THE STATUS OF LATE-FALL AND SPRING CHINOOK SALMON IN THE SACRAMENTO RIVER BASIN REGARDING THE ENDANGERED SPECIES ACT

Special Report
January 1997

Submitted to

National Marine Fisheries Service

on behalf of

Association of California Water Agencies
and
California Urban Water Agencies

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EXECUTIVE SUMMARY

This report provides an independent synthesis and analysis of data on the status of late-fall and spring chinook salmon in the Sacramento River Basin. The report focuses on the two main questions that NMFS must answer before making an ESA listing determination for late-fall and spring chinook in the Sacramento Basin:

(1) Do Sacramento late-fall and spring chinook qualify as Evolutionarily Significant Units (ESU) by themselves or in combination with other populations?

(2) Do the population trends, such as abundance, for each ESU indicate that the population will go extinct if special protections are not provided?

CHARACTERISTICS OF INDIGENOUS POPULATIONS

We found that natural production of late-fall chinook is limited to the main stem of the Sacramento River, primarily above Red Bluff (river km 248), and that natural production of native-type spring chinook continues in at least Deer Creek, Mill Creek, and the Sacramento River above Red Bluff. Natural production of spring chinook continues in other tributaries, but the repeated releases of hatchery spring chinook into Butte Creek, Big Chico Creek, Clear Creek, and the Feather River indicate it is probable that hatchery genotypes have substantially introgressed the wild-type populations that may have persisted there. Analysis of DNA genotypes is presently underway, and should make it possible to test this hypothesis. Spring and fall stocks have been mixed at Feather River Hatchery (FRH), and this has been reflected in CWT recoveries that now show time of river entry for FRH spring chinook to be intermediate to the historic timing for spring and fall chinook. So-called spring chinook that spawn in the Feather River are sustained by hatchery releases of the mixed spring-fall stock from FRH. Trucking of smolts from FRH to the San Francisco Bay-estuary for release since the 1985 brood has probably caused substantial straying of these fish throughout the Sacramento Basin.

Counts of adult "spring run" and "late-fall run" chinook passing Red Bluff Diversion Dam (RBDD) are subject to errors in run classification, such that trends in abundance may not be reliable. The majority of "spring run" and "late-fall run" counts of chinook overlap in time with counts of fall-run chinook, which are an order of magnitude more abundant. A subsample of the chinook passing the dam each day are examined for external features to determine their probable race, and the proportions estimated to be of each race are assigned to the total counts. Incorrect assignment of fall run to either spring run or the late-fall run have been demonstrated. Further, the opening of the gates at RBDD for up to 8 months of the year since 1986 have necessitated that an ever increasing portion of the spring and late fall run be predicted, rather than counted. Since 1986, there has been no actual counts at RBDD during the primary period of passage for late-fall run chinook. The run timing of spring run chinook has shifted at least one month later since 1975, which would bias the count prediction to be too low. Thus, counts of spring and late-fall chinook since 1980's have low reliability. The counts of all chinook over RBDD combined, in years before the gates at RBDD were removed, formed a single bell curve (Figure ES-1).

Genetics sampling in 1995 and 1996 indicated that spring chinook juveniles and adults, closely related to the Deer and Mill Creek genotypes, were found above RBDD. Although spawning time and perhaps migration time have shifted, native-type spring chinook still persist above RBDD. However, little genetic difference was found between the fall and late-fall runs. Given that fall and late-fall "races" within the main-stem Sacramento River presently spawn in the same area above Red Bluff Diversion Dam and overlap in spawning time, it is probable that a substantial portion of these populations interbreed.

We found that length-frequency distributions of wild juvenile spring chinook in Deer and Mill creeks and late-fall chinook from the upper Sacramento River overlap with each other and with fall chinook, such that length criteria cannot be used to distinguish the races. There is not even an obvious break, in all years, in the length frequencies of subyearling chinook passing RBDD that would allow accurate distinction of races in this area where river temperatures are relatively homogeneous through the fall and winter. Stream temperatures in the Feather River below Oroville Dam and in the Sacramento River below Keswick Dam average about 5°C warmer than in Deer and Mill creeks in the winter, resulting in much faster development of spring chinook eggs in the Sacramento and Feather rivers, than in Deer and Mill creeks. This causes an overlap in the time that spring chinook fry emerge in Deer and Mill creeks with the time fall and late-fall chinook fry emerge in the main stem. Any attempts to distinguish the race of juveniles sampled in the main stem, based on length criteria is subject to large error. On the other hand, mixed stock analysis, using genotypes from microsatellite DNA, shows promise for race discrimination of juvenile captured in the lower Sacramento River and delta.

TRENDS IN ABUNDANCE

The abundance of naturally spawning chinook (spring, fall, and late fall races combined) in the upper river has varied several fold since 1970, but there has been no consistent trend up or down. Sampling of juvenile outmigrants has demonstrated there is substantial natural production of chinook in the upper Sacramento River. Spawner escapement of spring chinook into Deer and Mill creeks, where race can be determined with certainty, was greatest in the 1970's, and peaked in 1975. Returns have remained at lesser numbers without any clear trend since 1975.

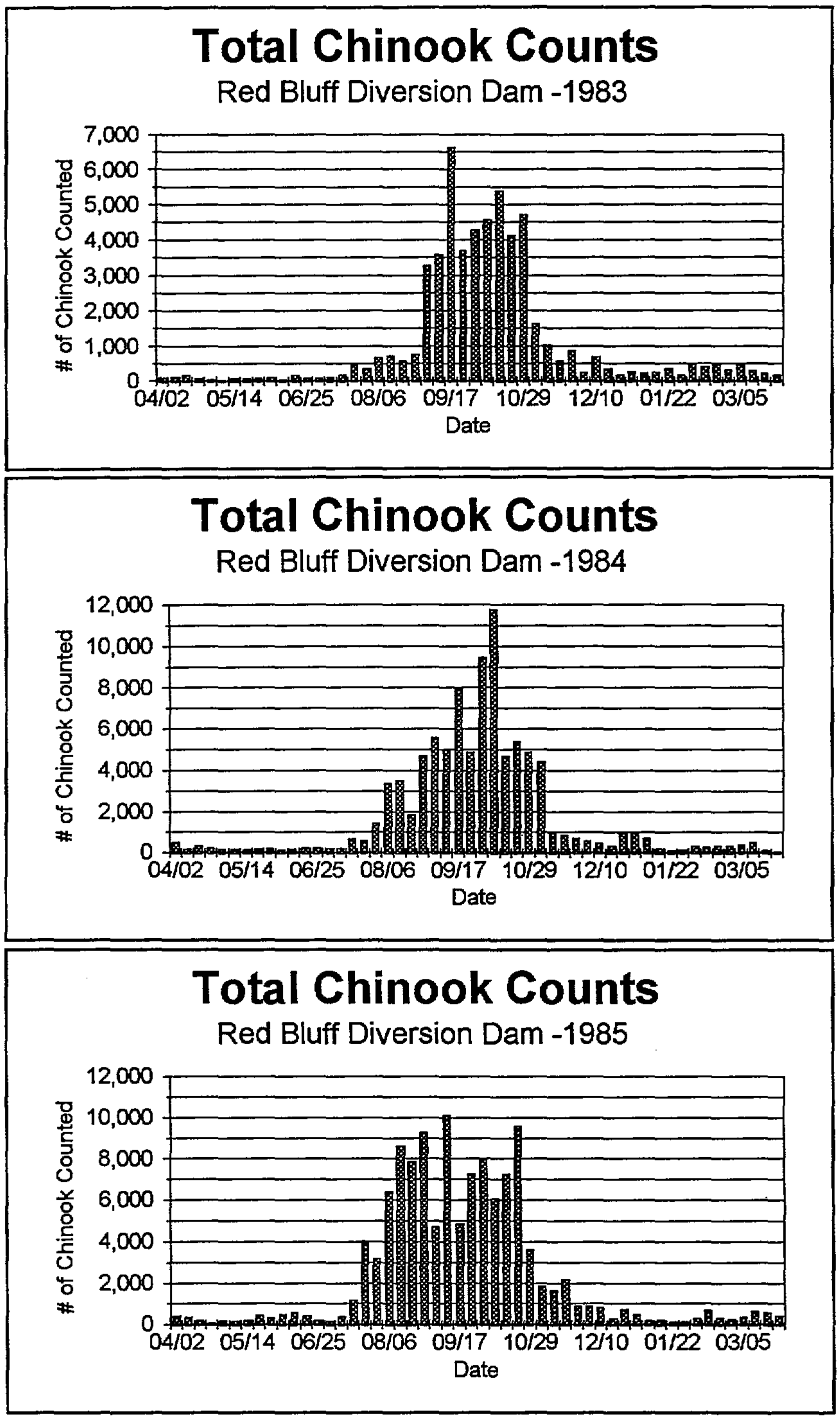


Figure ES-1. Summed weekly counts of all chinook races passing Red Bluff Diversion Dam during 1983-1985. Data from CDFG, Red Bluff.

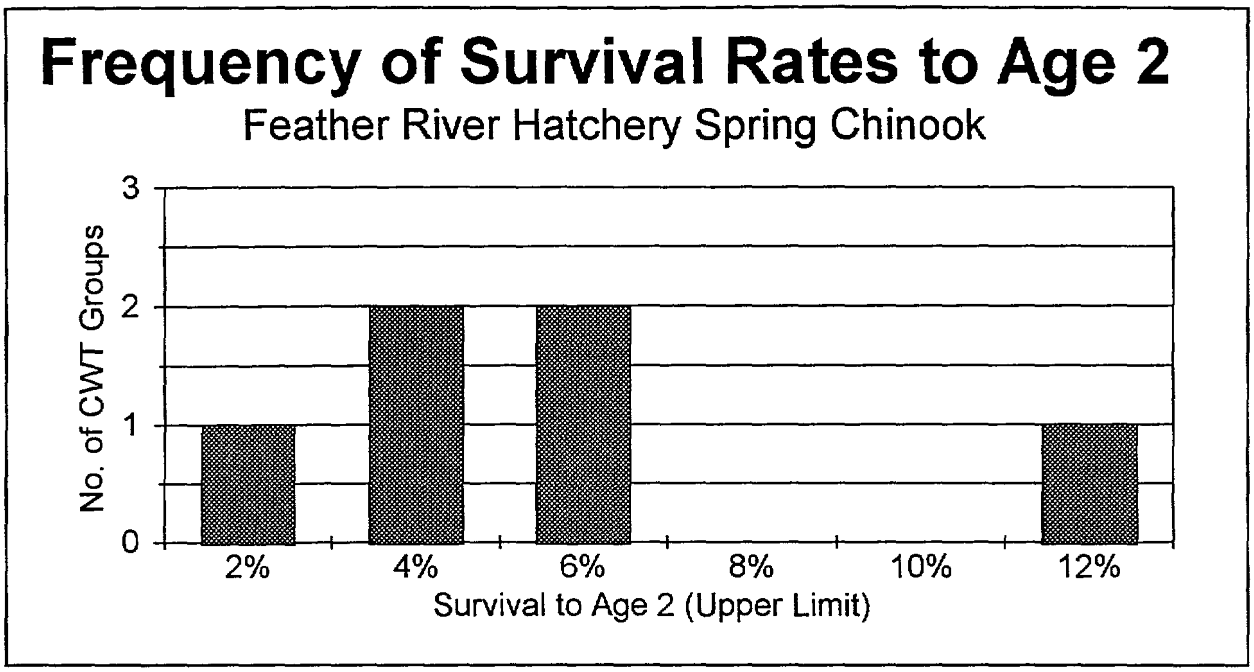
ESTIMATION OF SURVIVAL AND HARVEST RATES

We used cohort analysis of coded-wire tag (CWT) recoveries to estimate smolt-to-adult survival and harvest rates in the ocean for groups of CWT-marked spring chinook released from Feather River Hatchery and late-fall chinook released from Coleman National Fish Hatchery. These are the only marked-groups of hatchery fish that are likely to be related to indigenous populations. Most variation in survival occurs before age 2, so we examined survival to age 2 for differences between years. Smolt-to-age 2 survival ranged over 6-fold from 1.8% to 11.0% between broods of spring chinook, and over 20-fold from 0.2% to 4.6% between broods of late-fall chinook. This measure of early ocean survival indicates that ocean survival is definitely not constant, and is a primary factor influencing differences in run size between years. The frequency distribution of estimated survivals for both races are skewed, with low survivals occurring more frequently than high survivals (Figure ES-2). Lack of awareness among fishery managers of the skewed nature and wide range of these distributions, has probably led them to allow over harvest of naturally produced stocks in most years. Although survival rates have varied widely between broods, harvest rates have remained consistently high, with the exception of 1984 and 1985.

We found that 80% to 90% of spring chinook released as yearling smolts matured at age 4, and the cumulative harvest in the ocean through the spring of age 4 was 57% to 85% of the fish from each brood (Table ES-1). The cumulative harvest rate by time any fish matured at age 5 was 97% to 100%, which indicates that spring chinook have virtually no chance of surviving ocean harvest if they are destined to mature at age 5.

We found among late-fall chinook that 80% to 90% of females matured at age 4, and the cumulative harvest in the ocean through age 4 was generally 80% to 95% (Table ES-2). Males tended to mature at a younger age than females, so they were exposed less to harvest. Exposure to successive years of harvest in the ocean resulted in a mean of only 12.3% of females surviving from age 2 to river entry as adults, compared to 21.2% of males. Thus, survival of females is substantially more limiting to natural production than survival of males. Such high harvest rates (low survival rates) cannot be sustained by naturally reproducing stocks, except during occasional years of high ocean survival.

The increase in minimum size at which chinook may be kept in the ocean off of California, starting in 1996, should substantially reduce harvest rates on age 3 fish for both spring and late-fall chinook. The minimum size has been increased to 27 inches, and most spring and late-fall chinook do not reach that size until after the age 3 harvest season.



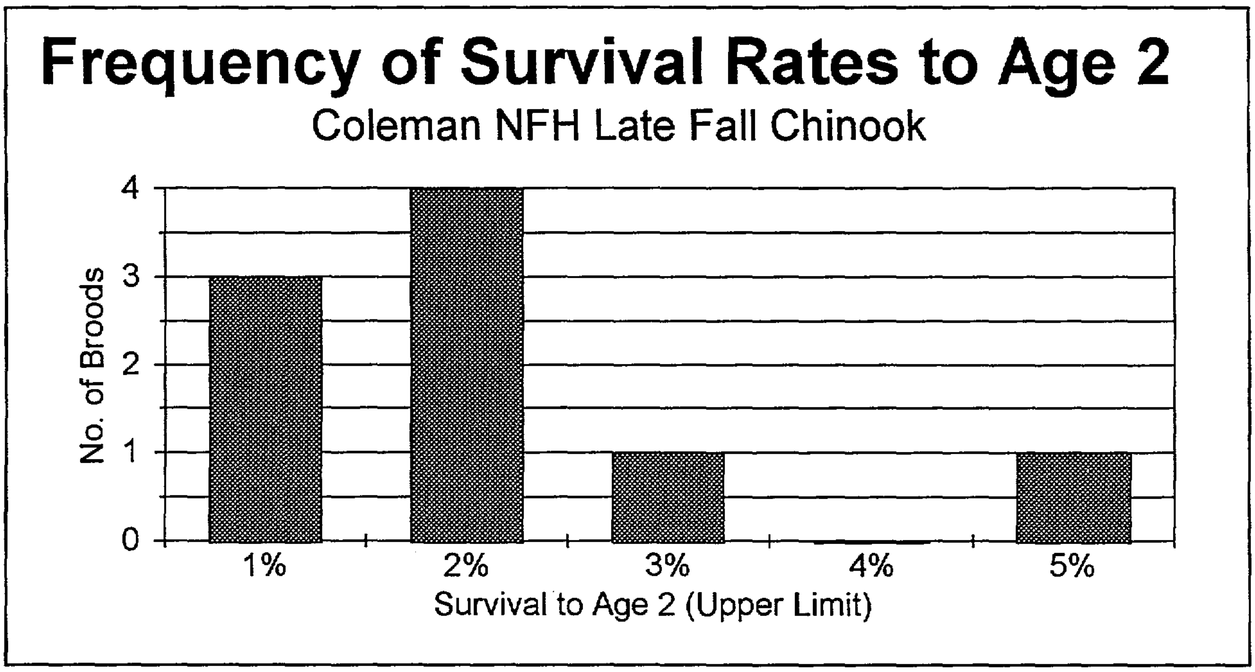


Figure ES-2. Frequency distribution of smolt-to-age 2 survival rates estimated for CWT groups of spring chinook released at or near Feather River Hatchery (top graph), and late-fall chinook from Coleman National Fish Hatchery (bottom graph).

Table ES-1. Cumulative percentage of spring chinook from each CWT group reared at Feather River Hatchery (FRH) that were harvested in the ocean by the time of maturity at either age 3, 4, or 5.

TagCode	Brood Year	Release Type	Weight (g)	Date	Location	% Harvested Before Maturity Age 3	Age 4	Age 5
060107	75	Yearling	75.6	12/76	FRH	**27%**	**57%**	**97%**
065809	76	Yearling	81	12/77	FRH	**57%**	**85%**	**100%**
065812	77	Yearling	75.6	01/25/79	Gridley	**18%**	**65%**	
B61001	84	Subyear	3.44	04/01/85	FRH	**22%**	**62%**	**100%**
B61004	85	Subyear	2.4	03/17/86	Gridley	**29%**	**74%**	**97%**
B61006	86	Subyear	3.81	03/03/87	FRH	**42%**	**66%**	

Table ES-2. Percentage of late-fall chinook from each CWT group that were harvested in the ocean at age 2 (OHARV2), age 3 (OHARV3), and age 4 (OHARV4) and the cumulative harvest rate through age 4.

TagCode	Brood Year	Release Type	Weight (g)	Release Date	OHARV2	OHARV3	OHARV4	Cumulative Oharv to Age 4
060301	75	Presmolt	7.09	9/75	0.00	0.12	1.00	1.00
060307	76	Presmolt	10.8	10/76	-----	-----	-----	-----
066012	77	Smolt	22.68	1/78	0.01	0.56	0.82	0.92
066013	78	Presmolt	9.07	10/10/78	0.00	0.40	0.71	0.82
066014	78	Smolt	19.72	01/08/79	0.00	0.60	0.82	0.93
066015	78	Smolt	19.72	01/03/79	0.00	0.60	0.75	0.90
066022	79	Smolt	18.98	02/11/80	0.00	0.31	0.83	0.88
066023	79	Smolt	18.36	02/06/80	0.00	0.29	0.72	0.80
066018	80	Smolt	18.07	02/03/81	0.00	0.39	0.93	0.96
066019	80	Smolt	18.98	02/05/81	0.00	0.46	0.84	0.91
066024	81	Smolt	12.92	01/27/82	0.00	0.21	0.54	0.64
066025	81	Smolt	13.46	01/27/82	0.00	0.20	0.48	0.58
052053	89	Smolt	19.72	01/26/90	-----	-----	-----	-----
052054	89	Smolt	15.85	12/13/89	-----	-----	-----	-----
0501010308	91	Smolt	34.5	01/06/92	0.00	0.23	0.75	0.81
0501010309	91	Smolt	35.89	01/06/92	0.00	0.34	0.75	0.83

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INTRODUCTION

The purpose of this report it to provide an independent synthesis and analysis of data on the status of late-fall and spring chinook salmon in the Sacramento River Basin that will be useful to NMFS in their determination of whether to list these chinook under the Endangered Species Act (ESA). It was not our intent to reiterate the substantial work completed on this subject by resource agencies, but rather to build on that foundation by summarizing and analyzing new or obscure data that may shed light on key issues. Some commonly available information has been repeated here to provide the appropriate context for the analyses we completed.

This report presents information to help resolve the two main questions that NMFS must answer before making an ESA listing determination for late-fall and spring chinook in the Sacramento Basin:

(1) Do Sacramento late-fall and spring chinook qualify as Evolutionarily Significant Units (ESU) by themselves or in combination with other populations?

(2) Do the population trends, such as abundance, for each ESU indicate that the population will go extinct if special protections are not provided?

We found that natural production of late-fall chinook is limited to the main stem of the Sacramento River, primarily above Red Bluff Diversion Dam (RBDD; river km 248), and that natural production of native-type spring chinook continues at least in Deer Creek, Mill Creek, and the Sacramento River above the RBDD. Natural production of spring chinook continues in other tributaries but appears to be the product of naturally spawning hatchery fish. According to NMFS policy, population trends must be based on natural production, and not hatchery production. Therefore, this report focuses on characterizing the remaining natural populations and the influences that hatcheries and harvest have had on them.

CHARACTERISTICS OF INDIGENOUS POPULATIONS

SPRING CHINOOK

Distribution of Spawning

Naturally producing runs of spring chinook are believed to be limited to east-side tributaries above the mouth of the American River, including Butte, Big Chico, Deer, Mill, Antelope, and Battle creeks, Feather River, and the Sacramento River above Red Bluff (Figure 1). In general, adult spring-run enter freshwater in the spring from March through June. Most spring-run enter the spawning tributaries before the hot summer months and hold over in cool-water habitats until spawning commences in late summer and early fall. Although spring chinook spawned extensively in the main-stem of the Sacramento River following closure of Shasta and Keswick dams, and in the Feather River following closure of Oroville Dam, those dams forced the spawning of spring chinook to overlap with fall chinook, such that, "populations of spring and fall-run chinook have interbred in the main stem Sacramento and Feather river (Mills and Fisher 1994)." So-called spring chinook that spawn in the Feather River today are sustained by hatchery releases of the mixed spring-fall stock from Feather River Hatchery (more on this later in the report). Similarly, CDFG had concluded by 1966 that spring-run chinook in the Yuba and American rivers were "extinct" as a result of hybridization with fall chinook where migration was blocked by dams (CDFG Bull 137).

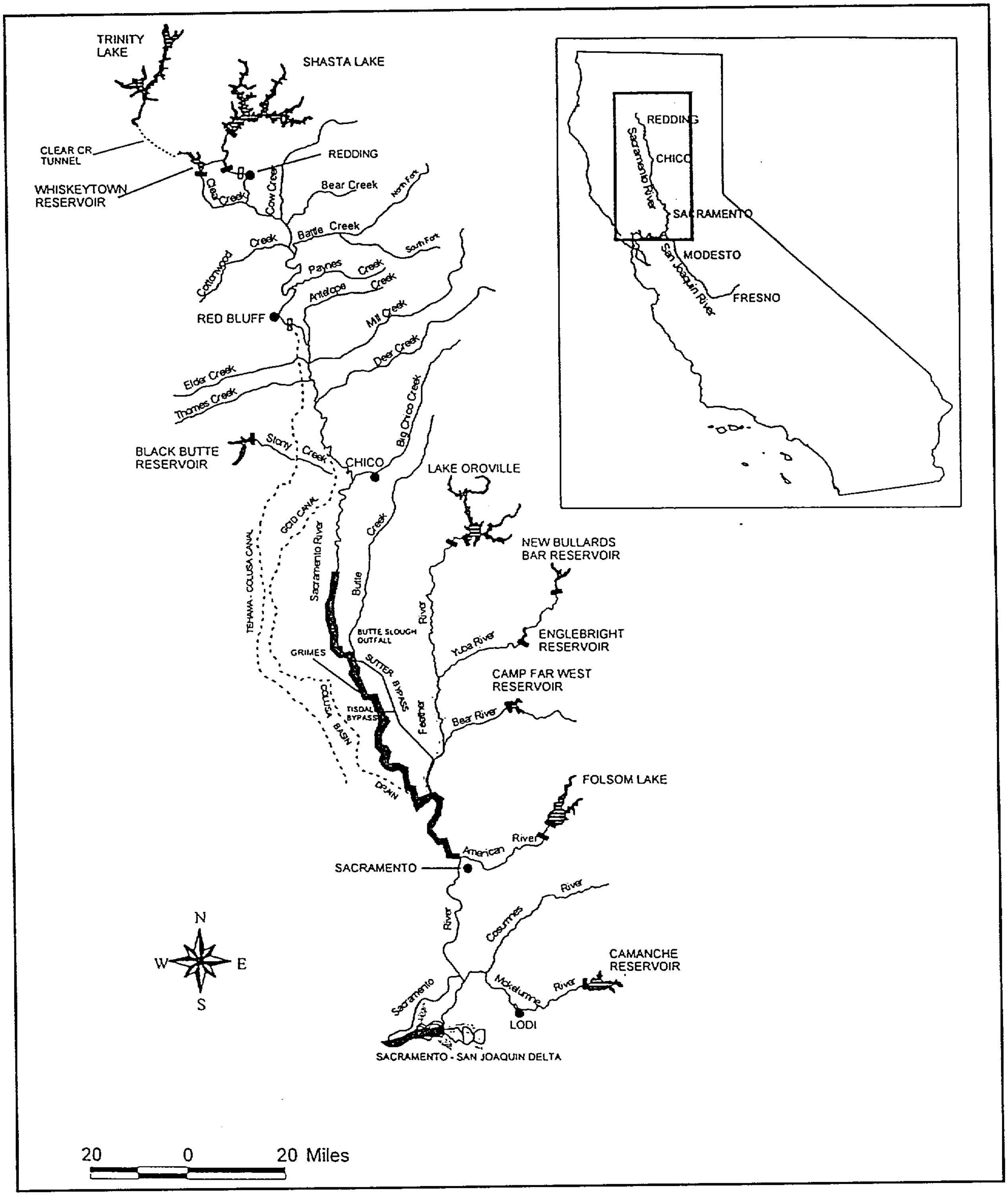


Figure 1. Map of the Sacramento River Basin.

Wild spring chinook runs have been produced most consistently without hatchery augmentation for the past several decades in Deer and Mill creeks (Mills and Fisher 1994). Stream surveys in Deer Creek during 1986 and 1987 identified the area from Ponderosa Way to the lower Highway 32 bridge crossing as the prime summer holding areas for spring-run salmon (personal communication, P. Moyle, UC Davis). This is a remote area within Lassen National Forest with little public use. Spawning in Deer Creek extends from the upper Falls, which are a migration barrier, downstream 30 miles to the vicinity of Ponderosa Way (Harvey 1994). The creek elevation at the upper extent of spawning is about 3,600 ft and about 1,640 ft at the downstream extent.

Surveys in Mill Creek (personal communication, P. Moyle, UC Davis) showed that spring-run salmon also preferred the upper canyon area where there was cold water and limited public access. The area extends through Lassen National Forest from Rancheria Creek to the Hole-in-the-Ground campground. Known spawning ranges over 50 miles from the hot springs near Lassen National Park boundary at 5,000 ft elevation to the confluence of Little Mill Creek (Harvey 1994) at 800 ft elevation.

Spring-run chinook spawning in Butte Creek is confined to much lower elevations than in Deer and Mill Creek. The majority of fish spawn upstream from the Parrott-Phelan diversion located a few miles west of Chico. Peak spawning density occurs from the upper limit of migration at Centerville Head Dam (elevation 1,130 ft) downstream to the Covered Bridge (elevation 400 ft), a distance of about 10 miles. In Butte Creek, there is spacio-temporal overlap of spawning in some years of fall and spring-run salmon (personal communication, K. Hill, CDFG, Rancho Cordova).

Butte Creek has unique physical feature in that a large portion of the water flowing down the creek during summer is transferred into the basin at two locations from the Feather River. Water is drawn out of the West Fork Feather River at the De Sabla Power

Plant and enters Butte Creek near Centerville, the upper limit of spring chinook spawning. Water is also diverted from Feather River via Western Canal and enters Butte Creek near Chico. Once the heavy irrigation withdrawals of water from Butte Creek begin in the late spring, nearly all of the water flowing in Butte Creek below the Western Canal is believed to be Feather River water.

Because Big Chico Creek is not a significant producer of spring-run chinook, it has not been intensively surveyed for adults in past years. The majority of spawning is thought to occur upstream from Iron Canyon. Iron Canyon is located within Bidwell Park, just west of the city of Chico.

Natural spawning of spring chinook in the Feather River is entirely overlapped with fall chinook, because the most intensive spawning of fall chinook (which are numerically dominant) extends from the upper limit of migration at the fish barrier dam down to Thermalito River Outlet. The historical distribution of spring chinook spawning was entirely upstream of the fish barrier dam, which is only at an elevation of 150 ft msl. Large numbers of spring chinook produced in Feather River Hatchery are forced to spawn naturally in this reach each year, because the ladder into the hatchery is closed as soon as the brood-taking goal is exceeded. CDFG has acknowledged in their annual memo reports on spawning surveys since the early 1980's that spring and fall chinook cannot be distinguished in those surveys.

Influence of Hatcheries

Historical Perspective of Hatchery Activities

We reviewed the Coleman National Fish Hatchery (CNFH) and Feather River Hatchery annual reports, the Bi-Annual Reports to California Legislature 1887 - 1950's and other documents concerning historic and current Sacramento basin hatchery practices (Shelby 1922, Leitritz 1970, McEwan and Nelson 1991). No one knows for sure when chinook salmon were first propagated in California, but there is evidence that private breeders were well established in California before public fish hatcheries came into being (Leitritz 1970). These early hatcheries usually released fry at a very young age or provided eggs for distribution elsewhere. Broodstock were usually collected by placing temporary weirs across the stream. Because most of the specific activities of these early hatcheries went undocumented, little can be said about their effects on the remaining spring-run in the upper Sacramento River Basin.

Early hatchery propagation efforts in California were both numerous and ambitious. Since the establishment of the Fish and Game Commission in 1870, 169 public fish hatcheries and egg collecting stations have been operated in California through the year 1960 (Leitritz 1970). It is not known how many private hatcheries operated during the same years. Despite the proliferation of these early hatcheries, there are no historical records indicating that any stocks were transferred in from outside the Sacramento Basin. On the other hand, chinook eggs and fry from the Sacramento Basin were widely distributed throughout California in the early days of hatchery operations.

Considerable hatchery activity occurred in or near the Sacramento basin tributaries where natural spring-run exist today. However, only two operate presently, Coleman and Feather River hatcheries, and only Feather River hatchery propagates spring chinook. The following is a brief history of the significant salmon hatcheries that may have contributed to the current Sacramento basin spring-run picture. Interestingly, the historical record offers varying dates for the operation of many of these early facilities:

Baird Hatchery: 1872-1883, 1888-1935

The Baird Hatchery, located on the McCloud River, was the first public salmon hatchery in California and was considered at the time the largest in the world. Over 25 million eggs were taken during the seasons of 1903 and 1905, but during the latter years of existence Baird served principally as an egg handling station for other hatcheries. Baird hatchery was inundated by Lake Shasta in 1943 (Leitritz 1970).

Mill Creek Hatchery: 1902 - 1945

The Bureau of Fisheries operated the Mill Creek Hatchery near Los Molinos from 1902 to 1945 in conjunction with the Sisson, Baird and Battle Creek hatcheries. In 1945 the work here was incorporated into operations of the newly built Coleman National Fish Hatchery (Leitritz 1970). It is noteworthy that Mill Creek is one of the tributaries that produces natural spring-run today.

Battle Creek Hatchery: 1895 - 1945

The Battle Creek Hatchery was located near Balls Ferry from 1895 to 1945. Records do not exist detailing the time of year fish were spawned and the size and locations fish were released; however, up to 60 million salmon eggs were taken in one year (Leitritz 1970). The eggs collected at Battle Creek were distributed throughout the state (and in some instances the world) by the California Fish Commission. Coleman National Fish Hatchery replaced Battle Creek Hatchery in 1945.

Coleman National Fish Hatchery: 1942 - present

Coleman National Fish Hatchery was constructed on Battle Creek in 1942 as part of the Central Valley Project to compensate for the loss of salmon spawning grounds above Shasta Dam. Coleman Hatchery replaced three others: Baird Hatchery, Battle Creek Hatchery (downstream from Coleman), and Mill Creek Hatchery.

During the 1940's both spring and fall chinook salmon were propagated at Coleman. Juvenile salmon production ranged from 3.5 to 23.4 million fall chinook annually, but usually less than 3 million spring chinook salmon (USFWS 1982; Table 1). All juvenile spring-run were released at the hatchery, and all spring-run propagation was suspended in 1951 (USFWS 1982). Warm water temperatures caused high mortalities among the spring-run broodstock held for ripening (FWS, Coleman annual reports 1943- 1952). Some adult spring-run were transferred to Deer and Battle Creeks, presumably to allow them to spawn naturally, but mortality was high due to warm water temperatures. It was concluded after the 1951 brood that the spring-run was more likely to be perpetuated if left to spawn undisturbed in the Sacramento River below Shasta Dam (USFWS 1982).

Table 1. Number of juvenile spring chinook, by brood year, released into the Sacramento Basin from Coleman National Fish Hatchery.

		Brood Year							
Basin	Stream	1942	1943	1944	1945	1947	1949	1950	1951
Sacramento R	Sacramento R	23,600	761,563	3,368,847	984,692	117,900	183,378	758,729	789,949

Feather River Hatchery (CDFG): 1967 - present

Feather River Hatchery is located on the Feather River near the base of Oroville Dam, and propagates both fall and spring run chinook salmon. The founding broodstock was spring and fall-run from the Feather River. Both spring and fall run chinook spawn naturally in the river adjacent to the hatchery. Until the early 1980's, most spring-run from the hatchery were released directly into the Feather River, but some smolts have been transported to the estuary for release since then.

The Feather River Hatchery released from 25,000 to over 1 million spring-run salmon each year between 1968 and 1994 (Table 2). Although the overwhelming majority of the fish were released in the Feather River, in recent years fish were also released into the Sacramento, Mokelumne and Yuba rivers, Big Chico, Butte, Coon, Clear and Antelope creeks. Spring-run were also released into Monterey Bay, Benicia, Mare Island and Vallejo. These outplantings began in the early 1980's and have continued to the present. Many of these distant outplants produced few, in any, returns. Of special significance are the releases into Butte, Antelope and Big Chico Creeks because these are tributaries with naturally spawning populations of spring-run. Returns of adult spring chinook to Butte Creek jumped from 43, 11, and 170 adults in 1983-85 to 1,254 in 1986, which indicates that plants of fry from Feather River Hatchery were probably the primary source of the large run in 1986. The repeated releases of juvenile spring chinook into Butte Creek, Big Chico Creek, and Clear Creek in combination with the small run sized found there, indicate it is probable that hatchery genotypes have substantially introgressed or replaced the wild-type populations that persisted there. Recent analysis of microsatellite DNA has established spring chinook from Butte Creek are distinctly different from those in Deer and Mill creeks (personal communication, M. Banks, Bodega Marine Laboratory, California), and we expect that forthcoming DNA analysis of spring chinook from Feather River Hatchery will confirm a close relationship of spring chinook in Butte Creek to those from Feather River Hatchery. On the other hand, Deer and Mill Creeks have not received any plants of hatchery fish and are likely to have remained genetically pure.

Table 2. Number of juvenile spring chinook, by brood year, released into the Sacramento Basin from Feather River Hatchery.

