Feather River Chinook Cohort Reconstruction
Brood Years 1998 and 1999
Fall and Spring Runs

June 16, 2006

Melodie L. Palmer-Zwahlen, Allen M. Grover, and Joseph A. Duran

California Department of Fish and Game
Marine Region
Ocean Salmon Project
475 Aviation Blvd., Suite 130
Santa Rosa, CA 95403

Table of Contents

Introduction

The Feather River Hatchery (FRH) is one of five major hatcheries producing Chinook (*Oncorhynchus tshawytscha*) salmon in the Central Valley (CV). It was built in 1967 to compensate for the loss of upstream salmon habitat with the construction of Oroville Dam (Painter et al 1977). The Feather River (FR) is the largest tributary of the Sacramento River below Shasta Dam; its watershed encompasses approximately 3,600 square miles of drainage from the western slope of the Sierra Nevada Mountains (Sommer et al 2001). It is operated by the California Department of Fish and Game (CDFG) and generally supports the second largest populations of fall and spring Chinook in the CV.

Since the 1990s, the Feather River Hatchery (FRH) has produced between 6 and 8 million fall Chinook each year. This represents about a third of the estimated 23-30 million fall Chinook produced annually by the CV hatchery system. In addition, it is the only CV hatchery currently producing spring Chinook, releasing between 2 and 4 million fish annually. Approximately 10-25% of these FRH releases are tagged with a small (0.5-1 mm) coded-wire-tag (CWT) in their snouts and visually marked with a clipped adipose fin (ad-clipped) during their first 6 to 12 months of life. Most west coast salmon hatcheries use CWTs to evaluate relative survival rates and evaluate various hatchery practices. A unique cwtcode links the salmon to a specific release group (e.g., hatchery, stock, date released, release site, release size). CWT recovery information can be used to piece together the life history of each cohort and help estimate the effects of fisheries on salmon populations. Information from hatchery fish can also be extrapolated to fish of natural origin.

The majority of FRH Chinook releases are “Production” fish; these are fall and spring Chinook produced primarily as mitigation to support commercial and sport ocean fisheries, as well as a river fishery in the Sacramento River and Feather River basins. During the last decade, most production fish were trucked from FRH to the Carquinez Straights and/or San Pablo Bay areas where they were either held in net pens for a few weeks to acclimate or released immediately into the water.

FRH also uses “Experimental” releases that are released at various locations and times within the Sacramento and San Joaquin River Basins. These fish are used to help address important fish management questions such as determining the rate at which juvenile salmon enter water diversions, the importance of the Yolo Bypass to salmon rearing, and the survival of juvenile Chinook salmon through the Sacramento-San Joaquin Delta. In addition, FRH fall Chinook juveniles and eggs have been reared at other hatcheries and net pen facilities (e.g., Mokelumne River Fish Installation, Central Coast Enhancement Project Avila Rearing Pens, Monterey Bay Salmon and Trout Project Net Pens, and San Francisco Tyee Club in Tiburon).

To evaluate the relative success (e.g., survival, fishery contribution, spawner escapement) of these FRH fall and spring releases, a cohort reconstruction (CR) model was developed for the ‘98 and ‘99 brood years (BYs). This model is an adaptation of the Klamath Basin Fall Chinook CR developed by the CDFG’s Ocean Salmon Project (OSP) and the National Marine Fisheries Service (NMFS) in 2001 (Goldwasser et al. 2001). The Pacific Fishery Management Council (PFMC) uses the Klamath CR, along with the Klamath Ocean Harvest Model (KOHM), to evaluate and manage Klamath fall Chinook stocks in California and Oregon ocean salmon fisheries (PFMC).

The ’98 BY and ‘99 BY were specifically selected because CWT recovery programs were improved in both CV carcass and hatchery surveys (and specifically in the FR) during the life of these broods (2000-2004). Recoveries of CWTs were also consistent in ocean salmon fisheries during this time.

Unfortunately, due to CDFG budget constraints and staffing shortages, sampling of CV inriver recreational fisheries was inconsistent during this time and recoveries of CWTs were not representative of the fishery; thus these data were not included in the CR and a known data gap exists.

Originally, the CR was to include only FRH fall Chinook, but early data analyses showed that the CR needed to include the FRH spring run because of (1) the inability to distinguish between spring and fall runs in the FR carcass survey and (2) the significant overlap of FRH spring and fall CWTs collected during their respective run times at the hatchery.

Although spring Chinook migrate from the ocean earlier (May-June), it's impossible to separate fall from spring natural components in the ocean and on the spawning grounds. There is general agreement by NOAA and CDFG (Myers et al. 1998; CDFG 1998) that these two runs have been crossbred at FRH historically and there is no true separation of hatchery spring and fall releases at this time (Reynolds et al. 1993; Brown and Greene 1993). The CR assumes that all maturing FRH Chinook leave the ocean by September 1 and any salmon caught in the ocean fisheries on or after this date (i.e., September, October, November or December) were remaining in the ocean and are part of the total ocean population available for the next season's fisheries (September through August). In addition, September 1 is considered the birthday for FRH Chinook remaining in the ocean and all ocean fish become one year older on this date.

The CR rebuilds each cohort by starting with the last appearance of any members of a cohort (usually age 5 river returns in September) and working backwards rebuilding the cohort's ocean population monthly through Age 2 September (also know as the starting ocean abundance). To the estimated abundance of fish in the ocean at a given time, each monthly step backwards adds estimated numbers of (1) fish lost to ocean fishery impacts; (2) fish lost to natural mortality; and (3) between August and September, fish that mature and enter the river. This occurs separately for each CWT release group and then the natural component is rebuilt; all groups are then summed to create the total population.

Description of Cohort Reconstruction (CR) Databases

The CR and the analyses based on it depend on the accuracy and reliability of the CWT data collected from fisheries, spawning ground surveys, and hatcheries. The creation of these databases and verification of the information in them provides the foundation of the CR. Considerable effort and attention went into uncovering and correcting errors, and identifying data gaps.

The number of CWT fish recovered in inland and ocean waters depends, in part, on the number of fish marked and released, the fraction of these fish that are legal-sized, and sampling levels. These parameters vary across time and area and thus must be accounted for in estimating total cohort abundance at age and to allow for meaningful comparisons across time and area. Four kinds of CWT recovery expansions are used in the analyses to account for: (1) sampling rates, (2) hatchery production, (3) ocean contacts (versus harvest), and (4) ocean impacts (versus harvest). Some CWTs are also used as surrogates for the natural component.

The expansion for sampling rate converts the observed number of each cwtcode collected during sampling to the number of tags with that code that would have been expected if all fish had been examined (a 100% sampling rate); it is specific to each sampling program (ocean and CV) at the time of recovery. The expansion for hatchery production converts these sample-expanded fish to the total number of fish produced (tagged and untagged) for that release and is specific to each CWT. The expansion for ocean contacts converts the number of legal-sized fish that were harvested to the number of fish of all sizes that were contacted by the fishing gear; it is specific to month, area, age and release type of the fish, and the minimum legal size limit in effect at the time of contact. The expansion for ocean impacts converts the contacts to total impacts, including harvest, hook-and-release mortality, and dropoff mortality; it is also specific to month, area, age and release type of the fish, and the fishery minimum size limit in effect at the time of contact.

The database format used by the FRH CR allows for the easy addition of new or corrected data for other BYs. In addition, this CR model can be modified for usage with other hatchery stocks once the CWT and core CR databases have been created.

Coded-Wire Tag (CWT) databases

FRH Release data and hatchery production factors

It is imperative the release information is correct since this is the basis for determining how all CWT recoveries are expanded for their total production, respectively. The production factor is calculated based on the ratio of CWT tagged to total number released. If this production factor is over or under estimated, it introduces bias into the estimated number of FRH salmon recovered in both the ocean and CV. Thus fishery impacts, inbasin return rates, CV stray rates, estimated natural escapement, and all other parameters calculated by the CR from CWT recoveries are affected.

Significant time was spent trying to match up FRH CWT release data (1995-2002 BYs) from these sources:

Pacific States Marine Fisheries Commission-Regional Marking Information System (RMIS)
FRH hatchery reports
CWT release reports (Big Eagle and Associates)
FRH daily fish planting data sheets
Northwest Marine Technology Mass Marking Reports
CDFG StateWide Hatchery Database

All salmon CWT releases on the west coast are reported by their respective agencies to the RMIS; this is the “central clearing house” for all CWT release and recovery data on the west coast. Unfortunately, numerous differences were found between the RMIS data and those reported on the original CWT release reports. In addition, we found different methodologies being used to determine the number of 1) salmon correctly tagged with CWTs, 2) salmon mortality prior to release, 3) salmon that shed CWTs prior to release, and 4) salmon released untagged. Since these data are used to determine each cwtcode’s production factor, it is important that a uniform method be developed for all California CWT releases in the future, especially when calculating the number of untagged releases that are released with several different cwtcodes. Each of these cwtcodes should have the same production factor if their shed and mortality rates are relatively the same.

It was also discovered that a significant number of untagged releases of FRH fall and spring salmon were not in the RMIS and we spent considerable time matching up tagged and untagged releases from FRH Hatchery Reports, FRH daily fish planting data sheets, and the Department’s StateWide Hatchery Database. Often these data varied among files and additional research was needed to determine which of these data were correct. In addition, there were some untagged releases that couldn’t be linked to any FRH CWT releases.

The CR release file database (**releasefile_frh.dbf**) contains 492 records and is the corrected "master" list of all fall and spring Chinook CWT releases for 1995-2002 BYs at FRH. These BYs are needed to determine the age composition of the spring and fall runs in the FR from 2000-2004. The release file also contains FR Chinook stocks raised and released at other hatcheries or facilities.

Each cwtcode was assigned to one of eight FRH release groups based on run, size at time of release, rearing site, and release location: 1) INBF – FRH fall fingerlings released within the FR and sections of the Sacramento River that would be included in their natural emigration path to San Francisco Bay; 2) TRKF – FRH fall fingerlings trucked to the Benicia or Carquinez Straights area and either placed in net pens for a few weeks to acclimate or released directly into San Pablo Bay; 3) FRHS – FRH spring fingerlings trucked to the Benicia or Carquinez Straights area and either placed in net pens for a few weeks to acclimate or released directly into San Pablo Bay; 4) XHAF/XHAY – fall fingerlings and yearlings released experimentally in the Yolo Bypass and various locations within the San Joaquin Basin. This release group also includes fingerlings reared and released at salmon enhancement programs in Avila and Monterey; 5) TRHY – FRH fall Chinook trucked to Tiberon and raised in net pens until their release into San Francisco Bay as yearlings; 6) FRW – 'wild' juvenile Chinook captured in traps on the FR and tagged; 7) OROF – FRH fall fingerlings released into Lake Oroville for a direct take fishery; and 8) OHFF – FRH fall Chinook reared and released in other CV hatcheries (Table 1).

At FRH, the run designation was determined by the time of escapement into the hatchery. Generally salmon that entered FRH on or before September 15 were considered spring Chinook by hatchery staff. Salmon entering FRH after this were generally considered fall run. Fingerling and yearling releases were determined by fish weight and date of release. Most fingerlings weigh less than 13 g and are released March through June at approximately 6 months of age; yearlings generally weigh more than 60 g and are released the following August through October. Figure 1 shows the various rearing sites and release locations of FRH fall and spring releases within the CV and San Francisco Bay area. Each release group contains several CWT release codes for each BY.

Information for each release group was thoroughly checked for missing or misreported data. In several cases, large groups of fish were released untagged. Based on their release location, release date(s) and release size, these fish were linked to similarly sized CWT fish released at approximately the same time in the same area (Appendix 1). When several CWT releases occurred; the proportion tagged with each cwtcode to the total tagged was used to represent the untagged fish. For example, if 20% of the tagged fish belonged to cwtcode A010101, then 20% of the additional untagged production was applied to this cwtcode. A hatchery production factor, f_H, is then calculated to determine how many hatchery fish are represented by the recovery of a single CWT.

$$f_H = \frac{(n_{tagged} + n_{shed} + n_{untagged} + n_{additional})}{n_{tagged}} , \qquad (1)$$

where n_{tagged} = number of CWTs released, n_{shed} = number of ad-clipped fish that shed CWT prior to release, $n_{untagged}$ = number of untagged salmon released in conjunction with CWT, and $n_{additional}$ = number of additional untagged salmon linked to cwtcode. The inverse of the f_H is the proportion tagged, p_{tagged}, which is used in the CR.

Underestimating the contribution of hatchery fish in the FR Basin biases the proportion of naturals returning to the system since the natural run is determined by subtracting hatchery fish from the total run. In addition, since scales are not collected in the FR Basin to age the natural component, CWTs, (expanded for both sampling and production) collected at FRH and in the carcass surveys (2002-2004) were used to determine the age composition of the total run into the basin during 2000-2004. Thus incorrect production factors can also bias the proportion of naturals by over- or under-estimating the total age 2, age 3, age 4, and age 5 returns.

Table 1. Release types in the FRH CWT release database (1995-2002 BYs).

Release type	Run	Release Location	Release size	Number of CWT releases
INBF	Fall	InBasin FRH Production – released in Feather River and Sacramento River basins	Fingerling	130 cwtcodes
TRKF	Fall	Trucked FRH Production – released in Carquinez Strait /San Pablo Bay area	Fingerling	66 cwtcodes
XHAF XHAY	Fall	Experimental FRH Production – released in Yolo Bypass & San Joaquin Basin; also includes salmon enhancement programs in Monterey & Avila	Fingerling Yearling	92 cwtcodes 1 cwtcode
FRW	Wild	Wild Chinook salmon trapped and tagged in the Feather River.	Fingerling	84 cwtcodes
FRHS	Spring	FRH spring releases – primarily trucked and released in Carquinez Strait /San Pablo Bay area	Fingerling	48 cwtcodes
TRKY	Fall	FRH fall Chinook trucked to Tiburon and raised to yearlings in net pets	Yearling	2 cwtcodes
OROF	Fall	FRH fall Chinook released into Lake Oroville for direct take fishery.	Fingerling	15 cwtcodes
OHFF	Fall	FRH fall Chinook raised and reared at other CV hatcheries	Fingerling	8 cwtcodes

Release Type	Release Location
INBF	**1** Feather River
FRWI	**2** Thermalito - Live Oak
INBF	**3** Live Oak
INBF	**4** Verona
XHAF	**5** Yolo Bypass – Fremont Weir
INBF	**6** Elkhorn Boat Ramp
INBF	**7** West Sacramento
INBF	**8** Ryde-koket
XHAF	**9** Georgianna Slough
INBF	**10** Isleton
XHAF	**11** Mouth of the Mokelumne River
TRKF	**12** Port Chicago
FRHS	**13** Crockett / Benicia
TRKF/FRHS	**14** Wickland Oil Net Pens
TRHY	**15** Tiburon Net Pens

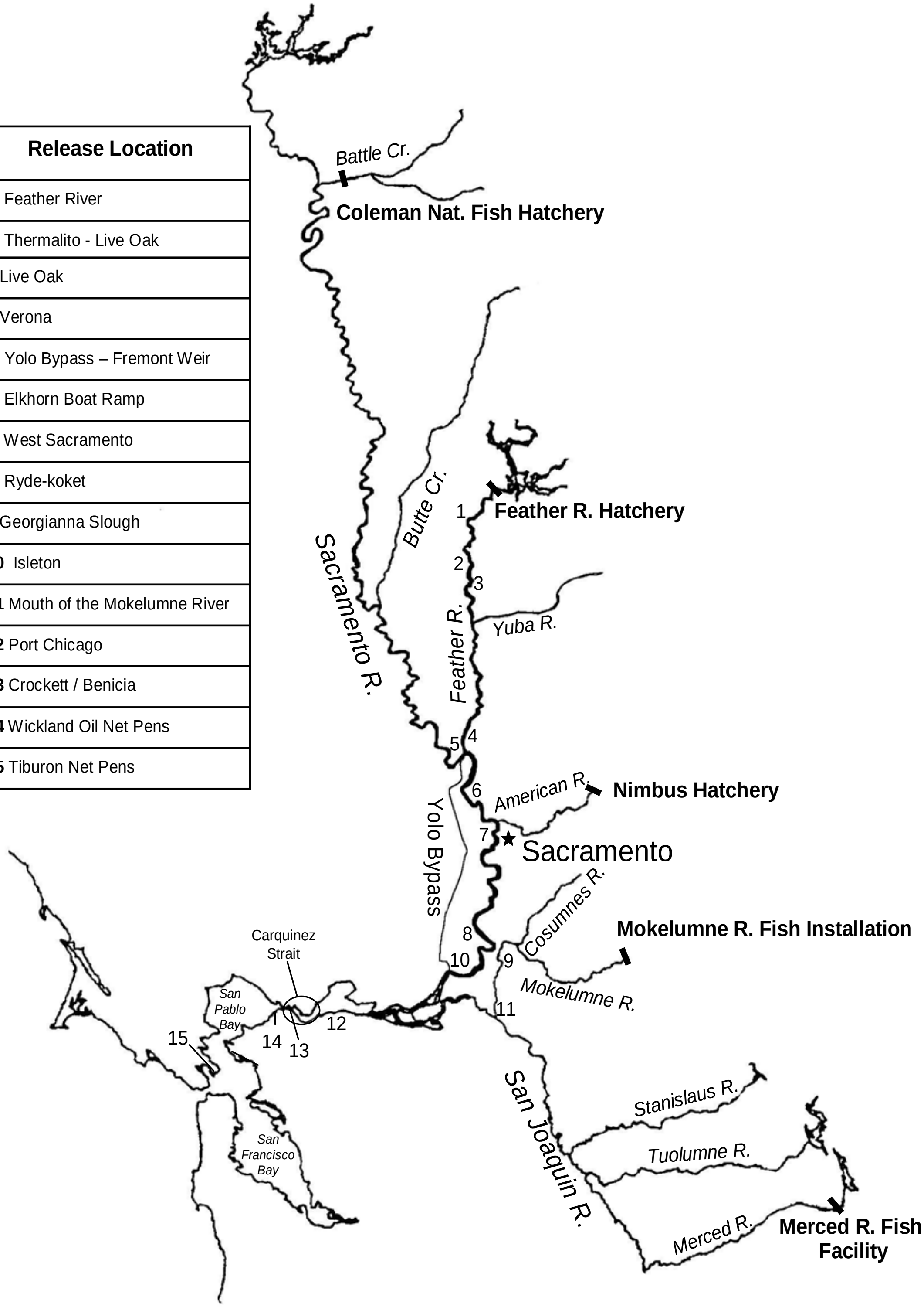


Figure 1. Location and release type of '98 and'99 FRH spring and fall CWT releases.

Ocean Salmon Fisheries CWT Recovery Data

All FRH cwtcodes recovered in ocean salmon fisheries during 1996 through 2004 on the west coast were downloaded from the RMIS system. Several programs and databases, operating in a series of steps were used to create a clean database of all ocean salmon fishery recoveries (n=34,587). Each recovery in the CR ocean recovery database (**alloceancwt.dbf)** was assigned a PFMC ocean fishery management area (Table 2; Figure 2) based on the port area where it was collected or its reported catch area. Several of these management areas are broken further into subareas because regulations differ among these areas on occasion. These are the management areas that the CR uses to determine fishery harvest and impact rates by time and fishery. All recovery agencies on the west coast strive to systematically sample at least 20% of commercial and sport salmon landings to have a statistically acceptable estimate of total tag recoveries for a given time-area stratum (Johnson 1990). Thus most ocean recoveries have a sample expansion factor of approximately 5.0. Less than 1% of all ocean CWTs had sample expansion rates greater than 7.0; these larger sample expansions generally occurred in the commercial fishery in Oregon and Washington during periods of reduced catch and effort when landings are generally few and sporadic. Sampling staff is usually reduced as the season winds down and it is difficult to maintain a 20% sample rate; however the bias associated with these unsampled landings should be small when compared to the overall catch.

Table 2. PFMC ocean fishery management areas, subareas, and their geographic boundaries.

PFMC Ocean Fishery Management Port Areas	Port / Catch Area
NO – Northern Oregon*	North of Heceta Head
NORN	North of Cape Falcon
NORS	Heceta Head to Cape Falcon
CO – Coos Bay	Between Heceta Head and Humbug Mtn. (Cape Blanco)
KO – KMZ Oregon	Between Humbug Mtn. (Cape Blanco) & CA/OR border
KC – KMZ California	Between CA/OR border and Horse Mtn.
FB – Fort Bragg	Between Horse Mtn. and Pt. Arena
SF – San Francisco	Between Pt. Arena and Pigeon Pt.
SOC1	Pt. Arena to Pt. Reyes
SOC2	Pt. Reyes to Pedro Pt.
SOC3	Pedro Pt. to Pigeon Pt.
MO – Monterey / Morro Bay*	South of Pigeon Pt.
SOC4	Pigeon Pt. to Pt. Sur
SOC5	South of Pt. Sur

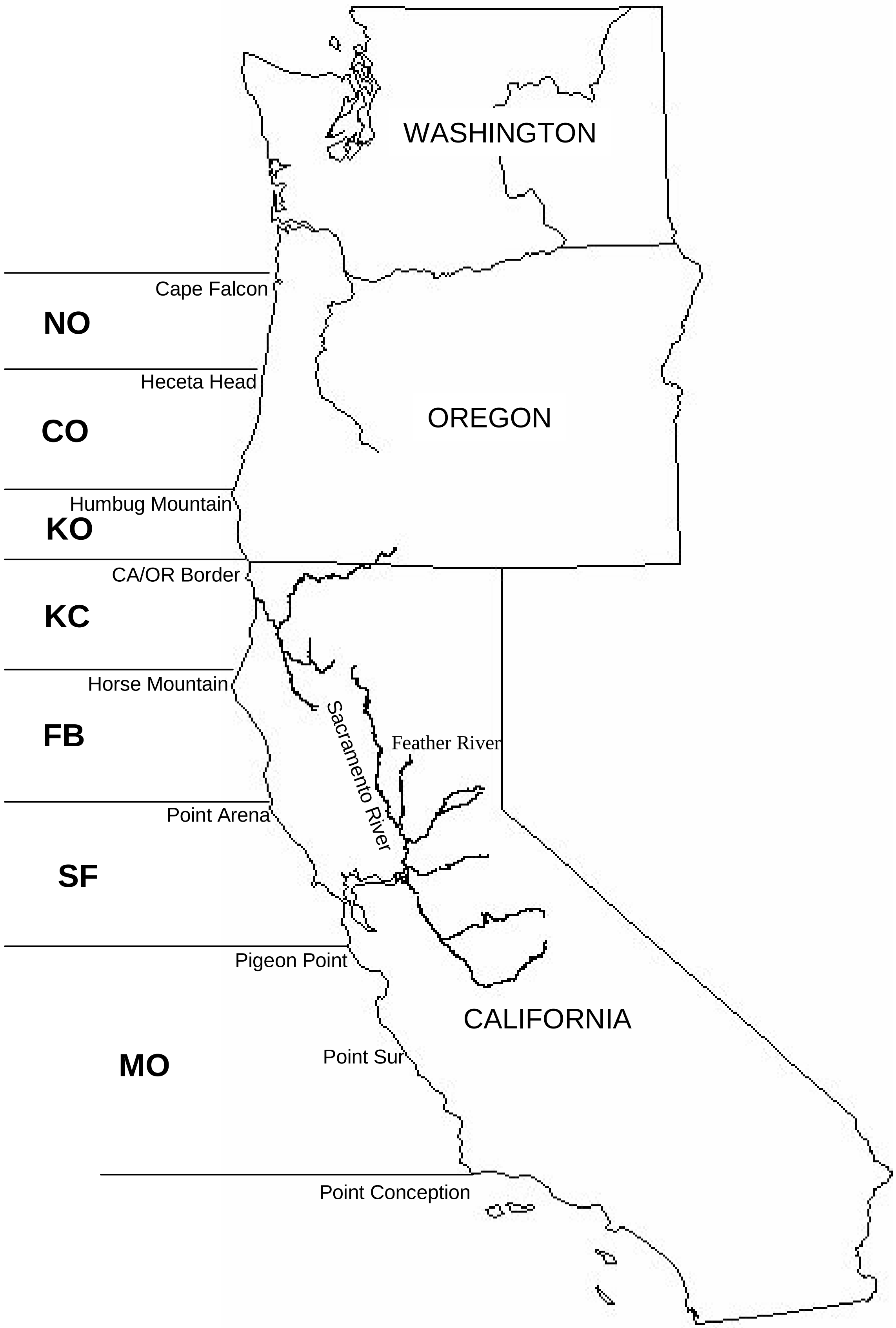


Figure 2. PFMC ocean fishery management port areas used in CR databases and programs.

