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Performance of the Chinook Salmon Enhancement Program in Willow Creek, Alaska, 1985-1992

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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 1992 was assessed using a roving creel survey at two sites on Willow Creek, a weir at Deception Creek (a tributary to Willow Creek), aerial peak spawning escapement surveys, and post spawning carcass surveys. Anglers expended an estimated 66,098 angler-hours to catch and harvest 10,540 and 7,081 chinook salmon, respectively. The majority of the effort (97%) occurred at the confluence of Willow Creek and Susitna River. During this "mouth" fishery, 18,271 angler-days were expended in 1992. This is an increase of over 12,800 angler-days since 1988, when hatchery fish were first recorded in the harvest. The hatchery contribution to the 1992 mouth fishery harvest from chinook salmon smolt stocked in the Willow Creek drainage was 51%. This is the highest contribution since the stocking program began in 1983. The 1989-1991 contributions were 38%, 36% and 26%, respectively. Escapement index counts and weir counts indicated a minimum of 2,643 spawners in Willow and Deception creeks combined. Carcass surveys in the mainstem of Willow Creek revealed a 12% hatchery contribution to the spawning escapement. Carcass surveys in Deception Creek indicated a relative hatchery contribution of 45% to the spawning escapement. The hatchery smolt release for 1992 was approximately 215,476.

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 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 1980-1992). 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 an additional 10,000 angler-days of chinook salmon fishing opportunity annually at Willow Creek during weekdays by 1994.

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

1. To 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. To estimate the catch rate and the angler success of chinook salmon in the Willow Creek sport fishery.

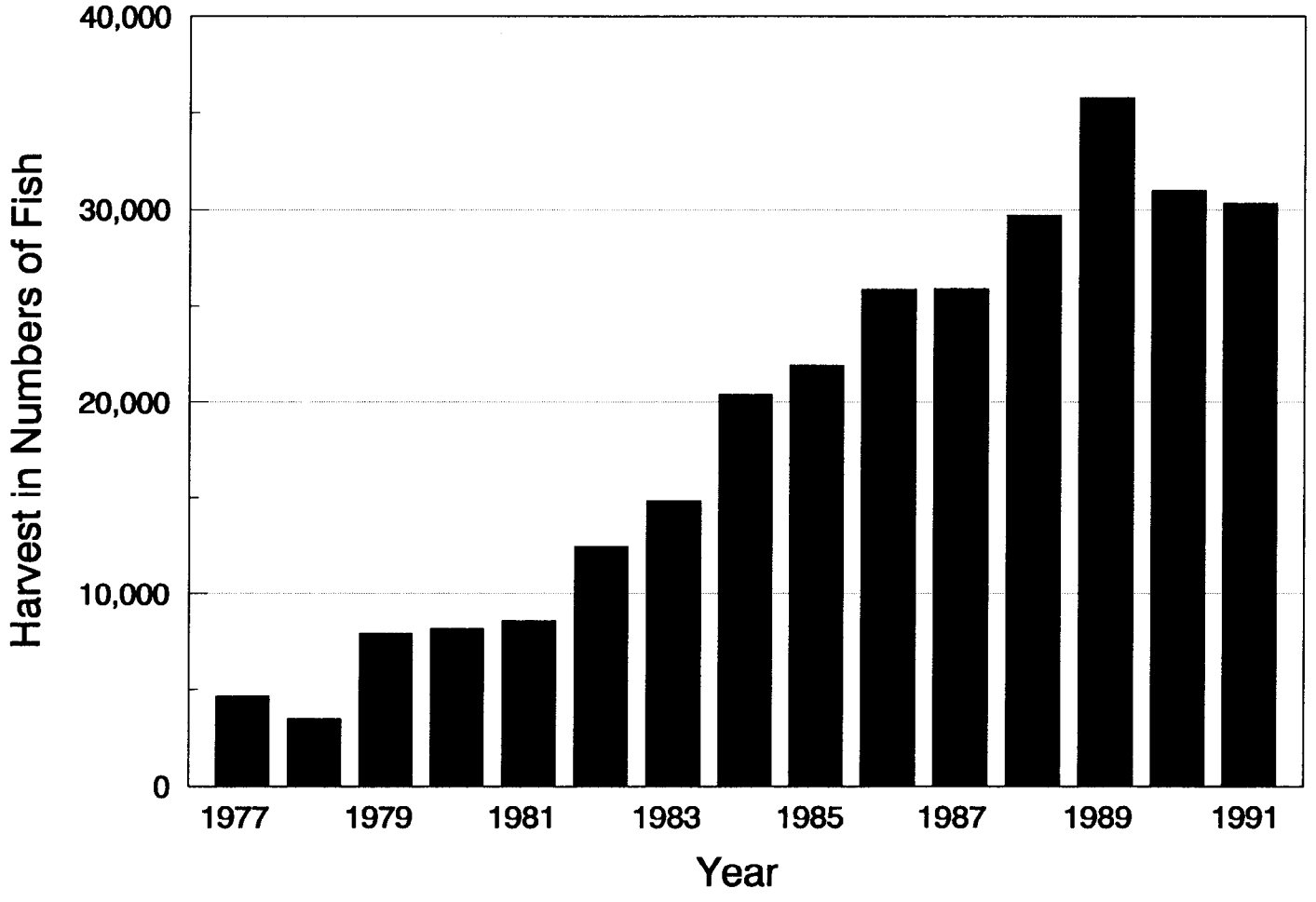


Figure 1. Yearly chinook salmon sport fish harvest in Northern Cook Inlet, 1977-1991.

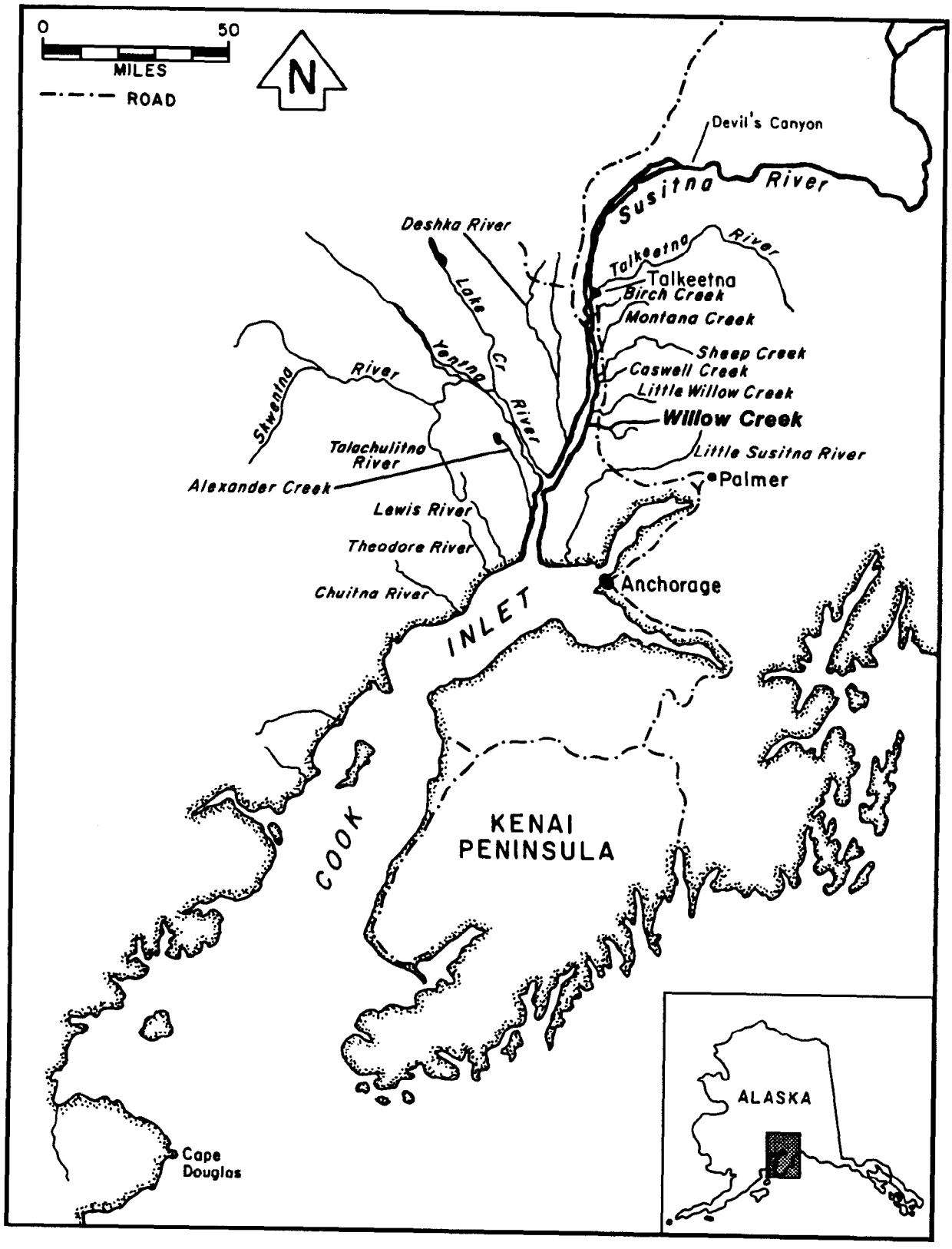


Figure 2. Map of Northern Cook Inlet and the Susitna River drainage.

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

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

5. To monitor chinook salmon escapement indices to determine if approximately 4,500 spawn naturally in Willow Creek in 1992.

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

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

8. To 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 6,000 returning adults (3% survival).

This report presents fish culture, creel survey, escapement, age, sex, length, and hatchery contribution data collected from the Willow Creek program in 1992. 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 29 May and 9 June (Figure 3). Approximately 32,000 (16%) of the 215,476 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 1992 egg take (Figure 3). All fish entering the weir complex were detained between the weirs until the egg take was complete. The egg take took place on 23, 27, 29 and 31 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.

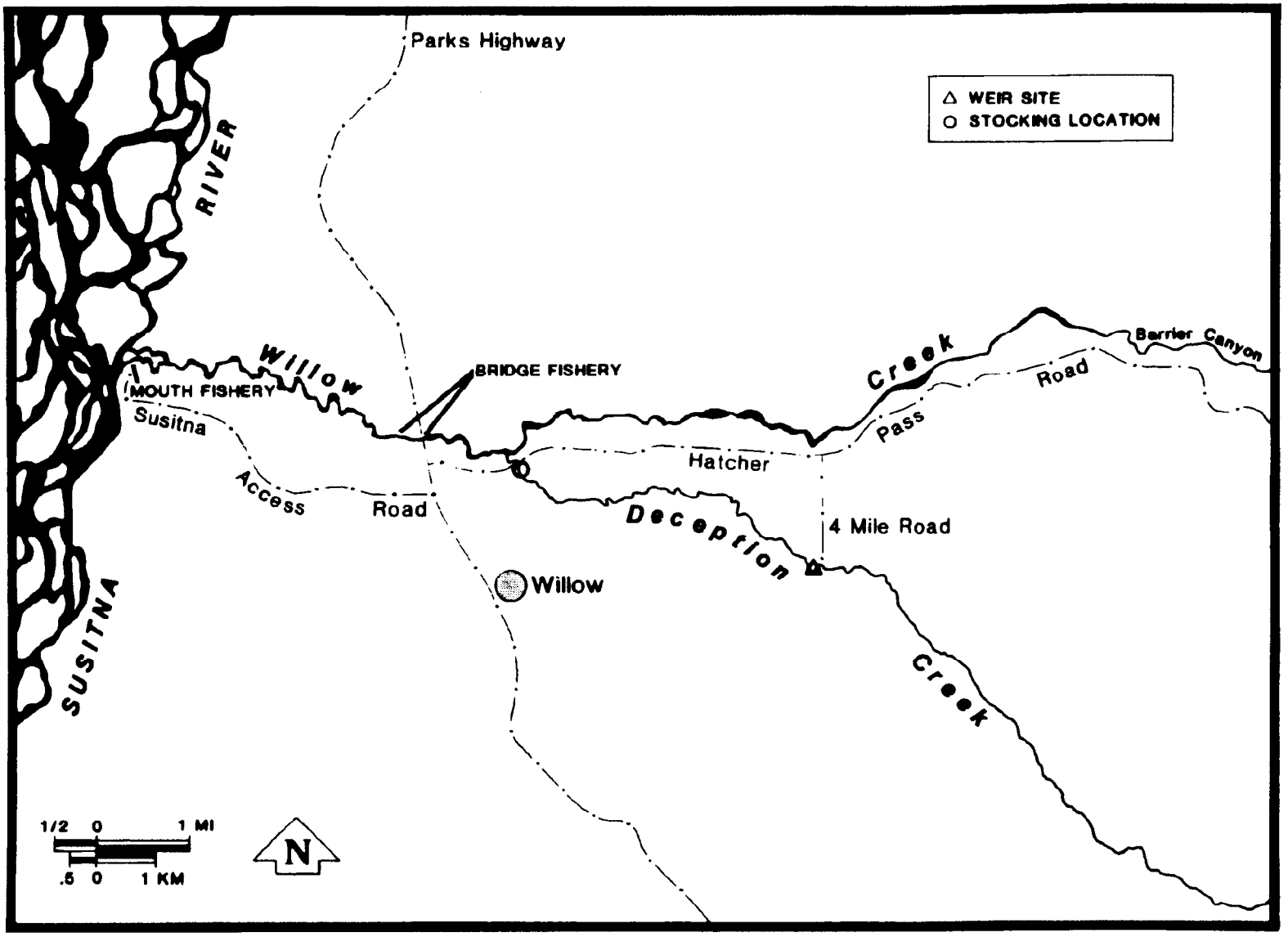


Figure 3. Map of Willow and Deception creeks showing the location of creel survey areas, carcass survey areas, smolt stocking sites, and egg-take sites.

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 upstream to the Parks Highway. This section was open daily to fishing from 1 January to 15 June. After 15 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 20 June and ending on 6 July. By emergency order, Willow Creek remained open 23 through 26 July. Additional fishing time was to be allowed by emergency order if strong hatchery returns were detected.

Willow Creek is road accessible allowing primary access to the fishery by vehicle and foot. The majority of anglers fished within 0.8 km (0.5 mi) of the Parks Highway bridge and at the mouth. Relatively few anglers fished at other locations. Two locations were surveyed in 1992 (Figure 3):

1. the head of the trail that leads to the mouth of Willow Creek, where anglers reach the stream by foot and fish in the vicinity of the creek's confluence with the Susitna River (mouth fishery);

2. the Parks Highway bridge, where anglers either access the creek from the road and fish near the bridge or use the private boat launch near the bridge (bridge fishery).