Brood Year	Date Broodstock Received	# Females Spawned	Number Released	Release Location	Release Date	Size at Release	Lifestage at Release
1993	-	1348	192,000	Feather	Jan 94	0.3 g	-
			1,701,800	Benicia	May 94	10.2 g	-
			1,029,900	Benicia	Jun 94	10.5 g	-
			1,034,800	Benicia	Jul 94	10.6 g	-
1992	-	577	212,142	Clear Creek	Mar 93	2.5 g	-
			50,150	Chico Creek	Mar 93	2.5 g	-
			701,900	Benicia	May 93	6.7 g	-
			385,600	Benicia	Jun 93	11.2 g	-
			200,500	Benicia	Jul 93	12.4 g	-
1991	Sept 7-Oct 1	1,264	306,253	Chico Creek	Feb-Mar 92	2.1-3.0 g	Fry
			99,975	Clear Creek	Mar 92	3.5 g	Fry
			2,198,075	Benicia	May-Jun 92	7.7-7.9 g	Fry
			252,000	Benicia	Jul 92	26.3 g	-
			566,450	Benicia	Aug 92	29.8 g	-
			614,300	Benicia	Sep 92	31.9 g	-
1990	Sept 7-Oct 1	580	260,032	Clear Creek	Feb-Mar 91	0.4-2.4 g	Fry
			222,400	Benicia	June 91	14.0 g	Fry
			1,462,450	Benicia	Jul-Aug 91	20.3-26.3 g	Fry
1989	Sept 7-Oct 1	1,520	178,500	Feather River	Jan 90	0.3 g	Fry
			150,384	Chico Creek	Jan 90	0.7 g	Fry
			966,500	Mokelumne River	Jan 90	1.1 g	Fry
			719,000	Feather River	Apr 90	3.4 g	Fry
			11,380	Sac. River	Jun 90	3.4 g	Fry
			185,000	Maritime Academy	Jun 90	10.6 g	Finger
			111,800	Mare Island	Jun 90	10	Finger
			2,306,500	Mare Is/Maritime Ac.	Jul-Aug 90	13.5-22.4 g	Finger
1988	Sept 7-Oct 1	1,652	502,000	Chico Creek	Dec 88	0.4 g	Fry
			1,202,780	Feather River	Dec 88-Apr 89	0.4-4.0 g	Fry
			1,515,500	Mokelumne River	Feb 89	2.5 g	Fry
			2,486,850	Benicia	Apr-Jun 89	5.8-14.9 g	Fry
			1,423,600	Benicia	July-Aug 89	17.0-20.3	Finger
1987	Sept 2-Oct 1	208	60,400	Chico Creek	Feb 87	1.7 g	Fry
			803,575	Benicia/Berkeley	Mar-May 87	8.4-14.0 g	Finger
1986	ND	ND	526,090	Benicia/Mare Island	Jul-Aug 87	16.5-20.0 g	Finger
1985	Sept 1-Oct 1	589	105,868	Big Chico Creek	March 86	2.2 g	Fry
			104,895	Feather River	March 86	2.3 g	Fry
			1,372,600	Benicia	Mar-May 86	6.3-7.4 g	Fry
1984	Sept 1-Oct 1	459	76,800	Dry Creek	Feb 85	1.2 g	Fry
			77,400	Auburn Ravine	Feb 85	1.3 g	Fry
			77,400	Daty Ravine	Feb 85	1.3 g	Fry
			96,800	Yuba City	Feb 85	1.2 g	Fry
			104,720	Coon Creek	Feb 85	0.7 g	Fry
			100,280	Secret Ravine	Feb 85	1.0 g	Fry
			53,156	Big Chico Creek	Apr 85	3.3 g	Fry

Brood Year	Date Broodstock Received	# Females Spawned	Number Released	Release Location	Release Date	Size at Release	Lifestage at Release
			53,372	Feather River	Apr-May 85	3.4 g	Fry
			32,400	Butte Creek	Apr 85	6.2 g	Fry
			50,310	Monterey Bay	Apr 85	8.4-8.9 g	Fry
			433,736	Vallejo	Apr-Jun 85	8.6-14.9 g	Fry
			257,350	Vallejo	Sept 85	28 g	Fingerling
1983	ND	ND	72,750	Vallejo	Sept 84	28 g	Finger
1982	Sept 1-Sept 30	426	106,600	Yuba River	Jan 83	0.33 g	Fry
			106,600	Butte Creek	Jan 83	0.33 g	Fry
			205,000	Antelope Creek	Jan 83	033 g	Fry
			110,200	Chico Creek	Feb 83	1.9 g	Fry
			298,050	Vallejo	May-Jun 83	9-11.4 g	Fry
1981	Sept 1-Oct 1	132	47,250	Maritime Academy	May 82	11 g	Finger
			260,988	Feather River	Nov 82	76	Year
1980	Sept 1-Sept 22	41	129,000	Feather River	Oct-Nov 81	45 g	Year
1979	Sept 4-Sept 28	167	465,325	Sac @ Rio Vista	May 80	7 g	Fry
			15,925	Yuba @ Nelson Bar	July 80	34.4 g	Finger
			139,009	Feather River	Oct 80	60 g	Year
1978	Sept 6-Oct 10	32	86,320	Feather River	Oct 79	56 g	Year
1977	Aug 24-Sept 16	95	126,625	Feather River	Oct 78-Jan 79	37-75 g	Year
1976	Sept 2-Sept 15	354	355,950	Sac @ Rio Vista	May77	6-8	Fry
			160,300	Feather River	Oct 77-Jan 78	50-90 g	Year
1975	Sept 2-Sept 11	309	487,550	Sac @ Rio Vista	May-June 76	5-7 g	Fry
			129,550	Feather River	Dec 76	63	
			93,500	Feather River	Jan 77	44 g	Year
1974	Sept 3-Sept 5	29	118,800	Feather River	Jan 76	63 g	Year
1973	Sept 1-Sept 5	98	61,600	Sac @ Rio Vista	May 74	6 g	Fry
			175,000	Feather River	Oct-Dec 74	29-45	Year
1972	Sept 6-Oct 1	90	50,000	Feather River	June-73	11	Finger
			211,459	Feather River	Sept-Dec 73	25-56 g	Year
1971	missing		167,705	Feather River	Nov 72-Feb 73	88 g	Year
1970	Aug 13-25	65	ND	Feather River	Jan-71	1 g	Fry
1969	Apr 1-Aug 25	121	106,000	Feather River	May 11-12-70	7.2 g	Finger
			71,900	Feather River	Oct 11-Nov 17-70	50 g	Year
1968	ND	ND	25,000	ND	Nov 28-29-69	ND	ND

Brood-taking practices at Feather River Hatchery have fostered interbreeding of spring and fall chinook, both in the hatchery and in the river. Spring chinook at Feather River Hatchery are arbitrarily determined to be all fish entering the hatchery between September 1 and September 30. In the first few years of hatchery operation, prespawning mortality was high on any adults allowed to enter the hatchery prior to September. Therefore, beginning in 1972, the ladder into the hatchery was not opened until September

1 (Table 3). Some fall chinook would already have been in the river by this time. The ladder was opened only long enough to allow entry of enough brood fish to meet the egg-take capacity, which was usually achieved during September. Any natural spawning of spring chinook out in the river would be entirely overlapped with fall chinook, because the most intensive spawning of fall chinook (which are numerically dominant) extends from the upper limit of migration at the fish barrier dam down to Thermalito River outlet.

Table 3 Dates that the ladder into Feather River Hatchery was operated for spring chinook salmon, 1969-1991.

Year	Ladder Opened	Ladder Closed
91-92	07-Sep	01-Oct
90-91	07-Sep	01-Oct
89-90	07-Sep	01-Oct
88-89	07-Sep	01-Oct
87-88	02-Sep	01-Oct
86-87	ND	ND
85-86	01-Sep	01-Oct
84-85	01-Sep	01-Oct
83-84	ND	ND
82-83	01-Sep	30-Sep
81-82	01-Sep	01-Oct
80-81	01-Sep	22-Sep
79-80	04-Sep	28-Sep
78-79	06-Sep	10-Oct
77-78	24-Aug	30-Aug
77-78	16-Sep	16-Sep
76-77	01-Sep	15-Sep
75-76	02-Sep	11-Sep
74-75	03-Sep	05-Sep
73-74	01-Sep	25-Sep
72-73	06-Sep	01-Oct
71-72	ND	ND
70-71	13-Aug	25-Aug
69-70	01-Apr	20-May
69-70	25-Aug	25-Aug

We found evidence that time of river entry for spring chinook from Feather River Hatchery (FRH) was intermediate to that for spring and fall chinook. Spring chinook enter

Deer and Mill creeks primarily from mid April to mid June, but FRH spring chinook apparently enter freshwater in June and July. This time of river entry is indicated by at least three pieces of evidence. First, spring chinook from FRH, as evidenced by the presence of marked fish, dip into the lower American River (downstream of the Feather River confluence) and sustain a popular sport fishery there beginning in late June and continuing through August (personal communication, F. Meyer, CDFG, Rancho Cordova). Secondly, recoveries of coded-wire tagged (CWT) spring chinook from FRH show that virtually all fish caught in the ocean at age 5 (all remaining fish mature at that age) are caught in June and July (see Figure 34 In a later section of this report). Third, FRH spring chinook of the 1991 and 1992 broods that were stocked in Clear Creek were, upon adult return, found spawning in Clear Creek in the fall, but they had been absent there during the summer (personal communication, F. Fisher, CDFG, Red Bluff). Some of these fish were detected at Red Bluff Diversion Dam, and their passage there extended from June through August. Thus, time of river entry for FRH "spring chinook" appears to have shifted later to a time intermediate with that of fall chinook.

Straying of Feather River Hatchery spring chinook upon adult return has probably been substantial in the 1990's, because annual releases of 0.8 to 3.9 million juveniles into the San Francisco Bay estuary were initiated with the 1985 brood (see Table 2). Cramer (1991) showed that straying of fall chinook released from Sacramento Basin hatcheries increased sharply as the distance they were released off station increased. Cramer (1991) estimated that straying outside the Feather River was 69% (95% confidence interval = 55.7% to 81%) of spawners returning from Feather River Hatchery fall chinook that had been trucked to the estuary for release. Those straying estimates were based on recoveries from 14 groups of CWT-marked fall chinook over a number of broods. Further, Cramer (1991) estimated that 29% (95% C.I. = ±8%) of those strays passed Red Bluff Diversion Dam, and that an additional 40% (95% C.I. = ±8%) spawned in the middle Sacramento River, upstream from the Feather River confluence. Thus, the tendency of fish released in the estuary to stray upstream of their home stream makes it highly probable that large numbers of Feather River Hatchery spring chinook have been straying into the Sacramento River above RBDD. Direct estimates of straying for CWT spring chinook are not possible because most natural spawning of spring chinook has not been surveyed.

Life History Characteristics

Adult Migration and Spawning

Spring-run chinook salmon begin migrating into Deer and Mill creeks in March, peak in May and conclude in June (personal communication, C. Harvey, CDFG, Redding). Redd counts indicate that spring-run chinook spawning typically begins in late August, peaks in September and concludes in October in both Deer and Mill creeks (Harvey 1995).

Observations by CDFG indicate that spring chinook begin entering Butte Creek in March and continue through June. Summer snorkel surveys have shown that most of these fish hold over summer in the uppermost reach, approximately from the steel bridge upstream to the natural barrier at Centerville. CDFG biologists have surveyed spring chinook spawning in Butte Creek and estimate over the last 12 years that the time of peak spawning varied less than one month and is generally the last week in September or first two weeks in October (personal communication, K. Hill, CDFG, Rancho Cordova). We were unable to obtain more specific data than these general descriptions of timing, and it appears that spawning in Butte Creek peaks later than in Deer and Mill Creek. We would expect later spawning in Butte Creek, because of the influence of the later spawning hatchery stock. Additionally, the warmer temperatures of Butte Creek during fall and winter at the elevation where spawning occurs would favor survival of a later spawning stock, such as that from FRH, than stocks in Deer and Mill creeks.

We reviewed spawning records at Feather River Hatchery to determine the time of peak spawning and whether it had changed over the years. Since 1973, spawning has started about the first of October, peaked in the first half of October, and continued to late October (Table 4). Thus, spawning of hatchery fish peaks about 2-3 weeks later than for wild spring chinook in Deer and Mill Creek, but peaks at a time similar to that of fish spawning in Butte Creek.

Table 4. Date and number of female spring chinook spawned at Feather River Hatchery , 1973-1975 and 1985-1995 (CDFG hatchery records).

		Number of Females Spawned													
Month	Day	1973	1974	1975	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Sep	28							130							
Sep	29					26		61							
Sep	30				57			153			68	98	63		
Oct	1	5			23					56	106		62		
Oct	2					17	59			52					153
Oct	3			24				107			239				
Oct	4		3		133			204	403					70	201
Oct	5							100				36	261		29
Oct	6					34	77	284	188						
Oct	7					36					130		173	298	
Oct	8										370	99	112		
Oct	9	14			218					276					
Oct	10		10	102					290						263
Oct	11							112	237					378	120
Oct	12							424		83				116	
Oct	13							77				99			
Oct	14						64						203		
Oct	15					187					283	97	354		
Oct	16	27	14	89	122				308						324
Oct	17														
Oct	18									97				395	
Oct	19						8		94			44			
Oct	20														122
Oct	21		2		36						56	78	120		
Oct	22					92				16					
Oct	23	37		76											
Oct	24													76	49
Oct	25														
Oct	26														
Oct	27											26			
Oct	28					16					12				
Oct	29														
Oct	30			18											
Oct	31	15													
	Totals	98	29	309	589	408	208	1,652	1,520	580	1,264	577	1,348	1,333	1,261

Although CDFG maintains the classification of "spring run" for counts of adult chinook passing RBDD, spring run fish cannot always be visually distinguished from the early portion of the fall chinook run. The majority of "spring run" counts overlap in time with the counts of fall-run chinook, which are an order of magnitude more abundant (Table 5; Appendices 1 - 3). In order to estimate racial composition of chinook passing RBDD, CDFG traps a sample of roughly 50 fish daily at RBDD, and examines them individually for brightness and maturation. They use these characteristics to judge the race of the fish, and the proportions judged to be from each race in these samples are applied to the RBDD counts. Thus, both the judgement of race for an individual fish, and the estimation of racial proportions in the counts are probablistic procedures that have associated error. This error would be small if there was little overlap of the runs, but in many years the counts of spring and fall chinook passing RBDD are at or near peak levels in the same week (Table 5). The potential for error is greatest for the spring chinook count, because only a small error in the assignment of fall chinook will make a substantial difference in the spring chinook count.

The potential for error in the assignment of chinook race at RBDD has been confirmed by observations of marked fish and genetics sampling. Adipose fin-clipped chinook, that would have been classified as spring chinook, were trapped at RBDD during May-June of 1994 and 1995, and the CWT's recovered from these fish showed some to be fall chinook from Coleman National Fish Hatchery, some to be fall chinook from Feather River Hatchery, and some to be "spring" chinook from Feather River Hatchery (personal communication, F. Fisher, CDFG, Red Bluff). Thus, the natural variation in run timing of hatchery fall chinook has been sufficient to produce returns of fish that would be classified as races other than fall chinook. In other sampling, a group of chinook trapped at Keswick Dam in 1995, and believed to be winter run, were trucked to Coleman National Fish Hatchery where they were held for ripening. A number of these fish did not mature during the winter-run spawning period, but turned out to be spring chinook (personal communication, J. Smith, USFWS, Red Bluff, California). Others that spawned late in the winter-run spawning period were determined by DNA analysis to most likely be spring chinook, and artificial spawning of these fish was halted to protect the genetic integrity of the winter run (personal communication, M. Banks, Bodega Marine Laboratory, U.C. Davis, California).

Another important factor influencing the counts of spring chinook passing Red Bluff Diversion Dam has been a change, beginning in 1987, in the dates the gates of the dam were pulled out. When the gates at RBDD are out, fish can pass freely up and downstream through the dam, such that passing fish cannot be counted. Prior to 1986, the gates were left in year round except for brief periods to perform dam maintenance. Hallock et al. (1982) and Vogel et al (1988) found from radio-tagging adult winter-run chinook that 43-44% of adults that approached RBDD while the gates were in were blocked from passing. In 1986-87 the gates at the dam were raised for two extended periods between December 1 and April 1 to allow the river to flow unimpeded through the dam. The radio tagging studies by Vogel et al. (1988) showed that chinook moved upstream past the dam within a few hours of approaching it when the gates were out, but fish were delayed more than a week, on average, when the gates were in. Accordingly, the Biological Opinion issued by NMFS regarding operation of RBDD has required that the gates be out during most of the winter-run migration period in years since 1987 (Table 6). By 1994, the gates at RBDD were opened starting September 15, such that the peak of the spring chinook run may have passed the dam when no counts were possible (Table 5). The proportion of the run that passed RBDD when the gates were out was assumed to be equal to the long-term average proportion that passed during that time.

Table 5. Weekly counts of adult chinook passing Red Bluff Diversion Dam that were assigned to each race, 1983-1986. Data from CDFG, Red Bluff.

End of	1983				1984				1985				1986			
Week	Winter	Spring	Fall	Late Fall	Winter	Spring	Fall	Late Fall	Winter	Spring	Fall	Late Fall	Winter	Spring	Fall	Late Fall
07-Jan	55			642	216			204	54			756	65			409
14-Jan	14			1,426	25			222	91			675	42			123
21-Jan	25			562	0			217	0			215	17			225
28-Jan	29			638	46			334	33			65	20			90
04-Feb	32			653	73			146	49			71	27			74
11-Feb	55			638	95			449	165			218	22			120
18-Feb	68			744	20			348	280			247	7			414
25-Feb	101			562	0			399	0			329	17			312
04-Mar	141			334	243			182	251			90	129			4
11-Mar	143			213	354			354	247			28	181			118
18-Mar	84			608	370			205	626			156	22			15
25-Mar	189	0		365	69	0		35	566	0		32	108			16
01-Apr	114	0		349	60	0		59	310	0		0	57	1		110
08-Apr	104	0		26	311	155		0	400	0		53	65	55		30
15-Apr	110	0		5	113	43		0	261	40		20	468	90		47
22-Apr	159	13		1	231	77		0	150	63		0	508	83		0
29-Apr	51	23			116	108			69	23			177	206		
06-May	36	7			44	134			78	124			88	153		
13-May	16	12			67	112			23	157			66	124		
20-May	70	5			12	136			51	152			97	185		
27-May	40	34			53	107			68	389			41	288		
03-Jun	53	19			50	140			44	272			100	608	20	
10-Jun	51	46			40	80			51	431			0	351	0	
17-Jun	0	49			16	144			52	526			39	505	49	
24-Jun	6	165	0		21	221	0		16	395	16		0	254	381	
01-Jul	15	59	0		0	220	0		0	205	0		8	526	726	
08-Jul	42	36	0		14	193	0		27	111	22		20	412	1,040	
15-Jul	8	111	0		4	197	0		0	215	164		0	723	1,427	
22-Jul	20	127	20		0	304	357		0	498	664		45	727	1,597	
29-Jul	0	196	245		0	236	353		0	748	3,294		28	320	1,331	
05-Aug	0	78	287		0	612	818		0	362	2,812		0	933	3,210	
12-Aug	0	94	576		0	2,271	1,109		0	1,154	5,256		0	1,926	2,631	
19-Aug		311	405			1,078	2,421			1,500	7,120			1,278	7,050	
26-Aug		72	504			154	1,702			800	7,046			1,763	6,908	
02-Sep		286	475			753	3,926			389	8,865			441	7,545	
09-Sep		324	2,930			295	5,277			428	4,276			1,513	11,176	
16-Sep		158	3,425			154	4,825			303	9,812			906	7,496	
23-Sep		921	5,701			223	7,729			122	4,749			1,668	8,405	
30-Sep		564	3,121			0	4,872			385	6,880			652	7,273	
07-Oct		196	4,064			0	9,462			264	7,735			0	10,796	
14-Oct		25	4,535			0	11,754			691	5,370			0	7,225	
21-Oct			5,283	108			4,512	159			6,495	765			6,234	724
28-Oct			3,966	165			3,823	1,562			8,915	665			3,654	1,030
04-Nov			3,866	843			4,507	371			2,969	653			2,385	878
11-Nov			1,524	120			3,961	455			1,661	198			1,109	1,418
18-Nov			630	398			606	421			1,142	517			853	739
25-Nov			206	370			489	368			1,267	920			456	540
02-Dec			173	694			379	324			317	575			1,706	832
09-Dec	21		37	187			178	414			449	425			868	810
16-Dec			58	625	46		145	267			284	549			636	1,094
23-Dec	16		0	350	21		0	289			35	258	23		494	1,076
30-Dec			15	149	70		49	851			92	654			192	1,022

Table 6. Dates that draw down and refilling of Red Bluff Diversion Dam was initiated each year since 1986. Data from USFWS, Red Bluff.

Year	Start of Draw-down	Gates out	Start of refill	Gates in
1986-87	Dec 1, 1986	Dec 14, 1986	Jan 21, 1987	Jan 23, 1987
	Feb 4, 1987	Feb 9, 1987	Apr 1, 1987	Apr 2, 1987
	Apr 2, 1987	Apr 3, 1987	Apr 3, 1987	Apr 4, 1987
1987-88	Nov 27, 1987	Dec 10, 1987	Feb 14,1988	Feb 16, 1988
	Mar 5, 1988	Mar 8, 1988	Mar 7, 1988	Mar 9, 1988
1988-89	Dec 1, 1988	Dec 9, 1988	Feb 1, 1989	Feb 4, 1989
	Feb 13, 1989	Feb 17, 1989	Apr 7, 1989	Apr 10, 1989
1989-90	Dec 1, 1989	Dec 9, 1989	Apr 1, 1990	Apr 2, 1990
1990-91	Dec 1, 1990	Dec 9, 1990	May 2, 1991	May 4, 1991
1991-92	Dec 3, 1991	Dec 11, 1991	May 2, 1992	May 4, 1992
1992-93	Oct 30, 1992	Nov 7, 1992	May 1, 1993	May 1, 1993
1993-94	Oct 15, 1993	Oct 23, 1993	May 2, 1994	May 3, 1994
1994-95	Sep 14, 1994	Sep 23, 1994	May 15, 1995	May 16, 1995
1995-96	Sep 15, 1995	Sep 23, 1995	May 15, 1996	May 15, 1996
1996-97	Sep 15, 1996	Sep 23, 1996	---	---

However, we found evidence that the passage time at RBDD for the segment of the run classified as "spring run" shifted about one month later in the 1980's than it was in the 1970's. We found the date of 50% passage of the "spring run" at RBDD was generally near July 1 during 1970 through 1977, and then shifted over a month later to between August 1 to September 1 during 1979 to 1988 (Figure 2). This shift has brought the run more in line with the early portion of the fall chinook, and may either reflect selection that favors later spawning or reflect interbreeding of spring and fall chinook. This shift in timing would have exacerbated the error generated during 1994-96 from predicting the proportion of the run that passed after September 15. Thus, counts of spring chinook at RBDD in the 1990's may not be reliable. Accordingly, trends in abundance of spring chinook during recent years are best determined by estimated escapements into Deer and Mill creeks.

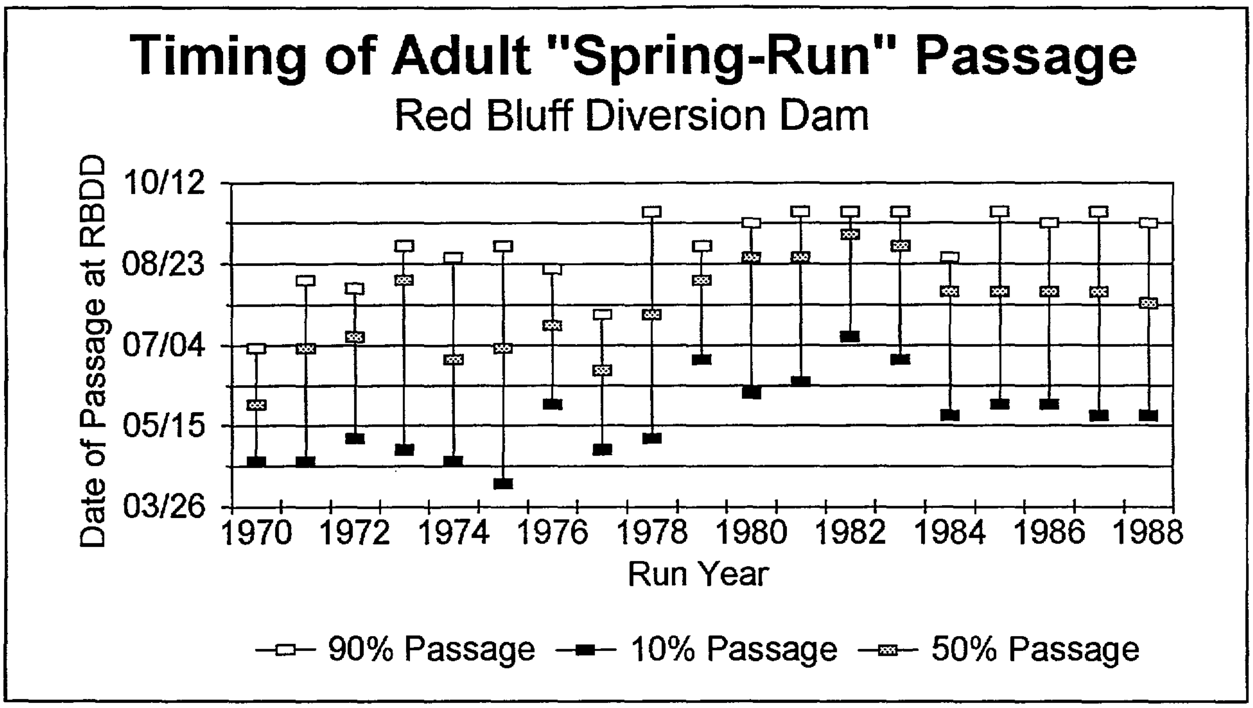


Figure 2. Timing of adult "spring run" passage at Red Bluff Diversion Dam, 1970-1988. Later years are not shown, because the gates at the dam were open during much of the spring after 1988, and counts were only partial until the gates closed. Data from CDFG, Red Bluff.

Spawning time in the main stem also has shifted later. There is little or no spawning in the main stem during late August to early October, the time that native spring chinook in Deer and Mill creeks spawn. CDFG made weekly flights to count salmon redds in the Sacramento River above RBDD from May through December for the first time in 1995, and found that redds were almost entirely absent during August and September (personal communication, F. Fisher, CDFG, Red Bluff). Only one redd was observed in August, six were observed in late September, and then redd counts climbed quickly through October to a peak of 2,556 on November 1 (Figure 3).

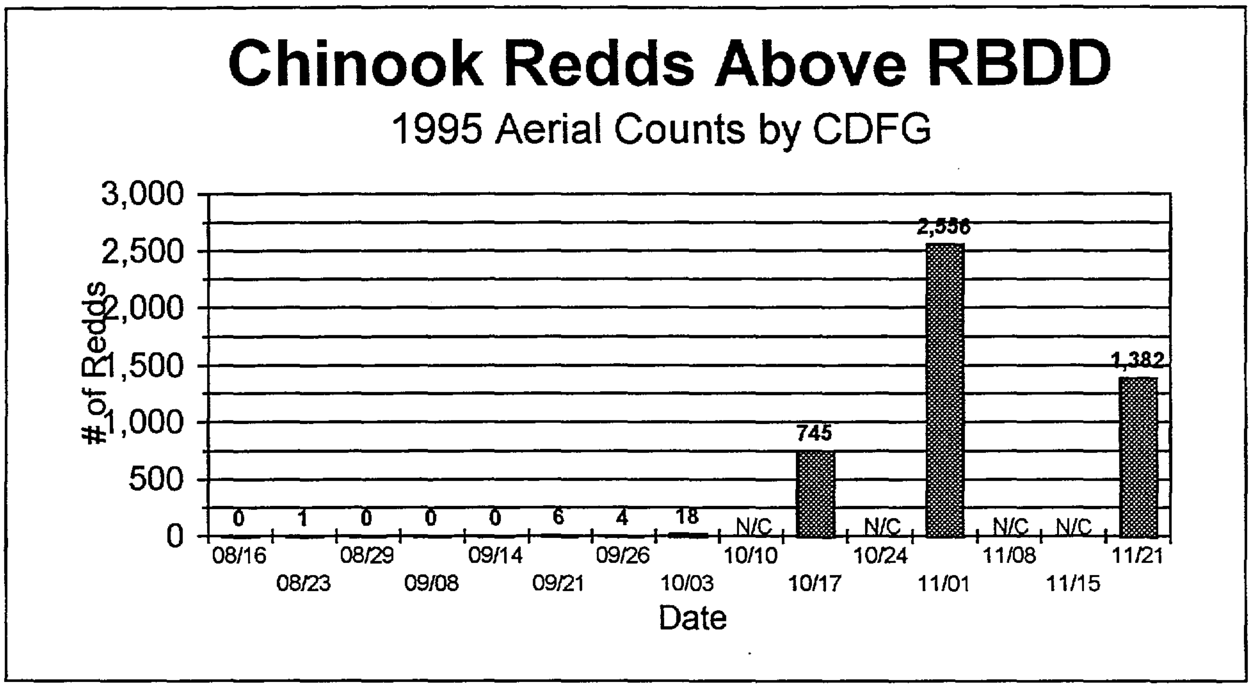
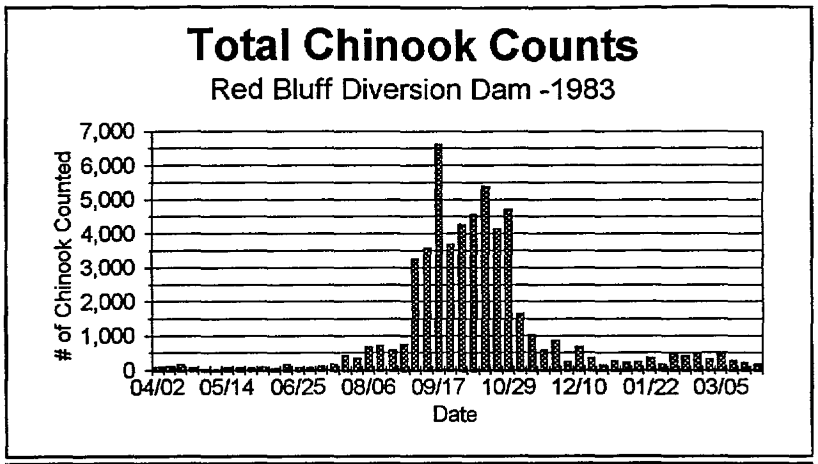
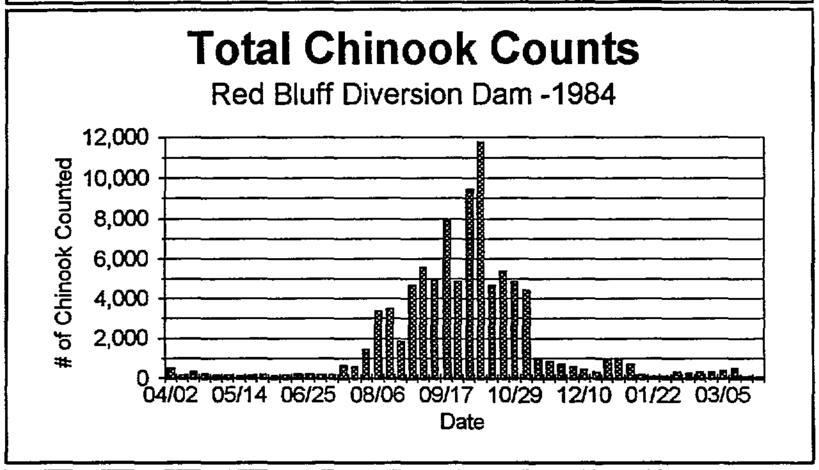


Figure 3. Aerial counts of chinook redds in the Sacramento River from Red Bluff Diversion Dam to Keswick Dam during 1995. N/C indicates no count. Data from personal communication, F. Fisher, CDFG, Red Bluff.

We aggregated the counts of chinook from all races crossing Red Bluff Diversion Dam for three consecutive years (1983-1985), and found that both spring and late-fall chinook appear to be tails of run timing for fall chinook, i.e. they appear to parts of the same run (Figure 4). We chose 1983-1985, because they were the last 3 years for which full counts were maintained at the dam year round, and because 3 years represents an essentially complete generation. We found that the temporal pattern of chinook passage for 1983-85 appeared the same for 1986-88. This pattern demonstrates that the spring, fall, and late-fall runs of chinook cannot be accurately discriminated on the basis of run timing.





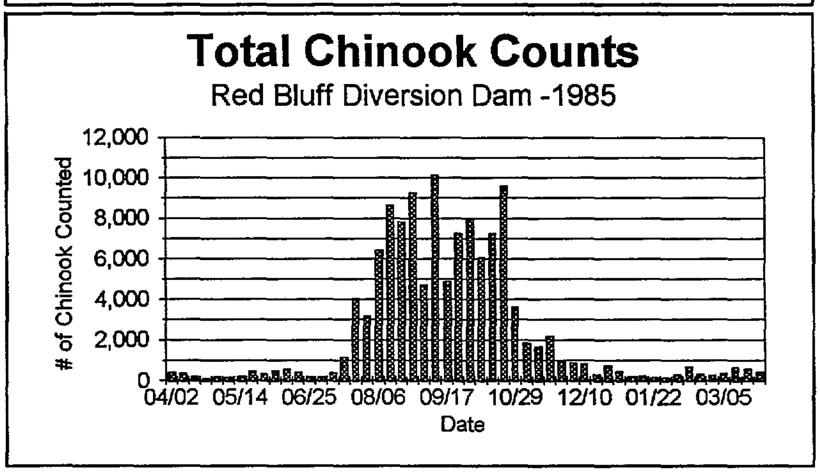


Figure 4. Summed weekly counts of all chinook races passing Red Bluff Diversion Dam during 1983-1985. Data from CDFG, Red Bluff.

Juvenile Rearing and Outmigration

We found conflicting descriptions in various reports for the life history of juvenile spring chinook in the Sacramento Basin. In an effort to resolve these differences, we reviewed data from juvenile sampling in areas as close to each spawning area as possible. We found that time of fry emergence, juvenile lengths on a given date, and time of emigration differed between populations and overlapped greatly with fall chinook in the main stem Sacramento River. In general, fry emerged earlier, juveniles were larger on a given date, and smolts emigrated earlier from the main-stem Sacramento River above Red Bluff than from the tributaries. There were additional differences between tributary populations, and fry emerged latest, juveniles were smallest on a given date, and smolts migrated latest from Deer and Mill creeks.

Deer and Mill Creeks

Sampling of juvenile chinook in Deer and Mill creeks began in February of 1994, and indicates that juveniles emigrate from the streams principally at two different life stages: a large portion of juvenile spring chinook move downstream from the spawning areas as fry, and a smaller fraction emigrate in the fall as yearlings. Harvey (1994 and 1995) sampled juveniles in both Deer and Mill creeks in 1994 and 1995 by electrofishing, seining, and screw-trapping to estimate the length frequency of smolts emigrating from the creeks, and determine the time of outmigration. No attempt was made to estimate juvenile abundance. Harvey (1994) began biweekly electrofishing surveys in early February, 1994, and continued to capture recently emerged fry (33-40 mm fork length) through the second week of June. Screw traps for sampling outmigrants were installed in September of 1994 in each stream at irrigation diversions, and sharp increases in catch of yearling chinook followed the first freshet of the season in November (Figure 5). Yearlings continued to be captured through the winter into March.

