Study of Wild Spring Chinook Salmon

in the John Day River System

1985 Final Report

by

R.B. Lindsay
W.J. Knox
M.W. Flesher
B.J. Smith
E.A. Olsen
L.S. Lutz

Oregon Department of Fish and Wildlife

506 S.W. Mill Street, P.O. Box 59

Portland, Oregon 97207

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ABSTRACT

A study of wild spring chinook salmon was conducted in the John Day River, Oregon, from 1978 through 1985. The objectives of the study were to (1) recommend harvest regulations to achieve escapement goals in the John Day River: (2) recommend adjustments in timing of fish passage operations at Columbia River dams that will increase survival of John Day migrants; (3) recommend habitat or environmental improvements that will increase production of spring chinook salmon; (4) determine escapement goals for wild spring chinook salmon in the John Day River; and (5) recommend procedures for hatchery supplementation in the John Day River in the event it becomes necessary to artificially maintain the run of spring chinook salmon.

Juveniles were captured as smolts during migration with scoop traps and beach seines and as fingerlings during summer rearing with beach seines. Juveniles were coded-wire tagged, and recoveries of tagged adults were used to assess contribution to ocean and Columbia River fisheries, timing of adult migrations through the Columbia River in relation to fishing seasons, and age and size of fish in fisheries, Scoop traps and seines were also used to determine timing of smolt migrations through the John Day River. In addition, recoveries of tagged smolts at John Day Dam, The Dalles Dam, and Jones Beach were used to determine migration timing through the Columbia River. We examined freshwater life history of spring chinook salmon in the John Day River and related it to environmental factors. We looked at adult holding areas, spawning, incubation and emergence, fingerling rearing distribution, size and growth of juveniles and scales. Escapement goals for the John Day River as well as reasons for declines in John Day stocks were determined by using stock-recruitment analyses. Recommmendations for hatchery supplementation in the John Day were based on results from other study objectives.

Only one ocean recovery of a coded-wire tagged spring.chinook salmon from the John Day River was reported during this study. Apparently, John Day spring salmon are not harvested to any significant degree in ocean fisheries. These findings are consistent with findings from upriver releases of hatchery spring chinook in Idaho. Also, no recoveries of marked John Day River chinook salmon came from sport or commercial fisheries in the Columbia River. Adults from the John Day River move through the Columbia River in April and May and the present fishing seasons will not affect John Day stocks as long as dates of the seasons remain the same.

Peak migration of smolts past Spray (km 274) in the John Day River occurred primarily during the first 2 weeks of April. Numbers migrating (1978-82 broods) ranged from 64,000 to 169,000 smolts annually. Movement of John Day smolts through the Columbia River occurred from mid-April through June. Measures to enhance passage at Columbia River dams should be implemented during this time period.

Holding areas used by adultchinook salmon-in the John Day River were pools with a depth greater than 1.5 m and with escape cover such as undercut banks, fallen trees,. boulders, or vegetation. The distribution of redds within spawning ground index areas varied annually in the Middle and North forks. The variation in distribution was related to variation in streamflow in the Middle Fork but not in the North Fork. Recommendations for adding additional survey sections to the index areas in the Middle and North forks are made so that these annual counts are better indicators of spawner abundance., Adult spring chinook salmon recovered as carcasses during spawning surveys, were primarily age 4. Virtually all of the adults sampled had migrated to the ocean in their second year (age 1).

In most years emergence of spring chinook salmon occurred from about mid-March to mid-June. 'Timing of emergence varied among forks of the John Day River and was related more to differences in water temperature's and accumulated thermal units than to differences in time of spawning. The distribution of fingerlings in the John Day basin was most extensive in late spring and early summer and least extensive in late summer. Distribution moved upstream as water temperature increased through summer.

No harvestable surplus of spring chinook salmon is currently being produced in the John Day River. The adult progeny returning to spawn have not been replacing themselves since the 1970 brood, and the system is currently underseeded. Declines since the 1970 brood are attributed to John Day Dam. With the possible exception of the mainstem John Day River, instream habitat improvement will not increase production of spring chinook salmon in the John Day basin until survival during passage through the Columbia River is increased. An escapement goal of 3,700 spawners to the John Day River should fully seed the habitat presently available in the basin.

Recommendations for hatchery supplementation are given in the event it becomes necessary to artificially maintain John Day stocks.-

INTRODUCTION

The John Day River,, Oregon, supports one of the few remaining runs of wild spring chinook salmon *(Oncorhgkchus* ***tshawytscha)*** in the Columbia basin. Hatchery-reared spring chinook salmon have never been released into the John Day River 'basin. The genetic resource represented by this wild stock must be maintained for the 'most effective use of spring chinook salmon habitat in the John Day River and for posible future restoration of spring chinook salmon runs in other Columbia River tributaries. Maintenance and restoration of wild runs of anadromous fish in the Columbia River 'basin is a major goal identified in the Northwest Power Planning Councils Columbia River Basin Fish and Wildlife Program (Anonymous' 1984a).

Spawning ground surveys conducted by the Oregon Department of Fish and Wildlife (ODFW) indicate that runs of adult spring chinook salmon into the John Day River have been declining since 1974. With the possible exception of the mainstem John Day River, escapement in recent years is far below that required to fully seed juvenile rearing areas. Escapement indexes in the early 1980s were among the lowest recorded in the John Day River system since the early 1960s. This decline has occurred in all upriver stocks of spring chinook salmon in the Columbia basin '(Anonymous 1984b).

Losses of migrating smolts and, adults at John Day, The Dalles, and Bonneville dams are a major cause 'of 'the depressed state of spring chinook salmon runs in the John Day River. The adverse effects of dams on migrating salmon(Hamilton and Andrew 1954; Schoeneman and Junge 1954; Schoeneman et al. 1961; Raymond 1969, 1979; Merrell et al. 1971,; Sims et al, 1978; Gibson et al, 1979; Damkaer 1983;. Damkaer and Dey 1984, 1985) and the resulting changes in stock-recruitment relationships for Columbia River stocks (Junge and Oakle 1966; Junge 1970; Salo and Stober197-7) have been well documented; Additional turbine construction and changes in operational procedures at dams, such as reduced spills, may intensify these problems in the future.

Plans for mitigating losses through hatchery production in the Columbia'and Snake rivers will likely result in increased fishing pressure on Columbia River stocks and increase the potential for overharvesting of wild fish. This could accelerate the decline of John Day River stocks unless measures can be found to offset or control harvest.

Habitat for spring chinook salmon in the John Day basin has been degraded'by extensive mining,' logging, and overgrazing, and by water withdrawals for irrigation, These impacts have reduced the amount,of suitable spawning and rearing habitat'for spring chinook salmon in the John Day River. Private landowners and public agencies have been working with ODFW in recent years to improve'instream conditions for resident and anadromous fishes. However, much of the instream habitat remains in poor condition.

ODFW began a study of Wild spring chinook salmon in the John Day River in 1978 to make recommendations that would minimize losses of juveniles and adults outside the system and enhance production within the basin, In the event that the stock cannot. be maintained naturally, data from this study and the literature were used to recommend a hatchery supplementation program for John Day River spring chinook salmon., The specific objectives of the John Day salmon study were (1) recommend harvest regulations to achieve escapement goals in the John Day River; (2) recommend adjustments in timing of fish passage operations at Columbia River dams that will increase survival of John Day River migrants; (3) recommend habitat or environmental improvemnts that will, increase the production of spring chinook salmon smolts; (4) determine escapement goals for wild spring chinook salmon in the John Day River; and, (5) recommend procedures for hatchery supplementation in the John Day River in the event it becomes necessary to artificially maintain the run of spring chinook salmon.

STUDY AREA

The John Day, River drains 20,300 sq km in east central Oregon,,. the third largest drainage area in thes tate (Figure l)., The John Day'basin includes the major part of Grant,' Wheeler, and Gilliam counties, and portions of Harney, Crook, Jefferson, Wasco, Sherman, Morrow, Umatilla, and Union counties From its source, in the Strawberry Mountains at an elevation near 1,800 m, the John Day River flows 457 km toits mouth at km 351'on the Columbia River The basin is bounded by the columbia River to the north, the Strawberry and Aldrich mountains to the south;' the Ochoco Mountains to the west, and the Blue Mountains to'the' east.

The main John Day River (hereafter called Mainstem) down to Picture Gorge near Dayville constitutes the Upper John Day Valley 2). Picture Gorge extends about 32 km along the Mainstem to Kimberly (Figure, 1) and creates a natural divide between the upper and' lower basin. The lower John 'Day River' from Service Creek downstre'am to Tumwater Falls (240 km) is included in the Oregon State Scenic Waterways System (Figure 1).

The largest tributary in the John Day basin is the North Fork John Day River (herepfter,called the North Fork), which enters the Mainstem at Kimberly (km 296,) and extends upstream 180 km to its headwaters in the Blue Mountains (Figure 3), Ttie Middle Fork Jdhn Day River (hereafter called the Middle Fork) originates just south of the North 'Fork and roughly parallels it for 120 km until they merge about 50 km above Kimberly (Figure .4), Other major tributaries, include Rock Creek .(km 35) South Fork John Day River (km 341), and Canyon Creek (km 399; Figure I)

The climate of the John Day basin is 'semiarid.,' The lower plateaus and valleys have a cover of native grasses, sage brush, and. junipers; The higher elevations are forested with mixed pines and firs. The major industries in the area are cattle ranching, lumbering, mining, tourism, and recreation. Much of the upper John Day Valleyconsists of irrigated pasture and hay fields. More than 2,500 water rights, mostly for irrigation, exist in the upper Mainstem and its tributaries (Anonymous 1985).

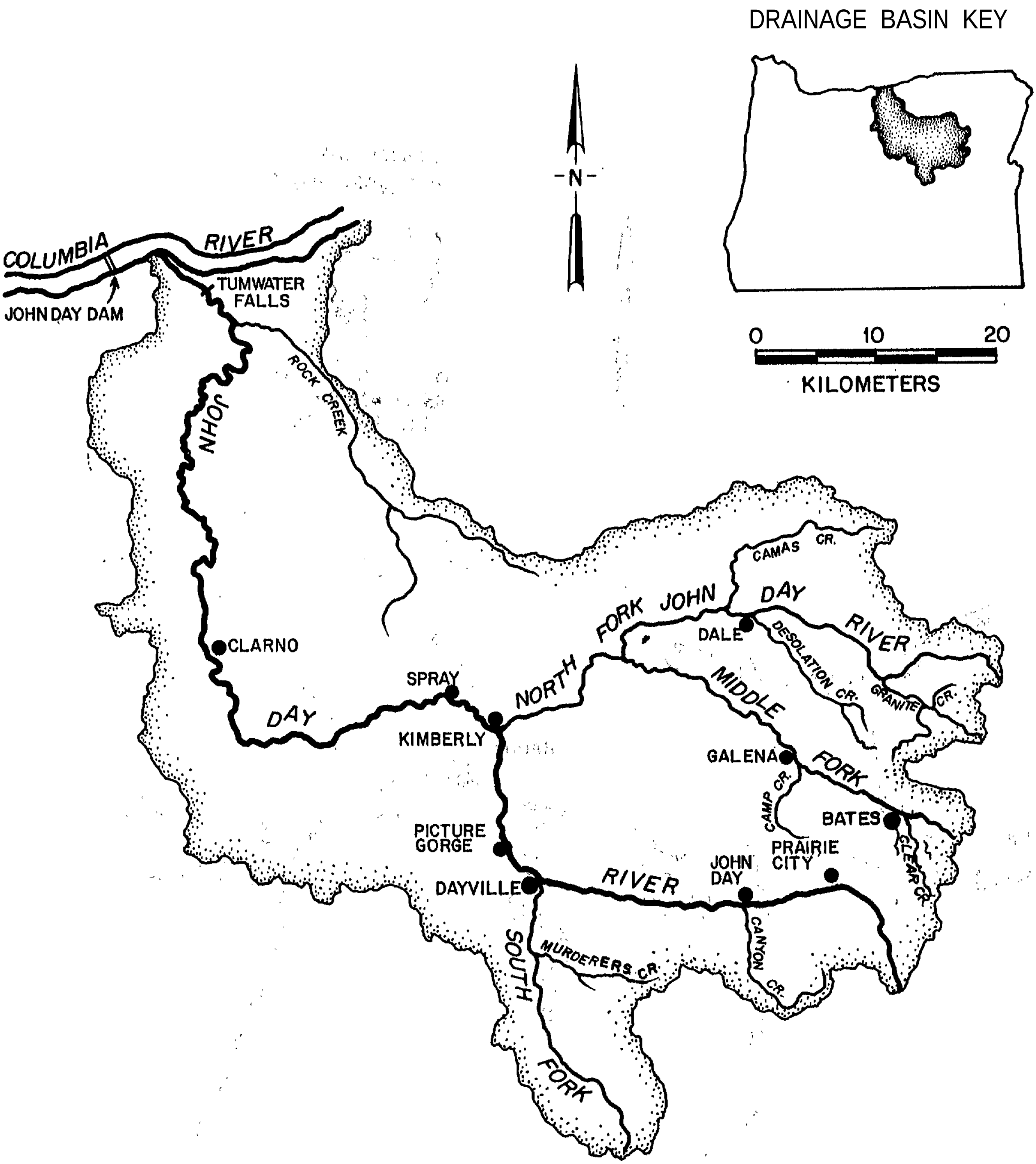

Figure 1. Map of John Day basin.

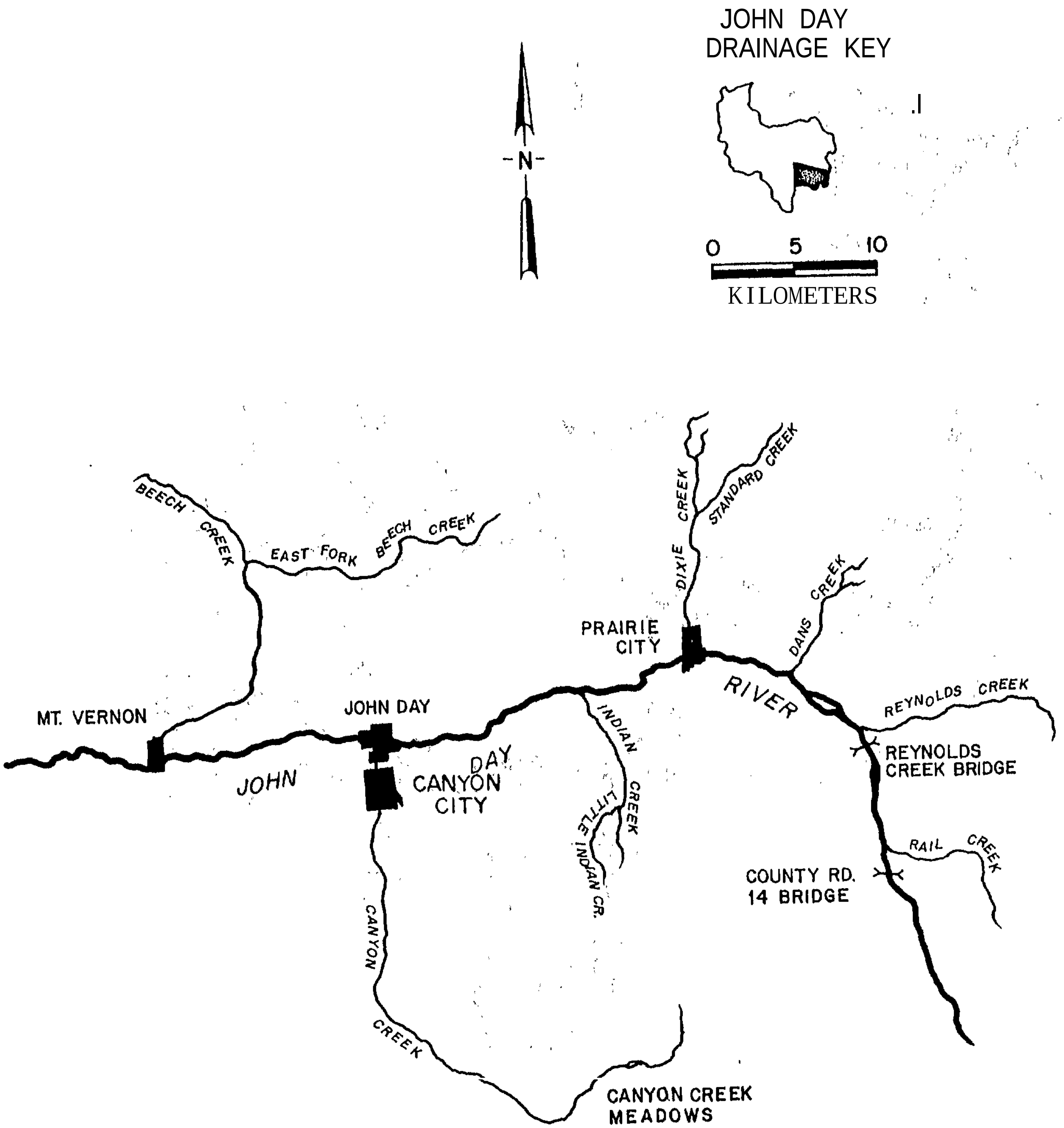

Figure 2. Map of upper Mainstem John Day River.

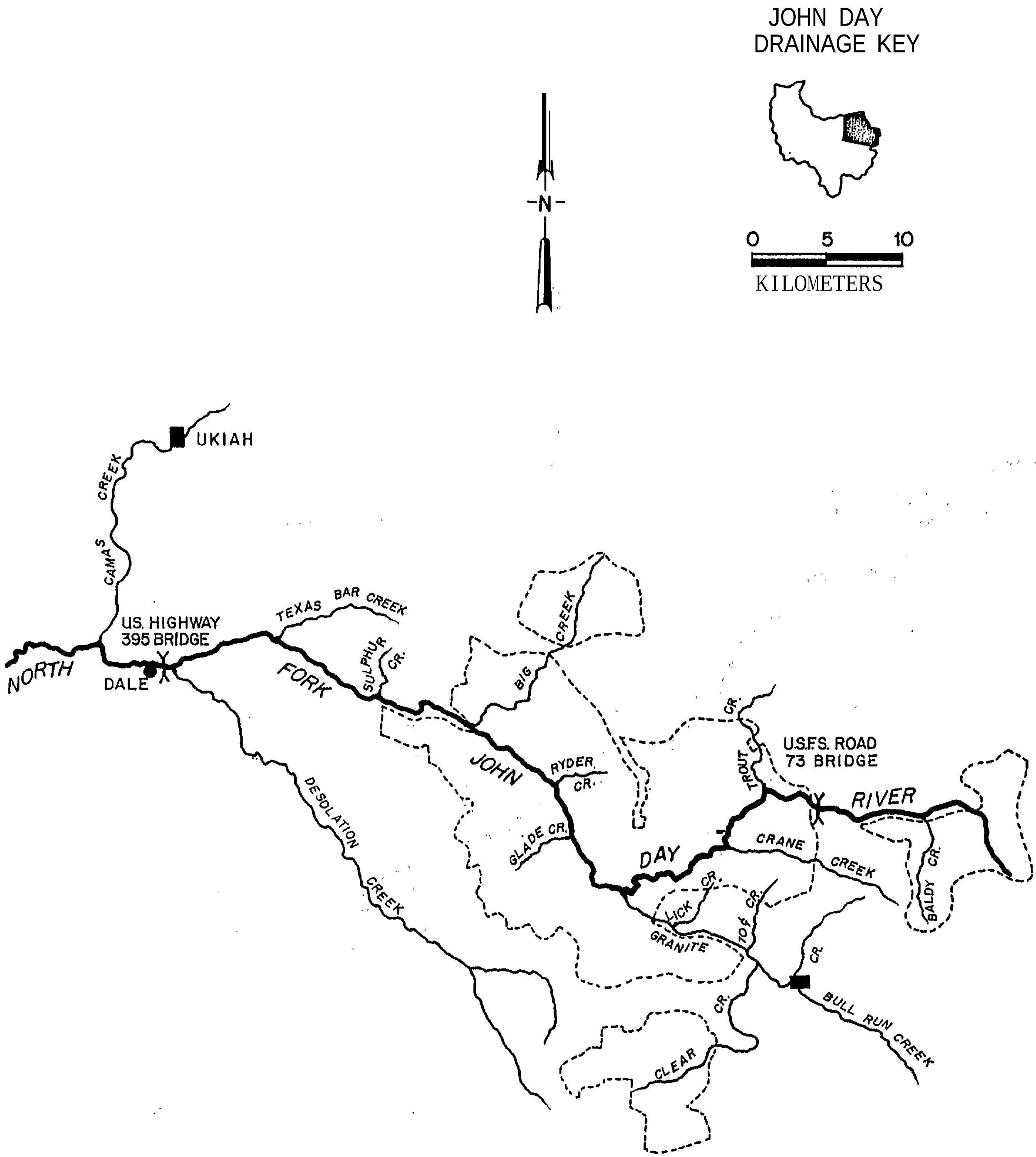

Figure 3. Map of the North Fork John Day River. Dashed line denotes boundaries of North Fork,John,Day wilderness.

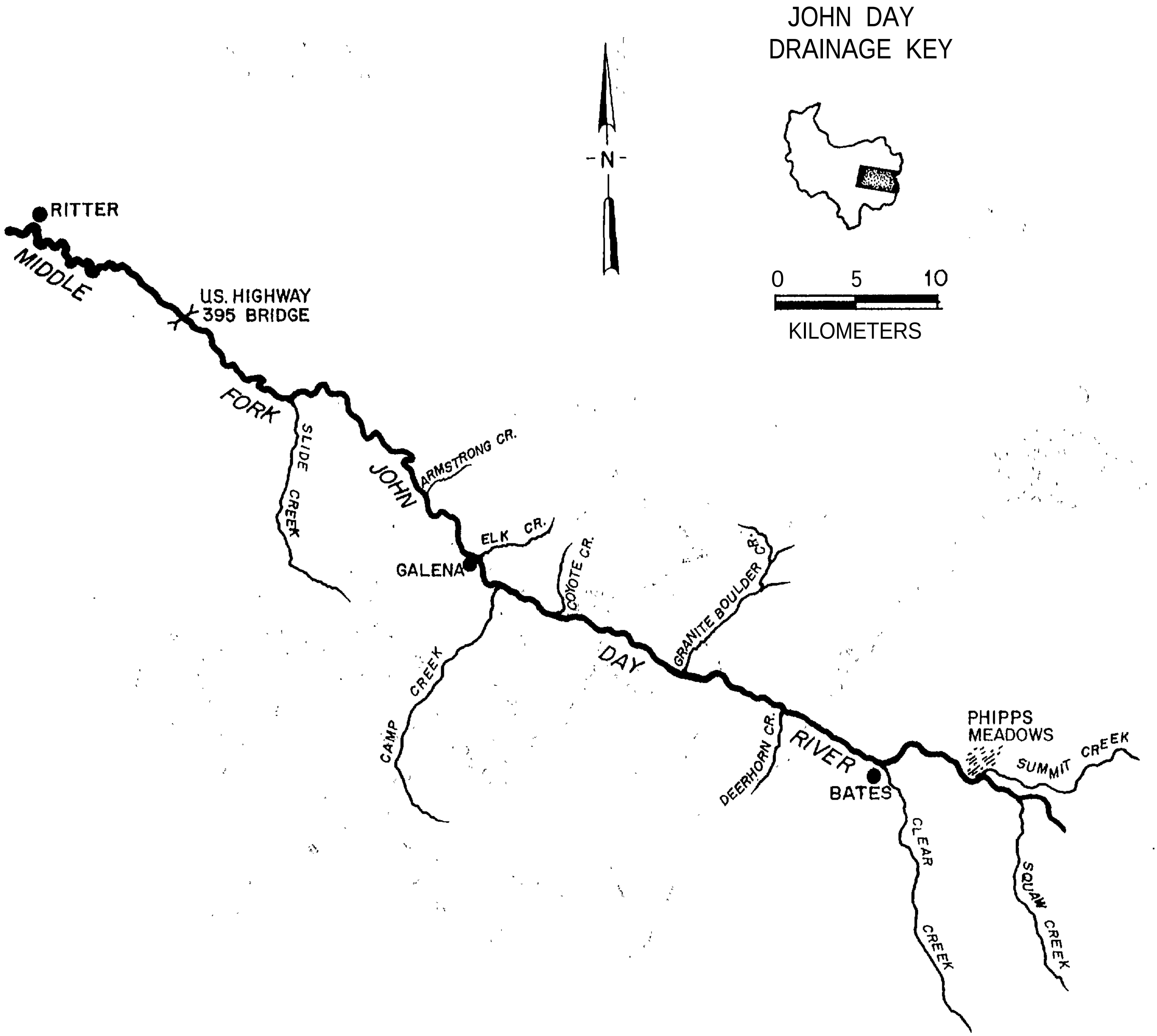

Figure 4. Map of the Middle Fork John Day River.

The spring chinook salmon runs in the John Day River are entirely native wild stocks. Summer steelhead *(Salmo gairdneri)* runs in the John Day River were supplemented with hatchery fingerlings in the 1960s. No hatchery steelhead have been released in the basin since 1969 and the present runs are considered to be native wild stock. Spring chinook salmon spawn in the Mainstem above Prairie City, in the Middle Fork above Armstrong Creek, and in the North Fork above Camas Creek including Granite Creek and its tributaries Clear and Bull Run Creeks. Summer steelhead use virtually all accessible tributaries in the John Day basin. Other game fish in the John Day River include resident rainbow trout *(Salmo gairnderi)*, cutthroat trout *(Salmo clarki)*, bull trout *(Salvelinus confluentus)*, brook trout *(Salvelinus fontinalis)*, mountain whitefish *(Prosopium williamsoni)*, channel catfish *(Ictalurus punctatus)*, bullheads *(Ictalurus* spp.), and smallmouth bass *(Micropterus dolomieui)*. Nongame fish in the John Day River include suckers *(Catostomus* spp.), northern squawfish *(Ptychocheilus oregonensis)*, redside shiner *(Richardsonius balteatus)*, dace *(Rhynichtys* spp.), chiselmouth *(Acrocheilus alutaceus)*, peamouth *(Mylocheilus caurinus)*, common carp *(Cyprinus carpio)*, and sculpins *(Cottus* spp.).

METHODS

Catch in Ocean and Columbia River

We used recoveries of marked spring chinook salmon from the John Day River to assess ocean distribution, age and size of recruitment to fisheries, contribution to ocean and Columbia River fisheries, and timing of adult migrations through the Columbia River in relation to fishing seasons. We captured juvenile spring chinook salmon in the John Day River and marked them with adipose fin clips and coded-wire tags (Ad+CWT) during the 1978-82 sampling seasons. We captured smolts (age 1) from February through June with modified Humphrey scoop traps and with beach seines (61 m x 2.4 m or 30 m x 2.4 m, 13 mm square mesh; Figure 5). We captured fingerlings (age 0) from June through October, 1978-81, with small beach seines (5 to 15 m x 2 m, 6.4 mm square mesh). Fingerlings were captured in rearing areas near the headwaters of the John Day River.

We assessed short-term handling and tagging mortality and tag retention by holding groups of about 60 juveniles (half marked and half unmarked) in live cages for 2 to 4 days after tagging. We then compared mortality of marked with that of unmarked fish and checked marked fish for retention of CWT's with a magnetic field detector. Long-term tag retention was assessed by checking recaptured fingerlings during summer and recaptured smolts during spring. Estimates of numbers of Ad+CWT marked smolts migrating from the John Day River were adjusted for tag retention.

We received reports of recoveries of Ad+CWT marked adults in sport and commercial fisheries in the ocean and in commercial, sport, tribal, and test fisheries in the Columbia River from the following agencies: Alaska Department of Fish and Game, Canada Department of Fisheries and Oceans, Washington Department of Fisheries (WDF), ODFW, and California Department of Fish and Game. We summarized dates and locations of recoveries to assess ocean distribution and timing of upstream migrations of John Day River spring chinook salmon through the Columbia River. This allowed us to recommend the timing of fishing seasons to regulate harvest of John Day River stocks. Recovery data also included the size of individual fish. We evaluated the potential of using size restrictions to regulate harvest by comparing the lengths of John Day River fish with the lengths of adults from other systems recovered in the same fisheries. Where we did not have adequate sample sizes of John Day River chinook in the catch, we used lengths of carcasses recovered during spawning surveys for comparison. We grouped fish into 5 cm length classes and used chi-square tests (Snedecor and Cochran 1967) for comparisons of length class composition.

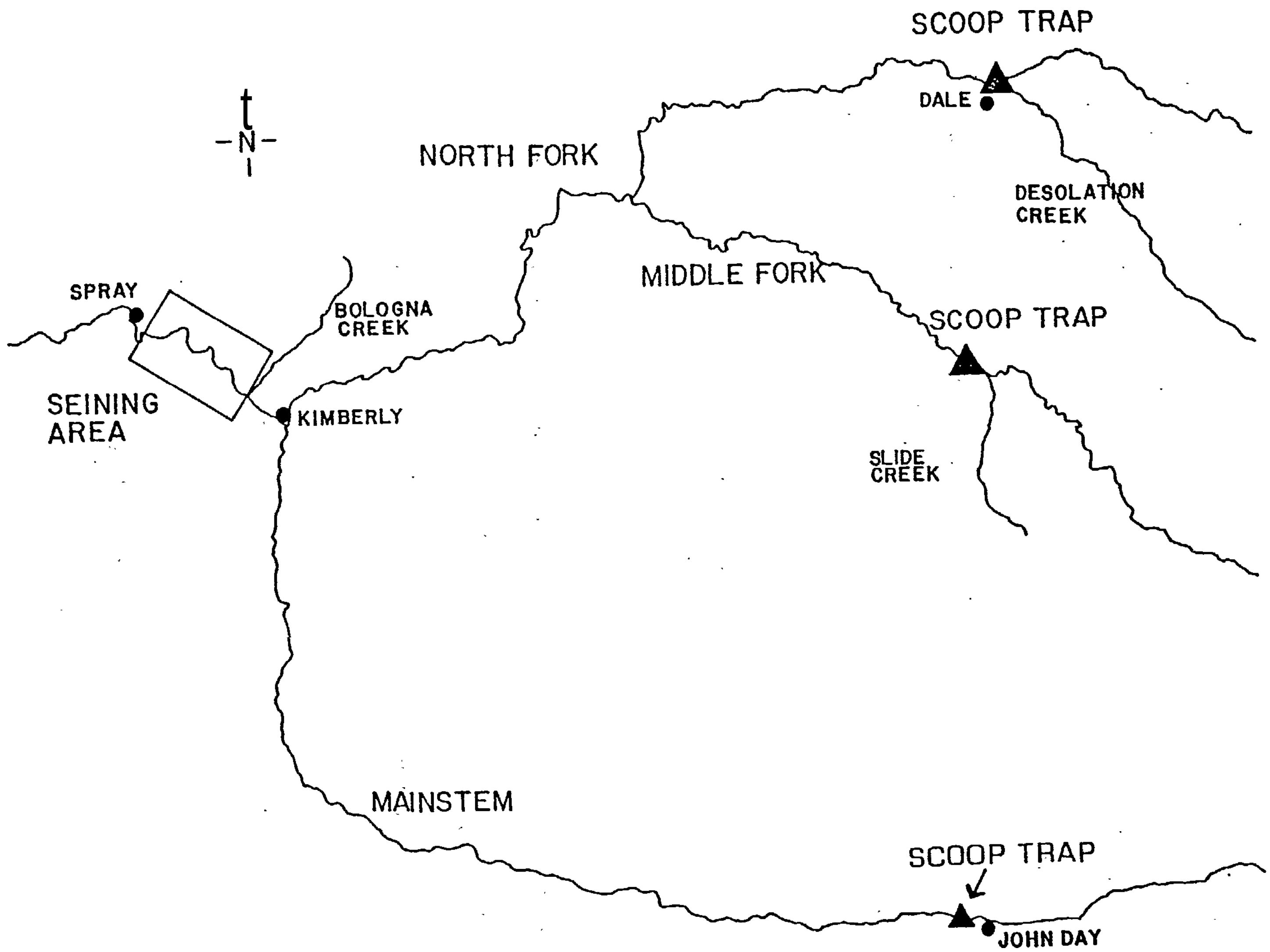

Figure 5. Trap sites and seining areas where-molts were captured in the John Day River.

The estimated catch of a given brood of spring chinook salmon from the John Day River (Ci) in a given fishery was obtained as

$$\hat{C}_i = \frac{C_{mi}}{\hat{p}_i S_r}$$

where

C_{mi} = the number of Ad+CWT marked fish of brood year i that were recovered in the fishery,

p_i = the proportion of the total number of smolts from brood year i that were marked Ad+CWT, and

S_r = sampling rate of the catch in the fishery.

The proportion p_i was obtained as

$$\hat{p}_i = \frac{M_i + F_i \hat{S}_i}{\hat{N}_i}$$

where

M_i = number of smolts from brood year i that were marked Ad+CWT during spring,

F_i = number of fingerlings from brood year i that were marked Ad+CWT during the summer before they smolted,

S_i = estimated fingerling-to-smolt survival rate for brood year i, and

N_i = estimated total number of smolts from brood year i.

We then divided the estimated number of spring chinook salmon from the John Day River in a given fishery by the total catch to determine the relative contribution of John Day River fish to that fishery.

Smolt Migration

We monitored timing of smolt migrations by sampling with traps and seines at various sites in the John Day River system (see Figure 5). We used modified Humphrey scoop traps to sample smolts in the North Fork near Desolation Creek (km 97), in the Middle Fork near Slide Creek (km 51), and in the Mainstem near the city of John Day (km 394). We trapped at these sites from early February through early June, 1980-84, except in the Mainstem where we used a rotary screen bypass trap in 1980. We checked scoop traps two or three times each week depending on catches and river flow. 'We plotted mean weekly catch per day of trap operation to assess timing of smolt migrations past the trap sites.

We seined five standard sites near Spray (km 274) (see Figure 5) 3 days a week from February through early June, 1979-84 to estimate timing of smolt migrations past Spray. A crew of three made standard seine hauls with a seine 61 m x 2.4 m, with 13 mm square mesh. The seine was set from a jet sled. Mean weekly catch per standard seine set was plotted to assess timing past Spray. We made additional seine sets in areas other than standard sites to obtain additional samples to estimate smolt abundance and survival,

In addition to sites near Spray, we sampled smolts in the lower Mainstem near Rock Creek (kms 35-64) (see Figure 1) with beach seines during 1982 and 1983. We also used a modified Craddock trap in 1983 and a boat mounted electrofisher in 1984. We plotted mean weekly catch per unit effort (seine haul, trap day, or hour of electrofishing) to assess smolt mlgration timing through the lower John Day River.

Smolts captured with traps and seines were marked Ad+CWT during 1978-82 and with cold brands during 1982-84. Also, we Ad+CWT marked fingerling chinook salmon captured with small beach seines in the headwaters of the John Day River system during the summers of 1978-81. 'Smolts marked Ad+CWT at scoop traps in 1980-82 were given a secondary mark (fin clip or cold brand) so we could distinguish them at Spray from fish marked as fingerlings the previous summer.