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

During all strata, for each of the two survey locations, days were sampled at random without replacement (WOR), and represented the first sampling stage in the stratified three-stage sample survey. Within each day sampled, sample periods were selected at random WOR from the available periods, and represented the second stage units. Within each selected sample period, three random-systematically chosen angler counts were conducted and represented the third sampling stage for the angler count data. For the angler interview data, the anglers interviewed represented the third stage of catch per unit effort (CPUE) or harvest per unit effort (HPUE) information. Strata definitions and sampling parameters for each survey location are listed in Appendix A1.

Creel Survey Data Collection

The following effort, catch, and harvest information was collected from each angler interviewed exiting at the mouth and bridge surveys:

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;

4. number of chinook salmon less than 16 inches in length harvested (kept) or released; and

5. the number and species of any resident fish harvested 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.

The bridge fishery was monitored by creel survey technicians stationed at the Parks Highway bridge area. Interviews were conducted with shore anglers fishing on either side of the creek and boat anglers exiting at the boat launches. Time not spent conducting angler counts was spent conducting interviews, inspecting the observed harvest for missing adipose fins and collecting biological data.

Creel Survey Data Analysis

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:

Procedures used to estimate angler effort for and the catch and harvest of chinook salmon in the 1992 Willow Creek creel survey were similar to those used in the 1991 survey of this fishery. The procedures outlined in Appendix A2 were followed to obtain estimates using a 3-stage roving estimation approach for the weekday strata (Tuesdays through Fridays). This approach involved using a systematic-random estimator to estimate angler effort on a sample by sample basis. Catch and harvest estimates for each sample were obtained by a ratio estimator: by combining the estimated effort (for the sample) with estimates of CPUE and HPUE obtained from the angler interviews. The CPUE and HPUE estimates were obtained by the jackknife estimation approach (Efron 1982). The jackknife approach for estimating CPUE and HPUE was used because most other estimators are known to be biased (for use as ratio estimators, i.e., for expansion), and the jackknife estimate has been shown to be less biased. Procedures exist for correcting some of this bias (see Cochran 1977, section 6.15, pages 174-177; and Smith 1980).

Estimates of angler effort for catch and harvest of chinook salmon for the weekend strata (Saturdays through Mondays) were obtained similarly, with simplifications due to the single-stage nature of the sampling in these type of strata (see Appendix A2 for details).

Catch Per Unit of Effort:

The CPUE of anglers fishing for chinook salmon in the Willow Creek sport fishery surveyed during 1992 was estimated by the procedures noted below. The anglers were treated as individual units in a test fishery operating under the traditional linear model:

$$[c/e]_i = q\,N + \epsilon_i$$

where: c/e is the catch per unit of effort during the *ith* angler-trip; N is abundance (of the fish); q is the catchability coefficient; and ϵ is random error with mean = 0 and variance = σ^2.

Hence the estimates of CPUE were obtained from unweighted means for each section of the fishery during each time period stratum as detailed by Peltz and Sweet (1992, in Appendix A2 of that report). The estimates obtained by these procedures were assumed to be indicative of the abundance of chinook salmon as they passed through the fishery.

Distribution of Angler Catches and Harvests:

The distribution of angler catch and harvest was used as a measure of angler success and was estimated as described in the following text. The "distribution of catch and harvest" was defined as the fraction p_k of angler-trips in which "k" or more fish were caught and "k" was expressed as k = 1 to k_{max}. Additionally, p_k was defined to be the proportion of angler-trips that resulted in the catch or harvest of zero chinook salmon for k = 0. If k_{max} = 5, then one set of data was analyzed six times to obtain all possible fractions p_k in a set. There were two sets of p_k's, one set for both catch and harvest. Besides the k_{max} iterations, there was stratification. For each iteration from 0 to k_{max}, there were calculations for each stratum in the fishery.

As an example, begin with the fraction of angler-trips in which one or more chinook salmon were caught. The first step was to code the data prior to calculation. The coding was necessary because not all sampling periods (days) were the same "size": more anglers fished during some periods than others. Ignoring these differences in size would have promoted bias in estimates of angler success when statistics were averaged across sampling periods within a stratum. The coding was adjusted for this possible discrepancy (Sukhatme et al. 1984). After coding, standard three-stage estimation procedures (Cochran 1977) were used to estimate the various proportions, their variances and standard errors for the weekday strata, as outlined in detail by Peltz and Sweet (1992), in Appendix A3 of that report.

The estimates were obtained in a similar manner for the weekend strata by applying equation A3.7 (from Peltz and Sweet 1992). In using equation A3.7, all day (i) and sample (j) subscripts were dropped for these single stage surveys. The variance of these stratum estimates of harvest distribution was obtained by dividing the result from using equation A3.11 (from Peltz and Sweet 1992) by the number of anglers interviewed within each stratum.

Assumptions:

The assumptions necessary for unbiased point and variance estimates of angler effort, catch, harvest, CPUE as an index of abundance, and catch and harvest distribution 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;

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; and

4. no significant fishing effort occurred during the hours not surveyed.

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. For unbiased estimates of CPUE as an index of abundance, the catchability coefficient (q) was assumed to not change in a manner that negated the use of CPUE as an index of abundance and that "good" (or for that matter "poor") anglers were not selectively fishing during certain periods or areas of the fishery. However, catch rates may be more reflective of good anglers (higher catchability coefficients) rather than higher abundance (and vice versa for poor anglers).

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 downstream of the weir. 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 post-spawn chinook salmon in Willow Creek from the canyon downstream to the Parks Highway bridge were also sampled (Figure 3). Length, sex information, and scales for aging 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 in 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. Due to sampling unequal proportions of fish observed with adipose finclips versus fish without adipose finclips, the age and sex data were post-stratified into marked versus unmarked components. 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 to not 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.

Contribution of Coded Wire Tagged Stocks

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 numbers of fish examined for a missing adipose fin as well as the number of fish observed to have a missing adipose fin. Heads were collected from the fish with a missing adipose fin and sent to the Fisheries Rehabilitation, Enhancement, and Development (FRED) Division laboratory for decoding. Carcasses from the chinook salmon escapement in the reaches of Willow Creek and Deception Creek upstream of the Parks Highway bridge 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 1986, 1988, 1989, and 1990 (Appendix B1). There was also the possibility of returns from the 1988 and

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 215,476 chinook salmon smolt were stocked in Deception Creek on two separate dates in 1992 (Appendix B1). Approximately 21% of the release was marked with an adipose clip. However, due to tag loss, only 16% of the release contained a valid coded wire tag.

A total brood stock of 51 female and 100 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 202 fish examined at the weir for egg take, an estimated 61% (SE = 36%) of the brood stock were of hatchery origin (Appendix B3). Over half of these eggs will be used to produce smolt for the 1993 Willow Creek stocking. The remainder will be used for other stocking projects.

Creel Survey Statistics

The total estimated angler effort for all survey sites was 66,098 angler-hours (Table 1) of which 64,443 angler-hours (97%) were at the mouth and 1,655 angler-hours (3%) were at the Parks Highway bridge.

Table 1. Estimated catch rate, effort, catch and harvest by strata for fish greater or equal to 16 inches during the Willow Creek chinook salmon creel survey in 1992.

Strata	Date	Number of anglers interviewed	CPUE (catch per angler-hour)	SE	Effort in angler-hours	SE	Catch	SE	Harvest	SE
Mouth:										
1	6/10-12	298	0.17	0.03	3,584	464	338	43	302	41
5&6	6/13-15	2,066	0.15	0.01	8,407	484	827	60	653	45
2	6/16-19	0					fishery closed			
7&8	6/20-22	3,488	0.39	0.01	15,031	1,160	3,612	298	2,293	183
3	6/23-26	2,044	0.28	0.01	16,001	639	3,152	249	2,131	185
9&10	6/27-29	2,876	0.20	0.01	13,574	972	1,647	129	1,144	86
4	6/30-7/03	0					fishery closed			
11&12	7/04-06	1,675	0.13	0.01	7,846	572	738	69	432	40
Subtotal		12,447	0.25	0.01	64,443	1,864	10,314	421	6,955	284
Highway:										
1	6/10-12						no survey			
5&6	6/13-15						no survey			
2	6/16-19						fishery closed			
7&8	6/20-22						no survey			
3	6/23-26						no survey			
9&10	6/27-29						no survey			
4	6/30-7/03						fishery closed			
11&12	7/04-06	318	0.15	0.02	1,655	188	226	36	126	18
Subtotal		318	0.15	0.02	1,655	188	226	36	126	18
Combined:										
1	6/10-12	298	0.17	0.03	3,584	464	338	43	302	41
5&6	6/13-15	2,066	0.15	0.01	8,407	484	827	60	653	45
2	6/16-19	0					fishery closed			
7&8	6/20-22	3,488	0.39	0.01	15,031	1,160	3,612	298	2,293	183
3	6/23-26	2,044	0.28	0.01	16,001	639	3,152	249	2,131	185
9&10	6/27-29	2,876	0.20	0.01	13,574	972	1,647	129	1,144	86
4	6/30-7/03	0					fishery closed			
11&12	7/04-06	1,993	0.13	0.01	9,501	601	964	78	558	44
Total		12,765	0.25	0.01	66,098	1,873	10,540	423	7,081	285

The total estimated harvest and catch of chinook salmon 16 inches and greater in Willow Creek was 7,081 and 10,540 fish, respectively (Table 1). The estimated catch at the mouth was 10,314 fish; 98% of the total. Estimated catch at the highway was 226. The estimated harvest at the mouth was 6,955 fish; 98% of the total. The estimated harvest at the highway was 126. During the Willow Creek fishery, 33% of the chinook salmon caught were released.

All chinook salmon under 16 inches in length reported caught, were kept (Appendix B4). The total estimated catch and harvest of chinook salmon under 16 inches was 249 fish. Fish under 16 inches were not included in hatchery return estimates.

Catch rates for the Willow Creek mouth fishery varied from 0.13 fish per angler-hour for the period of 4-6 July (strata 11 and 12) to 0.39 for the period of 20-22 June (strata 7 and 8). The mean catch rate for the Willow Creek mouth fishery during the entire season was 0.25 fish per angler-hour (Table 1).

Thirty-eight percent (SE = 1.0%) of the Willow Creek mouth angler-trips were successful, resulting in one or more fish harvested. Less than one percent (SE <0.05%) resulted in a two fish harvest, and the remaining 62% (SE = 0.9%) failed to harvest a fish (Appendix B5).

Escapement Survey Statistics

An aerial escapement index count of 1,660 was conducted on 24 July for Willow Creek. A ground survey was conducted on the escapement index area of Deception Creek, a tributary to Willow Creek, on 5 August; 983 chinook salmon were counted. Therefore, we estimated total minimum escapement for the system at approximately 2,640 fish.

Size, Sex, and Age Compositions

A total of 664 chinook salmon (9.4%) was sampled from the sport harvest at the mouth fishery for age, length, and sex. Age class 1.4 dominated the harvest at 40%, age 1.3 contributed 32%, and age 1.2 contributed 24%. Age classes 1.1 and 1.5 contributed the remaining 4%. The harvest consisted of 53% males and 47% females (Table 2). Mean lengths of males ranged from 389 mm for age 1.1 to 1,043 mm for age 1.5. Mean lengths of females ranged from 766 mm for age 1.3 to 963 mm for age 1.5 (Table 3).

Fifty-one percent of the mouth fishery harvest was 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 saltwater age.

Of the 202 carcasses examined during the carcass survey, 115 readable scales were collected. Age class 1.4 dominated with 56% of the sample, age 1.3 contributed 33%, age 1.2 contributed 9%. Age classes 1.1 and 1.5 contributed the remaining 2%. The surveyed carcasses consisted of 49% male and 56% female fish (Table 2). Mean lengths ranged from 1,013 mm for age-1.5 females to 380 mm for age-1.1 males (Table 3).

Table 2. Sex and age composition of chinook salmon sampled from the Willow Creek sport fishery and carcass surveys in 1992.

Fishery	Sex		Age Group[a] 1.1	1.2	1.3	1.4	1.5	2.2	2.3	2.4	Total
Mouth creel survey											
	Male	Harvest	92	1,647	1,126	720	70	0	0	0	3,656
		Percent	1.3	23.7	16.2	10.4	1.0	0.0	0.0	0.0	52.6
		SE (%)	0.5	2.1	1.9	1.6	0.6	0.0	0.0	0.0	2.5
	Female	Harvest	0	0	1,129	2,057	114	0	0	0	3,299
		Percent	0.0	0.0	16.2	29.6	1.6	0.0	0.0	0.0	47.4
		SE (%)	0.0	0.0	2.0	2.2	0.8	0	0	0	2.5
	Combined (n=664)[b]	Harvest	92	1,647	2,254	2,777	184	0	0	0	6,955
		Percent	1.3	23.7	32.4	39.9	2.7	0.0	0.0	0.0	100.0
		SE (%)	0.5	2.1	2.4	2.4	0.9	0.0	0.0	0.0	
Carcass surveys											
	Male	Index	1	10	25	20	0	0	0	0	56
		Percent	0.9	8.7	21.7	17.4	0.0	0.0	0.0	0.0	48.7
		SE(%)	0.9	2.6	3.9	3.6	0.0	0.0	0.0	0.0	4.7
	Female	Index	0	0	13	44	2	0	0	0	59
		Percent	0.0	0.0	11.3	38.3	1.7	0.0	0.0	0.0	51.3
		SE(%)	0.0	0.0	3.0	4.6	1.2	0.0	0.0	0.0	4.7
	Combined	Index	1	10	38	64	2	0	0	0	115
		Percent	0.9	8.7	33.0	55.7	1.7	0.0	0.0	0.0	100.0
		SE (%)	0.9	2.6	4.4	4.7	1.2	0.0	0.0	0.0	

[a] Fifty percent 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 3. 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 1992.

