City of Tacoma,
Department of Public Utilities, Light Division
Cowlitz Hydroelectric Project
FERC No. 2016

Settlement Agreement License Article 3.

Upstream Fish Passage: Barrier, Mayfield and Mossyrock

Report Results

1. INTRODUCTION

This report is prepared as a response to the March 13, 2002, Federal Energy Regulatory Commission (the Commission), Order Approving Settlement and Issuing New License, and the July 18, 2003, Commission Order Denying Rehearing and Lifting Stay for FERC Project No. 2016, Settlement Agreement License Article 3. The license article requires the City of Tacoma, Department of Public Utilities, Light Division (Tacoma) to file a report on adult anadromous fish traveling through the Cowlitz River Project within six (6) months of license issuance.

1.1. Project Description

The Cowlitz Project (FERC No. 2016) is located on the Cowlitz River, Lewis County, Washington between river mile (RM) 49.5 and RM 88.0. The project consists of Mossyrock Dam (RM 65.5), Mayfield Dam (RM 52.0), Riffe Lake reservoir, Mayfield Lake reservoir, two hydroelectric powerhouses, the transmission facilities associated with the dams, the Cowlitz Salmon Hatchery (RM 50.0), the Barrier Dam (RM 49.5), the Cowlitz Trout Hatchery (RM 42.0), recreational facilities at the reservoirs and lands within the Project boundary. Construction of the Project began with Mayfield Dam in 1956 and was completed with the construction of Mossyrock Dam ending in 1968. The Project has been operated and maintained continuously since original construction.

Tacoma Power built the Cowlitz Project between 1958 and 1968 and generation capacity was expanded in 1983. The original license for the project was issued November 28, 1951, and expired on December 31, 2001. A new thirty-five year license for the project was made effective on July 18, 2003.

Cowlitz Falls Project (FERC No. 2833) is located on the Cowlitz River, Lewis County, Washington between RM 88.0 and RM 101. The Project consists of Cowlitz Falls Dam (RM 88.0) and powerhouse, the transmission facilities associated with the Project and the Cowlitz Falls Fish Collection Facility located just below Cowlitz Falls Dam. Construction of the Project began in 1991 and was completed with initial operations in 1994. The Project has been operated and maintained continuously since original construction.

The original license for Cowlitz Falls Project was issued in 1986 and will expire on June 30, 2036.

1.2. FERC License Article

> <u>Settlement Article License Article 1</u> *Upstream Fish Passage: Barrier, Mayfield and Mossyrock. b) Within six months of license issuance, or as soon as practicable thereafter depending on the availability of marked fish, and updated on an annual basis thereafter, the Licensee shall file with the Commission a report on adult anadromous fish traveling through the Cowlitz River Project, prepared in collaboration with the Fisheries Technical Committee provided for in the August*

2000 Settlement Agreement, or if the Settlement Agreement has become void, with the U.S. Fish and Wildlife Service, National Marine Fisheries Service, Washington Department of Fish and Wildlife and Washington Department of Ecology (referred to as "the FTC or agencies"). The report shall include: 1) the most recent version of Tables 3, 4, and 5 from the report entitled Contribution Rate Benchmarks for Future Runs of Spring Chinook, Fall Chinook, and Coho Produced at the Cowlitz Salmon Hatchery that provide estimated age 3 recruits and survival equivalency that enables comparison of future broods to the benchmark run year and survival rate for each of these species, dated June 28, 2000 and filed with the Commission concurrently with the August 2000 Cowlitz River Hydroelectric Project Settlement Agreement; 2) tables estimating the annual number of adult recruits originating from the Cowlitz River basin upstream of the Toutle River, and including steelhead, cutthroat trout, and all other indigenous stocks that are produced at the hatcheries, along with an index of each stock to its benchmark values, or if not otherwise agreed, a default index of "1"; 3) a plan and schedule for studies, to be conducted at regular intervals, to evaluate whether the following criteria for implementing effective upstream passage through volitional facilities have been met: A) adult fish in Mayfield Lake are able to choose their tributary of origin and survive Mayfield Lake transit at rates determined by NMFS and USFWS, in consultation with the FTC or agencies, to be sufficient to achieve effective upstream passage through volitional facilities; and B) as determined based on the above-described tables with respect to: (i) the number of pre-spawners arriving at the Barrier Dam, in at least 3 of 5 consecutive brood years measured, and based on the 5-year rolling average, exceeds an abundance level which indicates natural recruitment above Mayfield Dam has achieved self-sustaining levels, as determined by the National Marine Fisheries Service in consultation with the FTC or agencies; (ii) the productivity level in 3 of 5 years and the 5-year rolling average, as measured at the Barrier Dam or other Cowlitz River fish counting facilities by the recruit/pre-spawner ratio, exceeds 1.0; and (iii) the disease management plan required by Article 8 has been implemented. c) For any annual report filed within 12 years of license issuance in which the results of the studies indicate that, within the next three years or less, the above criteria for volitional upstream passage will be met with respect to any salmonid species originating in the Tilton basin and with respect to either spring chinook salmon or late winter steelhead originating above Mossyrock Dam, the Licensee shall also include proposed preliminary designs and schedules for the construction of upstream passage systems for the Project. In the case of Barrier Dam, the proposed modifications shall provide for breaching the Barrier Dam. In lieu of breaching, a fish ladder may be constructed only if NMFS and USFWS determine, in consultation with the FTC or agencies, that a ladder is more appropriate than breaching for effective upstream passage. The proposed modifications for the Barrier Dam shall also include steps to disable the electrical field in the event of fish ladder construction or breaching the dam. In the case of Mayfield Dam, the upstream passage system proposed shall be a ladder with sorting facilities, unless prior to filing the report the NMFS and USFWS determine that a tram is more appropriate than a ladder for effective upstream passage, in which case the system proposed shall be a tram with sorting facilities. In the case of Mossyrock Dam, the passage system proposed shall be an adult trap and haul facility to facilitate adult transit above Cowlitz Falls Dam to be built before or concurrently with the upstream passage system at Mayfield Dam, unless prior to filing the report the USFWS and NMFS determine that a comparably-priced tram is more appropriate than a trap and haul facility based on studies that show fish are able to migrate through Riffe Lake, and it has also been determined that an adult upstream passage facility will be developed at Cowlitz Falls Dam. A draft report shall be provided to the FTC or agencies for review and comment. The Licensee *shall include with the report documentation of consultation and copies of comments and recommendations on the report, and specific descriptions of how the FTC's and agencies' comments are accommodated by the report. The Licensee shall submit the final report to the NMFS and USFWS for approval prior to filing with the Commission. Upon approval by NMFS and USFWS and filing with the Commission, the Licensee shall implement the proposals in the report. d) Upon meeting the criteria above for the construction of volitional upstream passage systems, the Licensee shall proceed expeditiously to complete the final design, permitting and construction of upstream passage systems. The final design shall be subject to the same review and approval process described in paragraph c) above. Once the report containing the final design and implementation schedule for the construction of upstream fish passage systems is approved by NMFS and USFWS and filed with the Commission, volitional upstream passage facilities shall be completed and made operational within one (1) year of meeting the criteria or approval of the final design, whichever is later, unless there is good cause for extending the period beyond one year. e) Within five years of license issuance, the Licensee shall establish an interest-bearing escrow account in the amount of $15 million to contribute to the total cost of constructing volitional upstream fish passage facilities. To minimize administrative cost and allow conservative growth, said escrow account may be held by the Licensee as a separate account (with Licensee being obligated to treat said account substantially similar to an escrow account), and said account may be invested, consistent with investment limitations on public agencies within the State of Washington. f) If at any time the Licensee files a report indicating that the above criteria are not likely to be met within 15 years following license issuance with respect to listed chinook salmon or steelhead originating above Mayfield Dam, the Licensee shall consult with the FTC or agencies, using the best available data at the time, regarding factors that may be contributing to the failure to meet such criteria, and the likelihood or not that such criteria will be met for the listed stocks in the foreseeable future. g) If preliminary or final upstream volitional fish passage design plans and implementation schedules have not been approved and filed with the Commission at the end of year 12, the Licensee must prepare and submit preliminary design plans and schedules in accordance with paragraphs c) and d) if the volitional upstream passage criteria set forth in paragraphs b) and c) have been met or are likely to be met for any salmonid species in the Tilton by year 15. The Licensee shall proceed expeditiously with final design and construction of volitional upstream passage facilities, unless otherwise directed under paragraph h) below. h) If within 14 years of license issuance the criteria for volitional upstream passage facilities, described in b), c) and g) above, have not been met and it is determined by the FTC or agencies, and affected Tribes, with the concurrence of NMFS and USFWS, that measures in addition to those provided for in the August 2000 Settlement Agreement are necessary to restore self-sustaining, natural production of ESA-listed stocks in the Cowlitz River basin, and that expenditure of the escrow fund on such additional measures in lieu of volitional upstream facilities is necessary and appropriate to achieve natural stock restoration, consistent with the express purpose of the license and the Settlement Agreement, and with applicable recovery plans for the listed Cowlitz River stocks, the Licensee shall submit to the Commission a plan to abandon volitional upstream passage and expend the funds in the escrow account for the purposes of protecting and promoting restoration and recovery of listed Cowlitz River stocks. If the above criteria have not been met for any salmonid species in the Tilton by year 15, the Licensee shall continue monitoring fishery conditions for future construction of upstream volitional fish passage, until either the criteria are met or a decision is made to abandon upstream volitional passage and fund other necessary and appropriate measures* *in accordance with this paragraph. i) Following construction of volitional upstream passage facilities, the Licensee, in consultation with the FTC or the agencies, shall monitor the effectiveness of the facilities. As deemed necessary by NMFS and USFWS, after consultation with the FTC, the Licensee shall implement such reasonable modifications as may be necessary to improve passage effectiveness. j) Any plan required to be filed pursuant to this article shall be prepared in consultation with the FTC or agencies. The Licensee shall include with the plan documentation of consultation and copies of comments and recommendations on the plan, and specific descriptions of how the FTC's or agencies' comments are accommodated by the plan. The Licensee shall submit the plan to the National Marine Fisheries Service and U.S. Fish and Wildlife Service for approval prior to filing with the Commission. Upon approval by NMFS and USFWS and filing with the Commission, the Licensee shall implement the plan.*

1.3. Table of Contents

2. SUMMARY

This initial annual report to FERC for Article 3 will consist of the following sections:

A: A Report On Adult Anadromous Fish Traveling Through The Cowlitz River Project

1. The number of adult salmonids returning to the Cowlitz Salmon Hatchery separator in 2002/2003 – **Table 1.**
2. The number of adult salmonids returning to the Cowlitz Trout Hatchery in 2002/2003 – **Table 2.**
3. The possible origins of adult salmonid returns to the Cowlitz River – **Tables 3 and 4.**
4. Adult salmonids hauled upstream of Mayfield Dam, Cowlitz River in 2002/2003 – **Appendix Tables.**
5. The current juvenile salmonid marking program in the Cowlitz River basin – **Table 5.**

B: Contribution Rate Benchmarks For Spring Chinook, Fall Chinook And Coho

1. The most recent versions of tables estimating age 3 recruits and survival equivalency scaling for Cowlitz River salmon stocks – **Tables 6, 7 and 8.**
2. The status of Fisheries and Hatchery Management Plan actions for determining the recruit per spawner (R/S) ratio in the Cowlitz River.

C: A schedule for future actions and returns of adults needed to determine the status of naturally produced adult anadromous fish traveling through the Cowlitz River Project.

1. **Table 9 -** Timetable of actions for unmarked naturally produced salmonid returns to the Cowlitz River basin.

D. References

E. Attachments

F. Appendices.

2.1. *Adult salmonid returns to the Cowlitz River basin:*

Adult salmonids traveling through the Cowlitz River Project return to the separator facility at the Cowlitz Salmon Hatchery at RM 50.0 – the upstream limit of volitional anadromous passage. These fish are a mix of hatchery and naturally produced fish and are trucked upstream into the upper Cowlitz River sub-basins by Tacoma Power. Adult fish are released into the Tilton River, above Mayfield Dam, and into the upper Cowlitz River basin, above Cowlitz Falls Dam at RM 88.0.

Hatchery fish are adults that return from smolts released from the Cowlitz Salmon or Trout hatcheries, and adult returns from hatchery fingerling or smolt releases in the upper Cowlitz River basin tributaries. Natural fish are adult returns from juveniles produced from adults released into the upper Cowlitz River basin tributaries. Not all hatchery juvenile releases (from the hatcheries or plantings in the tributaries) are marked; therefore an unmarked Chinook or steelhead adult return could be either a hatchery-produced fish or a naturally-produced fish.

Table 1. Number of adult salmonids returning to the Cowlitz Salmon Hatchery separator in 2002/2003 (no recycled fish included).

Week Ending	SPCH adults	SPCH jacks[1]	SPCH mini-jacks[2]	FCH adults	FCH jacks	CO adults	CO jacks	SRSH	SRSH jacks	WRSH	WRSH jacks	CT
04/06/02	1									496		1
04/13/02	4	1								1306		
04/20/02	5	1								775		
04/27/02	38	6						6		858	1	
05/04/02	41	7						11		455		
05/11/02	250	25						23		255		
05/18/02	283	25						25		103		
05/25/02	327	52						68		61		
06/01/02	335	38						58		7		
06/08/02	221	31						227		11		
06/15/02	275	47	9					300		5		
06/22/02	155	45	64					406		1		
06/29/02	391	68	107					669	2			
07/06/02	123	31	62					470	1			
07/13/02	227	35	104					740	5			

[1] Jacks = precocious males more than 2 years old
[2] Mini jacks = precocious males less than 2 years old

07/20/02	166	16	191					763	6			
07/27/02	223	30	137					1263	19			
08/03/02	224	29	107					734	2			
08/10/02	64	17	35					532	9			2
08/17/02	282	11	76					409	15			3
08/24/02	144	10	45	4				303	10			9
08/31/02	206	4	12	65	12	2		215	6			2
09/07/02	66	5	16	581	2	3		110				3
09/14/02	52	1	10	1145	28	224	2	181	1			13
09/21/02				1262	20	764	37	69				11
09/28/02				1941	42	3719	481	77				14
10/05/02				1536	36	4354	902	98				14
10/12/02				995	10	5591	989	56	1			9
10/19/02				885	30	5111	1416	13				5
10/26/02				342	10	6262	983	20				4
11/02/02				251	3	5671	986	28		1		14
11/09/02				220	4	5107	1061	44		3		22
11/16/02				12	1	6398	317	13		1		8
11/23/02						5698	256	17		6		3
11/30/02						4614	159	13		24		
12/07/02				2		4844	172	16		65		2
12/14/02						5398	255	22		70		13
12/21/02						5559	172	19	1	74		4
12/28/02						3099	79	7		148		
01/04/03						3251	51	3		94		1
01/11/03						3779	119	4		114		
01/18/03						2950	68	10		253		1
01/25/03						1729	58	6		151	1	1
02/01/03						1039	54	22	1	312		4
02/08/03						40	3			50		
02/15/03	1					67	7			234		1
02/22/03						7		2		204		2
03/01/03										289		
03/08/03	1									150		
03/15/03	9									399	2	
03/22/03	28									609		
03/29/03	13									355		1
Season Totals:	**4,155**	**535**	**975**	**9,241**	**198**	**85,280**	**8,627**	**8,072**	**79**	**7,939**	**4**	**167**

Table 2. Number of adult salmonids returning to the Cowlitz Trout Hatchery in 2002/2003 (no recycled fish included).

Week Ending	FCH	COHO	Early WRSH	SRSH	Late WRSH	Sea-run CUTT
Adults	3	53	1,711	2,910	760	22,396
jacks	0	1	4	0	0	0

Table 3. Possible origins of upper Cowlitz River basin adult returns in 2002/2003

	Hatchery Unmarked	Hatchery Marked	Natural Unmarked	Natural Marked
Spring Chinook	**Yes**[3]	**Yes**	**Yes**	**No**
Fall Chinook	**No**	**No**	**Yes**	**No**
Coho	**No**	**No**	**Yes**	**No**
Steelhead	**Yes**[3]	**Yes**	**Yes**	**No**
Cutthroat Trout	**No**	**No**	**No**	**Yes**

Table 4. Possible origins of lower Cowlitz River basin adult returns in 2002/2003

	Hatchery Unmarked	Hatchery Marked	Natural Unmarked	Natural Marked
Spring Chinook	**Yes**[4]	**Yes**	**Yes**	**No**
Fall Chinook	**Yes**	**Yes**	**Yes**	**No**
Coho	**No**	**Yes**	**Yes**	**Yes**[5]
Chum	**No**	**No**	**Yes**	**No**
Sockeye	**No**	**No**	**Yes**	**No**
Steelhead	**Yes**[6]	**Yes**	**Yes**	**Yes**[6]
Cutthroat Trout	**No**	**Yes**	**Yes**	**Yes**[6]

As an example, an adult spring Chinook adult returning to the Cowlitz Salmon Hatchery separator could originate from a hatchery release (and therefore be a marked fish), or a returning fish could originate from the upper Cowlitz River basin (and therefore be either marked or unmarked). Fish separator operators are unable to distinguish the origin of an unmarked spring Chinook adult, as it could be a naturally-produced fish or a hatchery-produced fish from the upper basin. The same situation applies to steelhead. A mix of marked and unmarked hatchery steelhead fry and

[3] Upper basin fry plants
[4] Including cooperative projects
[5] Juveniles marked at Mayfield Dam downstream migrant collector
[6] Tilton River fry plants

hatchery spring Chinook fingerlings are released into the Tilton River and upper Cowlitz River sub-basins under the current fisheries management regime (2003).

Table 5. The 2003 juvenile salmonid marking program in the Cowlitz River basin

Release Location	Spring Chinook	Fall Chinook	Coho	Steelhead	Cutthroat	Chum	Sockeye	Pink	NOTES
Cowlitz Trout Hatchery	**NA**	**NA**	**NA**	**100% adipose clip**	**100% adipose clip**	**NA**	**NA**	**NA**	
Cowlitz Salmon Hatchery	**100% ad clip + cwt**	**96% unmarked, 4% ad+cwt**	**100% ad clipped, 3% ad+cwt**	**NA**	**NA**	**NA**	**NA**	**NA**	
Mayfield Dam Collector	**Snout blank wire tag**	**Snout blank wire tag**	**Snout blank wire tag**	**Right cheek blank wire tag**	**Snout blank wire tag**	**NA**	**NA**	**NA**	**Smolts marked only**
Tilton River	**NA**	**NA**	**NA**	**Anal fin elastomer mark**	**Anal fin elastomer mark**	**NA**	**NA**	**NA**	**Fry plant marks**
Cowlitz Falls Fish Collector	**Un-marked & small portion elastomer marked**	**NA**	**Un-marked**	**Unmarked & small portion elastomer marked**	**Elastomer and alphanum. tag**	**NA**	**NA**	**NA**	**Smolt marks**
Upper Cowlitz River basin	**Ad clip + elastomer**	**NA**	**NA**	**Fry: ad clip, smolts: ad+rv**	**NA**	**NA**	**NA**	**NA**	**Fry & smolt plants**

2.2. *Contribution Rate Benchmarks for Spring Chinook, fall Chinook and coho*

Tables 6, 7 and 8 update the estimated age 3 recruits and survival equivalencies for spring chinook, fall chinook and coho salmon produced from the Cowlitz River basin. This work is based upon the formulations established in Cramer (2000) and are the same data sets contained in Cramer (2002). The calculations are based upon completed and verified data sets of coded wire tag (cwt) recoveries from tagged lots of Cowlitz River salmonids.

Table 6. Estimated age 3 recruits and survival equivalency scaling for Cowlitz spring chinook that enables comparison of future broods to the benchmark run year and survival rate. "Scaled Population" is the survival-equivalent recruitment to age 3.

Spring Chinook

Brood Year	Age 3-6 Catch	Age 3-6 Spawn	Age 3 Recruits	Observed Survival	Benchmark Scalar[7]	Scaled Population
1960	42,598	14,538	79,416			
1961	59,505	19,035	106,134		1.00	106,134
1962	17,950	8,288	36,077			
1963	12,357	4,092	22,619			
1964	11,784	5,298	23,950			
1965	13,863	7,543	29,784			
1966	24,940	8,866	46,598			
1967	11,241	5,445	22,836			
1968	14,097	3,155	24,201			
1969	40,085	8,755	67,740			
1970	42,251	17,955	82,506			
1971	46,041	20,089	91,810	7.00%	2.13	195,852
1972	103,557	24,283	168,951	8.70%	1.73	292,456
1973	47,755	15,190	85,249			
1974	49,964	9,763	79,717			
1975	52,070	12,103	92,535	7.10%	2.11	194,854
1976	79,267	18,502	134,031	23.00%	0.65	87,165
1977	47,815	23,991	101,233	18.40%	0.81	82,468
1978	17,376	8,455	36,329			
1979	28,155	16,425	60,920			
1980	25,398	14,751	54,370	2.60%	5.75	312,771
1981	9,626	7,391	24,666	5.90%	2.53	62,444
1982	7,270	4,821	17,625	3.60%	4.21	74,254
1983	25,724	18,829	63,909	14.90%	1.00	64,179
1984	21,946	10,509	47,709	7.60%	1.96	93,591
1985	11,138	4,266	23,139	6.20%	2.40	55,484
1986	10,536	5,356	23,735			
1987	7,586	5,285	18,003	6.20%	2.44	43,881
1988	12,836	9,652	32,056			
1989	9,539	7,063	24,086	3.30%	4.56	109,849
1990	1,296	1,861	4,978	1.28%	11.72	58,338
1991	640	1,573	3,932	0.64%	23.43	92,123
1992	496	1,965	4,008	0.58%	25.86	103,643
1993	346	1,096	2,297	0.28%	53.57	123,065
1994	688	1,332	3,618	0.42%	35.71	129,185

[7] See Cramer (2000)

Table 7. Estimated age 3 recruits and survival equivalency scaling for Cowlitz fall chinook that enables comparison of future broods to the benchmark run year and survival rate. "Scaled Population" is the survival-equivalent recruitment to age 3.

Fall Chinook

Brood Year	Age 3-6 Catch	Age 3-6 Spawn	Age 3-6 Recruits	Observed Survival	Benchmark Scalar	Scaled Population
1959	35,963	3,336	53,673			
1960	49,582	6,359	73,940		1.00	73,940
1961	49,208	6,420	72,099	2.4	1.00	72,099
1962	82,220	5,970	113,084	1.0	1.00	113,084
1963	45,291	4,731	64,075	3.1	1.00	64,075
1964	91,407	3,486	123,225	3.2	1.00	123,225
1965	70,282	4,023	101,492			
1966	191,428	9,311	263,881			
1967	114,078	12,652	161,372			
1968	38,480	7,210	60,182			
1969	92,385	5,083	125,417			
1970	42,078	4,661	62,190			
1971	27,592	5,086	44,293			
1972	45,488	3,837	63,416			
1973	24,674	2,681	36,333			
1974	38,381	3,037	53,774			
1975	29,910	4,756	45,674			
1976	25,310	3,424	37,475			
1977	21,552	4,419	36,354	1.3	1.69	61,523
1978	12,281	4,184	21,999	0.5	4.40	96,795
1979	8,974	4,301	17,305			
1980	17,925	8,196	38,524	1.1	2.00	77,049
1981	13,558	5,921	27,477	0.7	3.14	86,355
1982	14,421	4,797	25,355	0.8	2.75	69,726
1983	59,942	15,478	96,638	2.6	0.85	81,770
1984	62,496	19,894	115,808	2.8	0.79	90,992
1985	32,908	8,974	56,944	0.6	3.67	208,793
1986	7,577	6,267	21,503	0.4	5.50	118,269
1987	3,544	4,006	10,876	0.1	22.00	239,270
1988	7,686	2,917	16,885	0.2	11.00	185,739
1989	12,623	2,115	21,291	0.19	11.58	246,529
1990	3,514	6,050	13,515	0.45	4.91	66,369
1991	830	4,034	8,065	0.18	11.96	96,426
1992	1,929	5,080	11,463	0.32	6.79	77,832
1993	4,137	5,725	15,135	0.32	6.98	105,706
1994	746	915	2,749	0.29	7.46	20,513

Table 8. Estimated age 3 recruits and survival equivalency scaling for Cowlitz coho that enables comparison of future broods to the benchmark run year and survival rate. "Scaled Population" is the survival-equivalent recruitment to age 3.

Coho

Brood Year	Run Year	Adults at Fish Facility	Age 3 Catch	Age 3 Recruits	Observed Survival	Benchmark Scalar	Scaled Population
1958	1961	23,388	50,874	74,262			
1959	1962	22,701	56,701	79,402			
1960	1963	22,083	100,045	122,128			
1961	1964	25,546	98,731	124,277		1.00	124,277
1962	1965	22,774	100,408	123,182			
1963	1966	31,001	155,997	186,998			
1964	1967	18,801	98,401	117,202			
1965	1968	12,636	71,928	84,564			
1966	1969	4,913	16,292	21,205			
1967	1970	63,407	220,988	284,395	7.7%	1.04	296,689
1968	1971	33,239	203,860	237,099	12.2%	0.65	155,048
1969	1972	16,354	85,567	101,921	6.4%	1.26	128,280
1970	1973	19,954	209,591	229,545			
1971	1974	17,627	206,304	223,931			
1972	1975	23,000	423,936	446,936	7.0%	1.15	511,996
1973	1976	25,166	512,713	537,879			
1974	1977	10,299	286,933	297,232			
1975	1978	20,512	154,311	174,823			
1976	1979	13,912	148,918	162,830			
1977	1980	28,776	119,378	148,154			
1978	1981	27,003	132,617	159,620			
1979	1982	22,528	112,232	134,760			
1980	1983	24,493	69,690	94,183	3.8%	2.11	198,903
1981	1984	26,149	60,783	86,932	3.8%	2.12	183,898
1982	1985	18,610	60,781	79,391	2.6%	3.07	244,016
1983	1986	54,685	282,854	337,539	10.8%	0.74	250,091
1984	1987	18,716	69,192	87,908	3.2%	2.49	219,203
1985	1988	30,888	121,283	152,171	6.9%	1.16	177,199
1986	1989	35,886	165,941	201,827	7.9%	1.01	203,560
1987	1990	13,009	35,479	48,488	1.6%	5.10	247,495
1988	1991	46,303	162,033	208,336	8.8%	0.91	188,797
1989	1992	14,780	32,443	47,223	2.3%	3.51	165,820
1990	1993	5,641	10,837	16,478	0.8%	9.58	157,857
1991	1994	5,922	1,746	7,668	0.3%	24.13	185,052
1992	1995	7,637	9,118	16,755	0.4%	18.18	304,600
1993	1996	11,352	5,460	16,812	0.8%	9.88	166,099
1994	1997	15,694	8,494	24,188	1.0%	8.16	197,377
1995	1998	19,231	10,837	30,068	0.6%	13.33	400,806

Due to the mix of unmarked hatchery-produced and naturally produced spring Chinook and steelhead adults returning to the Cowlitz River basin in 2002/2003 (see Table 3) the annual number of naturally-produced adults cannot be calculated, thus the recruit/spawner (R/S) ratio cannot be calculated. The Cowlitz Fisheries Technical Committee, Fisheries and Hatchery Management Plan (FHMP) review draft (dated November 2003) recommends an end to releases of hatchery juveniles in the upper Cowlitz River. Thus the juvenile marking plan in the FHMP will provide for a more accurate identification of the origin of adult salmonids in the Cowlitz River basin in the future.