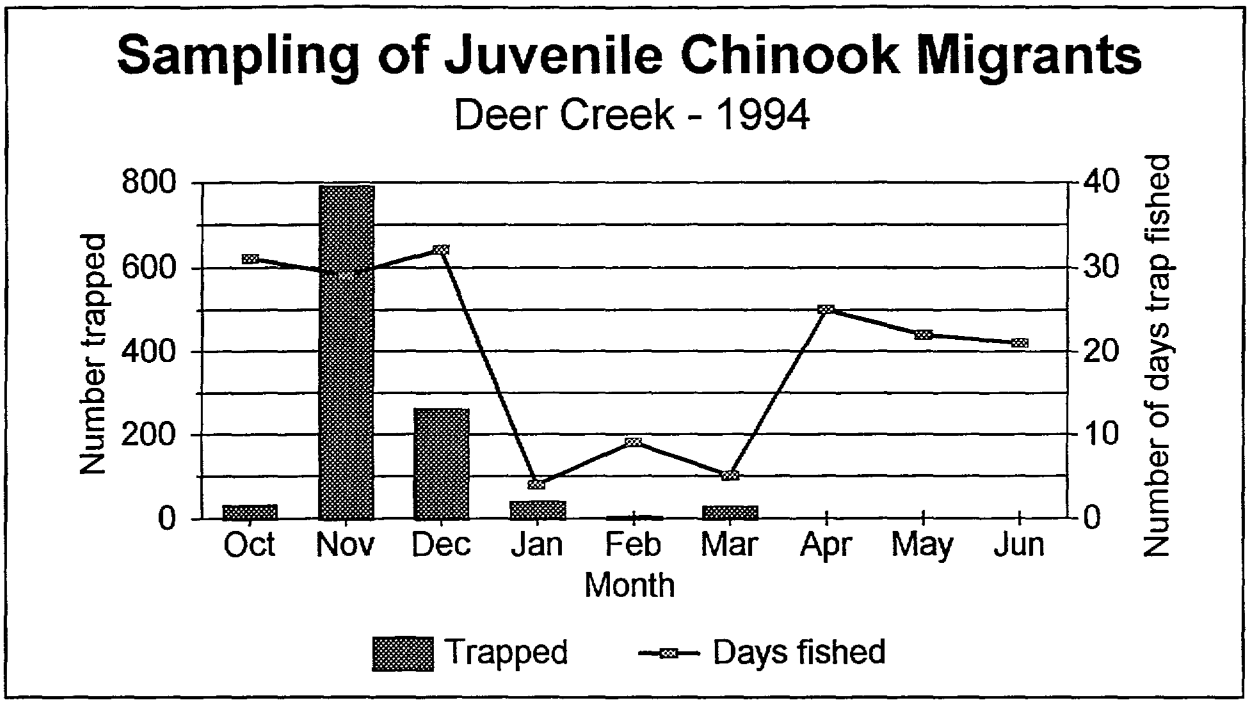


Figure 5. Number of juvenile chinook captured each month in a rotary-screw trap fished in Deer Creek at the canyon mouth, and number of days the trap fished (from Harvey 1995). The days of no fishing corresponded to periods of high flow, which tend to be periods of high fish movement.

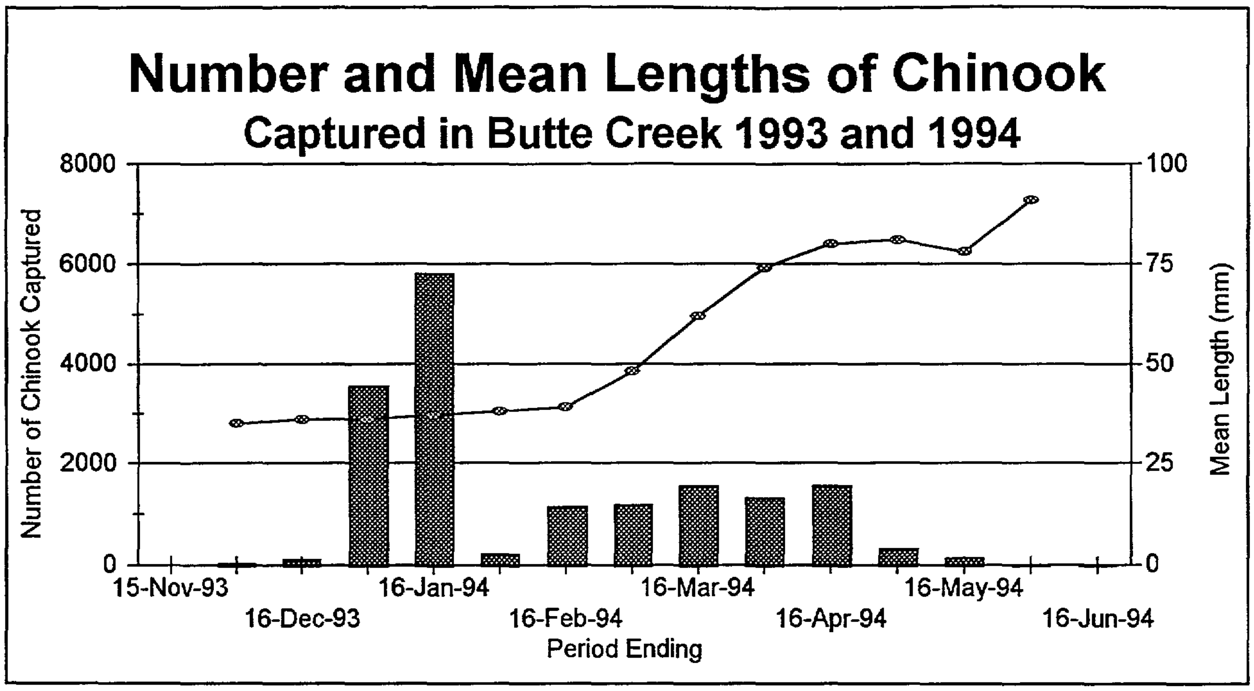
There is a strong tendency from the visual impact of Figure 5 for one to conclude that most juveniles emigrate in the fall; however, the sampling data indicate that the number of emigrants may have been equal or greater in February and March. We noted that catches on individual days in February and March were similar to catches in November and December, except following freshets. Sharp and temporary increases in catch during November and December were consistently associated with freshets. The trap was removed during freshets in January, February, and March, so the probable increased numbers of fish emigrating during those events went unsampled.

We discuss age at maturity in a separate section of this report, but we note here that juvenile sampling revealed the presence of many precocious males among yearling juveniles. Harvey (1994) reported that 29% of the 21 yearlings trapped while emigrating from Deer Creek between October 5 - 15, were precocial males showing sexual ripeness.

Butte Creek

The life history of juvenile spring chinook in Butte Creek differs from that in Deer and Mill Creeks, in that growth rates in the warmer water of Butte Creek are faster, and most fish emigrate as subyearlings during the spring. Yearling migrants in the fall, such as are common in Deer and Mill Creeks, are rare in Butte Creek. The CDFG has sampled juvenile chinook emigrating from Butte Creek during December 2, 1990 to June 14, 1991 by fishing a fyke net at the Parrot-Phelan diversion, and during 1994-96 by fishing screw traps. Sampling in 1994 and 1995 was at Adam's Dam near the town of Durham. The trap fished below both fall and spring-run chinook spawning, so both spring and fall-run juveniles were captured in the trap. In 1996 the trap was moved upstream about 5 miles to the Parrott-Phelan diversion where it was above the majority of fall-run spawning. Only a few fall-run chinook were seen spawning above the trap in 1996.

In all years of netting and trapping, greatest catches were of emergent fry in January and February, and the remaining juveniles grew rapidly to smolt size (70-100 mm fork length) by mid April (Figure 6). In the only two years with the same sampling methods, 1994 and 1995, catches of spring-run chinook were lower in 1995 than in 1994. During both years CDFG reported periods of non-sampling due to extreme weather and high flow, which are often the periods of peak juvenile movement. Although data for 1996 are not yet available, there was a substantial movement of fry beginning in late December through early January and over 100,000 fry were captured by mid February (personal communication, K. Hill, CDFG, Rancho Cordova).



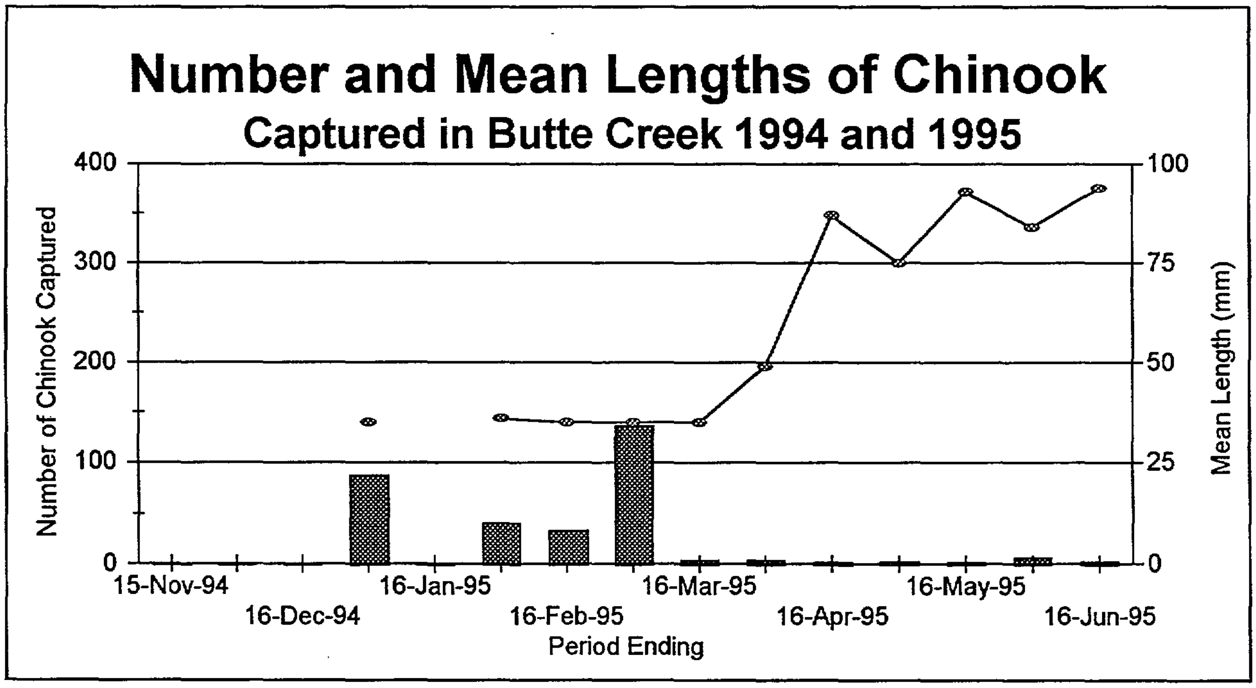


Figure 6. Number and lengths of spring-run chinook captured in the screw trap in Butte Creek during 1993-94 and 1994-95. Data from Kathy Hill, CDFG, Rancho Cordova. Number of chinook (Bar) and length of chinook (Line).

In addition to the upstream trap, a second screw trap was also placed near the mouth of Butte Creek next to the Sutter Refuge in January 1996. The trap was fished near the mouth to determine if fish that were passing the upstream trap were continuing out of Butte Creek into the main stem Sacramento, or if fry would stop to rear somewhere in lower Butte Creek. Catches in the upstream trap near Parrott-Phelan in 1996 again peaked as fry in January and February, but relatively few fry were captured at the downstream trap (personal communication, K. Hill, CDFG, Rancho Cordova). In contrast, catches in the downstream trap peaked in late March to early April and the fish were 70 mm to 100 mm fork length (personal communication, K. Hill, CDFG, Rancho Cordova)

Red Bluff Diversion Dam

We evaluated two sources of juvenile chinook sampling data at RBDD to determine the time of year and at what size the chinook classified as spring-run were passing the dam. RBDD is above the confluence of Deer and Mill Creeks, so any juveniles classified as spring chinook at RBDD were produced by main-stem spawners. During the 1980's an inclined plane fish trap sampled in the fishway at RBDD, and during 1983-88, the USFWS estimated the number of juvenile salmon entrained through the Tehama-Colusa Canal headworks.

From the inclined plane trap sampling at RBDD, the CDFG concluded that spring-run outmigration began in November and extended through May. Further, outmigrants were by far most numerous in December and January (Figure 7) as fry (CDFG 1990). CDFG (1990) reported, "*Salmon in each length interval in Table 1 were then assigned a racial designation based upon minimum/maximum lengths each race might possibly be for any month.*" Below, we have reproduced the table referred to by the CDFG report, to illustrate the dilemma in assigning race to these fish (Table 7). Note that there is no obvious break in the length frequencies that divides fall chinook from spring chinook on the early side or from late-fall chinook on the late side. The fish assigned to both the spring and late-fall races could easily be the early and late tails of the fall-run population. rather than separate races. Thus, there is a high potential for error in assigning juvenile chinook sampled at RBDD to a specific race.

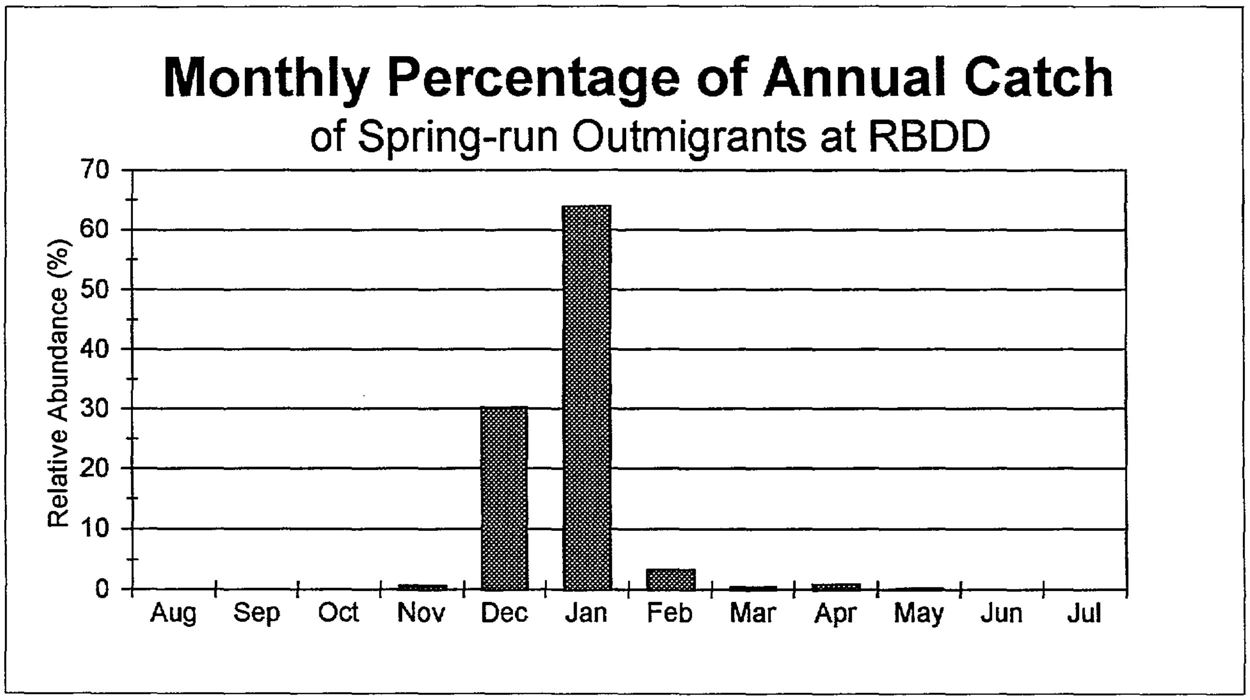


Figure 7. Monthly percentage of annual "spring-run" chinook juveniles caught in an inclined plane trap at RBDD, 1981,1982, 1984, and 1985. "Spring run" was defined by size criteria, not by parentage. Data from CDFG, Redding.

Table 7. Number of chinook salmon captured at Red Bluff Diversion Dam grouped by month and 5 mm intervals, for 1981, 1982, 1984 and 1985. From (CDFG 1990).

Length	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
(mm)		Fall			Late-Fall			Winter			Spring	
30-34	70	25	36	33	16	0	1	19	14	17	0	59
35-39	1,127	81	206	74	34	1	1	26	68	40	6	146
40-44	315	11	77	20	14	1	0	2	47	12	2	22
45-49	1	4	19	6	5	3	0	0	3	9	1	5
50-54	0	3	10	10	8	2	0	0	2	5	3	1
55-59	0	1	5	7	4	3	0	0	2	1	1	0
60-64	0	0	0	12	10	6	0	0	1	3	4	3
65-69	1	0	0	8	9	10	0	0	0	0	0	8
70-74	1	0	3	16	23	18	1	1	1	4	0	4
75-79	1	0	0	8	19	14	2	1	0	1	0	3
80-84	1	1	0	4	17	13	3	2	1	1	1	4
85-89	0	0	0	5	9	13	5	2	0	1	2	6
90-94	3	1	0	2	3	8	6	6	0	0	4	4
95-99	3	0	0	0	2	3	1	4	0	2	2	1
100-104	2	0	0	0	2	2	3	3	0	2	1	0
105-109	2	0	0	0	0	0	0	3	0	1	0	1
110	4	0	0	0	0	0	0	0	0	0	0	0
		Winter		Spring			Fall			Late-Fall		Winter

The USFWS sampled juvenile chinook entrainment into the Tehama-Colusa Canal headworks at RBDD for five consecutive years (1983-1988), and estimated the total number of downstream migrants approaching RBDD (Vogel et al. 1988). Their data shows substantial spikes in abundance of fry (< 40 mm fork length) in each year, except 1985, but the time of that peak varied during years of continuous sampling from December (1984), to January (1983) to February (1986). The criteria applied by CDFG (1990) in Table 7 would have assigned the peak outmigration of fry in 1984 (December 1983) to spring chinook, even though the estimated spawner escapement which produced these fry was 34,247 fall-run and 3,341 spring-run (Mills and Fisher 1994). In all years, the mean length of migrants remained below 40 mm during December through March. Vogel et al. (1988) made no attempt to divide these fish into races; rather, they point out that, "*The timing of the peak downstream migration past Red Bluff varied substantially* *depending on the type of water year.*" Thus, it appears that environmental factors, rather than the race of spawners, has the strongest influence on size and time of juvenile outmigration past RBDD.

Feather River

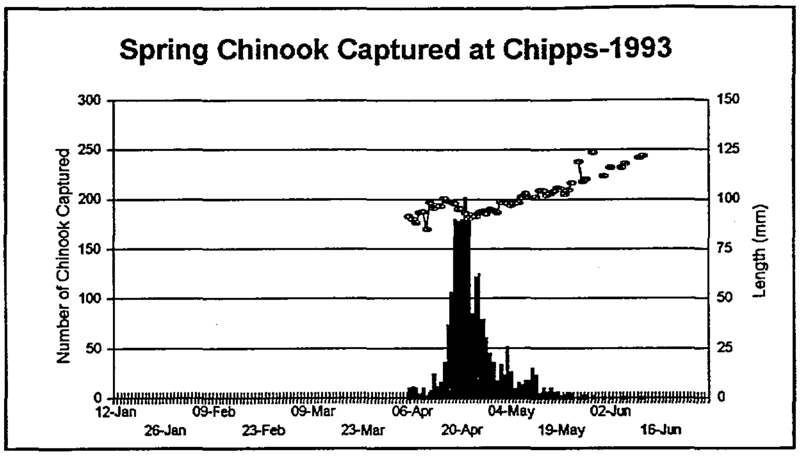
Because there is a large population of hatchery "spring chinook" that spawn naturally in the Feather River each year, we must understand when and how large the offspring are when they outmigrate, in order to interpret catches of juvenile chinook in the lower Sacramento River. Painter et al. (1977) sampled juvenile chinook in the Feather River during 1968-75, and found that emergent fry were captured in riffle fyke nets during late December through mid April in all years. Painter et al. found a single sharp peak in fry movement in most years, generally during mid January to mid February, and no evidence of a clear distinction in time or size between the appearance of spring and fall chinook. Painter et al. (1977) sampled outmigration of smolt-sized chinook only in 1975 and found a distinct peak in movement during the last week of May, but made no attempt to distinguish spring and fall chinook in the samples.

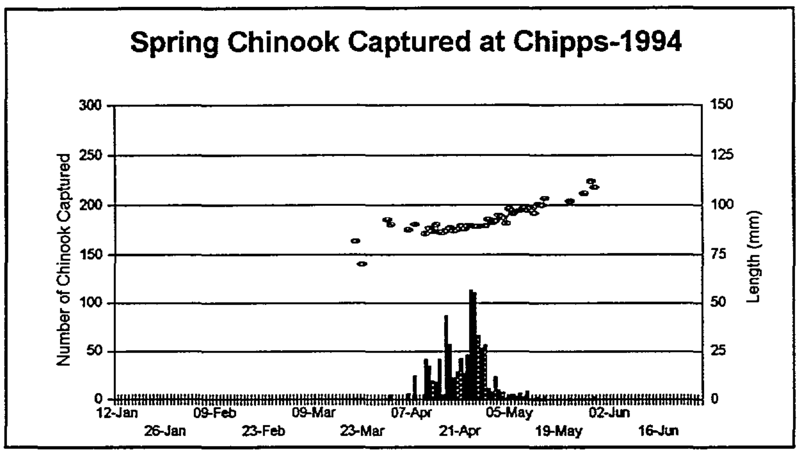
Estuary Trawl

We reviewed the USFWS Chipps Island trawling data for the years 1993 to 1995 to determine when spring-run abundance was highest near Chipps Island in each of the years. Trawling is conducted by the USFWS to monitor chinook passage through the lower Delta and is conducted on a routine schedule with standardized methods. Each year, catches of chinook classified as spring-run in the Chipps Island trawl began increasing in early April, peaked in late April and declined in May (Figure 8). However, when the length frequencies of chinook captured in the trawl are examined (Figure 9), there is no distinct change in the size distribution to suggest that spring chinook can be separated from fall chinook based on size. Further, the actual length data on chinook captured in the trawls show no change in lengths from mid April through May (Figure 9). Therefore, the increase in length of fish classified as spring chinook, as shown in Figure 8, is an artifact of applying the length criteria that increase through time. **We find no evidence to give us confidence that outmigration of true spring-run chinook peaked in late April, or that the catch of juveniles classified as spring-run is related to the abundance of true spring-run chinook.** Marking of hatchery fish and use of genetic stock identification techniques will be necessary to distinguish races of juvenile chinook in the estuary.

Delta Export Pumps

The time and size that juvenile chinook arrive in the San Francisco Bay-Delta is also indexed by the fish salvaged at the state and federal export pumps in the south Delta. These data have been thoroughly reviewed by Brown and Greene (1994), and provide a clear demonstration of the lack of distinction in size between races. Salvage data at the Central Valley Project pumps during December 1991 through May 1992 showed that yearling outmigrants tended to pass in late February through March, while subyearling migrants passed during April through mid May (Figure 10). The length frequencies of salvaged fish also clearly show the length criteria for dividing spring and fall chinook passed through the heart of the length frequency distribution of subyearling migrants, and incorrectly assigned most of the migrants to the spring run rather than to the fall run (Figure 10). **Thus, it is not at all clear from fish salvage data at the pumps, based on the racial classification according to length criteria, when the wild type spring-run chinook pass through the Delta**.





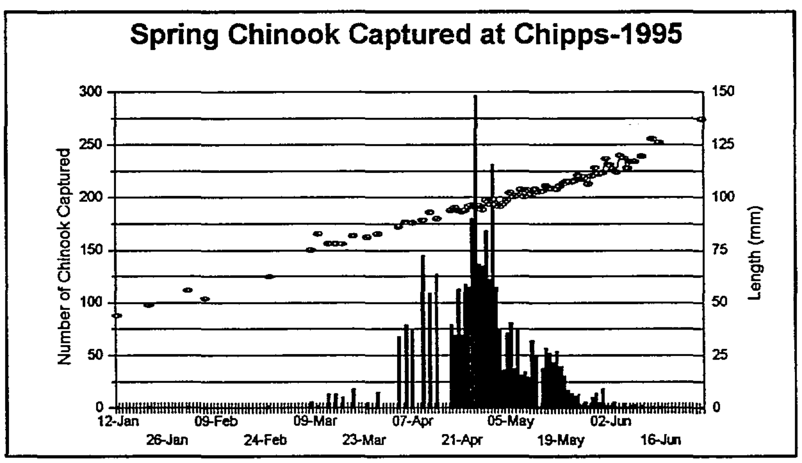


Figure 8. Number and timing of trawl catches of chinook classified as spring-run in the Sacramento River Delta, 1993 - 1995. These standardized trawl surveys are completed by the USFWS. Data from C. Alexander, USFWS Stockton.

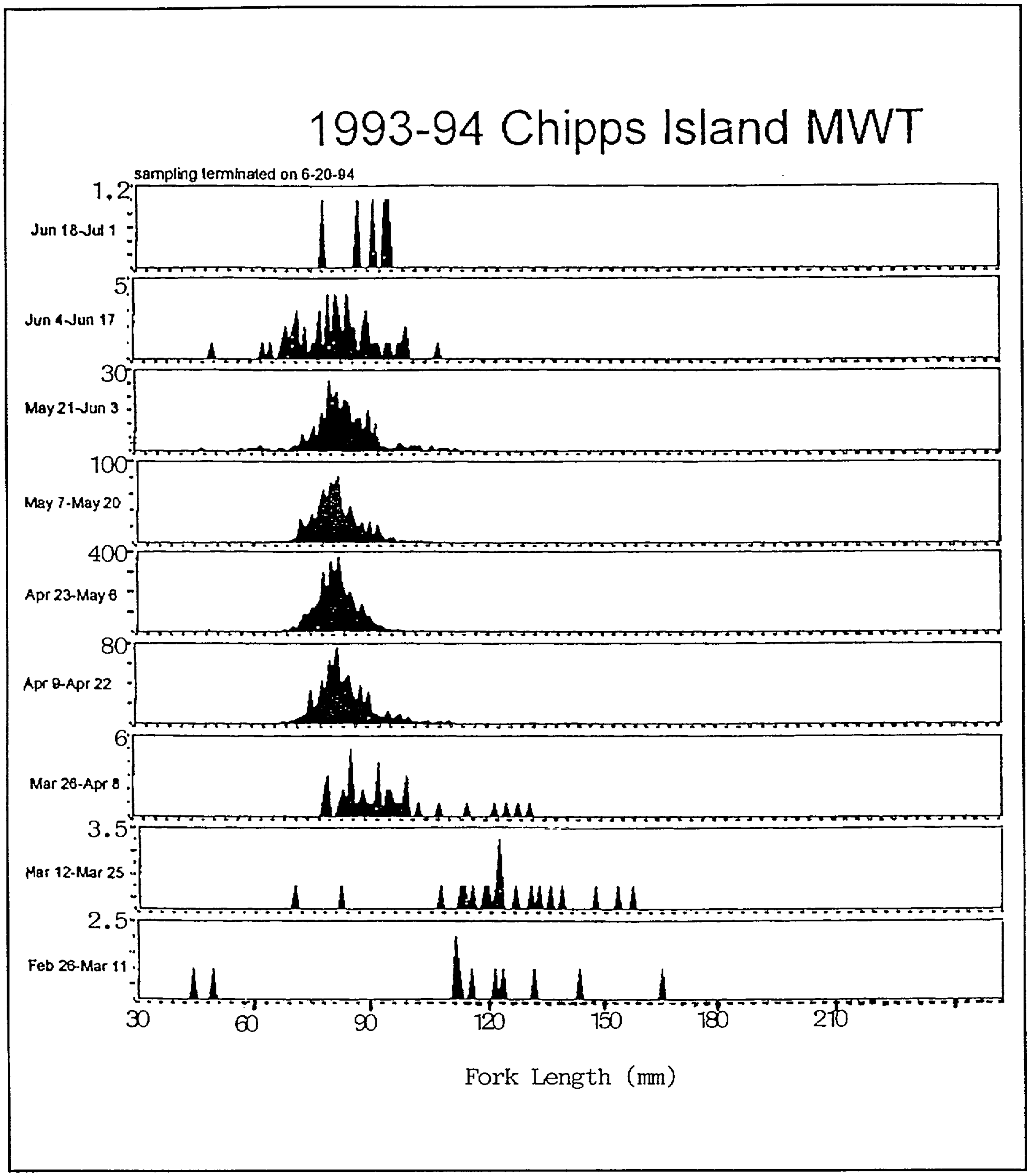


Figure 9. Length frequencies of juvenile chinook captured in standardized trawling during March-June 1994 by the USFWS in the Sacramento estuary near Chipps Island, 1993-94. Data from M. Pierce, USFWS, Stockton.

Data on microsatellite DNA from juvenile chinook collected at the State Water Project fish salvage facilities during the winter of 1995-96 indicate that length criteria incorrectly classified the race of a high percentage of those juvenile chinook. As discussed in the Genetics Profile section for spring chinook in this report, genetics profiles using microsatellite DNA are only partially developed at this time, and will be greatly expanded during the next 6 months. Data are available for a single DNA marker, the Ots-2 locus, for all four races of Sacramento chinook, and data from that locus have been applied to a mixed stock analysis of the racial composition for juvenile chinook collected at the State Pumps. This locus enables about two-thirds of winter-run chinook individuals to identified with certainty as being of that race (Banks et al. 1996). The mixed stock analysis indicated that only 5.2% of the juveniles collected were winter run, while the length criteria had classified 69% of the juveniles was winter run (Table 8; Banks et al. 1996). This example, focuses on the winter run, but is a demonstration that length criteria are a poor tool for distinguishing the race of juvenile chinook, once the races have mixed together.

Table 8. Example of racial classification of juvenile chinook according to size criteria compared to that with mixed stock analysis using DNA genotypes from the Ots-2 locus. Chinook were collected January 9 to April 3, 1996 at the State Water Project fish salvage facilities, and were sampled because their size was within or near the size criteria for winter-run chinook. Adapted from Banks et al. (1996).

	% Classified into Each Race	
Race Classification	**By Size Criteria**	**By Mixed Stock Analysis**
Spring-run	17%	35.4%
Late fall-run	14%	27.5%
Winter-run	69%	5.2%
Fall-run	0%	31%

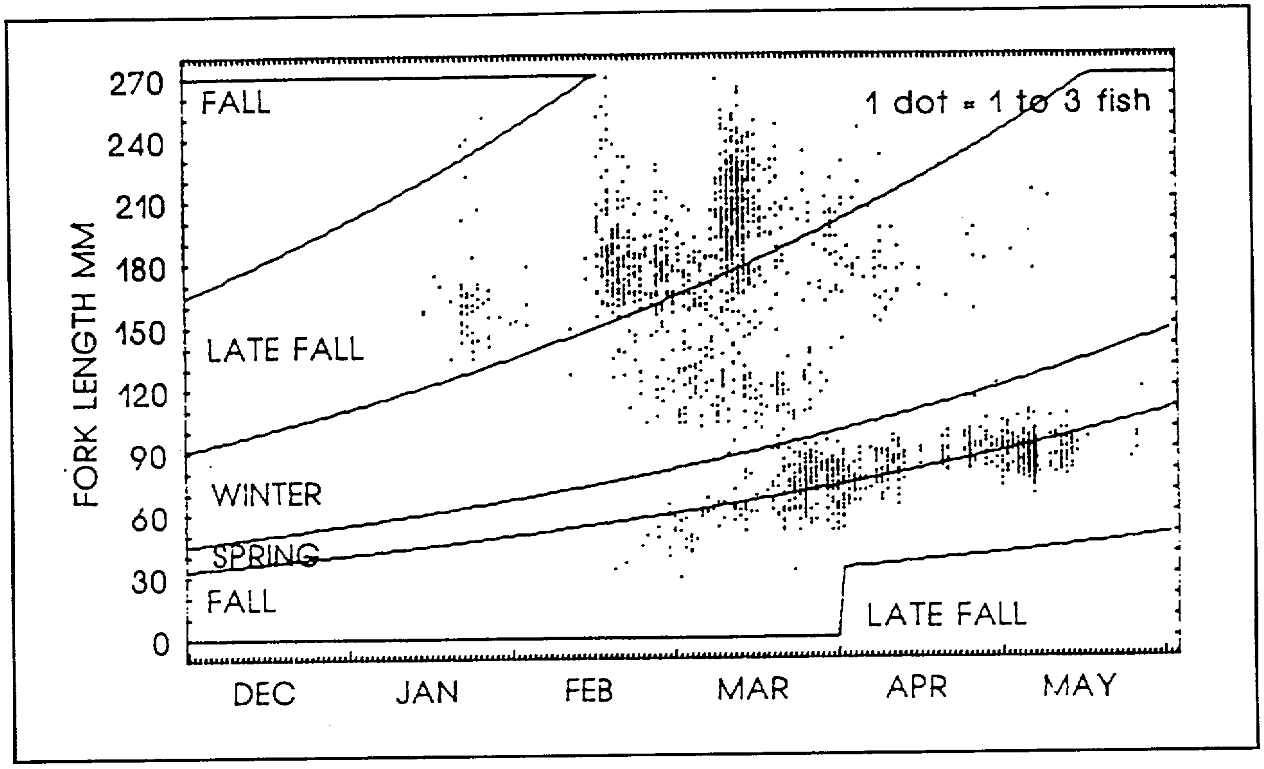


Figure 10. Length frequencies of juvenile chinook salvaged at the Central Valley Project pumps, December 1991 through May 1992, compared to the length criteria used to assign race. From Brown and Greene (1994).

Habitat Characteristics

The only habitat data that we examined for differences between populations were temperature and flow. These are the environmental variables that tend to drive selection for specific life history traits, such as spawning time and outmigration time. We found that runoff patterns were similar for all east-side tributaries, with high flows during January through May and low flows during July through October (Figure 11). On the other hand, we found the average stream temperatures differed between past and present spawning areas.