The migration timing of smolts from the John Day River through the Columbia River was determined by summarizing the dates that marked smolts were recovered at John Day Dam, at The Dalles Dam, and at Jones Beach in the Columbia River estuary. The National Marine Fisheries Service (NMFS) sampled smolts by dipping in the gatewells at John Day Dam (km 347) during 1979,‘1980, and,'1982-84 (Rich Johnson, NMFS, personal communication). ODFW sampled smolts by trapping in the ice-trash sluiceway at The Dalles Dam (km 308) during 1979-82 (Willis 1982). NMFS sampled smolts with beach and purse seines at Jones Beach (km 75) during 1979-83 (Dawley et al. 1984).

We used smolts marked at scoop traps and at Spray and subsequently recaptured at downstream sampling sites to estimate migrationrates through the John Day and Columbia rivers. Smolts were marked with brands unique to the location and week of capture in the John Day River. Mean migration rates from midweek of marking to date of recapture were calculated by

$$r = \frac{\sum_{i=1}^{n} r_i}{n}$$

where

r = mean migration rate (km/day),

r_i = migration rate of the ith fish in the recapture sample, and

n = number of marked fish recaptured.

Approximate 95% confidence intervals (CI) for estimates of mean migration rates were calculated as follows (Snedecor and Cochran 1967; Schaeffer et al. 1979):

$$95\%\ CI = \bar{r} \pm t\sqrt{\hat{V}(\bar{r})}$$

and

$$\hat{V}(\bar{r}) = \frac{1}{n}\,\frac{\sum_{i=1}^{n}(r_i-\bar{r})^2}{n-1}$$

Abundance and Survival

We used mark-recapture methods to estimate the abundance of smolts that migrated from the John Day River in 1980-84. We used a pooled Petersen estimate (all weeks combined, Seber 1973) with Chapman's modification (Ricker 1975) to estimate smolt abundance as follows:

$$\hat{N} = \frac{(M+1)(C+1)}{R+1}$$

where

$\hat{N}$ = estimated number of smolts migrating from the John Day River system in a given year,

M = number of smolts marked and released at scoop traps (all traps combined,

C = total number of smolts captured by seining at Spray,.and

R = number of marked smolts recaptured at Spray.

Approximate 95% confidence intervals (CI) for smolt abundance estimates were calculated by treating marked (R) and unmarked (C-R) smolts in the recapture sample as binomial variables (Seber 1973; Ott 1977):

$$95\%\ CI = \hat{N} \pm 2\sqrt{\hat{V}(\hat{N})},\ \text{and}$$

$$\hat{V}(\hat{N}) = \left(\frac{M^2B^2}{R^4}\right) R \left(1 - \frac{R}{M}\right) + \left(\frac{M^2}{R^2}\right) B \left(1 - \frac{B}{\hat{N}-M}\right)$$

where

$\hat{V}(\hat{N})$ = variance of estimated smolt abundance, and

B = number of unmarked smolts in the recapture sample (C - R)..

We estimated fingerling-to-smolt survival rates for 1978-80 brood spring chinook salmon in the John Day River by comparing the recovery rates at Spray of Ad+CWT marked smolts that were marked as fingerlings the previous summer with recovery rates at Spray of smolts marked Ad+CWT at scoop traps that spring (Seber 1973; Gibson et al. 1979). The estimates were obtained as

$$\frac{t/T}{d/D}$$

where

$\hat{S}$ estimated fingerling to smolt survival rate,

T = number of fingerlings marked and released during summer sampling (test group),

D = number of smolts marked and released at scoop traps (control group),

t = number of test group smolts recaptured at Spray, and

d = number of control group smolts recaptured at Spray.

Approximate 95% confidence intervals (CI) for estimates of survival rates were calculated as follows (Seber 1973):

$$95\%,\ CI = \hat{S} \pm 2\sqrt{\hat{V}(\hat{S})},$$

and $$\hat{V}(\hat{S}) = (1-\hat{P}_t)^{-4} \frac{D^2}{T^2} \left[V(\hat{P}_t)\right],$$

and $$V(\hat{P}_t) = \frac{(t/R)\ (1-t/R)}{R}.$$

We estimated egg-to-fingerling survival rates for 1978-80 broods by dividing the estimated number of fingerlings (back calculated from smolt abundance and fingerling-to-smolt survival estimates) by the estimated egg deposition for each brood (total redd count x average fecundity of females). We estimated average fecundities by entering mean lengths of female carcasses recovered -during spawning surveys into a regression of length on fecundity for Columbia basin spring chinook salmon (Galbreath and Ridenhour 1964)., We estimated egg-to-smelt survival rates by dividing smolt abundance estimates by egg deposition estimates. Smolt-to-adult survival rates were estimated by divid'ing the estimated adult returns for a given brood by the estimated smolt abundance for that brood. Adult returns from a given brood were estimated by multiplying each year's redd count by 3.0, the average number of adults per redd in the Warm Springs River (Jonasson and Lindsay 19831) and then partitioning adults into brood years based on age class composition of carcasses recovered during spawning surveys (ages determined by scale analysis).

Freshwater Life History

We examined freshwater' life history of spring chinook salmon 'in the John Day River and, related it to freshwater environmental factors. We looked at adult holding, spawning, incubation 'and emergence; fingerling rearing distribution, and size and growth of juveniles (fingerlings and smolts).

Adult Holding Areas

We characterized adult holding areas in Granite Creek and, in the Middle Fork from 15 June through 15 August 1980 and1981. Field personnel recorded qualitative descriptions of the stream habitat where adults were sighted during summer sampling of fingerlings. We recorded the location of the sighting, the type of habitat (pool, riffle, run), the relative velocity (slow, moderate, fast), a general description of the substrate, the amount and type of escape cover, the presence or absence of tributaries or springs, and the number of adults sighted.

Spawning

We surveyed spawning grounds in the John Day basin to estimate abundance arid age compostiion 'of spawners and, to determine temporal and spatial distribution of spawning. Spawning surveys were conducted'by walking downstream and counting redds,live fish, and carcasses. Redds were recorded as "occupied" if at least one live fish was near the redd, and as "unoccupied" if no live fish were near the redd. Carcasses were measured to the nearest centimeter (fork length),, sexed, and examined for an adipose fin clip. Scales were taken, from each carcass for determining age and for determining years spent in fresh and salt water. We collected snouts from carcasses with adipose fin clips, and we checked the snouts for coded-wire tags. We read coded-wire tags for stream of origin to determine the degree of homing of adults.

We surveyed all' known' spawning areas in the system (extensive surveys,; Table 1) each year from 1978 through -1985. Escapements of adult spring chinook salmon to the John Day River from 1978 to 1985 were estimated by multiplying'the total redds counted during extensive surveys by 3.0,'the average number of adults 'per redd observed in the Warm Springs River (Jonasson and Lindsay 1983)., Extensive surveys included "index areas" (Table 1) that were established by ODFW to monitor trends in spawning in the system. Index'surveys have been conducted since 1959 in all streams except the North Fork, which was first surveyed in 1964.

Table 1. Descriptionof extensive'and index spawning 'survey'sections in the John' Day River.'

Stream, survey type	Survey boundaries	Distance Km	Distance Miles
Mainstem:			
Extensive	Road #14 culvert (above Rail Creek)' to Depot Park Bridge in Prairie City	'22.5	14.0
Index	Road #14 culvert (above Rail Creek) to Dad's Creek	20.9	13.0
Middle Fork:			
Extensive	Fence across upper Phipps Meadow to Armstrong Creek	49.0	30.5
Index	Vinegar Creek to Beaver Creek	16.1	10.0
North Fork:			
Extensive	Baldy Creek to Desolation Creek	73.0	45.4
Index	Granite Creek to Cougar Creek (canyon; 12.9 km): and Big Creek, to Nye Creek (lower; 16.1 km)	29.0	18.0
Granite Creek:			
Extensive	First road crossing above granite to mouth	16.1	10.0
Index	First road crossing above Granite to Buck Creek	8.9	5.5
Clear Creek:[a]			
Extensive	Beaver Creek to mouth	8.0	5.0
Index	Road crossing above Red Boy Mine to mouth	6.4	4.0
Bull Run Creek:[a]			
Extensive	Boundary Creek Gard Station to mouth	5.0	3.1
Index	Boundary Creek Guard Station to mouth	5.0	3.1

[a] *Tributary of Granite Creek.*

We assessed temporal distribution of spawning with short, supplemental surveys (Table 2) in 'key spawning areas located within, index survey boundaries, to assure that extensive surveys represented the peak, of spawning and to recommend the timing of future index surveys. We conducted supplemental surveys at least once prior to and once following extensive surveys. All redds located during supplemental surveys were marked to assure that they would be recognized during subsequent surveys.

Table 2. Description of supplemental spawning survey sections in the John Day River.

Stream	Survey boundaries	Distance Km	Distance Miles
Mainstem	Fence crossing river 1 km below Graham . Creek to Deardorff Creek bridge	2.4	1.5
Middle Fork	Vinegar Creek to fence crossing at lower end of riparian fencing project	3.2	2.0
North Fork	Glade Creek to Ryder Creek (canyon)	3.9	2.4
	Camp Creek to Texas Bar Bridge (lower.)	6.0	3.7
Granite Creek	Tencent Creek to Buck Creek	3.4	2.1

We assessed the spatial distribution of spawning by establishing check points within extensive surveys and evaluating the proportion of total redds observed between check points each year. We used regression analysis to determine if changes in the proportion of total redds that occurred within a given stream section were related to streamflow. We used chi-square contingency tables (Snedecor and Cochran 1967) to determine if ratios of index redds to total redds varied significantly from 1978 to 1984. If the ratio varied significantly then check points within extensive surveys were evaluated to determine if a section could be added to the current index areas to provide a more consistent indicator of total redds.

We conducted periodic exploratory surveys in areas outside of extensive survey boundaries to determine if extensive surveys included all spring chinook salmon spawning in the John Day system. Exploratory surveys were not scheduled but were conducted as time allowed.

Emergence Timing

The timing of emergence'of spring chinook salmon fry was estimated by seining 17 standard sites in spawning areas of' the John Day River once a week from February through June, 1979-84'; The date when fry were first caught was designated the begining of emergence. Each' week at each standard site we' measured random subsamples of 20 to 25 fry to the nearest millimeter, fork length. Chinook salmon fry average 35 to 40 mm when they emerge and become free swimming (Rich 1920). We used the time when 5% or less of the catch consisted of fry ≤37 mn, fork length, as our index of the end of emergence. We sampled for the beginning and ending of emergence in 1980 and 1981 and for the ending of emergence in 1982-84.

In, addition, scales of fingerling chinook salmon collected in' the Mainstem, Middle Fork, North Fork, and Granite Creek throughout the 1979-81 sampling seasons 'were used to develop regressions of Julian day on circuli number Regression equations were calculated 'for each stream and brood year, and the intercepti'bf these lines (mean time of scale formation) were also used as an index of ‘emergence timing.

During the winters of 1980-81 and 1982-83 we used thermographs to record water temperatures in the Mainstem at Depot Park (km‘42'2), in the Middle Fork near the mouth of Vincent Creek (km 103), in the North Fork" near the mouth of Desolation Creek (km 97)? and in Granite Creek near the mouth of Clear Creek (1980-81 only). We used these data to calculate cumulative ttiermal units (one TU equals 1°F above freezing for 24 hours) on a weekly basis from the time of peak spawning (determined from supplemental surveys) to the beginning and ending of emergence. We plotted cumulative thermal units over time for each stream and compared dates of emergence with rates of accumulation of thermal units to determine if differences in emergence timing were related to water temperatures.

Disribution of Fingerling

We determined the distribution of fingerling spring chinook s'almon rearing in the John Day River by seining and electrofishing from June through October, 1978-84. We seined monthly to monitor seasonal changes in lower distribution. We began with the lowermost distribution observed in the previous month's sampling and worked upstream or downstream, making two or three, sets at sites, 3 to 16 km apart, until three consecutive sites did not produce any chinook salmon.. The last site where we caught chinook salmon was consiidered the lower limit of distribution. We placed recording thermographs throughout rearing areas in the Mainstem, Middle Fork, and North Fork to determine if chnged in lower distribution were related to'changes in water temperature. We calculated regressions of lower distribution (river kilometer) on mean maxim&stream temperature the week prior to distribution sampling at the following sites: Mainstem at Depot Park in Prairie City (km 422), Middle Fork at Slide Creek (km 51), 'and North Fork at Stony Creek (km 71).

To determine the upper rearing distribution of fingerlings, we sampled the headwaters of the Mainstem, Middle Fork, North Fork, and Granite Creek system by electrofishing in 1979 and 1980. We also sampled tributaries of the Mainstem, Middle Fork, and, North Fork in 1978-84. Sampling for 'upper distributio and tributary distribution was conducted by working upstream and shocking 30 m sections of stream every-O.8 km until three consecutive stream sections failed to produce any fish.' The last section where chinook salmon were captured was desingated the, upper limit of distribution.

Size and Grouth of Juveniles

We collected fingerlings and measured them to the nearest millimeter, fork length, at 15 standard sampling sites from the end of emergence through October, 1979-84, The Granite Creek system was sampled only 'during 1979-81. We sampled each site at least once each month by making two sets with small beach seines (5 to I5 m,x 2 m,,6.4 mm square Mesh) We estimated mean fork lengths of fingerlings in each stream by weighting mean lengths at each standard site within a stream by the catch per seine set (CPUE) at that site.

We measured fork lengths of smolts captured in scoop traps and in the Spray seining area to determine the size of spring chinook. salmon that migrated from the John Day River in 1979-84. A random' sample of up to'50 smolts were measured, each week at'each site. We used these data to compare sizes of smolts among the three main forks of the John Day River and to measure changes in size of smolts from the scoop traps to the Spray seining area.

Abundance of Fingerlings

We used the CPUE at standard sites as an index of abundance fo age 0 chinook salmon in the John Day River. Because of the limited number of suitable seining sites and the varying capture efficiencies, depending on the site's physical characteristics, we used CPUE only as a general indicator of areas in the John Day basin that support relatively large concentrations of rearing chinook salmon.

Scales

We collected scales from carcasses of adult spring chinook salmon during spawning ground surveys in 1978-85. We collected scales from finger'lings in 1979-81, from smolts in 1980-83, and from yearling residuals)age 1+ chinook dalmon that did not migrate) in 1981. Juvenile chinook salmon were captured withseines, electrofishing gear, and Humphrey scoop traps while we were sampling to meet other objectives of the study. Scales were taken from 'the left side of each fish. in the "key" area (Clutter and Whitesel 1956). The date, location of sample, and fork length (nearest 1 cm for adults and nearest 1 mn for juveniles) were recorded with each scale sample. Sex was also recorded with adult scales.

Scales were impressed in acetate cards with a hydraulic press at 6,000 psi, 200" F, for three minutes. Scales were examined with a microfiche projector at a magnification of86.1X. Scales were aged by counting-annuli. Radius of the scale nucleus, radius to each' ann'ul'us, radius~ at ocean entrance (for adult scales), and total scale radius were measured to the nearest 0.5 mn along a line 20" to the'dorsal side of the anterior-posterior axis of the scale image (Clutter and Whitesel 1956) The number of circuli to each annulus the number of circuli to ocean entrance (for adult scales), and total circuli were also recorded.

Age at spawning and age at ocean entrance were"determined for adults from scale samples. Age compostion was expressed as a percentage of the total spawners recovered in a given year in each'the Mainstem, Middle Fork, North Fork, and Granite Creek in 1978-83.

Scales collected from smolt in the Mainstem, Middle Fork; and North Fork, in 1981-83 were used to develop least-squares regressions of smot fork length on scale radius and of Julian day on circuli number. regression equations were developed, for each stream and 'brood year and were used to back-calculate size arid time of ocean entrance from adult scales.

We used,scale data from smolts captured at scoop traps in the Mainstem, Middle Fork, and North Fork in a discriminant analysis to determine if scale characteristics could be used to classify smolts to their stream of origin when they were captured below the concluence fo the three forks (i.e., in the seining area near Spray). The Statistical Package for the Social Sciences (SPSS);DISCRIMINAFiT subprogram (Klecka' 1975) was used to perform a stepwise analysis to select the "best" discriminating variables among the following scale measurements: radius of nucleus, number of circuli to the first annulus, first band width (scale radius, included in the first four circuli), second band width (scale radius included in the second five circuli), difference between band widths, average circuli spacing in first band, average circuli spacing to first annulus, and the ratio of average circuli spacing in the first band to average circuli spacing to the first annulus. Scale samples were divided into two groups--one to develop the "best" set of discriminating variables and'the other to test the rate of correct classification of scales of known origin with those discriminant functions.

Scale characteristics of resifual chinook collected in Granite Creek during 1981 were compared with scale characteristics of fingerlinga from Granite Creek and with scale characteristics of smolts collected in the North Fork to determine if fingerlings that will smolt may be distinguished from those that will become residuals. We used t-tests to compare first band width between fingerlings and residuals and to compare number of circuli to first annulus, radius to first annulus, and band widths 1 through 5 between smolts and residuals.

Stock-Recruitment

We examined the relationship between parent spawners and their progeny that returned as adults to the mouth of the Columbia River for the Mainstem Middle Fork, North Fork, and Granite Creek (includes Clear and Bull Run creeks). We used redd densities (redds/mile) in index areas as our measur of annual abundance of spawners in the John Day basin because distances of index surveys were not standardized until 1973. Prior to 1973 the total miles of index surveys ranged from 18.5 to 94.3. The index surveys have been standardized at 53.0 total miles since 1973. Because of these variation in survey distances, redd density was our only basis for comparing annual spawning activity and analysing stock-recruitment relationships.

Because survey dates prior to 1978 varied, we first tested the relationship between the date of th index durgey and the number- of redds counted by calculating regression equations of redd counts on Julian day of survey. If a significant relationship ($P < 0.05$) was found, then index counts were adjusted to a standard date-representing the time of peak spawning activity based on supplemental surveys conducted during 1978-84. Each year's spawning densities were then expanded by catch-to-escapement ratios in Columbia River spring chinook salmon fisheries (commercial, tribal, and sport fisheries combined; Table 3). By assuming that John Day River spring chinook salmon were caught at the same rate as other Columbia basin stocks, we were able to estimate returns of John Day River fish to the, mouth of the Columbia River. The estimated returns to the mouth of the Columbia River each year were partitioned into brood year by the averate proportion of 3-,4-,and 5-year-old carcasses,recovered 'during ,1978-84 spawning surveys.,. Total returns from a given brood were estimated (in terms of redds/mile) by summing the estimated returns of 3-, 4-,and 5-year-olds over three consecutiv years. These estimates were then devided bu the redd densities of the parent stock to estimate returns perspawner for each brood.

We could not, estimate returns per spawner for the entire John Day River system, (all streams combined) by the same methods used for individual streams because of differences. in amount habitat, length of index surveys, and redd counts and the estimated returns for these estimates for 1964-80 broods in the entire John Day system..by expanding each year's index redd counts and the estimated returns for each by the average ratio of index redds to total redds observed in each stream from 1978-84. Estimates of parent stock and returns for each brood (expanded for Columbia River catch), in units fo total redds, were summed over all streams in the system and returns per spawner were calculated for each brood.

We plotted, estimates of returns per spawner.on years to determine if any temporal trends existed. We then developed,Ricker and Bevertion-Holt stock-recruitment curves with regressions of natural log and inverse transformations, respectively, of returns per spawner on redd densities of parent stock for each brood (Ricker 1975). We examined the

Table 3. Catch and escapement of 'upriver spring chinook salmon that entered the Columbia River, 1957-84 (Anonymous 1987b). Numbers tabulated as thousands of fish.

Year	Upriver run[a]	Catch[b]	Escapement	Catch/escapement
1957	253.0	117.8'	135.2	0.87
1958	198.5	126.8	71.7	1.77
1959	137.5	77.0	60.5	1.27
1960	133.9	64.8	69.1	,0.94
1961	161.5	64.4	97.1	0.66
1962	199.8	112.4	87.4	,1.29'
1963	147.3	81.0	66.3	'1.22
1964	168.5	88.4	80.1	1.10
1965	175.5	110.9	64.6	'1.72
1966	175.2	64.8	110.4	0.59
1967	151.0	77.9	73.1	'1.07
1968	133.5	50;3	83.2	0.61
1969	216.5	75.9	140.6	0.54
1970	171.2	74.2	97.0	0.77
1971	168.0	55.2	112.8	0.49
1972	279.4	136.1	143.3	0.95
1973	232.9	124.9	108.0	1.16
1974	108.5	39.9	68.6	0.58
1975	104.1	0.0	104.1	0.00
1976	78.3	38.4	77.9	0.00
1977	143.6	[illegible]	102.4	0.38
1978	129.0	0.1	126.6	0.001
1979	51.5	0.0	51.0	0.00
1980	61.0	0.0	61.0	0.00
1981	65.8	0.0	63.4	0.00
1982	77.1	0.0	73.4	0.00
1983	57.8	0.0	56.8	0.00
1984	51.0	0.0	51.0	0.00

[a] Bonneville Dam count plus the lower river catch.
[b] Spring season commercial catch in zones 1-6 plus sport catch. There have been no spring seasons since 1977, but some catchvv salmon was estimated in winter fisheries. We did not use tinter catches in calculating catch:escapement ratios.

coefficients of determination to determine which model provided the best fit to the data. The model that provided the best fit was used to estimate spawning densities at replacement; at maximum recruitment, at maximum sustained yield, and a various rates of exploitation (Ricker 1975). To'convert estimates of redd densities to numbers of fish, we expanded the redds/mile by the length of the index sections to obtain estimates of the number of redds in the index area. We then expanded the number of redds in index sections by the average ration of redds in index areas to total redds observed in each stream in 1978-84 to estimate total redds. Total redds were then multiplies by 3.0 fish per redd (Jonasson and Lindsay 1983) to estimate total numbers of fish.

Hatchery Supplementation

Recommendations for hatchery supplementation in the John Day River were largely based on data collected under other study activities and from a review of existing literature. Recommendatiosn were madee for criteria that should be used to determine whether or not hatchery supplementation will be needed in the basin, for hatchery siting and alternatives, for brood stock collection, for rearing and release strategies, and for evaluation. Because recommendations for hatchery supplementation are based on the results form other study objectives, the discussion of supplementation is presented only in the DISCUSSION section of this report.

RESULTS

Catch in Ocean and Columbia River

We marked 87,662 juvenile spring chinook salmon in John Day River (75,794 as fingerlings and 11,868 as smolts) with Ad+CWT during the 1978-82 sampling seasons (Table 4). An estimated 21,758 of the chinook salmon marked as fingerlings survived to smolt (Table 4).

Table 4. Estimated number and percentage of spring chinook salmon, smolts coded-wire tagged in the John Day River, 1978-80 broods.

Brood Year	Number marked as fingerlings	Number of marked fingerlings surviving to smolt[a]	Number marked as smolts	Total number of marked smolts	Estimated smolt abundance	Percent-age marked
1978	31,311	9,237	3,079	12,316	169,000	7.3
1979	20,515	5,067	2,443	7,510	83,000	9.0
1980	18,480	6,505	1,336	7,841	94,000	8.3

a Estimated fingerling-to-smott survival rates were 29.5%> 24;7%, and 35.2% for 2978, 1979, and 2980 broods, respectively.

Only one ocean recovery of an Ad+CWT marked spring chinook salmon from the John Day River has been reported since tagging began'in 1978; The fish (1978 brood) was caught by a troller near Sitka, Alaska, on 24 June 1982 and was originally tagged in Granite Creek during summer 1979. A lag time of 2 years occurs between the sampling of coded-wire tags in ocean fisheries and the publishing of tag recovery reports (Robert Garrison, ODFW, personal communication) so additional recoveries of John Day River chinook may still be reported.

Eleven Ad+CWT marked spring chinook salmon from the John Day River were recovered in Columbia River fisheries during 1981-84 (Table 5). Eight were in ODFW and WDF test fisheries and"three were in Warm Springs tribal ceremonial fisheries (Table 5). All were recovered in April and May at age 4. There were 'no recoveries of marked John Day River chinook salmon in sport or commercial fisheries in the Columbia River.

Table 5. Columbia River recoveries of adult spring chinook salmon marked Ad+CWT as juveniles in the John Day River, 1981-84.

Date recovered	Number recovered	Location, fishery	River kilometer	Brood year
04/14/81	1	Corbett--test	203	1977
04/12/82	1	Woody Island--test	45	1978
04/14/82	1	Woody Island--test	45	1978
04/20/82	1	Woody Island--test	45	1978
05/08/82	1	Bonneville Pool--ceremonial	241	1978
04/12/83	1	Woody Island--test	45	1979
04/22/83	1	Corbett--test	203	1979
05/05/83	2	Bonneville Pool--ceremonial	241	1979
04/06/84	1	Corbett--test	203	1980
04/30/84	1	Corbett--test	203	1980

The small number of Ad+CWT marked spring chinook salmon from the John Day River caught in Columbia River fisheries precluded us from making comparisons of lengths of John Day River fish with those from other Columbia River tributaries in individual fisheries. However, we were able to compare lengths of carcasses collected during 1982 spawning surveys in the John Day River with the lengths of Ad+CWT marked chinook salmon from other Columbia River tributaries in the catch of test fisheries (Woody Island and Corbett combined) and Warm Springs tribal ceremonial fisheries in 1982. These three groups of fish had significantly different $fP < 0.005$) length class compositions in 1982 (Table 6) with carcasses from the John Day River generally being smaller than the marked fish caught in the test and ceremonial fisheries.

The estimated contribution of John Day River spring chinook salmon to test and tribal ceremonial fisheries in the Columbia River ranged from 2.7% to 20.8% (Table 7).

Smolt Migrartion

Spring chinook salmon smolts migrated past scoop traps in the Mainstem, Middle Fork, and North Fork of the John Day River from February through May, 1980-84. Traps were set during the month of February, as soon after the ice went out as possible in all years. However, the traps generally caught smolts immediately after being set indicating that, migrations from upper rearing areas had already begun. Peaks in smolt migrations past traps were difficult to identify because of variable river flows and problems with ice and debris, which affected trapping efficiencies. Catch rates at traps were generally highest from late February through mid-April. During 1984, flows in the North Fork remained relatively low, which increased the efficiency of the trap until mid-May. Catch of smolts at the North Fork trap in 1984 was three times

Table 6. Percent length class composition of spring chinoook salmon from John Day River spawning surveys and from Columbia River fisheries, 1982.

Source	n	Length class (cm) <61	61-65	66-70	71-/5	16-80	81-85	86-90	>90
John Day River spawning survey	277	7.6	18.8	44.0	17.0	5.4	3.6	1.8	1.8
Columbia River test	35	0.0	2.9	25.7	25.7	8.6	17.1	11.4	8.6
Warm Springs ceremonial	26	0.0	7.7	3.8	7.7	15.4	23.1	30.8	11.5

Table 7. Estimated relative contribution of John Day River spring'chinook salmon to Columbia River fisheries, 1981-84.

Year, fishery	Total catch	Number of John Day River CWT's recovered	Estimated catch of Johri Day River fish	Percent contribution of John Day River fish
1981:				
Corbett--test	405	1	(a)	(a)
1982 :				
Woody Isl and--test	197	3	41	20.8
Warm Sp--ceremonial	517	1	14	2.7
1983 :				
Woody Island--test	412	1	11	2.7
Corbett--test	271	1	11	4.1
Warm Sp--ceremonial	527	2	22	4.2
1984:				
Corbett--test	468	2	24	5.1

[a] *We did not estimate the percentage of marked smolts in the* 1977 *brood.*

as large as in any other year (Table 8) and catch rates peaked during the week of 25 February through 3 March.

Table 8. Catch of spring chinook salmon smolts at trapping and seining sites, 1980-84.

Sampling site	1980	1981	1982	1983	1984
Mainstem trap[a]	8	351	258	334	262
Middle Fork trap	722	611	80	14	166
North Fork trap	1,171	372	497	941	3,773
Spray seining area	1,723	2,202	658	1,642	2,168

a *A rotary screen bypass trap was used in 1980.*

We captured spring chinook salmon smolts at the Spray seining area from mid-February through mid-June, 1979-84. Catch at standard sites peaked during the first 2 weeks of April in all years except 1984 when there was no definite peak (Figure 6).

In 1981 we captured 365 juvenile chinook salmon during our first seining effort (13 February) at Spray. These fish appeared to be rearing there because they did not have the typical-appearance of smolts (i.e., loose scales and silvery color). We did not observe chinook salmon rearing in the lower river in any other year.

We had little success sampling chinook salmon smolts in the Rock Creek area of the lower John Day River (kms 35-64) in 1982-84. We captured 81 smolts in 639 seine hauls in 1982 and 18 smolts in 753 seine hauls in 1983 for CPUE's of 0.13 and 0.02 smolts per seine haul, respectively. CPUE was highest during late April in both years. We did not catch any smolts in the modified Craddock trap used in 1983, and we caught only two smolts by electrofishing in 1984.

Marked spring chinook salmon smolts from the John Day River were recaptured at John Day Dam from mid-April through early June in all years except 1979 when one smolt was recaptured in August (Table 9'). Recaptures at The Dalles Dam and at Jones Beach occurred from late April through June in 1979-83 (Table 9) but sample sizes were small (0 to 6 smolts annually).

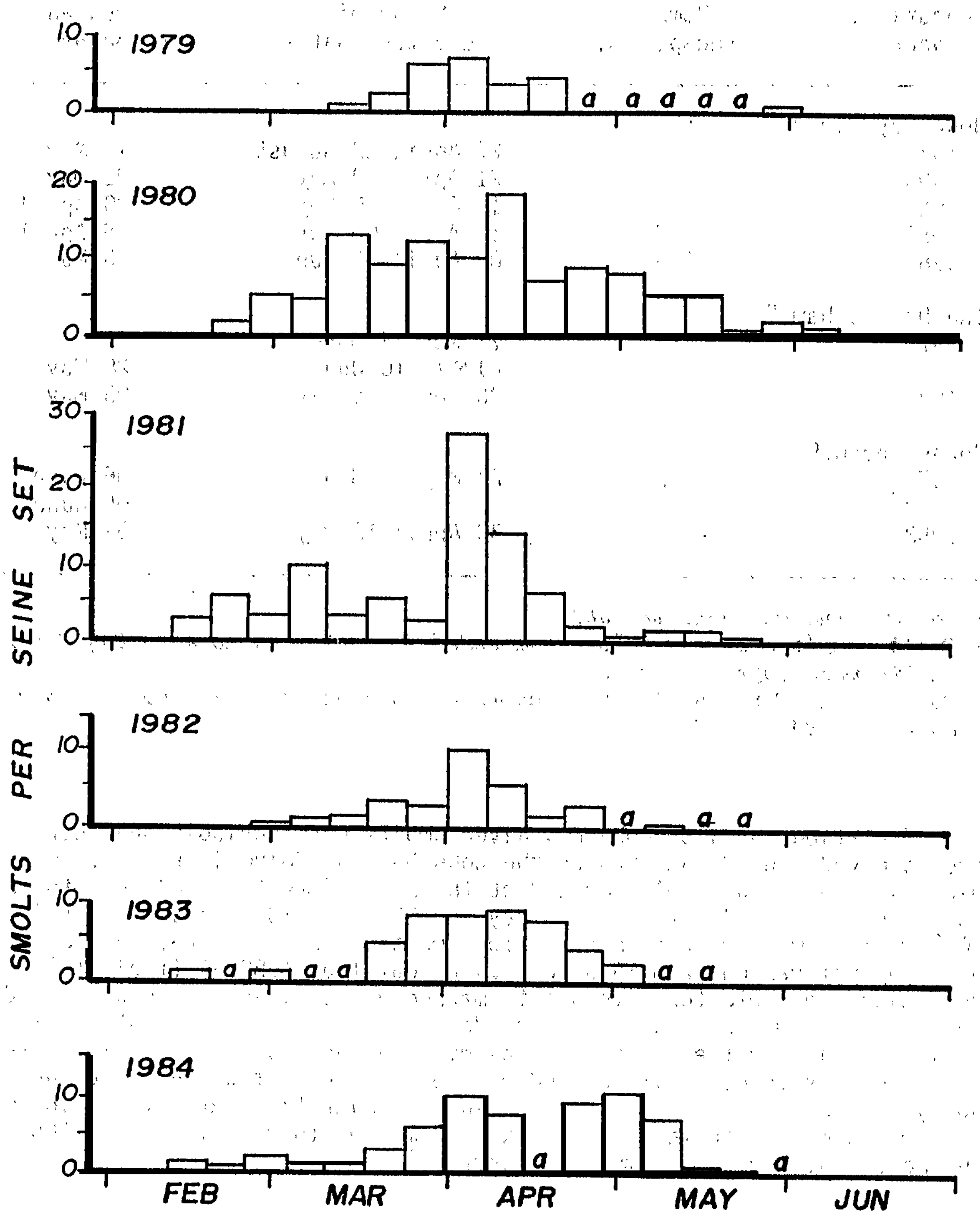

Figure 6. Timing of migration of spring chinook salmon smolts past Spray (km 286) in the John Day River, 1979-84 (a indicates incomplete sampling).

Table 9. Dates that smolts marked in the John Day River were recaptured in the Columbia River, 1979-84.

Location, year	Number recaptured	Range of recapture dates	Median recapture date
John Day Daniia			
1979	7	27 Apri 1-13 August	14 May
1980	62	21 April-22 May	01. May
1982	13	15 April-10 May	29,April'
1983	18	18 Apri,l-08 May	28 :April
1984	123	09 April-09 June	10,:May
The Dalles Dam:[b]			
1979	3	21 May-17 June	22 May
1980	6	02 May-10 June	28 May
1981	4	30 Apri 1-14 May	05 May
Jones Beach:c	2		
1979	1	27 May-22 June	06,June'
1980		--	05 June
1983	5	30 April-13 May	04 May

a No sampling was done in 1981,.
b Smot sampling at The Dalles Dam ended in 1982, but no John Day River smolts were captured in 1982.
c No John Day River smolts were captured in 1981 or 1982. No sampling was done in 1984.

