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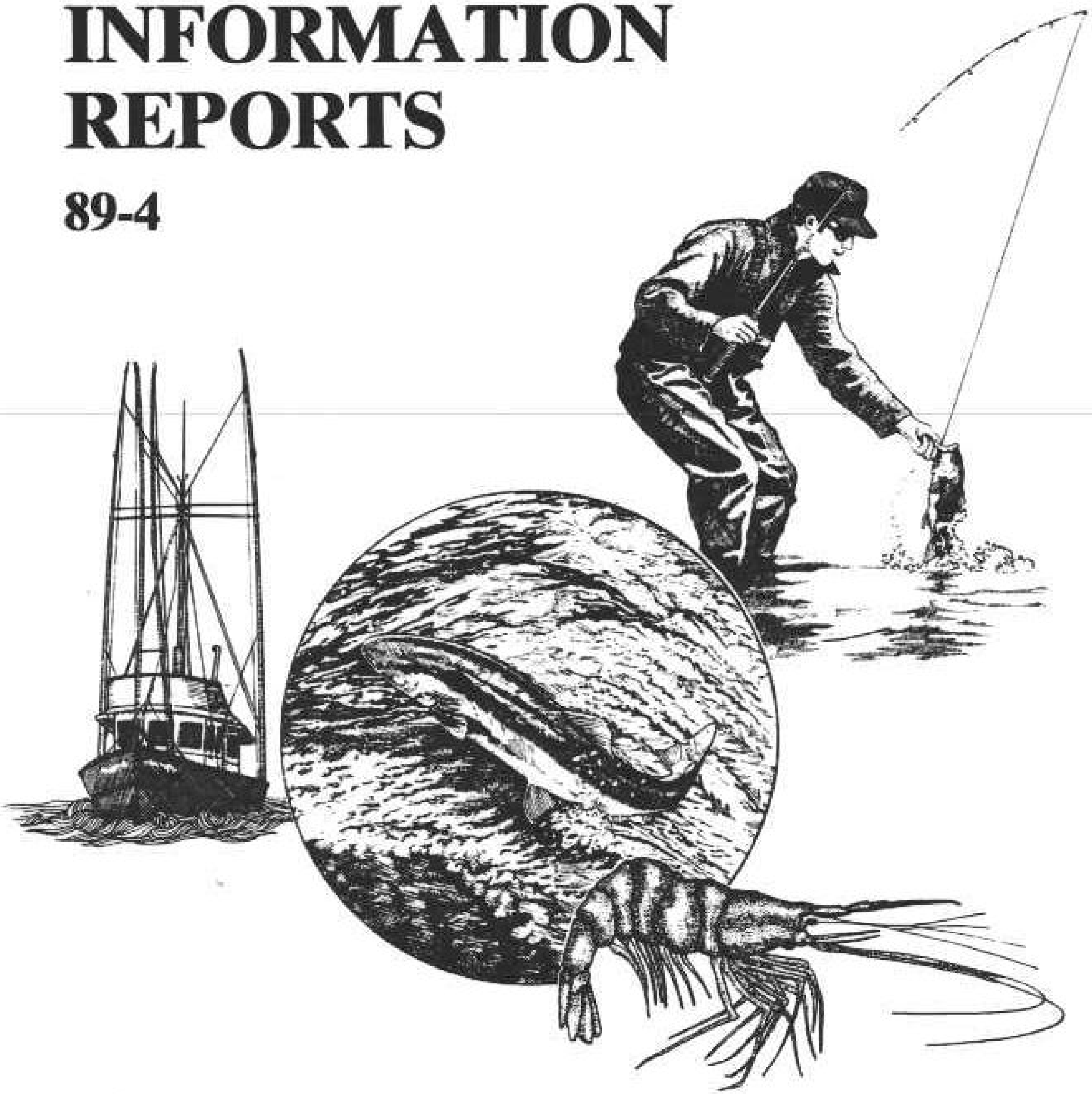

FISH DIVISION

Oregon Department of Fish and Wildlife

Spring Chinook Salmon in the Deschutes River, Oregon

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RECOMMENDATIONS

1. Spring chinook salmon in the Deschutes River basin should be managed under Option B (wild and hatchery fish) of the Oregon Department of Fish and Wildlife's Wild Fish Management Policy (OAR 635-07-525).

   The Wild Fish Policy states: "The protection and enhancement of wild stocks will be given first and highest consideration. Hatchery stocks of fish may be released where necessary to provide optimum benefits from the resource." The Warm Springs River, a tributary of the Deschutes River, supports one of the few remaining wild runs of spring chinook salmon in the Columbia River basin. This population is highly compensatory with a life history pattern that appears to adjust for limited winter habitat in the Warm Springs River with a fall migration into the mainstem Deschutes River. As a genetic resource of the Columbia River basin, this population warrants special consideration.

   Fish managers have a unique opportunity on the Deschutes River to maintain hatchery production of spring chinook salmon while minimizing the genetic risk of this production on wild fish. Virtually all of the spawning of spring chinook salmon in the Deschutes basin occurs in the Warm Springs River above the weir at Warm Springs National Fish Hatchery. Because all fish that arrive at the hatchery are captured, hatchery fish can easily be prevented from spawning in the wild as long as hatchery fish can be separated from wild fish.

   In addition, few spring chinook salmon in the Deschutes River are harvested in ocean or Columbia River fisheries under current regulations. Fisheries in the Deschutes River at Sherars Falls, where most harvest occurs, may already be limited by the amount of fishing area around the falls. Consequently, an increase in the number of hatchery fish may not increase the catch of wild fish in the Deschutes River. Management decisions to increase harvest of spring chinook salmon in the Columbia River, however, must consider effects on the wild population in the Deschutes River.

2. Until methods can be developed to accurately separate hatchery from wild fish without marking, all hatchery fish at Warm Springs National Fish Hatchery should be externally marked so that (1) no hatchery fish will be passed above Warm Springs National Fish Hatchery, and (2) size of the wild run can be monitored.

3. Operation of the scoop trap in the Warm Springs River should be continued to estimate abundance of juvenile migrants from the Warm Springs River. These data, along with that on adult return, may be used to predict adult returns in future years. Although a regression of adult return through the 1981 brood on juvenile abundance explained only 37% of the variation in return, multiple regression with explanatory variables such as number of fall migrants, size of migrants, Columbia River flow, ocean temperature, and upwelling, may improve our ability to predict as more data are collected. In the meantime, a stock-recruitment curve developed for spring chinook salmon based on the number of spawners in the Warm Springs River is the best predictor of adult return.

4. The optimum annual escapement goal for the Deschutes River should be 1,300 wild spring chinook salmon above Warm Springs National Fish Hatchery. The minimum escapement goal should be 1,000 wild fish above the hatchery. Fisheries should be restricted and no wild broodstock should be taken at Warm Springs National Fish Hatchery when predicted return above the hatchery is less than 1,000 wild fish. Fisheries on wild fish should be allowed when escapement above the hatchery is predicted to be between 1,000 and 1,300 wild fish. Within this range, Warm Springs National Fish Hatchery should also be permitted to take wild fish up to 10% of their broodstock. At an escapement above 1,300, fisheries should be allowed and Warm Springs National Fish Hatchery should be permitted to take broodstock to reach full capacity. Wild fish in excess of those taken in fisheries and those needed for broodstock should be passed upstream. The use of wild broodstock from the Warm Springs River for Round Butte Hatchery should also follow these guidelines. Hatchery fish in excess of hatchery need should be released into Shitike Creek (*see* Recommendation 9.d, page 3) or provided to the Confederated Tribes of the Warm Springs Reservation for consumptive use.

   Escapement goals for the Warm Springs River are based on a stock-recruitment analysis. The optimum goal of 1,300 is the number of spawners that needs to be passed above Warm Springs National Fish Hatchery to obtain the maximum number of recruits. The minimum escapement goal of 1,000 is the number of spawners that needs to be passed above the hatchery to insure maximum sustained yield from the population. Maximum sustained yield in the Deschutes River includes catch in fisheries, those used for broodstock, and prespawning mortality. For wild stocks, managing spawner abundance between maximum sustained yield and maximum sustained escapement (i.e., replacement) would provide a compromise between maximizing sustained harvest and maximizing genetic variation (McGie 1985). Although the stock-recruitment model does explain 98% of the variation in the relationship between parent spawners and recruits, it is based on limited data. Consequently, these goals should be considered preliminary.

5. The stock-recruitment relationship of wild spring chinook salmon in the Warm Springs River should be refined by continuing annual statistical creel surveys of recreational and Indian fisheries at Sherars Falls. Creel estimates and fish counts at Warm Springs National Fish Hatchery will give annual estimates of the number of recruits in the river. Redds should be counted annually to estimate the number of spawners.

6. Causes of the high prespawning mortality (44%) in the Warm Springs River and ways of reducing that mortality should be investigated. At a minimum, water quality in the Warm Springs basin must be maintained and should be improved to lower the risk of increasing prespawning mortality.

7. The routine inoculation of wild fish with erythromycin to control bacterial kidney disease above Warm Springs National Fish Hatchery should be stopped to eliminate the risk of developing resistant strains of bacteria and to prevent alteration of any genetic component of the wild stock. If the ratio of wild fish to redds above the hatchery exceeds 4.0 because of disease, inoculations should be resumed. Because water for the hatchery comes from the Warm Springs River, terminating inoculations

poses a risk of increasing the incidence of bacterial kidney disease in Warm Springs National Fish Hatchery. A large increase in the incidence of the disease in the hatchery may warrant a resumption of routine inoculation of wild fish; however, other methods of reducing the disease in the hatchery water supply should be investigated first.

8. Habitat improvement for spring chinook salmon in the Warm Springs River should concentrate on increasing summer rearing habitat for juveniles. Spawning gravel appears adequate to support 1,550 redds in the Warm Springs basin and is currently not limiting production. Although winter habitat in the Warm Springs River may be limited, it is probably not limiting production because juveniles migrate in fall into the Deschutes or Columbia rivers to winter. In addition, those that migrate in fall appear to survive winter at a higher rate than those that remain in the Warm Springs River.

9. The following options should be considered to increase production of spring chinook salmon in the Deschutes basin:

   a. Increase hatchery production by bringing Warm Springs National Fish Hatchery to full capacity. This should be done primarily by increasing return rate at the hatchery through a formal evaluation of rearing and release practices. Additional wild fish for broodstock could also be used consistent with guidelines given in Recommendation 4.

   b. Increase production of hatchery fish in Pelton ladder. The potential of Pelton ladder at Round Butte Hatchery to rear spring chinook salmon is unknown but is likely much greater than the 210,000 fish currently being reared there. Only about 6% of the ladder is presently being used to rear fish. Studies to determine rearing capacity of Pelton ladder have been identified in the Fish and Wildlife Program of The Northwest Power Planning Council, and funding from this source should be pursued.

   c. Establish a natural run of spring chinook salmon above White River Falls in White River. A proposal to develop a natural run of spring chinook salmon above White River Falls (ODFW et al. 1985) was rejected by the Oregon Fish and Wildlife Commission in 1985 largely because of concerns for wild trout in White River and its tributaries. These concerns should be addressed in a wild trout management plan for White River, and this plan along with the original White River proposal could be resubmitted to the Commission. Potential natural production in the White River basin was estimated at between 1,200 and 3,000 adult spring chinook salmon annually (ODFW et al. 1985).

   d. Increase natural production of spring chinook salmon in Shitike Creek by releasing surplus hatchery adults from Warm Springs National Fish Hatchery or Round Butte Hatchery. Because the run of spring chinook salmon is small and may be influenced by strays from Round Butte

Hatchery, Shitike Creek should not be managed exclusively for wild fish. Surplus hatchery fish should be released into the upper areas of the stream where habitat appears adequate but little spawning occurs.

10. The rearing and release strategy used for 1984-86 broods of spring chinook salmon at Round Butte Hatchery should be continued until at least 1989 when a partial analysis of returns from these broods can be made. The Research and Development Section of Oregon Department of Fish and Wildlife will prepare a completion report on the 1984-86 broods in 1991. Final recommendations for rearing and release at Round Butte Hatchery will be made at that time.

11. A study should be undertaken to determine why return rate for spring chinook salmon reared through winter in Pelton ladder is higher than rates for comparable groups reared in ponds at Round Butte Hatchery. Findings from this study may have broad application to other spring chinook salmon hatcheries in the Pacific Northwest.

12. At least 10% of each year's broodstock at Warm Springs National Fish Hatchery should be wild fish taken randomly from the run as long as the run is large enough to insure a minimum escapement of 1,000 fish above the hatchery. This would maintain similarities between hatchery and wild fish and would provide future options for supplemention in the event wild stocks decline. Wild spring chinook salmon that enter Pelton trap should also be incorporated into the broodstock at Round Butte Hatchery.

13. A statistically designed evaluation should be conducted at Warm Springs National Fish Hatchery to increase return rate and to reduce variation in return rate. Return rate of 1978-83 broods averaged 0.35% and varied from 0.02% to 0.8%. Experiments should be designed to determine the effects on survival of dry versus moist feed, of time and size of release, of fish marking, and of pond loading and density.

INTRODUCTION

The Deschutes River in Oregon supports one of the few remaining wild runs of spring chinook salmon *Oncorhynchus tshawytscha* in the Columbia basin. Hatchery spring chinook salmon are also released into the Deschutes River from Round Butte and Warm Springs National Fish hatcheries, located in the lower basin. In addition, a run of wild fall chinook salmon is present in the Deschutes River.

Spring chinook salmon spawned historically in the mainstem Deschutes and Metolius rivers above the present site of the Pelton-Round Butte hydroelectric complex (Newton 1973)(Figure 1). Below the dams, spring chinook salmon spawned in the Warm Springs River and probably in Shitike Creek. As a condition of the licenses granted to Portland General Electric Company (PGE) by the Federal Power Commission (now the Federal Energy Regulatory Commission) for the construction of Pelton and Round Butte dams, Portland General Electric Company agreed to maintain viable populations of wild spring chinook salmon and summer steelhead *O. mykiss* above the dams. Consequently, upstream passage facilities were provided for adults and downstream facilities for juveniles.

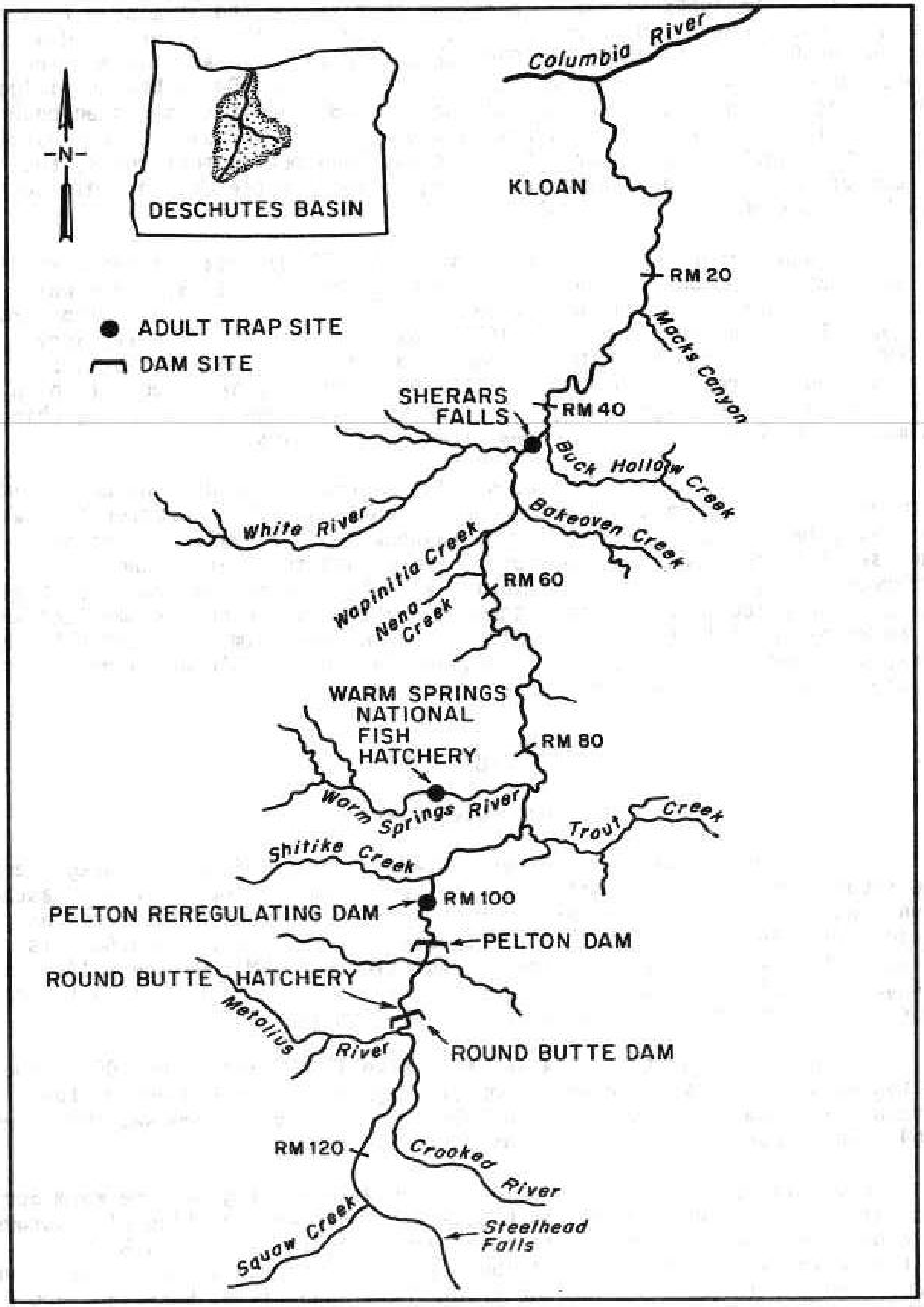

Figure 1. The Deschutes River below Steelhead Falls (RM 128).

By the late 1960s it became apparent that salmon and steelhead runs above the dams could not be sustained naturally because of the failure of downstream passage at Round Butte Dam. In 1970 PGE agreed to build and finance the operation of Round Butte Hatchery at the base of Round Butte Dam to mitigate for losses. Compensation was established at 1,800 adult summer steelhead and 1,200 adult and jack spring chinook salmon returning annually to the hatchery. Although mitigation for summer steelhead has been met in most years, the number of spring chinook salmon returning to Round Butte Hatchery did not reach mitigation level until 1985.

The Oregon Department of Fish and Wildlife (ODFW) began research studies of wild spring chinook salmon in the Deschutes River in 1975. Work was expanded in 1976 to include an evaluation of the spring chinook salmon program at Round Butte Hatchery. Also in 1975, the U.S. Fish and Wildlife Service (USFWS), at the request of the Confederated Tribes of the Warm Springs Reservation of Oregon, began more intensive studies of anadromous fish in the Warm Springs River (Diggs 1977). Much of what is known about spring chinook salmon in the Deschutes basin comes from these studies.

This report is one of four completion reports on anadromous and resident salmonids in the Deschutes River. Other reports have been written for fall chinook salmon, summer steelhead, and rainbow trout *O. mykiss*. The main purpose of these reports is to provide background information and recommendations to assist in developing a subbasin fisheries management plan for the lower 100 miles of the Deschutes River. This report summarizes what is known of the life history of wild spring chinook salmon and presents the background and status of hatchery programs for spring chinook salmon in the Deschutes basin through 1986.

STUDY AREA

Deschutes River

The Deschutes River basin covers 10,400 sq miles of central Oregon and is the second largest river basin in the state. From its source in the Cascade Mountains, it flows north entering the Columbia River 205 miles from the ocean. Flow in the Deschutes is relatively uniform, averaging 4,880 cfs (range 3,130-14,800 cfs) at Pelton Reregulating Dam (RM 100) and 6,160 cfs (range 3,560-23,900 cfs) at the mouth from 1976 through 1985. In a typical year, water temperature at the mouth ranges from 35°F to 68°F.

The upstream migration of anadromous fish is blocked at RM 100 by the Pelton-Round Butte hydroelectric complex (Figure 1). Pelton and Pelton Reregulating dams were completed in 1958, and Round Butte Dam was completed in 1964. Round Butte Hatchery was constructed in 1972.

The two largest tributaries below Pelton Reregulating Dam are Warm Springs and White rivers. White River is blocked to upstream migration of anadromous fish by a falls 2 miles above its confluence with the Deschutes River. Shitike Creek is the only other tributary providing a substantial year-round flow. Smaller tributaries include Trout, Nena, Wapinitia, Bakeoven, and Buck Hollow creeks.

Summer steelhead and rainbow trout support world famous recreational fisheries in the lower 100 miles of the Deschutes River. Resident rainbow trout and juvenile steelhead are most abundant in the Maupin-Pelton reach (RM 50-100). The major portion of the steelhead run enters the river from July through October. Spring and fall chinook salmon, coho salmon *O. kisutch*, sockeye salmon *O. nerka*, bull trout *Salvelinus confluentus* and mountain whitefish *Prosopium williamsoni* are salmonids that also inhabit the lower river. Other species present are northern squawfish *Ptychocheilus oregonensis*, chiselmouth *Acrocheilus alutaceus*, suckers *Catostomus* spp., sculpins *Cottus* spp., common carp *Cyprinus carpio*, dace *Rhinichthys* spp., redside shiner *Richardsonius balteatus*, and Pacific lamprey *Entosphenus tridentatus*.

The recreational fishery for chinook salmon occurs primarily in a 1-mile section of the Deschutes River from Buck Hollow Creek (RM 43) to Sherars Falls (RM 44). A subsistence fishery for salmon and steelhead by the Confederated Tribes of the Warm Springs Reservation of Oregon also occurs at Sherars Falls.

Warm Springs River

The Warm Springs River (Figure 2) produces most of the spring chinook salmon in the Deschutes basin. Except for a short distance at its headwaters, the river is located on the Warm Springs Indian Reservation. The Warm Springs River enters the Deschutes River at RM 84 and has a mean annual flow of 440 cfs and a minimum flow of about 220 cfs. The total drainage area is 540 sq miles. Because of numerous springs near its headwaters, flow in the Warm Springs River fluctuates little.

A series of hot springs enter the river between Warm Springs National Fish Hatchery (RM 9) and Kahneetah Resort (RM 8). Although most of the hot springs are small seeps, the spring at the resort produces about 50 gpm. Temperature of the hot springs ranges from 117°F to 182°F; however, their influence on water temperature in the river is minimal. Water temperature in the lower river near the hatchery often exceeds 60°F in summer and is only slightly above freezing in winter.

Two primary tributaries, Mill Creek (RM 21) and Beaver Creek (RM 19), drain into the Warm Springs River. Mill Creek contributes approximately 30% of the flow in the Warm Springs River and Beaver Creek adds an additional 15% (Robinson and Laenen 1976). Fish species present in the Warm Springs River are the same as those listed for the Deschutes River except that sockeye salmon and common carp are absent and brook trout *Salvelinus fontinalis* are present.

Shitike Creek

Shitike Creek (Figure 2) is the only other tributary of the Deschutes River with a run of spring chinook salmon. Shitike Creek originates at Harvey Lake in the Cascade Mountains and flows eastward through the Warm Springs Indian Reservation until it joins the Deschutes River near RM 93. The creek has a mean annual flow of 108 cfs and a summer low flow of about 30 cfs (Robinson and Laenen 1976). Summer temperature ranges from 57°F to 79°F in

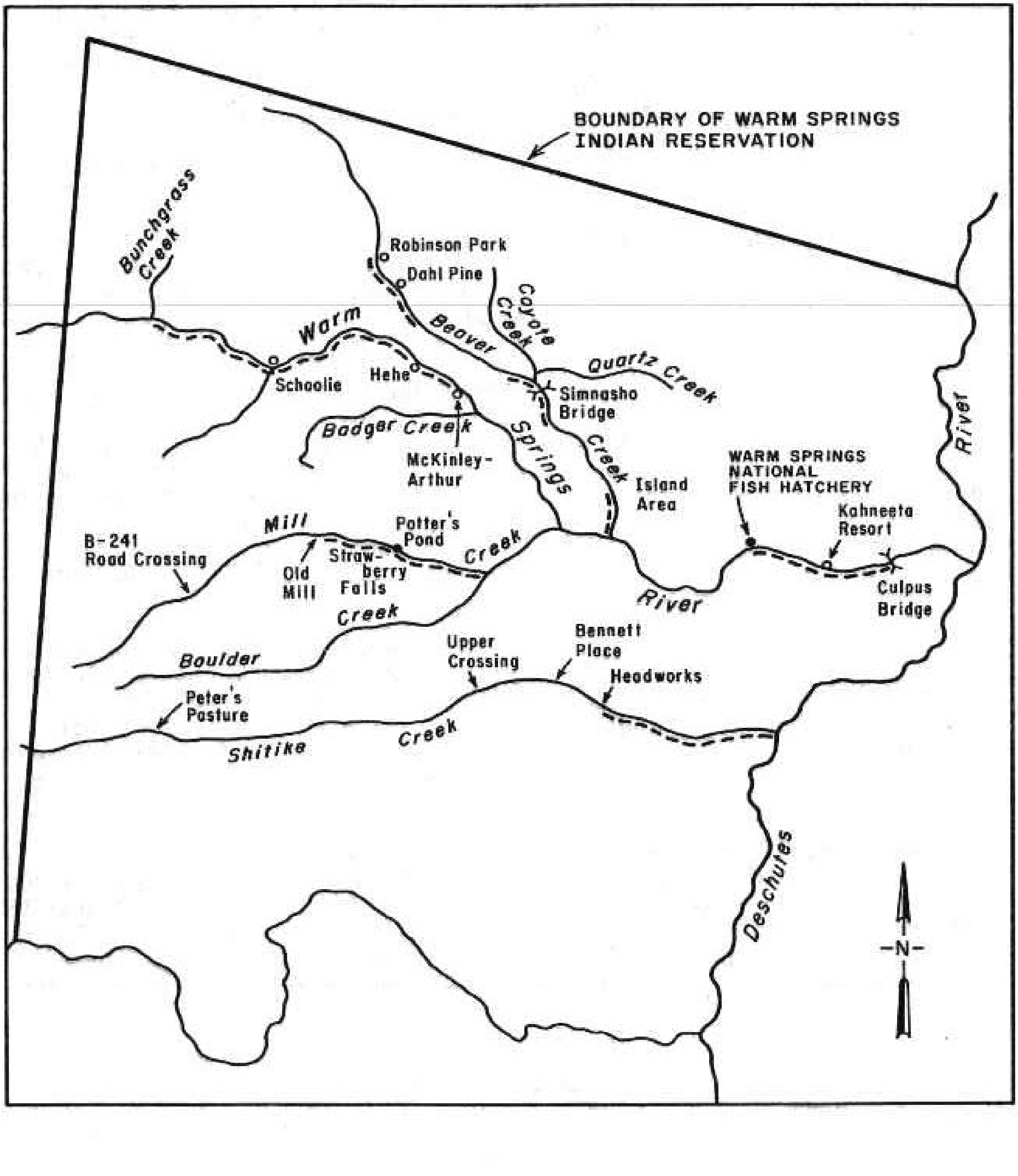

Figure 2. The Warm Springs River and Shitike Creek. Dashed line shows index areas for spawning ground surveys of spring chinook salmon.

the lower creek, while summer temperature in the Peters Pasture area (RM 25) averages lower than 50°F (Fritsch 1986). In addition to spring chinook salmon, salmonid species present include summer steelhead, rainbow trout, bull trout, and brook trout.

WILD SPRING CHINOOK SALMON

Adult Migration Timing

A steeppass fish trap located at the head of the fish ladder at Sherars Falls (Figure 3) was used to estimate migration timing of wild adult spring chinook salmon in 1977-80 and 1982. The trap was generally operated 5 days per week beginning in mid- to late April. Migration timing into the Warm Springs River was determined from fish captured at Warm Springs National Fish Hatchery.

Adult spring chinook salmon arrive at Sherars Falls in mid-April. The run generally peaks in May, and most fish have passed the falls by mid-June (Figure 4). The decrease in catch rate in the steeppass fish trap in mid-June was used as the separation date between spring and fall races of chinook salmon at Sherars Falls (Figure 4) although a few spring chinook salmon pass the falls in late June and early July (Jonasson and Lindsay 1988). Based on data in Jonasson and Lindsay 1988, summer chinook salmon are not present in the Deschutes River.