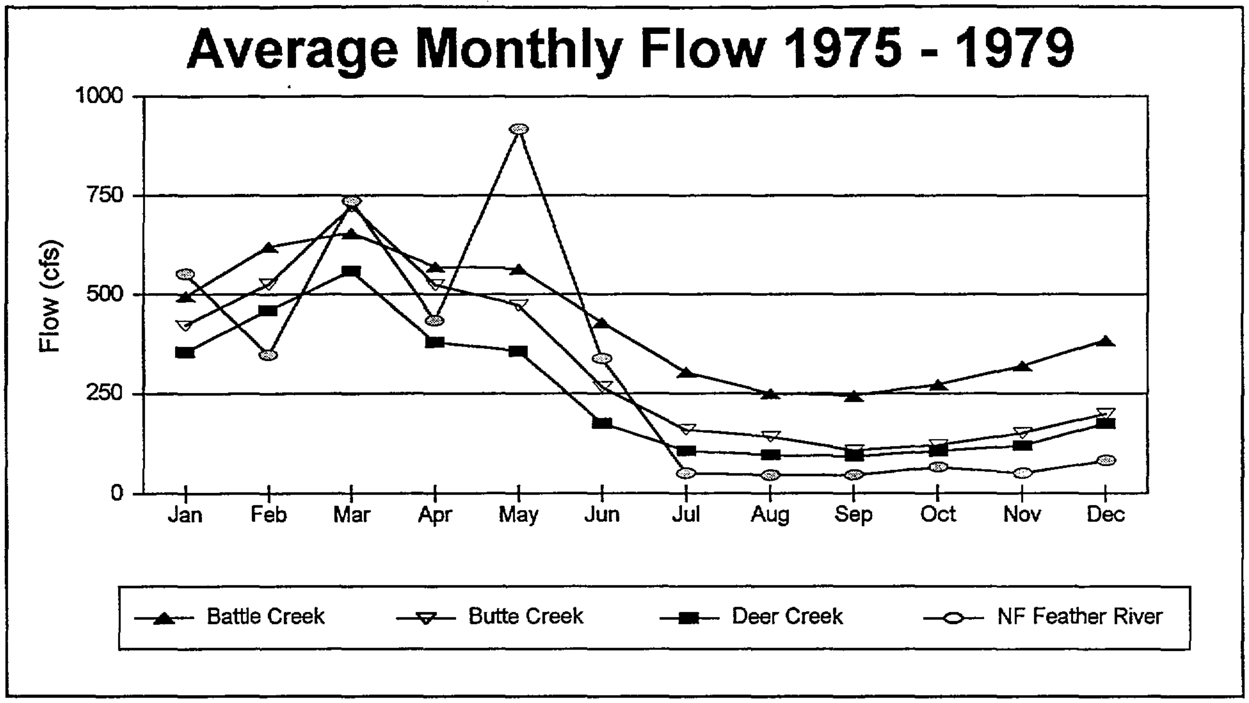
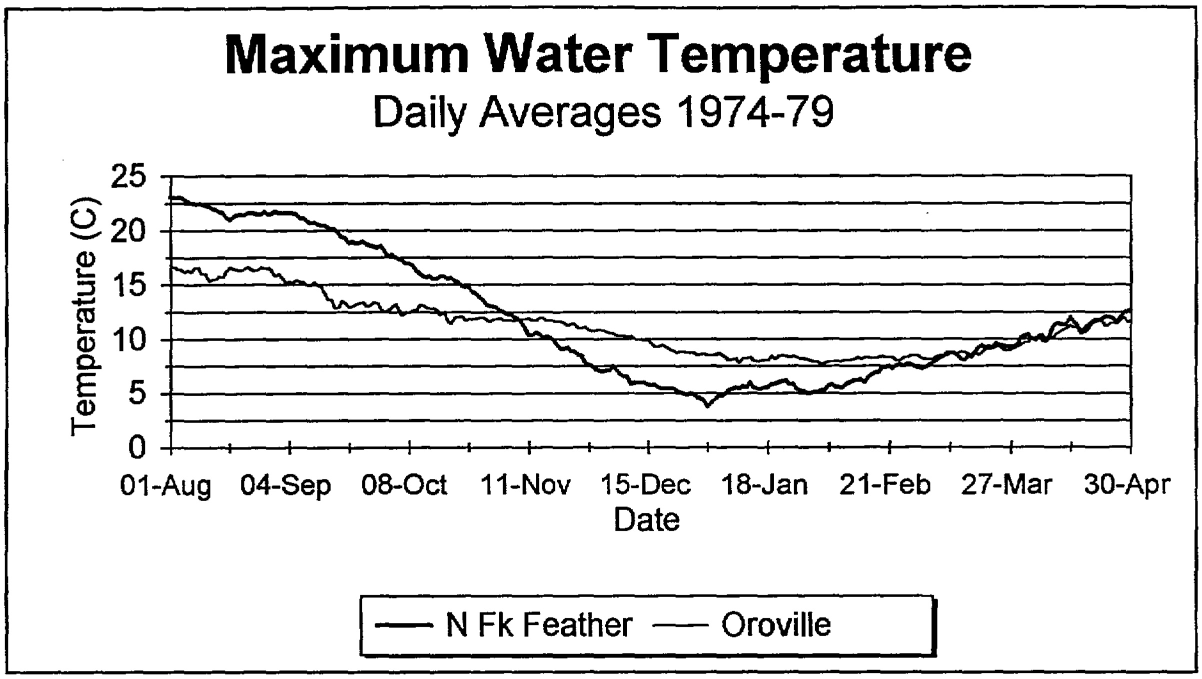


Figure 11. Mean monthly flows, 1975-79, in unimpounded tributaries that historically supported spring chinook. (USGS data)

We found the most substantial difference between stream temperatures above and below Oroville Dam on the Feather River. Temperature data were available for the unimpounded North Fork Feather River, and for the Feather River below Oroville Dam, where upstream migration of salmon is blocked. Water temperatures at Oroville reflect the modulating influence of drawing water year-round from the depths of a reservoir. Temperatures at Oroville average about 5°C cooler than in the North Fork during August and September, and about 5°C warmer than in the North Fork during mid November through December (Figure 12). Stream temperatures at Oroville average near 10°C in mid December, which is about 5°C warmer than in Deer, Mill, and Butte Creeks (Figures 12, 13, and 14). These are dramatic differences for egg incubation and would result in earlier emergence of fry in the Feather River than in Deer and Mill creeks if adults had spawned at the same time.



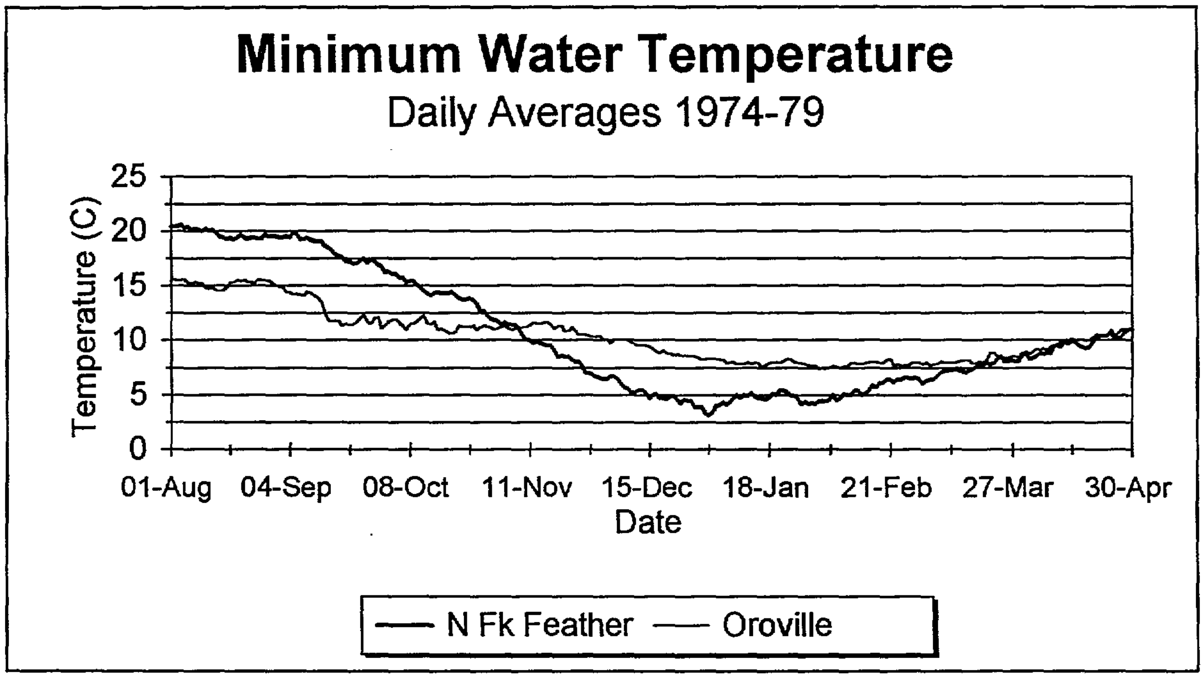


Figure 12. Mean maximum and minimum daily temperatures of the North Fork Feather River at Pulga and the Feather River at Oroville, 1974-79. (USGS data)

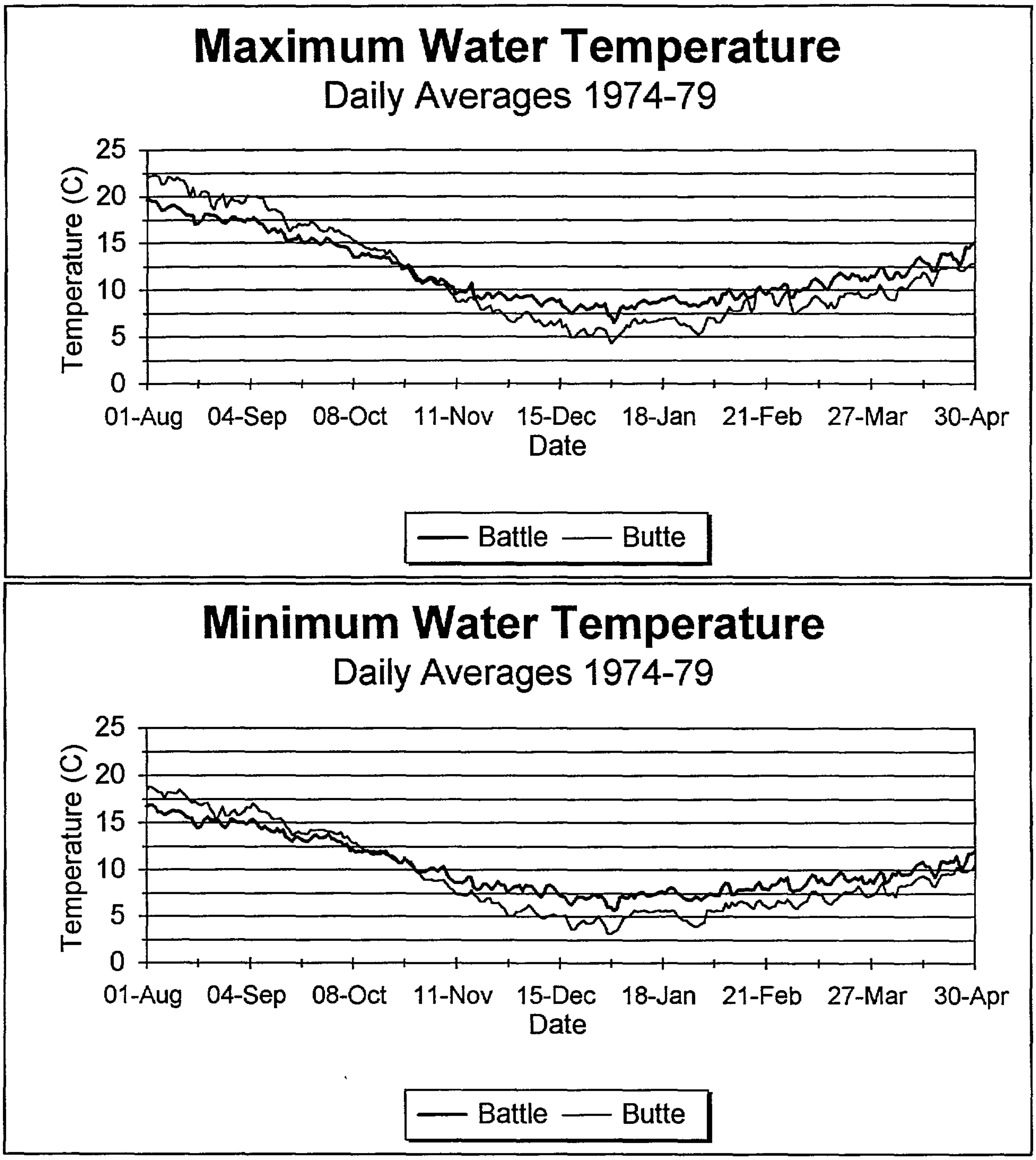


Figure 13. Mean maximum and minimum daily temperatures of Battle Creek below Coleman Hatchery and Butte Creek at near Chico, 1974-79. (USGS data)

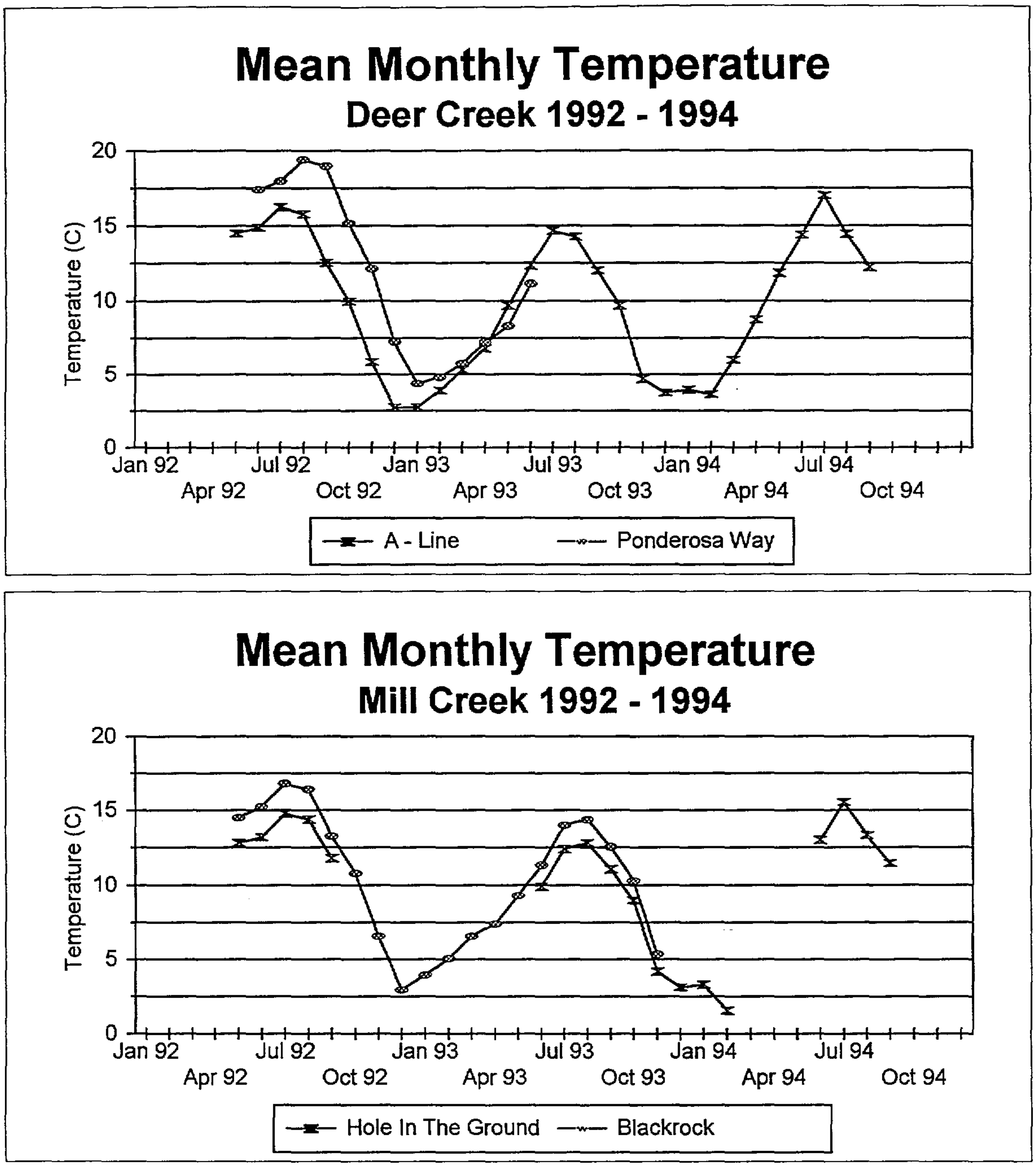


Figure 14. Mean monthly temperatures of Deer Creek at A-Line Crossing and Ponderosa Way, and of Mill Creek at Hole-in-the-Ground and Blackrock, 1992-1994. (Data from CDFG, Rancho Cordova).

Given that Deer and Mill Creeks still have much of their watersheds in wilderness areas, and that they have sustained wild populations without hatchery supplementation, it seems reasonable to regard the temperature regimes in these streams as models for temperatures that are favorable for spring chinook. Mean temperatures in the areas where adults hold over summer in both streams were 15-16°C in July and August (Figure 14). Mean Temperatures in September at the time of spawning were under 13°C. Temperatures in December and January during egg incubation dropped below 4°C and did not rise above 10°C again until May. By contrast, temperatures in Butte Creek did not drop to under 13°C until the second week in October, and temperatures began exceeding 10°C about April 1. These contrasts are slightly exaggerated, because the temperature gage in Butte Creek is downstream of the spawning area. Trends in these contrasts match with the observed differences in life history characteristics, i.e. later spawning but earlier fry emergence and faster spring growth in Butte Creek than in Deer or Mill.

There are also large differences in temperatures between the Sacramento River and its east-side tributaries during the period of spawning, egg incubation, and rearing for spring-run chinook. Throughout the Sacramento River from Red Bluff to Keswick Dam, mean river temperatures generally do not exceed 15°C at any time, first drop below 13°C in late October, and remain near 10°C through the winter (Figure 15; Turek 1990). Thus, compared to the east-side tributaries, temperature in the Sacramento would favor later spawning, cause more rapid egg development, and cause more rapid growth of fingerlings. These temperature differences between areas indicate that size criteria for assigning race of juvenile chinook on a given date in the upper Sacramento River (which is the area for which the criteria were developed) will be much too large for the size of fish in Deer, Mill, and Butte creeks.

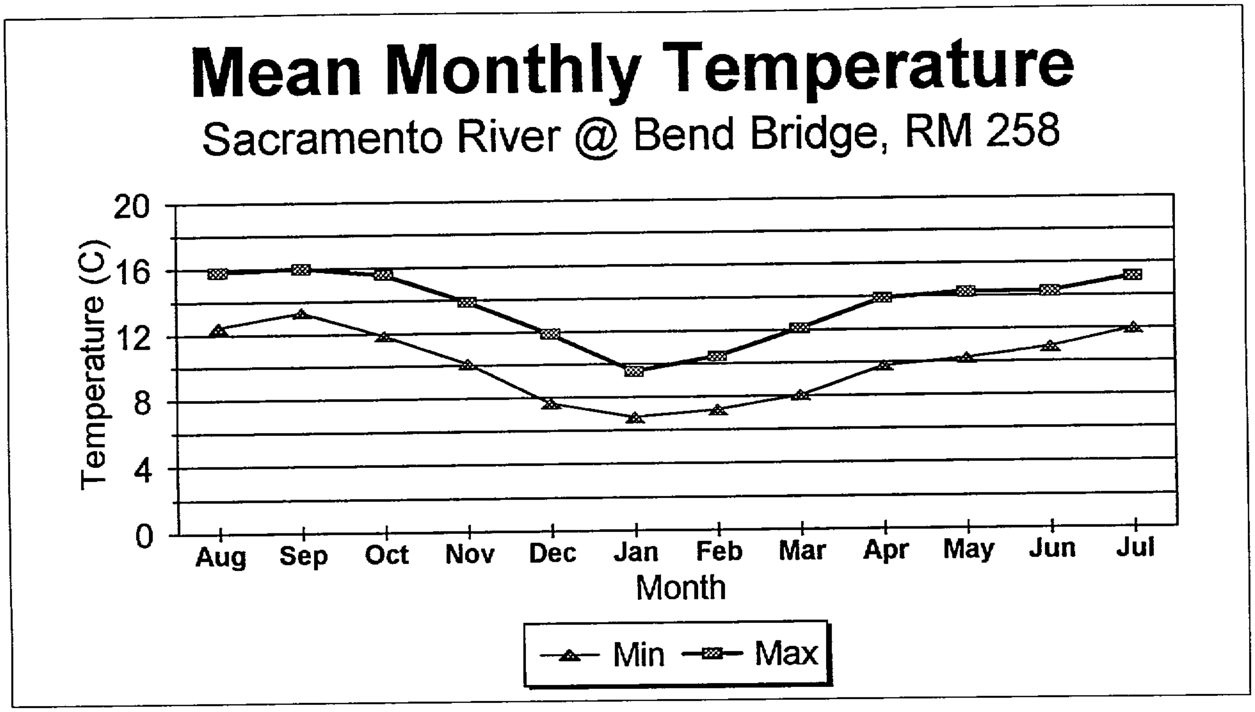


Figure 15. Mean monthly minimum and maximum temperatures of the Sacramento River near Bend Bridge (RM 258) during 1983-1989. (Data from Turek 1990)

Genetics Profile

After the listing of winter-run chinook in the Sacramento River as endangered, studies of the molecular genetics of Central Valley chinook were initiated to determine the extent that various races were genetically distinct. The most promising results have come from microsatellite DNA markers. Thus far, five microsatellites have been found that show strong potential for run discrimination among Central Valley chinook (Banks et al. 1996). In particular, one microsatellite named Ots-2 has been found that enables two-thirds of winter-run chinook individuals to be distinguished from all other races (Banks et al. 1996). Genetics experts at the Bodega Marine Laboratory are working to develop the baseline genetics data and validation testing necessary for a Mixed Stock Analysis (MSA) that distinguishes races of Central Valley chinook with a high degree of accuracy. MSA is a statistical procedure used to estimate the percentage that each stock composes of a sample of fish. The MSA, when based on five microsatellites, is expected to be capable of discriminating the race of an individual fish with a high degree of accuracy (personal communication, M. Banks, Bodega Bay Marine Laboratory, U.C. Davis, California). The MSA with data from five microsatellites is expected to be operational sometime during 1997.

Tissue samples have been collected from representative populations of the four major runs of chinook, and genetic analysis of these samples is proceeding. The winter run is represented by post-spawn carcasses collected from the Sacramento River near Redding during June through August. The spring run is represented by pooled samples of juveniles from Mill Creek in 1995, juveniles from Deer Creek in 1993 and 1994, and adults trapped at Keswick Dam in 1995. The fall run is represented by a collection of adults near Redding in November of 1995. The late-fall run is represented by a sample of adults returning to Coleman National Fish Hatchery in January of 1995. Some of these samples represent limited temporal segments of the run, so further sampling of baseline populations is needed. The sampling of baseline populations (known parentage) was expanded substantially in 1996, but analysis of most of these collections is not yet complete. Therefore, data are not presently available to answer many of the most pressing questions about genetic differences between stocks and races, but such data will become available within the next 6 months. Stocks sampled during 1996, for which the results should soon be available include each hatchery stock in the Central Valley, and several wild populations (personal communication, S. Greene, Department of Water Resources, Sacramento).

Preliminary analysis of 1995 data from several microsatellite DNA loci indicate that genetic differences between chinook races are by far greatest for winter run compared to the other three races (personal communication, M. Banks, Bodega Bay Marine Laboratory, U.C. Davis, California). This difference, based on Nei's statistic using five loci (only three of these had good discriminating power), was about five times greater than the difference between spring run and either fall or late-fall run (personal communication, M. Banks, Bodega Bay Marine Laboratory, U.C. Davis, California). The genetic distance between fall and late-fall runs was small. The genetic distances found between spring run and the other races supports the conclusion that spring run in Deer Creek, Mill Creek, and the upper Sacramento River are collectively a distinct population from the other races. A new microsatellite variant has been found in chinook collected from Butte Creek that uniquely distinguishes those chinook from all other chinook analyzed thus far in the Central Valley (personal communication, M. Banks, Bodega Bay Marine Laboratory, U.C. Davis, California). Chinook from Feather River Hatchery have yet to be analyzed, as of this writing, but we expect the fish in Butte Creek will be found to be similar to those from the Feather River Hatchery. This hypothesis should be testable by genetics data that will be obtained through the Bodega Marine Laboratory within the next few months.

LATE-FALL CHINOOK

Distribution of Spawning

The late-fall run was not distinguished by fishery managers until adult counts began at Red Bluff Diversion Dam (Mills and Fisher 1994), and it has been supplemented since then from Coleman Hatchery. Late-fall chinook migrate up the river during mid October through mid April and spawn in the main-stem Sacramento River from January through mid April. CDFG has completed aerial counts of redds in years since 1982 when water visibility permitted. Generally, about 89% of the redds observed in the main stem have been above Red Bluff Diversion Dam (personal communication, F. Fisher, CDFG, Red Bluff), where spring, fall, and winter-run chinook also spawn.

Influence of Hatcheries

We provided a historical review of hatchery activities with chinook in the Sacramento Basin in the previous section on spring chinook. Some of the early hatcheries in the upper Sacramento Basin may have reared late-fall chinook, but they were not designated as a distinct run until 1970, after they could be counted passing Red Bluff Diversion Dam (Mills and Fisher 1994). Coleman Hatchery recognized the existence of the late-fall race in 1957 when they started spawning fish after January 1 (USFWS 1982). In those years, these fish were called early winters (CDFG 1990). Brood fish were collected both from returns to the hatchery and from trapping at the base of Keswick Dam. During the early 1950's, the first years of brood collection at Keswick Dam, collections tended to start and finish later at Keswick than at the hatchery (Table 9). Brood fish were generally not collected past mid December from Battle Creek (which supplies the hatchery) until the late 1950's when offspring of the fish trapped at Keswick Dam would have begun returning. Even though offspring of the two brood sources were reared separately, and those of Keswick parentage were released near the base of Keswick Dam, it appears probable that many of the Keswick fish returned to Coleman Hatchery and became mixed in the Coleman Hatchery brood stock. It appears from the dates of collection that timing of the stock with which the hatchery began in 1943 was similar to today's "fall" run, which has peak spawning in mid October. Peak spawning of the "late-fall" run is in mid January.

Table 9. Source and number of juvenile fall and late-fall chinook, by brood year, released into the Sacramento Basin from Coleman National Fish Hatchery, 1943-1980 broods. Data from USFWS (1982).

Brood Year	Source of Spawners	Race	Date Collected	# Females	# Released Before April 14	# Released After April 15
1943	Balls Ferry	Fall	10/20 - 11/29	1,541	7,533,000	130,000
1944	Balls Ferry	Fall	10/18 - 11/20	2,006	10,019,000	257,000
1945	Balls Ferry	Fall	10/13 - 11/29	2,966	16,916,000	691,000
1946	Battle Cr.	Fall	10/18 - 11/20	1,801	9,625,000	301,000
1946	Keswick	Fall	11/4 - 12/5	2,379	13,185,000	290,000
1947	Battle Cr.	Fall	10/1 - 12/5	1,947	8,537,000	1,547,000
1948	Battle Cr.	Fall	10/1 - 11-30	614	1,608,000	1,915,000
1948	Keswick	Fall	10/16 - 10/30	27	ND	ND
1949	Battle Cr.	Fall	10/22 - 12/8	2,221	10,887,000	1,807,000
1950	Battle Cr.	Fall	10/22 - 12/18	1,384	8,107,000	1,566,000
1950	Keswick	Fall	11/2 - 12/22	508		

Brood Year	Source of Spawners	Race	Date Collected	# Females	# Released Spring	# Released Fall
1951	Battle Cr.	Fall	10/23 - 11/21	2,855	ND	ND
1951	Keswick	Fall	11/13 - 12/3	925		
1952	Battle Cr.	Fall	10/22 - 12/10	3,607	28,220,000	1,483,754
1952	Keswick	Fall	11/19 - 12/19	2,097		
1953	Battle Cr.	Fall	9/30 - 12/8	4,335	33,900,000	3,157,000
1953	Keswick	Fall	11/18 - 12/17	2,750		
1954	Battle Cr.	Fall	9/30 - 12/22	2,091	17,307,000	2,713,000
1954	Keswick	Fall	11/18 - 12/23	2,160		
1955	Battle Cr.	Fall	9/30 - 12/31	2,796	22,907,000	3,781,000
1955	Keswick	Fall	11/17 - 1/9	2,202		
1956	Battle Cr.	Fall	10/1 - 1/21	2,725	14,689,000	3,808,000
1956	Keswick	Fall	11/19 - 12/31	1,066		
1957	Battle Cr.	Fall	10/4 - 2/10	826	11,167,000	3,225,000
1957	Keswick	Fall / Late Fall	11/15 - 1/27	2,626		
1958	Battle Cr.	Fall	9/16 - 2/13	4,054	5,220,000	2,267,050
1958	Keswick	Fall / Late Fall	11/17 - 2/13	2,916		
1959	Battle Cr.	Fall	9/28 - 1/20	5,632	30,517,000	4,506,000
1959	Keswick	Fall / Late Fall	11/16 - 1/29	3,047		
1960	Battle Cr.	Fall	10/5 - 1/16	2,923	29,126,000	4,089,140
1960	Keswick	Fall / Late Fall	11/16 - 1/23	3,429		
1961	Battle Cr.	Fall	10/6 - 1/24	3,577	17,080,000	3,988,000
1961	Keswick	Fall / Late Fall	11/13 - 3/5	2,263		
1962	Battle Cr.	Fall	10/1 - 1/15	3,396	34,192,000	5,449,000
1962	Keswick	Fall / Late Fall	11/17 - 3/24	4,420		
1963	Battle Cr.	Fall	10/7 - 2/18	2,356	1,428,000	5,889,000
1963	Keswick	Fall / Late Fall	11/17 - 3/24	2,105		
1964	Battle Cr.	Fall	10/8 - ?	1,585	12,239,000	5,375,000
1964	Keswick	Fall / Late Fall	11/27 - 3/16	1,239		
1965	Battle Cr.	Fall	10/5 - 3/7	2,898*	2,597,000	7,483,000

Brood Year	Source of Spawners	Race	Date Collected	# Females	# Released Spring	# Released Fall
1965	Keswick	Late Fall	11/15 - 2/23	2,898*		
1966	Battle Cr.	Fall	10/3 - 3/25	1,907*	125,000	6,157,000
1966	Keswick	Late Fall	11/1 - 3/25	1,907*		
1967	Battle Cr.	Fall	10/13 - 3/25	3,094*	2,994,000	7,363,000
1967	Keswick	Late Fall	11/6 - 3/25	3,094*		
1968	Battle Cr.	Fall	10/1 - 3/21	2,077*	1,278,000	2,281,000
1968	Keswick	Late Fall	11/15 - 3/21	2,077*		
1969	Battle Cr.	Fall	10/10 - 1/110	2,951*	2,947,000	3,057,000
1969	Keswick	Late Fall	11/19 - 3/20	2,951*		
1970	Battle Cr.	Fall	10/16 - 3/22	3,335*	5,129,000	2,619,000
1970	Keswick	Late Fall	10/29 - 3/22	3,335*		
1971	Battle Cr.	Fall	10/22 - 3/8	1,811*		
1971	Keswick	Late Fall	10/22 - 3/8	1,811*	7,203,000	0
1972	Battle Cr.	Fall	10/6 - 1/5	913*	4,697,000	0
1972	Keswick	Late Fall	11/9 - 1/10	913*		
1973	Battle Cr.	Fall	10/12 - 12/12	1,547	4,927,000	0
1973	Keswick	Late Fall	1/24 - 3/15	310		
1974	Battle Cr.	Fall	10/18 - 12/6	1,097	1,910,212	0
1974	Keswick	Late Fall	12/10 - 3/7	638	33,000	1,896,000
1975	Battle Cr.	Fall	10/10 - 12/5	1,125	2,801,000	1,112,000
1975	Keswick	Late Fall	12/2 - 1/16	200	0	602,000
1976	Battle Cr.	Fall	9/2 - 12/3	1,552	6,519,000	593,000
1976	Keswick	Late Fall	12/10 - 2/11	273	0	628,000
1977	Battle Cr.	Fall	9/27 - 12/2	1,973	3,278,000	0
1977	Keswick	Late Fall	12/6 - 1/7	470	0	1,971,000
1978	Battle Cr.	Fall	10/12 - 12/1	452	427,000	1,213,000
1978	Keswick	Late Fall	12/8 - 2/9	325	0	982,000
1979	Battle Cr.	Fall	10/2 - 11/30	2,669	11,072,000	615,000
1979	Keswick	Late Fall	12/10 - 2/29	373	490,000	928,000
1980	Battle Cr.	Fall	10/10 - 11/28	3,580	14,495,000	0
1980	Keswick	Late Fall	12/1 - 2/11	814	ND	ND

Source: Report of the U.S. Fish and Wildlife Service on Problem No. A-6 of the Central Valley Fish and Wildlife Management Study. May 1982.

Race = race designation made by CNFH at the time the eggs were collected.

* = Combined totals

Staff at Coleman National Fish Hatchery began keeping separate records of the late-fall chinook they released in 1974 (Table 10). The hatchery has released from 200,000 to 2,500,000 yearling late fall chinook each year since 1974 (Tables 9 and 10). We provide two tables that overlap for some of the brood years they cover, because Table 9 provides data on brood source, but not release location, and Table 10 (derived from the

Coleman Hatchery computer database) lacks information on brood source, but does show release location. Most smolts have been released at the hatchery, although groups of up to 930,000 were trucked to below RBDD for release in 1982, 1983, 1985, and 1986 (Table 10). A portion of those groups were coded-wire tagged (CWT), and recoveries of those CWT's will be discussed in a later section of this report. Several experimental groups were released in the San Joaquin Delta in 1979 and 1993 as test fish for evaluating survival through specific areas of the Delta. The records of releases prior to 1980 give only the number of fish released, and not the size, date or life stage at release. Most release locations during those years are designated as "Sacramento River and tributaries", so we have listed those fish in Table 10 as being released in the Sacramento River.

Table 10. Number of juvenile late-fall chinook, by brood year, released into the Sacramento Basin from Coleman National Fish Hatchery, 1973-1993 broods. Data from USFWS, Red Bluff California.

Release			Brood Year									
Type	Waterbasin	Stream	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
Unknown	Sac R above Feather R	Below Red Bluff Dam						51,500	50,216	51,200		
	Sacramento R	Coleman NFH			211,282	215,209	202,736	248,403	50,600			
		Sacramento R	1,687,000	1,929,000	390,718	412,791	1,768,264	628,097	1,317,184			
Fingerlings	Sac R below Feather R	Ryde-Koket										
	San Joaquin Delta	Clifton CT Forebay										
		Georgianna Slough										
Pre-Smolt	Sacramento R	Coleman NFH										
	San Joaquin Delta	Clifton CT Forebay										
Smolt	Sac R above Feather R	Balls Ferry							41,146			
		Below Red Bluff Dam										938,558
		Old Mouth Battle Cr										
	Sacramento R	Below Red Bluff Dam										
		Coleman NFH								2,472,048	1,686,824	419,809
	San Joaquin Delta	Tracy Pumps										

Release			Brood Year										
Type	Waterbasin	Stream	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
Fingerlings	Sac R below Feather R	Ryde-Koket											34,929
	San Joaquin Delta	Clifton CT Forebay											12,960
		Georgianna Slough											33,668
Pre-Smolt	Sacramento R	Coleman NFH							52,282				
	San Joaquin Delta	Clifton CT Forebay										13,035	
Smolt	Sac R above Feather R	Balls Ferry											
		Below RBDD	219,955		103,704	317,988							
		Old Mouth Battle Cr							277,183				
	Sacramento R	Below RBDD		103,704									
		Coleman NFH	154,892	210,408	210,408	392,012	1,064,700	662,170	513,446	203,387	302,982	325,244	676,131
	San Joaquin Delta	Tracy Pumps										15,102	

There is evidence that a large portion of late-fall chinook reared at Coleman National Fish Hatchery end up spawning naturally above Red Bluff Diversion Dam. Counts of adipose-fin clipped chinook passing Red Bluff Diversion Dam during October through April (which should be predominantly late-fall run) are about double the number of these marked fish that enter Coleman National Fish Hatchery (see Table 11 later in this report). The proportion of fin-clipped late-fall chinook counted at Red Bluff that were accounted for entering Coleman Hatchery varied during 1978-1984 from 13.7% to 100% (this data is presented fully in the report section on cohort analysis of CWT groups). Because there is no sport fishery for late-fall chinook above Red Bluff, these missing fish must have spawned naturally (personal communication, F. Fisher, CDFG, Red Bluff). Thus, the natural spawning population must be substantially supplemented with the hatchery stock.