			Age Group								
Fishery	Sex		1.1	1.2	1.3	1.4	1.5	2.2	2.3	2.4	Total
Mouth[a]:											
	Male	Mean	389	611	741	943	1,043				
		Standard Error	5.8	3.1	6.7	11.2	9.7				
		Sample Size	17	224	101	60	5	0	0	0	407
	Female	Mean			766	903	963				
		Standard Error			4.7	4.0	21.5				
		Sample Size	0	0	87	163	5	0	0	0	255
	All	Mean	389	611	753	914	1,003				
		Standard Error	5.7	3.1	4.3	4.4	17.4				
		Sample Size	17	224	188	223	10	0	0	0	662
Carcass Surveys:											
	Male	Mean	380	600	765	958					
		Standard Error		18.2	15.4	19.6					
		Sample Size	1	10	25	20	0	0	0	0	56
	Female	Mean			808	904	1,013				
		Standard Error			12.6	7.3	17.5				
		Sample Size	0	0	13	44	2	0	0	0	59
	All	Mean	380	600	780	921	1,013				
		Standard Error		18.2	11.4	8.4	17.5				
		Sample Size	1	10	38	64	2	0	0	0	115

[a] Fifty percent 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.

Contribution of Coded Wire Tagged Stocks

From the estimated sport harvest of 6,955 chinook salmon at the mouth of Willow Creek, 4,607 were examined for a missing adipose fin. Of those examined, 295 (6.4% of those examined) were observed to have a missing adipose fin and a decodeable coded wire tag. Tags from six Willow Creek releases (1988 through 1991), two Montana Creek releases (1988 and 1989) and one Sheep Creek release (1989) were decoded (Appendix B6). 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 3,577 fish (SE = 246) or 51% (Table 4). There was an additional contribution of 87 (SE = 38) hatchery-produced fish (1%) from the Montana and Sheep Creek releases. The total hatchery contribution was 53%. The timing of the harvest of hatchery fish coincided with that of nonhatchery fish (Figure 4).

An estimated 126 chinook salmon were harvested at the Willow Creek highway bridge fishery. Of 118 fish examined, 3 (3%) were observed to have a missing adipose fin and a decodeable coded wire tag. These three fish represented two Willow Creek releases; 1988 and 1990 (Appendix B6). The contribution of hatchery-produced fish to this portion of the fishery was estimated at 17%.

Within the 202 carcasses examined during carcass surveys, 3 fish were found with a missing adipose fin. The three decodeable CWT's found in the heads of these fish were from 1988 and 1990 Willow Creek releases (Appendix B3). The estimated relative hatchery contribution to the Willow Creek escapement was 12% (SE = 9%). Deception Creek carcass surveys resulted in 115 carcasses examined, nine adipose finclips observed and six decodeable tags recovered. Three of these tagged fish originated from the Willow Creek 1989 release and one each from the 1988, 1990 and 1991 Willow Creek releases. No coded wire tags were recovered from the remaining three clipped fish (Appendix B3). Based on these tag recoveries, the estimated relative hatchery contribution to the Deception Creek escapement was 50% (SE = 45%). During the Deception Creek weir egg take, 202 fish were examined and 17 adipose finclips were observed. All 17 fish contained decodeable coded wire tags. Ten tags represented the 1990 Willow Creek release, one represented the 1989 Willow Creek release and six represented the Willow Creek 1988 release (Appendix B3). Based on these tag recoveries, the estimated relative hatchery contribution to the egg take was 61% (SE = 36%)

Tag recoveries occurred in several commercial fisheries for which no hatchery contribution estimates were made (Appendix B7). 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 1986-1992 are listed in Appendix B8. 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 1986-1992 are listed in Appendix B9.

DISCUSSION

The Willow Creek chinook salmon fishery has existed annually since 1979 (Table 5). From 1979 to 1992, the fishery has changed from a weekend-only fishery with a harvest quota of 300 fish to a 19-day season with a harvest of

Table 4. Estimated contribution of hatchery produced chinook salmon in the Willow Creek sport fishery harvest, 1992.

Strata[a]		1			5&6			7&8			3			9&10			11&12			Total		
Date		6/10-12			6/13-15			6/20-22			6/23-26			6-27-29			7/4-6					
Mouth Survey: Harvest		302			653			2,293			2,131			1,144			432			6,955		
SE		41			45			183			185			86			40			284		
Tag code	Release	Contr.[b]	SE	%	Contr.[b]	SE	%	Contr.[b]	SE	%	Contr.[b]	SE	%	Contr.[b]	SE	%	Contr.[b]	SE	%	Contr.[b]	SE	%
31-17-58	Willow 88	0	0	0.0	16	17	2.5	195	51	8.5	246	80	11.5	242	55	21.2	16	17	3.7	715	112	10.3
31-17-60	Willow 89	167	96	55.3	318	66	48.7	447	91	19.5	198	81	9.3	80	36	7.0	40	29	9.3	1250	175	18.0
31-17-34	Willow 90	24	23	7.9	61	21	9.3	167	36	7.3	110	40	5.2	14	10	1.2	17	12	3.9	393	64	5.7
31-18-52	Willow 90	25	24	8.3	70	24	10.7	238	44	10.4	262	58	12.3	35	16	3.1	35	19	8.1	666	84	9.6
31-18-51	Willow 90	25	24	8.3	35	16	5.4	124	30	5.4	126	42	5.9	79	25	6.9	45	23	10.4	434	68	6.2
31-19-33	Willow 91	0	0	0.0	21	14	3.2	8	8	3.2	73	36	3.4	17	12	1.5	0	0	0.0	119	41	1.7
	Total	241	104	79.8	521	78	79.8	1,179	123	51.4	1,015	145	47.6	468	74	40.9	153	47	35.4	3,577	246	51.4
31-17-59	Montana 88	0	0	0.0	10	11	1.5	0	0	0.0	14	16	0.7	0	0	0.0	0	0	0.0	24	19	0.3
31-18-31	Montana 89	0	0	0.0	15	16	2.3	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0	15	16	0.2
31-18-36	Sheep 89	0	0	0.0	17	18	2.6	0	0	0.0	0	0	0.0	14	14	1.2	17	18	3.9	48	29	0.7
	Total	0	0	0.0	42	26	6.4	0	0	0.0	14	16	0.7	14	14	1.2	17	18	3.9	87	38	1.3
Mouth Total		241	104	79.8	563	83	86.2	1,179	123	51.4	1,029	146	48.3	482	75	42.1	170	50	39.4	3,664	249	52.7
Highway Survey: Harvest		No Survey			No Survey			No Survey			No Survey			No Survey			126			126		
SE																	18			18		
Tag Code	Release																Contr.[b]	SE	%	Contr.[b]	SE	%
31-17-58	Willow 88																10	10	7.9	10	10	7.9
31-18-52	Willow 90																11	8	8.7	11	8	8.7
Highway Total																	21	13	16.6	21	13	16.6

[a] Strata 2 and 4 were closed by regulation.

[b] Contribution of hatchery fish to the harvest.

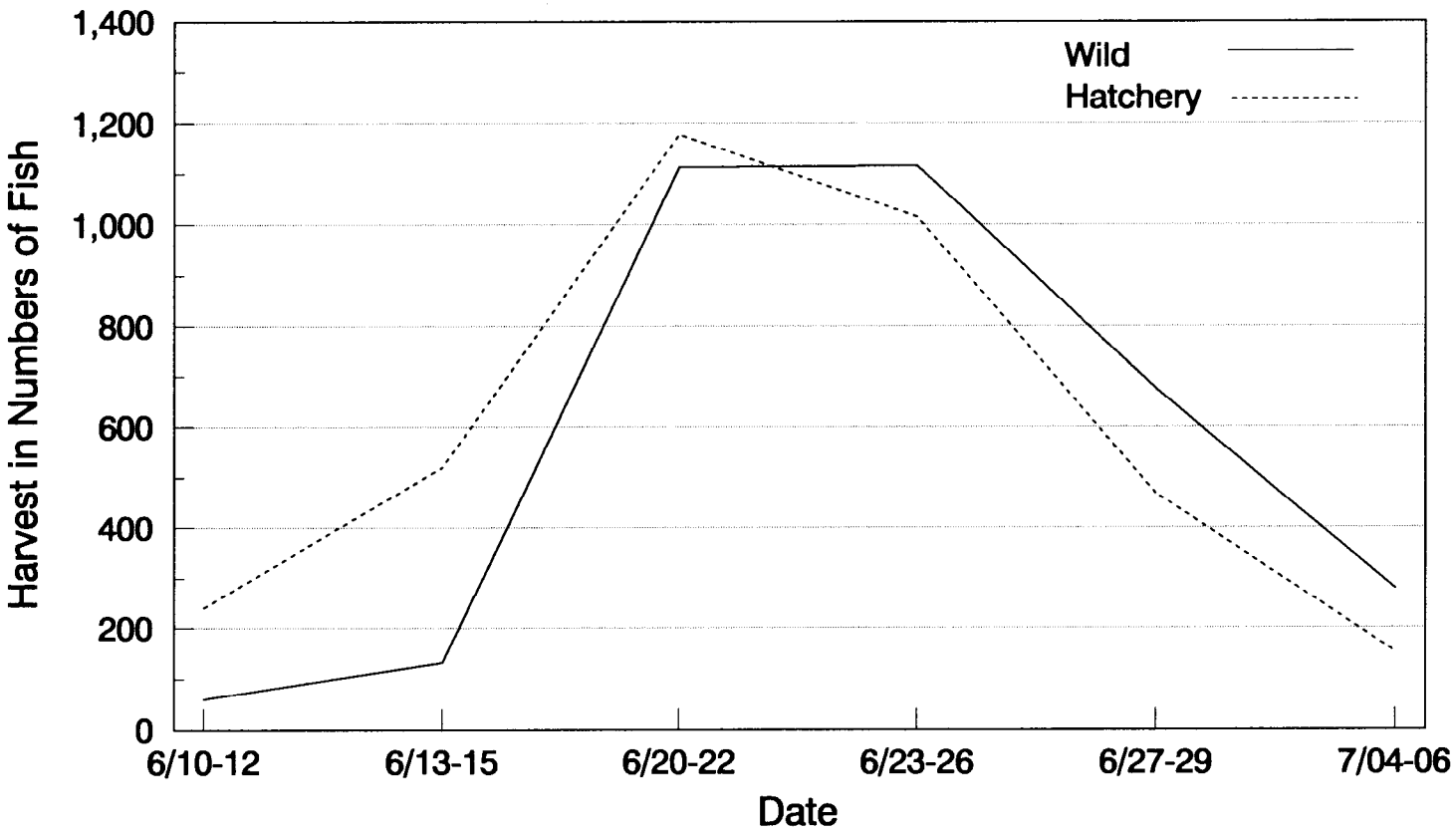


Figure 4. Number of nonhatchery and hatchery Willow Creek chinook salmon harvested by stratum in 1992.

Table 5. Estimated effort, harvest, and spawning escapement of Willow Creek chinook salmon for the period 1979-1992.

Year	Location of Creel Survey[a]	Season Length in Days		Effort in Angler Days[b]	Sport Harvest[c]				Willow Creek Escapement Index[d]				Deception Creek Escapement			
		Weekend	Weekday		Total[e]	Nonhatchery	Hatchery[f]	Percent Hatchery	Total	Nonhatchery	Hatchery	Percent Hatchery	Total	Nonhatchery	Hatchery	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

[a] Creel survey sites changed from year to year to accommodate the evolving fishery and remain representative of the harvest and effort.

[b] Source of data: 1979, Watsjold 1980; 1980, Watsjold 1981; 1981, Bentz 1982; 1982, Bentz 1983; 1983, Hepler and Bentz 1984; 1984, Hepler and Bentz 1985; 1985, Hepler and Bentz 1986; 1986, Hepler and Bentz 1987; 1987, Hepler et al., 1988; 1988, Hepler et al., 1989; 1989, Sweet and Webster 1990; 1990, Sweet et al., 1991, 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.

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 eight-fold from 1979 through 1991 (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 return of hatchery fish. The hatchery fish harvest exceeded the nonhatchery fish harvest for the first time in 1992. The combined nonhatchery and hatchery fish spawning escapement in 1992 remained comparable to previous years, however the nonhatchery fish escapement was the lowest in 9 years (Figure 7).

Fish Culture

Smolt for the Willow Creek chinook salmon project were stocked on two dates in 1992 (Appendix B1). On 29 May an estimated 179,724 fish were stocked. These fish were the designated production for Willow Creek and all the coded wire tagged fish were released in this group. On 9 June, an additional 35,752 chinook salmon smolt were stocked by hatchery staff without coordinating the stocking with the project biologist. These fish were the excess production from the same Willow Creek brood which were scheduled for stocking into Anchorage lakes. The second group of fish were stocked 11 days after the first group and were 1 gram heavier in average weight. None of these fish had CWT's. The tagged fish in the first group do not represent the second group because of the differences in date of release and size. However, the second group stocked must be included in the database. Therefore, the second release group will be included in the calculation of the total tagging proportion. Failure to include these fish in our calculations will result in underestimating hatchery returns and overestimating nonhatchery stock returns to a much greater degree than if we include the fish from the second stocking in the calculations. This situation can be eliminated in the future through better coordination between the hatchery staff and the project biologist.

The coded wire tagged smolt released in 1992 had poor tag retention (75.9%). Peltz and Starkey (*In Prep*) concluded that poor tag retention rates in 1992 smolt releases from Fort Richardson Hatchery were most likely due to using only one size of head mold for a wide range of fish sizes. In the future, fish should be graded as they are finclipped and different head mold sizes used to accommodate the variability in fish size.

The 1992 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 for spawning. A total of 151 fish was used for brood stock. Unless there is a shortage of natural spawners, this practice should continue in the future.