Once PFMC management areas were added to all ocean recoveries, a subset database was created that contains only the recoveries of FRH ’98 BY and ’99 BY fall and spring releases (n = 7,948). This CR database, **oceancwt.dbf**, is used directly in the CR to rebuild these cohorts. Table 3 shows the recovery of these CWTs (not expanded for sampling or production) by fishery, month, and management port area.

Table 3. FRH ’98 BY and ’99 BY fall & spring CWTs recovered by fishery, port area, and month.

Ocean sport salmon fisheries									
Port area	Jan-Mar	Apr	May	Jun	Jul	Aug	Sep	Oct-Dec	Total
NO			2	18	86	39	24	5	174
CO		3		33	81	26	12	1	156
KO			22	16	14	13	17	4	86
KC			19	28	12	8	6		73
FB	9	12	50	76	111	37			295
SF		38	106	97	302	124	18	46	731
MO	49	436	64	103	45	32	14		743
Total	58	489	263	371	651	279	91	56	2,258
Ocean commercial troll salmon fisheries									
Port area	Jan-Mar	Apr	May	Jun	Jul	Aug	Sep	Oct-Dec	Total
NO	3	49	273	211	234	339	474	193	1,776
CO	2	42	202	252	142	73	77	16	806
KO			2	3	3	9	8	3	28
KC						5	55		60
FB			72		168	99	12		351
SF			721	230	760	53	4		1,768
MO			526	307	68				901
Total	5	91	1,796	1,003	1,375	578	630	212	5,690
Total ocean salmon fisheries									
Port area	Jan-Mar	Apr	May	Jun	Jul	Aug	Sep	Oct-Dec	Total
NO	3	49	275	229	320	378	498	198	1,950
CO	2	45	202	285	223	99	89	17	962
KO			24	19	17	22	25	7	114
KC			19	28	12	13	61		133
FB	9	12	122	76	279	136	12		646
SF		38	827	327	1,062	177	22	46	2,499
MO	49	436	590	410	113	32	14		1,644
Total	63	580	2,059	1,374	2,026	857	721	268	7,948

CV Inland CWT Recovery Data

It was necessary to compile data from numerous sources throughout the CV. The various sampling entities included CDFG, California Department of Water Resources (DWR), U. S. Fish and Wildlife Service (USFWS), East Bay Municipal Utility District (EBMUD), and Sacramento consultants Jones & Stokes. These projects collected heads from adipose fin-clipped (ad-clipped) salmon that were sampled at CV hatcheries, on CV spawning grounds, and in the CV river recreational harvest during 2000-2004. Detailed descriptions of the various CV monitoring projects and their methodologies can be found in CDFG 2005.

All FRH '98 and '99 FRH CWTs recovered in the FR Basin were placed in the CR database **Inbasin_rec.dbf** and recoveries from all other CV river basins in the CR database **otherriverrec.dbf** (Table 4). Recoveries from the CV river recreational creel survey were subsequently removed from both databases due to the problems discussed below

Table 4. FRH '98 BY and '99 BY CWT recoveries by survey in the FR Basin & outside FR Basin.

Brood year 1998

	Feather River Basin Recoveries					Out of Basin Recoveries				
CV	CWTs		Sample Expanded CWTs			CWTs		Sample Expanded CWTs		
Surveys	#	%	#	%	avg expfct	#	%	#	%	avg expfct
Hatchery	3,804	88%	3,843	39%	1.0	80	42%	81	5%	1.0
Carcass	447	10%	4,263	43%	9.5	83	44%	490	32%	5.9
Creel*	53	1%	1,726	18%	32.6	27	14%	966	63%	35.8
total	4,304		9,832		2.3	190		1,537		8.1

Brood year 1999

	Feather River Basin Recoveries					Out of Basin Recoveries				
CV	CWTs		Sample Expanded CWTs			CWTs		Sample Expanded CWTs		
Surveys	#	%	#	%	avg expfct	#	%	#	%	avg expfct
Hatchery	1,223	79%	1,236	19%	1.0	14	32%	15	3%	1.1
Carcass	272	18%	3,820	59%	14.0	28	64%	460	82%	16.4
Creel*	44	3%	1,375	21%	31.3	2	5%	89	16%	44.5
total	1,539		6,431		4.2	44		564		12.8

* River recreational fishery creel data not used due to inconsistent sampling and sporadic CWT recovery.

Hatchery escapement monitoring and CWT recovery programs

The five salmon hatcheries in the CV are Coleman National Fish Hatchery (CNFH) on Battle Creek, Nimbus Fish Hatchery (NFH) on the American River, Mokelumne River Fish Installation (MRFI), Merced River Fish Facility (MRFF) and FRH. These hatcheries typically monitor 100% of the run returning to their respective hatchery to determine grilse (age 2) and adult hatchery escapement and to collect CWTs. This was the case for all hatcheries during 2000-2004 except at CNFH in 2003, when the fall run was too large to collect the heads from all ad-clipped salmon entering the hatchery. Approximately half of the observed CWTs were collected and the sample expansion factor for CNFH recoveries in 2003 was adjusted accordingly. NFH and MRFI salmon heads were processed at the OSP CWT lab in Santa Rosa while MRFF processed their heads at the CDFG La Grange office. These projects submit their data electronically to OSP to be included with other California ocean and inland data submitted to the RMIS. CNFH processed their salmon heads onsite and submits their data directly to the RMIS system.

During 2000-2004, all salmon entering FRH were sampled and heads collected from all ad-clipped fish (Table 5). The FRH fish ladder is opened two separate periods to differentiate between the spring and fall runs. Traditionally, the ladder is open during the first two weeks of September to allow the spring run to enter FRH, closed for a few days and then reopened again through late November to allow the fall run entry. Salmon less than 24 inches in total length are considered grilse during both runs. In 2003 and 2004, however, there was an attempt by DWR and CDFG to mark early spring run Chinook with floy-tags during May and June. These fish were then segregated and spawned separately as an "early" spring run when they returned to FRH in August and September.

Although FRH determines their "spring" and "fall" escapement based on the above run timing, there was significant overlap of the two runs during 2000-2004 based on the CWTs recovered at FRH. It has long been theorized that there has been hybridization due to the overlap both spatially and temporally since Oroville Dam was built. During the 2000-2004 period, there was considerable overlap of spring and fall FRH CWTs between runs. Expanded for both sampling and hatchery production, the proportion of FRH fall CWTs in the spring run ranged from 20% to 58% (Table 6, Figure 3). During the fall run, FRH spring CWTs accounted for 11% to 24% of the hatchery component during 2000-2004 (Table 6, Figure 4). There were only a few other CV stocks recovered in the spring run; however there were several stocks from other CV hatcheries taken in the fall run. Other CV stocks represented 1% to 4% of the hatchery component at FRH. Most of the strays in FRH were fall run Chinook from MRFI (release group MOKF) and MRFF (release group MERF). There were also a few fall Chinook from NFH (release group AMEF) and both fall (release group CFHF) and late fall (release group CFHL) Chinook from CNFH. During the 2002 fall run, there was one spring Chinook from Butte Creek (release group BUTS) taken at FRH. We should note that these non-FRH recoveries may be underestimated because we used production factors for these releases based on current RMIS data; we did not investigate if any addition untagged Chinook were also released with these non-FRH CWTS.

Table 5. Hatchery escapement at FRH and CWTs collected during spring and fall runs, 2000-2004.

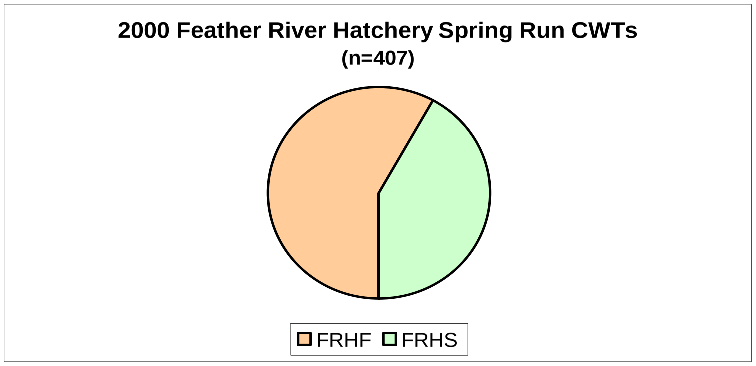
Run Year	FRH run	FRH escapement estimate	# fish sampled	# fish with ad-clip	% fish ad-clip rate	# CWTs recovered	CWT sample expansion	% no CWT found
2000	Spring	3,972	3,972	445	11.2%	407	1.0	9%
	Fall	18,146	18,146	1,189	6.6%	1,115	1.0	6%
	Total	22,118	22,118	1,634	7.4%	1,522	1.0	7%
2001	Spring	4,135	4,135	479	11.6%	439	1.0	8%
	Fall	24,872	24,872	2,778	11.2%	2,582	1.0	7%
	Total	29,007	29,007	3,257	11.2%	3,021	1.0	7%
2002	Spring	4,189	4,189	549	13.1%	503	1.0	8%
	Fall	20,507	20,507	1,532	7.5%	1,360	1.0	11%
	Total	24,696	24,696	2,081	8.4%	1,863	1.0	10%
2003	Spring	8,762	8,762	273	3.1%	228	1.0	16%
	Fall	14,967	14,958	1,247	8.3%	1,125	1.0	10%
	Total	23,729	23,720	1,520	6.4%	1,353	1.0	11%
2004	Spring	4,202	4,202	574	13.7%	488	1.0	15%
	Fall	21,304	21,304	2,278	10.7%	1,977	1.0	13%
	Total	25,506	25,506	2,852	11.2%	2,465	1.0	14%

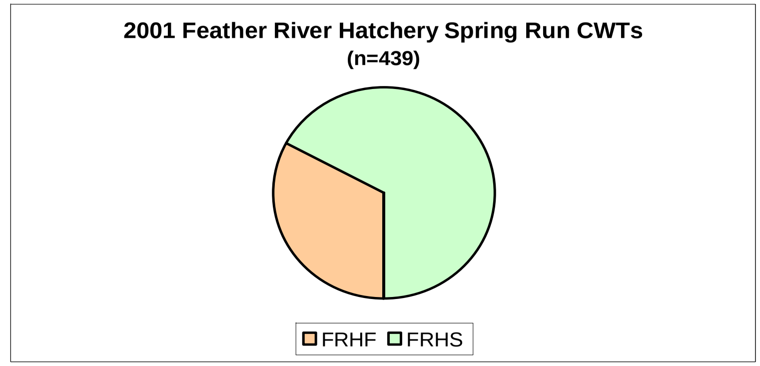
Table 6. CWTs collected at FRH by run timing, 2000-2004 (CWTs expanded for sampling and production)

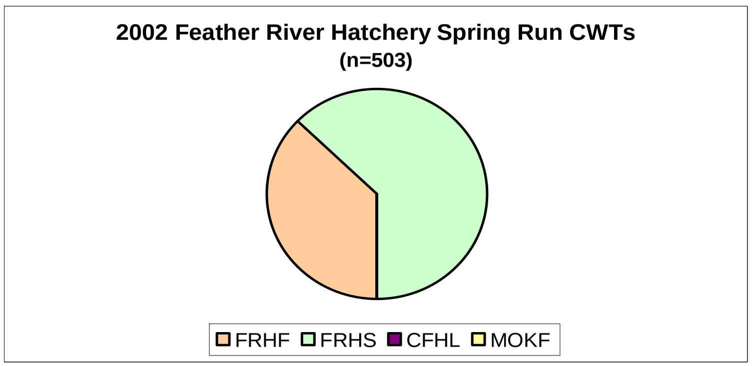
Spring Run	Total FRH escapement	# CWTs recovered	Expanded CWTs	% hatchery origin	# CWT recoveries FRH spring	# CWT recoveries FRH fall	# CWT recoveries other stocks	% CWT recoveries FRH spring	% CWT recoveries FRH fall	% CWT recoveries other stocks	FRH Operations adult count	FRH Operations grilse count	FRH Operations % grilse	FRH Operations ladder open date	FRH Operations ladder close date
2000	3,972	407	3,903	98%	1,635	2,267	0	42%	58%	0%	3,657	315	8%	09/01/00	09/15/00
2001	4,135	439	3,008	73%	2,020	988	0	67%	33%	0%	4,052	83	2%	09/01/01	09/15/01
2002	4,189	503	3,051	73%	1,913	1,137	2	63%	37%	0%	3,982	207	5%	09/03/02	09/15/02
2003	8,762	228	1,413	16%	1,134	279	0	80%	20%	0%	8,373	389	4%	08/18/03	09/15/03
2004	4,202	488	1,152	27%	621	530	1	54%	46%	0%	3,630	572	14%	09/13/04	09/18/04

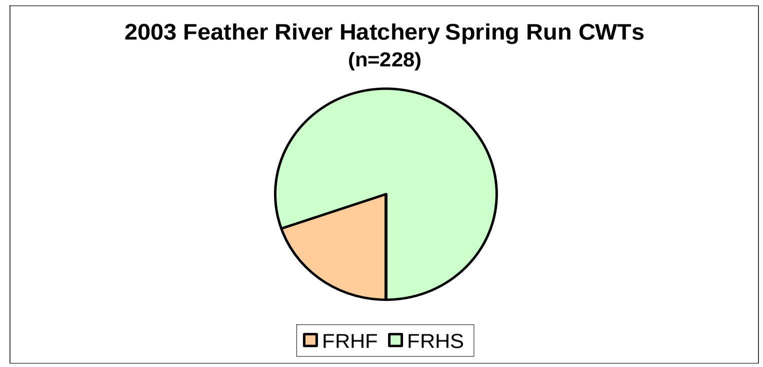
Fall Run	Total FRH escapement	# CWTs recovered	Expanded CWTs	% hatchery origin	# CWT recoveries FRH spring	# CWT recoveries FRH fall	# CWT recoveries other stocks	% CWT recoveries FRH spring	% CWT recoveries FRH fall	% CWT recoveries other stocks	FRH Operations adult count	FRH Operations grilse count	FRH Operations % grilse	FRH Operations ladder open date	FRH Operations ladder close date
2000	18,146	1,115	9,519	52%	1,041	8,124	353	11%	85%	4%	16,470	1,676	9%	09/27/00	12/08/00
2001	24,872	2,582	17,162	69%	2,888	14,002	271	17%	82%	2%	24,001	880	4%	09/26/01	12/07/01
2002	20,507	1,360	8,165	40%	1,337	6,657	171	16%	82%	2%	17,516	2,991	15%	09/15/02	11/18/02
2003	14,967	1,125	5,438	36%	1,289	4,061	87	24%	75%	2%	13,615	1,352	9%	09/24/03	11/24/03
2004	21,304	1,977	6,033	28%	1,277	4,683	74	21%	78%	1%	15,769	5,535	26%	09/21/04	11/29/04

Total Run	Total FRH escapement	# CWTs recovered	Expanded CWTs	% hatchery origin	# CWT recoveries FRH spring	# CWT recoveries FRH fall	# CWT recoveries other stocks	% CWT recoveries FRH spring	% CWT recoveries FRH fall	% CWT recoveries other stocks	FRH Operations adult count	FRH Operations grilse count	FRH Operations % grilse	FRH Operations ladder open date	FRH Operations ladder close date
2000	22,118	1,522	13,422	61%	2,676	10,392	353	20%	77%	3%	20,127	1,991	9%	09/01/00	12/08/00
2001	29,007	3,021	20,170	70%	4,908	14,991	271	24%	74%	1%	28,053	963	3%	09/01/01	12/07/01
2002	24,696	1,863	11,216	45%	3,250	7,793	173	29%	69%	2%	21,498	3,198	13%	09/03/02	11/18/02
2003	23,729	1,353	6,850	29%	2,422	4,340	87	35%	63%	1%	21,988	1,741	7%	08/18/03	11/24/03
2004	25,506	2,465	7,185	28%	1,898	5,213	75	26%	73%	1%	19,399	6,107	24%	09/13/04	11/29/04









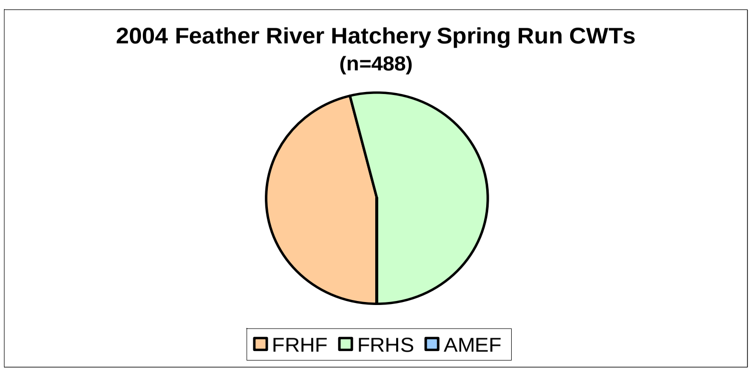


Figure 3. Composition of CWTs recovered at FRH during spring run, 2000-2004.

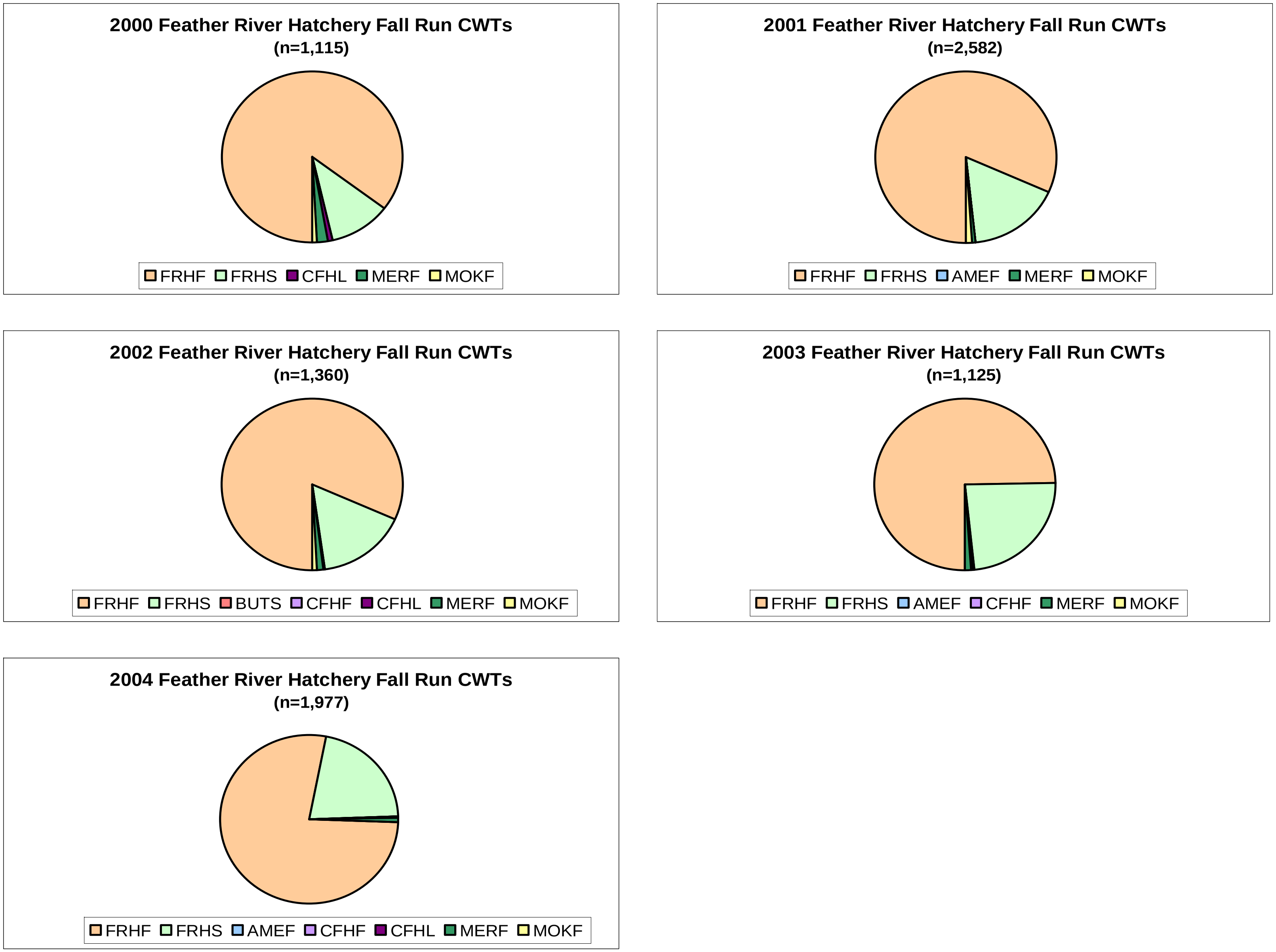


Figure 4. Composition of CWTs recovered at FRH during fall run, 2000-2004

Spawner escapement monitoring and CWT recovery programs

Various projects monitored spawner escapement throughout the CV during 2000–2004 (CDFG 2005). Escapement estimates were determined by variety of methods including carcass mark and recapture surveys, aerial redd counts, ladder or weir passage, snorkel surveys, and video monitoring. Many projects used a mark and recapture method that required the processing of thousands of salmon carcasses during a relatively short period of time. Often looking for ad-clipped salmon and/or the collection of CWTs was not a primary goal, if at all. In addition, there were remote areas only accessible by hiking through rugged terrain for several miles. Since already crews had to pack their equipment in and out of these areas, the collection and transporting of CWTs was just not feasible. Determining the sample expansion factors for CWTs that were collected was also complex due to various methods used in the estimation process (Mohr 2002). Sample expansion factors for CWTs collected during CV spawner escapement monitoring in 2000-2004 ranged from 2.0 to 68.5 (Table 6).

