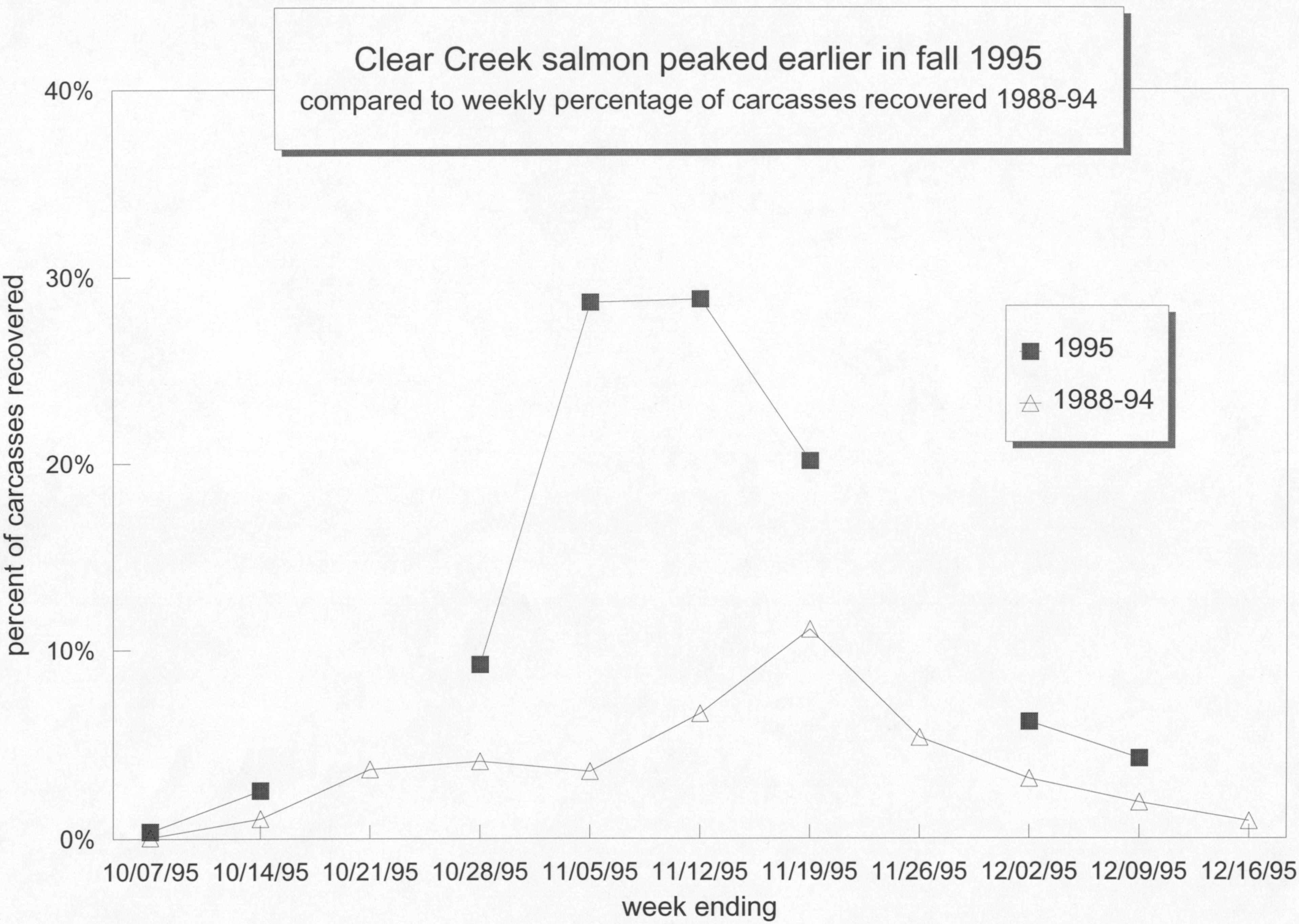
The peak of spawning in fall 1995 appears to have been one or two weeks before the average peak for years 1988 to 1994 (Figure 5). The early spawning peak may be due to 1) increased attraction flows provided by the increased minimum flow; 2) improved fish passage due to the increased minimum flow; 3) improved water temperatures for spawning provided by the increased minimum flow; 4) the presence of early spawning Feather River Hatchery hybrids; 5) the presence of other hatchery salmon which often spawn earlier than wild fish.