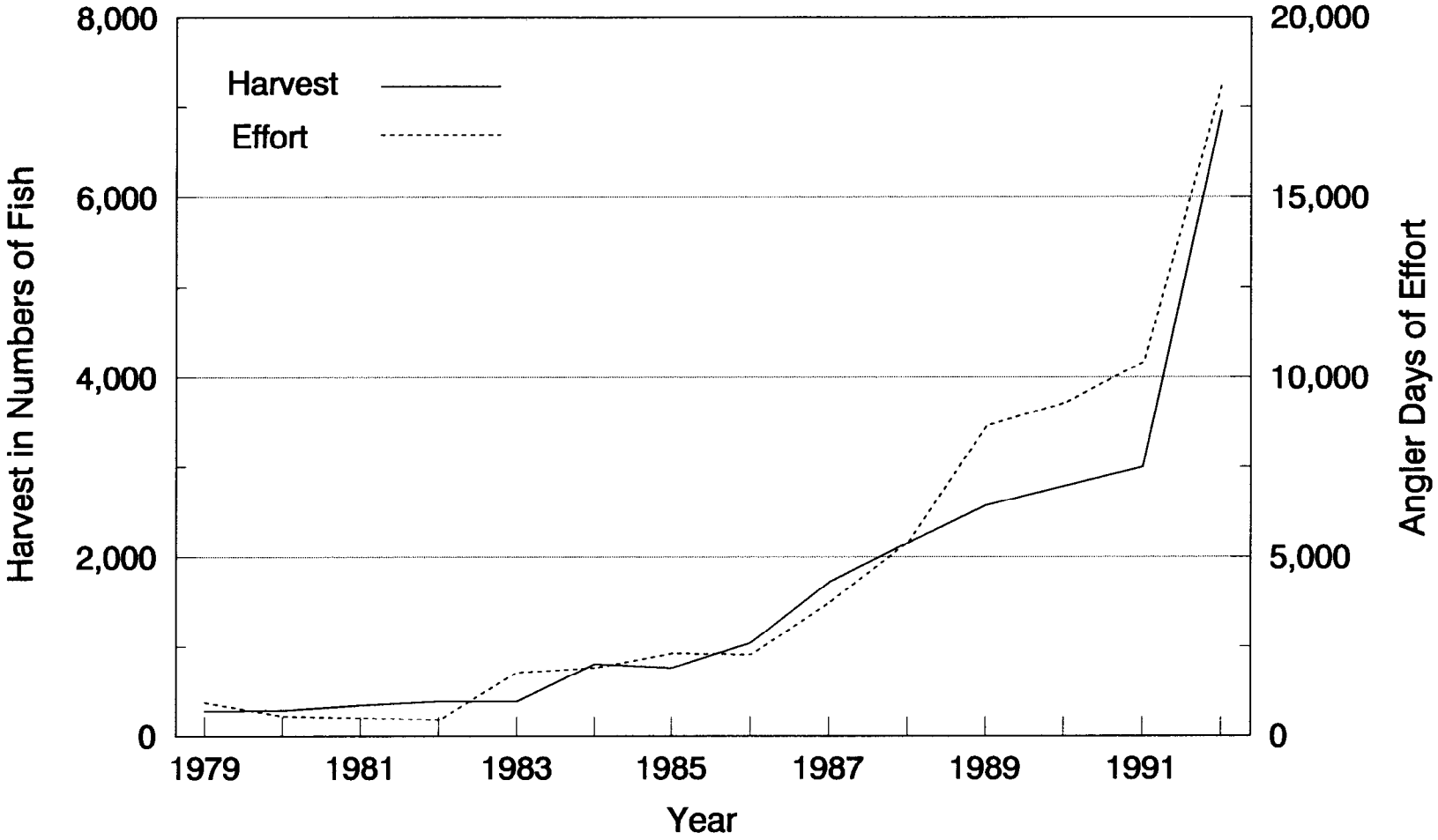
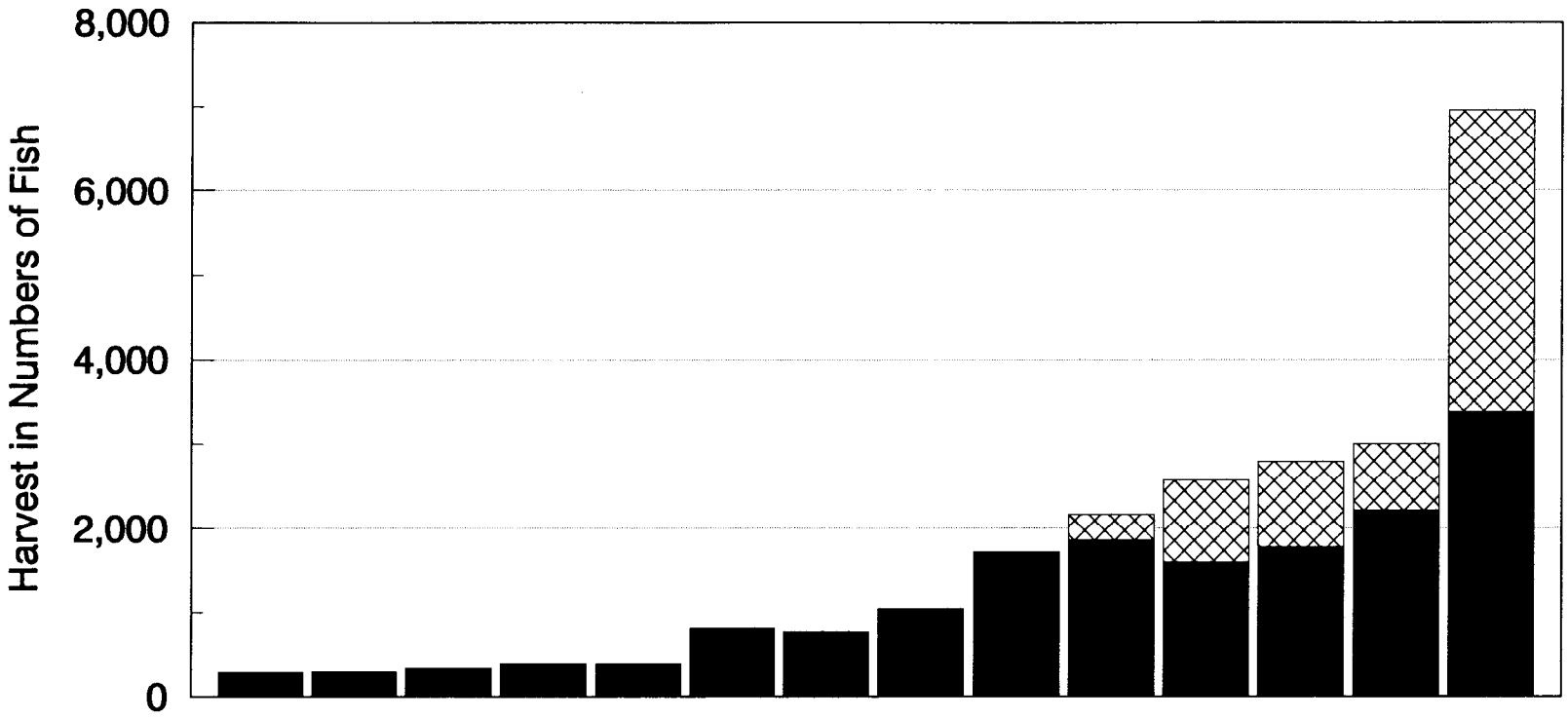
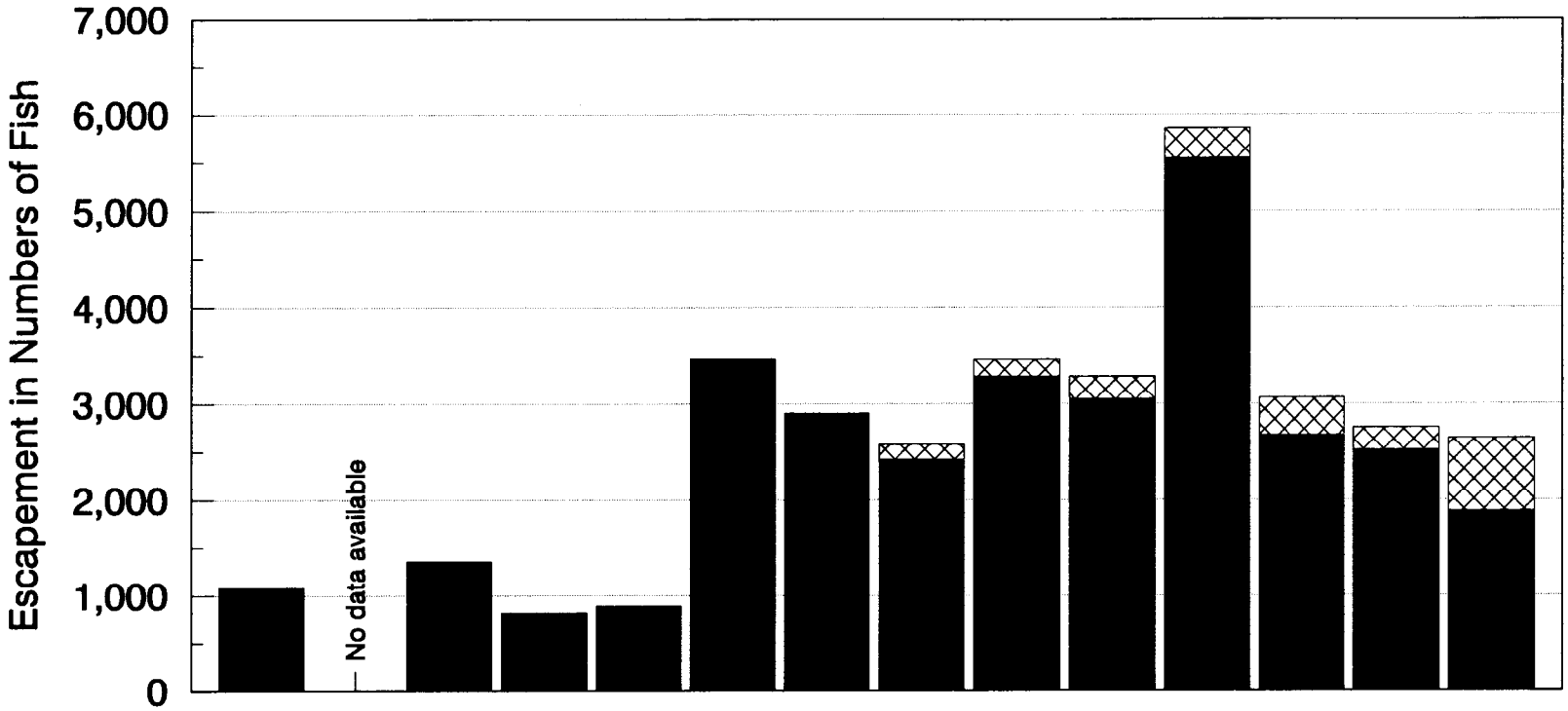


Figure 5. Numbers of chinook salmon harvested and angler days of effort expended sport fishing on Willow Creek, 1979-1992.



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

Figure 6. Numbers of nonhatchery and hatchery Willow Creek chinook salmon harvested, 1979-1992.



Year	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Hatchery	0	0	0	0	0	0	0	157	174	253	330	329	232	763
Non-Hatchery	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

Figure 7. Numbers of nonhatchery and hatchery chinook salmon in the Willow Creek and Deception Creek escapement index, 1979-1992.

Creel Survey Statistics

Angler effort, harvest and catch increased substantially at the mouth fishery in 1992. In 1991, an estimated 35,566 angler-hours of effort were expended (Peltz and Sweet 1992). In 1992, effort was approximately 81% (28,877 angler-hours) higher than 1991. The strong return allowed additional weekday openings in 1992. A large portion of the 1992 effort increase occurred during the emergency opening of the weekday period 23 June through 26 June. Sixteen thousand angler-hours were fished during this period alone (Table 1). All other strata also experienced increases in effort over 1991. The harvest and catch followed a similar trend as the effort. Harvest and catch increased in all strata with an additional 2,131 fish harvested during the added weekday openings. The estimated 1992 harvest of 6,955 fish at the mouth of Willow Creek was more than double the previous historic high of 2,997 fish in 1991 (Table 5).

The bridge fishery was monitored during the last two strata (4 July-6 July). Only a small amount of effort was observed prior to this period because only a few fish had moved upstream where they were accessible to this fishery. This scenario has been observed in previous years. Less than 24% of the catch and harvest during this time period occurred at the bridge fishery. Since the vast majority of the harvest will continue to occur at the mouth, the bridge creel survey should be discontinued. However, it may be prudent to reexamine the fishery on a cursory basis every year to determine if angler effort patterns have changed.

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 Creek. In 1992, the relative contribution of hatchery produced fish spawning in mainstem Willow Creek was 12.2%, the largest hatchery contribution to date (Table 5). The relatively large estimate of hatchery fish upstream of the Deception Creek confluence was probably a result of both the largest return of hatchery fish to date into Willow Creek and the higher proportion of tagged fish in more recent releases. Substantial numbers of hatchery fish continue to spawn in Deception Creek (Table 5). Carcass surveys on the mainstem of Willow Creek and Deception Creek should continue in 1993 to determine the contribution of hatchery fish to the spawning escapement in the mainstem of Willow Creek.

One of the goals of this project is to maintain the historical quantity of natural production in Willow Creek. The escapement objective is 4,500 fish. However, only the number of fish visible in the index area is recorded. No adjustment is made for conditions that would affect the count such as stream life or visibility. The resulting index number is a minimum escapement and is used as a relative measure of abundance from year to year. Historical escapement index counts are much lower than the stated 4,500 fish objective but have proven to be adequate to maintain the run (Table 5). The escapement objective will be restated in terms of an index so it can be directly compared to the actual index counts conducted each year. Escapement index counts from

1979 through 1991 produce a mean of 2,627, therefore the escapement objective will be restated as 2,600 fish.

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, nearly identical levels of age-1.3 fish, and a much higher proportion of age-1.2 fish in the creel survey. This observation may be attributable to the physical attributes of the sampling strategies. Samples were obtained from fish which were visible and accessible in the carcass survey. Carcasses of larger fish are more visible. Large fish also have a lower chance of washing downstream or being carried off by scavengers and predators than do small fish. Conversely, the creel survey sampled whatever fish the anglers caught and retained. Size selectivity could have occurred in the angler harvest. Large chinook salmon may also be more difficult to catch. Consequently, they could have a reduced opportunity to show up in the creel survey. If catch rates were good, anglers may have caught and released smaller fish in hope of harvesting a larger fish. Even though catch and harvest rates in 1992 were double 1991 levels, the rate of releasing fish was constant. In 1991 an estimated 33.2% of the catch was released compared to 32.7% in 1992. If people do release smaller fish in hopes of catching a larger fish, then it appears to happen at a constant rate regardless of run size. We are unable to determine if one sampling strategy provides a better estimate of the true age composition of the chinook salmon population than another. Both sampling strategies should be maintained.

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. Age composition data from the sport harvest have been collected since 1979 (Appendix B10). 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 (Table 6). Data collected prior to significant interaction of hatchery produced fish indicates 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 (Figure 8). The combined nonhatchery and hatchery returns for the most recently completed brood year (nonhatchery-1986 and hatchery-1987) are well within historic age composition levels. However, examination of only hatchery returns reveals a shift to a younger age at return. The percentage of fish which returned as age 1.4 (36.9%) is the smallest on record and substantially smaller than the historic mean (60.3%). Conversely, the percentage of fish returning at age 1.2 is the largest on record (34.8%). The age at return should be closely monitored as more hatchery brood classes return.

