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Performance of the Chinook Salmon Enhancement Program in Willow Creek, Alaska, 1985-1993

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September 1994

Alaska Department of Fish and Game

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ABSTRACT

The contribution of hatchery produced chinook salmon *Oncorhynchus tshawytscha* to the Willow Creek sport harvest and escapement in 1993 was assessed using a roving creel survey at the mouth of Willow Creek, a weir at Deception Creek (a tributary to Willow Creek), peak spawning escapement surveys, and postspawning carcass surveys. Anglers expended an estimated 53,542 angler-hours to catch and harvest 8,998 and 5,619 chinook salmon, respectively. During this fishery 15,298 angler-days were expended. This is a decrease of 3,000 angler-days from 1992 and an increase of almost 10,000 angler-days since 1988, when hatchery fish were first recorded in the harvest. The hatchery contribution to the 1993 harvest from chinook salmon smolt stocked in the Willow Creek drainage was 46%. This was the second largest contribution since the stocking program began in 1983. The 1989-1992 contributions were 38%, 36%, 26% and 51%, respectively. Escapement index counts and weir counts indicated a minimum of 3,448 spawners in Willow and Deception creeks combined. Carcass surveys in the mainstem of Willow Creek revealed a 13% hatchery contribution to the spawning escapement. Carcass surveys in Deception Creek indicated a relative hatchery contribution of 64% to the spawning escapement. The hatchery smolt release for 1993 was approximately 160,194.

KEY WORDS: chinook salmon, *Oncorhynchus tshawytscha*, Willow Creek, Deception Creek, fish culture, smolt, stocking, creel survey, sport effort, sport catch, sport harvest, escapement counts, population, hatchery contribution, age, sex, length.

INTRODUCTION

The sport fishery for chinook salmon *Oncorhynchus tshawytscha* in the Northern Cook Inlet (NCI) area (that portion of Cook Inlet north of the West Forelands) was closed periodically during the 1960s and 1970s because of small returns. Increases in the returns of chinook salmon to NCI drainages in the late 1970s allowed reopening of a limited sport fishery in 1979. An intensively managed and growing fishery has existed since that time (Figure 1).

Willow Creek, a tributary of the Susitna River (Figure 2), was designated as a potential recipient for chinook salmon enhancement in the Cook Inlet Regional Salmon Enhancement Plan (CIRPT 1981). Development of a chinook salmon enhancement program at Willow Creek was spurred by construction of a road to the mouth of Willow Creek and establishment of the Willow Creek Recreation Area at the mouth in the mid-1980s. A chinook salmon smolt stocking program was initiated at Willow Creek in 1985. With the exception of 1987, this stocking program has continued annually. An onsite creel survey has been conducted since 1979 to aid inseason management of the fishery. The creel survey was redesigned in 1988 to evaluate the enhancement program.

Willow Creek has developed into the most heavily utilized road-accessible sport fishery for chinook salmon in NCI (Mills 1980-1993). The primary purpose of the Willow Creek enhancement program is to increase chinook salmon fishing opportunities on a sustained yield basis by supplementing the existing natural run with hatchery fish. Natural chinook salmon production is relatively stable and appears near maximum. Present exploitation of this production also appears to be approaching maximum. Therefore, chinook salmon abundance must be increased if the fishery is to provide significant additional fishing opportunities.

The primary goals of the Willow Creek chinook salmon enhancement program are to:

1. maintain the present quality and quantity of natural chinook salmon production;

2. produce an additional 6,000 returning chinook salmon of which 4,000 would be available for harvest at Willow Creek on an annual basis by 1994; and

3. provide a minimum of 15,000 angler-days of chinook salmon fishing opportunity during the period 10 June to 10 July.

To help measure program performance and achieve project goals, the following objectives were identified:

1. estimate the angling effort, and catch (fish kept plus fish released) and harvest (fish kept only) in the Willow Creek chinook salmon sport fishery;

2. estimate the age, sex, and length compositions of chinook salmon harvested from Willow Creek;

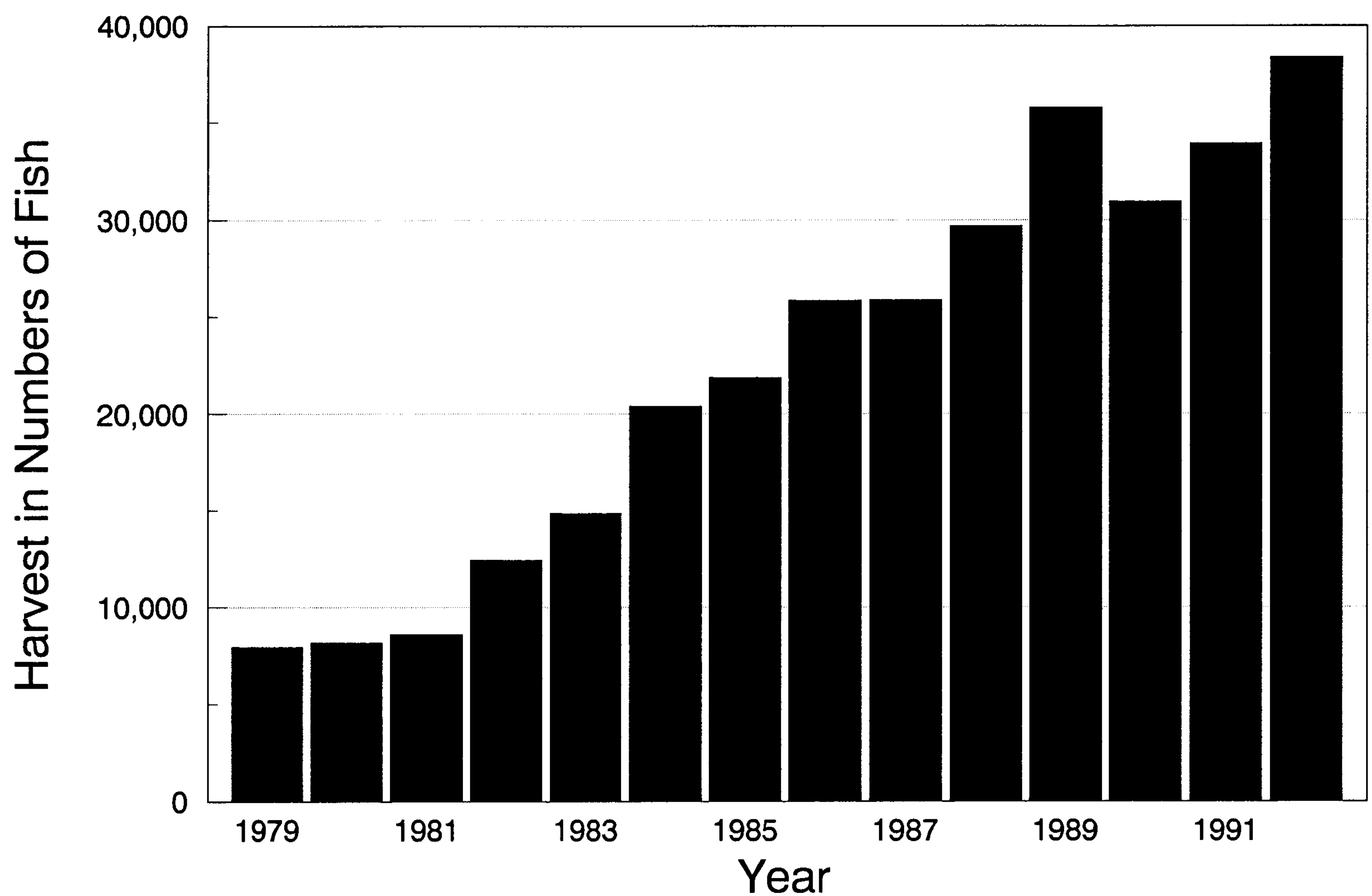


Figure 1. Sport harvest of chinook salmon in Northern Cook Inlet, 1979-1992 (Mills 1980-1993).

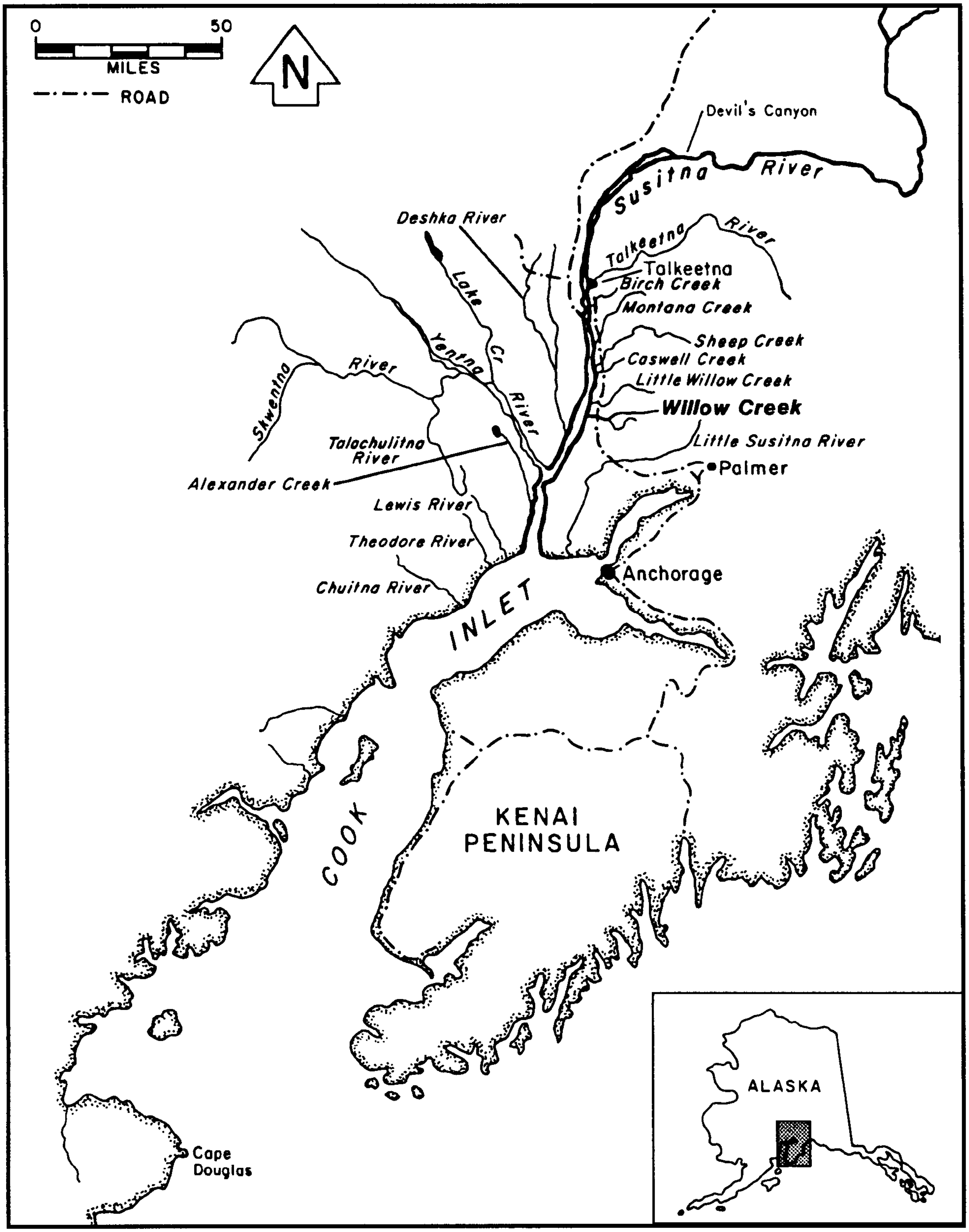


Figure 2. Map of Northern Cook Inlet and the Susitna River drainage.

3. estimate the age, sex, and length compositions of chinook salmon spawning in Willow Creek;

5. monitor chinook salmon escapement indices to determine if approximately 2,600 spawn naturally in Willow Creek in 1993;

6. estimate the contribution of stocked chinook salmon to the sport harvest, and estimate the relative contribution of stocked chinook salmon to the spawning escapement in Willow Creek;

7. collect and transport approximately 440,000 fertilized chinook salmon eggs from returning hatchery stock at the Deception Creek weir;

8. release approximately 200,000 chinook smolts, of which 40,000 will be marked with coded wire tags, into the Willow Creek drainage in order to yield 4,000 returning adults available for harvest.

This report presents fish culture, creel survey, escapement, age, sex, length, and hatchery contribution data collected from the Willow Creek program in 1993. Additionally, a compilation of all historic data used to evaluate this enhancement program is presented. Program success is evaluated by comparing historic performance to achievement of stated program goals and objectives. Finally, recommendations for consideration in future program planning are developed.

METHODS

Fish Culture

Chinook salmon smolt were released at the Deception Creek bridge on the Hatcher Pass Road on 1 June (Figure 3). Approximately 42,932 (27%) of the 160,194 smolt released were adipose finclipped and coded wire tagged following standard hatchery methodology (ADF&G 1983).

Two weirs were installed on Deception Creek on 6 July to capture brood stock for the 1993 egg take (Figure 3). All fish entering the weir complex were detained between the weirs until the egg take was complete. The egg take occurred on 19, 22 and 26 July. On those dates, fish were seined and checked for ripeness. Ripe fish were killed and placed on a clean tarp. Milt from males and eggs from females were combined at a 2:1 male to female ratio in a 5 gallon bucket (six males and three females). Water from Deception Creek was added to the bucket to initiate fertilization. After a 1 minute waiting period, excess milt, coagulated blood, and other debris were rinsed from the fertilized eggs. The clean eggs were put into plastic bags and placed in coolers for 45 to 90 minutes to water harden. The water-hardened eggs were packed in ice to keep them cool during shipment to Fort Richardson hatchery where they were incubated.

Creel Survey Design

Willow Creek was open to fishing for chinook salmon in all waters within a 0.4 km (0.25 mi) radius of the creek's confluence with the Susitna River and

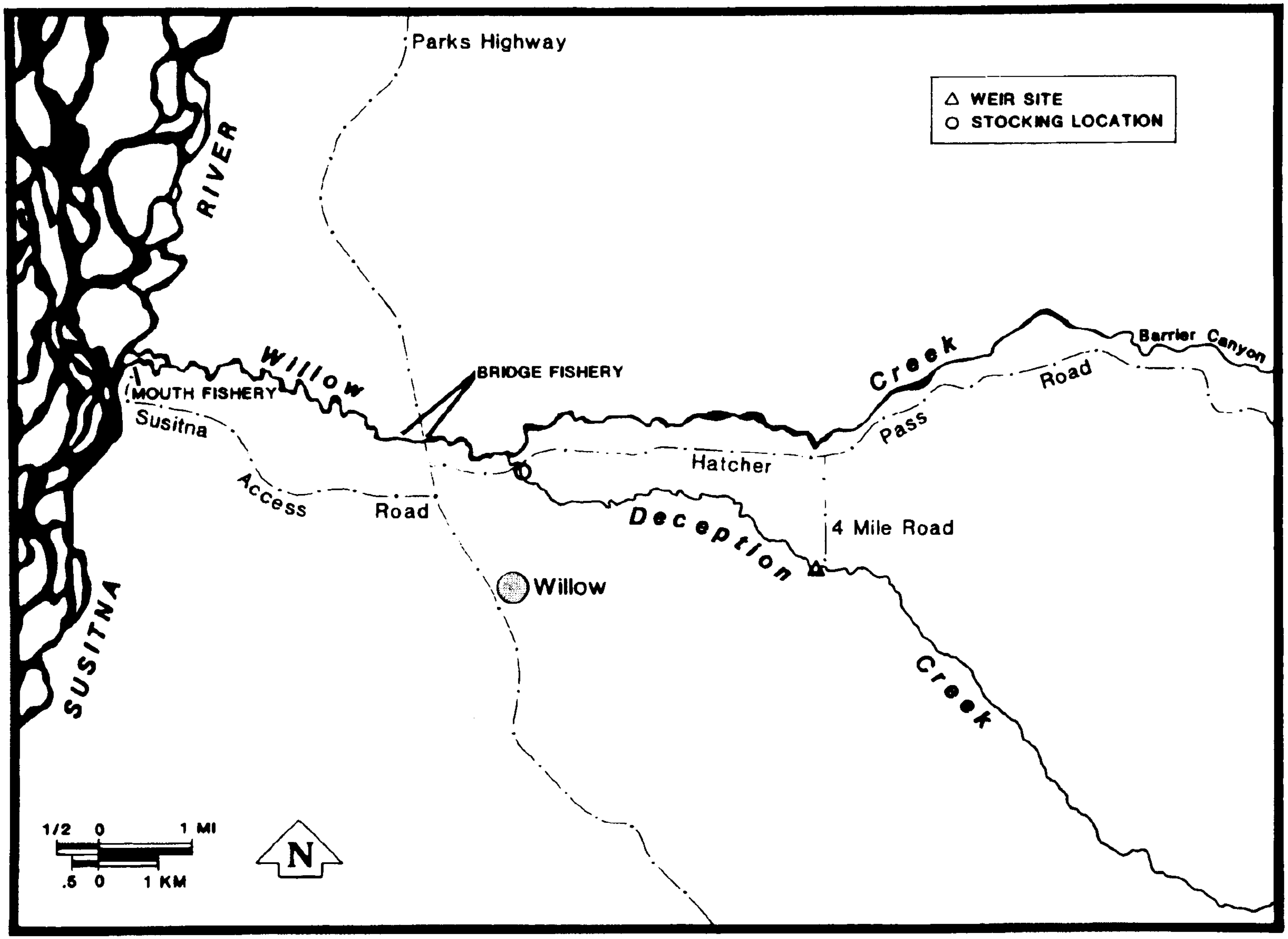


Figure 3. Map of Willow and Deception creeks showing the location of creel survey areas, carcass survey areas, smolt stocking sites, and egg take sites.

upstream to the Parks Highway. This section was open daily to fishing from 1 January to 21 June. After 21 June, Willow Creek was to open, by regulation, only during the 3-day periods of 0001 hours each Saturday to 2400 hours on Monday, commencing on 26 June and ending on 5 July.

Willow Creek is road accessible, allowing primary access to the fishery by vehicle and foot. The majority of anglers fished within 0.4 km (0.25 mi) of the mouth. Relatively few anglers fished at other locations such as the Parks Highway bridge area. Only the mouth area was surveyed in 1993 (Figure 3).

A roving creel survey (Neuhold and Lu 1957) was conducted to obtain estimates of angler effort, catch, and harvest for chinook salmon in the Willow Creek sport fishery. The fishery was sampled using a stratified, multi-stage, roving survey design.

Strata definitions and sampling parameters are listed in Appendix A1.

<u>Creel Survey Data Collection</u>

The following effort, catch, and harvest information were collected from each angler interviewed exiting the survey area:

1. whether the interview was from a completed-trip or incompleted-trip angler,

2. number of hours fished,

3. number of chinook salmon 16 inches (406 mm) and greater in length harvested (kept) or released.

Survey technicians monitored the mouth fishery at the head of the trail leading from the parking lot to the fishing area at the mouth of the creek. Time not spent conducting angler counts was spent interviewing exiting anglers, inspecting the observed harvest for adipose finclips, and collecting biological data.

<u>Creel Survey Data Analysis</u>

Angler count and interview data forms were visually checked for coding errors and corrected as necessary. Corrected data forms were sent to Research and Technical Services (RTS) for optical scanning. Resultant data files and summary printouts were also checked for errors and corrected as necessary. Corrected data files were sent to RTS for archiving (Appendix C).

Angler count and interview data files were processed by the Division of Sport Fish's creel survey analysis programs and analyzed according to the procedures outlined below.

