

**1991 Fall Run Chinook Salmon
Spawning Escapement
in the Yuba River**

Prepared for:

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Table of Contents

	Page
INTRODUCTION	1
Background	1
Objective	1
METHODS	2
Streamflows and Water Clarity	2
Sampling Methods	2
Field Surveys	2
Sex and Length Composition	4
Coded-Wire-Tagged Carcasses	5
Population Estimation	5
RESULTS	6
Streamflows and Water Clarity	6
Run Timing	6
Run Size	8
Spawning Distribution	8
Sex and Length Composition	10
Coded-Wire-Tag Recoveries	10
SUMMARY AND DISCUSSION	10
Run Timing	10
Run Size	11
Spawning Distribution	11
Historical Perspective	11
CITATIONS	12
References	12
Personal Communications	12
ACKNOWLEDGMENTS	12
Appendix. Weekly Recoveries of Tagged Carcasses and Weekly Population Estimates of Fall-Run Chinook Salmon in the Yuba River, 1991	A-1

List of Figures and Tables

Figure		Page
1	1991 Lower Yuba River Chinook Salmon Spawning Escapement Survey Reaches	3
2	Numbers of Fresh Chinook Salmon Carcasses Counted Weekly during 1991 Spawning Escapement Surveys on the Yuba River	7
Table		Page
1	1991 Yuba River Fall-Run Chinook Salmon Spawning Escapement Estimates Based on Pooling and Stratifying Mark-Recovery Data by Section	9

INTRODUCTION

Background

From 1953 to 1989, the California Department of Fish and Game (DFG) conducted annual surveys on the lower Yuba River to estimate fall-run chinook salmon spawning escapement (i.e., the number of salmon returning to spawn). Spawning escapement surveys were not conducted in 1990, however, and surveys were not planned by DFG in 1991. Yuba County Water Agency (YCWA), after discovering that DFG would not be conducting chinook salmon spawning escapement surveys in 1991, decided to conduct such surveys itself. YCWA contracted with Jones & Stokes Associates to conduct the 1991 surveys.

Since 1973, DFG estimated annual chinook salmon spawning escapement in the lower Yuba River using a modified Schaefer method (Schaefer 1951). The Schaefer method is a mark-recapture technique designed to estimate the number of fish in a population as a series of distinct units separated either spatially or temporally. DFG estimated the weekly number of salmon arriving and spawning in the Yuba River based on the number of salmon carcasses that were tagged and subsequently recovered during weekly carcass surveys. The recovery rate of tagged carcasses relative to the total number of tagged carcasses at large and the total number of carcasses examined provides the basis for estimating weekly spawning populations throughout the spawning season.

Objective

The primary objective of the 1991 spawning escapement surveys was to estimate total chinook salmon run size in the lower Yuba River. Additional information obtained from the surveys includes run timing and spawning distribution, the proportion of adults (age three and older) and grilse (age two), and the proportion of males and females.

An effort was made to follow DFG's survey methods and population estimation techniques to produce a spawning escapement estimate comparable to past estimates. YCWA believes there is a critical need to continue salmon spawning escapement monitoring in the Yuba River, especially in view of the ongoing drought, water transfers, and the California State Water Resources Control Board's recent lower Yuba River water-right hearing.

METHODS

Streamflows and Water Clarity

Because of their importance in determining the effectiveness of spawning escapement surveys, streamflows and water clarity were monitored during the spawning escapement surveys. YCWA telemetered daily flow data directly from the U.S. Geological Survey (USGS) gage below Englebright Dam near Smartville, California (Station 11418000), and from the USGS gage near Marysville, California (Station 11421000). Water clarity was visually estimated during the field surveys.

Sampling Methods

The study design for the 1991 survey was developed by consulting with Fred Meyer, the DFG fisheries biologist responsible for previous surveys, and by reviewing past sampling techniques used by DFG on the lower Yuba River. Mr. Meyer participated during the first survey in 1991 to ensure proper sampling methodologies consistent with past DFG surveys.

One modification was made to past sampling techniques to produce more accurate results. DFG typically does not tag grilse but obtains population estimates based on the recovery of tagged adult carcasses only. Estimates of grilse are based on the proportion of grilse observed among "fresh" carcasses. Because of potential bias associated with differential recovery rates of adults and grilse, we tagged both adult and grilse carcasses and kept separate counts of tagged and untagged grilse and adult carcasses recovered during subsequent surveys. This procedure permitted independent estimates of grilse and adult populations and produced more accurate population estimates.