Wild spring chinook salmon begin arriving at Warm Springs National Fish Hatchery generally after water temperature exceeds 50°F in late April or early May. The run peaks at the hatchery in late May (Figure 5). Few fish enter the hatchery from late June to mid-August, but a second, smaller peak occurs in late August or early September. In most years approximately 70% of the run has arrived at Warm Springs National Fish Hatchery by 1 June and 90% by 1 July. However, during the drought of 1977, 15% of the run arrived at the hatchery after mid-August, and an unusually large number spawned below the hatchery. Jacks tend to arrive at the hatchery later than adults. For fish that arrive at Sherars Falls prior to 15 June, we found a positive correlation ($r = 0.57$, $P < 0.01$) between the date fish enter the hatchery and the date they pass Sherars Falls (Figure 6).

The difference in the time wild spring chinook salmon were tagged at Bonneville Dam in 1975 and the time they were recaptured in the Warm Springs River indicated that migration rate averaged about 4.0 miles/day (Diggs 1977). Travel rate for spring chinook salmon tagged at Sherars Falls and recaptured at Warm Springs National Fish Hatchery averaged 2.0 miles/day and ranged from 1.2 to 4.1 miles/day in 1977-80. The slowest average travel rate was in the 1977 drought year.

Age Composition and Size

Scale samples and length measurements (nearest 1 mm fork length) were taken at Sherars Falls during creel surveys and at Warm Springs National Fish Hatchery to determine age and size of adult spring chinook salmon in the Deschutes River. Scales were mounted on gummed label cards and plastic

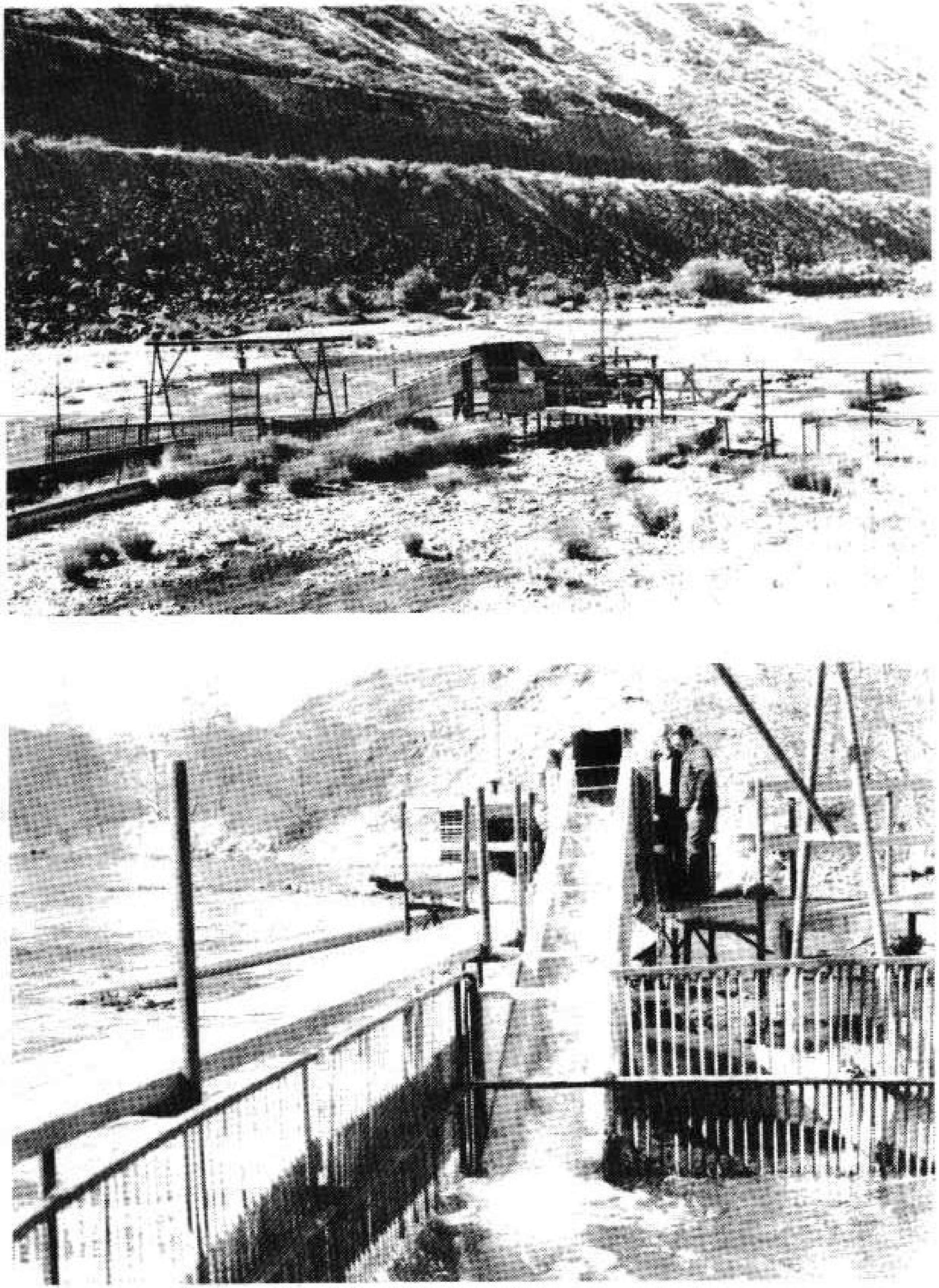

Figure 3. Steeppass fish trap located in the fish ladder at Sherars Falls.

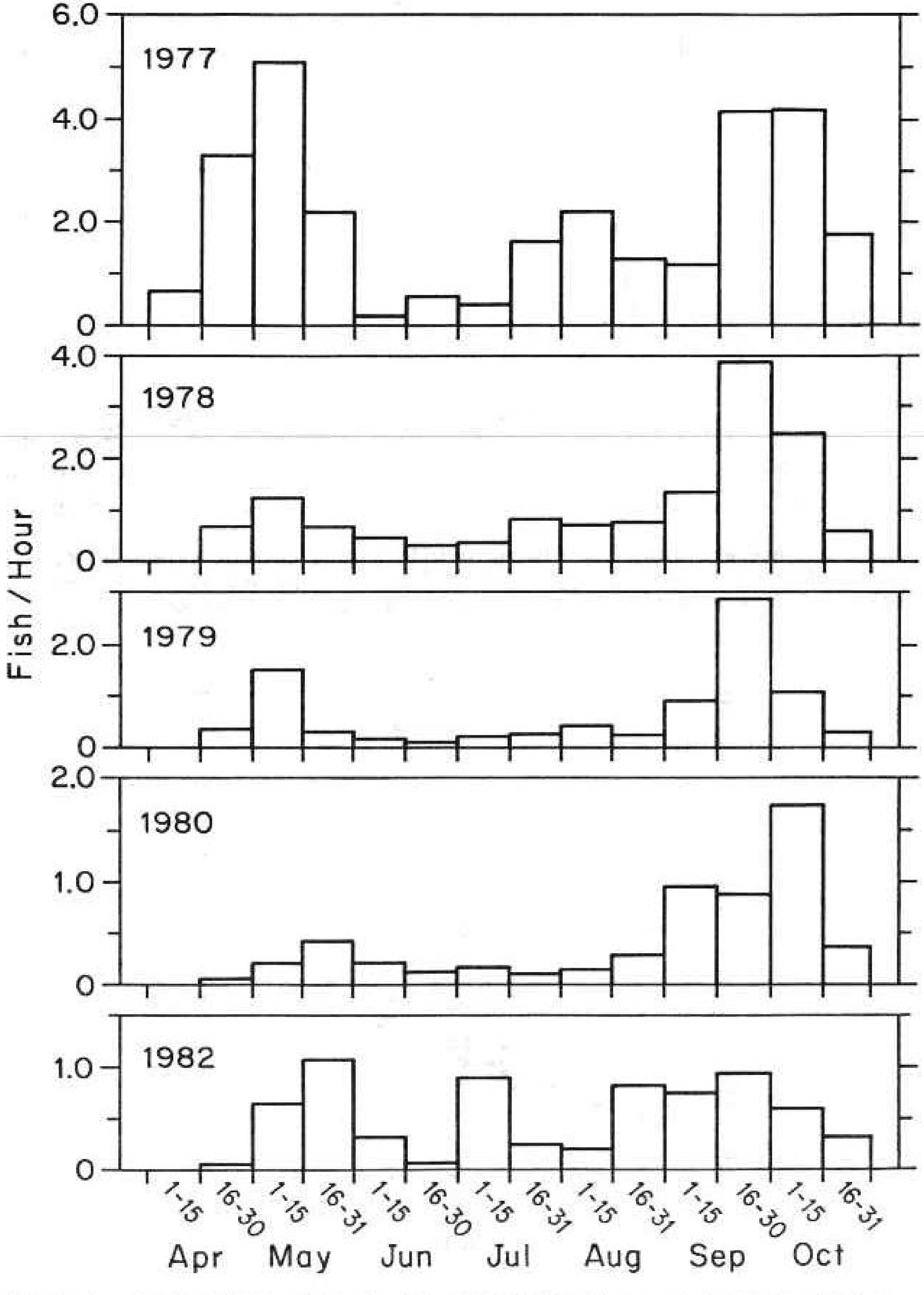

Figure 4. Semimonthly catch of wild adult chinook salmon (spring and fall races) in the steeppass fish trap at Sherars Falls, 1977-80 and 1982.

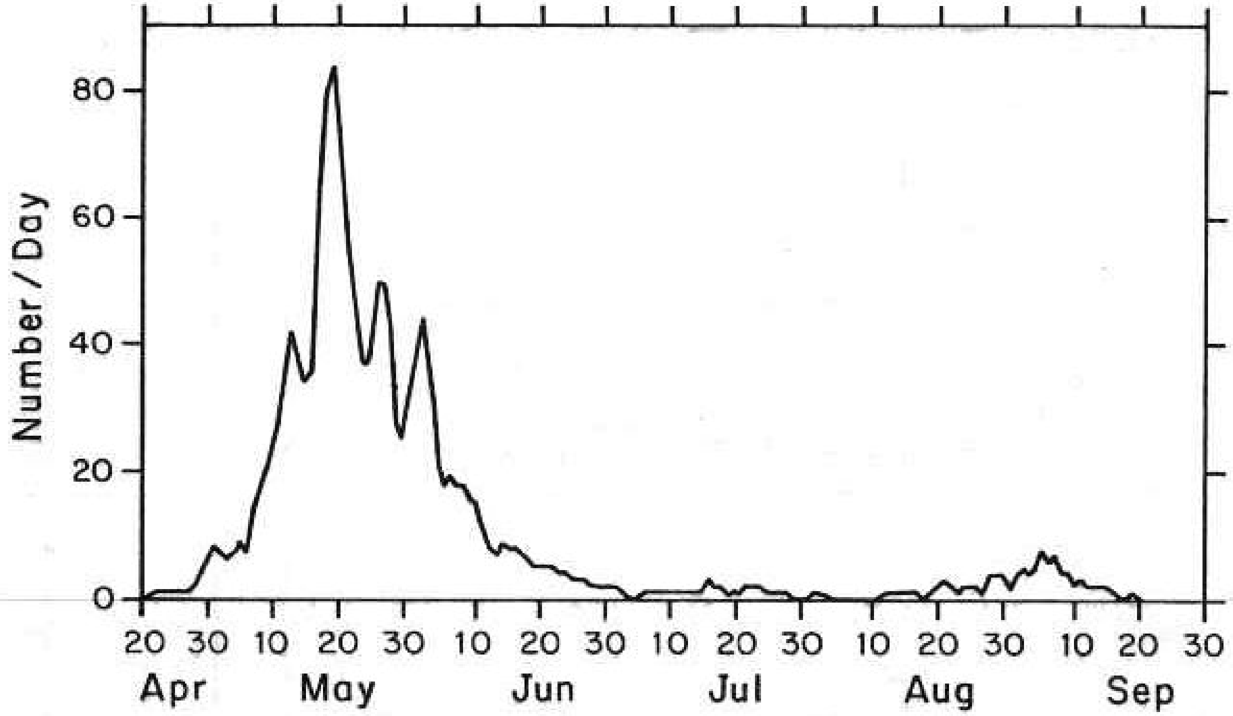

Figure 5. Average migration timing of wild spring chinook salmon at Warm Springs National Fish Hatchery based on 3-day running averages, 1977-86. 1984 and 1985 were excluded because hatchery fish were unmarked.

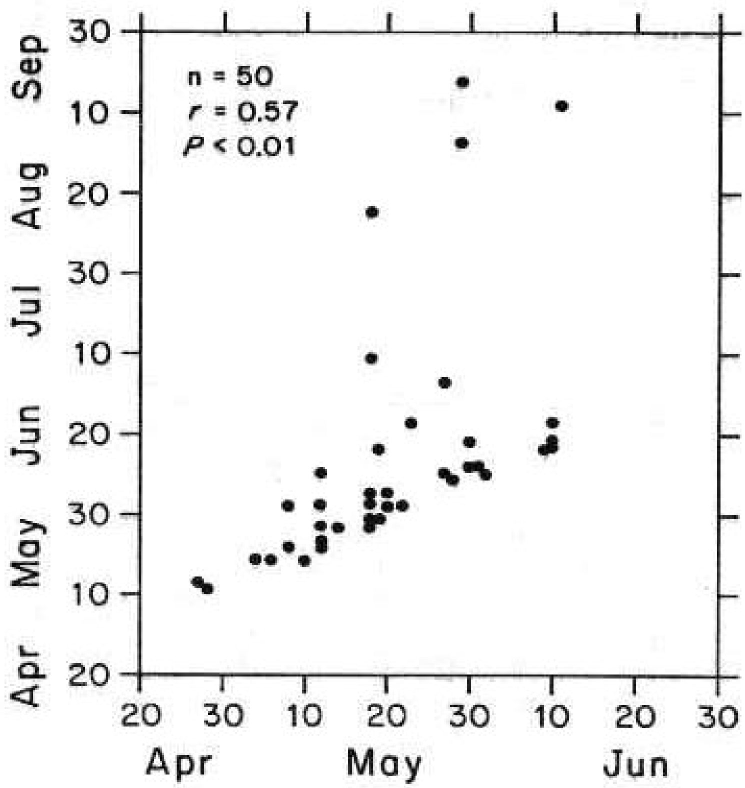

Figure 6. The relationship between the date fish passed Sherars Falls (x-axis) and the date they arrived at Warm Springs National Fish Hatchery, 1980.

acetate impressions of the cards were made. The scale impressions were viewed either on a microprojector at 150x or on a microfiche reader at 88x. Methods used to count and measure circuli followed those of Reimers (1973) and Clutter and Whitsel (1956). Measurements were recorded either on a strip of paper oriented along a line 20° to the dorsal side of the anterior-posterior axis of the scale or by using a computer assisted system consisting of an Altek Datatab digitizing tablet, an Altek datatab control model AC 90 C, an Apple IIC microcomputer, and Scale Reader II software (copyrighted, Robert E. Mullen, Oregon Department of Fish and Wildlife, Corvallis, Oregon).

Adult spring chinook salmon return to the Deschutes River predominantly at age 4. On the average, by run year or by brood year, about 4%-5% of the fish are age 3 (jacks) and about 17% are age 5 (Tables 1 and 2). Virtually all had migrated to the ocean as yearling (age 1) smolts. Fork lengths of wild adult spring chinook salmon in the Warm Springs River are shown in Figure 7.

Spawning Destination

Historically, in addition to the Warm Springs River, wild spring chinook salmon spawned in the upper Deschutes River above the present site of Round Butte Dam. When spawning surveys first began in 1951, salmon and salmon redds were observed in early September in the Metolius River and in Squaw Creek, tributaries of the upper Deschutes River (OSGC 1951-55). Spring chinook salmon were also found in the upper Deschutes River up to Steelhead Falls (RM 128). Spawning migrations into Crooked River were blocked by 1951 by a power plant near its confluence with the Deschutes (Newton 1973). Whether Crooked River was used for spawning by chinook salmon prior to 1951 is unknown.

Weekly aerial tracking of radio-tagged fish in 1979 and 1980 indicated that most wild spring chinook salmon that migrated above Sherars Falls after the dams were built entered the Warm Springs River to spawn. In 1979, 28 of 31 adult spring chinook salmon radio-tagged and marked with Floy dart tags at Sherars Falls entered the Warm Springs River. Two of the three tagged fish that did not migrate into the Warm Springs River remained in the Sherars Falls area. The third moved upstream about 2 miles before becoming stationary. All three fish presumably died and did not regurgitate their tags because no fish with Floy tags but without radio tags were observed at Warm Springs National Fish Hatchery. Almost identical results were obtained in 1980 when 30 of 33 chinook salmon radio-tagged at Sherars Falls entered the Warm Springs River. Most of the fish that pass Warm Springs National Fish Hatchery hold in the Warm Springs River canyon within about 7 miles of the hatchery until August when they continue upstream to spawning areas. Although radio tagging indicated that most wild spring chinook salmon enter the Warm Springs River, some spring chinook salmon do spawn in Shitike Creek. The location of holding areas for spring chinook salmon in Shitike Creek is unknown.

Table 1. Percent age composition of wild spring chinook salmon in the Deschutes River by run year, 1977-85.[a]

Run year	Age 3	Age 4	Age 5
1977	1	96	3
1978	3	64	33
1979	6	72	22
1980	5	73	22
1981	3	77	20
1982	5	76	19
1983	2	83	15
1984	8	80	12
1985[b]	7	84	9

[a] *Includes catch in Indian and recreational fisheries, broodstock collected at Sherars Falls for Round Butte Hatchery, and escapement to Warm Springs National Fish Hatchery.*
[b] *No creel survey of Indian fishery.*

Table 2. Percent age composition of wild spring chinook salmon in the Deschutes River by brood year, 1974-80.

Brood year	Age 3	Age 4	Age 5
1974	9	76	15
1975	4	78	18
1976	7	72	21
1977	2	71	25
1978	2	82	15
1979	5	83	12
1980	4	81	15

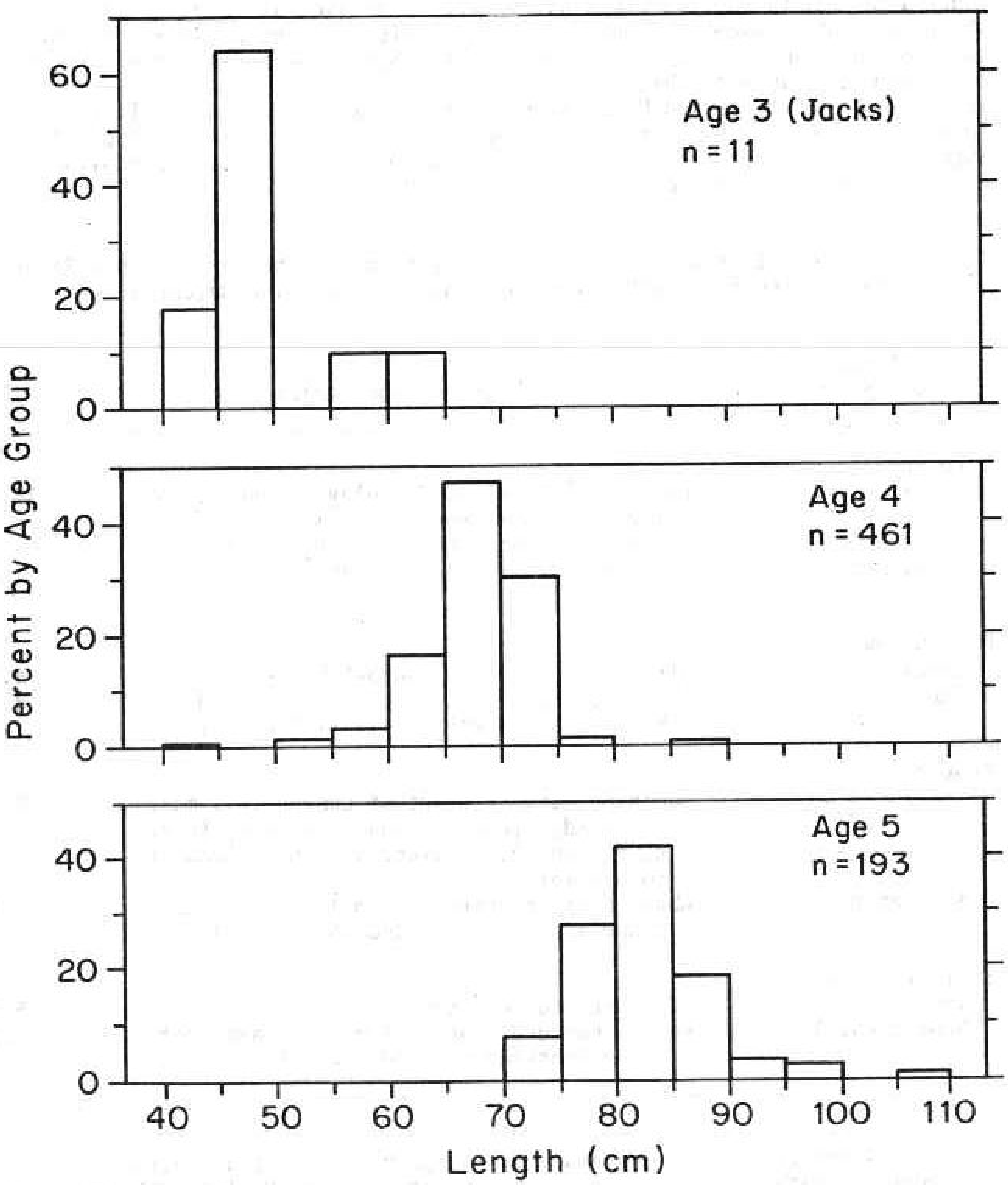

Figure 7. Length-frequency distribution by age of adult wild spring chinook salmon in the Warm Springs River, 1977-81.

Spawning Distribution

Spawning ground surveys have been conducted in the Warm Springs River since 1969 and in Shitike Creek since 1978 to provide an index of spawning abundance and to monitor changes in spatial distribution of spawning. Prior to 1975, the Confederated Tribes of the Warm Springs Reservation of Oregon conducted the surveys, which covered slightly more area than those made jointly by the tribes and USFWS since 1975. In 1975 areas where little spawning occurred were dropped to establish current index areas (Table 3). Supplemental surveys in areas outside of index areas are used to monitor changes in distribution of spawning.

Table 3. Description of spawning survey sections in the Warm Springs River and in Shitike Creek. WSNFH = Warm Springs National Fish Hatchery.

Stream, survey type	Survey boundaries	Miles
Warm Springs River:		
Index	Bunchgrass Creek to McKinley Arthur place (above Badger Creek; 12.5 miles) and WSNFH to Culpus Bridge (5.0 miles)	17.5
Supplemental	McKinley Arthur place to Badger Creek	1.8
Mill Creek:		
Index	Strawberry Falls to Boulder Creek	4.5
Supplemental	B-241 road bridge area (1.7 miles) and Old Mill to Strawberry Falls (1.8 miles)	3.5
Beaver Creek:		
Index	Robinson Park to start of canyon (6.1 miles), Old Bridge (above Simnasho Bridge) to the powerline (0.9) miles, and the island area (0.5 miles)	7.5
Supplemental	Above Robinson Park (1.5 miles) and from powerline to the island (6.0 miles)	7.5
Shitike Creek:		
Index	Headworks to the mouth	5.9
Supplemental	Peters pasture area (0.7 miles), and from upper crossing to headworks (4.5 miles)	5.2

Redds are counted in September by two people walking or rafting downstream. With the exception of the area below Warm Springs National Fish Hatchery where only one survey is made, two surveys are conducted, one in early September, the other in mid-September. During the first survey, redds are marked with painted rocks or with flagging. On the subsequent survey, unmarked redds are counted and added to the count of marked redds. Additional redd counts are made in areas where passage barriers were removed or where habitat improvements were made; however, these redd counts are kept separate from index counts. Carcasses are separated into jacks (<60 cm) and adults (≥60 cm). Since 1980, carcasses have also been routinely examined for obvious signs of bacterial kidney disease.

Spawning in the Warm Springs basin begins the last week in August and peaks by the second week in September. Spawning is completed by the last week in September.

On the average, about 76% of the spring chinook salmon spawn in the mainstem Warm Springs River (Tables 4 and 5), primarily between Hehe (RM 31) and Bunchgrass Creek (RM 41). An average of 18% and 5% of the redds are counted in Beaver and Mill creeks, respectively. Location of spawning gravel in the Warm Springs River and in Shitike Creek is described in **APPENDIX A**.

Table 4. Redds of spring chinook salmon counted in index areas of the Warm Springs River, 1969-86. Redds from surveys of supplemental areas are in parentheses and are not included in the index counts. WSNFH = Warm Springs National Fish Hatchery.

Year	Warm Springs River: Below WSNFH	Warm Springs River: Above WSNFH	Beaver Creek	Mill Creek	Total	Total Above WSNFH
1969	--	205	39	20	264	264
1970	--	119	41	12	172	172
1971	--	152	15	6	173	173
1972	--	75	12	0	87	87
1973	--	396	154	34	584	584
1974	--	172	31	13	216	216
1975	--	560	162	86	808	808
1976	--	834	161	71	1,066	1,066
1977	201	390	73	35	699	498
1978	8	620	119	49	796	788
1979	2	253	97	7	359	357
1980	3	86	22	6	117	114
1981	10	131	9	7	157	147
1982	12	309	72	25 (15)[a]	418 (15)	406 (15)
1983	5	287 (17)	104	22 (3)[a]	418 (20)	413 (20)
1984	14	211 (28)	128 (18)	14 (16)[a]	367 (62)	353 (62)
1985	21	236 (14)	81 (13)	15 (18)[b]	353 (45)	332 (45)
1986	11	292	66 (27)	25 (7)	394 (34)	383 (34)

[a] *Adult outplants.*
[b] *Seventeen were from outplants and one was from a supplemental survey.*

Table 5. Percent distribution of spring chinook salmon redds counted in index areas of the Warm Springs River, 1969-86. Redds from outplanted adults are not included. WSNFH = Warm Springs National Fish Hatchery.

Year	Warm Springs River Below WSNFH	Warm Springs River Above WSNFH	Beaver Creek	Mill Creek
1969	--	78	15	7
1970	--	69	24	7
1971	--	88	9	3
1972	--	86	14	0
1973	--	68	26	6
1974	--	80	14	6
1975	--	69	20	11
1976	--	78	15	7
1977	29	56	10	5
1978	1	78	15	6
1979	1	70	27	2
1980	3	73	19	5
1981	6	83	6	5
1982	3	74	17	6
1983	1	69	25	5
1984	4	57	35	4
1985	6	67	23	4
1986	3	74	17	6

Although the distribution of spawning among streams has remained fairly constant among years (Table 5), shifts within streams have occurred. In 1977, 201 redds were counted in the Warm Springs River between Warm Springs National Fish Hatchery and Kahneetah Resort. This count greatly exceeded those in other years and was probably related to low flow during the adult migration in 1977. Beaver dams probably reduced spawning in Beaver Creek above Dahl Pine (RM 14) from 1977 through 1982. Since the dams were removed in 1983, salmon heavily use the area between the upper end of Dahl Pine and Robinson Park (RM 18). Spawning in Mill Creek has generally shifted from the area below Potters Pond (RM 6) to the area above the pond. This is probably because of scouring of spawning gravel below Potters Pond and improved passage at the pond in 1983 and at Strawberry Falls (RM 7) in 1985.

Each year from 1982 through 1985 ripe hatchery and wild adults were outplanted in upper Mill Creek above Strawberry Falls, an area inaccessible to migrating fish. The purpose was to seed unused habitat in anticipation of having adults return after passage was provided at the falls. Redd counts and electrofishing for juveniles confirmed that adults had spawned successfully in upper Mill Creek as a result of this introduction.

Few redds were observed above the headworks in Shitike Creek (a diversion at RM 6 that supplied water to the town of Warm Springs) until it was dismantled in 1983 (Table 6). Since then, more chinook salmon have spawned in the upper part of this stream than in the past. Chinook salmon carcasses have been found just above Upper Crossing (RM 11). The total number of redds in Shitike Creek has also increased since 1983.

Table 6. Redd counts of spring chinook salmon in Shitike Creek, 1978-86.