Accordingly all future unmarked adult returns will be able to be distinguished as naturally-produced fish. The benefit of this change in the fisheries management practice is two-fold; it will allow for selective harvest of hatchery-produced fish in fisheries, while protecting naturally-produced adult salmonids. This recommendation, if implemented, will allow for the calculation of the recruit/pre-spawner ratio as called for in Article 3 (B) ii.

2.3. *A schedule for future actions and returns of adults needed to determine the status of naturally produced adult anadromous fish traveling through the Cowlitz River Project.*

The definition of pre-spawner in the SA mandates that the salmonid be a naturally-produced fish, thus adult returns from hatchery juvenile plants cannot be used in the calculation. Until such time as there are no unmarked adult returns from hatchery juvenile plants in the upper basin the S/R ration cannot be determined. The draft FHMP (November 7, 22003) recommends ending all upper basin hatchery juvenile plants. Accordingly all unmarked adult returns in the future would be naturally-produced fish and could be accounted for in the S/R ratio calculation. Table 9. lists the potential timetable for these actions to take place.

Table 9. Timetable of actions for unmarked naturally produced salmonid returns to the Cowlitz River basin

	Spring Chinook	Steelhead	Coho – Tilton River
FHMP submitted to FERC	**April 16, 2004**	**April 16, 2004**	**April 16, 2004**
FERC approval/start of implementation (assumed)	**October 16, 2004**	**October 16, 2004**	**October 16, 2004**
End of upper basin hatchery juvenile releases	**2005**	**2005**	**NA**
End of hatchery produced adult returns from upper basin	**2009**	**2009**	**2003**
Start of only naturally produced adult returns to upper basin	**2010**	**2010**	**2003**
Initial calculation of S/R ratio[8]	**2006**	**2007**	**2004**

2.4. *Summary*

In addition to the data reported herein, SA license article 3 calls for tables estimating the annual number of adults recruits originating from the Cowlitz River basin upstream of the Toutle River, and including steelhead, cutthroat trout and all other indigenous stocks that are produced at the hatcheries. This report lists the hatchery-origin returns, as for the reasons already detailed naturally-produced fish cannot be enumerated at this time.

An additional requirement under 3 (A) of the SA license article 3 calls for a plan and schedule of studies to evaluate if adult fish in Mayfield Lake are able to chose their tributary of origin and survive Mayfield Lake transit at rates acceptable to the federal fishery agencies. As detailed in Table 9. only naturally-produced coho are available to conduct this study presently. As coho are not one of the "trigger" species for determining the development of self-sustaining runs into the upper Cowlitz River basin, Tacoma Power will defer developing the schedule and study plan until such time as there are naturally-produced adult salmonids that originated in the upper Cowlitz River basin available for conducting this study (see Table 9.).

This report, and the accompanying data will be updated annually upon the date of this filing with FERC.

[8] Initial S/R calculations based upon the possibility of hatchery produced adults from the upper Cowlitz River basin.

2.5. *References*

Cramer, S. P. 2000. Contribution rate benchmarks for future runs of spring Chinook, fall Chinook and coho produced at Cowlitz Salmon Hatchery. Technical Report, July 5, 2000. S. P. Cramer & Associates. Gresham, OR. 32 pp.

Cramer, S. P. 2002. Evaluation of contribution to catch and escapement by spring Chinook, fall Chinook and coho produced at Cowlitz Salmon Hatchery.   Technical Report, April, 2002. S. P. Cramer & Associates. Gresham, OR. 30 pp.

Johnson, M., C. Fitch and M. LaRiviere. 2003. Cowlitz Salmon and Trout Hatchery Annual Report, January 1 – December 31, 2002. Washington Department of Fish and Wildlife & Tacoma Power, June 2003.

Appendix

The following data from Harmon (unpublished 2003) and Johnson, Fitch and LaRiviere (2003) detail the releases of adult salmonids into the upper Cowlitz River basins in 2002/2003:

Appendix Table 1. Unmarked adult fall chinook transported to Tilton basin in 2002, by month.

	Tilton River (Gust Backstrom Park)			Mayfield Lake (Ike Kinswa Park)		
Month	Male	Female	Jack	Male	Female	Jack
September	0	0	0	57	45	2
October	14	0	0	309	103	10
November	0	0	0	22	13	2
Total	**14**	**0**	**0**	**388**	**161**	**14**

Appendix Table 2. Adult coho transported to Mayfield Lake 2002/2003(Ike Kinswa State Park).

	Unmarked + BWT[9]			Unmarked			Ad only		
Month	Male	Female	Jack	Male	Female	Jack	Male	Female	Jack
September	10	4	0	6	3	0	226	84	61
October	156	89	12	103	48	37	3077	1733	1087
November	78	69	9	13	7	0	1142	964	267
December	40	32	0	7	10	0	0	0	0
Total	**284**	**194**	**21**	**129**	**68**	**37**	**4445**	**2781**	**1415**

Appendix Table 3. Adult coho transported to the Tilton River 2001/2002 (Gust Backstrom Park).

	Unmarked + BWT			Unmarked			Ad only		
Month	Male	Female	Jack	Male	Female	Jack	Male	Female	Jack
October	0	0	0	3	0	0	173	53	31
November	95	91	4	0	1	0	1598	1466	106
December	149	175	7	3	0	0	1773	1865	121
January	237	283	5	1	0	0	1207	1286	102
February	7	10	0	0	0	0	0	0	0
Total	**488**	**559**	**16**	**7**	**1**	**0**	**4751**	**4670**	**360**

Appendix 4. Adult steelhead returns to Cowlitz Salmon Separator transported to the Tilton River 2002/2003 (Gust Backstrom Park).

	Unmarked + BWT		Unmarked		Ad Only	
Month	Adults	Jacks	Adults	Jacks	Adults	Jacks
November	0	0	3	0	0	0
December	7	0	20	0	0	0
January	51	0	114	0	1	0
February	34	1	50	0	11	0
March	28	0	4	0	256	1
Total	**120**	**1**	**191**	**0**	**268**	**1**

Appendix Table 5. Fall chinook transported to upper Cowlitz River basin in 2002, by location.

	Unmarked			Marked		
	Male	Female	Jack	Male	Female	Jack
Lake Scanewa	3846	1746	149	121	73	7
Packwood	7	0	0	0	0	0
Total	**3853**	**1746**	**149**	**121**	**73**	**7**

[9] Blank wire tag

Appendix Table 6. Adult coho transported to upper Cowlitz River basin in 2002 by location.

	Marked			Unmarked		
Location	Male	Female	Jack	Male	Female	Jack
Lake Scanewa	26320[10]	19405	5855	3405	2426	358
Tilton River	8517[11]	6632	1706	133	58	36
Packwood	1889	1904	311	71	88	10
Total	**36726**	**27941**	**7872**	**3609**	**2572**	**404**

Appendix Table 7. Adult spring Chinook transported to upper Cowlitz River basin in 2002 by location.

	Marked			Unmarked		
Location	Male	Female	Jack	Male	Female	Jack
Lake Scanewa	738	675	21	197	186	23
Cispus River	66	66	7	20	19	3
Riffe Lake	0	0	641	0	0	0
Total	**804**	**741**	**669**	**217**	**205**	**26**

Appendix Table 8. Adult early winter steelhead transported to the Tilton River in 2002.

	Marked			Unmarked		
Location	Male	Female	Non-sexed	Male	Female	Non-sexed
Tilton River	601	477	535[12]	153	152	217

Appendix Table 9. Adult late winter steelhead transported to upper Cowlitz River basin in 2002 by location.

	Marked			Unmarked		
Location	Male	Female	Non-sexed	Male	Female	Non-sexed
Lake Scanewa	590[13]	404[14]	734	186	176	626[15]
Tilton River	0	0	12[16]	0	0	0
Cispus River	91[17]	79[18]	171[19]	26	29	8
Total	**681**	**483**	**917**	**212**	**205**	**634**

Appendix Table 10. Adult cutthroat transported to upper Cowlitz River basin in 2002 by location.

	Marked			Unmarked		
Location	Male	Female	Non-sexed	Male	Female	Non-sexed
Lake Scanewa	0	0	0	0	0	3
Tilton River	0	0	23	0	0	5
Total	**0**	**0**	**23**	**0**	**0**	**8**

[10] Includes 6 blank wire tag males and 2 blank wire tag females
[11] Includes 528 blank wire tag males, 467 wire tag females and 33 jacks
[12] Includes 84 right cheek tagged steelhead
[13] Includes 415 RV clipped steelhead males
[14] Includes 166 RV clipped steelhead females
[15] Includes 268 elastomer tagged steelhead
[16] Right cheek tagged
[17] Includes 60 RV clipped males
[18] Includes 27 RV clipped females
[19] Includes 55 elastomer tagged steelhead

ATTACHMENT No. 1

Contribution rate benchmarks for future runs of spring Chinook, fall Chinook and coho produced at Cowlitz Salmon Hatchery. Technical Report, July 5, 2000.

CONTRIBUTION RATE BENCHMARKS FOR FUTURE RUNS OF SPRING CHINOOK, FALL CHINOOK, AND COHO PRODUCED AT COWLITZ SALMON HATCHERY

TECHNICAL REPORT

July 5, 2000

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INTRODUCTION

THE PROBLEM

Historic contributions to catch and escapement by spring chinook, fall chinook and coho salmon produced at Cowlitz Salmon Hatchery are reviewed in this report to establish an appropriate standard for performance of future basin fish production. Previous analyses of fishery contribution from salmon produced at Cowlitz Hatchery have demonstrated that natural survival rates in the ocean, as well as harvest rates in both the ocean and river, have been highly variable between years since the hatchery began in 1968 (Cramer 1996; Harza and S.P. Cramer & Associates 1996; Cramer 1998; Cramer and Vigg 1999). This high variability complicates the logic for choosing benchmarks by which future hatchery performance should be judged.

Cramer (1996) estimated survival and harvest rates through cohort analysis for all coded-wire tag (CWT) groups that had been released from Cowlitz Salmon Hatchery, and found;

> *"Smolt-to-age 2 survival (ocean survival) varied substantially between broods for all species and was the dominant factor causing variation in run sizes between years. This measure of ocean survival varied 10-fold for spring chinook, 20-fold for fall chinook and 30-fold for coho. The frequency distributions for brood-year averages of smolt-to-age 2 survival of Cowlitz spring chinook, fall chinook, and coho each were skewed such that survival rates less than the mean were more common than survival rates greater than the mean." .."the protracted right tail of the skewed frequency distribution indicates that a typical mix of years with a net average production of adults that equals the mitigation goal would likewise include a few good years of returns substantially exceeding the mitigation goal, but a majority of*

years with returns less than the mitigation goal."

Because of the substantial variation in ocean survival, combined with large changes in harvest rates since 1968, Cramer (1996) recommended using the reconstructed population at the beginning of age 3 in the ocean as the best measure of salmon production resulting from the hatchery each brood year. Further, Cramer recommended,

> *"these ocean populations were also heavily affected by variation in early ocean survival, so it would be appropriate (for the purposes of assessing mitigation success) to develop a survival adjustment factor that would allow comparison of ocean populations on a survival equivalent basis."*

The report presented here describes a process for deriving a survival adjustment factor. A subset of Cowlitz Fisheries Technical Committee (FTC) discussed alternative approaches to scaling survival equivalency between years, and this report carries out the approach of choice from that group of biologists.

GOAL OF ANALYSES REPORTED HERE

The goal of analyses described in this report is to derive benchmark survival and production values that can be used as performance standards that should be achieved, on average, by future runs of salmon returning to the fish counting stations in the Cowlitz River. These standards are intended to reflect the intent of mitigation goals that were previously established using returns of fall chinook and coho to Mayfield Dam in 1964, and returns of spring chinook to the dam in 1965 as the model year. I refer in this report to these runs simply as the "model year".

APPROACH

ANALYTICAL STEPS

In order to compare the outcome of mitigation actions each year, an approach was needed that compensated for the two major sources of variation between broods that are unrelated to mitigation: (1) ocean survival, and (2) harvest rates. The measure of mitigation effectiveness should answer the question,

> **"Given equivalent survival in the ocean each year, has the number of adult recruits produced from the Cowlitz River been sustained at that which the Cowlitz River would have produced before the dams were built?"**

Thus, the ultimate measure of mitigation effectiveness is adult recruitment. However, survival in the ocean is not equivalent between years, and the fraction of adult recruits that are harvested each year is not constant. Therefore, an estimate of adult recruitment was needed that included some type of correction factor to compensate for differences ocean survival between years, and that included all fish that were taken by harvest. That is, mitigation should sustain "Survival Equivalent Recruitment". For example, in order to judge whether mitigation is achieved from a brood for which ocean survival drops to half of that in the model brood, then the number of recruits observed will have to be multiplied by 2 (this is called "weighting") in order to represent the recruits that would have occurred if ocean survival had not dropped. The approach can be expressed as follows:

Survival Equivalent Recruits = (Catch + Spawners + Natural Mortality) x Relative Ocean Survival

Further,

Relative ocean survival = Smolt-to-Age 2 $\text{Survival}_{\text{Model Year}}$/Smolt-to-Age 2 $\text{Survival}_{\text{Now}}$

In order to fill in the variables in this equation, we must derive estimates for two broad quantities:

1. Recruitment
2. Ocean survival

Estimation of Recruitment

The number of adults returning to fish counting stations each year is accurately measured, and is the best measure on which to base estimates of recruitment. Because not all fish destined to reach the fish facility can be uniquely distinguished from other fish in the run, all other components of recruitment must be reconstructed based on estimates of rates (harvest, straying, mortality) that are multiplied by the run size, as determined from the number of fish entering the fish counting facility. First, the number of fish entering the facility must be expanded to include the average fraction of hatchery spawners that stayed in the river to spawn (see Cramer 1996). The number of Cowlitz Salmon caught in the Cowlitz River is estimated annually by WDFW from angler punch cards and a telephone survey process. The fraction of Cowlitz fish that are harvested in the Columbia River and the ocean is only estimated for marked groups that can be uniquely identified as originating in the Cowlitz River. Thus, catch of Cowlitz fish in the Columbia River and ocean can only be estimated by multiplying the harvest rate (fraction) determined from representative marked groups, by the run size. Because the run size includes fish that are caught, the run must be reconstructed progressively downstream and back into the ocean by sequentially adding back in the catches that occur along the way. This process of run reconstruction was described by Cramer (1996), and illustrated in Figures 1-3.

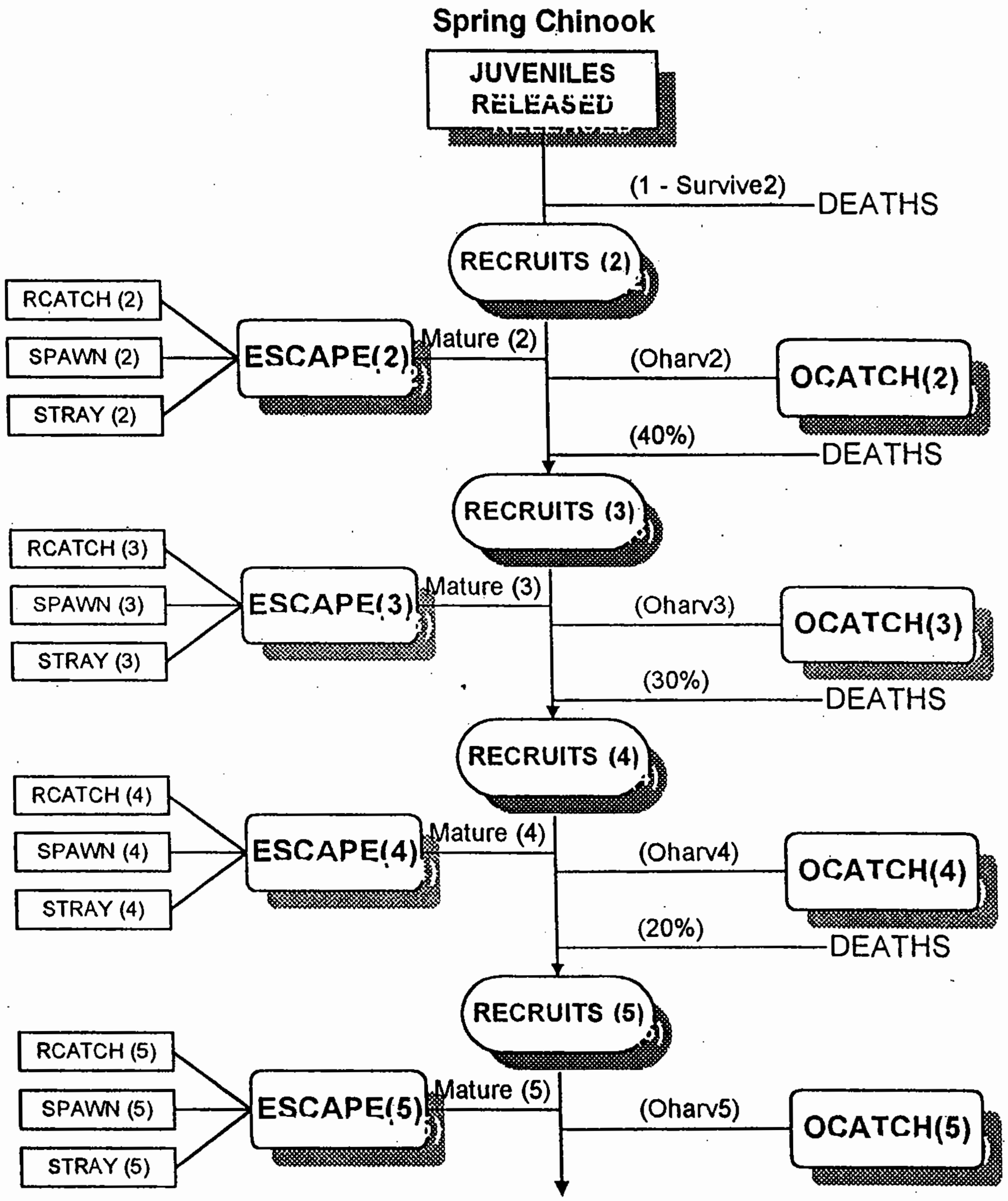

Figure 1. Diagram of general life-history categories accounted for in a cohort analysis of spring chinook. Note that maturation occurs each spring prior to the time that ocean harvest begins.

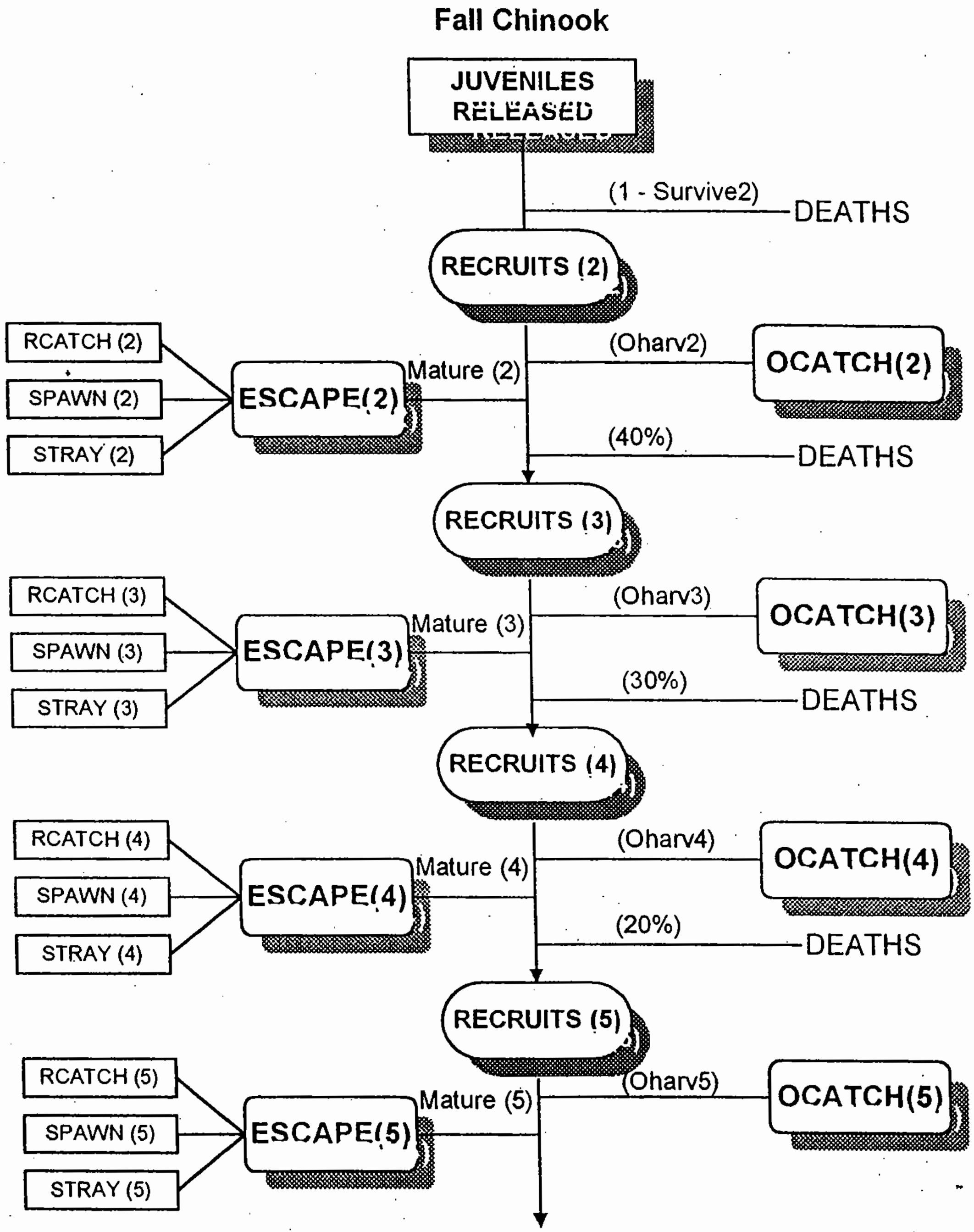

Figure 2. Diagram of general life-history categories accounted for in a cohort analysis of fall chinook. Note that maturation is assumed to occur each fall after ocean harvest is complete.

Coho

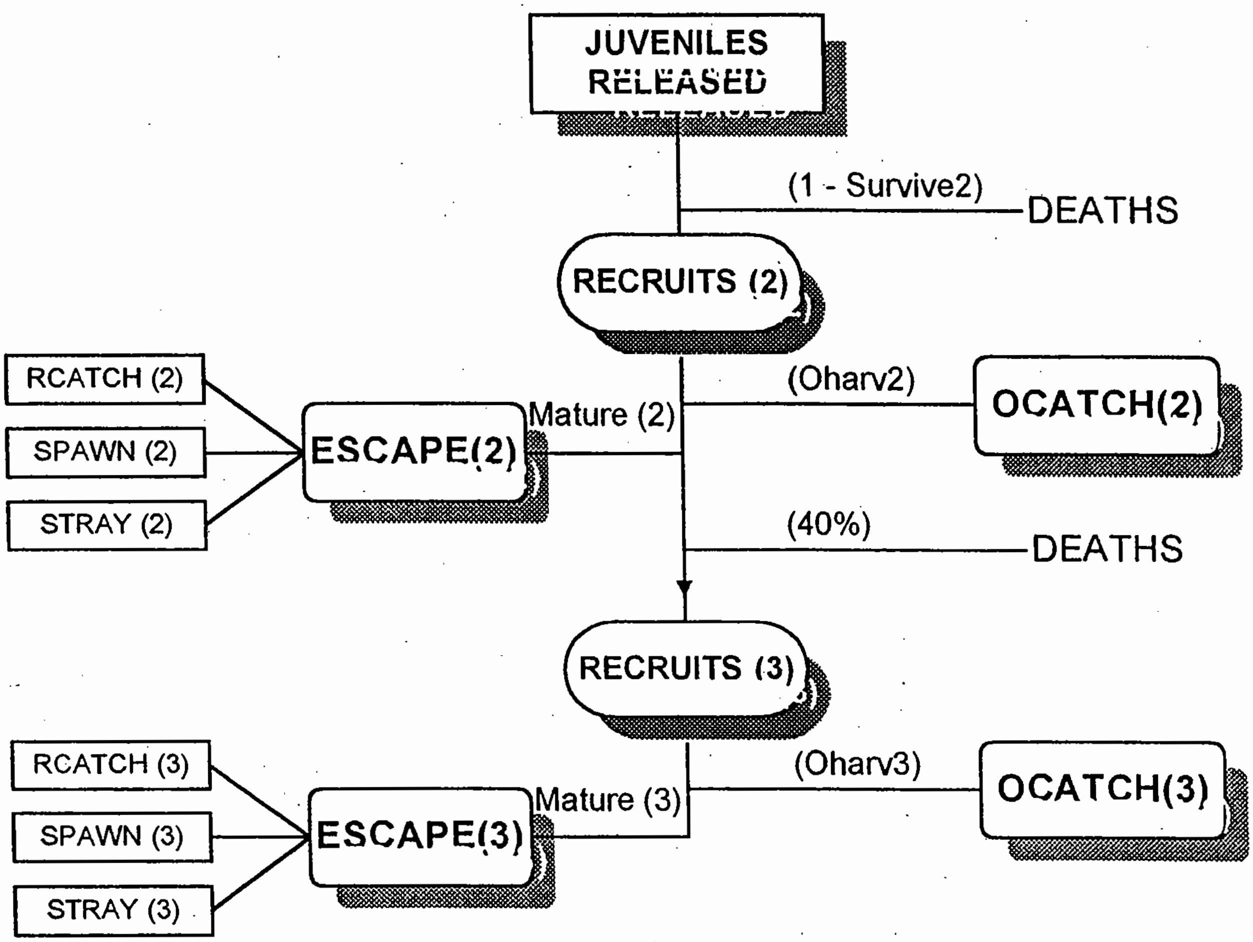

Figure 3. Diagram of general life-history categories accounted for in a cohort analysis of coho.

The majority of Cowlitz salmon recruits are captured in ocean and river fisheries, so the estimation of harvest rates plays a major role in determining size of reconstructed populations at age 3 (age 3 recruits). Cramer (1996) estimated harvest rates at each age in the ocean and the river for all broods that had releases of representatively marked fish. Further, Cramer (1996) also estimated harvest rates in the Columbia and Cowlitz River for years without marked groups by reconstructing catch and spawner escapement for all fish in the river. For coho, Cramer (1996) was also estimated ocean harvest rates back to 1961 based on the Oregon Production Index (OPI). Even after all of these estimates were compiled, there were still a number of years since 1968 for spring and fall chinook for which harvest rates were not estimated in the ocean or the river. As a first step toward filling in estimated missing harvest rates for each age, Cramer (1998) interpolated rates between adjacent years of data, and thereby derived estimates for missing years back to the 1977 brood for spring chinook and back to the 1971 brood for fall chinook. In this report, I have developed procedures to extend estimates for missing years back to the 1960 brood, as described next.

For ocean harvest rates, Cramer and Vigg (1999) reviewed the data that indicated harvest rates for lower Columbia chinook in the ocean were about 25% in 1950, and this increased to an average 59% during 1975-79 for CWT groups of Cowlitz spring chinook. Cramer (1996) concluded that ocean harvest rates on spring chinook and fall chinook from the Cowlitz River could be used as reasonable surrogates for one another, because the distribution of harvests in the ocean was similar and the harvest rates were correlated ($r = 0.73$) in the years when estimates from cohort analysis were available from both races. Accordingly, I used the same assumed harvest rates at age for spring and fall chinook in the ocean during the years from 1950 to 1975 in which direct estimates were not available. Cramer and Vigg (1999) present several data sets demonstrating that harvesting effort both by sport and commercial gears was increasing at a steady rate from 1950 to 1975, so I assumed that harvest rate increased linearly over time from 25% in 1950 to 59% in 1975.