Temperature

Increased minimum flows can improve spawning habitat by reducing high water temperatures that can harm fish and fish embryos. In the fall, salmon in Clear Creek require water temperatures below 56 ^{0} F. for spawning and egg incubation. Temperatures above 56 ^{0} can be


Increased Clear Creek flow decreased water temperatures
thereby increasing habitat suitable for salmon
temperature
flow at Igo
water temperature (F) near treatment plant
Clear Creek flow at Igo gage (cfs)
70
65
60
55
50
180
160
140
120
100
80
60
18-Jul-95
01-Aug-95
15-Aug-95
29-Aug-95
12-Sep-95
26-Sep-95
10-Oct-95
24-Oct-95
07-Nov-95
21-Nov-95
05-Dec-95


Clear Creek ramp down flows
mean daily flow at Igo
release from Whiskeytown
flow from Whiskeytown is after the days change in release
discharge (cfs)
250
200
150
100
50
0
25-Apr
27-Apr
29-Apr
01-May
03-May
05-May
07-May


Clear Creek salmon peaked earlier in fall 1995
compared to weekly percentage of carcasses recovered 1988-94
percent of carcasses recovered
40%
30%
20%
10%
0%
1995
1988-94
10/07/95
10/14/95
10/21/95
10/28/95
11/05/95
11/12/95
11/19/95
11/26/95
12/02/95
12/09/95
12/16/95
week ending

lethal. High temperatures can be a problem in Clear Creek especially in October, when both spring and fall chinook are spawning. Water temperatures in Clear Creek quickly dropped below 56 ^{0} after flows were increased in October (Figures 3 and 6), providing a benefit to spawning salmon.

The effect of increased minimum flows on water temperature in early winter 1995 is difficult to determine. Late November and early December water temperatures were 2.6 ^{0} higher in 1995 than the average for the preceding 4 years. Warmer water temperatures in early winter (Figure 6) may have been due to the increased thermal inertia of higher flows, or may have been due to unseasonably warm air temperatures. For instance, November 1995 was the warmest and driest November in Sacramento since record keeping began in 1877. Whiskeytown reservoir water temperatures were not examined in this analysis. Chinook salmon eggs develop fastest at 56 ^{0} F. Chinook develop slower as temperatures drop below 56 ^{0}. Although faster growth can be beneficial in some situations, factors such as food availability, and appropriate timing of later life stages with environmental conditions, complicate the analysis of the benefits of faster growth.