Year	Headworks to mouth (Index area)	Bennett Place to headworks	Upper crossing to Bennett Place
1978	3	2	--
1979	2	1	--
1980	14	0	--
1981	6	0	--
1982	16	--	--
1983	9	4	2
1984	5	6	10
1985	15	4	3
1986	11	2	4

Spawning Escapement

Estimates of escapement above the Pelton and Round Butte dam sites prior to construction of the dams varied considerably. The Oregon State Game Commission (now ODFW) estimated that 5,000 spring chinook salmon migrated above the sites in the early 1940s (OSGC 1949). This estimate was based on a spawning ground count made in 1942 in the upper Metolius River. The largest count of fish and redds above the dam sites from 1951 through 1955 was 649 (OSGC 1951-55). In addition, counts of spring chinook salmon at Pelton trap averaged about 330 in 1957-59, run years that were not affected by dams in the Deschutes River. The Dalles Dam in the Columbia River, which was completed in 1957, was thought to have had only a small effect on runs in the Deschutes River (Newton 1973).

The annual spawning escapement of adult spring chinook salmon in the Warm Springs River was determined from counts of fish passed above Warm Springs National Fish Hatchery. About 27% of the wild run that reached the hatchery each year from 1978 through 1986 was kept for broodstock (Table 7). An average of 1,125 wild adults was passed above Warm Springs National Fish

Table 7. Disposition of adult (age 4 and 5) spring chinook salmon that arrived at Warm Springs National Fish Hatchery, 1977-86.[a]

Run year	Wild fish: Kept for broodstock	Wild fish: Passed upstream	Hatchery fish: Kept for broodstock	Hatchery fish: Passed upstream[b]	Total
1977	0	1,505	0	0	1,505
1978	569	2,015	0	0	2,584
1979	416	906	0	0	1,322
1980	317	651	0	0	968
1981	511	1,014	0	0	1,525
1982	91	1,317	625	270	2,303
1983	442	1,081	185	170	1,878
1984	389	803	270	519	1,981
1985	322	777	586	487	2,172
1986	470	1,186	127	25	1,808

[a] *Wild jacks (age 3) were passed above the hatchery. Hatchery jacks were provided to the Confederated Tribes of the Warm Springs Indian Reservation of Oregon.*
[b] *Includes fish trucked above the hatchery as "outplants".*

Hatchery from 1977 through 1986 (Table 7). In addition, an average of 294 hatchery adults were passed above the hatchery from 1982 through 1986 (Table 7). Based on recovery rates of hatchery and wild adults marked with jaw tags and released upstream in 1983, hatchery fish spawned in the same areas as wild fish. Composition of the run at the hatchery is shown in Table 8.

Mortality of adults from the time they were passed above Warm Springs National Fish Hatchery until the time they spawned in fall was estimated from counts of fish passed above the hatchery, sex ratios of broodstock at the hatchery, and redd counts above the hatchery. Mortality estimates were based on the assumptions that each redd represented the completed effort of one female, and that the number of redds outside of survey areas was small. Redds from adults that were trucked from the hatchery to inaccessible spawning areas in Mill Creek ("outplants") were excluded. Prespawning mortality was the difference in the estimated number of females passed above the hatchery and the number of redds.

Excluding 1980 and 1981 when prespawning mortality averaged 74%, the 1977-86 average prespawning mortality was 44% (Table 9). Bacterial kidney disease (BKD) probably caused much of the increase in 1980-81 because mortality from the disease was also high in these years at Warm Springs National Fish Hatchery (Cates 1981). Wild fish may have contracted BKD when they were exposed to hatchery effluents in the Warm Springs River below the hatchery. By comparison, prespawning mortality of wild spring chinook in the

Table 8. Composition of spring chinook salmon that arrived at Warm Springs National Fish Hatchery, 1977-86.

Run year	Wild		Hatchery		Total
	Adult	Jack	Adult	Jack	
1977	1,505	101	--	--	1,606
1978	2,584	76	--	--	2,660
1979	1,322	73	--	--	1,395
1980	968	34	--	--	1,002
1981	1,525	50	--	85	1,660
1982	1,408	46	895	21	2,370
1983	1,523	18	355	16	1,912
1984	1,192	98	789	203	2,282
1985	1,099	56	1,073	6	2,234
1986	1,656	55	152	185	2,048

Rogue River, Oregon, from 1977 through 1981 averaged 12% for wild and 36% for hatchery fish (Cramer et al. 1985). Furunculosis (*Aeromonas salmonicida*) and columnaris (*Flexibacter columnaris*) were the primary causes of death in the Rogue River.

Prespawning mortality of fish passed above the hatchery in 1982-86 declined from 1980-81 levels but was still 15% higher than mortality observed in 1977-79 (Table 9). Hatchery and wild adults that arrive at Warm Springs National Fish Hatchery have been inoculated with erythromycin each year since 1982. As a result, mortality of broodstock at the hatchery has dropped dramatically and currently averages about 16% (*see* Table 27, page 55). Much of this 16% loss is caused by the injections. Although injections of erythromycin since 1982 may have decreased prespawning mortality of fish passed above the hatchery compared with 1980-81, the injections appear to have increased prespawning mortality compared to 1977-79.

We estimated an average spawning escapement of 56 adults in Shitike Creek in 1983-86 by expanding redd counts in Shitike Creek by three fish per redd, the average noted in the Warm Springs River (Table 9). Most of the fish in Shitike Creek appeared to be wild; however, some stray Round Butte Hatchery adults were observed below the headworks.

Juvenile Rearing and Migration

Migrating juvenile spring chinook salmon were captured in Humphreys floating scoop traps in the Deschutes and Warm Springs rivers (Figure 8). One trap, located at the mouth of the Deschutes River, was fished in 1976, 1977, and 1979. The second, located at Maupin, was fished in 1976-82 (two traps were fished side-by-side in 1980). A third trap, located in the Warm Springs

Table 9. Abundance and prespawning mortality of adult (ages 4 and 5) spring chinook salmon passed above Warm Springs National Fish Hatchery, 1977-86.

Year	Total number	Estimated number of females	Number of redds	Prespawning mortality (%)	Adults per redd
1977	1,505	872	498	43	3.0
1978	2,015	1,269	788	38	2.6
1979	906	562	357	36	2.5
1980	651	423	114	73	5.7
1981	1,014	588	147	75	6.9
1982[a]	1,540	1,001	406	59[b]	3.8
1983[a]	1,241	732	430	41[b]	2.9
1984[a]	1,282	782	399	49[b]	3.2
1985[a]	1,222	745	360	52[b]	3.4
1986	1,211	630	417	34[b]	2.9

[a] *Fish counts include hatchery fish passed upstream but exclude adult outplants in Mill Creek. Redd counts include redds in index and supplemental survey areas but exclude redds from adult outplants in Mill Creek.*

[b] *Adults were inoculated for bacterial kidney disease.*

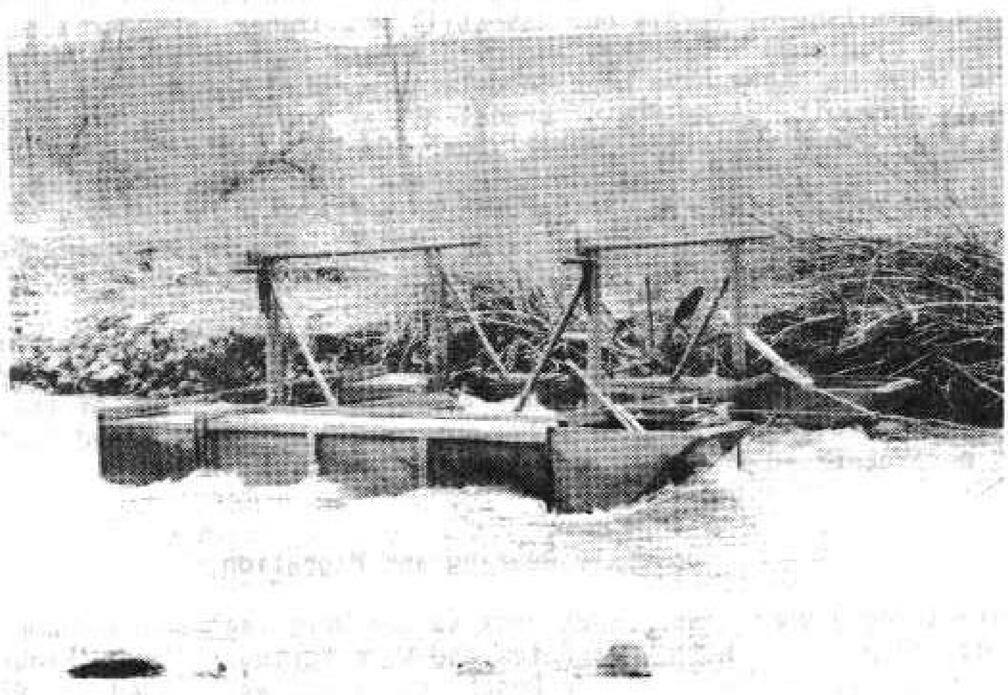

Figure 8. Floating scoop trap used to capture downstream migrant salmonids in the Warm Springs and Deschutes rivers.

River about 1 mile above its confluence with the Deschutes River, has been fished annually since 1976. Juvenile chinook salmon captured at the traps were counted and measured to the nearest 1 mm fork length. Scales were taken and treated as described for adults (*see* **Age Composition and Size**, page 9). All traps were operated at least 1 day per week during juvenile migration periods.

In 1978-80 approximately 25,000 wild juvenile spring chinook salmon were marked with adipose fin clips and coded-wire tags (Ad+CWT) and with freeze brands (Figures 9 and 10; **APPENDIX B**). Juveniles were captured with seines in the mainstem Deschutes River and in Beaver Creek and with seines and a Humphreys scoop trap in the Warm Springs River. Marked juveniles were recaptured in the Deschutes River with seines and scoop traps and in the Columbia River at The Dalles Dam. The National Marine Fisheries Service recaptured migrants in the Columbia River estuary. Recoveries of juveniles were used to estimate migration timing and migration rate through the Deschutes and Columbia rivers. Recoveries of marked adults were used to determine catch and catch distribution of Deschutes River spring chinook salmon in ocean and Columbia River fisheries.

Recovery information from coded-wire tagged fish in the Columbia River estuary and Pacific Ocean was obtained from the Regional Mark Processing Center of the Pacific Marine Fisheries Commission. The center compiles recoveries of juveniles by the National Marine Fisheries Service and by Oregon State University in an experimental ocean sampling program off the Oregon and Washington coasts.

Age 0 migrants were first captured in the migrant trap in the Warm Springs River in May. The smallest fish at this time were 50-59 mm. Because spring chinook salmon emerge from the gravel at about 35-40 mm (Rich 1920), emergence in the Warm Springs begins earlier, most likely in February or March, consistent with emergence dates observed in the John Day River (Lindsay et al. 1985).

Juvenile spring chinook salmon rear in all major spawning areas. Although relatively little is known about juvenile rearing in the Warm Springs River, some sampling of juveniles has occurred above the hatchery. USFWS estimated density of juveniles by electrofishing in sections of Beaver and Mill Creeks in 1983 (Table 10). USFWS also measured fish length during fall and winter of 1977-78 in the mainstem Warm Springs River between Hehe and Schoolie Ranger Station (RM 37)(Figure 11).

Juvenile spring chinook salmon rear seasonally in Boulder Creek (tributary to Mill Creek) and Badger Creek (tributary to Warm Springs River), although no known spawning occurs in either stream. Juveniles were found in both tributaries in summer 1983 and apparently had moved upstream from mainstem areas. Lindsay et al. (1985) documented similar upstream movement of juvenile spring chinook salmon into tributary streams in the John Day River.

USFWS collected information on juvenile spring chinook salmon in Shitike Creek in 1983 (Table 11). Although data are limited, juvenile chinook salmon appear to be rearing at lower density in Shitike Creek than in the Warm Springs River. Shitike Creek may be underseeded with spring chinook salmon, especially above the Bennett Place (RM 8).

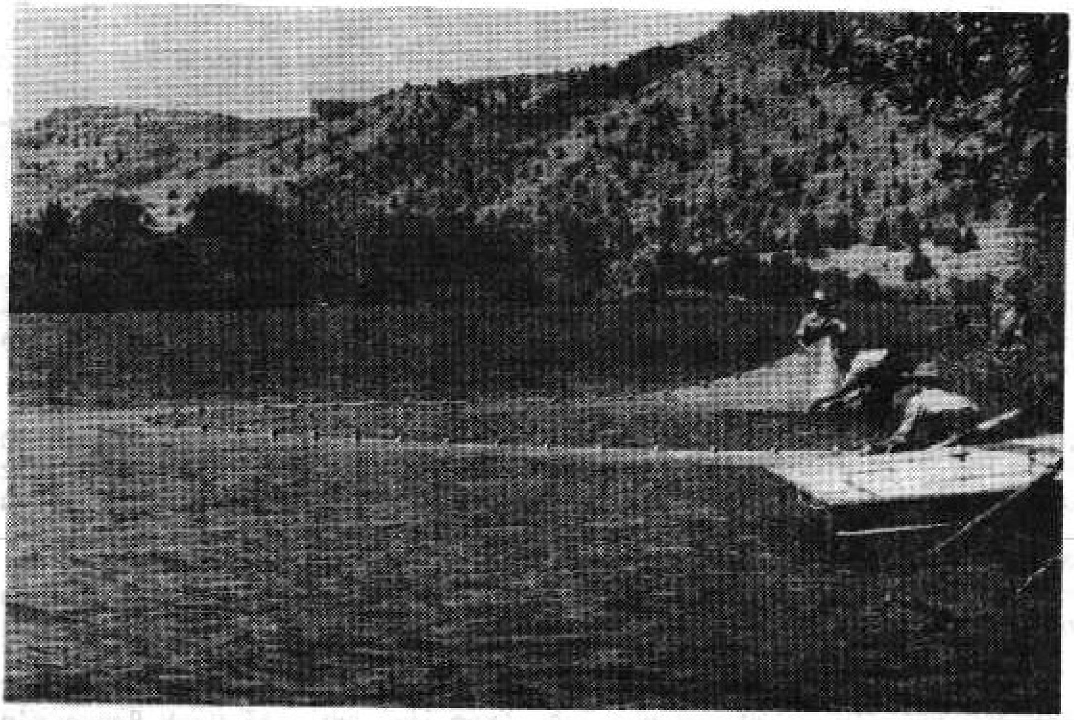

Figure 9. Seining for juvenile wild chinook salmon in the Deschutes River.

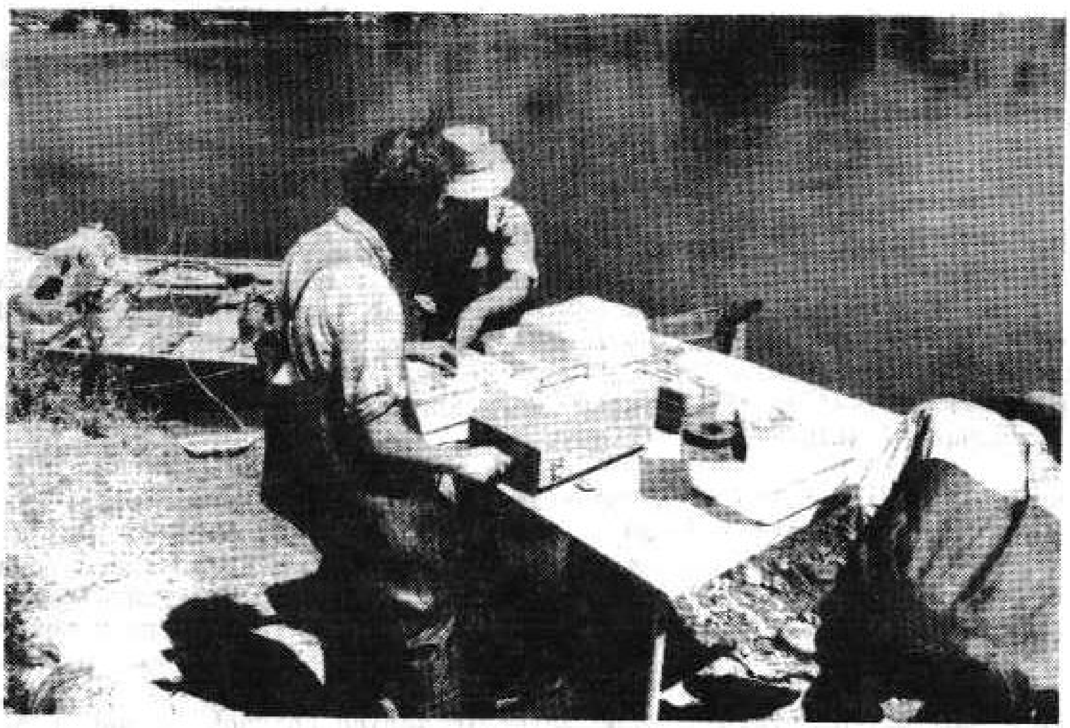

Figure 10. Coded-wire tagging juvenile wild chinook salmon in the Deschutes River.

Table 10. Population statistics for juvenile spring chinook salmon in two tributaries of the Warm Springs River, 17 August-8 September 1983. The ± 95% confidence limit for estimated abundance is in parentheses.

Stream, location	Estimated abundance	Density (fish/ sq m)	Fork length (mm) Mean	Fork length (mm) Range	Weight (g) Mean	Weight (g) Range	Biomass (g/sq m)
Mill Creek:							
Lower canyon	28 (7)	0.047	80.7	57-108	7.11	2.6-16.3	0.34
Just below Potters Pond	53 (4)	0.097	72.5	62-89	5.13	2.5-9.0	0.50
Potters Pond area	50 (16)	0.067	70.5	59-80	4.40	1.4-7.4	0.29
Above Potters Pond	56 (2)	0.079	78.7	69-109	7.71	5.1-17.0	0.61
Beaver Creek:							
Canyon above Simnasho Branch	72 (8)	0.074	82.5	69-100	6.95	2.8-14.3	0.52
Dahl Pine	25[a]	--	70.7	64-78	4.25	2.6-5.9	--

[a] *Number captured; no population estimate.*

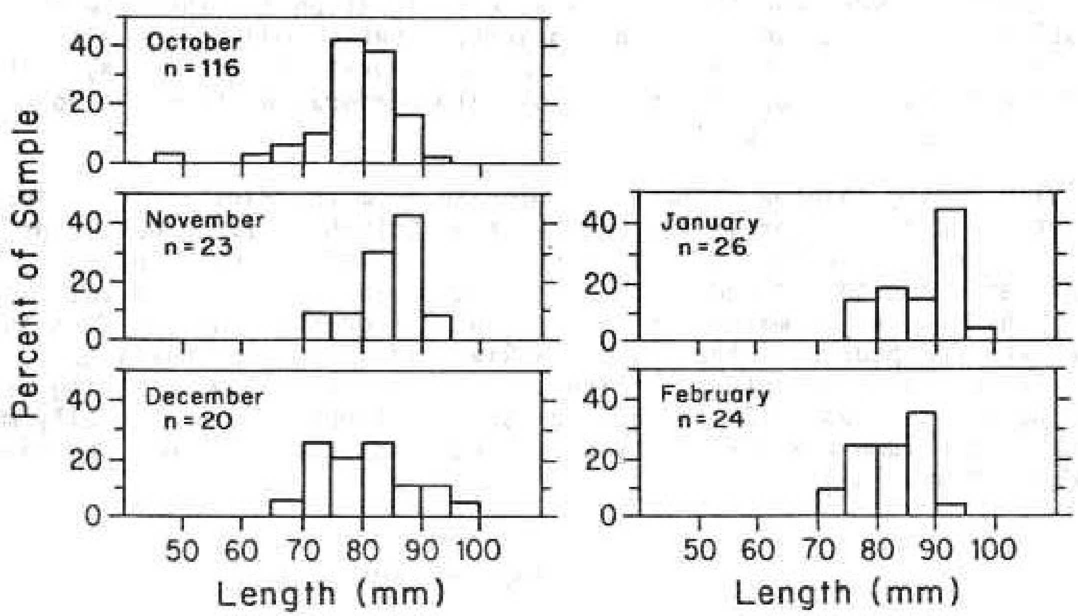

Figure 11. Length-frequency distributions for juvenile spring chinook salmon captured in the Warm Springs River between Hehe and Schoolie, October 1977 to February 1978.

Table 11. Population statistics for juvenile spring chinook salmon in Shitike Creek, 6-9 September 1983. The ± 95% confidence limit for estimated abundance is in parentheses.

Location	Estimated abundance	Density (fish/ sq m)	Fork length (mm)		Weight (g)		Biomass (g/sq m)
			Mean	Range	Mean	Range	
Community Center	7[a]	--	86	77-95	7.7	5.7-10.0	--
Thompson Bridge	20 (15)	0.008	83	73-97	7.0	5.3-10.8	0.09
Bennett Place	14[a]	--	81	68-93	7.0	4.7-10.1	--
Upper Crossing	11 (3)	0.007	79	72-90	7.9	5.9-10.5	0.06

[a] *Number captured; no population estimate.*

Juvenile spring chinook salmon in the Warm Springs River migrate downstream in two time periods: a fall migration from September through December, and a spring migration from February through May (Figure 12). Fall migrants are age 0 fish that generally range in size from 80 to 110 mm fork length (Figure 13) and do not exhibit a typical smolt-like appearance. Most spring migrants are age 1 yearlings that range from 90 to 130 mm fork length (Figure 13) and have the bright, silvery coloration typical of smolts. Some small age 0 fish also move downstream in late spring and early summer.

Data from juvenile chinook salmon marked with freeze brands at the Warm Springs trap and recaptured in the Deschutes and Columbia rivers indicate a relationship between the time of downstream migration and the rate of migration. Fish branded early in a migration period moved slower than those branded in the middle or near the end of the migration (Figure 14). The same pattern was observed for spring chinook salmon migrating from the John Day River (Lindsay et al. 1985)

Wild spring chinook salmon that migrate from the Warm Springs River in fall at age 0 overwinter in the Deschutes or Columbia rivers until spring of the following year before migrating seaward. Based on scale analyses, only 1% of the returning adults had migrated to the ocean at age 0. In addition, spring chinook salmon marked in fall as age 0 migrants from the Warm Springs River were recaptured in the Deschutes River in spring as yearlings. Fall migrants were also recaptured at The Dalles Dam the following spring as yearling smolts (Table 12). Yearling spring chinook salmon generally migrate through the Columbia River in May as do yearlings from the John Day River (Lindsay et al. 1985).

Juvenile Abundance and Survival

Each week, beginning in fall 1979, 50-100 juvenile spring chinook salmon were marked with a freeze brand or with a partial fin clip at the Warm Springs scoop trap and released 1.3 miles above the trap. The mean rate of recapture of these marked groups at the trap in fall and in spring was used to expand

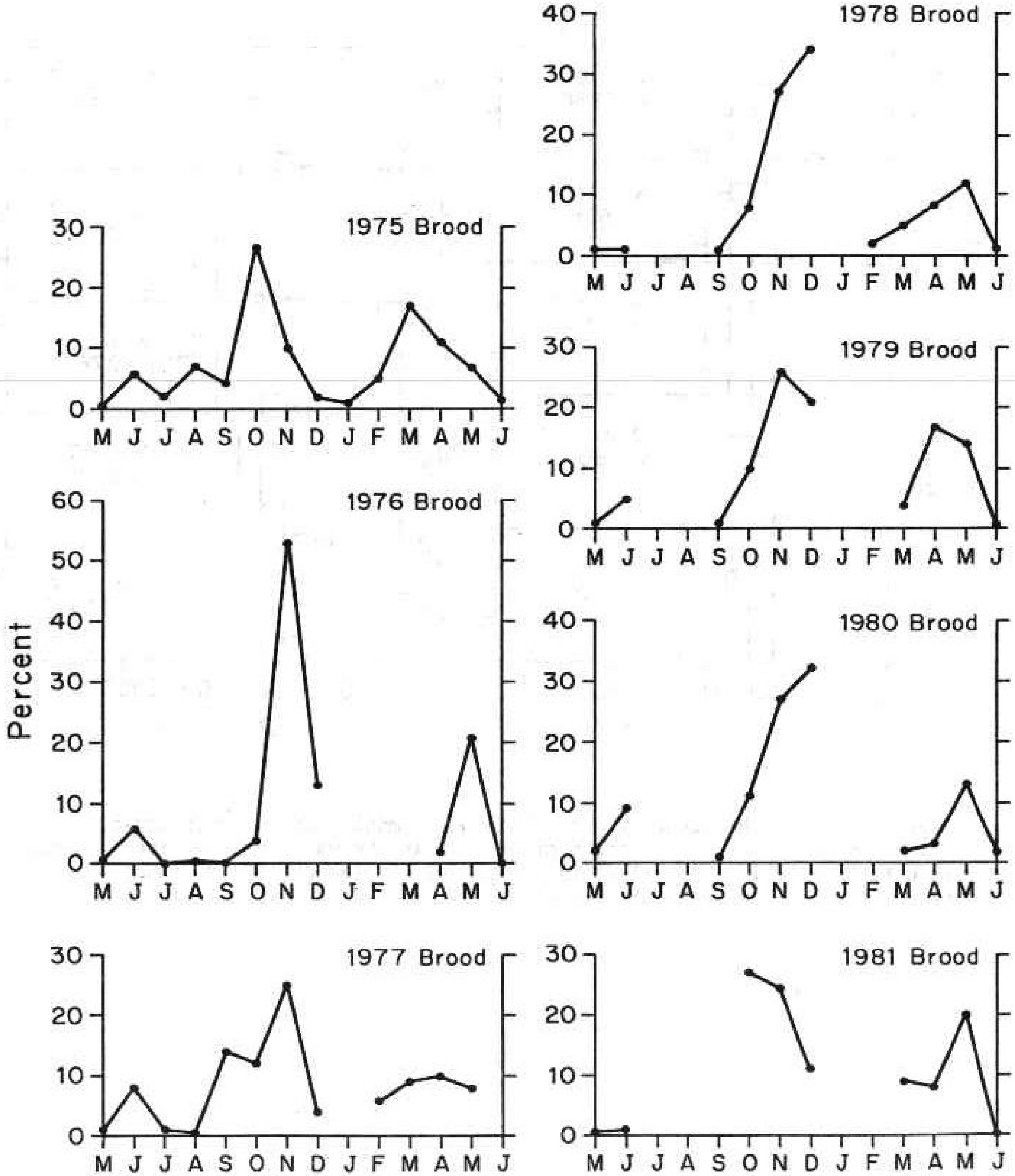

Figure 12. Timing of migration of wild juvenile spring chinook salmon from the Warm Springs River expressed as a percentage of the sum of the mean daily catch per month, 1975-81 broods.