Field Surveys

Eleven spawning escapement surveys were conducted at weekly intervals from October 1 through December 12, 1991. Each survey took 2 days and extended from the Highway 20 bridge at Parks Bar to Daguerre Point Dam (DFG's Section 2) on the first day, and from Daguerre Point Dam to the E Street bridge in Marysville (DFG's Sections 3 and 4) on the second day (Figure 1).

The river was surveyed by a three-person crew consisting of a boat operator and two surveyors on foot. The surveyors walked downstream on opposite river banks and sampled carcasses along the banks and in the river. The boat operator assisted in retrieving salmon from deep pools and transporting the surveyors around impassable areas. When needed, one of the surveyors helped the boat operator retrieve carcasses from deep pools. Gaffs were used to handle carcasses and retrieve carcasses from deep water.

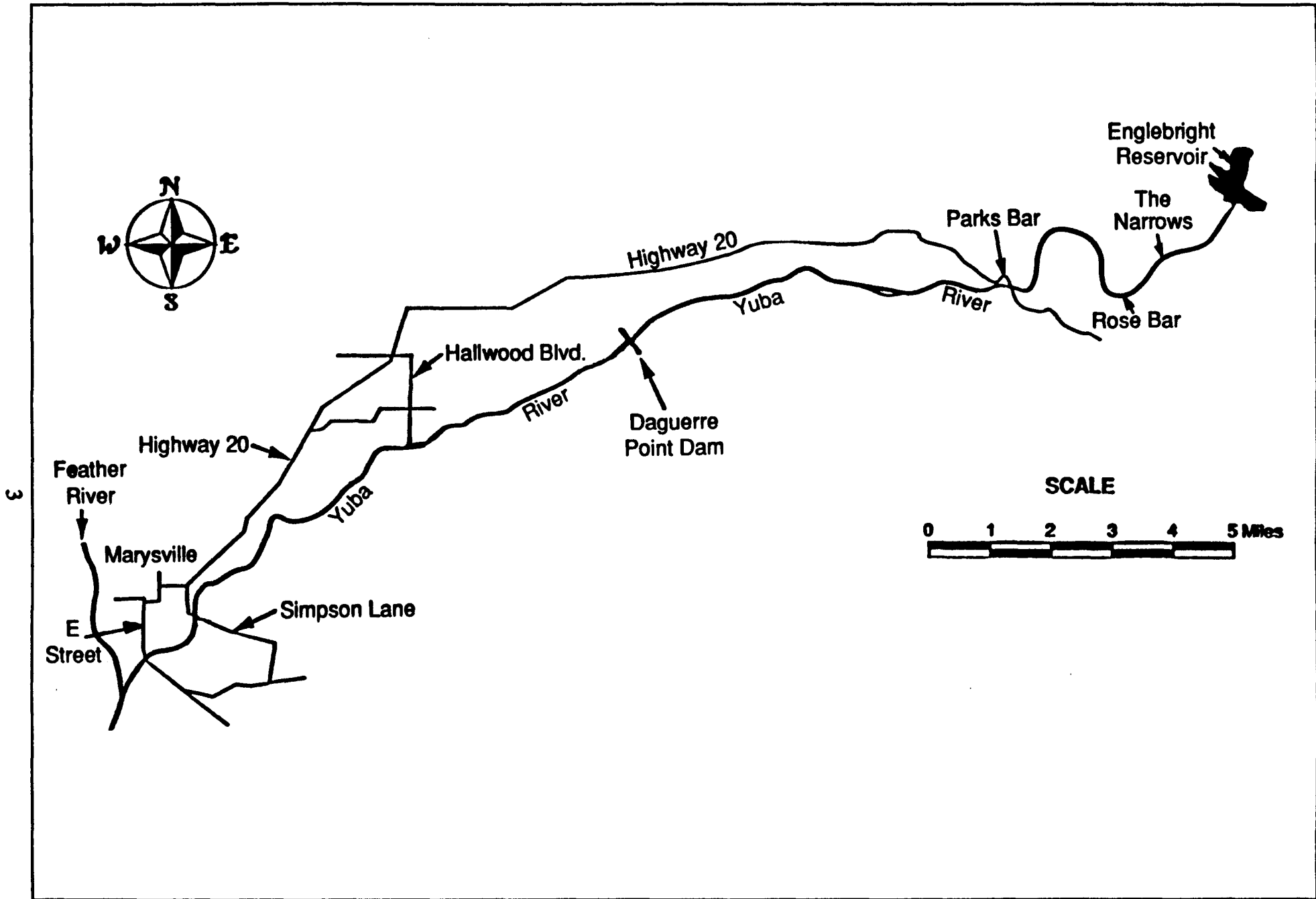


Figure 1. 1991 Lower Yuba River Chinook Salmon Spawning Escapement Survey Reaches

Untagged carcasses were classified as fresh or decomposing. A fresh carcass was identified by the presence of at least one clear eye or the presence of firm flesh and a shiny appearance. A hog ring with a short strip of surveying tape was secured to the lower jaw of each fresh carcass examined. A different color was used each week to identify the carcasses to a specific tagging week. Each fresh carcass was recorded as an adult or grilse based on size criteria provided by DFG; salmon greater than 26 inches in fork length were classified as adults and salmon less than 26 inches in fork length were classified as grilse (Meyer pers. comm.). The sex of each adult salmon was also recorded. After attaching a tag and recording relevant data, fresh carcasses were returned to the river by placing them in running water to disperse downstream.

Decomposing carcasses were identified by the milky appearance of the eyes, soft flesh, and the presence of fungus on the body. Decomposing carcasses were recorded as adult or grilse and chopped in half to prevent recounting. Many of the adults were too decomposed to confidently determine the sex.

Beginning with the second survey, all recovered tagged carcasses were identified as adult or grilse, recorded by tag color (i.e., week of tagging), and chopped in half.

