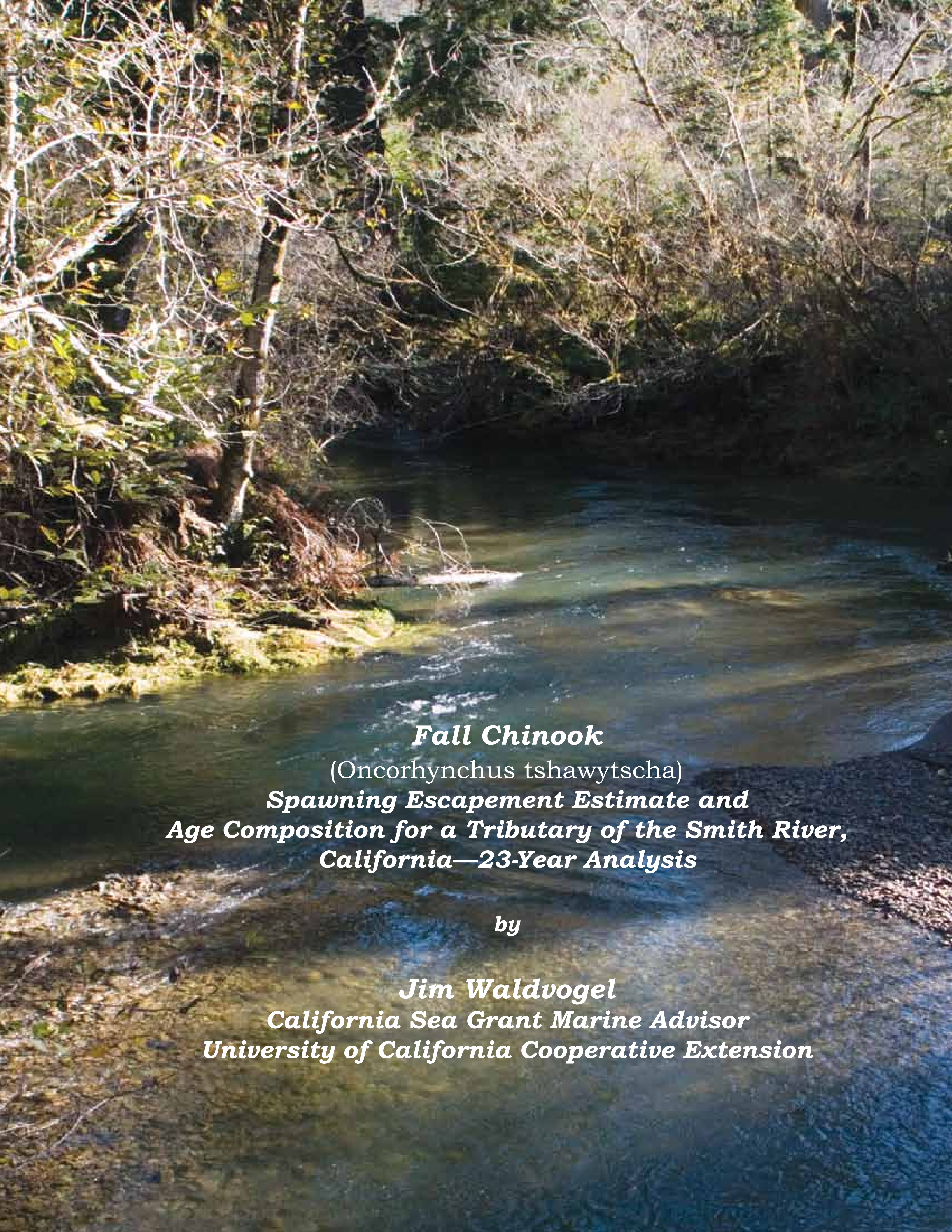

Fall Chinook

(Oncorhynchus tshawytscha)

Spawning Escapement Estimate and Age Composition for a Tributary of the Smith River, California—23-Year Analysis

by

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Abstract

In the fall of 1980, a spawning escapement study was initiated on the West Branch Mill Creek, a major fall chinook salmon (*Oncorhynchus tshawytscha*) tributary of the Smith River, Del Norte County, California. The purpose of the study was to estimate the relative abundance of spawning fall chinook in a defined study section over a period of more than 20 years as habitat changed. An age composition of the spawning population was also determined.

The 23-year analysis of the 2.7 kilometer (1.7 mile) study section of the West Branch Mill Creek provided "minimum" chinook spawning estimates from 1980—2002. The annual spawning chinook estimates ranged from 31–361 total chinook. The 23-year mean for chinook spawners was 151 fish (89 fish per mile). The spawner sampling verified that three distinct chinook runs exist for fall chinook entering the West Branch Mill Creek. Scale sample analysis was used to determine the age composition of West Branch Mill Creek chinook spawners. Age analysis for 22 years (1980 excluded) showed that the overall percentages for female spawners was 53% (4-year olds), 38% (3-year olds), and 9% (5-year olds). The age composition of male spawners showed a high degree of variability throughout the study. Male chinook of age 2, 3 and 4 were dominant annually, but 5- and 6-year-old fish were present in most spawning seasons.

All chinook carcasses from which scales were collected were also measured for length (over 1240 samples in 22 years). Decreases in mean length were documented for all age classes for each of the El Niño episodes that occurred during the study (1982–84; 1992–93; 1997–98). The decreases in mean length appeared to carry forward for each cohort's age class. The total number of chinook redds was tabulated by counting "fresh" redds during weekly spawning surveys. The mean number of redds was 117 for the 23-year period with a mean of 0.9 redds per adult salmon or 1.8 redds per female. The abundance of chinook spawners dramatically increased during the last three years of the study, probably a reflection of improved ocean survival during the recent Pacific Ocean Decadal Oscillation phenomenon.

Identifying juvenile salmonids.

Introduction

The Smith River is the largest undammed, free-flowing river in California, draining directly to the Pacific Ocean. It is located in the northwest corner of California in Del Norte County. The Smith has majestic stands of old growth coastal redwood trees, world-class salmon and steelhead fishing and is famous for its water quality (Voight and Waldvogel 2002). Considered the healthiest river system in California, the Smith River has "Wild and Scenic River" status, designation as a National Recreation Area, and exists within the California State Parks/Redwood National Park management authority.

In the fall of 1980 a salmon spawning escapement study was started on the West Branch Mill Creek, a tributary of the Smith River. This major fall chinook (*Oncorhynchus tshawytscha*) spawning stream was selected to determine the relative abundance of spawning chinook over a 20-year period as habitat changes occurred.

Discussions with the California Department of Fish and Game (CDFG) staff and Del Norte County Supervisors during the 1979–1980 Wild and Scenic River hearings indicated a need for long-term fishery information on the Smith River. Previous salmon and steelhead spawning populations on the Smith River consisted of old Department of Water Resources estimates from the mid-1960s. This Smith River study was implemented to provide some long-term chinook spawning escapement estimates for the Smith River system.

Description of Study Section

The West Branch Mill Creek historically had excellent runs of chinook salmon as reported by the CDFG surveys, local Native Americans, and timber company and State Park employees (Waldvogel 1985). This stream is also utilized by spawning runs of steelhead (*Oncorhynchus mykiss*), coho salmon (*O. kisutch*), chum salmon (*O. keta*), coastal cutthroat trout (*O. clarki*) and Pacific lamprey (*Lampetra tridentata*).

A study section of 2.7 km (1.7 miles) was identified on private land owned by Stimson Lumber Company (formerly Miller Rellim Redwood Company). The availability of an accessible site and cooperation with Stimson were factors in the study site selection. The West Branch has excellent chinook spawning densities, exceeding 40 adult chinook/mile (McGie 1981) and a consistent return of adult spawners.

The West Branch is characterized by a 1–3% gradient with clean spawning gravels and limited sand or silt. The creek bed is stable through winter flows that vary from 60 cubic feet per second (c.f.s.) to over 500 c.f.s. at peak flood events (Waldvogel 1985). Summer flows average 5–10 c.f.s. with water temperatures in the 55–62°F range (Howard 1998).

The West Branch has good pool-to-riffle ratios with large natural structures (redwood debris and bedrock outcrops) forming 5- to 8-foot-deep pools. Existing riparian habitat along the creek contains 40- to 50-year-old alders, maples, willows and redwoods. The creek has a moderate to dense canopy cover keeping summer water temperatures cool. The old growth redwood and Douglas fir adjacent to the study section was clear-cut in the late 1940s and early 1950s (Waldvogel 1985).