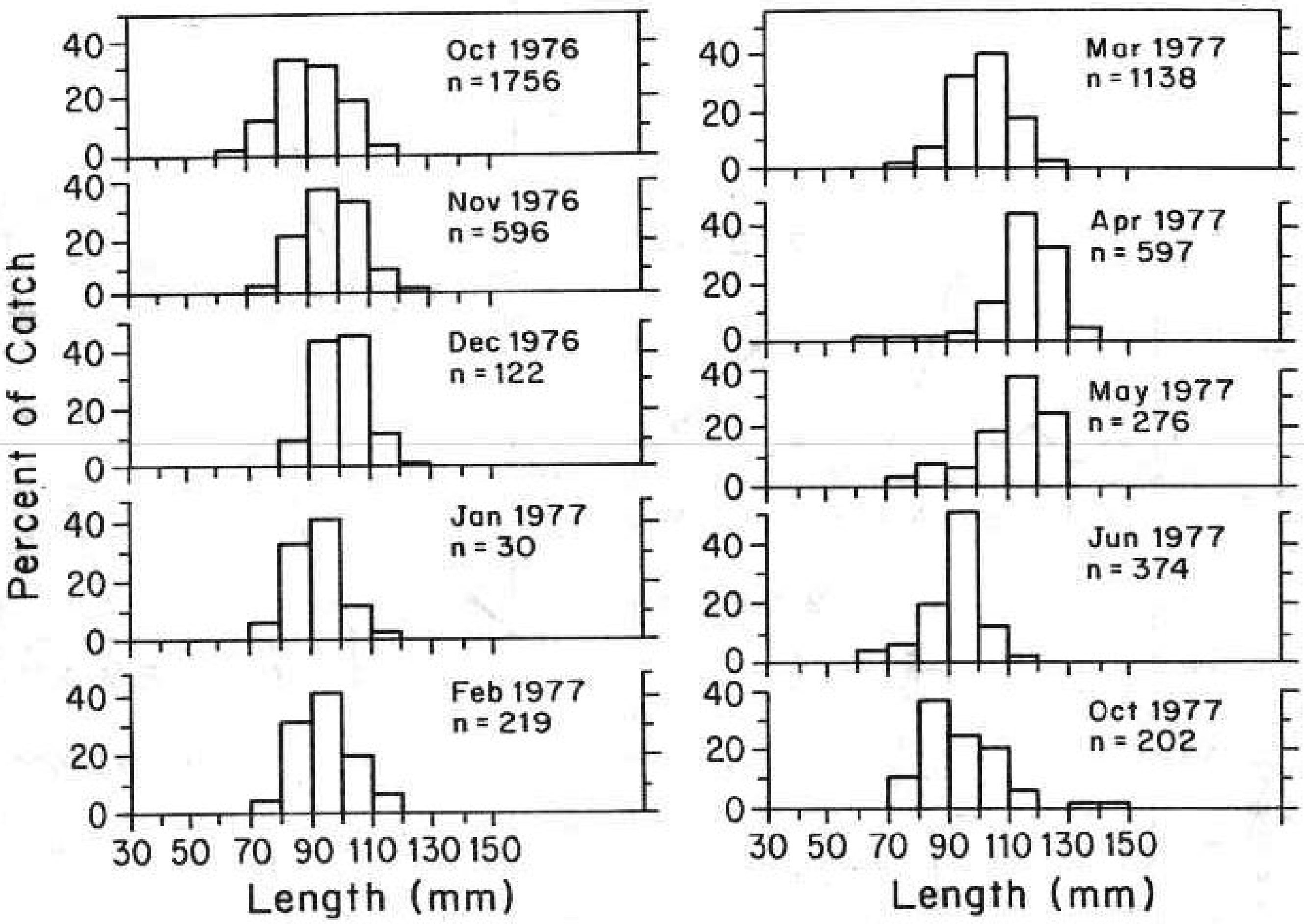

Figure 13. Length-frequency distributions by month for juvenile spring chinook salmon captured in the migrant trap in the Warm Springs River, October 1976 to October 1977. Distributions for July-September 1977 were not calculated because few fish were caught.

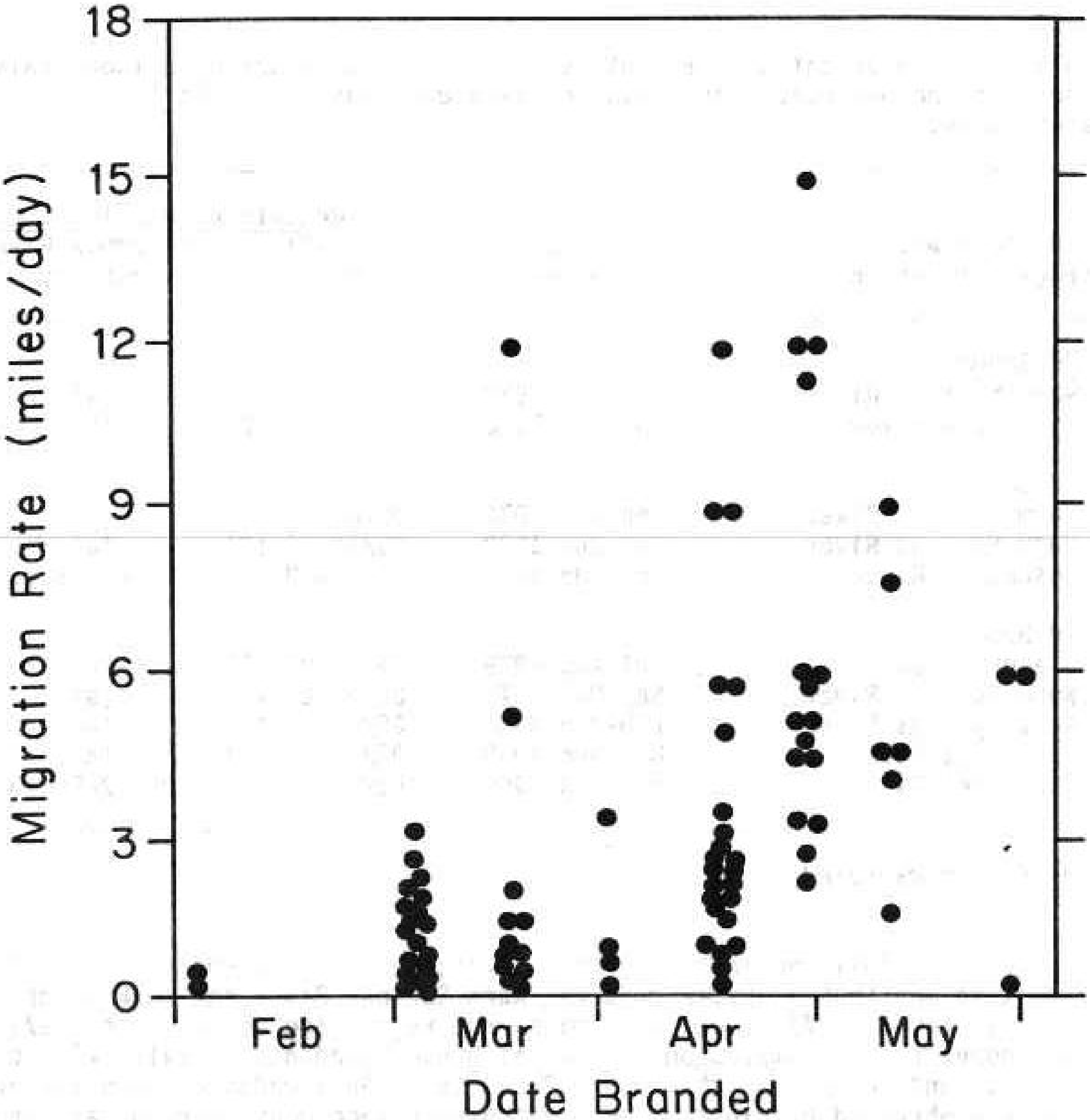

Figure 14. Relationship between time of migration and migration rate of yearling spring chinook salmon branded at the Warm Springs migrant trap and recaptured in the Deschutes and Columbia rivers, February-June, 1980. One fish branded in mid-March migrated 36 miles/day.

Table 12. Median dates of recapture of juvenile wild spring chinook salmon tagged in the Deschutes River system, 1978-80. Number caught is in parentheses.

Brood year, tagging location	Date tagged	Recapture location: The Dalles Dam	Recapture location: Columbia River estuary
1976 Brood:			
Warm Springs River	Apr-Jun 1978	05/24/78 (4)	(a)
Deschutes River	Apr-Jun 1978	06/10/78 (2)	(a)
1977 Brood:			
Warm Springs River	Sep-Dec 1978	05/03/79 (1)	(a)
Warm Springs River	Feb-Jun 1979	05/20/79 (2)	(a)
Deschutes River	Feb-Jun 1979	05/08/79 (3)	05/04/79 (1)
1978 Brood:			
Beaver Creek	Jul-Aug 1979	05/22/80 (3)	(a)
Warm Springs River	Sep-Dec 1979	05/08/80 (5)	(a)
Warm Springs River	Feb-Jun 1980	05/06/80 (5)	(a)
Deschutes River	Mar-Jun 1980	05/10/80 (3)	(a)
Deschutes River	Feb-Jun 1980	05/06/80 (8)	05/12/80 (3)

[a] *No fish recaptured.*

trap catch in fall and in spring to estimate the total number of juvenile chinook salmon that migrated from the Warm Springs River for 1978-81 broods. Estimates for 1975-77 broods were made from regression equations of 1978-81 brood population estimates on indexes of brood abundance in fall ($r^2 = 0.87$, $P < 0.10$) and in spring ($r^2 = 0.93$, $P < 0.05$). An abundance index for each brood was obtained by plotting mean catch rate each month during fall and spring migration periods and measuring the area under the curve. The abundance index for each of the 1975-77 broods was entered into the appropriate 1978-81 regression equation to obtain an estimate of the number of juveniles that migrated in fall and in spring.

The annual number of migrants from the Warm Springs River ranged from 35,235 to 131,943 for the 1975-81 broods (Table 13). The number of fish that migrated in fall generally exceeded the number that migrated in spring. The mean recapture rate of test groups released above the scoop trap ranged from 9% to 23% (Table 14). Streamflow during these tests explained a small but significant proportion of the variation in recapture rate (Figure 15).

The relationship between the number of juveniles that migrated in fall and spring and the number of redds that produced those juveniles is curvilinear and suggests survival in the Warm Springs River is density dependent (Figure 16). The survival rate of 1975-81 broods from egg deposition to migration was high when egg abundance was low, which tended to compensate for low spawner abundance (Figure 17; Table 15). Survival from smolt to adult averaged 3.0% and was highest when juvenile migrants numbered about 50,000 or less (Table 15).

Table 13. Number of wild juvenile spring chinook salmon that migrated from the Warm Springs River, 1975-81 broods. CL = Confidence limit.

Brood year	Time of migration Fall	Spring	Total	± 95% CL
1975	25,795	43,250	69,045	--
1976	47,041	26,043	73,084	--
1977	25,125	25,304	50,329	--
1978	74,727	57,216	131,943	62,123
1979	24,930	25,628	50,558	21,842
1980	20,579	14,656	35,235	18,644
1981	29,238	14,647	43,885	29,521

Table 14. Percent recapture in the Warm Springs trap of juvenile spring chinook salmon branded and released 1.3 miles above the trap, 1979-83.

Release dates	Number of groups released[a]	Mean number in each group	Mean percent recaptured
11/13-12/11/79	6	329	15.8
03/04-05/29/80	6	116	11.1
10/31-11/16/80	3	105	22.6
03/18-05/25/81	4	105	16.8
11/02-12/09/81	5	158	18.3
05/04-05/15/82	2	56	9.0
10/25-12/06/82	5	79	12.6
03/16-05/16/83	5	85	15.0

[a] *Excludes groups of fewer than 50 fish.*

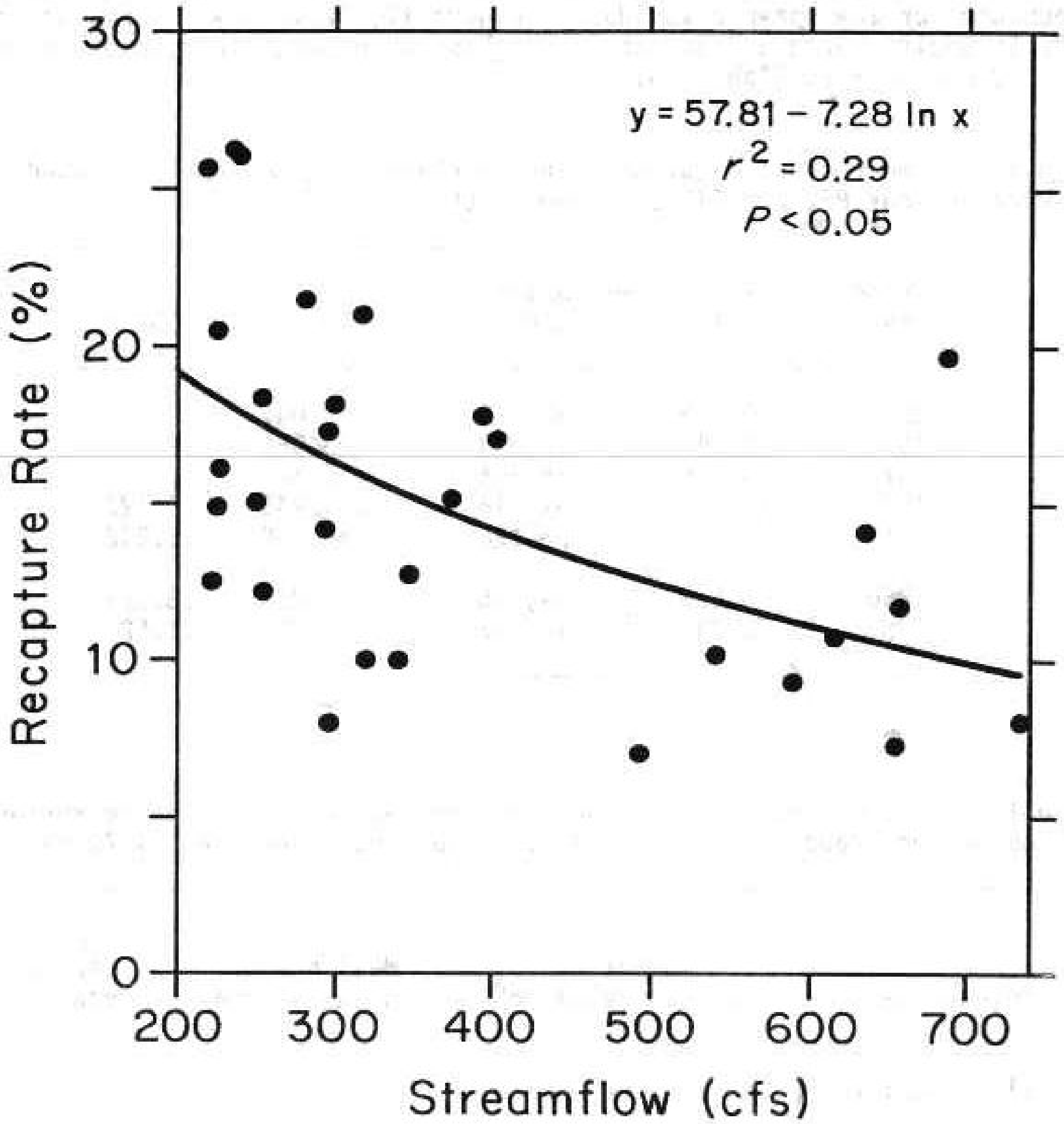

Figure 15. Relationship between the recapture rate of juvenile spring chinook salmon in the scoop trap and streamflow in the Warm Springs River.

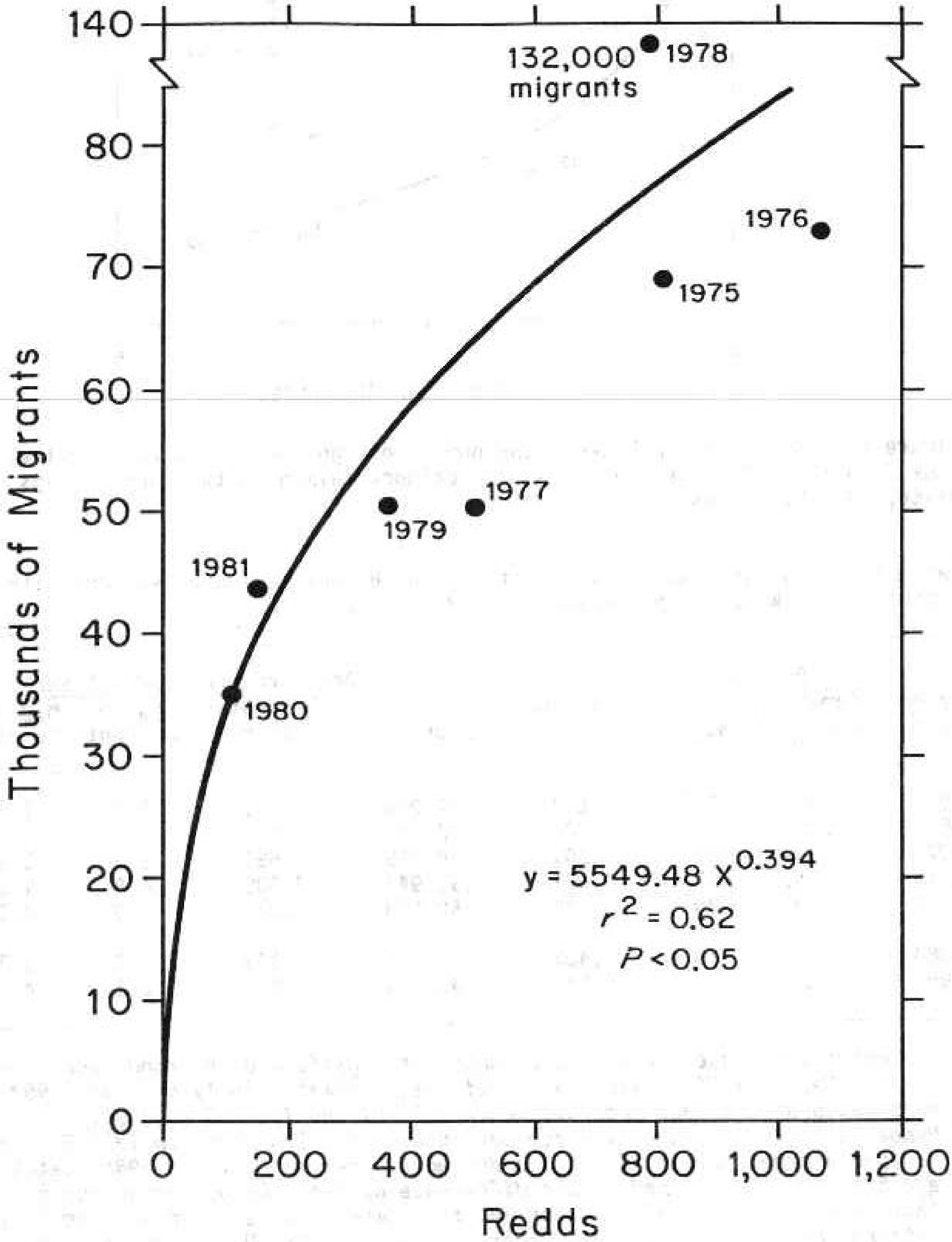

Figure 16. Relationship between number of fall and spring migrants from the Warm Springs River and number of redds above Warm Springs National Fish Hatchery that produced those migrants, 1975-81 broods.

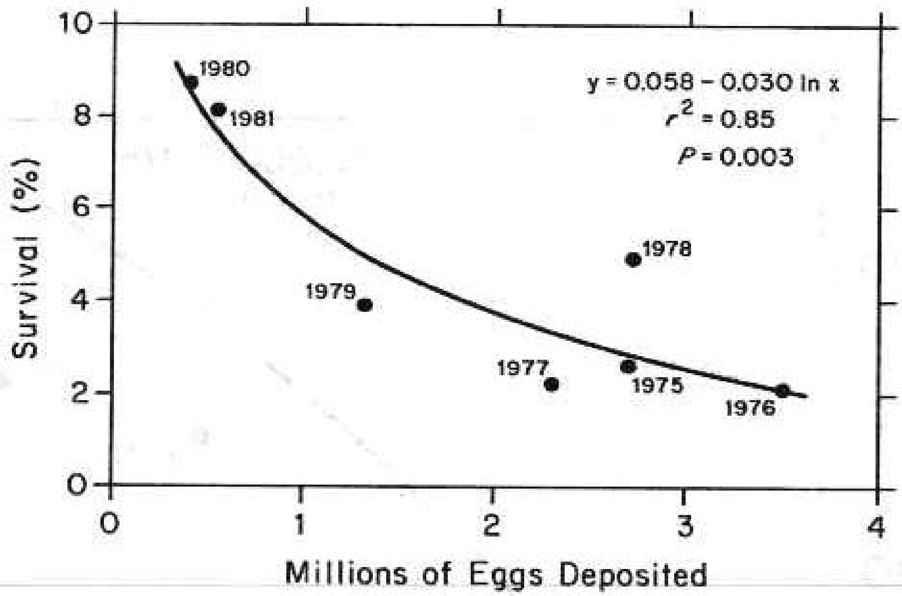

Figure 17. Relationship between the number of eggs deposited and survival from deposition to migration of spring chinook salmon in the Warm Springs River, 1975-81 broods.

Table 15. Abundance and survival of spring chinook salmon at various life stages in the Warm Springs River, 1975-81 broods.

Brood year	Parents: Females (redds)	Parents: Males	Millions of eggs[a]	Migrants	Adult return to Deschutes River	Percent survival: Egg-to-migrant	Percent survival: Migrant-to-adult
1975	808	495[b]	2.669	69,045	1,891	2.6	2.7
1976	1,066	653[b]	3.521	73,084	1,541	2.1	2.1
1977	699	428[b]	2.309	50,329	1,691	2.2	3.4
1978	796	467	2.671	131,943	2,009	4.9	1.5
1979	359	220	1.309	50,558	2,077	3.9	4.1
1980	117	63	0.403	35,235	1,162	8.7	3.3
1981	157	114	0.539	43,885	1,807[c]	8.1	4.1

[a] *Estimates were based on the mean number of eggs/female in broodstock at Warm Springs National Fish Hatchery except that estimates in 1975-77 and 1982 were based on the mean eggs/female in 1978-81 and 1983-85 (3,303).*

[b] *Number of males based on average percentage of males (38%) in 1977-85 runs.*

[c] *Because a creel survey was not conducted at Sherars Falls in 1986, catch of age 5 fish was estimated as the difference between the number of age 5 fish that entered the Deschutes River and the number that arrived at Warm Springs National Fish Hatchery. The number that entered the Deschutes River was estimated by dividing the number of age 5 fish that reached the hatchery by the average percentage of the run that reached the hatchery in years when creel surveys were conducted.*

The mean length of fall migrants was negatively correlated with their estimated abundance which suggests growth is also density dependent in the Warm Springs River (Figure 18). However, a relationship was not evident between the size of spring migrants and their abundance or between the size of spring migrants and the number of migrants the previous fall.

The negative correlation between mean length and abundance of fall migrants, indicates that summer habitat is limiting production of spring chinook salmon in the Warm Springs River (Figure 18). Although winter habitat may also be limited in the Warm Springs River, it is not limiting production because juveniles migrate in fall into the Deschutes or Columbia rivers. The amount of spawning gravel is currently not limiting production and appears adequate to support 1,550 redds based on estimates of 108,555 sq ft of gravel in the basin and 70 sq ft per redd (Diggs 1979).

Juvenile spring chinook salmon (1978 brood) that were coded-wire tagged during fall and spring migrations from the Warm Springs River were used to estimate a winter survival rate of fall migrants in the Deschutes and Columbia rivers. We assumed that all smolts migrated to the ocean in the spring at age 1 and that survival from smolt to returning adult for fall migrants was the same as that for spring migrants. By making these assumptions, the ratio of the adult return rate from fall migrants to the adult return rate from spring migrants gives an estimate of winter survival of fall migrants in the Deschutes and Columbia rivers.

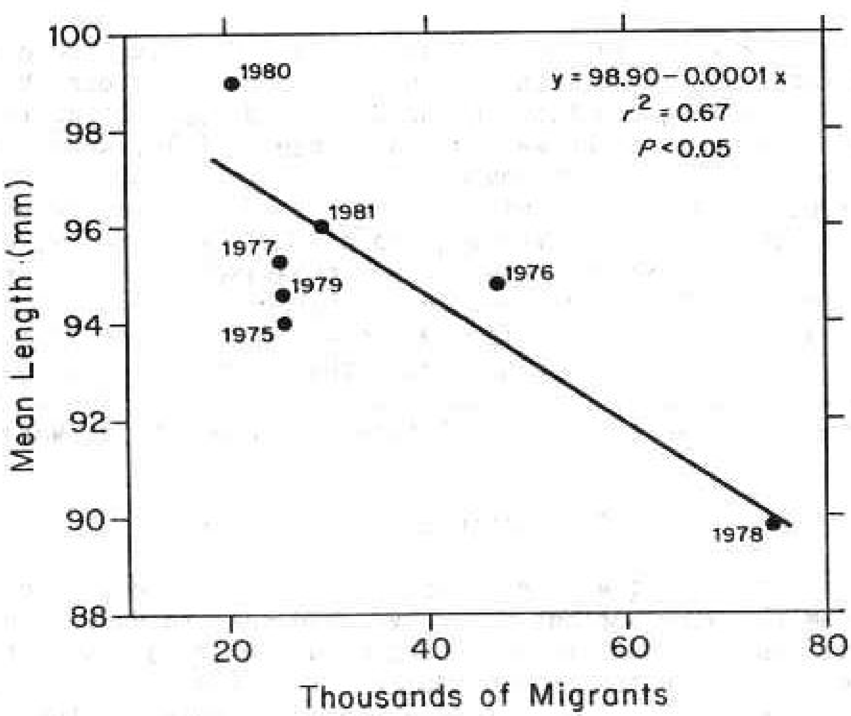

Figure 18. Relationship between mean length and abundance of juvenile spring chinook salmon that migrated from the Warm Spring River in fall, 1975-81 broods.

If our assumptions are correct, 52% of 1978 brood fall migrants survived through winter in the Deschutes or Columbia rivers. Based on scale analyses, the assumption that smolts migrated to the ocean at age 1 is correct (*see* **Age Composition and Size**, page 9). However, the assumption that survival of fall migrants from smolt to adult was the same as that for spring migrants may not be valid because smolts from fall migrants that reared in the Deschutes River until spring were larger than smolts from fish that overwintered in the Warm Springs River (Table 16). Consequently, smolt-to-adult survival could have been higher for fall fish than for spring fish and winter survival may have been lower than 52%. Tagged fall and spring migrants (1978 brood) from the Warm Springs River returned at a rate of 0.43% and 0.83%, respectively. These survival rates may have been lower than that based on total migrants from the 1978 brood shown in Table 14 because of the effects of tagging.

Table 16. Mean fork length (mm) of wild juvenile spring chinook salmon that spent the 1979-80 winter in the Warm Springs River and in the Deschutes River.

Month fish were sampled	Warm Springs River	Deschutes River
February	92.1	103.4
March	92.0	109.6
April	106.4	119.2

A group of 2,775 juvenile wild spring chinook salmon were marked with coded-wire tags and freeze brands in Beaver Creek in summer 1979. After adjusting for handling and tagging mortality and subtracting fish of this group that migrated past the Warm Springs trap in fall, we estimated that 20%, including those that may have moved into the Warm Springs River above the trap, survived the winter and migrated in spring. We estimated the same survival rate through winter for a group of 636 fish coded-wire tagged near Kahneetah on the Warm Springs River. By comparison, winter survival rate for 3 years in the John Day River averaged 30% (Lindsay et al. 1985). Because these data indicate that juveniles that overwinter in the Warm Springs River basin survive at a lower rate than those that overwinter in the Deschutes or Columbia rivers, it appears more advantageous for juvenile spring chinook salmon to migrate downstream in fall than to winter in the Warm Springs River.

Prediction of Adult Return

We calculated a regression of adult return on abundance of juvenile migrants from the Warm Springs River by brood year to determine if this relationship could be used to predict the number of adults that would return to the Deschutes River. Although adults return from both fall and spring migrants, the relationship with spring migrants explained the highest percentage of the variation in return to the Deschutes River (r^2 = 37%, P = 0.15)(Figure 19). Prior to the 1981 brood, this regression explained 61% of the variation in brood year return (P = 0.07). Spring chinook salmon from the

Deschutes River rear primarily north of the Columbia River after entering the ocean (*see* **HARVEST**, page 59). Favorable growing conditions in the ocean north of the Columbia River because of higher than normal water temperatures from El Nino may have resulted in an unusually high return of the 1981 brood, which migrated in 1983 (personal communication in March 1988 with Thomas Nickelson, Oregon Department of Fish and Wildlife, Corvallis, Oregon). Temperature of the ocean north of the Columbia River was also higher than normal in 1981 and may have resulted in the unusually high return of the 1979 brood (personal communication in March 1989 with Thomas Nickelson, Oregon Department of Fish and Wildlife, Corvallis, Oregon). Although flow in the Columbia River was high in 1983 and may have improved survival of the 1981 brood during downstream migration, flow was low in 1981 when the 1979 brood migrated downstream (Lindsay et al. 1985).