Migration rates of Jonh Day River smolts were variable and increased as smolts moved downstream through the John Day and Columbia rivers. Mean migration rates for smolts marked at the North Fork trap and recaptured at Spray were 3.2 km/day and 3.5 km/day, in 1983 and 1984, respectively (Table lo), whereas mean migration rates for smelts-marked at Spray and recaptured at John Day Dam ranged from15.5 to 17.9,km/day'from 1982+841 (Table 10). The mean migration rate for five smolts marked at Spray 'and recaptured at Jones Beach in 1983 was 23.3 km/day. In addition to increased migration rates as smolts moved downstream, we also observed an increase in migration rates over time. For example, smolts marked at the North Fork trap and recaptured at Spray in 1984 exhibited an increase in 'mean migration rates from 2.78 km/day for smolts marked in the first week of sampling to 8.5 km/day for those marked in the seventh week of sampling (Figure 7).,

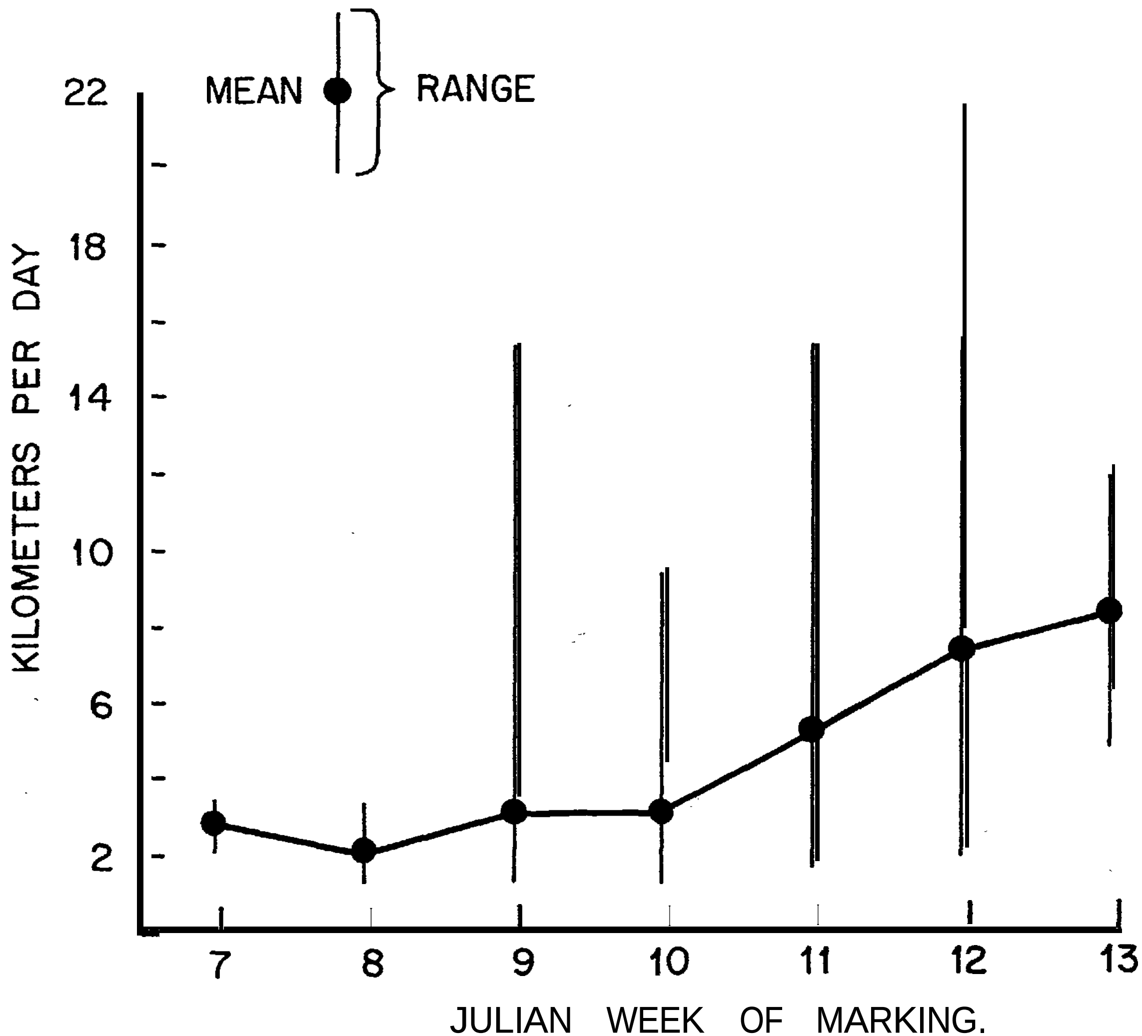

Figure 7. Migration rates for weekly mark groups from the North Fork scoop trap to the Spray seining area, 1984.

Table 10. Migration rates of spring chinook salmon smolts through the John Day and Columbia rivers, 1982-84. CI = confidence interval.

Reach, year	n	Distance (km)	Mean migration rate (km/day)	Approximate 95% CI
Mainstem trap to Spray:				
1983	9	117	8.3	+4.1
North Fork trap to Spray:				
1983	16	111[a]	3.2	±0.0
1984	101	108	3.6	f0.6
North Fork trap to John Day Dam:				
1984	83	398	7.1	to.7
Spray to John Day Dam:				
1982	9	282	17.9	±6.3
1983	14	282	15.5	+3.7
1984	35	282	18.4	+4.5
Spray, to Jones Beach':				
1983	5	554	23.3	f5.9

a Smolts were released 3 km above the trap site in 1983.

Abundance and Survival

The numbers of 1978-82 brood smolts that migrated from the John Day River ranged from 64,000 to 169,000 (Table 11). Survival rates of John Day River spring chinook salmon averaged 5.5% from egg to smolt and 1.2% from smolt to adult (Table 12).

Table 11. Estimatd abundance (thousands) of spring chinook salmon in the John Day River at several life history stages, 1978;85 broods. CL = confidence limits.

Brood year	Eggs	Fingerlings	Smolts Number	Smolts (95% CL)	Adult' returns
1978	2,510	573	169	80-257	1,650
1979	2,310	336	83	52-113	1,040
1980	1,090	267	94	1-211	1,240
1981	1,440	--	64	40-89	--
1982	1,750	--	78	64-93	--
1983	1,490	--	--	--	--
1984	1,420	--	--	--	--
1985	2,013	--	--	--	--

Table 12. Estimated percent-survival of spring chinook salmon in the John Day River at several life history stages, 1978-82 broods. CL = confidence limits.

Brood year	Egg to fingerling	Fingerling to smolt (95% CL)	Egg to smolt	Smolt to adult	Egg to adult
1978	22.8	29.5 (13.5445.5.)	6.7	0.98	0.066.
1979	14.5	24.7 (14.7-34.7)	3.6	1.25	0.045,
1980	[illegible]		[illegible]		
1981	24--5	35.2 (0-72.1) --	4.4	1.?? --	0.110
1982	--	II	4.5	--	

Adult Holdings Areas

We recorded 15 sightings of adult spring chinook salmon holding in the Middle Fork and in Granite Creek in summer 1980 and 15 sightings in the North Fork and in the Granite Creek system in summer 1981. Most of these observations were in pools in the Granite Creek system. Adults were consistently found in pools with a depth greater than 1.5 m and with escape cover such as undercut banks, fallen trees or other debris, boulders, or vegetation. Surface area and substrate composition of the pools were variable.

Spawning

We counted 306 to 641 redds annually in extensive surveys from 1978 through 1984 (Table 13). Estimated spawning escapements based on redd counts and 3.0 fish/redd in these years ranged from 918 in 1980 to 1,923 in 1979 (Table 13). The average redd densities observed during index surveys have been declining since 1973 (Figure 8). These declines are most noticeable in the North Fork and Granite Creek systems, which have dropped from a high of 20.5 and 44.5 redds/mile, respectively, in the late 1960s to less than 5 redds/mile in 1983 and 1984 (Table 14).

Table 13. Salmon redds counted during extensive (Ext) and index surveys and estimated spawning escapements (at 3 fish/redd) in the John Day River, 1978-85.

Year	Mainstem		Middle Fork		North Fork		Granite Cr.[a]		Total		Estimated escapement
	Ext	Index	Ext	Index	Ext	Index	Ext	Index	Ext	Index	
1978	59	59	188	93	168	109	196	160	611	421	1,833
1979	74	68	171	118	250	200	146	130	641	516	1,923
1980	16	16	97	58	104	78	89	78	306	230	918
1981	53	51	47	26	179	138	122	110	401	325	1,203
1982	51	49	131	62	173	105	143	122	498	338	1,494
1983	138	133	81	51	114	76	56	46	389	306	1,167
1984	80	73	150	67	82	63	63	48	375	251	1,125
1985	120	116	80	40	156	110	160	132	516	398	1,548

[a] Includes Clear and Bull Run creeks.

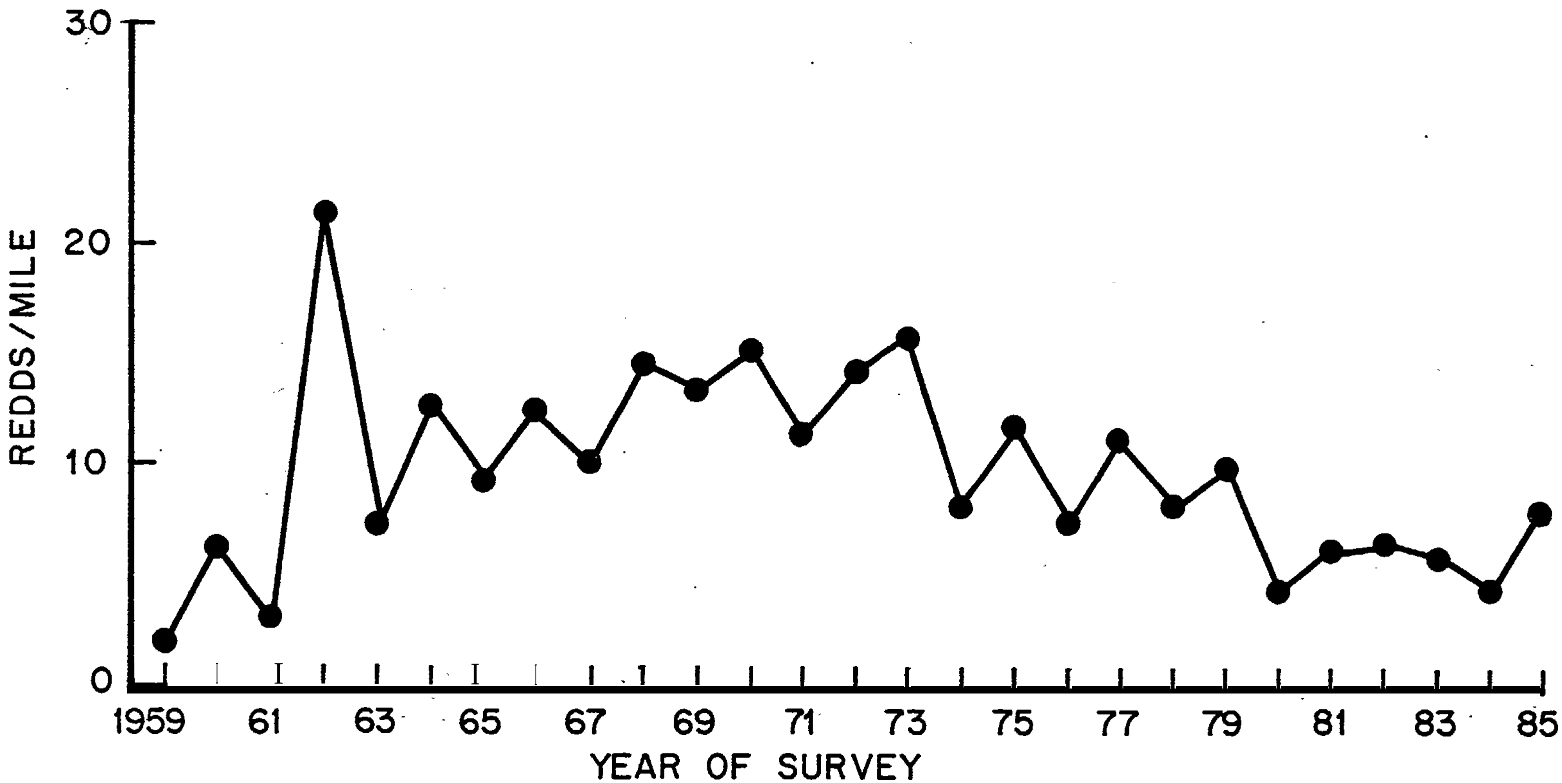

Figure 8. Average redd densities in index areas (all streams combined) in the John Day River system, 1959-85.

Table 14. Redd density in index areas of the John Day River system in redds/mile (r/m) and redds/kilometer (r/k), 1959-85.

Year	Mainstem		Middle Fork		North Fork		Granite Creek system[a]	
	r/m	r/k	r/m	r/k	r/m	r/k	r/m	r/k
1959	0.3	0.2	0.0	0.0	--	--	5.3	3.3
1960	0.7	0.4	3.2	2.0	--	--	12.7	7.9
1961	3.0	1.9	1.1	0.7	--	--	4.5	2.8
1962	12.2	7.6	2.8	1.7	--	--	37.2	23.1
1963	0.8	0.5	0.4	0.3	--	--	23.3	14.5
1964	1.3	0.8	3.6	2.2	7.8	4.9	34.6	21.5
1965	5.8	3.6	3.7	2.3	8.1	5.0	18.3	11.4
1966	9.3	5.8	6.5	4.0	10.3	6.4	28.8	17.9
1967	7.4	4.6	1.7	1.1	5.5	3.4	23.0	14.3
1968	0.7	0.4	0.4	0.3	8.8	5.5	44.5	27.7
1969	9.3	5.8	4.8	3.0	20.5	12.7	15.5	9.7
1970	8.3	5.2	7.6	4.7	16.8	10.4	27.1	16.9
1971	7.0	4.4	4.1	2.6	11.8	7.3	23.0	14.3
1972	3.9	2.4	5.1	3.2	10.5	6.5	38.2	23.7
1973	8.9	5.5	4.3	2.7	19.4	12.1	27.0	16.8
1974	2.5	1.6	8.1	5.0	7.2	4.5	15.9	9.9
1975	7.1	4.4	8.9	5.5	11.7	7.3	19.1	11.9
1976	4.6	2.9	6.6	4.1	6.2	3.9	13.5	8.4
1977	4.9	3.1	5.8	3.6	14.5	9.0	17.3	10.7
1978	4.5	2.8	10.7	6.7	5.9	3.7	13.8	8.6
1979	5.2	3.2	11.8	7.3	11.1	6.9	10.8	6.7
1980	1.2	0.8	5.8	3.6	4.3	2.7	6.5	4.0
1981	3.9	2.4	2.6	1.6	7.7	4.8	9.2	5.7
1982	3.8	2.4	6.2	3.9	5.5	3.4	10.2	6.3
1983	10.2	6.3	5.1	3.2	4.2	2.6	3.9	2.4
1984	5.6	3.5	6.7	4.2	3.5	2.2	4.0	2.5
1985	8.9	5.6	4.0	2.5	6.1	3.8	11.0	6.8

[a] *Includes Granite, Clear, and Bull Run creeks.*

Almost all spawning occurred within extensive survey boundaries. However, we did find limited spawning activity in the following exploratory survey areas: (1) Mainstem from Depot Park downstream to Hall Hill--two redds in 1983; (2) Mainstem from Trout Farm downstream to culvert above Rail Creek--two redds in 1983; (3) North Fork of Desolation Creek (Tributary of the North Fork)--two redds in 1978; (4) North Fork from Desolation Creek downstream to Camas Creek--one redd in 1978 and three redds in 1979; and, (5) Clear Creek (tributary of Granite Creek) from Ruby Creek downstream to Beaver Creek--three redds in 1982 and two redds in 1983.

The average ratios of redds from index surveys to total redds (from extensive surveys) in 1978-85 spawning surveys ranged from 0.55 in the Middle Fork to 0.95 in the Mainstem. Results of a chi-square test revealed that ratios of index to total redds in the Mainstem and in Granite Creek were not significantly different among years, 1978-85 ($P > 0.05$). However, ratios in the Middle Fork and in North Fork were significantly different (P q 0.005) indicating that these index areas are not consistent indicators of totlal spawning in these streams; The upper Middle Fork (above Clear Creek' and above the present index area) received a high proportion of the spawning activity in some'years (Appendix A). We calculated a regression of 'the percentage of the total Middle Fork redds above Clear Creek on the mean August-September discharge at Ritter (km 23) for 1978-84 and found a significant positive correlation ($r = 0.93$; $P < 0.05$), which indicates that a large proportion of the total spawning occurs in the upper Middle Fork in years when flow is high. We analyzed redd counts between extensive survey check points in the Middle Fork from 1978-84 (Appendix A) and found that adding the reach. from Crawford Creek bridge (km 114) downstream to Vinegar Creek (km 105) to the index would provide a more consistent indicator of total-redds. When we added this section to index surveys conducted during 1978-84 we increased the average index redd to total redd ratios from 0.55 to 0.81 and the ratios were no longer significantly different ($P > 0.10$) among years.

We found that the upper North Fork (above Granite Creek) received. 20% or more of the spawning in some years (Appendix A). We calculated a regression of the percentage of total redds above Granite Creek on mean August-September flow at Monument (km q minus Middle Fork flow; but we did not find a significant correlation (i" = 0.54). We evaluated extensive survey check points from 1978-84 (Appendix A) and found that adding the reach from Crane Creek (km 150) downstream to Granite Creek (km 139) to the North Fork index would provide a more consistent indicator of total redds.

Spring chinook salmon begin spawning in the John Day River in late August and continue through September based on observations of redds'and live fish during the 1978-84 supplemental surveys. Results of 1978-81 supplemental surveys indicated that spawning activity peaked earliest in the Mainstem and Granite Creek and latest in the Middle Fork and lower North Fork. These results suggest that redd counts would be maximized if index surveys are conducted from 9 through 20 September as listed in Table 15.

Table 15. Dates index spawnig ground surveys in the John Day River should be conducted to maximize redd counts.

Stream	Survey dates
Mainstem	09"lO.September
Middle Fork	17-18 September
Upper North Fork	15-16 September
Lower North Fork	19-20 September
Granite Creek system[a]	11-12 September

a Includes Granite, Clear, and Bull Run creeks.

Coded-wire tag recoveries from spawning surveys suggest that the spring chinook salmon runs in the John Day River may be composed of three separate substocks. The majority of Ad,+CWT adults recovered during spawning ground surveys. had returned to the stream where they were tagged as rearing juveniles (Table'16). Because we observed this homin to natal streams within the John Day system we considered populations in the Mainstem, Middle Fork, and North Fork system (includes Granite Creek) to be separate substocks.

Table 16. Coded-wire'tag recoveries from spawning ground surveys in the John Day River, 1981-85.

Tagging area, life stage	Number, recovered by stream		
	Middle .Fork	North Fork	Granite Creek
Spray:			
Smolt	2	8	5
Middle Fork:			
Fingerling,	12	0	0
Smolt	4	0	0
North Fork:			
Fingerling	0	6	2
Smolt	0	2	1
Granite Creek system:[a]			
Fingerling	0	2	27

a Includes Granite, Clear, and Bull Run creeks.

Emergence Timing

Emergence began as early as 25 February and lasted as late as 7 July, but in most years emergence occurred from mid-March until mid-June (Table 17). We could not evaluate the-effects of annual variations in winter temperature on emergence timing in individual streams because we had only 2 years (1980-81 and 1982-83) of winter temperature data (thermographs malfunctioned in other years). However, we were able to compare differences in winter temperatures (in terms of accumulated thermal units) and emergence timing among spawning areas in the John Day basin for the 1980-81 and 1982-83 winters. We compared accumulated thermal units from peak spawning to(the beginning of emergence in the Mainstem, the Middle Fork, the North Fork, and Granite Creek in winter 1980-81. We also compared accumulated thermal units from peak spawning to the end of emergence in the Minstem, the Middle Fork, and the North Fork in winter 1982-83 (we did not sample for the beginning of emergence in any streams nor did we sample Granite Creek in 1983).

Table 17. Comparisons of emergence timing based on field sampling and on mean time of scale formation in the John Day,River, 1979-81.

Year, stream	Beginning of emergence[a]	End of emergence[b]	Mean date of scale formation[c]
1979:			
Mainstem	(d)	28 May	16 May
Middle Fork	(d)	07 May	21 April
North Fork	(e)	(e)	08 June
Granite Creek	27 April	12 June	12 June'
1980:			
Mainstem~	25 February	04 May	15 May
Middle Fork	19 March	15 May	03 May
North Fork	22 April	03 June	01 June'
Granite Creek	23 April	16 June	06 June
1981:			
Mainstem	12 March	30 April	09 May
Middle Fork	(d)	25 May	22 April
North Fork	01 April	14 June	25 May'
Granite Creek	07 April	19 June	05 June

a *First sampling date when emergent fry were captured.*
b *Time when less than 5% of the fry sampled were less than 37 mm, fork length.*
C *Estimated from intercept of regression of julian day on circili number.*
cl *Emergence underway when sasmoling began.*
e *No Sampling.*

Because water temperatures were higher, emergence began earlier in the Mainstem and Middle Fork than in the North Fork and Granite Creek systems, which accumulated fewer thermal unit's over'the same time period during the winter of 1980-81 ('Figure.9). Results were similar from peak spawning to the 'end of emergence in 1982-83; the upper Malnstem and Middle Fork acquired thermal units faster than' the North Fork systme and the end of emergence was correspondingly earlier (Figure 10). The'" relative timing of emergence was similar among streams in other years when we sampled for emergence (Table,l7). Because differences in water temperatures and the accumulation of thermal units by developing embryos was large, the relative timing of emergence among the four streams was not related to the relative timing'of spawning the previous fall.

Emergence timing based on scale analysis generally agrees with that based on seining in each stream except that timing based on scales was earliest in the Middle Fork followed by the Mainstem (Table 17). There was a strong linear relationship (r ranged from 0.79 to 0.94) between Julian day and circuli number from scales of fingerlings collected in the Mainstem, Middle Fork, North Fork, and Granite Creek during 1979-81. The intercepts of these regressions (mean time of scale formation) were useful indexes of relative emergence timing among streams. Estimated mean dates of scale formation from 1979-81 were earliest' in the Middle Fork followed by the Mainstem, North Fork, and Granite Creek.

Distrfbution'of Fingerlings

During, this study, fingerling spring chinook salmon in the John Day River were observed from Spray on the Mainstem to above Trail' Creek (km 168) in the North Fork, throughout the Granite Creek system (includes Clear an4 Bull Run Creeks); in the Middle Fork, from the mouth to Squaw Creek (km 118); and in the upper Mainstem from Bridge Creek (km 356) to Graham Creek (km 442). Juvenile chinook salmon were distributed most extensively during late spring and early summer (Appendix B). However, as water temperatures changed, the lower limits of distribution changed drastically in summer and early fall.

We found significant relationships ($P < 0.05$) between the lower distribution of juvenile chinook salmon and-mean maximum temperatures the week prior, to sampling in the Niddle and North Forks fr = 0.77 and 0.7.6 respectively;. Figures 11 and 12). We omitted two data points from the analysis of the Middle Fork because they were the earliest samples from 1983 and '1984 and we believe that downstream distribution from spawning areas was incomplete (Figure 11). We did not obtain a significant relationship between distribution and temperature in the Mainstem ($r = 0.32$). In general, distribution extended downstream after emergence, (May to July), then as water temperatures increased and flows decreased the lower limit of distribution moved upstream (up to 104 km in the North Fork in 1978; Appendix B). By late September and early October, a. shift back downstream usually took place concurrent with decreasing water temperatures and increasing flows. In most years distribution narrowed during August although in some years it had narrowed by July.

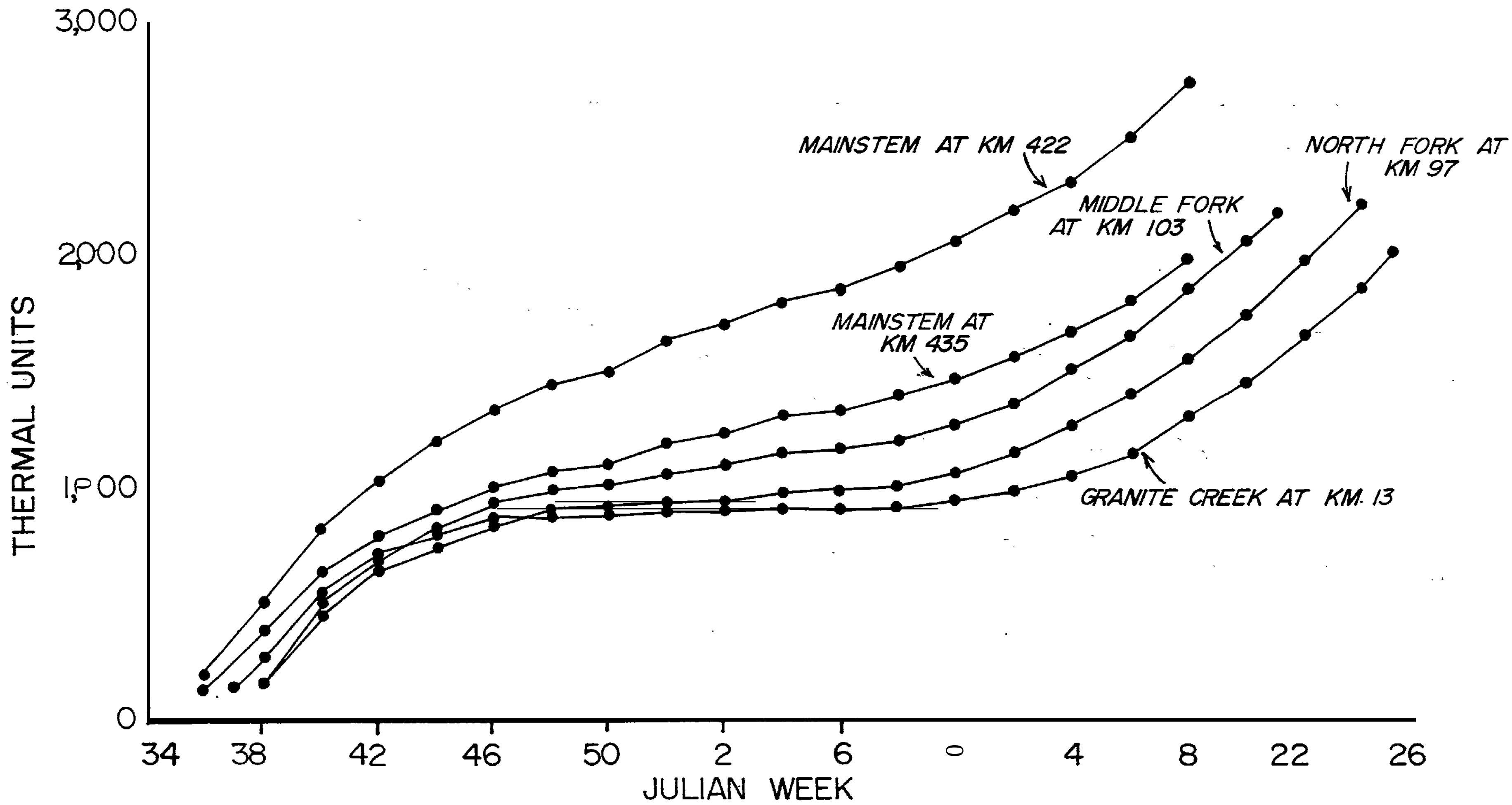

Figure 9. Cumulative thermal units from week of peak spawning to week of end of emergence in the John Day River spawning areas, 1980-81.

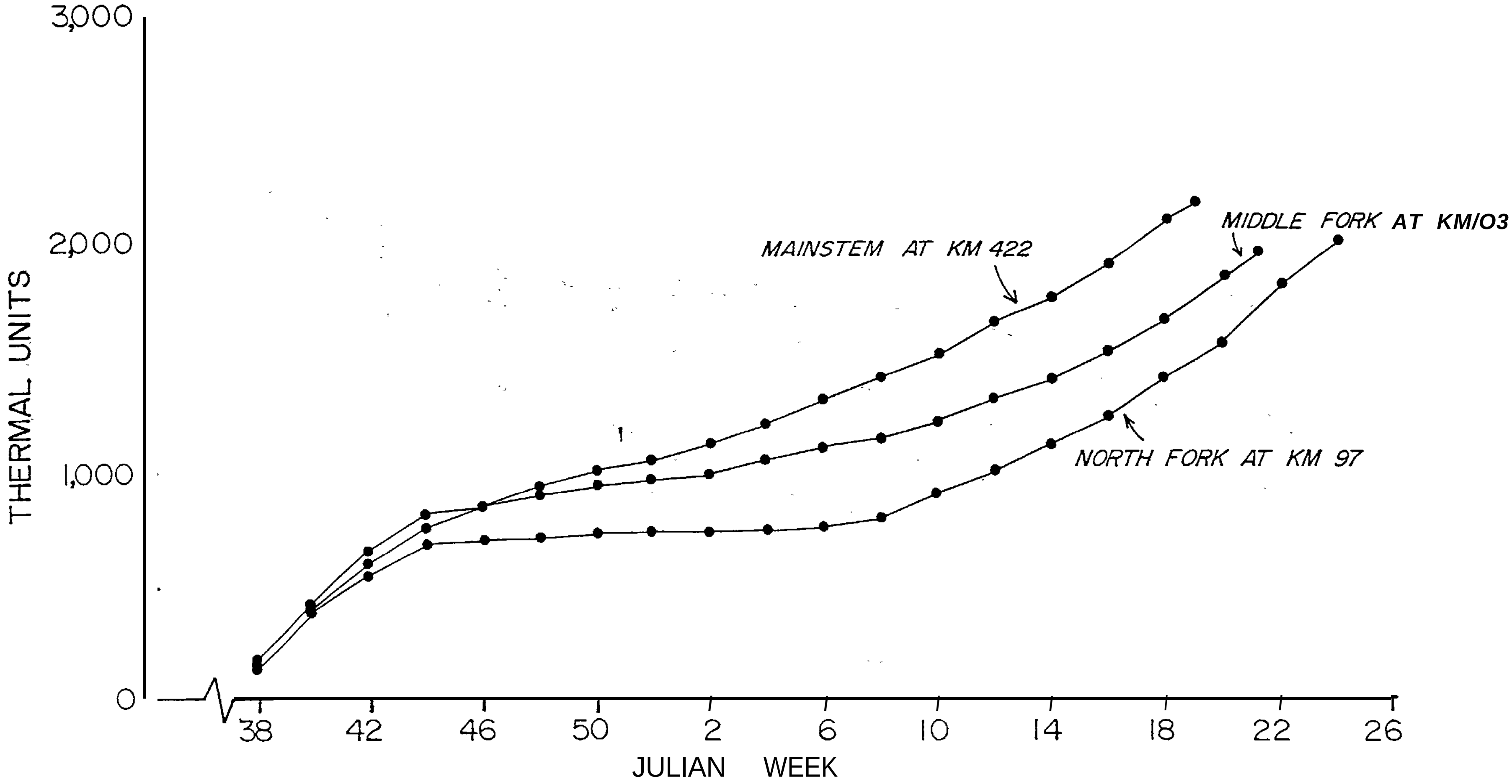

Figure 10. Cumulative thermal units from week of peak spawning to end of emergence, 1982-83.

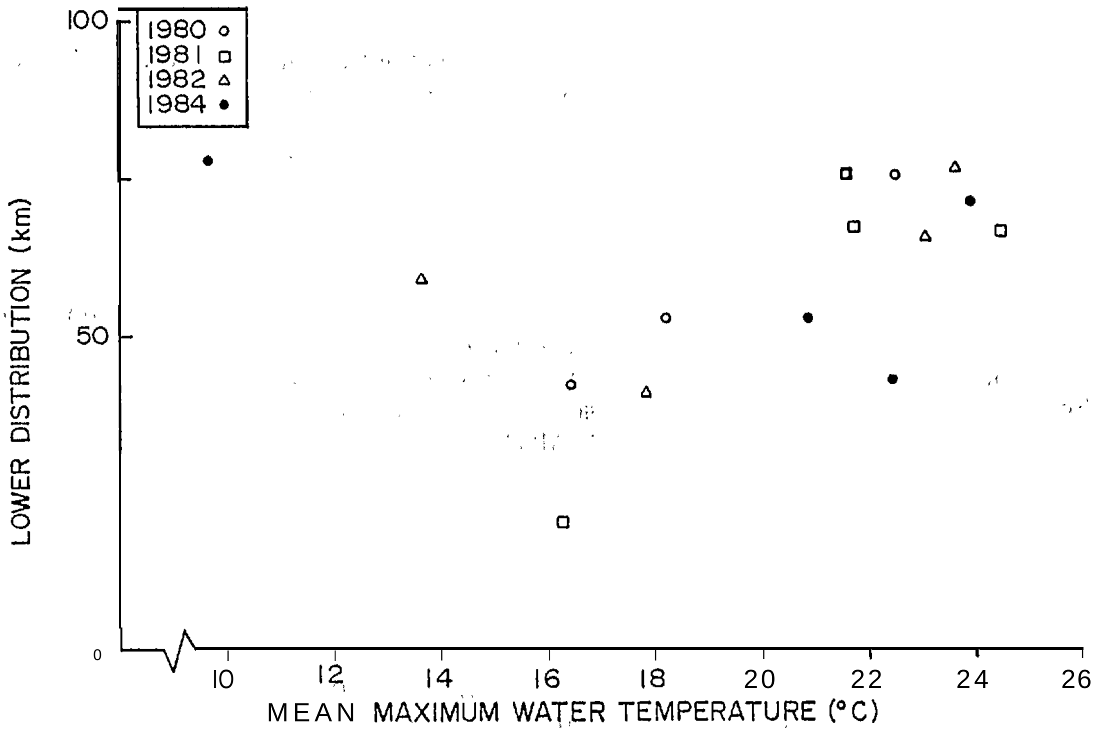

Figure 11. Relation between juvenile distribution in the Middle Fork and water temperature the week prior to sampling, 15 June to 15 Septemer, 1980-82 and 1984. Water temperature was measured at km 51.

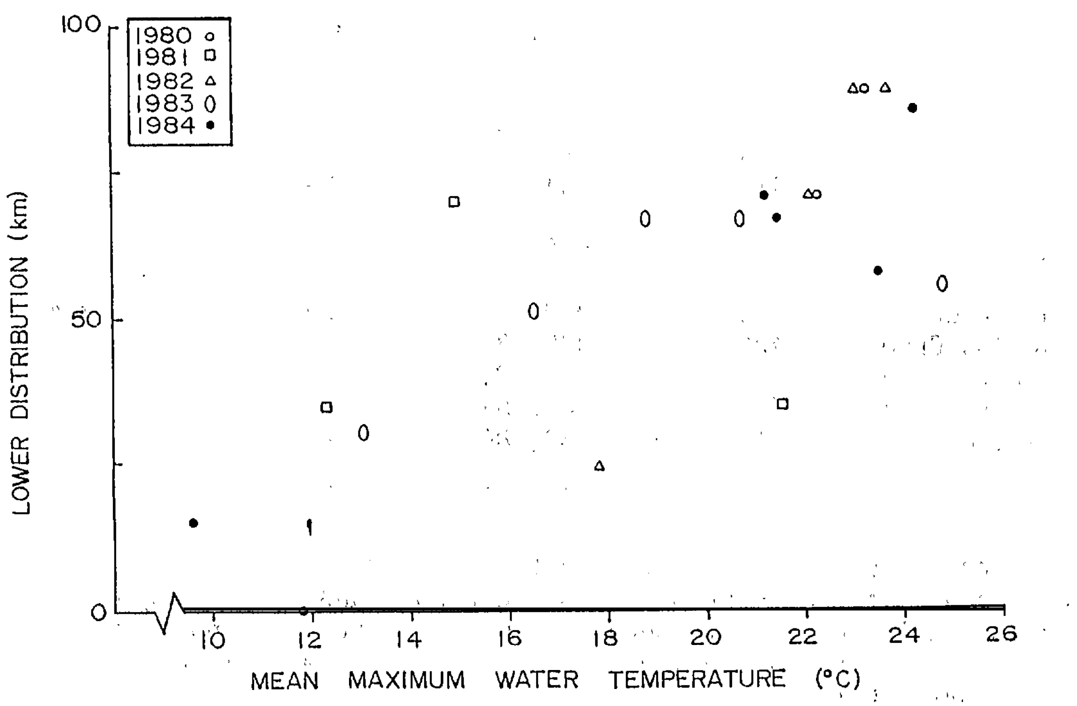

Figure 12. Relation between juvenile distribution in the North Fork and water temperature the week prior to sampling, 156 June to 15 September, 1980 84. Water temperature was measured at km 71.