Habitat surveys of the West Branch by the CDFG (Anonymous 1977; Millan 1980) and a private consulting firm, CH2M Hill, (Kaczynski 1979) rate the spawning gravels and habitat of the creek as very good to excellent. The creek upstream from the study section is part of the Del Norte Redwoods State Park. Approximately one mile downstream from the study section, and below the confluence of the West and East Branches, Mill Creek flows through Redwood National Park and old growth redwood habitat. In June 2002, the Mill Creek watershed (owned by Stimson Lumber Company) was acquired by Save the Redwoods League and donated to California State Parks.

Students watching spawning chinook.

Methods

Many tributaries in the Smith River system have steep gradients with rocky stream banks and high winter flows, making them difficult to survey. The 2.7-km study section of the West Branch Mill Creek was selected because of its historic fall chinook salmon runs and accessibility as a "walkable" spawning survey stream. The West Branch can be surveyed when flows drop below 150 c.f.s. (stream flow rate) and this flow rate usually occurs 3–4 days after a heavy rain. The creek clears quickly and flows of 70–100 c.f.s. are common during winter months.

Surveys were conducted once a week (flow rates permitting), beginning with the heavy rains in November and continuing through mid-March. All surveys originated in the upper study section to facilitate walking downstream and occurred between 10:00 am and 2:00 pm for optimum viewing light. It is necessary to cross the stream 20 to 25 times during surveys and walking upstream during winter flows is difficult (Waldvogel 1988).

Data collected during the weekly spawning surveys included: c.f.s., visual water clarity, weather conditions, water temperature (°F), number of live chinook seen, number of carcasses recovered, salmon skeletons noted, and the number of fresh redds. All carcasses were jaw-marked using hog rings with colored flagging, sex determined, fork length (cm) measured, and scale samples taken for aging (except in 1980). No carcasses were weighed, but all chinook were checked for fin clips, coded wire tags (CWT) presence, hook scars and completeness of spawning (ibid).

The annual relative abundance spawning estimates of chinook salmon were determined using combination counts of live fish and carcasses. This method provided "minimum" spawning escapement estimates and did not require making a total spawning population estimate. Since the West Branch clears so quickly and weekly spawning surveys were conducted, most of the live chinook and carcasses were seen during surveys.

A running tally of the highest combination of live chinook seen and carcasses recovered from previous weeks' surveys was established. The estimates were made separately for each of the three runs during a season. The estimates using minimum chinook counts provided good relative abundance comparisons between spawning seasons.

Scale samples for aging were cleaned using standard washing techniques. All scales were read utilizing a microfiche machine. Verification of correct aging was obtained by viewing multiple scales.

Results

Spawning surveys of the West Branch Mill Creek began each season with the heavy rains in November and concluded in February/March when the last spawning fall chinook were observed. Table 1 lists the number of surveys conducted each season.

Table 1: Number of Spawning Surveys Conducted on West Branch Mill Creek Study Section (1980–2002).

Season	Surveys Completed	Unsurveyable Weeks	Inclusive Dates
1980	12	2	Nov. 25–Feb. 10
1981	11	3	Nov. 6–Jan. 25
1982	9	4	Nov. 22–Feb. 3
1983	9	5	Nov. 28–Feb. 27
1984	13	4	Nov. 13–Mar. 7
1985	12	5	Oct. 30–Feb. 28
1986	11	1	Nov. 24–Feb. 20
1987	12	2	Dec. 4–Mar. 3
1988	13	1	Nov. 9–Feb. 28
1989	11	1	Dec. 7–Feb. 22
1990	9	1	Dec. 2–Feb. 28
1991	12	1	Nov. 26–Feb. 12
1992	10	5	Nov. 25–Mar. 2
1993	9	1	Dec. 13–Mar. 9
1994	10	5	Nov. 19–Feb. 25
1995	7	3	Nov. 16–Feb. 1
1996	7	2	Nov. 2–Feb. 11
1997	9	5	Nov. 13–Jan. 23
1998	8	4	Nov. 24–Feb. 4
1999	9	4	Nov. 22–Feb. 11
2000	10	2	Nov. 28–Feb. 27
2001	9	4	Nov. 23–Feb. 11
2002	9	4	Nov. 13–Jan. 18

Chinook Spawning Escapement

Chinook salmon spawning counts were estimated annually. Minimum spawning escapement estimates ranged from 31–361 total chinook between 1980 and 2002, with a 23-year mean of 151 fish (Figure 1).

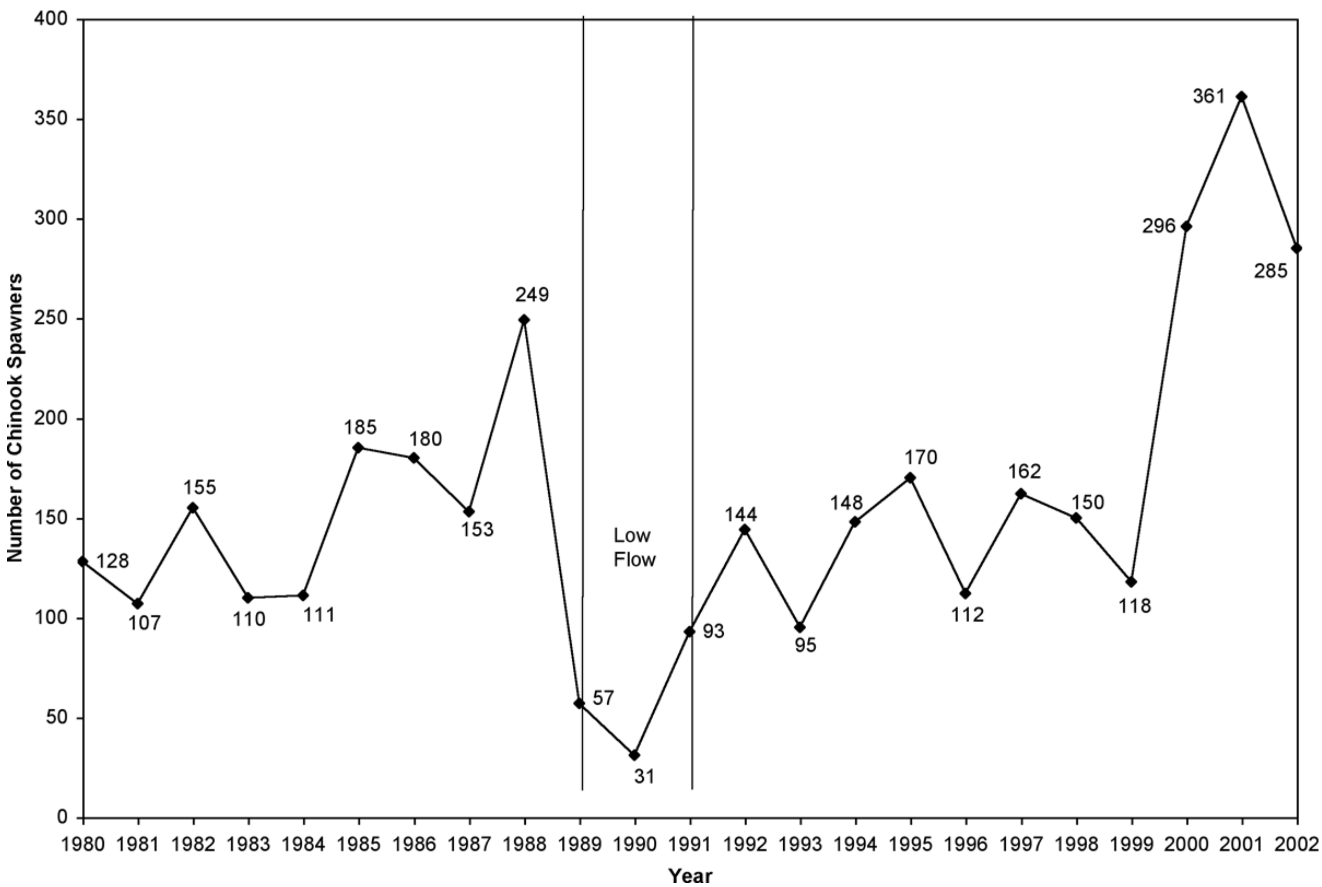

Figure 1: Minimum chinook spawning estimates for West Branch Mill Creek, Smith River.