The assumed harvest rates in the ocean corresponded to a rate for fully vulnerable adults, so I assumed that rate corresponded to the harvest rate for age 4. In order to estimate harvest rates for other ages, I assumed that the ratio of harvest rates between ages that Cramer (1996) estimated for the 1971-76 broods would have applied during previous broods back to 1960. Those age specific harvest rates and their relative value compared to age 4 were as follows:

	Age 2	Age 3	Age 4	Age 5
Mean Harvest Rate	1.9%	33.1%	58.2%	72.1%
Relative to Age 4	0.03	0.57	1.00	1.24

These relative multipliers for harvest rates at each age were applied to both spring and fall chinook for broods before 1971. The resulting predictions for harvest rates at each age are presented for spring chinook, fall chinook, and coho in Appendix 1.

I estimated river harvest rates for fall chinook based the relationship between harvest rate and commercial effort that was demonstrated by Cramer and Vigg (1999). Cramer and Vigg (1999) showed for fall chinook that harvest rates during 1965 to 1994 were highly correlated ($R^2 = 76\%$, $P < 0.01$) to the number of days open to fishing during August 20 to September 20 (Figure 4). August 20 to September 20 is the time when most fall chinook pass through the river and when the majority of catch occurs. I used the number of days open to commercial fishing during August 20 to September 20 each year from 1960 forward, and applied those numbers to the regression equation in Figure 4 to estimate river harvest rate on fall chinook. Because harvest rate in the Columbia River was generally similar between ages of adult chinook, I assumed that harvest rates estimated by regression applied equally to ages 3 through 6.

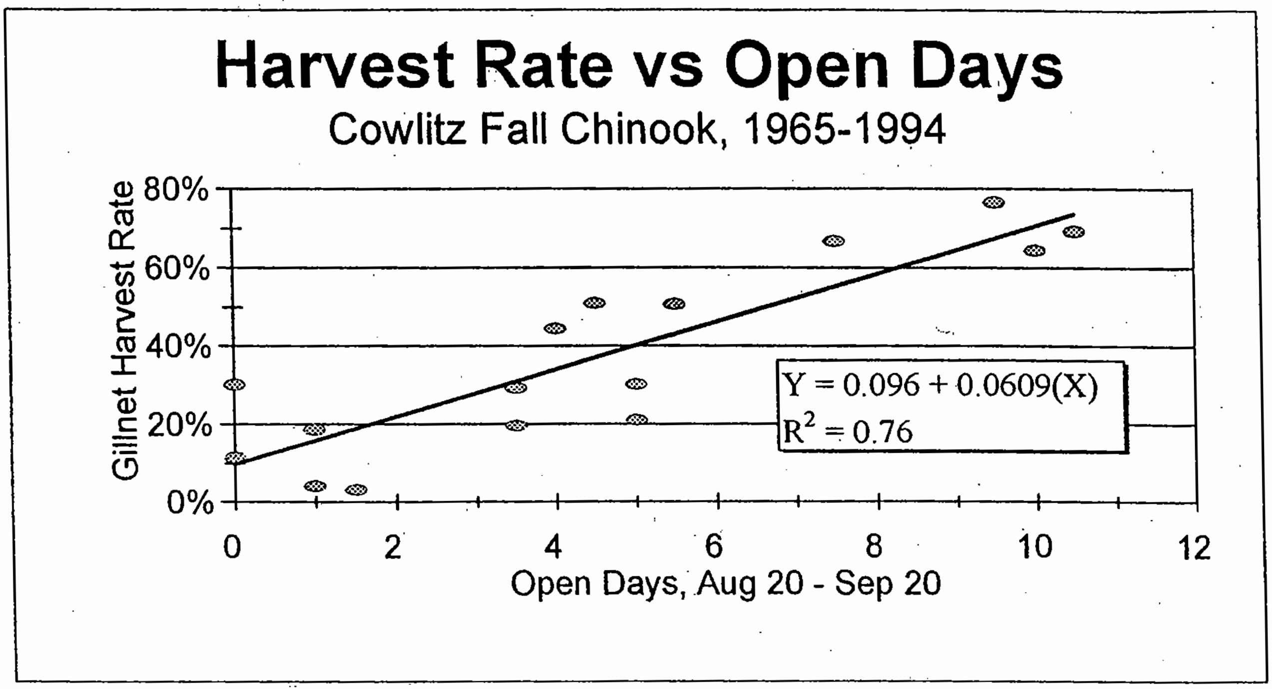

Figure 4. Correlation of harvest rate on fall chinook in the lower Columbia River to the number of days open to commercial fishing during August 20 to September 20. From Cramer and Vigg (1999).

I estimated river harvest rates for spring chinook prior to 1970 based on reported catch and escapement of spring chinook through the Columbia River below Bonneville Dam, as reported by ODFW and WDFW (1998). That is, harvest rate was estimated as zone 1-5 catch, plus sport catch, divided by total estimated run entering the Columbia River. Again, I assumed the harvest rate applied equally across all ages.

I have now identified the following components of information that are needed to estimate Survival Equivalent Recruits:

Catch = Cowlitz Sport Catch estimated from harvest rate x run + Columbia Catch estimated from harvest rate x run

		+ Ocean Catch estimated from harvest rate x run
Spawners	=	Adults entering the fish facility
		+ hatchery adults spawning naturally
		+ adults that strayed to other areas
Natural Mortality	=	Fish that died in the ocean each winter and fish that died in the river of natural causes during their return to spawn. These mortalities are estimated as constant fractions that have been assumed by the Pacific Fishery Management Council for the ocean and by Cramer (1996) for the river. See Figures 1-3.
Relative Ocean Survival	=	This is the ratio of survival to age 2 for the model year divided by the year in question

ESTIMATION OF OCEAN SURVIVAL

<u>Alternatives Rejected</u>

A creative approach was required to account for the variation in ocean survival between broods. Marked groups of each species or race of fish reared at Cowlitz Salmon Hatchery have only been released in a portion of the years since the hatchery began releasing fish in 1968. Thus, there are no data with which to directly estimate survival and harvest rates of Cowlitz Hatchery fish in many years, and specifically there is no such data for the 1964 and 1965 run years that were used as the benchmark years for establishing run sizes that the hatchery should be designed to produce. Therefore, several surrogate measures of survival and harvest rate were identified and later examined for data availability and correlation of trends to those on the Cowlitz River. Subsequent examinations indicated that several potential surrogate measures for survival trends of Cowlitz salmon were inappropriate. The final approach was chosen through a process of eliminating alternatives that were found to be inappropriate. Alternatives that were rejected are as follows:

Willamette River spring chinook. Survival to age 2 was estimated by cohort analysis by Cramer et al. (1996) from all available CWT data from the Willamette Basin during the 1970's and 1980's, and these survival rates were found to be uncorrelated to survival of Cowlitz Hatchery spring chinook (Figure 4).

Kalama Hatchery spring chinook. This was found to be the only lower Columbia hatchery that released spring chinook through the 1960's and 1970's. However, no suitable marking studies were conducted during the 1960's, and the program shifted from all smolt releases to a large component of fingerling and fry releases during the 1960's (Table 1). A large share of fish spawned naturally or were caught in sport fisheries , and neither were surveyed during most of the 1960's.

Fall Chinook from other Lower Columbia Hatcheries. A recent study of fall chinook salmon populations in the Columbia Basin by Skalski et al. (1996), indicated that the ocean distribution of all 34 stocks that were compared were significantly ($P<0.05$) different from the Priest Rapids test group. More surprisingly, Skalski et al. (1996) found that even the nine replicate release groups of the same brood (1987) from the same hatchery (Priest Rapids) had significantly different ($P<0.01$) ocean distributions from one another. Skalski et al. found that the outcome of the multiple regression explaining smolt survival was determined by whichever reference stock was chosen, and that no two reference stocks yielded the same choice of best explanatory variables.

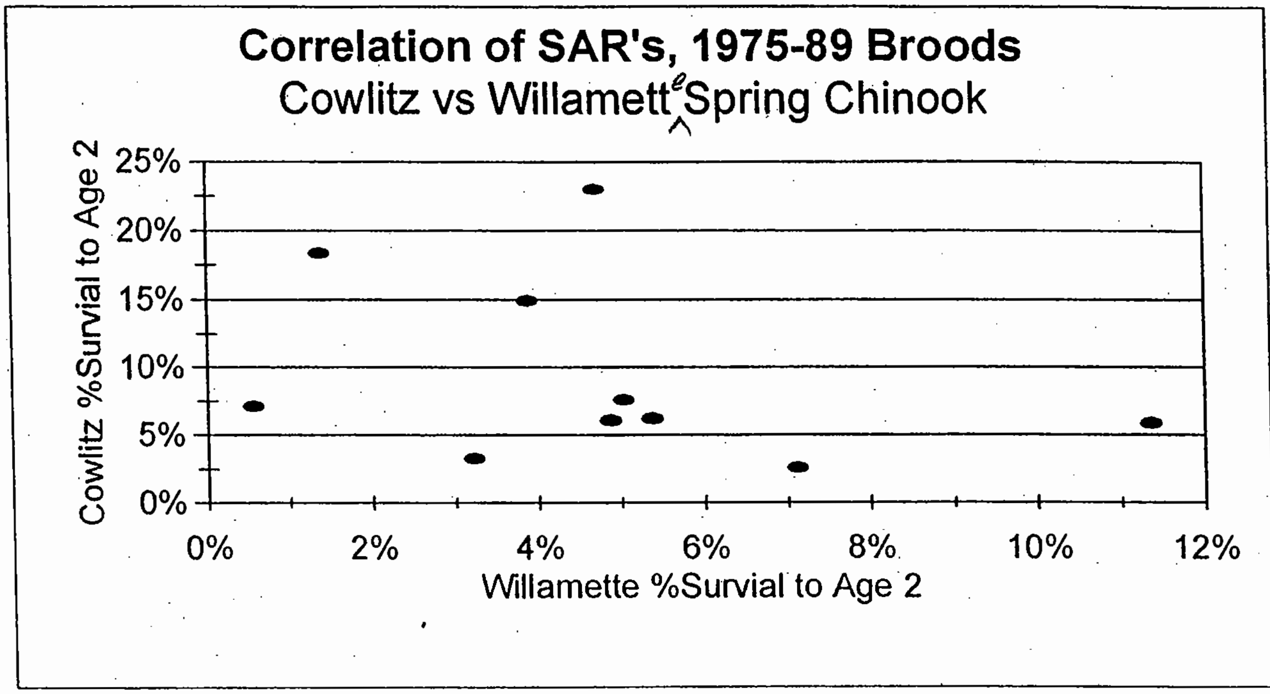

Figure 4. Scatter plot that indicates lack of correlation in smolt-to-age 2 survival rates between Cowlitz and Willamette spring chinook. Survival rates were estimated by cohort analysis of CWT recoveries from the 1975-89 broods.

Table 1. Releases of juvenile spring chinook from Kalama Falls Hatchery. These data show variation in release dates and sizes that would confound comparisons of survival with Cowlitz Hatchery. Sparsity of escapement monitoring would further confound comparisons between hatcheries.

Hatchery	Stream	Life Stage	Year Release	Year Brood	CWT's Released	Total Release	Release Date	Weight (grams)
Kalama Falls	Kalama R	Yearling	1964	1962		46,657	02/24/64	35
Kalama Falls	Kalama R	Yearling	1964	1962		82,641	03/09/64	35
Kalama Falls	Kalama R	Yearling	1964	1962		49,413	03/10/64	35
Kalama Falls	Kalama R	PreSmolt	1964	1963		34,124	12/09/64	12
Kalama Falls	Kalama R	PreSmolt	1964	1963		48,950	12/09/64	21
Kalama Falls	Kalama R	Yearling	1965	1963		73,180	04/04/65	23
Kalama Falls	Kalama R	Yearling	1965	1963		122,620	04/04/65	45
Kalama Falls	Kalama R	Yearling	1966	1964		64,000	04/04/66	45
Kalama Falls	Kalama R	Yearling	1967	1965		253,409	04/14/67	35
Kalama Falls	Kalama R	Yearling	1969	1967		125,280	04/24/69	38
Kalama Falls	Kalama R	Yearling	1970	1968		184,254	03/23/70	22

Hatchery	Stream	Life Stage	Year Release	Year Brood	CWT's Released	Total Release	Release Date	Weight (grams)
Kalama Falls	Kalama R	Fingerling	1970	1969		144,430	05/27/70	2
Kalama Falls	Kalama R	PreSmolt	1970	1969		92,922	09/16/70	27
Kalama Falls	Kalama R	Yearling	1971	1969		90,774	02/25/71	76
Kalama Falls	Kalama R	Fingerling	1971	1970		19,264	06/09/71	1
Kalama Falls	Kalama R	PreSmolt	1971	1970		27,945	09/03/71	20
Kalama Falls	Kalama R	Yearling	1971	1970	27,945	27,945		20
Kalama Falls	Kalama R	Yearling	1972	1970	71,230	71,230		77
Kalama Falls	Kalama R	Fingerling	1972	1971		62,350	06/21/72	2
Kalama Falls	Kalama R	PreSmolt	1972	1971	35,142	72,402	09/21/72	18
Kalama Falls	Kalama R	PreSmolt	1972	1971		32,774	09/21/72	18
Kalama Falls	Kalama R	Yearling	1973	1971	28,420	91,831	04/09/73	65
Kalama Falls	Kalama R	Yearling	1973	1971		4,547	04/09/73	65
Kalama Falls	Kalama R	PreSmolt	1973	1972		16,765	09/04/73	25
Kalama Falls	Kalama R	PreSmolt	1973	1972		13,616	09/06/73	20
Kalama Falls	Kalama R	PreSmolt	1973	1972		76,209	09/12/73	17
Kalama Falls	Kalama R	Yearling	1974	1972		131,299	03/06/74	45
Kalama Falls	Kalama R	PreSmolt	1974	1973		44,275	10/28/74	36
Kalama Falls	Kalama R	PreSmolt	1974	1973		24,947	10/28/74	48
Kalama Falls	Kalama R	Yearling	1975	1973		44,118	04/01/75	101
Kalama Falls	Kalama R	PreSmolt	1975	1974	27,999	335,073	08/26/75	25
Kalama Falls	Kalama R	Yearling	1976	1974	16,460	195,940	02/26/76	45
Kalama Falls	Kalama R	PreSmolt	1976	1975		162,622	08/25/76	27
Kalama Falls	Kalama R	PreSmolt	1976	1975		57,420	09/13/76	31
Kalama Falls	Kalama R	Yearling	1977	1975		283,704	03/23/77	57
Kalama Falls	Kalama R	Yearling	1978	1976		100,320	02/21/78	52
Kalama Falls	Kalama R	Yearling	1978	1976		19,686	04/07/78	89
Kalama Falls	Kalama R	Fingerling	1978	1977		136,986	05/24/78	3
Kalama Falls	Kalama R	Fingerling	1978	1977		187,680	05/26/78	2
Kalama Falls	Gobar Cr	Yearling	1979	1977		10,500	02/22/79	22
Kalama Falls	Kalama R	Yearling	1979	1977		131,240	03/12/79	23
Kalama Falls	Kalama R	Yearling	1979	1977		10,697	03/21/79	24
Kalama Falls	Kalama R	Yearling	1980	1978		116,506	02/14/80	16
Kalama Falls	Kalama R	Yearling	1981	1979		497,700	02/18/81	22
Kalama Falls	Kalama R	Yearling	1981	1979		103,100	03/31/81	43
Kalama Falls	Kalama R	Yearling	1982	1980		160,000	04/15/82	45
Kalama Falls	Kalama R	Yearling	1984	1982		325,900	04/17/84	45
Kalama Falls	Gobar Cr	Yearling	1985	1983		569,300	02/21/85	35
Kalama Falls	Kalama R	PreSmolt	1985	1984		25,000	09/27/85	18
Kalama Falls	Kalama R	PreSmolt	1985	1984		30,000	09/27/85	18
Kalama Falls	Gobar Cr	Yearling	1986	1984		404,000	02/20/86	32
Kalama Falls	Gobar Cr	Yearling	1987	1985		176,000	02/11/87	60
Kalama Falls	Gobar Cr	Yearling	1988	1986		300,200	02/16/88	48
Kalama Falls	Kalama R	PreSmolt	1989	1988		80,100	10/20/89	15
Kalama Falls	Kalama R	PreSmolt	1989	1988		80,300	10/20/89	22
Kalama Falls	Kalama R	Fingerling	1990	1989		111,900	05/18/90	3
Kalama Falls	Kalama R	Yearling	1991	1989		110,800	04/03/91	38

Alternative Chosen

Best available predictions of survival and harvest rates were derived from variation in run sizes to the Cowlitz Hatchery fish facilities, as well as trends in harvest rates estimated from years when marked groups were released. This required that we make a series of assumptions that were believed to be reasonable, based on professional judgement. These assumptions differed slightly for each race, depending on data available. Cramer (1996) examined the databases from all marking studies at Cowlitz Hatchery and found data available to estimate survival and harvest rates for spring and fall chinook in about half of the years since the mitigation agreement for Cowlitz salmon began (1967). For coho, Cramer (1996) was able to estimate harvest rates for all years since 1967, but survival to age 2 could only be estimated in about half of the years. In particular, no direct estimates of survival for Cowlitz River salmon stocks were possible from the limited data available during the 1960s'.

One assumption that we applied to all species and races of salmon and trout released for Cowlitz mitigation was that survival rates in the ocean probably varied within different ranges during the ocean regimes of 1946 to 1976 and 1977 to 1994. Numerous studies have described the physical and biological differences that distinguish these regimes (see Hare et al. 1999 for review), and differences in survival ranges between these two regimes are apparent from lower Columbia hatcheries. Accordingly, we assumed that smolt-to-age 2 survival during the mid 1960's when mitigation run sizes were established, should be estimated from broods that entered the ocean and reared there most of their years during the 1946-1976 ocean regime.

Spring Chinook

The approach for establishing benchmark survival rates for spring chinook differs substantially from that for fall chinook and coho, because survival to age 2 for spring chinook during the cool-wet climate regime of 1946-1976 was only estimated for 2 broods, 1971 and 1972. Further, those two broods showed no indication of having survivals different from the range of estimated values for the 1975-1990 broods. We concluded that the best indicator of survival differences between years was the change in run sizes to Mayfield Dam prior to initiation of the hatchery. That run size was estimated during 1962 to 1966, and ranged from 2,854 to 17,274. That range of 5.8 fold was still less than the range of 8.8 fold variation in survival for the 1975-1990 broods.

In order to calibrate (connect) the range in run sizes during 1962-66 to the range in survivals during the 1975-90 broods, we assumed that the lowest run for 1962-66 had a survival to age 2 that was equivalent to the lowest survival estimated for the 1975-90 broods. That survival was 2.6% for the 1980 brood. If we assume the smolt-to-age 2 survival was 2.6% for fish that produced the 1963 run of 2,854, then we deduce that the 1964 run, which was 5.76 times greater (17,274) must have had a survival that was 5.76 times greater; which would be 15%. Thus, a survival of 15% was chosen as the benchmark (Table 2). That survival rate was actually reached or exceeded in 3 of 13 broods after 1973 for which survival could be estimated by cohort analysis.

Fall Chinook

Benchmark survivals for fall chinook were estimated by taking the geometric mean of smolt-to-age 2 survivals from 1964-1967 broods for all lower Columbia hatcheries combined (Cramer 1996). Those survivals ranged from 1% to 3.2% with a geometric mean of 2.2%. Thus, 2.2% was used as the benchmark survival rate corresponding to the mitigation model year of 1964 (Table 2). We used the geometric mean (mean of logarithms), because Cramer (1996) showed that the frequency distribution of survivals was log-normal.

Coho

Benchmark survivals for coho were estimated by taking the geometric mean of smolt-to-age 2 survivals from 1967-1969, and 1972 broods of coho. Estimates for the first three of these broods were derived from fin mark experiments for all lower Columbia hatcheries combined (Cramer 1996), and the 1972 brood was actually from Cowlitz Hatchery. Those survivals ranged from 7% to 16.1% with a geometric mean of 8.0%. Thus, 8% was used as the benchmark survival rate corresponding to the mitigation model year of 1964 (Table 2). Again, we used the geometric mean (mean of logarithms), because Cramer (1996) showed that the frequency distribution of survivals was log-normal.

Table 2. Benchmark smolt-to-age 2 survival rates that are estimated to apply to the salmon runs in 1964 and 1965 that became the models for mitigation goals.

Species	Run Year	Survival to Age 2	Method
Spring Ch	65	**15.0%**	Assume 1962 = worst survival = 2.6%. Then 1965 target is 5.76 times more
Fall Ch	64	**2.2%**	Geometric mean of 1961-64 broods
Coho	64	**8.0%**	Geometric mean of 1967-69, 72 broods

RESULTS

Reconstructed recruitment back to the start of age 3 for each brood since 1960 showed wide ranges in of recruitment between broods for each race and species (Tables 3-5). Even the recruitment from the 1960-64 broods that were spawned, reared and smolted before Mayfield Dam was complete, varied by a factor of 7.6 for spring chinook, 1.8 for fall chinook, and 1.6 for coho. Estimated recruitment to age 3 (before age 3 catch) in the model year was as follows:

Species	Model Year	Age 3 Recruits
Spring Chinook	1965	106,134
Fall Chinook	1964	71,735
Coho	1964	124,277

These abundances of age 3 recruits will now serve as the standard of comparison for future broods. Note that the age 3 recruits actually correspond to a single brood rather than a run composed of several broods. Adult coho are all age 3, so the age 3 recruits for 1964 were produced by the 1961 brood. The majority of adult chinook are age 4, so the age 3 recruits for spring and fall chinook were estimated for the brood that began 4 years prior to the model run year (i.e. the 1960 brood for fall chinook and the 1961 brood for spring chinook).

In order to make survival-equivalent comparisons of future recruitment at age 3 to that during the model years, one must first weight the future run for any difference in ocean survival from that which occurred in the model year. This weight ; referred to as relative ocean survival, is simply the ratio of the survival in the model year to the survival in the future brood. That is:

Relative Survival Weight = [survival to age 2 in model year]/[survival to age 2 in future brood]

Relative survival then, equals 1.0 if the future brood has the same survival as the model brood, is > 1 if the present brood survived less than the model brood, and is < 1 if the present brood survived better than the model brood. Now, to calculate the survival equivalent recruitment, we calculate:

Survival Equivalent Recruitment = Age 3 Recruits x Relative Survival Weight

For example, the 1976 brood of spring chinook had age 3 recruitment of 134,031 and age 2 survival of 23%. This 23% survival is greater than the 15% survival estimated for the model year. To calculate how recruitment from the 1976 brood compared to the 1965 model recruitment, we have

1976 Survival-Equivalent Recruitment = 134,031 x (15%/23%) = 87,165

This survival-equivalent recruitment is less than the 106,134 fish for the model year, so we conclude that recruitment of spring chinook for the 1976 brood fell below the mitigation target.

Table 3. Estimated age 3 recruits and survival equivalency scaling for Cowlitz spring chinook that enables comparison of future broods to the benchmark run year and survival rate. "Scaled Population" is the survival-equivalent recruitment to age 3.

Spring Chinook

Brood Year	Age 3-6 Catch	Age 3-6 Spawn	Age 3 Recruits	Observed	Benchmark Scalar	Scaled Population
1960	42,598	14,538	79,416			
1961	59,505	19,035	106,134		1	106,134
1962	17,950	8,288	36,077			
1963	12,357	4,092	22,619			
1964	11,784	5,298	23,950			
1965	13,863	7,543	29,784			
1966	24,940	8,866	46,598			
1967	11,241	5,445	22,836			
1968	14,097	3,155	24,201			
1969	40,085	8,755	67,740			
1970	42,251	17,955	82,506			
1971	46,041	20,089	91,810	7.0%	**2.13**	195,852
1972	103,557	24,283	168,951	8.7%	**1.73**	292,456
1973	47,755	15,190	85,249			
1974	49,964	9,763	79,717			
1975	52,070	12,103	92,535	7.1%	**2.11**	194,854
1976	79,267	18,502	134,031	23.0%	**0.65**	87,165
1977	47,815	23,991	101,233	18.4%	**0.81**	82,468
1978	17,376	8,455	36,329			
1979	28,155	16,425	60,920			
1980	25,398	14,751	54,370	2.6%	**5.75**	312,771
1981	9,626	7,391	24,666	5.9%	**2.53**	62,444
1982	7,270	4,821	17,625	3.6%	**4.21**	74,254
1983	25,724	18,829	63,909	14.9%	**1.00**	64,179
1984	21,946	10,509	47,709	7.6%	**1.96**	93,591
1985	11,138	4,266	23,139	6.2%	**2.40**	55,484
1986	10,536	5,356	23,735			
1987	7,586	5,285	18,003	6.1%	**2.44**	43,881
1988	12,836	9,652	32,056			
1989	9,539	7,063	24,086	3.3%	**4.56**	109,849
1990	4,642					
1991	5,384					

Table 4. Estimated age 3 recruits and survival equivalency scaling for Cowlitz fall chinook that enables comparison of future broods to the benchmark run year and survival rate. "Scaled Population" is the survival-equivalent recruitment to age 3.

Fall Chinook

Brood Year	Age 3-6 Catch	Age 3-6 Spawn	Age 3 Recruits	Observed	Benchmark Scalar	Scaled Population
1959	35,479	3,336	72,981			
1960	49,015	6,359	71,735	*2.4%*	1.00	71,735
1961	49,016	6,420	111,095	*1.0%*	**1.00**	111,095
1962	80,905	5,970	62,986	*3.1%*	**1.00**	62,986
1963	44,604	4,731	109,089	*3.2%*	**1.00**	109,089
1964	81,882	3,486	96,336			
1965	66,997	4,023	261,865			
1966	190,126	9,311	158,822			
1967	112,412	12,652	58,958			
1968	37,671	7,210	120,290			
1969	88,957	5,083	60,815			
1970	41,149	4,661	42,442			
1971	26,382	5,086	57,285			
1972	41,053	3,837	33,142			
1973	22,502	2,681	53,774			
1974	38,381	3,037	45,674			
1975	29,910	4,756	37,248			
1976	25,157	3,424	36,318	1.3%	**1.67**	60,696
1977	21,532	4,419	21,999	0.5%	**4.51**	99,268
1978	12,281	4,184	17,274			
1979	8,958	4,301	38,524	1.1%	**1.98**	76,297
1980	17,925	8,196	27,477	0.7%	**3.32**	91,327
1981	13,558	5,921	25,355	0.8%	**2.86**	72,427
1982	14,421	4,797	96,831	2.6%	**0.86**	83,024
1983	60,003	15,478	116,539	2.8%	**0.77**	90,242
1984	62,676	19,894	57,021	0.6%	**3.99**	227,302
1985	32,895	8,974	21,545	0.4%	**5.89**	126,898
1986	7,585	6,267	10,876	0.1%	**19.34**	210,324
1987	3,544	4,006	17,955	0.2%	**9.77**	175,378
1988	7,865	2,917	21,291			
1989						
1990						

Table 5. Estimated age 3 recruits and survival equivalency scaling for Cowlitz coho that enables comparison of future broods to the benchmark run year and survival rate. "Scaled Population" is the survival-equivalent recruitment to age 3.