Distribution usually increased during September;- however, during some years it increased as early as August (Appendix B).

In most years we found fingerlin chinook salmon in many of the tributaries within the John Day basin (Tables 18-20) even though, based on spawning surveys, they were not spawned there. We found fingerlings in some tributaries below the lower limits of distribution in the main rivers. We did not sample all tributaries in the basin, but of the 45 tributaries sampled from 1978-84, 62% contained chinook in at least one of the years they were sampled. Thermographs were installed in tributaries of the Middle Fork within known rearing areas from 1981 through 1984 to compare water temperatures in the tributaries with those in the main river. In general, tributaries of the Middle Fork were cooler than the main river throughout summer (Figures 13 and 14).

Table 18. Tributaries of the upper Mainstem John Day River sampled for juvenile spring chinook salmon, 1980, 1982, and 1984.

Tributary	Location, (river km)	Years sampled	Years juveniles were present	Upper limit of distribution (km)
Fields Creek	366	1984		
Moon Creek	374	1984		--
Riley Creek	381	1984		
Beech Creek	385	1982, 84	1984	1.0
Laycock Creek	391	1982	--	--
Canyon Creek	398	1982, 84	--	--
Dog Creek	404	1984		--
Indian Creek	414	1984	1984	3.2
Bear Creek	416	1984		--
Dixie Creek	422	1984	1984	0.8
Dads Creek	426	1980, 84	1984	3.4
Reynolds Creek	435	1980, 84	--	--
Deardorff Creek	438	1980, 84	--	“”
Roberts Creek	444	1980, 84	--	“”
Rail Creek	444	1980, 84	--	--

Upper distribution in the North Fork and in the upper Mainstem coincided with the.uppermost spawning areas, and fingerling salmon were present in these areas throughout summer and fall. , Fingerlings in the Middle Fork were found rearing in Squaw Creek (km 118) and in the river near Squaw Creek above all known spawning areas. These fish had evidently moved upstream following emergence. The reasons for this upstream movement are probably similar to the stimulus for movements into the tributaries.

Table 19. Tributaries of the Middle Fork John Day River sampled for juvenile spring chinook salmon, 1979-84.

Tributary	Location (river km)	Years sampled	Years juveniles were present	Upper limit of distribution (km)
Eightmile Creek	19	1982	1982	0.8
Granite Creek	40	1982, 84	1984	1.8
Slide Creek	52	1979-83	1979, 81	0.1
Indian Creek	56	1981-83	1981	2.7
Huckleberry Creek	60	1984	1984	0.5
Big Creek	63	1981-83	1981	1.1
Camp Creek	77	1980-83	1980, 81, 83	12.0
Coyote Creek	82	1982, 84	1984	0.3
Big Boulder Creek	86	1980-83	1980-83	2.1
Beaver Creek	90	1982-84	1984	0.3
Granite Boulder Creek	92	1980-83	1980, 83	4.0
Butte Creek	93	1980-83	1980-83	3.2
Deerhorn Creek	100	1982, 84	1984	2.4
Davis Creek	104	1982	--	--
Vinegar Creek	105	1982	--	--
Clear Creek	107	1979-81, 83	1979-81, 83	4.0
Summit Creek	116	1979-80, 83	--	--
Squaw Creek	118	1979-81, 83	1979, 80	1.0

Table 20. Tributaries of the North Fork John Day River sampled for juvenile spring chinook salmon, 1978, 1979, and 1982-84.

Tributary	Location (river km)	Years sampled	Years juveniles were present	Upper limit of distribution (km)
Rudio Creek	8	1984	1984	4.0
Cottonwood Creek	26	1982-84	--	--
Deer Creek	28	1982, 83	1982 83	2.4
Wall Creek	36	1982, 83	1982: 83	1.6
Ditch Creek	57	1982, 83	1982, 83	1.6
Mallory Creek	60	1982, 83	1982, 83	3.6
Potamus Creek	62	1979, 82, 83	1979	0.1
Stony Creek	72	1982, 83	1982, 83	3.2
Camas Creek	92	1978, 82	1978	0.1
Desolation Creek	97	1978	1978	5.0
Texas Bar Creek	105	1978	--	--
Big Creek	123	1978	--	--

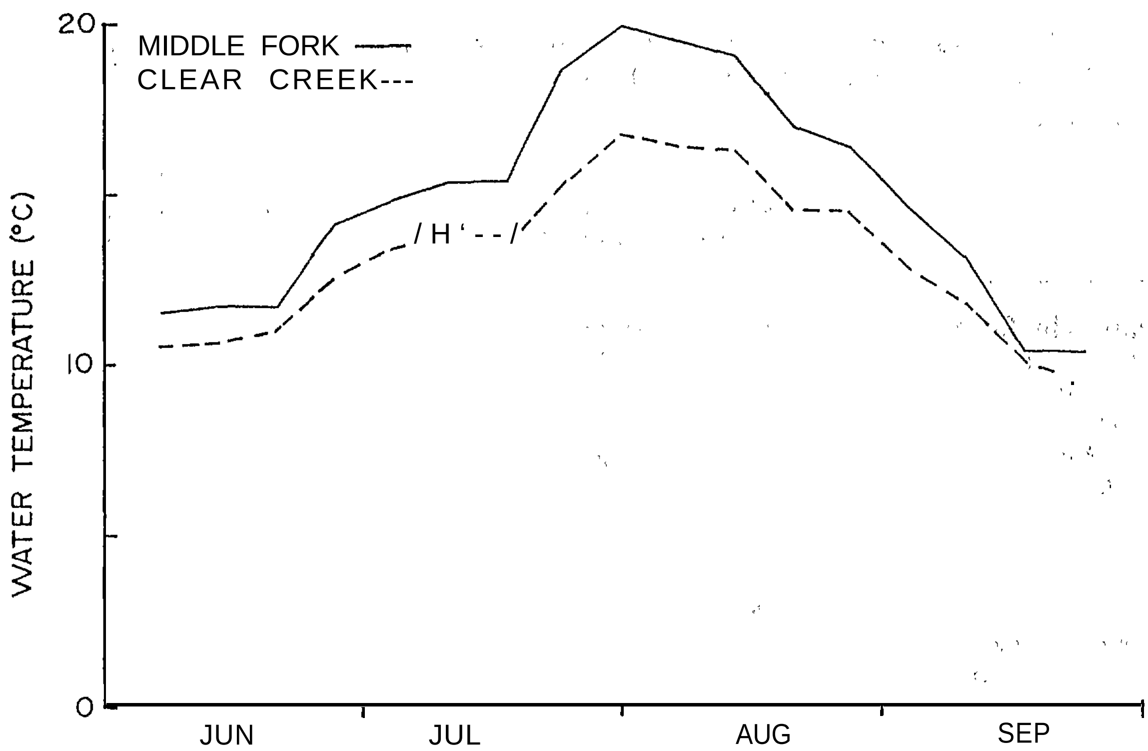

Figure 13. Mean weekly water temperature in Clear Creek (km 107) and the Middle Fork (km 103), 1983.

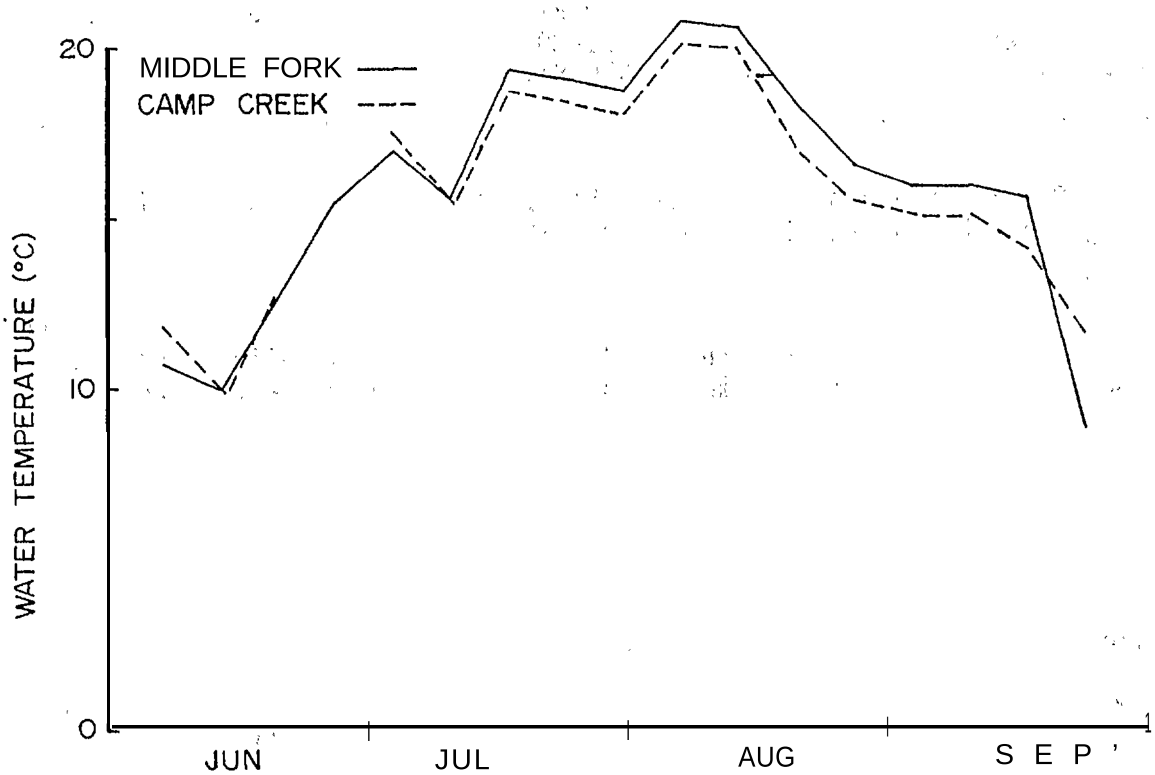

Figure 14. Mean weekly water temperatures in Camp Creek (km 76) and the Middle Fork (km 76), 1981.

Size and Growth of Juveniles

Fork lengths of fingerling spring chinook salmon sampled in individual streams of the John Day basin were similar from 1979 through 1984 (Figure 15). Chinook salmon in the upper Mainstem and in the Middle Fork usually emerged earliest and were larger than those in the North Fork system throughout the summer months (Appendix C). By September and October mean fork lengths of fingerlings from the Middle Fork and from the North Fork were similar to those in the Mainstem.

Growth was greatest during June and July when water temperatures were rising and flows were stablizing (Figure 15). Growth decreased in August, September, and October in the Middle Fork and in the Mainstem. This apparent reduction in growth may have resulted from migration of larger chinook salmon or decreased vulnerability of larger fish to our sampling gear because we rarely caught fingerlings greater than 100-110 mm, fork length, even though some juveniles reached this size as early as mid-July (Appendix C).

Smolts captured in scoop traps from 1980-84 were largest in the Mainstem and smallest in the North Fork (Table 21). Smolts captured in the Spray seining area were slighlty smaller than those captured in the Rock Creek area (Table 21). Smolt size generally increased over time at all sampling sites during each spring sampling season (Appendix C).

Abundance of Fingerlings

Although abundance was not estimated in each of the major forks because seining gear was only effective in a few sites, there were areas in the John Day basin where we consistently found large numbers of fingerling chinook salmon. Sites where we consistently caught rearing chinook salmon were areas of low velocity such as pools, eddies, secondary channels, side channels, and deep runs or glides.

Within the North Fork, large numbers of fingerling were found in side channels and in the main river around Nye (km 108), Sheep (km 115), Oriental (km 117), and Lick (km 120) creeks. Above Lick Creek, access was severely limited and very little sampling occurred. However, from observations during extensive spawning ground surveys through this area, areas with several of the stream characteristics mentioned above were observed near Ryder (km 130) and Backout (km 138) creeks, near Gutridge Mine (km 142), above the mouth of Granite Creek, and near Trail Creek (km 163) at the North Fork Campground. We recorded some of our largest catches of rearing salmon while coded-wire tagging fingerlings in the Granite Creek system in 1978-81. Areas where we caught large numbers include Buck Creek to Squaw Creek, Tencent Creek to Clear Creek, the lower 6 km of Clear Creek, and the lower 4 km of Bull Run Creek. In the upper Mainstem, we caught large numbers of fish near Reynolds Creek (km 435), in the split channels below French Lane (km 433), and near Prairie City just above Depot Park (km 422). The Middle Fork had large numbers of fingerlings from Clear Creek (km 107) downstream to Deerhorn Creek (km 100), in the side channel between Butte Creek (km 93) and Beaver Creek (km 90), and in an alcove just above Camp Creek Bridge (km 77).

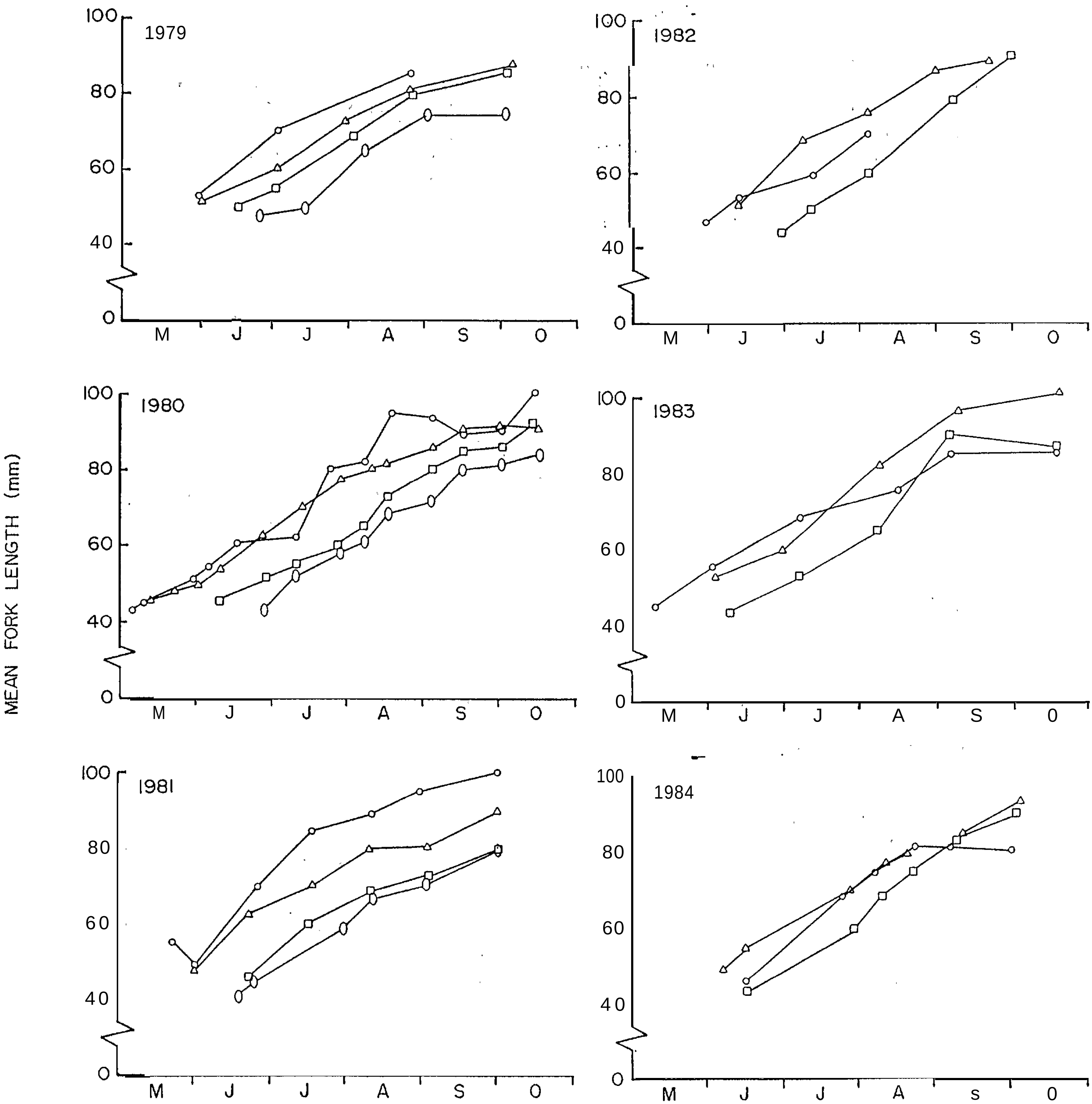

Figure 15. Mean lengths of juvenile chinook salmon in the Mainstem (0), Middle Fork (A), North Fork (O), and Granite Creek (0), 1979-84.

Table 21. Lengths of spring chinook salmon smolts sampled at trapping and seining sites 1978-84,

Sampling site, year	Sample size	Fork length (mm) mean	range
Mainstem Scoop trap (km 397):			
1981	309	108	88-138
1982	234	113	88-134
1983	255	108	84-130
1984	206	99	82-123
Middle Fork Scoop trap (km 51):			
1980	441	105	81-127
1981	374	98	78-129
1982	51	91	86-117
1983	14	108	96-122
1984	151	104	77-126
North Fork Scoop trap (km 97):			
1980	502	94	70-I. 24
1981	301	96	76-131
1982	192	93	78-113
1983	477	92	72-119
1984	386	96	72-117
Spray seining area (kms 275-293):			
1980	718	104	80-3.34
1981	525	108	85-3.34
1982	244	106	80-132
1983	405	113	88-140
1984	542	110	90-l 36
Rock Creek seining area (kms 35-64):			
1982	77	110	91-135
1983	18	126	109-140

Although the tributaries do not seem to rear as many chinook salmon as the main rivers, we consistently captured fingerlings in certain, tributaries. These tributaries included Indian and Beech creeks (kms 414 and 385, respectively) in the Mainstem; Clear, Butte, and Big Boulder creeks (kms 107, 93, and 86, resprctively) in the Middle Fork; and, Desolation, Stony, Wall, and Deer creeks (kms 97, 72, 36, and 28, respectively) in the North Fork (see Tables 18-20).

Scales

The average age composition of adult spring chinook salmon recovered as carcasses during spawning surveys in 1978-85 ranged from 1% to 5% age 3, 54% to 89% age 4, and 8% to 44% age 5 (Table 22). Virtually all of the adults sampled had migrated to the ocean in their second year (age 1).

The relationship between fork length and scale radius for juvenile spring chinook salmon in the John Day River was highly variable. Coefficients of determination (r^2) ranged from 0.21 to 0.54 indicating that little of the variation in fork length was explained by variation in scale radius. However, the mean fork lengths at ocean entrance, back-calculated from adult scales (Table 23), were reasonable when compared with measured fork lengths of smolts captured at scoop traps. Estimated mean fork lengths at ocean entrance were 5 to 20 mn larger than mean fork lengths from scoop trap samples and reflected growth of smolts or differential survival of smolts of different sizes during downstream migrations.

We were unable to use regressions of Julian day on circuli number from smolt scales to back-calculate time of ocean entrance from adult' scales. These regressions were highly variable and we found little or no linear relationship. We attempted to correlate other scale measurements (e.g., number of circuli to the first annulus, number of clrculi beyond the first annulus, total scale radius, and circuli spacing) to Julian day but no model allowed us to adequately predict Julian day, by using smolt scale characteristics.- Therefore, our best measure of timing of ocean entrance is recaptures of marked smolts in' the Columbia River estuary at Jones Beach (see Table 9).

We were unable to accurately distinguish among Mainstem, Middle Fork, and North Fork smolts by using discriminant analysis of scale characteristics. When discriminant functions were tested with scales of known origin (smolts collected at scoop traps in 1980-83). the percentage correctly classified to stream of origin ranged from 51 to 58. These classification rates are too low to apportion estimates of smolt abundance at Spray to the three major forks.

We were unable to use scale characteristics during the first year of growth to distinguish juveniles that would smolt from those that would not (residuals) in Granite Creek.

Table 22, Percent age class composition of spring chinook salmon carcasses recovered in the John Day River, 1978-85.

Stream, year	Sample size	Age 3	Age 4	Age 5
Mainstem:				
1978	3	0	100	0
1979	22	0	100	0
1980	4	0	50.0	50.0
1981	8	0	62 05	37.5
1982	5	0	80.0	20.0
1983	22	0	95.5	4.5
1984	43	2 3	88.4	9.3
1985	58	10.3	82.8	6.9
Middle Fork:				
1978	56	3.6	94.6	1.8
1979	44	0	95.5	4.5
1980	17	5.9	29.4	64.7
1981	14	0	78.6	21.4
1982	33	0	97.0	3.0
1983	45	2.2	91.1	6.7
1984	56	5.4	87.5	7.1
1985	27	3.7	59.3	3700
North Fork:				
1978	36	0	38.9	6101
1979	32	0	84.4	15.6
1980	29	0	58.6	4104
1981	125	4.0	72.0	24.0
1982	77	2.6	88.3	901
1983	67	0	76.1	2309
1984	42	4.8	85.7	9.5
1985	87	9.2	77.0	13.8
Granite Creek system:[a]				
1978	85	2.4	37.6	60.0
1979	46	2.2	71.7	26.1
1980	36	0	66.7	3303
1981	67	1.5	88.1	10.4
1982	98	4.1	87.8	801
1983	42	2.4	64.3	33.3
1984	50	10.0	82.0	800
1985	110	4.5	88.2	703

[a] *Includes Granite, Clear, and Bull Run creeks.*

Table 23. Mean fork length of smolts at ocean entrance back-calculated from scales of adult spring chinook salmon from the John Day River. CI = confidence limits.

Stream, brood year	Age	Sample size	Mean fork length (mm)	95% CI
Mainstem:				
1979	4	21	125,	f1.7
Middle Fork:				
1978	4	32	124	±2.8
1978	5	3	124	-111.9
1979	4	38	122	±2.6
1980	3	1	130	--
North Fork:				
1978	3	5	112	f4.4
1978	4	68	116	±1.6
1978	5	15	118	±4.8
1979	3	2	125	±4.5
1979	4	46	116	±1.8
Granite Creek:				
1978	3	1	98	--
1978	4	85	110	±1.1
1978	5	13	112	f3.3

Stock-Recruitment

The timing of spawning ground surveys conducted prior to 1978 has varied and this variation appears to have affected the accuracy of past redd counts in the Middle Fork. Index surveys prior to 1978 were conducted between Julian days 247 and 260 with the general trend of later surveys over time. We found a significant relationship between Julian day of index surveys and number of redds counted in the Middle Fork (r = 0.65; P<0.005). Therefore, we adjusted all index counts in the Middle Fork prior to 1978 to Julian day 263, the time of peak redd counts in supplemental surveys of the Middle Fork during 1978-80. We did not find significant relationships between index redd counts and date of survey in other streams in the John Day basin.

The majority of carcasses that we recovered during spawning surveys in 1978-85 were age 4 (see Table 22). We observed differences in age class composition amoung spawning streams in the John Day system. On the average, the North Fork and Granite Creek systems had a higher proportion of age 5 spawners 'than the Middle Fork and Mainstem (see Table 22). The age class structures that we used to apportion a given year's spawning stock were 5% age 3, *.70% age 4, and 25% age 5 for the North Fork and Granite Creek and 5%'age 3, 90% age 4, and 5% age 5 for the Middle Fork and Mainstem.2 We used 5% age 3 for all streams even though we did not observe more than 3.1% in any year's carcass recoveries (see Table 22). Three year olds are smaller and predominantly males so they are less likely than the larger, 4- and 5-year-olds to be recovered during spawning surveys.

We observed a sharp decline in returns per spawner throughout the John Day River beginning with the 1970 brood. The North Fork and Granite Creek systems have remained at or below replacement since the 1970 brood (Figures 16 and 17). The Middle Fork has been below replacement since the 1976 brood (Figure 18) and the Mainstem has fluctuated above and below the replacement level since the 1970 brood (Figure 19). All estimates of return per spawner were above the replacement level before 1970. Estimates of returns per spawner for all streams in the John Day system combined ranged from 1.8 to 2.4 for 1964 through 1969 broods and from 0.5 to 1 .O for 1970 through 1979 broods (Figure 20).

Returns per spawner at a given density of spawning stock was consistently less for 1970 through 1979 broods than for pre-1970 broods in all streams in the John Day River (Figures 21-24). We found that the shape of this relatioship also changed. This change was most evident in the Mainstem and in Granite Creek where plots of returns per spawner on spawning stock density for pre-1970 broods were curvelinear and asymptotic with returns per spawner decreasing as density of spawning stock increased,(i.e. compensatory relationship; Figures 21 and 24). In contrast, returns per spawner was independent of the density of spawning stock for the 1970-79 broods (Figures 21 and 24).

Because we observed a shift in return per spawner relationships, we separated the data into pre-1970 and 1970-79 broods before generating Ricker and Beverton-Holt stock-recruitment curves. We found significant relationships between spawners and recruits for pre-1970 broods in all streams except the Middle Fork with both Ricker and Beverton-Holt models (Table 24). We plotted the Beverton-Holt curves because they provided a slightly better fit of the data. We found little or no relationship between spawners and recruits for 1970 through 1979 broods with either model (Table 24; Figures 25-28).

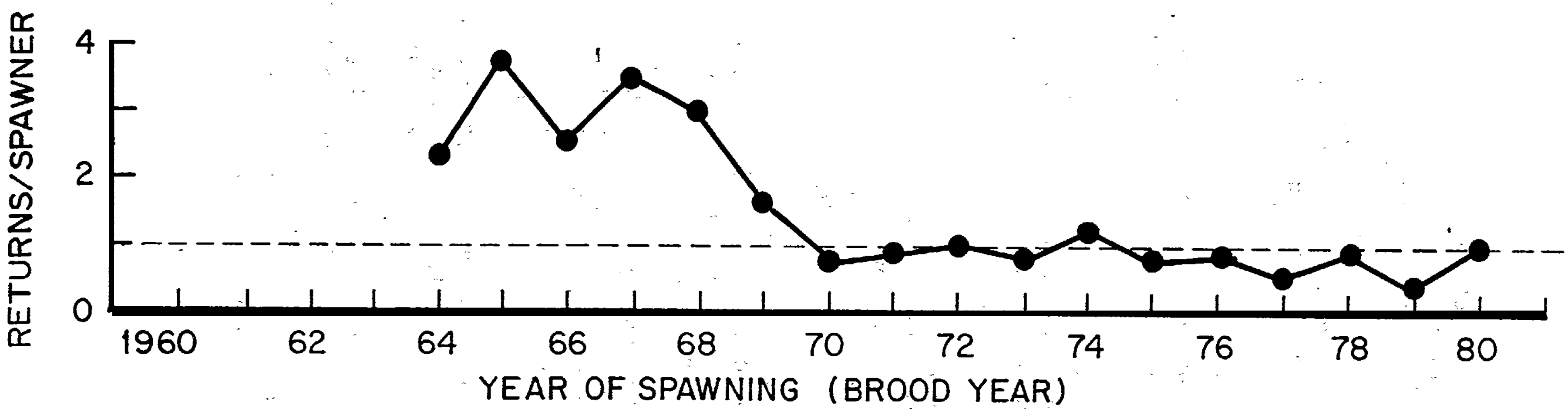

Figure 16. Estimated returns per spawner in the North Fork John Day River, 1964-80 broods.

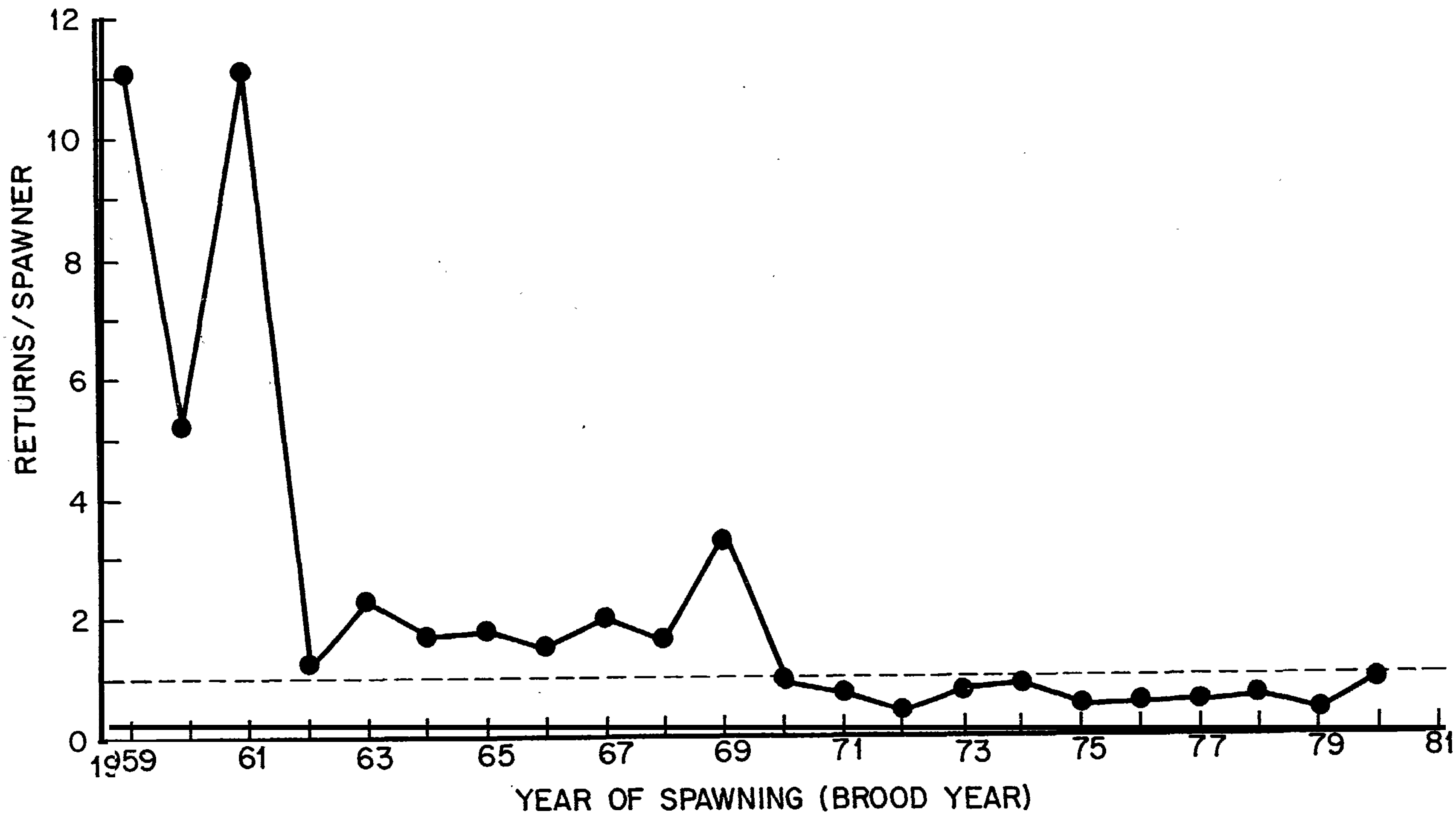

Figure 17. Estimated returns per spawner in the Granite Creek system (includes Clear and Bull Run creeks; Bull Run Creek was inaccessible to spawning salmon until 1962), 1959-80 broods.

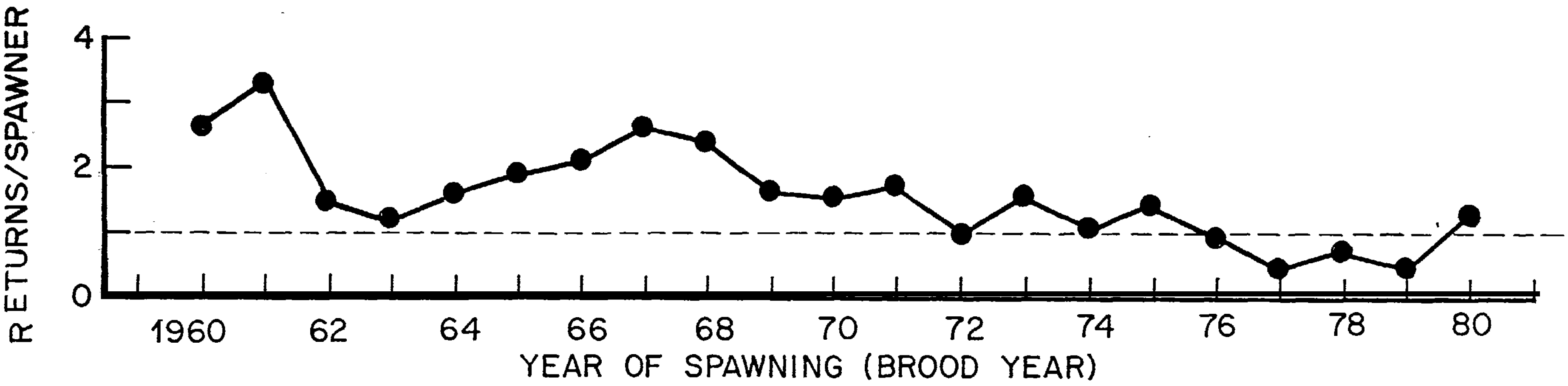

Figure 18. Estimated returns per spawner in the Middle Fork John Day River, 1960-80 broods.