Angler Effort, Catch, and Harvest:

Standard procedures were used to calculate estimates of angler effort for, and catch and harvest of, chinook salmon (Appendix A2). These procedures are outlined in detail in Bernard et al. (*In prep*). The following is a brief summary:

Strata	Procedure Description
1	3-stage Design: (1) days (random), (2) periods (systematic), (3A) angler counts (systematic) for the effort estimates, (3B) angler interviews ("random") for the CPUE and HPUE estimates
2, 5, 7, & 9	1-stage Design: (1A) angler counts (systematic) for the effort estimates, (1B) angler interviews ("random") for the CPUE and HPUE estimates
3, 4, 6, 8, & 10	2-stage Design: (1) periods (systematic), (2A) angler counts (systematic) for the effort estimates, (2B) angler interviews ("random") for the CPUE and HPUE estimates

Assumptions:

The assumptions necessary for unbiased point and variance estimates of angler effort, catch and harvest included the following:

1. anglers interviewed at each section of the fishery were representative of the total angler population;

2. anglers accurately reported their hours of fishing effort, the number of fish caught, and the number of fish released; and

3. the angler count process was approximately instantaneous, or the survey technician was assumed to travel substantially faster than anglers move about or exit or enter the fishery.

The above assumptions were most likely valid with the exception of assumption 2. Not all anglers were able to remember the hours of fishing effort and tended to report a number of hours between the length of the trip and the actual number of hours spent fishing on the trip.

Escapement Surveys

Chinook salmon spawning in Willow Creek were counted by aerial survey (helicopter). Spawners in Deception Creek were counted at a weir placed across Deception Creek and by walking the creek from the forks downstream to its confluence with Willow Creek. Escapement surveys were conducted during the peak spawning period which was identified through frequent inspections of spawning activity. Escapement data reported were the number of observed fish, both alive and dead.

Raw survey counts of chinook salmon in Willow Creek were not expanded to account for stream life, poor visibility, or missed fish. The actual number of chinook salmon observed was reported as the escapement index and was considered to be a minimum escapement estimate.

Size, Sex, and Age Compositions

Chinook salmon harvested in the sport fishery were sampled for age, length, and sex information. Carcasses of postspawn chinook salmon in Willow Creek from the canyon downstream to the confluence with Deception Creek were also sampled (Figure 3). Length, sex information, and scales were collected from every fish possible. However, some fish were badly decomposed which precluded scale collection and accurate measuring.

Sampled fish were measured from the middle of the eye to fork of the tail, to the nearest 5 mm. The sex of those fish selected for age composition was recorded. Three scales were collected on the left side of each fish approximately two rows above the lateral line and on the diagonal row downward from the posterior insertion of the dorsal fin as described in Clutter and Whitesel (1956). Scales were mounted on adhesive-coated cards and thermohydraulic impressions were made in cellulose acetate. Age determinations were made by examination of scale impressions using a microfiche reader. Ages were designated using the European method (Koo 1962). Age, sex, and length data were recorded on standard biological mark-sense forms.

Examination of scales during 1989 and 1990 indicated that freshwater growth in scales from hatchery-produced fish was indistinguishable from that of nonhatchery fish when viewed on a microfiche reader (Sweet and Webster 1990; Sweet et al. 1991). Therefore, hatchery-produced and natural fish were combined by saltwater age classes.

Estimates of age composition (proportion) for the subsampled chinook salmon were calculated for each stratum of the creel survey. Estimates of proportion of fish harvested by sex and age class across all strata were obtained by a weighted means procedure. Complete details of the estimation procedure are presented in Appendix A3 of this report.

Estimates of mean length by age group of chinook salmon subsampled from the sampled harvest were calculated by the procedures outlined in Sokal and Rohlf (1981, Boxes 4.2 and 7.1, pages 56 and 139). Length-at-age was assumed not to vary substantially from stage to stage or stratum to stratum, and as such, samples of fish lengths were treated as if collected by a simple random sampling program.

<u>Contribution of Coded Wire Tagged Stocks</u>

In addition to the age, sex, and length information, chinook salmon harvested at Willow Creek were examined for a missing adipose fin (indicating the presence of a coded wire tag or CWT). Daily records were kept of both the number of fish examined and the number of fish observed to have a missing adipose fin (clipped fish). Heads were collected from the clipped fish and sent to the Commercial Fisheries Management and Development Division laboratory for decoding. Carcasses from the chinook salmon escapement in the reaches of Willow Creek and Deception Creek upstream of their confluence were also inspected for adipose finclips to recover associated CWT's and estimate relative hatchery contributions.

Data collected included number of carcasses observed, number of fish inspected for adipose finclips, number of clips observed, mid-eye to fork length, and scale collection. Heads from fish with a missing adipose fin were collected and decoded as described above. Adult chinook salmon were expected to return to Willow Creek from the stocking of smolt in 1989, 1990, 1991, and 1992 (Appendix B1). There was also the possibility of returns from the 1989 Montana Creek and Sheep Creek smolt releases (Appendix B2) (Chlupach 1990).

No sampling was conducted to estimate hatchery contribution for nontarget commercial, sport, or subsistence fisheries. Some level of interception was likely.

Contribution to the Sport Harvest:

Hatchery contributions were estimated for the sport fishery using the procedures of Clark and Bernard (1987). A bootstrap procedure was used to estimate the variances and standard errors of these estimates (Efron 1982). The equations presented in Clark and Bernard (1987) could not be used to estimate these variances due to the presence of sampling error in the estimates of total harvest. Estimates were obtained either separately for each stratum, or by select combinations of strata. Within any 3-day weekend, the two strata that comprise the weekend fishery (i.e., the first 12-hour period and the last 60-hour period) were combined. It was not possible to separate the CWT data collected in these two periods.

The specific calculations and procedures followed to obtain the estimated contributions to the sport fishery are detailed in Appendix A4.

Contribution to the Escapement:

The estimates of relative contribution to the escapement by coded wire tag code were estimated by adapting the equations presented in Clark and Bernard (1987) as outlined in Appendix A4.

RESULTS

Fish Culture

An estimated 160,194 chinook salmon smolt were stocked in Deception Creek on 6 June in 1993 (Appendix B1). Approximately 42,939 (27% of the release) were coded wire tagged and marked with an adipose clip. However, due to tag loss, 39,626 (25% of the release) contained a valid coded wire tag. The tag retention for this release group was 93.2%, a considerable improvement over the 1992 tag retention of 75.9%.

A total brood stock of 57 female and 123 male fish (a 2:1 male to female ratio) were artificially spawned to obtain an estimated 391,500 chinook salmon eggs. Based on coded wire tag recovery from 133 fish examined at the weir for egg take, an estimated 46% (SE = 15%) of the brood stock were of hatchery origin (Appendix B3). Over half of these eggs will be used to produce smolt for the 1994 Willow Creek stocking. The remainder will be used for other stocking projects.

Creel Survey Statistics

An estimated 53,542 (SE = 1,979) angler-hours of effort were expended at Willow Creek in 1993 (Table 1). The total estimated harvest and catch of

Table 1. Estimated effort, catch and harvest by strata for fish greater or equal to 16 inches during the Willow Creek chinook salmon creel survey in 1993.

Strata	Date	Number of anglers interviewed	Effort in angler-hours	SE	Catch	SE	Harvest	SE
1,2&3	6/10-14	664	9,222	410	1,113	223	765	125
4	6/15-18	685	10,960	549	1,834	243	1,088	116
5&6	6/19-21	1,215	12,411	1,465	2,864	183	1,727	150
7&8	6/26-28	1,314	13,699	935	2,512	204	1,642	144
9&10	7/03-05	700	7,250	651	675	78	397	43
Total		4,578	53,542	1,979	8,998	436	5,619	272

chinook salmon 16 inches and greater equalled 5,619 (SE = 272) and 8,998 (SE = 436) fish, respectively (Table 1). During the Willow Creek fishery, 38% of the chinook salmon caught were released.

Escapement Survey Statistics

An aerial escapement index counted 2,227 chinook salmon on 20 July for Willow Creek. A ground survey was conducted on the escapement index area of Deception Creek, a tributary to Willow Creek, on 3 and 8 August; 1,221 chinook salmon were counted. Therefore, we estimated minimum escapement for the system at approximately 3,448 fish (Table 2).

Size, Sex, and Age Compositions

A total of 420 chinook salmon (7.5%) was sampled from the sport harvest for age, length, and sex. Age class 1.3 dominated the harvest at 44%, age 1.4 contributed 40%, and age 1.2 contributed 16%. Age class 1.5 contributed less than 1%. The harvest consisted of 56% males and 44% females (Table 3). Mean lengths of males ranged from 611 mm for age 1.2 to 1,170 mm for age 1.5. Mean lengths of females ranged from 595 mm for age 1.2 to 975 mm for age 1.5 (Table 4).

Forty-six percent of the harvest consisted of hatchery-produced fish of all age groups. Scales from hatchery-produced fish were indistinguishable from nonhatchery fish scales. Therefore, all fish are grouped together by salt-water age.

Of the 308 carcasses examined during the carcass survey, 215 readable scales were collected. Age class 1.4 dominated at 74%, age 1.3 contributed 18%, age 1.2 contributed 8%. Age class 1.5 contributed less than 1%. The surveyed carcasses consisted of 41% male and 59% female fish (Table 3). Mean lengths ranged from 618 mm for age-1.2 males to 1,010 mm for age-1.5 females (Table 4).

Contribution of Coded Wire Tagged Stocks

From the estimated sport harvest of 5,619 chinook salmon at the mouth of Willow Creek, 1,443 were examined for a missing adipose fin. Of those examined, 90 (6.2%) were observed to have a missing adipose fin and a decode-able coded wire tag. Tags from five Willow Creek releases (1989 through 1991) were decoded (Appendix B4). The estimated contribution to the harvest of hatchery-produced chinook salmon at the Willow Creek mouth fishery originating from fish released in the Willow Creek drainage was 2,590 fish (SE = 297) or 46% (Table 5). The timing of the harvest of hatchery fish and nonhatchery fish displayed differing characteristics in 1993 (Figure 4). Both started equally, however the nonhatchery harvest climbed to its peak on 19-21 June while the hatchery harvest dropped during the same period. Hatchery harvest then rose again to equal the nonhatchery harvest during the 26-28 June fishing period after which they both dropped off. The hatchery return seemed to have remained at a somewhat consistent level while the nonhatchery return created a definite peak.

Among the 398 carcasses examined during carcass surveys on Willow Creek, 12 fish were found with a missing adipose fin. The six decodeable CWT's found in

Table 2. Estimated effort, harvest, and spawning escapement of Willow Creek chinook salmon for the period 1979-1993.

Year	Location of Creel Survey[a]	Season Length in Days: Weekend	Season Length in Days: Weekday	Effort in Angler Days[b]	Sport Harvest[c]: Total[e]	Sport Harvest[c]: Nonhatchery	Sport Harvest[c]: Hatchery[f]	Sport Harvest[c]: Percent Hatchery	Willow Creek Escapement Index[d]: Total	Willow Creek Escapement Index[d]: Nonhatchery	Willow Creek Escapement Index[d]: Hatchery	Willow Creek Escapement Index[d]: Percent Hatchery	Deception Creek Escapement: Total	Deception Creek Escapement: Nonhatchery	Deception Creek Escapement: Hatchery	Deception Creek Escapement: Percent Hatchery
1979	Highway	8		975	285	285			848				239			
1980	Highway	8		612	292	292			--[g]				--[g]			
1981	Mouth and highway	8		540	345	345			991				366			
1982	Mouth and highway	8		504	390	390			592				229			
1983	Mouth and highway	8		1,811	393	393			771				121			
1984	Mouth and highway	8		1,939	805	805			2,789				675			
1985	Mouth and highway	8		2,338	763	763			1,856				1,044			
1986	Mouth and highway	8		2,313	1,043	1,043	--[h]		2,059		--[h]		521	364	157	30.1
1987	Mouth, highway, Susitna Landing	8	4	3,770	1,720	1,720	--[h]		2,768		--[h]		692	518	174	25.1
1988	Mouth, highway, Susitna Landing	8	4	5,444	2,160	1,834	326	15.1	2,496		--[h]		790	537	253	32.0
1989	Mouth, highway, Susitna Landing	8	8	8,685	2,570	1,594	976	37.9	5,060	4,907	153	3.0	800	623	177	22.1
1990	Mouth and highway	8	10	9,313	2,789	1,761	1,028	36.9	2,365	2,316	49	2.1	700	420	280	40.0
1991	Mouth	10	8	10,461	2,997	2,210	787	26.3	2,006	2,006	0	0.0	747	515	232	31.1
1992	Mouth	8	11	18,271[i]	6,955	3,378	3,577	51.4	1,660	1,457	203	12.2	983	423	560	57.0
1993	Mouth	8	10	15,298	5,619	3,029	2,590	46.1	2,227	1,935	292	13.1	1,221	502	719	59.0

a Creel survey sites changed from year to year to accommodate the evolving fishery.

b Source of data: Watsjold 1980 and 1981; Bentz 1982 and 1983; Hepler and Bentz 1984, 1985, 1986 and 1987; Hepler et al. 1988 and 1989; Sweet and Webster 1990; Sweet et al. 1991; Peltz and Sweet 1992. In years where effort in angler-days was not reported, total estimated effort was divided by the mean length of the angler-day to obtain the number of angler-days.

c A harvest quota of 300 chinook salmon governed the fishery from 1979 through 1983.

d Escapement index counts are from aerial counts during peak spawning activity.

e All harvest estimates are from inseason creel surveys.

f All hatchery harvest estimates are from coded wire tag recovery programs associated with the creel survey.

g No survey

h Small numbers of hatchery fish probably returned but recovery of coded wire tags was not recorded. All production was attributed to nonhatchery fish returns.

i Effort in angler days assumed to equal the number of angler-trips estimated during angler catch and harvest distribution analysis.

Table 3. Sex and age composition of chinook salmon sampled from the Willow Creek sport fishery and carcass surveys in 1993.

			Age Group[a]								
Fishery	Sex		1.1	1.2	1.3	1.4	1.5	2.2	2.3	2.4	Total
Creel survey											
	Male	Harvest	0	885	1,294	966	8	0	0	0	3,254
		Percent	0.0	15.8	23.0	17.2	0.2	0.0	0.0	0.0	56.1
		SE (%)	0.0	1.7	2.1	1.9	0.1	0.0	0.0	0.0	2.5
	Female	Harvest	0	36	1,152	1,251	25	0	0	0	2,465
		Percent	0.0	0.7	20.1	22.2	0.5	0.0	0.0	0.0	43.9
		SE (%)	0.0	0.5	2.0	2.1	0.3	0	0	0	2.5
	Combined (n=420)[b]	Harvest	0	921	2,446	2,218	33	0	0	0	5,619
		Percent	0.0	16.4	43.5	39.5	0.6	0.0	0.0	0.0	100.0
		SE (%)	0.0	1.8	2.4	2.4	0.3	0.0	0.0	0.0	
Carcass surveys											
	Male	Index	0	17	18	54	0	0	0	0	89
		Percent	0.0	7.9	8.4	25.1	0.0	0.0	0.0	0.0	41.4
		SE(%)	0.0	1.8	1.9	3.0	0.0	0.0	0.0	0.0	3.4
	Female	Index	0	0	20	105	1	0	0	0	126
		Percent	0.0	0.0	9.3	48.8	0.5	0.0	0.0	0.0	58.6
		SE(%)	0.0	0.0	2.0	3.4	0.5	0.0	0.0	0.0	3.4
	Combined	Index	0	17	38	159	1	0	0	0	215
		Percent	0.0	7.8	17.7	74.0	0.5	0.0	0.0	0.0	100.0
		SE (%)	0.0	1.8	2.6	3.0	0.5	0.0	0.0	0.0	

[a] Approximately 50% of the Willow Creek mouth harvest consisted of hatchery-produced fish whose ages were 0.1, 0.2, 0.3 or 0.4. Scales from hatchery-produced fish were indistinguishable from wild fish scales. Therefore, both are included in age groups 1.1, 1.2, 1.3 and 1.4.

[b] n = sample size.

Table 4. Mean length (mid-eye to fork-of-tail) in millimeters, by sex and age group, of Willow Creek chinook salmon sampled from the sport fishery and carcass surveys in 1993.

Fishery	Sex		Age Group 1.1	1.2	1.3	1.4	1.5	2.2	2.3	2.4	Total
Creel Survey[a]:											
	Male	Mean		611	798	966	1,170				790
		Standard Error		5.3	5.7	9.7					9.7
		Sample Size	0	76	100	70	1	0	0	0	247
	Female	Mean		595	811	925	975				864
		Standard Error		5.0	4.8	7.5	45.0				6.5
		Sample Size	0	2	87	81	2	0	0	0	172
	All	Mean		611	804	944	1,040				820
		Standard Error		5.2	3.8	6.2	70.0				6.5
		Sample Size	0	78	187	151	3	0	0	0	419
Carcass Surveys:											
	Male	Mean		618	792	980					873
		Standard Error		9.8	10.7	9.5					16.6
		Sample Size	0	17	18	54	0	0	0	0	89
	Female	Mean			818	921	1,010				905
		Standard Error			9.7	4.5					5.3
		Sample Size	0	0	20	105	1	0	0	0	126
	All	Mean		618	806	941	1,010				892
		Standard Error		9.8	7.4	4.9					7.6
		Sample Size	0	17	38	159	1	0	0	0	215

[a] Approximately 50% of the Willow Creek mouth harvest consisted of hatchery-produced fish whose ages were 0.1, 0.2, 0.3 or 0.4. Scales from hatchery-produced fish were indistinguishable from wild fish scales. Therefore, both are included in Willow Creek age groups 1.1, 1.2, 1.3 and 1.4.

Table 5. Estimated contribution of hatchery produced chinook salmon in the Willow Creek sport fishery harvest, 1993.

Strata		1,2&3			4			5&6			7&8			9&10			Total		
	Date	6/10-14			6/15-18			6/19-21			6/26-28			7/3-5					
	Harvest	765			1,088			1,727			1,642			397			5,619		
	SE	125			116			150			144			43			272		
Tag code	Release	Contr.[a]	SE	%	Contr.[a]	SE	%	Contr.[a]	SE	%	Contr.[a]	SE	%	Contr.[a]	SE	%	Contr.[a]	SE	%
31-17-60	Willow 89	70	74	9.2	109	78	10.0	0	0	0.0	203	125	12.4	0	0	0.0	382	164	6.8
31-17-34	Willow 90	121	59	15.8	283	84	26.0	173	77	10.0	29	31	1.8	113	40	28.5	719	138	12.8
31-18-52	Willow 90	62	43	8.1	120	55	11.0	88	47	5.1	150	68	9.1	33	20	8.3	453	110	8.1
31-18-51	Willow 90	31	33	4.1	121	55	11.1	118	62	6.8	332	97	20.2	66	29	16.6	668	135	11.9
	Total 90	214	80	28.0	524	114	48.1	379	109	21.9	511	122	31.1	212	50	53.4	1,840	222	32.8
31-19-33	Willow 91	72	50	9.4	84	47	7.7	69	49	4.0	105	65	6.4	38	24	9.6	368	109	6.5
	Total	356	120	46.6	717	139	65.8	448	120	25.9	819	187	49.9	250	59	63.0	2,590	297	46.1

[a] Contribution of hatchery fish to the harvest.