Adult chinook salmon counts were separated from jack (2-year old) counts to allow comparisons of spawning estimates from the West Branch Mill Creek with Oregon coastal stream estimates (McGie 1981, 1982). Figure 2 depicts these chinook adult and jack estimates as fish per mile (fish/mile) statistics.

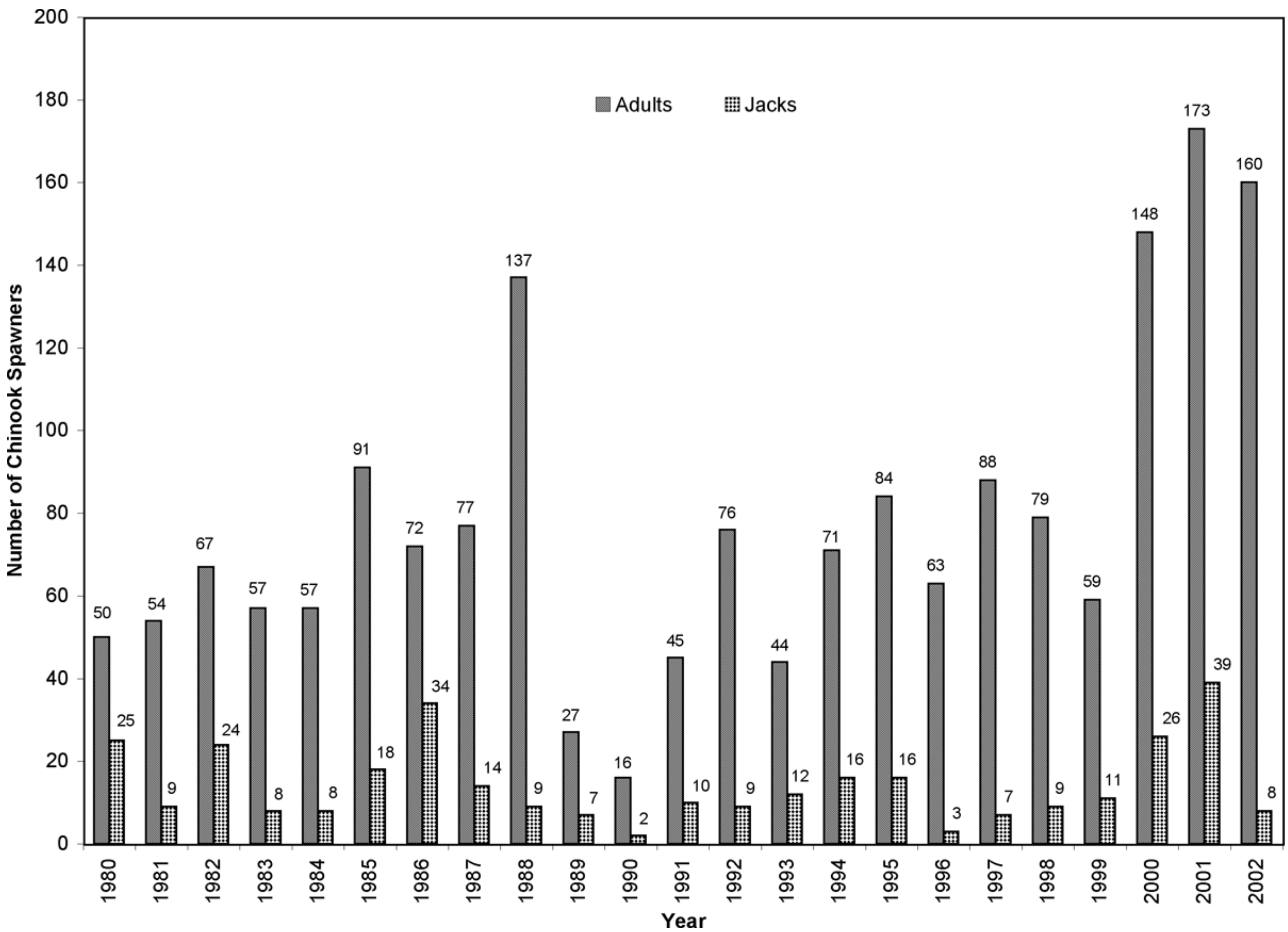

Figure 2: Adult and jack chinook spawners per mile in West Branch study section.

The adult estimates ranged from 16 fish/mile to 173 fish/mile with a mean of 78 fish/mile. Jack counts varied widely from 2 jacks/mile to 39 jacks/mile with a mean of 14 jacks/mile.

The male-to-female ratio of adult chinook spawners in the West Branch was determined each season. Ratios of male to female spawners varied annually from 1.0:1.0–1.0:1.5 with an overall ratio of 1.0:1.1. Nineteen seasons documented more female than male adult spawners.

Timing of Chinook Runs

The 23 years of chinook spawner sampling verified that three distinct runs exist for fall chinook entering the West Branch Mill Creek. The timing of these runs was first described by Waldvogel (1985 and 1988) and no major variations have occurred since that period.

The three distinct runs are:

Run #1: Enters the West Branch during mid-November and lasts until mid-December. Run #1 comprised the largest number of chinook spawners in all years except 1981, 1983, 1990, and 2002.

Run #2: Enters the study section during late December and lasts until mid-January. In most years this run comprised the second largest number of spawners.

Run #3: Enters the study section in late January and lasts until mid-February. This run was always characterized by a small number of adult spawners with few jacks. The third run usually spawned in mixed association with the first steelhead spawners.

The three distinct chinook runs had some spawning overlap during several seasons. The run timing was dependent on stream flows, which varied annually. However, the time of return for each run did not change significantly.

Trapping juvenile salmonids.

Table 2 shows the number of chinook spawners for each run timing in the West Branch study section from 1980 through 2002. Results indicated that the first run was annually the largest (except 1981, 1983, 1990, and 2002) and comprised 71% of all chinook spawning in the West Branch during the past 23 years. Run #2 was the second largest return comprising 26% of the chinook spawners. The late run (#3) was always the smallest and represented only 3% of annual returns.

Table 2: Number of Chinook Spawners in Specific Runs in West Branch Mill Creek Study Section (1980–2002).

Year	Run #1	Run #2	Run #3	Total
1980	93	31	4	128
1981	47	60	0	107
1982	89	53	13	155
1983	34	74	2	110
1984	89	12	10	111
1985	153	32	0	185
1986	145	21	14	180
1987	135	18	0	153
1988	215	34	0	249
1989	37	20	0	57
1990	13	15	3	31
1991	66	23	4	93
1992	93	47	4	144
1993	75	16	4	95
1994	100	35	13	148
1995	139	31	0	170
1996	90	21	1	112
1997	134	21	7	162
1998	110	28	12	150
1999	109	9	0	118
2000	279	14	3	296
2001	274	66	21	361
2002	22	251	12	285
Total	2541	932	127	3600
Percent	70.6	25.9	3.5	

Age Composition

Scale samples were taken from all fresh chinook carcasses recovered and the age was determined using methods described by Waldvogel (1983, 1984a, 1984b). Table 3 tabulates the age composition (number of fish) for male and female fall chinook scale-sampled in the study section from 1981–2002. The total number of chinook aged from scale samples was 1250.

Table 3: Age Composition and Cohort Summation of Male and Female Chinook in West Branch Mill Creek Study Section (1981–2002).