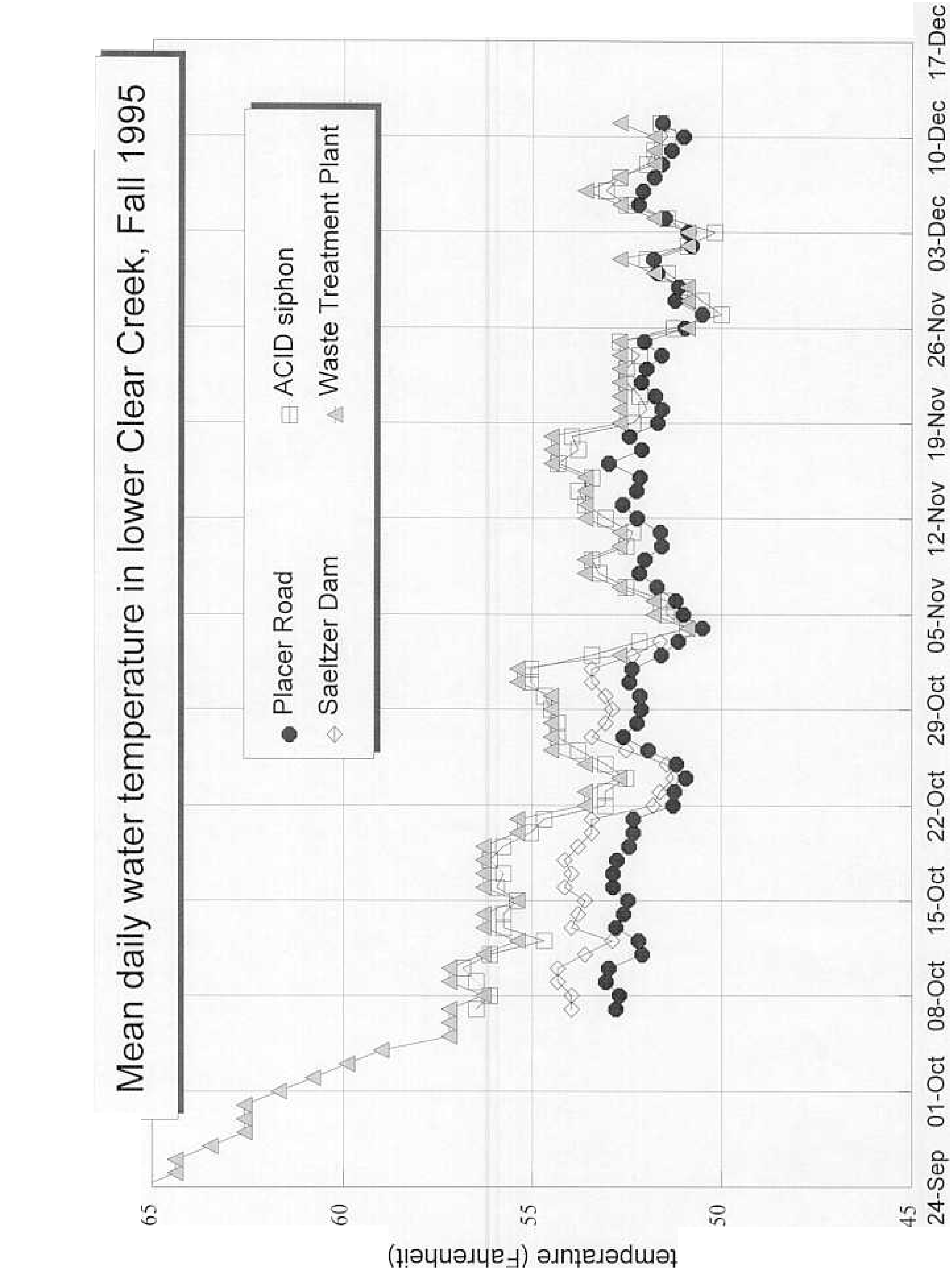
Spawning Habitat

Increased minimum flows increased the amount of available salmon spawning habitat in Clear Creek. The width of the wetted perimeter of Clear Creek was measured in five locations before and after increases in flow were made from Whiskeytown Reservoir. Mean stream width increased from 43.3 feet at 70 cfs, to 53.7 feet at 100 cfs, and to 57.7 feet at 150 cfs (Figure 7). The 33 percent overall increase in stream width is likely an underestimate of the increase in spawning area because of the shape of the Clear Creek stream channel. Regulated flows from Whiskeytown Reservoir have produced an unnatural stream channel, with steep sides and vegetation growing close to the low flow channel. When stream flows increase, vegetation and steep stream banks prevent the stream from spreading laterally, so the stream increases in depth. This increase in depth was important for salmon in Clear Creek. Based on visual observations before the flow increases, much of the spawning gravel in Clear Creek was in water too shallow for spawning. Much more of the spawning gravel was available to salmon after the flow increases.