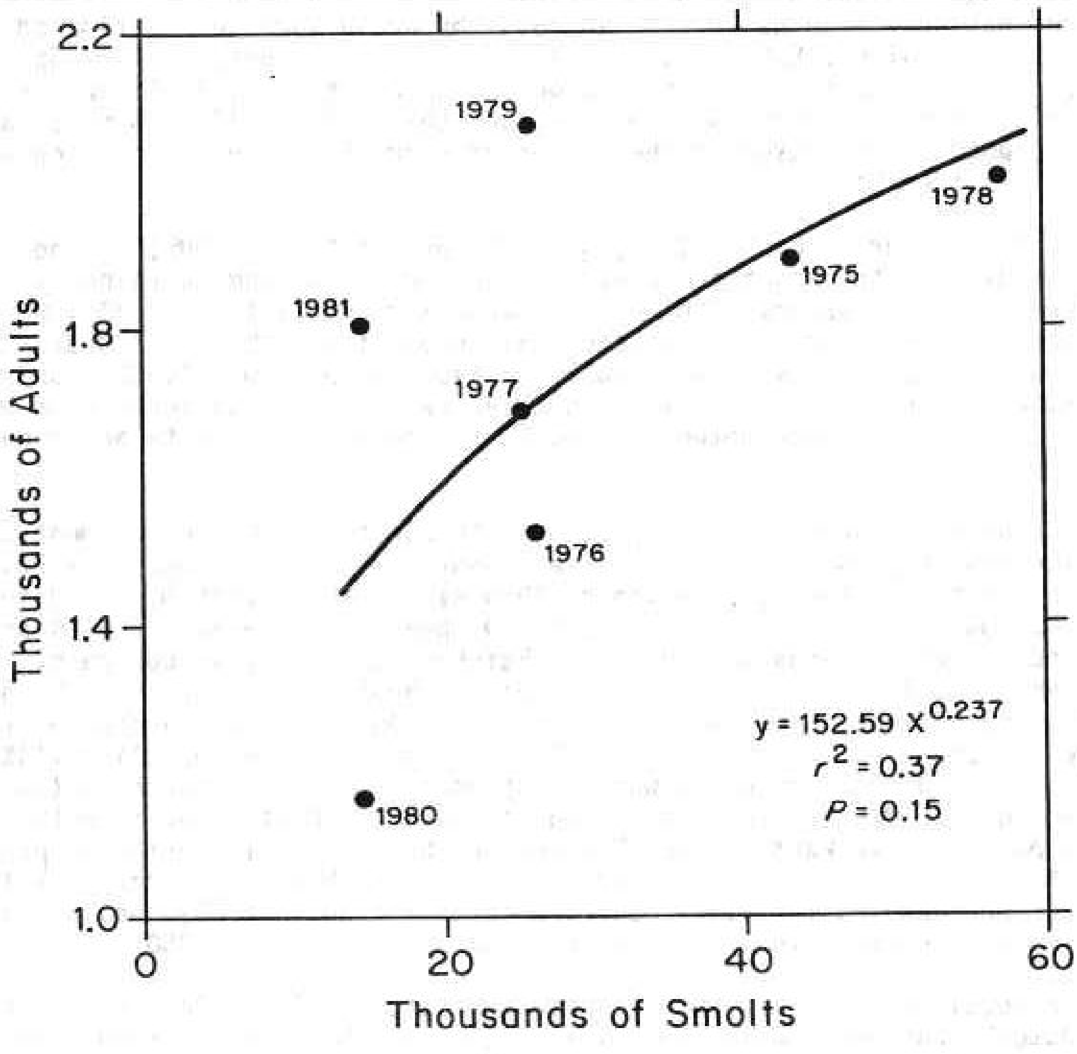

Figure 19. Relationship between the number of juvenile spring chinook salmon that migrated from the Warm Springs River in spring and adult returns to the Deschutes River from these migrants, 1975-80 broods.

Escapement Goal

We developed a stock-recruitment curve to establish an escapement goal for wild fish in the Warm Springs River. From our perspective, an escapement goal for a wild stock should provide for harvest while still maintaining as much genetic diversity as possible. For wild stocks, managing spawner abundance between maximum sustained yield and replacement on a stock-recruitment curve would provide a compromise between maximizing sustained harvest and maximizing genetic variation (McGie 1985).

We constructed a stock-recruitment curve by estimating the number of parents present at time of spawning in fall and by estimating the number of adult recruits produced by those parents. The number of parents (spawners) was estimated from the number of redds counted in the Warm Springs basin multiplied by the number of females and males per redd. We assumed that each female constructed only one redd and that the sex ratio of males to females in the wild was equivalent to the sex ratio observed in broodstock at Warm Springs National Fish Hatchery. Recruits by brood year were estimated from creel surveys of Deschutes River fisheries and from counts at Warm Springs National Fish Hatchery. Catch from ocean and Columbia River fisheries was negligible for the years used to construct the curve (1975-81 broods) and was not included in estimates of the number of recruits. Age composition was determined from scales.

A Ricker curve (Ricker 1975) gave the best fit (r^2 = 98%) to the spawner-recruit data in the Deschutes River (Figure 20). Maximum sustained yield occurred at 548 spawners (Table 17). Maximum recruits (R_m = 2,330) were produced with 727 spawners. Replacement level, i.e., the level where the stock would replace itself with no harvestable surplus was 1,568 fish. A spawning escapement of 727 wild fish above Warm Springs National Fish Hatchery would provide a balance between managing for genetic diversity and managing for harvest.

Because the number of spawners used to construct the recruitment curve was the number present in fall, it represents, on the average, only 56% (excluding the high mortality years, 1980-81) of those that migrated into the Warm Springs River in spring (*see* Table 9, page 22). Because adults are counted at Warm Springs National Fish Hatchery as they move upstream, escapement goals for the Warm Springs River should be in terms of the number of fish passed above the hatchery in spring. Adjusting the number of spawners needed to produce maximum recruits (727) for prespawning mortality (44%) and ignoring the proportion of spawning that occurs below the hatchery (3% excluding 1977 drought year) gives an estimate of about 1,300 fish that need to be passed above Warm Springs National Fish Hatchery in spring to produce R_m. A minimum escapement of 1,000 fish above the hatchery, even with the highest prespawning mortality observed to date (75% in 1980), would still result in more redds than the historic low of 117 seen in 1980.

A total harvest rate of 69% including catch in fisheries, fish taken for broodstock, and prespawning mortality would, on the average, result in 727 wild fish spawning in fall. Currently, prespawning mortality in the Warm Springs River "harvests" 44% of the fish before they spawn. In addition, in 1978-85 Warm Springs National Fish Hatchery "harvested" for broodstock an average of 27% of the run that reached the hatchery. Combined with a 30%

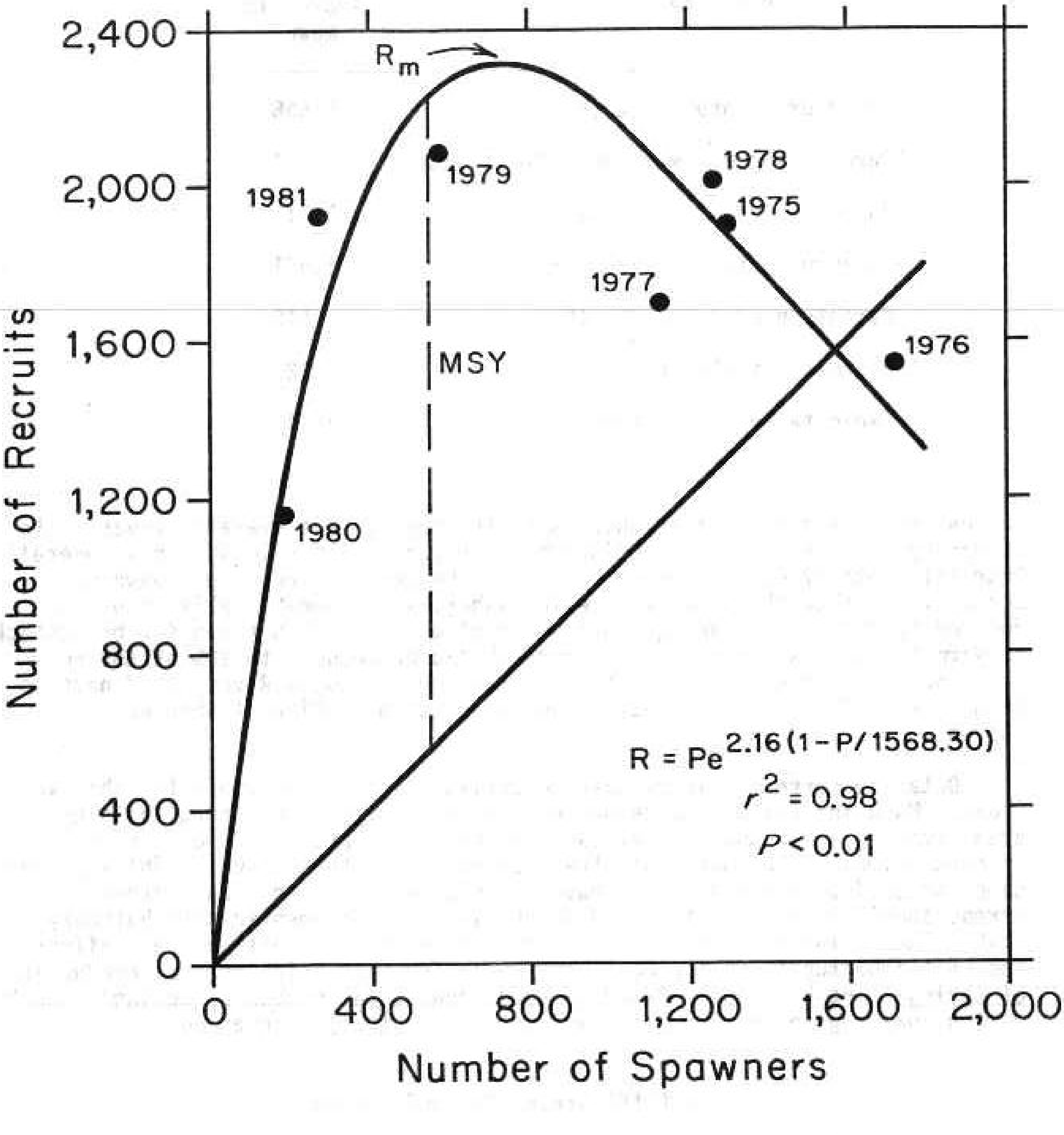

Figure 20. Stock-recruitment curve for spring chinook salmon in the Warm Springs River, 1975-81 broods.

Table 17. Stock-recruitment parameters for wild spring chinook salmon in the Deschutes River, 1975-81 broods.

Parameter	Geometric mean
Replacement abundance (Pr)	1,568
Parents for maximum recruitment (Pm)	727
Maximum recruitment (Rm)	2,312
Maximum sustained yield (MSY)	1,681
Parents needed for MSY (Ps)	548
Recruits at MSY (Rs)	2,229
Exploitation rate at MSY	75.4%

harvest rate in fisheries at Sherars Falls, the current overall harvest rate of spring chinook salmon in the Deschutes River is 71%. To obtain an overall "harvest" rate of 69%, assuming little can be done to reduce prespawning mortality, either the harvest rate in fisheries at Sherars Falls should be reduced to 25% or the average percentage of the wild fish taken for broodstock at Warm Springs National Fish Hatchery should be reduced to 20% of the run reaching the hatchery. "Harvest" rates in the Deschutes River would have to be decreased further if harvest in ocean or Columbia River fisheries increased.

Data are currently inadequate to estimate escapement goals for Shitike Creek. More information is needed on run size, migration timing, holding area, rearing area, and habitat factors that limit production of spring chinook salmon. The number of stray hatchery fish that spawn in Shitike Creek needs to be determined and will have an important influence on whether the stream should be managed for wild production or supplemented with hatchery fish. Except for White River above White River falls, Shitike Creek offers the best opportunity in the Deschutes basin for increasing natural production of spring chinook salmon. Based on redd counts, the number of spring chinook salmon spawning in Shitike Creek appears to be slowly increasing.

HATCHERY SPRING CHINOOK SALMON

Since 1966, about 10 million hatchery spring chinook salmon have been released into the lower Deschutes basin. Juveniles released into the mainstem Deschutes River prior to 1972 were reared at Wizard Falls, Oak Springs, and Fall River hatcheries (Deschutes River system)(**APPENDIX C**). The first known stocking of spring chinook salmon in the Warm Springs River occurred in 1958. Eggs were obtained from Carson National Fish Hatchery for hatchboxes and for a pilot hatchery operated by the U.S. Bureau of Commercial Fisheries near Schoolie Ranger Station on the Warm Springs River. Hatchboxes were also located at a site on Beaver Creek in the 1960s. Releases of salmon into the Warm Springs River and into Shitike Creek prior to construction of Warm Springs National Fish Hatchery are summarized in **APPENDIX C**.

PGE constructed Round Butte Hatchery to mitigate for losses of wild spring chinook salmon and summer steelhead in the Deschutes River above Pelton and Round Butte dams. The hatchery began operation in 1972. In 1963 the Warm Springs Tribal Council requested that USFWS determine the feasibility of a permanent fish hatchery on the Warm Springs Indian Reservation. A site was selected on the Warm Springs River about 9 miles upstream from its confluence with the Deschutes River. Warm Springs National Fish Hatchery was authorized by federal statute in 1966. Construction began in 1972 and fish production began in 1978. Since 1972, spring chinook salmon have been reared and released into the lower Deschutes basin only from Round Butte and Warm Springs National Fish hatcheries (**APPENDIX C**).

Round Butte Hatchery

Different groups of spring chinook salmon were released from Round Butte Hatchery to determine the time, size, and location of release that would allow the hatchery to meet mitigation. Fish reared from egg-take to February-July of the following year were termed "spring subyearling releases"; fish reared from egg-take until fall of the following year were termed "fall subyearling releases"; and, fish reared from egg-take until spring of the second year were termed "spring yearling releases". Eggs were incubated on regular hatchery water (50°F) or, beginning in 1977, on chilled (42°F) and regular hatchery water. Size of the fish was generally a function of incubation temperature and of time of release. Marked spring chinook salmon were released into Pelton Reservoir (Lake Simtustus), Pelton Reregulating Reservoir, or the Deschutes River immediately below Pelton Reregulating Dam. Chinook salmon were also transferred to Pelton ladder where they reared for various periods of time under relatively natural conditions until they migrated.

Pelton ladder is a concrete channel (10 ft wide, 6 ft deep, and 2.8 miles long) with a usual flow of about 8 cfs and a potential flow of 40 cfs. The ladder was originally designed to pass adult chinook salmon and summer steelhead above Pelton Dam. It was abandoned for adult passage after facilities at Round Butte Dam, located above Pelton Dam, failed to pass juveniles downstream.

In 1976 the wild chinook salmon study by ODFW on the Deschutes River was expanded to include a 5-year evaluation of the spring chinook salmon program at Round Butte Hatchery in an attempt to increase the return rate of adults. In 1981 the hatchery evaluation was extended for three additional brood years (1981-83). Coupled with the experimental releases that began in 1977 under the original 1976 proposal, the 1981 extension gave ODFW the opportunity to compare several rearing strategies for spring chinook salmon (Table 18).

In 1984 the hatchery began a trial production program based on initial returns of experimental releases since 1977. Under this trial program, about 80% of the spring chinook salmon are being reared in Pelton ladder from

November to the following spring. The remaining 20% are being reared in the hatchery and released as yearlings in spring. Combinations of fin clips and coded-wire tags are being used to evaluate return rate as well as to evaluate the effects of fin clips. This phase of spring chinook salmon studies at Round Butte Hatchery will be completed in 1991.

Table 18. Rearing strategies for spring chinook salmon that were tested at Round Butte Hatchery, 1977-83 broods.

Experimental group	Incubation temperature (°F)	Rearing temperature (°F)	Month of release	Age at release (months)
Fast-incubated:				
Spring subyearling	50	50	May	8
Fall subyearling	50	50	Oct	14
Slow-incubated:				
Fall subyearling	42	50	Oct	14
Spring yearling	42	50	Mar-Apr	18-19
Spring yearling, Pelton ladder[a]	42	Variable	Mar-May	18-20

[a] *Fish were transferred to Pelton ladder in November.*

Run Timing and Broodstock Collection

Adult spring chinook salmon arrive at Pelton trap at the base of Pelton Reregulating Dam in early May. Fifty percent of the return enter the trap by the first week in June and 75% enter by about mid-June. Jacks tend to arrive a week later than adults.

Broodstock is collected randomly from Pelton trap throughout the migration period. About 200-300 adults are held in ponds for spawning at the hatchery. The Confederated Tribes of the Warm Springs Reservation of Oregon are provided surplus fish after snouts have been removed from those with coded-wire tags. Prespawning mortality averaged 10% from 1974 through 1983 (excludes the 1976 brood because 60% were collected by electrofishing, which caused high prespawning mortality). Prespawning mortality increased in 1984-86 to 17% because adults were injected with erythromycin to reduce bacterial kidney disease in their progeny.

Current Spawning and Rearing Procedures

Egg take for spring chinook salmon at Round Butte Hatchery occurs in late August and early September. Fecundity averages about 3,400 eggs per female. One male is generally used to fertilize the eggs of three females. Approximately 30% more eggs are taken at the hatchery than the number of smolts needed for release. The eggs are water hardened for 1 hour and disinfected in a 10 ppm iodophor solution for 10 minutes. The eggs are then moved to Heath incubators and, beginning with the 1984 brood, are placed in chilled water.

After the eggs have eyed (about 50 days) they are shocked and sorted to remove dead and blank eggs. Hatching occurs 14-21 days later. The chiller is turned off in late December and the fry are reared in normal 50°F hatchery water. In late January the fry are transferred to 6 ft circular tanks until they reach a size of about 250 fish/lb in early April. The fry are then transferred to a single Burrows pond until mid-May when they are split into two ponds. The fish are split again into four ponds after they are marked in June. Fish reared in the ladder are transferred there in November and allowed to migrate volitionally the following March or April.

Depending on the types of experiments being conducted, all chinook salmon are either marked with fin clips or Ad+CWT in June at a size of 40-50 fish/lb. Tag retention is determined just prior to release by crowding the fish in a pond and taking 8 to 10 independent samples of about 100 fish each. Each fish is then examined for an adipose fin clip. The presence of a coded-wire tag is determined by using a field detector.

Coded-wire tags from returning adults are recovered from snouts of fish collected in recreational and Indian fisheries at Sherars Falls and from fish captured in Pelton trap. Return rates are calculated as a percentage of the juveniles released with coded-wire tags or fin clips that return as marked adults.

Disease

Bacterial kidney disease is the principal disease in spring chinook salmon at Round Butte Hatchery. Annual treatment for BKD consists of an injection of adults with 11-20 mg/kg body weight of erythromycin when they enter Pelton trap in spring and a second injection in holding ponds in early July. Juveniles are given two, 21 day feedings of Oregon Moist Pellet composed of 4.5% erythromycin by weight. The first feeding occurs in late February or early March and the second in July.

In addition to BKD, spring chinook salmon at Round Butte Hatchery carry infectious hemopoetic necrosis and viral erythrocytic necrosis viruses; however, there has never been an outbreak of either disease in chinook salmon at the hatchery. The presence of viruses in the hatchery prevents Deschutes River fish from being transferred to other river basins.

The Deschutes River also contains the sporozoan *Ceratomyxa shasta*, which can infect fish in Pelton ladder and those in the mainstem Deschutes. Fish in the hatchery are not infected because the hatchery's water supply is from springs. Rearing in Pelton ladder and releases from the ladder and the hatchery are, in part, scheduled at times when *C. shasta* is at a low level. *C. shasta* in chinook salmon in the Deschutes River is described by Ratliff (1981, 1983). Diseases and parasites found in spring chinook salmon at Round Butte Hatchery are listed in **APPENDIX D**.

Juvenile Migration

Juveniles released from Round Butte Hatchery in spring as subyearlings or yearlings were usually first captured at The Dalles Dam 1-2 days after release. Median passage at the dam was 1-3 weeks after release (Table 19). Juveniles released in spring were recaptured in the Columbia River estuary 5-10 days after release with median passage 2-4 weeks after release. Juveniles released in October were generally recaptured at The Dalles Dam the following spring in April and May although little sampling occurs at the dam in fall and winter.

Passage times at The Dalles Dam and through the Columbia River estuary cannot be compared because of differences in sampling schedules between the two locations and because of small sample sizes. In several instances, for example, the median passage date at The Dalles Dam is the same or later for a given release group than the median passage date at the estuary, approximately 146 miles downstream from The Dalles Dam.

Two tagged juvenile hatchery spring chinook salmon were recovered in the ocean. One fish, released in early April 1979, was recaptured in mid-June 1979 off Clatsop Spit near the mouth of the Columbia River. Another fish, released in mid-May 1980, was recaptured in early June 1980 off Willapa Bay, Washington.

Return Rate

Releases of subyearling spring chinook salmon were emphasized in the Deschutes River from 1967 through 1977. These releases looked promising because winter water temperature in most hatcheries on the Deschutes River are high enough to produce fingerling that migrate in their first spring. Rearing juveniles for only a few months also reduces hatchery costs and, because the fish are smaller than those released later, increases the number that can be reared. Subyearlings migrate rapidly through the Deschutes and Columbia rivers, which should enhance survival. Unfortunately, by 1978 results showed that these fish did not survive to return. Excluding a small group with an unusually high return rate in 1966, return rate in 1966-76 from these subyearlings averaged less than 0.01% (Tables 20 and 21).

From 1967 through 1976, return rate from fall releases of subyearling chinook salmon averaged 0.14% and from yearling spring releases 0.09%, about ten times higher than from subyearling spring releases ($P < 0.01$) (Tables 20 and 21). Although return rate from fall releases was higher than that from yearling spring releases, the difference was not significant ($P > 0.05$). Because these two releases were often made in different years, between year variation in survival may have masked differences related to time of release.

Some fish released in fall remained in the Deschutes and Columbia rivers until spring before they migrated to the ocean. A slow-incubated group released in October 1978 (1977 brood) was significantly larger ($P < 0.01$) at ocean entry (based on scale analyses) than at release (14.8 cm versus 13.1 cm). The change in length may have been due to growth between time of release and ocean entry, higher survival of larger fish, or a combination of both. Growth would likely occur if chinook salmon released in October wintered in the Deschutes or Columbia rivers before migrating the following spring.

To determine the extent of winter residence of these juveniles, we separated scale patterns of returning adults into groups that entered the ocean in fall-winter and those that entered in spring. A fall-winter pattern had no circuli showing freshwater growth after the freshwater annulus or no annulus. A spring pattern showed freshwater growth after the freshwater annulus was completed in late February or early March. Based on these criteria, 54% of the adults that returned from the October release had migrated to the ocean in the spring and 42% had migrated in fall or winter. Four percent could not be separated.

Table 19. Median dates of recapture at the Dalles Dam and in the Columbia River estuary of tagged juvenile spring chinook salmon from Round Butte Hatchery (RBH), 1976-79 broods. The number recaptured is in parentheses.

Brood year, rearing location[a]	Release date	Median date of recapture at: The Dalles Dam	Columbia River estuary
1976 Brood:			
RBH	05/02/77	--	05/30/77 (4)
RBH	06/03/77	--	06/24/77 (6)
1977 Brood:			
RBH	05/31/78	06/14/78 (111)	06/14/78 (98)
RBH	10/04/78	--	11/27/78 (1)
RBH	10/04/78	04/26/79 (79)	04/25/79 (3)
RBH	04/09/79	04/30/79 (284)	04/28/79 (44)
1978 Brood:			
Pelton ladder	05/10/79	06/05/79 (79)	06/06/79 (30)
RBH	05/30/79	06/11/79 (373)	06/08/79 (107)
RBH	04/14/80	04/23/80 (118)	05/02/80 (30)
1979 Brood:			
Pelton ladder	05/12/80	06/03/80 (18)	06/12/80 (2)
Pelton ladder	03/02/81	04/30/81 (16)	05/01/81 (5)
RBH	03/10/81	04/29/81 (10)	04/25/81 (10)
RBH	04/24/81	04/30/81 (32)	05/03/81 (12)

[a] *Fish reared at RBH were trucked below Pelton Reregulating Dam and released. Those in Pelton ladder entered the Deschutes River on their own volition.*

Table 20. Percent return of hatchery chinook salmon to Pelton trap from juveniles released into the Deschutes River, 1966-71 broods.[a] WF = Wizard Falls, OS = Oak Springs, MF = Marion Forks, FR = Fall River. Ad = adipose, RM = right maxillary, LM = left maxillary, LV = left ventral, RV = right ventral, LP = left pectoral, RP = right pectoral.

Brood year, hatchery[b]	Release date	Release site	Fin clip	Return: Adults	Return: Jacks	Return: Total
1966:						
WF	10-11/67	Pelton Reregulating Dam	Ad-RM	0.06	0.09	0.15
OS	06/67	Pelton Reregulating Dam	Ad-LM	0.60	0.97	1.57
1967:						
WF	10/68	Pelton Reregulating Reservoir	Ad-LV	0.17	0.06	0.23
OS	07/68	Pelton Reregulating Reservoir	Ad-RV	0.01	<0.01	0.01
1968:						
WF	11/69	Pelton Reregulating Dam	Ad-RM	0.07	0.01	0.08
WF	07/70	Pelton Reregulating Reservoir	Ad-RM			
OS	07/69	Pelton Reregulating Dam	RV-RM	<0.01	<0.01	0.01
1969:						
WF	12/70-01/71	Pelton Reregulating Dam	LP-LM	0.06	0.06	0.12
WF	01/71	Pelton Reregulating Dam	LP-RM	0.00	0.00	0.00
OS	11/70	Pelton Reregulating Dam	LV-LM	0.06	0.18	0.24
1970:						
WF	03/72	Pelton Reregulating Dam	LV-RP	0.08	0.06	0.14
OS	03/72	Pelton Reregulating Dam	RV-LP	0.11	0.10	0.21
1971:						
FR	03/73	Pelton Reregulating Dam	LV-RV	0.01	<0.01	0.01

[a] No distinction was made between races of chinook salmon, but based on timing into Pelton trap, most were believed to be spring chinook salmon.

Table 21. Percent return of hatchery chinook salmon to Pelton trap from marked juveniles reared at Round Butte Hatchery, 1972-76 broods. D = dorsal, Ad = adipose, LP = left pectoral, RP = right pectoral, LV = left ventral, RV = right ventral, An = Anal, LM = left maxillary.

<table>
<tr><th rowspan="2">Brood year, release date</th><th rowspan="2">Release site</th><th rowspan="2">Mark</th><th colspan="3">Return</th></tr>
<tr><th>Adults</th><th>Jacks</th><th>Total</th></tr>
<tr><td>1972:[a]</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>04/27/73</td><td>Pelton ladder</td><td>D-LP</td><td>0.00</td><td>0.00</td><td>0.00</td></tr>
<tr><td>04/27/73</td><td>Lake Simtustus</td><td>LP</td><td rowspan="2"><0.01</td><td rowspan="2">0.00</td><td rowspan="2"><0.01</td></tr>
<tr><td>06/05/73</td><td>Pelton Reregulating Reservoir</td><td>LP</td></tr>
<tr><td>03/04-05/74</td><td>Pelton Reregulating Dam</td><td>Ad-LP</td><td>0.02</td><td>0.01</td><td>0.03</td></tr>
<tr><td>1973:[a]</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>04/10-16/74</td><td>Lake Simtustus</td><td>LV</td><td><0.01</td><td><0.01</td><td>0.01</td></tr>
<tr><td>04/23/74</td><td>Pelton Reregulating Reservoir</td><td>RV</td><td>0.01</td><td><0.01</td><td>0.01</td></tr>
<tr><td>04/23/74</td><td>Pelton Reregulating Reservoir</td><td>An</td><td rowspan="2">0.01</td><td rowspan="2">0.00</td><td rowspan="2">0.01</td></tr>
<tr><td>05/10/74</td><td>Pelton ladder</td><td>An</td></tr>
<tr><td>06/03/74</td><td>Pelton Reregulating Dam</td><td>D-RP</td><td>0.00</td><td>0.00</td><td>0.00</td></tr>
<tr><td>02/14,18/75</td><td>Pelton Reregulating Dam</td><td>LV-LM</td><td>0.02</td><td>0.04</td><td>0.06</td></tr>
<tr><td>1974:</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>06/03/75</td><td>Pelton Reregulating Dam</td><td>D-LP</td><td>0.00</td><td>0.00</td><td>0.00</td></tr>
<tr><td>10/20/75</td><td>Pelton Reregulating Dam</td><td>D-LV</td><td rowspan="2">0.04</td><td rowspan="2">0.00</td><td rowspan="2">0.04</td></tr>
<tr><td>12/19/75</td><td>Pelton Reregulating Dam</td><td>D-LV</td></tr>
<tr><td>1975:</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>10/05/76</td><td>Pelton Reregulating Reservoir</td><td>Ad+CWT</td><td>0.03</td><td>0.01</td><td>0.04</td></tr>
<tr><td>10/05/76</td><td>Pelton Reregulating Reservoir</td><td>Ad+CWT</td><td>0.02</td><td>0.00</td><td>0.02</td></tr>
<tr><td>06/14/76</td><td>Pelton Reregulating Reservoir</td><td>Ad+CWT</td><td>0.00</td><td>0.00</td><td>0.00</td></tr>
<tr><td>1976:</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>05/02/77</td><td>Pelton Reregulating Dam</td><td>Ad+CWT</td><td><0.01</td><td>0.00</td><td><0.01</td></tr>
<tr><td>06/03/77</td><td>Pelton Reregulating Dam</td><td>Ad+CWT</td><td>0.00</td><td>0.00</td><td>0.00</td></tr>
<tr><td>06/03/77</td><td>Pelton Reregulating Dam</td><td>Ad+CWT</td><td><0.01</td><td>0.00</td><td><0.01</td></tr>
</table>

[a] *No distinction was made between races of chinook salmon, but based on timing into Pelton trap, most were believed to be spring chinook salmon.*

Spring chinook salmon released directly into the Deschutes River returned at a higher rate than those released into Pelton or Pelton Reregulating reservoirs, although differences were not significant ($P > 0.05$). Return rate averaged 0.07% and 0.05% from releases of 1967-76 broods into the river and into the reservoirs, respectively. Returns from releases into Pelton ladder were excluded from this analysis.