	MALES							FEMALES					
Year			Age			Cohort				Age			Cohort
	2	3	4	5	6			2	3	4	5	6	
1981	2	6	6	9	1			0	2	32	3	0	
1982	5	3	8	2	0			0	13	13	1	0	
1983	6	12	5	1	0			0	10	10	0	0	
1984	3	8	6	0	0			0	7	8	1	0	
1985	24	4	19	5	1	1979-11		0	7	48	8	0	1979-24
1986	34	5	4	8	2	1980-30		0	9	22	9	0	1980-26
1987	21	16	12	3	2	1981-43		0	7	25	5	0	1981-64
1988	10	11	23	8	1	1982-15		0	11	66	7	0	1982-34
1989	3	2	1	3	0	1983-49		0	0	15	2	0	1983-41
1990	1	0	2	0	0	1984-76		0	4	0	0	0	1984-75
1991	3	9	3	2	0	1985-33		0	5	10	0	0	1985-26
1992	6	7	6	10	0	1986-16		0	14	16	3	0	1986-0
1993	7	3	1	0	0	1987-16		0	3	2	1	1	1987-18
1994	12	4	4	4	0	1988-16		1	19	2	0	0	1988-22
1995	8	10	5	5	0	1989-15		0	16	8	0	0	1989-16
1996	4	7	2	7	0	1990-18		0	9	8	1	0	1990-5
1997	4	10	8	4	1	1991-24		0	15	18	4	0	1991-28
1998	8	10	4	3	0	1992-28		0	18	4	5	0	1992-29
1999	12	8	5	4	0	1993-26		0	16	2	2	0	1993-32
2000	16	14	13	4	0	1994-22		0	40	15	3	0	1994-21
2001	3	8	6	4	5	1995-28		0	15	4	3	1	1995-24
2002	3	3	0	3	0	1996-33		0	6	12	2	1	1996-35
	195	160	143	89	13	TOTALS		1	246	340	60	3	

Aging results indicated that the West Branch "runs" were dominated by 4-year-old females from 1981–1992 when 67% of the female spawners were 4-year olds, 23% were 3-year olds and 10% were 5-year olds. However, from 1993 through 2002, 3-year-old females dominated when spawners were composed of 62% 3-year olds, 30% 4-year olds and 8% 5-year olds. Overall percentages for female spawners was 53% (4-year olds), 38% (3-year olds) and 9% (5-year olds) for the 1981–2002 period. Two- and 6-year-old female spawners were rare, occurring only four times.

The age composition of male spawners showed a high degree of variability throughout the 22-year period. Chinook males of ages 2, 3 and 4 were dominant annually, but 5- and 6-year-old fish were also present in most spawning seasons.

Chinook Salmon Growth

All chinook carcasses from which scales were collected were also measured for fork length (cm). Mean length-by-age class is depicted in Figure 3 for the 1981–2002 seasons. Decreases in mean length were documented for each of the El Niño episodes that occurred in 1982–1984, 1992–1993, and 1997–1998.

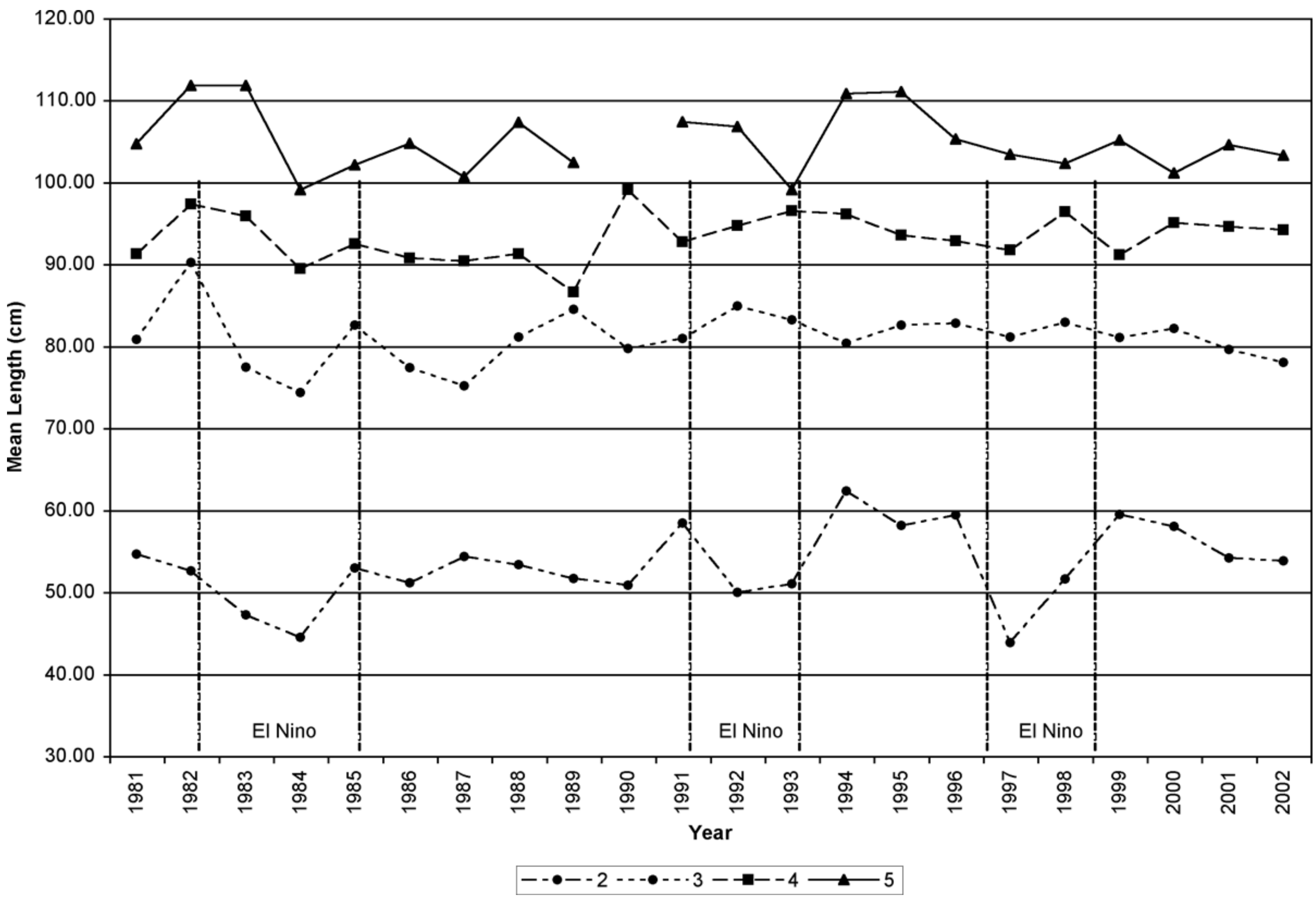

Figure 3: Mean length (cm) of chinook adults by age in West Branch study section.

The mean lengths (cm) of male and female chinook sampled each season were tabulated for all ages (1,250 sampled). Figure 4 shows a length-frequency histogram of all chinook sampled in West Branch Mill Creek from 1981–2002. The averaged mean lengths for chinook are listed in Table 4. Male chinook lengths were larger for all ages except 3-year-old chinook.