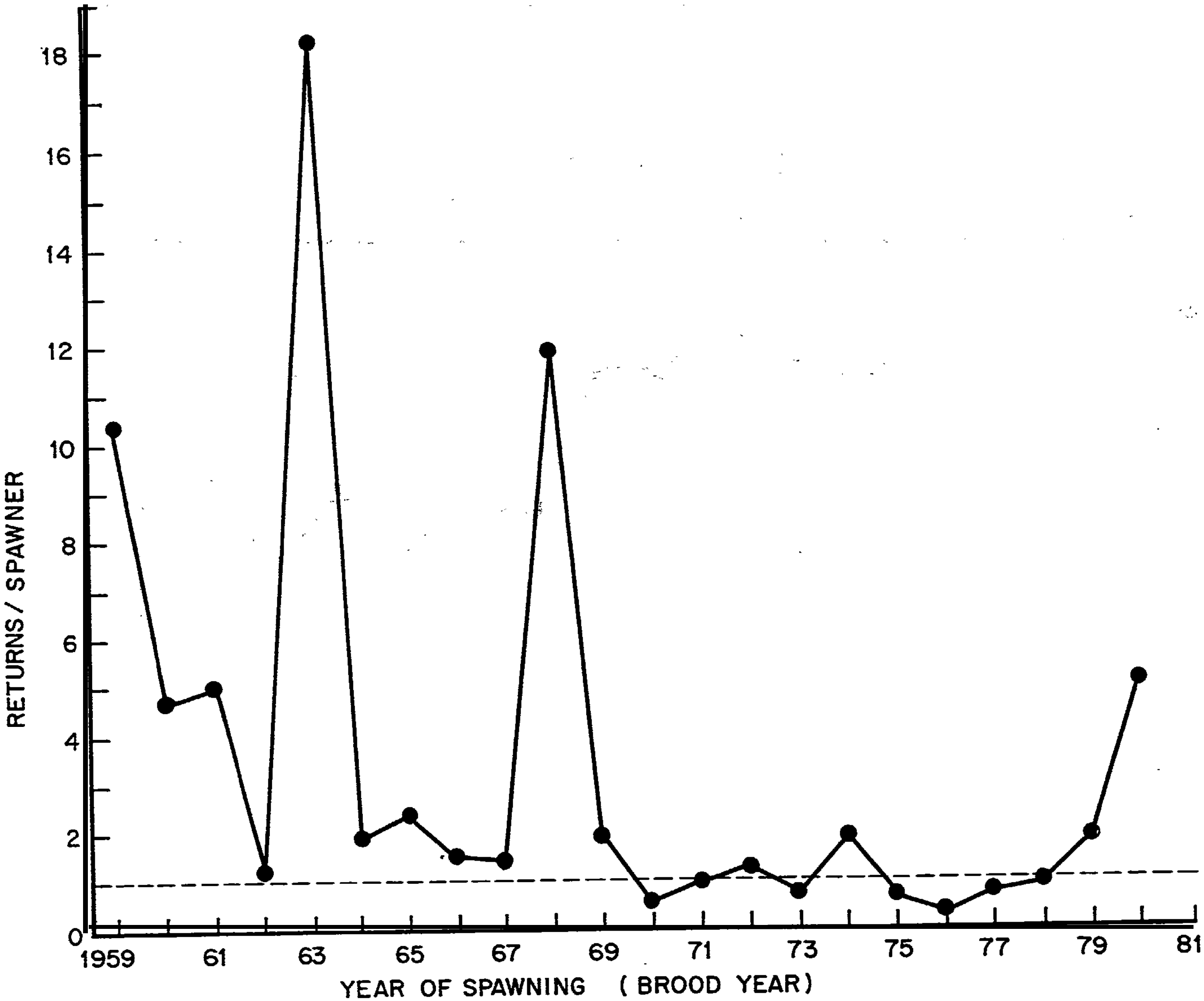

Figure 19. Estimated returns per spawner in the Mainstem John Day River, 1959-80 broods.

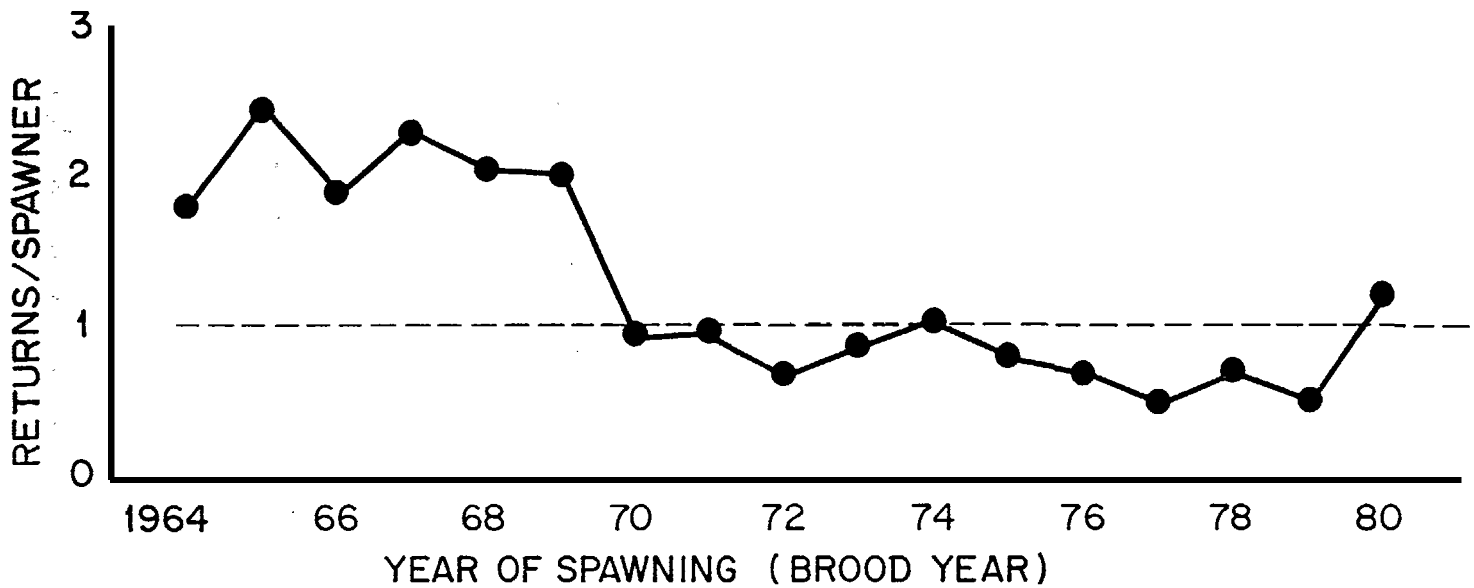

Figure 20. Estimated returns per spawner in the John Day River system (all streams combined), 1964-80 broods.

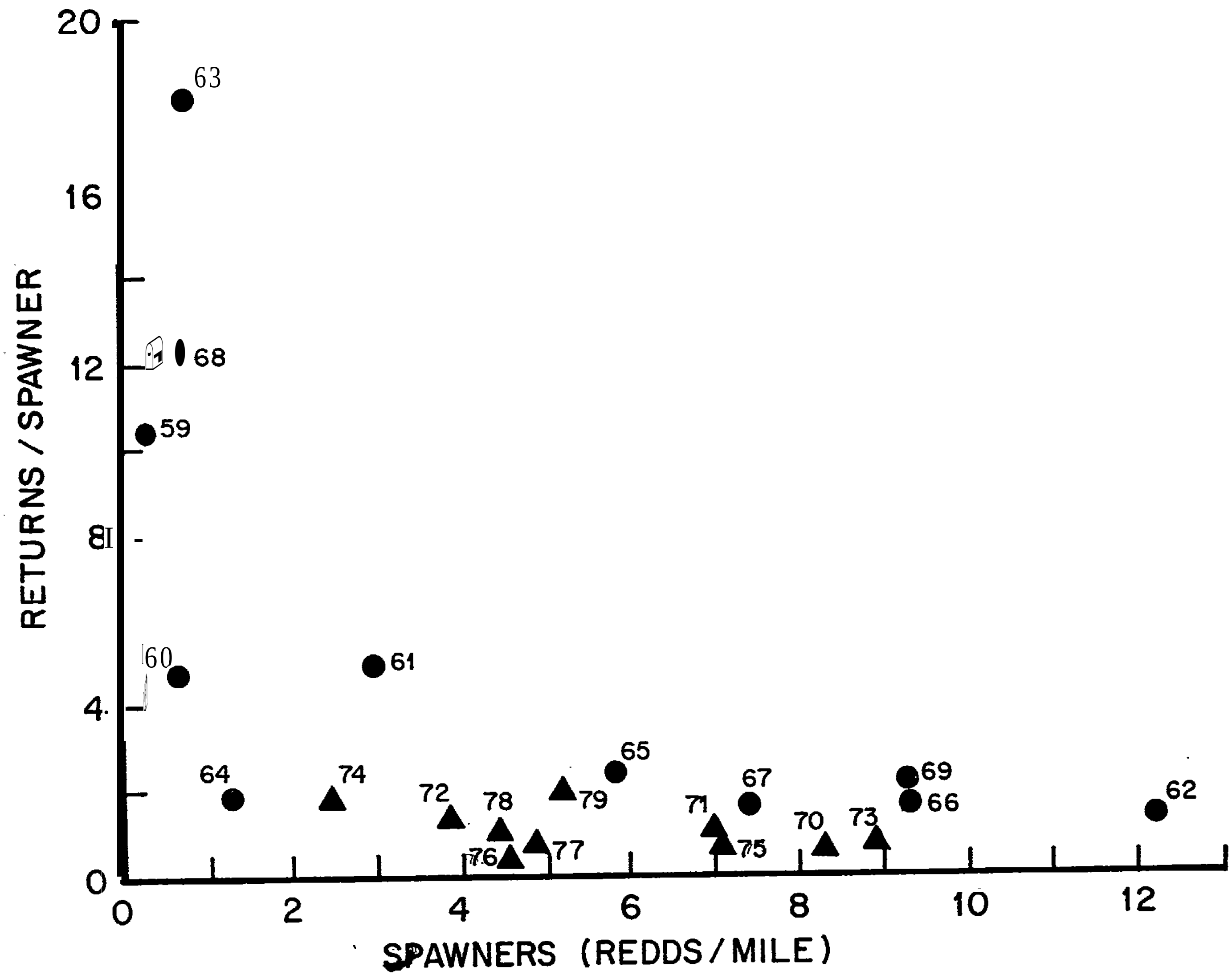

Figure 21. Relationship between spawning stock density and returns/spawner for 1969-79 broods in the Minstem John Day River. ● = 1959-69 broods, ▲ = 1970-79 broods.

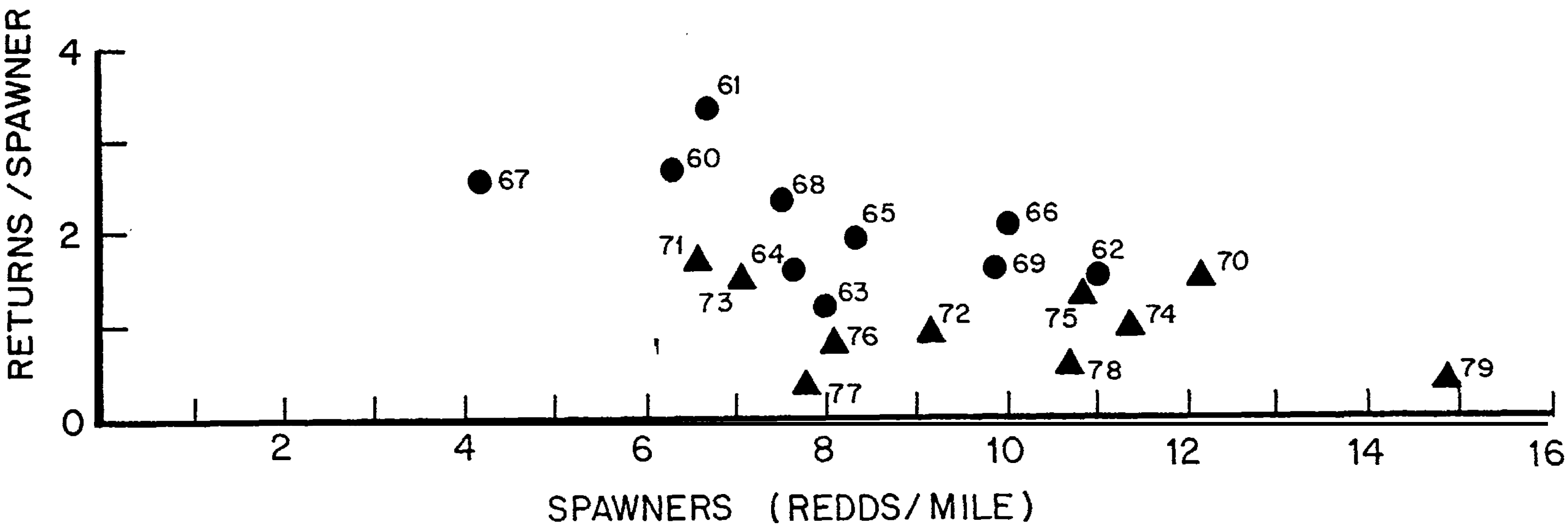

Figure 22. Relationship between spawning stock density and returns/spawner for 1960-79 broods in the Middle Fork John Day River. ● = 1959-69 broods, A= 1970-79 broods.

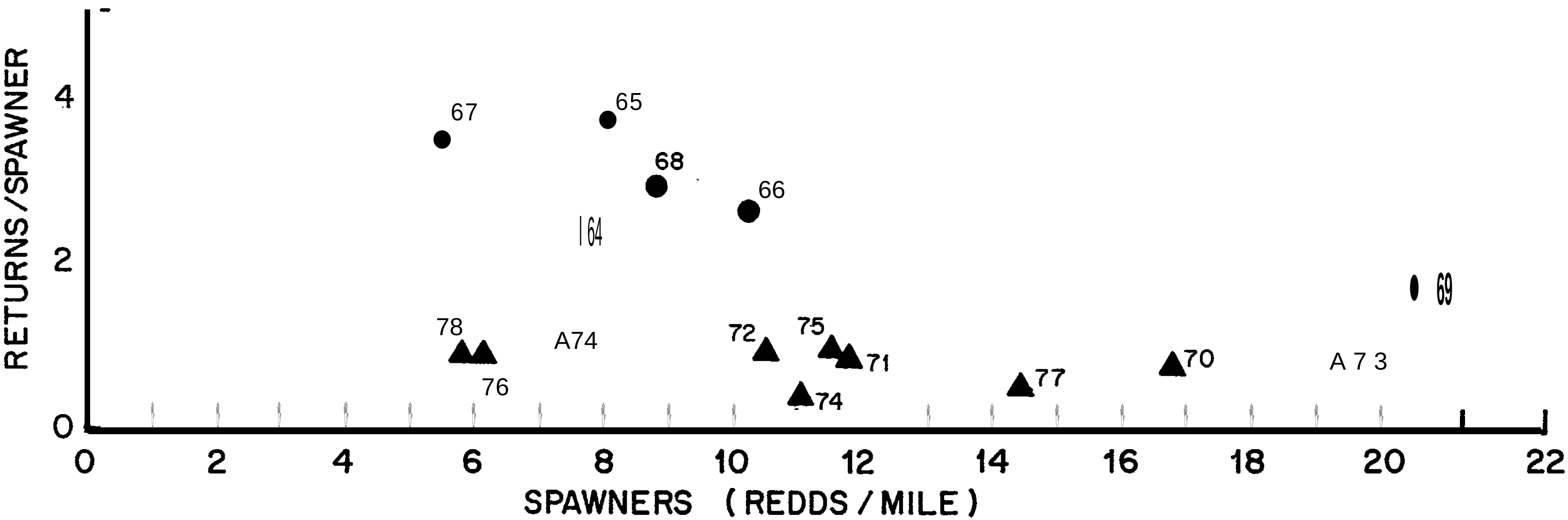

Figure 23. Relationship between spawning stock density and returns/spawner for 1964-79 broods in the North Fork John Day River. ● = 1964-69 broods, A = 1970-79 broods.

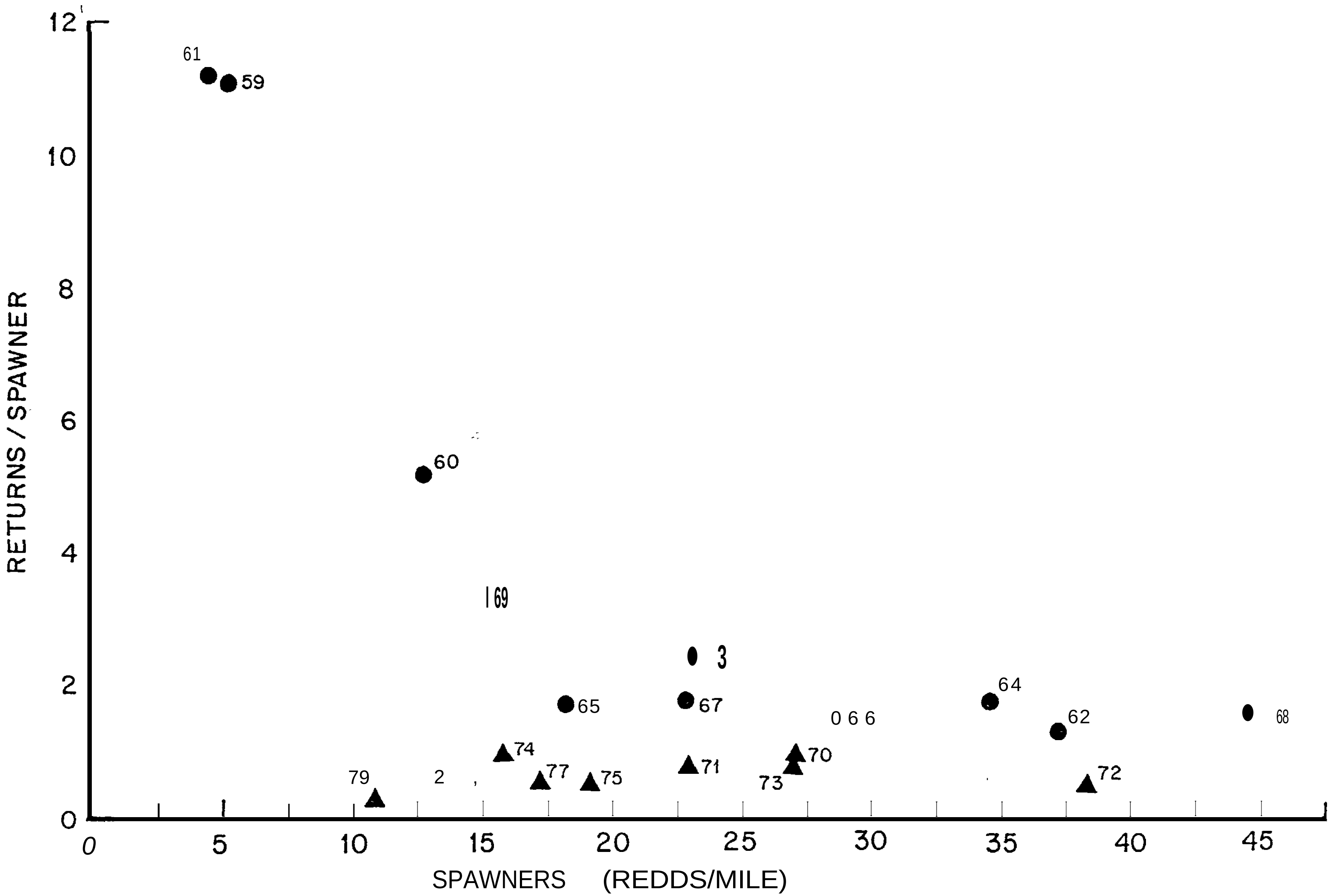

Figure 24. Relationship between spawning stock density and returns/spawner for 1959-79 broods in the Granite Creek system (includes Clear and Bull Run creeks). ● = 1959-69 broods, ▲ = 1970-79 broods.

Table 24. Stock-recruitment parameters for spring chinook salmon in the John Day River using Ricker and Beverton-Holt models. S = parent spawning stock; R = recruits.

Model, stream, brood years	a	B	r^2	*P*
Ricker (ln R/S = a + BS)				
Mainstem:				
1959-69	2.09	-0.18	0.65	<0.005
1970-79	0.49	-0.11	0.18	>0.20
Middle Fork:				
1960-69	1.43	-0.10	0.36	>0.05
1970-79	0.65	-0.08	0.14	>0.20
North Fork:				
1964-69	1.48	-0.05	0.74	(0.025
1970-79	-0.02	-0.02	0.09	>0.20
Granite Creek:[a]				
1959-69	2.23	-0.05	0.76	<0.001
1970-79	-0.58	0.004	0.02	>0.50
Beverton-Holt (S/R = B + aS)				
Mainstem:				
1959-69	,0.Q6'	0.14	0.76	<0.001
1970-79	0.08	0.81	0.06	>0.50
Middle Fork:				
1960-69	0.05	0.16	0.30	>0.10
1970-79	0.12	0.18	0.14	>0.20
North Fork:				
1964-69	0.02	0.17	0.83	(0.025
1970-79	0.03	1.07	0.05	>0.50
Granite Creek:[a]				
1959-69	0.02	0.06	0.81	<o .001
1970-79	,-0.006	1.82	0.01	>0.50

[a] *Includes Clear and Bull Run creeks.*

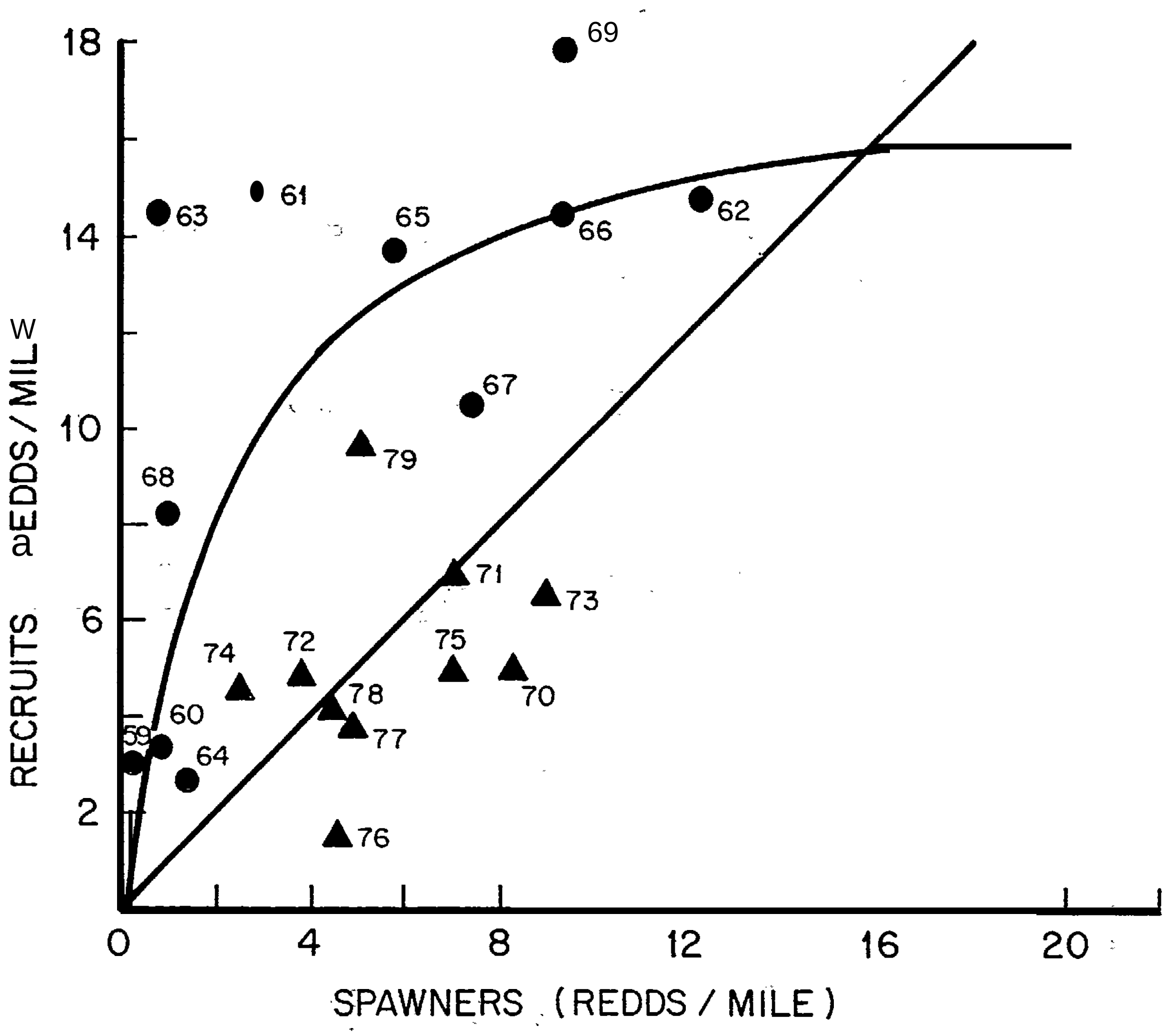

Figure 25. Beverton-Holt stock-recruitment curve for 1959-69 broods in the Mainstem John Day River. Data for 1970-79 broods (A) are plotted for comparison.

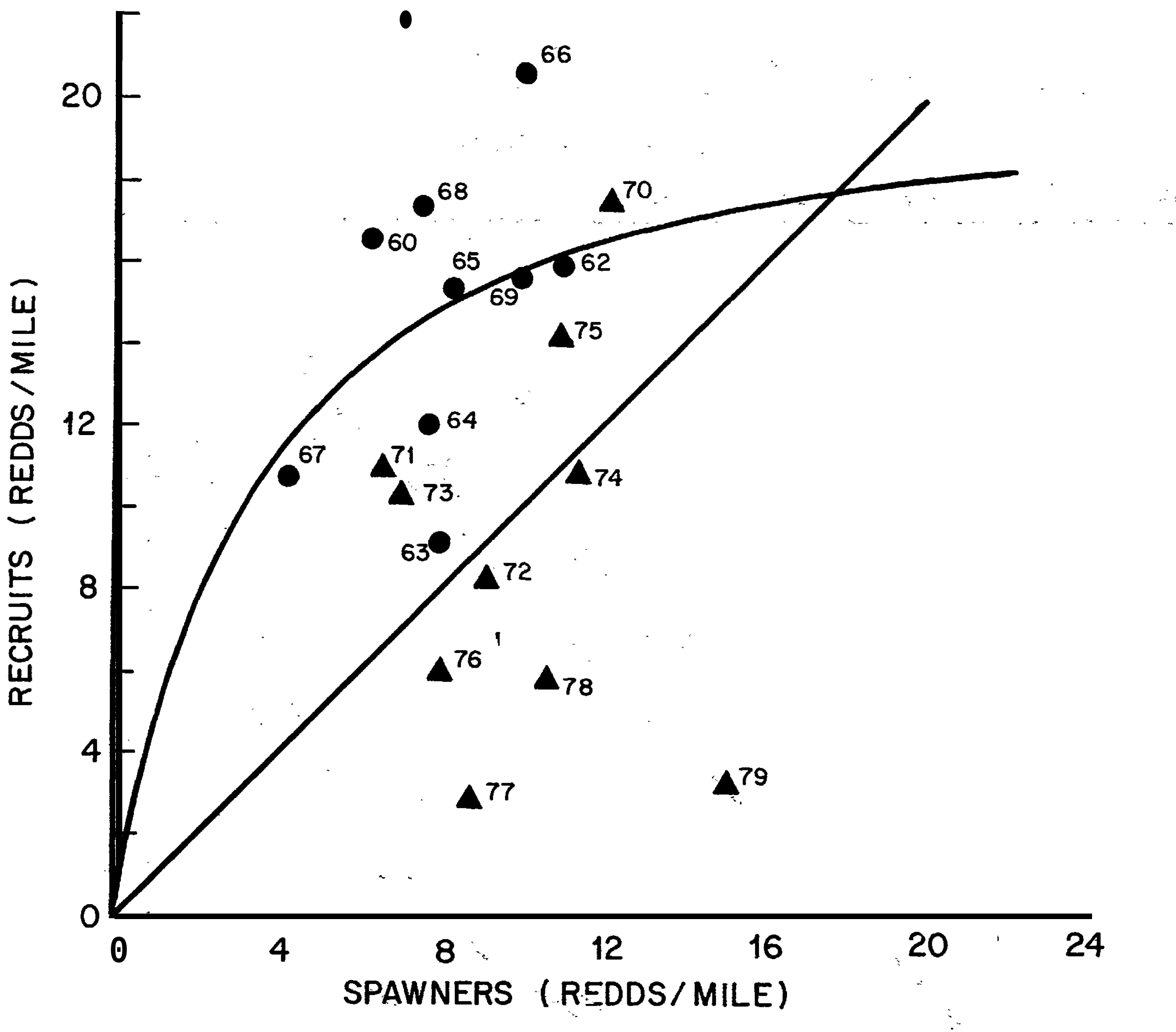

Figure 26. Beverton-Holt stock-recruitment curve for 1960-69 broods in the Middle Fork John Day River. Data for 1970-79 broods (A) are plotted for comparison.

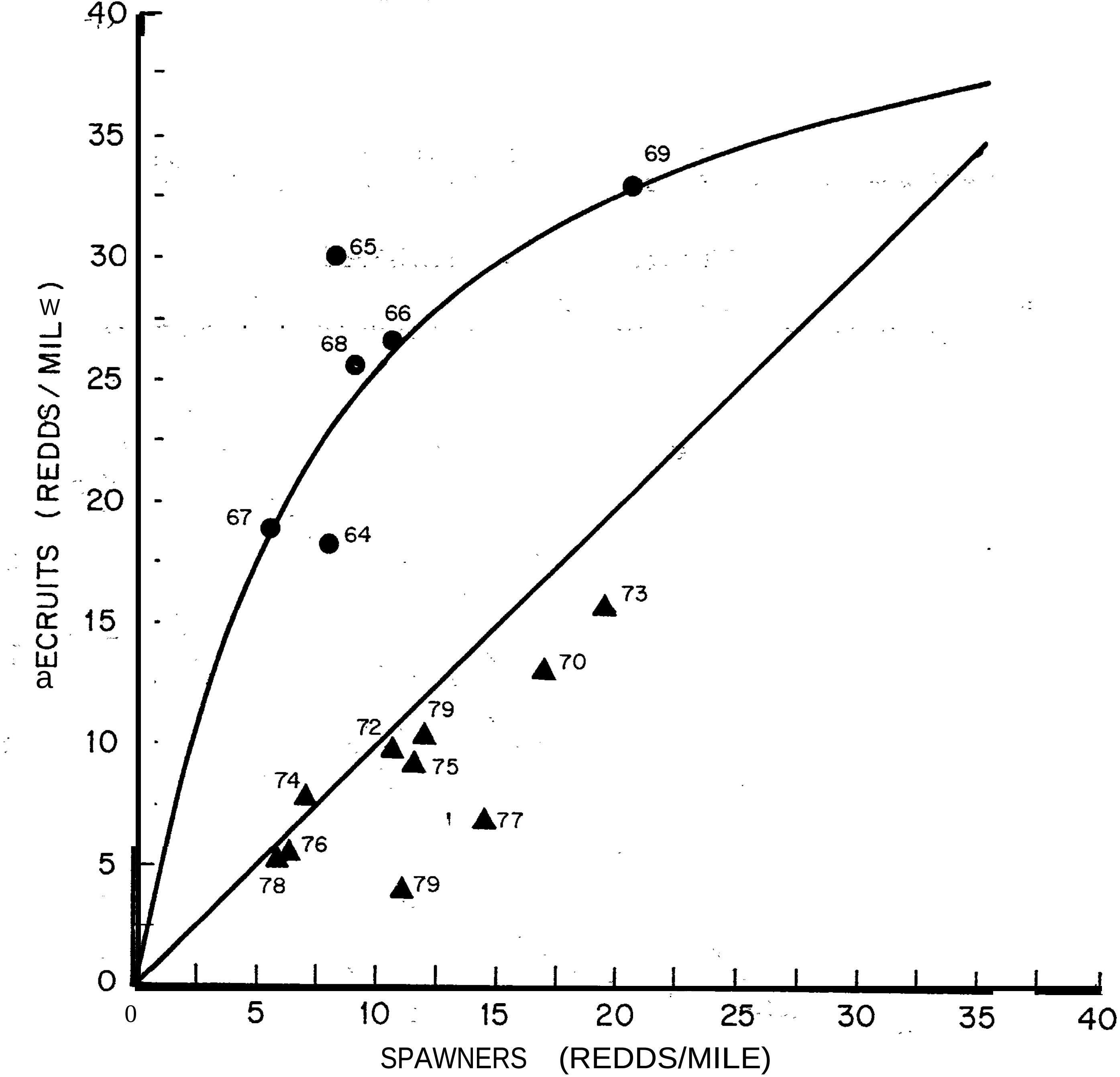

Figure 27.. Beverton-Holt stock recruitment curve for 1964-69 broods in the North Fork John Day River. Data for 1970-79 broods (A) are plotted for comparison.

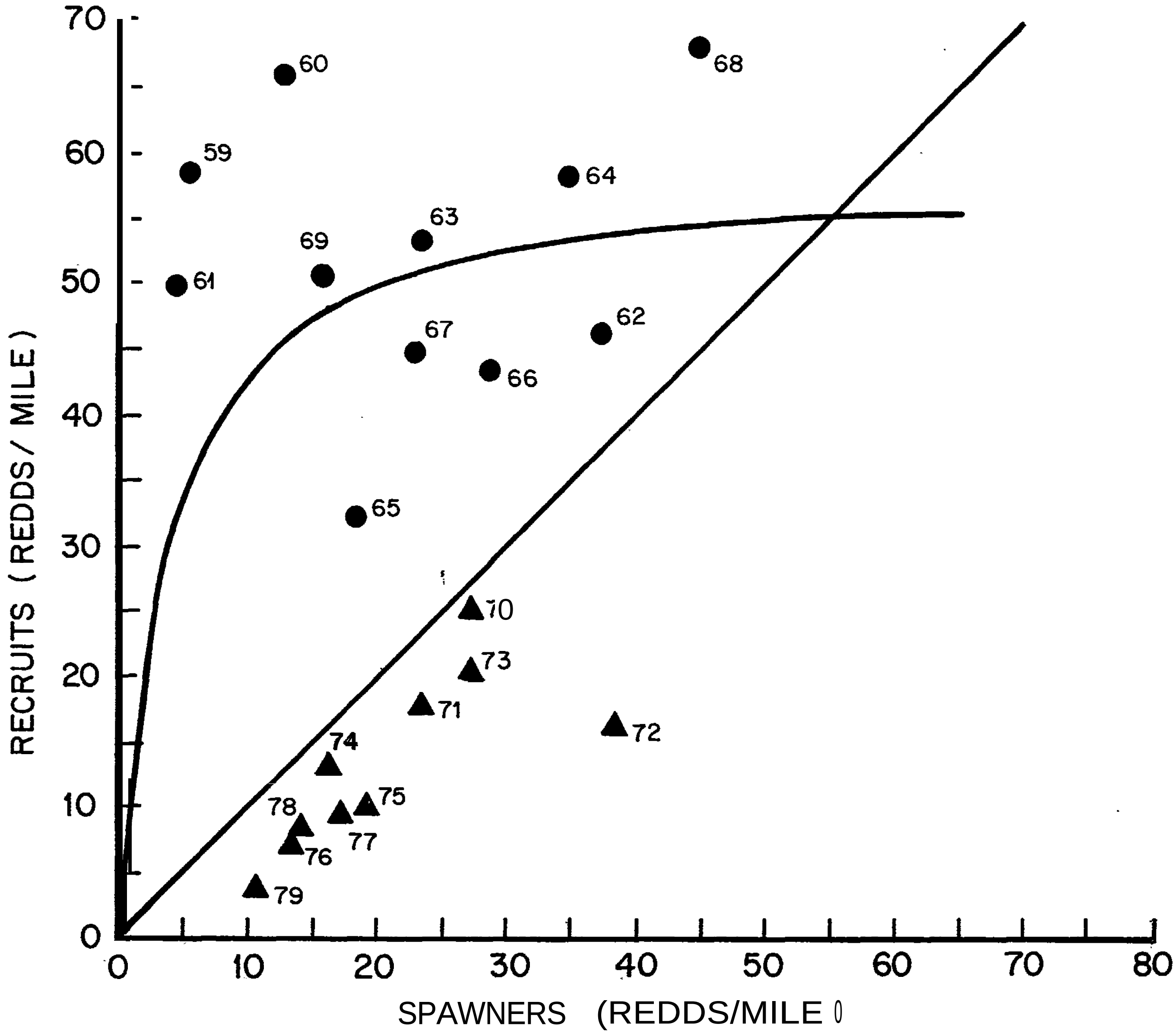

Figure 28. Beverton-Holt stock-recruitment curve for 1959-69 broods in the Granite Creek system (includes Clear and Bull Run creeks). Data for 1970-79 broods (A) are plotted for comparison.