Life History Characteristics

Adult Migration and Spawning

Adult chinook classified as late-fall run enter the Sacramento River from mid October through mid April, which overlaps with the late portion of the numerically dominant fall chinook run (see Table 5 and Appendices 1 - 3). Overlap of the fall and late-fall runs is greatest in late October and early November when good numbers of both runs are often passing RBDD. The procedure for distinguishing fall and late-fall chinook was described in the section on spring chinook, and is likely to incorporate errors associated both with subsampling and with the ability to discriminate the races based on a fish's external appearance.

Counting of late-fall chinook at RBDD has been greatly impaired since 1986 by raising of the gates at the dam during winter. Passage of late-fall run generally peaks during December (see Table 5), and the gates at RBDD have been removed during December every year, beginning in 1986. The number of fish passing the dam when the gates are up cannot be counted, so it is predicted by assuming that the proportion of the run passing during periods of no count is equal to the long-term average for that period. Thus, counts of late-fall chinook after 1985 are largely predictions rather than counts. By 1992, the dates during which gates were out at RBDD (see Table 6) included almost the entire period of passage for late-fall run chinook.

Juvenile Rearing and Outmigration

As we found for spring-run juveniles, the use of length criteria to distinguish late-fall chinook produces highly uncertain results, because of overlap in size with other races. CDFG (1990) sampled juvenile outmigrants at RBDD during 1981-1985 by fishing an inclined plane trap in the east fishway for 12-18 hours per day, and they draw the following conclusion regarding the late-fall race from their studies:

> *"This race has a long outmigration period. Migrants appear April through June as fry and July through November as smolts (Figure 6). Late-fall chinook are most numerous in April, the fry mode. The later smolt mode makes up almost 28% of the outmigrations and is the largest smolt contribution of the four races."*

We have included the CDFG Figure referred to in this quote as our Figure 16. It does appear clear from this and other sampling that late-fall spawners have a greater tendency to produce yearling smolts than the spring-run and fall-run segments of the population.

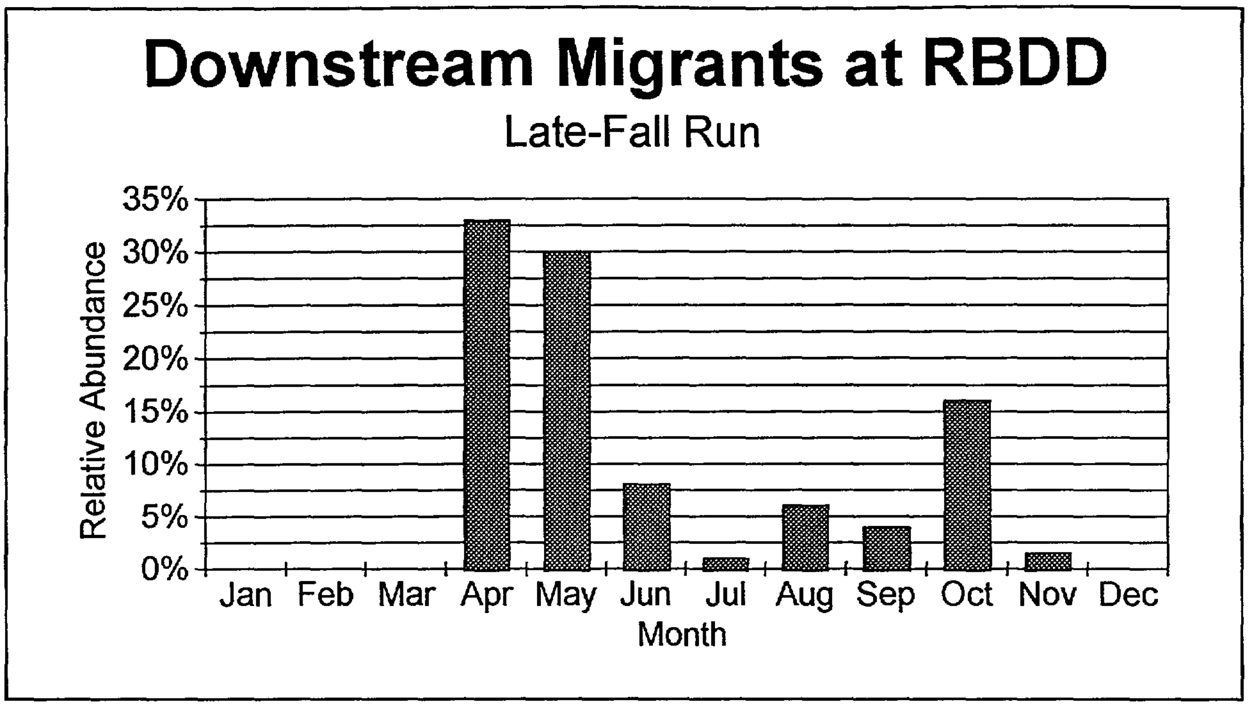


Figure 16. Percentage of total juvenile chinook outmigrants classified as late-fall run that past Red Bluff Diversion Dam each month, 1981, 1982, 1984, and 1985. From CDFG (1990).

CDFG (1990) used length criteria to assign the race of juveniles captured in their sampling, and the monthly length frequency of all fish they captured, including the dividing lines they used to distinguish races, were shown previously in Table 7. Careful examination of Table 7 shows by reading across rows that the dividing lines between fall and late-fall juveniles are indistinct, and that the fish classified as late-fall chinook appear to be a continuation of those classified as fall chinook. These data are consistent with the conclusion that late-fall chinook (1) cannot be clearly separated from fall chinook based on length, and (2) that late-fall chinook may be a late tail of the fall chinook run, rather than a distinct population. Only the juvenile winter-run chinook show a distinctive length frequency at RBDD (see Table 7).

We did not review data further downstream in the main stem, because the distinction of races, based on juvenile lengths, is certain to become even more confused downstream. Peak spawning of spring chinook is 5-6 months earlier than that of late-fall chinook, yet both runs from different portions of the basin are producing emergent fry in April and May. We previously cited work by CDFG in Deer Creek that showed emergent spring chinook fry were present into June (Harvey 1994). Table 7 shows that most late-fall chinook emerge as fry in April and May.

The time and size that yearling chinook arrived in the San Francisco Bay-Delta is apparent from the fish salvaged at the state and federal export pumps in the south Delta. Salvage data at the Central Valley Project pumps during December 1991 through May 1992 show that yearling outmigrants tended to pass in late February through March, and fit the size criteria for either late-fall or winter-run (see Figure 10; Brown and Greene 1994). Further analysis of length frequencies of fin-clipped fish salvaged at the state pumps that year showed that the length frequencies of the late-fall chinook released from Coleman Hatchery completely overlapped the length frequencies of marked winter-run released from Coleman Hatchery (Brown and Greene 1994). We note further that the lengths of spring-run yearling chinook trapped in Deer Creek (Harvey 1994) fall within the criteria for late-fall and winter-run yearlings. Thus, the yearling migrants salvaged at the pumps from mid February to mid April are likely a mixture of spring, late-fall, and winter-run juveniles. This is born out by the genetics data from fish salvaged at the state water project, as described in the section on spring chinook (see Table 8).

Habitat Characteristics

The annual temperature pattern in the Sacramento River above Red Bluff is the same as that described for spring chinook, except spawning and incubation occur at different times. Mean river temperatures generally do not exceed 15°C at any time, and remain near 10°C through the winter (Turek 1990) when late-fall chinook spawn. Thus, egg development would be rapid, but fry emergence would be later than for the "spring-run" and "fall-run" portions of the population spawning above RBDD.

Genetic Profile

Preliminary analysis of data on microsatellite DNA has indicated there is only a small genetic difference between fall and late-fall run chinook (see Genetic Profile section for Spring Chinook). Although the difference is small, it has been consistent for samples from several groups of fish, which indicates there may be little interbreeding of the two races (personal communication, M. Banks, Bodega Marine Laboratory, U.C. Davis, California). However, genetics samples have not been taken over a time continuum of spawners from October through February at Coleman National Fish Hatchery to determine if the change in gene frequencies is gradual or abrupt. A gradual change in gene frequencies across spawning time would indicate interbreeding of the early and late portions of each race.

TRENDS IN ABUNDANCE

The evidence reviewed thus far suggests that the spring-run, fall-run and late-fall run chinook passing RBDD form a continuum run timing and spawning timing. As a result, there is imprecision in distinction of these runs in the counts of adults passing RBDD, and in the catches of juveniles in traps at RBDD. The counts of adult chinook passing RBDD can be useful for evaluating changes in the relative proportion of chinook that pass the dam during specific periods of the year. Only the winter-run above RBDD appears to be distinctive in its spawning and passage timing. Analyses of recent population trends in wild-type spring chinook should be limited to Deer and Mill Creeks where these populations persist in an apparently native form.

SPAWNER ABUNDANCE

Sacramento Main Stem

We determined the abundance of natural spawning chinook above RBDD by subtracting returns to Coleman Hatchery from the counts at RBDD (Table 11). We excluded run size estimates after 1985 for late-fall chinook and after 1993 for spring and fall chinook, because counts were incomplete for a large portion of those runs (gates at RBDD were out). The abundance of natural spawners above RBDD for each race varied several fold since 1970, and there was no consistent long-term trend for either fall or late-fall chinook (Figure 17). Additionally, the variation was poorly correlated to the returns of fish to Coleman National Fish Hatchery, which indicates that the abundance of natural spawners is probably not determined by the number of hatchery fish that fail to enter the hatchery. Cramer (1991) analyzed all CWT's recovered from Coleman Hatchery fall chinook through the 1984 brood, and concluded, "the predicted proportion of hatchery fish (*fall-run*) in the escapement varied from 17% to 79% and averaged 40% during 1975 to 1987." Thus, the analyses completed by Cramer (1991) led to a conclusion similar to that derived in this report: there is substantial natural production of chinook in the Sacramento River above Red Bluff Diversion Dam. This conclusion is further corroborated by the large number of juvenile chinook estimated to pass Red Bluff Diversion Dam (Vogel et al. 1988) each year before hatchery fish were released.

The meaning of spring chinook counts under 1,000 fish during 1991-1993 is unclear. We showed previously that the median and 90 percentile passage dates at RBDD for spring chinook shifted over one month later between the 1970's and the 1980's. This change in timing increased the overlap in run timing of spring and fall chinook. If run timing for spring chinook has continued to shift later, many spring chinook may now be classified as fall chinook. Further, such changes could not be detected from the RBDD counts, because draw-down of the reservoir now begins September 15, while a large share of the run has yet to pass the dam. Given these uncertainties associated with the RBDD counts in the 1990's, we believe the best available indices for recent trends in abundance of naturally spawning spring chinook are the escapement estimates for Deer and Mill creeks. Trends in spring chinook spawner abundance in Butte Creek and the Feather River should be considered separately, because genetics data (at least for fish in Butte Creek) indicate they differ substantially from spring chinook in Deer Creek, Mill Creek, and the upper Sacramento River.

Table 11. Numbers of adult and jack chinook classified as spring, fall, and late fall that passed Red Bluff Diversion Dam and either spawned naturally or entered Coleman National Fish Hatchery, 1970-1995. RBDD counts from CDFG, Red Bluff. Hatchery returns from USFWS, Red Bluff.

Run	RBDD Counts			Coleman Returns	
Year	Late Fall	Fall	Spring	Fall	Late
1970	16,741	75,650	3,652	6,356	3,060
1971	32,651	63,918	5,830	3,645	1,209
1972	23,010	42,503	7,346	3,221	549
1973	7,855	53,891	7,762	4,540	403
1974	19,659	54,952	3,933	3,036	705
1975	16,198	63,091	10,703	3,312	1,498
1976	10,602	60,719	25,983	4,446	609
1977	12,586	40,444	13,730	5,636	756
1978	10,398	39,826	5,903	1,882	1,853
1979	9,481	62,108	2,900	8,729	829
1980	6,807	37,610	9,696	9,503	867
1981	4,913	53,744	21,025	13,223	2,605
1982	15,190	48,431	23,438	19,760	1,886
1983	7,163	42,046	3,931	8,756	958
1984	8,436	73,254	8,147	21,648	628
1985	8,286	97,707	10,747	16,320	388
1986	Inc	104,873	16,691	12,481	788
1987	Inc	100,063	11,204	16,321	803
1988	Inc	139,966	9,781	13,579	457
1989	Inc	84,057	5,255	11,986	882
1990	Inc	55,710	3,922	14,635	192
1991	Inc	44,937	773	10,683	279
1992	Inc	41,376	431	7,275	903
1993	Inc	56,896	388	7,587	752
1994	Inc	Inc	Inc	18,991	716
1995	Inc	Inc	Inc	26,677	1,385

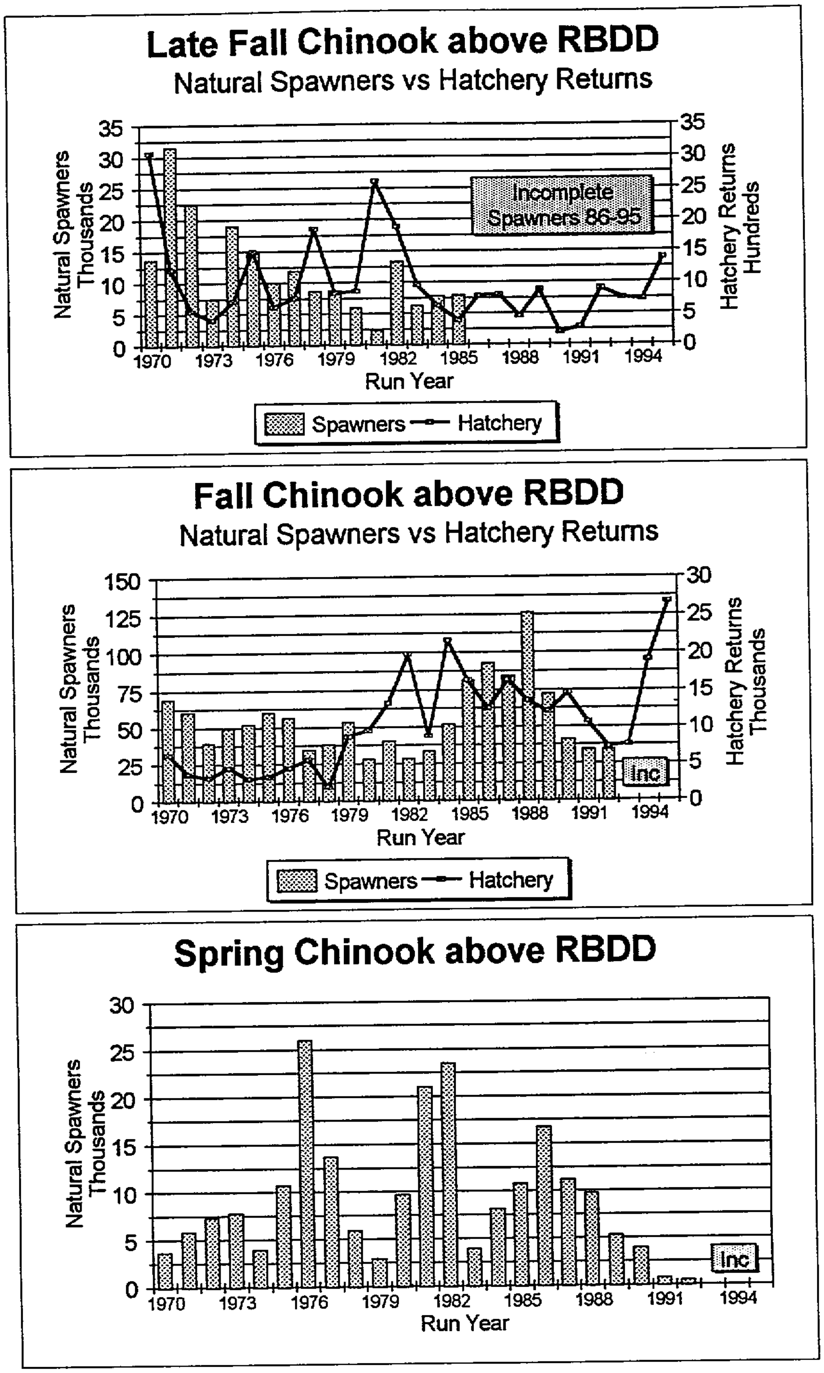


Figure 17. Annual abundance of chinook spawning naturally (spawners) above Red Bluff Diversion Dam, compared to the number of each race entering Coleman National Fish Hatchery (hatchery). Data from Table 11.

Deer, Mill, and Butte Creeks

Spawner escapement of spring chinook into Deer and Mill Creeks has been estimated in most years since 1970 by CDFG. Escapements were greatest in the 1970's, and peaked in 1975 (Figure 18). Returns have remained at lesser numbers without any clear trend since 1975 (Figure 18). The proportion of spring chinook harvested in the ocean each year during 1974-76 (≈60%) was probably about 10% less than in the 1990's (≈70%), as indicated by the harvest rate index for Central Valley chinook salmon (PFMC 1995; see Figure 35). Thus, the total contribution (catch + escapement) of spring chinook from Deer and Mill creeks during the early 1970's was greater than in years since then.

Spawner escapement of spring chinook into Butte Creek jumped sharply in recent years, and has varied in pattern different from that for Deer and Mill creeks (Figure 18). Interpretation of these trends should await genetic analyses spring chinook from Feather River Hatchery (FRH) to determine if many of the Butte Creek fish may have originated there. We believe it likely that a high portion of fish in Butte Creek are destined for Feather River Hatchery, and were attracted into Butte Creek by the Feather River water that makes up lower Butte Creek throughout the summer. Further, juvenile spring chinook from Feather River were released in Butte Creek during 1983 and 1985.

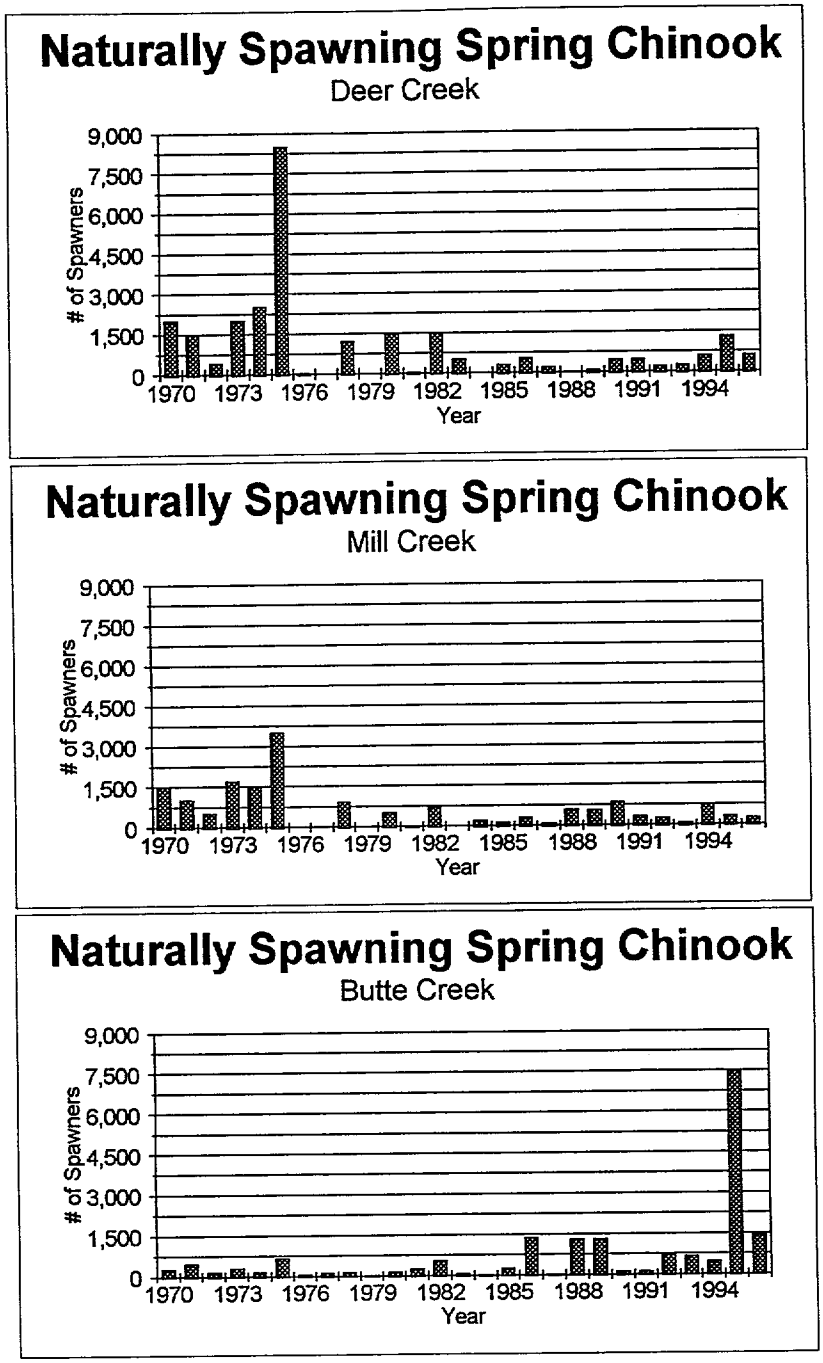


Figure 18. Annual estimates of naturally spawning spring-run chinook in Deer, Mill, and Butte creeks. Data through 1991 from Mills and Fisher (1994). Data for 1992-95 from CDFG, Red Bluff.

JUVENILE ABUNDANCE

The abundance of juveniles each year can provide an index of natural production; however, we found no satisfactory index of juvenile abundance extending for more than two years. Indices of juvenile spring-run abundance from trap catches are meaningful within Deer, Mill and Butte creeks, but the present time-series of data is too short to assess trends. We found most measures of juvenile spring chinook in the main-stem Sacramento to be unsatisfactory as an index of production, because results were contradictory between different measures within the same year. For example, trawl catches in the Delta of juveniles classified as spring chinook follow a different temporal pattern and different relative magnitudes between years than catches at standard seining stations. The inconsistency between indexes probably is aggravated by erroneous assignment of race, based on fish length.

It is generally agreed by fishery managers that juvenile spring-run chinook in the lower Sacramento River cannot be reliably distinguished from fall-run based on size at a given time of year. Currently, a growth curve developed by CDFG is used to assign juvenile chinook to one of the four Sacramento River chinook runs. The classification system works on the premise that, at any given time of year, there exists a distinguishable size difference among the four races of juvenile chinook. However, in the case of spring, fall, and late-fall juveniles, size overlap prevents the precise classification of individuals to a run. The overlap of juvenile lengths is the result of juveniles from the two races growing in habitats with different temperature regimes that produce overlap of emergence times and different growth rates.

The inaccuracy of using length criteria to distinguish juvenile spring chinook from juvenile fall chinook is especially apparent from the sampling in Deer, Mill and Butte creeks where most production of wild spring chinook occurs. The <u>mean</u> lengths of juvenile chinook captured in the Deer Creek screw trap during November, 1994 through March 1995 are outside the entire size range identified by CDFG for spring chinook at that time (Table 12).

Because of the inability to accurately distinguish races of juvenile chinook once they are in the main-stem Sacramento River, we believe that existing analyses of juvenile abundance for spring and late-fall chinook in the lower Sacramento River can be misleading. An additional problem with sampling of juvenile chinook in the main stem is that hatchery and natural juveniles cannot be distinguished. **Therefore, we recommend that juvenile abundance indices in the main stem Sacramento should not be used to evaluate population trends of naturally producing chinook until a representative proportion of all hatchery fish are marked, or until a mixed stock analysis of known accuracy can be performed with DNA genotypes.**

FACTORS INFLUENCING POPULATION TRENDS

A key part of determining the probability of extinction lies in understanding the factors causing decline and whether or not those factors have changed. If it can be clearly demonstrated why the populations have declined, then we can determine with confidence what actions are needed to reverse the decline.

Table 12. Fork lengths of juvenile chinook sampled in Deer and Butte creeks compared to the length intervals used by CDFG to identify spring chinook. Length data from Harvey (1995) and K. Hill, personal communication, CDFG, Rancho Cordova. Length criteria supplied by USFWS, Stockton, California.

Approximate Date Ending	CDFG Spring-run Criteria Min	CDFG Spring-run Criteria Max	1994 Butte Cr Mean Length	1995 Butte Cr Mean Length	1994 Deer Cr Mean Length
Oct 30	0	35	-	-	-
Nov 15	0	39	-	-	-
Nov 30	0	44	-	-	-
Dec 15	36	48	-	-	-
Dec 30	40	53	-	-	-
Jan 15	45	59	37	-	-
Jan 30	49	66	38	36	-
Feb 15	55	73	39	35	34
Feb 30	59	79	48	35	34
Mar 15	66	88	62	35	36
Mar 30	72	97	74	49	36
Apr 15	80	108	80	87	34
Apr 30	89	119	81	75	34
May 15	98	132	78	93	59.5
May 30	108	145	91	84	59.5
Jun 15	120	162	-	94	72.5
Jun 30	133	178	-	-	72.5
Jul 15	146	197	-	-	-
Jul 30	161	217	-	-	-
Aug 15	179	242	-	-	-
Aug 30	199	268	-	-	-
Sep 15	220	269	-	-	-
Sep 30	243	269	-	-	-
Oct 15	268	269	-	-	104
Oct 30	0	35	-	-	104
Nov 15	0	39	-	-	91
Nov 30	0	44	-	-	91
Dec 15	36	48	-	-	93
Dec 30	40	53	-	-	93
Jan 15	45	59	-	-	95
Jan 30	49	66	-	-	95
Feb 15	55	73	-	-	94
Feb 30	59	79	-	-	94
Mar 15	66	88	-	-	106
Mar 30	72	97	-	-	106

All lengths are in mm.
Butte Creek data from Kathy Hill, CDFG.
Deer Creek Data from Harvey, 1994.
Spring-run length criteria from CDFG Sacramento Basin Chinook Race Designation Criteria

In order to determine if and in what way smolt-to-adult survival and harvest rates have changed, we used recoveries of coded-wire tagged (CWT) fish to estimate these parameters from the late 1970's to the present. We began by applying a procedure known as "cohort analysis" of marked groups released from Sacramento Basin hatcheries. Cohort analysis is presently the method used by the Pacific Salmon Commission to estimate ocean harvest rates as a basis for setting ocean harvest regulations for salmon in the U.S.-Canada Treaty area (1988). Cohort analysis is a method that can be used with recoveries of CWT fish to estimate the survival, the proportion harvested, and the proportion that mature at each age. Cohort analysis is an accounting procedure that proceeds backwards in time from the oldest age group to the youngest using recovery data to reconstruct the population at successively younger ages, so that the proportion of fish maturing and harvested at each age can be estimated.

ESTIMATION OF SURVIVAL AND HARVEST RATES BY COHORT ANALYSIS OF MARKED GROUPS

Estimated recoveries as catch or as spawners from groups of marked spring chinook from Feather River Hatchery and late-fall chinook from Coleman National Fish Hatchery provided the data needed to complete a cohort analysis for each group. All fish implanted with CWT's are also marked with an adipose fin clip (Ad), so the fish could be identified as having a CWT.

Cohort analysis required that the number of CWT-Ad fish which end up in each of four possible categories be estimated: 1) those captured in ocean fisheries, 2) those captured in river fisheries, 3) those spawned in a hatchery, and 4) those spawned naturally. Excellent sampling programs are in place to recover CWT's from fish harvested in ocean fisheries, and all fish returning to hatcheries are examined for CWT's. On the other hand, natural spawning is only partially surveyed and in-river sport catch was not surveyed in most years.

We used the Pacific States Marine Fisheries Commission (PSMFC) database as our source for CWT recoveries in the ocean, and the CDFG database as our source for recoveries in freshwater. The number of CWT's recovered in ocean fisheries have been expanded by the recovering agency to account for the sampling fraction, and all recoveries (plus their expansions) are compiled in the regional database maintained by PSMFC.

METHODS

Analytic Procedure

Survival to age 2, maturity rate for each sex at each age, and ocean harvest rate at each age were estimated by cohort analysis for each CWT group. The procedure is simply an expanded accounting system of the number of fish from each release group that were caught in ocean fisheries, caught in river fisheries, escaped to spawn in the river, or escaped to spawn in a hatchery. Additionally, estimates of the number of fish that died between each of these events are incorporated into the accounting. The procedure begins with the oldest age group and works back through time to reconstruct the population at successively younger ages. Calculations differ between spring and late-fall chinook, because each ocean harvest season must be split into the spring and summer periods for spring chinook, but not for late-fall chinook. Calculations are based on the relationship:

Spring Chinook

$$\text{Recruit}(i) = [\text{Recruits}(i+1) / \text{Survive}(i+1)] + [\text{Spawn}(i) + \text{Stray}(i) + \text{Rcatch}(i)] + \text{OcatchB}(i) + [\text{OcatchA}(i+1) / \text{Survive}(i+1)]$$

Where

Recruit(i)	is the number of fish alive at age i on June 30
Spawn(i)	is the number of fish at age i returning to the hatchery
Stray(i)	is the number of fish at age i that spawn in the river or other hatcheries
Rcatch(i)	is the number of fish at age i caught in river fisheries
OcatchA(i)	is the number of fish at age i caught in ocean fisheries in the spring (before July 1)
OcatchB(i)	is the number of fish at age i caught in ocean fisheries in the summer (after June 30)
Survive(i)	is the proportion of fish that survive through winter from age i to age i+1

Late-Fall Chinook

$$Recruit(i) = [Recruits(i + 1) / Survive\ (i + 1)] + [Spawn(i) + Stray(i) + Rcatch(i)] + Ocatch(i)$$

Where

Recruit(i)	is the number of fish alive at age i in the spring when harvest begins
Spawn(i)	is the number of fish at age i returning to the hatchery
Stray(i)	is the number of fish at age i that spawn in the river or other hatcheries
Rcatch(i)	is the number of fish at age i caught in river fisheries
Ocatch(i)	is the number of fish at age i caught in ocean fisheries
Survive(i)	is the proportion of fish that survive through winter from age i to age i+1

These components of the cohort accounting are diagramed in Figures 19 and 20. Sacramento spring and late-fall chinook occasionally survive to age 5, so we began the analysis at age 5 by assuming that no fish would remain alive after age 5.

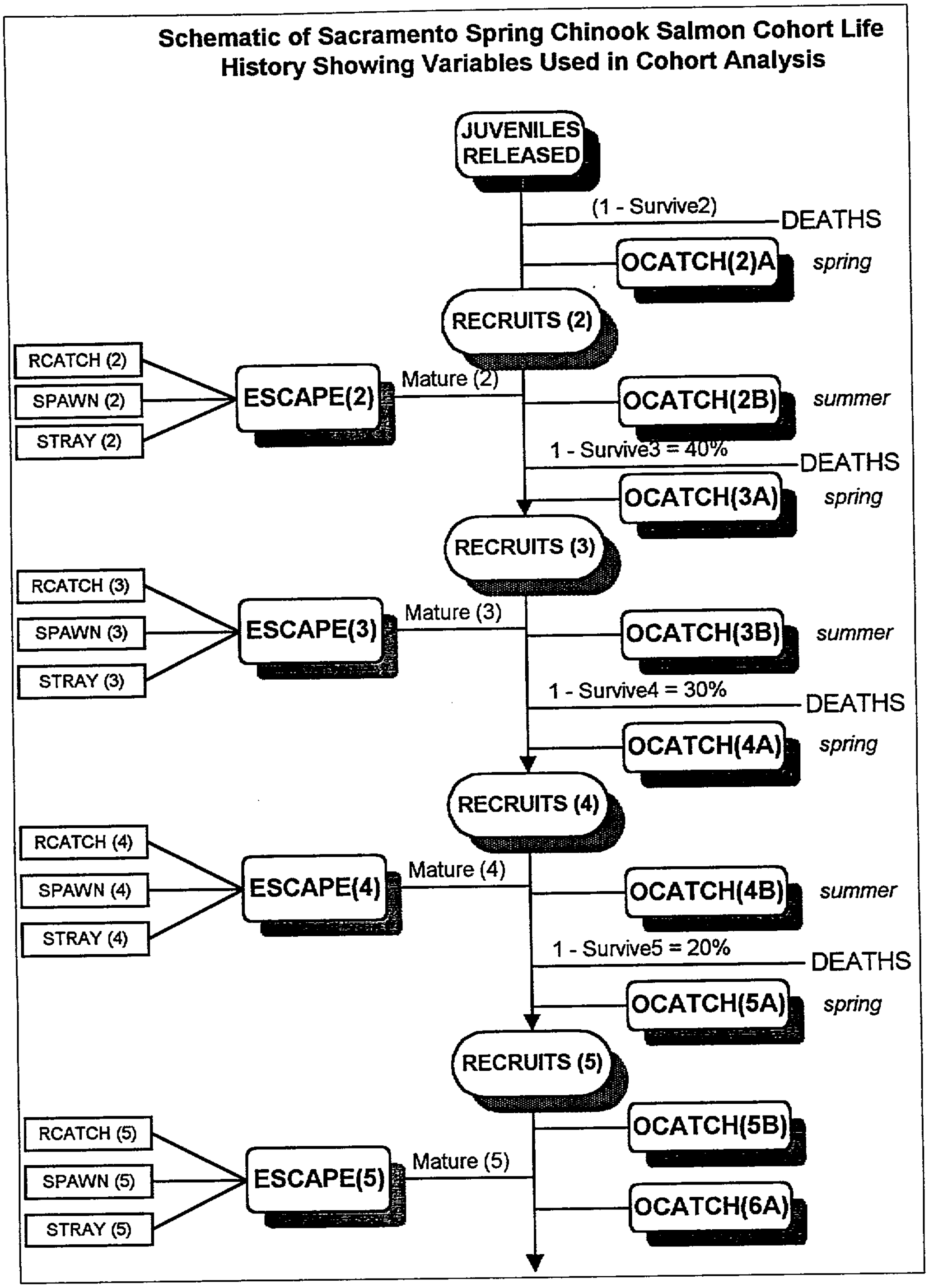


Figure 19. Diagram of general life-history categories accounted for in the cohort analysis of spring chinook. In the actual analyses, we accounted separately for males and females among chinook.