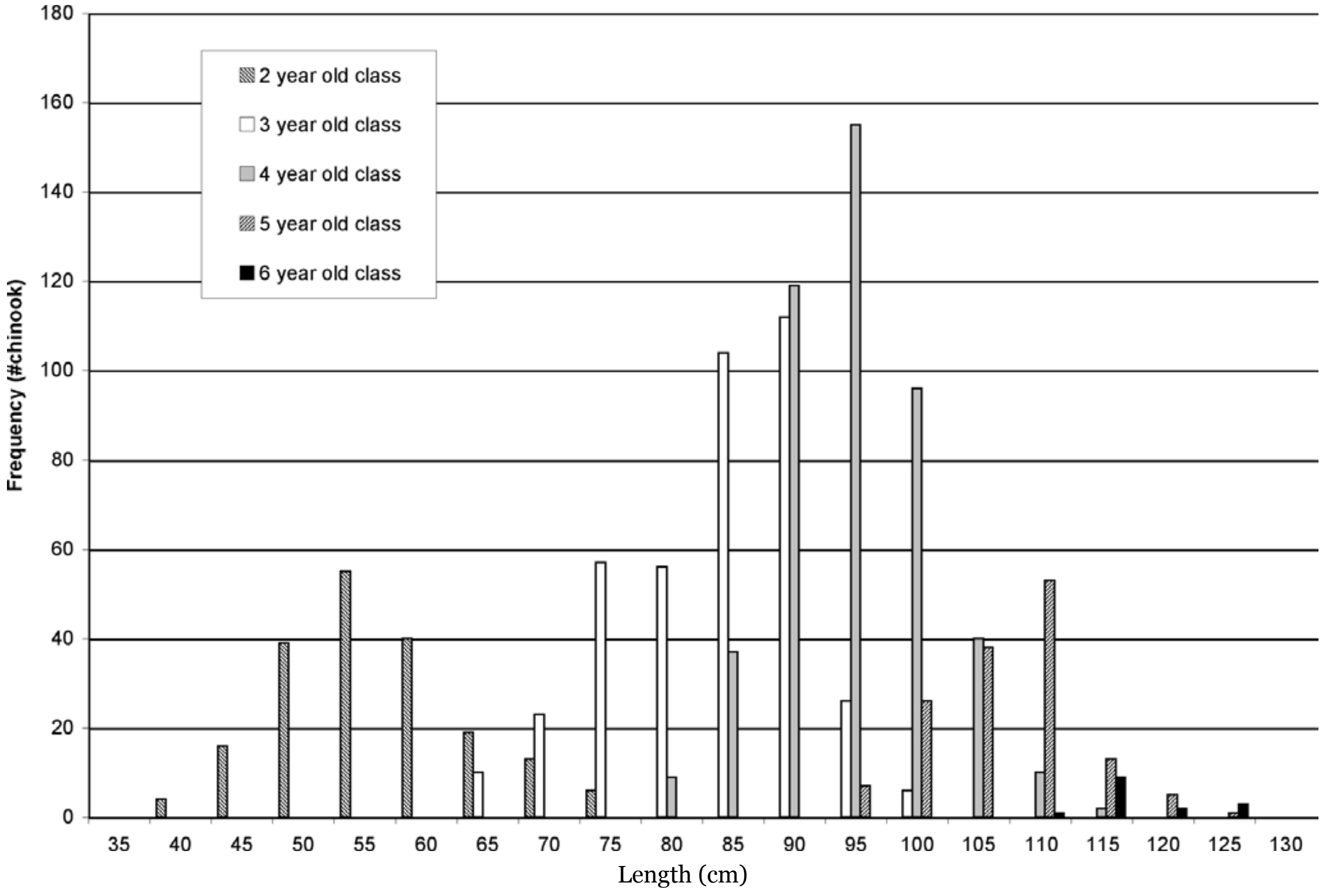

Figure 4: Length-frequency histogram of chinook salmon sampled in West Branch Mill Creek, 1981–2002.

Table 4: Averaged Mean Lengths (cm) of Male and Female Chinook Sampled for all Ages in West Branch Mill Creek Study Section (1981–2002).

	2 yr.	3 yr.	4 yr.	5 yr.	6 yr.
Male	54.0	79.7	96.8	107.6	116.2
Female	0	82.0	90.5	100.6	108.6

Hatchery Salmon

Rowdy Creek Fish Hatchery (RCFH) is a nonprofit salmonid enhancement hatchery located on a tidewater tributary (Rowdy Creek) of the lower Smith River. The hatchery planted yearling chinook salmon smolts in the West Branch Mill Creek from 1977–1982. These plantings were part of their salmon enhancement efforts within the Smith River system and the smolts were progeny of wild Smith River chinook stock.

Waldvogel (1985) reported the numbers of fin-marked hatchery chinook smolts released in the West Branch. Adults from these plants appeared in the spawning chinook population from 1981–1987 (Table 5).

Table 5: Percent and Number of Hatchery Chinook Detected from Carcass Samples and Scale Reading in West Branch Mill Creek Study Section (1981–1987).

Year	Chinook sampled	Hatchery fish	Percent
1981	73	12	16.5
1982	55	10	18.2
1983	56	12	21.4
1984	52	19	36.5
1985	119	3	2.5
1986	97	4	4.1
1987	91	0	0

After 1986, the age classes of hatchery adult chinook that were progeny of RCFH smolts planted in the West Branch disappeared from the river fishery (1982 smolts would be 4-year olds in 1986). From 1987 through 2002 an occasional hatchery chinook appeared in the West Branch scale samples. These returns ranged from 0–4% and were assumed to be upriver strays from the RCFH releases in the lower Smith River. Studies by Waldvogel (1981, 1983, 1984a, 1984b) documented hatchery straying of chinook into the Smith River and statistically analyzed RCFH chinook returns.

Redd Counts

The total number of chinook redds were tabulated each season by counting new “fresh” redds during weekly spawning surveys (Table 6). Two statistics were determined from this count utilizing the total number of spawning adult chinook recorded in the study section: redds-per-adult chinook and redds-per-female.

Table 6: Chinook Salmon Redd Counts in West Branch Mill Creek Study Section (1980–2002).

Year	No. Redds	Redds per Adult	No. Adults	Redds per Female	No. Females
1980	84	1.0	85	1.7	50
1981	153	1.7	92	3.1	50
1982	236	2.1	114	3.9	60
1983	139	1.4	97	2.7	52
1984	135	1.4	97	2.8	49
1985	224	1.4	155	2.4	93
1986	126	1.0	122	2.0	63
1987	110	0.9	130	1.7	65
1988	184	0.8	233	1.5	124
1989	45	1.0	46	1.9	24
1990	26	1.0	27	1.7	15
1991	47	0.6	77	1.5	31
1992	85	0.7	129	1.3	68
1993	56	0.8	74	1.3	42
1994	100	0.8	121	1.7	58
1995	103	0.7	143	1.5	69
1996	87	0.8	107	1.7	51
1997	101	0.7	150	1.2	82
1998	71	0.5	134	1.0	73
1999	72	0.7	100	1.4	52
2000	157	0.6	252	1.2	131
2001	202	0.7	294	1.4	144
2002	132	0.5	272	0.9	143
MEAN	117	0.9	132	1.8	69

Hook Scars

The presence of hook scars on chinook carcasses that were scale sampled were recorded from 1981–2002. Hook scars are the result of chinook salmon that have escaped hooking in ocean commercial and sport fisheries. The mean percent of hook scars for the 21 seasons was 5.8%. The weighted mean percent was 5.3%. The annual percent of hook scarring varied from 0–28.6% during the sampled years.

Discussion

Spawning chinook.

Since the purpose of this research was to make an annual relative spawning escapement estimate for chinook, the need for a total spawning population estimate was not necessary. Early in the analysis of the 1980 and 1981 sampling seasons it was clear that the Petersen method for estimates and the Schaefer method for stratified populations could not be applied to this small Mill Creek tributary. Marking and recovery programs for live adults were nonexistent in the Smith River system and the number of marked carcass recoveries in the West Branch was low due to high predator removal and erratic flows. These factors resulted in extremely high over-estimation (20–50 times) of the spawning population in the West Branch if the above total spawning population estimation methods were used.

Therefore, the use of a combination count of live salmon and carcasses provided an adequate estimate of spawners for relative abundance comparisons over the long-term study period. Since the West Branch Mill Creek clears so quickly and weekly spawning counts were conducted, most of the spawning salmon or their resultant carcasses were observed during the surveys.

Chinook Spawning Escapement

The chinook spawning estimates (Figure 1) show varying numbers of spawners. The two consecutive low escapement years, 1989 and 1990, with estimates of 57 and 31 chinook respectively, were the direct reflection of two unusually low rainfalls for the peak spawning month of December. In both years only 2 inches of rain fell in early December allowing limited movement of spawning chinook into the study section, followed by over 30 days of virtually no precipitation and no spawner movement. Although few spawners in the study section were observed both these years, the lower mainstem of Mill Creek and the mainstem Smith River exhibited high chinook spawner activity. All other spawning seasons from 1980–2002 had adequate rainfall patterns to allow continual movement of chinook spawners into the West Branch study section.

Certain relevant comments and conclusions can be made from the spawning estimate results in Figure 1. The low chinook escapements in 1983 and 1984 (110 and 111 fish respectively) were a direct result of severe El Niño ocean conditions. Most West Coast chinook salmon spawning surveys showed significant decreases in spawner counts during this episode (Nicholas and Downey 1983; Nicholas and Hankin 1988). Chinook returns to RCFH and the Patrick's Creek spawner counts in the upper Smith River (U.S. Forest Service study) reflected similar decreases in chinook populations in 1983 and 1984.

The mean escapement count for the West Branch from 1980–1984 was 122 chinook. From 1985 through 1988 the mean escapement was 192 chinook. This increase may be attributed to two factors. First, ocean conditions improved dramatically for the survival of chinook salmon after the 1983–1984 El Niño episode. This was evidenced by a rapid recovery of chinook populations all along the Pacific coast after El Niño conditions passed (Myers et al. 1998; Nehlsen et al. 1991). Second, the Pacific Fisheries Management Council allowed no commercial fishing in the Klamath Management Zone in 1985. The increases in chinook escapement in West Branch Mill Creek may have reflected both factors. It is not possible to determine which factor had the greater effect on escapements since they occurred simultaneously. However, the increased returns after El Niño conditions reflect escapement levels higher than those recorded in West Branch before El Niño (1980–1982).