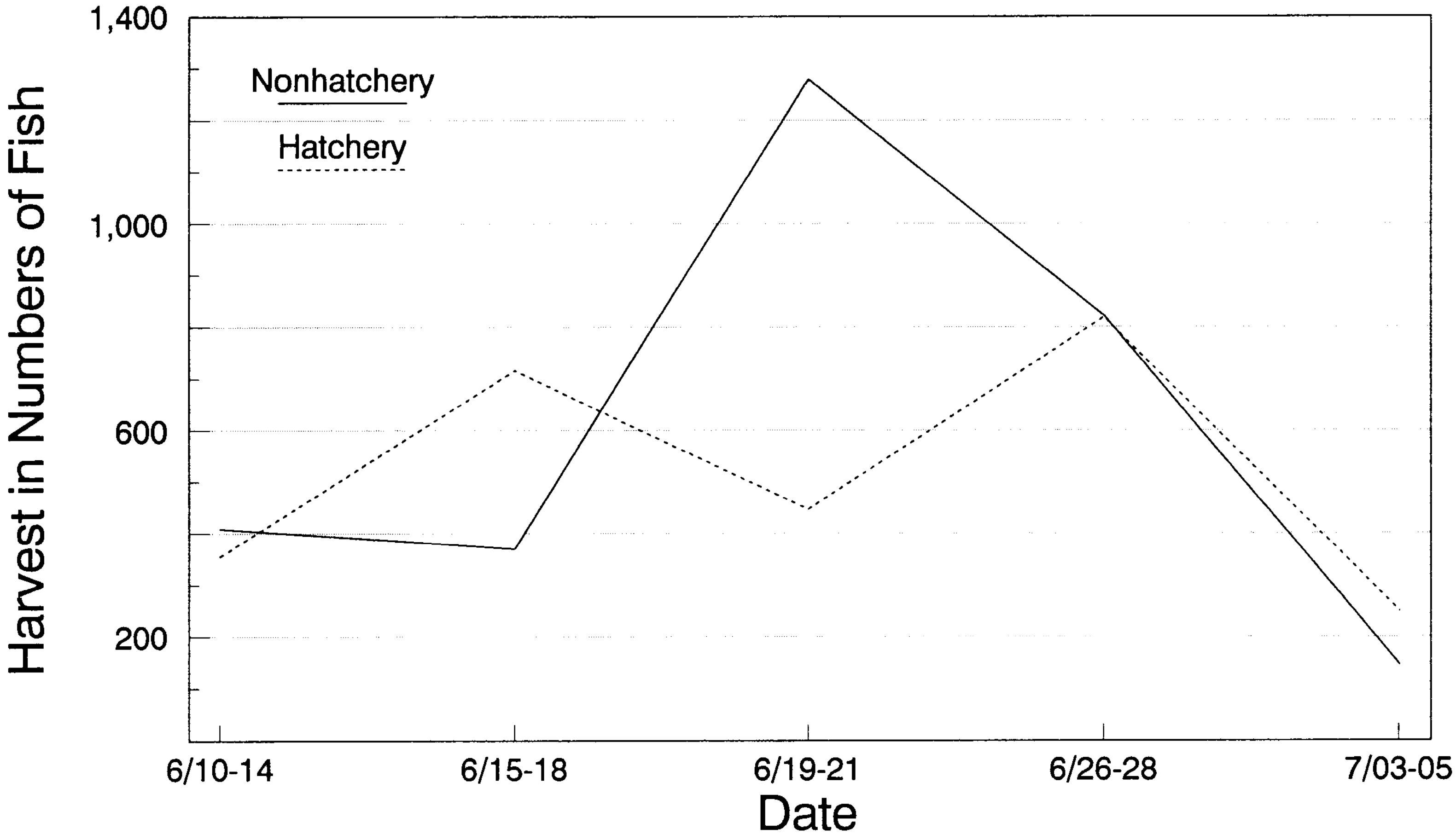


Figure 4. Number of nonhatchery and hatchery Willow Creek chinook salmon harvested by stratum, 1993.

the heads of these fish were from 1989 and 1990 Willow Creek releases (Appendix B3). The estimated relative hatchery contribution to the Willow Creek escapement was 13% (SE = 6%). Deception Creek carcass surveys resulted in 308 carcasses examined, 40 adipose finclips observed and 23 decodeable tags recovered. These tagged fish originated from the Willow Creek 1989, 1990 and 1991 releases (Appendix B3). Based on these tag recoveries, the estimated relative hatchery contribution to the Deception Creek escapement was 64% (SE = 14%). During the Deception Creek weir egg take, 133 fish were examined and 11 adipose finclips were observed. All 11 fish contained decodeable coded wire tags representing the 1989, 1990 and 1991 Willow Creek releases (Appendix B3). Based on these tag recoveries, the estimated relative hatchery contribution to the egg take was 46% (SE = 15%)

Tag recoveries occurred in several commercial fisheries for which no hatchery contribution estimates were made (Appendix B5). Coded wire tag recoveries of Willow Creek chinook salmon in the Willow Creek creel survey, Willow Creek escapement surveys, and Deception Creek escapement (egg take and carcass survey) for 1986-1993 are listed in Appendix B6. The estimated hatchery return of Willow Creek releases to the Willow Creek creel survey, Willow Creek escapement survey, and Deception Creek escapement (egg take and carcass survey) for 1986-1993 are listed in Appendix B7.

DISCUSSION

The Willow Creek chinook salmon fishery has existed annually since 1979 (Table 2). From 1979 to 1993, the fishery has changed from a weekend-only fishery with a harvest quota of 300 fish to a 19-day season with a harvest reaching 7,000 fish. Harvest patterns have also changed. The initial fishery in 1979 took place at the Parks Highway bridge. The construction of a road to the stream mouth in 1988 has shifted the majority of the fishery downstream to the mouth area. Fishery monitoring has changed over time to adjust to changes in the fishery. Consequently, direct comparisons of data among years is in some instances of limited value. It is possible, however, to make some general observations. Participation and harvests in the fishery have grown substantially since 1979 (Figure 5). Harvest of nonhatchery fish gradually increased approximately ten-fold from 1979 through 1993 (Figure 6). Harvests of nonhatchery fish increased substantially during 1984, 1987, and 1992. These steps in the harvest are most likely correlated to events such as adding additional fishing time and improvements in access. The 1992 increase in the harvest of nonhatchery fish is most likely a result of the popularity of this fishery relating to the large return of hatchery fish. The hatchery fish harvest exceeded the nonhatchery fish harvest for the first time in 1992. During the 1993 season the nonhatchery harvest again exceeded the hatchery harvest. The combined nonhatchery and hatchery fish spawning escapement in 1992 and 1993 contained a slightly higher percentage of hatchery fish than previous years. During 1993 the nonhatchery fish escapement was comparable to historical levels (Figure 7).

Fish Culture

The 1993 egg take of 391,500 eggs was sufficient to meet the Willow Creek program goal and provide eggs for planned area landlocked lake stockings. In an effort to increase genetic diversity, a 2:1 male to female ratio was used

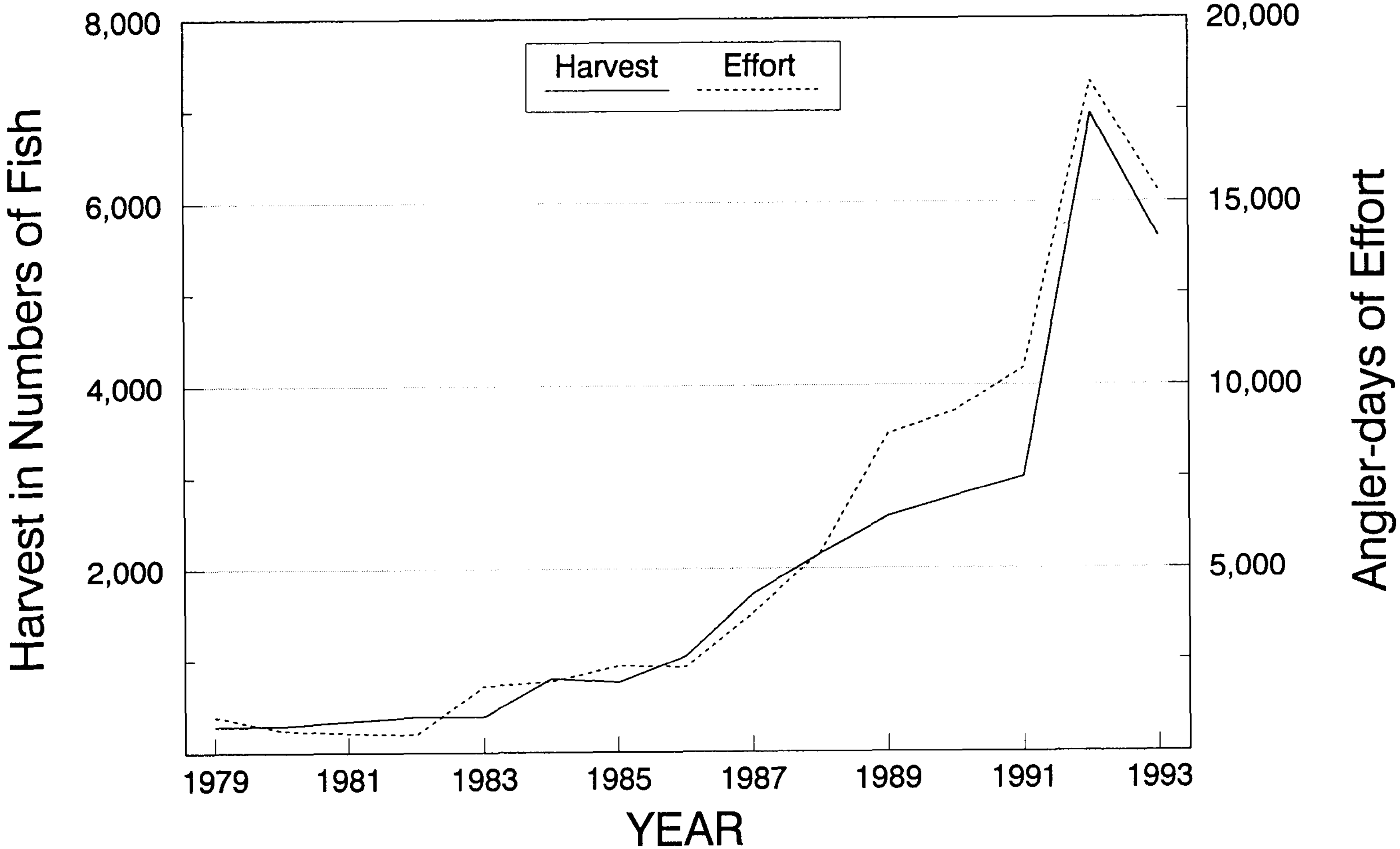
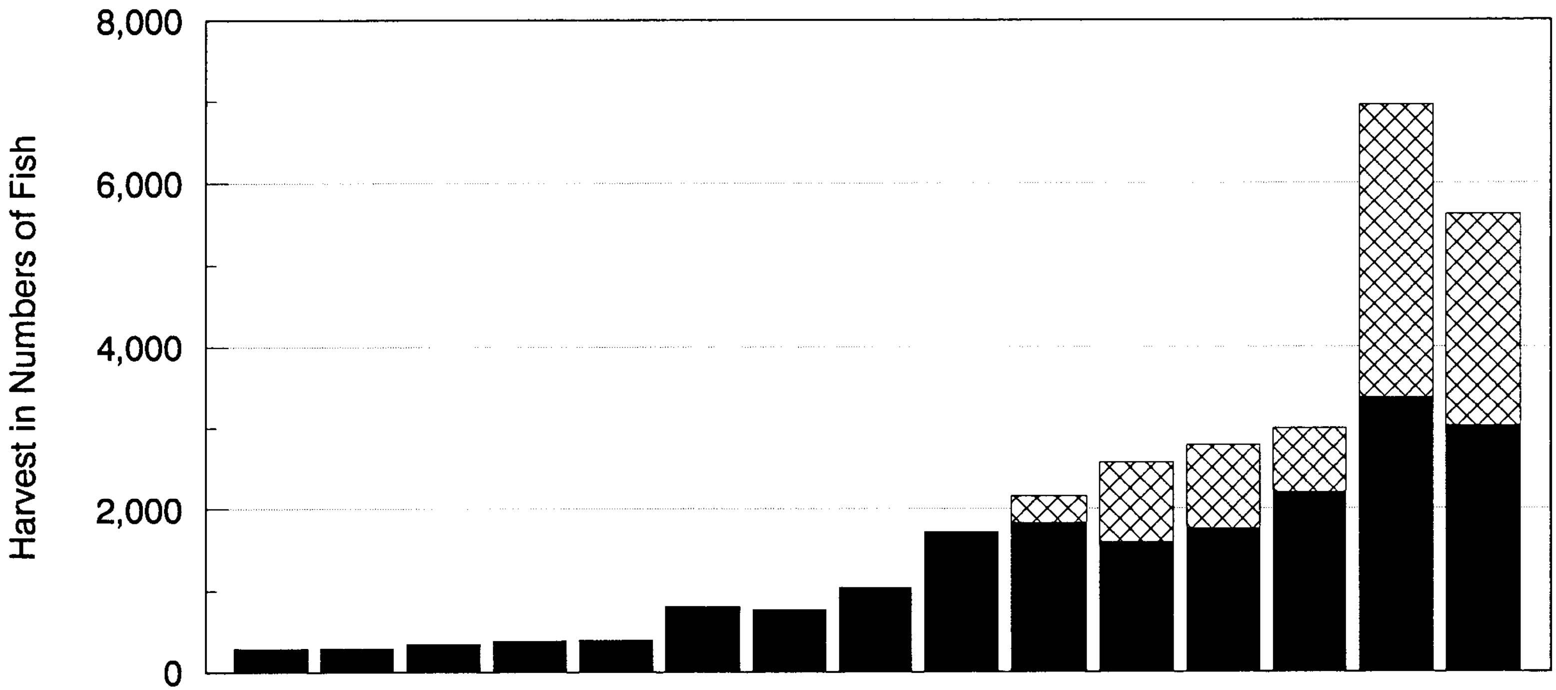
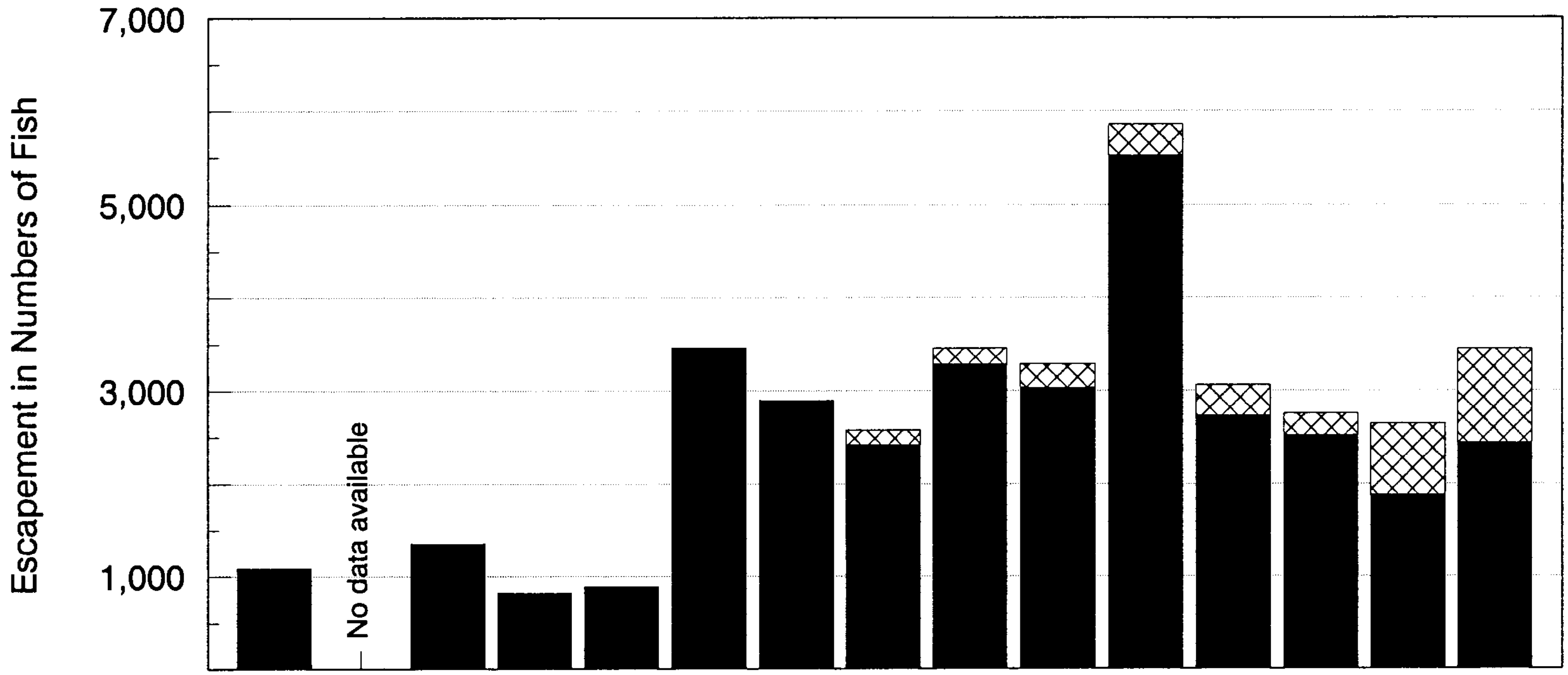


Figure 5. Numbers of chinook salmon harvested and angler days of effort expended sport fishing on Willow Creek, 1979-1993.



	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
Nonhatchery	285	292	345	390	393	805	763	1,043	1,720	1,834	1,594	1,761	2,210	3,378	3,029
Hatchery	0	0	0	0	0	0	0	0	0	326	976	1,028	787	3,577	2,590

Figure 6. Numbers of nonhatchery and hatchery chinook salmon harvested in Willow Creek, 1979-1993.



	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
Nonhatchery	1,087	0	1,357	821	892	3,464	2,900	2,423	3,286	3,033	5,530	2,736	2,521	1,880	2,437
Hatchery	0	0	0	0	0	0	0	157	174	253	330	329	232	763	1,011

Figure 7. Numbers of nonhatchery and hatchery chinook salmon in the Willow Creek and Deception Creek escapement index, 1979-1993.

for spawning. A total of 180 fish was used for brood stock. Unless there is a shortage of natural spawners, this practice should continue in the future.

Creel Survey Statistics

The 1993 angler effort, harvest and catch decreased slightly from 1992. In 1993, an estimated 53,542 angler-hours of effort were expended, a decrease of approximately 12,500 from 1992. This decrease may be attributable to differences in the calendar years. Willow Creek is open to continuous fishing through the third Monday in June and on Saturday, Sunday, and Monday for 2 consecutive weeks commencing on the fourth Saturday in June. In 1992, the fishery was open continuously through June 15. In 1993, the fishery was open continuously through June 21. Due to a large return and the early closure of continuous fishing in 1992, additional fishing days were added by emergency order during the peak of the season. To address conservation concerns and since continuous fishing extended until June 21 in 1993, no extra days were added during the peak of the fishery. Consequently, even though the number of days open to fishing was almost identical between years, the different time periods in which the effort was applied may have resulted in a decrease in participation in 1993. The harvest and catch followed a trend similar to the effort. Even though down from 1992, the 1993 effort, harvest and catch are well above all other previous years (Table 2).