On October 29, 1991, a survey of the lower Yuba River from Englebright Dam to the Highway 20 bridge (DFG's Section 1) was conducted by a Jones & Stokes Associates fisheries biologist and a field technician to examine the extent of spawning above the principal survey reach. A canoe was used because of poor access and the need to portage around a portion of the Narrows reach. DFG has conducted only partial surveys of this reach in recent years, and has typically assumed that 15.5% of the run spawns in this reach based on the average number of adults estimated in 1966-1971 (Konhoff pers. comm.). Although a population estimate could not be made in this reach in 1991, a sample of fresh carcasses were marked with a distinctive tag to determine the extent to which carcasses from this reach enter the surveyed reach below the Highway 20 bridge.

Sex and Length Composition

Separate population estimates for adult male and female chinook salmon were not possible because of difficulty in determining the sex of highly decomposed carcasses (tagged and untagged) during tag recovery efforts. Therefore, the sex composition of adult salmon was based on the proportion of males and females observed weekly among fresh carcasses. Attempts to distinguish between male and female grilse by external characteristics were largely unsuccessful, although these smaller salmon are typically age 2 males.

During the November 13-14 and 20-21 surveys, the fork lengths of 110 adult and 28 grilse carcasses were measured to determine length composition.

Coded-Wire-Tagged Carcasses

All fresh carcasses were examined to determine the presence or absence of an adipose fin. A missing adipose fin indicates the presence of a coded-wire-tag that is implanted in the snout of hatchery-reared salmon before they are released as juveniles. These tags contain information on race, hatchery of origin, and planting date. If the adipose fin was absent, the location, fork length, and sex of the carcass were recorded. The snout of the carcass was removed by making a vertical cut through the head just behind the eye. The lower jaw was left intact. The carcass was then tagged with a hog ring and released back into the river. The snout was placed in a plastic bag with the recorded information and returned to DFG for tag detection, extraction, and reading.

Population Estimation

The Schaefer model, as modified by DFG, is expressed using the terms of Ricker (1975) as follows:

$$N = \sum N_{ij} - \sum \left(R_{ij} \times \frac{M_i}{R_i} \times \frac{C_j}{R_j} \right) - \sum \frac{i}{2} M_i$$

- where
- i = week of tagging (starting with week 1),
 - j = week of recovery (starting with week 2),
 - N = total population estimate,
 - N_{ij} = weekly population estimate,
 - R_{ij} = number of fish tagged in the i th tagging period that are recaptured in the j th recovery period,
 - M_i = number of fish tagged in the i th period of tagging,
 - C_j = number of fish examined in the j th period of recovery,
 - R_i = total recoveries of fish tagged in the i th period, and
 - R_j = total recoveries of tagged fish in the j th period.