Comparable length (Appendix B11) and sex (Appendix B12) data from the sport harvest 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 (96.6%) and 3-ocean (62.6%) fish return as males while most 4-ocean (65.8%) fish return as females (Figure 9). The 1992 harvest contained 100% males in the 2-ocean age class, 54% males in the 3-ocean age class and 73% females in the 4-ocean age class (Figure 9).

Table 6. Estimated age at return of Willow Creek chinook salmon by brood year based on sport harvest data collected during the period 1979-1992.

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
	Hatchery	1,023	833	1,084	2,940	34.8	30.0	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		2,077	17.0	83.0		100.0
	Hatchery	222	1,443		1,665	13.3	86.7		100.0
	Total	575	3,167		3,742	15.4	84.6		100.0
1988	Nonhatchery	820			820	100.0			100.0
	Hatchery	1,675			1,675	100.0			100.0
	Total	2,495			2,495	100.0			100.0
Brood Years 1975 to 1985					Mean	13.0	26.7	60.3	100.0
					Maximum	21.8	47.5	82.3	
					Minimum	3.4	4.9	41.8	

[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. The brood year for hatchery fish is actually N+1.

[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.

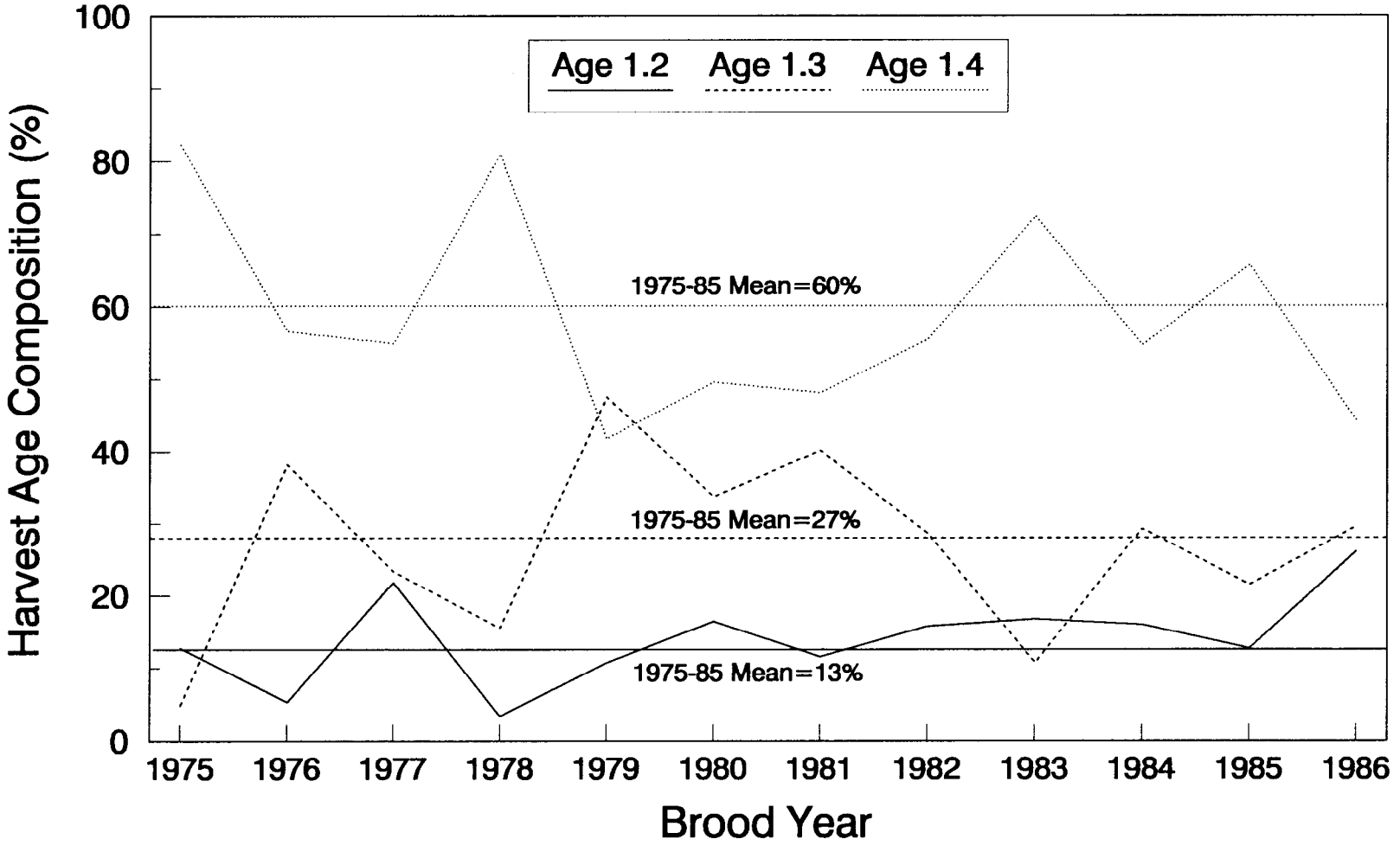


Figure 8. Willow Creek chinook salmon estimated age composition at return for brood years 1975-1986 based on sport harvest data.

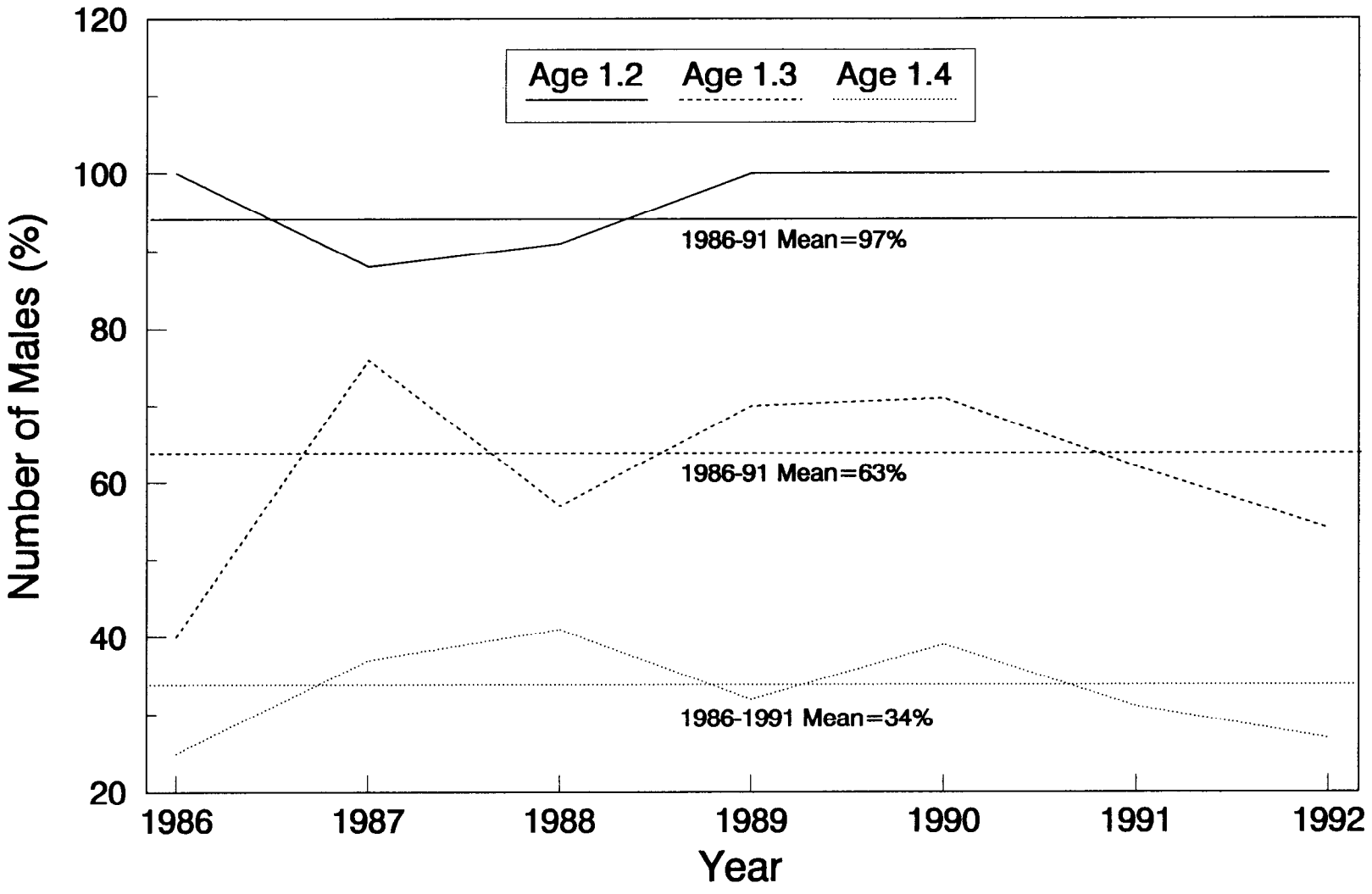


Figure 9. Willow Creek chinook salmon estimated percentage of males by age class from sport harvests for the period 1986-1992.

Based on 1988-1991 means, average length differences among age classes in the sport harvest are obvious with age 2-ocean, 3-ocean, and 4-ocean fish averaging 602 mm, 827 mm, and 949 mm respectively (Figure 10). Mean lengths for the 1992 harvest were 611 mm, 753 mm and 914 mm for 2-ocean, 3-ocean, and 4-ocean fish, respectively. The 3-ocean and 4-ocean mean lengths fell below the range of 1986-1991 data (Appendix B11). Additional years of data are needed to detect any trends. For all years, 3-ocean females are larger than 3-ocean males, but 4-ocean females are smaller than 4-ocean males.

Contribution of Coded Wire Tagged Stocks

The 1992 estimated hatchery contribution to the Willow Creek chinook salmon fishery was the largest to date (Table 5). The total predicted hatchery return for 1992 was 5,831 (Peltz and Sweet 1992). The estimated actual hatchery return was 4,340 fish (Appendix B9). The predicted return of 4-ocean fish was much greater than the actual estimated return, 2,819 and 1,060, respectively. The opposite was true of 3-ocean fish with 456 predicted and 1,457 actual estimated returns. The predicted return of 2-ocean fish was 2,556 with an estimated actual return of 1,549. Past performance of hatchery smolt stocking at Willow Creek has been well below expectations. Eight 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 expectations (Figure 11). Brood year 1987 returned as age 4-ocean fish this year in smaller numbers than predicted. However, the 1987 brood year is the most successful return to date at 73% of the projected level (Figure 11). Although still incomplete, returns from subsequent brood years have improved and are much closer to returning at projected levels.

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 indices to Willow and Deception creeks since 1979 have been below the 4,500 fish escapement objective every year except 1989 (Figure 7). These indices are a combination of peak aerial survey and foot counts and are therefore not directly comparable to an absolute escapement objective. Since 1979, the count indices have averaged 2,627 fish. In the future, the escapement objective will be restated as an index of 2,600 fish for comparison with prior year escapement indices, rather than an absolute number. The historic quantity of natural chinook salmon production has been maintained as evidenced by attainment of the annual index of 2,600 naturally spawning fish.

Lack of substantial age and sex composition data from enhanced returns prevents us from measuring maintenance of fish quality. 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 brood year were completed in 1992 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. The historic age and sex data

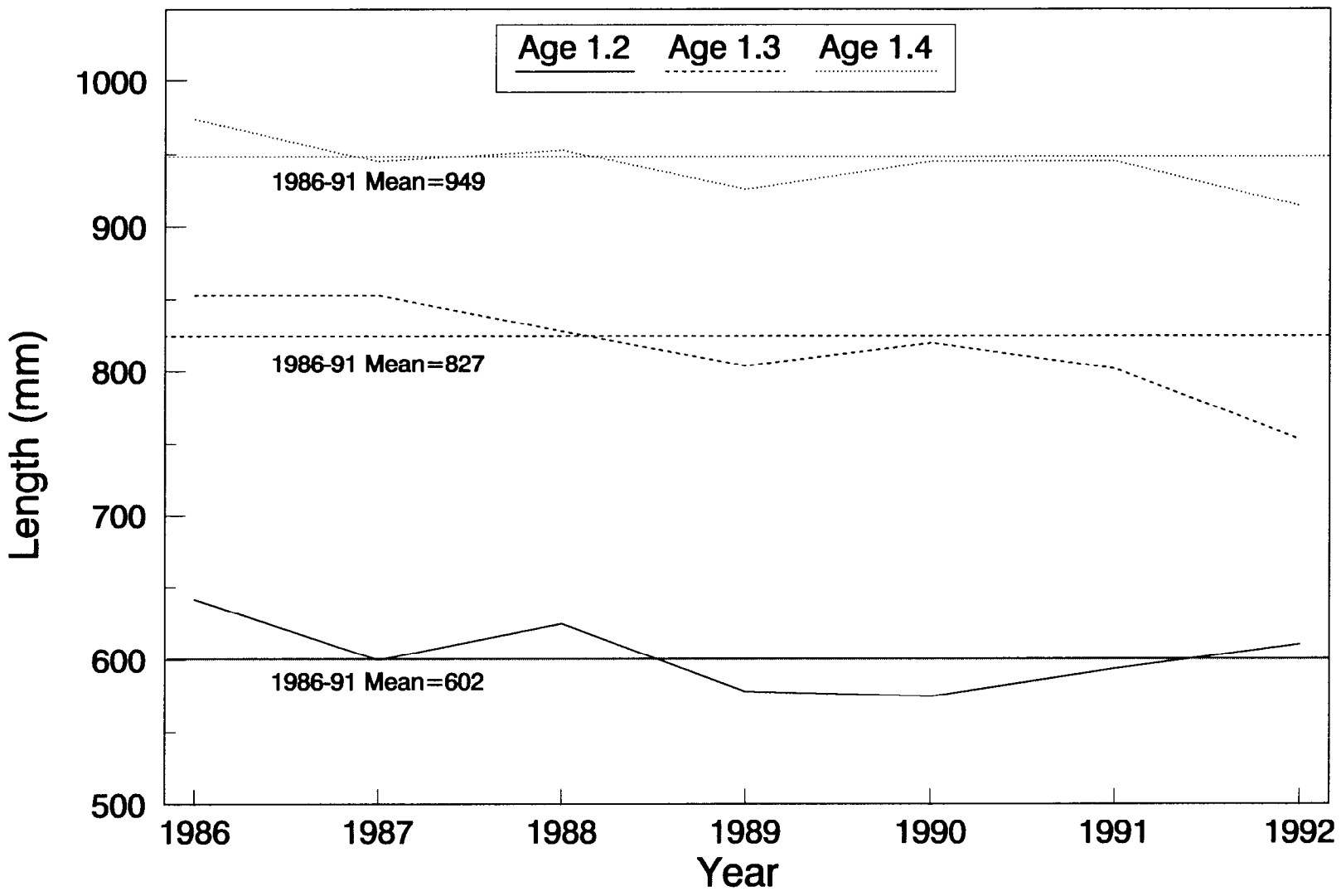


Figure 10. Willow Creek chinook salmon estimated mean length by age class from sport harvests for the period 1986-1992.