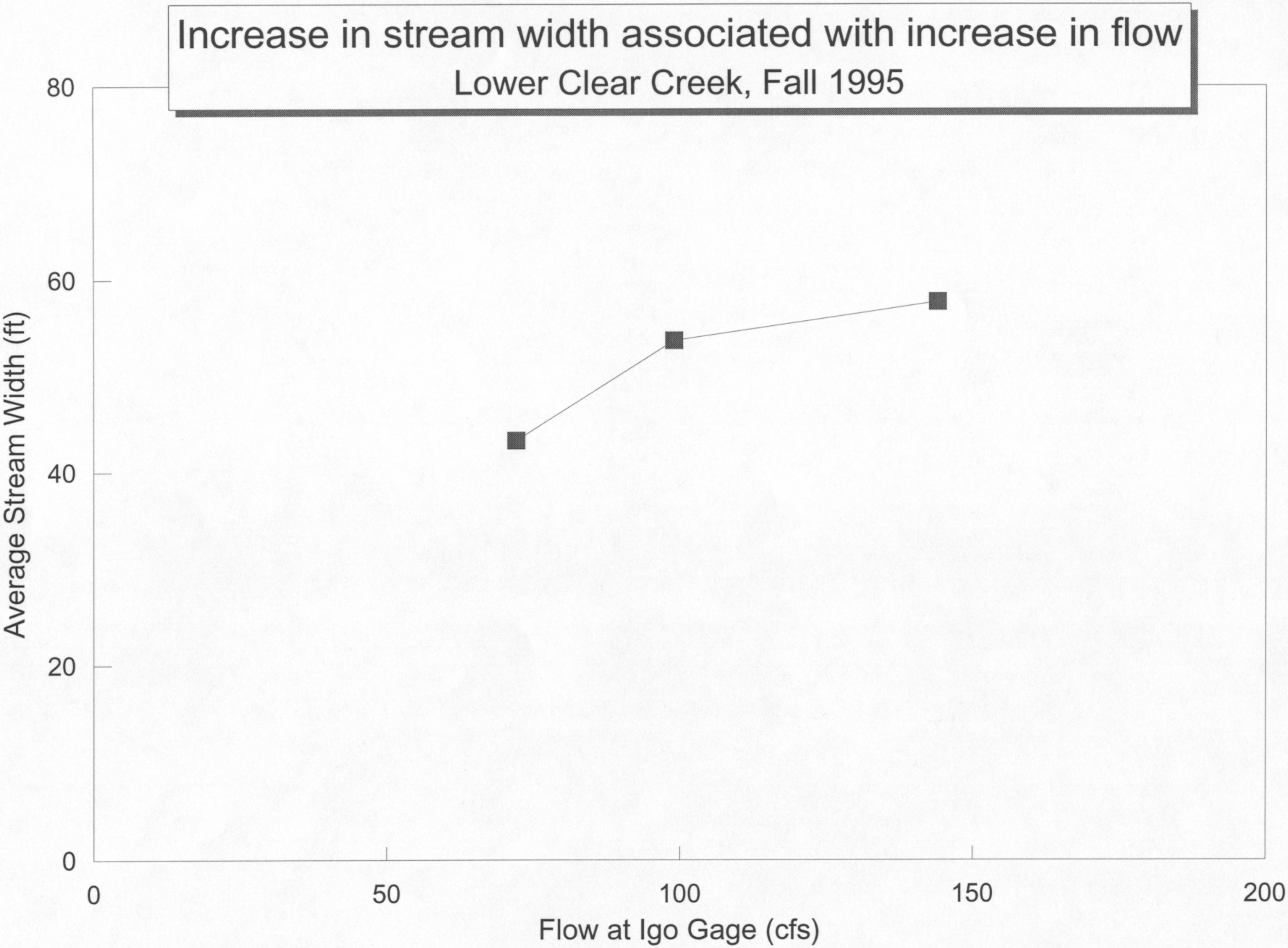
The instream flow model developed by DWR (1986) was used to calculate the increase in optimum salmon spawning habitat associated with various flows. The model is based on actual stream measurements, which take into account the unnatural shape of the stream channel. For instance, October minimum flows were increased from 50 cfs in past years to 150 cfs in 1995. The model predicted that increasing minimum flows from 50 to 150 cfs would produce an increase in optimum quality habitat of 97% for spawning and 15% for rearing (Figure 8).