A creel survey has been conducted on the Willow Creek chinook salmon fishery since 1979. The primary purpose of the creel survey is to collect inseason estimates of effort, harvest and catch. However, the present management scheme in conjunction with preseason forecasting has greatly reduced the functional utility of the inseason estimates generated from the creel survey. The amount of future fishing effort will probably remain between 10,000 and 20,000 angler-days per year. Effort is dependent on the numbers of returning fish and the length of the season, neither of which are anticipated to increase much beyond existing levels. Consequently, quantifying effort is probably not necessary. Harvest statistics are necessary to monitor yearly performance of the fishery and the enhancement program. However, these statistics are available from another source. Table 6 compares harvest estimates from the creel survey to those generated from the statewide harvest mail survey (SHS). The numbers are comparable for every year. Since 1987 the SHS estimate has been larger than the creel survey estimate. This is probably attributable to the fact that the SHS estimates the chinook salmon harvest in all of Willow Creek and the creel survey has primarily estimated harvest at the mouth of Willow Creek. Catch estimates, although not as important as harvest, can also be obtained from the SHS. Consequently, a creel survey to determine harvest, effort and catch is no longer necessary. Harvest can be obtained from the SHS. Also, effort and harvest trends and the abundance of fish in the creek can be determined through onsite presence without the formal creel survey procedure.

Escapement Survey Statistics

The spawning escapement surveys on Willow and Deception creeks served as functional indices of the spawning population. These surveys were necessary to measure the effectiveness of fisheries management in obtaining the escapement goal. The main function of the carcass surveys was to estimate the relative hatchery contribution to the mainstem of Willow Creek and Deception

Table 6. Comparison of the statewide harvest survey and creel survey harvest estimates for Willow Creek chinook salmon, 1979-1992.

Year	Statewide Harvest Survey[a]	Creel Survey[b]
1979	459	285
1980	289	292
1981	585	345
1982	629	390
1983	534	393
1984	774	805
1985	1,063	763
1986	1,017	1,043
1987	1,987	1,720
1988	2,349	2,160
1989	2,846	2,570
1990	3,237	2,789
1991	3,208	2,997
1992	8,884	6,955

[a] Estimates include fish under 16 inches in length and harvest from the entire fishery.

[b] Creel survey estimates do not reflect the number of fish under 16 inches or harvest from the entire fishery during all years.

Creek. In 1993, the relative contribution of hatchery produced fish spawning in mainstem Willow Creek was 13.1%, the largest hatchery percentage to date (Table 2). This contribution was similar to the 1992 contribution of 12.2%, both of which are well above all previous years. The increase is probably due to the substantial increase in hatchery returns overall making it more likely to recover a hatchery fish in the escapement. The 1993 hatchery contribution (59%) in the Deception Creek escapement was also the highest percentage to date with the 1992 contribution only slightly lower (57%). This is similar to the increase in Willow Creek and is probably also caused by the large increase in the return of hatchery fish (Table 2). Carcass surveys on the mainstem of Willow Creek and Deception Creek should continue in 1994 to determine the contribution of hatchery fish to the escapement.

Size, Sex, and Age Compositions

Comparison of age composition between creel survey and carcass survey data revealed a higher proportion of age-1.4 fish in the carcass sample, 40% versus 74%. Levels of age-1.3 fish in the creel and carcass surveys were 44% and 18%, respectively, age-1.2 composition was 16% and 9%, respectively. This year, as in past years, the carcass survey resulted in a higher percentage of large fish than the creel survey. The probable explanation is that larger fish have a greater chance of being observed during the carcass survey simply because they are larger and more easily visible. They also would be available for sampling longer because they would not wash away or decompose as quickly as smaller fish. Although creel surveys also have certain potential biases (Peltz and Sweet 1993), in all likelihood they provide the best estimate of age composition of the returning chinook salmon. The age composition data from the carcass survey are of limited use and should be discontinued in the future.

As indicated in previous reports, it is possible to use historical age, length, and sex data from sport harvested chinook salmon from Willow Creek to determine trends in these parameters for the sport harvested population (Peltz and Sweet 1992, 1993). Age composition data from the sport harvest have been collected since 1979 (Appendix B8). If the age composition of the escapement is the same as that of the sport harvest, we can construct a brood table which lists the age composition by brood year rather than year at return. Data collected prior to significant interaction of hatchery produced fish indicate that the majority of fish (60.3%) return after 4 years residence in the ocean with lesser numbers after 3 (26.7%) and 2 (13.0%) years (Table 7, Figure 8). We now have two complete brood year returns, 1986 and 1987, since significant numbers of hatchery fish have been added. Comparison of hatchery and nonhatchery returns by age class for the 1986 brood year reveals approximately 20% fewer hatchery fish returning as 4-ocean fish. The same trend is seen in the 1987 brood year where there are also approximately 20% fewer 4-ocean hatchery fish returning. The 1986 brood year 2-ocean return of hatchery fish is twice the nonhatchery return and well above the historical mean; the 3-ocean return of both hatchery and nonhatchery fish is comparable to the historical mean. The 1987 brood year hatchery and nonhatchery 2-ocean returns were comparable to each other and with the historical mean. The 3-ocean return was substantially higher for the hatchery component. On the basis of these two completed brood year returns it is apparent that the hatchery fish return at a younger age than nonhatchery fish. It is obvious that males are returning at a younger age since the percentage of 2-ocean fish has increased

Table 7. Estimated age at return of Willow Creek chinook salmon by brood year based on sport harvest data collected during the period 1979-1993.

Brood Year[a]	Origin	Estimated Number Returning by Age Class[bc] 1.2	1.3	1.4	Total Return	Estimated Percent Returning by Age Class[b] 1.2	1.3	1.4	Total Return
1973	Wild			1,043	1,043				
1974	Wild		192	155	347				
1975	Wild	137	53	885	1,075	12.8	4.9	82.3	100.0
1976	Wild	85	613	908	1,606	5.3	38.2	56.6	100.0
1977	Wild	204	218	514	936	21.8	23.3	54.9	100.0
1978	Wild	85	386	2,006	2,477	3.4	15.6	81.0	100.0
1979	Wild	386	1,708	1,502	3,595	10.7	47.5	41.8	100.0
1980	Wild	555	1,136	1,667	3,357	16.5	33.8	49.6	100.0
1981	Wild	513	1,775	2,124	4,412	11.6	40.2	48.1	100.0
1982	Wild	543	984	1,906	3,434	15.8	28.7	55.5	100.0
1983	Wild	1,450	926	6,238	8,614	16.8	10.7	72.4	100.0
1984	Wild	871	1,602	2,986	5,459	16.0	29.3	54.7	100.0
1985	Wild	590	995	3,048	4,633	12.7	21.5	65.8	100.0
1986	Nonhatchery	850	1,295	2,851	4,996	17.0	25.9	57.1	100.0
1987	Hatchery	1,023	833	1,084	2,940	34.8	28.3	36.9	100.0
	Total	1,873	2,128	3,935	7,936	23.6	26.8	49.6	100.0
1987	Nonhatchery	353	1,724	2,471	4,548	7.8	37.9	54.3	100.0
1988	Hatchery	222	1,443	793	2,458	9.0	58.7	32.2	100.0
	Total	575	3,167	3,264	7,006	8.2	45.2	46.6	100.0
1988	Nonhatchery	820	1,700		2,521	32.6	67.4		100.0
1989	Hatchery	1,675	2,380		4,055	41.3	58.7		100.0
	Total	2,495	4,080		6,576	38.0	62.0		100.0
1989	Nonhatchery	1,294			1,294	100.0			100.0
1990	Hatchery	429			429	100.0			100.0
	Total	1,723			1,723	100.0			100.0
Brood years 1975 to 1985					Mean	13.0	26.7	60.3	
Nonhatchery brood years 1986 and 1987					Mean	12.4	31.9	56.2	
Hatchery brood years 1987 and 1988					Mean	21.9	44.5	34.6	

[a] Nonhatchery fish are all age 1 freshwater and hatchery fish are all age 0. Hatchery fish and nonhatchery fish are grouped by smolt year.

[b] Other age classes exist (1.1, 1.5, 2.2, 2.3, 2.4, 2.5) but never make up more than 5% of the return on a combined basis.

[c] These data assume the age composition of the Willow Creek escapement and sport harvest are comparable.

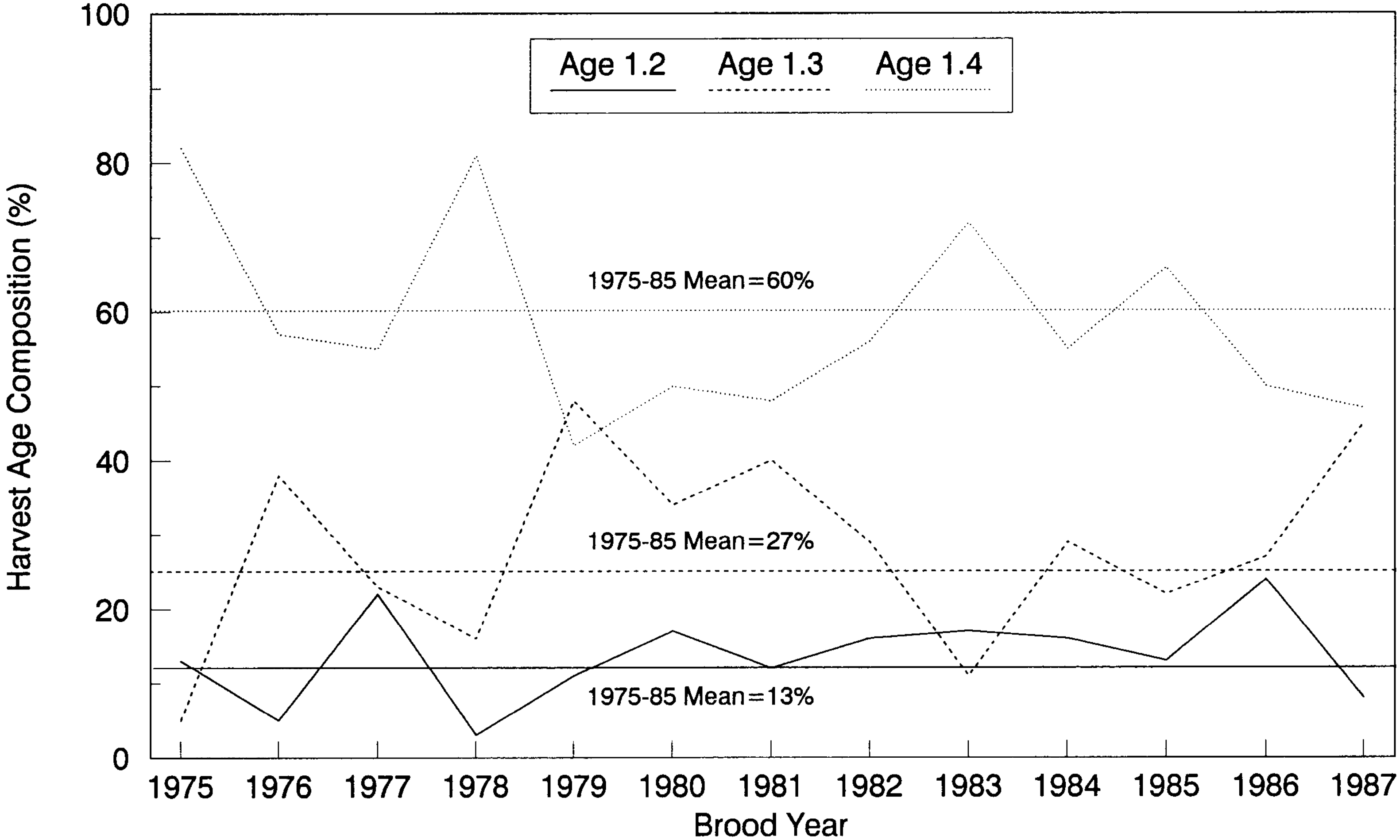


Figure 8. Willow Creek chinook salmon estimated age composition at return for brood years 1975-1987 based on sport harvest data.

substantially and is almost exclusively males (jacks). In addition, 1-ocean males have been abundant since hatchery releases were initiated. These fish are difficult to quantify in both creel and escapement surveys because of their small size (< 400 mm). Other researchers (Bilton et al. 1984, and Martin and Wertheimer 1989) have documented a decline in age at return of hatchery releases (particularly males) as the size of the smolt increases. It may be possible to reduce the occurrence of jacking in the Willow Creek chinook salmon smolt releases by reducing the size of the smolt released. However, this could cause a reduction in marine survival so this course of action is not advocated at this time. The age at return should continue to be closely monitored as additional brood years complete their return.

Comparable length (Appendix B9) and sex (Appendix B10) data have been collected since 1986. Sex composition in the sport harvest varies among age classes. Based on the mean of data collected in 1986-1991, the majority of 2-ocean (97%) and 3-ocean (63%) fish return as males while most 4-ocean (66%) fish return as females (Figure 9). When the 1992 and 1993 data are combined, the resulting mean percent by age class showed a significant difference ($\chi^2 = 5.537$, df = 1, $p = 0.019$) for age 3-ocean fish (63% male prior to 1992 and 54% male for 1992 and 1993 combined). This may be attributed to the shift in age composition caused by the increased number of jacks from the hatchery returns. Since more males are returning earlier after 1 and 2 years in the ocean, there are fewer surviving males to return as 3-ocean males. No significant difference in sex ratio for the 4-ocean and 2-ocean age groups was detected ($\chi^2 = 0.007$ df = 1, $p = 0.935$ and $\chi^2 = 5.029$, df = 1, $p = 0.025$, respectively) (Figure 9).

Based on 1986-1991 means, average length differences among age classes in the sport harvest are obvious with 2-ocean, 3-ocean, and 4-ocean fish averaging 602 mm, 827 mm, and 949 mm, respectively (Appendix B9). In 1992 and 1993 the mean length of 2-ocean fish lies well within the 90% confidence interval (CI) of the historical mean indicating no change in length. The 1992 3-ocean and 4-ocean fish, however, lie slightly below the historical mean CI indicating a possible decrease in mean length during that year. The 1993 3-ocean and 4-ocean mean lengths, however, lie within the historical mean CI indicating no change in mean length (Figure 10). Scale samples and length measurements should continue to be collected from the sport harvest as additional data to monitor any trends in decreasing length and changing sex ratios are needed.

Contribution of Coded Wire Tagged Stocks

The 1993 estimated hatchery contribution to the Willow Creek chinook salmon fishery was the second largest to date (Table 2). The total predicted hatchery return for 1993 was 6,986 (Peltz and Sweet 1993). The estimated actual hatchery return was 3,602 fish (Appendix B7). The predicted return of 4-ocean fish was much greater than the actual estimated return, 2,528 and 793, respectively. The same was true of 3-ocean fish with 3,440 predicted and 2,380 actual estimated returns. The predicted return of 2-ocean fish was 1,018 with an estimated actual return of 429 (Table 8).

Past performance of hatchery smolt stocking at Willow Creek has been well below expectations. Nine brood years of chinook salmon smolt have been stocked since the Willow Creek project started in 1983 (Appendix B1). Returns from brood years 1983, 1984, and 1985 are completed and were far below

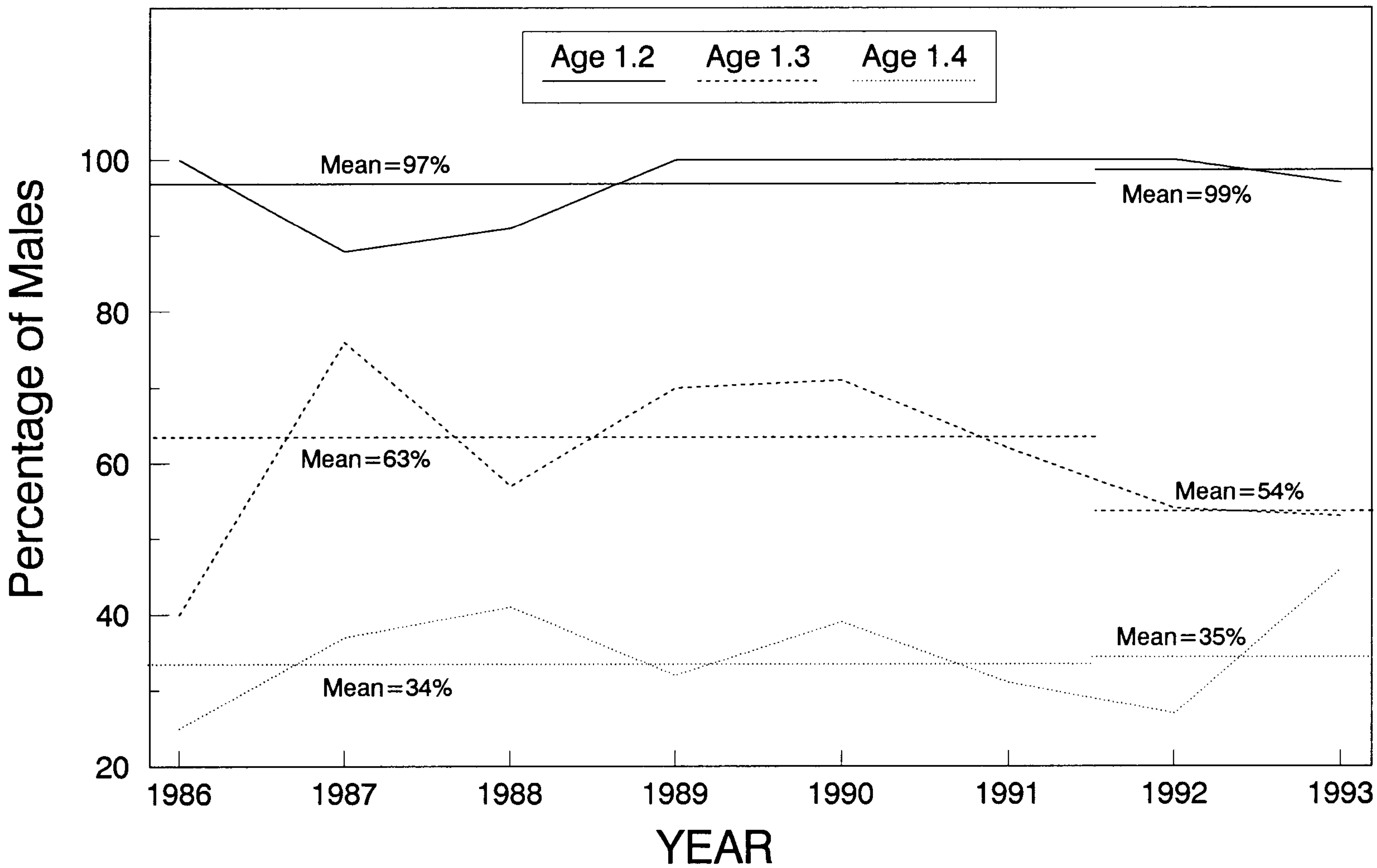


Figure 9. Willow Creek chinook salmon estimated percentage of males by age class from sport harvests for the period 1986-1993.