No harvestable surplus of spring chinook salmon is currently being produced in the John Day River. The adult progeny returning to spawn are not even replacing the spawning stock that produced them. The Beverton-Holt models for pre-1970 broods (with values expanded from index redd densities to total numbers of fish by index to total redd ratios and 3.0 fish/redd) indicate that the John Day River would have sustained a run of about 6,800 fish in the absence of any harvest (replacement level). Maximum sustained yield would have been approximately 3,300 fish at a parent stock abundance of 1,750 fish and an exploitation rate of 65% (Table 25). Sustained yields at 25% and 40% exploitation rates would have been approximately 1,600 and 2,400 fish, respectively (Table 25).

Table 25. Estimates of equilibrium spawner abundance and sustained yields at replacement, maximum sustained yield (MSY), and at 25% and 40% exploitation rates (u) for pre-1970 brood spring chinook salmon in the, John Day River using Beverton-Holt stock-recruitment curves.

Item	Mainstem	Middle Fork	North Fork	Granite Creek[a]	Total for the John Day system
Replacement: '(Spawners = Recruits)	644	972	2,833	2,329	6,770
MSY	298	411	1,186	1,394	3,289
Spawners at MSY	173	280	823	467	1,743
Exploitation rate at MSY	0.63	0.60	0.59	0.75.	0.65
Spawners required to sustain u = 0.25	458	681	1,981	1,707	4,827
Sustained yield at u = 0.25	153	227	661	569	1,610
Spawners required to sustain u = 0.40	346	507	1,471.	1,335	3,659
Sustained yield at u = 0.40	231	338	980	890	2,4,39

d *Includes Clear and Bull Run creeks.*

DISCUSSION

Catch in Ocean and Columbia River

Apparently spring chinook salmon from the John Day River are not harvested to any great extent in ocean fisheries because only one Ad+CWT marked fish from the John Day River was recovered in ocean fisheries. In contrast, 11 marked chinook from the John Day River were recovered in Columbia River fisheries and 71 were recovered during spawnig surveys in 1981-85. We estimated that 21,758 marked smolts migrated from the John Day River'from 1979-82 (7% to 9% of each years smolt run). This is a small marked group compared with Ad+CWT releases from hathceries, which often number hundreds of thousands annually (Johnson 1985). However, our recovery data are similar to data obtained from large hatchery releases of marked spring chinook salmon. For example, Rapid River Hatchery, Idaho, released 249,257 Ad+CWT marked smots in 1979 and obtained only one recovery in the ocean, 35 recoveries in Columbia River fisheries, and 179 recoveries at the hatchery (Duke 1984). Upriver stocks of Columbia River spring chinook salmon are apparently not being harvested to any great extent in the ocean.

A number of hypotheses have been developed to explain this lack of ocean harvest. These include (1) the' majority of spring chinook (those that spawn at age 4) are not large enough to be vulnerable to ocean fishing gear; (2) intensive ocean fisheries are occurring in late spring and early summer after spring chinook salmon have beguntheir upstream migrations; and, (3) spring chinook salmon are distributed far off-shore in the ocean whereas ocean fisheries are concentrated in near shore areas (Rodney Duke, Idaho Fish and Game, personal communication). The hypotheses about timing and distributio of ocean fisheries suggest that ocean harvest is on fall chinook salmon, which remain in the ocean longer and are distributed closer to shore than are spring chinook salmon. Data from Idaho hatcheries support these hypotheses because many of their marked fall chinook salmon are recovered in ocean fisheries from Alaska and Canada to the mouth of the Columbia River (Duke 1984). Idaho Department of Fish and Game is planning tyo release approximately 500,000 marked spring chinook salmon smolts from Rapid River, Sawtooth, and Dworshak hatcheries in 1986 to obtain more information about the extent of ocean harvest of Columbia River spring chinook salmon (Rodney Duke, Idaho Department of Fish and Game, personal communication).

Spring chinook salmon from the John Day River were caught in lower Columbia River test fisheries and in Indian ceremonial fisheries in April and May. None were caught in the commercial and sport fisheries, which have ended in March in recent years. Therefore, it appears that commercial and sport fisheries in the lower Columbia River will not impact John Day River stocks as long as the dates of the seasons remain the same.

John Day River spring chinook salmon can not be isolated from other stocks in Columbia River fisheries by size restrictions. Although John Day River fish were smaller, on the average, than other stocks harvested in the Columbia River, sizes overlapped. Also, length restrictions could result in increased harvest of larger, (age 5) fish from the John Day River and other systems and reduced harest of smaller individuals from systems that currently support a harvestable surplus.

Estimates of the relative contribution of John Day stocks to Columbia River fisheries are based on few adult recoveries (1 to 3 fish) and on estimates of smolt abundance and. fingerling-to-smolt survival. Therefore, the potential exists for large errors in these estimates. We believe that the 20.8% estimate for the Wood Island test fishery in 1982 is likely to be in error and that the 3% to 5% estimates for other fisheries and other years are more representative.

Smolt Migration

Recapture data in the Columbia River indicate that smolts from the John Day River enter the Columbia from April through May and enter the Columbia River estuary in May and June. Measures to enhance downstream passage in the Columbia River should be used during April through June to provide the most benefit to smolts from the John Day River.

We were unable to use regressions of Julian day on circuli nurnber from smolt scales to back-calculate time of ocean entrance from asult scales because there was little or no linear relationship. Schluchter and Lichatowich (1977) reported successful application of this method on the Rogue River. However, smolts in the John Day are yearlings (age 1) whereas those in the Rogue are primarily age 0. Because circuli are not consistently formed overwinter, the relationship between Julian day and circuli number may be poor when based on scales from yearling smolts (Mary Buckman, ODFW, personal communication). In addition, Schluchter and Lichatowich (1977) sampled juvenile chinook salmon throughout the lower Rogue River from km, 116 to the estuary. We were unable to capture chinook salmon smolts in the lower John Day River or in. the Columbia River where they mix with other stocks. All of our samples came from scoop traps near the headwaters of the John Day River. We might have been able to use this method successfully if we had sampled John Day River smolts throughout their migration route,

We also used scale data to estimate the size of John Day River smolts at oceati entrance. The r^2 values calculated for regressions of fork length on scale radius are low when compared with those from studies of chinook salmon in other Oregon streams (Reimers and Downey 1982; Schluchter and Lichatowich 1977). However, these regressions produced plausible estimates of size at ocean entrance when compared with smolt lengths measured at scoop traps and at Spray in the John Day River. The relatively low r^2 values that we calculated for John Day River chinook may result from a narrow range of fork lengths in the samples (72 to 138 mn). Lichatowich (1975) reported a low r^2 (0.37) for a fork length on scale radius regression and attributed it to a narrow range of fork lengths (80 to 130 mm) that were sampled at Savage Rapids in the Rogue River. Other possible reasons for low r^2 values are high'ly variable environmental conditions throughout the John Day River that may cause,, local variations in the relationships fo fish growth and scale: grouth or errors in the collecting, 'mounting and reading of scales.

Abundance

We did not meet all of the conditions of.a pooled Petersen estimator in our estimates of the number of smolts migrating from John Day River. Migrating salmon smolts constitute a time stratified population (Schaefer 1951; Chapman and Junge 1956; Seber 1973; Ricker 1975). We used different marks each week to separate our sampling into weekly strata. The use of a pooled Petersen estimator to calculate abundance of a stratified population requires that the following conditions be met to assure that a consistent (unbiased) estimate is obtained (Chapman and Junge 1956; Seber 1973; Ricker 1975); (1) a constant proportion of the population present in each stratum is' marked; (2) a constant proportion of the population present in each stratum is captured, in the recapture sample; (3) the movement of individuals between strata is uniform; and, (4) the expected number of marked individuals in each stratum is proportional to the number unmarked. These conditions need to be met in addition to the assumptions of a simple Petersen estimate of no differential mortality of marked and unmarked individuals, equal vulnerability to the recapture gear, mark retention, random mixing of marked and unmarked fish, and negligible recruitment during sampling (Ricker 1975). The basic assumptions of a Petersen estimate were met because (1) we tested for'delayed mortality and found no difference between marked and unmarked fish; (2) the distance between scoop traps and the seining area near Spray was sufficient to allow random mixing: (3) marked and unmarked smolts were equally vulnerabel to capture with seines; (4) freeze brands generally last at least one month; and, (5,) we were only dealing with a single-age population so there was no recruitment during sampling. We probably did not meet the first condition of a pooled Petersen estimator because the efficiency of the traps was affected by changes in river flow and periodic accumulations of ice and debris. Seining efficiency may also have been affected by river flow because of changes in the physicl characteristicsof standard seining sites. However, we were.more likely to have met condition 2 of the polled Petersen estimator because three days of seining were pooled for each week of sampling and we sampled alternate sites when flows affected standard sites. We used chi-square contingency tables as outlined by Seber (1973) to test whether we met conditions 3 and4 of the pooled Petersen estimator. We used data from 1984 for these tests because in that year we marked and recaptured the largest number of fish. We found that the proportion of each mark group recovered at Spray (condition 3) was significantly different at the α= 0.05 level (χ^2=16.83; 7 df). We found that the proportion of marked and unmaked smolts in weekly recapture samples (condition 4) were not significantly different at the α = 0.05 level. (X279.74; 8 df). In both of these, analyses we pooled early and late weeks of the sampling season to avoid introducing zero count cells into the analyses [Snedecor and Cochran 1967). The significant difference in recapture rates among mark groups (conditon 3) suggests that 'movement between strata was not uniform and probably resulted from increases in migration rates as the season progressed. The' lack of significant, differences in ratios of marked to unmarked smolts in the recapture samples (condition 4) indicates that this ratio was fairly constant for the entire smolt population present in the Spray seining area during each week of sampling. This would occur if we marked a consistent proportion of the smolts passing our trap sites and if downstream movement was uniform; or, if nonuniform, marking and , movement resulted In a relatively constant proportion of marked and unmarked smolts in the Spray area.

Survival

The 3.6% to 8.6% egg-to-smolt survival rates estimated for spring chinook salmon in the John Day River' are within the range of survival rates reported in other Columbia River tributaries. Egg-to-smolt survival rates in the Deschutes River, Oregon, has ranged from 2.3% to 10.0% for 1975-80 broods (Lindsay, et al. 1982). Major and Mighell (1969) reported'egg-to-smolt survival rates of 5.4% to 16.4% for the Yakima River, Washington, in '1957-63. Bjornn (1978) reported egg-to-smolt survival rates of 4.0% to 15.9% in the Lemhi. River, Idaho, in 1962-75. The higher rates observed in these streams (>la%) probably resulted from flow control from impoundments, which enhanced survival in the Yakiam River (Major and Mighell 1969), and from a high proportion of juveniles in the Lemhi River that'moved out of the system in the fall and were included in smolt abundance estimates (Bjornn 1978).

smolt-to -adult survival rates for Columbia basin spring chinook salmon are related to passage conditions, Bjornn (1978) reported a smo'lt-to-adult survival rate of 2.19% for'1963 brood spring chinook salmon in the Lemhi River when only four dams were present in the Snake and lower Columbia rivers: Survival declined to 0.18% after three more dams were added. Lindsay et,a1."(1982) reported smolt-to-adult survivla rates of 2.0% to 3.2% for wild spring chinoook salmon in the Deschutes River, Oregon. These fish must pass only two Columbia River dams during their migrations. The,0.98% to 1.25% survival rates that we estimated for John-Day River spring chinook salmon seem low considering these fish pass only three dams. However, we believe that problems associated with John Day Dam and it's proximity to the mouth of the John Day River may increase mortality of John Day'River spring chinook salmon. We will discuss some of these problems in more detail in the discussion of stock-recruitment analyses.

Freshwater life History

Adult Holding Areas

The deep pools used by adult chinook salmon for holding areas appear to be abundant in all streams in the John 'Day River except the upper Mainstem. We rarely observed adults holding in the Mainstem. Much of the habitat in the upper Mainstem consists of high gradient riffles and runs with 'abundant riparian vegeation. Adults appear to use small pockets of deep water near root wads, and undercut banks for holing areas in the Mainstem. Habitat improvements that increase the number of large deep pools could increase the capacity of the upper Mainstem for holding adult chinook salmon before spawning. However, adult holding habitat is probably not currently limiting spring chinook salmon producito in the' Mainstem.

Spawning

Index counts of salmon redds that are based on,a single nannual survey must occur near the-same time, each year relative to spawinign activity to reflect annual variations in 'abundance, of spawners rather than differences in timing of spawning surveys. The number of red'ds counted throughout the spawning season‘ (supplemental surveys) increased to a maximum and'then leveled out or decreased as spawning ended and, redds 'became covered with silt or algae or were otherwise difficult to identify. Surveys conducted on the recommended dates (see Table 15) will generally reflect annual'differences in abundance of spawners, The dates of maximum redd counts were relatively consistent although we did observe some year to year variation ranging from 6 days in Granite Creek to as much as 18 days in the upper North Fork. This variation probably resulted from actual differences in timing of spawning, differences in scheduled dates of supplemental surveys, and differences among personnel b in the number of redds counted. We noted that redds,in the upper North Fork and in Granite Creek remain visible up to two weeks after the peak redd counts, so surveys conducted after the recommended dates in these streams are likely to result in near maximum redd counts.

Two additional counts that would help assure maximum redd counts are the number of live fish and the number of occupied redds.(redds with at least one live fish on or near them). If'more live fish than redds are observed, or if more than 50% of the redds are occupied, then the survey was probably too early and should be repeated the following week. These guidelines, along with the 'recommended dates for index surveys (see Table 15) should assure that index surveys will accurately reflect annual variations in spawner abundance.

The index area that is surveyed should also represent a constant proportion of the total redds each year to be an accurate indicator of spawner abundance. Because redd distribution in the Middle Fork was affected by streamflow, we recommend adding the section from Crawford Creek bridge to Vinegar Creek to the index area in the Middle Fork. This would include the section of the Middle Fork where spawner density varies with flow and will result in a more consistent index. This section is approximately 6 miles (10 km) long and could be sampled with only one additional staff day. The current index survey requires only two staff days to complete, so this addition would not require a'large increase in personnel.

The index area in the Middle Fork was probably a better indicator of total spawning in the past (before the mid-1970s) because the mill located at Bates (km 107),restricted spawning upstream. Chinook salmon did not spawn above Bates (Errol Claire, ODFW, personal communication) because of poor water quality,associated with the mill and domestic sewage from the,town (Steve Gardels, Oregon Department of Environmental Quality, personal communication), A diversion dam also created a partial barrier to upstream migration. The Bates milll, the town, and the diversion dam were removed in 1976. This allowed chinook salmon to use the upper Middle Fork and probably changed the relationship between the index counts and total counts in the system.

Changes in redd distribution in the North Fork may have been related to streamflow, as they'were in the Middle Fork, but we did not have a good measure of streamflow in the upper North Fork. The North Fork gauging station is located 115 km downstream from the mouth of Granite Creek at Monument (km 24), and many tributaries enter the North Fork between these sites. We recommend adding the section from Crane Creek to Granite Creek to the North Fork index area to obtain a more consistent indicator of total redds. This would add approximately 7 miles to'the index and would require two additional staff days to complete the survey. The North Fork index currently'covers 18 miles (29 km) and requires six staff days to'complete.

Emergence

We found close agreement between estimates of relative timing of emergence and relative timing of scale'formation among major spawning areas in the John Day River. Estimates of mean time of scale formation are within or slightly later than the ranges of emergence time estimated from field sampling (see Table 17)., We expect this because scale formation in salmonids occurs after emergence. In their study of Yellowstone cutthroat 'trout *(Salmo clarkii* lewisiil in Arnica Creek, Wyoming, Brown and Bailey (1952) reported that fry were first captured on 10 July whereas fry with scales were first captured on 8 August. Clutter and Whitesel (1956) reported'that sicjete saknib (Oncorhynchus nerka) emerge at about 27 inn and begin to develop scales at' about 38 nn, Mean time of scale formation is a useful index of emergence timing but actual emergence occurs earlier.

Dustruvytui of Fingerlings

Water temperature appears to limit the downstream, distribution of fingerling chinook salmon in the Middle and North forks. We found no clear relationship between temperature and distribution in the Manstem.l High water temperatures, in the summer months in the Middle and North forks appear to reduce the amount of usable habitat for rearing chinook. However, this reduction in the amount of usable habitat is not limiti'ng chinook salmon production because stock-recruitment analyses suggest that instream habitats are presently underseeded. If escapements into the

John Day system increase with improved,passage in the Columbia River or through hatchery supplementation, then'this reduction in habitat would likely limit the production of chinook salmon.

We identified areas in the John Day River system where large numbers of rearing chinook salmon were found. The habitat characteristics of these areas included eddies, runs with moderate depths and velocities, and side channels (especially in the North Fork system). However, these were the habitat types where we were also best able'to use our sampling gear (beach seines). Other researchers have found that age 0 chinook salmon prefer relatively shallow areas with moderate velocities and that they move to deeper and faster water as they grow (Lister and Genoe 1970; Everest and Chapman 1972). Our results tend to concur with these findings. An evaluation of the habitats in the areas we identified would be useful in developing guidelines for habitat improvements aimed at increasing the amount of suitable rearing habitat for fingerling chinook salmon in the John Day River system once full seeding has been reached.

Stock-Recruitment

The age composition of chinook salmon runs is highly variable (Larkin and Hourston 1964; Junge and Oakley 1966; Van Hyning 1973; Bjornn 1978). We observed considerable variability among years within streams in the age class composition of carcasses recovered during spawning ground surveys. This was especially true of the percentages of age 4 and age 5 fish with 5-year-olds composing over 50% of the carcasses recovered in some years. However, we used a constant age class structure for each stream for developing our stock-recruitment relationships.

Carcass recoveries are likely to be biased toward larger individuals. Larger carcasses are more easily seen in deep pools and around rocks and woody structure in streams when conducting spawning surveys. Bjornn (1978) found differences of as much as 25% between age class composition of spring chinook salmon sampled at a weir and carcass recoveries in the Lemhi River, Idaho. In 7 out of 9 years of his Lemhi River study, the percentage of 5-year-olds in carcass recoveries exceeded the percentage recorded at the weir. By averaging age 'class compostion over 7 return years we hoped to minimize the potential for errors that may have resulted from small samples sizes. We also made some arbitrary adjustments to the age structure to correct for sampling bias. Reisenbichler (1980) tested estimates of stock-recruitment parameters derived from an assumed constant age class composition against estimates derived from known, variable age, composition and found little difference in the curves or in the estimated parameters. He concluded that moderate deviations from a constant age structure have little effect on stock-recruitment analyses.

We adjusted the redd counts used to develop stock-recruitment curves to account for harvest in spring in commercial, Indian ceremonial, and sport fisheries in the Columbia River prior to 1977. No spring seasons have been held since 1977. We did not make adjustments for other fisheries. Some John Day River chinook salmon were harvested in Indian ceremonial and subsistance fisheries in the Columbia and John Day rivers and in a John Day River sport fishery that ended in 1977. Although these fisheries were not intensively monitored, we assumed harvest was negligible. In addition, some fishin mortality undoubtedly occurs in the ocean. We did not adjust for ocean harvest because only one ocean recovery of a coded-wire tagged chinook salmon from the John Day River has been reported. If a significant amount of harvest occurred in these fisheries, returns per spawner would be underestimated for the broods involved.

The sharp reduction in returns per spawner beginning with the 1970 brood corresponds with changes in the Columbia River. John Day Dam was completed in 1968 but the powerhouse was not completed until 1972, the year that 1970 brood smolts would have migrated downstream. Also, in 1973 the powerhouse at The Dalles Dam was expanded 57% from 14 to 22 turbines. Junge and Oakley (1966) reported similar reductions in returns per spawner in upper Columbia River stocks following completion of McNary Dam.

Schoeneman et al. (1961) found that mortality of juveniles passing through turbines at McNary Dam was more than five times greater than spillway mortality. We plotted the annual percentage of total outflow used for power generation (the remainder was spill and, fishway flow) in April and May at John Day Dam and from April through June at The Dalles and Bonneville dams (Figures 29-31; Nicholas Dodge, U.S. Corps of Engineers, personal communication). From 1972 through 1981 more than 75% of the outflow at John Day Dam was through the powerhouse. In 1973 and from 1977 through 1981 more than 90% of the outflow was through the powerhouse. During the higher flow years of 1982-84, the powerhouse accounted for 64%-77% of total April-May outflow (Figure 29). The 1980 brood: returned above replacement level (see Figure 20), which corresponds to smolt migrations'during 1982,,when spill at John Day Dam was about 30% of outflow. Powerhouse flow at The Dalles Dam accounted for less than 65% of the total outflow in 1961 through 1972, 50%-98% in 1973-80, and '68%-80% in 1981-84 (Figure 30). The percentage of Bonneville Dam outflow used for power production has remained below 70% except for the drought years of 1973 and 1977 (Figure 31). The completion of John Day Dam and the expansion of the powerhouse at The Dalles Dam, which resulted in reductions in spill, appear to be the main factors causing reductions in returns per spawner and declines in John Day River spring chinook salmon.

Spring chinook salmon from the John Day River may be subjected to higher mortality'at John Day Dam than other stocks because.of the proximity of the river mouth to the dam and the powerhouse. The mouth of the John Day River is located on the south shore of the Columbia River approximately 4 km upstream of John Day Dam. The powerhouse is located on the south half of John Day Dam and the spillways are on the north half. Studies of the distribution of 'downstream migrating salmon have shown that most fish migrate near the shorelines (Schoeneman and Junge 1954; Rees 1957; Mains and Smith 1964; Monan et al. 1969). If migrants from the John Day River follow the south shoreline of the Columbia River

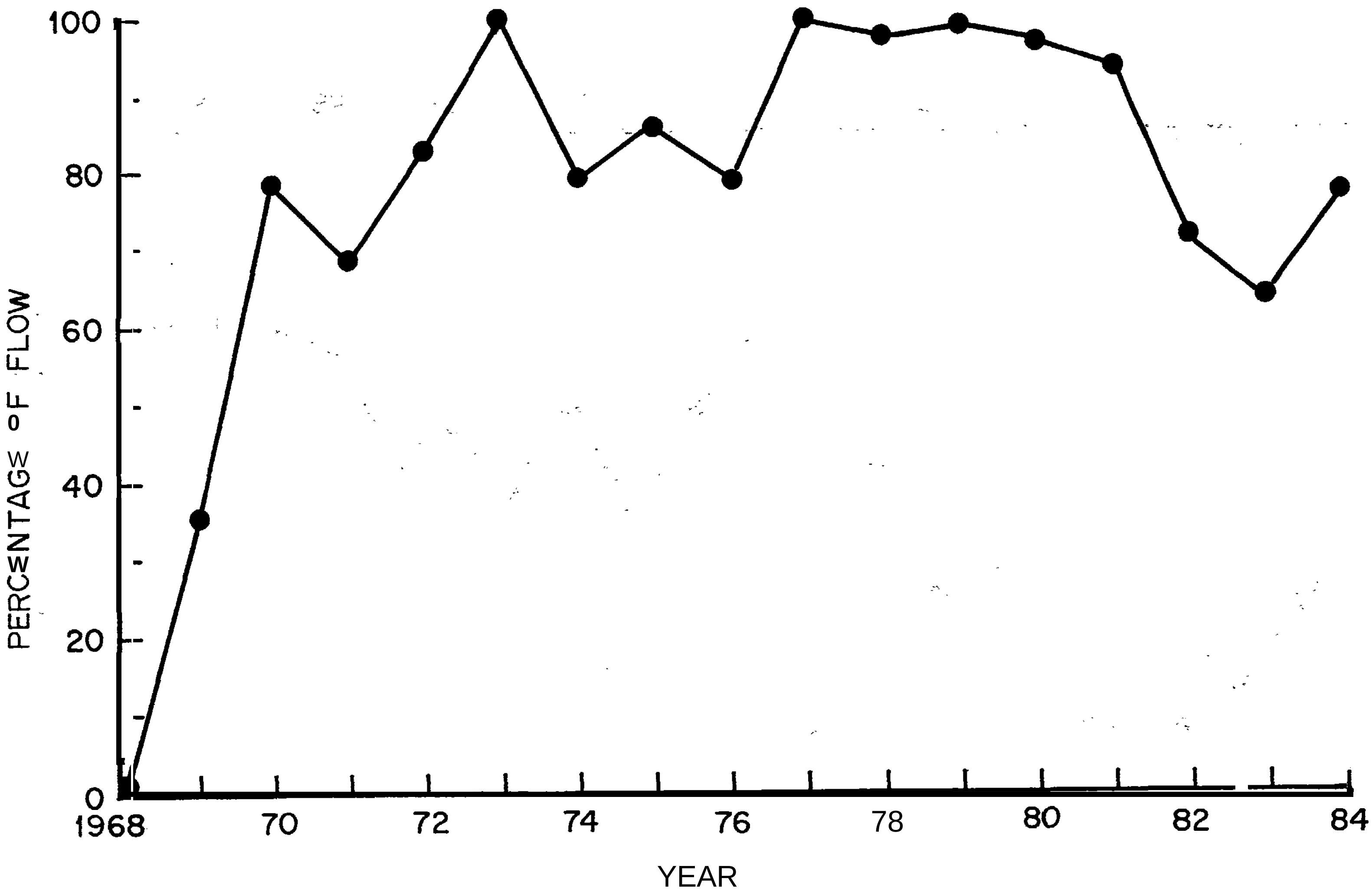

Figure 29. Percentage of total April-May outflow that passed through the powerhouse at John Day Dam, 1968-84.

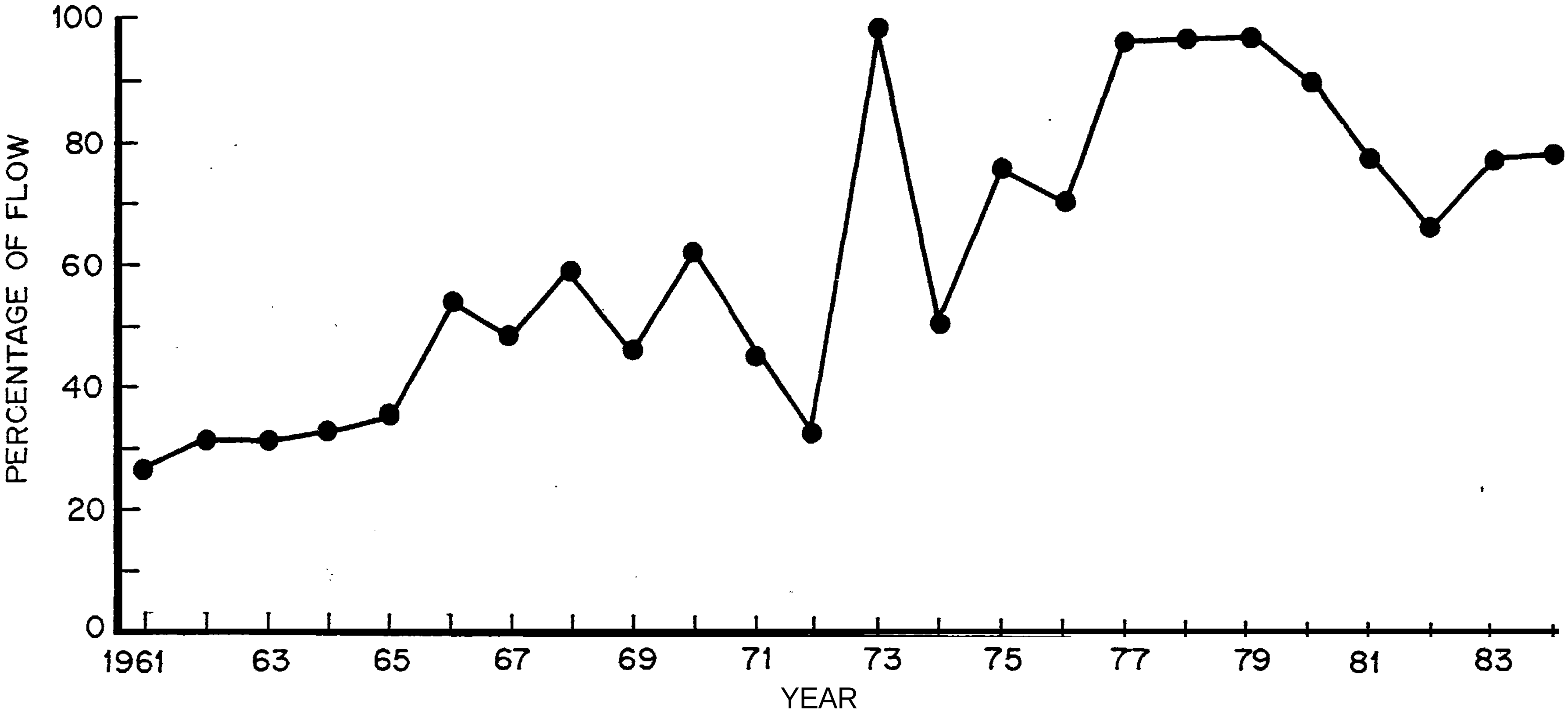

Figure 30. Percentage of total April-June outflow that passed through the powerhouse at The Dalles Dam, 1961-84.

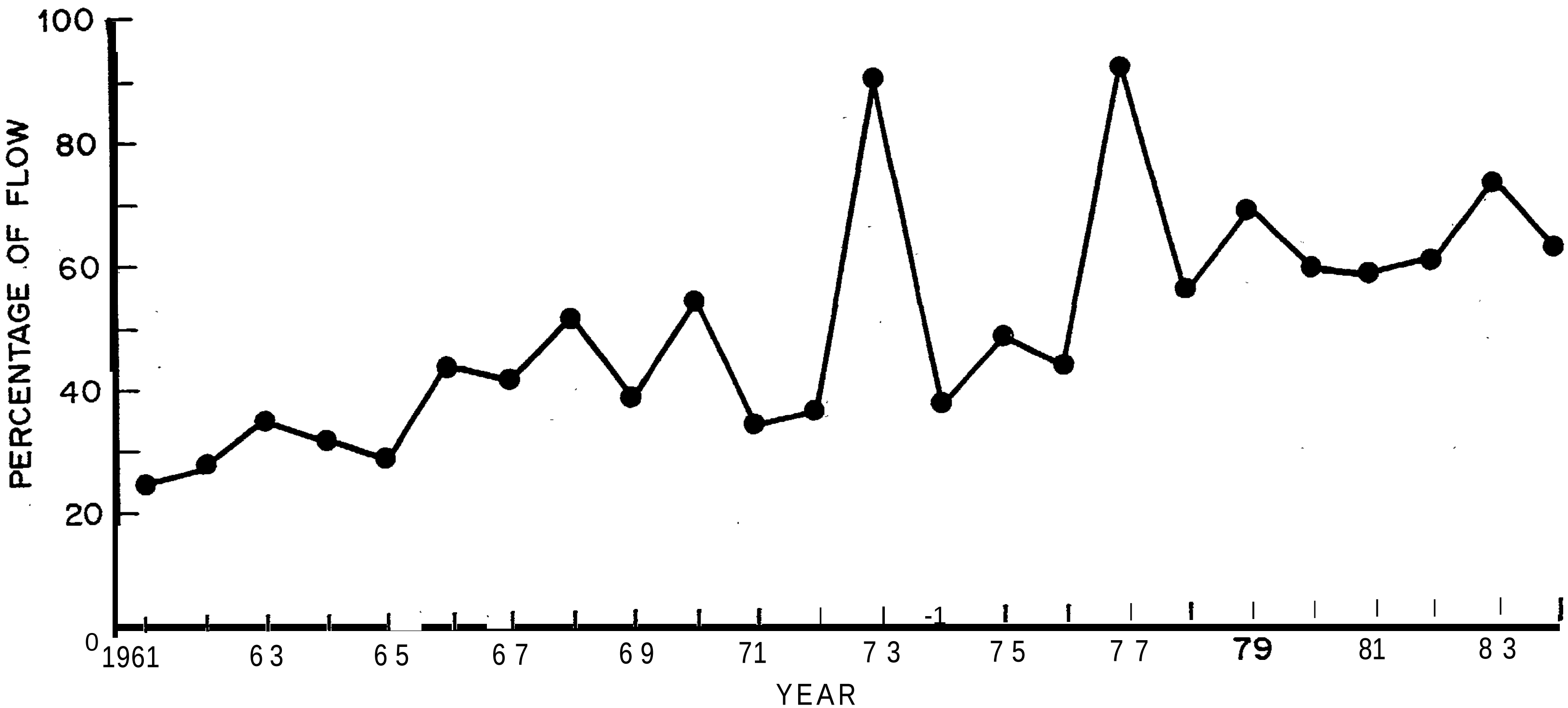

Figure 31. Percentage of total April-June outflow that passed through the powerhouse at Bonneville Dam, 1961-84.

they would be more likely to pass through the powerhouse than over the spillway. This would result in higher mortality than would occur if they were evenly distributed across river or if they were moving along the north shoreline.