The DWR monitored the spawner escapement in the FR basin during 2000-2004. They conducted a carcass mark and recapture survey on a 16-mile section considered the most natural spawning area in the FR basin. This section was further divided into two subsections: the high-flow channel (HFC) and the low-flow channel (LFC). Separate spawner estimates and sample expansions were generated for each section and then combined. In addition, estimates were broken out into grilse (age 2 salmon less than 26.8" in total length) and adult components. Sampling generally began during early September when the first spawners were observed and ended in mid-December when the run finished.

Prior to 2002, sampling for ad-clipped salmon and collecting CWTs was not a priority for the DWR carcass survey; thus the recovery rate of CWTs was extremely low and biased the hatchery contribution during 2000-2001 (Table 7). In 2002, DWR added a "CWT crew" to their efforts (B. Cavallo, DWR, pers. comm.). The CWT crew preceded the carcass survey team and collected heads, scales and otoliths from all observed ad-clipped fish. The focus of the CWT crew was to sample a subset of all carcasses and accurately determine the rate that hatchery salmon occurred in the sampled population.

In 2000, the DWR estimated 116,900 salmon spawned in the FR basin (Table 7). They examined 53,300 carcasses and recovered 208 heads from ad-clipped fish; 187 (90%) of these heads contained CWTs. The observed ad-clip rate for the entire carcass survey was 0.4%. In addition, there was no way to determine if CWTs were collected in the HFC or LFC sections, so all CWTs were given a combined sample expansion factor of 2.2 from both areas.

In 2001, an estimated 178,700 salmon spawned in the FR basin (Table 7). DWR examined 51,404 carcasses and recovered 282 heads from ad-clipped fish; 244 (87%) of these heads contained CWTs. The observed ad-clip rate for the entire carcass survey was 0.5%. Sample expansions ranged from 2.7 to 6.1.

In 2002, the FR spawner estimate was 105,200 salmon (Table 7). The CWT crew examined a subset of 5,780 carcasses and collected 458 heads from ad-clipped fish; 369 (81%) of these heads contained CWTs. The observed ad-clip rate for the survey was 7.9%. Sample expansions ranged from 16.3 to 23.9.

In 2003, DWR estimated 89,900 salmon spawned in the FR basin (Table 7). The CWT crew examined 6,057 carcasses and collected 414 heads from ad-clipped fish; 346 (84%) of these heads contained CWTs. The observed ad-clip rate for the survey was 6.8%. Sample expansions ranged from 11.3 to 25.7.

In 2004, an estimated 54,200 salmon spawned in the FR. The CWT crew examined 3,800 carcasses and collected 256 heads from ad-clipped fish; 213 (83%) of these heads contained CWTs. The observed ad-clip rate for the survey was 6.7%. Sample expansions ranged from 13.1 to 17.2.

Table 7. Feather River spawner escapement survey data (fall and spring runs) by area, 2000-2004.

Run Year	FR area	Spawner escapement estimate	# Carcasses sampled in M&R survey	# Carcasses sampled by CWT crew	# fish with ad-clip	% fish ad-clip rate	# CWTs recovered	CWT sample expan.	% no CWT found
2000	LFC	73,432	44,874						
survey dates	HFC	43,509	8,382						
Sep 5-Dec 14	Total	116,941	53,256		208	0.4%	187	2.2	10%
2001	LFC	107,096	39,601		251	0.6%	218	2.7	13%
survey dates	HFC	71,606	11,803		31	0.3%	26	6.1	16%
Sep 10-Dec 12	Total	178,702	51,404		282	0.5%	244	3.5	13%
2002*	LFC	71,038	38,093	4,351	419	9.6%	337	16.3	20%
survey dates	HFC	34,125	8,884	1,426	39	2.7%	32	23.9	18%
Sep 3-Dec 20	Total	105,163	46,977	5,777	458	7.9%	369	18.2	19%
2003*	LFC	51,964	29,475	4,579	382	8.3%	323	11.3	15%
survey dates	HFC	37,983	9,910	1,478	32	2.2%	23	25.7	28%
Sep 2-Dec 17	Total	89,947	39,385	6,057	414	6.8%	346	14.9	16%
2004*	LFC	37,058	19,164	2,832	233	8.2%	193	13.1	17%
survey dates	HFC	17,113	4,115	997	23	2.3%	20	17.2	13%
Sep 7-Dec 15	Total	54,171	23,279	3,829	256	6.7%	213	14.1	17%

*DWR added a "CWT crew" to subsample the carcass population for CWTs in conjunction with its mark and recapture (M&R) survey

River recreational harvest CWT recovery program

Although CDFG began the Central Valley Salmon and Steelhead Harvest Monitoring Project (CVSSHMP) in 1998 to estimate harvest of adult Chinook salmon and steelhead in the major rivers and streams of the CV (Massa and Schroyer 2003), sampling was inconsistent and sporadic during 2000-2002. In addition, due to budget cuts, the CVSSHMP didn't sample at all during 2003 and 2004.

In 2000, the census was conducted on the Sacramento, American, Feather, Yuba, San Joaquin, Mokelumne, and Stanislaus rivers. The study area consisted of 554 miles of river divided up into 18 sections, ranging from 1 to 56 miles per section. The entire year was sampled in all sections. This represents the largest area and time period encompassed by the creel census during the 2000-2004 period. The CVSSHMP sampled 2,951 salmon and 175 heads were recovered from ad-clipped fish (Table 8). The estimated inriver Chinook salmon harvest was 70,800 for the entire CV in 2000. Sample expansions for the 114 CWTs recovered ranged from 5.1 to 103.5.

In 2001, the census was reduced to the Sacramento, American and Feather rivers. The study area consisted of 377 miles of river divided up into 13 sections at 1 to 56 miles per section. Sacramento River sections were sampled January and July through December. The American and Feather rivers were sampled January and March through June. The CVSSHMP sampled 1,494 salmon and 113 heads were recovered from ad-clipped fish (Table 8). The total estimated inriver Chinook salmon harvest was 46,100 for the CV. This estimate represents only a portion of the CV inriver sport harvest, since none of the rivers were sampled the entire year. Sample expansions for the 85 CWTs recovered ranged from 8.3 to 62.8.

In 2002, the census was conducted on the Sacramento, American and Feather rivers only. All Sacramento River sections were sampled during Chinook salmon season. The American and Feather river sections were sampled the entire year except for January. The CVSSHMP sampled 3,391 salmon and 275 heads were recovered from ad-clipped fish (Table 8). The 2003 estimated inriver Chinook salmon harvest was 110,900 for the CV. This estimate represents the highest harvest reported by the CVSSHMP since its inception in 1998. Sample expansions for the 225 CWTs recovered ranged from 17.5 to 57.9.

In 2003 and 2004, budget cuts and staffing problems disrupted normal sampling. No official CV inriver salmon estimates were calculated from the few data gathered in the CV.

We spent considerable time trying to fill in the missing data gaps but we were not comfortable with the assumptions we had to make or the overall effects of these data on the CR. Due to the spottiness of these data, combined with the high sample expansion rates being applied to the few CWTs collected, we chose to throw out these creel data completely when determining the total FR run (fall and spring combined) and in rebuilding the ’98 and ’99 BYs.

Table 8. Recreational creel survey (all runs) in FR basin and other areas of CV, 2000-2004

Year	Creel location	Harvest estimate	# fish sampled	avg sample expansion rate	# fish sampled ad-clip	% fish ad-clip rate	# CWTs recovered	% no CWT found
2000	Feather River	18,062	820	22.0	54	6.6%	26	52%
	Other CV areas	52,767	2,131	24.8	121	5.7%	88	27%
	Total CV	70,829	2,951	24.0	175	5.9%	114	35%
2001	Feather River*	701	17	41.2	3	17.6%	2	33%
	Other CV areas	45,390	1,477	30.7	110	7.4%	83	25%
	Total CV	46,091	1,494	30.9	113	7.6%	85	25%
2002	Feather River	33,461	1,207	27.7	125	10.4%	103	18%
	Other CV areas	77,427	2,184	35.5	150	6.9%	122	19%
	Total CV	110,888	3,391	32.7	275	8.1%	225	18%
2003				No CV creel survey conducted				
2004				No CV creel survey conducted				

*Represents only subset of Feather River harvest due to low sampling effort

Other Core CR databases

Ocean Fisheries Regulations database

The CR ocean fisheries regulations database (**regulations_ocean,dbf**) contains all ocean salmon fishery regulations in effect from 1983 through 2004 by major port area, date, fishery (commercial troll and sport), and minimum size limit (PFMC 2005). The CR programs **getkohmarea.prg** and **getlimit.prg** use this database respectively 1) to determine whether the default PFMC fishery management area for each cwt recovery was actually open on the given sample date; and 2) to obtain the minimum size limit in effect on the sample date. If either program encounters a problem, it flags the record for user intervention. All flagged records were reviewed, given a correct fishery management area, and placed in **fixedkohm.dbf** (n=10) so that these problem data will be corrected automatically during future downloads and model runs.

Ocean Salmon Fisheries Catch and Effort database

The CR ocean fisheries catch and effort database (**fishingeffort.dbf**) contains the number of Chinook salmon landed and fishing effort by commercial and recreational ocean salmon fisheries in both California and Oregon from 1983 through 2004 (PFMC 2005). Although the effort data are not used in the CR, it is included with the catch for analysis of contact rates per unit of effort. These data will be needed if an FRH ocean harvest model is developed. Sport effort is measured in angler-days fished, while commercial effort is in boat-days fished.

Ocean Fisheries Hook-and-Release Mortality Rates (HRM) database

In modeling non-retention ocean fishery impacts on sublegal salmon, we use the hook-and-release "shaker" mortality rates (HRM) as adopted by the PFMC in 2001. A 26% HRM rate is used for all commercial ocean salmon fisheries coastwide and a 14% HRM rate for the recreational salmon fishery north of Point Arena, California. For the recreational fishery south of Point Arena (San Francisco and Monterey), a shaker mortality rate, s_O, by month and management area, is calculated based on the proportion of anglers using mooch and troll gear in the area (San Francisco or Monterey area) and the HRMs of 42.2% (Grover et al. 2002) and 14% for these two gear types, respectively:

$$s_O = (p_{mooch} * 0.422) + (p_{troll} * 0.14) \tag{2}$$

These rates, by month, area, and year during 2000 through 2004, are contained in the CR hook-and-release mortality rates database (**hookmort.dbf**).

Critical analyses needed for the cohort reconstruction

Age composition analysis

Determining the age composition of Chinook escapement in the FR is a critical component of the CR. Age structured run size estimates are necessary to rebuild the cohorts through time. In the Klamath Basin, scales are systematically collected from all salmon returning to the hatcheries, in the fisheries, and on the spawning grounds. These scales, combined with CWTs from known age fish, are used to determine the proportion of age 2, age 3, age 4 and age 5 fish escaping to the Klamath Basin. The grilse proportion (age 2) is also checked against length frequency data to ensure that the jack to adult ratio is correct.

Because scales were not collected in the FR during 2000-2004, CWTs collected at the hatchery and in the carcass survey were the only data available to estimate age proportions. The total Chinook run in the FR is the sum of all hatchery returns and the natural escapement. Originally, the estimated sport harvest in the FR was also included in the total run, but due to sporadic sampling among years discussed earlier, coupled with an extremely low CWT recovery rate, these data were deleted because they significantly overestimated the natural component in certain years during preliminary CR. In general, the model determines the number of naturally spawning fish by subtracting the hatchery component (i.e., CWTs expanded for sampling and production) from the total escapement at age.

The age composition at FRH was determined for each run using CWTs expanded for sampling and production (Table 9) except for Fall 2001. Because the number of grilse (salmon less than 24" total length) counted at the hatchery was much higher than the proportion of age 2 CWTs collected, the actual count was used since it appeared to most closely represent the observed run. These grilse were then removed from the total fall run and the remaining fish were then apportioned using the normalized adult proportions.

Until 2002, the carcass survey in the FR was also sporadic with a minimum effort to recover CWTs; thus during 2000 and 2001, the total age composition observed at FRH was used to breakout the adult component. Although the number of grilse has been found to be underestimated due to the size-dependent recovery rate of salmon carcasses in mark-recapture surveys (Zhou 2002), the proportion of age 2 fish used was based on the actual number of grilse (salmon less than 26.8" in total length) observed by DWR in the field instead of the CWT age composition. During 2002-2004, the DWR "CWT crew" was created and a higher sample rate was achieved. Age 2 proportions were again based on the actual count of grilse while the apportionment of adults based on the normalized adult proportions of CWTs collected in the carcass survey.

Table 9. Feather River fall and spring Chinook hatchery and natural escapement and age composition, 2000-2004 (Yellow='98 BY; Green='99 BY)

	Total Run [a]	Age 2 [b]	Age 3	Age 4	Age 5	Feather River CWT age composition [b] Age 2	Age 3	Age 4	Age 5
2000									
Hatchery - fall	18,146	7,004	7,041	3,920	181	0.386	0.388	0.216	0.010
Hatchery - spring	3,972	413	1,907	1,648	4	0.104	0.480	0.415	0.001
Natural escapement [c]	116,941	**7,017**	66,903	41,634	1,387	**0.060**	0.572	0.356	0.012
Total returns	139,059	14,434	75,850	47,202	1,572	0.104	0.545	0.339	0.011
2001									
Hatchery - fall	24,872	**880**	20,868	3,124	0	**0.035**	0.839	0.126	0.000
Hatchery - spring	4,135	128	2,907	1,088	12	0.031	0.703	0.263	0.003
Natural escapement [c]	178,702	**9,114**	144,003	25,509	75	**0.051**	0.806	0.143	0.000
Total returns	207,709	10,122	167,778	29,721	88	0.049	0.808	0.143	0.000
2002									
Hatchery - fall	20,507	3,794	5,947	10,766	0	0.185	0.290	0.525	0.000
Hatchery - spring	4,189	205	2,044	1,919	21	0.049	0.488	0.458	0.005
Natural escapement [d]	105,163	**11,397**	28,760	64,218	788	**0.108**	0.273	0.611	0.007
Total returns	129,859	15,396	36,751	76,903	809	0.119	0.283	0.592	0.006
2003									
Hatchery - fall	14,967	1,736	7,828	5,328	75	0.116	0.523	0.356	0.005
Hatchery - spring	8,762	517	1,551	6,659	35	0.059	0.177	0.760	0.004
Natural escapement [d]	89,947	**4,369**	38,515	47,063	0	**0.049**	0.428	0.523	0.000
Total returns	113,676	6,623	47,893	59,050	110	0.058	0.421	0.519	0.001
2004									
Hatchery - fall	21,304	6,455	11,525	3,089	256	0.303	0.541	0.145	0.012
Hatchery - spring	4,204	1,270	2,089	710	139	0.302	0.497	0.169	0.033
Natural escapement [d]	54,171	**5,591**	30,589	16,890	1,100	**0.103**	0.565	0.312	0.020
	79,679	13,316	44,204	20,690	1,495	0.167	0.555	0.260	0.019

[a] Run estimates from updated 2000-2004 FRH Hatchery reports, DWR Feather River carcass survey reports 2000-2004, and pers comm.. with Ana Kastner, FRH manager.

[b] Age composition of hatchery returns based on FRH cwt age composition, except for 2001 FRH fall where actual grilse counts used (bold).

[c] Actual grilse counts used for natural escapement (bold); FRH CWT adult proportions (red) used for natural adult age composition.

[d] Actual grilse counts used for natural escapement (bold); Feather River carcass survey CWT adult proportions (red) used for natural adult age composition.

Size-at-age analysis

The size-at-age analysis gives an estimate of the size distribution of ocean fish for each month and age class. These distributions, in combination with a minimum size limit for legally caught fish, provide estimates of p_{legal}, which is the proportion of fish of each age that are of legal size during a given month. This information is used in the CR to expand harvests to fishery contacts. A contact is a fish of any size that encountered the gear and was brought to the boat.

In the past, both CR and ocean harvest models have assumed the proportion of fish of legal size to be an age-specific constant, regardless of the actual size limit, the month of the year, or the particular characteristics of a certain stock. This simplification has made it impossible, when shaping a fishery, to assess the effect of shifting its minimum size limit. Working with the actual size distribution makes it possible to use the size limit quantitatively as a management tool.

Preliminary analysis showed the length distribution between expanded fall (n=377,476) and spring (n=92,727) recoveries to be almost identical. In addition, the length distribution between FRH fingerlings released inbasin and those trucked showed no significant difference. Thus these data were combined for the size-at-age analysis. We removed recoveries with extremely small or large lengths for their respective age (e.g., age 2 fish with reported length of ≥32 inches) since these outliers tended to skew the normal size distribution and increased the standard deviation during preliminary analyses. We believe the majority of these data represent cases where the lengths were simply misreported in the fisheries.

The size-at-age analysis used FRH spring and fall fingerling length data (24,574 CWTs) from ocean troll and sport CWT recoveries during 1996-2004, expanded for both sampling and production. Only CWTs recovered in Oregon and California ocean salmon fisheries in which a minimum size limit of 20 inches total length or greater was in effect were used to reduce the bias associated with using a truncated subset of the size distribution of the population (n=470,203 expanded CWTs). Due to their infrequency and known low contribution in the troll fishery, age 2 CWT recoveries from the troll fishery were removed; thus only sport recoveries were used to determine mean length for age 2 by month.

The analysis assumed a normal size distribution, and provided estimates of the mean and standard deviation of the length distribution. One major statistical issue in this analysis is that the recoveries represent only a truncated subset of the size distribution of the population. Fish below the legal size limits were rarely retained, and are represented in the database by only a relatively small number of records. Consequently, simple statistics of the recovered fish would overestimate the actual mean and underestimate the standard deviation of the whole population. We avoided these biases by using maximum likelihood methods (program written in R code by M. Mohr, NMFS, Southwest Region, Santa Cruz) to estimate the most likely normal distribution from which the fish were drawn, given the observed sizes and the size limit in effect at the time of capture. Figure 5 illustrates the relation between the observed distribution and the estimated distribution. Because of the size limit, part of the distribution is not visible to sampling, but maximum likelihood methods allow the entire distribution to be estimated. The technique is slightly more powerful than suggested here because it can associate with each fish the minimum size limit in effect at the time of its capture, instead of assuming a uniform size limit on fish captured in disparate years or locations.

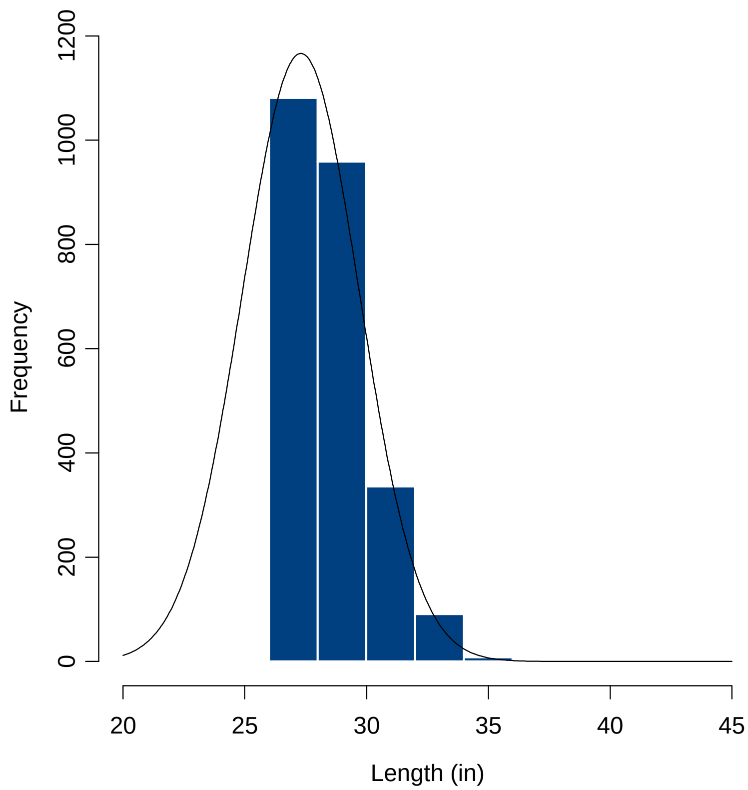


Figure 5. The relationship between the observed size distribution (bars) and the estimated size distribution (curve), given a minimum legal size of 26 inches.

The size-at-age analysis estimated the mean length and standard deviation in length for each month and age class separately. Since most of the catch, and thus CWT recoveries, in these fisheries occur between April and October each year, there were months where the sample size was too low or even nonexistent to yield a valid, independent estimate of mean length. We derived estimates for low-recovery months by noting that the mean size during the winter is likely to lie between that of the previous fall and that of the following spring/summer; thus a straight line was drawn between the last fall and first spring points. The following adjustments were made:

Age 2

- January – April means: linearly interpolated between May Age 2 and an Age 1 August FRH salmon recovered in “No minimum size limit” fishery. Slope = 0.95.
- January – April standard deviation: 2.10 taken from May Age 2.

Age 3

- November – March means: linearly interpolated between October and April. Growth rate constant. Slope = 0.84.
- November – March standard deviations: linearly interpolated between October and April.

Age 4

- November – March means: linearly interpolated between October and April. Growth rate constant. Slope = 0.57.
- November – March standard deviations: linearly interpolated between September and May.

Age 5

- September – August means: linearly extrapolated from August Age 4 through August Age 5 . Growth rate constant. Slope = 0.44
- September – August standard deviations: taken from August Age 4.

Given the estimated population mean and standard deviation, we then used the standard formula for the cumulative normal probability distribution to calculate the proportion of fish above any specified legal threshold. Table 10 shows the proportion legal of these data at various minimum size limits.

Figure 6 shows the mean length and standard deviation in length for FRH fall and spring ocean recoveries of ages 2 through 5. During the previous size-at-age analyses of Klamath Basin fall Chinook, we noticed a decrease in mean size at ages 2-4 during September. In the FRH size-at-age analyses, the decline in size occurs primarily in August for ages 2-3. This apparent decline in size during these months can be understood on the level of the population rather than the individual fish. Maturing fall fish (fish entering the river at this time) are generally larger than fish of the same age that are not mature and remain in the ocean. Thus fish remaining in the ocean tend to be smaller members of the population, so the mean size of the fish in the ocean declines during this time.