The modified Schaefer model includes an additional term that is subtracted from the original estimate to compensate for replacement of tagged fish released back into the popu-

lation; Schaefer's original model was based on sampling without replacement because tagging and sampling for tags were geographically separated. This term is the total number of fish tagged, beginning with the second week of tagging.

RESULTS

Streamflows and Water Clarity

Mean daily Yuba River discharge during the 1991 chinook salmon escapement surveys ranged from 884 cubic feet per second (cfs) to 2,190 cfs at the Smartville gage and from 596 cfs to 2,090 cfs at the Marysville gage. Flows of approximately 2,200 cfs at Smartville and 2,100 cfs at Marysville occurred during the first week of October. Beginning on October 10, flows at Smartville and Marysville declined steadily at a rate of approximately 200 cfs per day and reached levels of approximately 900 cfs and 600 cfs, respectively, by October 17. Flows at Smartville remained at approximately 900 cfs throughout the remainder of the survey period, while flows at Marysville fluctuated between approximately 600 and 800 cfs.

Yuba River flows and water clarity during the 1991 salmon escapement surveys provided excellent conditions for sampling and recovery of carcasses throughout the river. All tag recovery efforts occurred during constant Englebright releases of approximately 900 cfs. Water clarity during the escapement surveys varied between 5 and 10 feet and averaged approximately 8 feet.

Run Timing

The condition of tagged carcasses recovered 1 or 2 weeks after tagging indicated that carcasses decomposed rapidly. Therefore, fresh carcasses were believed to represent fish that had died within a week before tagging. Weekly counts of fresh carcasses provided the closest approximation of the temporal distribution of spawning (Figure 2).

No spawning activity or carcasses were observed during the first survey on October 1, 1991. Small numbers of live salmon were observed in the Yuba River above Daguerre Point Dam and in the fish ladder at Daguerre Point Dam. Continuation of the survey below the dam on October 1-2 was considered unnecessary.

Salmon carcasses and spawning activity were first observed on October 8 and 9 (Figure 2). A marked increase in the number of fresh carcasses and level of spawning activity was observed during the October 16-17 survey. During subsequent surveys, the weekly count of fresh carcasses peaked during October 23-24 and declined thereafter. Few live salmon were observed during the last two surveys (December 4-5 and 11-12) and few fresh carcasses could be found during December 11-12.