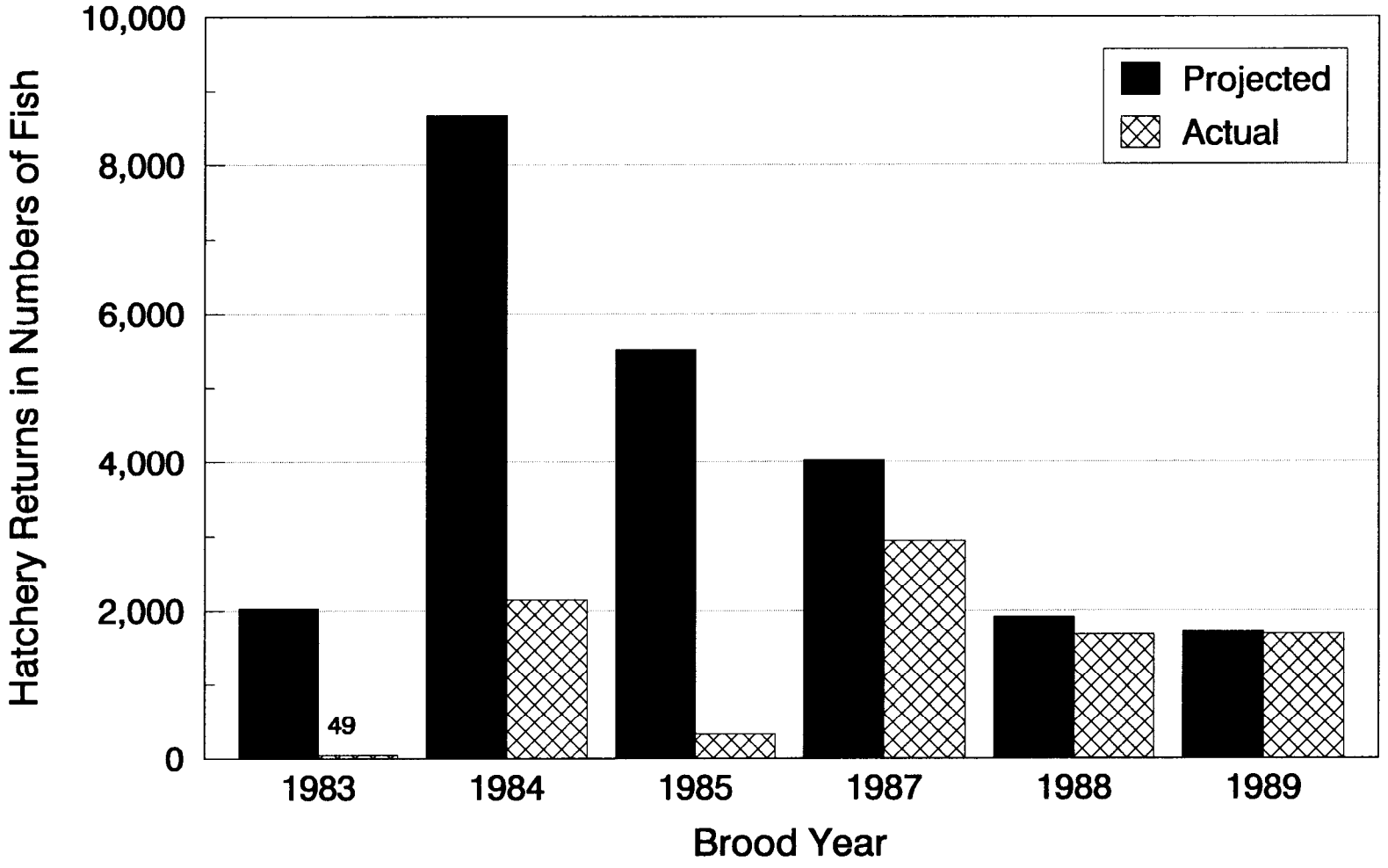


Figure 11. Willow Creek chinook salmon projected and actual hatchery returns by brood year from return years 1986-1992.

compiled in Appendices B10, B11, and B12 as well as Figures 8 and 9 should provide a basis for future comparison.

Another indicator of quality is maintenance of historic harvest timing (Appendix B13). However, for Willow Creek the fishery harvest pattern reflects the harvest when the opportunity exists to catch fish and does not necessarily reflect the availability of fish to be harvested. In 1992, with the opening of four 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 B13). 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.

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. In 1991 we compared our estimated actual hatchery return to a projection based on a 6,000 fish (3%) return. Since we do not measure any chinook salmon production other than that which is available for harvest, it now appears a more meaningful comparison would be to the 4,000 fish (2%) projected to be available for harvest. Figures 11 and 12 are based on a projected 2% availability of the hatchery release to the harvest. 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). Utilizing data from the brood table (Table 6) and historic age composition (Appendix B7) allowed us to project 1992 returns (Peltz and Sweet 1992) at an estimated 10,000 fish, of which approximately 56.5% would be of hatchery origin. The actual estimated return in 1992 was 7,081 harvest and 2,643 escapement index for a minimum of 9,734 of which approximately 45% or 4,381 fish were of hatchery origin. In 1992 we came close to meeting our goal with a minimum of approximately 4,400 hatchery fish returning. Since the 1992 projections were accurate in terms of total return, we made projections for 1993 (Appendix B14). The 1993 projected Willow Creek chinook salmon return is estimated to be approximately 12,500 fish of which slightly over half are projected to be of hatchery origin. If the 1993 projections prove to be accurate, then we will achieve our program production goal in 1993.

The last goal of the enhancement program was to provide 10,000 additional angler-days of participation during weekdays in June. This goal was previously addressed by Peltz and Sweet (1992). It was established that the baseline level of measurement of fishing effort should be approximately 5,500 angler-days of effort. It was also pointed out that for past years it is difficult to differentiate weekend data from weekday data so it wasn't possible to determine effort during weekdays only. Based on these factors, it may be best to rephrase this goal. We suggest that this goal be changed "to provide a minimum of 15,000 total angler days of participation during the period 10 June to 10 July". Angling effort nearly doubled in 1992 and harvest of chinook salmon more than doubled. We exceeded our goal by over 3,000 angler-days in 1992. Despite this unprecedented increase we only increased

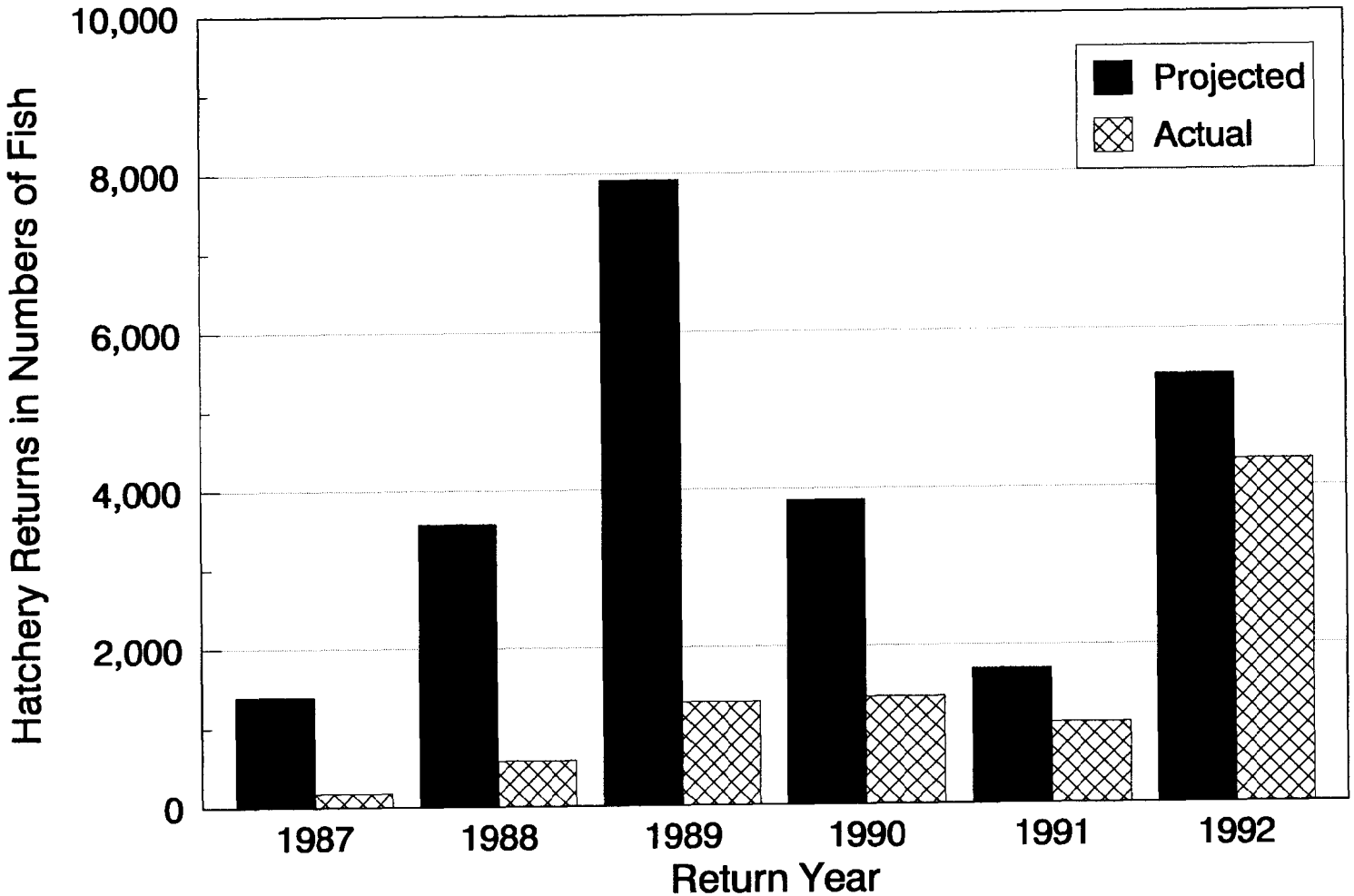


Figure 12. Willow Creek chinook salmon projected and actual hatchery returns for the period 1987-1992 assuming a 2% return.

the open fishing period by 1 day. The fishery was closed 30 June through 3 July to allow the fish unmolested movement upstream. Willow Creek anglers appear to be extremely efficient and in order to maintain adequate escapement levels periodic fishery closures will probably be necessary. It may not be possible to add any more days of fishing time above existing levels.

Peltz and Sweet (1992) established the database for measuring the performance and success of the Willow Creek chinook salmon enhancement program. The developmental phase of this program is scheduled to be completed by 1994. Following data collection in 1994, a program completion report will be written. All existing data will be incorporated into this database to develop conclusions and make a recommendation as to whether the Willow Creek chinook salmon enhancement program should be discontinued, continued, or modified.

Recommendations

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

1. All smolt stocked should be represented by the coded wire tagged fish which are released. Planning can eliminate the stocking of a group of smolt without tag representation as occurred in 1992.

2. As long as brood stock is abundant, a male to female ratio of 2:1 should be continued to increase genetic diversity and maintain a healthy hatchery gene pool.

3. Coded wire tagging should be rigidly monitored to insure better quality control. Fish should be graded during clipping and different size head molds should be used on small, medium, and large fish.

4. The upstream creel surveys should be discontinued in 1993. However harvest patterns may change and should be reexamined periodically.

5. Carcass surveys should continue to determine if hatchery fish are spawning with nonhatchery fish in mainstem Willow Creek.

6. Continue to obtain age, length, and sex data from sport harvests and carcass surveys. We have not determined which is a better indicator of the true population characteristics, and both are needed to fully evaluate return information. We have had difficulty obtaining the desired sample sizes in the carcass surveys. Survey frequency may need to be increased.

7. Further hatchery return projections should be based on a 2% survival rate of smolt releases representing hatchery fish available for harvest in Willow Creek.

8. Restate the present goal of providing 10,000 additional angler-days of opportunity during weekdays to providing a minimum of 15,000 angler-days of participation during the period 10 June to 10 July.

9. The brood table developed has potential as a valuable management tool. The projected total number of fish to Willow Creek in 1992

was extremely close to actual return numbers. This process should be further refined as more data are assimilated and yearly projections should be used to help form management strategies for the upcoming year.

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APPENDIX A

Appendix A1. Willow Creek chinook salmon creel survey strata definitions and sampling location parameters, 1992.

Strata for the 1992 Willow Creek chinook salmon creel survey were defined as follows:

1 = 10 June - 13 June;
2 = 16 June - 19 June;
3 = 23 June - 26 June;
4 = 30 June - 3 July;
5 = 13 June (0000-1159);
6 = 13 June (1200) - 15 June (2359);
7 = 20 June (0000-1159);
8 = 20 June (1200) - 22 June (2359);
9 = 27 June (0000-1159);
10 = 27 June (1200) - 29 June (2359);
11 = 4 July (0000-1159);
12 = 4 July (1200) - 6 July (2359).

Mouth Fishery:

A summary of the sampling characteristics for the mouth fishery component of the creel survey were as follows:

1. Dates: 10 June thru 6 July, Strata 1,3,5-12. Fishery was closed during strata 2 and 4.

2. Fishing and sampling period: 24 hour fishing day consisting of six 4-hour periods.

3. 10 June through 12 June two periods were sampled each day. All following weekends (Saturday, Sunday, and Monday) after 12 June six periods were sampled each day. Four periods were sampled each weekday.

4. Zero to three angler counts (taking 20 minutes to conduct) were taken each period (start time was selected at random).

Park's Highway Fishery:

A summary of the sampling characteristics for the Park's Highway fishery component of the creel survey were as follows:

1. Dates: 4 July thru 6 July. Strata 11 and 12.

2. Fishing and sampling period: 24 hour fishing day consisting of six 4-hour periods.

3. All of the 4-hour periods were sampled each day.

4. Zero, one or two angler counts (taking 20 minutes to conduct) were taken each period (start time for count was selected at random).