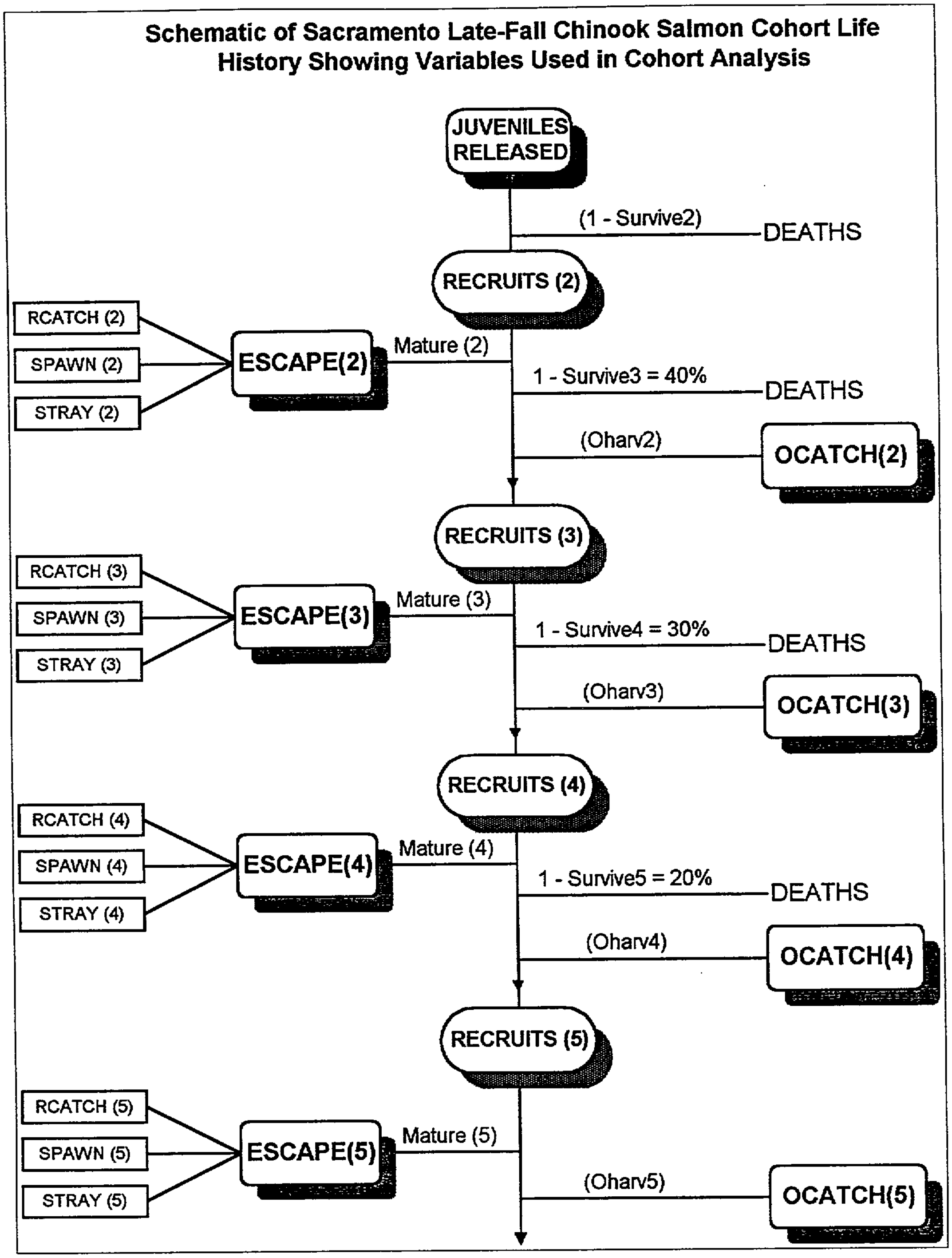


Figure 20. Diagram of general life-history categories accounted for in the cohort analysis of late-fall chinook. In the actual analyses, we accounted separately for males and females among chinook.

We assumed that ocean harvest of spring chinook through June included fish that matured that year, and that harvest of spring chinook after July 1 was only on fish that would not mature that year. Ocean harvest of late-fall chinook takes both maturing and immature fish through the entire season. We used the frequency distribution for month-of-catch in the ocean fisheries to determine that spring chinook continue to be caught through June in the year they are maturing. This is clearest from catches of age 5 spring chinook, which were all taken in June and July (Figure 21). Rarely do fish return to the hatchery at age 6, so most of the fish caught at age 5 must have been on their way to home to spawn. The age 4 fish also show highest catches in May and June, although the fishery remains open through the summer. By contrast, ocean catches of late-fall chinook, which have a similar geographic distribution of catch to that of spring chinook, peak in August. Late-fall chinook remain in the ocean throughout the summer, so the timing of their catch probably reflects the timing that would be expected for catch of non-maturing spring chinook. Therefore, we used June 30 as the cutoff date after which all catches of spring chinook were assumed to be on immature fish. Spring catches prior to June 30 were assumed to harvest mature and immature spring chinook at an equal rate, ie. the cohort model did not move maturing fish out of the ocean until July 1. There would be some error in this assumption, because angler catches in freshwater indicate that many FRH spring chinook enter freshwater prior to July 1, but we assume this was compensated by a similar number of fish that entered freshwater after July 1.

Once we calculated the number of recruits at the oldest age (age 5), we had to assign natural survival rate to calculate the expanded number these fish would have represented at the time of recruitment to age 4. All natural mortality was assumed to occur in the winter between seasons of ocean fishing.

We assumed:

Survive(2) = 0.6

Survive(3) = 0.7

Survive(4) = 0.8

These are the over-winter survival rates assumed by the Pacific Salmon Commission (PSC 1988) for chinook salmon.

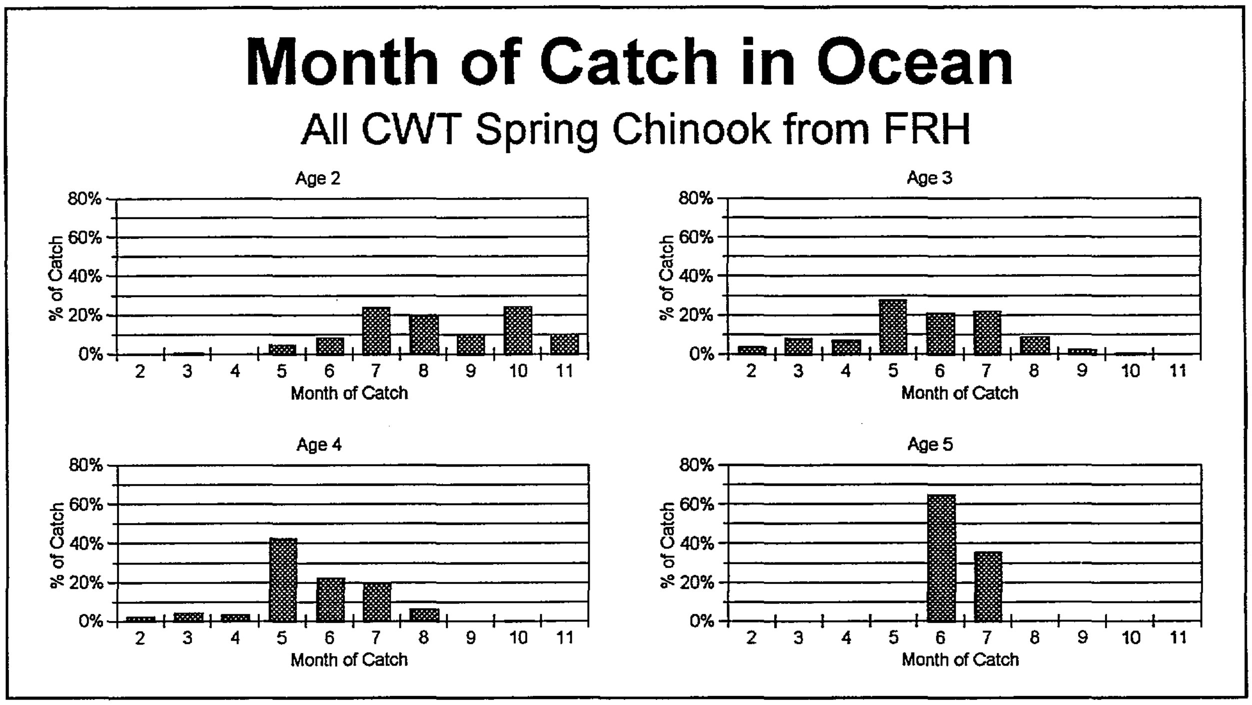


Figure 21 Month of catch in the ocean at each age for CWT marked spring chinook reared at Feather River Hatchery, 1975-1986 broods. Data from PSMFC database.

After we extended this procedure backwards in time to age 2, we had all of the information necessary to calculate survival rate to age 2, maturity rates at age, and ocean harvest rates at age. These estimates were derived as follows for spring chinook (ChS), and late-fall chinook (ChLF):

Survive(2)	= Recruit(2)/Number released
Escape(i)	= Rcatch(i) + Spawn(i) + Stray(i)
Mature(i,ChS)	= Escape(i)/Recruit(i)
Mature(i,ChLF)	= Escape(i)/[Recruit(i)-Ocatch(i)]
OharvA(i,ChS)	= OcatchA(i)/[Recruit(i) + OcatchA(i)]
OharvB(i,ChS)	= OcatchB(i)/[Recruit(i) - Escape(i)]
Oharv(i,ChS)	= OharvA(i) + OharvB(i)*(1-OharvA(i))
Oharv(i,ChLF)	= Ocatch(i)/Recruit(i)

Different equations for spring chinook maturity and ocean harvest rates were necessary, as shown above, because maturing spring chinook leave the ocean each year in the middle of the harvest season, while late-fall chinook mature after harvest for the season is complete.

Sex Composition

We included additional levels of accounting to the cohort procedure described above, such that maturity rates could be estimated for each sex at each age. CWT data provided information on sex composition at each age from fish returning to the hatchery or recovered on the spawning grounds.

We assumed the sex composition at a given age for fish returning to the hatchery would be the same as for fish caught by anglers in the river. We did not need to make assumptions about fish in the hatchery, because sex was identified for those fish. If the sex composition at a given age had to be determined from a sample size of less than 10 expanded CWT recoveries, we used the average sex composition at that age calculated from all broods with n >10. The sex composition of the ocean harvest was assumed to be equal to that among all subsequent returns (all ages combined) to the hatchery from that cohort.

Accounting for In-river Harvest

In river harvest was not surveyed for either spring or late-fall chinook in most years, but significant fisheries occur. There is a popular fishery for spring chinook in the Feather River which Fred Meyer (personal communication, CDFG, Rancho Cordova) estimates to harvest about 10% of the run. Spring chinook from Feather River Hatchery (FRH) have also been found to produce a substantial fishery from late June through August in the lower American River (personal communication, F. Meyer, CDFG, Rancho Cordova). These fish are apparently attracted into the mouth of the American River by cooler water temperatures than in the main Sacramento River. Harvest in the American River is estimated to be about 20% of the FRH run (personal communication, F. Meyer, CDFG, Rancho Cordova). Accordingly, we assumed the overall freshwater harvest rate on FRH spring chinook was 30% for all CWT groups.

There is little angling effort during winter for late-fall chinook, so we assumed the in-river harvest was zero.

Accounting for Natural Spawning

Late Fall Chinook

Spawned carcasses of late-fall chinook are not surveyed, so there are no recoveries of naturally spawning CWT's. CDFG completes aerial counts of redds in years since 1982 when water visibility permits. Generally about 89% of the redds observed in the main stem are above Red Bluff Diversion Dam (Table 13). Accordingly, we assumed that 10.7% of CWT's were in the unsampled area below Red Bluff Diversion Dam.

Table 13. Aerial counts of late-fall chinook redds in the Sacramento River above and below Red Bluff Diversion Dam. Water conditions prevented counts in the years that show no data. Data from personal communication, F. Fisher, CDFG, Red Bluff.

Year	Below	Total	%Below
1980			
1981			
1982			
1983			
1984			
1985	33	178	18.5%
1986	5	141	3.5%
1987			
1988	27	542	5.0%
1989			
1990	30	207	14.5%
1991	21	114	18.4%
1992	5	123	4.1%
1993			
		Average	10.7%

It is clear from the counts of adipose-fin clipped chinook passing Red Bluff Diversion Dam during October through April (Table 14) that many late-fall chinook must spawn naturally. The number of CWT's recovered from late fall chinook at the hatchery represents only about half of the adipose fin-clipped late fall run passing Red Bluff Diversion Dam. This proportion varied between years (13.7%-100%) during 1978-1984 (Table 14), the only years for which full counts of fin-clipped fish passing Red Bluff Diversion Dam were maintained. Accordingly, we used these direct estimates of unaccounted fin clips to represent the proportion of CWT fish that spawned naturally in those specific years. For all years without a specific estimate, we used the 1978-1984 average value of 49.4% fin clips reaching the hatchery as the percentage of CWT's accounted for by returns to the hatchery. This average did not include the first run year of 1977, because only age 2 jacks were returning with CWT's in that year, and hatchery personnel may not have examined fish carefully for marks.

Table 14. Number and percentage of fin-clipped chinook passing Red Bluff Diversion Dam (RBDD) during October through April that were subsequently observed at Coleman National Fish Hatchery (CNFH). RBDD expansion includes 10% passage at night, but not for 11% spawning below the dam. Data from personal communication, F. Fisher, CDFG, Red Bluff (TCFF = Tehama Colusa Fish Facility).

Run Year	Counted @ RBDD	RBDD Expanded	Recovered @CNFH	Recovered @RBDD	Recovered @TCFF	Expanded Battle Creek	Trap @ Keswick	% Recovered
1976								
1977	27	30						0.0%
1978	126	139	15	2	2			13.7%
1979	231	254	96	26	12			52.7%
1980	148	163	72	3	3	3	2	51.0%
1981	288	317	78		8	30		36.6%
1982	228	251	82		1	7	62	60.6%
1983	201	221	53		8			27.6%
1984	41	45	44		3			104.2%
							Mean 78-84	**49.5%**

Spring Chinook

Carcasses of naturally spawning spring chinook in the Feather River are only recovered incidentally during surveys for fall chinook. A large portion of hatchery fish are expected to spawn naturally, because the hatchery ladder is generally not opened until early September. Spawning surveys in the Feather River normally begin in mid October, but were started in early October of 1981 in hopes of recovering CWT's from spawning of age 4 fish of the 1977 brood. Only 1 CWT fish was recovered on the spawning surveys compared to 36 in the hatchery. In that year, 469 chinook classified as spring run entered the hatchery, but the estimated total run was 1,200 fish (Fred Meyer (1982) estimated the run was 1,000 spawners plus 200 fish caught by sport anglers). Thus, hatchery escapement was only about 40% of the run. For the purposes of our cohort analysis, we assumed that CWT's recovered in the hatchery represented half of the spawners from each CWT group.

Unsampled Sources of Mortality

One of the two unsampled sources of mortality that we included in the cohort analysis was hooking mortality in ocean fisheries. We assumed shaker deaths were equal to the landed catch at age 2 for both spring and late-fall chinook, and that shaker deaths at age 3 were 5% of the landed catch. These rates were based on data from the Winter Chinook Ocean Harvest Model developed by CDFG (1989). That model was applied to fall chinook and to winter-run chinook and estimated shaker deaths by assuming that 26% of all sublegal fish that were captured and released later died. The number of sublegal fish captured was calculated by assuming that sublegal fish were caught at the same rate as legal-sized fish of the same age, and the proportion that were of legal size in each month was determined from an estimated length-frequency distribution for each age. The average shaker mortality at age 2 for fall chinook during 1985-88 was estimated by the

Winter Chinook Ocean Harvest Model to be equal to 95% of actual landings at age 2 and only about 1% of actual landings at age 3. For winter chinook, shaker deaths averaged 5% of actual landings at age 3. The size of fish in a given month at age 2 varies between races, and spring-run chinook might be slightly larger than fall-run, while late-fall run are likely to be slightly smaller than fall run. Both spring chinook and late-fall chinook that are naturally produced are known to have a greater proportion of yearling smolts than fall chinook, and these fish produced by yearling smolts would be smaller at a given age in the ocean than fish produced by subyearling smolts.

The second unsampled source of mortality that we incorporated in the cohort analysis was the proportion of adults that die while holding in freshwater to await spawning. To account for this prespawning mortality, we assumed that 20% of spring chinook died after the river sport fisheries were complete, but before spawning. McConnaha and Anderson (1992) concluded that 20% was the most representative value for prespawning mortality of spring chinook within subbasins of the Columbia River. We assumed a no prespawning mortality for late-fall chinook, which unlike spring chinook, do not have to hold several months in warm water.

Special Data Treatments

Recoveries from several CWT groups of late-fall chinook were too few to be used in all analyses. We eliminated CWT groups from the analysis of maturity rates, but not survival rates, if the group had less than 200 fish surviving to age 2. These limits were based on the findings of Hankin (1990) that sampling rates of such small populations yielded unreliable results. There were two CWT groups of late-fall chinook from the 1989 brood that produced few adults and that were released at similar times and sizes, so we combined the groups (#052053 and #052054).

We calculated mean parameter values and their 95% confidence intervals for each brood year by using analysis of variance, with brood years as treatments and fish weight at release as a covariate. For most parameters, the raw estimate for each CWT group served as an observation in the analysis. Parameters were expressed as proportions that generally ranged from 20% to 80%. For some parameters that had values often less than 10%, such as survival rate and straying rate, we applied the arcsine transformation before making statistical comparisons. This transformation equalizes the variance of proportions, a condition necessary for proper application of analysis of variance (Snedecor and Cocharan 1967). This transformation has little influence on proportions between 20% to 80%, so it was unnecessary for most of the parameters we analyzed.

FINDINGS FROM COHORT ANALYSIS

We started the analysis for each population parameter by testing whether there were significant ($P<0.05$) differences between CWT groups released at different locations or life stages (e.g. fry, fingerling, smolt) within the same brood. If analysis of variance showed no difference between release ages or locations, we combined the data sets to increase sample size for estimating brood year means of each parameter.

SPRING CHINOOK

Sixteen CWT groups were released during the 1975-1991 broods, but only six groups were released at or near the hatchery. We only used those groups released at or near the hatchery for our analyses, because a high level of straying was likely for those groups released well off station. A high rate of straying was likely to bias our results, because the lack of spawning surveys would have caused spawning escapement to be under estimated. Each of the six groups released at or near the hatchery was from a different brood (no replication), so analysis of variance between broods was not possible. Therefore, we calculated the mean, confidence intervals, and frequency distributions across all CWT groups for each parameter. We were able to use analysis of variance to test for differences between yearling and subyearling releases, because three broods (1975-1977) were released as yearlings and three broods (1984-1986) were released as subyearlings. Parameter estimates for each of the six groups are presented in Table 15.

Table 15. Life history parameters estimated by cohort analysis for six CWT groups of spring chinook released at or near Feather River Hatchery.

TagCode	Br	Release Type	Weight	Date	Location	Release	Survive2	MATR2M	MATR2F	MATRM3	MATR3F	MATR4M	MATR4F	StrayRT	OHARV2
060107	75	Yearling	75.6	12/76	FRH	90,825	2.99%	0.00	0.00	0.19	0.03	0.86	0.86	0.01	0.00
065809	76	Yearling	81	12/77	FRH	71,105	11.00%	0.00	0.00	0.15	0.12	0.90	0.92	0.10	0.11
065812	77	Yearling	75.6	01/25/79	Gridley	50,046	4.19%	0.11	0.00	0.30	0.20	0.73	0.78	0.25	0.02
B61001	84	Subyear	3.44	04/01/85	FRH	48,614	3.92%	0.10	0.01	0.72	0.49	0.74	0.74	0.00	0.03
B61004	85	Subyear	2.4	03/17/86	Gridley	100,699	4.63%	0.05	0.01	0.63	0.51	0.81	0.88	0.00	0.06
B61006	86	Subyear	3.81	03/03/87	FRH	98,392	1.82%	0.03	0.01	0.66	0.70	1.00	1.00	0.00	0.08

TagCode	Br	Release Type	Weight	Date	Location	Release	Oharv2a	Oharv2b	Oharv3a	Oharv3b	Oharv3	Oharv4a	Oharv4b	Oharv4	Oharv5
060107	75	Yearling	75.6	12/76	FRH	90,825	0.00	0.00	0.27	0.21	0.43	0.24	0.93	0.95	0.00
065809	76	Yearling	81	12/77	FRH	71,105	0.00	0.11	0.51	0.51	0.76	0.27	0.89	0.92	1.00
065812	77	Yearling	75.6	01/25/79	Gridley	50,046	0.01	0.02	0.16	0.53	0.61	0.08	1.00	1.00	
B61001	84	Subyear	3.44	04/01/85	FRH	48,614	0.01	0.02	0.20	0.33	0.46	0.28	0.75	0.82	1.00
B61004	85	Subyear	2.4	03/17/86	Gridley	100,699	0.00	0.05	0.24	0.48	0.61	0.30	0.77	0.84	0.44
B61006	86	Subyear	3.81	03/03/87	FRH	98,392	0.02	0.06	0.37	0.34	0.58	0.11		0.11	

Straying

We began our analysis with straying rates, because the number of strays had to be accounted for before survival, harvest, and maturity rates could be estimated. Straying of hatchery chinook was minimal. We use the term "stray" to refer to any hatchery fish spawning outside of the main Feather River.

We use the term "straying rate" to refer to the following quantity:

Straying Rate = No. Strays / Freshwater Escapement

where the number of strays and the freshwater escapement refer specifically to the group of interest.

Straying rate was 0% for all three subyearling groups, and ranged from 1% to 25% between the three yearling groups (Table 15). We did not carry analysis of this particular parameter any further for spring chinook, because the sampling was inadequate to accurately estimate straying. Most of the strays were recovered in the upper Sacramento River at Red Bluff Diversion Dam, Tehama Colusa Fish Facility, or Coleman National Fish Hatchery. The one group with an estimated 25% straying rate was trucked a short distance downstream (to Gridley) for release, so it may have encountered unique circumstances that caused the high straying.

Survival

We used estimates of survival to age 2 as the primary index of smolt-to-adult survival. Studies by Fisher and Pearcy (1988) with sampling of juvenile coho in the near-shore ocean have demonstrated that most of the between-year variation in smolt-to-adult survival takes place during the first few months after juveniles enter the ocean. The same is probably true for chinook salmon.

Smolt-to-age 2 survival ranged over 6-fold from 1.8% to 11.0% between all six groups (Table 15). Mean survival was 4.8%. There was no significant difference between yearling and subyearling releases (P=0.38). The frequency distribution of estimated survivals shows that the high survival brood (11.0% in 1976) was substantially different from the other five broods (1.8% to 4.6%) (Figure 22).

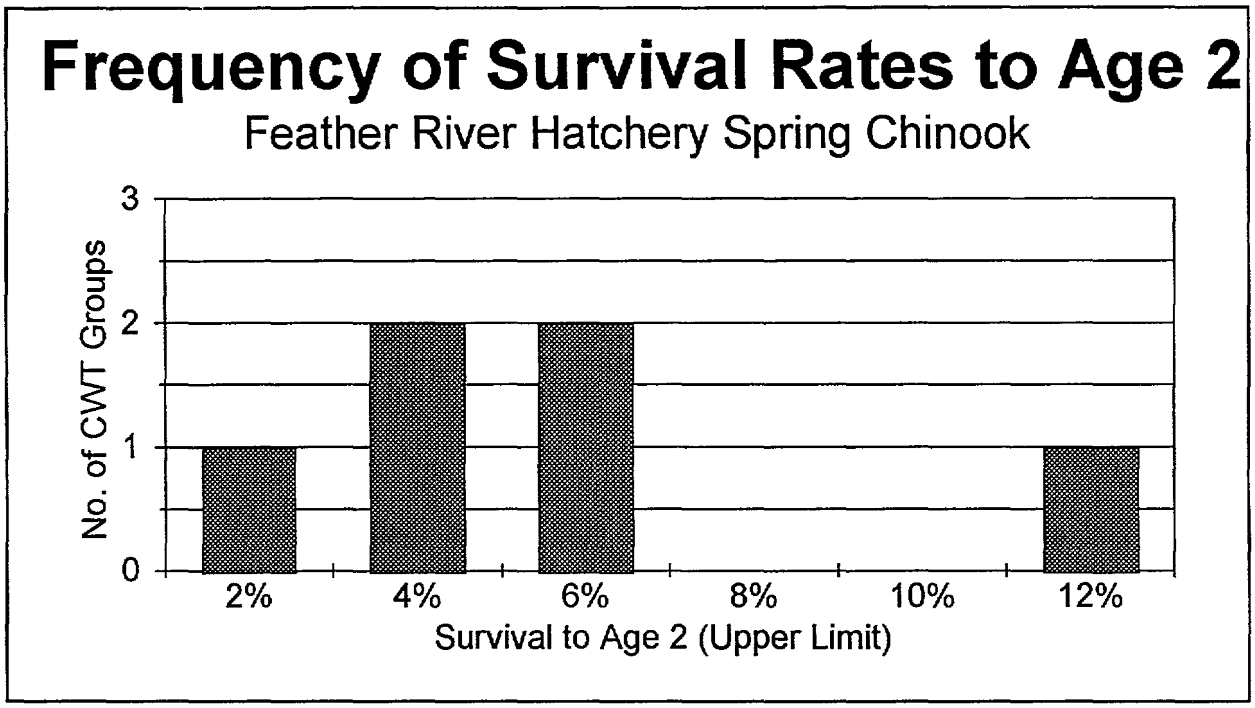


Figure 22. Frequency distribution of smolt-to-age 2 survival rates estimated for CWT groups of spring chinook released at or near Feather River Hatchery, 1974-76 and 1984-86 broods. Both subyearling and yearling releases included.

Age at Maturity

The proportion of fish maturing at each age, determines the average number of years a fish must survive in the ocean and be exposed to ocean fisheries, and influences the size a fish will be when it leaves the ocean and enters freshwater. Because the maturity rates at each age have such an influence on the cumulative harvest rates a cohort experiences over its lifespan, we will present the analyses of maturity rate before we enter the discussion of harvest rates.

Sex Composition

Previous analyses of maturity rates for chinook salmon have demonstrated that maturity rates differ between the sexes. Females tend to mature at an older age than males (Cramer and Vigg 1996; Cramer et al. 1996). Generally, the delayed maturity of females, compared with males, results in higher harvest rates on females than males. For that reason, we estimated maturity and harvest rates at each age separately for males and females.

The mean proportion that males composed each year of all CWT spring chinook returning to the Feather River Hatchery illustrates that females mature at an older age, and compose a larger percentage of age 3 and 4 fish than males (Figure 23). Males generally composed 80% to 100% of age 2 fish, and about 40% of the age 3 and 4 fish. In our cohort analysis, when we lacked sufficient sex data for a specific age and year, we used the mean values of 91% males at age 2, 45% males at age 3, and 39% males at age 4 and 5, as derived from years that had at least 10 CWT recoveries for which sex was recorded.

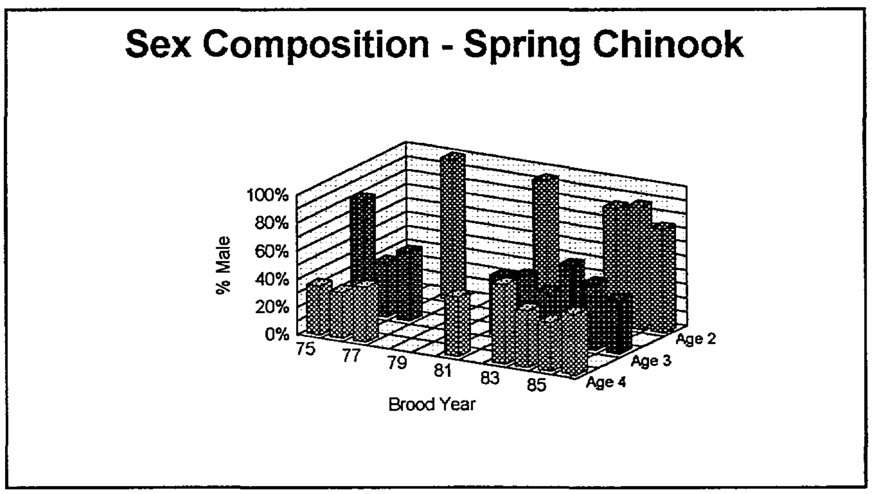


Figure 23. Mean percentage that males composed at each age for each brood year of CWT-Ad marked spring chinook returning to Feather River Hatchery. Years without bars had insufficient or no data.

Male Maturity Rates

The proportion of male spring chinook that matured at each age from the six broods for which we had estimates ranged from 0% to 11% at age 2, 19% to 72% at age 3, and 73% to 100% at age 4 (see Table 15). The proportion of males that matured at age 3 was significantly greater ($P < 0.01$) among fish released as subyearlings (mean = 67%) than among those released as yearlings (mean = 21%; Figure 24). This difference is consistent with findings for spring chinook in the Willamette Basin (Cramer et al. 1996). Maturity rates of females at age 3 showed the same trend as males, and there was no significant difference between males and females. There was no significant difference ($P= 0.83$) between release types in maturity rate at age 4, and these rates were spread evenly between broods from 75% to 100% (Figure 25). The proportion that matured at age 2 did not appear to be related to the proportion that matured at age 3. Any remaining males matured at age 5.

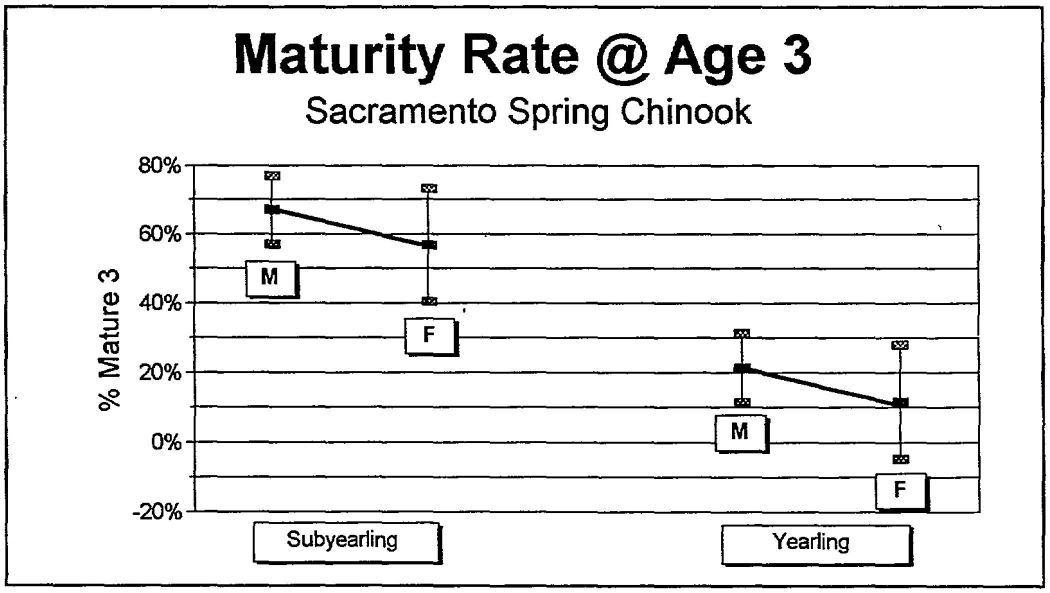


Figure 24. Means and 95% confidence intervals for estimated percentage of male and female spring chinook that matured at age 3 from juveniles released as subyearlings or yearlings.

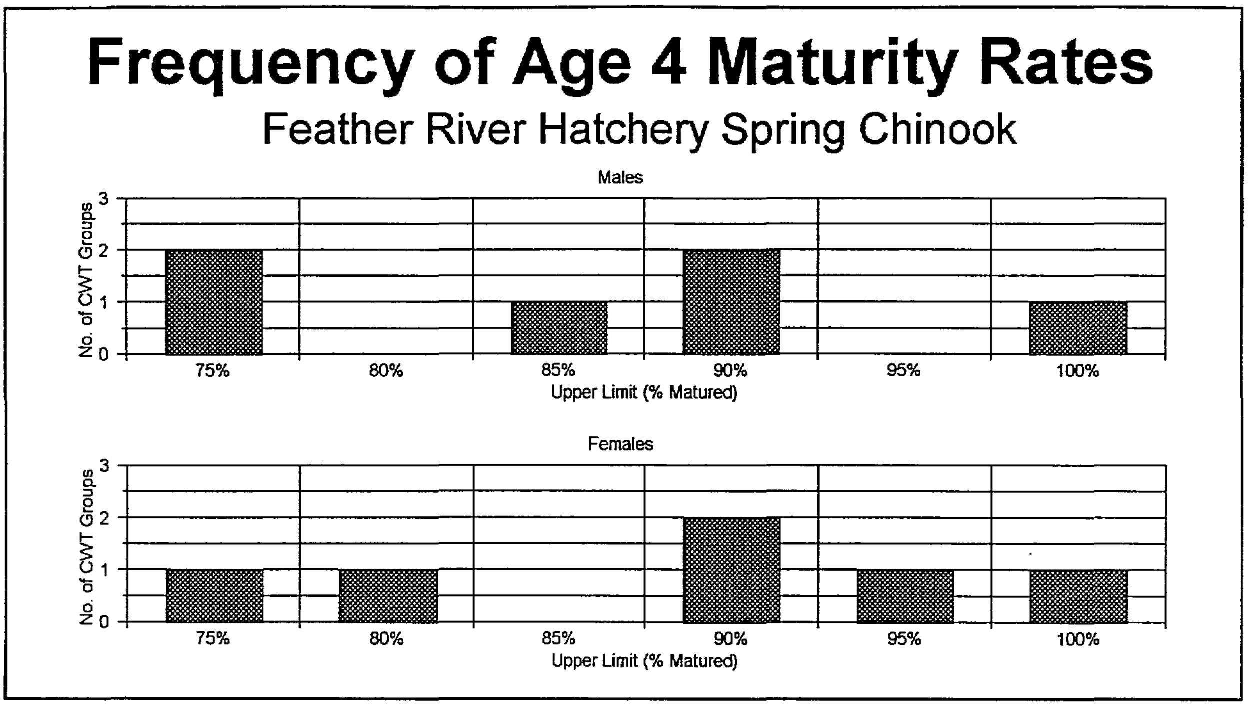


Figure 25 Frequency distribution of maturity rates at age 4 estimated for CWT groups of spring chinook released at or near Feather River Hatchery, 1974-76 and 1984-86 broods. Both subyearling and yearling releases included.

The finding that maturity is delayed among fish released as yearlings compared to those released as subyearlings has important implications regarding production of wild spring chinook. Sampling of wild juveniles (discussed in a separate section of this report) shows that most emigrate from Deer and Mill creek in the fall and winter, similar to the release time of hatchery yearlings. Thus, the proportion of wild chinook maturing at age 3 is probably in the vicinity of 20%, which means that most face ocean harvest through age 4.

Female Maturity Rate

The proportion of female spring chinook that matured at each age from the six broods for which we had estimates ranged from 0% to 1% at age 2, 3% to 70% at age 3, and 74% to 100% at age 4 (see Table 15). The proportion that matured at age 3 and 4 did not differ significantly from that for males. As was true for males, the proportion of females that matured at age 3 was significantly greater ($P < 0.01$) among fish released as subyearlings (mean = 57%) than among those released as yearlings (mean = 12%; see Figure 24). The proportion of wild females from Deer and Mill creeks maturing at age 3 is probably in the vicinity of 10% (because most smolt as yearlings), which means that most face ocean harvest through age 4.

Ocean Harvest Rates

We divided the harvest rate at each age into that which occurred in the spring (before July 1, denoted as "a") and that which occurred in the summer (denoted as "b"), because only the harvest in the spring affected the fish that matured in that year. For example, fish which do not mature at age 3 will then be exposed to the harvest rate in the summer of their third year and again in the spring of their fourth year, but not in the summer of their fourth year if they mature at age 4.

Ocean harvest rates tended to be higher in the summer than in the spring and to increase with age (Table 16; Figure 26). Ocean harvest rate averaged 5% in the summer of age 2, 29% in the spring of age 3, 40% in the summer of age 3, 21% in the spring of age 4 and 87% in the summer of age 4. There was substantial variation about these means (Figure 26). The net result of these harvest rates was that 57% to 85% of fish destined to mature at age 4 were harvested (Table 16). As we showed previously, 80% to 90% of naturally produced spring chinook are expected to skip maturing at age 3, and then 80% to 100% of those alive at age 4 will mature then. The cumulative harvest rate by time of maturity at age 5 is 97% to 100%, and indicates that spring chinook have virtually no chance of surviving ocean harvest if they are destined to mature at age 5. This intense selection against older age at maturity must certainly have altered the gene frequencies in the population, since age at maturity of chinook has been demonstrated to be highly heritable (Nicholas and Hankin 1988).