Beginning in 1977, some groups of spring chinook salmon at Round Butte Hatchery were incubated in chilled rather than regular hatchery water. As a result, the survival rate of groups in chilled water (slow-incubated) has been consistently higher than that of groups incubated in regular hatchery water (fast-incubated) (Tables 22 and 23).

Until 1980, only fast-incubated subyearling chinook salmon were transferred into Pelton ladder in early spring. These fish were forced out of the ladder prior to June because of the high infectivity of *C. shasta* in summer (Ratliff 1983). Slow-incubated subyearlings (1979 brood) were transferred into the ladder for the first time in November 1980 where they reared until they migrated in early spring 1981.

The survival rate of slow-incubated fish reared in Pelton ladder has been much higher, on the average, than that of groups reared in hatchery ponds (Tables 22 and 23). Fish transferred to the ladder rear under more natural conditions than those reared in ponds (Table 24). Density and loading are lower in the ladder than in the hatchery. Water temperature is variable and the fish migrate on their own volition. All these factors may result in higher survival of fish that rear in the ladder.

The mean rate of return of 1.63% from spring chinook salmon reared in Pelton ladder (Table 22) is higher than that from fish reared in other hatcheries in the Columbia basin. Return rate (including Deschutes River catch) of 1978-83 broods of spring chinook salmon from Warm Springs National Fish Hatchery averaged 0.35% with rates from individual release groups ranging from 0.02% to 0.84% (see Table 29, page 58). Little White Salmon National Fish Hatchery and Carson National Fish Hatchery, which are on tributaries of the Columbia near the Deschutes River, obtained mean return rates (including instream catch) of 0.24% and 0.16%, respectively, for 1977-82 broods. Mullan

Table 22. Mean percent return of spring chinook to Deschutes River fisheries and to Round Butte Hatchery by experimental group, 1977-83 broods.

Experimental group	Number of brood years	Number of releases	Return		
			Adult	Jacks	Total
Fast-incubated:					
Spring subyearling	4	5	0.03	0.00	0.03
Fall subyearling	5	5	0.06	0.12	0.18
Slow-incubated:					
Fall subyearling	5	5	0.21	0.07	0.28
Spring yearling	7	8	0.35	0.13	0.48
Spring yearling, Pelton ladder	5	8	1.28	0.35	1.63

Table 23. Percent return of experimental groups of hatchery spring chinook salmon to Round Butte Hatchery, 1977-83 broods. The return rate in parentheses includes harvest at Sherars Falls.[a]

Experimental group	Release date	Return		
		Adults	Jacks	Total
1977 Brood				
Fast-incubated:				
Spring subyearling	05/31/78	<0.01 (0.01)	0.00 (0.00)	<0.01 (0.01)
Slow-incubated:				
Fall subyearling	10/04/78	0.33 (0.33)	0.09 (0.17)	0.42 (0.50)
Spring yearling	04/09/79	0.15 (0.15)	0.03 (0.06)	0.18 (0.21)
1978 Brood				
Fast-incubated:				
Spring subyearling	05/30/79	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Spring subyearling, Pelton ladder	05/10/79	0.05 (0.05)	0.00 (0.00)	0.05 (0.05)
Slow-incubated:				
Spring yearling	04/14/80	0.29 (0.42)	0.11 (0.13)	0.40 (0.55)
1979 Brood				
Fast-incubated:				
Fall subyearling	10/06/80	<0.01 (<0.01)	0.00 (0.00)	<0.01 (<0.01)
Spring subyearling, Pelton ladder	05/12/80	0.03 (0.04)	0.00 (0.00)	0.03 (0.04)
Slow-incubated:				
Spring yearling	03/10/81	0.22 (0.34)	0.04 (0.12)	0.26 (0.46)
Spring yearling	04/24/81	0.54 (0.76)	0.19 (0.31)	0.73 (1.07)
Spring yearling, Pelton ladder	03/02/81	1.16 (1.62)	0.32 (0.54)	1.48 (2.16)
1980 Brood				
Fast-incubated:				
Fall subyearling	10/05/81	0.01 (0.01)	0.01 (0.01)	0.02 (0.02)
Slow-incubated:				
Fall subyearling	10/05/81	0.02 (0.02)	<0.01 (<0.01)	0.02 (0.02)
Spring yearling	03/23/82	0.04 (0.04)	0.02 (0.02)	0.06 (0.06)
Spring yearling Pelton ladder	03/01/82	0.72 (0.73)	0.15 (0.40)	0.87 (1.13)

[a] *Return rates were calculated from the number of fish in a group that were verified as having an Ad+CWT at release. Fisheries at Sherars Falls were closed in 1981 and 1984.*

Table 23. Continued.

Experimental group	Release date	Return		
		Adults	Jacks	Total
1981 Brood				
Fast-incubated:				
Fall subyearling	10/11/82	<0.01 (<0.01)	0.04 (0.04)	0.04 (0.04)
Slow-incubated:				
Fall subyearling	10/11/82	0.23 (0.35)	0.05 (0.05)	0.28 (0.40)
Spring yearling	03/21/83	0.19 (0.32)	0.07 (0.07)	0.26 (0.39)
Spring yearling, Pelton ladder	03/02/83	1.30 (2.05)	0.34 (0.34)	1.64 (2.39)
Spring yearling, Pelton ladder	03/21/83	1.33 (1.98)	0.38 (0.38)	1.71 (2.36)
1982 Brood[b]				
Fast-incubated:				
Spring subyearling	05/24/83	0.07 (0.07)	0.00 (0.00)	0.07 (0.07)
Fall subyearling	10/06/83	0.01 (0.01)	0.02 (0.07)	0.03 (0.08)
Slow-incubated:				
Fall subyearling	10/05/83	0.06 (0.06)	0.01 (0.02)	0.07 (0.08)
Spring yearling	04/16/84	0.16 (0.16)	0.07 (0.12)	0.23 (0.28)
Spring yearling, Pelton ladder	03/05/84	1.04 (1.04)	0.19 (0.34)	1.23 (1.38)
Spring yearling, Pelton ladder	04/16/84	1.28 (1.28)	0.25 (0.50)	1.53 (1.78)
1983 Brood[b]				
Fast-incubated:				
Fall subyearling	10/09/84	0.17 (0.25)	0.47 (0.47)	0.64 (0.72)
Slow-incubated:				
Fall subyearling	10/08/84	0.17 (0.29)	0.10 (0.10)	0.27 (0.39)
Spring yearling	04/02/85	0.40 (0.61)	0.23 (0.23)	0.63 (0.84)
Spring yearling, Pelton ladder	03/09/85	0.36 (0.67)	0.11 (0.11)	0.47 (0.78)
Spring yearling, Pelton ladder	04/01/85	0.50 (0.86)	0.20 (0.20)	0.70 (1.06)

[b] *No creel survey in 1986.*

Table 24. Comparison of selected rearing conditions for juvenile spring chinook salmon in Pelton ladder and in Round Butte Hatchery.

Rearing condition	Ladder	Hatchery
Density	0.4 lb/cu ft[a]	1.4 lb/cu ft[b]
Loading	7.3 lb/gpm[a]	10.0 lb/gpm[b]
Water temperature (November-April)	Variable, 40°-55°F	Constant, 50°F
Food	Oregon Moist Pellet supplemented with natural food	Oregon Moist Pellet
Migration	Volitional--individual timing, no handling stress	Trucked below reregulating dam

[a] *Values were figured at 210,000 fish at 8 fish/lb in the lower three sections (1,143 ft) of the ladder.*
[b] *Values were figured at 30,000 fish per pond at 6 fish/lb.*

(1982) estimated an overall survival rate (including ocean and Columbia River catch) of 0.6% for hatchery spring chinook salmon based on a study by Wahle et al. (1981) where over 4 million juveniles (1970 and 1971 broods) were marked and released from 21 Columbia basin hatcheries.

Because of the high return rate from the ladder, ODFW started a trial production program at Round Butte Hatchery beginning with the 1984 brood. Under this program, 210,000 juvenile spring chinook salmon (slow-incubated) are transferred to the ladder in November and reared until March or April of the following year. A control group of 60,000 is reared in the hatchery and released as yearlings at the same time as those in the ladder. If returns remain high for ladder-reared fish under this trial production program, then ladder rearing will likely become the standard production program at the hatchery. This should allow PGE to meet their mitigation obligation of 1,200 spring chinook salmon annually to Pelton trap (Figure 21).

Fish released from Round Butte Hatchery return primarily at age 4 (Table 25). Almost 80% of the age 4 returns to the hatchery are female (Table 26).

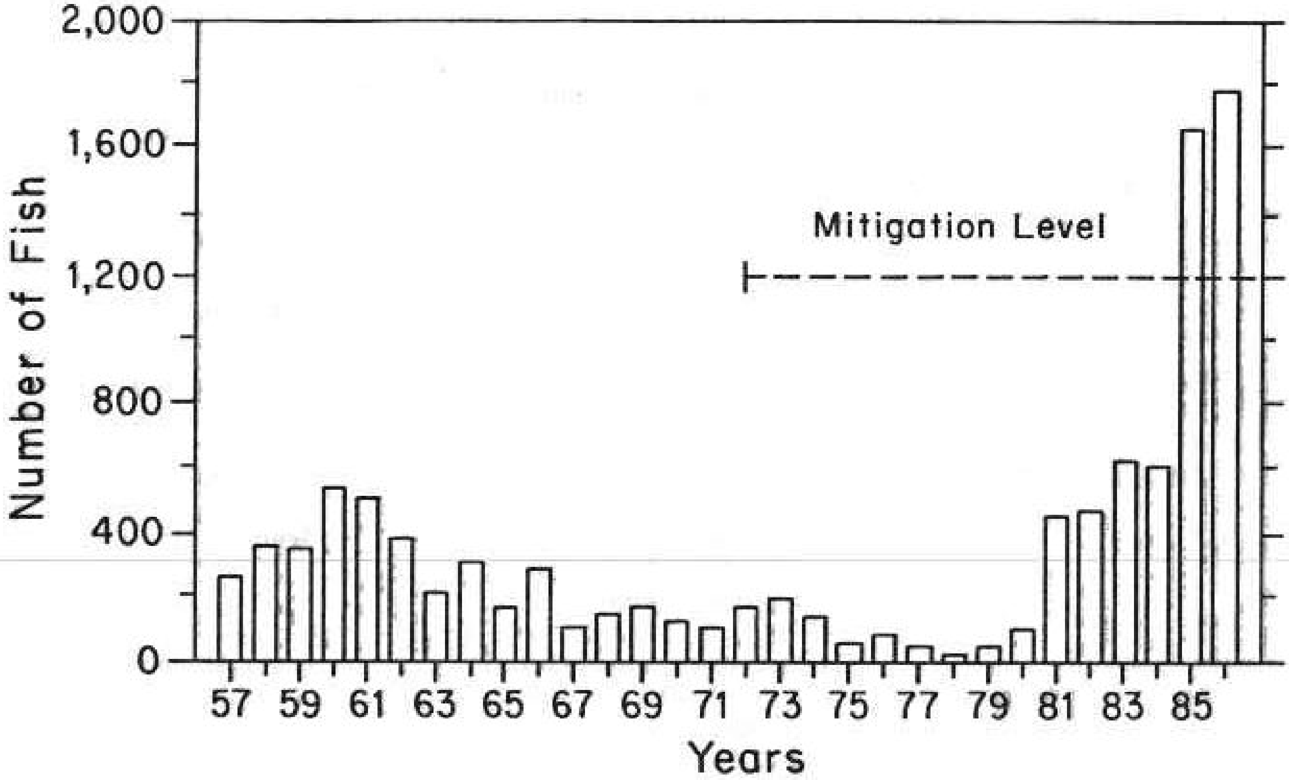

Figure 21. Number of adult and jack spring chinook salmon that entered Pelton trap on the Deschutes River, 1957-86. Counts are tabulated in **APPENDIX E.**

Table 25. Percent age composition of hatchery spring chinook salmon that returned to Round Butte Hatchery, 1977-82 broods.

Brood year	Age 3	Age 4	Age 5	n
1977	21	79	0	284
1978	29	70	1	358
1979	22	76	2	656
1980	18	81	1	259
1981	22	76	2	1,393
1982	19	79	2	1,483

Table 26. Percent sex composition of age 4 hatchery spring chinook salmon that returned to Round Butte Hatchery, 1977-81 broods.

Brood year	Males	Females	n
1977	21	79	261
1978	25	75	277
1979	17	83	525
1980	14	86	234
1981	30	70	1,223

Warm Springs National Fish Hatchery

Original plans were to rear 400,000 spring chinook salmon, 140,000 steelhead, and 154,000 rainbow trout at Warm Springs National Fish Hatchery. Because of severe problems with infectious pancreatic necrosis and glochidia, steelhead and rainbow trout production was reduced in 1981. With the concurrence of the Confederated Tribes of the Warm Springs Reservation of Oregon, production goals were changed to 1.2 million spring chinook salmon and 13,500 rainbow trout.

Run Timing and Broodstock Collection

About 60% of the hatchery spring chinook salmon and 80% of the wild spring chinook salmon arrive at Warm Springs National Fish Hatchery by 31 May (Figure 22). This may be a real difference in migration timing between hatchery and wild fish or the difference may be due to a slowing of migration as fish approach their spawning destination. In the latter case, the migration rate of hatchery fish would slow as they approach the hatchery whereas wild fish would proceed above the hatchery to their spawning destination.

In 1982, the only year when the steeppass fish trap at Sherars Falls was fished and a substantial number of wild and hatchery (Round Butte and Warm Springs National Fish hatcheries) spring chinook salmon returned to the Deschutes, the hatchery run peaked about 1 week later than the wild run at Sherars Falls (Figure 23). Also in 1982 only 33% of the hatchery adults compared with 70% of the wild fish had arrived at Warm Springs National Fish Hatchery by 7 June. By 1 July, 73% of the hatchery adults and 92% of the wild adults had arrived.

The rearing history of the 1978 brood, however, probably explains the difference in migration timing in 1982. Because of mortality prior to spawning, 50% rather than the desired 60% to 70% of the broodstock were fish that had arrived before 1 June. Mechanical failures in the hatchery caused additional losses during incubation. At the time of release, only 6% of the juveniles were from parents that had arrived before 1 June.

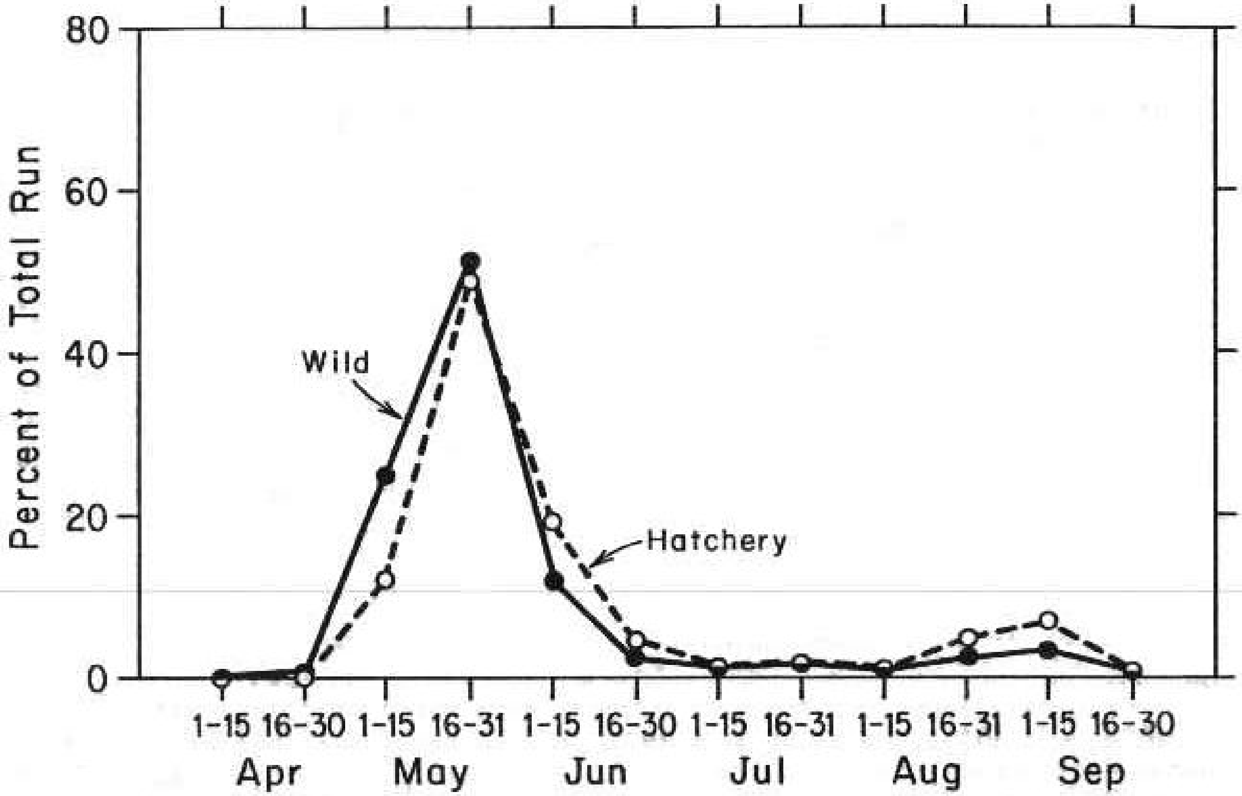

Figure 22. Run timing of wild and hatchery adult spring chinook salmon at Warm Springs National Fish Hatchery, 1983 and 1985-87. The 1980 brood was not marked at the hatchery so return in 1984 was excluded from this comparison.

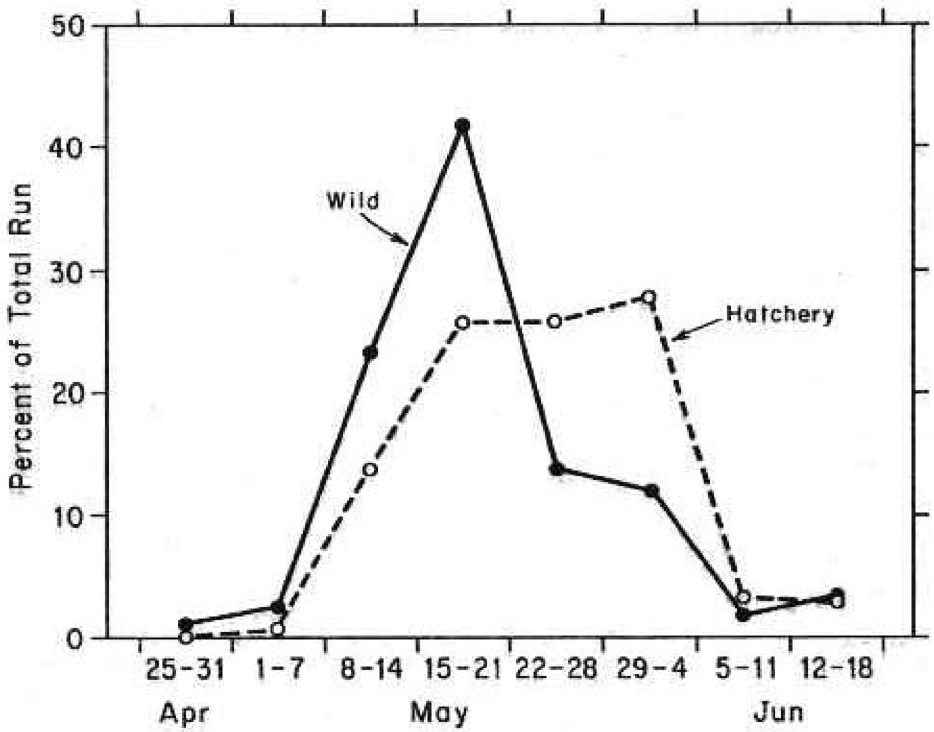

Figure 23. Migration timing of wild and hatchery adult spring chinook salmon at Sherars Falls, 1982.

A difference in migration timing between hatchery and wild fish was also noted for a group of fish that originated from eggs transferred to Warm Springs National Fish Hatchery from Round Butte Hatchery in 1983. Fish from these eggs returned to Warm Springs National Fish Hatchery as adults about 1 week later than wild or hatchery fish that originated in the Warm Springs basin.

Broodstock at Warm Springs National Fish Hatchery are collected randomly throughout the run in proportion to their time of return. Approximately 70% of the broodstock is collected from late April through May with a minimum of 90% collected by 1 July. The hatchery has collected an average of 575 fish each year since it began operation in 1978 (Table 27). Nine hundred to one thousand adults are required for full production depending on the size (fecundity) of females and the sex ratio of the run.

Current Spawning and Rearing Procedures

Ripe fish are sorted and spawned every 5 or 6 days beginning in mid-August until spawning is complete in mid-September. In general, one female is spawned with one male and the eggs (about 3,300 eggs/female on the average) from each pair are incubated separately to reduce bacterial kidney disease in juveniles. Because females outnumber males by about 1.6:1 (Table 27), some males are used to fertilize several females. Fish that exhibit gross signs of bacterial kidney disease are not spawned.

Table 27. Number of spring chinook salmon held and spawned at Warm Springs National Fish Hatchery, 1978-86.

Run year	Adults held for broodstock[a]	Adults spawned		Prespawning mortality (%)	Eggs/ female
		Males	Females		
1978	546	119	206	40	3,355
1979	416	112	187	28	3,647
1980	317	54	112	48	3,443
1981	517	102	162	49	3,435
1982	645	178	358	17	2,680[b]
1983	604	206	301	16	3,089
1984	659	213	339	16	3,124
1985	835	289[c]	430	14	3,028
1986	634	257	282	15	2,850

[a] *Includes only adults used for spawning and those found dead in the pond prior to spawning.*
[b] *Age 4 only.*
[c] *Some males (number not recorded) were discarded because of obvious infections of bacterial kidney disease.*

Eggs from each female are placed in separate incubation units to water harden in a 75 ppm iodophor solution for 30 minutes. Eggs are incubated in chilled water until the temperature of regular hatchery water from the Warm Springs River drops to 52°F. The eggs are then incubated on river water (33°-52°F).

After the eggs have eyed in about 6 weeks, they are shocked, sorted to remove dead eggs, and counted. They are then placed into Heath incubators with about 6,500 eggs to a tray. Eggs hatch in November and the fry are moved to hatchery troughs inside the hatchery building by late December or early January. In March, after they are actively feeding, the fry are transferred outside to Burrows ponds.

Beginning with the 1982 brood, the Confederated Tribes of the Warm Springs Reservation of Oregon has marked all fish released from Warm Springs National Fish Hatchery with ventral fin clips. Fish are marked to allow separation of wild and hatchery spring chinook salmon that return so that only wild fish will be passed above the hatchery. Fish are marked in late April or early May.

By late summer, from 10% to 55% of the juveniles are considerably larger than their counterparts and begin to show characteristics of smolting. Mortality of these fish is high if they are held until spring. Juveniles are graded and the large fish are released in early October at 9-10 fish/lb after being treated with the antibiotic oxytetracycline (OTC). These fish can be identified by the OTC fluorescence in their vertebrae when they return as adults. Small juveniles are reared until mid-April and released at 15-20 fish/lb. Spring chinook salmon are generally released from the hatchery by being forced from the ponds through the fish ladder. Cates (1981) describes a volitional release from the hatchery.

Disease

Although many fish pathogens have been identified in the Warm Springs River (**APPENDIX D**), BKD is the primary disease of spring chinook salmon at Warm Springs National Fish Hatchery as it is at Round Butte Hatchery. The disease has caused mortality in adults and in juveniles since the hatchery began rearing fish in 1978. From 1978 through 1981, the disease caused an average of 41% mortality of broodstock each year (Table 27). Inoculation with the antibiotic erythromycin since 1982 has helped reduce this mortality to 16% annually.

When they arrive at the hatchery, all spring chinook salmon are anesthetized and inoculated with erythromycin at the rate of 11 mg/kg body weight. All fish are dipped in malachite green solution to prevent fungus, and those held for spawning are placed in a holding pond. Wild fish that are passed upstream are allowed to recover in a release channel and to voluntarily swim out of the hatchery. A second inoculation of erythromycin is given to broodstock at least 30 days prior to spawning. Broodstock are periodically treated with formalin or malachite green to control fungus until spawning begins in mid-August.

Bacterial kidney disease generally causes mortality in juveniles from June through August although losses are sometimes high just prior to release in spring. Efforts to reduce juvenile mortality from the disease include: culling broodstock of obviously infected adults; one-to-one spawning of males and females; separate incubation; screening of broodstock by the enzyme-linked immunosorbant assay (ELISA) and the fluorescent antibody technique (FAT); and evaluating diet. Warm Springs National Fish Hatchery does not use feed medicated with erythromycin.

Juvenile Migration

Smolts released from Warm Springs National Fish Hatchery in April (1978 and 1979 broods) passed The Dalles Dam and the Columbia River estuary in April and May with median passage at both locations 3-4 weeks after release (Table 28). Some smolts released in November remained in the Warm Springs or Deschutes rivers until spring before migrating to the ocean.

One tagged juvenile salmon from Warm Springs National Fish Hatchery was recovered in the ocean. The fish was released in April 1980 and was caught in late May 1980 off the mouth of the Columbia River.

Table 28. Median date of recapture at The Dalles Dam and in the Columbia River estuary of tagged spring chinook salmon from Warm Springs National Fish Hatchery, 1978-79 broods. The number recaptured is in parentheses.

Brood year, release date	Median date of recapture at:	
	The Dalles Dam	Columbia River estuary
1978:		
04/01/80	05/07/80 (26)	05/10/80 (8)
04/07/80	05/06/80 (316)	05/08/80 (51)
1979:		
11/06/80	04/30/81 (2)	04/23/81 (2)
04/02/80	04/30/81 (17)	04/15/81 (24)
04/09/80	05/13/81 (319)	05/08/81 (64)

Return Rate

Spring chinook salmon released from Warm Springs National Fish Hatchery returned at rates ranging from 0.02% to 0.84% (Table 29). Groups with the poorest health at release generally returned at the lowest rate. In addition, fin clipping may have contributed to poor returns of the 1982 and 1983 broods. In general, return rate of fish released in fall has been comparable to that of fish released in spring (Table 29).

Table 29. Percent return of hatchery spring chinook salmon to Warm Springs National Fish Hatchery, 1978-83 broods. The return rate in parentheses includes harvest at Sherars Falls.