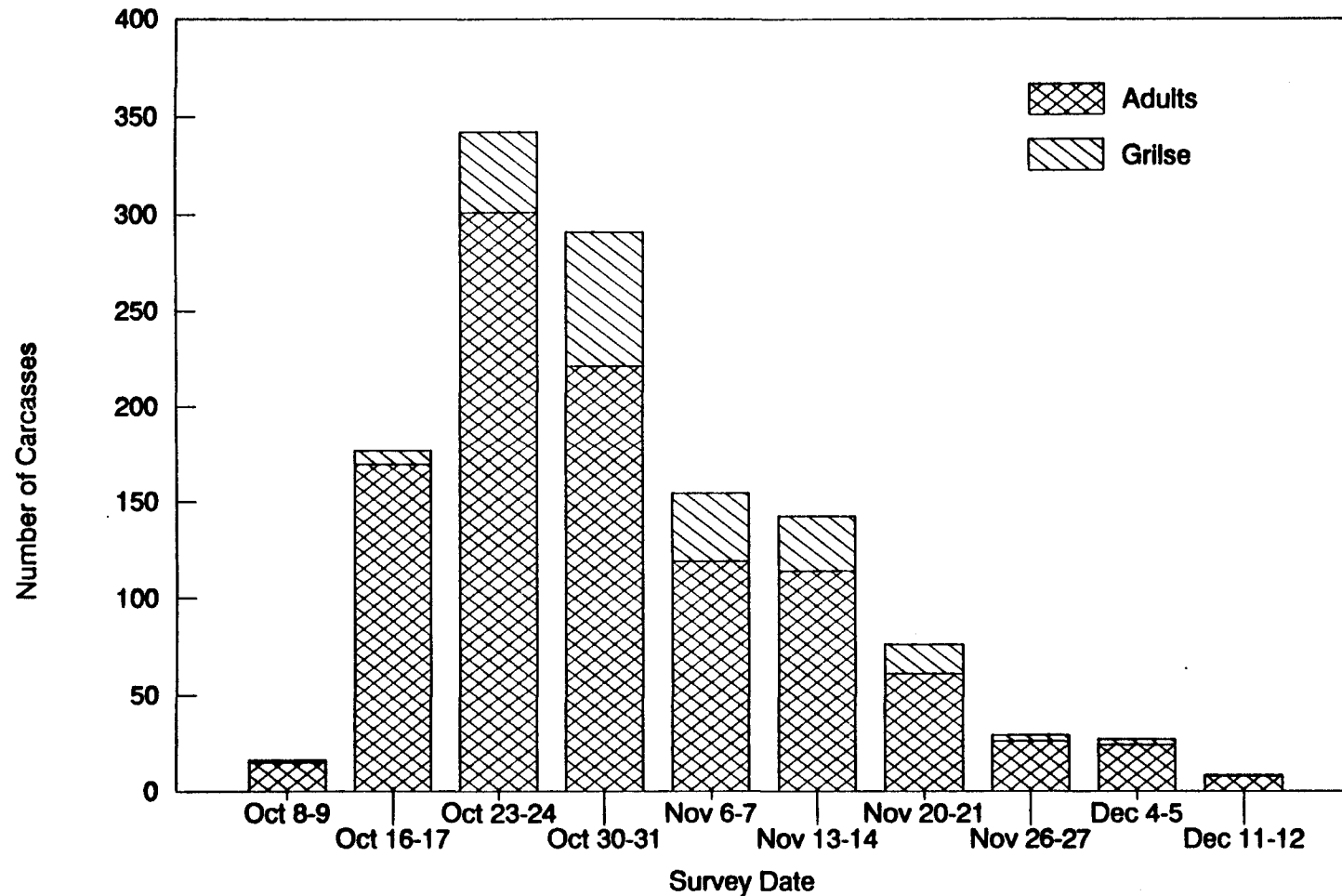


Figure 2. Numbers of Fresh Chinook Salmon Carcasses Counted Weekly during 1991 Spawning Escapement Surveys on the Yuba River

While the abundance of adult carcasses followed the pattern above, the abundance of grilse carcasses peaked 1 week later (Figure 2). Few grilse carcasses were found during October 8-9 and 16-17, but the number of grilse carcasses increased rapidly during the following week and peaked during the last week of October (October 30-31). Few grilse carcasses were found after the November 20-21 survey.

Run Size

A total of 6,058 (5,014 adults and 1,044 grilse) chinook salmon carcasses was collected between the Highway 20 and E Street bridges during the 1991 spawning escapement surveys. Of these, 1,252 were tagged as fresh carcasses and 526 tagged carcasses were recovered. Average recovery rates of adult and grilse carcasses were 44% and 36%, respectively.

Pooling of all tag-recovery data resulted in a spawning escapement estimate of 13,979 salmon (11,243 adults and 2,736 grilse) in the Yuba River, assuming 15.5% of the total population spawned above the Highway 20 (Table 1).

Stratifying tag-recovery data by survey section resulted in a slightly higher estimate of total spawning escapement (Table 1). Estimates of 7,221 salmon (5,771 adults and 1,450 grilse) between the Highway 20 bridge and Daguerre Point Dam and 4,958 salmon (3,904 adults and 1,054 grilse) between Daguerre Point Dam and the E Street Bridge results in an estimate of 12,179 salmon. Adding 15.5% results in a total spawning escapement of 14,413 salmon (11,450 adults and 2,963 grilse).

Weekly recoveries of tagged carcasses and weekly population estimates are summarized in Appendix Tables 1-12.

Spawning Distribution

Assuming that 15.5% of the run spawned above the Highway 20 bridge, the stratified population estimates indicate that 50.1% of the run spawned between the Highway 20 bridge and Daguerre Point Dam and 34.4% of the run spawned below Daguerre Point Dam.

During the October 29, 1991 survey from Englebright Dam to the Highway 20 bridge, relatively few live salmon and carcasses were observed above the Narrows. In this reach, spawning gravels were scarce and limited to small patches at the head of riffles. Significant spawning activity was first observed below the Narrows reach at Rose Bar, which marks the first major spawning riffle below Englebright Dam.