New regulations on ocean harvest starting in 1996 may reduce harvest rates on spring chinook, particulary those from Deer and Mill creeks. The minimum size at which chinook may be kept was increased to 27 inches in the ocean south of Humbug Mountain (southern Oregon) in 1996. Because a high proportion of juvenile spring chinook from Deer and Mill Creek tend to enter the ocean as yearlings, they would be smaller at age 3 in the ocean than spring chinook from the main stem, Butte Creek, or Feather River. Thus, many of the 3-year old chinook from Deer and Mill Creek might be protected from harvest during all or a portion of their age 3 year by the new size minimum of 27 inches. This protection is also likely to extend, although to a lesser degree, to spring chinook from other areas of the Sacramento Basin as well.

Table 16. Percentage of fish from each CWT group that were harvested in the ocean by the time of maturity at either age 3, 4, or 5. These harvest rates are cumulative over the full set of years that fish of the specified age were in the ocean.

		Release				% Harvested Before Maturity		
TagCode	Br	Type	Weight	Date	Location	Age 3	Age 4	Age 5
060107	75	Yearling	75.6	12/76	FRH	**27%**	**57%**	**97%**
065809	76	Yearling	81	12/77	FRH	**57%**	**85%**	**100%**
065812	77	Yearling	75.6	01/25/79	Gridley	**18%**	**65%**	
B61001	84	Subyear	3.44	04/01/85	FRH	**22%**	**62%**	**100%**
B61004	85	Subyear	2.4	03/17/86	Gridley	**29%**	**74%**	**97%**
B61006	86	Subyear	3.81	03/03/87	FRH	**42%**	**66%**	

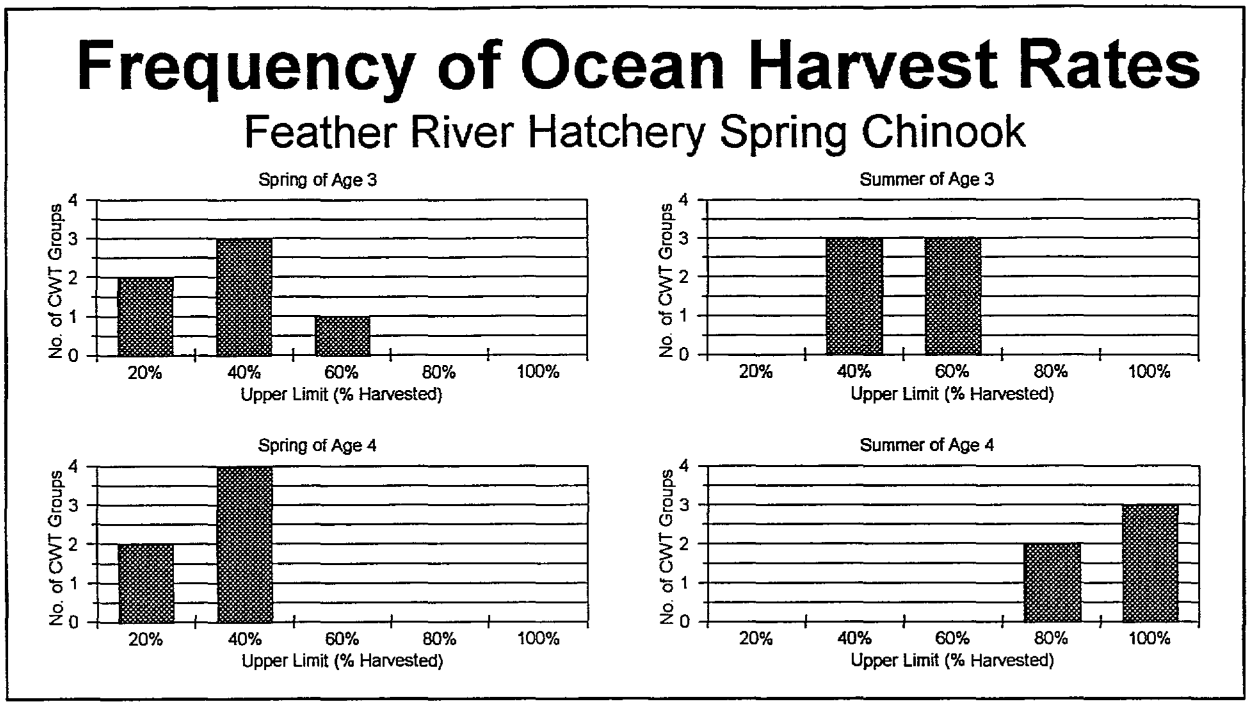


Figure 26. Frequency distribution of ocean harvest rates at ages 3 and 4 during spring (February-June) and summer (July-September), as estimated for CWT groups of spring chinook released at or near Feather River Hatchery, 1974-76 and 1984-86 broods.

LATE-FALL CHINOOK

There were 16 CWT-Ad marked groups of late-fall chinook, 1975-1991 broods, reared at Coleman National Fish Hatchery, and four broods, 1978-1981, included comparable groups released at the hatchery and below Red Bluff Diversion Dam (about 20 miles downstream). Therefore, we first used analysis of variance for each parameter of interest to test for differences in survival related to the different release locations. Maturity and harvest rates showed no difference between CWT groups released at the two locations.

Straying

Straying rate, the proportion of spawners found outside the Sacramento River above Red Bluff, was zero for all but one group (Table 17). All four CWT groups that were trucked and released below Red Bluff Diversion Dam had no strays observed. Thus, there is apparently a high homing fidelity among late-fall chinook.

Table 17 Straying, survival and maturity rates of late-fall chinook estimated by cohort analysis for CWT groups released from Coleman National Fish Hatchery.

Tag Code	Br	Release Type	Weight	Release Date	Recrt2M	Recrt2F	Release	Survive2	MATR2M	MATR3M	MATR3F	MATR4M	MATR4F	StrayRT
060301	75	Presmolt	7.09	9/75	256	202	192,267	0.24%	0.00	0.52	0.24	—	—	—
060307	76	Presmolt	10.8	10/76	66	107	202,315	0.09%	—	—	—	—	—	—
066012	77	Smolt	22.68	1/78	2,569	2,336	197,668	2.48%	0.00	0.28	0.18	1.00	1.00	0.12
066013	78	Presmolt	9.07	10/10/78	226	188	185,212	0.22%	0.07	0.44	0.54	1.00	1.00	0.00
066014	78	Smolt	19.72	01/08/79	223	458	37,080	1.83%	0.02	0.33	0.12	1.00	1.00	0.00
066015	78	Smolt	19.72	01/03/79	196	329	45,628	1.15%	0.06	0.89	0.16	—	1.00	0.00
066022	79	Smolt	18.98	02/11/80	1,361	981	45,481	5.15%	0.01	0.19	0.08	1.00	0.90	0.00
066023	79	Smolt	18.36	02/06/80	936	835	45,236	3.92%	0.01	0.25	0.08	1.00	1.00	0.00
066018	80	Smolt	18.07	02/03/81	288	477	46,548	1.64%	0.00	0.39	0.18	0.00	0.16	0.00
066019	80	Smolt	18.98	02/05/81	549	547	49,766	2.20%	0.00	0.22	0.03	0.07	0.06	0.00
066024	81	Smolt	12.92	01/27/82	191	223	49,003	0.85%	0.02	0.33	0.06	1.00	0.76	0.00
066025	81	Smolt	13.46	01/27/82	140	259	47,254	0.85%	0.03	0.38	0.03	1.00	1.00	0.00
052053	89	Smolt	19.72	01/26/90	36	0	44,959	0.08%	—	—	—	—	—	—
052054	89	Smolt	15.85	12/13/89	78	28	47,733	0.22%	—	—	—	—	—	—
0501010308	91	Smolt	34.5	01/06/92	495	476	50,351	1.93%	0.12	0.59	0.46	1.00	1.00	0.00
0501010309	91	Smolt	35.89	01/06/92	863	438	54,840	2.37%	0.07	0.38	0.32	1.00	1.00	0.00

Survival

Mean survival rate to age 2 varied significantly ($P < 0.01$) between broods, but not between locations that smolts were released. The mean survival rate from smolt to age 2 was higher (2.3%) for fish released below Red Bluff Diversion Dam than fish released at the hatchery (1.7%), but the 95% confidence intervals overlapped (Figure 27). Accordingly, we included the data from both release locations when we calculated mean survival rates for each brood. An analysis of covariance between broods showed that differences were highly significant (P=0.002), and that fish weight at release was significantly (P=0.018) related to survival. Brood year means for survival rate, adjusted by analysis of covariance for smolt weight, ranged from 0.2% to 4.6% (Figure 28). Thus, survival varied more than 20-fold. The frequency distribution of smolt-to-age 2 survival shows that survival was most often between 1% to 2% (Figure 29).

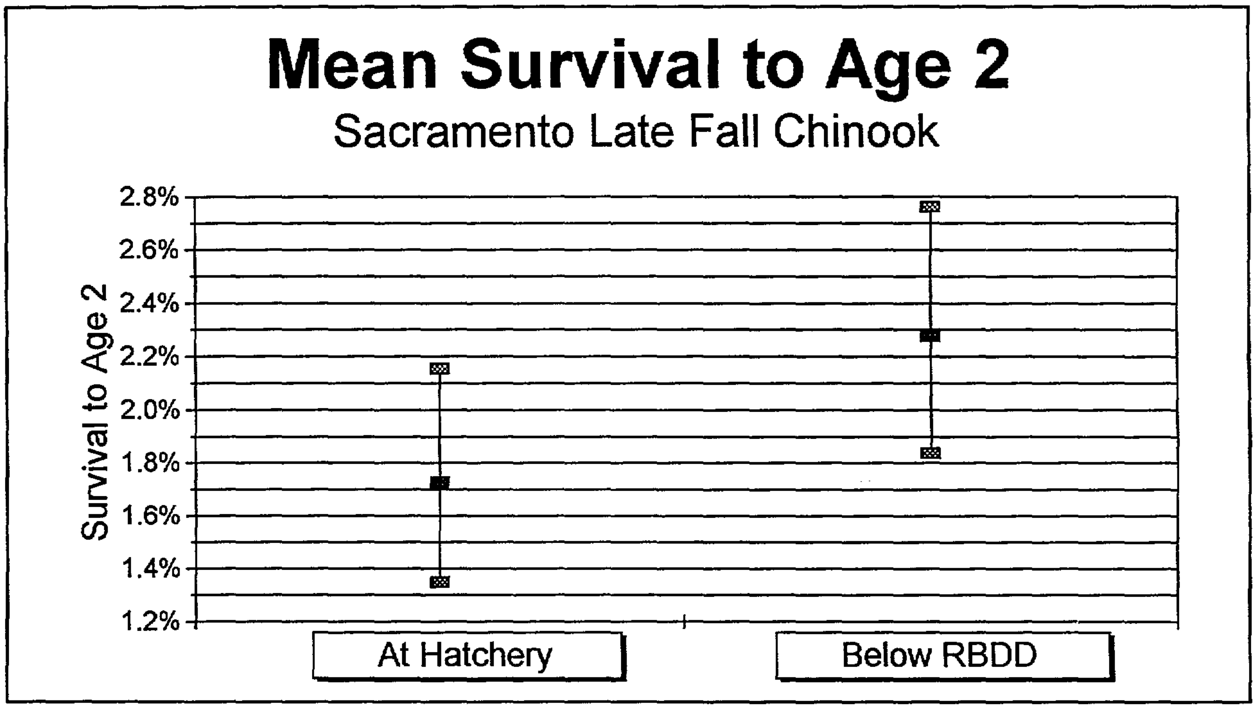


Figure 27. Means and 95% confidence intervals for estimates of survival to age 2 compared between CWT groups of late-fall chinook released at Coleman National Fish Hatchery versus below Red Bluff Diversion Dam. Release groups from 1978-1981 broods.

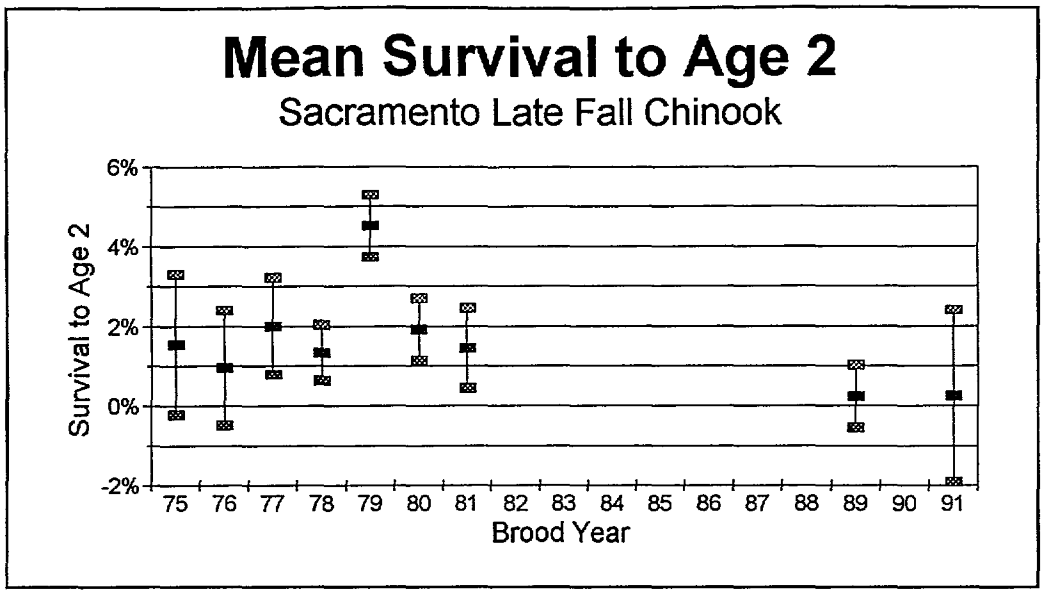


Figure 28. Means and 95% confidence intervals of estimated survival to age 2 for late-fall chinook released from Coleman National Fish Hatchery, 1975-1991 broods. Means are adjusted by analysis of covariance for differences in smolt weight.

Age at Maturity

On any given day of the year, late-fall chinook and spring chinook differ in age by about 5 months. Late-fall chinook spawn after January 1 in the new year, while spring chinook spawn in the preceding late summer. Thus, fish from the two races entering freshwater in the same year would spawn in different calendar years and their offspring would be designated by different brood years. We found that this difference in brood year designation for fish that spawn in the same water year (October-September) caused some mistakes in the databases of PSMFC and CDFG for assigning ages the CWT fish that were recovered. We corrected the few mistakes we found before proceeding with the cohort analysis.

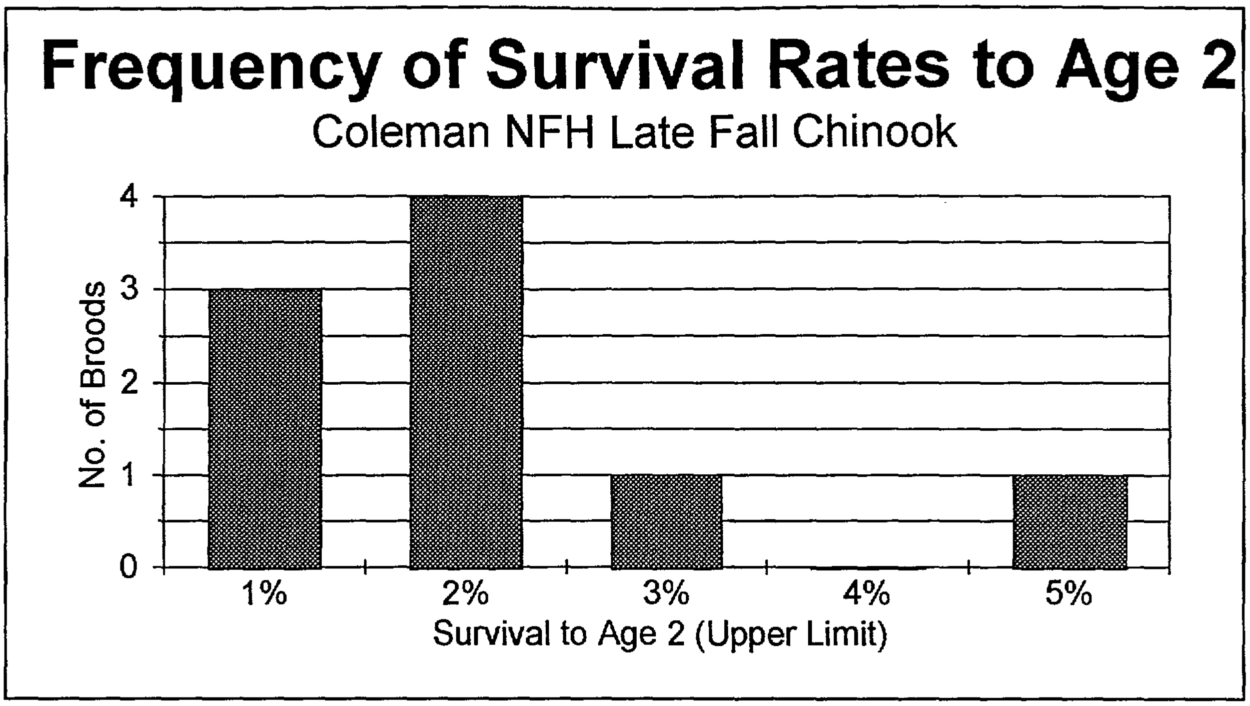


Figure 29. Frequency distribution of smolt-to-age 2 survival rates, as estimated for CWT groups of late-fall chinook reared at Coleman National Fish Hatchery, 1975-1991 broods.

Data from CWT groups of the 1976 and 1989 broods were not included in the analyses of age at maturity because sample sizes were insufficient (< 200 recruits at age 2).

Sex Composition

As with spring chinook, the mean proportion that males composed each year of all CWT fall chinook returning to the Coleman National Fish Hatchery illustrated that females matured at an older age, and composed an increasing percentage of each successive age class (Figure 30). All age 2 returns to the hatchery were males, although the only broods for which there were 10 or more of these fish were the 1989 and 1991 broods. Age 3 fish were generally 60% to 80% males, and age 4 fish were 30% to 50% males (Figure 30). In our cohort analysis, when we lacked sufficient sex data for a specific age and year, we used the mean values of 64% males at age 3 and 44% males at age 4 and 5 derived from years that had at least 10 CWT recoveries for which sex was recorded.

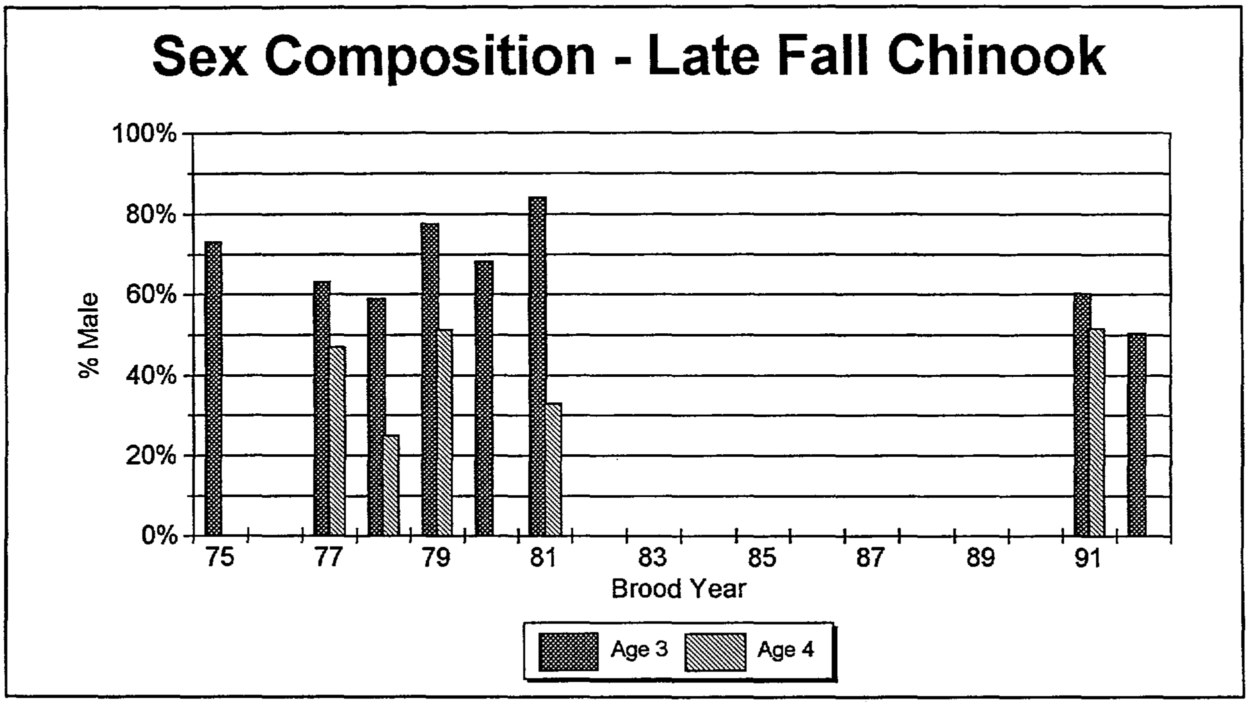


Figure 30. Mean percentage that males composed at ages 3 and 4 for each brood year of CWT-Ad marked late-fall chinook returning to Coleman National Fish Hatchery. Years without bars had insufficient or no data.

Male Maturity Rates

Mean maturity rates for males across the seven broods with data were 2.5% at age 2, 39.2% at age 3, and 100% at age 4 (excluding the 1980 brood)(see individual group values in Table 17). These maturity rates were highly variable (Figure 31) within and between broods (see Table 17), but the differences between broods were not significant at age 2 (P=0.069) or at age 3 (P=0.588). Weight of smolts was not a significant covariate for maturity rate at any of these ages.

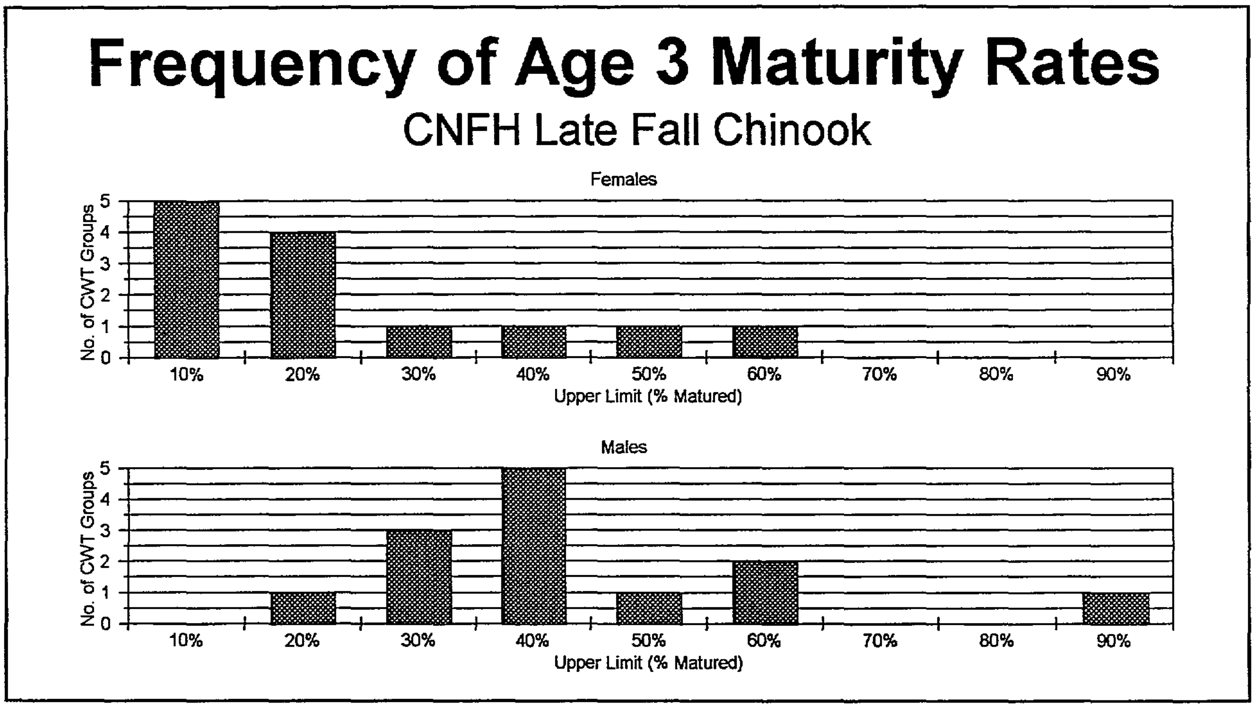


Figure 31. Frequency distribution of male and females maturity rates at age 3 estimated for CWT groups of late-fall chinook released Coleman National Fish Hatchery, 1975-1991 broods.

For some reason, perhaps related to el Nino, few fish returned at age 4 and some returned at age 5 from the 1980 brood. It appears that the poor ocean conditions for growth and survival of salmon during the 1983 el Nino caused fish of the 1980 brood that would normally have matured at age 4 to delay and mature at age 5. Age 4 fish of the 1980 brood would have entered freshwater in the fall of 1983, the year of a severe el Nino.

The high variability we found in age at maturity of late-fall chinook leads us to the conclusion that the timing of river entry for this race must coincide with a time in the ocean when fish are near a size threshold that strongly influences the onset of maturity. Under such circumstances, slight differences in their growth rates in the ocean between years could cause large changes in the proportion maturing at each age.

Female Maturity Rate

As was true for males, the difference in average maturity rates of females between broods was significant ($P < 0.05$) at each age, and fish weight at the time of release was a significant ($P < 0.01$) covariate for maturity at age 3 only (larger fish at release had higher maturity rates at age 3). Weight was not a significant covariate for maturity rates at ages 4 and 5. Generally, between 10% and 30% of females matured at age 3 and the remainder matured at age 4 (Figure 32). Age 5 fish were rare. As with males, the maturity rate of females at age 4 for the 1980 brood was anomalously low, and was most likely related to the el Nino that created poor conditions in the ocean for growth and survival of salmon during 1983.

The proportion of females that matured at age 3 (MATUR3F) was significantly ($P < 0.01$) less than the proportion of males that matured at age 3 (MATUR3M). A paired "t" test between CWT groups for the two sexes gave $t = -3.83$ with a significance value of $P = 0.002$. The mean difference (MATUR3M-MATUR3F) was -0.207 ± 0.118. **Thus, the proportion of females that matured at age 3 averaged 20 percentage points lower than for males. Later maturity of females than males would have resulted in females experiencing a greater cumulative mortality to harvest in the ocean than for males**.

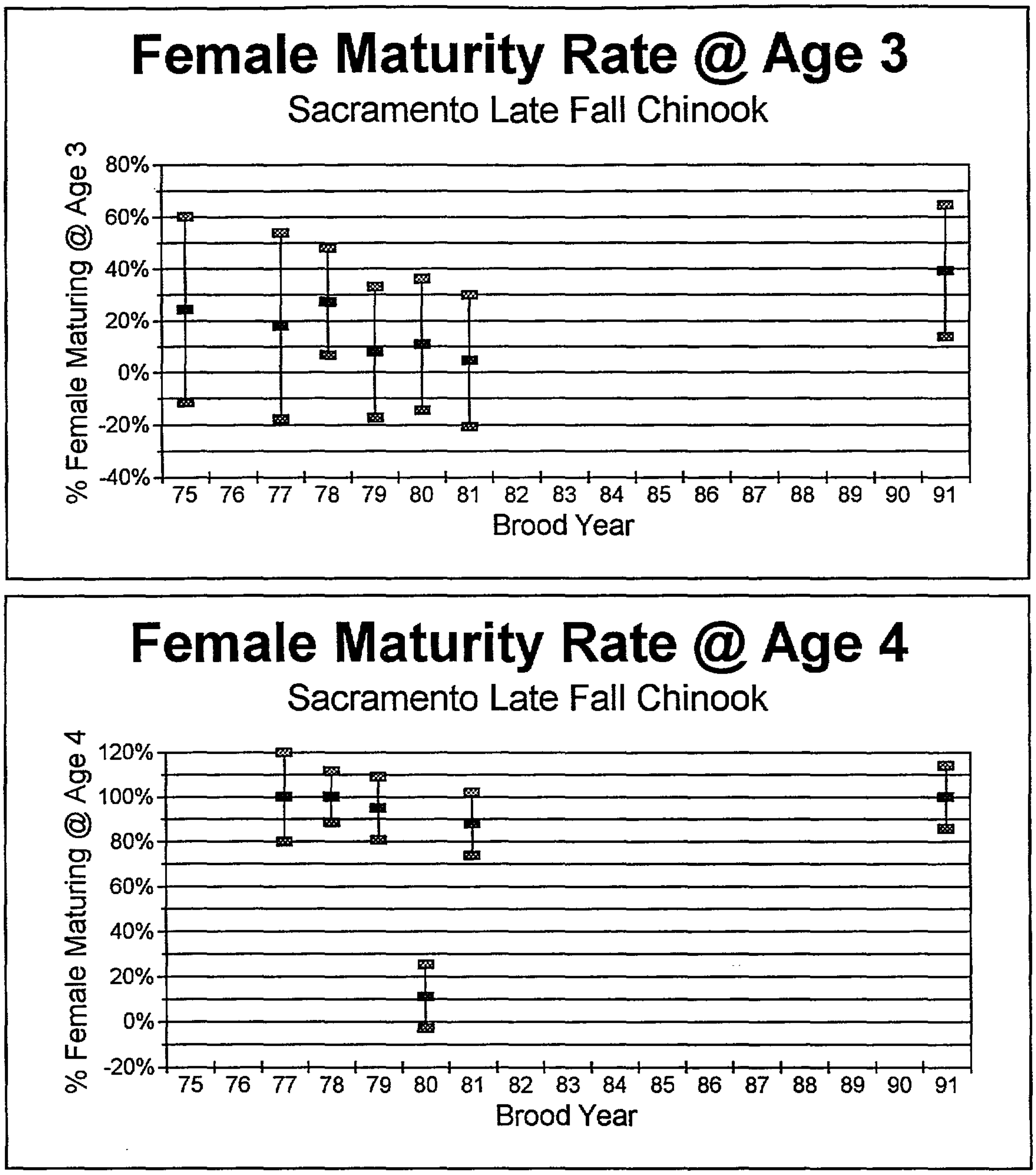
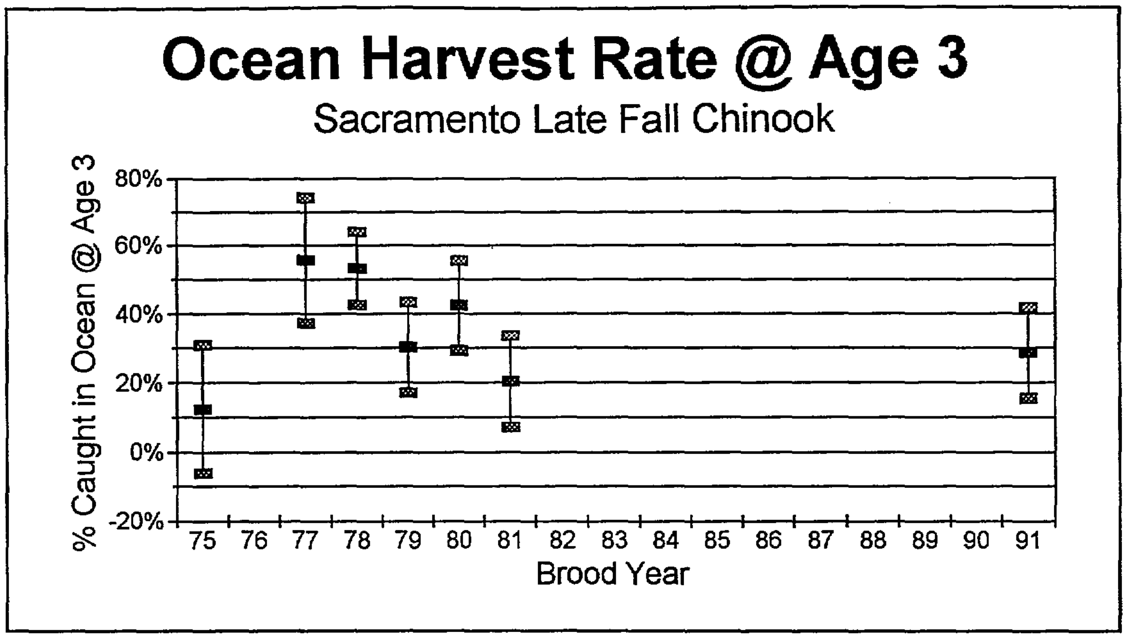


Figure 32. Means and 95% confidence intervals of estimated maturity rates for females at age 3 and 4 for late-fall chinook released from Coleman National Fish Hatchery, 1975-1991 broods. Means are adjusted by analysis of covariance for differences in smolt weight.

Ocean Harvest Rates

The difference between broods in average harvest rates on late-fall chinook in the ocean was significant ($P<0.01$) at each age. Data from CWT groups of the 1976 and 1989 broods were not included in the analyses of ocean harvest rate or age at maturity because sample sizes were insufficient (< 200 recruits at age 2). Rarely were fish harvested at age 2 (see Table 18). Fish were only partially vulnerable (some were of sublegal size) to the ocean fisheries at age 3, and mean harvest rates ranged from 12% to 58% (Figure 33). The weight of fish at release was significant ($P=0.002$) as a covariate in the analysis for age 3 fish, but not for age 4 fish. Larger fish at release tended to be caught more at age 3. This finding is logical, because the mean fork length of age 3 fish at return to the hatchery in winter is generally 22 to 26 inches. This size at return indicates that many of the age 3 cohort would have been of sublegal size during at least a portion of the harvest season, which began the previous February. Late-fall chinook were caught in the ocean primarily during May through September (Figure 34).



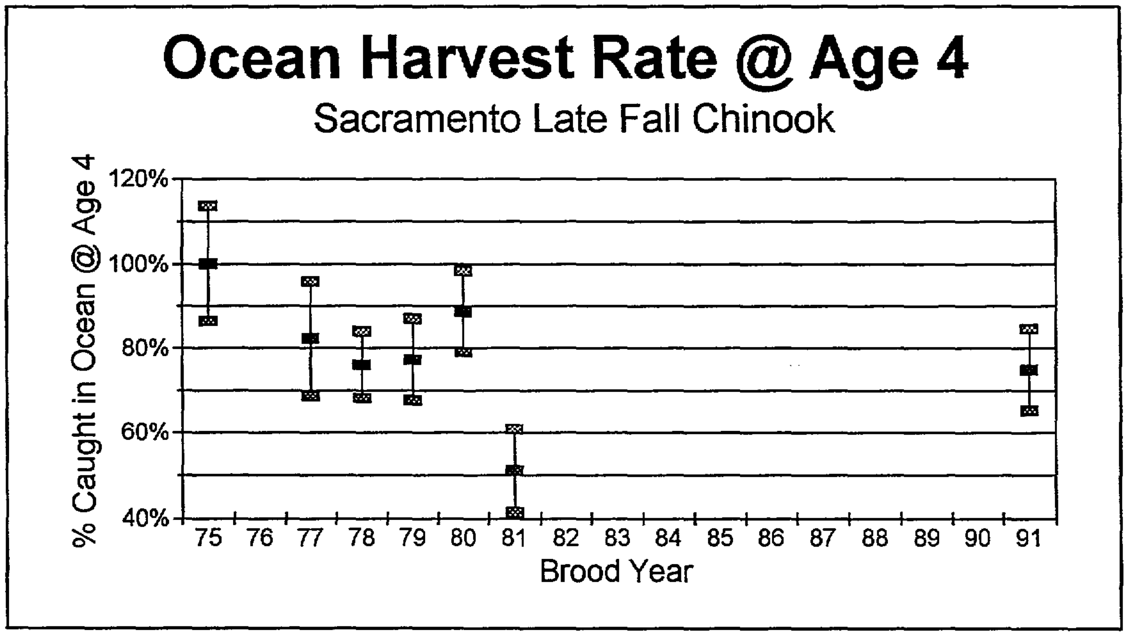


Figure 33. Means and 95% confidence intervals for estimated harvest rates in the ocean for age 3 and 4 late-fall chinook from Coleman National Fish Hatchery, 1975-1991 broods.