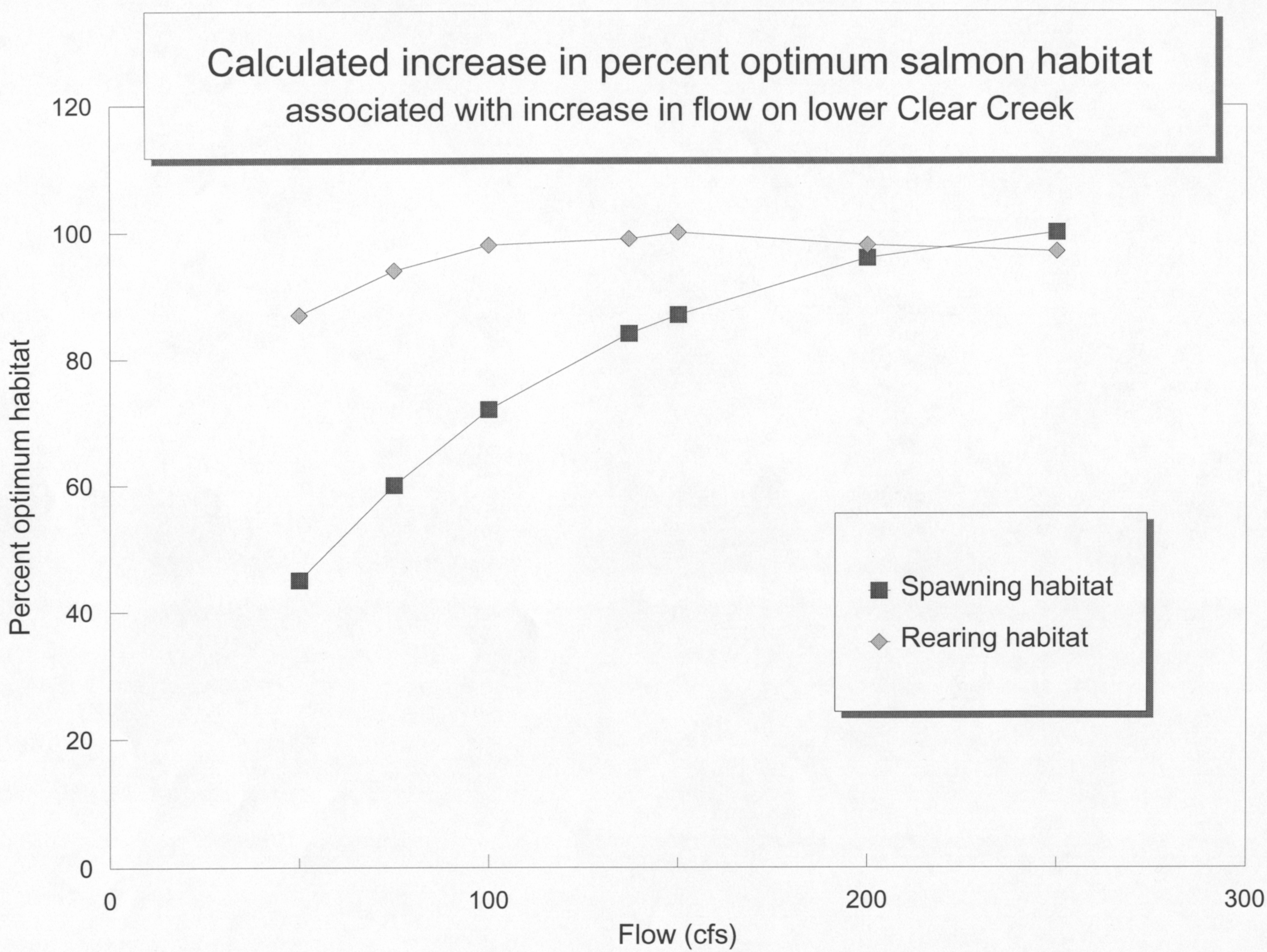
Spawning Escapement

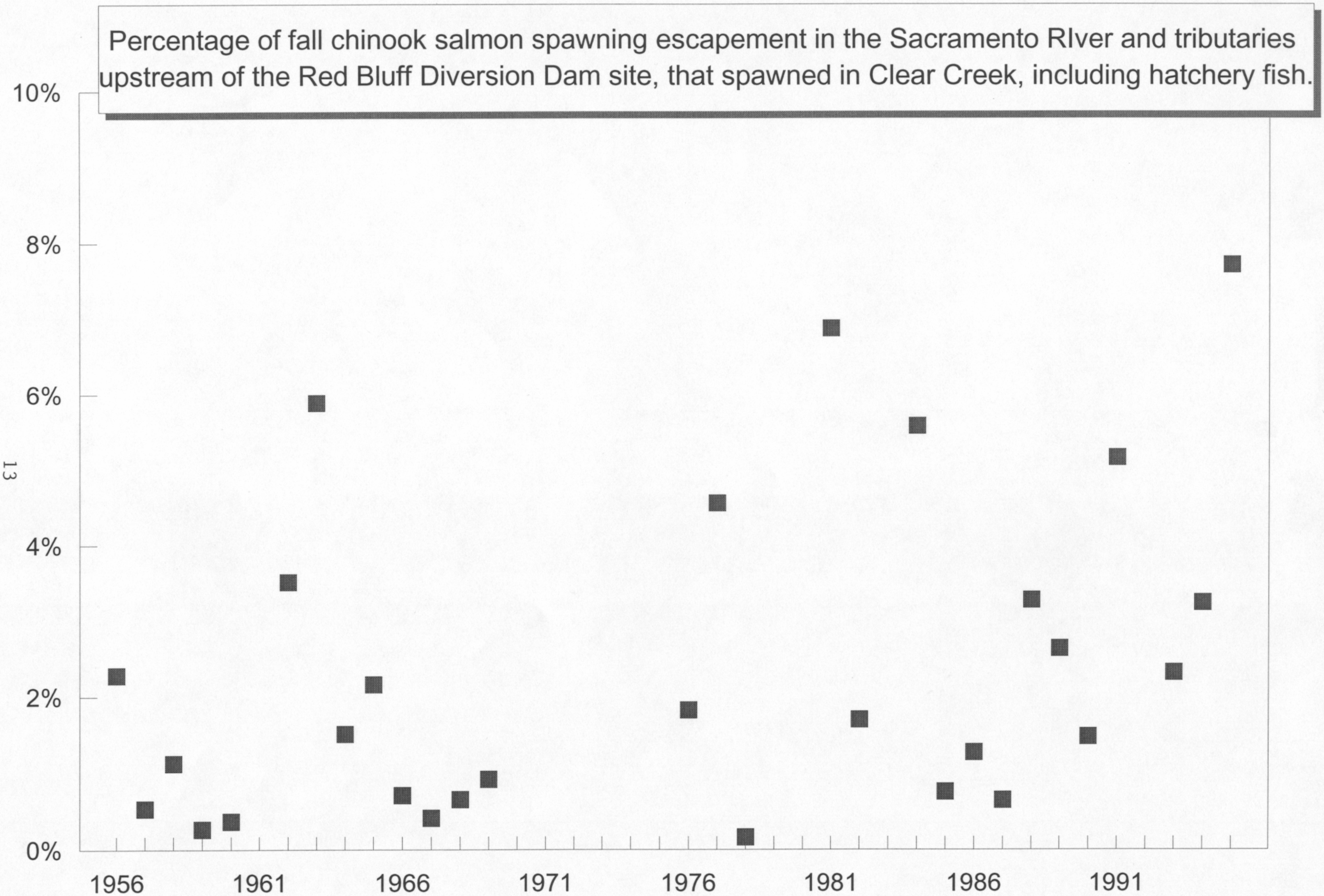
An estimated 9,298 fall chinook salmon spawned in Clear Creek in 1995. A total of 4,115 carcasses were examined. This is a very large number of fish for Clear Creek (Figure 1). Superimposition of redds was not a significant problem (Colleen Harvey, personal communication). Pre-spawning mortality was low (1.2%), suggesting that most salmon were able to access spawning habitat in Clear Creek.