A total of 76 fresh carcasses (72 adults and 4 grilse) was tagged with a distinctive tag during the October 29 survey. During subsequent surveys, two of these carcasses were

**Table 1. 1991 Yuba River Fall-Run Chinook Salmon Spawning
Escapement Estimates Based on Pooling and Stratifying
Mark-Recovery Data by Section**

Section	Pooled Data		Stratified Data	
	Adult	Grilse	Adult	Grilse
Rose Bar to Highway 20 bridge	--	--	1,775	459
Highway 20 bridge to Daguerre Point Dam	--	--	5,771	1,450
Daguerre Point Dam to E Street bridge	<u>--</u>	<u>--</u>	<u>3,904</u>	<u>1,054</u>
Total ^a	11,243	2,736	11,450	2,963

^a Total population estimate assumes 15.5% of run spawned between Rose Bar and the Highway 20 bridge.

recovered immediately below the Highway 20 bridge on October 31, and another was recovered farther downstream on November 13.

Sex and Length Composition

Adult male and female salmon comprised 53% and 47%, respectively, of the total number of fresh adult carcasses examined. Based on the estimated adult population of 11,243 fish, the run was composed of 5,959 adult male salmon and 5,284 adult female salmon. Male and female grilse could not be readily identified, although most of these smaller salmon are typically age 2 males.

Fork lengths of adult male salmon ranged from 26 to 41 inches and averaged 35 inches. Fork lengths of adult female salmon ranged from 26 to 39 inches and averaged 31 inches. Grilse fork lengths ranged from 18 to 25 inches and averaged 22 inches.

Coded-Wire-Tag Recoveries

Twenty-two adipose-clipped salmon were found in the Yuba River between the Highway 20 and E Street bridges during the 1991 spawning escapement surveys. Two were found above the Highway 20 bridge during the October 29 survey. The tags indicated that nearly all of the tagged fish were spring-run chinook salmon originating from the Feather River Salmon and Steelhead Hatchery (Meyer pers. comm.).

SUMMARY AND DISCUSSION

Run Timing

High, cool flow releases from New Bullards Bar and Englebright Reservoirs in September and October, 1991, resulted in early upstream migration and spawning of chinook salmon in the lower Yuba River. Although the exact time of river entry is unknown, upstream migration of early spawning chinook salmon probably began in late September. Weekly observations of spawning activity and fresh carcasses indicated that spawning began during the first week of October (October 1-8), increased rapidly during the second week (October 9-16), and reached a peak during the third week (October 17-23). During subsequent weeks, the number of spawning salmon declined and most of the run had spawned by December 4.

Run Size

Assuming that 15.5% of the population spawned above the Highway 20 bridge, as DFG has assumed in developing past estimates, the estimated 1991 fall-run chinook salmon spawning escapement in the Yuba River was 13,979 fish (11,243 adults and 2,736 grilse). Stratifying tag-recovery data by survey section resulted in a slightly higher estimate of 14,413 fish (11,450 adults and 2,963 grilse).

The lower recovery rates of grilse compared to that of adults suggest that separate estimates of adults and grilse improve the accuracy of the population estimate. Further stratification of the mark-recovery data by sampling reach is also warranted when recovery rates differ between reaches. The result, however, is a reduction in sample size that could reduce the reliability of estimates made for separate reaches and the population as a whole. Nevertheless, differences in total population estimates based on data pooling and stratification were insignificant.

Spawning Distribution

Assuming that 15.5% of the run spawned above the Highway 20 bridge, 50.1% of the 1991 fall-run chinook salmon escapement spawned between the Highway 20 bridge and Daguerre Point Dam and 34.4% of the run spawned below Daguerre Point Dam.

When annual escapement surveys are limited to the reaches below the Highway 20 bridge, as done in the past, the influx of untagged carcasses from above the Highway 20 bridge to the survey reach below the bridge would tend to inflate population estimates derived from carcass recovery data. The magnitude of this error is likely to increase with river discharge and increasing spawner abundance above the Highway 20 bridge. During the 1991 spawning season, the influx of carcasses to the survey reach below the Highway 20 bridge could not be determined, but did occur to some extent based on the recovery of three carcasses tagged above the bridge during the October 29 survey.