Appendix A2. Estimation equations for angler effort for, and catch and harvest of, chinook salmon in the 1992 sport fishery in Willow Creek.

Weekday 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 weekday strata (i.e., strata 1-4). 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;

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

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:

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

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

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

-continued-

[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:

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

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:

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

where:

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

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

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

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

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.

-continued-

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;

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

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:

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

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

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

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

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

-continued-

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:

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

-continued-

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

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

$\hat{V}[\hat{E}_{hij}]$ = 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);

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

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.

-continued-

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:

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

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 estimable (i.e., at least two periods sampled in which effort could be estimated); d'_{3h} equals 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.

Weekend Strata. Estimates of angler effort, catch, and harvest along with their variances for the weekend strata 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 either 12 hours or 60 hours dependent upon the stratum. 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 for the weekend strata were calculated directly from equation A2.15, above. The estimated variance of the harvest estimate was obtained similarly by substitution.

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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.

Combined Stratum 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, 1992.

Estimates of the percentage of chinook salmon by age class and sex, as well as the apportioned abundances by these classifications were calculated in a post-stratified manner according to whether or not the sampled fish was adipose finclipped (referred to as a marked grouping, below). Additionally, temporal post-stratification was performed with the temporal components essentially grouping the sampling strata to describe periods in the fishery. The first step in obtaining these estimates was to calculate the proportion in each class for each marked grouping within each temporal component:

$$\hat{p}_{u\lambda t} = \frac{n_{u\lambda t}}{n_{\lambda t}} ; \qquad \text{(A3.1)}$$

where:

$n_{u\lambda t}$ = the number of chinook salmon classified as category u (where the types of categories were the various age classes for age composition or male/female for the sex composition estimates) that were in marked grouping λ and temporal component t; and

$n_{\lambda t}$ = the number of chinook salmon sampled for age or sex composition within mark grouping λ and temporal component t.

The next step involved estimating the harvest of each category (age class or sex) within each "stratum" (combination of mark grouping and temporal component):

$$\hat{N}_{u\lambda t} = \hat{p}_{u\lambda t}\,\hat{N}_{\lambda t} ; \qquad \text{(A3.2)}$$

where:

$\hat{N}_{\lambda t}$ = the estimated harvest of chinook salmon of mark grouping λ within temporal component t. This value was obtained for the adipose finclipped mark group by applying the procedures outlined in Appendix A4 with θ set to one (i.e., no expansion for tagging fraction, since by definition all adipose finclipped fish are marked). The estimated value of $N_{\lambda t}$ for the fish without adipose finclips was obtained by subtracting the value of the estimated harvest of adipose finclipped fish from the estimated harvest in total for all fish for the temporal component (obtained as outlined in Appendix A2).

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Next the harvest of chinook salmon in each category over all strata was estimated as:

$$\hat{N}_u = \sum_{\lambda=1}^{g} \sum_{t=1}^{s} \hat{N}_{u\lambda t} \; ; \qquad \text{(A3.3)}$$

where: g and s represent the number of mark groupings and temporal components, respectively (where g = 2 by definition).

Next the proportion of chinook salmon in each category was estimated as:

$$\hat{p}_u = \frac{\hat{N}_u}{\hat{N}} \; ; \qquad \text{(A3.4)}$$

where:

$\hat{N}$ = the total estimated harvest of chinook salmon over all groupings and all temporal components;

$$= \sum_{u=1}^{c} \hat{N}_u \; ; \text{ and} \qquad \text{(A3.5)}$$

c = the number of categories (age groups or sex groups).

The percentage in each age group was found as the above proportions times 100%.

The variance of the estimated proportion of chinook salmon in each category was calculated approximately (using the Delta Method, see Seber 1982, section 1.3.3, pages 7-9) by:

$$\hat{\hat{V}}[\hat{p}_u] \approx \left[\frac{\hat{N}_u}{\hat{N}} \right]^2 \left[\frac{\hat{\hat{V}}[\hat{N}_u]}{\hat{N}_u^2} + \frac{\hat{\hat{V}}[\hat{N}]}{\hat{N}^2} - \frac{2\,\hat{\hat{V}}[\hat{N}_u]}{\hat{N}_u\,\hat{N}} \right] ; \qquad \text{(A3.6)}$$

-continued-

where:

$\hat{V}[\hat{N}_u]$ = the estimated variance for the estimated harvest of chinook salmon over all groupings and all temporal components, obtained as the sum of variances of the components;

$$= \sum_{\lambda=1}^{g} \sum_{t=1}^{s} \hat{V}[\hat{N}_{u\lambda t}] \; ; \qquad \text{(A3.7)}$$

$\hat{V}[\hat{N}_{u\lambda t}]$ = estimated variance for the estimated harvest for each category within each mark grouping/temporal component stratum, obtained from Goodman's (1960) formula for the variance of the product of random variates:

$$= \hat{p}_{u\lambda t}^2 \, \hat{V}[\hat{N}_{\lambda t}] + \hat{N}_{\lambda t}^2 \, \hat{V}[\hat{p}_{u\lambda t}] - \hat{V}[\hat{N}_{\lambda t}] \, \hat{V}[\hat{p}_{u\lambda t}] \; ; \qquad \text{(A3.8)}$$

$\hat{V}[\hat{N}_{\lambda t}]$ = estimated variance for the estimated harvest of chinook salmon within each size grouping/temporal component stratum; this value was obtained for the adipose finclipped mark grouping by applying the procedures outlined in Appendix A4 with θ set to one (i.e., no expansion for tagging fraction, since by definition all adipose finclipped fish are marked). The estimated value of $\hat{V}[\hat{N}_{\lambda t}]$ for the fish without adipose finclips was obtained by adding the variance of the estimated harvest of adipose finclipped fish with the variance from the estimated harvest in total for all fish for the temporal component (obtained as outlined in Appendix A2);

$\hat{V}[\hat{p}_{u\lambda t}]$ = estimated variance for the estimated proportion of each category within each mark grouping/temporal component stratum, obtained from the standard equation for the variance of a binomial parameter (adapted from equation 3.8 in Cochran 1977, page 52);

$$= \left[1 - \frac{n_{\lambda t}}{\hat{N}_{\lambda t}} \right] \left[\frac{\hat{p}_{u\lambda t} \, (1 - \hat{p}_{u\lambda t})}{(n_{\lambda t} - 1)} \right] \; ; \text{ and} \qquad \text{(A3.9)}$$

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$\hat{V}[N]$ = estimated variance of the total estimate of harvest, which for use with these procedures was equated to the sum of the individual harvest for each category[1];

$$= \sum_{u=1}^{c} \hat{V}[N_u] \quad . \qquad \text{(A3.10)}$$

Variances in terms of percentages were obtained by multiplying the variance estimates for the proportions by the square of 100%. Standard errors were obtained by taking the square root of the variance estimates.

[1] This formula for estimating the total harvest estimate variance was used so that the covariance term in equation A3.6, above, was approximated by the variance of the individual components.

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, 1992.

Contributions of Coded Wire Tagged Stocks to the 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. The notation used in the following equations essentially followed that used by Clark and Bernard (1987), with additional subscripts used to denote individual stratum (or combined strata periods). The first step involved 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):

$\hat{n}_{1A_h}$ = 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: $\hat{N}_h$ equaled the estimated harvest of all chinook salmon within each stratum; n_{2h} was the number of chinook salmon inspected for missing adipose fins from the sampled harvest in each fishery stratum; a_{1h} equaled the number of chinook salmon with a missing adipose fin which were counted and marked with a head strap from each stratum; a_{2h} equaled the number of chinook salmon heads previously marked with a a head strap which arrived at the tag lab, from fish originally sampled from stratum *h*; m_{1h} equaled 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} was the number of coded wire tags which were removed from the chinook salmon heads and decoded, from chinook salmon sampled from stratum *h*; m_{ah} was 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 equaled the proportion of a particular hatchery release which contained a coded wire tag of the unique tag code *A*.

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Estimates of across strata (or initially combined strata) contributions by tag code, as well as by combined tag codes was 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 included 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 (see Appendix A2, hence no simulation will be involved). The bootstrap resampling primarily involved estimation of the variance due to the coded wire tag (CWT) sampling program. Equation A4.1 was first divided into three components (in the following presentation subscripts denoting strata and particular tag codes have been dropped):

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

The first component (N) was harvest as estimated from the creel survey, and the third component (θ) was obtained from the tag lab database and was assumed to be known for the hatchery tag codes. The second component $[(m_1/m_2)(a_1/a_2)(m_c/n_2)]$ corresponded to statistics garnered through harvest sampling (and lab work); for convenience, M was defined as the result of the arithmetic operations in this second component. Each of these three components was 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[1];
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.

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[1] Sometimes heads can not be cinch strapped even though an adipose finclip is detected, since anglers sometimes cut off the fish's head.

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 (B=1000) of M_b were so generated and their values were 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 was estimated as:

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

Estimates of the variance of across strata contributions by tag code, as well as by combined tag codes, were 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 of Coded Wire Tagged Stocks 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 represented the proportion of harvested fish of the particular tag code. The adaptation to equation [10] from Clark and Bernard 1987 involved dividing both sides of the equation by the unestimated total "harvest" value (i.e., in equation A4.1, above). The resulting term on the left-hand side of the equation was n_1 / N (without the stratum subscript or "^" to denote estimates) which was defined as the relative contribution, and was 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 were 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 A4.2, 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} equaled the number of tagged chinook salmon of a particular tag code sampled from the escapement; and n2 equaled 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 1985-1992 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	Percent Valid Coded Wire Tagged[a]	Percent Marked[b]	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	8.1%		3	49	<0.05%	1989
1984	Deception	214,384	11,038		13.8	6/11-12/85	31-16-45	5.1%		26	1,230	0.6%	1989
	Deception	218,743	10,708		14.0	6/20/85	31-16-47	4.9%		29	911	0.4%	1989
1985	Deception	49,668	9,933		16.7	5/01/86	31-17-33[e]	20.0%		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					14.4%		9	264	0.1%	1990
1987	Deception	201,091	20,936		10.9	7/12/88	31-17-58	10.4%		142	2,940	1.5%	1992
1988	Deception	240,885	19,851		13.0	5/31/89	31-17-60	11.4%		73	1,665	0.7%[f]	1993
1989	Deception	219,362	41,570		14.4	5/24/90	31-17-34	19.0%		49	442		1994
	Deception	219,432	40,575		13.4	5/24/90	31-18-51	18.5%		53	502		1994
	Deception	216,697	40,438		13.9	5/24/90	31-18-52	18.7%		79	731		1994
		655,491	122,765							181	1,675	0.3%[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					21.6%		11	138	0.04%[f]	1995
1991	Deception	179,724	33,464	44,089	13.5	5/29/92	31-21-03						1996
	Deception	35,752			14.5	6/09/92							
		215,476	33,464	44,089				15.5%	20.5%				

[a] The estimated number of fish that possessed 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 the interception in the commercial fishery (Copper River, Cook Inlet), nontarget sport fisheries (Homer, Susitna River) or straying from Willow Creek.

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

[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 1987 and 1988 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 1992.

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	8/05-11	202	3	3	185	2\31-17-58	9.5%	7.4%
						1\31-18-52	2.7%	4.2%
						Total	12.2%	8.5%
Deception Creek	8/05-10	115	9	9	0	1\31-19-33	5.5%	15.9%
						1\31-17-58	8.4%	24.5%
						3\31-17-60	31.7%	30.5%
						1\31-18-52	4.7%	13.8%
						3\ no tag		
						Total	50.1%	44.5%
Deception Creek weir egg take	7/23-31	202	17	17	201	3\31-17-34	7.8%	10.3%
						6\31-17-58	28.5%	19.6%
						1\31-17-60	6.0%	24.0%
						4\31-18-51	10.7%	10.5%
						3\31-18-52	8.0%	10.6%
						Total	61.0%	35.9%
Total		519	29	29	386			

Appendix B4. Estimated effort, catch and harvest by strata for fish less than 16 inches during the Willow Creek chinook salmon creel survey in 1992.

Strata	Date	Number of anglers interviewed	Effort in angler-hours	SE	Catch	SE	Harvest	SE
Mouth:								
1	6/10-12	298	3,584	464	17	8	17	8
5&6	6/13-15	2,066	8,407	484	26	6	26	6
2	6/16-19	0			fishery closed			
7&8	6/20-22	3,488	15,031	1,160	83	18	83	18
3	6/23-26	2,044	16,001	639	47	16	47	16
9&10	6/27-29	2,876	13,574	972	24	7	24	7
4	6/30-7/03	0			fishery closed			
11&12	7/04-06	1,675	7,846	572	48	11	48	11
Subtotal		12,447	64,443	1,864	245	30	245	30
Highway:								
1	6/10-12				no survey			
5&6	6/13-15				no survey			
2	6/16-19				fishery closed			
7&8	6/20-22				no survey			
3	6/23-26				no survey			
9&10	6/27-29				no survey			
4	6/30-7/03				fishery closed			
11&12	7/04-06	318	1,655	188	4	2	4	2
Subtotal		318	1,655	188	4	2	4	2
Combined:								
1	6/10-12	298	3,584	464	17	8	17	8
5&6	6/13-15	2,066	8,407	484	26	6	26	6
2	6/16-19	0			fishery closed			
7&8	6/20-22	3,488	15,031	1,160	83	18	83	18
3	6/23-26	2,044	16,001	639	47	16	47	16
9&10	6/27-29	2,876	13,574	972	24	7	24	7
4	6/30-7/03	0			fishery closed			
11&12	7/04-06	1,993	9,501	601	52	12	52	12
Total		12,765	66,098	1,873	249	30	249	30

Appendix B5. Estimates of the catch and harvest distribution of chinook salmon during the 1992 Willow Creek (mouth) creel survey.