Coho

Brood Year	Run Year	Adults at Fish Facility	Age 3 Catch	Age 3 Recruits	Observed	Benchmark Scalar	Scaled Population
1957	1960						
1958	1961	23,388	50,874	74,262			
1959	1962	22,701	56,701	79,402			
1960	1963	22,083	100,045	122,128			
1961	1964	25,546	98,731	124,277		1.00	124,277
1962	1965	22,774	100,408	123,182			
1963	1966	31,001	155,997	186,998			
1964	1967	18,801	98,401	117,202			
1965	1968	12,636	71,928	84,564			
1966	1969	4,913	16,292	21,205			
1967	1970	63,407	220,988	284,395	*7.7%*	**1.04**	296,689
1968	1971	33,239	203,860	237,099	*12.2%*	**0.65**	155,048
1969	1972	16,354	85,567	101,921	*6.4%*	**1.26**	128,280
1970	1973	19,954	209,591	229,545			
1971	1974	17,627	206,304	223,931			
1972	1975	23,000	423,936	446,936	7.0%	**1.15**	511,996
1973	1976	25,166	512,713	537,879			
1974	1977	10,299	286,933	297,232			
1975	1978	20,512	154,311	174,823			
1976	1979	13,912	148,918	162,830			
1977	1980	28,776	119,378	148,154			
1978	1981	27,003	132,617	159,620			
1979	1982	22,528	112,232	134,760			
1980	1983	24,493	69,690	94,183	3.8%	**2.11**	198,903
1981	1984	26,149	60,783	86,932	3.8%	**2.12**	183,898
1982	1985	18,610	60,781	79,391	2.6%	**3.07**	244,016
1983	1986	54,685	282,854	337,539	10.8%	**0.74**	250,091
1984	1987	18,716	69,192	87,908	3.2%	**2.49**	219,203
1985	1988	30,888	121,283	152,171	6.9%	**1.16**	177,199
1986	1989	35,886	165,941	201,827	7.9%	**1.01**	203,560
1987	1990	13,009	35,479	48,488	1.6%	**5.10**	247,495
1988	1991	46,303	162,033	208,336	8.8%	**0.91**	188,797
1989	1992	14,780	32,443	47,223	2.3%	**3.51**	165,820
1990	1993	5,641	10,837	16,478	0.8%	**9.58**	157,857
1991	1994	6,922	2,041	8,963	0.3%	**24.13**	216,300

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APPENDIX 1

Table A1. Age-specific parameter values used on Spring Chinook for ratios of total catch to reported catch (T/R Ratio), ocean harvest rate (Oharv), river harvest rate (Rharv), and percentage of hatchery fish spawning naturally in the home stream (not strays). Bolded values were predicted using assumptions described in the text. Non-bolded values were estimated from marked groups.

Brood Year	Strayrate	Age 2 Ratio T/R	Age 3 Ratio T/R	Age 4 Ratio T/R	Age 5 Ratio T/R	Oharv2	Oharv3	Oharv4	Oharv5	Rharv2	Rharv3	Rharv4	Rharv5
58	0.0%	**3.70**	**1.16**	**1.01**	**1.02**	**1.4%**	**23.5%**	**41.3%**	**51.1%**	**11.3%**	**54.4%**	**54.4%**	**54.4%**
59	0.0%	**3.70**	**1.16**	**1.01**	**1.02**	**1.4%**	**24.3%**	**42.7%**	**52.8%**	**11.3%**	**48.7%**	**48.7%**	**48.7%**
60	0.0%	**3.70**	**1.16**	**1.01**	**1.02**	**1.5%**	**25.1%**	**44.0%**	**54.5%**	**11.3%**	**45.8%**	**45.8%**	**45.8%**
61	0.0%	**3.70**	**1.16**	**1.01**	**1.02**	**1.5%**	**25.8%**	**45.4%**	**56.2%**	**11.3%**	**52.0%**	**52.0%**	**52.0%**
62	0.0%	**3.70**	**1.16**	**1.01**	**1.02**	**1.6%**	**26.6%**	**46.8%**	**57.9%**	13.0%	**35.7%**	**35.7%**	**35.7%**
63	0.0%	**3.70**	**1.16**	**1.01**	**1.02**	**1.6%**	**27.4%**	**48.1%**	**59.6%**	10.0%	**43.8%**	**43.8%**	**43.8%**
64	0.0%	**3.70**	**1.16**	**1.01**	**1.02**	**1.6%**	**28.2%**	**49.5%**	**61.3%**	14.0%	**25.7%**	**25.7%**	**25.7%**
65	0.0%	**3.70**	**1.16**	**1.01**	**1.02**	**1.7%**	**28.9%**	**50.8%**	**62.9%**	9.0%	**19.8%**	**19.8%**	**19.8%**
66	0.0%	**3.70**	**1.16**	**1.01**	**1.02**	**1.7%**	**29.7%**	**52.2%**	**64.6%**	8.0%	**35.2%**	**35.2%**	**35.2%**
67	0.0%	**3.70**	**1.16**	**1.01**	**1.02**	**1.8%**	**30.5%**	**53.6%**	**66.3%**	9.0%	**25.3%**	**25.3%**	**25.3%**
68	0.0%	**3.70**	**1.16**	**1.01**	**1.02**	**1.8%**	**31.2%**	**54.9%**	**68.0%**	16.0%	**33.8%**	**33.8%**	**33.8%**
69	0.0%	**3.70**	**1.16**	**1.01**	**1.02**	**1.9%**	**32.0%**	**56.3%**	**69.7%**	39.0%	**39.0%**	**39.0%**	**39.0%**
70	0.0%	**3.70**	**1.16**	**1.01**	**1.02**	**1.9%**	**32.8%**	**57.6%**	**71.4%**	54.0%	**20.6%**	**20.6%**	**20.6%**
71	0.0%	**3.70**	**1.16**	**1.01**	**1.02**	5.0%	27.0%	47.6%	80.2%	27.0%	31.3%	32.6%	29.8%
72	0.0%	**3.70**	**1.16**	**1.01**	**1.02**	1.7%	42.1%	61.0%	84.6%	39.0%	55.8%	30.6%	29.4%
73	0.0%	**3.70**	**1.16**	**1.01**	**1.02**	**2.1%**	**32.8%**	**58.8%**	**73.4%**	55.0%	**47.3%**	**33.0%**	**30.4%**
74	0.0%	**3.70**	**1.16**	**1.01**	**1.02**	1.7%	39.7%	66.8%	58.8%	50.0%	55.8%	31.2%	32.3%
75	0.0%	**3.70**	**1.16**	**1.01**	**1.02**	0.0%	22.5%	59.9%	70.0%	26.0%	46.4%	37.5%	30.0%
76	0.0%	**3.70**	**1.16**	**1.01**	**1.02**	1.0%	34.7%	55.4%	65.6%	20.0%	52.3%	34.4%	37.5%
77	0.0%	15.65	1.11	1.02	1.02	1.5%	16.2%	46.7%	58.9%	43.0%	52.7%	41.9%	27.9%
78	0.0%	12.87	1.16	1.02	1.01	**3.1%**	**20.6%**	**47.9%**	**58.7%**	65.0%	**41.7%**	**37.2%**	**31.8%**
79	0.0%	3.26	1.15	1.01	1.01	**3.1%**	**20.6%**	**47.9%**	**58.7%**	28.0%	**41.7%**	**37.2%**	**31.8%**
80	0.0%	5.28	1.14	1.01	1.01	7.4%	21.2%	43.3%	49.8%	45.0%	11.3%	44.1%	29.6%
81	0.0%	3.78	1.24	1.01	1.00	2.6%	10.3%	46.2%	60.6%	44.0%	50.4%	28.4%	32.1%
82	0.0%	2.46	1.15	1.01	1.06	1.5%	16.5%	48.6%	70.4%	31.0%	18.4%	21.5%	30.0%
83	0.0%	3.21	1.13	1.05	1.03	1.0%	14.4%	56.3%	72.1%	7.0%	37.0%	18.7%	27.2%
84	0.0%	5.34	1.26	1.04	1.03	2.3%	10.7%	56.0%	48.3%	19.0%	65.5%	25.1%	30.6%
85	0.1%	1.85	1.31	1.04	1.01	1.2%	11.7%	54.9%	25.0%	27.0%	74.9%	29.2%	41.7%
86	0.2%	4.80	1.23	1.02	1.04	**1.3%**	12.4%	47.7%	60.2%	7.0%	25.0%	35.9%	37.5%
87	0.4%	8.80	1.14	1.08	1.00	1.3%	18.7%	43.9%	48.3%	11.0%	24.4%	37.8%	13.8%
88	0.0%	17.60	1.25	1.04	1.02	**1.5%**	**16.4%**	**53.8%**	**51.3%**	9.0%	**20.4%**	**32.6%**	**16.3%**
89	0.0%	3.39	1.33	1.04	1.10	1.6%	14.1%	63.7%	54.3%	31.0%	16.4%	27.3%	18.8%
90	0	**1**	**1**	**1**	**1**	1.5%	21.6%			9.0%	15.7%		
91		**1**	**1**	**1**	**1**	**1.5%**				23.0%			
										0.2%	0.4%	0.3%	26.6%

Table A2. Age-specific parameter values used on Fall Chinook for ratios of total catch to reported catch (T/R Ratio), ocean harvest rate (Oharv), river harvest rate (Rharv), and percentage of hatchery fish spawning naturally in the home stream (not strays). Bolded values were predicted using assumptions described in the text. Non-bolded values were estimated from marked groups.

Brood Year	%Spawn In Hatch	Age 2 Ratio T/R	Age 3 Ratio T/R	Age 4 Ratio T/R	Age 5 Ratio T/R	Oharv2	Oharv3	Oharv4	Oharv5	Rharv2	Rharv3	Rharv4	Rharv5
1958	0.769	3.70	1.16	1.01	1.02	1.4%	23.5%	41.3%	51.1%	64.4%	64.4%	64.4%	64.4%
1959	0.769	3.70	1.16	1.01	1.02	1.4%	24.3%	42.7%	52.8%	64.4%	64.4%	64.4%	64.4%
1960	0.769	3.70	1.16	1.01	1.02	1.4%	25.1%	44.0%	54.5%	58.3%	58.3%	58.3%	58.3%
1961	0.769	3.70	1.16	1.01	1.02	1.2%	20.4%	35.8%	44.4%	69.4%	69.4%	69.4%	69.4%
1962	0.769	3.70	1.16	1.01	1.02	1.8%	31.2%	54.9%	68.0%	66.8%	66.8%	66.8%	66.8%
1963	0.769	3.70	1.16	1.01	1.02	1.6%	28.4%	49.9%	61.7%	64.6%	64.6%	64.6%	64.6%
1964	0.769	3.70	1.16	1.01	1.02	1.9%	32.6%	57.3%	70.9%	76.6%	76.6%	76.6%	76.6%
1965	0.769	3.70	1.16	1.01	1.02	1.7%	28.9%	50.8%	62.9%	64.4%	64.4%	64.4%	64.4%
1966	0.769	3.70	1.16	1.01	1.02	1.7%	29.7%	52.2%	64.6%	73.5%	73.5%	73.5%	73.5%
1967	0.769	3.70	1.16	1.01	1.02	1.8%	30.5%	53.6%	66.3%	58.3%	58.3%	58.3%	58.3%
1968	0.769	3.70	1.16	1.01	1.02	1.8%	31.2%	54.9%	68.0%	37.0%	37.0%	37.0%	37.0%
1969	0.769	3.70	1.16	1.01	1.02	1.9%	32.0%	56.3%	69.7%	70.5%	70.5%	70.5%	70.5%
1970	0.769	3.70	1.16	1.01	1.02	1.9%	32.8%	57.6%	71.3%	40.0%	40.0%	40.0%	40.0%
1971	0.769	3.70	1.16	1.01	1.02	5.0%	27.0%	47.6%	80.2%	27.0%	31.3%	32.6%	29.8%
1972	0.769	3.70	1.16	1.01	1.02	1.7%	42.1%	61.0%	84.6%	39.0%	55.8%	30.6%	29.4%
1973	0.769	3.70	1.16	1.01	1.02	2.1%	32.8%	58.8%	73.4%	55.0%	47.3%	33.0%	30.4%
1974	0.769	3.70	1.16	1.01	1.02	1.7%	39.7%	66.8%	58.8%	50.0%	55.8%	31.2%	32.3%
1975	0.769	3.70	1.16	1.01	1.02	0.0%	22.5%	59.9%	70.0%	26.0%	46.4%	37.5%	30.0%
1976	0.769	3.70	1.16	1.01	1.02	1.0%	34.7%	55.4%	65.6%	20.0%	52.3%	34.4%	37.5%
1977	0.58	15.65	1.11	1.02	1.02	3.8%	27.6%	42.6%	33.2%	68.0%	43.2%	30.1%	0.0%
1978	0.86	12.87	1.16	1.02	1.01	2.1%	19.5%	55.4%	46.8%	24.0%	9.4%	18.8%	0.0%
1979	0.91	3.26	1.15	1.01	1.01	2.3%	17.9%	46.6%	34.8%	36.0%	10.6%	24.1%	2.3%
1980	0.67	5.28	1.14	1.01	1.01	2.5%	16.3%	37.8%	22.7%	35.0%	11.8%	29.3%	4.5%
1981	0.79	3.78	1.24	1.01	1.00	3.9%	8.6%	39.5%	23.8%	60.0%	67.0%	19.6%	25.0%
1982	0.83	2.46	1.15	1.01	1.06	2.3%	12.4%	35.1%	45.9%	86.0%	48.8%	51.1%	29.8%
1983	0.74	3.21	1.13	1.05	1.03	1.6%	18.3%	41.6%	32.9%	37.0%	61.1%	44.5%	21.2%
1984	0.78	5.34	1.26	1.04	1.03	2.4%	10.3%	34.6%	19.2%	42.0%	57.2%	50.8%	12.3%
1985	0.79	1.85	1.31	1.04	1.01	0.9%	7.9%	41.9%	59.6%	38.0%	81.2%	30.2%	0.0%
1986	0.68	4.80	1.23	1.02	1.04	3.2%	7.5%	36.8%	28.4%	31.6%	25.0%	3.2%	27.2%
1987	0.8	8.80	1.14	1.08	1.00	3.3%	14.8%	18.5%	26.9%	24.3%	0.9%	21.1%	0.0%
1988	0.68	17.60	1.25	1.04	1.02	3.3%	14.7%	32.1%	78.6%	60.9%	9.5%	4.2%	30.0%
1989	0.69	3.39	1.33	1.04	1.10	2.1%	21.4%	70.7%	23.9%	64.5%	0.0%	11.4%	10.7%
1990	0.86	1	1.3	1	1	3.0%	41.3%			56.3%	4.2%		
1991	0.88	1	1	1	1	3.0%				30.4%			
Averages from 1971-1976						1.9%	33.1%	58.3%	72.1%	36.2%	48.2%	33.2%	31.6%

Table A3. Parameter values used on Coho for ocean harvest rate (Oharv), river harvest rate (Rharv). Bolded values were predicted using assumptions described in the text. Non-bolded values were estimated from marked groups.

Brood Year	Run Year	Harvest Rate River	Harvest Rate Ocean
1957	1960		
1958	1961	*24.6%*	**58.3%**
1959	1962	*34.6%*	**56.3%**
1960	1963	*35.3%*	**72.1%**
1961	1964	*39.1%*	**66.2%**
1962	1965	*48.4%*	**64.2%**
1963	1966	*59.3%*	**59.3%**
1964	1967	*47.9%*	**69.2%**
1965	1968	*46.5%*	**72.1%**
1966	1969	*31.4%*	**66.2%**
1967	1970	48.6%	56.6%
1968	1971	34.7%	78.5%
1969	1972	14.6%	81.2%
1970	1973	*62.0%*	**77.1%**
1971	1974	*62.4%*	**79.0%**
1972	1975	77.7%	76.9%
1973	1976	*66.6%*	**86.0%**
1974	1977	**79.6%**	**83.0%**
1975	1978	**28.4%**	**83.6%**
1976	1979	**64.9%**	**75.6%**
1977	1980	**58.2%**	**53.5%**
1978	1981	**51.6%**	**65.0%**
1979	1982	**66.8%**	**49.7%**
1980	1983	5.9%	72.4%
1981	1984	57.1%	29.9%
1982	1985	60.0%	41.5%
1983	1986	75.2%	34.8%
1984	1987	62.2%	43.6%
1985	1988	67.4%	37.7%
1986	1989	64.0%	50.7%
1987	1990	34.8%	58.9%
1988	1991	64.1%	38.1%
1989	1992	39.8%	48.0%
1990	1993	31.4%	50.1%
1991	1994	9.8%	14.4%

APPENDIX 2

RECONSTRUCTION OF RUN AGE COMPOSITION

Runs of spring and fall chinook are composed of several ages of fish, with each age originating from a different brood year. These different aged fish often have experienced different survival and harvest rates from one another. For example, cohort analyses of CWT groups consistently show that age 3 chinook are substantially less vulnerable to ocean fisheries than age 4 and 5 chinook. Therefore, in order to accurately reconstruct a brood back to recruitment at age 3, one must divide each run into is component age groups, so that different harvest rates can be applied to each group. However, age data were only available for each run back to 1980. In order to reconstruct brood strength back to 1960, I had to develop a method for estimating age composition of the adults and jacks returning to the fish facility.

Spring Chinook

Counts of adult spring chinook at the fish facility were composed of age 4 through age 6 fish, and jacks were composed of both age 2 and age 3 fish. For the 1980-95 runs in which age composition was estimated directly by WDFW from scale samples, there was no correlation between the abundance of age 2 jacks in one year and the abundance of their age 3 brothers and sisters the following year. On the other hand, there was a strong correlation between the abundance of age 3 jacks in one year and the abundance of age 4 adults the next years ($r = 0.97$; Figure A1). Likewise, there was also a correlation of age 4 abundance in one year to age 5 abundance the next year ($r = 0.69$). In order to use these correlations to reconstruct age composition of the runs before 1980, I had to first estimate the age composition of the adult run (ages 4-6), and then use the regression of age 3 on age 4 abundance to estimate the abundance of age 3 jacks.

The age composition of the adult run was not constant between years, because of varying brood strength. In general, the years in which age composition was estimated from scales showed that the percentage of age 4 fish in the run was higher on years when the run increased, and lower on the years when the run decreased. Thus, if the run increased from one year to the next, it generally reflected the influx of age 4 fish from a strong brood. When the run decreased, it generally reflected a reduced abundance of the brood contributing age 4 fish, so the age 5 fish composed a higher percentage of the run in those years. I used the change in run size to help gain a more accurate estimate of age composition of the run in a given year (Table A4).

Table A4. Percent age composition of the adult spring chinook returning to Cowlitz Salmon Hatchery, 1980-95.

Run Trend	Years	% Age 4 Mean	% Age 4 20th%	% Age 4 80th%	% Age 5 Mean	% Age 6 Mean
Increasing	7	75.9%	65.9%	85.9%	23.5%	0.6%
Decreasing	8	59.6%	44.4%	72.0%	39.5%	1.0%

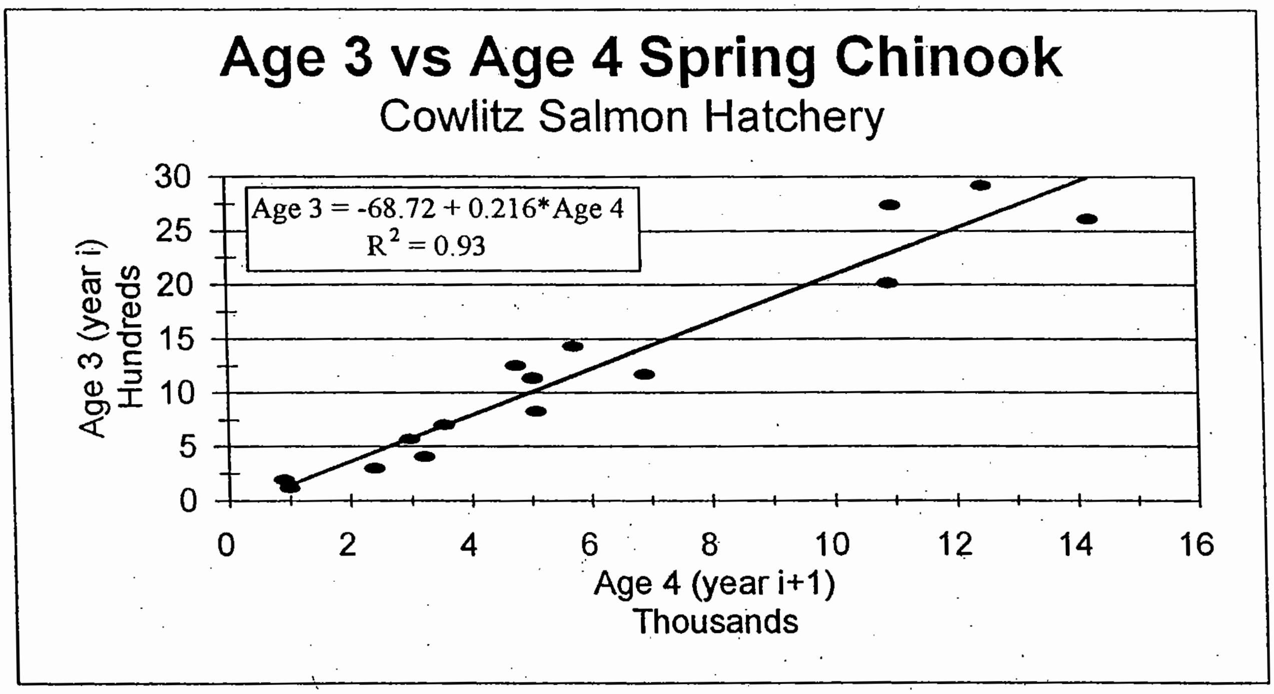

Figure A1 Correlation of age 3 jack returns in one year to age 4 adult returns in the next year for spring chinook at Cowlitz Salmon Hatchery, 1980-95 return years.

Given the above information, I reconstructed the age composition of each run prior to 1980 according to the following steps:

1. Determine whether the adult run decreased or increased from the previous year.
2. Assign the age 4-6 age composition as per Table A4.
3. Calculate the number of adults at each age by multiplying the percentage at each

age times the adult count.

4. Estimate the number of age 3 fish in the run by the regression of age 3 fish in year i on age 4 abundance in year i+1 (see Figure A1).
5. Estimate the abundance of age 2 fish by subtracting the abundance of age 3 fish from the total jack returns.

For the run year 1964, the above procedure predicted more age 3 fish than the total jack count, so I assumed all jacks were age 3, and used the jack count for the number of age 3 fish. That left zero fish at age 2. No other adjustments were needed for specific years.

Final results of the age reconstruction are shown in Table A5.

Table A5 Age composition of the spring chinook returns to Mayfield Dam and the fish facilities at Cowlitz Salmon Hatchery. Predicted values of age-specific returns are shown in bold and were calculated as explained in text.

Run	Returns to Fish Facility							% of Age 4-6 Adults		
Year	Adults	Jacks	Age 2	Age 3	Age 4	Age 5	Age 6	Age 4	Age 5	Age 6
1960										
1961	---									
1962	2,998	740	**442**	**298**	**1,786**	**1,183**	**30**			
1963	2,854	1,945	**160**	**1,785**	**1,700**	**1,126**	**28**			
1964	11,335	2,282	**0**	**2,282**	**8,599**	**2,667**	**70**			
1965	17,274	3,487	**2,382**	**1,105**	**13,104**	**4,064**	**106**			
1966	9,139	2,552	**2,062**	**490**	**5,443**	**3,606**	**90**			
1967	4,347	2,966	**2,358**	**608**	**2,589**	**1,715**	**43**			
1968	4,140	4,298	**3,320**	**978**	**3,141**	**974**	**25**			
1969	6,400	4,697	**3,619**	**1,078**	**4,855**	**1,506**	**39**			
1970	7,009	2,065	**1,337**	**728**	**5,317**	**1,649**	**43**			
1971	6,202	1,828	**1,575**	**253**	**3,694**	**2,447**	**61**			
1972	2,507	2,448	**1,602**	**846**	**1,493**	**989**	**25**			
1973	5,592	5,045	**2,635**	**2,410**	**4,242**	**1,316**	**34**			
1974	15,152	4,873	**2,208**	**2,665**	**11,494**	**3,565**	**93**			
1975	16,712	11,165	**8,043**	**3,122**	**12,678**	**3,931**	**103**			
1976	19,509	13,478	**11,506**	**1,972**	**14,799**	**4,589**	**120**			
1977	15,889	11,563	**10,434**	**1,129**	**9,463**	**6,269**	**157**			
1978	9,329	17,570	**16,668**	**902**	**5,556**	**3,681**	**92**			
1979	7,561	3,664	**1,731**	**1,933**	**4,503**	**2,983**	**75**			
1980	15,860	3,041	426	2,615	9,283	6,483	94	16.1%	58.5%	40.9%
1981	20,865	3,503	2,364	1,139	14,219	7,172	215	14.0%	65.8%	33.2%
1982	12,230	3,486	742	2,744	5,046	7,076	114	22.2%	41.2%	57.8%
1983	13,319	4,580	2,565	2,015	10,991	2,246	81	25.6%	82.5%	16.9%
1984	13,645	1,334	502	832	10,931	2,690	24	8.9%	80.1%	19.7%
1985	6,806	4,617	4,210	407	5,090	1,743	0	40.3%	74.5%	25.5%

Run	Returns to Fish Facility							% of Age 4-6 Adults		
Year	Adults	Jacks	Age 2	Age 3	Age 4	Age 5	Age 6	Age 4	Age 5	Age 6
1986	5,591	4,974	2,054	2,920	3,225	1,431	62	51.3%	68.4%	30.3%
1987	13,679	3,491	2,058	1,433	12,481	1,160	38	20.3%	91.2%	8.5%
1988	9,080	2,479	2,178	301	5,715	3,336	29	21.4%	62.9%	36.7%
1989	5,659	1,528	959	569	2,404	3,207	92	21.1%	42.2%	56.2%
1990	4,525	12,533	11,846	687	2,916	1,458	150	73.5%	64.4%	32.2%
1991	5,384	5,488	4,314	1,174	3,554	1,760	65	50.5%	66.1%	32.7%
1992	7,922	6,191	4,936	1,255	6,897	1,020	36	43.8%	86.7%	12.8%
1993	6,194	578	383	195	4,766	1,575	6	8.3%	75.1%	24.8%
1994	1,881	561	440	121	911	991	6	22.7%	47.7%	51.9%
1995		426	281	145	1,011	730	51	19.2%	56.4%	40.7%
1996										

Bolded Values are Predicted. Unbolded were actually observed.

Fall Chinook

Separate counts of adult and jack fall chinook were maintained at the fish facility since 1962. Adults were composed of age 3 through age 6 fish, and jacks were composed of predominantly of age 2 fish, although some were age 3 in some years. Thus, fall chinook differed from spring chinook in that nearly all age fall chinook were classified as adults, while all age 3 spring chinook were classified as jacks. This difference made it more difficult to predict the age composition of fall chinook runs prior to 1980, because three age groups, rather than two, contributed substantially to each adult run.