Mean daily water temperature in lower Clear Creek, Fall 1995
Placer Road
Saeltzer Dam
ACID siphon
Waste Treatment Plant
temperature (Fahrenheit)
65
60
55
50
45
24-Sep
01-Oct
08-Oct
15-Oct
22-Oct
29-Oct
05-Nov
12-Nov
19-Nov
26-Nov
03-Dec
10-Dec
17-Dec


Increase in stream width associated with increase in flow
Lower Clear Creek, Fall 1995
Average Stream Width (ft)
0
20
40
60
80
0
50
100
150
200
Flow at Igo Gage (cfs)


Calculated increase in percent optimum salmon habitat
associated with increase in flow on lower Clear Creek
Percent optimum habitat
0
20
40
60
80
100
120
Flow (cfs)
0
100
200
300
Spawning habitat
Rearing habitat



Percentage of fall chinook salmon spawning escapement in the Sacramento RIver and tributaries upstream of the Red Bluff Diversion Dam site, that spawned in Clear Creek, including hatchery fish.
10%
8%
6%
4%
2%
0%
1956
1961
1966
1971
1976
1981
1986
1991

The contribution of the Clear Creek spawning escapement to escapement in the upper Sacramento River system was examined to determine if the large number of Clear Creek chinook in 1995 reflected a system-wide increase in fish numbers. The percent contribution of Clear Creek fall chinook spawning escapement, to the upper Sacramento River system fall chinook spawning escapement was 7.7% in 1995 (Figure 9), higher than any other year on record. The average contribution for the period of record from 1956 to 1995 was 2.4%. These percentages include fish that were produced by or returned to the Coleman National Fish Hatchery. The high percent contribution of Clear Creek fish to the upper Sacramento River system fall chinook spawning escapement suggests that the large number of salmon in Clear Creek was not due to system-wide conditions, but to improved conditions in Clear Creek.