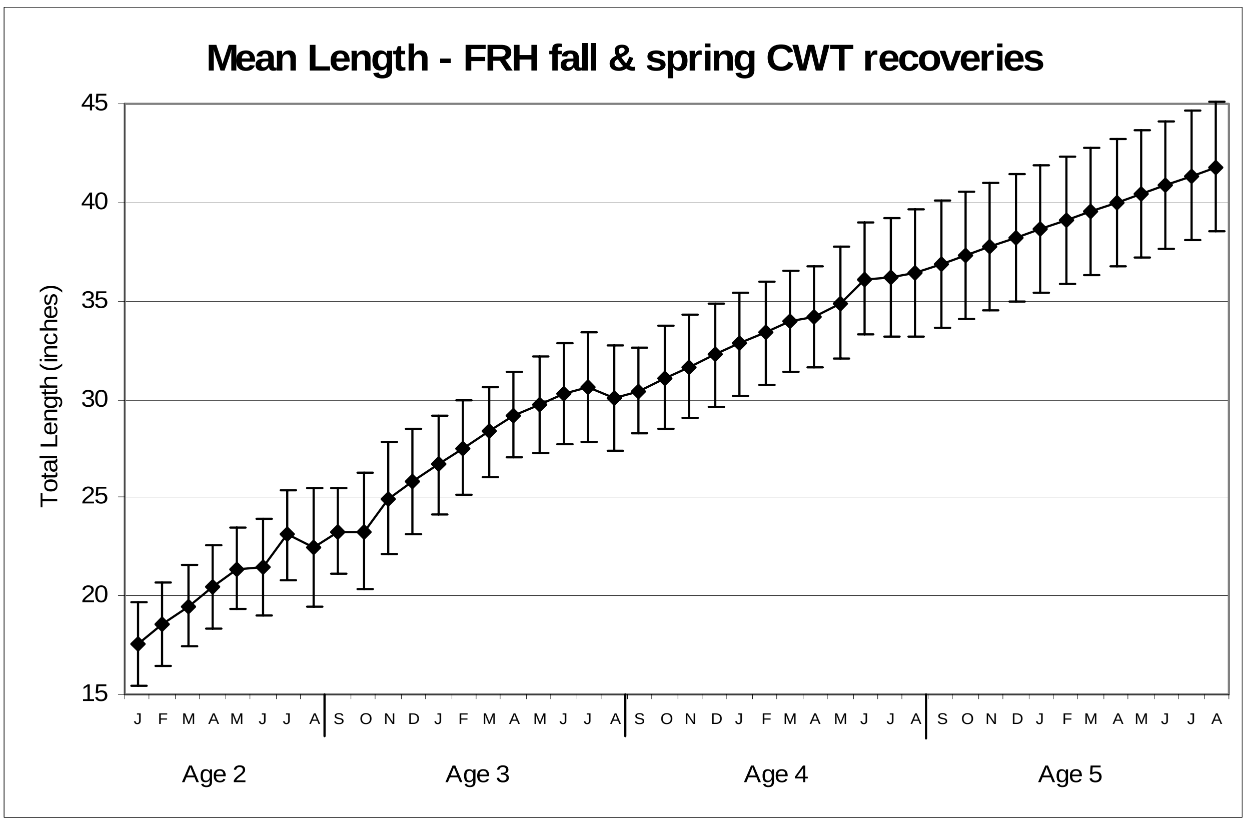


Figure 6. Mean length and standard deviation of FRH fall and spring CWT (expanded for sampling and production) recovered in west coast ocean salmon fisheries by age and month.

Table 7. Mean length of FRH Chinook recovered in ocean fisheries by age and month and proportion legal by minimum size limit.

Ocean Age	Month	Sample Size	Mean Length	Standard Deviation	Proportion legal with minimum size limit (inches) in effect 0	20"	21"	22"	24"	26"	27"	28"
2	Jan		17.6	2.10	1.00	0.13	0.05	0.02	0.00	0.00	0.00	0.00
2	Feb		18.6	2.10	1.00	0.24	0.12	0.05	0.00	0.00	0.00	0.00
2	Mar		19.5	2.10	1.00	0.41	0.24	0.12	0.02	0.00	0.00	0.00
2	Apr		20.5	2.10	1.00	0.58	0.40	0.23	0.05	0.00	0.00	0.00
2	May	2,522	21.4	2.10	1.00	0.75	0.58	0.39	0.11	0.01	0.00	0.00
2	June	6,287	21.5	2.47	1.00	0.73	0.58	0.42	0.16	0.03	0.01	0.00
2	July	9,875	23.1	2.29	1.00	0.91	0.82	0.68	0.35	0.10	0.04	0.02
2	Aug	6,508	22.5	2.99	1.00	0.80	0.69	0.57	0.31	0.12	0.07	0.03
3	Sept	2,182	23.3	2.16	1.00	0.94	0.86	0.73	0.37	0.11	0.04	0.01
3	Oct	1,039	23.3	2.94	1.00	0.87	0.78	0.67	0.41	0.18	0.10	0.05
3	Nov		25.0	2.81	1.00	0.96	0.92	0.86	0.64	0.36	0.24	0.14
3	Dec		25.8	2.67	1.00	0.99	0.96	0.92	0.75	0.47	0.33	0.21
3	Jan		26.7	2.54	1.00	1.00	0.99	0.97	0.85	0.60	0.45	0.30
3	Feb		27.5	2.41	1.00	1.00	1.00	0.99	0.93	0.73	0.58	0.42
3	Mar		28.3	2.27	1.00	1.00	1.00	1.00	0.97	0.85	0.72	0.56
3	Apr	42,643	29.2	2.14	1.00	1.00	1.00	1.00	0.99	0.93	0.85	0.71
3	May	108,447	29.7	2.45	1.00	1.00	1.00	1.00	0.99	0.93	0.86	0.76
3	June	83,538	30.3	2.54	1.00	1.00	1.00	1.00	0.99	0.95	0.90	0.82
3	July	81,607	30.6	2.78	1.00	1.00	1.00	1.00	0.99	0.95	0.90	0.83
3	Aug	42,108	30.1	2.67	1.00	1.00	1.00	1.00	0.99	0.94	0.88	0.78
4	Sept	21,177	30.4	2.17	1.00	1.00	1.00	1.00	1.00	0.98	0.94	0.87
4	Oct	7,247	31.1	2.60	1.00	1.00	1.00	1.00	1.00	0.98	0.94	0.88
4	Nov		31.7	2.60	1.00	1.00	1.00	1.00	1.00	0.99	0.96	0.92
4	Dec		32.2	2.60	1.00	1.00	1.00	1.00	1.00	0.99	0.98	0.95
4	Jan		32.8	2.60	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.97
4	Feb		33.4	2.60	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.98
4	Mar		34.0	2.60	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99
4	Apr	5,437	34.2	2.60	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99
4	May	15,183	34.9	2.83	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99
4	June	12,761	36.1	2.84	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
4	July	8,973	36.2	3.04	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
4	Aug	2,737	36.4	3.26	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
5	Sept		36.9	3.26	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
5	Oct		37.3	3.26	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
5	Nov		37.8	3.26	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
5	Dec		38.2	3.26	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
5	Jan		38.7	3.26	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
5	Feb		39.1	3.26	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
5	Mar		39.6	3.26	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
5	Apr		40.0	3.26	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
5	May		40.5	3.26	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
5	June		40.9	3.26	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
5	July		41.4	3.26	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
5	Aug		41.8	3.26	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Cohort reconstruction model

The CR model uses catch-at-age methods similar to those of Pope (1972) and Hilborn and Walters (1992). Figure 7 shows the databases and processes that underlie the basic CR model. The diagram shows that the model is not formulated in a competing risks framework, although fish are confronted simultaneously by, for instance, the possibilities of being eaten and being harvested. Instead, this model presents the risks sequentially, with fisheries first, followed by natural mortality, and then, the possibility of maturation. Because the monthly time steps are relatively short and the monthly rates low, the actual difference between the results of this formulation and those from a competing risks one are likely to be minor.

The CR uses a series of Microsoft Visual Foxpro databases and programs for manipulating these data. This system makes it easy to error check the many repeated calculations, to modify the formulas, and to update the CRs as new data become available. Hard-coded parameters in the programs have been avoided where possible. Although, we focused only on reconstructing the ‘98 BY and ‘99 BY for FR spring and fall runs, the databases and programs are created and written to reconstruct all broods and stocks where data are available. In addition, the CR can process the CWT release, recovery, and other pertinent data and reconstruct the cohorts in a single pass of the data, usually within a minute.

Overall, the CR begins by rebuilding the hatchery stocks first from their last appearance at age 5 inriver to their starting ocean population at age 2 in September. Hatchery cohorts are then summed to give a total population by age and month of hatchery fish. Subtracting the hatchery population inriver at age 5 from the total age 5 FR Run then gives us the last appearance of the natural population. The CR then rebuilds the natural population using INBF ocean impacts, maturation, and stray rates, along with natural mortality and the inriver escapement by age, to the natural starting ocean population at age 2. Summing the hatchery and natural components you can then determine maturation rates, stray rates, ocean impacts and other parameters for the entire cohort.

Elements of the analysis

The CR includes all ’98 and ‘99 FRH spring and fall Chinook from age 2 September through age 5 August. For hatchery fish, each release type is treated separately (the cwtcode-specific production factors having already been applied), and the natural fish are added last. We generally follow Prager and Mohr (2001) in denoting rates with lower case letters and counts with upper case letters; ocean quantities with subscripted “O” and river quantities with “R”; and, among other variables, in our choice of C, H, and I to indicate contacts, harvest, and impacts, respectively. Particular months are specified with an additional subscript.

The fundamental variables of the analysis are:

N_O = The number of fish in the ocean at the beginning of each month;

C_O = The number of fish contacted by fisheries in the ocean during the month;

I_O = The number of fish killed in the ocean during the month by harvest, hook-and-release mortality, and dropoff mortality (total fishery impacts);

M = The number of fish that mature and leave the ocean, whether to the FR Basin or as strays to other CV areas;

N_R = The number of mature fish that enter the FR Basin;

Q = The number of fish that mature and stray into rivers other than the FR;

C_R = The number of fish contacted in the FR Basin by sport fishery;

I_R = The number of fish killed in the river by sport harvest or dropoff mortality;

E = The number of fish that survive to spawn;

E_n = The number of fish that spawn in natural areas.

For modeling purposes, all maturing fish are assumed to enter the river simultaneously at the end of August. The parameters may be divided into those that are determined externally and those that are estimated by the CR. The parameters that are determined externally include:

s_O = Ocean hook-and-release ("shaker") mortality rates (s_O), which are fishery-, time-, and area-specific. The rates used are the current rates adopted by the PFMC (STT 2000). Sport fishery recoveries in the SOC (south of Pt Arena in California) are further refined by year, major port area, and month based on the estimated relative proportion of anglers mooching and trolling during those fisheries;

d_O = The ocean dropoff mortality rate (d_O), which, according to policy that has been adopted by the PFMC (STT 2000), is 5% and is applied to total estimated contacts;

v_O = The ocean natural mortality rate (v_O), is applied as a monthly rather than an annual rate. For age 2 fish, the monthly natural mortality rate is 0.0561257 (corresponding to 50% annually), and for older fish it is 0.0184235 (corresponding to 20% annually). The annual rates are from KRTT (1986).

d_R = The river dropoff mortality rate (d_R) is 2.04% for the river sport fisheries, and is applied to the estimated harvest (KRTT 1986).

As discussed earlier, CV sport harvest data are not currently used in this CR; however if consistent sampling and collection of CWTs occur in the future, the databases and programs are written to incorporate these data. However, river hook-and-release mortality (HRM) rates are not currently incorporated in the CR because all hooked fish are assumed to be harvested due to a "no minimum size limit" for Chinook salmon in the FR and other CV sport fisheries; however this assumption is not entirely correct since there are now periods when the retention of Chinook salmon is prohibited and must be released. Currently, there are no data available to estimate the contact rate in these non-retention fisheries. The CDFG's Klamath and Trinity River projects use 10% as their HRM for their respective sport fisheries. The CR would be more accurate with river HRM included, especially because a few hooking mortality studies (both freshwater and ocean) have found some evidence that a higher hooking mortality rate may apply to larger fish (STT 2000).

Depredation by sea lions is included in the ocean dropoff mortality of 5%; no attempt has been made to incorporate recent work that estimates the actual rate of loss. The CDFG's OSP conducted observation trips onboard Commercial Passenger Fishing Vessels during 1999-2002 and found that although there were differences in pinniped depredation rates among ports and months, overall the annual depredation rate in California ocean fisheries statewide was less than 5%.

Figure 8 shows the sequence of steps that occur in the CR over a two-month period. The parameters that are estimated by the CR include:

c_O = Ocean contact rates (c_O), which are calculated as C_O / N_O, where C_O is the number of contacts in the month. Both C_O and N_O are specific to year, release type, age, and month. The numerator, and consequently the contact rate, is also management area- and fishery-specific;

h_O = Ocean harvest rates (h_O), which are calculated as H_O / N_O, where H_O is the number of fish harvested during the month. Both H_O and N_O are specific to year, release type, age, and month. The numerator, and consequently the harvest rate, is also Fishery management area- and fishery-specific;

i_O = Ocean impact rates (i_O), which are calculated as $(H_O + S_O + D_O) / N_O$, where S_O is hook-and-release mortality and D_O is dropoff mortality. The quantities are specific to the year, release type, age, and month. The numerator, and consequently the impact rate, is also Fishery management area- and fishery-specific;

m = Maturation rate (m), which is calculated as $M / (M + N_{O,Sep})$, and is year-, release type-, and age-specific;

q = The straying rate (q), which is calculated as Q / M, and is year-, release type-, and age-specific;

h_R = FR fall and spring Chinook harvest rates (h_R), which are calculated as H_R / N_R, where H_R and N_R are specific to the year, release type, and age. The numerator, and consequently the harvest rate, is also fishery-specific.

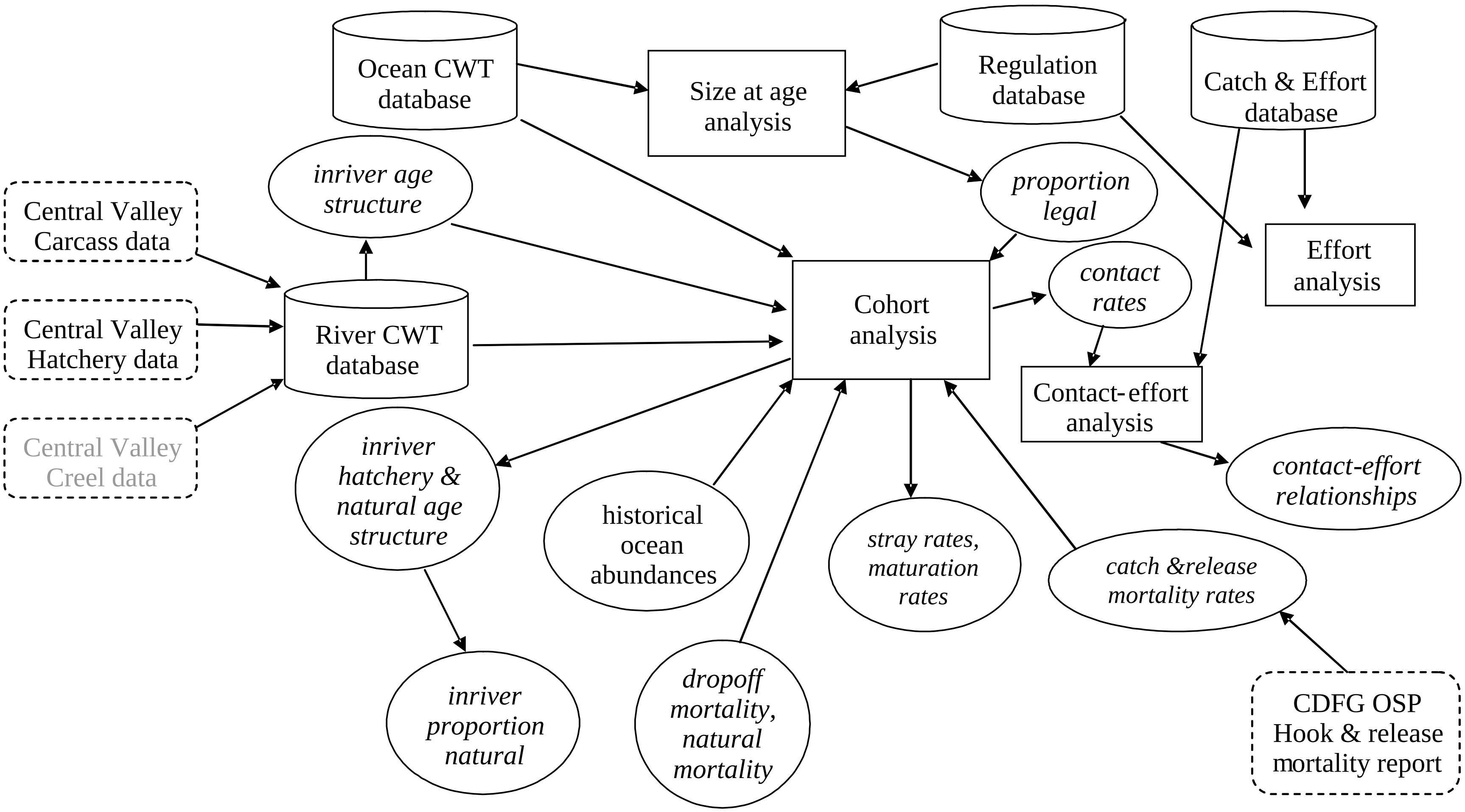


Figure 7. Overview of the databases and complex processes involved in the cohort reconstruction (Figure from Goldwasser et al 2001).

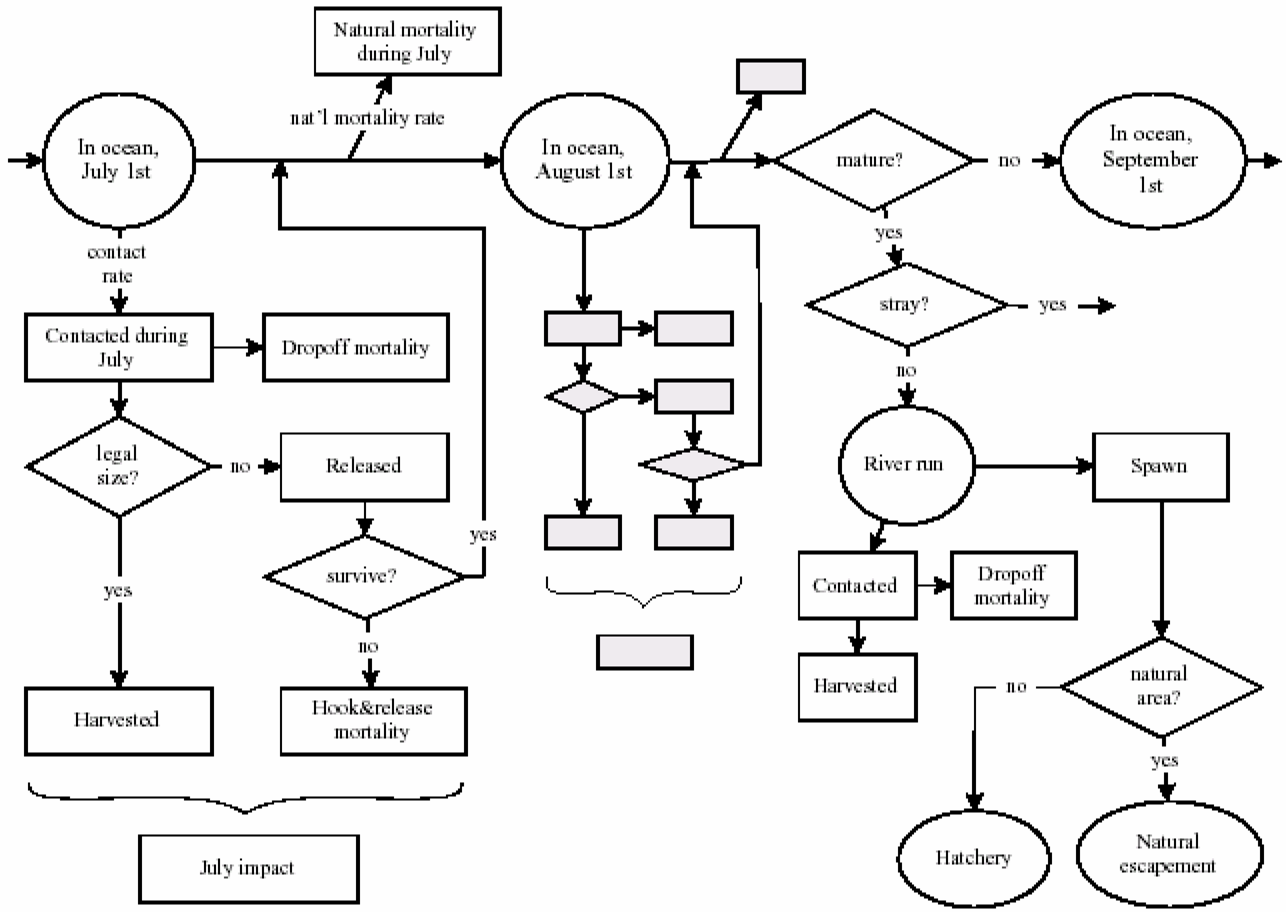


Figure 8. The sequence of events that underlies the cohort reconstruction; two monthly time-steps are shown. Along the top are the ocean populations and the natural mortality that subtracts from them. Sequences to the left are the fish that are contacted by ocean fisheries, and indicates the age- and fishery-specific factors that determine whether they survive the contact. Dropoff mortalities are additional mortalities calculated as a proportion of contacts. In the right region are August-specific factors that involve maturation of fish and their return to the Central Valley Basin at the end of August. Strays include FRH fall and spring Chinook CWTs collected at other Central Valley hatcheries and in carcass surveys outside the FR (Figure from Goldwasser et al 2001).

The calculation sequence for hatchery fish

The CR of hatchery fish proceeds backwards through time, from the last appearance of any member of a cohort (usually at age 5) to their starting ocean abundance at age 2 in September. To the estimated abundance of fish in the ocean at a given time, each monthly step backwards adds estimated numbers of (1) fish lost to ocean fishery impacts; (2) fish lost to natural mortality; and (3) between August and September, fish that mature and enter the river.

The following calculations are specific to each release type of FRH fall and spring, as well as to a given month, year, and age; some quantities are also specific to port of landing. The oceanwide abundance at the beginning of month *t* is estimated as follows:

$$N_{O,t} = I_{O,t} + \frac{M + N_{O,t+1}}{1 - v_O}, \tag{5}$$

where $M = N_R + Q$ is nonzero only for *t* = August. The impacts of ocean fisheries include all sources of gear-related mortality, including harvest, shaker mortality, and dropoff mortality. Harvest and shaker mortality estimates are a function of estimated contacts and the proportion legal. Of the ocean contacts, all legal-sized fish die as harvest. Most fish smaller than the minimum legal size limit are released, but a proportion of the released fish also die because of hooking injuries. This hook-and-release mortality depends on the fishing method and gear used (STT 2000). Other fish, regardless of size, encounter the gear and escape before being landed, but die because of wounds received or because of depredation. Dropoff mortality is calculated as 5% of total contacts (STT 2000). These fish are not part of the estimated total contacts as represented in the formulas, although some kind of contact is clearly involved.