The United States Army Corps of Engineers is currently modifying the smolt bypass system and installing travelling screens in turbine intakes at John Day Dam (Anonymous 1984b)YImprovements in the bypass system are scheduled to be completed in 1986.: If these modifications are successful in reducing passage mortalities at John Day Dam, returns per spawner for John Day River stocks should increase beginning with the 1985 brood. Willis (1982) found that when the ice-trash sluiceway at The Dalles Dam was operated as a smotl bypass system and 20% or more of the flow was spilled, 70%"or more of the smolts passing the dam used either spillway or sluiceway passage routes. When 5% or less of the flow was spilled, less than 50% of the smolts passed the spillway and sluiceway. We recommend that the ice-trash sluiceway- at The Dalles Dam be operated as a smolt bypass system and that 20% or more of the 'outflow be spilled from April through June at The Dalles Dam and from April through May at John Day Dam in future years. We also recommend that index spawning surveys be used to estimate returns per spawner for future broods (Appendix E) to determine if survival improves'following modifications of passage facilities at John Day Dam..,

John Day Dam may also affect adult.spring chinook salmon returning to the John Day River. John Day Dam is known'to cause delays in migrations of adult spring chinook. salmon (Damkaer 1983; Damkaer and Dey 1984, 1985), Damkaer (1983)"has reported evidence of increased mortalities associated with delays. Damkaer and Dey (1985) suggest that the delays result from industrial pollutants from upstream sources and from an aluminum plant located on the north shore of the river adjacent to the dam.. Because pollutants were concentrated near the north fish ladder at John Day Dam, upstream migrating salmon preferred the south fish ladder? Damkaer and Dey (1985) also showed that effects of flow from the John Day River on temperature and turbidity in the Columbia River were most prevalent near the south shore. Therefore, adults from the John Day River would be expected to use the south fish ladder at John Day Dam. The effectiveness of the south fish ladder at John Day Dam is limited at times because of turbulence near the entrance caused by the first powerhouse unit (Burton Carnegie, ODFW, personal communication). These problems with adult fish passage at John Day Dam could also reduce the number of recruits from spawners in the John Day River.

Adult fish passage problems including injuries, nitrogen supersaturation, migration delays, and fallback have also been identified at Bonneville Dam. Merrell et al. (1971) reported a mortality of 16.8% for summer chinook salmon passing Bonneville Dam in 1955. They stated that deaths resulted from physical injuries and nitrogen supersaturation and were generally associated with high river flows (>250,000 cfs) and large spills. Because. adult spring chinook salmon destined for the John Day River migrate through the Columbia River in April and May, we examined April-May flows at Bonneville Dam from 1963 to 1984, the years when the majority of 1959-79 brood adults returned to the John Day River. Flows exceeded 250,000.cfs in 4 out of 11 years from 1963 through

1973 (1959-69 broods of age 4 fish) and in 9 out of 11 years from 1974 through 1984 (1970-79 broods of age 4 fish; Nicholas' Dodge, U.S, Army Corps of Engineers, personal communicastion). These data suggest that 1970-79 broods were subjected to higher adult mortality at Bonneville Dam than earlier broods, and this may have contributed, to changes in stock-recruitment relationships in the John Day River. Spillway deflectors were installed at Bonneville Dam in 1975 to reduce nitrogen supersaturation (Junge and, Carnegie 1976)? However,,,migration delays and fallback continue to affect adult chinook salmon passing Bonneville Dam,, especially in years when river flows are high (Gibson et al, 1979; Turner et al. 1984).

Junge (1970) stated that smolt kills have a greater effect on stock-recruitment relationships than adult kills of similar proportion. However, it appears that John Day River spring chinook salmon are subjected to both smolt and adult kills; and, although smolt kills have the greatest effect on returns per spawner, the combined effects of these mortalities on a declining stock will accelerate their decline,

Results of our stock-recruitment analyses revealed that the reduction in returns per spawner beginning with the 1970 brood changed the shape as well as the height of stock-recruitment curves. Junge (1970) stated that smolt kills would reduce the height of stock-recruitment curves by a constant percentage but would not change their shape because the effects of population density are most severe during freshwater residence prior to, smolt migrations. If only the height of our curves had changed, we would have obtained fits with stock-recruitment models as good for 1970-79 broods as we had with pre-1970 broods. However we found little relationship between spawner abundance and returns per spawner 'for 1970-79 broods in contrast to the compensatory relationships we observed for pre-1970 broods.

In his analysis, Junge (1970) assumed that the smolt mortality rate at dams would be constant each year. However, we believe mortality rates at dams were variable, especially at John Day Dam, and may have masked any instream compensation that may have occurred when spawner abundance was low. For example, the abundance of parent spawners for 1975-79 broods in Granite Creek were among the lowest recorded in that stream (see Figure 24) yet we did not observe any compensatory increase in returns per spawner for those broods. The 1975-79 broods would have smolted during 1977-81 when 90% to 100% of the flow past John Day.Dam went through the powerhouse (see Figure 29). Mortality during passage was probably higher in these years than in years when more water was spilled.

The relationship between spawning stock and returns per spawner for 1970-79 broods is density independent for all streams in the John Day basin. These density independent relationships were most evident in the North Fork and Granite Creek systems where we observed relatively wide ranges of spawner abundance but near constant returns per spawner (see Figures 23 and 24).

Stock-recruitment curves for pre-1970 broods in the North Fork and Granite Creek systems indicated streams approached full seeding (where curve becomes asymptotic) at 20 to 25,redds'permile (see Figures.27 an'd '28). Redd 'densities in these streams in recent years have been 10 redds per mile or less. This suggests that these streams are underseeded and that compensatory mortality should be low. At low levels of abundance, depensatory mortality factors become increasingly important.' Predation on,emerging fry, rearing juveniles,, and migrating smolts has been identified as an important depensatory mortality factor affecting salmon stocks (Hunter 1959; Larkin and Hourston 1964; Junge and Oakley 1966; Van Hyning 1973). Predator populations in the John Day and Columbia Rivers are not likely limited by the abundance of spring chinook salmon juveniles. Therefore, we would expect predators to take a relatively fixed number of spring chinook salmon as prey. The depensatory action of predators and the relatively high rate of density independent mortality during dam passage may also explain why we have not obs'erved any compensatory increases in returns per spawner in the North Fork and Granite Creek systems in recent years.

The Mainstem has a lower production potential than that of the North Fork and of Granite Creek. Stock-recruitment curves for 1959-69 broods suggest that 6 to 8 redds per mile would seed the Mainstem (see Figure 25). Trends in return per spawner (see Figure 21) show that returns to the Mainstem have been above the replacement level for the 1972, 1974, 1979, and 1980 broods. Results for the 1972, 1974, and 1980 broods suggest that instream compensation occurred and survival to smolts was higher than in the other forks because parent spawner abundance for these broods was low.

Several factors may be responsible for the higher returns per spawner in the Mainstem. The instream environment in the Matnstem is not as harsh as in the North Fork, especially in the winter. Temperatures in the Mainstem rarely reach' freezing for extended periods in the winter as they do in the North Fork and Granite Creek. We have not observed large ice flows in the upper Mainstem as we have in the North Fork system. Juveniles in the Mainstem are also larger than those in the North Fork system and that may increase their survival. Smolts from the Mainstem averaged 110 mn and may have survived better than smaller smolts in the North Fork that averaged 94 rnn (see Table 20). Schoeneman et al. (1961) found that small smolts had higher mortality rates than large smolts during downstream migrations. Lastly, irrigation withdrawals, which reduce flows and increase temperatures, could limit the amount of suitable habitat for spring chinook salmon in the'Mainstem, and these space limitations would be compensatory in their effect on the population (Chapman 1966; Stevens and Miller 1983). Irrigation withdrawals affect the Mainstem more than other streams in the John Day basin.

Habitat may be limited at the current levels of escapement in the Mainstem. Habitat in the upper Mainstem is composed mostly of high-gradient riffles and runs. This is, in part, a result of the channelization that occurred after the floods in the winter of 1964-65. We have not conducted physical surveys of the habitat, but the upper Mainstem appears to have fewer pools compared with other streams in the system. Much of the good pool habitat in the Mainstem is located farther downstream in areas that are affected by water withdrawals for irrigation, In some years these areas are not used by chinook salmon in the warm summer months. Water use patterns are not likely to change in the Mainstem, so an increase in pool habitat in the upper Mainstem (primarily above the town of Praire City; secondarily above the town of John Day) would likely increase production of spring chinook salmon.

In the Mainstem the 1979 brood had an unusually high return of 1.86 adults per spawner. We did not observe a return per spawner value above replacement for the 1979 brood in other streams in the system. The Mainstem was treated with rotenone from 5 km above Prairie City (the lower end of spring chinook salmon spawning), downstream in fall of 1979 near the end of spawning. Although chemical treatment of streams is not always successful (Meffe 1983; Moyle et al. 1983), this project appears to have enhanced survival of the 1979 brood perhaps by eliminating competition and predation with other species. These results also suggest that,rearing area may be limited for spring chinook salmon in the Mainstem.

The stock-recruitment relationships for the Middle Fork do not display the same trends as other streams in th John Day basin, and the data do not fit either the Ricker or Beverton-Holt stock-recruitment models. Possible reasons for these differences include (1) inconsistencies in the collection of data and (2) major changes in the instream habitat during the time spawning surveys have been conducted. We have already discussed sampling problems associasted with the dates that surveys were conducted, the relatively small proportion of total redds included in index surveys, and the variability of the relationship between index redds and total redds in the Middle Fork. In addition to these inconsistencies in the data, there were water quality problems associated with the town of Bates (km 108) and the lumber mill located near the headwaters of the Middle Fork (Steve Gardells, Oregon Department of Environmental Quality, personal comunication). In the early 1960s, counts of coliform bacteria from domestic sewage in the Middle Fork were 60/100 ml above Bates and 24,000/100 ml below the town and the lumber mill. Some improvements were made -in the waste disposals system at Bates in the mid-1960s, but problems persisted. A sample of the Middle Fork below the outflow of the ,mill pond in 1971 had coliform counts of 70,000/100 ml and a BOD of 2 mg/L. The mill pond itself had a BOD of 22 mg/L. Prior to 1971, mill operators were allowed to drain their mill pond at any time. In 1971 they were required to obtain a permit to drain their pond and permission was only given during high flows; however, some unauthorized draining of the pond was reported after 1971. Another mill practice, the decking and sprinkling of logs directly over the river, leached tannic acids into the water. Beginning in 1971 operators were required to deck logs at least 25 ft from the river and to divert runoff from sprinkling away from the river. A diversion dam at'Bates also prevented chinook salmon from moving into the upper Middle Fork.

The Bates mill was closed, and the town and dam were removed in 1976. The improvements that occurred in 1971 and 1976 probably resulted in changes in available spawning and rearing habitat, survival, and consequently in stock-recruitment relationships for spring chinook salmon in the Middle Fork. Improvements occurred in the early 197Os, the same time as changes occurred in the Columbia River, and this may explain why returns per spawner in the Middle Fork did not drop below replacement beginning with the 1970 brood. Returns per spawner in the Middle Fork have been below replacement since the 1976 brood suggesting that after a short period of adjustment, the Middle Fork stock is now also declining.

Another factor affecting production of spring chinook salmon in the Middle Fork is numerous, chemical treatment projects. The lower 68 km were treated with rotenoune in 1966;, the lower 5 km was treated with rotenone in 1973; the reach from Phipps Meadow (km 120) to Vincent Creek (km 104) was treated with rotenone. and the Lower 104 km was treated with squoxin in 1974; and, the reach from Phipps Meadow to the mouth was treated with rotenone in 1982. Because sampling and water quality problems affected our analyses of the Middle Fork, we so not know what effect the 1966, 1973, and 1974 treatments had on spring chinook salmonm populations. The exception is the 1982 project, which covered nearly a11 known spawning and rearing areas in the Middle Fork.

In 1983 only 14, 1.981 brood smolts were captured in the Middle Fork scoop trap. Catches in other years ranged from 80 to 667 smolts. However, in 1985 we: counted 80 redds in the Middle Fork (see Table 14) and 59% of the carcassed we recovered were age 4 (1981 brood; see Table 21). Although the redd count in the Middle Fork decreased 35% in 1985 from the previous 7 year average compared to a 40% increase, in 1985 in other streams in the basin, the redd counts in the. Middle Fork in 1985 suggest that a large number! of 1981,brood~chinook salmon survived the" chemical treatment project in 1982 and returned to spawn. We have-~ observed chinook salmon rearing in tributaries of the Middle Fork andin the main river above Phipps Meadow, and large numbers of juveniles may have been rearing in these areas'atthe time of the chemical treatment project in 1982. However,' if this had occurred we shouldhave been able, to catch more chinook salmon in theMiddle Fork scoop trap in 1983. Another possibility is that age 4 adults from other streams strayed into the Middle Pork to spawn in l985; however, ourcoded wire tag recoveries from other broods -indicate that straying is rare. Atthis time we do‘ not know why returns to the Middle Fork were higherthan expected;

The chemical treatment 'project in the Middle Fork in I982 also affected the'1982 brood, 'which, was incubating during the treatment. During the summer of 1983 and during smolt migrations of 1984, 20%~ and 8%, respectively, of the 1982 brood chinook salmon; sampled in the Middle Fork were deformed. Most of these deformities were abnormal developmnet of the caudal peduncle. The deformities appear to have resulted from treating eggs with roenone because we observed very few seformities in other broods- less than 5% deformity occurs in spring chinook fingerlings, in a hatchery;,(Randy Robarts, ODFW, personal communication.) compared with 20% of the 1982 brood in the Middle Fork, which suggests lack of predation was not a factor in the high deformity rate. Marking et al. (1983) found that cotenone killed fish eggs but eggs were more resistant than other life stages. Garrison (1.968) found that significant mortality occurred when fall chinook salmon embryos were exposed to 1.0 ppm rotentone at 12°C for 24 hours. In 1982 rotenone was applied over redds in the Middle Fork at 1.0 to 1.5 ppm for 48 hours and water temperatures averaged 13'C. Therefore, the potential was present for significant mortality of the developing embryos. The effects of rotenone on developing embroyos should be investigated before spawning grounds are treated in the future. We recommend that chemical treatment projects not be conducted in spring chinook salmon spawning and rearing areas until, such studies are completed.

Although the primary factors affecting stock-recruitment relationships for John Day River spring chinook salmon are dams in the Columbia River, the John Day River has been affected by many activities that also may have altered spring chinook salmon production. The John Day River system has been mined extensively for gold since the late 1800s. Much of the mining was done by dredges, and tailings from these dredges are visible throughout the system. Dredging has created barriers in streams such as Clear and Bull Run creeks (Granite Creek system), where the entire stream was flowing underground through the porous tailings. Habitat improvements have restored surface flow in many of these areas. Dredging also created temporary side channels in the North Fork that trapped juvenile chinook during low flows. Settling ponds and mine shafts at inactive mine sites in the mountains near the Granite Creek system have repeatedly released turbid waters and sediments 'into the Granite Creek system. These waters are known to contain heavy metals such as copper and zinc (John Andrews, U.S. Forest Service, personal communication). In 1982 we conducted a 3-day bioassay, in conjunction with the United States Forest Service, in the effluents from Red Boy and Poor Boy (0.4 km below Red Boy) mines, which flow into Clear Creek, and in Tencent Creek, a tributary of Granite Creek that has been altered by mining activities. Juvenile chinook salmon were placed in live cages in the mine effluents, in Tencent Creek, and in Granite and Clear creeks immediately upstream of these test sites. We observed 100% mortality of test fish in the Red Boy Mine outflow and no mortality in the other groups. Some mine effluents are toxic to chinook salmon, but these appear to be diluted to sublethal concentrations in Granite and Clear creeks.

Grazing by domestic livestock has affected streams and riparian areas throughout the John Day River. Useable habitat is also reduced by water withdrawals for irrigation. Irrigation withdrawals occur mainly in the Mainstem and in some sections of the Middle Fork. Irrigation ditches were screened in the late 1950s (Tom Hunt, ODFW, personal communication) and have since been maintained by ODFW.

Extensive road building and timber harvest have occurred in the John Day River basin. Timber harvest and the associated road building can alter stream habitat by increasing temperatures, peak flows, and sediment loads in streams (Hall and Lantz 1969; Burns 1972). Timber harvest and road construction have been increasing during the time period covered by our stock-recruitment analyses (1959 to present), whereas, most of the affects from mining and water withdrawals occurred prior to the time spawning surveys were made.

Severe flooding during the winter of 1964-65 also, altered habitat for spring chinook salmon. These floods altered stream banks and substrates throughout the John Day system and prompted the United States Army Corps of Engineers to channelize much of the Mainstem below Prairie City (Anonymous 1972). Returns per spawner for 1963 and 1964 broods, however, did not appear to have been affected by these floods (see Figure 20).

Although the instream disturbance discussed above and the water quality problems in the, Middle Fork may have affected production of spring chinook salmon, many recent efforts have been made to improve habitat for spring chinook salmon in the John Day River. Irrigation ditches throughout the system have been screened. Some sections of the Middle Fork have been fenced. The removal of Bates and the mill improved water quality in the Middle Fork. Barriers created by dredge spoils have been removed, and spawning gravel and instream structures have been placed in the Granite Creek system. Instream improvements in the North Fork have included side channel modifications and placement of instream cover. Also, much of the upper North Fork was given protection as wilderness in 1984.

Although human activity within the John Day River has reduced spring chinook salmon production from historic levels, returns per spawner for 1959-69 broods remained above replacement (see Figure 20). Instream habitats have not degraded significantly in recent years, but instead have probably improved. Yet, stock-recruitment analyses and trends in spawner abundance show production is still declining. The instream habitat has the capacity to produce chinook salmon at a level comparable with that of the 1960s, but mortality at Columbia River dams has resulted in the decline of John Day River spring chinook salmon. Recent trends in the North Fork system show an average return per spawner of.-0.72 and redd densities that are one-fourth or less of those observed in the late 1960s. If these trends continue, spring chinook salmon in the North Fork, historically the most productive stream in the basin, will be reduced to a remnant run in less than 30 years. Many instream habitat conditions could be improved in the John Day River system, but instream improvements will not increase production of spring chinook salmon unless they are accompanied by increased survival during passage through the Columbia River.

Hatchery Supplemeritation

The ODFW Wild Fish Policy (Anonymous 1983) states, "The protection of wild stocks will be given first and highest consideration . . .'I This implies that the introduction of hatchery fish would only be used as a last resort to maintain the spring chinook salmon run in the John Day basin. Alteration of the genetic composition of the stocks and competition between hatchery and wild fish could result from hatchery introductions. Solazzi et al. (1983) found that releases of hatchery presmolt coho salmon (*Oncorhynchus kisutch*) resulted in decreased production of wild juvenile coho salmon. Hatchery and wild salmon will compete when there is overlap in their food habits and in the habitats they occupy (Nicholls et al. 1979; Nicholas and Herring 1983). Therefore, introductions of hatchery salmon should be well planned to reduce the potential for adverse effects on wild stocks.

Because the John Day River supports one of the last runs of wild spring chinook salmon remaining in the Columbia River basin, a hatchery program should be used only as the last alternative to prevent the extinction of John Day River stocks. Also, a hatchery program should be used only to supplement wild production until passage at Columbia River dams has improved to the point where return per spawner exceeds replacement for at least three brood years. John Day River stocks have been declining since the 1970 brood and could approach extinction in 20-30 years. Because brood stock will be difficult to collect at low abundance, the stock may be essentially extinct before that time. The operation of John Day Dam is the main reason for these declines. The smolt passage system at John Day Dam is being modified, and travelling screens are being installed in turbine intakes. These modifications are scheduled to be completed in 1986 (Burton Carnegie, ODFW Engineering Section, personal communication). Screening of turbine intakes at The Dalles Dam was scheduled to begin in 1985. Any increase in smolt-to-adult survival that results from these modifications should be reflected in returns per spawner for 1985 and later broods. By 1992 we will have complete returns from three consecutive broods (1985, 1986 and 1987) that migrated downstream following the modifications at John Day Dam. If returns per spawner for these broods are not above replacement in all streams in the John Day basin, we should begin collecting adults for broodstock from the John Day River in 1993. Brood stock should be collected in 1993 so that adequate numbers are available for trapping, and so that collections would not take a large proportion of the wild stock.

Hatchery Location and Alternatives

The John Day basin does not contain any known suitable sites for a spring chinook salmon hatchery (Jerry Bauer, ODFW, personal communication). However, ground water sources have not been thoroughly evaluated, and some areas, such as the city of John Day, have wells that supply 1,000-1,500 gpm (Jerry Rodgers, Oregon Department of Water Resources, personal communication). The availability of suitable well sites is limited because of the recent geology of the basin and because of its many fault zones. The water requirement for a hatchery is approximately 1.0 gpm for each 6 lbs of fish (Jerry Bauer, ODFW, personal communication). Approximately 650 gpm would be needed to produce 100,000 smolts at 26 fish/lb. (about the average smolt size produced naturally in the John Day River). Therefore, areas with adequate well water should be evaluated as an option for a hatchery site if hatchery supplementation becomes necessary in the John Day basin.

Other alternatives to hatchery production for supplementation include (1) incubation 'boxes, (2) spawning channels adjacent to stream channels,, (3') rearing channels' asjacent 'to Stream 'channel's, or (4) any combination of 1, 2, or 3 that would 'increase'early-life survival (Mundie 1974; Senn et al 1984). A number of side channels that could be developed for supplemntal rearing 'already exist in the North Fork system. Some considerations for side channel development include providing a supplemental food 'supply, maintaining suitable flow, providingwinter cover, and minimizing sedimentation (Mundie 1974). However, because of flow and water temperature extremes and because of difficult winter access to many areas of the John Day basin, developing side channels to supplement wild stocks may not be practical.

Ponds have been used to hatch and rear chinook salmon in some areas (Senn et al. 1984). Pond rearing can be an economical alternative for supplementing produciton, but it requires that predation be minimized and that suitable temperatures and dissolved oxygen concentrations be maintained year round (Higley and Bond 1973). Pon'ds in the John Day basin that could be considered for supplemental rearing include Trout Farm pond on the upper mainstem (km 451) and Bates pond on the Middle Fork (km 108). These ponds are currently stocked with hatchery rainbow trout. We do not know of any ponds in the upper North Fork system suitable for rearing chinook salmon.

Probably the most practical method of supplementing John Day stocks would be to spawn and' rear spring chinook salmon at an offsite hatchery and release smolts from the facility into the John Day River system. An offsite hatchery should be located as close to the John Day basin as possible to minimize'stress and mortality from transportation. This would require building a new hatchery or expanding an existing one because most existing hatcheries are being used to meet specific mitigation objectives.

Brood Stock

In compliance with ODFW policy stating. that "Indigenous stocks will be utilized as the hatchery product whenever practical..." we recommend only native John Day stocks be used for hatchery supplementation. This -restriction would minimize changes in thegenetic composition of the stocks, and reduce the chnce of introducing pathogens into the system. A recent study at Marion Forks Hatchery in the Willamette River system showed that native stocks produced higher return 'rates than introduced stocks (Smith et'al. 1984). We also recommend-that 10% of the brood stock be composed of wild returns 'each year after hatchery fish "begin returning. This would assure that the genetic structure of the hatchery stock would closely resemble the'wild's'tock. All hatchery fish should be marked before release so that the origin of returning adults could be distinguished.

Methods of obtaining wild spring chinook salmon for hatchery brood stock include electrofishing, gill netting, dip netting, seining, trapping at weirs and snagging (Senn et al. 1984). Drift boat electrofishing was found to be the most effective method of collecting wild chinook salmon in Oregon coastal streams for use in private hatcheries (Hooton 1978). ODFW employees used dip nets to capture adults in the fall from small tributaries of Elk River for use in Elk River Hatchery (Reimers 1979). Drift gill nets were fished in deep holes to collect wild adults from the Chetco River for hatchery brood stock (Tim Downey, ODFW, personal communication). The Salmon River Hatchery in Oregon uses an electric weir to block upstream migrations and divert salmon into the hatchery pond outlet (Mullen 1979). Wild adults are collected with a weir trap in the Imnaha River, Oregon, for supplementing brood stock at Lookingglass Hatchery (Rich Carmichael, ODFW, personal communication). Permanqnt racks are used at many hatcheries to divert adults into holding ponds (Senn et al. 1984). Temporary racks and weirs have also been used successfully for adult collection (Bjornn 1975; Senn et al. 1984). The use of a temporary rack or weir structure may be effective in the John Day system if it can be installed when river flows and associated debris flows are decreasing in the late spring before adult chinook have reached upstream holding areas. Weirs should be installed in each of the main tributaries in the John Day River (Mainstem above the mouth of the North Fork, Middle Fork, and North Fork) used by spring chinook salmon for spawning. Each fork should be managed separately because coded-wire tag returns from the spawning grounds suggest that each may be a distinct substock. If temporary structures do not work, we recommend collecting. adults by electrofishing, seining, dip netting, or snagging in late August and early September in upstream holding and spawning areas. Late collections would have the advantage of obtaining ripe or near ripe fish that could be spawned without holding them for extended periods. Collections from the spawning grounds would also prevent selection for migration timing that could result from temporary racks or weirs installed during only a part of the migration period.

Rearing and Release

The best rearing and release strategy for hatchery supplementation of wild spring chinook salmonruns would mimic the wild run as closely as possible with respect to timing of smolt migrations, size of fish, and location where migrations begin (Reimers 1979). Migrations of wild spring chinook salmon smolts past Spray (km 275-293) began in mid-February, peaked during the first or second week of April, and decreased through early June during 1979-84. We also observed some downstream movements in the fall in the North Fork and Granite Creek in 1979. In 1981 we observed presmolt chinook rearing in the Spray area during early February. Large fall migrations of presmolt chinook salmon have occurred in other Columbia River tributaries presumably for overwinter rearing in larger sections of stream (Bjornn 1978; Lindsay et al. 1980). Although fall migrations occur in the wild population in the John Day, these are redistributions within the stream and not migrations to the ocean. We recommend releases of smolts in spring to minimize the potential for competition among wild and hatchery fish. In addition, fingerling-to-smolt survival rates were only 25% to 35%. Others have. recommended spring smolt releases from hatcheries over fall presmolt releases because they produced higher return rates (Wallis 1968; Jonasson and Lindsay 1983; Smith et al. 1984).

In spring sampling from 1979 through 1984, lengths of wild smolts from the North Fork and from Granite Creek averaged 94 mm, from the Middle Fork averaged 103 mm, and from the Mainstem averaged 110 mm (see Table 21). Although these were three distinct size groups, they would be difficult to reproduce in a hatchery. We recommend that smolts released in the John Day basin range from 90 to 110 mm, fork length'. Our sampling of smolts at sites below the confluence of the main tributaries of the John Day River (km 275 at Spray and km 35 at Rock Creek) has revealed that mean size increases during downstream migrations. Some researchers have suggested that a minimum size threshold at ocean entrance influences survival (Schluchter and Lichatowich 1977; Reimers and Downey 1982). Some experimentation with various release sizes, within the range of those observed in the wild population (see Table 21), should be used to determine optimum size at release.

The sites that we recommend for smolt releases are: Mainstem at Prairie City; Middle Fork at Bates; North Fork at the mouth of Desolation Creek and at North Fork Campground; and Granite Creek system at Squaw Creek Campground, at the mouth of Clear Creek, and at the mouth of Bull Run Creek. Releases should be made from mid-February through April except during periods of peak spring runoff. These release strategies should mimic the timing of wild smolt migrations and assure that returns from these plantings home to all major spawning areas in the system. Release strategies should be evaluated by differentially marking groups of smolts released at different times and sites during the early years of hatchery supplementation to determine which release strategies produce the highest return rates.

The numbers of smolts recommended for release in the John Day River are based on stock-recruitment relationships before the completion of John Day Dam. If we assume that the current spawner distribution and instream survival rates are similar to what existed before John Day Dam was completed, then the only major changes have been in the abundance of adults and smolts and in smolt-to-adult survival rates, Current smolt-to-adult survival has averaged 1.2%, and egg-to-smolt survival has averaged 5.5% (see Table 12). Stock-recruitment analyses show that for pre-1970 broods 3,700 spawners would sustain a return of approximately 6,200 adults (see Table 25, spawners plus yield at 40% exploitation). If we assume an average fecundity of 4,000 eggs per female, 3 fish per redd, and 5.5% survival from egg-to-smolt, then smolt-to-adult survival would have been approximately 2.5% before John Day Dam was completed. This is approximately double the current smolt-to-adult survival rate. Current smolt abundance has been 80,000 to 100,000 so we recommend releasing 100,000 hatchery reared smolts annually into the John Day River to offset changes in survival. If we also assume that the proportion of total smolts migrating from each fork is similar to the proportion of total spawning in each fork, then these releases should be allocated to each fork as follows (based on the average proportion of total redds in each fork in 1978-85): (1) 16% in the Mainstem; (2) 25% in the Middle Fork; (3) 33% in the North Fork; and, (4) 26% in the Granite Creek system. If we further assume that we can obtain 4,000 eggs per female and an egg-to-smolt survival of 75% in a hatchery, then the recommended supplementation would require collecting 6 females from the Mainstem, 9 females from the Middle Fork, 11 females from the North Fork, and 9 females from Granite Creek. If 1 male is used to fertilize the eggs of 3 females then this supplementation would require taking only 45 to 50 adults from the wild. If the returns per spawner from this combination of wild and hatchery production do not stay above the replacement level, then additional adults would need to be collected and additional smolts released. More smolts may need to be released in each of the streams to obtain adequate returns for evaluating release strategies.

Although we recommend spring smolt releases for supplementing wild spring chinook salmon runs in the John Day River system, some presmolt fingerling releases may be required because of problems with access to some areas in the spring (especially in the North Fork system) and because of potential water shortages that may reduce winter hatchery capacity as has occurred at Lookingglass Hatchery (Rich Carmichael, ODFW, personal communication). Fingerling releases should be made in early summer or early fall to avoid high spring flows and midsummer high temperatures. Fingerlings released in June or early July should average 50-60 mm, fork length, with smaller individuals being released into the North Fork and Granite Creek and larger individuals into the Middle Fork and Mainstem. Fingerlings released in September and October should average 85-90 mm in all streams except Granite Creek where they should average 75 to 80 mm, fork length. Size at release is more critical for fingerling releases because of the potential for competition with wild fingerlings. Release sites should be within the limits of juvenile distribution that we observed during our sampling in 1978-84.

Evaluation

Adipose fin clips and coded-wire tags (Ad+CWT) should be used to mark all hatchery chinook salmon released into the John Day River system. These marks will be used for distinguishing among wild and hatchery adult returns, for comparing returns from different release strategies by using separate tag codes for each release group, and for evaluating the contribution of hatchery produced chinook salmon from the John Day River to ocean and to Columbia River fisheries. Marking smolts with AD+CWT should also be used to evaluate the necessity for managing each fork separately by monitoring the amount of straying among the major forks of the John Day River.

We also recommend installing rack or weir trapping structures below major spawning areas in each of the three main tributaries (Mainstem, Middle Fork and North Fork) in the system to count adults that return and to determine the proportion of the returns that are of wild and of hatchery origin. Potential trapping sites are the North Fork between Camas Creek and Texas Bar Creek, the Middle Fork between US Highway 395 bridge and Big Creek, and the Mainstem between Dog Creek 'and Indian Creek. Each rack should extend completely across the stream and should have a trap box located in the deepest portion of the stream. Counting wild adults at a trap would be the best method to estimate returns per spawner for wild fish since redds would be constructed by both wild and hatchery fish. Trends in return per spawner should be used to evaluate the success of hatchery supplementation (if stocks remain above replacement) and to determine if a harvestable surplus is being produced. If the stocks are not maintained above replacement, the numbers of smolts released each year should be increased. Scales should be collected from adults captured at these traps to better estimate age composition of returns because carcass recoveries tend to be biased toward larger individuals. These traps could also be used to collect brood stock.

Extensive spawning surveys should be conducted during the early years of hatchery supplementation to collect a maximum number of coded-wire tags from carcasses for use in evaluating return rates from different release strategies. Extensive surveys would be the best method of assessing total spawning escapement and the proportion of wild and hatchery returns (from carcass recoveries) if traps are not successful. However, carcass recoveries tend to be biased, which may make it difficult to evaluate different release strategies if these strategies change age composition. Extensive surveys could also be used to determine the number of redds produced from a known number of adults released above the traps. This would allow better estimation of the total escapement of adults in future years.

RECOMMENDATIONS

1. Escapement goals for the John Day basin should be 3,700 adult spring chinook salmon annually (see Table'25). Based' on stock-recruitment analyses, this level of escapement would fully seed the instream habitat and would provide a potential production of about 6,200 returning adults (40% exploitation rate). However., this production potential will not be realized until passage condltions'improve in the Columbia River.

2. Passage of juveniles at Columbia River dams, particularly John Day Dam, should be improved because mortality at the dams is the main reason for the decline of spring chinook salmon in the John Day River. Existing habitat in the basin must also be protected.

3. Measures to enhance downstream passage of juvenile chinook salmon in the Columbia River should be used from April through,June to provide the most benefit to smolts from the Jdh'n Day River. We recommend that at least 20% of the flow' be spilled during April 'and May at John Day Dam and during April through June at The Dalles Dam.

4. Because few spring chinook salmon from upper Columbia River tributaries appear to be harvested in the ocean, restrictions on ocean fisheries to protect upriver spring chinook salmon are presently unnecessary.

5. Because Ad+CWT marked spring chinook salmon from the John Day River were recovered in lower Columbia River test fisheries during April and May of 1981-84, commercial and sport salmon fisheries in the Columbia River should be closed from at least mid-March through May to prevent harvest of John Day River stocks.

6. Fisheries on spring chinook salmon in the John Day, basin should remain closed because of the low return per spawner'.

7. Habitat improvements in streams other than the Mainstem are not likely to enhance spring chinook salmon production at this time because the'streams are currently underseeded.

8. The amount of pool habitat in the Mainstem should be increased first above Praire City and second above the town of John Day. Spawning escapement and returns per spawner should be monitored to determine if increases in pool habitat result in increased production.in the Mainstem.

9. Holding pools constructed for adult spring chinook salmon. should be deeper than 1.5 meters and should provide escape cover such as undercut banks, boulders, or woody structure. Holding pools appear to be in short supply in the Mainstem, but they are probably not limiting production.

10. Because tributaries of the John Day River-are used extensively by juvenile chinook salmon for rearing, land and stream management practices should provide adequate upstream passage and habitat protection in these tributaries.

11. Future chemical (rotenone) treatment projects should be restricted to stream sections below major spawning and rearing areas of spring chinook salmon. We recommend that chemical treatment projects not be conducted above Prairie City in the Mainstem, above Beaver Creek bridge (below the Oxbow Ranch) in the Middle Fork, and above Desolation Creek in the North Fork.

12. The effects of rotenone on spring chinook salmon embryos should be investigated.

13. Futrue index surveys should be conducted on or within five days following the dates listed in Table 15. The number of live fish and occupied redds should be recorded during surveys, and surveys should be repeated if more live' fish than redds are observed or if more than half of the redds are occupied.

14. The section of the Middle Fork from Crawford Creek bridge to Vinegar Creek should be added to the spawning survey index area so future surveys will accurately' reflect spawner abundance in the Middle Fork. This would 'be an addition of 6 miles and would require only one more staff day to conduct the survey.

15. The section of'the North Fork from Crane Creek. to Granite Creek should be considered for add'ition to the North Fork index if the personnel are available. This would provide a better index of spawner abundance in the North Fork.

16. Returns per spawner from index surveys (as outlined in Appendix E) should be calculated to detemine if this relationship is improving as smolt passage facilities are'modified at Columbia River dams.

17. If calculations of returns per spawner for 1985, 1986, and 1987 broods (broods that will migrate downstream following modifications of smolt passage facilities at John Day Dam) are not above 1.0 (replacement) for all streams in the John Day basin, then the collection of returninq adults for hatchery brood stock should begin in 1993.