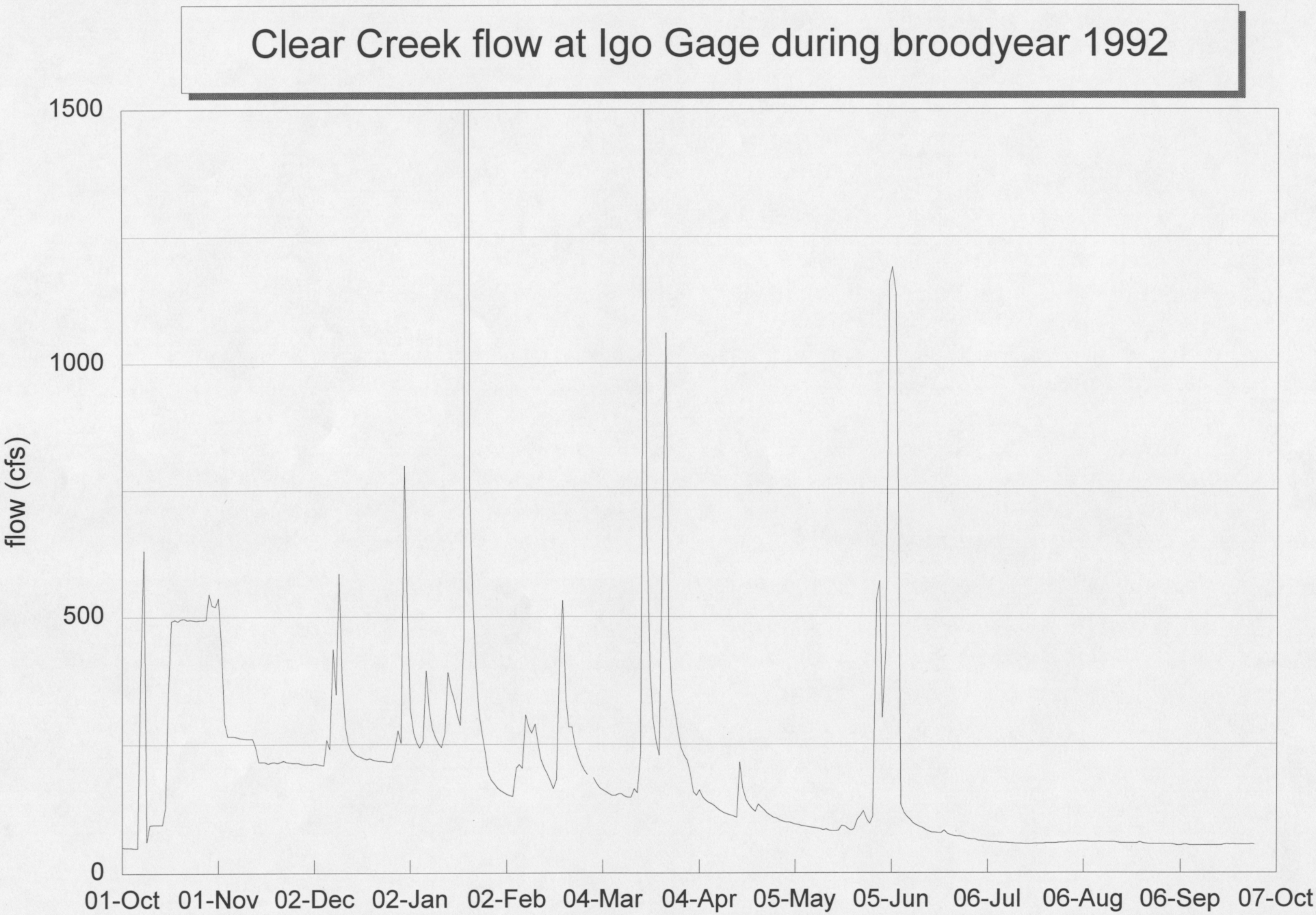
The large number of salmon spawning in Clear Creek also may have been due to water conditions during 1992 and 1993. Most of the salmon returning to spawn in fall 1995 were spawned in the fall of 1992 and migrated out in 1993. Flows in fall 1992 were unusually high in Clear Creek. In an attempt to reduce high water temperatures in the mainstem Sacramento River, Clear Creek minimum flows were increased from October 15 through April 1 (Figure 10). Flows were initially increased to approximately 500 cfs for 17 days. Flows greater than 200 cfs were maintained until January 27, 1993. In addition ten relatively short pulses of high flow occurred during outmigration in Spring 1993. The Feather River salmon were planted on March 22, 1993. Complete escapement estimates could not be made in fall 1992.

Hatchery fish

Coded wire tags (CWT) can be used to identify a fish's origin, usually a fish hatchery. CWT fish also have their adipose fins clipped off, to serve as an external signal that they have been tagged. Of the 4,115 Clear Creek carcasses examined in 1995, 62 were adipose fin clipped and CWTs were recovered from 44 of these fish. Twenty-six (59%) of the CWT fish were returning adults from the spring chinook planted into Clear Creek from the Feather River Hatchery in the early 1990's. All of the remaining 18 CWT fish were stray fall chinook, 8 originating from the Coleman National Fish Hatchery and 10 originating from the Feather River Hatchery.

In order to re-establish spring chinook, 200,000 juveniles from the Feather River Hatchery were planted in Clear Creek annually in 1991, 1992 and 1993. Half of each years plant in 1992 and 1993 were coded-wire tagged. These Feather River "spring"-run fish are commonly believed to derive from a stock of hybrid fall and spring chinook. These hybrids migrate into freshwater earlier than fall chinook and also spawn earlier. All of the CWT Feather River Hatchery fish examined were attracted into Clear Creek before November. Most of the Feather River CWT fish were recovered before CWT hatchery strays were collected. Ninety-one percent of all the CWT fish were attracted into Clear Creek before November.