Group released	Release date	Return		
		Adults	Jacks	Total
1978 Brood:				
Spring yearling	04/1-14/80	0.54 (0.79)	0.05 (0.05)	0.59 (0.84)
1979 Brood:				
Fall subyearling	11/06/80	0.05 (0.06)	0.01 (0.02)	0.06 (0.08)
Spring yearling	04/2-16/81	0.07 (0.09)	<0.01 (<0.01)	0.07 (0.09)
1980 Brood[a]:				
Fall subyearling and spring yearling	11,12/81 and 03/82	0.39 (0.04)	0.01 (0.02)	0.40 (0.42)
1981 Brood[b]:				
Fall subyearling	10/05/81	0.35 (0.52)	0.12 (0.12)	0.47 (0.64)
Spring yearling	04/12/83	0.33 (0.49)	0.03 (0.03)	0.36 (0.52)
1982 Brood[b,c]:				
Fall subyearling	10/24/83	0.04 (0.04)	<0.01 (<0.01)	0.04 (0.04)
Spring yearling	04/13/83	0.01 (0.01)	<0.01 (<0.01)	0.02 (0.02)
1983 Brood[c]:				
Fall subyearling	10/16/84	0.04 (0.06)	0.03 (0.04)	0.07 (0.10)
Spring yearling	04/09/85	0.08 (0.11)	0.02 (0.03)	0.09 (0.14)

[a] *Because the 1980 brood was not marked, return rates were obtained by using fish scales to differentiate between hatchery and wild fish.*

[b] *No creel survey in 1986.*

[c] *Does not include age 5 fish.*

The percentage of age 4 fish is higher and the percentage of age 5 fish lower in broods of hatchery fish than in broods of wild fish in the Warm Springs River (Table 30). The percentage of age 5 hatchery fish by brood year was about one half that of wild fish. Five percent of the 1978-80 brood hatchery returns to Warm Springs National Fish Hatchery were jacks (age 3), higher than the percentage in the wild run. By comparison, age 5 fish averaged only 1% and jacks 23% of the return to Round Butte Hatchery (*see* Table 25, page 52).

Table 30. Percent age composition of hatchery and wild spring chinook salmon in the Warm Springs River, 1978-80 broods.

Brood year	Hatchery fish			Wild fish		
	Age 3	Age 4	Age 5	Age 3	Age 4	Age 5
1978	6	86	8	2	82	15
1979	7	88	5	5	83	12
1980	2	91	7	4	81	15

HARVEST

The Regional Mark Processing Center of the Pacific Marine Fisheries Commission compiles coded-wire tag recoveries from fish sampling programs of California, Oregon, Washington, British Columbia, and Alaska. The center summarizes recoveries in ocean recreational and commercial fisheries; in Puget Sound recreational and net fisheries; in Columbia River recreational, net, and test fisheries; and at USFWS hatcheries.

Columbia and Deschutes rivers fisheries accounted for 67% to 95% of the harvest of 1975-79 brood years of wild and hatchery spring chinook salmon that were coded-wire tagged in the Deschutes River (Table 31). In general, most of the harvest occurred in the Deschutes River (Table 31). Wild fish appeared to contribute more to ocean and Columbia River fisheries than hatchery fish perhaps because a higher percentage of wild fish mature at age 5. However, the difference could also be a function of the few wild fish that were tagged and recovered. The total harvest rate of wild and hatchery spring chinook salmon in ocean and river fisheries averaged 35% (Table 32).

Wahle et al. (1981) reported a much higher percent catch of Deschutes River hatchery spring chinook salmon in ocean fisheries than we found. However, Wahle et al. (1981) failed to account for catch from Deschutes River fisheries, which would have substantially reduced their estimates of the percent contribution to ocean fisheries.

Of the tagged fish from the Deschutes River caught in ocean fisheries, 39% of the wild and 43% of the hatchery fish were caught south of the Columbia River (Table 32). Wahle et al. (1981) reported that 4%-10% of the spring chinook salmon from the Columbia River basin were caught south of the Columbia River. However, Wahle et al. (1981) noted that hatchery spring chinook salmon from the Deschutes River contributed substantially more to California and Oregon fisheries than did most other spring chinook salmon stocks from the Columbia River basin. **APPENDIX F** gives more detailed summaries of catch distribution of wild and hatchery spring chinook salmon from the Deschutes River as well as lengths of fish caught in ocean and freshwater fisheries.

Table 31. Percent distribution of catch of tagged spring chinook from the Warm Springs River (wild, 1977-79 broods), from Round Butte Hatchery (1975-79 broods), and from Warm Springs National Fish Hatchery (1978-79 broods).[a] CA = California, OR = Oregon, WA = Washington, BC = British Columbia, AK = Alaska.

Origin	Ocean fisheries					River fisheries	
	CA	OR	WA	BC	AK	Columbia	Deschutes
Wild	5	8	12	8	0	24	43
Round Butte Hatchery	8	0	5	2	0	10	76
Warm Springs National Fish Hatchery	0	0	2	3	0	8	87

[a] *Detailed summaries are in APPENDIX F.*

Table 32. Catch and escapement (number) of tagged spring chinook salmon from the Warm Springs River (wild, 1977-79 broods), from Round Butte Hatchery (1975-79 broods), and from Warm Springs National Fish Hatchery (1978-79 broods).[a] CA = California, OR = Oregon, WA = Washington, BC = British Columbia, AK = Alaska, CR = Columbia River, DR = Deschutes River.

Origin	Catch in ocean fisheries					Catch in river fisheries		Escape-ment	Harvest rate
	CA	OR	WA	BC	AK	CR	DR		
Wild	5	8	12	8	0	24	44	141	42
Round Butte Hatchery	54	0	33	11	0	68	540	1,431	33
Warm Springs National Fish Hatchery	0	0	12	15	0	49	513	1,368	30

[a] *Detailed summaries are in APPENDIX F.*

On the average, spring chinook salmon were harvested in the Columbia River below Bonneville Dam from late February to early May and above Bonneville Dam primarily in April (Table 33). Although Table 33 shows coded-wire tagged fish were not caught in the Deschutes River until mid-May, creel and trap samples at Sherars Falls show that some spring chinook salmon are

Table 33. Range of yearly median dates that tagged spring chinook salmon appeared in Columbia and Deschutes river fisheries, 1975-79 broods.

Origin	Below Bonneville	Above Bonneville	Deschutes River
Wild (1977-79 broods)	02/25-04/06	04/13-04/21	05/13-05/21
Round Butte Hatchery (1975-79 broods)	03/06-05/02	04/02-04/20	05/13-05/30
Warm Springs National Fish Hatchery (1978-79 broods)	03/03-04/25	04/20-05/10	05/17-05/23

present in the Deschutes in mid-April (*see* **Adult Migration Timing**, page 9). In general, age 5 fish enter the Columbia and Deschutes Rivers first, followed by age 4 and age 3 fish. **APPENDIX G** shows migration timing by age for the brood years that were tagged in the Deschutes River.

Most spring chinook salmon in the Deschutes River are harvested in a 1-mile section from Sherars Falls downstream to the mouth of Buck Hollow Creek. Statistical creel surveys to estimate catch and effort in Indian and recreational fisheries were conducted periodically during the early 1970s and annually from 1976 through 1985. The methods used to calculate catch and effort estimates are shown in **APPENDIX H**.

As the abundance of spring chinook salmon increases in the Deschutes River, the time it takes recreational and Indian fishermen to catch a salmon at Sherars Falls decreases (Figure 24). Run size in the Deschutes River has generally increased since 1982 largely because of Round Butte and Warm Springs National Fish hatcheries (Table 34). As a consequence, catch and effort in recreational and Indian subsistence fisheries at Sherars Falls has also increased (Tables 35 and 36).

Indian and recreational fishermen harvested an average of 29% of the wild spring chinook salmon at Sherars Falls in years when creel surveys were conducted at the falls. They harvested 31% of the hatchery spring chinook salmon in 1982 and 1983, the only years that marked fish returned to both Round Butte and Warm Springs National Fish hatcheries and that complete creel surveys were conducted at Sherars Falls. Recreational fisherman harvest a higher percentage of jacks than Indian fisherman (Table 37).

Three hundred sixteen hatchery adult salmon in 1985 and 461 in 1986 were trucked from Pelton trap to below Sherars Falls during spring to increase catch of hatchery fish. Because only the recreational fishery was surveyed in 1985 and 1986, we estimated total harvest of recycled fish at Sherars Falls by adjusting the recreational catch by the ratio of recreational to Indian catch (2:1). Of the fish released, 14% and 2% were harvested in 1985 and 1986, respectively, in fisheries at Sherars Falls. Evenson and Cramer (1984) estimated that 9.5% of recycled spring chinook salmon in the Rogue River were caught by anglers. In spite of the low percentage caught in the Rogue River, the benefit:cost ratio was still 2.7:1 (Evenson and Cramer 1984). Further evaluation is needed to estimate the benefit:cost ratio of recycling spring chinook salmon in the Deschutes River.

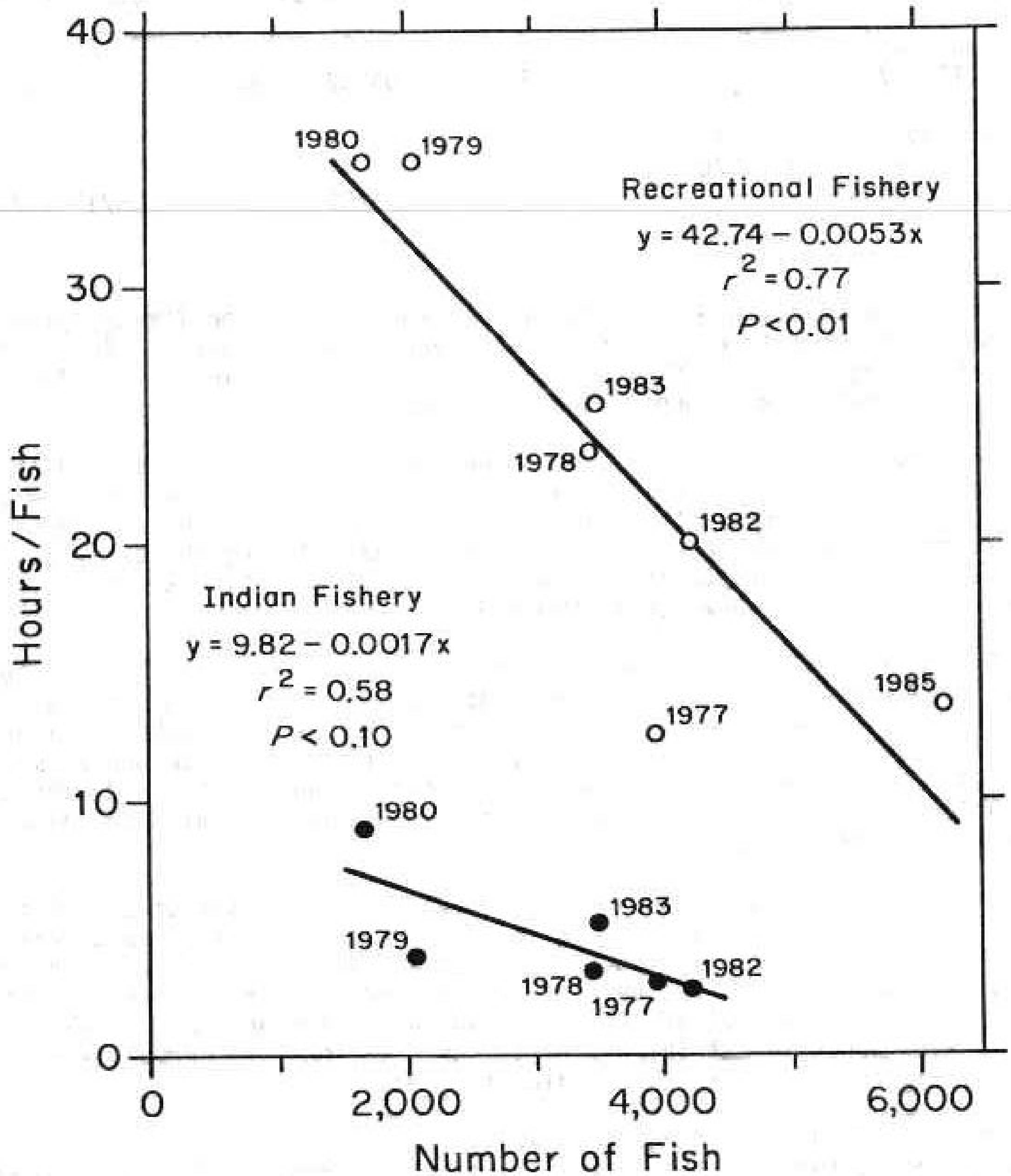

Figure 24. Relationship between run size and catch rate of spring chinook salmon in recreational and Indian fisheries at Sherars Falls.

Table 34. Annual run size of spring chinook salmon in the Deschutes River, 1977-85.[a]

Year	Wild fish	Hatchery fish	Total
1977	3,895	54	3,949
1978	3,460	24	3,484
1979	2,028	50	2,078
1980	1,512	162	1,674
1981	1,575	538	2,113
1982	2,170	2,039	4,209
1983	2,069	1,429	3,498
1984	1,290	1,596	2,886
1985	1,803	4,384	6,187

[a] *Detailed summaries of catch, escapement and return of wild and hatchery fish used to estimate run size are shown in APPENDIX G.*

Table 35. Catch statistics of the recreational fishery for spring chinook salmon at Sherars Falls, 1974-85.[a]

Year	Angler days	Hours fished	Harvest			
			Adults		Jacks	
			Hatchery	Wild	Hatchery	Wild
1974	1,862	9,888	0	332	0	26
1975[b]	0	0	0	0	0	0
1976[b]	0	0	0	0	0	0
1977	3,426	13,899	5	962	2	145
1978	2,525	12,091	0	503	0	9
1979	2,458	12,032	0	304	0	41
1980	2,481	13,845	8	298	52	39
1981[b]	0	0	0	0	0	0
1982	4,093	20,894	416	458	106	57
1983	3,148	16,487	234	311	76	27
1984[b]	0	0	0	0	0	0
1985	4,193	22,321	971	400	208	53

[a] *No creel survey in 1986.*
[b] *Closed to recreational angling.*

Table 36. Catch statistics of the Indian subsistence fishery for spring chinook salmon at Sherars Falls, 1971-84.[a]

Year	Hours fished	Harvest			
		Adults		Jacks	
		Hatchery	Wild	Hatchery	Wild
1971	2,080	0	1,500	0	50
1974	1,872	0	1,026	0	107
1976	4,120	0	941	0	221
1977	1,149	0	383	0	8
1978	569	0	173	0	0
1979	784	0	199	0	0
1980	992	0	113	0	0
1981[b]	0	0	0	0	0
1982	900	126	197	12	4
1983	1,653	106	188	19	2
1984[b]	0	0	0	0	0

[a] *No creel survey in 1972, 1973, 1975, 1985, and 1986.*
[b] *Closed to fishing.*

Table 37. Percent age composition of wild spring chinook salmon in recreational and Indian fisheries at Sherars Falls, 1977-85.

Run year	Recreational fishery			Indian fishery		
	Age 3	Age 4	Age 5	Age 3	Age 4	Age 5
1977	13	84	3	<1	97	3
1978	2	65	33	0	66	34
1979	12	68	20	0	77	23
1980	12	68	20	0	77	23
1981[a]	--	--	--	--	--	--
1982	11	71	18	2	79	19
1983	8	72	20	1	77	22
1984[a]	--	--	--	--	--	--
1985[b]	12	82	6	--	--	--

[a] *Season closed.*
[b] *No creel survey of Indian fishery.*

Table 38 lists the origin of stray, coded-wire tagged spring chinook salmon that have been collected in fisheries at Sherars Falls, at Round Butte Hatchery, and at Warm Springs National Fish Hatchery. Most stray fish in the Warm Springs River originated from Round Butte Hatchery. However, with the exception of 1985 when 23 fish strayed into the Warm Springs, strays from Round Butte Hatchery usually numbered less than 10. In 1985 only three of the 23 strays were recycled fish that were trucked from Round Butte Hatchery and released below Sherars Falls.

Table 38. Origin of stray spring chinook salmon captured in fisheries at Sherars Falls, in Pelton trap, and in the Warm Springs River. OR = Oregon, WA = Washington, ID = Idaho, CA = California.

Origin of mark or tag	Number	Brood years
Cole Rivers Hatchery, OR	9	1976, 1979-81, 1983
Butte Falls Hatchery, OR	2	1977
Carson National Fish Hatchery, WA	1	1978
Leavenworth National Fish Hatchery, WA	2	1978
Lower Granite Dam	4 (wild)	1975, 1978, 1981
Kooskia National Fish Hatchery, ID	11	1975-76, 1978, 1981
McCall Hatchery, ID	1	1981
MacKay Hatchery, ID	1	1977
Rapid River Hatchery, ID	7	1977-78
Trinity River, CA	2	1976, 1981

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APPENDIX A

Location of Spawning Gravel in the Warm Springs River and in Shitike Creek

Small pockets of salmon spawning gravel exist from Warm Springs National Fish Hatchery downstream to the lower end of Kahneetah Village. This area has not been heavily used by chinook salmon with the exception of the drought year 1977. Incubation temperature greater than 56°F may result in low survival (Leitritz and Lewis 1980)[1] below Warm Springs National Fish Hatchery. Fine sediment may also limit spawning success in this area.

The area from the hatchery upstream to Badger Creek (RM 27) consists of large pools separated by boulder-strewn rapids and runs. Very little spawning gravel is present in this area. Most of the spawning in the Warm Springs River occurs above Badger Creek. Excellent spawning gravel is scattered throughout the area from below Hehe (RM 31) to the upper end of Warm Springs Meadow (RM 39).

In Mill Creek little spawning gravel exists below the confluence of Boulder Creek (RM 4). In 1977 approximately 13,000 sq ft of spawning habitat existed between Boulder Creek and Potters Pond. Floods since that time have severely scoured the upper part of this section and current spawning habitat is now probably less than 13,000 sq ft. The loss of spawning habitat below Potters Pond was probably offset when the dam at Potters Pond washed out and allowed access to the upper part of the basin. The stream above Strawberry Falls, accessible since 1984, contains pockets of suitable gravel with excellent spawning areas in the upper portion that are currently not being used. Some outplanting of adults from Warm Springs National Fish Hatchery has occurred in these areas.

Spawning gravel in Beaver Creek is widely scattered in the canyon between Simnasho Bridge (RM 7) and the confluence with the Warm Springs River. Scattered pockets of spawning gravel exist above Simnasho Bridge with the highest concentration from the Dahl Pine area upstream to Robinson Park. Beaver dams reduce the number of adult chinook salmon that reach Robinson Park and upstream spawning areas in some years.

In Shitike Creek spawning habitat is primarily located in the lower 6 miles of the creek and in the vicinity of the Bennett Place (RM 8). Since the headworks at RM 6 for the town of Warm Springs was removed in 1983, no major block to the upstream migration of spring chinook salmon exists in Shitike Creek.

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[1] Leitritz, E., and R.C. Lewis. 1980. Trout and salmon culture (hatchery methods). University of California, California Fish Bulletin Number 164, Berkeley.

APPENDIX B

Number of Wild Juvenile Spring Chinook Salmon Coded-Wire Tagged in the Warm Springs and Deschutes Rivers, 1978-80

Dates tagged	Number released	Brood year	Release site	Capture method	Mean fork length (mm)	Tag code[a]
Apr-Jun 1978	140	1976	Warm Springs River to Sherars Falls	Seine	130.0	H7 02 01
Apr-Jun 1978	8	1976	Pelton to Warm Springs River	Seine	110.0	H7 02 04
Apr-Jun 1978	301	1976	Sherars Falls to mouth	Seine	120.0	H7 02 05
Apr-Jun 1978	835	1976	Warm Springs River	Trap	107.8	07 16 05
May-Jun 1978	335	1977	Warm Springs River	Trap	84.3	07 16 05
Sep-Dec 1978	921	1977	Warm Springs River	Trap	96.1	07 16 07
May-Jun 1979	118	1978	Warm Springs River	Trap	83.1	07 18 29
Sep-Dec 1979	4,655	1978	Warm Springs River	Trap	87.5	07 18 30
Feb-May 1979	280	1977	Sherars Falls to mouth	Seine	120.5	07 18 31
Dec 1979	1,514	1978	Warm Springs River	Trap	88.6	07 18 32
Feb-Jun 1979	1,099	1977	Warm Springs River to Sherars Falls	Seine	131.5	07 18 33
Mar-Jun 1979	96	1977	Deschutes River RM 50	Trap	128.0	07 18 38
Feb-Jun 1979	1,599	1977	Warm Springs River	Trap	107.0	07 18 39
Mar-Jun 1979	41	1977	Deschutes River RM 1	Trap	125.0	07 18 40
Jul-Aug 1979	2,775	1978	Beaver Creek (Warm Springs River)	Seine	59.2	07 20 29
Sep-Nov 1979	636	1978	Warm Springs River RM 2-7	Seine	94.0	07 20 30
May-Jun 1980	116	1979	Warm Springs River	Trap	86.9	07 21 48
Feb-Jun 1980	3,827	1978	Warm Springs River	Trap	102.4	07 21 49
Feb-May 1980	384	1978	Deschutes River RM 50	Trap	116.7	07 21 51
Feb-Mar 1980	2,672	1978	Warm Springs River to Sherars Falls	Seine	101.9	07 21 52
Apr-Jun 1980	1,347	1978	Warm Springs River to Sherars Falls	Seine	112.6	07 18 47

[a] "H" indicates half-length coded-wire tags.

APPENDIX C

Releases of Hatchery Spring Chinook Salmon into the Lower Deschutes Basin

Appendix Table C-1. Releases of juvenile spring chinook salmon into the Deschutes River, 1966-71 broods.[a] WF = Wizard Falls, OS = Oak Springs, MF = Marion Forks, FR = Fall River. Ad = adipose, RM = right maxillary, LM = left maxillary, LV = left ventral, RV = right ventral, LP = left pectoral, RP = right pectoral.

Brood year, hatchery	Release date	Release site	Number released	Size at release (fish/lb)	Fin clip
1966:					
WF	10-11/67	Pelton Reregulating Dam	71,150	6.2	Ad-RM
OS	06/67	Pelton Reregulating Dam	9,900	11.0	Ad-LM
1967:					
WF	10/68	Pelton Reregulating Reservoir	66,557	5.2	Ad-LV
OS	07/68	Pelton Reregulating Reservoir	40,103	9.3	Ad-RV
MF[b]	01/68	Pelton ladder	24,685	1,200.0	No mark
1968:					
WF	02/69	Lake Simtustus	150,168	133.4	No mark
WF	02/69	Pelton ladder	100,036	107.5	No mark
WF	02-03/69	Pelton Reregulating Reservoir	103,935	90.8	No mark
WF	11/69	Pelton Reregulating Dam	56,557	6.2	Ad-RM
WF	07/70	Pelton Reregulating Reservoir	220	2.8	Ad-RM
OS	05/69	Pelton Reregulating Reservoir	40,470	38.0	No mark
OS	07/69	Pelton Reregulating Dam	54,230	8.5	RV-RM
1969:					
WF	03/70	Lake Simtustus	149,588	91.0	No mark
WF	03-04/70	Pelton ladder	104,107	95.0	No mark
WF	06/70	Pelton Reregulating Reservoir	22,600	100.0	No mark
WF	12/70-01/71	Pelton Reregulating Dam	36,797	4.8	LP-LM
WF	01/71	Pelton Reregulating Dam	10,163	4.5	LP-RM
OS	05/70	Pelton Reregulating Reservoir	8,905	36.8	No mark
OS	11/70	Pelton Reregulating Dam	51,792	4.2	LV-LM
1970:					
WF	03/71	Lake Simtustus	150,000	100.0	No mark
WF	03/71	Pelton Reregulating Reservoir	90,206	97.0	No mark
WF	03/71	Pelton Reregulating Reservoir	8,472	120.0	No mark
WF	03/72	Pelton Reregulating Dam	61,013	5.9	LV-RP
OS	06/71	Pelton Reregulating Dam	20,510	70.0	No mark
OS	03/72	Pelton Reregulating Dam	52,730	5.9	RV-LP
1971:					
WF	04/72	Lake Simtustus	165,229	79.0	No mark
OS	04/72	Pelton ladder	71,258	117.0	No mark
FR	03/73	Pelton Reregulating Dam	117,853	6.7	LV-RV

[a] No distinction was made between races of chinook salmon, but most were believed to be spring chinook salmon.

[b] Santiam River stock.

Appendix Table C-2. Releases of salmon into Warm Springs basin and Shitike Creek, 1957-72.

Year released, species or race of salmon	Origin	Release site	Number released	Size
1957:				
Sockeye	Leavenworth	Long Lake	30,000	Fingerling
1958:				
Coho	Little White Salmon	Warm Springs River	106,600	Eggs
Spring chinook	Carson	Warm Springs River	100,000	Eggs
Fall chinook	Spring Creek	Warm Springs River	300,000	Eggs
1961:				
Spring chinook	Carson	Warm Springs River	75,313	Subsmolts
1962:				
Spring chinook	Carson	Quartz Creek	150,000	1,000 fish/lb
1963:				
Coho	Unknown	Beaver Creek	225,000	Eggs
1964:				
Coho	Eagle Creek and Oxbow	Beaver Creek	685,400	Eggs
Spring chinook	McKenzie River	Warm Springs River	399,000	Fry
Spring chinook	McKenzie River	Mill Creek	232,000	Fry
Spring chinook	McKenzie River	Beaver Creek	66,000	Fry
1965:				
Coho	Carson	Warm Springs River	515,000	60 fish/lb
Coho	Carson	Badger Creek	34,425	25 fish/lb
Coho	Carson	Beaver Creek	100,000	--
Spring chinook	Eagle Creek	Warm Springs River	500,044	196 fish/lb
Coho	Unknown	Warm Springs River	34,325	25 fish/lb
1966:				
Coho	Unknown	Shitike Creek	417	Adults
Spring chinook	Eagle Creek	Warm Springs River	200,000	200 fish/lb
Spring chinook	Eagle Creek	Warm Springs River	500,000	1,700 fish/lb
Coho	Unknown	Beaver Creek	500,000	Eggs
1967:				
Spring chinook	Eagle Creek	Warm Springs River	211,500	34 fish/lb
Fall chinook	Little White Salmon	Warm Springs River	502,500	1,139 fish/lb
Coho	Unknown	Shitike Creek	450	Adults
1968:				
Fall chinook	Little White Salmon	Warm Springs River	1,000,000	856 fish/lb
Spring chinook	Round Butte	Warm Springs River	470,340	Eggs
Chinook	Unknown	Shitike Creek	121	Adults
Coho	Unknown	Shitike Creek	717	Adults
1969:				
Spring chinook	Carson	Warm Springs River	450,017	Eggs
1970:				
Chinook	Carson	Warm Springs River	24,906	Eggs
Chinook	Round Butte	Beaver Creek	65	Adults
Chinook	Round Butte	Beaver Creek	207	Jacks
Coho	Round Butte	Beaver Creek	1	Adult
Sockeye	Round Butte	Beaver Creek	19	Adults
1971:				
Chinook	Round Butte	Warm Springs River	155,426	Eggs
1972:				
Chinook	Round Butte	Warm Springs River	80,000	Eggs

Appendix Table C-3. Releases of juvenile spring chinook salmon from Round Butte Hatchery into the Deschutes River 1972-84 broods.[a] D = dorsal, LP = left pectoral, RP = right pectoral, Ad = adipose, LV = left ventral, RV = right ventral, An = anal, LM = left maxillary.