The mean escapement from 1991–1999 was 132 chinook. Three of those years (1993, 1996, and 1999) recorded low chinook counts and were influenced by very high rainfalls during December and January. In 1996, 38 inches of rain occurred in late December through January. Sampling and stream surveys were difficult during these periods, reflecting reduced chinook counts.

The dramatic increases in chinook escapements for 2000, 2001, and 2002 (record highs of 296, 361, and 285 fish respectively) are believed to be a reflection of increased ocean production and salmon survival from the Pacific Ocean Decadal Oscillation phenomenon (NOAA 2001). This oceanographic cycle shifts every 20 to 25 years and creates favorable ocean conditions for salmon off Washington, Oregon and California. Several more years of West Branch monitoring will ascertain if these conditions persist.

Results from the West Branch spawning estimates of fish-per-mile (Figure 2) for the 23 seasons are similar to fall chinook spawning densities of excellent Oregon coastal index streams as defined by McGie (1982). McGie estimated the average number of chinook spawners in 11 standard index streams from 1970–1981. The range of Oregon adult chinook spawners varied from 39–82 fish/mile and jack counts ranged from 5–23 fish/mile. Streams that exceeded 40 adult chinook spawners per mile were classified as excellent spawning streams (McGie 1981).

The 78 chinook/mile mean adult spawner count for West Branch Mill Creek meets the criteria as an excellent chinook stream. The only years when the chinook-per-mile spawner counts were below 40 fish/mile were during the extremely low-flow access years of 1989 and 1990.

The spawning escapement of jacks in the West Branch showed a wide range (2 fish/mile–39 fish/mile) but were quite similar to McGie's index streams. Regressions were run to determine if a relationship exists between the number of jacks returning in one year and the resulting number of adults returning in subsequent years (Figure 5). The regressions yielded an R2 of 0.2969, indicating that jack counts cannot reliably predict subsequent spawning escapement in the West Branch Mill Creek.

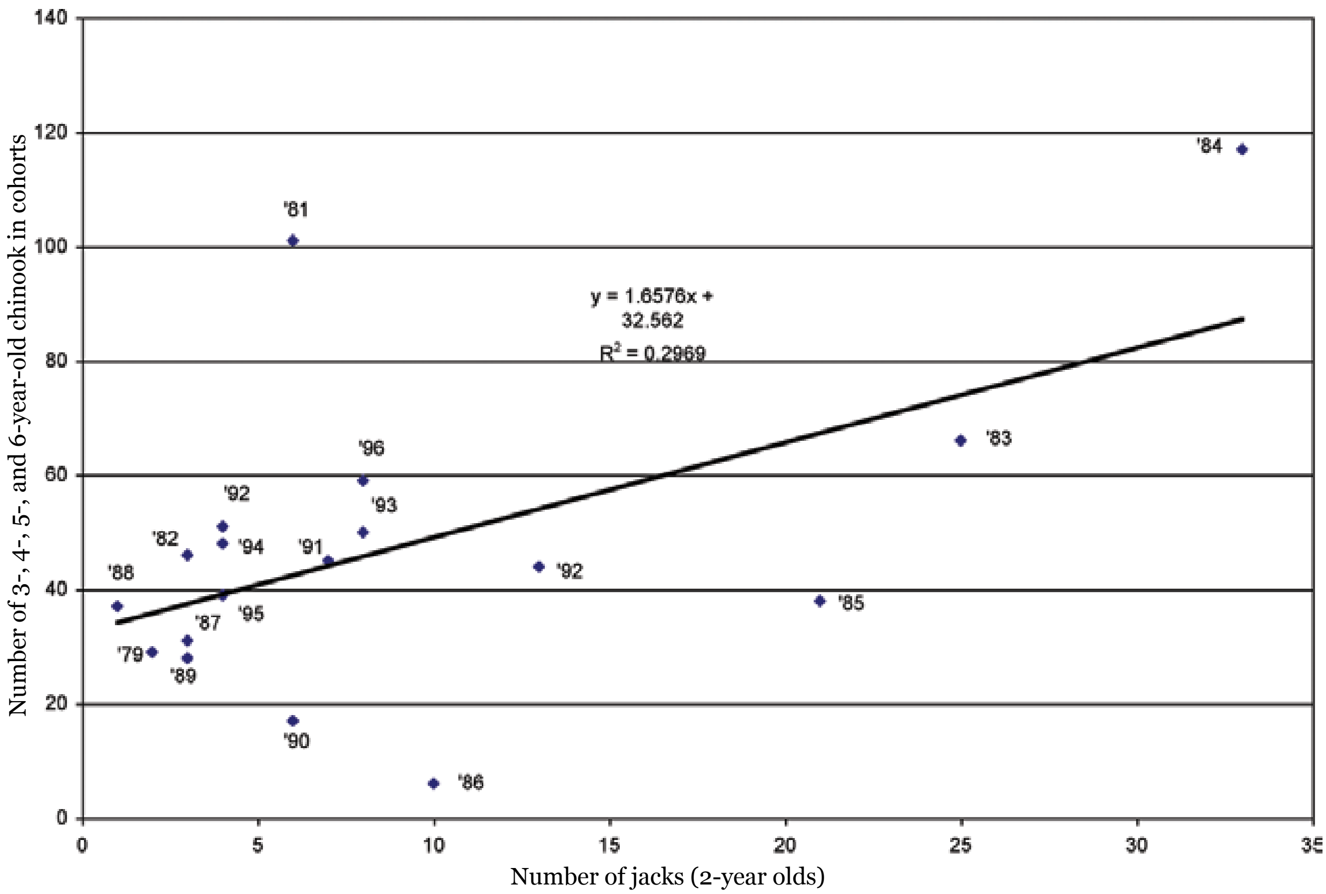

Figure 5: Regression of the number of 2-year-old (jack) chinook and subsequent numbers of 3-, 4-, 5- and 6-year-old chinook in 18 cohort years (1979–1996) in the West Branch Mill Creek.

Jack returns may indicate, however, a strong year class presence (Bender 1975; Hankin and Healey 1986; Healey 1991). Jack counts in 1985 and 1986 may have been indicators of strong year classes in the West Branch Mill Creek cohort summations (Table 3). Conversely, a small jack count in 1983 produced a strong cohort for 1981.

The age composition and cohort summations (Table 3) reflected a change over time in age composition of female spawners in the West Branch. The dominance of 4-year-old female spawners (66%) for the first 12 years (1981–1992) was similar to results in Healey (1991) and Snyder (1931) for Klamath River chinook spawners. However, the change in the West Branch to a dominance of 3-year-old female spawners (62%) for the next ten years (1993–2002) is not clearly explainable.

It is well documented that El Niño events in 1982–83 and 1992–93 affected ocean production (Huyer and Smith 1985; Quinn et al. 1978), resulting in influences over many marine species including Pacific salmon. A delayed age structure alteration may have occurred from these oceanographic conditions over several generations. The changing Pacific Decadal Oscillation during its last 20–25 year cycle (1977–1998) also may have influenced the age shift of female spawners.

When the age composition was averaged over the 22-year sampling period, the dominance of 4-year-old female spawners was still apparent but was reduced to 53% (4-year olds) and 38% (3-year olds). The overall age composition masks the female shift in spawner age over time. Only continued long-term monitoring will determine if this change becomes permanent or is simply a biological variability. Male spawners did not show any pattern of age composition changes during the study period.

Recovering chinook carcasses.

Chinook Growth

Studies by Bigler et al. (1996) and Ricker (1981) have shown that the abundance of North Pacific salmon nearly doubled during the period of 1975–1993, coupled with a corresponding decrease in average adult size at maturity. The size (mean length) at maturity of West Branch Mill Creek chinook is shown in Figure 3. All year classes (2-, 3-, 4-, and 5-year olds) exhibited slight increases (not significant) in mean lengths over the 22-year sampling period.