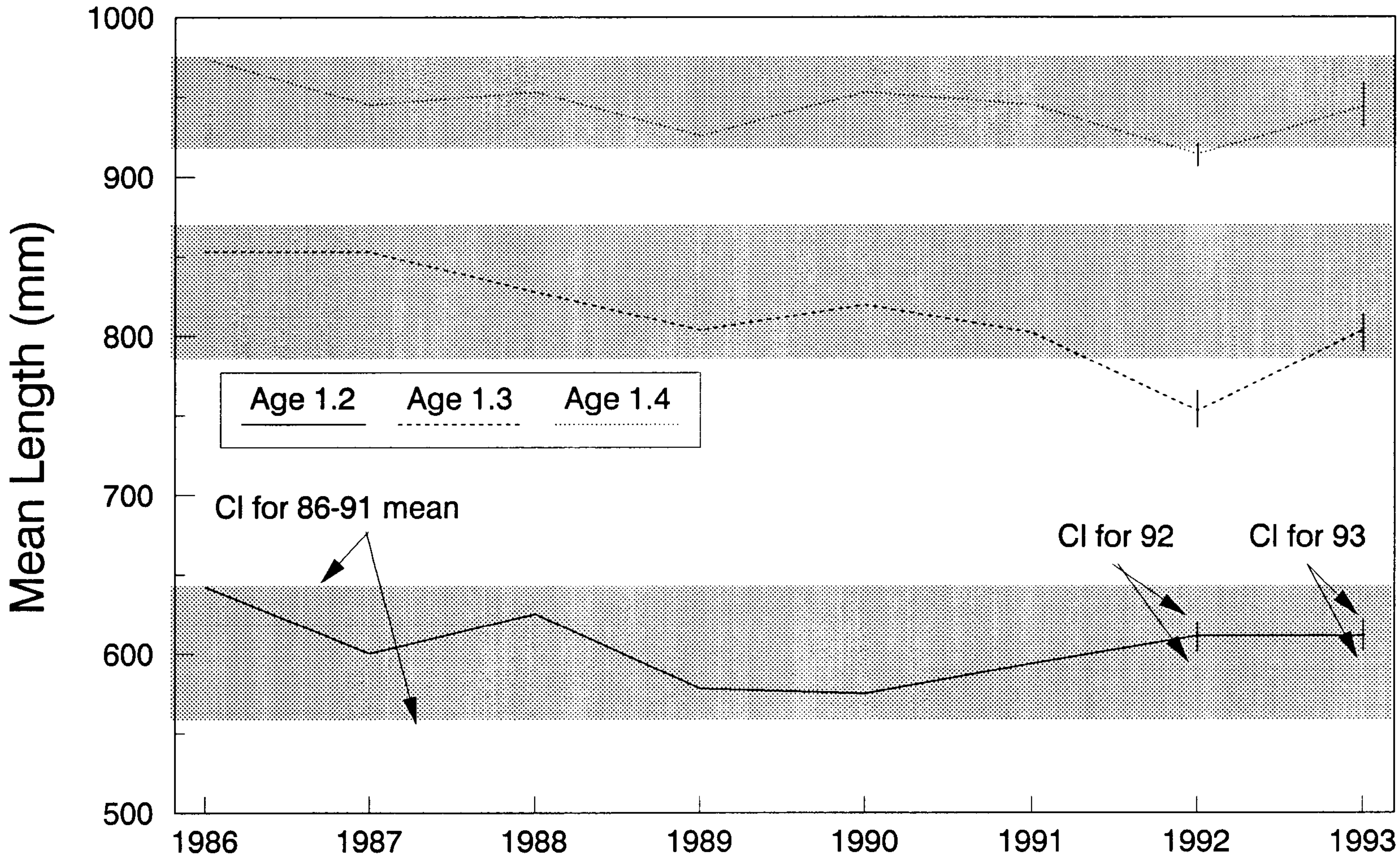


Figure 10. Willow Creek chinook salmon estimated mean length by age class from sport harvests for the period 1986-1993.

Table 8. Comparison of predicted returns and estimated actual returns to Willow Creek, 1992-1994.

Return Year	4 Ocean						3 Ocean					
	Nonhatchery		Hatchery		Total		Nonhatchery		Hatchery		Total	
	Est act[a]	Pred[b]	Est act[a]	Pred[b]	Est act[a]	Pred[b]	Est act[a]	Pred[b]	Est act[a]	Pred[b]	Est act[a]	Pred[b]
1992[c]	2,851	3,258	1,084	2,819	3,935	6,077	1,724	725	1,443	456	3,167	1,181
1993[c]	2,471	3,258	793	2,528	3,264	5,786	1,700	1,684	2,380	3,440	4,080	5,124
1994[d]		3,209		2,089		5,298		3,451		858		4,309

Return Year	2 Ocean						Total					
	Nonhatchery		Hatchery		Total		Nonhatchery		Hatchery		Total	
	Est act[a]	Pred[b]	Est act[a]	Pred[b]	Est act[a]	Pred[b]	Est act[a]	Pred[b]	Est act[a]	Pred[b]	Est act[a]	Pred[b]
1992[c]	820	512	1,675	2,556	2,495	3,068	5,395 56%	4,495 44%	4,202 44%	5,831 56%	9,597	10,326
1993[c]	1,294	566	429	1,018	1,723	1,584	5,465 60%	5,508 44%	3,602 40%	6,986 56%	9,067	12,494
1994[d]		784		474		1,258		7,444		3,421		10,865

a Estimated actual return (harvest plus escapement).

b Predicted return using age composition by brood year, Peltz and Sweet (1992 and 1993).

c Hatchery and nonhatchery returns were calculated using the historical age composition combining hatchery and nonhatchery returns.

d Age composition used for calculating returns was derived separately for hatchery and nonhatchery returns from recent brood years.

expectations (Figure 11). However, the 1987 (1.5% minimum survival) and 1988 (1% minimum survival) brood years have shown a considerable improvement over past years (Figure 11, Appendix B1). The current rate of return has provided sufficient numbers of available chinook salmon to meet our project goal. However, these returns have included returns from a release of 650,000 fish which contributed heavily to the returns in 1992 and 1993. Although still incomplete, returns from subsequent brood years indicate returns similar to brood years 1987 and 1988 (Figure 11). If we continue to accomplish a 1%-1.5% return from a 200,000 fish release we can expect 2,000 to 3,000 fish available for harvest. We will then fall short of our goal of 4,000.

Enhancement Program Evaluation

Success of the Willow Creek chinook salmon enhancement program was measured through attainment of three goals.

The first program goal is to maintain the quality and quantity of natural chinook salmon production. The escapement index goal for Willow and Deception creeks is 2,600 naturally spawning fish. This historic quantity of natural chinook salmon production has been maintained every year since the introduction of hatchery fish as evidenced by attainment of the annual index of 2,600 fish (Table 2).

In order to measure maintenance of fish quality we need size, age and sex composition data from enhanced returns. Returns from the first three brood years (1983-1985) were too small to provide meaningful information to the database and no eggs were collected in 1986. Returns from the 1987 and 1988 brood years were completed in 1992 and 1993 and provided our first data for comparison to previous years. These data suggest that the hatchery-produced fish return at a younger age than nonhatchery fish and may be smaller in size. Subsequent brood years are not yet complete and should be monitored for these trends. The historic age, length and sex data compiled in Appendices B8, B9, and B10 as well as Figures 8, 9 and 10 should provide a basis for future comparison.

Another indicator of quality is maintenance of historic harvest timing (Appendix B11). For Willow Creek, however, the harvest pattern reflects fishing opportunity and does not necessarily reflect the availability of fish to be harvested. For example in 1992, with the opening of 4 additional weekdays during the 22-29 June time period, there were 7 days available to harvest fish compared to 3 in past years. The added fishing time increased the percent of the total harvest taken during this period. Also, the fishery was closed 30 June through 3 July which in the past has been a period of high harvest (Appendix B11). It opened again on 4-6 July allowing only 3 days fishing opportunity from 29 June through 11 July resulting in a small percent of the total harvest being taken during this time period. Appendix B11 indicates the final time period (approximately the first week in July) in 1992 and 1993 has a reduced percentage of the harvest compared to previous years. This may be due to the lateness of the open dates combined with the fishery characteristics. In the earlier years people fished the Parks Highway area of the creek more heavily whereas now very little effort is in this upstream area. With the historical changes in the characteristics of this fishery and the varied dates which are open for fishing it is difficult to detect changing trends in harvest timing.

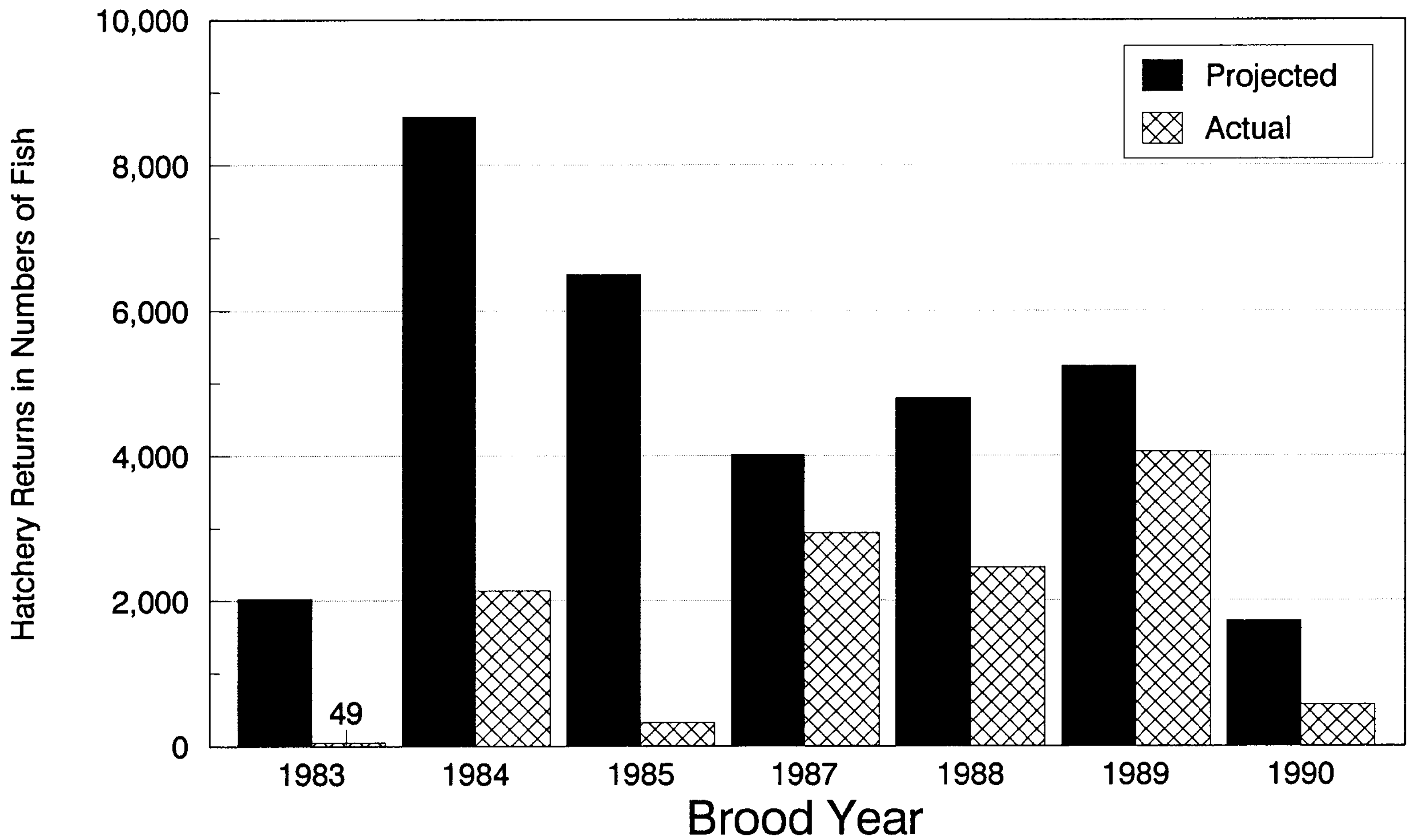


Figure 11. Willow Creek chinook salmon projected and actual hatchery returns by brood year from return years 1983-1990.

The second program goal is to produce (through supplemental hatchery production) 6,000 returning chinook salmon adults (3% marine survival from a 200,000 fish release) of which 4,000 (2% of a 200,000 fish release) are available for harvest in Willow Creek. Returns from the first three brood years did not come close to equaling this projection (Figure 11). However, returns from subsequent releases indicate that the difference between projected and actual returns has decreased considerably (Figures 11 and 12). Hatchery returns of approximately 4,300 fish in 1992 exceeded our goal while the 1993 hatchery return of approximately 3,600 fish nearly attained our goal. However, both these return years included fish from a 650,000 smolt release in 1989. A smolt release of 400,000 in 1990 also contributed to the 1993 return. If we maintain the 1%-1.5% survival that resulted from the 1987 and 1988 brood years and release 200,000 fish as planned, we can expect a return of approximately 2,000 to 3,000 hatchery fish. This will be short of our 4,000 fish goal. If the 4,000 fish return goal is to be maintained, approximately 100,000 to 200,000 additional smolt will need to be stocked.

Utilizing data from the brood table (Table 7) and historic age composition (Appendix B8) allowed us to project 1993 returns (Peltz and Sweet 1993) at an estimated 12,500 fish, of which approximately 56% would be of hatchery origin. The actual estimated return in 1993 was 5,619 harvest and 3,448 escapement index for a minimum of 9,067 of which approximately 40% or 3,602 fish were of hatchery origin. Comparison of the predicted and estimated actual returns are presented in Table 8. The prediction of nonhatchery returns has been quite accurate. However, prediction of hatchery returns has been poor. The poor prediction of hatchery returns has two probable causes. The first cause is that after two complete brood year returns it appears that age composition by brood year differs for hatchery and nonhatchery returns (Table 7). The second cause is that survival rates have not reached the assumed level of 2% (Appendix B1). Consequently, in order to improve our estimation of hatchery returns, the estimated return for 1994 in Appendix B12 has been calculated using the separate hatchery and nonhatchery age composition percentages in Table 7 and the assumed survival rate has been reduced to 1%. The predicted return of hatchery fish in 1994 is approximately 3,400, very close to our goal of 4,000. However, again this return results from smolt releases of 650,000 and 400,000 fish. The overall predicted return in 1994 is approximately 11,000 (Appendix B12). As we acquire additional years of data the prediction of future returns will become more refined.

The last goal of the enhancement program was to provide a minimum of 15,000 angler-days of participation during the period 10 June thru 10 July. Angler participation seems to be driven by the opportunity to catch fish. We have had a large increase in hatchery returns in the past 2 years, which combined with a stable return of over 4,000 nonhatchery fish since 1987 has resulted in a corresponding increase in angler effort. In 1992 we exceeded our goal by 3,000 angler-days and in 1993 we attained our goal of 15,000 angler-days. During these 2 years, the combined return of hatchery and nonhatchery chinook salmon was over 9,000 fish. If the combined hatchery and nonhatchery returns remain near 9,000 fish we may be able to maintain our goal of providing 15,000 angler-days of fishing a year.

The program goals of this project have undergone changes from the original goals stated in Peltz and Sweet (1992). The basis of these changes is documented in the previous reports by Peltz and Sweet (1992 and 1993). These

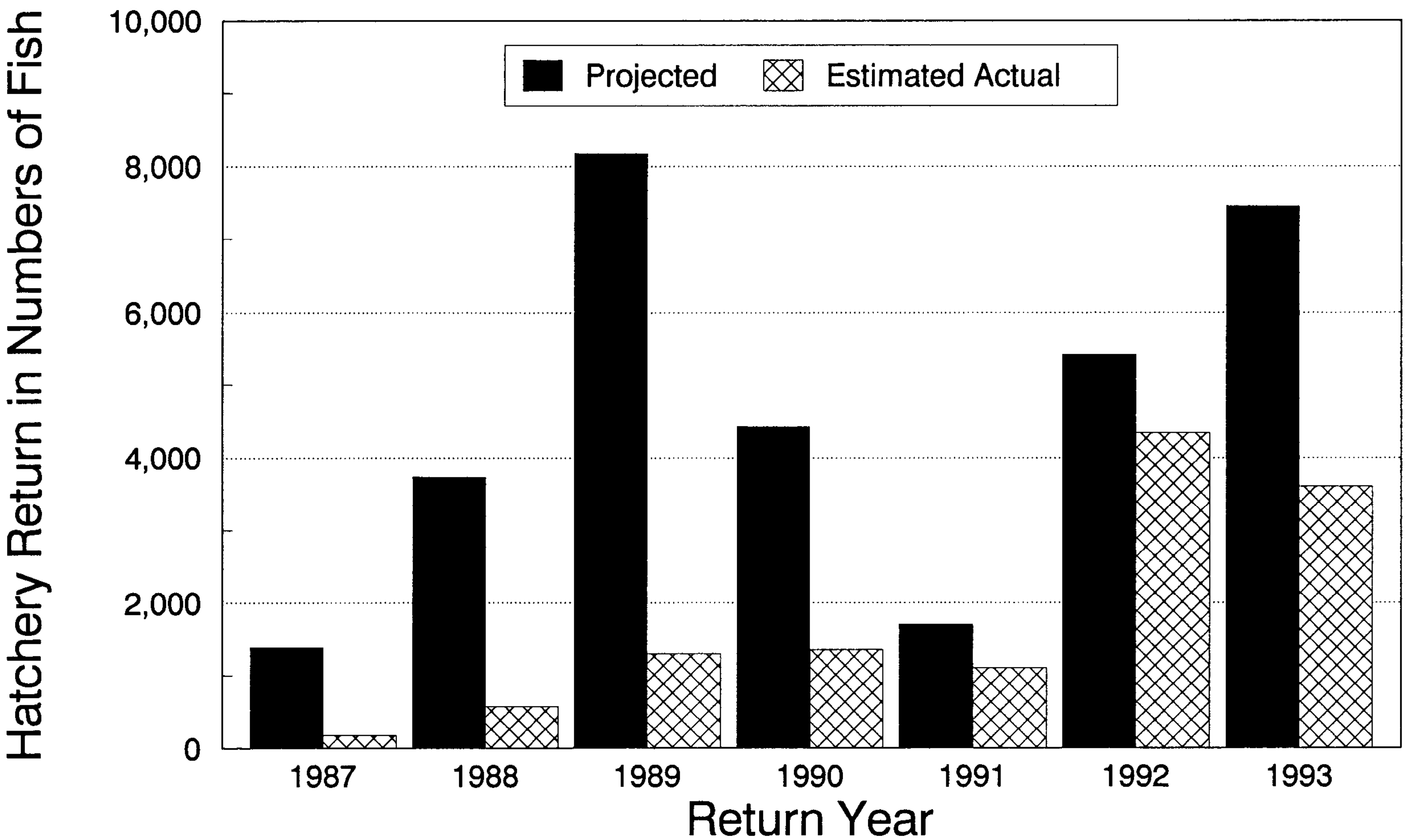


Figure 12. Willow Creek chinook salmon projected and actual hatchery returns for the period 1987-1993 assuming a 2% return.

reports also established the database for measuring the performance and success of the Willow Creek chinook salmon enhancement program. The developmental phase of this project is now complete and based on data assimilated to date, the Willow Creek chinook salmon project appears to be successful. However, monitoring certain parameters is still necessary to assure that our initial assessment of success is accurate. Additional monitoring in the future may be accomplished at reduced levels of manpower and funding if recommendations in this report are adopted.

RECOMMENDATIONS

Based on data analysis and discussion presented in this report, we recommend the following:

1. Discontinue the creel survey monitoring the sport fishery for statistically valid estimates of effort, harvest and catch. The Statewide Harvest Survey should be an adequate source for finalized estimates of these data.

2. Continue to obtain age, length, and sex data from sport harvests. Discontinue sampling of carcasses in escapement surveys.

3. Continue to monitor the sport harvest for adipose finclipped fish and collect heads for coded wire tag recovery.

4. Examination of carcasses for adipose finclipped fish and collection of heads for coded wire tag recovery in escapement surveys should continue to determine if hatchery fish are spawning with nonhatchery fish in mainstem Willow Creek.