There was a high correlation of returns at one age to the returns at the next older age in the next year. Returns of age 3 fish were highly correlated ($r = 0.93$) to returns of age 2 fish the year before. Returns of age 4 fish were also correlated to the returns of age 3 fish the previous year ($r = 0.69$). Although these are high correlations, I could not use them to estimate age composition, because the age 3 returns were sometimes mixed into the jack counts. Age 3 fish composed from 0% up to 67% of the jack count during 1980-95. Further, age 3 fish only composed an average of 32% of the adult returns, while age 4 fish composed an average 59.8%. Because of the jack counts could not be used to accurately estimate age 4 composition of the run in future years, the age composition of adult returns could not be accurately estimated base on prior jack returns. Further, the age composition of adult counts could not be predicted from increasing or decreasing run sizes, because the run increase could come from either a strong age 3 or age 4 component.

Due to a lack of correlations that could predict age composition of the adult returns, I assumed runs prior to 1980 had the average age composition observed for adult returns from 1980 to 1995 (Table A6). I also assumed that all jacks prior to 1980 were age 2. Errors in the assumed age of jacks would have minor effects on the adult age composition, since only a portion of the age 3 fish were counted as jacks, and all age 3 fish combined averaged only 32.9% of the adult count. The resulting predicted returns of fall chinook at each age back to 1962 are shown in Table A7.

Table A6. Percent composition of the fall chinook counted as adults at the Cowlitz Fish Facility during 1980-1995. The actual mean values summed to 104% (because some age 3 fish were counted as jacks rather than adults) so the mean values reported here have been weighted to sum to 100%.

	Age 3	Age 4	Age 5	Age 6
Mean	**31.7%**	**59.8%**	**8.3%**	**0.3%**
80th Percentile	38.1%	71.2%	8.7%	0.2%
20th Percentile	20.1%	51.2%	4.3%	0.0%

Table A7 Age composition of the fall chinook returns to Mayfield Dam and the fish facilities at Cowlitz Salmon Hatchery. Predicted values of age-specific returns are shown in bold and were calculated as explained in text.

Run	Returns to Fish Facility								% of Adult Run		
Year	Adults	Jacks	Age 2	Age 3	Age 4	Age 5	Age 6	Age 3	Age 4	Age 5	Age 6
1960											
1961	4,339	1,596	**1,596**	**1,374**	**2,594**	**360**	**11**				
1962	2,236	562	**562**	**708**	**1,337**	**185**	**6**				
1963	3,244	1,927	**1,927**	**1,027**	**1,939**	**269**	**8**				
1964	8,125	2,210	**2,210**	**2,572**	**4,857**	**674**	**21**				
1965	5,518	5,188	**5,188**	**1,747**	**3,299**	**458**	**14**				
1966	6,492	3,773	**3,773**	**2,055**	**3,881**	**538**	**17**				
1967	4,018	5,986	**5,986**	**1,272**	**2,402**	**333**	**11**				
1968	3,189	4,667	**4,667**	**1,010**	**1,906**	**265**	**8**				
1969	3,340	11,828	**11,828**	**1,057**	**1,997**	**277**	**9**				
1970	11,794	8,646	**8,646**	**3,734**	**7,051**	**978**	**31**				
1971	14,393	2,151	**2,151**	**4,557**	**8,605**	**1,194**	**38**				
1972	3,581	1,135	**1,135**	**1,134**	**2,141**	**297**	**9**				
1973	6,063	1,473	**1,473**	**1,920**	**3,625**	**503**	**16**				
1974	3,721	1,024	**1,024**	**1,178**	**2,225**	**309**	**10**				
1975	6,138	1,934	**1,934**	**1,943**	**3,669**	**509**	**16**				
1976	2,797	745	**745**	**886**	**1,672**	**232**	**7**				

Run	Returns to Fish Facility							% of Adult Run			
Year	Adults	Jacks	Age 2	Age 3	Age 4	Age 5	Age 6	Age 3	Age 4	Age 5	Age 6
1977	2,579	1,236	**1,236**	**817**	**1,542**	**214**	**7**				
1978	2,860	1,792	**1,792**	**906**	**1,710**	**237**	**7**				
1979	6,155	801	**801**	**1,949**	**3,680**	**511**	**16**				
1980	1,968	221	221	709	1,088	171	0	36.0%	55.3%	8.7%	0.0%
1981	4,697	976	976	966	3,346	385	0	20.6%	71.2%	8.2%	0.0%
1982	4,284	1,130	993	1,118	2,941	360	2	26.1%	68.7%	8.4%	0.0%
1983	5,969	498	166	2,965	3,054	277	4	49.7%	51.2%	4.6%	0.1%
1984	5,117	586	169	1,016	4,394	124	0	19.9%	85.9%	2.4%	0.0%
1985	6,434	3,348	2,928	1,835	4,177	837	5	28.5%	64.9%	13.0%	0.1%
1986	10,757	1,923	1,695	7,613	2,644	728	0	70.8%	24.6%	6.8%	0.0%
1987	11,699	1,267	943	4,454	7,245	318	0	38.1%	61.9%	2.7%	0.0%
1988	13,793	953	529	1,755	11,869	598	0	12.7%	86.1%	4.3%	0.0%
1989	11,376	861	344	2,291	6,229	3,351	22	20.1%	54.8%	29.5%	0.2%
1990	6,357	473	393	1,501	3,735	981	220	23.6%	58.8%	15.4%	3.2%
1991	3,549	184	199	1,002	2,360	235	9	28.2%	66.5%	6.6%	0.2%
1992	2,356	534	293	509	1,705	145	6	21.6%	72.4%	6.2%	0.2%
1993	2,907	712	259	1,849	1,302	206	0	63.6%	44.8%	7.1%	0.0%
1994	5,777	398	398	1,945	3,718	304	4	33.7%	64.4%	5.3%	0.1%
1995		388	388	1,458	1,921	437	0				

Bolded Values are Predicted. Unbolded were actually observed.

Coho

Age composition of coho did not need to be predicted, because the separate counts of jacks and adults correspond to the only two ages at which coho return (age 2 jacks and age 3 adults).

ATTACHMENT No. 2

Evaluation of contribution to catch and escapement by spring Chinook, fall Chinook and coho produced at Cowlitz Salmon Hatchery. Technical Report, April, 2002.

EVALUATION OF CONTRIBUTION TO CATCH AND ESCAPEMENT BY SPRING CHINOOK, FALL CHINOOK, AND COHO PRODUCED AT COWLITZ SALMON HATCHERY

TECHNICAL REPORT

April 2002

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INTRODUCTION

Past contributions to catch and escapement by spring chinook, fall chinook and coho salmon produced at the Cowlitz Salmon Hatchery are reviewed and compared to appropriate performance standards in order to evaluate Cowlitz Salmon Hatchery mitigation success. The Cowlitz Salmon Hatchery was constructed to maintain anadromous fish runs that formerly returned to the Cowlitz River above Mayfield Dam. The fisheries mitigation agreement stipulates that the Cowlitz Salmon Hatchery produce enough fish such that, in combination with naturally produced fish, the number of fish returning to the separation facilities at the hatchery are as follows:

- 25,000 coho salmon
- 17,300 spring chinook salmon, and
- 8,300 fall chinook salmon

Previous analyses of fishery contribution from salmon produced at the Cowlitz Salmon Hatchery have demonstrated that natural survival rates in the ocean, as well as harvest rates in both the ocean and river, have been highly variable between years since the hatchery began in 1968 (Cramer 1996; Harza and S.P. Cramer & Associates 1996; Cramer 1998; Cramer and Vigg 1999). This high variability complicates the logic for choosing benchmarks by which future hatchery performance should be judged.

Cramer (1996) estimated survival and harvest rates through cohort analysis for all coded-wire tag (CWT) groups that had been released from Cowlitz Salmon Hatchery, and found;

"Smolt-to-age 2 survival (ocean survival) varied substantially between broods for all species and was the dominant factor causing variation in run sizes between years."

And that;

". . . a typical mix of years with a net average production of adults that equals the

mitigation goal would likewise include a few good years of returns substantially exceeding the mitigation goal, but a majority of years with returns less than the mitigation goal."

Because of the substantial variation in ocean survival, combined with large changes in harvest rates since 1968, Cramer (1996) recommended using the reconstructed population at the beginning of age 3 in the ocean as the best measure of salmon production resulting from the hatchery each brood year. The ultimate measure of mitigation effectiveness is thus, adult recruitment. However, as stated above, both ocean survival and the fraction of adult recruits harvested each year are not constant. Therefore, any estimate of adult recruitment must include a correction factor (i.e. scalar) to compensate for differences in ocean survival between years, and must include all fish taken by harvest. The measure of mitigation effectiveness should answer the question,

> **"Given equivalent survival in the ocean each year, has the number of adult recruits produced from the Cowlitz River been sustained at that which the Cowlitz River would have produced before the dams were built?"**

Methods for estimating contribution rates to catch and spawner escapement, and comparing them to mitigation goals were developed by Cramer (2000). Cramer (2000) was able to apply those methods to data on returns of fish to the Cowlitz River and on recoveries of coded-wire tagged (CWT) fish from the Cowlitz Salmon Hatchery through the 1989 brood for spring chinook, through the 1987 brood for fall chinook, and through the 1991 brood for coho. The report presented here updates those analyses to the most recent broods possible with the data presently available, and provides detailed instruction on the modeling procedures and protocol (appendix 3). These updated analyses carry through the 1994 brood for spring and fall chinook, and through the 1995 brood for coho.

APPROACH

ANALYTICAL STEPS

In order to compare the outcome of mitigation actions each year, an approach was developed by Cramer (1996) which compensated for the two major sources of variation between broods that are unrelated to mitigation: (1) ocean survival, and (2) harvest rates.

This approach can be expressed as follows:

Survival Equivalent Recruits = (Catch + Spawners + Natural Mortality) x Relative Ocean Survival

Further,

Relative ocean survival = Smolt-to-Age 2 $\text{Survival}_{\text{Model Year}}$/Smolt-to-Age 2 $\text{Survival}_{\text{Now}}$

In order to fill in the variables in this equation, estimates for two broad quantities must be derived:

1. Recruitment
2. Ocean survival

Estimation of Harvest and Recruitment Through Cohort Analysis

The number of adults returning to fish counting stations each year is accurately measured, and is the best measure on which to base estimates of recruitment. Because not all fish destined to reach the fish facility can be uniquely distinguished from other fish in the run, all other components of recruitment must be reconstructed based on estimates of rates (harvest, straying, mortality) that are multiplied by the run size, as determined from the number of fish entering the fish counting facility. The number of Cowlitz Salmon caught in the Cowlitz River is estimated annually by WDFW from angler punch cards and a telephone survey process. The fraction of Cowlitz fish that are harvested in the Columbia River and the ocean is only estimated for marked groups that can be uniquely identified as originating in the Cowlitz River. Thus, catch of Cowlitz fish in the Columbia River and ocean can only be estimated by multiplying the harvest rate, determined from representative marked groups, by the run size. Because the run size includes fish that are caught, the run must be reconstructed progressively downstream and back into the ocean by sequentially adding back the catches that occur along the way. This process of run reconstruction was described by Cramer (1996), and is illustrated in Figures 1-3.

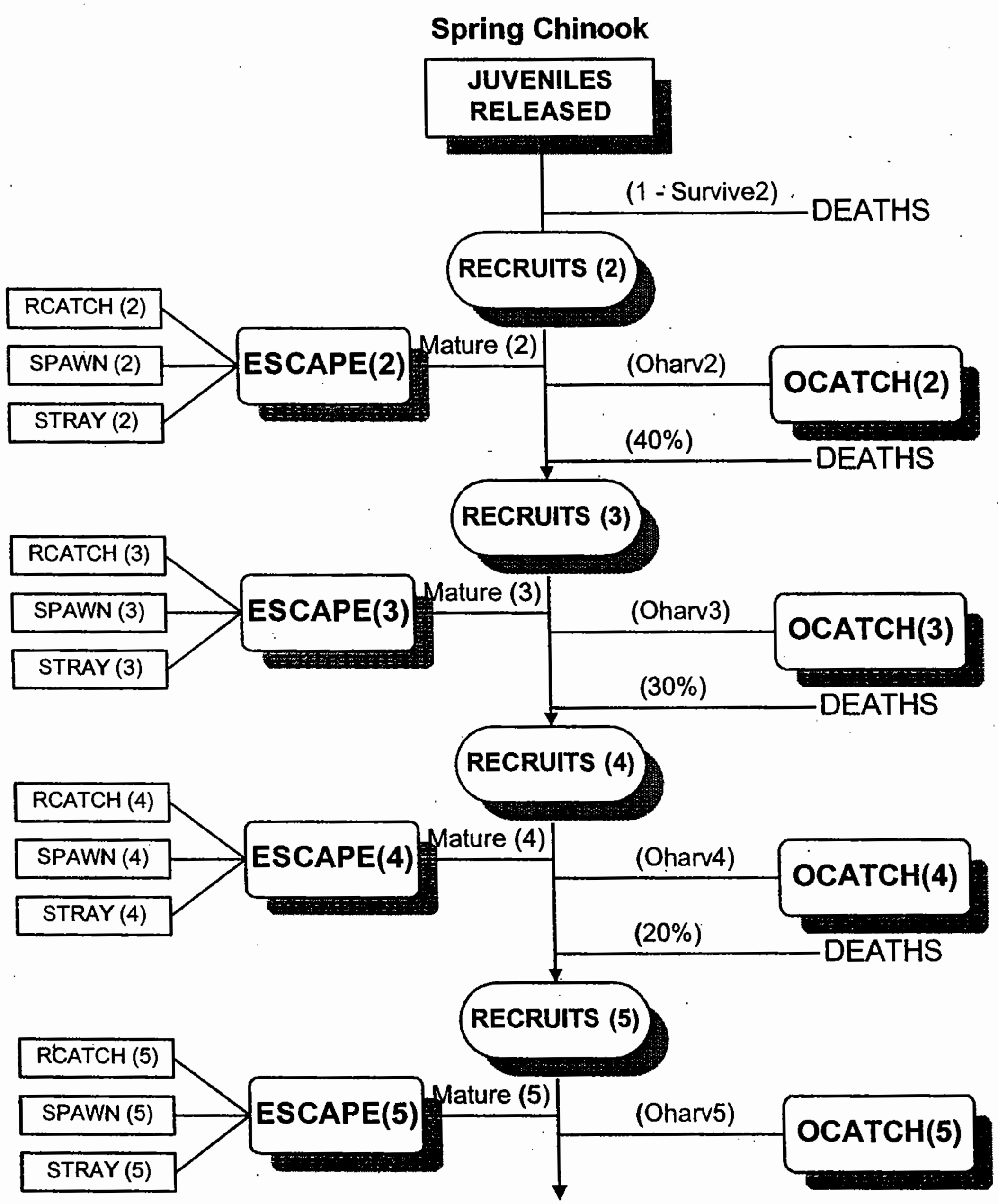

Figure 1. Diagram of general life-history categories accounted for in the cohort analysis of spring chinook. Note that maturation occurs each spring prior to the time that ocean harvest begins.

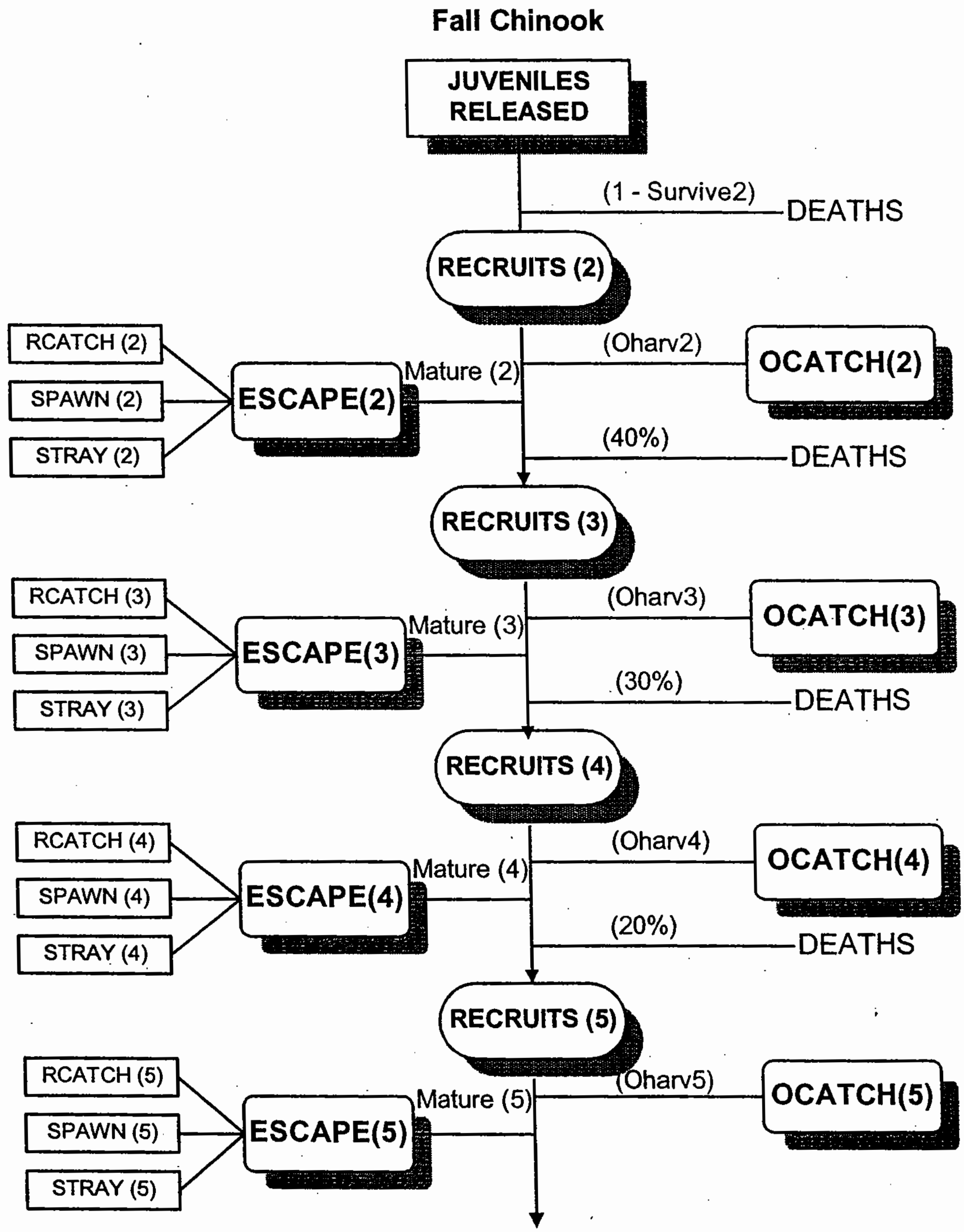

Figure 2. Diagram of general life-history categories accounted for in the cohort analysis of fall chinook. Note that maturation is assumed to occur each fall after ocean harvest is complete.

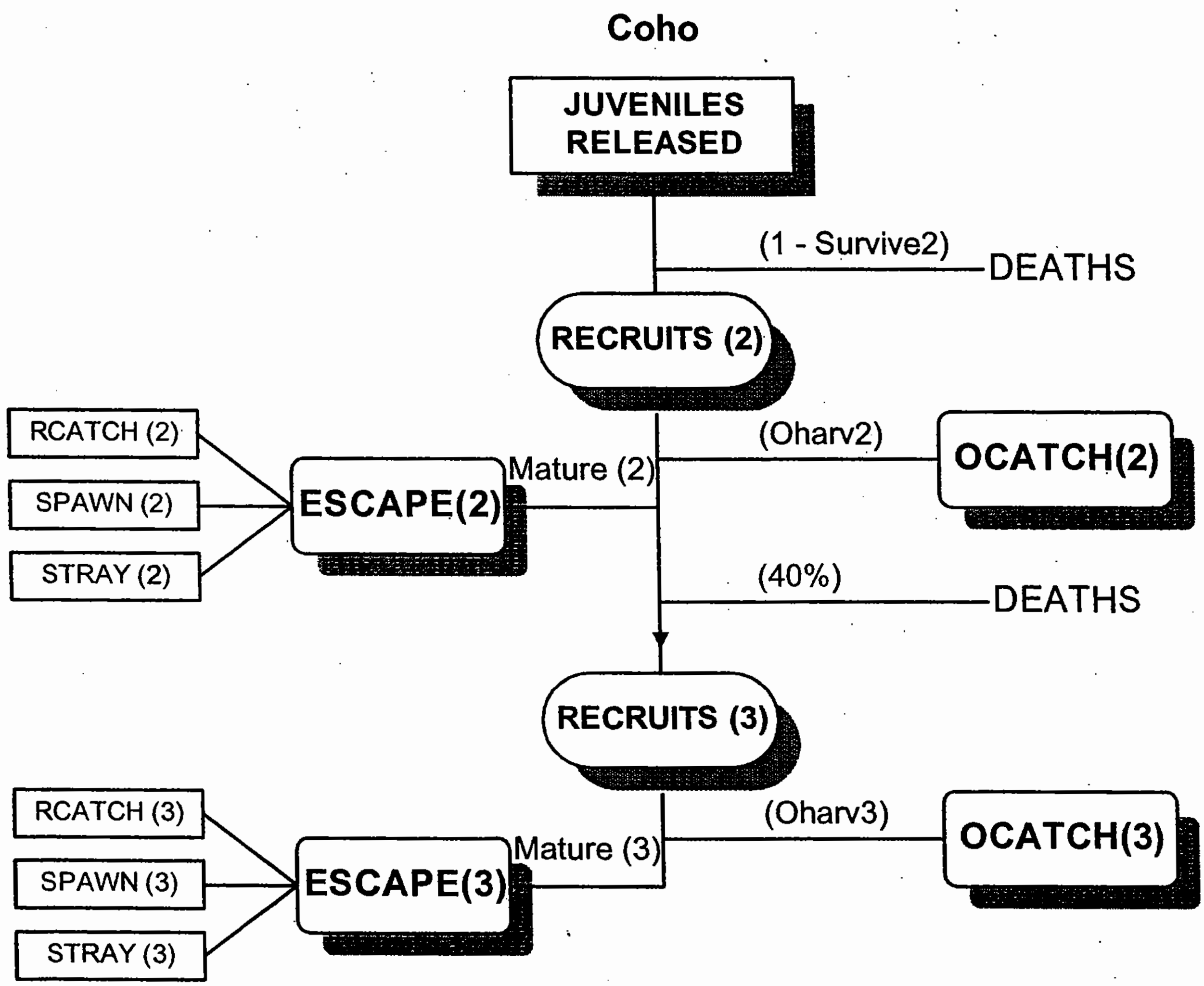

Figure 3. Diagram of general life-history categories accounted for in the cohort analysis of coho.

The majority of Cowlitz salmon recruits are captured in ocean and river fisheries, so the estimation of harvest rates plays a major role in determining the size of reconstructed populations at age 3 (age 3 recruits). Through cohort analysis, Cramer (1996) estimated harvest rates at each age in the ocean and the river for all broods that had releases and recaptures of representatively marked fish. Cramer (2000) then developed procedures to extend estimates for missing years back to the 1960 brood.

For this report, the process of cohort analysis was again used to derive estimates of harvest rate (both in freshwater and the ocean) and recruitment for each species at each age through the 2000 return year. In the current analysis, however, the estimation of recent harvest rates both in the ocean and in the river was very difficult due to the extreme low numbers of CWT-marked fish that survived from the 1990-1995 broods, and the low or absent CWT recoveries in the various sport and commercial fisheries during the later 1990s. Many of the fisheries produced no CWT recoveries for some age groups (because both the CWT population and the fraction of fish harvested were small).

After completing the first round of cohort analyses for the 1990- 1995 broods, there were many missing estimates of harvest rate, both in the river and in the ocean, for each species. However, from data on total landings and escapement it was apparent that a significant fraction of fish was indeed harvested each year. These missing harvest rates would not allow for an accurate population reconstruction. Thus, there was a need to supply surrogate values of harvest rate for several age groups, in several fisheries, in several years of the analysis. The methods for deriving the surrogate harvest rate values are described in Appendix 2.

ESTIMATION OF OCEAN SURVIVAL

The best available predictions of survival and harvest rates were derived from variation in run sizes to the Cowlitz Hatchery fish facilities, as well as trends in harvest rates estimated from years when marked groups were released (cohort analysis). This requires a series of assumptions that are believed to be reasonable, based on professional judgement. These assumptions differ slightly for each species, depending on data available, and are described in detail in Cramer (1996 & 2000).

Spring Chinook

The approach for establishing benchmark survival rates for spring chinook was developed by Cramer (2000) and differs substantially from that for fall chinook and coho. Cramer (2000) concluded that the best indicator of survival differences between years was the change in run sizes to Mayfield Dam prior to initiation of the hatchery. That run size was estimated during 1962 to 1966, and ranged from 2,854 to 17,274.

In order to calibrate (connect) the range in run sizes during 1962-66 to the range in survivals during more recent broods, it was assumed that the lowest run for 1962-66 had a survival to age 2 that was equivalent to the lowest survival estimated for the 1975-90 broods. That survival was 2.6% for the 1980 brood. If we assume the smolt-to-age 2 survival was 2.6% for fish that produced the 1963 run of 2,854, then we deduce that the 1964 run, which was 5.76 times greater (17,274) must have had a survival that was 5.76 times greater; which would be 15%. Thus, a survival of 15% was chosen as the benchmark for spring chinook (Table 1).

Fall Chinook

Benchmark survival for fall chinook was estimated by taking the geometric mean of smolt-to-age 2 survivals from 1964-1967 broods for all lower Columbia hatcheries combined (Cramer 1996). Those survivals ranged from 1% to 3.2% with a geometric mean of 2.2%. Thus, 2.2% was used as the benchmark survival rate for fall chinook, corresponding to the mitigation model year of 1964 (Table 1). The geometric mean (back-transformed mean of logarithms), was used because Cramer (1996) showed that the frequency distribution of survivals was log-normal.

Coho

Benchmark survival for coho was estimated by taking the geometric mean of smolt-to-age 2 survivals from 1967-1969, and 1972 broods of coho. Estimates for the first three of these broods were derived from fin mark experiments for all lower Columbia hatcheries combined (Cramer 1996), and the 1972 brood was actually from Cowlitz Hatchery. Those survivals ranged from 7% to 16.1% with a geometric mean of 8.0%. Thus, 8% was used as the benchmark survival rate corresponding to the mitigation model year of 1964 (Table 1). Again, the geometric mean (back-transformed mean of logarithms) was used because Cramer (1996) showed that the frequency distribution of survivals was log-normal.

Table 1. Benchmark smolt-to-age 2 survival rates that are estimated to apply to the salmon runs in 1964 and 1965 that became the models for mitigation goals.

Species	Run Year	Survival to Age 2	Method
Spring Ch	65	**15.0%**	Assume 1962 = worst survival = 2.6%. Then 1965 target is 5.76 times more
Fall Ch	64	**2.2%**	Geometric mean of 1961-64 broods
Coho	64	**8.0%**	Geometric mean of 1967-69, 72 broods

RESULTS

Reconstructed recruitment back to the start of age 3 for each brood since 1960 showed wide ranges in recruitment between broods for each race and species (Tables 2-4). Even the recruitment from the 1960-64 broods that were spawned, reared and smolted before Mayfield Dam was complete, varied by a factor of 7.6 for spring chinook, 1.8 for fall chinook, and 1.6 for coho. Estimated recruitment to age 3 (before age 3 catch) in the model year was as follows:

Species	Model Year (Brood Year)	Age 3 Recruits
Spring Chinook	1965 (1961)	106,134
Fall Chinook	1964 (1960)	73,940
Coho	1964 (1961)	124,277

These abundances of age 3 recruits serve as the standard of comparison for future broods. Note that the age 3 recruits for fall chinook in model year 1964 differs from the 71,735 value previously reported in Cramer (2000). This was due to the discovery of an error in a single variable in the model equation. Correcting the equation resulted in subtle changes in all past age 3 recruit values for fall chinook.