Ocean impacts are then estimated by adding these three sources of mortality:

$$\begin{aligned} I_O &= H_O + S_O + D_O \\ &= H_O + s_O \cdot (C_O - H_O) + d_O \cdot C_O. \end{aligned} \tag{6}$$

The ocean contacts are calculated by expanding the legal-sized portion of the ocean harvest, $H_{O,legal}$, by the proportion legal, p_{legal}, for that release type-, month-, and fishery-specific minimum size limit in effect:

$$C_O = \frac{H_{O,legal}}{p_{legal}}. \tag{7}$$

The difference between contacts and harvest, $(C_O - H_O)$, equals the difference between the sublegal portions of the contacts and harvest, $(C_{O,sublegal} - H_{O,sublegal})$, because every legal-sized fish is assumed to have been retained. This difference then represents the hook-and-release mortality on sublegal fish that were released; the 100% impact rate on harvested sublegals is already included in H_O. This difference is taken to be zero in the few cases for which it would otherwise be negative.

In a few cases (n=17), the number of actual sublegal recoveries exceeded the estimate of sublegal contacts as calculated with the above expansion using formula 7. This was generally caused by a small sample size where one sublegal fish, expanded for sampling and production, exceeded the HRM for the few legal size fish harvested. In addition, only a very small fraction of the estimated size distribution for ages 3 through 4 was below the legal limit. We resolved the discrepancies by adding the excess sublegal recoveries to the estimates of the sublegal contacts and total contacts.

To estimate ocean harvest of hatchery fish, each FR fall run Chinook CWT recovery is expanded for sampling, production, and CWTs that were not processed successfully:

$$H_O = \sum_{\substack{\text{fall chinook} \\ \text{CWT recoveries}}} \left(\frac{1}{p_{sampled} \cdot p_{tagged} \cdot p_{processed} \cdot p_{decoded}} \right), \qquad (8)$$

where $p_{sampled} = n_{sampled} / \hat{L}$ is the proportion of the catch sampled at the dock, and p_{tagged} is the proportion of the hatchery release group that is tagged. The quantity p_{tagged} is the inverse of the hatchery production factor and is specific to each cwtcode. On some occasions, a CWT is not found in a head from an ad-clipped salmon. Our assumption is that the fish shed its tag prior to their release from the hatchery and the hatchery production factor for all releases already account for these occurrences. In addition, Oregon and Washington have begun to mass mark Chinook salmon and most of these ad-clipped fish do not contain a CWT. The factors $p_{processed}$ and $p_{decoded}$ account for losses of CWTs between sampling at the dock and successful reading of the code, as described below.

An adjustment is made for cases in which the head was taken in the sample but not processed due to various reasons (e.g., confiscated by warden, lost in the field) and those in which the extracted CWT was not successfully decoded because the CWT was either 1) lost during the retrieval or reading process, 2) was damaged and unreadable, or 3) has unresolved discrepancies among its readings. The following quantities demarcate the relevant steps:

n_{heads} = number of heads taken in sample;

$n_{processed}$ = number of heads processed;

$n_{extracted}$ = number of CWTs extracted;

$n_{decoded}$ = number of CWTs that were successfully decoded. (9)

The factor $p_{processed}$ accounts for fish that were taken at the dock but not processed:

$$p_{processed} = \frac{n_{processed}}{n_{heads}} \quad . \qquad (10)$$

Fish that were not processed included some fish that would have been found to lack CWTs had they been processed. Among the heads that were processed, the tags that were extracted but not read successfully are taken into account with $p_{decoded}$, the proportion of extracted CWTs that were successfully decoded:

$$p_{decoded} = \frac{n_{decoded}}{n_{extracted}} \quad . \qquad (11)$$

Assignments to specific release groups cannot be made for CWTs not processed successfully, so these factors lump release groups while remaining specific to a port, month, year and fishery. Equation 8 shows how these four factors combine in the calculation of the ocean harvest of hatchery fish, and Equation 6 shows how the harvest is incorporated in the calculation of total fishery impact.

CR of FRH '98 BY hatchery releases

Table 11 shows the rebuilding of the individual FRH release groups for the '98 BY at FRH from their last appearance as escapement to their age 2 September starting ocean population. Each release group can be tracked through its 5-year life cycle as ocean impacts, natural maturity, maturation, and straying reduces its population on a monthly basis.

The trucked fall releases (TRKF) produced the largest '98 BY hatchery starting population of 617,000, representing a 10.0% survival to age 2 of the 6.2 million TRKF released (Table 12). Approximately 65,500 TRKF returned to the FR basin with an additional 3,000 TRKF straying to other areas within the CV. The overall stray rate for TRKF releases was 4.4% (Table 13). Trucked spring releases (FRHS) had a starting ocean population of almost 182,700 salmon, a 10.1% survival rate to age 2. Almost 24,700 FRHS returned to the FR basin with an additional 700 FRHS straying to other basins. The overall stray rate for FRHS releases was 2.7%. Inbasin fall releases (INBF) had a starting population of 30,800, with an age 2 survival rate of 2.4%. Approximately 4,400 INBF returned to the FR and 100 INBF strayed to other CV areas. INBF releases had an overall stray rate of 2.8%. The experimental '98 fall releases (XHAF) had the lowest survival rate (1.9%) to age 2 with a starting population of 1,600 salmon. Approximately 700 XHAF returned to the FR and over 100 strayed within the CV. The XHAF had the highest overall stray rate (15.8%) of all '98 FRH releases. Although the '98 Lake Oroville releases (OROF) were not part of the FRH primary releases, we did include their few recoveries in the CR to ensure they weren't counted as part of the natural component.

Almost all of the '98 hatchery releases matured completely by age 4; more than 99% of all age 4 ocean populations, except XHAF, returned to spawn at this time (Table 13). This highlights an important issue regarding the CR when only a few CWTs are collected, combined with low sampling rate or high production factors. Because only a handful of age 5 FRH releases were recovered in the ocean fisheries and the CV, an individual CWT can greatly affect the age 5 ocean population and corresponding maturity and stray rates. In 2003, there were only two '98 XHAF CWTs recovered throughout the CV; both of these strayed into the upper Sacramento area. One was recovered at CNFH and had a sample expansion of 2;

however the other was picked up in the Battle Creek carcass survey and had a sample expansion of 69. Overall the survey sampled 945 salmon out of an estimated run of 64,800 and only 64 of 104 heads collected had a valid CWT. The original sample expansion was 101.2 to account for 31 unreadable CWTs, but we reduced the expansion to represent only the valid CWTs taken in the sample. Even then, this one recovery was more than the age 4 XHAF recoveries in both the ocean and CV combined. Thus the maturity rate at age 4 for XHAF was only 28%. In addition, when the complete ’98 BY cohort was rebuilt, it artificially increased the stray rate observed at age 5 for the brood as a whole. We considered dropping these particular recoveries from the CR but felt it strongly demonstrated how low sampling levels, combined with sporadic collection of CWTs, could significantly affect the CR.

Appendix 2 shows the recovery of all ’98 BY CWT releases by release group and individual cwtcode within the CV.

Table 11. Cohort Reconstruction of 1998 brood year Feather River Hatchery releases.

				Inbasin Releases (INBF)						Trucked Fall Releases (TRKF)						Trucked Spring Releases (FRHS)						
Brood year	Run year	Ocean Age	Month	Ocean impacts	Feather R returns	Outside Basin	CWT population	Maturity Rate	Stray Rate	Ocean impacts	Feather R returns	Outside Basin	CWT population	Maturity Rate	Stray Rate	Ocean impacts	Feather R returns	Outside Basin	CWT population	Maturity Rate	Stray Rate	
1998	1999	2	Sep				30,803						617,033						182,652			
1998	1999	2	Oct				29,074						582,401						172,400			
1998	1999	2	Nov				27,442						549,714						162,724			
1998	1999	2	Dec				25,902						518,861						153,591			
1998	2000	2	Jan				24,448						489,739						144,971			
1998	2000	2	Feb				23,076						462,252						136,834			
1998	2000	2	Mar				21,781						436,308						129,154			
1998	2000	2	Apr				20,558						411,820						121,905			
1998	2000	2	May	19			19,405						388,706			78			115,063			
1998	2000	2	Jun	123			18,297			2,179			366,890			253			108,532			
1998	2000	2	Jul	91			17,154			2,462			344,242			329			102,202			
1998	2000	2	Aug	100			16,106			1,968			322,597			476			96,155			
1998	2000	3	Sep	30	235	6	14,866	0.02	0.03	1,168	4,058	122	298,453	0.01	0.03	316	179		90,129	0.00	0.00	Age 2 return inriver
1998	2000	3	Oct	73			14,003			859			280,600			187			84,773			
1998	2000	3	Nov	35			13,148			337			264,040			137			79,839			
1998	2000	3	Dec				12,378			72			248,903						75,229			
1998	2001	3	Jan				11,683						234,865						71,006			
1998	2001	3	Feb				11,027						221,683						67,021			
1998	2001	3	Mar	29			10,408			455			209,241			128			63,260			
1998	2001	3	Apr	359			9,797			7,355			197,068			2,766			59,588			
1998	2001	3	May	1,398			8,908			29,214			179,065			6,441			53,633			
1998	2001	3	Jun	541			7,371			9,895			147,091			2,454			46,323			
1998	2001	3	Jul	1,069			6,704			24,605			134,668			5,468			43,060			
1998	2001	3	Aug	344			5,531			12,606			108,036			2,614			36,899			
1998	2001	4	Sep	144	3,487	86	1,518	0.70	0.02	5,127	40,631	2,167	50,874	0.46	0.05	1,589	12,865	202	20,587	0.39	0.02	Age 3 return inriver
1998	2001	4	Oct	42			1,349			1,132			44,905			318			18,649			
1998	2001	4	Nov				1,283			100			42,966						17,993			
1998	2001	4	Dec				1,259						42,077						17,662			
1998	2002	4	Jan				1,236						41,302						17,336			
1998	2002	4	Feb				1,213						40,541						17,017			
1998	2002	4	Mar	2			1,191			256			39,794			51			16,703			
1998	2002	4	Apr	61			1,167			1,411			38,809			390			16,345			
1998	2002	4	May	73			1,085			3,927			36,709			1,020			15,662			
1998	2002	4	Jun	101			993			4,368			32,178			989			14,372			
1998	2002	4	Jul	81			876			3,547			27,298			459			13,137			
1998	2002	4	Aug	38			780			1,177			23,314						12,444			
1998	2002	5	Sep	3	692	34	3	1.00	0.05	91	20,833	704	191	0.99	0.03	17	11,686	482	46	1.00	0.04	Age 4 return inriver
1998	2002	5	Oct							64			98						29			
1998	2002	5	Nov										33						28			
1998	2002	5	Dec										33						28			
1998	2003	5	Jan										32						27			
1998	2003	5	Feb										31						27			
1998	2003	5	Mar										31						26			
1998	2003	5	Apr										30			20			26			
1998	2003	5	May										30						6			
1998	2003	5	Jun										29						6			
1998	2003	5	Jul										29						5			
1998	2003	5	Aug										28						5			
1998	2003		Sep								28			1.00	0.00		5			1.00	0.00	Age 5 return inriver
Total Central Valley returns					**4,414**	**127**	**0.03**	total stray rate INBF			**65,549**	**2,992**	**0.04**	total stray rate TRKF			**24,735**	**683**	**0.03**	total stray rate FRHS		

Table 11 (cont.) Cohort Reconstruction of 1998 brood year Feather River Hatchery CWT releases.

				Experimental Releases (XHAF)						Oroville Lake Fall Releases (OROF)						
Brood year	Run year	Age	Month	Ocean impacts	Feather R returns	Outside Basin	CWT population	Maturity Rate	Stray Rate	Ocean impacts	Feather R returns	Outside Basin*	CWT population	Maturity Rate	Stray Rate	
1998	1999	2	Sep				5,882						167			
1998	1999	2	Oct				5,552						158			
1998	1999	2	Nov				5,240						149			
1998	1999	2	Dec				4,946						140			
1998	2000	2	Jan				4,668						133			
1998	2000	2	Feb				4,406						125			
1998	2000	2	Mar				4,159						118			
1998	2000	2	Apr				3,926						111			
1998	2000	2	May	10			3,705						105			
1998	2000	2	Jun	23			3,488			4			99			
1998	2000	2	Jul	58			3,270			4			90			
1998	2000	2	Aug	45			3,031						82			
1998	2000	3	Sep	43	61	7	2,750	0.02	0.11				77	0.00	0.00	Age 2 return inriver
1998	2000	3	Oct	19			2,555						73			
1998	2000	3	Nov	11			2,394						69			
1998	2000	3	Dec				2,249						65			
1998	2001	3	Jan				2,123						61			
1998	2001	3	Feb				2,004						58			
1998	2001	3	Mar				1,891						54			
1998	2001	3	Apr	82			1,785						51			
1998	2001	3	May	289			1,608						49			
1998	2001	3	Jun	89			1,294						48			
1998	2001	3	Jul	189			1,183			3			47			
1998	2001	3	Aug	66			975			9			43			
1998	2001	4	Sep	11	647	52	194	0.78	0.07	2	7		27	0.19	0.00	Age 3 return inriver
1998	2001	4	Oct	10			179						25			
1998	2001	4	Nov				166						24			
1998	2001	4	Dec				163						24			
1998	2002	4	Jan				160						23			
1998	2002	4	Feb				157						23			
1998	2002	4	Mar				154						22			
1998	2002	4	Apr	3			152						22			
1998	2002	4	May				145						22			
1998	2002	4	Jun	15			143						21			
1998	2002	4	Jul				125			4			21			
1998	2002	4	Aug				123						17			
1998	2002	5	Sep		22	6	93	0.23	0.21		16			1.00	0.00	Age 4 return inriver
1998	2002	5	Oct				91									
1998	2002	5	Nov				90									
1998	2002	5	Dec				88									
1998	2003	5	Jan				86									
1998	2003	5	Feb				85									
1998	2003	5	Mar				83									
1998	2003	5	Apr				82									
1998	2003	5	May	3			80									
1998	2003	5	Jun				76									
1998	2003	5	Jul				75									
1998	2003	5	Aug				73									
1998	2003		Sep			72		1.00	1.00							Age 5 return inriver
	Total Central Valley returns				**730**	**137**	**0.16**	total stray rate XHAF			**23**	**0**	**0.00**	total stray rate OROF		

* Note: Sept 2003 Age 5 XHAF out of basin is recovery of two cwts: Battle Creek carcass survey with a sample expansion of 69 and CNFH with sample expansion of 2; causes Age 4 XHAF maturity rate to be artificially low

Table 12. Survival of FRH release groups to Age 2 September CWT ocean population (from cohort reconstruction of ' 98 BY & '99 BY).

Brood Year 1998							
FRH release group	# salmon produced	% original production	Age 2 September CWT population	% Age 2 survival	% Age 2 cwt population	Pre-Age 2 mortality	% mortality prior Age 2
INBF	1,296,271	13.5%	30,803	2.4%	3.7%	1,265,468	97.6%
TRKF	6,185,324	64.4%	617,033	10.0%	73.8%	5,568,291	90.0%
FRHS	1,804,060	18.8%	182,652	10.1%	21.8%	1,621,408	89.9%
XHAF	315,877	3.3%	5,882	1.9%	0.7%	309,995	98.1%
Total Releases	9,601,532		836,370	8.7%		8,765,162	91.3%

Brood Year 1999							
FRH release group	# salmon produced	% original production	Age 2 September CWT population	% Age 2 survival	% Age 2 cwt population	Pre-Age 2 mortality	% mortality prior Age 2
INBF	1,129,748	12.0%	15,801	1.4%	5.0%	1,113,947	98.6%
TRKF	5,818,261	61.5%	144,294	2.5%	45.3%	5,673,967	97.5%
FRHS	2,119,204	22.4%	147,483	7.0%	46.3%	1,971,721	93.0%
XHAF	357,306	3.8%	1,604	0.4%	0.5%	355,702	99.6%
TRHY	29,388	0.3%	9,141	31.1%	2.9%	20,247	68.9%
Total Releases	9,453,907		318,323	3.4%		9,135,584	96.6%

Table 13. Stray and maturity rates of FRH '98 BY and '99 BY release groups by age.

Brood Year	Stray Rate					Maturity Rate			
1998	Age 2	Age 3	Age 4	Age 5	Average	Age 2	Age 3	Age 4	Age 5
INBF	0.026	0.024	0.047	--	0.028	0.016	0.702	0.996	1.00
TRKF	0.029	0.051	0.033	0.000	0.044	0.014	0.457	0.991	1.00
FRHS	0.000	0.015	0.040	0.000	0.027	0.002	0.388	0.996	1.00
XHAF	0.106	0.074	0.214	1.000	0.158	0.024	0.783	0.229	1.00
Total Brood	0.031	0.035	0.033	0.404		0.015	0.510	0.990	1.00

Brood Year	Stray Rate					Maturity Rate			
1999	Age 2	Age 3	Age 4	Age 5	Average	Age 2	Age 3	Age 4	Age 5
INBF	0.000	0.007	0.119	0.000	0.052	0.010	0.313	0.950	1.000
TRKF	0.000	0.002	0.000	0.000	0.001	0.011	0.302	0.931	1.000
FRHS	0.002	0.001	0.098	0.302	0.059	0.004	0.275	0.934	1.000
XHAF	0.091	0.355	0.000	--	0.279	0.014	0.599	1.000	--
TRHY	0.109	0.241	0.316	0.000	**0.268**	0.004	0.257	0.941	1.000
Total Brood	0.029	0.023	0.040	0.095		0.017	0.179	0.950	1.000

CR of FRH ’99 BY hatchery releases

Table 14 shows the rebuilding of the individual FRH release groups for the ’99 BY from their last appearance as escapement to their age 2 September starting ocean population. Each release group can be tracked through its 5-year life cycle as ocean impacts, natural maturity, maturation, and straying reduces its population on a monthly basis.

The trucked spring releases (FRHS) produced the largest ’99 hatchery starting population of 147,500, representing a 7.0% survival to age 2 of the 2.1 million FRHS released (Table 12). About 15,000 FRHS returned to the FR basin with an additional 900 straying to other areas within the CV. The overall stray rate for the ’99 FRHS releases was 5.9% (Table 13). Trucked fall releases (TRKF) had a starting ocean population of 144,300 salmon, which represented a 2.5% survival rate to age 2. An estimated 13,700 TRKF returned to the FR basin with only 16 addition salmon straying to other basins. This was the lowest overall stray rate (0.001%) among all FRH ’98 BY and ’99 BY hatchery releases. Inbasin fall releases (INBF) had a starting population of 15,800, with an age 2 survival rate of 1.4%. Approximately 1,500 INBF returned to the FR and less than 100 INBF strayed to other CV areas. INBF releases had an overall stray rate of 5.2%. The fall releases trucked to Tiburon and released as yearlings (TRHY) had the highest survival rate of all FRH ’98 BY and ‘99 BY hatchery releases. Approximately 31.1% of the 29,000 yearlings releases survived to a September age 2 population of 5,822. It should be noted, however, that these fish were released just the month before (August 2000) and spent most of their first year protected in net pens. Approximately 500 TRHY returned to the FR and an additional 200 strayed to other areas. This release group had the second highest overall stray rate (26.8%) of all FRH hatchery releases. The experimental fall releases (XHAF) had a starting population of 1,600 salmon and the lowest survival rate (0.4%) of all FRH ’98 BY and ’99 BY releases. It also had the highest overall stray rate of all ’98 and ’99 FRH releases with 64 out of 230 (27.9%) XHAF straying outside the FR Basin. The high stray rate observed for FRHS at age 5 is occurs because one CWT was recovered in the upper Sacramento River carcass survey.

Almost 95% of all the ’99 releases matured by age 4 (Table 13); again relatively few CWTs were recovered in the ocean fisheries or CV escapement as age 5.

Appendix 3 shows the recovery of all ’99 CWT releases by release group and individual cwtcode within the CV.

Table 14. Cohort Reconstruction of 1999 brood year Feather River Hatchery CWT releases.

				Inbasin Releases (INBF)						Trucked Fall Releases (TRKF)						Trucked Spring Releases (FRHS)						
Brood year	Run year	Ocean age	month	Ocean impacts	Feather R returns	Outside basin	CWT population	Maturity rate	Stray rate	Ocean impacts	Feather R returns	Outside basin	CWT population	Maturity rate	Stray rate	Ocean impacts	Feather R returns	Outside Basin	CWT population	Maturity Rate	Stray Rate	
1999	2000	2	Sep				15,801						144,294						147,483			
1999	2000	2	Oct				14,914						136,196						139,205			
1999	2000	2	Nov				14,077						128,552						131,392			
1999	2000	2	Dec				13,287						121,337						124,018			
1999	2001	2	Jan				12,541						114,526						117,057			
1999	2001	2	Feb				11,838						108,099						110,487			
1999	2001	2	Mar				11,173						102,031						104,286			
1999	2001	2	Apr				10,546						96,305						98,433			
1999	2001	2	May				9,954						90,900						92,908			
1999	2001	2	Jun				9,395						85,798			35			87,694			
1999	2001	2	Jul	12			8,868			47			80,982			27			82,739			
1999	2001	2	Aug	13			8,359			200			76,393			167			78,069			
1999	2001	3	Sep	4	81		7,796	0.01	0.00	104	763		71,153	0.01	0.00	165	272		73,258	0.00	0.00	Age 2 return inriver
1999	2001	3	Oct	72			7,355			56			67,061			386			68,990			
1999	2001	3	Nov				6,874						63,245						64,754			
1999	2001	3	Dec				6,489						59,695						61,119			
1999	2002	3	Jan				6,124						56,345						57,689			
1999	2002	3	Feb				5,781						53,182						54,451			
1999	2002	3	Mar	17			5,456			143			50,197			466			51,395			
1999	2002	3	Apr	242			5,134			926			47,245			2,885			48,071			
1999	2002	3	May	429			4,618			5,186			43,719			4,108			42,650			
1999	2002	3	Jun	606			4,112			3,919			37,823			4,584			37,832			
1999	2002	3	Jul	472			3,442			4,637			33,279			4,785			32,636			
1999	2002	3	Aug	153			2,915			2,363			28,114			1,566			27,338			
1999	2002	4	Sep	271	841	6	1,863	0.31	0.01	2,663	7,621	16	17,640	0.30	0.00	2,255	6,947	7	18,344	0.27	0.00	Age 3 return inriver
1999	2002	4	Oct	205			1,562			2,241			14,701			1,682			15,792			
1999	2002	4	Nov				1,332						12,230						13,850			
1999	2002	4	Dec				1,307						12,005						13,595			
1999	2003	4	Jan				1,283						11,784						13,345			
1999	2003	4	Feb	3			1,260						11,567			24			13,099			
1999	2003	4	Mar	8			1,233			263			11,354			137			12,834			
1999	2003	4	Apr	55			1,202			901			10,886			384			12,462			
1999	2003	4	May	187			1,126			1,644			9,801			1,313			11,856			
1999	2003	4	Jun	124			922			1,230			8,007			604			10,348			
1999	2003	4	Jul	53			784			508			6,652			124			9,565			
1999	2003	4	Aug	18			717			207			6,031			131			9,267			
1999	2003	5	Sep		574	78	34	0.95	0.12	26	5,325		392	0.93	0.00	33	7,548	824	596	0.93	0.10	Age 4 return inriver
1999	2003	5	Oct				34			83			359			16			553			
1999	2003	5	Nov				33						271						527			
1999	2003	5	Dec				33						266						517			
1999	2004	5	Jan				32						261						507			
1999	2004	5	Feb				31						256						498			
1999	2004	5	Mar	5			31						252						489			
1999	2004	5	Apr				26						247						480			
1999	2004	5	May	4			25			61			243			20			471			
1999	2004	5	Jun				21			132			178						443			
1999	2004	5	Jul				20			29			45			33			435			
1999	2004	5	Aug				20						16						395			
1999	2004		Sep		20			1.00	0.00		16			1.00	0.00		270	117		1.00	0.30	Age 5 return inriver
	Total Central Valley returns				**1,517**	**84**	**0.05**	total stray rate INBF			**13,725**	**16**	**0.00**	total stray rate TRKF			**15,037**	**948**	**0.06**	total stray rate FRHS		

Table 14 (cont). Cohort Reconstruction of 1999 brood year Feather River Hatchery CWT releases.