5. The brood table developed has potential as a valuable management tool. The projected total return of fish to Willow Creek in 1992 and 1993 was close to actual return numbers. This process should be further refined as more data are assimilated. Yearly projections can be used to help form management strategies for the upcoming year. Without the creel survey there is no estimate of harvest available prior to the beginning of the next season. Consequently, if predicting returns is important to managers, another method of obtaining an estimate of harvest must be developed.

6. Since the developmental stage of this project is complete, yearly reports are no longer necessary. Existing databases should be maintained and yearly statistics of interest can be included in the Cook Inlet Area Management Report. A periodic progress report should be written to document the future success or failure of the project. The next detailed report should be written following data collection in 1996.

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APPENDIX A

Appendix A1. Willow Creek chinook salmon creel survey strata definitions, 1993.

Stratified multi-stage sample surveys were conducted to obtain estimates of angler effort for, and catch and harvest of, chinook salmon for the Willow Creek 1993 mouth fishery. The sampling procedure itself was the roving-type creel survey (Neuhold and Lu 1957). The individual strata are defined as follows:

Stratum	Description	Date - times (hours)
1.	Early Season Weekday	10 June (0000) - 11 June (2359)
2.	Early Season Weekend	12 June (0000-1159)
3.	Early Season Weekend	12 June (1200) - 14 June (2359)
4.	Early Season Weekday	15 June (0000) - 18 June (2359)
5.	Early Season Weekend	19 June (0000-1159)
6.	Early Season Weekend	19 June (1200) - 21 June (2359)
7.	Late Season Weekend	26 June (0000-1159)
8.	Late Season Weekend	26 June (1200) - 28 June (2359)
9.	Late Season Weekend	3 July (0000-1159)
10.	Late Season Weekend	3 July (1200) - 5 July (2359)

The weekday type of strata are defined as Tuesday through Friday with the first weekday type of strata truncated to being only a Thursday and a Friday. There are two types of weekend type of strata: the first 12-hour period of each Saturday (0000-1159) is the first type, and the remaining 60 hours from 1200 hours on each Saturday to 2359 hours on each Monday is the second type. The weekend type of strata were split in this fashion due to the large degree of angler effort expected during the first 12-hour period of each 3-day weekend, as evidenced from an analysis of previous creel survey information (1991 and 1992 data).

Note that all strata were open by regulation to fishing.

Notation for periods within each stratum start with period A at the beginning of each stratum.

During the first weekday stratum (stratum 1) both days were selected for surveying and represent the first sampling stage in a stratified three-stage sample survey. Within each day sampled, sample periods were selected systematically at random from the available periods, and represent the second stage sampling units. Each sample period is 4 hours long, so there are six possible periods within each day. Within each selected sample period random-systematically chosen angler counts were conducted and represent the third sampling stage for the angler count data. For the angler interview data, the anglers sampled for interviewing represent the third stage, for catch per unit effort (CPUE) or harvest per unit effort (HPUE) information.

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During the second weekday stratum (stratum 4) the 96 hours composing the stratum were defined as one contiguous period for sampling (i.e., calendar days ignored). This decision resulted from past surveys indicating that the fishery essentially operates "round-the-clock" starting about the second weekend of June (12 June this year). For this stratum a two-stage sample survey was conducted, with 8-hour periods selected systematically at random from the 12 periods during the 96 hours possible. Angler count times were selected systematically at random, and represent the second stage sampling units for estimating angler effort. The angler interviews conducted within each sampled period represent the second stage sampling units for the estimation of CPUE and HPUE.

During the 12-hour period type of strata (i.e., strata 2, 5, 7, and 9) the entire stratum was surveyed and as such was treated as one sampling period (e.g., 12 June, Period A from 0000 hours to 1159 hours). Accordingly, the sample survey for these type of strata is a single stage design. During these type of strata random-systematically chosen angler counts were conducted and represent the first (and only) sampling stage for the angler count data. Anglers sampled for interviewing represent the first stage for CPUE and HPUE estimation.

During the strata consisting of the remaining 60-hour period for each weekend (i.e., strata 3, 6, 8, and 10) the design of the survey was similar to that used for stratum 4. A total of 12, 5-hour periods were defined as the first-stage units in a two-stage sampling design. Periods were selected systematically at random. As for all other types of strata, angler count times were selected systematically at random within each sampled period, and represent the final sampling stage for estimating angler effort. Angler interviews conducted within each sampled period when not conducting counts represent the second stage units for estimating CPUE and HPUE in these two-stage designs.

The sampling design for 1993 represents a slight modification of the design developed and successfully implemented during 1992. The modifications to the 1992 design primarily were directed at more efficiently surveying the fishery (i.e., expending less sampling resources while maintaining precision). The collection of a large amount of data during 1992 with a similar design enabled the modification of the design along with optimal allocation of sampling effort resulting in goal-expected precisions for parameter estimates.

The periods to sample within strata with multiple sampling periods, as noted above were selected systematically. During stratum 1 (10 and 11 June) two 4-hour periods out of the total of six periods within each day were selected at random from the following possible systematic combinations:

(1) period A (0000-0359) and period D (1200-1559);
(2) period B (0400-0759) and period E (1600-1959); or
(3) period C (0800-1200) and period F (2000-2359).

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Similarly, during stratum 4, six 8-hour periods out of the total of 12 periods within the 96 hours possible were selected at random from the following possible systematic combinations:

(1) 15 June-period A (0000-0759),
15 June-period C (1600-2359),
16 June-period E (0800-1559),
17 June-period G (0000-0759),
17 June-period I (1600-2359), and
18 June-period K (0800-1559); or

(2) 15 June-period B (0800-1559),
16 June-period D (0000-0759),
16 June-period F (1600-2359),
17 June-period H (0800-1559),
18 June-period J (0000-0759), and
18 June-period L (1600-2359).

During stratum 3 (the 60-hour stratum starting at 1200 hours on 12 June) a total of four, 5-hour periods out of 12 total periods were selected at random from the following possible systematic combinations:

(1) Saturday-period A (1200-1659),
Sunday-period D (0300-0759),
Sunday-period G (1800-2259), and
Monday-period J (0900-1359);

(2) Saturday-period B (1700-2159),
Sunday-period E (0800-1259),
Sunday-Monday/period H (2300/Sunday-0359/Monday), and
Monday-period K (1400-1859); or

(3) Saturday-Sunday/period C (2200/Saturday-0259/Sunday),
Sunday-period F (1300-1759),
Monday-period I (0400-0859), and
Monday-period L (1900-2359).

During strata with 12, 5-hour periods (i.e., strata 6, 8, and 10) a total of six periods were selected at random from the following systematic combinations:

(1) Saturday-period A (1200-1659),
Saturday-Sunday/period C (2200/Saturday-0259/Sunday),
Sunday-period E (0800-1259),
Sunday-period G (1800-2259),
Monday-period I (0400-0859), and
Monday-period K (1400-1859); or

(2) Saturday-period B (1700-2159),
Sunday-period D (0300-0759),
Sunday-period F (1300-1759),
Sunday-Monday/period H (2300/Sunday-0359/Monday),
Monday-period J (0900-1359), and
Monday-period L (1900-2359).

-continued-

Since only one period was defined for all other strata (i.e., strata 2, 5, 7, and 9) then the entire period was surveyed as Period A.

The times to conduct angler counts as noted above were selected systematically. During stratum 1, a count was expected to take approximately 20 minutes to conduct. A total of three systematic counts was conducted within each sampled period for stratum 1. Each 20-minute count was scheduled 1 hour and 20 minutes apart. Since each period was 4 hours in length, there were four possible systematic combinations of three counts each. For example, for the period from 0000 to 0359, the four possible sets of start-times for the counts were: (1) 0000, 0120, and 0240; (2) 0020, 0140, and 0300; (3) 0040, 0200, and 0320; or (4) 0100, 0220, and 0340.

During stratum 4 each angler count was expected to take approximately 30 minutes to conduct. A total of five systematic counts were conducted within each sampled period for this stratum. Accordingly, a total of 15 possible 32-minute count times was defined, with 1 hour and 36 minutes between each count. As such a total of three possible systematic combinations of five counts each existed within each 8-hour period. The possible combinations were for the period from 0000 to 0759: (1) 0000, 0136, 0312, 0448, and 0624; (2) 0032, 0208, 0344, 0520, and 0656; or (3) 0104, 0240, 0416, 0552, and 0728.

During the strata with 12, 5-hour periods (i.e., strata 3, 6, 8, and 10) a total of three systematic counts were conducted within each sampled period. A total of nine possible count times each separated by approximately 33 minutes were defined, with 1 hour and 40 minutes between each count. As such a total of three systematic combinations of three counts each existed within each 5-hour period. For example, the possible combinations for period A were: (1) 1200, 1340, and 1520; (2) 1233, 1413, and 1553; or (3) 1306, 1446, and 1626.

During the strata defined as the first 12 hours of each 3-day weekend (i.e., strata 2, 5, 7, and 9), six random-systematically chosen angler counts were conducted and represent the first (and only) sampling stage for the angler count data. Since these strata were hours in length, there were four possible sets of start-times: (1) 0000, 0200, 0400, 0600, 0800, 1000; (2) 0030, 0230, 0430, 0630, 0830, 1030; (3) 0100, 0300, 0500, 0700, 0900, 1100; or (4) 0130, 0330, 0530, 0730, 0930, 1130.

The numbers of count samples to conduct was determined by evaluating the count and interview data collected during 1992. The number of counts selected represents a compromise between the optimal number in terms of the precision of the harvest estimates (Appendix B1), the number that would not lead to biases due to such patterns as cycles in angling effort, and the number of counts that allowed for the optimal number of harvested chinook salmon checked for adipose finclips. Additionally, the lowest number of counts to conduct within each sampled period was set to three which is the minimal number necessary to utilize the variance estimator recommended by Wolter (1985) for estimating the variance of an estimate from systematic sampling.

Appendix A2. Estimation equations for angler effort for, and catch and harvest of, chinook salmon in the 1993 sport fishery in Willow Creek.

Weekday Type of Strata. Estimates of angler effort for, and catch and harvest of chinook salmon as well as other species were estimated according to the following procedures for the first weekday type of strata (i.e., stratum 1). The first step involved obtaining the jackknife estimated sample mean of CPUE (or HPUE) as follows:

$CPUE^{*}_{hijk}$ = the jackknifed CPUE for angler *k* in sample *j* within day *i* and stratum *h*;

$$= \frac{\sum_{\substack{o=1 \\ o \neq k}}^{m_{hij}} c_{hijo}}{\sum_{\substack{o=1 \\ o \neq k}}^{m_{hij}} e_{hijo}} ; \qquad (A2.1)$$

where: c_{hijo} and e_{hijo} were the catch and effort of each interviewed angler; and m_{hij} equaled the number of interviewed anglers in each sampled period.

The jackknife mean CPUE for each sample within each sampled day was then obtained as:

$$\overline{CPUE}^{*}_{hij} = \frac{\sum_{k=1}^{m_{hij}} CPUE^{*}_{hijk}}{m_{hij}} . \qquad (A2.2)$$

Then the bias correction (adapted from Efron 1982, equation 2.8, page 6) was performed:

$$\overline{CPUE}^{*\dagger}_{hij} = [m_{hij} (\overline{CPUE}_{hij} - \overline{CPUE}^{*}_{hij})] + [\overline{CPUE}^{*}_{hij}] ; \qquad (A2.3)^{1}$$

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1 If the bias correction resulted in a negative value, then the uncorrected jackknife statistic was used instead of the bias corrected version in all following equations.

where:

$$\overline{CPUE}_{hij} = \frac{\sum_{o=1}^{m_{hij}} c_{hijo}}{\sum_{o=1}^{m_{hij}} e_{hijo}} . \qquad (A2.4)$$

The bias-corrected jackknife mean was then expanded by the estimated angler effort for the sample to obtain the estimated catch for each sampled period:

$$\hat{C}_{hij} = \hat{E}_{hij} \; \overline{CPUE}^{*\dagger}_{hij} ; \qquad (A2.5)$$

where:

$$\hat{E}_{hij} = \text{estimated angler effort (in hours) for each sample;}$$

$$= H_{hij} \; \bar{x}_{hij} ; \qquad (A2.6)$$

$$\bar{x}_{hij} = \text{mean angler count for each sampled period;}$$

$$= \frac{\sum_{q=1}^{r_{hij}} x_{hijq}}{r_{hij}} ; \qquad (A2.7)$$

H_{hij} was the number of hours in each sampling period within each day (equal to 4 hours as per schedule); r_{hij} equaled the total number of angler counts conducted for each sample; and x_{hijq} was the number of anglers counted fishing during each count.

The harvest for the sample was estimated similarly by substituting the appropriate harvest statistics into equations A2.1 to A2.5, above.

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Estimates of angler effort, catch, and harvest for each day sampled were obtained as follows:

$\bar{\hat{Y}}_{hi}$ = mean of the sample estimates for each sampled day; in which Y represents E, C, or H for effort, catch, and harvest, respectively;

$$= \frac{\sum_{j=1}^{p_{hi}} \hat{Y}_{hij}}{p_{hi}} ; \qquad (A2.8)$$

where: $\hat{Y}_{hij}$ was the estimated sample value for effort (E, as obtained from equation A2.6, above), catch or harvest (C or H, as obtained from equation A2.5, above).

The estimated daily effort, catch, and harvest were obtained by expanding by the number of sampling periods in the day:

$$\hat{Y}_{hi} = P_{hi} \bar{\hat{Y}}_{hi} . \qquad (A2.9)$$

Similarly, the stratum mean of the daily estimates was obtained as follows:

$$\bar{\hat{Y}}_{h} = \frac{\sum_{i=1}^{d_h} \bar{\hat{Y}}_{hi}}{d_h} . \qquad (A2.10)$$

The estimated stratum effort, catch, and harvest were obtained by expanding by the number of days in each stratum:

$$\hat{Y}_{h} = D_h \bar{\hat{Y}}_{h} . \qquad (A2.11)$$

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The variance of the estimated catch for each stratum was obtained by the three-stage variance equation (following the approach outlined by Cochran 1977), omitting the finite population correction factor (fpc) for the third stage units:

$$\hat{V}[\hat{C}_h] = \left[(1 - f_{1h}) \frac{D_h^2}{d_h} S_{1h}^2 \right] + \left[f_{1h} \frac{D_h^2}{d_{2h}^2} \sum_{i=1}^{d_h} (1 - f_{2hi}) \frac{P_{hi}^2}{p_{hi}} S_{2hi}^2 \right] + \left[f_{1h} \frac{D_h^2}{d_{3h}^2} \sum_{i=1}^{d_h} f_{2hi} \frac{P_{hi}^2}{p_{3hi}^2} \sum_{j=1}^{p_{hi}} \hat{V}[\hat{C}_{hij}] \right]; \quad \text{(A2.12)}$$

where:

$$S_{1h}^2 = \frac{\sum_{i=1}^{d_h} (\hat{C}_{hi} - \bar{\hat{C}}_h)^2}{d_h - 1}; \quad \text{(A2.13)}$$

$$S_{2hi}^2 = \frac{\sum_{j=1}^{p_{hi}} (\hat{C}_{hij} - \bar{\hat{C}}_{hi})^2}{p_{hi} - 1}; \quad \text{(A2.14)}$$

$\hat{V}[\hat{C}_{hij}]$ = the within period variance for the estimated sample catch, obtained by Goodman's (1960) formula for the variance of a product of independent random variates:

$$= \hat{E}_{hij}^2 \, s_{3hij}^{*2} + (\overline{CPUE}_{hij}^{*\dagger})^2 \, \hat{V}[\hat{E}_{hij}] - s_{3hij}^{*2} \, \hat{V}[\hat{E}_{hij}]; \quad \text{(A2.15)}$$

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s^{*2}_{3hij} = jackknife estimate of the variance for the jackknifed sample mean CPUE (adapted from Efron 1982, equation 3.2, page 13);

$$= \frac{(m_{hij} - 1)}{m_{hij}} \sum_{k=1}^{m_{hij}} (CPUE^{*}_{hijk} - \overline{CPUE^{*}_{hij}})^2 ; \qquad (A2.16)$$

$\hat{V}[\hat{E}_{hij}]$ = estimated variance of the angler effort estimate for each sample, obtained by using the successive differences formula appropriate for systematic samples (adapted from Wolter 1985, equation 7.2.4, page 251);

$$= \frac{H^2_{hij}}{r_{hij}} \frac{\sum_{q=2}^{r_{hij}} \left[x_{hijq} - x_{hij(q-1)} \right]^2}{2\,(r_{hij} - 1)} ; \text{ and} \qquad (A2.17)$$

d_{2h} equals the number of days sampled in which the among sampling period variances were estimable (i.e., at least two periods sampled in which catch or harvest could be estimated); d_{3h} equaled the number of days sampled in which the within sampling period variances were estimable (i.e., at least two periods in which at least two anglers were interviewed with a mean angler count greater than zero or a mean angler count equal to zero); and p_{3hi} equaled the number of periods in which the within period variances were estimable within each day sampled.

Variance estimates for the estimated harvest were obtained by replacing the appropriate harvest statistics (h's and H's) for the catch statistics (c's and C's) in equations A2.12 through A2.15, above.

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Stratum estimates of the variance of the angler effort were obtained in a similar manner to those for catch and harvest. The primary difference occurred in the third major term in equation A2.12:

$$\hat{V}[\hat{E}_h] = \left[(1 - f_{1h}) \frac{D_h^2}{d_h} s_{1h}^2 \right] + \left[f_{1h} \frac{D_h^2}{d_{2h}'^2} \sum_{i=1}^{d_h} (1 - f_{2hi}) \frac{P_{hi}^2}{p_{hi}} s_{2hi}^2 \right] + \left[f_{1h} \frac{D_h^2}{d_{3h}'^2} \sum_{i=1}^{d_h} f_{2hi} \frac{P_{hi}^2}{p_{3hi}'^2} \sum_{j=1}^{p_{hi}} \hat{V}[\hat{E}_{hij}] \right]. \quad \text{(A2.18)}$$

The values for the terms in equation A2.18 were obtained by replacing the catch statistics (C's) by the appropriate effort statistics (E's) in equations A2.13 and A2.14 (equation A2.17 was used as is in the final term of equation A2.18). The term d'_{2h} equaled the number of days sampled in which the among sampling period variances were are estimable (i.e., at least two periods sampled in which effort could be estimated); d'_{3h} equaled the number of days sampled in which the within sampling period variances were estimable (i.e., at least two periods with multiple angler counts conducted); and p'_{3hi} equaled the number of periods in which the within period variances were estimable within each day sampled.

The second weekday stratum (stratum 4) was defined as one continuous 96-hour stratum with calendar days ignored. Estimates of angler effort, catch, and harvest along with their variances were calculated by using equations A2.1 to A2.11, above; however, in applying these equations the *i* subscript was dropped since days were not a sampling stage for this stratum. Twelve 8-hour sampling periods were defined within this 96-hour stratum. Results from equation A2.11 represented the estimated stratum effort, catch, and harvest.

The variance estimate for the estimated catch for stratum 4 was calculated from equations A2.12 (without the middle major term), A2.13, A2.15, and A2.16, above. The estimated variance of the harvest estimate was obtained similarly by substitution.

Similarly, the estimated variance for the angler effort estimate was calculated from equation A2.17, above. Again, in applying these equations the *i* subscript was dropped.

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Weekend Type of Strata. Estimates of angler effort, catch, and harvest along with their variances for the 12-hour weekend strata (i.e, strata 2, 5, 7, and 9) were calculated by using equations A2.1 to A2.7, above. In applying these equations all *i* and *j* subscripts were dropped since days were not a sampling stage for these strata and only one period existed within each stratum. The "H_{hij}" term in equation A2.6 equated to 12 hours. The results from equation A2.5 and A2.6 represented the stratum estimates of catch and effort, respectively. Harvest was estimated similarly by substitution.