A significant proportion of salmon spawning in Clear Creek in 1995 were of hatchery origin. The CWT fish can be used to estimate the percentage of the Clear Creek fall chinook that originated in a Sacramento River basin hatchery for each brood year. The total number of fish released from each hatchery can be multiplied by the ratio of CWT fish in Clear Creek to CWT fish from each hatchery release. Different estimates result from changes in the basic


Clear Creek flow at Igo Gage during broodyear 1992
flow (cfs)
0
500
1000
1500
01-Oct
01-Nov
02-Dec
02-Jan
02-Feb
04-Mar
04-Apr
05-May
05-Jun
06-Jul
06-Aug
06-Sep
07-Oct

assumptions of these calculations, including the straying rate of Nimbus Hatchery fish, the recovery and survival rate of fry versus older fish, and inclusion of CWT groups not collected in Clear Creek. Overall in 1995, estimates of hatchery contribution to the Clear Creek fall-run were 11% to 48%.

Fish Stranding Surveys

Initial visual survey (May 1)- Few salmonids appeared to be susceptible to stranding during the flow ramp down to 75 cfs. Juvenile salmonids were observed most commonly in the mainstem habitats of Clear Creek. Most isolated pools did not contain salmonids. Therefore few fish were stranded by the flow decrease to 75 cfs. Some side channels still connected to the mainstem, contained salmonids that would have been susceptible to stranding if releases were ramped down to 50 cfs. Therefore the 75 release was maintained to allow fish to move out of the side channels. One side channel contained at least a thousand salmonids and was chosen for further monitoring.

Second visual survey (May 3)- Many fewer salmonids were seen in side channels on May 3 than on May 1. We saw no indication (tracks, carcasses, birds nearby) that birds were preying on fish in the survey area. This suggests that delaying the final flow decrease allowed salmon to leave side channel habitats and avoid stranding. Flows were then decreased to 50 cfs.

Electrofishing survey (May 3)- 119 fish from 10 species were collected in 5 samples- four from side channel habitats and one from the main channel in the vicinity of the side channels. Speckled dace (*Rhinichthyes osculus*) was the most common species found in side channel habitats (104 fish / hour), but were absent from the mainstem sample. Conversely, chinook salmon (*Oncorhynchus tshawytscha*) catch rate was four times higher in mainstem habitats (122 fish / hour) than in side channel habitats (30 fish / hour). Length distribution of salmonids was similar in side channel and main channel habitats. (mean 49.4 and 50.1 mm fork length, respectively; Chi square $P = 0.8$). Both fall and late-fall chinook salmon were present, based on length criteria developed for chinook salmon in the mainstem Sacramento River (Greene 1992).

These observations are consistent with the hypothesis that salmonids moved out of the side channels during the delay in the ramp down. A better test of the hypothesis would involve more extensive sampling of side channels before and during a flow decrease. In addition, salmon captured within side channels were more common near side channel entrance and exits, and therefore were more likely to avoid stranding. Salmonids may have moved out of the side channels in response to decreases in water depth or increases in water temperature associated with lower flows. Hopefully salmonids left Clear Creek before temperatures got too high. Salmonid outmigration timing could be monitored with fyke or screw traps to get a better idea of when to ramp down flows in Clear Creek.

These data suggest that future flow ramp downs should mimic a natural flow decrease. Natural flow events are characterized by large initial flow decreases followed by gradually smaller decreases. Natural flow events are also associated with changes in turbidity and temperature which may stimulate downstream migration of salmon. Flow increases of a few days may investigated in future years.

Monitoring during the flow decrease in 1996 indicated that: 1) the ramp down rate of 25 cfs per day was sufficient to avoid stranding down to 75 cfs, and 2) that a more gradual ramp down rate was required below 75 cfs. These results are consistent with the idea that a flow decrease that mimics natural flow events will minimize stranding.

Summary

Increased minimum flows in Clear Creek 1995:

1) Improved fish passage into Clear Creek.
2) Improved Clear Creek water temperatures in October.
3) Increased the amount of spawning and rearing habitat in Clear Creek.
4) Contributed to record numbers of fall chinook adults spawning in Clear Creek.

Acknowledgements

I would like to thank everyone who performed field work and data processing including Michael Bornstein, Jason Dunham, Colleen Harvey, Gail Kuenster, Harry Rectenwald, Jane Vorpagel and the CDFG carcass recovery crew. I would like to thank Colleen Harvey for making spawning survey records available. I also appreciate the input and comments provided by Colleen Harvey, Rich Johnson, Craig Martin, Kevin Niemela, Harry Rectenwald, Jim Smith, and Caryl Williams.

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