18. Groundwater resources in the John Day basin shou ld be exp lored to determine if any sites have suitable groundwater supplies to support a hatchery.

19. John Day River spring chinook salmon should be used exclusively as brood stock for supplementing chinook salmon runs in the John Day basin.

20. Brood stock should be collected from each major fork of the John Day River (Mai'nstem, Middle Fork, North Fork, and Granite Creek), and each stream should be managed separately if it becomes necessary to supplement the wild runs with hatchery reared fish.

21. If it becomes necesssary to supplement the wild John Day River chinook salmon runs, then the supplementation should be done by planting 100,000 smolts (16,000 in the Mainstem, 25,000 in the Middle Fork, 33,000 in the North Fork, and 26,000 in Granite Creek) annually between 15 February and 30 April. Smolts should be released at the following sites: Mainstem at Prairie City; Middle Fork at Bates; North Fork at the mouth of Desolation Creek and at North Fork Campground; and, Granite Creek at Squaw Creek Campground, at the mouth of Clear Creek, and at the mouth of Bull Run Creek.

FOOTNOTES

1 *Redd counts in the Warm Springs River in 1980 and 1981 were excluded in calculating the average number of fish per redd because of exceptionally high spawner mortality in those years.*

2 *These age structures were calculated from data collected in 1978-84.*

REFERENCES

Anas, R.E., and S. Murai. 1969. Use of scale characters and a discriminant function for classifying sockeye salmon *(Oncorhynchus nerka)* by continent of origin. International North Pacific Fisheries 'Commission Bulletin 26:157-192.

Anonymous, 1972. Review report, John Day River and tributaries, Oregon. U.S. Army Corps of Engineers, Walla Walla District, Walla Walla, WA, USA.

Anonymous. 1983. General department policies. Oregon Department of Fish and Wildlife, Portland, OR, USA.

Anonymous. 1984a. Columbia River basin fish and wildlife program. Northwest Power Planning Council, Portland, OR, USA.

Anonymous. 1984b. Columbia River fish runs and fisheries, 1960-83: Status Report. Oregon Department of Fish and Wildlife and Washington Department of Fisheries, Portland, OR, USA.

Anonymous. 1985. John Day River basin minimum streamflow report, Oregon Water Resources Department, Salem, OR, USA.

Bjornn, T. C. 1975. Salmon and steelhead production and yield studies, Lemhi Big Springs Creek. Idaho Department of Fish, and Game, Salmon and Steelhead Investigations, Project F-49-R-13 Job Performance Report, Boise, ID, USA.

Bjornn, T.C. 1978. Survival, production, and yield of trout and chinook salmon in the Lemhi River, Idaho. University of Idaho, College of Forestry, Wildlife and Range Sciences, Bulletin No. 27, Moscow, ID, USA.

Brown, C.J.D., and J.E. Bailey. 1952. Time- and pattern of scale formation in Yellowstone cutthroat trout *Salmo clarkii lewsii.* Transactions of the American Microscopical Society 71:120-124.

Burns, J.W. 1972. Some effects of logging and associated road construction on northern California streams. Transactions of the American Fisheries Society 101:1-17.

Chapman, D.G., and C.O. Junge. 1956. The estimation of the size of a stratified animal population. Annals of Mathematical Statistics 27:375-389.

Chapman, D.W. 1966. Food and space as regulators of salmonid populations in streams. The American Naturalist 100:345-357.

Clutter, R.I., and L.E. Whitesel. 1956. Collection and interpretation of sockeye salmon scales. International Pacific Salmon Fisheries Commission Bulletin IX.

Cook, R.C. 1982. Stock identification of sockeye salmon *(Oncorhyzchus nerka)* with scale pattern recognition. Cariadian Journal of Fisheries and Aquatic Sciences 39:611-617.

Cook, R.C., and G.E. Lord. 1978. Identification of stocks of Bristol Bay sockeye salmon, *Oncorhpchus nerka,* by evaluating scale patterns with a polynomial discriminant method, Fishery Bulletin 76:415-423.

Damkaer, D.M. 1983. Effects of water-borne pollutants on fish-passage at John Day Dam, Columbia River. United States National Marine Fisheries Service, Northwest and Alaska Fisheries Center, Contract DACW57-82-F-037, Report to United States Army Corps of Engineers, Seattle, WA, USA.

Damkaer, D.M., and D.B. Dey. 1984. Adult fish delay at John Day Dam. United States National Marine Fisheries Service, Northwest and Alaska Fisheries Center, Contract DACW57-83-F-0323, Report to United States, Army Corps of Engineers, Seattle, WA, USA.

Damkaer, D.M., and D.B. Dey. 1985. Effects of water-borne pollutants on salmon-passage at John Day Dam, Columbia River (1982-1984). United States National Marine Fisheries Service, Northwest and Alaska Fisheries Center, Contract DACW57-84-F-0173, Report to United States Army Corps of Engineers, Seattle, WA, USA,

Dawley, E.M., R.D. Ledgerwood, T.H. Blahm, R.A. Kirn, and A.E. Rankis. 1984. Migrational characteristics and survival, of juvenile salmonids entering the Columbia River estuary during 1983. United States National Marine Fisheries Service, Northwest and Alaska Fisheries Center, Agreement DE-A179-83BP39625, Report to Bonneville Power Administration, Seattle, WA, USA.

Duke, R.C1984. Anadromous fish marking and recovery. Idaho Department of Fish and Game, Salmon and Steelhead Investigations, Project F-73-R-5, Job Performance Report, Boise, ID, USA.

Everest, F.H., and D.W. Chapman. 1972. Habitat selection and spacial interaction by juvenile chinook salmon and steelhead trout in two Idaho streams. Journal of the Fisheries Research Board of Canada 29:91-100.

Galbreath, J.L., and R.L. Ridenhour. 1964. Fecundity of Columbia River chinook salmon. Fish Commission of Oregon Research Briefs 10(1):16-27.

Garrison, R.L. 1968. The toxicity of Pro-Noxfish to salmonid eggs and fry. The Progressive Fish-Culturist 30:35-38.

Gibson, G., R. Michimoto, F. Young, and C.O. Junge. 1979. Passage problems of adult Columbia River chinook salmon and steelhead, 1973-78. Oregon Department of Fish and Wildlife, Contract DACW57-78-C-0044, Report to United States Army Corps of Engineers, Portland, OR, USA.

Hall, J.D., and R.L. Lantz. 1969. Effects of logging on the habitat of coho salmon and cutthroat trout in coastal streams. Pages' 355-376 in T.G. Northcote, editor. Symposium on salmon and trout in streams. University of British Columbia, Vancouver, Canada.

Hamilton, J.A.R., and F. J. Andrew. 1954, An investigation of the effect of Baker Dam on downstream-migrant salmon. International Pacific Salmon Fisheries Commission Bulletin VI.

Higley, D.L., and C.E. Bond. 1973. Ecology and production of juvenile spring chinook salmon, *Oncorhanchus tshawgtscha*, in a eutrophic reservoir. Fishery Bulletin 71:'87,7-891.

Hooton, R.M. 1978. Progress report on native broodstock collections on the Yaquina, Siuslaw and Coos Rivers. Oregon Department, of Fish and Wildlife, Information Reports (Fish) 78-8, Portland, OR, USA.

Hunter, J.G. 1959. Survival and production of pink and chum salmon in a coastal stream. Journal of the Fisheries Research Board of Canada 161835-886.

Johnson, J;K. 1985. Pacific salmonid coded wire tag releases through 1984. Pacific Marine Fisheries Commission, Regional Mark Processing Center, Portland, OR, USA.

Jonasson, B.C., and R.B. Lindsay. 1983. An ecological and fish cultural study of Deschutes River salmonids: Oregon Department of Fish and Wildlife, Fish Research Project F-88-R-13, Annual Progress Report, Portland, OR, USA.

Junge, C.O. 1970. The effect of superimposed mortalities on reproduction curves. Fish Commission of Oregon, Research Reports 2(1):1-8.

Junge, C.O. and B.E. Carnegie. 1976. Dam operations and adult fish passage, 1975.^ uregc Department of Fish and Wildlife, Contract No. DACW68-75-C-0129, Report to United States Army Corps of Engineers, Portland, OR, USA.

Junge, C.O., and A.L. Oakley. 1966. Trends in production rates for upper Columbia River runs of salmon and' steelhead and possible effects of changes in turbidity. Fish Commiss'in of Oregon Research Briefs 12(1):22-43.

Klecka, W.R. 1975. Discriminant 'analysis,., Pages 434-467 in N;H. Nye, 'C.H. Hull, J.C. Jenkins,'K. Steinbrenner, and D.H. Brent,' editors. Statistical package for the social sciences, second edition. McGraw-Hill, Inc., New York, NY, USA.

Larkin, P.A., and A.S. Hourston. 1964. A model for simulation of the population biology of Pacific salmon. Journal of the Fisheries Research Board of Canada 21:1245-1265.

Lear, W.H., and R.K. Misra, 1978. Clinal variation in scale characters of Atlantic' salmon' *(Salmo salar)* based on discriminant function analysis. Journal of the fisheries Research Board of Canada' 35:43-47

Lichatowich, J.A: 1975. Rogue basin evaluation program.., Oregon Wildlife Commission, Fish Research Project DAcW57-75-C-0109+, "Quarterly report, Portland, OR, 'USA.

Lindsay,, R.B., G,L. Concannon, J.S. Ziller, R.K. Schroeder, and K. Andersqn,. 1980. An ecological and fish cultural, study of Deschutes River salmonids. Oregon Department of Fish and Wildlife, Fish Research Project F-88-R-10, Annual Progress Report, Portland, OR, USA.

L'indsay, R.B., J.S. Zill'er, and R.K. Schroeder. 1982. An ecological and fish cultural study of Deschutes River salmonids. Oregon Department of Fish and Wildlife, Fish research Project F-88-R-13, Annual Progress Report,, Portland, OR, USA.

Lister, D.B., and H.S. Genoe. 1970. Stream habitat utilization by cohabiting underyearlings.of chinook *fOyworhpzchus.tshat@scha)* and coho (0. *kisutch)* salmon in the Big Quaicum River, British, Columbia. Journal of the Fisheries Research Board, of Canada 27:1215-1224.

Mains,:E.M., and J.M. Smith. 1964. “The distribution, size, time and current preferences of seaward'migrant chinook salmon in the Columbia and Snake Rivers. Washington Department of Fisheries, Research Paper 2(3):5-43.

Major, R.L., and J.L. Mighell, 1969.Egg-to-migrant survival of spring chinook sai'mon *(dticoihgnchbs tshawytscha)* in the Yakima River, Washington. Fishery Bulletin 67:347-359.

Marking,'L.L., T.D. Bills, J.J. rach, and S.J. Grabowski. 1983. Chemical control of fish and fish eggs in the Garrison Diversion Unit, North Dakota. North American Journal of Fisheries-Management 3:410-418.

Meffe,. G,.K.', 1983. Attempted, chemical,' renovation of an Arizona springbrook for management of the endangered Sonoran topminnow. North American Journal of Fisheries Management 3,:315-321.

Merrell, T,?R., M.D.,Col,lins, and J.W. Greenough. 1971., 'An estimate of mortality of chinook salmon in the Columbia River near Bonneville Dam during the summer, run of 1955. Fishery Bulletin 68:461-489.

Monan, G.E., R.J. McConnell, J.R. Pugh, and J.R. Smith. 1969. . Distribution of debris and downstream-migrating.sqlmon in the Snake River above Brownlee Reservoir. Transactions of the American Fisheries Society 98:239-244.

Moyle, P.B., B. Vondracek; and G.D. Grossman. 1983. Responses of fish populations in the North Fork of the' Feather River; California, to treatments with fish toxicants.. North American Journal of Fisheries Management 3:48-60.

Mullen, R.E. 1979. Salmon River project. Oregon Department of Fish and Wildlife, Fish Research Project AFC-76-3, Annual Progress report, Portland, OR, USA.

Mundie, J.H. 1974. Optimization fo the salmonid nursery stream. Journal of the Fisheries Research Board of Canada 31:1827-1837.

Nicholas, J.W., and M.L. Herring. 1983. Distribution and relative. abundance of hatchery and wild salmon juveniles in the study areas of the Yaquina, Siuslaw, and Coos rivers,. Oregon Department of Fish and Wildlife, Information Reports (Fish) 83-7, Portland, OR,,USA.

Nicholas, J.W., P.E. Reimers, and J.M. Hutchison. 1979. The potential impact of releasing hatchery coho'salmon on wild juvenile chinook salmon in the Siuslaw Esturay. Oregon Department of Fish and Wildlife, Information Reports (Fish) 79-7, Portland, OR, USA.

Ott, L. 1977. An introduction to statistical methods and data analysis. Duxbury Press, North) Scituate, MA, USA.

Raymond, H.L. 1969. Effect of John Day Reservoir on the migration rate of juvenile chinook salmon in the Columbia River. Transactions of the American Fisheries Society 98:513-514.

Raymond,' H.L. 1979. 'Effects of dams and impoundments on migration; of juvenile chinook salmon and steelhead from the Snake River; 1966 to 1975. Transactions of the American Fisheries Society 108:505-529.

Rees,, W.H: 1957. The vertical and horizontal distribution of seaward migrant salmon in the forebay of 'Baker Dam. Washington:Department of Fisheries, Research Paper 2(1):5-17.

Reimers, P.E. 1979. Success in a hatchery program with fall 'chinook salmon by simulating the natural life history of the stock. Progressive Fish Culturist 41:,192-195.'

Reimers, P.E., and T.W. Downey; 1982; Population, dynamics of fall chinook salmon in Sixes River. Oregon Department of Fish and Wildlife, Fish Research Project AFC-102, Annual Progress Report, Portland, OR,'USA.

Reisenbichler, R.R. 1980. Effect of degraded environment and increased fishing on abundance' of' fall-run chinook salmon,, ***(Oncorhynohus tshaugtscha)*** **,** in several California streams>. United Stated Fish and Wildlife Service, Seattle, WA, USA. (Draft.)

Rich,, W.H.. 1920. Early.history and.seaward migrationof chinook salmon in the Columbia and Sacramento Rivers. United States Bureau of Fisheries Bulletin,37(887,):1-73..

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish. populations. Fisheries Research' Board of Canada' Bulletin 191.

Salo, E.O., and Q.J. Stober. 1977. Man's impact on the Columbia River stocks of salmon Pages 36"45, in W. Van Winkle, editor. Proceedings. of the conference on assessing the effects of power-plant-induced mortality on fish popoulations. Pergamon Press, New York, NY, USA.

Schaefer, M.B. 1951. Estimation of size of animal populations by marking experiments. United States Fish and Wildlife Service, Fisheries Bulletin 69:191-203.

Scheaffer, R.L., W. Mendenhall, and L. ott. 1979. Elementary survey sampling, 2nd edition. Duxbury Press, North Scituate, MA, USA.

Schluchter, M.D. and J.A. Lichatowich. 1977. Juvenile life histories of Rogue, River spring chinook salmon, ***Oncorhynchus tshaqjtscha,*** (Walbaum), as determined by scale analysis. Oregon Department of Fish and Wildlife, Information Reports (Fish) 77-5, Portland, OR, USA.

Schoeneman, D.E. and C.O. Junge; Jr. 1954;, Investingations of mortalities to downstream migrant salmon at two dams on the Elwha River. Washington Department of Fisheries, Research Bulletin 3:1-51.

Schoeneman, D.E., R.T. Pressey, and C.O:' Junge, Jr. 1961 Mortalities of downstream migrant salmon at McNary Dam. Transactions of the American Fisheries Society,90:68-72.

Seber, G.A.F. 1973. The estimation of animal abundance and related parameters. Hafner Press; New York;NY, USA.

Senn, H., J. Mack, and L. Rothfus, 1984. Compendium of low-cost' Pacific salmon and steelhead trout production facilities and practices in the Pacific Northwest Fish' Management Consultants, Project 83-353, Report to Bonneville Power Administration,, Portland, OR, USA.

Sims, C.W., W.W. Bentley, and R.C. Johnsen. 1978. Effects of power peaking operations on juvenile salmon and steelhead trout migrations-progress 1977., United States National Marine Fisheries Service, Norhtwest and Alaska.Fisheries Center, Contract DACW68-77-C-0025; Report to United States Army Corps of Engineers, Seattle, WA, USA.

Smith, E.M., R.H. Williams, and J.C. Zakel. 1984. Willamette River salmon studies. Oregon Department of Fish and Wildlife, Fish Research Project F-102-R-5 (Ext), Annual Progress Report, Portland, OR, USA.

Snedecor, G.W., and W.G. Cochran. 1967. Statistical methods, 6th edition. The Iowa State University Press, Ames, IA, USA.

Solazzi, M.F., S.L. Johnson, and T.E. Nickelson. 1983. The effectiveness of stocking hatchery coho presmolts to increase the rearing density of juvenile coho salmon in Oregon coastal streams. Oregon Department of Fish and Wildlife, Information Reports (Fish) 83-1, Portland, OR, USA.

Stevens, D.E., and L.W. Miller. 1983. Effects of river flow on abundance of young chinook salmon, American shad, longfin smelt, and delta smelt in the Sacramento-San Joaquin River system. North American Journal of Fisheries Management 3:425-437.

Turner, A.R., Jr., D.M. Shew, L.M. Beck, R.J. Stansell, and R.D, Peters. 1984. Evaluation of adult fish passage at Bonneville Lock and Dam in 1983. United States Army Corps of Engineers, Portland District, Cascade Locks, OR, USA.

Van Hyning, J.M. 1973. Factors affecting the abundance of fall chinook salmon in the Columbia River. Fish Commission of Oregon, Research Report 4(1):1-87.

Wallis, J. 1968. Recommended time, size, and age for release of hatchery reared salmon and steelhead trout. Fish Commission of Oregon, Portland, OR, USA.

Willis, C.F. 1982. Indexing of juvenile salmonids migrating past The Dalles Dam, 1982. Oregon Department of Fish and Wildlife, Fish Research Project DACW57-78-C-0056 (P00003), Annual Progress Report, Portland, OR, USA.

APPENDIX A

Redd Counts

Appendix Table A-l. Percent distribution of chinook redds counted in extensive surveys in the Mainstem, 1978-85. See Figure 2 for location of survey sections.

Year	Road 14 bridge to Reynolds Creek bridge	Reynolds Creek bridge to Dans Creek	Dans Creek to Prairie City
1978	31	66	3
1979	30	42	28
1980	19	69	12
1981	16		
1982	46	4057	4420
1983	33	35	19
1984	[illegible]	35	33
1985	40	40	20

Appendix Table A-2. Percent distribution of chinook redds counted in extensive surveys in the Middle Fork, 1978-85. See Figure 4 for location of survey sections.

Year	Upper Phipps Meadows to Clear Creek	Clear Creek to Deer-horn Creek	Deerhorn Creek to Granite-Boulder Creek	Granite-Boulder Creek to Coyote Creek	Coyote Creek to Elk Creek	Elk Creek to Armstrong Creek
1978	24	32	24	12	7	1
1979	9	44	23	19	4	1
1980	15	57	18	7	0	3
1981	4	28	30	28	4	6
1982	27	34	18	8	11	2
1983	14	46	21	10	7	2
1984	35	33	11	14	7	0
1985	29	33	14	13	8	5

Table A-3. Percent distribution of chinook salmon redds counted in extensive surveys in the North Fork, 1978-85. See Figure 3 for location of survey sections.

Year	Baldy Creek to Road 73	Road 73 to Trout Creek	Trout Creek to Crane Creek	Crane Creek to Tub Springs	Tub Springs to Granite Creek
	1		9	1	9
1978 1979	2	3	1	3	0
1980	2	5	4	7	4
		2		6	
1981	0	3	1	12	5
1982	0	4	1	7	6
1983	0	4	1	9	5
1984					0
1985	1	3	3	7:	3

Year	Granite Creek to Ryder Creek	Ryder Creek to Big Creek'	,Big Creek to Sulphur Creek	Sulphur Creek to Texas Bar Creek'	Texas Bar Creek to Desolation Creek
			18		
1978	45	4	25	25	9
1979	42	10		13	7
1980			21	4	2
	30				
1981	31	10	25	15	7
1982	34	5	12	12	6
1983	37	12	17	15	7
1984			10	11	6
1985	50	4			7

Appendix Table A-4. Percent distribution of chinook salmon redds counted in extensive surveys in the Granite Creek system, 1978-85. See Figure 3 for location of survey sections.

Year	Road 73 to Bull Run Creek	Bull Run to Ten Cent Creek	Ten Cent Creek to Lick Creek	Lick Creek to mouth	Clear Creek	Bull Run Creek
1978	8	15	33	16	13	16
1979	3	32	28	6	21	11
1980	1.	25	31	6	34	3
1981	0	26	23	7	39	6
1982	0	25	23	10	34	9
1983	4	36	34	16	7	4
1984	2	32	27	13	14	13
1985	5	28	23	13	21	10

APPENDIX B

Lower Limit (river kilometer) of Distribution of Age 0 Spring Chinook Salmon in the John Day River, 1978-84,

Area, year	June	July	August	September	October
Mainstem (above mouth of North Fork):					
1978			418	----	
1979	404	404	423	423	(a)
1980	404	404		423	423
1981	404	386	387	387	--
1982	423	404	414	--	436
1983				--	--
1984	356	374	366	381	381
Mainstem (below mouth of North Fork):					
1978	284	--	--	--	--
1979	275	--	--	--	--
Middle Fork:					
1978	44	64	--	--	64
1979	21	43	74	74	53
1980	43	75	75	53	43
1981	21	67	67	54	--
1982	75	41	66	77	(b)
1983	74	74	77	74	--
1984	77	53	43	43	43
North Fork:					
1978	10	--	114	--	
1979	13	42	89	89	42
1980	0	72	88	70	70
1981	25	36	80	70	--
1982	36	25	72	(a)	(b)
1983	32	52	55	68	
1984	9	68	57	72	25

[a] *No chinook captured during sampling.*
[b] No *chinook present because of a chemical treatment project.*

APPENDIX C

Lengths of Juvenile Spring Chinook Salmon Sampled in the John Day River System

Appendix Table C-1. Lengths of age 0 spring chinook salmon (1977 brood) sampled in selected areas of the John Day River system, 1978. CI = confidence interval.

Area, date	Sample size	Fork length (mm)		
		Range	Mean	95% CI
Mainstem (km 423):				
09 August	36	79-113	94	±2
Middle Fork:				
18 July	34	59-79	69	±1
26 July	38	52-85	75	±1
08 August	50	71-91	80	±1
24 August	21	79-97	86	±1
North Fork (km 119):				
10 July	50	40-62	50	±1
25 July	45	49-78	59	±1
10 August	44	53-75	65	±1
28 August	42	57-79	66	±1
11 September	41	58-89	70	±1
25 September	40	67-89	77	±1
09 October	49	61-84	74	±1
23 October	65	64-94	77	±1
Bull Run Creek in Granite Creek system:				
11 July	51	44-66	52	± 1
08 August	37	47-74	59	± 1
22 August	57	51-72	61	± 1
26 September	49	62-84	72	± 1
10 October	60	59-87	73	± 1
26 October	45	64-89	77	± 1
08 November	60	64-90	76	± 1

Appendix Table C-2. Lengths of age 0 spring chinook salmon (1978 brood) sampled in the John Day, River system, 1979. CI = confidence interval.

Area, date	Sample size	Fork length (mm) Range	Mean	95% CI
Mainstem:				
18 June	53	44-76	53	±1
17 July	41	57-87	70	±2
04 September	18	74-100	85	±2
Middle Fork:				
19 June	63	39-70	52	±2
16 July	63	51-78	59	±1
13 August	43	56-84	73	±2
05, September	36	66-88	80	+2,
16 October	22	73-97	87	+2
15 November	25	78-98	90	+2
North Fork:				
02 July	74	40-76	50	±1
18 July	44	56-80	54	±2
15 August	36	56-81	68	±2
06, September	41	61-90	80	±2
15 October	42	76-95	85	±1
Granite Creek:				
10 July	149	38-63	48	±1
25 July	100	41-65	49	±1
21 August	109	46-76	63	±1
18 September	93	56-91	73	±1
18 October	76	55-94	75	±1

Appendix Table C-3. Lengths of age 0 spring chinook salmon (1979 brood) sampled in the John Day River system, 1980.

Area, date	Sample size	Fork length (mm) Range	Mean	95% CI
Mainstem:				
05 May	77	36-63	43	±1
12 'May	41	37-54	44	±1
27 May	46	42-71	51	±1
09 June	40	46-71	54	±1
23 June	57	49-88	60	±1
07 July	29	54-92	63	±1
21 July	24	61-100	81	±2
05 August	61	66-110	83	±2
21 August	49	70-106	94	±1
03 September	38	75-106	93	±2
16 September	27	78-110	89	±2
30 September		84-100	91	±3
13 October	2:	87-114	101	±3
Middle Fork:				
15 May	104	34-53	44	±1
22 May	74	.37-71	48	±1
30 May	85	37-66	49	±1
12 June	73	39-74	54	±1
26 June	70	'47-82	62	±1
'11 July	84	57-92	71	±1
25 July	63	55-91	78	±1
11 August	71	64-97	80	±1
19 August	73	66-99	81	±1
02 September	19	69-96	86	±2
16 September	19	77-101	90	±3
30 September	14	83-106	92	±3
14 October	51	74-105	92	±2

Appendix Table C-3. Continued.

Area, date	Sample size	Fork length (mm)		
		Range	Mean	95% CI
North Fork:				
10 June	111	36-64	45	±1
25 June	110	38-69	52	±1
08 July	96	38-68	56	±1
22 July	78	49-74	60	±1
05 August	49	56-76	66	±1
18 August	63	61-83	72	±1
02 September	69	69-96	80	±1
17 September	29	75-101	85	±2
29 September	48	64-101	86	±2
10 October	29	59-96	87	±2
Granite Creek:				
25 June	132	36-56	43	+1
09 July	180	37-79	52	+1
23 July	178	47-75	58	+1
06 August	181	51-78	61	+1
19 August	184	53-86	68	+1
03 September	106	58-84	72	+1
la September	156	63-93	80	“1
01 October	195	62-104	81	tl
15 October	153	64-105	84	+1

Appendix Table C-4. Lengths of age 0 spring chinook salmon (1980 brood) sampled in the John Day River system, 1981. CI = Confidence interval.

Area, date	Sample size	Fork length (mm)		
		Range	Mean	95% CI
Mainstem:				
21 May	5	45-62	55	±3
02 June	28	43-72	50	±1
26 June	9	54-89	70	±4
15 July	19	62-97	84	±2
11 August	14	79-97	88	±3
28 August	43	82-108	95	±2
29 September	21	95-112	101	±2
Middle Fork:				
02 June	75	37-62	48	±1
25 June	46	50-75	63	±2
15 July	72	55-90	71	±2
10 August	52	64-113	80	±3
03 September	44	59-102	82	±2
29 September	46	72- 99	86	±2
North Fork:				
22 June	134	37-61	47	±1
14 July'	56	50-73	60	±1
10 August	100	57-84	68	±1
02 September	59	63-91	75	±1
28 September	58	69-96	80	±1
Granite Creek:				
17 June	162	37-54	42	±1
23 June	205	36-69	46	±1
24 July	179	41-79	58	±1
10 August	117	49-87	67	±1
31 August	138	53-92	72	±1
28 September	150	57-95	80	±1

Appendix Table C-5. Lengths of age 0 spring chinook salmon (1981 brood) sampled in the John day River system, 1982. CI = confidence interval.

Area, date	Sample size	Fork length (mm) Range	Mean	95% CI
Mainstem:				
28 May	15	42-52	47	±2
15 June	36	43-62	52	±1
13 July	40	45-95	60	±2
02 August	65	56-101	70	±2
Middle Fork:				
15 June	16	41-59	51	±2
06 July	34	55-80	69	±1
03 August	33	59-87	76	±2
01 September	55	76-97	87	±1
20 September	25	82-101	90	±2
North' Fork:				
29 June	95	36-55	44	±1
12 July	94	41-63	52	±1
03 August	23	46-75	60	±1
07 September	38	69-91	80	±2
30,September		66-102	91	±2

Appendix Table C-6. Lengths of age.0 spring chinook salmon (1982 brood) sampled in the John Day River system; 1983. CI = condidence interval.

Area, date	Sample size	Fork length (mm)		
		Range	Mean	95% CI
Mainstem:				
06 May	30	37-51	45	±1
03 June	27	43-64	55	±2
05 July	88	51-95	68	±2
18 August	45	63-92	77	±2
08 September	81	73-103	85	±1
21 October	24	76-98	86	±2
Middle Fork:				
03 June	11	38-67	53	±4
27 June	41	41-87	63	±2
08 August	49	65-112	83	±2
09 September	17	88-105	97	±2
21 October	37	86-115	101	±2
North Fork:				
05 June	127	31-55	42	±1
10 July	97	37-69	53	±1
08 August	75	53-82	67	±1
07 September	20	68-102	90	±3
21 October	27	77-110	86	

Appendix Table C-7. Lengths of age 0 spring chinnool salmon (1983'brood) sampled in the John Day River system, 1984. CI = confidence interval.

Area, date	Sample size	Fork length (mm)		
		Range	Mean	95% CI
Mainstem:				
la June	52	38-68	47	±1
23 July	56	52-168	69	±2
06 August	30	60-96	75	±3
21 August	42	66-101	81	±2
05 September	35	69-100	al	±2
02 October	66	71-95	81	±1
Middle Fork:				
05 June	66	38-64	48	+1
20 June	86	43-72	53	+1
25 July	72	52-94	70	f2
	72			
09 August	104	58400	77	c2
20 August		63-100	80	fl
10 September	74	68;lOl	85	+1
05 October	42	76-105	94	f2
North Fork:				
19 June	130	36-49	43	t1
26 July	71	47-74	60	f1
08 August	67	55-90	68	+2
23 August	31	63-87	75	+2
07 September	23	54-91	83	f3
04 October	32	73-101	90	f2

Appendix Table C-8. Lengths of migrating spring chinook salmon smolts (age 1) captured by seine near Spray (km 275) and Rock Creek (km 35) in the John Day River from February to May, 1978-84.

Area, year	Sample size	Fork length, (mm) Range	Mean
Spray:			
197a[a]	224	85-134	109
1979[b]	164	81-122	98
1980	718	80-134	104
1981	525	85-134	108
1982	244	80-132	106
1983	403	88-140	113
1984	542	90-136	110
Rock Creek:			
1982	77	91-140	111
1983	18	109-140	126

a *April* ***and*** *Ma@* only
b *March to May only.*

Appendix Table C-9. Lengths of migrating spring chinook salmon smolts (age 1) captured in scoop traps in the Mainstem (km 394), the Middle Fork (km 51), and the North Fork (km 97) John Day River from February to May, 1980-84.

Area, year	Sample size	Fork length (mm)	
		Range	Mean
Mainstem:			
1980[a]	9	90-117	107
1981	309	88-138	108
1982	234	88-134	113
1983	255	84-130	108
1984	206	82-123	99
Middle Fork:			
1980	441	al-127	105,
1981	374	78-122	98
1982	51 .	86-117	102
1983	14	96-122	108
1984	151’	77-126	104
North Fork:			
1980	503	70-124	94
1981	301		96
1982	192	76-113	93
1983	477	72-119	92
1984	386	72-117	96

a Smotts were captured in a rotary screen bypass trap (km 394).

APPENDIX D

Juvenile Spring Chinook Salmon Marked Ad+CWT,in the John Day River System, 1978-82

Brood year	Tag code	Release area	Marking period	Number released[a]
1976	07 17 01	Mainstem (km 253-298)	April-June 1978	407
1977	H7 01. 06	(b)	June-October 1978	9,351
1977	07 17 02	Mainstem (km 253-298)	February-May 1979	740
1978	07 19 39	Middle Fork	June-August 1979	3,546
1978	07 19 40	Granite Creek	June-July 1979	8,029
1978	07 19 41	North Fork'	June-August 1979	5,042
1978	07 19 42	Mainstem (km 418-443)	June 1979	9
1978	07 20 24	Granite Creek	July-August 1979	5,888
1978	07 20 25	Granite Creek	August-October 1979	8,797
1978	07 20 26	Mainstem (km 282)	February-May 1980	1,548
1978	07 20 27	Middle Fork (km 51)	March-June 1980	608
1978	07 20 28	Norht Fork (km 97)	February-May 1980	923
1979	07 20 56	Mainstem (km 418-443)	September 1980	98
1979	07 20 57	Middle Fork	June-September 1980	4,056
1979	07 20 58	North Fork	June-September 1980	7;397
1979	07 20 59	Granite Creek	July-September 1980	8;447
1979	07 20 60	Granite Creek	September!1980	517
1979	07 20 61	Mainstem (km 282)	February-May 1981	,608
1979	07 20 62	Mainstem (km 394)	February-April '1981	232
1979	07 20 63	Middle Fork (km 51)	March-April 1981	'333
1979	07 21 01	North Fork (km 97)	February-April 1981	270
1980	07 21 02	Middle Fork	May-June 1981	$863
1980	07 23 51	Granite Creek	September 1981	236
1980	07 23 52	North Fork	June-September 1981	4,731
1980	07 23 54	Granite Creek	June-September 1981	7,518
1980	07 23 55	Middle Fork	June-September 1981	1,575
1980	07 23 56	North Fork	September 1981	557
1980	07 23 53	Mainstem (km 282)	March-May 1982	612
1980	07 26 58	Mainstem (km 35)	March-May 1982	71
1980	07 26 59	Mainstem (km 394)	March-May 1982	243
1980	07 26 60	Middle Fork (km 51)	March-May 1982	46
1980	07 26 61	North Fork (km 97)	March-April 1982	364

a *Adjusted for tag loss.*
b *Releases were made in the Mainstem, Middle Fork, North Fork, and Granite Creek system of the John Day River.*

APPENDIX E .

Example of Calculating Returns Per Spawner for 1965-68 Broods in the Mainstem. Redds Per Mile are Adjusted for Catch-to-Escapement Ratios in Columbia River (c/e) and for Age Composition of 5% Age 3, 90% Age 4, and 5% Age 5.

Year of spawning	Reddds/ mile	c/e	Adjusted redds/mile	Brood year returns in redds per mile: '1965	1966	1967	1968
1968	9.3	0.61	1.13	[illegible]a			
1969	8.3	0.54	14.32	12.89b	0.72a		
1970	7.0	[illegible]	[illegible]			0.73a	
1971	3.9	[illegible]	[illegible]	0.73c	10.52c	9.39b	0.52a
1972	[illegible]	0.95	7.60			0:38	6.84b
1973	8.9	1.16	19.22				0.96c

Brood year	Total return (redds per mile)	Parent spawners (redds per mile)	Return per parent spawner
1965	13.68	5.8	2.36
1966	14.42	9.3	1.55
1967	10.50	7.4	1.42
1968	8.32	0.7	11.89

a *Age 3.*
b *Age 4.*
c *Age 5.*