Brood year, release date	Release site	Number released	Size at release (fish/lb)	Fin clip or coded-wire tag code
1972:[b]				
04/27/73	Pelton ladder	50,122	76.6	D-LP
04/27 73	Lake Simtustus	182,283	63.7	LP
06/05/73	Pelton Reregulating Reservoir	65,678	50.6	LP
03/04-05/74	Pelton Reregulating Dam	145,214	6.7-7.2	Ad-LP
1973:[b]				
04/10-16/74	Lake Simtustus	81,110	65.0	LV
04/19/74	Lake Simtustus	65,635	61.0	No mark
04/23/74	Pelton Reregulating Reservoir	81,704	61.1	No mark
04/23/74	Pelton Reregulating Reservoir	86,775	65.0	No mark
04/23/74	Pelton Reregulating Reservoir	1,320	60.0	An
05/10/74	Pelton ladder	23,964	55.0	An
06/03/74	Pelton Reregulating Dam	61,560	26.2	D-RP
06/11/74	Lake Billy Chinook	15,000	75.0	No mark
02/14-18/75	Pelton Reregulating Dam	103,629	5.5	LV-LM
1974:				
06/03/75	Pelton Reregulating Dam	20,150	30.0	D-LP
10/20/75	Pelton Reregulating Dam	4,267	5.6	D-LV
12/19/75	Pelton Reregulating Dam	14,448	13.0	D-LV
1975:				
10/05/76	Pelton Reregulating Reservoir	27,579	9.3	09 04 06
10/05/76	Pelton Reregulating Reservoir	12,051	9.3	09 04 07
1976:				
05/02/77	Pelton Reregulating Dam	62,040	40.0	09 16 01 and 09 16 02
06/03/77	Pelton Reregulating Dam	36,675	25.0	09 16 03
06/03/77	Pelton Reregulating Dam	35,625	25.0	09 16 04
1977:				
05/31/78	Pelton Reregulating Dam	47,802	28.4	07 16 11
05/31/78	Pelton Reregulating Dam	47,598	32.3	07 16 12
05/31/78	Pelton Reregulating Dam	26,394	23.7	07 16 15
10/04/78	Pelton Reregulating Dam	26,640	13.0	07 16 54
10/04/78	Pelton Reregulating Dam	25,908	13.2	07 16 55
04/09/79	Pelton Reregulating Dam	42,000	9.1	07 16 53

[a] Experimental releases totaling 70,013 were made into Pelton ladder from 1975 to 1979 (1974-77 broods) to determine migration timing but were not included in this table.

[b] Race was not differentiated but most were believed to be spring chinook salmon.

Appendix Table C-3. Continued.

Brood year, release date	Release site	Number released	Size at release (fish/lb)	Fin clip or coded-wire tag code
1978:				
05/10/79	Pelton ladder[c]	14,579	19.7	07 18 24
05/30/79	Pelton Reregulating Dam	54,300	22.0	07 18 25
04/14/80	Pelton Reregulating Dam	32,865	8.0	07 19 49
04/14/80	Pelton Reregulating Dam	30,758	8.8	07 19 50
04/14/80	Pelton Reregulating Dam	29,993	8.0	07 19 51
1979:				
05/12/80	Pelton ladder[c]	22,245	20.0	07 21 53
10/06/80	Pelton Reregulating Dam	29,264	5.9	07 21 54
03/10/81	Pelton Reregulating Dam	30,450	7.3	07 23 10
04/24/81	Pelton Reregulating Dam	29,200	4.9	07 23 09
03/02/81	Pelton ladder[d]	25,446	8.8	07 23 11
1980:				
10/05/81	Pelton Reregulating Dam	48,472	5.7	07 23 47
10/05/81	Pelton Reregulating Dam	29,430	11.4	07 23 49
03/02/82	Pelton ladder[d]	28,656	5.9	07 23 48
03/23/82	Pelton Reregulating Dam	25,010	4.8	07 23 50
1981:				
10/11/82	Pelton Reregulating Dam	28,538	6.4	07 25 20
10/11/82	Pelton Reregulating Dam	59,118	23.6	07 27 15
03/21/83	Pelton Reregulating Dam	57,340	9.3	07 27 14
03/02/83	Pelton ladder[d]	48,495	12.2	07 27 16
03/21/83	Pelton ladder[d]	24,847	12.2	07 27 17
1982:				
05/24/83	Pelton Reregulating Dam	28,979	19.2	07 28 36
10/05/83	Pelton Reregulating Dam	53,550	16.3	07 28 43
10/06/83	Pelton Reregulating Dam	28,200	5.6	07 28 37
04/16/84	Pelton Reregulating Dam	28,790	5.2	07 28 39
04/16/84	Pelton Reregulating Dam	28,991	5.2	07 28 40
03/05/84	Pelton ladder[d]	54,000	9.5	07 28 42
04/15/84	Pelton ladder[d]	51,000	8.4	07 28 41
1983:				
10/08/84	Pelton Reregulating Dam	60,797	12.4	07 31 31
10/09/84	Pelton Reregulating Dam	30,394	6.5	07 31 32
04/02/85	Pelton Reregulating Dam	57,749	5.8	07 31 28
03/09/85	Pelton ladder[d]	60,725	7.6	07 31 29
04/01/85	Pelton ladder[d]	60,770	7.6	07 31 30
1984:				
03/12/86	Pelton Reregulating Dam	62,952	5.7	07 33 20
03/11/86	Pelton ladder[d]	65,931	7.7	07 33 21
03/11/86	Pelton ladder[d]	75,349	7.7	LV-LM
03/11/86	Pelton ladder[d]	73,529	7.7	LP

[c] Fish were transferred from the hatchery to Pelton ladder in March and allowed to migrate on their own volition beginning on the release date.

[d] Fish were transferred from the hatchery to Pelton ladder in late October or early November and allowed to migrate on their own volition beginning on the release date.

Appendix Table C-4. Releases of juvenile spring chinook salmon from Warm Springs National Fish Hatchery into the Warm Springs River, 1978-83 broods. OTC = one oxytetracycline mark; 2-OTC = two oxytetracycline marks; RV = right ventral; LV = left ventral.

Brood year, release date	Number released	Size at release (fish/lb)	Mark or coded-wire tag code
1978:			
04/7-14/80	168,000	19	05 6 27
04/1-14/80	10,890	19	05 6 28
1979:			
11/06/80	26,852	9	05 8 20
11/06/80	27,816	9	05 8 21
04/02/81	66,700	8	05 8 22
04/09-16/81	170,167	18	05 8 23
04/02/81	32,300	8	05 8 24
04/09/81	88,970	20	05 8 25
1980:			
11/16-12/18/81[a]	65,303	12	No mark
03/29/82	142,884	12	No mark
1981:			
10/05/82	68,557	10	OTC[b]
10/05/82[b]	13,965	10	RV; OTC
10/05/82[b]	25,950	6	LV; OTC
04/12/83	154,954	15	2-OTC
04/12/83[b]	27,645	15	LV; 2-OTC
04/12/83[b]	27,257	15	RV; 2-OTC
1982:			
10/24/83	61,864	9	LV; OTC
04/13/84	625,995	18	LV
1983:			
10/16/84[b]	345,544	9	RV; OTC
10/16/84[b]	77,937	10	LV; OTC
04/09/85[b]	321,194	19	RV
04/09/85[b]	61,650	17	LV
1984:[c]			
10/01/85	46,822	9	RV
10/01/85	279,001	9	LV
04/09/86	62,011	17	RV; OTC
04/09/86	358,353	17	LV; OTC

[a] *Volitional release.*
[b] *Fish obtained from Round Butte Hatchery.*
[c] *Fish with low levels of bacterial kidney disease were given an RV fin clip. Those with moderate levels, an LV fin clip.*

APPENDIX D

Parasites and Diseases of Spring Chinook Salmon in Hatcheries in the Lower Deschutes Basin

Appendix Table D-1. Parasites and diseases of spring chinook salmon in Round Butte Hatchery.

Parasites	Bacterial and viral diseases
Ceratomyxa shasta *Myxidium minteri*	Bacterial kidney disease (*Renibacterium salmoninarum*) Furunculosis (*Aeromonas salmonicida*) Cold water disease (*Cytophaga psychrophila*) Infectious hematopoietic necrosis Viral erythrocytic necrosis

Appendix Table D-2. Parasites and diseases of spring chinook salmon in Warm Springs National Fish Hatchery.

Parasites	Bacterial and viral diseases
Glochidia *Sanguinicola* *Nanophyetus* *Hexamita* *Ichthyobodo* *Scyphidia* *Epistylis* *Neascus* (black spot) *Ceratomyxa shasta* *Salminicola wardi* Miracidia	Bacterial kidney disease (*Renibacterium salmoninarum*) Furunculosis (*Aeromonas salmonicida*) Columnaris (*Flexibacter columnaris*) Cold water disease (*Cytophaga psychrophila*) *Pseudomonas* Gill disease Infectious hematopoietic necrosis Viral erythrocytic necrosis

APPENDIX E

Number of Spring Chinook Salmon that Entered Pelton Trap in the Deschutes River, 1957-86

Run year	Adults	Jacks	Total
1957	211	48	259
1958	359	7	366
1959	287	71	358
1960	488	59	547
1961	440	71	511
1962	363	24	387
1963	164	46	210
1964	284	34	318
1965	139	26	165
1966	295	3	298
1967	97	6	103
1968	117	29	146
1969	124	49	173
1970	111	16	127
1971	112	0	112
1972	56	115	171
1973	97	95	192
1974	124	5	129
1975	31	24	55
1976	41	43	84
1977	39	8	47
1978	20	4	24
1979	45	5	50
1980	54	48	102
1981	375	78	453
1982	370	93	463
1983	576	47	623
1984	272	332	604
1985	1,388	261	1,649
1986	1,549	315	1,864

APPENDIX F

Catch Distribution and Escapement of Spring Chinook Salmon From the Deschutes River

Appendix Table F-1. Estimated catch and escapement of wild spring chinook salmon coded-wire tagged in the Deschutes River, 1977-79 broods.[a] CA = California, OR = Oregon, WA = Washington, BC = British Columbia, AK = Alaska, CR = Columbia River, DR = Deschutes River.

Location, time of of tagging	Ocean fisheries					River fisheries		Escapement in DR	Harvest rate (%)
	CA	OR	WA	BC	AK	CR	DR		
Warm Springs River, fall	5	0	0	0	0	0	15	41	33
Warm Springs River, spring	0	0	9	8	0	12	7	40	47
Deschutes River, spring	0	8	3	0	0	12	22	60	43

[a] *Although some 1976 brood fish were coded-wire tagged, none were recovered.*

Appendix Table F-2. Estimated catch and escapement by age and brood year of tagged wild spring chinook salmon, 1977-79 broods. CA = California, OR = Oregon, WA = Washington, BC = British Columbia, AK = Alaska, CR = Columbia River, DR = Deschutes River.

Brood year, location, and time of tagging	Age 3							Age 4							Age 5							Escapement		
	CA	OR	WA	BC	AK	CR	DR	CA	OR	WA	BC	AK	CR	DR	CA	OR	WA	BC	AK	CR	DR	Age 3	Age 4	Age 5
1977:																								
Warm Springs, fall	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
Warm Springs, spring	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	7	0	0	4	2
Deschutes, spring	0	0	0	0	0	0	0	0	2	3	0	0	2	0	0	0	0	0	0	0	0	1	3	0
1978:																								
Warm Springs, fall	5	0	0	0	0	0	0	0	0	0	0	0	0	11	0	0	0	0	0	0	4	3	30	6
Warm Springs, spring	0	0	0	0	0	0	0	0	0	0	0	0	3	7	0	0	0	0	0	2	0	0	25	7
Deschutes, spring	0	0	0	0	0	0	0	0	6	0	0	0	7	14	0	0	0	0	0	3	8	1	36	19
1979:																								
Warm Springs, spring	0	0	0	8	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	2	0	0
Total	5	0	0	8	0	0	0	0	8	12	0	0	12	32	0	0	0	0	0	12	12	7	100	34

Appendix Table F-3. Percent distribution of catch of coded-wire tagged wild spring chinook salmon, 1977-79 broods. CA = California, OR = Oregon, WA = Washington, BC = British Columbia, AK = Alaska, CR = Columbia River, DR = Deschutes River.

Brood year	Percentage catch by area						
	CA	OR	WA	BC	AK	CR	DR
1977	0	11	42	0	0	47	0
1978	7	9	0	0	0	21	63
1979	0	0	33	67	0	0	0

Appendix Table F-4. Estimated catch and escapement by release group of tagged spring chinook salmon from Round Butte Hatchery, 1975-79 broods. CA = California, OR = Oregon, WA = Washington, BC = British Columbia, AK = Alaska, CR = Columbia River, DR = Deschutes River.

Incubation type, time of release, age	Ocean fisheries					River fisheries		Escapement	Harvest rate (%)
	CA	OR	WA	BC	AK	CR	DR[a]		
Fast, spring, subyearling[b]	48	0	4	0	0	0	6	21	73
Fast, fall, subyearling[c]	0	0	0	0	0	1	0	15	6
Slow, fall, subyearling	0	0	0	0	0	18	44	250	20
Slow, spring, yearling	0	0	15	0	0	30	310	759	32
Slow, spring, yearling, Pelton Ladder[d]	6	0	14	11	0	19	180	386	37
Total	54	0	33	11	0	68	540	1,431	33

[a] *Fisheries were closed in 1981 and 1984 which affected catch of some age groups.*
[b] *Eleven percent of the juvenile releases were from Pelton ladder.*
[c] *Juveniles were released into Pelton Reregulating Reservoir.*
[d] *Fish reared at RBH are trucked below Pelton Reregulating Dam and released. Those in Pelton ladder entered the Deschutes River on their own volition.*

Appendix Table F-5. Estimated catch and escapement by age and brood year of tagged spring chinook salmon from Round Butte Hatchery, 1975-79 broods.[a] CA = California, OR = Oregon, WA = Washington, BC = British Columbia, AK = Alaska, CR = Columbia River, DR = Deschutes River.

Brood year, rearing location	Date of release	Age 3							Age 4							Age 5							Escapement		
		CA	OR	WA	BC	AK	CR	DR	CA	OR	WA	BC	AK	CR	DR	CA	OR	WA	BC	AK	CR	DR	Age 3	Age 4	Age 5
1975:																									
RBH	10/76	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	3	12	0
1976:																									
RBH	05/77	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0[b]	1	0	0
RBH	06/77	27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0[b]	1	0	0
1977:																									
RBH	05/78	0	0	2	0	0	0	4	0	0	0	0	0	0	0[b]	0	0	0	0	0	0	0	4	0	0
RBH	10/78	0	0	0	0	0	1	44	0	0	0	0	0	17	0[b]	0	0	0	0	0	0	0	52	197	0
RBH	04/79	0	0	0	0	0	0	13	0	0	0	0	0	0	0[b]	0	0	0	0	0	0	0	13	63	0
1978:																									
Pelton ladder	05/79	0	0	2	0	0	0	0[b]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	3	0
RBH	05/79	0	0	0	0	0	0	0[b]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RBH	04/80	0	0	0	0	0	0	17[b]	0	0	0	0	0	7	117	0	0	0	0	0	0	0	107	274	5
1979:																									
Pelton ladder	05/80	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0[c]	5	1	0
Pelton ladder	03/81	0	0	0	0	0	0	54	6	0	14	11	0	17	126	0	0	0	0	0	2	0[c]	83	297	6
RBH	10/80	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0[c]	0	0	1
RBH	03/81	0	0	0	0	0	0	24	0	0	0	0	0	2	38	0	0	0	0	0	0	0[c]	11	68	1
RBH	04/81	0	0	8	0	0	9	35	0	0	7	0	0	8	66	0	0	0	0	0	4	0[c]	56	159	2
Total		48	0	12	0	0	10	193	6	0	21	11	0	52	347	0	0	0	0	0	6	0	342	1,074	15

[a] Fish reared at RBH are trucked below Pelton Regulation Dam and released. Fish reared in Pelton ladder enter the Deschutes River on their own volition.

[b] Fishery closed until 22 June.

[c] Fishery closed until 18 June.

Appendix Table F-6. Percent distribution of catch of tagged spring chinook salmon from Round Butte Hatchery, 1975-79 broods. CA = California, OR = Oregon, WA = Washington, BC = British Columbia, AK = Alaska, CR = Columbia River, DR = Deschutes River.

Brood year	Percentage catch by area						
	CA	OR	WA	BC	AK	CR	DR
1975	0	0	0	0	0	100	0
1976	100[a]	0	0	0	0	0	0
1977	0	0	3	0	0	22	75
1978	0	0	1	0	0	5	93
1979	1	0	7	3	0	10	79
Total	8	0	5	2	0	10	75

[a] *Fast-incubated, age 0, spring release.*

Appendix Table F-7. Estimated catch and escapement by release group of coded-wire tagged spring chinook salmon from Warm Springs National Fish Hatchery, 1978-79 broods. CA = California, OR = Oregon, WA = Washington, BC = British Columbia, AK = Alaska, CR = Columbia River, DR = Deschutes River.

Time, age of release	Ocean fisheries					River fisheries		Escape-ment	Harvest rate (%)
	CA	OR	WA	BC	AK	CR	DR		
Fall, subyearling	0	0	0	3	0	3	10	34	32
Spring, yearling	0	0	12	12	0	46	503	1,334	30

Appendix Table F-8. Estimated catch and escapement by age and brood year of coded-wire tagged spring chinook salmon from Warm Springs National Fish Hatchery, 1978-79 broods. CA = California, OR = Oregon, WA = Washington, BC = British Columbia, AK = Alaska, CR = Columbia River, DR = Deschutes River.

Brood year, date of release	Age 3							Age 4							Age 5							Escapement		
	CA	OR	WA	BC	AK	CR	DR	CA	OR	WA	BC	AK	CR	DR	CA	OR	WA	BC	AK	CR	DR	Age 3	Age 4	Age 5
1978:																								
04/01/80	0	0	0	0	0	0	0[a]	0	0	0	0	0	2	34	0	0	0	0	0	0	7	0	83	9
04/07/80	0	0	3	0	0	0	10[a]	0	0	2	0	0	19	373	0	0	0	8	0	15	19	85	810	80
1979:																								
11/06/80	0	0	0	0	0	0	4	0	0	0	0	0	0	6	0	0	0	3	0	3	0[b]	6	27	1
04/02/81	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0[b]	2	13	0
04/09/81	0	0	0	0	0	0	0	0	0	5	4	0	3	60	0	0	0	0	0	7	0[b]	13	220	19
Total	0	0	3	0	0	0	14	0	0	7	4	0	24	473	0	0	2	11	0	25	26	106	1,153	109

[a] Fishery closed until 22 June.
[b] Fishery closed until 18 June.

Appendix Table F-9. Percent distribution of catch of coded-wire tagged spring chinook salmon from Warm Springs National Fish Hatchery, 1978-79 broods. CA = California, OR = Oregon, WA = Washington, BC = British Columbia, AK = Alaska, CR = Columbia River, DR = Deschutes River.

Brood year	Percentage catch by area						
	CA	OR	WA	BC	AK	CR	DR
1978	0	0	1	2	0	7	90
1979	0	0	7	7	0	13	73

Appendix Table F-10. Fork length (cm) of tagged Deschutes River spring chinook salmon harvested in ocean and freshwater fisheries. RBH = Round Butte Hatchery, WSNFH = Warm Springs National Fish Hatchery.

Age	Ocean			Freshwater		
	Mean	Range	*N*	Mean	Range	*N*
			Wild chinook salmon (1977-79 broods)			
3	63.5	--	1	--	--	--
4	71.2	52-79	5	70.4	65-74	15
5	--	--	--	82.5	78-85	7
			RBH chinook salmon (1975-79 broods)			
3	60.3	40-70	7	54.7	40-72	313
4	68.3	65-74	6	72.1	50-90	1,126
5	--	--	--	85.8	80-102	8
			WSNFH chinook salmon (1978-79 broods)			
3	55.0	--	1	49.7	34-67	76
4	68.0	67-69	2	70.0	50-88	422
5	77.6	60-90	4	81.0	66-93	68

APPENDIX G

Dates That Spring Chinook Salmon From the Deschutes River Were Harvested in Columbia River and Deschutes River Fisheries

Appendix Table G-1. Median date of harvest in Columbia River and Deschutes River fisheries of tagged wild spring chinook salmon from the Deschutes River, 1977-79 broods. Number of fish observed is in parentheses.

Age, brood year	Below Bonneville Dam	Above Bonneville Dam	Deschutes River
Age 4:			
1977	--	04/13 (2)	(a)
1978	04/06 (3)	04/21 (1)	05/13 (10)
1979	--	--	--
Age 5:			
1977	03/31 (1)	--	--
1978	02/25 (2)	--	05/21 (5)
1979	--	--	(b)

[a] *Fishery closed until 22 June.*
[b] *Fishery closed until 18 June.*

Appendix Table G-2. Median dates of harvest in Columbia River and Deschutes River fisheries of tagged spring chinook salmon from Round Butte Hatchery, 1975-79 broods. Number of fish observed is in parentheses.

Age, brood year	Below Bonneville Dam	Above Bonneville Dam	Deschutes River
Age 3:			
1977	--	04/08 (1)	05/17 (29)
1978	--	--	(a)
1979	05/02 (1)	--	05/30 (72)
Age 4:			
1975	--	04/14 (1)	--
1977	04/08 (2)	04/02 (7)	(a)
1978	04/16 (6)	--	05/21 (32)
1979	04/10 (14)	04/20 (7)	05/13 (95)
Age 5:			
1976	--	--	(a)
1979	03/06 (3)	--	(b)

[a] *Fishery closed until 22 June.*
[b] *Fishery closed until 18 June.*

Appendix Table G-3. Median date of harvest in Columbia River and Deschutes River fisheries of tagged spring chinook salmon from Warm Springs National Fish Hatchery, 1978-79 broods. Number of fish observed is in parentheses.

Age, brood year	Below Bonneville Dam	Above Bonneville Dam	Deschutes River
Age 3:			
1978	--	--	(a)
1979	--	--	05/23 (2)
Age 4:			
1978	04/25 (8)	05/10 (1)	05/17 (146)
1979	04/08 (1)	04/28 (2)	05/19 (25)
Age 5:			
1978	03/03 (4)	04/20 (1)	05/18 (10)
1979	03/06 (5)	--	(b)

[a] *Fishery closed until 22 June.*
[b] *Fishery closed until 18 June.*

APPENDIX H

Methods for Estimating Salmon Harvest in the Deschutes River

Recreational Fishery:

For half-month interval h (h = 1, 2 . . . H) let

N_h = number of days in half-month sample interval,

n_h = number of sample days in half-month interval,

X_{hik} = number of fish of species k caught on day i (i = 1, 2 . . . n_h),

f_h = n_h/N_h = sampling fraction for half-month interval h, and

$\bar{X}_{hk} = \sum_{i=1}^{n_h} X_{hik})/n_h$ = mean daily catch of species k in half-month interval h.

Estimates are made separately for weekends and weekdays. Two randomly selected weekdays and one alternating weekend day are sampled each week. All anglers on a sample day are interviewed. Total catch of species k in interval h is estimated by

$$\hat{X}_{hk} = N_h \bar{X}_{hk}.$$

Variance for catch of species k in interval h is estimated by

$$S^2_{x_{hk}} = \frac{1}{n_h - 1} \sum_{i=1}^{n_h} (X_{hik} - \bar{X}_{hk})^2,$$

$$V(\bar{X}_{hk}) = \frac{S^2_{x_{hk}}}{n_h} (1-f_h), \text{ and}$$

$$V(\hat{X}_{hk}) = V(\bar{X}_{hk}) N^2{}_h.$$

Season total of catch of species k is estimated by

$$\hat{X}_k = \sum_{h=1}^{H} N_h \bar{X}_{hk} = \sum_{h=1}^{H} \hat{X}_{hk}.$$

Season variance is estimated by

$$\hat{V}(\hat{X}_k) = \sum_{h=1}^{H} \hat{V}(\hat{X}_{hk}).$$

Final season catch estimate is made by summing the season total catch for weekends and weekdays. Confidence interval is calculated by pooling the season variances for the weekend and weekday estimates.

$$95\% \text{ confidence interval} = \hat{X}_k \pm t_{0.05} \sqrt{\Sigma V (\hat{X}_k)}$$

where the number of degrees of freedom is approximated by $\sum_{h=1}^{H} (n_h - 1)$.

Indian Fishery:

Each day is divided into six, 4-hour time blocks. Depending on the length of the creel, about eight to ten of each of the six time blocks are randomly sampled throughout the season. All fisherman within a time block are interviewed. Estimates are made separately for each time block and these estimates are summed to obtain the final season estimate.

The six time blocks are:

1 = 0000-0400 hours	4 = 1200-1600 hours
2 = 0400-0800 hours	5 = 1600-2000 hours
3 = 0800-1200 hours	6 = 2000-2400 hours

N_h = number of times that block h (h = 1, 2, . . . 6) occurs during the season.

N_h = 46 when season is 16 April-31 May,
N_h = 61 when season is 16 April-15 June.

n_h = number of times that block h is sampled during the season.

X_{hik} = number of fish of species k caught in block h on day i (i = 1, 2 . . . n_h).

Y_{hi} = number of nets observed in block h on day i.

Z_{hi} = number of fisherman hours in block h on day i.

f_h = n_h/N_h = sampling fraction for block h.

$\bar{X}_{hk} = (\sum_{i=1}^{n_h} X_{hik})/n_h$ = mean daily catch of fish species k during block h.

$\bar{Y}_h = (\sum_{i=1}^{n_h} Y_{hi})/n_h$ = daily mean for nets observed during block h.

$\bar{Z}_h = (\sum_{i=1}^{n_h} Z_{hi})/\ n_h$ = daily mean for fishermen hours during block h.

$\hat{X}_{hk} = N_h\bar{X}_{hk}$ = total catch of fish species k during block h.

$\hat{Y}_h = N_h\bar{Y}_h$ = total nets fished during block h.

$\hat{Z}_h = N_h\bar{Z}_h$ = total fishermen hours during block h.

$\hat{X}_k = \sum_{h=1}^{6} N_h\bar{X}_{hk} = \sum_{h=1}^{6} \hat{X}_{hk}$ = season total catch of fish species k.

$\hat{Y} = \sum_{h=1}^{6} N_h\bar{Y}_h = \sum_{h=1}^{6} \hat{Y}_h$ = season total nets fished

$\hat{Z} = \sum_{h=1}^{6} N_h\bar{Z}_h = \sum_{h=1}^{6} \hat{Z}_h$ = season total fisherman hours.

Variance and Confidence interval:

$S^2_{x_{hk}} = \frac{1}{n_h - 1} \sum_{i=1}^{n_h} (X_{hik} - \bar{X}_{hk})^2$ = sample variance for catch of fish type K in block h,

$V(\bar{X}_{hk}) = \frac{S^2_{x_{hk}}}{n_h} (1-f_h)$ = variance of the mean in block h,

$V(\hat{X}_{hk}) = V(\bar{X}_{hk})\ N^2_h$ = variance of the total in block h,

$V(\hat{X}_k) = \sum_{h=1}^{6} V(\hat{X}_{hk})$ = variance of the season total.

$$95\% \text{ confidence interval} = \hat{X}_k \pm t_{0.05} \sqrt{V(\hat{X}_k)} \text{ with d.f.} = \sum_{h=1}^{6} (n_h - 1)$$

The variance and confidence interval for Y(nets) and Z (fisherman hours), were estimated by substituting the appropriate variables in the above formulas for X_{hk} and X_k.

APPENDIX I

Run Size Estimates of Spring Chinook Salmon in the Deschutes River

Appendix Table I-1. Number of wild spring chinook salmon (adults and jacks) in the Deschutes River, 1977-85. RBH = Round Butte Hatchery, WSNFH = Warm Springs National Fish Hatchery.

Run year	Indian catch	Recreational catch	Broodstock for RBH	Escapement to WSNFH	Total
1977	391	1,107	194	2,203[a]	3,895
1978	173	512	115	2,660	3,460
1979	199	345	89	1,395	2,028
1980	113	337	60	1,002	1,512
1981[b]	0	0	0	1,575	1,575
1982	201	515	0	1,454	2,170
1983	190	338	0	1,541	2,069
1984[b]	0	0	0	1,290	1,290
1985	195[c]	453	0	1,155	1,803

[a] *Includes an estimated 603 fish (201 redds x 3 fish/redd) that spawned below Warm Springs National Fish Hatchery.*
[b] *Fisheries closed.*
[c] *No creel survey of the Indian fishery, catch was estimated from the mean ratio of Indian to recreational catch in 1977-80 and 1982-83.*

Appendix Table I-2. Number of hatchery spring chinook salmon (adults and jacks) in the Deschutes River, 1977-85. RBH = Round Butte Hatchery, WSNFH = Warm Springs National Fish Hatchery.

Run year	Indian catch	Recreational catch	Return to: RBH	Return to: WSNFH	Total
1977	0	7	47	0	54
1978	0	0	24	0	24
1979	0	0	50	0	50
1980	0	60	102	0	162
1981[a]	0	0	453	85	538
1982	138	522	463	916	2,039
1983	125	310	623	371	1,429
1984[a]	0	0	604	992	1,596
1985	477[b]	1,179	1,649	1,079	4,384

[a] *Fisheries closed.*
[b] *No creel survey of the Indian fishery, catch was estimated from the mean ratio of Indian to recreational catch of wild fish in 1977-80 and 1982-83.*