Stratum	Estimated number of angler-Trips	Parameter	Proportion of angler-trips that caught or harvested the noted number of chinook salmon: Caught[a]	SE	Harvested[b]	SE
1 (10 June - 12 June)	1,074	0 fish	0.705	0.103	0.724	0.106
		1 or more fish	0.295	0.039	0.276	0.040
		2 or more fish	0.017	0.007	0.000	0.000
		3 or more fish	0.000	0.000	0.000	0.000
		4 or more fish	0.000	0.000	0.000	0.000
		5 or more fish	0.000	0.000	0.000	0.000
		6 or more fish	0.000	0.000	0.000	0.000
5 (13 June 0000-1159 hrs)	307	0 fish	0.771	0.024	0.801	0.023
		1 or more fish	0.229	0.024	0.199	0.023
		2 or more fish	0.023	0.009	0.017	0.007
		3 or more fish	0.000	0.000	0.000	0.000
		4 or more fish	0.000	0.000	0.000	0.000
		5 or more fish	0.000	0.000	0.000	0.000
		6 or more fish	0.000	0.000	0.000	0.000
6 (13 June 1200 hrs - 15 June 2359 hrs)	2,072	0 fish	0.693	0.011	0.718	0.011
		1 or more fish	0.307	0.011	0.282	0.011
		2 or more fish	0.028	0.004	0.001	0.001
		3 or more fish	0.012	0.003	0.000	0.000
		4 or more fish	0.007	0.002	0.000	0.000
		5 or more fish	0.005	0.002	0.000	0.000
		6 or more fish	0.002	0.001	0.000	0.000
2 (16 June - 19 June)		Fishery Closed By Regulation				
7 (20 June 0000-1159 hrs)	825	0 fish	0.491	0.020	0.535	0.020
		1 or more fish	0.509	0.020	0.465	0.020
		2 or more fish	0.066	0.010	0.000	0.000
		3 or more fish	0.032	0.007	0.000	0.000
		4 or more fish	0.015	0.005	0.000	0.000
		5 or more fish	0.014	0.005	0.000	0.000
		6 or more fish	0.008	0.003	0.000	0.000
8 (20 June 1200 hrs - 22 June 2359 hrs)	3,569	0 fish	0.420	0.009	0.471	0.009
		1 or more fish	0.580	0.009	0.529	0.009
		2 or more fish	0.124	0.006	0.006	0.001
		3 or more fish	0.064	0.005	0.000	0.000
		4 or more fish	0.035	0.003	0.000	0.000
		5 or more fish	0.020	0.003	0.000	0.000
		6 or more fish	0.013	0.002	0.000	0.000
3 (23 June - 26 June)	4,605	0 fish	0.507	0.024	0.534	0.024
		1 or more fish	0.493	0.036	0.466	0.035
		2 or more fish	0.098	0.010	0.000	0.000
		3 or more fish	0.052	0.006	0.000	0.000
		4 or more fish	0.023	0.004	0.000	0.000
		5 or more fish	0.013	0.003	0.000	0.000
		6 or more fish	0.006	0.002	0.000	0.000
9 (27 June 0000-1159 hrs)	776	0 fish	0.629	0.026	0.653	0.026
		1 or more fish	0.371	0.026	0.347	0.026
		2 or more fish	0.053	0.012	0.000	0.000
		3 or more fish	0.029	0.009	0.000	0.000
		4 or more fish	0.015	0.007	0.000	0.000
		5 or more fish	0.000	0.000	0.000	0.000
		6 or more fish	0.000	0.000	0.000	0.000

-continued-

Appendix B5. (Page 2 of 2).

Stratum	Estimated number of angler-trips	Parameter	Proportion of angler-trips that caught or harvested the noted number of chinook salmon: Caught[a]	SE	Harvested[b]	SE
10 (27 June 1200 hrs - 29 June 2359 hrs)	2,778	0 fish	0.653	0.009	0.690	0.009
		1 or more fish	0.347	0.009	0.310	0.009
		2 or more fish	0.054	0.005	0.002	0.001
		3 or more fish	0.024	0.003	0.002	0.001
		4 or more fish	0.014	0.002	0.001	0.001
		5 or more fish	0.009	0.002	<0.0005	<0.0005
		6 or more fish	0.005	0.001	0.000	0.000
4 (30 June - 3 July)		Fishery Closed By Regulation				
11 (04 July 0000-1159 hrs)	709	0 fish	0.683	0.023	0.760	0.021
		1 or more fish	0.317	0.023	0.240	0.021
		2 or more fish	0.104	0.015	0.000	0.000
		3 or more fish	0.027	0.008	0.000	0.000
		4 or more fish	0.007	0.004	0.000	0.000
		5 or more fish	0.002	0.002	0.000	0.000
		6 or more fish	0.000	0.000	0.000	0.000
12 (04 July 1200 hrs - 06 July 2359 hrs)	1,556	0 fish	0.794	0.011	0.832	0.011
		1 or more fish	0.206	0.011	0.168	0.011
		2 or more fish	0.033	0.005	0.000	0.000
		3 or more fish	0.017	0.004	0.000	0.000
		4 or more fish	0.004	0.002	0.000	0.000
		5 or more fish	0.002	0.001	0.000	0.000
		6 or more fish	0.001	0.001	0.000	0.000
Season Total	18,271	0 fish	0.585	0.009	0.621	0.009
		1 or more fish	0.415	0.010	0.379	0.010
		2 or more fish	0.074	0.003	0.002	<0.0005
		3 or more fish	0.036	0.002	<0.0005	<0.0005
		4 or more fish	0.018	0.001	<0.0005	<0.0005
		5 or more fish	0.010	0.001	<0.0005	<0.0005
		6 or more fish	0.005	0.001	0.000	0.000

[a] Maximum observed catch equals 13.

[b] Maximum observed harvest equals 5.

Appendix B6. Number of chinook salmon inspected, number of adipose finclips observed, number of heads collected, and coded wire tag returns by strata from Willow Creek creel surveys in 1992 (only fish greater than or equal to 16 inches).

	Strata								
Date	1 6/10-12	5&6 6\13-15	2[a] 6\16-19	7&8 6\20-22	3 6\23-26	9&10 6\27-29	4[a] 6\30-7\3	11&12 7\4-6	Total
Mouth Survey									
# fish inspected	74	517	---	1,842	980	863	---	328	4,607
# clips observed	9	61	---	142	77	50	---	20	359
# heads collected	8	47	---	139	72	50	---	16	332
Coded wire tag recoveries									
31-17-58[b]	0	1	---	16	11	19	---	1	48
31-17-60[c]	3	16	---	29	7	5	---	2	62
31-17-34[d]	1	7	---	25	9	2	---	2	46
31-18-52[e]	1	8	---	35	21	5	---	4	74
31-18-51[f]	1	4	---	18	10	11	---	5	49
31-19-33[g]	0	2	---	1	5	2	---	0	10
31-17-59[h]	0	1	---	0	1	0	---	0	2
31-18-31[i]	0	1	---	0	0	0	---	0	1
31-18-36[j]	0	1	---	0	0	1	---	1	3
No tag	(2)	(6)	---	(15)	(8)	(5)	---	(1)	(37)
Total CWT returns	6	42	---	124	64	45	---	15	295
Parks Highway Bridge Survey (only 7/4-6 surveyed):									
# fish inspected	---	---	---	---	---	---	---	118	118
# clips observed	---	---	---	---	---	---	---	3	3
# heads collected	---	---	---	---	---	---	---	3	3
Coded wire tag recoveries									
31-17-58[b]	---	---	---	---	---	---	---	1	1
31-18-52[e]	---	---	---	---	---	---	---	2	2
Total CWT returns								3	3

[a] Fishery closed.
[b] Willow Creek 1988 release.
[c] Willow Creek 1989 release.
[d] Willow Creek 1990 release.
[e] Willow Creek 1990 release.
[f] Willow Creek 1990 release.
[g] Willow Creek 1991 release.
[h] Montana Creek 1988 release.
[i] Montana Creek 1989 release.
[j] Sheep Creek 1989 release.

Appendix B7. Tag recoveries from chinook salmon stocked in Willow, Montana, and Sheep creeks and recovered in nontarget fisheries, 1986-1992.

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
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 B8. 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), 1986-1992.

	Brood Year	1983	1984		1985		1987	1988	1989			1990	Total Tags	Total Fish
	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	Recovered	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
Total		3	26	29	5	9	142	73	49	53	79	11	479	13,108

[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 B9. 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), 1986-1992.

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	1,109
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
Total		49	1,230	911	60	264	2,940	1,665	442	502	731	138	8,932

[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 B10. Estimated yearly age composition of Willow Creek chinook salmon from 1979-1992 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
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: 1979, Watsjold 1980; 1980, Watsjold 1981; 1981, Bentz 1982; 1982, Bentz 1983; 1983, Hepler and Bentz 1984; 1984, Hepler and Bentz 1985; 1985, Hepler and Bentz 1986; 1986, Hepler and Bentz 1987; 1987, Hepler et al. 1988; 1988, Hepler et al. 1989; 1989, Sweet and Webster 1990; 1990, Sweet et al. 1991; 1991, Peltz and Sweet 1992.

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

Appendix B11. Estimated mean lengths by age and sex from sport harvests of Willow Creek chinook salmon, 1986-1992.

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)	Sample Size	Length (mm)	Sample Size	Length (mm)	Length (mm)	Sample Size	Length (mm)	Sample Size	Length (mm)	Length (mm)
1986	22	642	0	0	642	22	841	33	861	853	17	1027	49	955	974
1987	35	600	0	0	600	33	841	13	883	853	20	961	34	936	945
1988	61	619	6	690	625	133	822	95	836	828	70	975	116	939	953
1989	36	578	0	0	578	63	790	27	835	804	112	952	245	914	926
1990	173	575	0	0	575	61	801	23	871	820	88	983	135	934	953
1991	56	594	0	0	594	117	786	66	830	802	107	980	205	926	945
1992	234	611	0	0	611	101	741	87	766	753	60	944	163	903	914
1986-1991															
Mean		601	No estimate		602		814		853	827		980		934	949
Maximum		642			642		841		883	853		1,027		955	974
Minimum		575			575		786		830	802		952		914	926

[a] Source of data: 1986, Hepler and Bentz 1987; 1987, Hepler et al. 1988; 1988, Hepler et al. 1989; 1989, Sweet and Webster 1990; 1990, Sweet et al. 1991; Peltz and Sweet 1992.

Appendix B12. Estimated sex composition by age class for sport fish harvests of Willow Creek chinook salmon, 1986-1992.

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
1986-1991												
Mean		96.6		3.4		62.6		37.4		34.2		65.8
Maximum		100.0		0.0		76.1		23.9		41.0		59.0
Minimum		88.1		11.9		40.0		60.0		25.4		74.6

[a] Source of data: 1986, Hepler and Bentz 1987; 1987, Hepler et al. 1988; 1988, Hepler et al. 1989; 1989, Sweet and Webster 1990; 1990, Sweet et al. 1991; Peltz and Sweet, 1992.

Appendix B13. Seasonal timing of sport harvest by percent for Willow Creek chinook salmon, 1986-1992.

1986[a]		1987[b]		1988[c]		1989[d]		1990[e]		Mean 86-90		1991[f]		1992	
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
6/21-22	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
6/28-29	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
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

[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.

Appendix B14. Calculation of 1993 estimated return of chinook salmon to Willow Creek.

Historical Age Composition by Brood Year from Table 7	2 ocean	13.0%
	3 ocean	26.7%
	4 ocean	60.3%

Estimated Returns from 1987 and 1988 Brood Years from Table 7

Brood Year	Origin	Estimated Return By Age Class 1.2	1.3	Total Return
1987	Nonhatchery	353	1724	2077
	Hatchery	222	1443	1665
	Total	575	3167	3742
1988	Nonhatchery	820		820
	Hatchery	1675		1675
	Total	2495		2495

Estimation of 4 ocean return in 1993:

The combined 2 and 3 ocean returns should compose 39.7% of the total return from the 1987 brood year.

If	2077	=	39.7% of the nonhatchery return	
Then	x	=	60.3%	
Or	x	=	(60.3% x 2077) / 39.7%	
	x	=	3,258 nonhatchery 4 ocean return	
If	1665	=	39.7% of the hatchery return	
Then	x	=	60.3%	
Or	x	=	(60.3% x 1665) / 39.7%	
	x	=	2,528 hatchery 4 ocean return	
Total 4 ocean return		=	3258 + 2528	nonhatchery + hatchery
		=	5,786	total

Estimation of 3 ocean return in 1993:

The 2 ocean return should compose 13.0% of the total return from the 1988 brood year.

If	820	=	13.0% of the nonhatchery return	
Then	x	=	26.7%	
Or	x	=	(26.7% x 1299) / 13.0%	
	x	=	1,684 nonhatchery 3 ocean return	
If	1675	=	13.0% of the hatchery return	
Then	x	=	26.7%	
Or	x	=	(26.7% x 1675) / 13.0%	
	x	=	3,440 hatchery 3 ocean return	
Total 3 ocean return		=	1684 + 3440	nonhatchery + hatchery
		=	5,124	total

-continued-

Estimation of 2 ocean return in 1993:

Smolt release in 1991	391,669	
Estimated survival rate	2.0%	
Estimated percent 2 ocean	13.0%	
Predicted 2 ocean hatchery return	=	391,669 x 2.0% x 13.0%
	=	1,018
Predicted 2 ocean nonhatchery return	=	Historic mean 1975 to 1988
	=	566
Total 2 ocean return	=	1,018 + 566 hatchery + nonhatchery
	=	1,584 total

Total predicted return in 1993

	Nonhatchery	Hatchery	Total
4 ocean	3,258	2,528	5,786
3 ocean	1,684	3,440	5,124
2 ocean	566	1,018	1,584
Totals	5,508	6,986	12,494
Percent	44.1	55.9	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, 1992.

Data Files

M004DSZ2.DTA	Willow Creek, mouth, creel survey angler interview data file, 1992;
M004DCZ2.DTA	Willow Creek, mouth, creel survey angler count data file, 1992;
M004UCZ2.DTA	Willow Creek, Parks Highway, creel survey angler interview data file, 1992;
M004USZ2.DTA	Willow Creek, Parks Highway, creel survey angler count data file, 1992;
M004DBA2.DTA	Willow Creek, mouth, creel survey biological data file, 1992;
M0040BA2.DTA	Willow Creek carcass survey biological data file, 1992;
M1290BA2.DTA	Deception Creek egg take biological data file, 1992;

Analysis Programs

UCSP92.EXE	RTS program to analyze raw data files from direct-expansion and roving creel surveys and generate estimates of angler effort, catch, and harvest;
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 data;
WIL92CPU.SAS	SAS® System program used to estimate CPUE as index of abundance;
WIL92CHD.SAS	SAS® System program used to estimate distribution of angler catch and harvest;
WILMKS92.WK1	Lotus 1-2-3® worksheet used to weight and apportion chinook salmon harvest estimates by sex and age, within and across all stratum;

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.