Future surveys would be improved considerably by including the spawning area above the Highway 20 bridge. It is recommended that one three-person crew survey the reach between Rose Bar and the Highway 20 bridge while another three-person crew surveys the reach between the Highway 20 bridge and Daguerre Point Dam on the first survey day. A single crew would finish by surveying the reach below Daguerre Point Dam on the second day.

Historical Perspective

The 1991 Yuba River fall chinook salmon spawning run of 13,979 fish exceeded average Yuba River run size of 13,000 fish from 1953-1989. During this period, annual

spawning escapement ranged from 1,000 fish in 1957 to 39,000 fish in 1982. Chinook salmon spawning escapement in 1991 is noteworthy in that average run size for the lower Yuba River was achieved despite prevailing drought conditions that have contributed to lower than average chinook salmon runs in most Central Valley streams since 1989.

CITATIONS

References

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Meyer, F. Fishery biologist. California Department of Fish and Game, Rancho Cordova, CA. ~~October 1, 1991 - field survey;~~ April 7, 1992 - telephone conversation.

ACKNOWLEDGMENTS

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**Appendix. Weekly Recoveries of Tagged Carcasses and
Weekly Population Estimates of Fall-Run
Chinook Salmon in the Yuba River, 1991**

Appendix Table 5. Weekly Recoveries of ADULT Chinook Salmon Carcasses (R_j) Tagged in Successive Weeks, Total Number of Carcasses Tagged Each Week (M_i), and Total Number of Carcasses Recovered and Examined for Tags (C_j) in the Yuba River BETWEEN THE HIGHWAY 20 BRIDGE AND THE DAGUERRE POINT DAM

Week of Recovery (j)	Week of Tagging (i)									Tagged Carcasses Recovered (R_j)	Total Carcasses Recovered (C_j)
	Oct. 8-9	Oct. 16-17	Oct. 23-24	Oct. 30-31	Nov. 6-7	Nov. 13-14	Nov. 20-21	Nov. 26-27	Dec. 4-5		
Oct. 16-17		1								1	134
Oct. 23-24	0	14								14	322
Oct. 30-31	1	13	62							76	652
Nov. 6-7		6	19	56						81	588
Nov. 13-14			3	7	57					67	444
Nov. 20-21			1	2	5	23				31	344
Nov. 26-27					1	5	17			23	133
Dec. 4-5						1	1	5		7	50
Dec. 11-12							1	0	1	2	24
Tagged carcasses recovered (R_i)	2	33	85	65	63	29	19	5	1	302 ^{46%}	2,691
Total carcasses tagged (M_i)	10	88	172	151	93	78	42	16	9	659	
M_i / R_i	5.00	2.67	2.02	2.32	1.48	2.69	2.21	3.20	9.00		

Appendix Table 6. Weekly Estimates of ADULT Chinook Salmon Carcasses in the Yuba River BETWEEN THE HIGHWAY 20 BRIDGE AND THE DAGUERRE POINT DAM

Week of Recovery (j)	Week of Tagging (i)									Total	
	Oct. 8-9	Oct. 16-17	Oct. 23-24	Oct. 30-31	Nov. 6-7	Nov. 13-14	Nov. 20-21	Nov. 26-27	Dec. 4-5		
Oct. 16-17	670									670 ✓	
Oct. 23-24	0	859								859 ✓	
Oct. 30-31	43	297	1,076							1,416 ✓	
Nov. 6-7		116	279	944						1,339 ✓	
Nov. 13-14			40	108	558					706 ✓	
Nov. 20-21			22	52	82	686				842 ✓	
Nov. 26-27					9	78	217			304 ✓	
Dec. 4-5						19	16	114		149 ✓	
Dec. 11-12							27	0	108	135 ✓	
Total	713	1,272	1,417	1,104	649	783	260	114	108	6,420	
Adjusted total										-649	5,771

Appendix Table 7. Weekly Recoveries of GRILSE Chinook Salmon Carcasses (R_j) Tagged in Successive Weeks, Total Number of Carcasses Tagged Each Week (M_i), and Total Number of Carcasses Recovered and Examined for Tags (C_j) in the Yuba River BETWEEN THE HIGHWAY 20 BRIDGE AND THE DAGUERRE POINT DAM