This slight increase in length is consistent with Bigler's findings that California Sacramento River chinook were one of two stocks that increased in size over time (the only California chinook population he documented). A study by Roni and Quinn (1995) compared mean length at age for 108 populations of chinook obtained at sea. This study included juvenile and adult fish and did not account for size at maturity. However, no consistent relationship existed between latitude or migration distance and mean length. West Branch Mill Creek length data was therefore not comparable to these research results.

Accurate estimations of the age and sex composition of a specific chinook population are important to document the characteristics of any stock. Zhou (2002) examined the influences of stream flow and the sex and size of the chinook on their probability of carcass recovery in the spawning grounds. Zhou utilized 11 seasons of mark-recapture data for fall chinook on the Salmon River (Oregon), a system comparable in size to the Smith River.

Although the West Branch Mill Creek surveys and carcass recoveries were not complemented by any down-river mark and recapture programs, the results of Zhou's study mirrored many of the observations in Mill Creek. Zhou's results included:

1) no significant differences in recovery rates for males and females,

2) probability of recovery generally increased as fish size increased and stream flow decreased, and,

3) this probability leveled off for very large fish and increased slightly at high stream flows.

Observations in the West Branch Mill Creek found each of Zhou's results to be true for this system although no direct measurements were made. One difference was that as flows decreased, predator extraction of carcasses increased for short time periods. Within 4–6 days, as carcasses deteriorated, animals would not bother them.

Spawner Timing and Residency on Redds

The appearance of three distinct chinook spawning runs in the West Branch Mill Creek was well documented during the 23-year study. The timing and spatial distribution of these runs was comparable to long-term records for Elk River (Reimers 1978; Burch and Reimers 1978), a coastal Curry County, Oregon river similar to the Smith River system. Table 2 results show that the first and second chinook runs in West Branch were present each season. However, the third run was not always evident (absent 7 of the 23 years) and represented only 3.5% of the West Branch chinook spawners.

Spawning date is a crucial life history trait in chinook (linking parents to their offspring) and is highly inheritable in salmonids (Quinn et al. 2002). The migration is largely under genetic control in most

Observing spawners.

salmonids (Allen 1959). Some influences by stream flows may also alter migration timing as documented in the West Branch for some seasons.

Time of residency on redds for female chinook is not well documented. Neilson and Geen (1981) observed the residence time of spawning female chinook in British Columbia (Morice River). Results showed that as the spawning season progressed, the residency time at the redd site decreased. The same redd residency pattern for chinook was observed on the West Branch Mill Creek.

Although no specific time data was recorded, the first chinook run into the study section reflected female redd residency from 10–21 days (late November through mid-December). The second chinook run appeared to spawn more quickly with residency from 7–15 days. The late run of chinook into the West Branch appeared to last only 5–10 days. This shorter spawning residency may also account for the occasional recording of no chinook in the third run during years when flows sustained high levels.

The pattern of redd residency by female chinook in the West Branch was almost identical to that observed by Reimers (1978) on Elk River. The pattern was also equivalent to residency times observed by Dave McLeod of the California Department of Fish and Game (personal communication, 1999) in other Northern California stream surveys on the Mad River, Eel River, Van Duzen River and Rowdy Creek (Smith River).

Chinook Spawning Behavior

Spawning adult chinook were observed during daylight hours under all weather conditions and flow regimes. Most females paired up with a single male chinook. However, numerous instances were observed where a large dominant male "serviced" two to three females on a single spawning riffle. Many spawning chinook pairs were observed making one or two redds, but never more than two.

When no large adult male chinook were present, spawning females could be seen with two to three "jack" males. If a large male appeared, he would chase away the jacks. Occasionally three or four large males (30–40 lbs.) would be seen fighting (biting and ramming each other) to gain dominance over females present.

Chinook movement within the study section was consistent when stream flows were adequate (over 100 c.f.s.). However, once flows decreased below 100 c.f.s. and water clarity increased, chinook spawner movements were negligible. Spawning activity was more apparent on overcast, cloudy days. Bright sunlight negatively affected spawners and caused them to hide under woody debris or undercut stream bank locations.

Female spawners normally resided directly over the redd area or just adjacent to the redd. Males frequently backed off from the redd area (when not spawning with females) and rested in deep pools or side channels downstream from the redd site. Males tended to die-off a little sooner than females (3–5 days) and slowly moved downstream as they died. Females appeared to stay at the redd site until death and their carcasses were generally found closer to their spawning site.

Redd size was highly variable and was somewhat dependent on stream width and flow rates. Many redds in the West Branch Mill Creek system were quite large and often encompassed a complete riffle or run area. It was not uncommon to see a single redd that was 5 meters wide by 8–10 meters in length.

Spawning chinook pair.

Coho spawner.

Observations

Information was collected and observations were recorded during this 23- year chinook study that did not relate to the estimation of chinook escapement or the analysis of the age composition. These observations are presented here to document the results and provide anecdotal information on salmonid populations within the Mill Creek watershed. This information includes counts of coho and chum salmon present during the surveys, observations of fish movement during differing flow regimes, predator observations, and general spawning habitat changes over time.

Coho Salmon

Coho salmon (*Oncorhynchus kisutch*) entered the West Branch in December and completed spawning by late February. The Smith River does not have large numbers of coho spawners, however, coho were observed in the study section every year.

All spawning coho salmon observed were seen in the upper one-third of the West Branch study section. This section contained habitat more suited for coho spawning. Areas of West Branch Mill Creek upstream of the study section also contained coho spawners in excess of numbers recorded in the study section (Howard and Albro 1998).

During the 1987 season coho salmon appeared with the first run of chinook spawners in the West Branch. Scale samples indicated that all of these coho were of hatchery origin. However, none of the coho were fin clipped nor had coded wire tags. This was the first time that coho appeared in the West Branch in early December.

Rowdy Creek Fish Hatchery had released 22,000 unmarked coho salmon smolts 2 years earlier. They were expecting a good 3-year-old adult return from this release in 1987 (personal communication, Bob Will, RCFH). However, a high-water event in early December resulted in few adults returning to the hatchery. It appears that many of these coho may have bypassed Rowdy Creek, continued up the mainstem Smith River and dispersed in tributaries like Mill Creek during the high flows.

Table 7 lists the number of coho salmon observed in the West Branch study section and dates of spawning for the 23-year period. Coho generally entered the West Branch in mid-December or early January with high stream flows.

Table 7: Number (by sex) and Spawning Dates of Coho Salmon in West Branch Mill Creek Study Section (1980–2002).

Year	Spawning Date	Total	Males	Females	Jacks
1980	Dec. 23–Jan. 14	11	5	2	4
1981	Jan. 10–Jan. 25	2	1	0	1
1982	Dec. 26–Jan. 8	4	1	2	1
1983	Jan. 7–Jan. 13	3	1	2	0
1984	Jan. 4–Feb. 27	6	3	2	1
1985	Dec. 20–Feb. 7	28	12	13	3
1986	Dec. 8–Jan. 26	11	3	5	3
1987 1st run	Dec. 16–Jan. 4	14	5	7	3
1987 2nd run	Jan. 13–Feb. 2	13	8	4	1
1988	Dec. 28–Jan. 7	5	3	1	1
1989	Dec. 7–Feb. 14	13	5	5	3
1990	Jan. 30–Feb. 13	2	1	0	1
1991	Dec. 17–Jan. 14	7	2	3	2
1992	Dec. 5–Feb. 1	7	4	1	2
1993	Dec. 13–Jan. 17	22	13	7	2
1994	Dec. 6–Jan. 5	9	4	5	0
1995	Nov. 28–Jan. 5	21	10	11	0
1996	Dec. 17–Jan. 13	11	5	6	0
1997	Nov. 21–Jan. 23	3	1	2	0
1998	Jan. 20–Feb. 4	3	2	1	0
1999 2 runs	Nov. 22–Dec. 6 & Feb. 1–3	8	4	3	1
2000 2 runs	Dec. 18–Jan. 3 & Feb. 2–20	16	8	5	3
2001	Dec. 10–Jan. 18	14	7	7	0
2002	Dec. 23–Jan. 18	25	13	11	1

Chum Salmon

Chum salmon (*Oncorhynchus keta*) are not common in California river systems but the southern distribution of this species extends into Northern California (Healey 1991). Chum salmon were observed in the West Branch study section in sporadic periods and always in early December with the first chinook runs. Table 8 lists the appearance of chum salmon in the study section. All chum salmon spawning occurred in the lower one-fourth of the West Branch Mill Creek study section.