				Trucked Fall Yearling Releases (TRHY)						Experimental Releases (XHAF)						
Brood year	Run year	Age	Month	Ocean impacts	Feather R returns	Outside basin	CWT population	Maturity rate	Stray rate	Ocean impacts	Feather R returns	Outside Basin	CWT population	Maturity Rate	Stray Rate	
1999	2000	2	Sep				9,141						1,604			
1999	2000	2	Oct				8,627						1,514			
1999	2000	2	Nov				8,143						1,429			
1999	2000	2	Dec				7,686						1,349			
1999	2001	2	Jan				7,255						1,273			
1999	2001	2	Feb				6,848						1,202			
1999	2001	2	Mar				6,463						1,135			
1999	2001	2	Apr				6,101						1,071			
1999	2001	2	May				5,758						1,011			
1999	2001	2	Jun				5,435						954			
1999	2001	2	Jul	16			5,130			8			900			
1999	2001	2	Aug	12			4,827						842			
1999	2001	3	Sep	5	17	2	4,526	0.00	0.11		10	1	784	0.01	0.09	Age 2 return inriver
1999	2001	3	Oct	4			4,267						740			
1999	2001	3	Nov				4,024						698			
1999	2001	3	Dec				3,798						659			
1999	2002	3	Jan				3,585						622			
1999	2002	3	Feb				3,384						587			
1999	2002	3	Mar	2			3,194						554			
1999	2002	3	Apr	58			3,013			19			523			
1999	2002	3	May	267			2,789			50			476			
1999	2002	3	Jun	276			2,476			36			418			
1999	2002	3	Jul	324			2,160			56			375			
1999	2002	3	Aug	154			1,802			9			313			
1999	2002	4	Sep	118	315	100	1,203	0.26	0.24	6	115	63	120	0.60	0.36	Age 3 return inriver
1999	2002	4	Oct	136			1,065			2			112			
1999	2002	4	Nov				911						108			
1999	2002	4	Dec				895						106			
1999	2003	4	Jan				878						104			
1999	2003	4	Feb				862						102			
1999	2003	4	Mar	6			846						100			
1999	2003	4	Apr	55			825			9			98			
1999	2003	4	May	143			756			21			87			
1999	2003	4	Jun	105			601			12			65			
1999	2003	4	Jul	116			487			9			52			
1999	2003	4	Aug	33			364						42			
1999	2003	5	Sep		209	97	19	0.94	0.32		41			1.00	0.00	Age 4 return inriver
1999	2003	5	Oct	5			19									
1999	2003	5	Nov				13									
1999	2003	5	Dec				13									
1999	2004	5	Jan				13									
1999	2004	5	Feb				13									
1999	2004	5	Mar				12									
1999	2004	5	Apr	3			12									
1999	2004	5	May	8			9									
1999	2004	5	Jun				1									
1999	2004	5	Jul				1									
1999	2004	5	Aug				1									
1999	2004		Sep		1			1.00	0.00							Age 5 return inriver
	Total Central Valley returns				**542**	**199**	**0.27**	total stray rate TRKY			**166**	**64**	**0.28**	total stray rate XHAF		

The calculations for natural Feather River Chinook

The CR of natural FR fish also builds backwards through time, from the last appearance in the river at age 5 to its starting ocean abundance at age 2 in September. Although there were some 'natural' FR Chinook trapped and tagged within the river basin during '98 and '99, recoveries in both the ocean fisheries and CV basin were too few for use in rebuilding the natural run. After examining the recovery of all FRH release groups within the Central Valley and in the ocean fisheries, it seemed most reasonable to use the FRH fall Chinook released inbasin (INBF) as a surrogate group since they have the most similar migration path and were released during the same time as when 'wild 'fry were being trapped and tagged in the Feather River. We assume these fish have the same survival, maturation, stray, and fishery harvest rates as the naturals.

Before rebuilding the natural cohort, the CR sums all ocean impacts, FR returns, and outside basin returns of all hatchery release groups into a single "hatchery fish" cohort by age and month. The starting point for the natural cohort is the age 5 return of naturals to the FR. The CR calculates this by subtracting the age 5 FR hatchery returns from the total age 5 FR Run. For example, in 2003, the total age 5 FR run was 110 salmon (Table 9) and there were 33 age 5 FR hatchery returns (Table 15). Subtracting the hatchery component from the total run gives us a natural run of 77 age 5 salmon in the FR (Table 15).

To determine the number of naturals that stray, the CR first determines the total number of naturals maturing, M. For the hatchery fish, $M = N_R + Q$, which can be rewritten to give us the estimate of the hatchery straying rate $q = 1-(N_R / M)$. The FR CR uses the average stray rate of INBF releases for all complete broods ages 2-5 as a surrogate stray rate for all naturals. Since there are only two complete broods in this CR, this stray rate only represents what occurred over the 2000-2004 period. As more broods are added to the CR, this rate will become a long-term average of straying within the basin. The Klamath CR currently incorporates 26 broods in determining this rate.

For the '98 and '99 broods, the average stray rate of INBF releases was .03185. This stray rate was used to calculate the number of maturing natural fish, $M = N_R / (1-q)$ for all ages of both broods. Thus in 2003, the total number of naturals maturing at age 5 was 80 (M = 77 ÷0.96815), with 3 naturals (Q = 80 * .03185) straying outside the basin. These totals are then added to the natural ocean abundance at the beginning of September.

Applying the natural mortality rate and ocean fishery impact rate of INBF releases, the ocean abundance at the start of August can be calculated. To the estimated abundance of natural fish in the ocean at a given month, each monthly time step backwards adds estimated numbers of (1) natural fish lost to ocean fishery impacts; (2) natural fish lost to natural mortality; and (3) between August and September, natural fish that mature and enter the rivers. Determining these numbers is complicated by possible differences between the hatchery and natural components.

Figure 9 shows how, given an estimate of the impact and straying rates of hatchery fish, estimates of the size of the hatchery component of the inriver run, and the estimate of the total inriver run (which comes from the age composition analysis), it is possible to derive estimates of the abundance of the natural component of the ocean population and the fishery impact on that component. In particular,

$$N_{O,t} = \frac{M + N_{O,t+1}}{(1-i_{O,t}) \cdot (1-v_O)} \qquad (13)$$

and

$$I_{O,t} = N_{O,t} \cdot i_{O,t} \quad (14)$$

where $i_{O,t}$ is the impact rate by brood year, age and month estimated from INBF fish and applied to the natural population. It also shows how the CR brings together the quantities N_O, N_R, M, and I_O in reconstructing a single month in the history of a cohort. Once the estimates for the natural component are known, the totals for all components of the cohort can be calculated by summation.

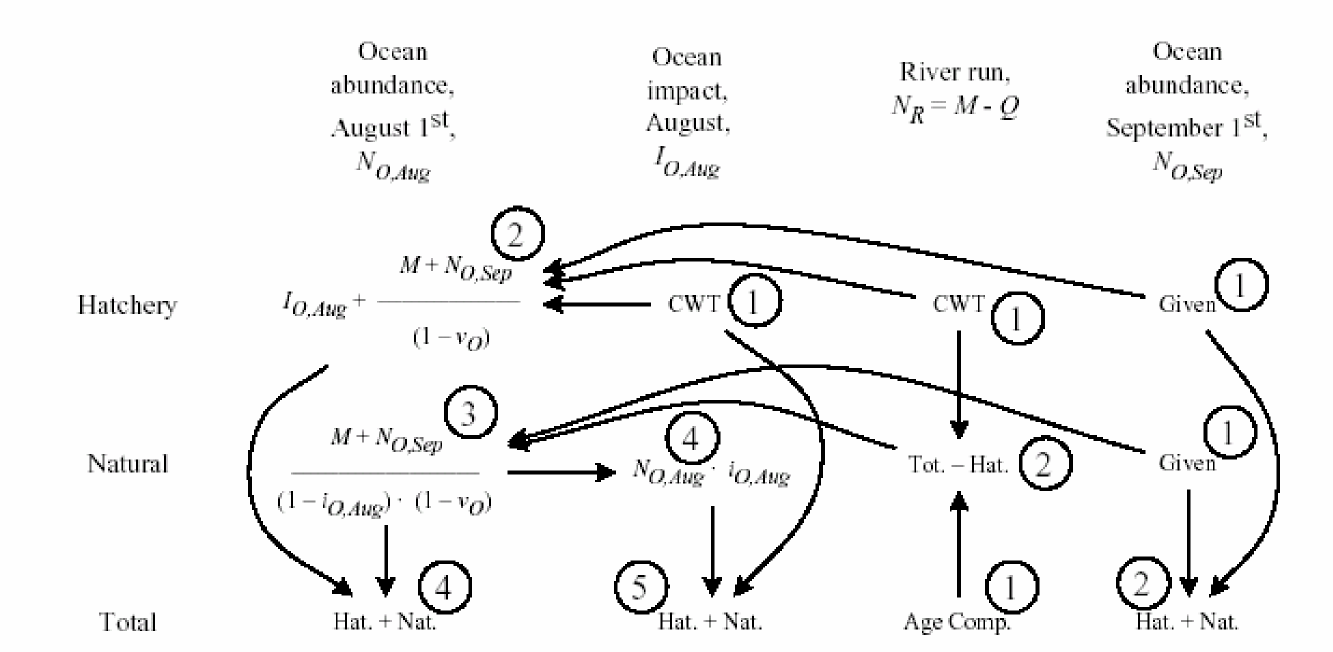


Figure 9.The sequence of calculations for one month of the cohort reconstruction (time advances left to right). The calculations iterate backwards in the order indicated by the numbers in circles; quantities with higher numbers are calculated after those with lower numbers. The span from August 1st to September 1st is shown; other months are simpler because of the absence of the river run (N_R=M=0). Fishery impacts occur between the columns for $N_{O,Aug}$ and $I_{O,Aug}$; natural mortality, maturation, and straying occur between the columns for $I_{O,Aug}$ and N_R. For the last appearance of a cohort, the "Given" value at the beginning of the following month is taken to be zero; for all other months the value is the result from the previous step. In the reconstruction, each hatchery release type has its own row and calculations are performed separately. CWT=number of CWT hatchery fish recovered, expanded for sampling and production; Age comp = number of fish by age entering the FR as estimated by age composition analysis; v_O = natural mortality rate; $i_{O,Aug}$ = ocean fishery impact rate calculated for INBF releases and applied to naturals.

Complete CR of FRH '98 BY and '99 BY

The complete CR of both the natural and hatchery components of the '98 and '99 BYs are shown in Tables 15 and 16, respectively. The tables also show the maturity rates, stray rates, and the natural proportion of escapement by age for the each BY. Overall, the starting ocean abundance of the '98 BY (2.1 million) was almost twice that of the '99 BY (1.2 million). Since approximately the same number of FRH releases were produced in each BY (approximately 9 million Chinook) and most of the difference between broods occurs in the hatchery population, it appears most directly related to the FRH '99 BY releases having a much lower survival rate to age 2 (Table 9). This may be directly related to the outbreak of IHN that occurred during the rearing of some '99 FRH releases (Appendix 1). In addition, there is no way to determine if oceanic conditions and other environmental factors were not as favorable during the first year for the FRH '99 BY.

Table 15. Complete cohort reconstruction of 1998 brood year Feather River fall and spring hatchery and natural Chinook.

				Hatchery Fish				**Natural Fish**				Total				
Brood year	Run year	Ocean Age	Month	Ocean impacts	Feather R returns	Outside FR basin	Hatchery population	Ocean impacts	Feather R returns	Outside FR basin	Natural Population	Cohort Population	Maturity rate	Stray rate outside FR basin	Proportion natural in escapement	
1998	1999	2	Sep				836,536				1,244,708	2,081,244				
1998	1999	2	Oct				789,585				1,174,848	1,964,433				
1998	1999	2	Nov				745,269				1,108,909	1,854,178				
1998	1999	2	Dec				703,440				1,046,671	1,750,111				
1998	2000	2	Jan				663,959				987,926	1,651,885				
1998	2000	2	Feb				626,694				932,478	1,559,172				
1998	2000	2	Mar				591,520				880,142	1,471,662				
1998	2000	2	Apr				558,321				830,743	1,389,064				
1998	2000	2	May	108			526,985	780			784,117	1,311,102				
1998	2000	2	Jun	2,581			497,306	4,960			739,372	1,236,677				
1998	2000	2	Jul	2,945			466,957	3,676			693,192	1,160,149				
1998	2000	2	Aug	2,590			437,970	3,941			650,816	1,088,786				
1998	2000	3	Sep	1,556	4,533	135	406,275	1,177	9,901	326	600,342	1,006,617	0.02	0.03	0.69	Age 2 return inriver
1998	2000	3	Oct	1,138			382,004	2,960			565,536	947,540				
1998	2000	3	Nov	519			359,489	1,397			531,001	890,490				
1998	2000	3	Dec	72			338,823				499,880	838,703				
1998	2001	3	Jan				319,738				471,824	791,562				
1998	2001	3	Feb				301,793				445,343	747,135				
1998	2001	3	Mar	612			284,855	1,180			420,347	705,202				
1998	2001	3	Apr	10,561			268,289	14,499			395,641	663,930				
1998	2001	3	May	37,343			243,263	55,206			359,750	603,012				
1998	2001	3	Jun	12,979			202,126	21,252			298,933	501,059				
1998	2001	3	Jul	31,335			185,662	42,962			272,565	458,227				
1998	2001	3	Aug	15,638			151,484	13,504			225,373	376,858				
1998	2001	4	Sep	6,873	57,636	2,507	73,200	8,943	110,142	3,624	94,201	167,401	0.51	0.04	0.65	Age 3 return inriver
1998	2001	4	Oct	1,501			65,106	2,602			83,687	148,793				
1998	2001	4	Nov	100			62,433				79,591	142,023				
1998	2001	4	Dec				61,185				78,124	139,309				
1998	2002	4	Jan				60,057				76,685	136,743				
1998	2002	4	Feb				58,951				75,272	134,223				
1998	2002	4	Mar	310			57,865	138			73,885	131,750				
1998	2002	4	Apr	1,866			56,495	3,796			72,389	128,884				
1998	2002	4	May	5,020			53,623	4,559			67,330	120,952				
1998	2002	4	Jun	5,472			47,707	6,268			61,614	109,321				
1998	2002	4	Jul	4,091			41,457	4,999			54,326	95,783				
1998	2002	4	Aug	1,216			36,678	2,381			48,418	85,096				
1998	2002	5	Sep	111	33,249	1,225	333		43,653	1,436	99	433	0.99	0.03	0.57	Age 4 return inriver
1998	2002	5	Oct	64			218				98	316				
1998	2002	5	Nov				151				96	247				
1998	2002	5	Dec				148				94	242				
1998	2003	5	Jan				146				92	238				
1998	2003	5	Feb				143				91	234				
1998	2003	5	Mar				140				89	229				
1998	2003	5	Apr	20			138				87	225				
1998	2003	5	May	3			116				86	201				
1998	2003	5	Jun				111				84	195				
1998	2003	5	Jul				109				83	191				
1998	2003	5	Aug				107				81	188				
1998	2003		Sep		33	72			77	3			1.00	0.40	0.43	Age 5 return inriver
				Total CV returns	95,451	3,939	0.04 hatchery stray rate		163,773	5,388	0.03 natural stray rate					

Table 16. Complete Cohort Reconstruction of 1999 brood year Feather River fall and spring hatchery and natural chinook.

				Hatchery Fish				Natural Fish				Total		Outside	Proportion	
Brood year	Run year	Age	Month	Ocean impacts	Feather R returns	Outside Basin	Hatchery population	Ocean impacts	Feather R returns	Outside basin	Natural Population	Cohort Population	Maturity rate	Basin strayrate	natural in escapement	
1999	2000	2	Sep				318,323				906,055	1,224,378				
1999	2000	2	Oct				300,457				855,202	1,155,659				
1999	2000	2	Nov				283,594				807,203	1,090,797				
1999	2000	2	Dec				267,677				761,898	1,029,575				
1999	2001	2	Jan				252,653				719,136	971,789				
1999	2001	2	Feb				238,473				678,774	917,247				
1999	2001	2	Mar				225,089				640,677	865,766				
1999	2001	2	Apr				212,455				604,719	817,174				
1999	2001	2	May				200,531				570,778	771,310				
1999	2001	2	Jun	35			189,276				538,743	728,019				
1999	2001	2	Jul	110			178,620	672			508,506	687,126				
1999	2001	2	Aug	392			168,492	749			479,331	647,823				
1999	2001	3	Sep	278	1,143	3	157,518	215	8,979	295	442,447	599,965	0.02	0.03	0.89	Age 2 return inriver
1999	2001	3	Oct	518			148,414	4,091			417,412	565,826				
1999	2001	3	Nov				139,596				390,123	529,719				
1999	2001	3	Dec				131,761				368,227	499,988				
1999	2002	3	Jan				124,366				347,560	471,926				
1999	2002	3	Feb				117,386				328,053	445,439				
1999	2002	3	Mar	628			110,797	956			309,641	420,438				
1999	2002	3	Apr	4,129			103,986	13,724			291,360	395,346				
1999	2002	3	May	10,040			94,252	23,991			262,054	356,306				
1999	2002	3	Jun	9,420			82,660	34,198			233,677	316,337				
1999	2002	3	Jul	10,273			71,891	26,754			195,804	267,695				
1999	2002	3	Aug	4,245			60,482	8,435			165,936	226,418				
1999	2002	4	Sep	5,314	15,839	192	39,169	19,368	20,912	688	132,999	172,168	0.18	0.02	0.57	Age 3 return inriver
1999	2002	4	Oct	4,267			33,232	14,667			111,538	144,770				
1999	2002	4	Nov				28,431				95,086	123,517				
1999	2002	4	Dec				27,908				93,334	121,242				
1999	2003	4	Jan				27,393				91,615	119,008				
1999	2003	4	Feb	28			26,889	249			89,927	116,816				
1999	2003	4	Mar	415			26,366	597			88,025	114,392				
1999	2003	4	Apr	1,404			25,473	3,900			85,817	111,291				
1999	2003	4	May	3,308			23,626	13,323			80,408	104,035				
1999	2003	4	Jun	2,075			19,943	8,836			65,849	85,793				
1999	2003	4	Jul	809			17,539	3,783			55,963	73,502				
1999	2003	4	Aug	389			16,422	1,291			51,219	67,641				
1999	2003	5	Sep	59	13,697	998	1,042		45,353	1,492	2,163	3,205	0.95	0.04	0.76	Age 4 return inriver
1999	2003	5	Oct	105			965				2,123	3,088				
1999	2003	5	Nov				844				2,084	2,928				
1999	2003	5	Dec				829				2,046	2,875				
1999	2004	5	Jan				813				2,008	2,822				
1999	2004	5	Feb				798				1,971	2,770				
1999	2004	5	Mar	5			784	298			1,935	2,719				
1999	2004	5	Apr	3			765				1,606	2,371				
1999	2004	5	May	93			748	256			1,577	2,325				
1999	2004	5	Jun	132			643				1,296	1,939				
1999	2004	5	Jul	61			501				1,273	1,774				
1999	2004	5	Aug				432				1,249	1,681				
1999	2004		Sep		307	117			1,187	39			1.00	0.09	0.74	
Total Central Valley inriver returns					30,986	1,311	0.04		76,431	2,514	0.03					
							hatchery stray rate				natural stray rate					

Additional Analyses for Hatchery Evaluation and Management

Since two of the primary goals of FRH releases are to 1) support ocean fisheries and 2) produce spawners that will return to their natal hatchery, the following analyses evaluate the estimated contribution of FRH hatchery releases to the ocean fisheries and the recovery rates and straying of FRH CWTs in the FR Basin and CV.

Estimated hatchery contribution of FRH '98 BY and '99 BY to ocean fisheries

Since 6-8 million Chinook are produced annually by FRH as mitigation to support ocean fisheries, this basic analysis looks at the contribution of these releases by release type, age, time, area, and fishery so that hatchery managers can evaluate various release strategies to meet this goal. To remain consistent with the PFMC ocean salmon management system, the fishery seasons run from September through the following August.

There were 5,056 and 2,892 FRH CWTs recovered in the ocean fisheries for '98 BY and '99 BY releases, respectively. Expanded for sampling and hatchery production, an estimated 137,100 FRH '98 BY and 55,000 '98 BY fall and spring Chinook were harvested in the ocean fisheries during their respective five-year life span (Table 17). Appendices 4 and 5 show the specific contribution of these hatchery fish to California and Oregon ocean salmon fisheries by release group, PFMC management area, age, and month. Total estimated sport and commercial landings are directly from the PFMC (2006). We do not attempt to estimate the contribution of FR natural Chinook to the ocean fisheries in this analysis.

An estimated 92,800 and 44,300 FRH '98 BY Chinook were landed in commercial and recreational ocean salmon fisheries, respectively (Table 17; Appendix 4). Approximately 81% of commercial and 66% of sport FRH '98 BY landings were age 3 fish (Table 18). They first appeared at age 2 in both fisheries during May; however due to their relative small size, almost 99% of the age 2 fish were taken in the sport fishery due to its lower minimum size limit. Overall, the FRH '98 BY contributed about 3% at age 2 to the total sport landings in California and Oregon. At age 3, FRH '98 BY releases contributed 22% and 15% to total ocean sport and commercial landings, respectively (Appendix 4). At age 4, these releases contributed approximately 3% to each fishery and by age 5, only a handful of the FRH '98 BY are recovered in the commercial fishery, contributing less that a quarter of one percent.