In order to make survival-equivalent comparisons of future recruitment at age 3 to that during the model years, one must first weight the future run for any difference in ocean survival from that which occurred in the model year. This weight , referred to as relative ocean survival, is simply the ratio of the survival in the model year to the survival in the future brood. That is:

Relative Survival Weight = [survival to age 2 in model year]/[survival to age 2 in future brood]

Relative survival then, equals 1.0 if the future brood has the same survival as the model brood, is > 1 if the present brood survived less than the model brood, and is < 1 if the present brood survived better than the model brood. Now, to calculate the survival equivalent recruitment, we calculate:

Survival Equivalent Recruitment = Age 3 Recruits x Relative Survival Weight

For example, the 1976 brood of spring chinook had age 3 recruitment of 134,031 and age 2 survival of 23%. This 23% survival is greater than the 15% survival estimated for the model year. To calculate how recruitment from the 1976 brood compared to the 1965 model recruitment, we have

1976 Survival-Equivalent Recruitment = 134,031 x (15%/23%) = 87,165

This survival-equivalent recruitment is less than the 106,134 fish for the model year, so we conclude that recruitment of spring chinook for the 1976 brood fell below the mitigation target.

Spring Chinook

Brood Year	Age 3-6 Catch	Age 3-6 Spawn	Age 3 Recruits	Observed Survival	Benchmark Scalar	Scaled Population
1960	42,598	14,538	79,416			
1961	59,505	19,035	106,134		1.00	106,134
1962	17,950	8,288	36,077			
1963	12,357	4,092	22,619			
1964	11,784	5,298	23,950			
1965	13,863	7,543	29,784			
1966	24,940	8,866	46,598			
1967	11,241	5,445	22,836			
1968	14,097	3,155	24,201			
1969	40,085	8,755	67,740			
1970	42,251	17,955	82,506			
1971	46,041	20,089	91,810	7.00%	**2.13**	195,852
1972	103,557	24,283	168,951	8.70%	**1.73**	292,456
1973	47,755	15,190	85,249			
1974	49,964	9,763	79,717			
1975	52,070	12,103	92,535	7.10%	**2.11**	194,854
1976	79,267	18,502	134,031	23.00%	**0.65**	87,165
1977	47,815	23,991	101,233	18.40%	**0.81**	82,468
1978	17,376	8,455	36,329			
1979	28,155	16,425	60,920			
1980	25,398	14,751	54,370	2.60%	**5.75**	312,771
1981	9,626	7,391	24,666	5.90%	**2.53**	62,444
1982	7,270	4,821	17,625	3.60%	**4.21**	74,254
1983	25,724	18,829	63,909	14.90%	**1.00**	64,179
1984	21,946	10,509	47,709	7.60%	**1.96**	93,591
1985	11,138	4,266	23,139	6.20%	**2.40**	55,484
1986	10,536	5,356	23,735			
1987	7,586	5,285	18,003	6.20%	**2.44**	43,881
1988	12,836	9,652	32,056			
1989	9,539	7,063	24,086	3.30%	**4.56**	109,849
1990	1,296	1,861	4,978	1.28%	**11.72**	58,338
1991	640	1,573	3,932	0.64%	**23.43**	92,123
1992	496	1,965	4,008	0.58%	**25.86**	103,643
1993	346	1,096	2,297	0.28%	**53.57**	123,065
1994	688	1,332	3,618	0.42%	**35.71**	129,185

Table 2. Estimated age 3 recruits and survival equivalency scaling for Cowlitz spring chinook that enables comparison of future broods to the benchmark run year and survival rate. "Scaled Population" is the survival-equivalent recruitment to age 3.

Fall Chinook

Brood Year	Age 3-6 Catch	Age 3-6 Spawn	Age 3 Recruits	Observed Survival	Benchmark Scalar	Scaled Population
1959	35,963	3,336	53,673			
1960	49,582	6,359	73,940	[illegible]	**1.00**	73,940
1961	49,208	6,420	72,099	2.40%	**1.00**	72,099
1962	82,220	5,970	113,084	1.00%	**1.00**	113,084
1963	45,291	4,731	64,075	3.10%	**1.00**	64,075
1964	91,407	3,486	123,225	3.20%	**1.00**	123,225
1965	70,282	4,023	101,492			
1966	191,428	9,311	263,881			
1967	114,078	12,652	161,372			
1968	38,480	7,210	60,182			
1969	92,385	5,083	125,417			
1970	42,078	4,661	62,190			
1971	27,592	5,086	44,293			
1972	45,488	3,837	63,416			
1973	24,674	2,681	36,333			
1974	38,381	3,037	53,774			
1975	29,910	4,756	45,674			
1976	25,310	3,424	37,475			
1977	21,552	4,419	36,354	1.30%	**1.69**	61,523
1978	12,281	4,184	21,999	0.50%	**4.40**	96,795
1979	8,974	4,301	17,305			
1980	17,925	8,196	38,524	1.10%	**2.00**	77,049
1981	13,558	5,921	27,477	0.70%	**3.14**	86,355
1982	14,421	4,797	25,355	0.80%	**2.75**	69,726
1983	59,942	15,478	96,638	2.60%	**0.85**	81,770
1984	62,496	19,894	115,808	2.80%	**0.79**	90,992
1985	32,908	8,974	56,944	0.60%	**3.67**	208,793
1986	7,577	6,267	21,503	0.40%	**5.50**	118,269
1987	3,544	4,006	10,876	0.10%	**22.00**	239,270
1988	7,686	2,917	16,885	0.20%	**11.00**	185,739
1989	12,623	2,115	21,291	0.19%	**11.58**	246,529
1990	3,514	6,050	13,515	0.45%	**4.91**	66,369
1991	830	4,034	8,065	0.18%	**11.96**	96,426
1992	1,929	5,080	11,463	0.32%	**6.79**	77,832
1993	4,137	5,725	15,135	0.32%	**6.98**	105,706
1994	746	915	2,749	0.29%	**7.46**	20,513

Table 3. Estimated age 3 recruits and survival equivalency scaling for Cowlitz fall chinook that enables comparison of future broods to the benchmark run year and survival rate. "Scaled Population" is the survival-equivalent recruitment to age 3.

Coho

Brood Year	Run Year	Adults at Fish Facility	Age 3 Catch	Age 3 Recruits	Observed Survival	Benchmark Scaler	Scaled Population
1958	1961	23,388	50,874	74,262			
1959	1962	22,701	56,701	79,402			
1960	1963	22,083	100,045	122,128			
1961	1964	25,546	98,731	124,277		1.00	124,277
1962	1965	22,774	100,408	123,182			
1963	1966	31,001	155,997	186,998			
1964	1967	18,801	98,401	117,202			
1965	1968	12,636	71,928	84,564			
1966	1969	4,913	16,292	21,205			
1967	1970	63,407	220,988	284,395	7.67%	**1.04**	296,689
1968	1971	33,239	203,860	237,099	12.23%	**0.65**	155,048
1969	1972	16,354	85,567	101,921	6.36%	**1.26**	128,280
1970	1973	19,954	209,591	229,545			
1971	1974	17,627	206,304	223,931			
1972	1975	23,000	423,936	446,936	6.98%	**1.15**	511,996
1973	1976	25,166	512,713	537,879			
1974	1977	10,299	286,933	297,232			
1975	1978	20,512	154,311	174,823			
1976	1979	13,912	148,918	162,830			
1977	1980	28,776	119,378	148,154			
1978	1981	27,003	132,617	159,620			
1979	1982	22,528	112,232	134,760			
1980	1983	24,493	69,690	94,183	3.79%	**2.11**	198,903
1981	1984	26,149	60,783	86,932	3.78%	**2.12**	183,898
1982	1985	18,610	60,781	79,391	2.60%	**3.07**	244,016
1983	1986	54,685	282,854	337,539	10.80%	**0.74**	250,091
1984	1987	18,716	69,192	87,908	3.21%	**2.49**	219,203
1985	1988	30,888	121,283	152,171	6.87%	**1.16**	177,199
1986	1989	35,886	165,941	201,827	7.93%	**1.01**	203,560
1987	1990	13,009	35,479	48,488	1.57%	**5.10**	247,495
1988	1991	46,303	162,033	208,336	8.83%	**0.91**	188,797
1989	1992	14,780	32,443	47,223	2.28%	**3.51**	165,820
1990	1993	5,641	10,837	16,478	0.84%	**9.58**	157,857
1991	1994	5,922	1,746	7,668	0.33%	**24.13**	185,052
1992	1995	7,637	9,118	16,755	0.44%	**18.18**	304,600
1993	1996	11,352	5,460	16,812	0.81%	**9.88**	166,099
1994	1997	15,694	8,494	24,188	0.98%	**8.16**	197,377
1995	1998	19,231	10,837	30,068	0.60%	**13.33**	400,806

Table 4. Estimated age 3 recruits and survival equivalency scaling for Cowlitz coho that enables comparison of future broods to the benchmark run year and survival rate. "Scaled Population" is the survival-equivalent recruitment to age 3.

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APPENDIX 1

Table A1. Age-specific parameter values used on Spring Chinook for ratios of total catch to reported catch (T/R Ratio), ocean harvest rate (Oharv), river harvest rate (Rharv), and percentage of hatchery fish spawning naturally in the home stream (not strays). Bolded values through 1989 were predicted using assumptions described in Cramer (2000) and in Appendix 2 for broods after 1989. Non-bolded values were estimated from marked groups.

Brood Year	Stray Rate	Age 2 T/R	Age 2 T/R	Age 4 T/R	Age 5 T/R	Oharv2	Oharv3	Oharv4	Oharv5	Rharv2	Rharv3	Rharv4	Rharv5
1958	0.0%	3.70	1.16	1.01	1.02	1.4%	23.5%	41.3%	51.1%	11.3%	54.4%	54.4%	54.4%
1959	0.0%	3.70	1.16	1.01	1.02	1.4%	24.3%	42.7%	52.8%	11.3%	48.7%	48.7%	48.7%
1960	0.0%	3.70	1.16	1.01	1.02	1.5%	25.1%	44.0%	54.5%	11.3%	45.8%	45.8%	45.8%
1961	0.0%	3.70	1.16	1.01	1.02	1.5%	25.8%	45.4%	56.2%	11.3%	52.0%	52.0%	52.0%
1962	0.0%	3.70	1.16	1.01	1.02	1.6%	26.6%	46.8%	57.9%	13.0%	35.7%	35.7%	35.7%
1963	0.0%	3.70	1.16	1.01	1.02	1.6%	27.4%	48.1%	59.6%	10.0%	43.8%	43.8%	43.8%
1964	0.0%	3.70	1.16	1.01	1.02	1.6%	28.2%	49.5%	61.3%	14.0%	25.7%	25.7%	25.7%
1965	0.0%	3.70	1.16	1.01	1.02	1.7%	28.9%	50.8%	62.9%	9.0%	19.8%	19.8%	19.8%
1966	0.0%	3.70	1.16	1.01	1.02	1.7%	29.7%	52.2%	64.6%	8.0%	35.2%	35.2%	35.2%
1967	0.0%	3.70	1.16	1.01	1.02	1.8%	30.5%	53.6%	66.3%	9.0%	25.3%	25.3%	25.3%
1968	0.0%	3.70	1.16	1.01	1.02	1.8%	31.2%	54.9%	68.0%	16.0%	33.8%	33.8%	33.8%
1969	0.0%	3.70	1.16	1.01	1.02	1.9%	32.0%	56.3%	69.7%	39.0%	39.0%	39.0%	39.0%
1970	0.0%	3.70	1.16	1.01	1.02	1.9%	32.8%	57.6%	71.4%	54.0%	20.6%	20.6%	20.6%
1971	0.0%	3.70	1.16	1.01	1.02	5.0%	27.0%	47.6%	80.2%	27.0%	31.3%	32.6%	29.8%
1972	0.0%	3.70	1.16	1.01	1.02	1.7%	42.1%	61.0%	84.6%	39.0%	55.8%	30.6%	29.4%
1973	0.0%	3.70	1.16	1.01	1.02	2.1%	32.8%	58.8%	73.4%	55.0%	47.3%	33.0%	30.4%
1974	0.0%	3.70	1.16	1.01	1.02	1.7%	39.7%	66.8%	58.8%	50.0%	55.8%	31.2%	32.3%
1975	0.0%	3.70	1.16	1.01	1.02	0.0%	22.5%	59.9%	70.0%	26.0%	46.4%	37.5%	30.0%
1976	0.0%	3.70	1.16	1.01	1.02	1.0%	34.7%	55.4%	65.6%	20.0%	52.3%	34.4%	37.5%
1977	0.0%	15.65	1.11	1.02	1.02	1.5%	16.2%	46.7%	58.9%	43.0%	52.7%	41.9%	27.9%
1978	0.0%	12.87	1.16	1.02	1.01	3.1%	20.6%	47.9%	58.7%	65.0%	41.7%	37.2%	31.8%
1979	0.0%	3.26	1.15	1.01	1.01	3.1%	20.6%	47.9%	58.7%	28.0%	41.7%	37.2%	31.8%
1980	0.0%	5.28	1.14	1.01	1.01	7.4%	21.2%	43.3%	49.8%	45.0%	11.3%	44.1%	29.6%
1981	0.0%	3.78	1.24	1.01	1.00	2.6%	10.3%	46.2%	60.6%	44.0%	50.4%	28.4%	32.1%
1982	0.0%	2.46	1.15	1.01	1.06	1.5%	16.5%	48.6%	70.4%	31.0%	18.4%	21.5%	30.0%
1983	0.0%	3.21	1.13	1.05	1.03	1.0%	14.4%	56.3%	72.1%	7.0%	37.0%	18.7%	27.2%
1984	0.0%	5.34	1.26	1.04	1.03	2.3%	10.7%	56.0%	48.3%	19.0%	65.5%	25.1%	30.6%
1985	0.1%	1.85	1.31	1.04	1.01	1.2%	11.7%	54.9%	25.0%	27.0%	74.9%	29.2%	41.7%
1986	0.2%	4.80	1.23	1.02	1.04	1.3%	12.4%	47.7%	60.2%	7.0%	25.0%	35.9%	37.5%
1987	0.4%	8.80	1.14	1.08	1.00	1.3%	18.7%	43.9%	48.3%	11.0%	24.4%	37.8%	13.8%
1988	0.0%	17.60	1.25	1.04	1.02	1.5%	16.4%	53.8%	51.3%	9.0%	20.4%	32.6%	16.3%
1989	0.0%	3.39	1.33	1.04	1.10	1.6%	14.1%	63.7%	54.3%	31.0%	16.4%	27.3%	18.8%
1990	2.7%	3.43	1.12	1.07	1.15	1.3%	8.2%	16.1%	18.5%	9.0%	30.7%	30.5%	6.9%
1991	8.6%	1.26	1.80	1.26	1.04	0.9%	9.1%	16.5%	19.0%	26.8%	21.8%	5.1%	7.8%
1992	0.0%	6.90	1.64	1.06	1.08	0.0%	1.9%	19.9%	22.9%	14.8%	21.9%	3.5%	11.6%
1993	4.5%	18.40	1.29	1.06	1.03	12.0%	8.1%	4.9%	5.7%	8.5%	13.1%	11.6%	4.3%
1994	3.0%	3.10	1.80	1.04	1.03	0.0%	5.2%	13.7%	15.7%	1.3%	16.2%	4.3%	22.0%
1995	6.1%	6.90	1.93	1.12	1.02	1.1%	1.4%	40.2%	46.2%	3.4%	6.8%	16.1%	7.8%

Table A2. Age-specific parameter values used on Fall Chinook for ratios of total catch to reported catch (T/R Ratio), ocean harvest rate (Oharv), river harvest rate (Rharv), and percentage of hatchery fish spawning naturally in the home stream (not strays). Bolded values through 1989 were predicted using assumptions described in Cramer (2000) and in Appendix 2 for broods after 1989. Non-bolded values were estimated from marked groups.

Brood Year	Stray Rate	Age 2 T/R	Age 2 T/R	Age 4 T/R	Age 5 T/R	Oharv2	Oharv3	Oharv4	Oharv5	Rharv2	Rharv3	Rharv4	Rharv5
1958	**0.77**	**3.70**	**1.16**	**1.01**	**1.02**	**1.4%**	**23.5%**	**41.3%**	**51.1%**	**64.4%**	**64.4%**	**64.4%**	**64.4%**
1959	**0.77**	**3.70**	**1.16**	**1.01**	**1.02**	**1.4%**	**24.3%**	**42.7%**	**52.8%**	**64.4%**	**64.4%**	**64.4%**	**64.4%**
1960	**0.77**	**3.70**	**1.16**	**1.01**	**1.02**	**1.4%**	**25.1%**	**44.0%**	**54.5%**	**58.3%**	**58.3%**	**58.3%**	**58.3%**
1961	**0.77**	**3.70**	**1.16**	**1.01**	**1.02**	**1.2%**	**20.4%**	35.8%	**44.4%**	69.4%	69.4%	69.4%	69.4%
1962	**0.77**	**3.70**	**1.16**	**1.01**	**1.02**	**1.8%**	**31.2%**	54.9%	**68.0%**	66.8%	66.8%	66.8%	66.8%
1963	**0.77**	**3.70**	**1.16**	**1.01**	**1.02**	**1.6%**	**28.4%**	49.9%	**61.7%**	64.6%	64.6%	64.6%	64.6%
1964	**0.77**	**3.70**	**1.16**	**1.01**	**1.02**	**1.9%**	**32.6%**	57.3%	**70.9%**	76.6%	76.6%	76.6%	76.6%
1965	**0.77**	**3.70**	**1.16**	**1.01**	**1.02**	**1.7%**	**28.9%**	**50.8%**	**62.9%**	**64.4%**	**64.4%**	**64.4%**	**64.4%**
1966	**0.77**	**3.70**	**1.16**	**1.01**	**1.02**	**1.7%**	**29.7%**	**52.2%**	**64.6%**	**73.5%**	**73.5%**	**73.5%**	**73.5%**
1967	**0.77**	**3.70**	**1.16**	**1.01**	**1.02**	**1.8%**	**30.5%**	**53.6%**	**66.3%**	**58.3%**	**58.3%**	**58.3%**	**58.3%**
1968	**0.77**	**3.70**	**1.16**	**1.01**	**1.02**	**1.8%**	**31.2%**	**54.9%**	**68.0%**	**37.0%**	**37.0%**	**37.0%**	**37.0%**
1969	**0.77**	**3.70**	**1.16**	**1.01**	**1.02**	**1.9%**	**32.0%**	**56.3%**	**69.7%**	**70.5%**	**70.5%**	**70.5%**	**70.5%**
1970	**0.77**	**3.70**	**1.16**	**1.01**	**1.02**	**1.9%**	**32.8%**	**57.6%**	71.3%	**40.0%**	**40.0%**	**40.0%**	**40.0%**
1971	**0.77**	**3.70**	**1.16**	**1.01**	**1.02**	5.0%	27.0%	47.6%	80.2%	27.0%	31.3%	32.6%	29.8%
1972	**0.77**	**3.70**	**1.16**	**1.01**	**1.02**	1.7%	42.1%	61.0%	84.6%	39.0%	55.8%	30.6%	29.4%
1973	**0.77**	**3.70**	**1.16**	**1.01**	**1.02**	2.1%	**32.8%**	**58.8%**	73.4%	55.0%	**47.3%**	**33.0%**	**30.4%**
1974	**0.77**	**3.70**	**1.16**	**1.01**	**1.02**	1.7%	39.7%	66.8%	58.8%	50.0%	55.8%	31.2%	32.3%
1975	**0.77**	**3.70**	**1.16**	**1.01**	**1.02**	0.0%	22.5%	59.9%	70.0%	26.0%	46.4%	37.5%	30.0%
1976	**0.77**	**3.70**	**1.16**	**1.01**	**1.02**	1.0%	34.7%	55.4%	65.6%	20.0%	52.3%	34.4%	37.5%
1977	0.58	15.65	1.11	1.02	1.02	3.8%	27.6%	42.6%	33.2%	68.0%	43.2%	30.1%	0.0%
1978	0.86	12.87	1.16	1.02	1.01	2.1%	19.5%	55.4%	46.8%	24.0%	9.4%	18.8%	0.0%
1979	0.91	3.26	1.15	1.01	1.01	**2.3%**	**17.9%**	**46.6%**	**34.8%**	36.0%	**10.6%**	**24.1%**	**2.3%**
1980	0.67	5.28	1.14	1.01	1.01	2.5%	16.3%	37.8%	22.7%	35.0%	11.8%	29.3%	4.5%
1981	0.79	3.78	1.24	1.01	1.00	3.9%	8.6%	39.5%	23.8%	60.0%	67.0%	19.6%	25.0%
1982	0.83	2.46	1.15	1.01	1.06	2.3%	12.4%	35.1%	45.9%	86.0%	48.8%	51.1%	29.8%
1983	0.74	3.21	1.13	1.05	1.03	1.6%	18.3%	41.6%	32.9%	37.0%	61.1%	44.5%	21.2%
1984	0.78	5.34	1.26	1.04	1.03	2.4%	10.3%	34.6%	19.2%	42.0%	57.2%	50.8%	12.3%
1985	0.79	1.85	1.31	1.04	1.01	0.9%	7.9%	41.9%	59.6%	38.0%	81.2%	30.2%	0.0%
1986	0.68	4.80	1.23	1.02	1.04	3.2%	7.5%	36.8%	28.4%	31.6%	25.0%	3.2%	27.2%
1987	0.80	8.80	1.14	1.08	1.00	3.3%	14.8%	18.5%	26.9%	24.3%	0.9%	21.1%	0.0%
1988	0.68	17.60	1.25	1.04	1.02	3.3%	14.7%	32.1%	78.6%	60.9%	9.5%	4.2%	30.0%
1989	0.69	3.39	1.33	1.04	1.10	2.1%	21.4%	70.7%	23.9%	64.5%	0.0%	11.4%	10.7%
1990	0.88	3.43	1.12	1.07	1.15	**2.4%**	8.0%	9.2%	30.4%	53.0%	39.0%	0.5%	2.4%
1991	**0.77**	1.26	1.80	1.26	1.04	1.5%	**6.0%**	1.9%	37.3%	49.5%	0.8%	4.6%	**1.4%**
1992	**0.77**	6.90	1.64	1.06	1.08	**2.4%**	4.0%	10.0%	11.5%	6.8%	6.3%	11.2%	3.0%
1993	**0.77**	18.40	1.29	1.06	1.03	**2.4%**	1.0%	25.2%	54.0%	24.2%	11.3%	20.0%	7.2%
1994	**0.77**	3.10	1.80	1.04	1.03	**2.4%**	**1.7%**	**23.4%**	**33.3%**	**44.8%**	**19.0%**	**8.7%**	**9.3%**
1995	**0.77**	6.90	1.93	1.12	1.02	**2.4%**	2.4%	21.5%	**33.3%**	66.7%	8.7%	23.4%	1.7%

Table A3. Parameter values used on Coho for ocean harvest rate (Oharv), river harvest rate (Rharv). Bolded values through 1989 were predicted using assumptions described in Cramer (2000) and in Appendix 2 for broods after 1989. Non-bolded values were estimated from marked groups.

Brood Year	Run Year	Harvest Rate River	Harvest Rate Ocean
1958	1961	**24.6%**	**58.3%**
1959	1962	**34.6%**	**56.3%**
1960	1963	**35.3%**	**72.1%**
1961	1964	**39.1%**	**66.2%**
1962	1965	**48.4%**	**64.2%**
1963	1966	**59.3%**	**59.3%**
1964	1967	**47.9%**	**69.2%**
1965	1968	**46.5%**	**72.1%**
1966	1969	**31.4%**	**66.2%**
1967	1970	48.6%	56.6%
1968	1971	34.7%	78.5%
1969	1972	14.6%	81.2%
1970	1973	**62.0%**	**77.1%**
1971	1974	**62.4%**	**79.0%**
1972	1975	77.7%	76.9%
1973	1976	**66.6%**	**86.0%**
1974	1977	**79.6%**	**83.0%**
1975	1978	**28.4%**	**83.6%**
1976	1979	**64.9%**	**75.6%**
1977	1980	**58.2%**	**53.5%**
1978	1981	**51.6%**	**65.0%**
1979	1982	**66.8%**	**49.7%**
1980	1983	5.9%	72.4%
1981	1984	57.1%	29.9%
1982	1985	60.0%	41.5%
1983	1986	75.2%	34.8%
1984	1987	62.2%	43.6%
1985	1988	67.4%	37.7%
1986	1989	64.0%	50.7%
1987	1990	34.8%	58.9%
1988	1991	64.1%	38.1%
1989	1992	39.8%	48.0%
1990	1993	31.4%	50.1%
1991	1994	9.8%	14.4%
1992	1995	10.7%	48.9%
1993	1996	12.1%	23.2%
1994	1997	19.7%	19.2%
1995	1998	**13.1%**	**26.4%**

APPENDIX 2

DERIVATION OF SURROGATE HARVEST RATES

Due to the extreme low numbers of CWT-marked fish that survived from the 1990-1995 broods, and the low or absent CWT recoveries in the various sport and commercial fisheries, estimation of recent harvest rates (both in the ocean and in the river) was very difficult. Cohort analysis is an efficient and accurate method for estimating harvest rates, as long as sufficient numbers of tagged fish are recovered. Without sufficient recoveries for each age group, in each fishery, in each year of the analysis, harvest rate estimation may be inaccurate or simply not possible.

After completing the first round of cohort analyses, it was clear from the many missing harvest rate values, that there were not enough CWT recoveries to accurately estimate harvest rates. However, from data on total landings and escapement it was clear that a significant fraction of fish were indeed harvested each year. Thus it became necessary to supply surrogate values of harvest rate where needed in order to accurately rebuild individual cohorts and derive meaningful and accurate harvest rate estimates. The methods we used for deriving the surrogate harvest rates are described in the following sections:

SPRING CHINOOK

For brood years 1990- 1995, ocean harvest rates for ages 2-4 (Oharv2- Oharv4) spring chinook were determined through cohort analysis from CWT recoveries. There were, however, few age 5 recoveries in any fishery due to the low numbers of fish remaining to mature at that age. This required that surrogate values for ocean harvest rate on age 5 spring chinook (Oharv5) be derived so that an accurate population reconstruction (back to age 2) would be possible.

To accomplish this, we examined ocean harvest rates from past cohort analyses on Cowlitz spring chinook (Cramer 2000). From these data it was clear that age 5 chinook are harvested (on average) at a greater rate than age 4 chinook. In order to estimate ocean harvest rates for age 5 chinook, we assumed that the average ratio of harvest rates between age 4 and age 5 spring chinook estimated for the1971- 1989 broods would apply to the 1990- 1995 broods. These harvest rates, their ratios, and the average multiplier were as follows:

Table A4. Average ratio of age 5 to age 4 ocean harvest rates for Cowlitz spring chinook. Only years with harvest rates estimated from CWT recoveries are used. Data from Cramer (2000).