Week of Recovery (j)	Week of Tagging (i)									Tagged Carcasses Recovered (R_j)	Total Carcasses Recovered (C_j)
	Oct. 8-9	Oct. 16-17	Oct. 23-24	Oct. 30-31	Nov. 6-7	Nov. 13-14	Nov. 20-21	Nov. 26-27	Dec. 4-5		
Oct. 16-17		0								0	7
Oct. 23-24			3							3	44
Oct. 30-31			2	4						6	151
Nov. 6-7				1	8					9	143
Nov. 13-14				1	3	9				13	131
Nov. 20-21				1	1	2	8			12	76
Nov. 26-27						1	3	1		5	26
Dec. 4-5							1	1	2	4	12
Dec. 11-12									0	0	5
Tagged carcasses recovered (R_i)	0	5	7	12	12	12	2	2	0	52	40% ^o 595
Total carcasses tagged (M_i)	0	6	26	45	23	20	7	2	0	129	
M_i / R_i	--	1.20	3.71	3.75	1.92	1.67	3.50	1.00	--		

Appendix Table 8. Weekly Estimates of GRILSE Chinook Salmon Carcasses in the Yuba River BETWEEN THE HIGHWAY 20 BRIDGE AND DAGUERRE POINT DAM

Week of Recovery (j)	Week of Tagging (i)									Total	
	Oct. 8-9	Oct. 16-17	Oct. 23-24	Oct. 30-31	Nov. 6-7	Nov. 13-14	Nov. 20-21	Nov. 26-27	Dec. 4-5		
Oct. 16-17	0									0	
Oct. 23-24		53								53	
Oct. 30-31		60	374							434	
Nov. 6-7			59	477						536	
Nov. 13-14			37	113	174					324	
Nov. 20-21			24	24	24	84				156	
Nov. 26-27					10	26	18			54	
Dec. 4-5						5	11	6		22	
Dec. 11-12								0	0	0	
Total	0	113	494	614	208	115	29	6	0	1,579	
Adjusted total										-129	1,450

Appendix Table 9. Weekly Recoveries of ADULT Chinook Salmon Carcasses (R_{ij}) Tagged in Successive Weeks, Total Number of Carcasses Tagged Each Week (M_i), and Total Number of Carcasses Recovered and Examined for Tags (C_j) in the Yuba River BETWEEN DAGUERRE POINT DAM AND THE E STREET BRIDGE

Week of Recovery (j)	Week of Tagging (i)									Tagged Carcasses Recovered (R_j)	Total Carcasses Recovered (C_j)
	Oct. 8-9	Oct. 16-17	Oct. 23-24	Oct. 30-31	Nov. 6-7	Nov. 13-14	Nov. 20-21	Nov. 26-27	Dec. 4-5		
Oct. 16-17	2									2	133
Oct. 23-24	0	23								23	323
Oct. 30-31		4	31							35	390
Nov. 6-7		4	6	35						45	334
Nov. 13-14			4	5	10					19	254
Nov. 20-21				1	3	13				17	128
Nov. 26-27						6	5			11	82
Dec. 4-5							0	4		4	56
Dec. 11-12							1	0	5	6	37
Tagged carcasses recovered (R_i)	2	31	41	41	13	19	6	4	5	162	419% 1,737
Total carcasses tagged (M_i)	5	81	129	70	26	36	19	10	15	391	
M_i/R_i	2.50	2.61	3.15	1.71	2.00	1.89	3.17	2.50	3.00		

Appendix Table 10. Weekly Estimates of ADULT Chinook Salmon Carcasses in the Yuba River BETWEEN DAGUERRE POINT DAM AND THE E STREET BRIDGE

Week of Recovery (j)	Week of Tagging (i)									Total	
	Oct. 8-9	Oct. 16-17	Oct. 23-24	Oct. 30-31	Nov. 6-7	Nov. 13-14	Nov. 20-21	Nov. 26-27	Dec. 4-5		
Oct. 16-17	333									333	✓
Oct. 23-24	0	844								844	✓
Oct. 30-31		116	1,087							1,203	✓
Nov. 6-7		78	140	444						662	✓
Nov. 13-14			168	114	267					549	✓
Nov. 20-21				13	45	185				243	✓
Nov. 26-27						85	118			203	✓
Dec. 4-5							0	140		140	✓
Dec. 11-12							20	0	93	113	✓
Total	333	1,038	1,395	571	312	270	138	140	93	4,290	
Adjusted total										<u>3,904</u>	