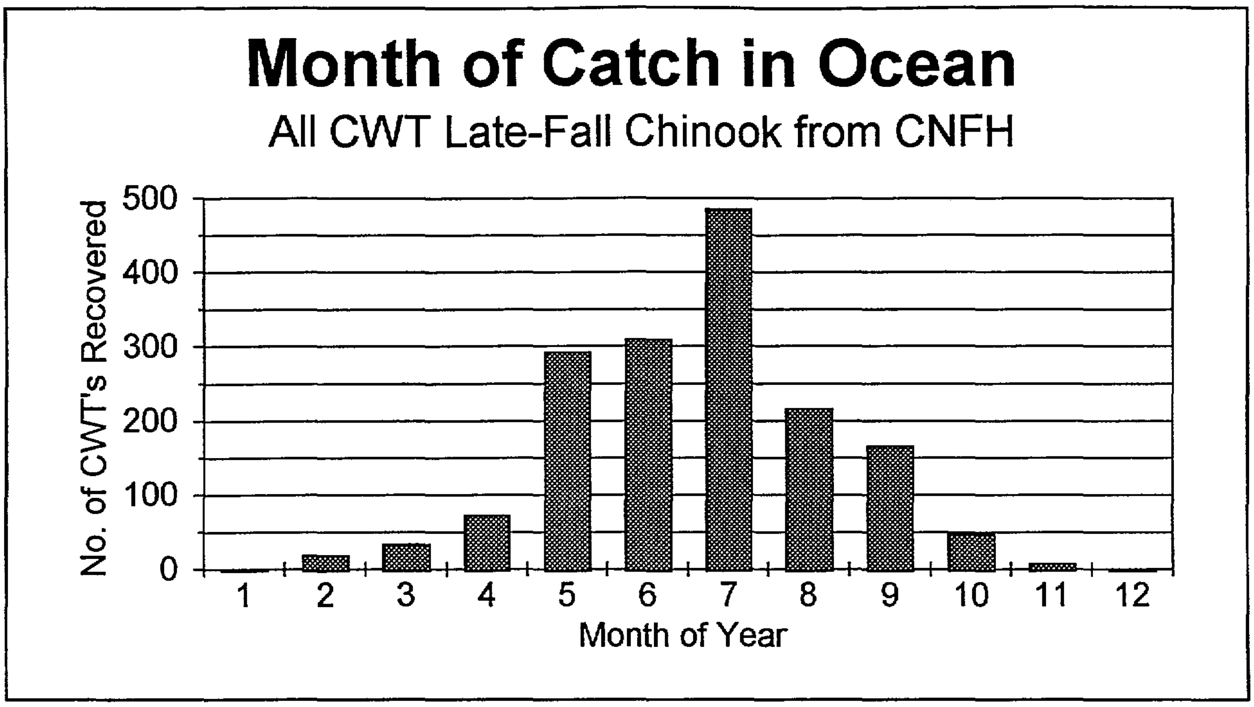


Figure 34. Month of catch in the ocean for all ages combined of CWT marked late-fall chinook reared at Coleman National Fish Hatchery, 1975-1991 broods. Data from PSMFC database.

Mean harvest rates on age 4 fish ranged from 75% to 100%, except for a 51% harvest rate on the 1981 brood (Figure 33). This lower harvest rate on age 4 fish of the 1981 brood occurred during the summer of 1985, which was the year of the all-time low in the harvest rate index for Central Valley chinook (Figure 35). Comparison of the harvest rates estimated by cohort analysis for each CWT-marked brood of late-fall chinook to the harvest rate index for Central Valley chinook during the early 1980's indicates that harvest rates on age 3 fish fall 10 to 30 percentage points below the index, while harvest rates on age 4 fish are 10 to 30 percentage points above the index. **Because the majority of late-fall chinook do not mature until age 4, most of these fish would have been exposed to harvest at both age 3 and age 4. This cumulative harvest rate in the ocean would have been 80% to 90% for all broods except the 1981 brood (Table 18). Such high**

harvest rates cannot be sustained by a naturally reproducing stock, except in years of high ocean survival. We have already shown that ocean survival has varied over 20 fold between the broods for which we have estimates, and if we assume that survival of naturally produced fish has varied similarly between years, it is clear that the naturally produced population must have been over harvested in many years.

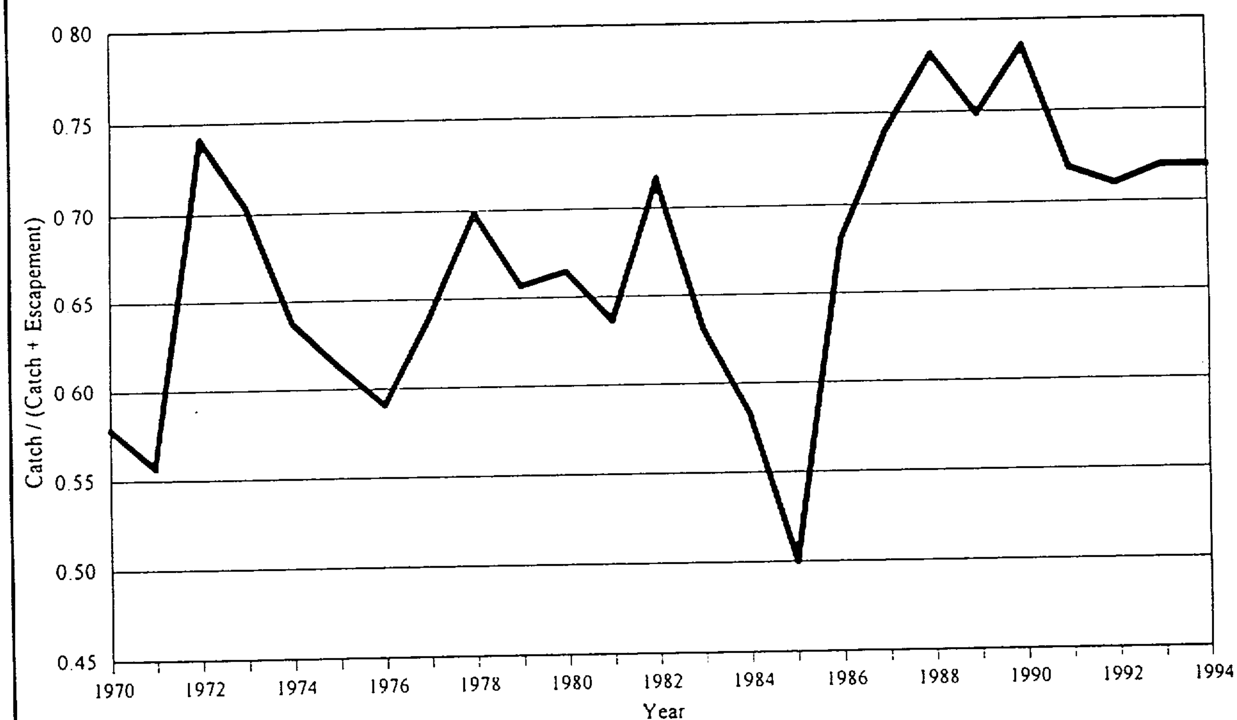


Figure 35. Harvest rate index for Central Valley chinook salmon. From PFMC (1995). The index is comprised of ocean harvest of chinook of all stocks south of Point Arena, California, and spawning escapements of all races of chinook salmon into Central Valley streams, excluding inland recreational harvest.

Table 18. Ocean harvest rates of late-fall chinook estimated by cohort analysis for CWT groups released from Coleman National Fish Hatchery, 1975-1991 broods.

Tag Code	Br	Release Type	Weight	Release Date	RECRT2M	RECRT2F	OHARV2	OHARV3	OHARV4	Cumulative Oharv to Age 4
060301	75	Presmolt	7.09	9/75	256	202	0.00	0.12	1.00	1.00
060307	76	Presmolt	10.8	10/76	66	107	—	—	—	—
066012	77	Smolt	22.68	1/78	2,569	2,336	0.01	0.56	0.82	0.92
066013	78	Presmolt	9.07	10/10/78	226	188	0.00	0.40	0.71	0.82
066014	78	Smolt	19.72	01/08/79	223	458	0.00	0.60	0.82	0.93
066015	78	Smolt	19.72	01/03/79	196	329	0.00	0.60	0.75	0.90
066022	79	Smolt	18.98	02/11/80	1,361	981	0.00	0.31	0.83	0.88
066023	79	Smolt	18.36	02/06/80	936	835	0.00	0.29	0.72	0.80
066018	80	Smolt	18.07	02/03/81	288	477	0.00	0.39	0.93	0.96
066019	80	Smolt	18.98	02/05/81	549	547	0.00	0.46	0.84	0.91
066024	81	Smolt	12.92	01/27/82	191	223	0.00	0.21	0.54	0.64
066025	81	Smolt	13.46	01/27/82	140	259	0.00	0.20	0.48	0.58
052053	89	Smolt	19.72	01/26/90	36	0	—	—	—	—
052054	89	Smolt	15.85	12/13/89	78	28	—	—	—	—
0501010308	91	Smolt	34.5	01/06/92	495	476	0.00	0.23	0.75	0.81
0501010309	91	Smolt	35.89	01/06/92	863	438	0.00	0.34	0.75	0.83

We used the estimates of maturity rate and ocean harvest rate to calculate the proportion of age 2 recruits from a given brood that survived to river entry. A portion of these recruits died of natural causes each year in the ocean (see Methods for assumed rates), so the proportion that survived to river entry was affected by age at maturity as well as by ocean harvest rates. The differences in survival to river entry between males and females resulted entirely from differences in age-specific maturity rates between the sexes. **The mean percentage of females that survived from age 2 to river entry (12.3%) averaged only slightly more than half of the percentage of males that survived (21.2%). (Figure 36). This comparison shows that survival of females is more limiting to natural production than survival of males**. On the other hand, hatchery production has not been limited by harvest rates, i.e. returns have been sufficient to meet egg take goals. **The low percentage of females that survive from the time of ocean recruitment (age 2) until they enter freshwater is likely to be below that which would**

enable optimum natural production, given the observed smolt-to-age 2 survival rates.

As described for spring chinook, the increase in size limits for landing of chinook off the California Coast in 1996 will reduce the take of late-fall chinook at age 3. The new size limit is 27 inches, and most age 3 late-fall chinook are only 22 to 26 inches long when they return to the hatchery. Thus, the harvest rates of 12% to 58% at age 3 should drop to near zero.

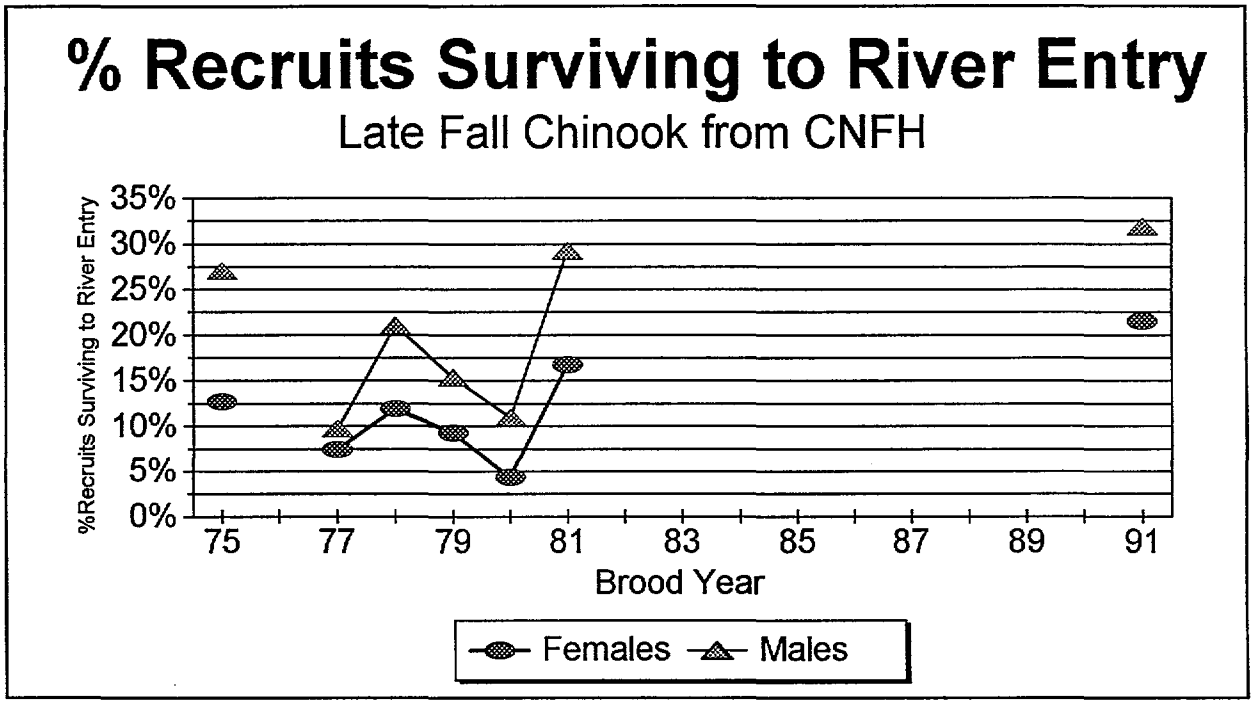


Figure 36. Percentage of female and male fall chinook recruits at age 2 that ultimately survived to river entry at any age, 1975-1991 broods. Estimates derived from mean maturity rates and ocean harvest rates estimated for CWT-Ad marked fish from Coleman National Fish Hatchery. This estimate does not include variation in smolt-to-age-2 survival, but does include the assumed rates of over-winter survival between each age.

CHANGES IN OCEAN SURVIVAL OF CENTRAL VALLEY CHINOOK

The dramatic variation in smolt-to-age 2 survival that we found between broods of spring and late-fall chinook is of such a magnitude that much of that variation must be driven by differences between in years in the ocean. In-river sampling of juveniles has established that there are large differences between years in the survival of smolts as they migrate downstream; however, that variation has not been 10 to 20 fold as we found between broods of CWT marked hatchery fish. Further, most hatchery releases of spring and late-fall chinook occur during the fall or winter months; a time period when variation in survival of CWT fall chinook groups has shown no correlation to river temperature or water withdrawals (Cramer 1991). If much of this variation in survival is related to changing ocean conditions, then other stocks of salmon rearing off of the West Coast should show similar variation in survival.

We compared the brood year means that we estimated for smolt-to-age 2 survival in the Sacramento Basin to indices of smolt-to-adult survival for spring chinook in the Rogue River, because of the similarity in their ocean distribution. For this comparison, we only used the yearling smolt releases during fall or winter. The Rogue River spring chinook were CWT groups released in October from Cole Rivers Hatchery (river km 253), and the index of survival used for those groups was ocean catch plus hatchery returns (all ages) divided by the number of smolts released. The comparison shows that the unusually high survival of Feather River spring chinook from the 1976 brood corresponded to unusually high survival for the Rogue spring chinook as well (Figure 37). Variation in survival of late-fall chinook did not appear to track with that for Rogue spring chinook; however, the data sets did not overlap for any years of high survival of the Rogue stock. This comparison, although limited, is consistent with the theory that early ocean survival of salmon varies on a regional scale, and that large variation in smolt-to-adult survival is common to chinook stocks inside and outside the Sacramento Basin.

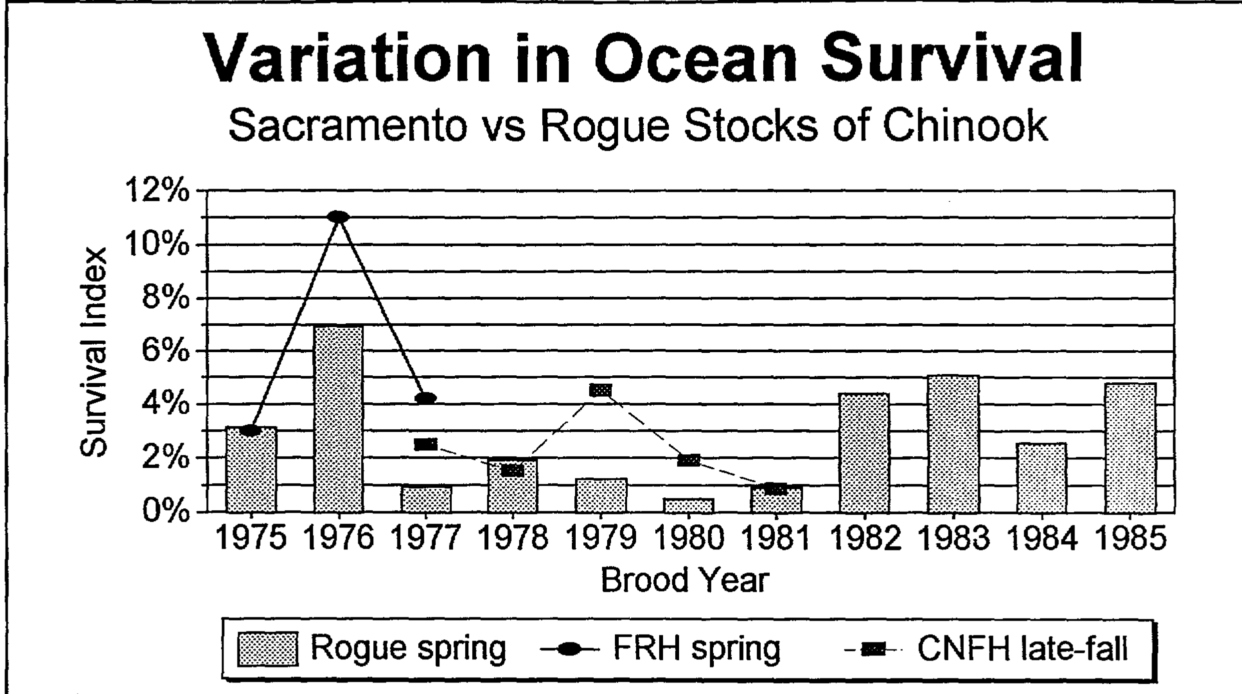


Figure 37. Variation between broods in indices of ocean survival for spring and late-fall chinook in the Sacramento Basin compared to spring chinook in the Rogue River. Sacramento indices are mean smolt-to-age 2 survival for yearling smolt releases presented in this report. Rogue River data are ocean catch plus hatchery return divided by smolts released during October (CWT marked fish), and were taken from Evenson and Ewing (1987 and 1990).

ONGOING CORRECTIVE ACTIONS

Ongoing corrective actions are both numerous and extensive. Volumes of reports have been and are being written to describe these actions, so we make no attempt to reiterate that information here. Restoration actions specifically for spring chinook have been described by Mills and Ward (1996), and that list includes the major actions that would benefit late-fall chinook as well. The major investments of money and effort by private stakeholders and public resource agencies to restore anadromous fish and their habitat in the Central Valley has escalated at an exponential rate in the last decade.

Federal involvement in these actions is extensive and includes, to name a few, the Anadromous Fish Doubling Plan under the Central Valley Improvement Act, the CALFED Bay-Delta Ecosystem Restoration Program, and the Biological Opinions for winter-run chinook and delta smelt. Actions within the Sacramento River and Delta that have been designed to protect winter-run chinook under the ESA are the same actions that would be designed to protect the spring and late-fall runs, because the naturally-produced smolts of all three of these groups tend to emigrate as yearlings during mid fall through early spring. It is difficult to imagine that additional federal intervention would not duplicate ongoing restoration activities.

RECOMMENDATIONS

We have limited our recommendations to those topics for which we present specific data in this report. This report focuses on the distinction of chinook races, indices of abundance, and life history parameters that can be estimated from cohort analysis of CWT recoveries. We found that a major limiting factor in identifying abundance trends was the lack of a means to accurately distinguish races of chinook where they are mixed together.

1. All chinook released from Sacramento Basin hatcheries should be marked. This is necessary so that naturally produced fish, when sampled in the river or in the ocean, can be distinguished from hatchery fish, and take of natural fish can be restricted to less than that for hatchery fish.

2. Development of genetic baseline data sufficient to enable accurate discrimination of unique chinook races within the Central Valley should be vigorously pursued. The tool needed is a mixed stock analysis capable of distinguishing the race of

individual juvenile chinook captured in the Bay-Delta. The accuracy of this tool needs to be greatest for distinguishing the less abundant races of chinook, including the spring and late-fall races, unless the genetics data indicate that these life histories do not warrant designation as a distinct race.

3. Given the mandate of the state and federal Endangered Species Acts to conserve wild populations, the harvest rates of naturally-produced Sacramento chinook in ocean fisheries should be reduced, particularly in years when ocean survival is low. The present practice of allowing high harvest rates across all year types is a certain recipe for eventual depletion of wild stocks. Additional analyses of the probability distributions for recruits per spawner in key wild populations is needed to determine the rates of harvest that can be sustained over the long term. Analyses of sustainable harvest rates should focus on females, because they are harvested at a higher rate than males.

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APPENDICES

Appendix 1. Weekly counts of chinook classified as fall-run passing Red Bluff Diversion Dam 1970-1988.

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
May 28										
Jun 4										
Jun 11										
Jun 18	0	0	0	0	0	0	0	0	0	0
Jun 25	0	0	0	0	0	0	0	0	0	0
Jul 2	0	0	0	0	47	0	0	0	0	0
Jul 9	140	0	0	0	67	57	0	0	0	0
Jul 16	623	60	185	97	268	192	128	16	37	0
Jul 23	627	49	123	103	231	314	208	0	27	0
Jul 30	744	99	284	28	284	228	324	818	147	5
Aug 6	1,655	521	907	0	207	629	733	1,354	234	40
Aug 13	1,053	545	482	16	781	1,760	1,062	1,754	297	621
Aug 20	1,009	1,636	738	101	726	1,678	1,580	750	391	1,069
Aug 27	1,457	2,458	1,141	110	1,589	3,820	3,112	814	293	738
Sep 3	2,397	2,594	1,095	1,068	1,916	3,911	3,736	291	1,746	2,218
Sep 10	2,712	3,292	1,783	2,351	3,127	4,086	4,113	659	3,277	2,667
Sep 17	2,956	3,357	3,685	4,102	5,941	5,354	7,710	2,651	394	3,557
Sep 24	5,518	5,693	4,604	3,443	5,210	7,177	7,639	7,269	1,404	5,766
Oct 1	8,082	7,391	4,783	5,772	4,993	8,245	5,677	5,258	2,351	7,737
Oct 8	9,790	8,885	6,489	7,250	6,203	4,416	5,249	3,995	3,287	5,063
Oct 15	10,668	5,006	4,282	6,915	5,362	4,079	3,956	3,915	5,059	10,912
Oct 22	5,412	3,025	2,878	6,497	5,118	4,639	4,102	1,527	2,551	5,432
Oct 29	8,108	6,109	2,365	3,513	3,683	2,773	3,623	4,606	3,673	4,375
Nov 5	3,923	4,240	2,271	3,568	2,906	2,311	2,207	1,353	2,866	3,958
Nov 12	3,138	3,247	1,197	2,164	3,016	1,664	1,979	959	2,402	1,465
Nov 19	2,168	3,400	1,556	1,084	1,680	1,978	1,614	435	4,270	1,896
Nov 26	1,780	1,592	826	1,603	1,467	2,194	1,020	1,316	950	1,326
Dec 3	629	311	498	1,192	87	969	501	530	326	1,635
Dec 10	149	202	127	901	43	281	211	100	2,531	1,011
Dec 17	752	206	204	1,106	0	172	32	13	1,313	617
Dec 24	160	0	0	907	0	164	203	61	0	0
Totals	75,650	63,918	42,503	53,891	54,952	63,091	60,719	40,444	39,826	62,108

Appendix 1. Continued.

	1980	1981	1982	1983	1984	1985	1986	1987	1988
May 28							20		90
Jun 4							0		41
Jun 11							49	6	118
Jun 18	0	0	0	0	0	16	381	30	0
Jun 25	0	0	0	0	0	0	726	73	155
Jul 2	0	0	0	0	0	22	1,040	163	0
Jul 9	0	0	304	0	0	164	1,427	194	1,249
Jul 16	4	8	423	20	357	664	1,597	354	1,092
Jul 23	369	0	386	245	353	3,294	1,331	189	887
Jul 30	166	0	377	287	818	2,812	3,210	318	1,044
Aug 6	85	31	734	576	1,109	5,256	2,631	1,387	3,024
Aug 13	180	43	407	405	2,421	7,120	7,050	3,478	7,571
Aug 20	208	231	1,243	504	1,702	7,046	6,908	2,770	13,994
Aug 27	354	208	1,563	475	3,926	8,865	7,545	4,911	5,690
Sep 3	303	2,190	3,700	2,930	5,277	4,276	11,176	4,108	2,064
Sep 10	783	3,330	3,935	3,425	4,825	9,812	7,496	4,170	4,274
Sep 17	2,297	5,290	4,959	5,701	7,729	4,749	8,405	11,924	16,927
Sep 24	2,658	6,369	5,481	3,121	4,872	6,880	7,273	11,378	14,239
Oct 1	2,836	5,610	5,774	4,064	9,462	7,735	10,796	9,309	15,790
Oct 8	4,204	8,861	5,809	4,535	11,754	5,370	7,225	11,156	13,324
Oct 15	4,516	3,828	4,859	5,283	4,512	6,495	6,234	6,892	9,817
Oct 22	3,966	3,592	3,360	3,966	3,823	8,915	3,654	8,276	6,998
Oct 29	3,335	5,909	2,181	3,866	4,507	2,969	2,385	7,655	8,463
Nov 5	4,797	4,697	1,211	1,524	3,961	1,661	1,109	6,292	3,785
Nov 12	1,702	1,812	698	630	606	1,142	853	3,031	2,362
Nov 19	1,958	772	254	206	489	1,267	456	1,334	1,143
Nov 26	1,434	312	445	173	379	317	1,706	665	1,638
Dec 3	803	383	186	37	178	449	868		1,674
Dec 10	163	128	44	58	145	284	636		1,227
Dec 17	327	77	98	0	0	35	494		935
Dec 24	162	63	0	15	49	92	192		351
Totals	37,610	53,744	48,431	42,046	73,254	97,707	104,873	100,063	139,966

Appendix 2. Weekly counts of chinook classified as spring-run passing Red Bluff Diversion Dam 1970-1988.

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
Mar 19	0	81	0	0	0	0	0	96	12	6
Mar 26	0	177	173	0	0	0	0	98	58	0
Apr 2	0	40	171	6	0	432	97	184	30	2
Apr 9	0	23	171	141	0	754	358	228	23	13
Apr 16	314	230	10	113	278	679	361	276	40	0
Apr 23	225	241	151	349	189	408	91	437	287	8
Spr 30	76	150	32	294	200	236	486	631	39	19
May 7	263	119	112	71	107	309	343	746	172	11
May 14	290	253	297	121	290	255	293	894	198	22
May 21	426	188	231	46	281	186	348	902	306	37
May 28	333	192	184	156	275	425	353	869	362	32
Jun 4	136	318	294	341	168	375	361	783	54	32
Jun 11	287	119	393	224	127	340	787	594	50	31
Jun 18	468	229	364	254	194	385	956	895	121	47
Jun 25	221	449	435	337	127	266	1,214	850	163	133
Jul 2	473	374	608	172	198	496	1,528	472	330	195
Jul 9	140	428	671	141	251	312	4,279	1,986	317	207
Jul 16	0	432	515	153	234	239	1,338	1,313	272	99
Jul 23	0	244	455	241	115	227	2,009	701	120	57
Jul 30	0	527	1,052	192	52	168	1,714	514	274	99
Aug 6	0	368	434	322	41	412	3,045	76	162	229
Aug 13	0	648	220	471	156	821	1,889	98	44	562
Aug 20	0	0	209	951	146	733	3,268	87	183	281
Aug 27	0	0	164	1,101	321	838	532	0	141	291
Sep 3	0	0	0	1,404	183	905	139	0	720	283
Sep 10	0	0	0	161	0	365	46	0	685	102
Sep 17	0	0	0	0	0	137	110	0	137	0
Sep 24	0	0	0	0	0	0	38	0	533	0
Oct 1	0	0	0	0	0	0	0	0	70	102
Oct 8	0	0	0	0	0	0	0	0	0	0
	3,652	5,830	7,346	7,762	3,933	10,703	25,983	13,730	5,903	2,900

Appendix 2. Continued.

	1980	1981	1982	1983	1984	1985	1986	1987	1988
Mar 19	0	0	0	0	0	0			
Mar 26	0	0	0	0	0	0	1		
Apr 2	3	0	0	0	155	0	55		13
Apr 9	8	0	11	0	43	40	90	23	15
Apr 16	61	62	35	13	77	63	83	8	86
Apr 23	147	85	128	23	108	23	206	74	122
Spr 30	115	144	93	7	134	124	153	190	108
May 7	170	204	71	12	112	157	124	266	100
May 14	129	208	103	5	136	152	185	418	116
May 21	145	167	174	34	107	389	288	401	667
May 28	146	412	330	19	140	272	608	352	329
Jun 4	156	644	111	46	80	431	351	411	187
Jun 11	135	573	150	49	144	526	505	370	531
Jun 18	138	367	497	165	221	395	254	373	751
Jun 25	164	204	347	59	220	205	526	242	112
Jul 2	231	321	275	36	193	111	412	400	602
Jul 9	331	309	568	111	197	215	723	377	624
Jul 16	523	391	1,873	127	304	498	727	236	347
Jul 23	161	372	123	196	236	748	320	91	80
Jul 30	347	415	192	78	612	362	933	594	209
Aug 6	230	488	310	94	2,271	1,154	1,926	1,791	756
Aug 13	345	1,217	1,039	311	1,078	1,500	1,278	225	382
Aug 20	928	1,452	1,147	72	154	800	1,763	280	1,204
Aug 27	1,205	2,534	1,495	286	753	389	441	697	422
Sep 3	1,027	5,015	2,131	324	295	428	1,513	247	0
Sep 10	1,501	2,129	5,549	158	154	303	906	870	599
Sep 17	714	1,038	3,676	921	223	122	1,668	765	1,069
Sep 24	369	1,258	1,834	564	0	385	652	1,503	350
Oct 1	267	751	755	196	0	264	0	0	0
Oct 8	0	265	421	25	0	691	0	0	0
Totals	9,696	21,025	23,438	3,931	8,147	10,747	16,691	11,204	9,781

Appendix 3. Weekly counts of chinook classified as late-fall run passing Red Bluff Diversion Dam 1970-1988.

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
Oct 8	0	587								
Oct 15	0	1,723	0	49	98	0	0	0	124	0
Oct 22	0	823	151	160	169	119	67	0	73	0
Oct 29	0	1,743	307	124	460	403	457	123	52	0
Nov 5	535	3,373	322	84	554	327	559	184	83	0
Nov 12	598	623	74	51	730	118	455	377	132	82
Nov 19	241	2,671	139	26	1,000	181	541	185	292	187
Nov 26	959	2,199	343	123	2,860	888	514	363	175	152
Dec 3	1,066	1,191	798	189	1,770	616	1,051	717	102	545
Dec 10	1,344	1,297	1,044	143	1,204	1,058	1,123	616	173	226
Dec 17	544	2,184	2,060	175	1,128	4,402	697	103	69	1,264
Dec 24	1,441	549	1,071	144	2,028	754	1,656	630	1,005	1,419
Jan 1	556	263	799	228	2,984	1,979	521	680	1,603	1,605
Jan 8	3,451	1,228	132	497	697	1,130	530	743	2,027	498
Jan 15	1,382	467	328	266	342	417	342	277	162	500
Jan 22	1,264	486	447	291	212	425	152	226	216	497
Jan 29	652	760	626	330	1,173	643	103	1,515	284	289
Feb 5	1,322	1,061	402	338	567	680	388	529	971	490
Feb 12	332	2,087	1,162	330	85	247	156	625	681	412
Feb 19	133	2,018	401	1,342	324	358	467	1,389	567	590
Feb 26	34	983	854	551	96	798	344	1,283	564	589
Mar 5	424	333	768	304	204	459	195	453	579	28
Mar 12	360	156	875	195	137	57	209	189	123	61
Mar 19	0	2,700	2,623	702	217	75	41	298	164	17
Mar 26	54	792	1,775	428	280	64	13	676	38	11
Apr 2	21	297	3,046	149	157	0	21	270	31	10
Apr 9	28	57	2,463	244	37	0	0	135	108	4
Apr 16	0	0	0	392	146	0	0	0	0	5
Totals	16,741	32,651	23,010	7,855	19,659	16,198	10,602	12,586	10,398	9,481

Appendix 3. Continued.

	1980	1981	1982	1983	1984	1985	1986	1987	1987-88	1988-89
Oct 8										
Oct 15	0	0	904	108	159	765	724			
Oct 22	127	0	157	165	1562	665	1030	724	135	107
Oct 29	168	0	808	843	371	653	878	1030	386	235
Nov 5	252	689	432	120	455	198	1418	878	540	923
Nov 12	250	1413	761	398	421	517	739	1418	915	946
Nov 19	196	155	239	370	368	920	540	739	1457	
Nov 26	393	31	705	694	324	575	832	540	1054	
Dec 3	307	665	1063	187	414	425	810	832	652	
Dec 10	233	725	185	625	267	549	1094	810	586	
Dec 17	207	214	672	350	289	258	1076	1094	571	
Dec 24	395	125	1498	149	851	654	1022	1076	770	
Jan 1	328	96	642	204	756	409	1031	1022	759	
Jan 8	292	102	1426	222	675	123	507	1031	719	
Jan 15	816	249	562	217	215	225	167	507	727	
Jan 22	1019	93	638	334	65	90	128	128	357	
Jan 29	15	110	653	146	71	74	641	167	346	
Feb 5	355	33	638	449	218	120	657	641	393	
Feb 12	736	169	744	348	247	414	701	657	451	
Feb 19	173		562	399	329	312	530	701	283	
Feb 26	372	6	334	182	90	4	343	530	78	
Mar 5	108	18	213	354	28	118	253	343	136	
Mar 12	25	6	608	205	156	15	548	253	138	
Mar 19	18	14	365	35	32	16	349	548	26	
Mar 26	17	0	349	59	0	110	31	349	66	
Apr 2	5	0	26	0	53	30		31	44	
Apr 9	0	0	5	0	20	47			0	
Apr 16	0	0	1	0	0	0			8	
Totals	6,807	4,913	15,190	7,163	8,436	8,286	16,049	16,049	11,597	2,211