Brood Year	Harvest Rates		Harvest Ratio
	Age 4	Age 5	
1971	47.6%	80.2%	1.69
1972	61.0%	84.6%	1.39
1974	66.8%	58.8%	0.88
1975	59.9%	70.0%	1.17
1976	55.4%	65.6%	1.18
1977	46.7%	58.9%	1.26
1980	43.3%	49.8%	1.15
1981	46.2%	60.6%	1.31
1982	48.6%	70.4%	1.45
1983	56.3%	72.1%	1.28
1984	56.0%	48.3%	0.86
1985	54.9%	25.0%	0.45
1986	47.7%	60.2%	1.26
1987	43.9%	48.3%	1.10
1989	63.7%	54.3%	0.85
Average Ratio Multiplier			**1.15**

This average multiplier was applied to harvest rates of age 4 spring chinook in order to obtain estimates of harvest rate for age 5 spring chinook in the 1990- 1995 broods. The resulting estimates are presented in Table A1.

CWT recoveries were also scarce in the freshwater (i.e. river) fisheries for all ages of Cowlitz spring chinook from brood years 1990- 1995. In order to obtain an accurate population reconstruction, it was required that surrogate river harvest rates be estimated. Harvest rates in both the Columbia River and the Cowlitz River were estimated by reconstructing the entire landings and escapement of lower Columbia spring chinook (Table A5). Those values were substituted into the cohort analysis for the values of total river harvest (Rharv) by brood year and age.

Table A5. Harvest rates for spring chinook in the Columbia and Cowlitz Rivers as well as total river harvest. Columbia River run and catch data in thousands of adult spring chinook destined for areas below Bonneville dam. Columbia River data from PFMC (2002). Cowlitz River harvest rates estimated from catch, escapement, and natural spawner data provided by WDFW. Rharv= Col r. harv. + [Cow r. harv. (1- Col r. harv.)].

	Columbia River					Cowlitz River					Total River				
						Harvest Rates by age					Harvest Rates by age				
Run Year	Run Size	Comm Catch	Sport Catch	Total Catch	Harvest Rate	2	3	4	5	6	2	3	4	5	6
1977	92.1	6.8	3.1	9.9	10.7%										
1978	106.7	13.5	5	18.5	17.3%										
1979	68.7	5.5	1.7	7.2	10.5%										
1980	73	0.4	0.8	1.2	1.6%	59.0%	65.7%	39.1%	20.3%	35.8%	59.6%	66.3%	40.1%	21.6%	36.9%
1981	93.8	6.7	3.4	10.1	10.8%	20.3%	47.7%	23.9%	8.3%	9.3%	28.9%	53.4%	32.1%	18.1%	19.0%
1982	110.3	4.6	2.2	6.8	6.2%	17.2%	49.7%	44.6%	27.3%	34.8%	22.3%	52.8%	48.0%	31.8%	38.8%
1983	91.6	5.4	2.2	7.6	8.3%	17.8%	60.5%	39.6%	24.3%	0.0%	24.6%	63.8%	44.6%	30.6%	8.3%
1984	114.6	8.2	1.7	9.9	8.6%	10.4%	39.1%	34.5%	38.8%	0.0%	18.2%	44.4%	40.1%	44.1%	8.6%
1985	831.7	9.9	1.1	11	1.3%	7.3%	7.8%	29.1%	30.8%	100.0%	8.5%	9.0%	30.0%	31.7%	100.0%
1986	90.6	8.6	4.4	13	14.3%	11.1%	19.3%	28.6%	31.5%	0.0%	23.9%	30.9%	38.8%	41.3%	14.3%
1987	132.4	10.6	2.4	13	9.8%	20.0%	35.4%	24.5%	11.9%	0.0%	27.9%	41.8%	31.9%	20.6%	9.8%
1988	146	13.2	3.2	16.4	11.2%	2.4%	29.9%	25.2%	24.8%	0.0%	13.3%	37.8%	33.6%	33.3%	11.2%
1989	136.9	12.4	2.5	14.9	10.9%	2.6%	23.1%	31.4%	18.7%	27.1%	13.2%	31.4%	38.9%	27.6%	35.1%
1990	151.4	16.2	9.1	25.3	16.7%	1.6%	60.9%	34.1%	30.5%	64.9%	18.1%	67.5%	45.1%	42.1%	70.8%
1991	130.2	11.7	4.1	15.8	12.1%	22.1%	50.2%	38.5%	38.0%	25.8%	31.5%	56.3%	46.0%	45.5%	34.8%
1992	102	5.1	4.1	9.2	9.0%	5.8%	19.5%	22.4%	7.0%	0.0%	14.3%	26.8%	29.4%	15.4%	9.0%
1993	89.7	2.1	1.4	3.5	3.9%	0.0%	51.2%	30.8%	30.2%	0.0%	3.9%	53.1%	33.5%	32.9%	3.9%
1994	60.5	1.6	1.6	3.2	5.3%	0.0%	43.2%	36.2%	32.6%	0.0%	5.3%	46.2%	39.5%	36.1%	5.3%
1995	50.3	0.2	0	0.2	0.4%	0.0%	21.6%	7.0%	6.5%	7.6%	0.4%	21.9%	7.3%	6.9%	7.9%
1996	42.4	0.9	0	0.9	2.1%	0.0%	11.2%	1.4%	1.5%	4.0%	2.1%	13.1%	3.5%	3.6%	6.0%
1997	46.3	1.9	0	1.9	4.1%	0.0%	12.6%	7.8%	7.8%	20.0%	4.1%	16.2%	11.6%	11.6%	23.3%
1998	53.2	2.2	0.1	2.3	4.3%	0.0%	2.6%	0.0%	0.0%	0.0%	4.3%	6.8%	4.3%	4.3%	4.3%
1999	62.1	1.9	0	1.9	3.1%	0.0%	9.9%	22.0%	25.3%	0.0%	3.1%	12.7%	24.4%	27.5%	3.1%

Built into the cohort analysis model (for each age of fish) is a user-defined variable for unsampled harvest. This variable allows for sources of unsampled harvest to be accounted for in both the harvest rate estimation and the population reconstruction. Therefore, if a river fishery had less than three CWT recoveries in a given year for a given age of spring chinook, those CWT recoveries were excluded and the surrogate values of harvest rate (from Table A5) were inserted into the unsampled harvest variable and used in the reconstruction. For example, if the Columbia River fishery had a total of 10 CWT recoveries in 1990 for age 4 chinook and the Cowlitz sport fishery had only 2, the 2 recoveries in the Cowlitz were excluded and the Cowlitz (age-specific) harvest rate was used instead. Similarly, if neither fishery had more than four recoveries the total river harvest rate would be used. The resulting estimates are presented in Table A1.

FALL CHINOOK

For brood years 1990- 1993 & 1995, most ocean harvest rates for ages 3-5 (Oharv3-Oharv5) fall chinook were determined through cohort analysis from CWT recoveries. However, only 1991 had any ocean recoveries for age 2 chinook, and 1994 had no recoveries for any age group. Thus, it was necessary to derive surrogate ocean harvest rates for the missing brood years for accurate population reconstruction. Once again we looked to past cohort analyses (Cramer 2000) to help derive our surrogate values. For age 2 fall chinook, we assumed that the average harvest rate from brood years 1985- 1989 and 1991 would be a reasonable surrogate for the missing years. During this time period there appeared to be no significant regulatory changes which would alter the harvest rates on the age 2 fish. Thus, this average harvest rate was used in the missing years 1990 and 1992-1995.

Brood years 1994 and 1995 were also missing ocean harvest rates for age 5 fall chinook. To obtain surrogate harvest rates for these years we assumed that the average ocean harvest rate from 1990- 1993 would be a reasonable surrogate for both missing years. Again, during this time there were no regulatory changes which would have altered the harvest rates on the age 5 fish. Thus, this average harvest rate was used in the missing years 1994 and 1995. For the remainder of the missing ocean harvest rates (age 3 chinook in 1991 and 1994, and age 4 chinook in 1994) surrogates were derived by taking the average harvest rate of the year prior and the year after. For example, the missing harvest rate in 1994 was obtained by taking the average from 1993 and 1995. The resulting estimates are presented in Table A2.

CWT recoveries were also absent from the freshwater fisheries in nearly all years, for all ages of Cowlitz fall chinook from brood years 1990- 1995. In order to obtain an accurate population reconstruction, it was required that surrogate river harvest rates be estimated. Surrogate river harvest rates were estimated and used in the same way as was described for spring chinook. That is, harvest rates in both the Columbia River and the Cowlitz River were reconstructed from total catch and escapement of lower Columbia fall chinook (Table A6), and those values applied to the cohort analysis in order to obtain estimates of total river harvest (Rharv) by brood year and age (Table A2).

Table A6. Harvest rates for fall chinook in the Columbia and Cowlitz Rivers as well as total river harvest. Columbia River run and catch data for adult LRH fall chinook from fall chinook database (WDFW unpublished data). Cowlitz River harvest rates estimated from catch, escapement, and natural spawner data provided by WDFW. Rharv= Col r. harv. + [Cow r. harv. (1- Col r. harv.)].

	Columbia River			Cowlitz River					Total River (Rharv)				
				Harvest Rates by age					Harvest Rates by age				
Run Year	Run Size	Total Catch	Harvest Rate	2	3	4	5	6	2	3	4	5	6
1980	105,584	31,690	30.0%										
1981	94,854	1,861	2.0%										
1982	139,466	41,979	30.1%										
1983	88,066	11,536	13.1%										
1984	102,446	29,876	29.2%										
1985	110,985	17,105	15.4%										
1986	154,821	80,022	51.7%										
1987	344,080	176,219	51.2%										
1988	309,949	174,721	56.4%										
1989	130,887	34,777	26.6%										
1990	59,954	4,281	7.1%	41.1%	11.9%	9.9%	9.7%	0.0%	45.3%	18.2%	16.4%	16.2%	7.1%
1991	62,680	11,467	18.3%	34.7%	20.8%	7.2%	9.3%	0.0%	46.6%	35.3%	24.2%	25.9%	18.3%
1992	62,617	7,729	12.3%	46.4%	16.7%	13.1%	11.2%	0.0%	53.0%	27.0%	23.8%	22.2%	12.3%
1993	52,344	7,478	14.3%	41.1%	14.7%	12.8%	12.9%	0.0%	49.5%	26.9%	25.3%	25.4%	14.3%
1994	53,596	0	0.0%	6.8%	0.8%	0.5%	0.4%	0.0%	6.8%	0.8%	0.5%	0.4%	0.0%
1995	46,349	1,467	3.2%	21.7%	3.2%	1.5%	1.0%	0.0%	24.2%	6.3%	4.6%	4.1%	3.2%
1996	72,557	4,214	5.8%	41.4%	8.2%	5.8%	5.2%	0.0%	44.8%	13.5%	11.2%	10.7%	5.8%
1997	55,197	5,511	10.0%	63.0%	10.0%	11.1%	9.9%	0.0%	66.7%	19.0%	20.0%	18.9%	10.0%
1998	43,829	3,810	8.7%	0.0%	0.0%	0.0%	0.0%	0.0%	8.7%	8.7%	8.7%	8.7%	8.7%
1999	40,000	**3,734**	**9.3%**	41.0%	34.2%	15.5%	0.0%	0.0%	46.5%	40.4%	23.4%	9.3%	**9.3%**

COHO

Harvest rates, in both the ocean and freshwater, for coho salmon from the Cowlitz river were estimated from CWT recoveries for brood years 1992- 1994. However, there were no recoveries from either location for brood year 1995. This required that a surrogate harvest rate value be estimated in both locations for 1995. To obtain the surrogate value, we assumed that the average harvest rate (estimated separately in both the ocean and the river) from brood years 1991 - 1994 was a reasonable surrogate for the missing rate. During this time period there appeared to be no significant regulatory changes which would alter the harvest rates on either jack or adult coho. Thus, these average harvest rates was used in the missing brood year 1995. The resulting estimates are presented in Table A3.

APPENDIX 3

ANALYTICAL MODELING STEPS

OBJECTIVE 1. Identify the CWT-marked fish of each species released from Cowlitz Salmon Hatchery each year since the latest tabulation.

Task 1.1 Sort and download detailed tag and release information from the Pacific States Marine Fisheries Commission (PSMFC) database: Regional Mark Information System (RMIS, www.rmis.org/index.html).

OBJECTIVE 2. Identify the CWT-marked fish of each species recovered in the various fisheries.

Task 2.1 Actual expanded mark recoveries can be sorted and downloaded from the PSMFC Regional Mark Information System. Only "sample types" of 1, 2, or 3 are used in the recovery data.

Using the fishery code and recovery site code, all recoveries of chinook are labeled as Ocean, Hatchery, Stray, Net, or River-Sport. All recoveries in the ocean and Puget Sound are labeled as ocean. All recoveries at the Cowlitz Salmon Hatchery are labeled as hatchery. All Cowlitz hatchery fish recovered in tributaries other than the Cowlitz River are labeled as stray. All recoveries from the Columbia River commercial gillnet fishery are labeled as net. All non-commercial recoveries from the Columbia or Cowlitz Rivers are labeled as river-sport. The age of each recovered fish is determined by subtracting the brood year from the run year.

After labeling each recovery, all hatchery and net recoveries are sorted by sex. Sex ratios are then determined by species, age and year. Any unsexed samples are assigned a sex based on the male/female percentage for the particular run year and age where sex data is available. If there is no sex data for the specific run and age, then averages by age are used.

Using the fishery code and recovery site code, all recoveries of coho are split into the following categories: Hatchery, Buoy 10, Net, River-Sport, Ocean north (north of Columbia River), Ocean south (south of Columbia River) and Strays. All recoveries at the Cowlitz Salmon Hatchery are labeled as hatchery. All recoveries in the sport fishery that were estuary fisheries are labeled as ocean, except for those from the Columbia River estuary which are labeled as Buoy 10. All recoveries from the Columbia River commercial gillnet fishery are labeled as net. All non-commercial recoveries from the Columbia or Cowlitz Rivers are labeled as river-sport. All Cowlitz hatchery fish recovered in tributaries other than the Cowlitz River are labeled as stray.

OBJECTIVE 3. Estimate parameters for use in cohort analysis (**Cohort** worksheets).

Chinook

T/R Ratio: This ratio (located on the parameter tab of the cohort analysis worksheet) is equal to total harvest related deaths divided by reported catch in the ocean, and is calculated for spring and fall chinook at ages 2- 6. Data is acquired from the Pacific Salmon Commission's "Annual Chinook Cohort Analysis" (contact: Rishi Sharma, CRITFC, PSC). Total ocean catch at age is equal to total fishery catch. Total harvest related death is equal to the sum of total catch plus total shaker mortality plus total CNR legal and sub-legal mortality.

Sex Ratio: This ratio (located on the parameter tab of the cohort analysis worksheet) is the percentage of males by year and age, and is determined from the CWT recoveries (refer to Task 2.1).

Coho

Harvest Rates in Cowlitz River: Harvest rates in the Cowlitz River are estimated by year for ages 2-4 coho salmon. This parameter (located on the harvest rate tab of the cohort analysis worksheet) is estimated using data for Cowlitz Salmon Hatchery escapement, natural spawn escapement and sport catch from within the Cowlitz river. Estimates of harvest rate on age 3 coho are used as estimates for age 4 coho (Contact: Kelly Harlan, WDFW).

OBJECTIVE 4. Estimate age-specific survival to ocean recruitment, age-specific maturity rates, and age-specific harvest rates for each CWT-marked group of each species.

Task 4.1 All tag groups and their associated CWT recovery numbers are entered manually into the cohort analysis worksheet (located on the cohort tab of the cohort analysis worksheet). Survival, maturity, and harvest rate parameters are then estimated automatically for each marked group.

Task 4.2 Only CWT groups with a sufficient number (> 200) of recruits to age two (**RECRUIT2**) are used in the final cohort analysis. Data may be combined from similar CWT groups with low **RECRUIT2** numbers to obtain a single group with a **RECRUIT2** value greater than 200. In combining tag groups, only groups of the same brood year, the same general weight, and the same general time of release are considered for grouping. If a tag group has < 200 recoveries and can not be combined with other similar tag groups, it is not included in the cohort analysis.

OBJECTIVE 5. Estimate recruitment to age 3 for each species and brood year.

Run reconstructions for each species (**Opop** worksheets) are completed using the results of the final cohort analyses from Objective 4. The run reconstruction estimates the total number of fish from Cowlitz Salmon Hatchery, marked and unmarked of each species, that would have reached age 3 in the ocean in the absence of harvesting.

Task 5.1 Obtain averages by species, brood year, and age for the variables: stray rate (**StrayRT**), ocean harvest (**OHARV**), river harvest (**Rharv**), and maturity rate (**MATR**) from the final cohort analysis.

Chinook

Task 5.2 For chinook, all averages (from task 5.1), along with the variables: **% males** at age and the **T/R ratio** (from the parameter tab of the cohort analysis worksheet) are input into the harvest rate tab of the **Opop** model worksheet.

Once these values have been entered, the number of fish of each age returning to the Cowlitz hatchery is entered into the immature tab of the **Opop** model worksheet. Various parameters are then calculated automatically within this page. Run year is then entered on the catch tab of the **Opop** model worksheet and various parameters are again calculated automatically within this page. Finally, both run year and brood year are entered into the Opop3 tab of the **Opop** model worksheet and age 3 ocean population is calculated automatically.

Coho

Task 5.3 For coho, the averages of **Oharv** and **Rharv** (from task 5.1) for age 3 fish and the averages of **Surv** and **Matr** (from task 5.1) for age 2 fish are input into the model. Also input are other parameters such as: adults returning to the hatchery by year, and harvest rates within the Cowlitz River by year. Various parameters, including age 3 ocean population, are then calculated automatically within this page.

OBJECTIVE 6. Estimate the survival-equivalent adjustment to recruitment.

Task 6.1 After the number of age 3 recruits is estimated for each species, it is then scaled to an ocean survival equivalent to that for the mitigation model year. The scaling factor used is the ratio of survival-to-age 2 in the model year to that for the brood year of interest (observed survival). The smolt-to-age 2 survival rate for the mitigation model year is 15.0% for spring Chinook, 2.2% for fall Chinook, and 8.0% for coho (Table 1). The final **"scaled population"** is the product of the scaling factor and the age 3 recruits. This value is compared to the age 3 population in the model year (Table 2) to evaluate the mitigation success of the Cowlitz Salmon Hatchery.

Table 1. Benchmark smolt-to-age 2 survival rates in 1964 and 1965 that became the models for mitigation.

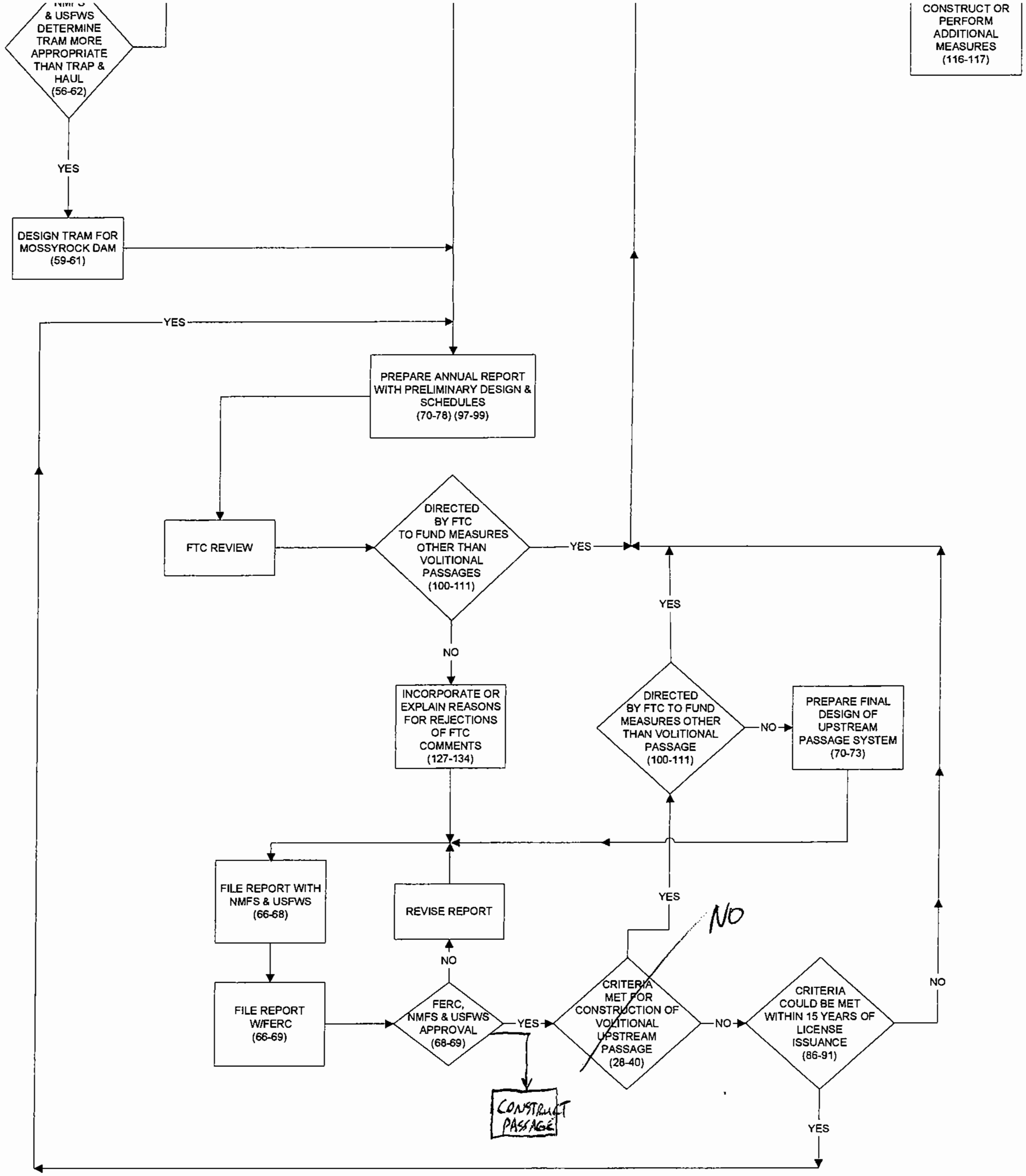
Species	Run Year	Survival To Age 2	Method
Spring Ch	65	15.0%	Assume 1962 = worst survival = 2.6%. Then 1965 target is 5.76 times more
Fall Ch	64	2.2%	Geometric mean of 1961-64 broods
Coho	64	8.0%	Geometric mean of 1967-69, 72 broods

Table 2. Reconstructed recruitment back to the start of age 3 in the model year to be used as the performance standard for Cowlitz Salmon Hatchery.

Species	Model Year (Brood Year)	Age 3 Recruits
Spring Chinook	**1965 (1961)**	**106,134**
Fall Chinook	**1964 (1960)**	**73,940**
Coho	**1964 (1961)**	**124,277**

ATTACHMENT No. 3

Flow chart for SA license article 3.



Rev. ont 11/26
Comments to Tom

NUMBERS IN PARENTHESIS
REFER TO LINE NUMBERS
ON THE ATTACHED
REFERENCE KEY

November 14, 2003

Tacoma Power Cowlitz River Project - License No. 2016
Flow Chart/Decision Tree Reference Key
Settlement Agreement Article 3. Upstream Fish Passage: Barrier, Mayfield and Mossyrock.

1. **a)** The Licensee, in consultation with the National Marine Fisheries Service and U.S.
2. Fish and Wildlife Service shall provide and maintain effective upstream fish passage at
3. the Barrier Dam, Mayfield Dam and Mossyrock Dam through trap and haul facilities
4. immediately upon license issuance, and continuing until volitional upstream passage
5. systems have been implemented in accordance with this article.

6. **b)** Within six months of license issuance, or as soon as practicable thereafter depending
7. on the availability of marked fish, and updated on an annual basis thereafter, the
8. Licensee shall file with the Commission a report on adult anadromous fish traveling
9. through the Cowlitz River Project, prepared in collaboration with the Fisheries Technical
10. Committee provided for in the August 2000 Settlement Agreement, or if the Settlement
11. Agreement has become void, with the U.S. Fish and Wildlife Service, National Marine
12. Fisheries Service, Washington Department of Fish and Wildlife and Washington
13. Department of Ecology (referred to as "the FTC or agencies"). The report shall include:

14. **1)**the most recent version of Tables 3, 4, and 5 from the report entitled *Contribution*
15. *Rate Benchmarks for Future Runs of Spring Chinook, Fall Chinook, and Coho Produced*
16. *at the Cowlitz Salmon Hatchery* that provide estimated age 3 recruits and survival
17. equivalency that enables comparison of future broods to the benchmark run year and
18. survival rate for each of these species, dated June 28, 2000 and filed with the
19. Commission concurrently with the August 2000 Cowlitz River Hydroelectric Project
20. Settlement Agreement;

21. **2)** tables estimating the annual number of adult recruits
22. originating from the Cowlitz River basin upstream of the Toutle River, and including
23. steelhead, cutthroat trout, and all other indigenous stocks that are produced at the
24. hatcheries, along with an index of each stock to its benchmark values, or if not otherwise
25. agreed, a default index of"1 ";

26. **3)** a plan and schedule for studies, to be conducted at
27. regular intervals, to evaluate whether the following criteria for implementing effective
28. upstream passage through volitional facilities have been met: **A)** adult fish in Mayfield
29. Lake are able to choose their tributary of origin and survive Mayfield Lake transit at rates
30. determined by NMFS and USFWS, in consultation with the FTC or agencies, to be
31. sufficient to achieve effective upstream passage through volitional facilities; and **B)** as
32. determined based on the above-described tables with respect to: **(i)** the number of pre-
33. spawners arriving at the Barrier Dam, in at least 3 of 5 consecutive brood years
34. measured, and based on the 5-year rolling average, exceeds an abundance level which
35. indicates natural recruitment above Mayfield Dam has achieved self-sustaining levels, as
36. determined by the National Marine Fisheries Service in consultation with the FTC or
37. agencies; **(ii)** the productivity level in 3 of 5 years and the 5-year rolling average, as
38. measured at the Barrier Dam or other Cowlitz River fish counting facilities by the
39. recruit/pre-spawner ratio, exceeds 1.0; and **(iii)** the disease management plan required by
40. Article 8 has been implemented.

c) For any annual report filed within 12 years of license issuance in which the results of the studies indicate that, within the next three years or less, the above criteria for volitional upstream passage will be met with respect to any salmonid species originating in the Tilton basin and with respect to either spring Chinook salmon or late winter steelhead originating above Mossyrock Dam, the Licensee shall also include proposed preliminary designs and schedules for the construction of upstream passage systems for the Project. In the case of Barrier Dam, the proposed modifications shall provide for breaching the Barrier Dam. In lieu of breaching, a fish ladder may be constructed only if NMFS and USFWS determine, in consultation with the FTC or agencies, that a ladder is more appropriate than breaching for effective upstream passage. The proposed modifications for the Barrier Dam shall also include steps to disable the electrical field in the event of fish ladder construction or breaching the dam. In the case of Mayfield Dam, the upstream passage system proposed shall be a ladder with sorting facilities, unless prior to filing the report the NMFS and USFWS determine that a tram is more appropriate than a ladder for effective upstream passage, in which case the system proposed shall be a tram with sorting facilities. In the case of Mossyrock Dam, the passage system proposed shall be an adult trap and haul facility to facilitate adult transit above Cowlitz Falls Dam to be built before or concurrently with the upstream passage system at Mayfield Dam, unless prior to filing the report the USFWS and NMFS determine that a comparably-priced tram is more appropriate than a trap and haul facility based on studies that show fish are able to migrate through Riffe Lake, and it has also been determined that an adult upstream passage facility will be developed at Cowlitz

Falls Dam. A draft report shall be provided to the FTC or agencies for review and comment. The Licensee shall include with the report documentation of consultation and copies of comments and recommendations on the report, and specific descriptions of how the FTC's and agencies' comments are accommodated by the report. The Licensee shall submit the final report to the NMFS and USFWS for approval prior to filing with the Commission. Upon approval by NMFS and USFWS and filing with the Commission, the Licensee shall implement the proposals in the report.

d) Upon meeting the criteria above for the construction of volitional upstream passage systems, the Licensee shall proceed expeditiously to complete the final design, permitting and construction of upstream passage systems. The final design shall be subject to the same review and approval process described in paragraph c) above. Once the report containing the final design and implementation schedule for the construction of upstream fish passage systems is approved by NMFS and USFWS and filed with the Commission, volitional upstream passage facilities shall be completed and made operational within one (1) year of meeting the criteria or approval of the final design, whichever is later, unless there is good cause for extending the period beyond one year.