At all ages and in both fisheries, the majority of these FRH '98 BY contributions were fall releases that were trucked and released in the Carquinez Strait/San Pablo Bay area (TRKF). The TRKF releases contributed more than 78% of all estimated FRH '98 BY landings (Table 17). Approximately 107,000 TRKF were landed in the ocean fisheries (Table 17). Trucked spring releases (FRHS) accounted for 18% of the contribution with almost 25,000 FRHS landed in the fisheries. Inbasin fall releases (INBF) and experimental fall releases (XHAF) accounted for 3% and 1% of total estimated FRH '98 BY landings, respectively. Most of the FRH '98 BY sport landings occurred in the Monterey, San Francisco, and Fort Bragg areas. Commercial FRH '98 BY landings were more spread out with significant landings occurring in San Francisco and Monterey, as well as in the Northern Oregon and Coos Bay port areas (Appendix 4).

Although showing trends similar to the '98 BY, the FRH '99 BY releases contributed much less overall to the ocean fisheries (Appendix 5). An estimated 40,000 and 14,900 FRH '99 BY releases were landed in commercial and recreational ocean salmon fisheries, respectively (Table 17). Approximately 63% of commercial and 78% of sport FRH '99 BY landings were age 3 fish (Table 18). Most of the FRH '99 BY landings in both fisheries were age 3 fish (Table 18). The FRH '99 BY releases first appeared at age 2 in the sport fishery during April and in the July commercial fishery. Overall, the FRH '99 BY releases contributed less than 1% at age 2 to total sport landings in California and Oregon. The commercial contribution is less at one-tenth of a percent. Most of the ’99 BY fishery contribution occurred at age 3. The FRH ‘99 BY releases contributed 5% and 4% to total ocean sport and commercial landings, respectively (Appendix 5). At age 4, these releases contributed approximately 2% to each fishery and by age 5, only a few of the ’99 BY are recovered in the commercial fishery, contributing about half a percent (Appendix 5).

The majority of the FRH ’99 BY contributions in both fisheries were fall and spring releases that were trucked and released in the Carquinez Strait/San Pablo Bay area. The TRKF releases contributed more than 47% of all estimated FRH ’99 BY landings while the FRHS contributed 44% (Table 17). Approximately 26,000 TRKF and 24,000 FRHS were landed in the ocean fisheries (Table 17). Inbasin fall releases accounted for 5% of all FRH ’99 BY landings, with almost 2,800 INBF taken in ocean fisheries. Fall Chinook trucked to Tiburon and released as yearlings (TRKY) and experimental fall releases (XHAF) accounted for 3% and 0.4% of total FRH ‘99 BY landings, respectively. Most of the FRH ’99 BY sport landings occurred in the Monterey, San Francisco and Fort Bragg areas. Commercial ’98 BY landings were more spread out with significant landings occurring in San Francisco and Monterey as well as in Northern Oregon and Coos Bay areas (Appendix 5).

It should be noted that these estimates slightly overestimate the contribution of FRH releases to the NO (northern Oregon) area because they also include Washington and Canadian (British Columbia) CWT recoveries whereas the total NO commercial and sport Chinook landings include only those ports in northern Oregon (i.e., Tillamook, Newport, Columbia River). Table 19 shows the breakout of FRH recoveries collected in WA and BC fisheries. An estimated 813 ‘98 BY and 556 ‘99 BY releases were landed in British Columbia and Washington, representing 3% and 5%, respectively, of all FRH commercial FRH landings in the northern Oregon sector. An estimated 986 ’98 BY and 553 ’99 BY landed in Washington and British Columbia sport fisheries, representing 53% and 45%, respectively, of all sport FRH recoveries in the NO management area. If this trend continues and FRH contact rates by time, area, and fishery are going to be used in the future management of ocean fisheries, then the catch and effort data north of Oregon will need to be incorporated into the CR and the programs modified to include Washington (WA) and British Columbia (BC) as separate port management areas, at least for the sport fishery. We should also note that there was an unusual northern shift in the distribution of Chinook during 2001-2003 and these may prove to be outliers as more data are collected.

Table 17. Estimated landings of FRH '98 BY and '99 BY release groups by age in commercial and sport ocean salmon fisheries.

FRH '98 BY landings

Commercial	Age 2	Age 3	Age 4	Age 5	Total	% total		Commercial	Age 2	Age 3	Age 4	Age 5	Total
INBF	4	2,608	344	2	2,958	2.2%		INBF	0.0%	2.8%	0.4%	0.0%	3.2%
TRKF	89	58,704	13,882	148	72,823	53.1%		TRKF	0.1%	63.3%	15.0%	0.2%	78.5%
FRHS	0	13,269	3,240	16	16,525	12.1%		FRHS	0.0%	14.3%	3.5%	0.0%	17.8%
XHAF	7	462	28	3	499	0.4%		XHAF	0.0%	0.5%	0.0%	0.0%	0.5%
Total	100	75,043	17,493	169	92,805	67.7%		Total	0.1%	80.9%	18.8%	0.2%	

Sport	Age 2	Age 3	Age 4	Age 5	Total	% total		Sport	Age 2	Age 3	Age 4	Age 5	Total
INBF	284	991	172	0	1,447	1.1%		INBF	0.6%	2.2%	0.4%	0.0%	3.3%
TRKF	5,973	22,125	6,120	0	34,218	25.0%		TRKF	13.5%	50.0%	13.8%	0.0%	77.3%
FRHS	982	5,920	1,335	0	8,237	6.0%		FRHS	2.2%	13.4%	3.0%	0.0%	18.6%
XHAF	115	254	9	0	378	0.3%		XHAF	0.3%	0.6%	0.0%	0.0%	0.9%
Total	7,353	29,290	7,637	0	44,280	32.3%		Total	16.6%	66.1%	17.2%	0.0%	

Combined	Age 2	Age 3	Age 4	Age 5	Total	% total		Combined	Age 2	Age 3	Age 4	Age 5	Total
INBF	287	3,600	516	2	4,406	3.2%		INBF	0.2%	2.6%	0.4%	0.0%	3.2%
TRKF	6,062	80,829	20,002	148	107,042	78.1%		TRKF	4.4%	59.0%	14.6%	0.1%	78.1%
FRHS	982	19,188	4,575	16	24,762	18.1%		FRHS	0.7%	14.0%	3.3%	0.0%	18.1%
XHAF	121	716	37	3	877	0.6%		XHAF	0.1%	0.5%	0.0%	0.0%	0.6%
Total	7,453	104,333	25,130	169	137,086			Total	5.4%	76.1%	18.3%	0.1%	

FRH '99 BY landings

Commercial	Age 2	Age 3	Age 4	Age 5	Total	% total		Commercial	Age 2	Age 3	Age 4	Age 5	Total
INBF	0	1,192	747	8	1,948	3.5%		INBF	0.0%	3.0%	1.9%	0.0%	4.9%
TRKF	0	11,876	7,632	315	19,823	36.1%		TRKF	0.0%	29.7%	19.1%	0.8%	49.6%
FRHS	0	11,280	5,392	66	16,738	30.5%		FRHS	0.0%	28.2%	13.5%	0.2%	41.9%
XHAF	0	93	50	0	144	0.3%		XHAF	0.0%	0.2%	0.1%	0.0%	0.4%
TRHY	5	710	583	15	1,313	2.4%		TRHY	0.0%	1.8%	1.5%	0.0%	3.3%
Total	5	25,151	14,404	405	39,965	72.8%		Total	0.0%	62.9%	36.0%	1.0%	

Sport	Age 2	Age 3	Age 4	Age 5	Total	% total		Sport	Age 2	Age 3	Age 4	Age 5	Total
INBF	23	651	131	0	805	1.5%		INBF	0.2%	4.4%	0.9%	0.0%	5.4%
TRKF	293	4,323	1,540	0	6,156	11.2%		TRKF	2.0%	29.0%	10.3%	0.0%	41.2%
FRHS	206	6,316	925	0	7,447	13.6%		FRHS	1.4%	42.3%	6.2%	0.0%	49.9%
XHAF	7	67	7	0	81	0.1%		XHAF	0.1%	0.4%	0.0%	0.0%	0.5%
TRHY	25	316	94	0	435	0.8%		TRHY	0.2%	2.1%	0.6%	0.0%	2.9%
Total	555	11,672	2,696	0	14,923	27.2%		Total	3.7%	78.2%	18.1%	0.0%	

Combined	Age 2	Age 3	Age 4	Age 5	Total	% total		Combined	Age 2	Age 3	Age 4	Age 5	Total
INBF	23	1,843	878	8	2,752	5.0%		INBF	0.0%	3.4%	1.6%	0.0%	5.0%
TRKF	293	16,199	9,172	315	25,979	47.3%		TRKF	0.5%	29.5%	16.7%	0.6%	47.3%
FRHS	206	17,595	6,317	66	24,185	44.1%		FRHS	0.4%	32.1%	11.5%	0.1%	44.1%
XHAF	7	161	57	0	225	0.4%		XHAF	0.0%	0.3%	0.1%	0.0%	0.4%
TRHY	30	1,026	677	15	1,748	3.2%		TRHY	0.1%	1.9%	1.2%	0.0%	3.2%
Total	559	36,824	17,101	405	54,888			Total	1.0%	67.1%	31.2%	0.7%	

Table 18. Estimated landings of FRH '98 BY and '99 BY releases in ocean commercial and recreational salmon fisheries by port area and age.

Port	Commercial						Sport						Both Fisheries					
Area	Age 2	Age 3	Age 4	Age 5	Total	%	Age 2	Age 3	Age 4	Age 5	Total	%	Age 2	Age 3	Age 4	Age 5	Total	%
'98 BY																		
NO	3	24,101	6,036	142	30,282	33%	31	1,487	357	0	1,874	4%	35	25,587	6,393	142	32,157	23%
CO	0	9,661	2,170	0	11,831	13%	160	1,379	182	0	1,721	4%	160	11,040	2,351	0	13,552	10%
KO	0	162	158	0	320	0%	56	741	201	0	998	2%	56	903	359	0	1,318	1%
KC	0	0	752	27	779	1%	91	1,156	103	0	1,350	3%	91	1,156	855	27	2,129	2%
FB	0	578	1,097	0	1,675	2%	639	4,089	2,149	0	6,878	16%	639	4,667	3,246	0	8,552	6%
SF	89	26,927	4,713	0	31,729	34%	3,716	9,101	2,292	0	15,109	34%	3,805	36,028	7,005	0	46,838	34%
MO	7	13,615	2,568	0	16,190	17%	2,660	11,337	2,354	0	16,350	37%	2,666	24,952	4,922	0	32,540	24%
Total	100	75,043	17,493	169	92,805		7,353	29,290	7,637	0	44,280		7,453	104,333	25,130	169	137,086	
	0%	81%	19%	0%		68%	17%	66%	17%	0%		32%	5%	76%	18%	0%		

Port	Commercial						Sport						Both Fisheries					
Area	Age 2	Age 3	Age 4	Age 5	Total	%	Age 2	Age 3	Age 4	Age 5	Total	%	Age 2	Age 3	Age 4	Age 5	Total	%
'99 BY																		
NO	0	3,395	8,145	209	11,749	29%	4	815	413	0	1,231	8%	4	4,209	8,557	209	12,980	24%
CO	0	2,568	1,979	61	4,608	12%	73	849	149	0	1,071	7%	73	3,417	2,128	61	5,679	10%
KO	0	149	28	0	177	0%	0	109	230	0	339	2%	0	258	258	0	516	1%
KC	0	67	315	0	382	1%	0	340	121	0	461	3%	0	407	436	0	843	2%
FB	0	2,503	1,262	0	3,765	9%	70	1,587	561	0	2,218	15%	70	4,089	1,823	0	5,982	11%
SF	74	10,575	1,562	66	12,276	31%	333	2,812	342	0	3,487	23%	407	13,386	1,904	66	15,763	29%
MO	0	5,895	1,115	68	7,078	18%	75	5,161	880	0	6,116	41%	75	11,056	1,995	68	13,194	24%
Total	74	25,151	14,404	405	40,034		555	11,672	2,696	0	14,923		629	36,824	17,101	405	54,958	
	0%	63%	36%	1%		73%	4%	78%	18%	0%		27%	1%	67%	31%	1%		

Table 19. Estimated landings of FRH '98 BY and '99 BY releases to commercial and sport fisheries in northern Oregon sector.

	Commer	Estimated		Sport	Estimated		Total	Estimated		'98 BY		
FRH '98 BY	CWTs	landings	%prop	CWTs	landings	%prop	CWTS	landings	%prop	CWTs	%comm	%sport
British Columbia (BC	1	19	0.1%	1	81	4%	2	100	0.3%	BC	19%	81%
Washington (WA)	40	794	3%	35	905	48%	75	1,699	5%	WA	47%	53%
Oregon-NON*	15	265	1%	9	321	17%	24	586	2%	OR-NON	45%	55%
Oregon-NOS*	1,065	29,204	96%	32	568	30%	1,097	29,772	93%	OR-NOS	98%	2%
Total NO	1,121	30,282		77	1,875		1,198	32,157		Total NO	94%	6%
BC & WA only	41	813	3%	36	986	53%	77	1,799	6%	BC&WA	45%	55%

	Commer	Estimated		Sport	Estimated		Total	Estimated		'99 BY		
FRH '99 BY	CWTs	landings	%prop	CWTs	landings	%prop	CWTS	landings	%prop	CWTs	%comm	%sport
British Columbia (BC	10	125	1%	1	17	1%	11	142	1%	BC	88%	12%
Washington (WA)	32	431	4%	43	536	44%	75	967	7%	WA	45%	55%
Oregon-NON*	21	793	7%	5	40	3%	26	833	6%	OR-NON	95%	5%
Oregon-NOS*	592	10,400	89%	48	638	52%	640	11,038	85%	OR-NOS	94%	6%
Total NO	655	11,749		97	1,231		752	12,980		Total NO	91%	9%
BC & WA only	42	556	5%	44	553	45%	86	1,109	9%	BC&WA	50%	50%

	Commer	Estimated		Sport	Estimated		Total	Estimated		Total		
Total	CWTs	landings	%prop	CWTs	landings	%prop	CWTS	landings	%prop	CWTs	%comm	%sport
'98 BY	3,540	11,534	7%	1,528	5,711	17%	5,068	17,244	10%	'98 BY	67%	33%
'99 BY	2,151	6,965	8%	736	2,749	20%	2,887	9,714	11%	'99 BY	72%	28%

* - Northern Oregon ports broken into 2 areas: NON - north of Cape Falcon (Columbia Basin), NOS - south of Cape Falcon to Heceta Head (Tillamoo

Recovery rate and straying of FRH ’98 and ’99 BY CWTs in the CV

To evaluate various release strategies used for the ’98 BY and ’99 BY, we summarized the recovery of FRH CWTs by hatcheries and carcass surveys throughout the CV. CWTs were only expanded for sampling so that the recovery rate of each cwtcode could be individually evaluated, based directly on the actual number of CWTs released. Following is a brief overview of the recovery rate of ’98 BY and ’99 BY CWTs in the CV and the proportion of these straying outside the FR basin, including the Yuba River.

Approximately 1.8 and 1.7 million fall and spring Chinook produced at FRH were tagged with CWTs in 1998 and 1999, respectively (Table 20). Of these, almost 1.4 million INBF were released within the FR and Sacramento River basins, while 800,000 TRKF and 600,000 FRHS were trucked to the Carquinez Strait - San Pablo Bay area. An additional 650,000 XHAF were released experimentally in the Yolo bypass and San Joaquin basin. In 1998, there were also 185,000 FRH fall fingerlings planted into Lake Oroville and almost 135,000 ‘natural’ fry were trapped and tagged in the FR. In 1999, approximately 30,000 FRH fall fingerlings were also transported to Tiburon where they were raised in net pens until their release as yearlings (FRHY) in late August 2000. There were an additional 182,000 FRH ’99 BY fall Chinook taken to Avila/Morro Bay for a Central Coast enhancement project. None of these fingerlings were tagged so there is no way to estimate their CV or ocean recovery.

The overall recovery rate for FRH ’98 BY CWTs taken in the CV was 0.5% (Table 20). Of the 8,654 FRH ’98 BY salmon recovered in the CV during 2000-2003, there were 570 (7%) fish that strayed outside the FR basin. The FRHS had the highest CV recovery rate (0.9%) with 2,770 (97%) FRHS recovered in the FR basin and 94 (3%) straying outside the basin during 2000-2003 (Table 20; Figure 10). TRKF had the second highest recovery rate (0.7%), with 2,918 (93%) TRKF recovered in the FR and 220 (7%) TRKF straying outside of the FR basin. INBF had a CV recovery rate of 0.3%, with 2,133 (94%) recovered in the FR and 125 (6%) INBF straying. The XHAF had the lowest recovery rate (0.1%) of all FRH ’98 BY releases. In addition, the XHAF had the highest proportion of recoveries straying. There were 264 (67%) XHAF recovered in the FR basin and 130 (33%) XFAF recovered outside the basin. FRW and OROF recoveries were too low to evaluate and were not considered part of the total FRH ’98 BY.

Approximately 75% of the stray FRH ’98 BY fish were recovered in carcass surveys on the upper Sacramento River and its tributaries (Appendix 2). Almost 9% were recovered at CNFH and 6% in the Yuba River carcass survey. The remaining FRH ’98 BY strays were picked up at the other three CV hatcheries and in carcass surveys on the American, Mokelumne, Merced and Stanislaus rivers. The recovery rate and straying proportion of all FRH ’98 BY CWTs by release group and individual cwtcode is in Appendix 2.

The overall recovery rate for FRH ’99 BY CWTs taken in the CV was 0.3% (Table 20). Of the 5,529 FRH ’99 BY salmon recovered in the CV during 2001-2004, there were 474 (9%) fish that strayed outside the FR basin. The FRHY had the highest CV recovery rate (2.5%), with 520 (73%) FRHY recovered in the FR basin and 195 (27%) straying outside the basin (Table 20; Figure 10). FRHS had the second highest recovery rate (0.7%), with 2,107 (94%) FRHS recovered in the FR and 133 (6%) straying outside the basin. Both INBF and TRKF had a CV recovery rate of 0.2%. There were 1,427 (95%) INBF recovered in the FR and 82 (6%) straying. The TRKF had much less straying with only 1 of the 846 TRKF returning to the CV straying outside the FR basin (Table 20). The XHAF had the lowest recovery rate (0.1%) of all FRH ’99 BY releases. In addition, the XHAF had the highest proportion of recoveries straying. There were 156 (67%) XHAF recovered in the FR basin and 130 (32%) recovered outside the basin. FRW recoveries were too low to evaluate and were not considered part of the total FRH ’99 BY.

Approximately 59% of the stray FRH ’99 BY fish were recovered in carcass surveys on the upper Sacramento River and its tributaries (Appendix 3). Almost 28% and 10% of the strays were recovered in the Yuba River and American River carcass surveys, respectively. The remaining FRH ’99 BY strays were picked up in the Mokelumne River carcass survey and at CNFH, NFH, and MRFF. The recovery rate and straying proportion for all FRH ’98 BY CWTs by release group and individual cwtcode is in Appendix 3.

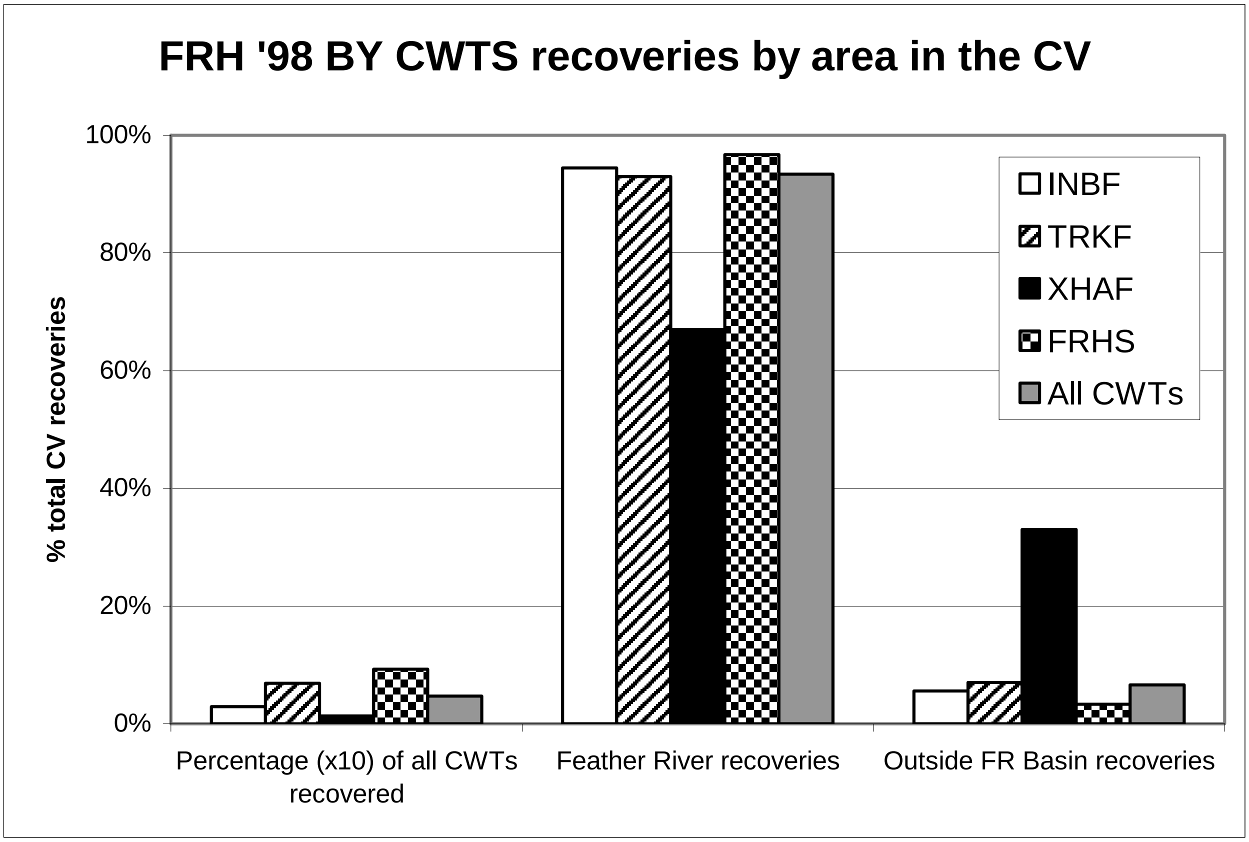
To evaluate the success of FRH ’98 BY and ’99 BY releases in contributing to ocean fisheries or returning as FRH spawners, Appendix 6 shows the recovery of CWTs, expanded only for sampling, in the ocean fisheries and at FRH by release group, age, and individual cwtcode. These recovery data, should help hatchery managers determine which specific release strategies (i.e., time of release, release location, release size) give the most ‘bang for the buck.” These data, combined with the CR, should also identify which release strategies are not working (i.e., few, if any, recoveries and/or high stray rates in the CV).

Table 20. FRH '98 & '99 BY CWT recoveries, expanded only for sampling, by release group & CV area.