The variance estimates for the estimated catch were calculated directly from equations A2.15 and A2.16, above. The estimated variance of the harvest estimate was obtained similarly by substitution.

Similarly, the estimated variance for the angler effort estimate was calculated from equation A2.17, above. Again in applying these equations all *i* and *j* subscripts were dropped.

Estimates of angler effort, catch, and harvest along with their variances for the 60-hour weekend strata (i.e, strata 3, 6, 8, and 10) were calculated by using equations A2.1 to A2.11, above. Estimation procedures were similar to those described above for the second weekday stratum (i.e. stratum 4). In applying these equations the *i* subscript was dropped since days were not a sampling stage for these strata. Twelve 5-hour periods were defined within each stratum. The "H_{hij}" term in equation A2.6 equated to 60 hours. Results from equation A2.11 represented the estimated stratum effort, catch, and harvest.

The variance estimates for the estimated catch were calculated from equations A2.12 (without the middle term), A2.13, A2.15, and A2.16, above. The estimated variance of the harvest estimate was obtained similarly by substitution.

Similarly, the estimated variance for the angler effort estimate was calculated from equation A2.17, above. Again, in applying these equations the *i* subscript was dropped.

Combined Strata Estimates. Total angler effort, catch, or harvest across all strata (or select combinations of strata) and the associated variances were obtained by summing (assuming independence).

Appendix A3. Estimation equations for the age composition in proportions and in numbers for the fish harvested in the chinook salmon sport fishery in Willow Creek, 1993.

Estimates of age composition (proportion) by sex for the subsampled chinook salmon were calculated. The first step involved grouping the information collected from contiguous sets of sampling strata. Chi-squared contingency table tests were conducted to evaluate the similarity of age compositions across grouped strata. Similarly, the proportion sampled of the estimated chinook salmon harvested within each stratum was evaluated for adherence to proportional sampling. If either proportional sampling is indicated or if the age compositions do not appreciably differ among strata, then the procedures outlined below were applied to each data set (creel survey and carcass survey, separately) regardless of sampling strata. Otherwise, estimates of age composition (proportion) for the subsampled chinook salmon were calculated for each stratum (or possibly grouped strata). Each proportion was calculated according to the following procedures:

$\hat{p}_{uh}$ = estimated proportion of the sampled chinook salmon harvested or in the spawning escapement samples that are age *u* within each stratum (stratum refers only to harvest age composition estimates);

$$= \frac{n_{uh}}{n_h}; \qquad \text{(A3.1)}$$

where: n_{uh} equals the number of the sampled chinook salmon either harvested within each stratum for the creel surveys or the number sampled from the escapement that are age *u*; and n_h equals the total number of chinook salmon sampled within each creel survey or escapement stratum.

The variance of the estimated proportion of chinook salmon harvested or in the escapement was estimated approximately by the standard equation for the variance of a binomial proportion (Cochran 1977, equation 3.8, page 52):

$$\hat{V}[\hat{p}_{uh}] \approx (1 - \frac{n_h}{\hat{H}_h}) \frac{p_{uh}(1 - p_{uh})}{n_h - 1} \text{ or } \frac{p_{uh}(1 - p_{uh})}{n_h - 1}; \qquad \text{(A3.2)}$$

where: $\hat{H}_h$ equals the estimated harvest of chinook salmon in each stratum. The second term on the right-hand side of equation (after the or) is used for the escapement samples, since we do not know the absolute magnitude of the escapement (and cannot calculate an fpc).

The estimated proportion by age class (across all strata or select combinations of strata for the creel survey) was obtained by first estimating the number of chinook salmon by age class in each stratum:

$\hat{N}_{uh}$ = estimated number of fish harvested which are age class *u*;

$$= \hat{H}_h \hat{p}_{uh} . \qquad \text{(A3.3)}$$

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The variance of the estimated number of fish harvested which are age class *u*, is obtained by Goodman's (1960) equation for the variance of the product of two random variates:

$$\hat{V}[\hat{N}_{uh}] = \hat{H}_h^2 \hat{V}[\hat{p}_{uh}] + \hat{p}_{uh}^2 \hat{V}[\hat{H}_h] - \hat{V}[\hat{p}_{uh}] \hat{V}[\hat{H}_h] ; \quad \text{(A3.4)}$$

where: $\hat{V}[\hat{H}_h]$ equals the variance of the estimated harvest for each stratum.

Next estimate the number of fish in the harvest in each age class by summing the numbers across strata:

$$\hat{N}_u = \sum_{h=1}^{s} \hat{N}_{uh}. \quad \text{(A3.5)}$$

The variance of the estimated number of each age fish in the harvest was obtained by summing the corresponding variances (assuming independence, see Kish 1965, equation 2.8.7, page 61). Finally, the proportion of each age class across strata was obtained as follows:

$$\hat{p}_u = \frac{\hat{N}_u}{\hat{N}} ; \quad \text{(A3.6)}$$

where:

$$\hat{N} = \sum_{u=1}^{C} \hat{N}_u ; \quad \text{(A3.7)}$$

and C = the number of classes to combine.

The variance of this estimate was obtained only approximately using the usual estimator for the variance of a ratio of random variables (see equation 15 on page 181 in Mood et al. 1974):

$$\hat{V}[p_u] \approx \left[\frac{\hat{N}_u}{\hat{N}} \right]^2 \left[\frac{V[\hat{N}_u]}{\hat{N}_u^2} + \frac{V[\hat{N}]}{\hat{N}^2} - \frac{2\,V[\hat{N}_u]}{\hat{N}_u \hat{N}} \right] ; \quad \text{(A3.8)}$$

where:

$$\hat{V}[\hat{N}] = \sum_{u=1}^{C} \hat{V}[\hat{N}_u] . \quad \text{(A3.9)}$$

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Appendix A3. (Page 3 of 3).

Estimates of mean length by age group of chinook salmon subsampled from the sampled harvest were also calculated. The procedures outlined by Sokal and Rohlf (1981, Boxes 4.2 and 7.1, pages 56 and 139) were used to obtain the estimates of each mean and its standard error. Note, that although the harvest was sampled by a stratified multi-stage approach, the samples of fish lengths were treated as if collected by a simple random sampling program. Length at age was assumed to not vary substantially from stage to stage or stratum to stratum.

Appendix A4. Estimation equations for the hatchery contribution of stocked chinook salmon to the sport fishery in Willow Creek, the escapement to Willow Creek as observed via carcass surveys, and to the escapement through the Deception Creek weir, 1993.

Hatchery contributions were estimated for the sport fishery using the procedures of Clark and Bernard (1987). A bootstrap procedure was used to estimate the variances and standard errors of these estimates (Efron 1982). The equations presented in Clark and Bernard (1987) could not be used to estimate these variances due to the presence of sampling error in our estimates of total harvest. Estimates were obtained either separately for each stratum, or by select combinations of strata. Combination of strata can occur if either the relative contribution rate of each CWT release lot does not vary among the strata to be combined <u>or</u> if the sampling fractions (number inspected for adipose finclips versus the estimated harvest) are similar among the strata to be combined. As such, within any 3-day weekend the two strata that comprise the weekend fishery (i.e., the first 12-hour period and the last 60-hour period) were combined. Combination of strata will only be necessary (prior to data analysis) if insufficient numbers of chinook salmon were inspected for adipose finclips or insufficient tags were decoded (regardless of tag code). Contingency table analyses comparing the sampling fractions among strata and comparing the marked (adipose finclipped) to unmarked ratios among strata were used to determine if strata can be combined.

The notation used in the following equations essentially follows that used by Clark and Bernard (1987), with additional subscripts used to denote individual stratum (or combined strata periods). The first step will involve estimating the contribution to each stratum (or combined strata) in the fishery of each particular tag code (using equation [10] from Clark and Bernard (1987):

$\hat{n}_{1Ah}$ = estimated contribution of stocked fish from release associated with unique tag code *A* for fishery stratum *h*;

$$= \left[\frac{\hat{N}_h}{n_{2h}}\right]\left[\frac{a_{1h}}{a_{2h}}\right]\left[\frac{m_{1h}}{m_{2h}}\right]\left[\frac{m_{ah}}{\theta_A}\right]; \qquad \text{(A4.1)}$$

where: $\hat{N}_h$ equals the estimated harvest of all chinook salmon within each stratum; n_{2h} is the number of chinook salmon inspected for missing adipose fins from the sampled harvest in each fishery stratum; a_{1h} equals the number of chinook salmon with a missing adipose fin which were counted and marked with a head strap from each stratum; a_{2h} equals the number of chinook salmon heads previously marked with a head strap which arrived at the tag lab, from fish originally sampled from stratum *h*; m_{1h} equals the number of coded wire tags which were detected in the chinook salmon heads at the tag lab, from those sampled from stratum *h*; m_{2h} is the number of coded wire tags which were removed from the chinook salmon heads and

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decoded, from chinook salmon sampled from stratum *h*; m_{ah} is the number of coded wire tags dissected out of the chinook salmon heads and decoded as the unique tag code *a*, originally sampled from stratum *h*; and θ_A equals the proportion of a particular hatchery release which contains a coded wire tag of the unique tag code *A*.

Estimates of across strata (or initially combined strata) contributions by tag code, as well as by combined tag codes were obtained by summing the estimates across the strata and tag codes, as appropriate.

Bootstrapping was used to calculate the variance of the contribution estimate. The components of variance for the contribution estimate include components from the harvest estimation procedure (i.e., the creel survey) and the harvest sampling program. Estimated harvest was considered normally distributed and its variance was calculated in closed form. The bootstrap resampling primarily involved estimation of the variance due to the CWT sampling program. Equation 10 was first divided into three components (in the following presentation subscripts denoting strata and particular tag codes have been dropped):

$$\frac{N \left[\dfrac{m_1}{m_2} \; \dfrac{a_1}{a_2} \; \dfrac{m_c}{n_2} \right]}{\theta}.$$

The first component (N) is harvest as estimated from the creel survey, and the third component (θ) is obtained from the tag lab database and is assumed to be known for the hatchery tag codes. The second component $[(m_1/m_2)(a_1/a_2)(m_c/n_2)]$ corresponds to statistics garnered through harvest sampling (and lab work); for convenience, M is defined as the result of the arithmetic operations in this second component. Each of these three components is the product of three distinct and independent programs.

The bootstrap was used to simulate the variation in the second component by resampling data from the harvest sampling program. Each fish counted in the harvest sampling program was placed into one of the following six categories depending on its progress through the program:

1. Adipose fin was present, therefore head was not retained;
2. Adipose fin was missing, either the head was strapped and sent to lab, but never arrived, or the head was not strapped or sent to the lab;

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3. Head arrived at lab, but contained no CWT;
4. Head contained a CWT, but tag was not decoded;
5. Tag was decoded, but did not carry the appropriate code; and
6. Tag did carry the appropriate code.

A multinomial, empirical density distribution with six cells was created with the data from the harvest sampling program. Respective to the categories above, the probabilities of drawing a single sample from this distribution was calculated from the original data as follows:

$$\frac{n_2 - a_1}{n_2} \quad \frac{a_1 - a_2}{n_2} \quad \frac{a_2 - m_1}{n_2} \quad \frac{m_1 - m_2}{n_2} \quad \frac{m_2 - m_c}{n_2} \quad \frac{m_c}{n_2} .$$

The bootstrap technique began by drawing with replacement a sample of size n_2 from the empirical distribution according to the probabilities based on the original data. Once such a sample was drawn (call it sample b), the result was tallied to obtain a new set of statistics $\{a^*_1, a^*_2, m^*_1, m^*_2, m^*_c\}_b$ and a value of M_b. A large number (say B numbers) of M_b are so generated, their values can be used as an empirical distribution with mean and variance. These statistics were calculated as:

$$V[\bar{M}] = \frac{\sum_{b=1}^{B} (M_b - \bar{M})^2}{B - 1} \quad \text{with} \quad \bar{M} = \frac{\sum_{b=1}^{B} M_b}{B} . \qquad (A4.2)$$

Then the variance of the contribution was estimated as:

$$\hat{V}[\hat{n}_1] = \theta^{-2} (\hat{V}[\bar{M}] \hat{N}^2 + \hat{V}[\hat{N}] M^2 - \hat{V}[\bar{M}] \hat{V}[\hat{N}]) . \qquad (A4.3)$$

Estimates of the variance of across strata contributions by tag code, as well as by combined tag codes, was obtained by summing the variances across the strata and tag codes, as appropriate. The resulting estimates of variance were assumed to be conservative in that the covariances among contribution estimates by tag code within each sampling stratum were assumed to be negative (Clark and Bernard 1987).

Standard errors (SE's) were obtained as the square root of the appropriate variance.

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Relative Contributions to the Escapement:

The estimates of relative contribution to the escapement by coded wire tag code were estimated by adapting the equations presented in Clark and Bernard (1987). These estimates represent the proportion of harvested fish of the particular tag code. The adaptation to equation [10] from Clark and Bernard 1987 involves dividing both sides of the equation by the unestimated total harvest value (i.e., in equation 11, Appendix 2). The resulting term on the left-hand side of the equation is n_1 / N (without the stratum subscript or "^" to denote estimates) which is defined as the relative contribution, and is calculated by:

$$\hat{p}_{c_A} = \left[\frac{1}{n_2} \frac{a_1}{a_2} \frac{m_1}{m_2} \frac{m_{cA}}{\theta_A} \right] ; \qquad (A4.4)$$

where: all other terms are as defined above (without the stratum subscripts).

As was done in the estimation of the absolute contributions the variance of the relative contribution estimate was estimated by bootstrapping the harvest sampling data (i.e., generation of B replications of {a^*_1, a^*_2, m^*_1, m^*_2, m^*_c} and M) resulting in the bootstrap estimates from equation A4.1, above. Then the variance of the relative contribution estimate was estimated by:

$$\hat{V}[\hat{p}_{c_A}] = \frac{\hat{V}[\bar{M}]}{\theta_A^2} ; \qquad (A4.5)$$

where: m_{cA} equals the number of tagged chinook salmon of a particular tag code sampled from the escapement; and n_2 equals the number of chinook salmon examined in the escapement sampling for the presence of CWT's.

APPENDIX B

Appendix B1. Numbers of chinook salmon smolt stocked into the Willow Creek drainage from 1985-1993 with corresponding release and recovery information.

Brood Year	Release Location	Total Smolt Release	Valid Coded Wire Tagged[a]	Number Marked[b]	Mean Size	Release Date	Tag Code	Proportion Coded-Wire Tagged	Total Tag Recoveries	Min. Est. Rtn.[c]	Min.Est Surv. to Adult[d]	Last Rtn. Year
1983	Deception	101,256	8,152		18.0	6/13/85	31-16-42	.0805	3	49	<0.05%	1989
1984	Deception	214,384	11,038		13.8	6/11-12/85	31-16-45	.0515	26	1,230	0.6%	1989
	Deception	218,743	10,708		14.0	6/20/85	31-16-47	.0490	29	911	0.4%	1989
1985	Deception	49,668	9,933		16.7	5/01/86	31-17-33[e]	.2000	5	60	0.1%	1990
	Deception	127,904	18,400		12.2	5/10/86	31-17-27					
	Deception	147,877			11.4	5/10/86						
		275,781	18,400					.0667	9	264	0.1%	1990
1987	Deception	201,091	20,936		10.9	7/12/88	31-17-58	.1041	142	2,940	1.5%	1992
1988	Deception	240,885	19,851		13.0	5/31/89	31-17-60	.0824	87	2,458	1.0%	1993
1989	Deception	219,362	41,570		14.4	5/24/90	31-17-34	.1895	90	1,373		1994
	Deception	219,432	40,575		13.4	5/24/90	31-18-51	.1849	84	1,286		1994
	Deception	216,697	40,438		13.9	5/24/90	31-18-52	.1866	107	1,396		1994
		655,491	122,765						181	4,055	0.6%[f]	
1990	Deception	168,777			11.2	5/21/91						
	Deception	70,258	31,167		12.3	5/31/91	31-19-33					
	Willow	73,756			12.3	5/28/91						
	Willow	78,878	31,167		12.3	5/30/91	31-19-33					
		391,669	62,334					.1591	26	567	0.1%[f]	1995
1991	Deception	179,724	33,464	44,089	13.5	5/29/92	31-21-03					
	Deception	35,752			14.5	6/09/92						
		215,476	33,464	44,089				.1553	0	0		1996
1992	Deception	160,194	39,626	42,939	14.9	6/01/93	31-21-60	.2473	0	0		1997

[a] Estimated number possessing a coded wire tag at the time of release.

[b] Fish that were adipose finclipped and coded wire tagged.

[c] Minimum estimated return to Willow Creek includes estimated CWT recoveries from sport fishery harvest (creel survey), estimated escapement (carcass surveys) and Deception Creek egg take. No estimate is made for interception in commercial fisheries, nontarget sport fisheries or straying from Willow Creek.

[d] Minimum estimated return (estimated from total CWT recoveries) divided by total smolt release times 100.

[e] 31-17-33 are Deshka River chinook mistakenly released in Willow Creek.

[f] Incomplete estimate. All age classes have not yet returned.

Appendix B2. Numbers of chinook salmon smolt stocked into Montana and Sheep creeks in 1988 and 1989 with corresponding release information.

Brood Year	Tag Code	Number Tagged	Number Released	Expansion Factor	Proportion Tagged	Mean Size (gm)	Lifestage	Release Date	Release Location	Dominant Return
1987	31-17-59	21,615	132,465	6.1	0.1632	10.9	smolt	7/05/88	Montana Creek	1992
1987	No tag		132,125		0.0000	10.9	smolt	7/07/88	Sheep Creek	1992
1988	31-18-31	20,391	177,789			12.3	smolt	6/07/89	Montana Creek	1993
	No tag		7,317			12.3	smolt	6/12/89	Montana Creek	
	Total	20,391	185,106	9.1	0.1102					
1988	31-18-36	20,263	181,252			12.3	smolt	6/06/89	Sheep Creek	1993
	No tag		26,927			12.3	smolt	6/12/89	Sheep Creek	
	Total	20,263	208,179	10.3	0.0973					

Appendix B3. Coded wire tag recoveries and relative contribution of hatchery produced fish from Willow and Deception Creek carcass surveys and Deception Creek weir egg collection in 1993.

Location	Date	Carcasses Examined	Adipose Clips	Heads Collected	Scales Collected	Coded wire tag Recoveries Number/Tag code	Relative Contribution	SE
Willow Ck. canyon downstream to Deception Creek confluence	7/23-8/9	398	12	12	266	3\31-17-60	9.1%	5.2
						1\31-17-34	1.3%	1.3
						1\31-18-51	1.4%	1.4
						1\31-18-52	1.3%	1.4
						6\ no tag		
							13.2%	5.7
Deception Creek carcass surveys	8/3-8	308	40	31	0	4\31-17-60	20.3%	10.0
						7\31-17-34	15.5%	5.9
						7\31-18-52	15.7%	5.7
						3\31-18-51	6.8%	3.9
						2\31-19-33	5.3%	3.6
						8\ no tag		
						Total	63.6%	14.0
Deception Creek weir egg take	7/19-26	133	11	11	184	1\31-17-60	9.1%	8.8
						3\31-17-34	11.9%	7.0
						2\31-18-51	8.1%	5.7
						3\31-18-52	12.1%	7.0
						1\31-19-33	4.7%	4.6
						Total	46.0%	15.1
Total		839	63	54	450			

Appendix B4. Number of chinook salmon inspected, number of adipose finclips observed, number of heads collected, and coded wire tag returns by strata from the Willow Creek creel survey in 1993 (only fish greater than or equal to 16 inches).