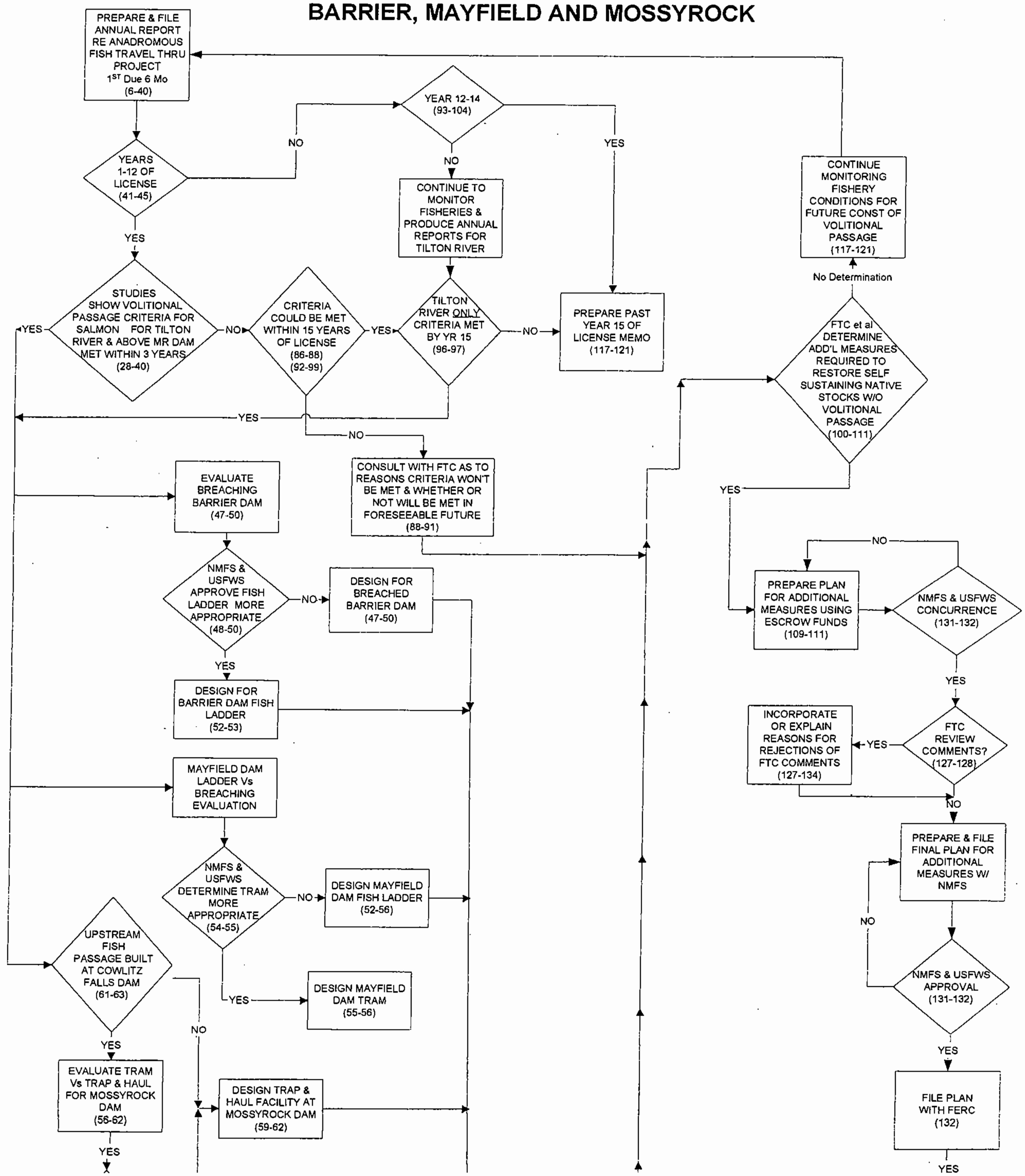
e) Within five years of license issuance, the Licensee shall establish an interest-bearing escrow account in the amount of $15 million to contribute to the total cost of constructing volitional upstream fish passage facilities. To minimize administrative cost and allow conservative growth, said escrow account may be held by the Licensee as a separate account (with Licensee being obligated to treat said account substantially similar to an escrow account), and said account may be invested, consistent with investment limitations on public agencies within the State of Washington.

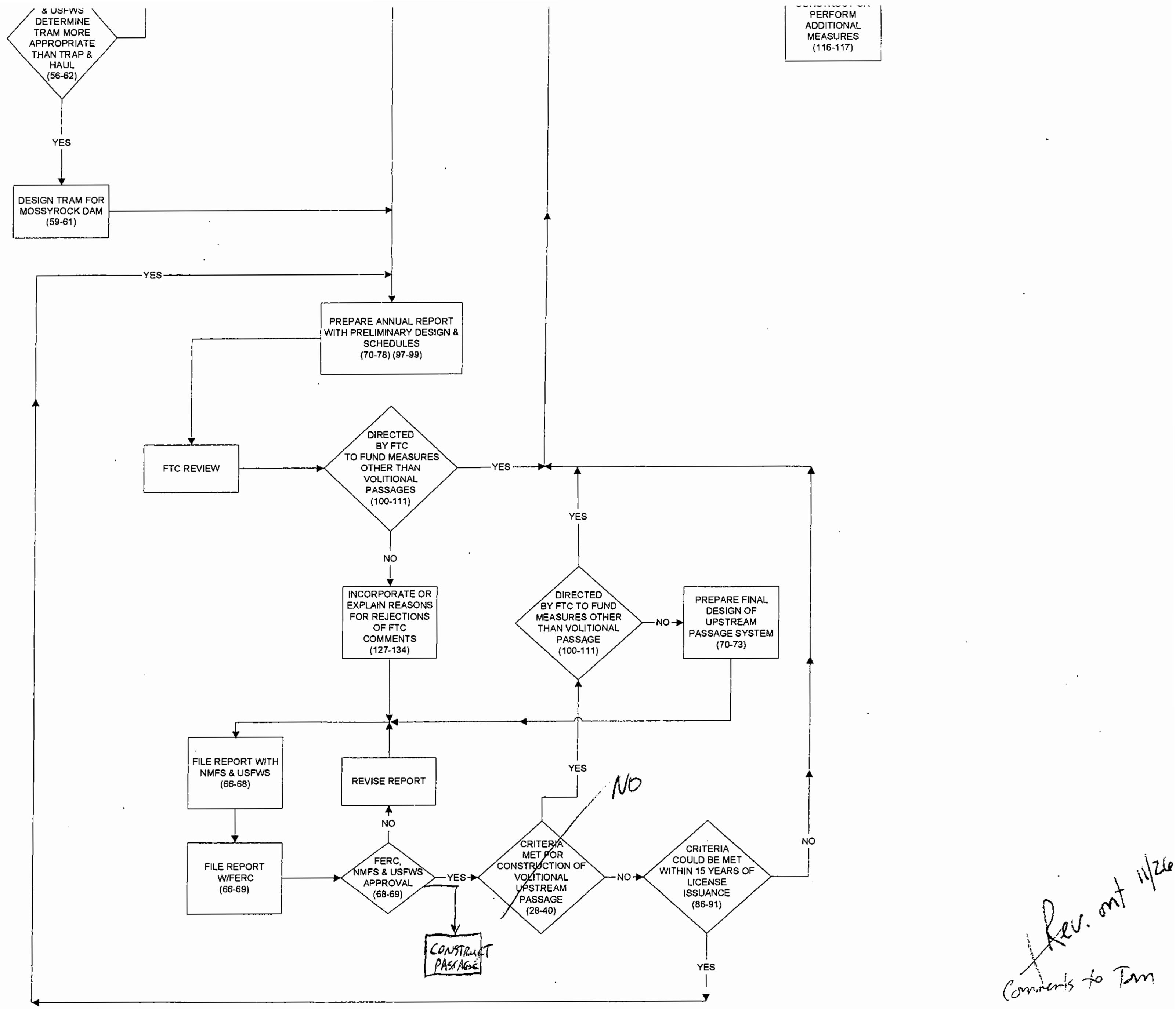
f) If at any time the Licensee files a report indicating that the above criteria are not likely to be met within 15 years following license issuance with respect to listed Chinook salmon or steelhead originating above Mayfield Dam, the Licensee shall consult with the FTC or agencies, using the best available data at the time, regarding factors that may be contributing to the failure to meet such criteria, and the likelihood or not that such criteria will be met for the listed stocks in the foreseeable future.

g) If preliminary or final upstream volitional fish passage design plans and implementation schedules have not been approved and filed with the Commission at the end of year 12, the Licensee must prepare and submit preliminary design plans and schedules in accordance with paragraphs c) and d) if the volitional upstream passage criteria set forth in paragraphs b) and c) have been met or are likely to be met for any salmonid species in the Tilton by year 15. The Licensee shall proceed expeditiously with final design and construction of volitional upstream passage facilities, unless otherwise directed under paragraph h) below.

h) If within 14 years of license issuance the criteria for volitional upstream passage facilities, described in b), c) and g) above, have not been met and it is determined by the FTC or agencies, and affected Tribes, with the concurrence of NMFS and USFWS, that measures in addition to those provided for in the August 2000 Settlement Agreement are

TACOMA POWER
COWLITZ RIVER PROJECT–LICENSE NO. 2016
SETTLEMENT AGREEMENT - ARTICLE 3 - UPSTREAM FISH PASSAGE
BARRIER, MAYFIELD AND MOSSYROCK





NUMBERS IN PARENTHESIS REFER TO LINE NUMBERS ON THE ATTACHED REFERENCE KEY

November 14, 2003

necessary to restore self-sustaining, natural production of ESA-listed stocks in the Cowlitz River basin, and that expenditure of the escrow fund on such additional measures in lieu of volitional upstream facilities is necessary and appropriate to achieve natural stock restoration, consistent with the express purpose of the license and the Settlement Agreement, and with applicable recovery plans for the listed Cowlitz River stocks, the Licensee shall submit to the Commission a plan to abandon volitional upstream passage and expend the funds in the escrow account for the purposes of protecting and promoting restoration and recovery of listed Cowlitz River stocks. The draft plan shall be submitted to the FTC or agencies for 30-day review and comment period. The Licensee shall include with the plan documentation of consultation and copies of comments and recommendations on the plan, and specific descriptions of how the FTC ' s or agencies' comments are accommodated by the plan. The Commission reserves the right to require changes to the plan. Upon Commission approval, the Licensee shall implement the plan. If the above criteria have not been met for any salmonid species in the Tilton by year 15, the Licensee shall continue monitoring fishery conditions for future construction of upstream volitional fish passage, until either the criteria are met or a decision is made to abandon upstream volitional passage and fund other necessary and appropriate measures in accordance with this paragraph.

i) Following construction of volitional upstream passage facilities, the Licensee, in consultation with the FTC or the agencies, shall monitor the effectiveness of the facilities. As deemed necessary by NMFS and USFWS, after consultation with the FTC, the Licensee shall implement such reasonable modifications as may be necessary to improve passage effectiveness.

127. **j)** Any plan required to be filed pursuant to this article shall be prepared in consultation
128. with the FTC or agencies. The Licensee shall include with the plan documentation of
129. consultation and copies of comments and recommendations on the plan, and specific
130. descriptions of how the FTC's or agencies' comments are accommodated by the plan.
131. The Licensee shall submit the plan to the National Marine Fisheries Service and U.S.
132. Fish and Wildlife Service for approval prior to filing with the Commission. Upon
133. approval by NMFS and USFWS and filing with the Commission, the Licensee shall
134. implement the plan.

ATTACHMENT No. 4

Cowlitz River Adult Fish Transportation brochure.

Cowlitz River Project
TACOMA POWER

Cowlitz River
Adult Fish Transportation

Managing fisheries on the Cowlitz River requires transporting wild and hatchery salmon and steelhead past the Cowlitz River Project dams and reservoirs. This is called trap-and-haul. In addition, surplus hatchery-origin adult salmon and steelhead are often transported back to the lower river to give anglers another chance to catch these fish. This is called recycling.

TRAP-AND-HAUL

Construction of Mayfield Dam and Mossyrock Dam in the 1960s blocked natural fish passage up and down part of the Cowlitz River. Tacoma Power built the Cowlitz Salmon Hatchery and Cowlitz Trout Hatchery to mitigate the reduction in wild salmon and steelhead caused by the dams and reservoirs.

Upstream migrating adult fish are collected at the Cowlitz Salmon Hatchery and sorted by species and origin. Hatchery-origin fish are either kept at the hatchery for brood stock, recycled back to the lower river or hauled upstream. Wild salmon are transported by truck to one of four sites on the Tilton, Cowlitz and Cispus rivers where they continue their journey to spawn. The release sites are shown on the inside map.

Winter steelhead, fall chinook, spring chinook, coho and sea-run cutthroat trout are transported to each upper basin release site.

RECYCLING

Anglers on the lower Cowlitz River benefit from recycling surplus hatchery-origin adult fish back to the lower river. The three recycling release sites in the lower Cowlitz River are shown on the inside map. Recycled fish are marked at the hatchery so they are not counted twice (or more times) as new returning adults.

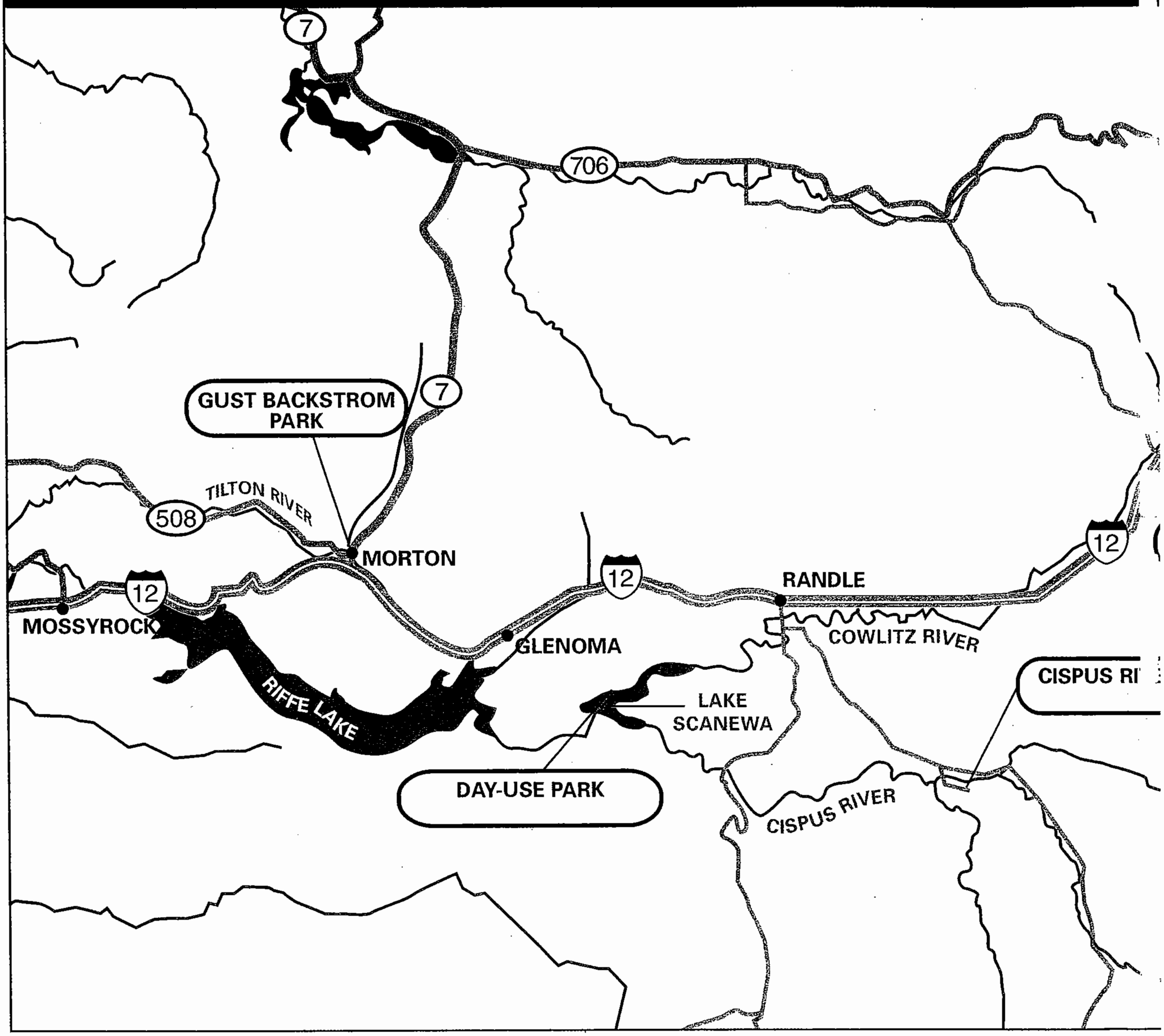
HATCHERY MANAGEMENT

Tacoma Power owns and pays all costs for the Cowlitz River salmon and trout hatcheries. The Washington Department of Fish and Wildlife manages and operates them. Tacoma Power employees are responsible for sorting the returning adult fish and for all fish transportation.

THE FUTURE

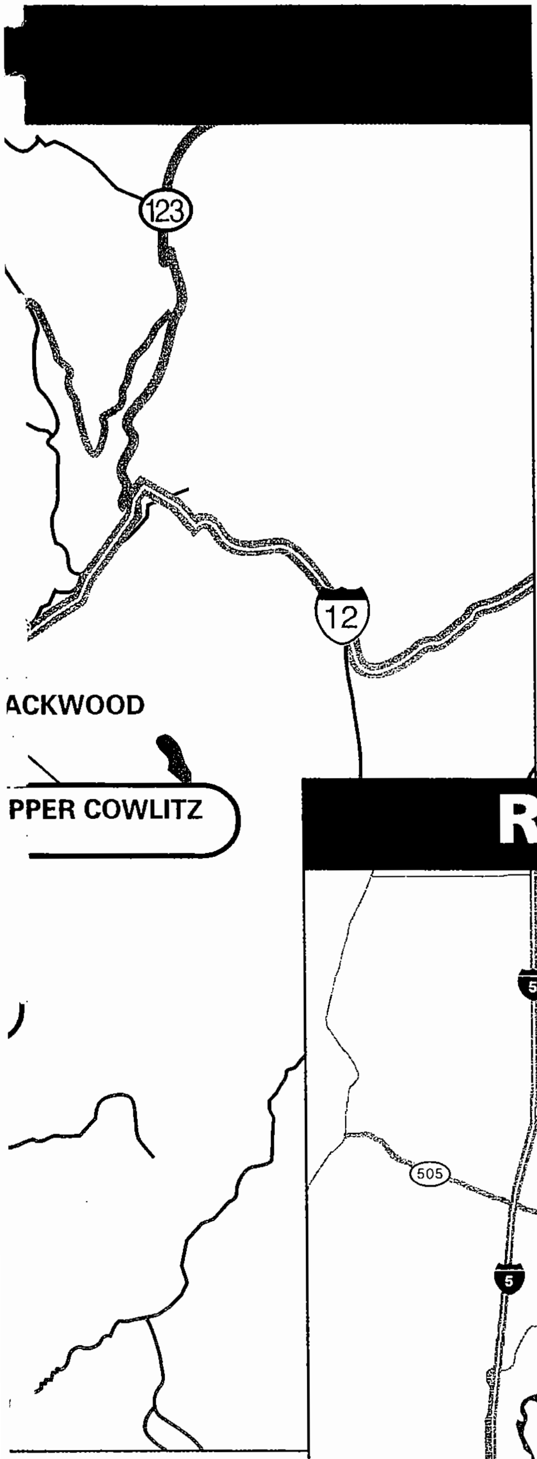
Tacoma Power's new Cowlitz River Project federal license calls for reassessing and improving upstream and downstream fish passage and survival. A fisheries technical committee, which includes biologists from state and federal agencies, Tacoma Power, the Yakama Nation and a representative from Trout Unlimited and American Rivers, is directing the scientific studies needed to determine the most effective fish-passage enhancements.

Trap & Haul Release Site

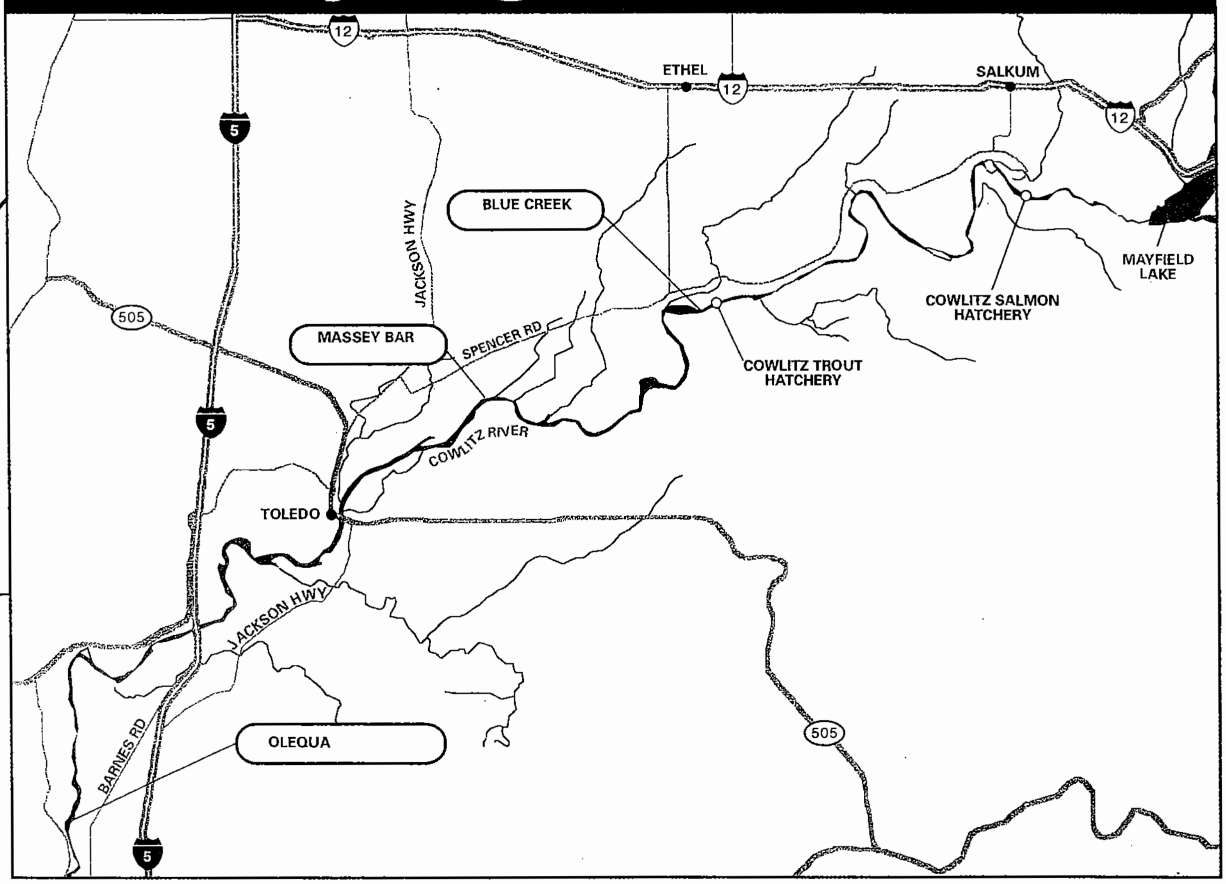


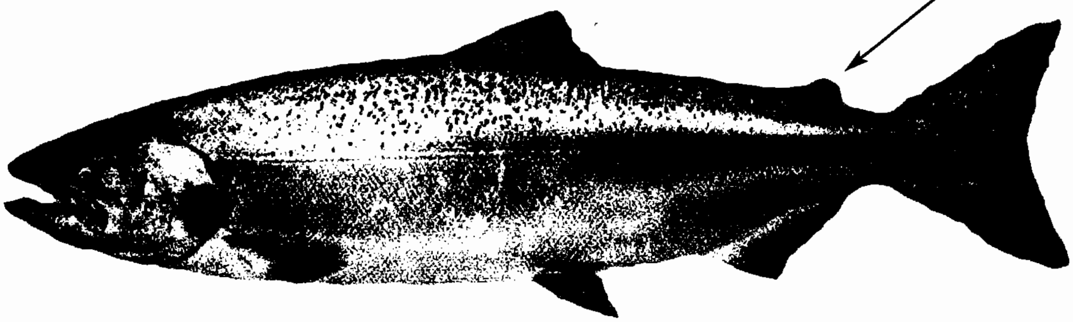
PUBLIC ACCESS SITES:

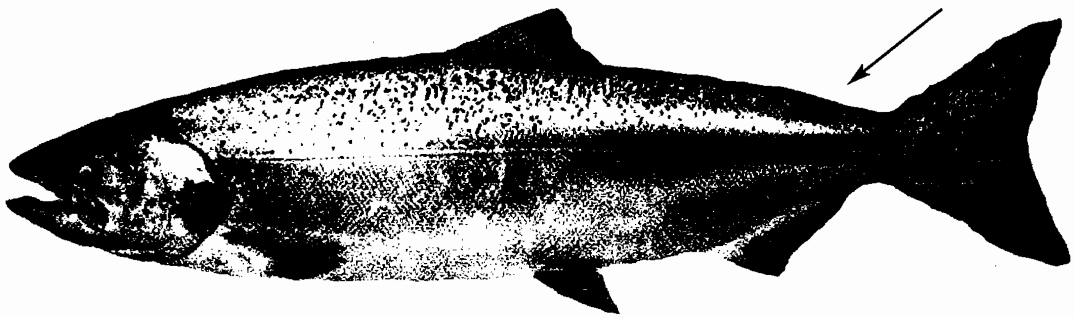
- Olequa Boat Launch
- Massey Bar Boat Launch
- Blue Creek Boat Launch
- Barrier Dam Boat Launch
- Gust Backstrom Park, Morton
- Lake Scanewa Day-Use Park



Recycling Release Sites







THE FUTURE OF SPORT SALMON FISHING IN WASHINGTON STATE

Because of declining numbers of some Pacific Northwest wild chinook and coho salmon, fishery managers are challenged to provide salmon fishing seasons while protecting wild salmon. Historically, restrictions facing salmon anglers are due primarily to an angler's inability to identify wild salmon from hatchery salmon.

Today, fish managing agencies are marking hatchery salmon by removing the adipose fin (the fatty fin on the salmon's back located between the dorsal fin and tail). This activity will help anglers identify a hatchery salmon from a wild salmon, and offers selective fishing opportunity primarily for hatchery fish while protecting wild salmon.

For more information call Tacoma Power's Fishing Line toll free at 1-888-502-8690 or visit our Web site at www.tacomapower.com

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This information is correct as of March 2003. Changes in programs and services may be made without notice.

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