'98 BY FRH CWT release Group	# CWT tagged	# CWTs recovered: Feather River	# CWTs recovered: Outside FR basin	# CWTs recovered: Total recoveries	% total CWT recovered	%recoveries by area: Feather basin	%recoveries by area: Outside Basin
In-basin FRH fall releases (INBF)	771,624	2,133	125	2,258	0.3%	94%	6%
Trucked FRH fall releases (TRKF)	457,538	2,918	220	3,138	0.7%	93%	7%
Experimental FRH fall releases (XHAF)	301,057	264	130	394	0.1%	67%	33%
Trucked FRH spring releases (FRHS)	309,587	2,770	94	2,864	0.9%	97%	3%
Wild Feather River releases (FRW) *	133,043	4		4	0.0%	100%	
Lake Oroville FRH fall releases (OROF) *	184,936	18		18	0.0%	100%	
FRH '98 BY total	1,839,806	8,085	570	8,654	0.5%	93%	7%

'99 BY FRH CWT release Group	# CWT tagged	# CWTs recovered: Feather River	# CWTs recovered: Outside FR basin	# CWTs recovered: Total recoveries	% total CWT recovered	%recoveries by area: Feather basin	%recoveries by area: Outside Basin
In-basin FRH fall releases (INBF)	618,963	1,427	82	1,509	0.2%	95%	5%
Trucked FRH fall releases (TRKF)	372,607	845	1	846	0.2%	100%	0.1%
Experimental FRH fall releases (XHAF)	347,747	156	62	218	0.1%	71%	29%
Trucked FRH spring releases (FRHS)	300,322	2,107	133	2,240	0.7%	94%	6%
Tiburon FRH fall yearlings (FRHY)	28,888	520	195	715	2.5%	73%	27%
Wild Feather River releases (FRW) *	144,217	1		1	0.0%	100%	
FRH '99 BY total	1,668,527	5,055	473	5,529	0.3%	91%	9%

* - FRW and OROF releases not included in total number of CWTs released by FRH or recovered in CV.



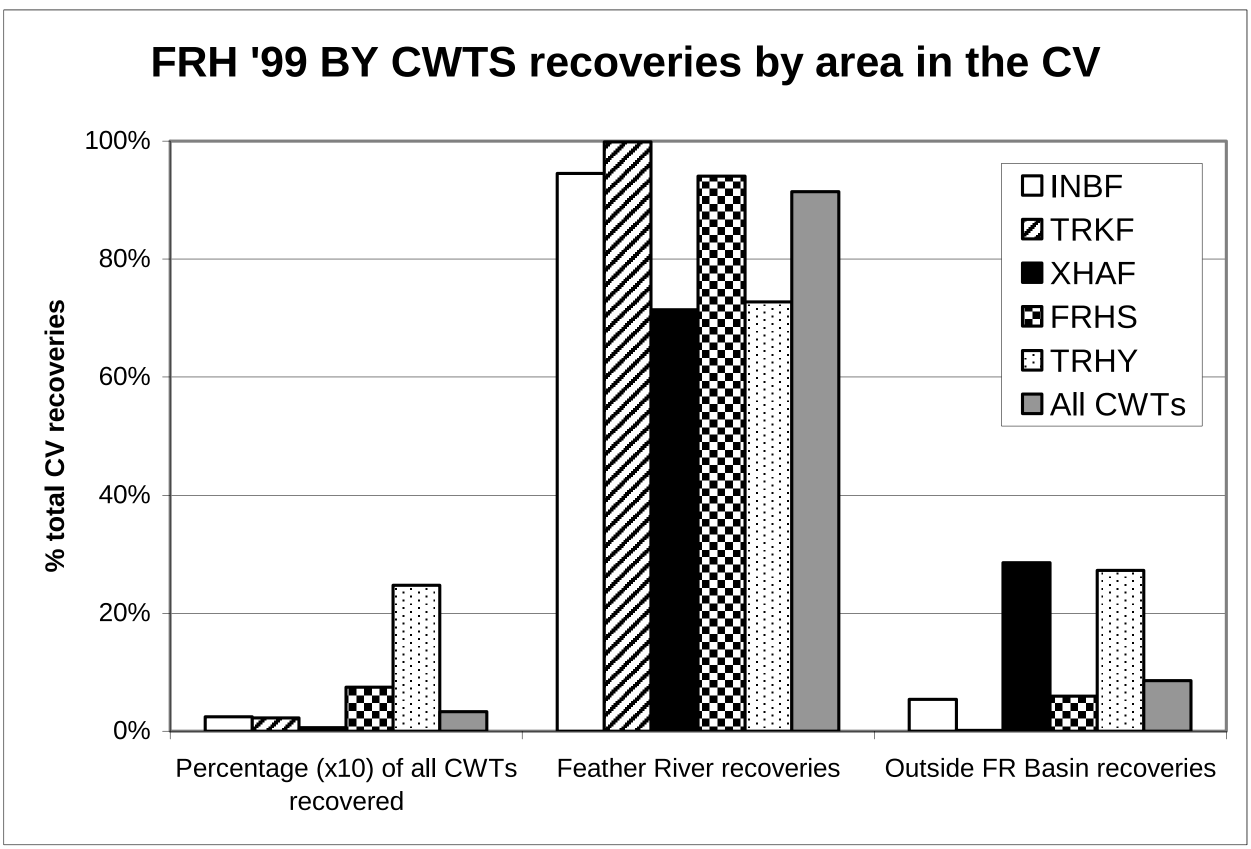


Figure 10. Proportion of FRH '98 BY and '99 BY recoveries in the FR and outside the basin.

Recommendations

This work represents the first attempt at rebuilding populations by cohort for a CV stock during their 5-year life cycle using a detailed accounting CR model of ocean fisheries, hatchery returns, and escapement monitoring. These analyses provide estimates of population parameters such as survival, maturation and stray rates, along with fishery parameters such as ocean population size and contribution to the fisheries by time, area, and age.

Population size and run size at age provides the basis to forecast ocean abundances by cohort and to evaluate preseason conservation objectives for the stock. Ocean fishery contact rates can be derived from the CR and used to predict future harvest given the ocean abundance forecasts and a proposed ocean fishing season. These parameters can then be used to evaluate fishery management objectives in terms of ocean harvest rates or river spawning escapement goals. Since these parameters can be variable from year to year, a relatively long time series of CRs is recommended to account for inter-annual variability. Varying sampling methodologies and the inconsistency of coded-wire tag (CWT) recovery programs in CV inriver harvest and escapement surveys add to the overall variability, potential bias, and uncertainty of these estimates.

The CR and associated analyses are only as good as these data used. There is a definite “garbage in, garbage out” relationship. The CR of FRH ’98 BY and ’99 BY involved a significant amount of time correcting hatchery release and CV recovery data. There were also data that had to be thrown out and information gaps that couldn’t be filled. Although the CR does provide a general overview of the FRH ’98 BY and ’99 BY, we know it is missing key information (e.g., CV river recreational harvest estimates and associated CWTs) and represents only a fraction of these cohorts at best. Accurate return and straying rates for FRH releases cannot be determined without consistent sampling AND adequate CWT collection at the hatcheries, in the escapement and river recreational fisheries throughout the Central Valley.

The most important components feeding into the CR are the CWT release information, ocean CWT recoveries, inland CWT recoveries, and the age composition of the total run. Missing, incorrect, or incomplete information in any of these databases can significantly affect the CR and its outputs. Since significant monies are spent producing millions of salmon each year in the CV, it is imperative that programs exist to accurately document their release, their recovery in both ocean and inland waters, and to evaluate their relative success in meeting hatchery goals.

To make CRs a valuable tool for both hatchery and fishery managers, all of the following must occur: 1) constant fractional marking; 2) improved monitoring and collection of CWTs throughout the CV at all hatcheries, in carcass surveys, and in the river recreational creel survey; and 3) age determination of the run for all rivers and tributaries supporting important CV salmon stocks.

1) Constant fractional marking in California; Correct release data submitted to RMIS

Each year, approximately 40 million Chinook salmon are produced at California hatcheries. We need a mechanism to track all releases and identify these fish from natural stocks. The initial step is to implement a constant fractional marking program of Chinook salmon production at all CV hatcheries. Newman et al (2004) recommends a system-wide constant fractional marking program of at least 33% for all production salmon released from hatcheries in the CV. This will provide a sound basis for expanding CWTs collected from all monitoring programs to the total hatchery production that are either harvested or return to the spawning grounds and hatcheries. It is also essential when determining the production and escapement of natural stocks.

It is just as important that all California hatchery releases are submitted correctly to the RMIS system so that these data are easily accessible for analyses. All release information should be cross-checked and validated against CWT release reports, annual hatchery reports, daily fish planting data sheets, NMT mass marking reports and the CDFG StateWide Hatchery Database. The RMIS and other CWT databases should contain identical information. In addition, the methodology used to estimate the total number of fish tagged, shed rates, and other pertinent release information should be standardized among all tagging entities in California. We found significant differences among releases. Although this is tedious work, the hatchery production factor is among the most important data being used throughout the CR and associated analyses.

2) Improve monitoring and collection of CWTs throughout the CV at hatcheries, in spawner escapement surveys, and in river recreational fisheries.

All CV monitoring programs should produce accurate estimates of salmon escapement or harvest, as well as collect representative samples of CWTs for the estimation of their respective contribution to the population being surveyed. This will require the coordination of various monitoring programs operating in very different environments throughout the CV.

We recommend a standardization of sampling and CWT collection at all CV hatcheries. Although most CV hatcheries monitor 100% of their escapement, there is generally no official documentation of the number of salmon sampled and CWTs collected on a daily basis. We recommend a data sheet be used to document all daily hatchery sampling and for recording pertinent CWT information (e.g., headtag number, sex, length, date, run). Often the only information OSP receives with the CV CWTs they process is on the headtag attached to each head. On occasion, critical information has not been recorded and it was impossible to determine when and/or where this CWT was collected. Since each CWT recovery must be uploaded to the RMIS with its respective catch-sample data, these data are thrown out. FRH began using a daily data sheet in 2000 and these data have proved extremely useful in cleaning up these data.

There are numerous methodologies currently being used in the CV to determine spawner escapement. Carcass surveys are known to be complex and contain assumptions that can lead to bias (Zhou 2002, Mohr 2002). Any refinement of methodology or incorporation of technology that minimizes these potential biases should be implemented.

Probably the biggest problem we identified during this work was the lack of a cohesive sampling program for the CV river recreational fishery. We found the creel sampling during 2000-2004 to be so inconsistent and the collection of CWTs so sporadic that we chose to throw out these data completely. Not only is a statistically sound program needed throughout the CV in all major sections of the fishery, but the collection of CWTs also needs to be a primary component. During the 2000-2002 creel survey, angler cooperation with the collection of heads from ad-clipped salmon was “not optimal” (D. Massa, CDFG, pers. comm.). OSP also had this problem during sampling of the ocean recreational fishery until they were able to get Section 8226 of the California Fish and Game Code adopted in the early 1990s. This law requires any person in possession of a salmon with a missing adipose fin to immediately relinquish the head of this salmon to any authorized agent or employee of the Department, at no charge, for the recovery of the CWT. It also makes it illegal to intentionally conceal, cull, or release into the waters, a salmon with a missing adipose fin that it is otherwise legal to possess. Educating the angling public about the importance of CWT data in fisheries and resource management, as well as Section 8226, should be an important part of any salmon creel survey in California.

A consistent statewide protocol for processing heads, reading and validating CWTs, and reporting their associated catch-sample data is needed to improve the overall quality of California data. We strongly recommend that a centralized CWT laboratory be created for processing, validating, and reporting all CWTs collected in California, similar to those existing in other west coast states and Canada. Currently, OSP is officially responsible for processing all CWTs collected in the ocean fisheries and uploading these data, along with their associated catch-sample data, to the RMIS. In addition, OSP verifies all California CWTs collected outside of the state.

In recent years, OSP has had a contract with DWR to process CWTs from various CV inland programs. Although the OSP has just completed its cleanup of the 2000-2004 inland CWT recovery data, it has been a relatively ad hoc effort and there are still pertinent data missing from various CV projects. The RMIS system requires that all California CWT recovery data (ocean and inland) be submitted in one file. In addition, each CWT recovery must have an associated record in the California 'catch-sample' file that is uploaded to the RMIS at the same time. Thus these missing or incomplete data will not be included when these files are uploaded to the RMIS.

Since many CV projects simply send their CWT data electronically to OSP, there is no way to verify CWTs that stray or are stocks of special concern (e.g., endangered Sacramento River winter run Chinook, threatened Central Valley spring run Chinook). Also OSP found that approximately 20% of CWTs are found in or behind the eye region during their processing of ocean heads. Since many programs cut the snout just before the eye, this may also account for the high proportion of inland heads without CWTs observed in the FR and other carcass surveys. CV hatcheries are still using 'half-tags' (CWTs 0.5mm in length) due to the small size of the fish during tagging. Although the tube detector used by OSP detects these smaller tags, many projects are still using the older 'V' detectors that aren't sensitive enough to detect these CWTs. We also believe these half-tags are being missed in Oregon and Washington when their respective ocean salmon fisheries are electronically sampled with hand-held wands.

Currently, a single program exists that is responsible for submitting cwtcodes used in California to the RMIS (Bob Kano, CDFG). A similar program needs to be established for reporting CWTs collected in California. A centralized CWT lab could easily fill this role by requiring any project that collects CWTs in California to submit their sampling and recovery data to this program. A CALFED proposal has recently been submitted to expand the OSP Santa Rosa laboratory into a full-time centralized processing facility. If established, it could provide fishery, hatchery and other resource managers with real-time CWT data needed to monitor estimates of harvest impacts or spawner escapement of various salmon stocks. Differences detected between pre-season predictions and actual landings or escapements could also allow ocean and inriver salmon allocations to be adjusted as needed.

3) Age determination of the run for all rivers and tributaries supporting CV salmon stocks.
This is among the most critical components of the CR since it is used to determine the natural component of the run by age and in rebuilding each cohort at various points throughout its life. The age structure should be representative of the total run, not just the hatchery component as was used in this work. CALFED has just funded a project that will systematically collect salmon scales throughout the CV to determine the age structure of fourteen key runs of Chinook

Once this project has been established, a technical work group(s) of CV biologists should be created similar to the Klamath River Technical Advisory Team (KRTAT). Each year, this team of experts would gather for several days to review CV escapement and harvest estimates and to determine the age composition of the various runs. The team would then produce an annual CV age composition report similar to the one created by the KRTAT every year (KRTAT 2006a). After the CV tech team has several years of data, it could then start producing ocean stock abundance estimates based on cohort "sibling regression" (KRTAT 2006b).

Combined with good estimates of river harvests, hatchery returns and spawning escapement, these age structures will make it possible to create CRs for important CV stocks and determine the contribution of hatchery and natural fish to these populations. This CR model was specifically written so that it could be modified to rebuild the cohort population for brood years 1983 through 2004 for most California Chinook salmon stocks. The CR will also estimate population parameters such as total ocean abundance, ocean harvest rates, maturation rates, and stray rates, as well as produce the data needed to forecast ocean stock abundances by age. Using these population parameters and ocean harvest data, a CV ocean harvest model can be constructed to predict ocean fishery impacts given a proposed fishing season and minimum spawner requirements.

Acknowledgments

We wish to sincerely thank Randy Brown and Bradley Cavallo of the California Department of Water Resources, and Stan Allen of the Pacific States Marine Fisheries Commission for the opportunity to conduct this research.

A detailed understanding of the operations at FRH would not have been possible without the assistance of Anna Kastner, Steve Brightwell, Bob Kano, and Dave Krueger of the California Department of Fish and Game. Our data verification was facilitated by Alicia Seesholtz, Jason Kindopp and Ryon Kurth of DWR; Doug Killam, Colleen Harvey-Arrison, Tracey McReynolds, Mike Healey, Tim Heyne, Terry West, Bob Anderson, Mike Cozart, Duane Massa, Wade Sinnen and Mark Hampton of CDFG; Stephanie Theis of Jones and Stokes; Michelle Workman of EBMUD; and Kevin Niemela, Bob Null, Ceasar Blanco, and J.D. Wikert of USFWS. A special thanks to Alice Low of CDFG for answering our historical literature questions. Last, but not least, our sincere gratitude to Michael Mohr of NOAA, Santa Cruz, for providing the maximum-likelihood programs used in our size-at-age analyses and his continued technical and statistical support of this work.

Literature cited

Brown, R.L., and S. Greene. 1993. An Evaluation of the Feather River Hatchery as Mitigation for Construction of the California State Water Project's Oroville Dam. In: Environmental Enhancement of Water Projects. Proceedings from the 1993 Seminar Sponsored by U.S. Committee on Irrigation and Drainage. Sacramento, CA.

CDFG (California Department of Fish and Game). 1998. A Status Review of the Spring-Run Chinook Salmon, *Oncorhynchus tshawytscha* in the Sacramento River Drainage. Candidate Species Status Report 98-01 to The Fish and Game Commission. Sacramento, California. 230p.

CDFG. 2005. Existing Program Summary: Central Valley Salmon and Steelhead Monitoring Programs. Contributors: IEP Salmon Escapement Project Work Team and IEP Juvenile Monitoring Project Work Team, Edited by A. Low. Sacramento, California. 162p.

DWR (California Department of Water Resources). 2002. Emigration of Juvenile Chinook Salmon in the Feather River, 1998-2001. Sacramento, CA, 26p.

Grover, M.A., M.S. Mohr, and M.L. Palmer-Zwahlen. 2002. Hook-and-Release Mortality of Chinook Salmon from Drift Mooching with Circle Hooks: Management Implications for California's Ocean Sport Fishery. Pages 39-56 *in* J.A. Lucy and A.L. Studholme, editors. Catch and Release in Marine Recreational Fisheries. American Fisheries Society, Symposium 30, Bethesda, Maryland.

Goldwasser, L., M.S. Mohr, A.M. Grover, and M.L. Palmer-Zwahlen. 2001. The supporting databases and biological analyses for the revision of the Klamath Ocean Harvest Model. Available from M.S. Mohr, NOAA Fisheries, 110 Shaffer Road, Santa Cruz, CA 95060.

Hilborn, R., and C.J. Walters. 1992. Quantitative fisheries stock assessment. Chapman and Hall, New York.

Johnson, J.K. 1990. Regional Overview of Coded Wire Tagging of Anadromous Salmon and Steelhead in Northwest America. Amer. Fish. Soc. Symp. 7:892-816. (updated in 2004 by K. Johnson)

KRTAT (Klamath River Technical Advisory Team). 2006a. Klamath River Fall Chinook Age-Specific Escapement, River Harves, and Run Size Estimates, 2005 Run. Technical Report to Klamath Fishery Management Council. Available from Yreka Fish and Wildlife Office, U.S. Fish and Wildlife Service, 1829 S. Oregon Street, Yreka, California 96097. 16pp.

KRTAT. 2006b. Ocean Abundance Projections and Prospective Harvest Levels for Klamath River Fall Chinook, 2006 Season. Technical Report to Klamath Fishery Management Council. Available from Yreka Fish and Wildlife Office, U.S. Fish and Wildlife Service, 1829 S. Oregon Street, Yreka, California 96097. 26pp.

KRTT (Klamath River Technical Team). 1986. Recommended spawning escapement policy for Klamath River fall-run Chinook. Technical Report to Klamath Fishery Management Council. Available from Yreka Fish and Wildlife Office, U.S. Fish and Wildlife Service, 1829 S. Oregon Street, Yreka, California 96097. 73 pp.

Massa, D.A. and T. Schroyer. 2003. Central Valley Salmon and Steelhead Harvest Monitoring Project, 2002 Angler Survey. California Department of Fish and Game (CDFG), Rancho Cordova, California. 43p.

Mohr, M.S. 2002. Expansion of CWT Recoveries in Central Valley Carcass Surveys. Available from M.S. Mohr, NOAA Fisheries, 110 Shaffer Road, Santa Cruz, CA 95060.

Mohr, M.S., A.M. Grover, M.L. Palmer-Zwahlen, and M. Burner. 2001. Klamath Ocean Harvest Model Revision Documentation Outline. Available from M.S. Mohr, NOAA Fisheries, 110 Shaffer Road, Santa Cruz, CA 95060.

Myers, J.M., R.G. Kope, G.J. Bryant, D. Teel, L.J. Lierheimer, T.C. Wainwright, W.S. Grant, F.W. Waknitz, K. Neely, S.T. Lindley, and R.S. Waples. 1998. Status review of Chinook salmon from Washington, Idaho, Oregon, and California. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-35, 443 p.

Newman, K.B., A.C. Hicks and D.G. Hankin. 2004. A Marking, Tagging, and Recovery Program for Central Valley Hatchery Chinook Salmon. 72p.

Pipal, K. A. 2005. Summary of Monitoring Activities for ESA-Listed Salmonids in California's Central Valley. U.S. Dept. Commer., NOAA Tech. Memo. NMFS, 208p.

PFMC (Pacific Fisheries Management Council). 2006. Review of 2005 Ocean Salmon Fisheries. Prepared by Salmon Technical Team and Staff Economist. Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 200, Portland, Oregon 97220-1384. 306 pp.

Pope, J.G. 1972. An investigation of the accuracy of virtual population analysis using cohort reconstruction. International Commission for Northwest Atlantic Fisheries, Bulletin number 9:65-74.

Prager, M.H., and M.S. Mohr. 2001 The harvest rate model for Klamath River fall Chinook salmon, with management applications and comments on model development and documentation. North American Journal of Fisheries Management 21(3):533-547.

Reynolds, F.L., T.J. Mills, R. Benthin, and A. Low. 1993. Restoring Central Valley Streams: A plan for action. California Department of Fish and Game (CDFG), Sacramento, CA, 184p.

RMPC (Regional Mark Processing Center). 1997. Regional Mark Information System, User Manual. Version 2.0. Prepared for the Pacific States Marine Fisheries Commission, 45 SE 82nd Drive, Suite 100 Gladstone, Oregon 97027-2522.

Sommer, T., D. McEwan, and R. Brown. 2001. Factors affecting Chinook spawning in the lower Feather River. In: Brown, R.L. (Ed.), *Contributions to the Biology of Central Valley Salmonids*. CDFG Fish Bulletin 179, Vol. 1 (269-297).

STT (Salmon Technical Team). 2000. STT recommendations for hooking mortality rates in 2000 recreational ocean Chinook and coho fisheries. March supplemental report B.2. Pacific Fishery Management Council, 2130 S.W. Fifth Avenue, Suite 224, Portland, Oregon 97201. 18 pp.

USFWS (U.S. Fish and Wildlife Service). 2002. Comprehensive Assessment and Monitoring Program (CAMP), Annual Report 2000. Prepared by CH2M HILL. Sacramento, California.

Wixom, L.H., J. Pisciotto, and C. Lake. 1995. Final Performance Report – Sacramento River System Sport Fish Catch Inventory. California Department of Fish and Game (CDFG), Inland Fisheries Division. 76.

Zhou, S. 2002. Size-Dependent Recovery of Chinook Salmon in Carcass Surveys. Trans. of the Amer. Fish. Soc. 131:1194-1202.