	Strata					
Date	1,2&3 6/10-14	4 6/15-18	5&6 6/19-21	7&8 6/26-28	9&10 7/3-5	Total
# fish inspected	145	257	352	553	136	1,443
# clips observed	12	37	20	47	23	139
# heads collected	11	35	18	25	22	111
Coded wire tag recoveries						
31-17-60[a]	1	2	0	3	0	6
31-17-34[b]	4	12	6	1	7	30
31-18-51[c]	1	5	4	11	4	25
31-18-52[d]	2	5	3	5	2	17
31-19-33[e]	2	3	2	3	2	12
No tag	(1)	(8)	(3)	(2)	(7)	(21)
Total CWT returns	10	27	15	23	15	90

a Willow Creek 1989 release.

b Willow Creek 1990 release.

c Willow Creek 1990 release.

d Willow Creek 1990 release.

e Willow Creek 1991 release.

Appendix B5. Tag recoveries from chinook salmon stocked in Willow, Montana, and Sheep creeks and recovered in nontarget fisheries, 1986-1993.

Year	Tag Code	Recovery Date	Statistical Area	Name of the Fishery
Willow Creek releases:				
1986		No Recoveries		
1987	31-16-47	11-Jul-87	331-	Kotzebue Sound subsistence Fishery (Sheshalic)
1988		No Recoveries		
1989	31-17-27	14-Jul-89	157-	Southeast troll fishery outside waters
1990	31-17-58	11-Jun-90	247-	Cook Inlet gill net
	31-17-60	22 Oct-90	56N-155W	High seas trawl
1991	31-17-58	31-May-91	212-	Copper River gill net
	31-17-58	20-May-91	244-10	Homer sport fishery
	31-17-58	18-Jun-91	224-30	Crooked Creek sport fishery
	31-17-60	20-May-91	212-	Copper River gill net
	31-18-51	16-Jul-91	212-	Copper River gill net
1992	31-18-52	16-Jun-92	225-	Prince William Sound
	31-18-52	20-Jun-92	212-	Copper River gill net
	31-18-52	9-Nov-92	113-41	Southeast troll fishery
1993	31-18-51	28-Oct-93	113-41	Southeast troll fishery
	31-18-52	2-Jul-93	113-	Southeast troll fishery
	31-17-34	27-May-93	212-	Copper River gill net
	31-17-34	12-Jun-93	212-	Copper River gill net
Montana Creek releases:				
1990	31-17-59	23-Oct-90	55N-155W	High seas trawl
1992	31-18-31	8-Jun-92	244-20	Homer sport fishery
Sheep Creek releases:				
1992	31-18-36	16-Oct-92	113-41	Southeast troll fishery

Appendix B6. Coded wire tag recoveries of Willow Creek chinook salmon in the Willow Creek creel survey, Willow Creek escapement surveys, and Deception Creek escapement (egg take and carcass survey), 1986-1993.

	Brood Year	1983	1984		1985		1987	1988	1989			1990	Total	Total
	Tag Code	31-16-42	31-16-45	31-16-47	31-17-33	31-17-27	31-17-58	31-17-60	31-17-34	31-18-51	31-18-52	31-19-33	Tags Recovered	Fish Examined
Year	Recovery Location													
1986	Deception Ck. E.T.[a]	1	2	2	0	0	0	0	0	0	0	0	5	296
1987	Deception Ck. E.T.[a]	2	6	16	0	0	0	0	0	0	0	0	24	692
1988	Willow Ck. C.S.[b]	0	2	2	0	0	0	0	0	0	0	0	4	528
	Deception Ck. E.T.[a]	0	1	3	1	0	0	0	0	0	0	0	5	358
1989	Willow Ck. C.S.[b]	0	10	5	0	1	0	0	0	0	0	0	16	1,005
	Willow Ck. Esc.	0	1	0	0	0	0	0	0	0	0	0	1	632
	Deception Ck. E.T.[a]	0	3	0	1	1	0	0	0	0	0	0	5	358
1990	Willow Ck. C.S.[b]	0	1	1	0	5	33	1	0	0	0	0	41	1,309
	Willow Ck. Esc.	0	0	0	1	0	1	0	0	0	0	0	2	703
	Deception Ck Esc.[c]	0	0	0	2	2	22	1	0	0	0	0	27	659
1991	Willow Ck. C.S.[b]	0	0	0	0	0	19	5	0	0	0	0	24	1,063
	Willow Ck. Esc.	0	0	0	0	0	0	0	0	0	0	0	0	270
	Deception Ck. Esc.[c]	0	0	0	0	0	10	0	0	0	0	0	10	309
1992	Willow Ck C.S.[b]	0	0	0	0	0	48	62	46	49	74	10	289	4,607
	Willow Ck. Esc.	0	0	0	0	0	2	0	0	0	1	0	3	202
	Deception Ck. Esc.[c]	0	0	0	0	0	7	4	3	4	4	1	23	115
1993	Willow Ck C.S.[b]	0	0	0	0	0	0	6	30	25	17	12	90	1,443
	Willow Ck. Esc.	0	0	0	0	0	0	3	1	1	1	0	6	398
	Deception Ck. Esc.[c]	0	0	0	0	0	0	5	10	5	10	3	33	441
Total		3	26	29	5	9	142	87	90	84	107	26	608	13,388

[a] E.T. = egg take.

[b] C.S. = creel survey; only chinook salmon greater than 16 inches are included.

[c] Deception Creek weir and Deception Creek carcass survey combined.

Appendix B7. Estimated hatchery return of Willow Creek releases to the Willow Creek creel survey, Willow Creek escapement survey, and Deception Creek escapement (egg take and carcass survey), 1986-1993.

	Brood Year	1983	1984		1985		1987	1988	1989			1990	Estimated Minimum
	Tag Code	31-16-42	31-16-45	31-16-47	31-17-33	31-17-27	31-17-58	31-17-60	31-17-34	31-18-51	31-18-52	31-19-33	Return
Year	Recovery Location												
1986	Deception Ck. E.T.[a]	21	68	68	0	0	0	0	0	0	0	0	157
1987	Deception Ck. E.T.[a]	28	28	118	0	0	0	0	0	0	0	0	174
1988	Willow Ck. C.S.[b]	0	159	167	0	0	0	0	0	0	0	0	326
	Deception Ck. E.T.[a]	0	55	182	16	0	0	0	0	0	0	0	253
												Total	579
1989	Willow Ck. C.S.[b]	0	609	320	0	47	0	0	0	0	0	0	976
	Willow Ck. Esc.	0	153	0	0	0	0	0	0	0	0	0	153
	Deception Ck. E.T.[a]	0	128	0	16	33	0	0	0	0	0	0	177
												Total	1,306
1990	Willow Ck. C.S.[b]	0	30	56	0	152	767	23	0	0	0	0	1,028
	Willow Ck. Esc.	0	0	0	17	0	32	0	0	0	0	0	49
	Deception Ck Esc.[c]	0	0	0	11	32	224	13	0	0	0	0	280
												Total	1,357
1991	Willow Ck. C.S.[b]	0	0	0	0	0	601	186	0	0	0	0	787
	Willow Ck. Esc.	0	0	0	0	0	0	0	0	0	0	0	0
	Deception Ck Esc.[c]	0	0	0	0	0	232	0	0	0	0	0	232
												Total	1,019
1992	Willow Ck. C.S.[b]	0	0	0	0	0	715	1,250	393	434	666	119	3,577
	Willow Ck. Esc.	0	0	0	0	0	158	45	0	0	0	0	203
	Deception Ck. Esc.[c]	0	0	0	0	0	211	148	49	68	65	19	560
												Total	4,340
1993	Willow Ck. C.S.[b]	0	0	0	0	0	0	382	719	668	453	368	2,590
	Willow Ck. Esc.	0	0	0	0	0	0	203	29	31	29	0	292
	Deception Ck. Esc.[c]	0	0	0	0	0	0	208	183	85	183	61	720
												Total	3,602
Total		49	1,230	911	60	264	2,940	2,458	1,373	1,286	1,396	567	12,534

[a] E.T. = egg take.
[b] C.S. = creel survey; only chinook salmon greater than 16 inches are included.
[c] Deception Creek weir and Deception Creek carcass survey combined.

Appendix B8. Estimated yearly age composition of Willow Creek chinook salmon from 1979-1993 based on sport fish harvests with a corresponding estimate of minimum run size.

Year[b]	Sample Size	Age Class by Percent[a] 1.2[c]	1.3[c]	1.4[c]	Sport Harvest	Escapement Indices	Estimated Minimum Run Size
1979	152	10.0	14.0	76.0	285	1,087	1,372
1980	120	29.0	18.0	53.0	292		292
1981	155	12.0	36.0	52.0	345	1,357	1,702
1982	308	7.0	18.0	75.0	390	821	1,211
1983	896	30.0	30.0	40.0	393	892	1,285
1984	1,113	13.0	40.0	47.0	805	3,464	4,269
1985	448	14.0	24.0	62.0	763	2,900	3,663
1986	143	15.0	38.0	46.0	1,043	2,580	3,623
1987	148	28.0	31.0	41.0	1,720	3,460	5,180
1988	344	16.0	49.0	35.0	2,160	3,286	5,446
1989	362	7.0	19.0	74.0	2,570	5,860	8,430
1990	413	32.0	17.0	51.0	2,789	3,065	5,854
1991	361	10.0	37.0	53.0	2,997	2,753	5,750
1992	664	26.0	33.0	41.0	6,955	2,643	9,598
1993	420	16.4	43.5	39.5	5,619	3,448	9,067
1979-1991							
Mean		17.2	28.5	54.2			
Maximum		32.0	49.0	76.0			
Minimum		7.0	14.0	35.0			

[a] Other age classes exist (1.1, 1.5, 2.2, 2.3, 2.4, 2.5) but never make up more than 5% of the return on a combined basis.

[b] Source of data: Watsjold 1980 and 1981; Bentz 1982 and 1983; Hepler and Bentz 1984, 1985, 1986 and 1987; 1987, Hepler et al. 1988 and 1989; Sweet and Webster 1990; Sweet et al. 1991; Peltz and Sweet 1992 and 1993.

[c] All fish (hatchery and nonhatchery) are reported as having one freshwater annulus even though hatchery produced fish have no freshwater annulus. It is not possible to distinguish between hatchery and nonhatchery fish scales.

Appendix B9. Estimated mean lengths by age and sex for Willow Creek chinook salmon, 1986-1993.

Age Class	1.2						1.3						1.4					
	Male		Female		Combined		Male		Female		Combined		Male		Female		Combined	
Year[a]	Sample Size	Length (mm)	Sample Size	Length (mm)	Length (mm)	SE	Sample Size	Length (mm)	Sample Size	Length (mm)	Length (mm)	SE	Sample Size	Length (mm)	Sample Size	Length (mm)	Length (mm)	SE
1986	22	642	0	0	642	3.0	22	841	33	861	853	2.0	17	1027	49	955	974	1.9
1987	35	600	0	0	600	14.0	33	841	13	883	853	13.1	20	961	34	936	945	14.1
1988	61	619	6	690	625	15.0	133	822	95	836	828	6.0	70	975	116	939	953	7.4
1989	36	578	0	0	578	12.0	63	790	27	835	804	9.8	112	952	245	914	926	3.5
1990	173	575	0	0	575	16.0	61	801	23	871	820	19.8	88	983	135	934	953	9.6
1991	56	594	0	0	594	48.0	117	786	66	830	802	14.9	107	980	205	926	945	14.4
1992	224	611	0	0	611	3.1	101	741	87	766	753	4.3	60	944	163	903	914	4.4
1993	76	611	2	595	611	5.2	100	798	87	811	804	3.8	70	966	81	925	944	6.2
1986–1991																		
Mean		601	No estimate		602			814		853	827			980		934	949	
SE					28.1						23.2						16.1	
90% CI					556–648						789–865						923–975	

[a] Source of data: Hepler and Bentz 1987; Hepler et al. 1988 and 1989; Sweet and Webster 1990; Sweet et al. 1991; Peltz and Sweet 1992 and 1993.

Appendix B10. Estimated sex composition by age class for sport fish harvests of Willow Creek chinook salmon, 1986-1993.

Age Class	1.2				1.3				1.4			
	Male		Female		Male		Female		Male		Female	
Year[a]	Sample Size	Percent	Sample Size	Percent	Sample Size	Percent	Sample Size	Percent	Sample Size	Percent	Sample Size	Percent
1986	22	100.0	0	0.0	22	40.0	33	60.0	17	25.4	50	74.6
1987	37	88.1	5	11.9	35	76.1	11	23.9	22	36.7	38	63.3
1988	53	91.4	5	8.6	97	57.1	73	42.9	48	41.0	69	59.0
1989	27	100.0	0	0.0	47	70.1	20	29.9	85	31.7	183	68.3
1990	134	100.0	0	0.0	48	70.6	20	29.4	82	39.2	127	60.8
1991	35	100.0	0	0.0	83	61.5	52	38.5	60	31.4	131	68.6
1992	224	100.0	0	0.0	102	54.0	87	46.0	60	26.8	164	73.2
1993	76	97.4	2	2.6	100	53.2	88	46.8	70	46.4	81	53.6
1986-1991 Mean		97%		3%		63%		37%		34%		66%
1992-1993 Mean		99%		1%		54%		46%		36%		64%

[a] Source of data: Hepler and Bentz 1987; Hepler et al. 1988 and 1989; Sweet and Webster 1990; Sweet et al. 1991; Peltz and Sweet 1992 and 1993.

Appendix B11. Seasonal timing of sport harvest by percent for Willow Creek chinook salmon, 1986-1993.

1986[a]		1987[b]		1988[c]		1989[d]		1990[e]		Mean 86-90		1991[f]		1992[g]		1993	
Date	%	Date	%	Date	%	Date	%	Date	%	Date	%	Date	%	Date	%	Date	%
6/14-15	21					6/09-16	2	6/09-15	6	6/08-16	6	6/08-14	5	6/10-15	14	6/10-14	14
6/21-22	22	6/20-21	21	6/18-20	26	6/17-19	7	6/16-18	11	6/15-22	17	6/15-17	8	6/20-22	33	6/15-21	50
6/28-29	36	6/27-29	45	6/25-27	38	6/24-26	35	6/23-25	38	6/22-29	38	6/22-24	37	6/23-29	47	6/26-28	29
7/05-06	21	7/04-06	34	7/02-11	36	7/01-03	56	6/30-7/04	44	6/29-7/11	39	6/29-7/01	50	7/04-7/06	6	7/03-7/05	7

a Hepler and Bentz 1987

b Hepler et al. 1988

c Hepler et al. 1989

d Sweet and Webster 1990

e Sweet et al. 1991

f Peltz and Sweet 1992

g Peltz and Sweet 1993

Appendix B12. Calculation of 1994 estimated return of chinook salmon to Willow Creek.

Nonhatchery			Hatchery		
Age composition	2 ocean	12%	Age composition	2 ocean	22%
for brood years	3 ocean	32%	for brood years	3 ocean	44%
1986-1987	4 ocean	56%	1987-1988	4 ocean	34%
from Table 6			from Table 6		

Estimated Returns from 1988 and 1989 Brood Years from Table 6

Brood Year	Origin	Estimated Return By Age Class 1.2	1.3	Total Return
1988	Nonhatchery	820	1,700	2,521
	Hatchery	1,675	2,380	4,055
	Total	2,495	4,080	6,576
1989	Nonhatchery	1,294		1,294
	Hatchery	429		429
	Total	1,723		1,723

Estimation of 4-ocean return in 1994:

The combined 2- and 3-ocean returns should compose 44% of the nonhatchery total and 66% of the hatchery return from the 1988 brood year.

If	2521	=	44% of the nonhatchery return
Then	x	=	56%
Or	x	=	(56% x 2521) / 44%
	x	=	3,209 nonhatchery 4-ocean return
If	4055	=	66% of the hatchery return
Then	x	=	34%
Or	x	=	(34% x 4055) / 66%
	x	=	2,089 hatchery 4-ocean return

Total 4-ocean return = 3209 + 2089 nonhatchery + hatchery
= 5,298 total

Estimation of 3-ocean return in 1994:

The 2-ocean return should compose 12% of the total nonhatchery and 22% of the hatchery return from the 1989 brood year.

If	1294	=	12% of the nonhatchery return
Then	x	=	32%
Or	x	=	(32% x 1294) / 12%
	x	=	3,451 nonhatchery 3-ocean return
If	429	=	22% of the hatchery return
Then	x	=	44%
Or	x	=	(44% x 429) / 22%
	x	=	858 hatchery 3-ocean return

Total 3-ocean return = 3451 + 858 nonhatchery + hatchery
= 4,309 total

-continued-

Appendix B12. (Page 2 of 2).

Estimation of 2-ocean return in 1994:

Smolt release in 1992	215,476
Estimated survival rate	1.0%
Estimated percent 2-ocean hatchery	22%

Predicted 2-ocean hatchery return	=	215,476 x 1.0% x 22%	
	=	474	
Predicted 2-ocean nonhatchery return	=	Historic mean 1980 to 1989	
	=	784	
Total 2-ocean return	=	474 + 784	hatchery + nonhatchery
	=	1,258	total

Total predicted return in 1994

	Nonhatchery	Hatchery	Total
4 ocean	3,209	2,089	5,298
3 ocean	3,451	858	4,309
2 ocean	784	474	1,258
Totals	7,444	3,421	10,865
Percent	68.5	31.5	100.0

APPENDIX C

Appendix C. Computer data files and analysis programs developed for the chinook salmon stocking, creel survey, and escapement studies on Willow Creek, 1993.

Data Files

M004DCZ3.DTA	Willow Creek, mouth, creel survey angler interview data file, 1993;
M004DSZ3.DTA	Willow Creek, mouth, creel survey angler count data file, 1993;
M004DBA3.DTA	Willow Creek, mouth, creel survey biological data file, 1993;
M0040BA3.DTA	Willow Creek carcass survey biological data file, 1993;
M1290BA3.DTA	Deception Creek egg take biological data file, 1993;

Analysis Programs

CS93.EXE	RTS program to analyze raw data files from direct-expansion and roving creel surveys and generate estimates of angler effort, catch, and harvest and associated variances;
BRA31WIL.RD	RTS report descriptive file for stage 1 of a stratified, three-stage, roving creel survey;
BRA32WIL.RD	RTS report descriptive file for stage 2 of a stratified, three-stage, roving creel survey;
BRA33WIL.RD	RTS report descriptive file for stage 3 of a stratified, three-stage, roving creel survey;
SFXTAB.EXE	RTS program used to cross-tabulate biological data files and produce either "discrete" or "continuous" tables of age, sex, length, and weight data;
MENU91.BAT	Series of RTS programs used to generate listing, frequency, and litho code reports from raw mark-sense data files for identifying data recording errors;
WILMKS93.WK1	Lotus 1-2-3, worksheet used to weight and apportion chinook salmon harvest estimates by sex and age, within and across all stratum;
WIL93Z.SAS	SAS system program used to analyze raw data files from roving creel surveys and generate estimates of angler effort, catch and harvest with their associated variances.

Data files are archived with the Alaska Department of Fish and Game, Sport Fish Division, Research and Technical Services Unit, 333 Raspberry Road, Anchorage, Alaska 99518-1599. Contact Gail Heineman or Donna Buchholz (267-2369) for copies of the files and descriptions of the file format.