Table 8: Chum Salmon Counts and Dates of Observation in West Branch Mill Creek Study Section (1980–2002).

Year	Period	Total	Males	Females
1980		0	0	0
1981		0	0	0
1982		0	0	0
1983		0	0	0
1984	Dec. 8–Dec. 20	4	2	2
1985	Dec. 13–Dec. 20	2	1	1
1986	Dec. 8–Dec. 23	8	3	5
1987	Dec. 16	1	0	1
1988	Dec. 4–Dec. 13	5	2	3
1989		0	0	0
1990		0	0	0
1991		0	0	0
1992		0	0	0
1993		0	0	0
1994		0	0	0
1995	Dec. 22	2	1	1
1996	Dec. 17	1	1	0
1997		0	0	0
1998	Dec. 22	1	1	0
1999		0	0	0
2000		0	0	0
2001	Nov. 27–Dec. 10	4	1	3
2002	Dec. 5	2	1	1

Predators

Chinook spawners and carcasses were annually affected by predators. Resident river otters would catch live chinook early in the season or feed on fresh carcasses through February. Black bear tracks were seen annually during most surveys. Many carcasses showed signs of bear-feeding activity. Badly decomposed carcasses were often smashed and had been rolled on by bears. However, only three times during the 23-year survey were live bears sighted by the researcher feeding along the West Branch. After a high flood event in 1986 (February), a small black bear cub was found dead on a gravel bar in the study section. It had apparently drowned while trying to cross the stream.

Other predators observed utilizing chinook carcasses or jack-sized spawners were mink, raccoons, two eagles, red-tailed hawks and great blue herons. No estimates could be made for the number of chinook carcasses removed from the stream banks by predators, but during periods of low flows it was believed to be significant.

Pre-spawning Mortalities

Only one female chinook was detected that had died before spawning during the entire 23-year study. That chinook had a sport fishing hook located in its gills (inside the mouth). Four or five fresh male chinook (jacks from 3–7 lbs.) were found dead over the study period and all appeared to have suffered some type of injury from predators (otter bites).

Habitat Alterations

Spawning and rearing habitat in the West Branch Mill Creek is excellent. Clean spawning gravel is abundant and the minor amounts of fine sediments present are mostly coarse sand. Large woody debris is located throughout the system, with numerous deep pools and spawning riffles.

It was noted during the 23-year study that the West Branch Mill Creek stream bed is essentially stable. However, some habitat changes did occur and were generally the result of major water events. During one major flood event (February 14, 1986), a 200-yard section of the stream was relocated approximately 50 yards to the east of its previous site. This event occurred over a 48-hour period of flows exceeding 1,500 c.f.s.

Occasionally, a deep pool that had existed for 10–15 years would disappear (fill in) during a major flow event. In contrast, a new deep pool might be created during other flow events in a location where a knee-deep riffle had existed for the past 10 years. These types of stream dynamics and alterations were noted throughout the system. The overall ratio of pools to riffles did not seem to change over time, although there were radical relocations of certain structures (woody debris) after high flow events. These habitat changes were not recorded nor measured during this long-term study; rather they were noted as observations.

One small slide into the West Branch (about 20 yards wide) did occur in the late 1980s. It was the result of a road failure from an adjacent logging road. Sediment input from this slide only existed for one season and disappeared by the next year. It appeared to have a minor effect on spawning ground habitat and occurred in the lower one-fourth of the West Branch study section. Stimson Lumber Company quickly stabilized the site the next summer.

The California State Parks removed an asphalt roadway in the mid-1980s that crossed through the West Branch Mill Creek (located in the Mill Creek Campground) and replaced it with a bridge. The roadway had provided fish access through two to three large culverts under the road. The structure had been in place for 15–20 years and was located approximately one-half mile upstream from the West Branch study section. Gravel movement had been hindered by the roadway, and large quantities of good spawning gravel were collecting above the structure for over one-quarter mile.

After removal of the structure, the researcher noted large quantities of gravel moving through the West Branch study section for 5–6 years. The movement was directly affected by high flow events each season. For 2–4 years some existing deep holes in the upper study section were partially filled and numerous spawning riffles were replenished with gravel. After 6–7 years the system appeared to equalize its ratio of pools and riffles.

Spawning chinook.

Mill Creek during spawning season.

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Juvenile salmonids.

Literature Cited

Allen, G.H. 1959. Behavior of chinook and silver salmon. *Ecology* 40:108–113.

Anonymous. 1977. Stream habitat surveys of tributaries of the Smith River, California. Calif. Dept. Fish and Game. Survey sheets of West Branch Mill Creek. 3 pp.

Bender, R.E. 1975. The sport harvest of hatchery and wild fall Chinook salmon from Eel River in 1973. Oregon Fish Comm. Coastal Rivers Investg. Info. Rep. 74-10.

Bigler, B.S. et al. 1996. A review of size trends among North Pacific salmon. *Can. J. Fish. Aqua. Sci.* 53: 455–465.

Burch, W.A. and P.E. Reimers. 1978. Temporal and spatial distribution of fall chinook salmon spawning in Elk River. Oregon Dept. Fish and Wildlife Info. Rep. 78-3.

Hankin, D.G. and M.C. Healey. 1986. Dependence of exploitation rates for maximum yield and stock collapse on age and sex structure of chinook salmon stocks. *Can. J. Fish. Aqua. Sci.* 43:1746–1759.

Healey, M.C. 1991. Life history of chinook salmon. In: Pacific Salmon Life Histories. C. Groot and L. Margolis, eds. Univ. British Columbia Press, Vancouver, BC: pp. 311–393.

Howard, C. and P. Albro. 1998. Fall salmon spawning escapement estimates for West and East Branch Mill Creek and Rock Creek, Smith River: Third interim report. Rellim Redwood Co. internal report. 7 pp.

Huyer, A. and R.L. Smith. 1985. The signature of El Niño off Oregon, 1982–1983. *J. Geophys. Res.* 90:7133–7142.

Kaczynski, V.W. 1979. Biological stream survey of West Branch Mill Creek. CH2M Hill Consultants (R13204.A0). 9 pp.

McGie, A.M. 1981. Trends in the escapement and production of fall chinook and coho salmon in Oregon. Oregon Dept. Fish and Wildlife Info. Rep. 81-7.

McGie, A.M. 1982. Spawning chinook, coho and chum salmon surveys in coastal watersheds of Oregon, 1981. Oregon Dept. Fish and Wildlife Res. Rep. 38 pp.

Millan, L.A. 1980. Stream survey for West Branch Mill Creek, Smith River, California. Calif. Dept. Fish and Game. 10 pp.

Myers, J.M. et al. 1998. Status review of chinook salmon from Washington, Idaho, Oregon and California. NOAA Tech. Memo. NMFS-NWFSC-35.

Nehlsen, W. et al. 1991. Pacific salmon at the cross-roads: stocks at risk from California, Oregon, Idaho and Washington. *Fisheries* 16(2): 4–21.

Neilson, J.D. and G.H. Geen. 1981. Enumeration of spawning salmon from spawner residence time and aerial counts. *Trans. Amer. Fish. Soc.* 110:554–556.

Nicholas, J.W. and D.G. Hankin. 1988. Chinook salmon populations in Oregon coastal river basins: Descriptions of life histories and assessment of recent trends in run strengths. Oregon Dept. Fish and Wildlife. Info. Rep. 88-1.

Nicholas, J.W. and T.W. Downey. 1983. Coastal chinook salmon studies, 1980–83. Oregon Dept. Fish and Wildlife. Prog. Rep. 33 pp.

NOAA. 2001. The potential consequences of climate variability and change. Report of the National Coastal Assessment Group. U.S. Global Change Res. Prog. 8 pp.

Quinn, T.P. et al. 2002. Artificial selection and environmental change: countervailing factors affecting the timing of spawning by coho and chinook salmon. *Trans.*

Amer. Fish. Soc. 131:591–598.
Quinn, W.H. et al. 1978. Historical trends and statistics of the southern oscillation (El Niño) and Indonesian droughts. *Fish. Bull.* 76(3):663.
Reimers, P.E. 1978. Measuring long-term changes in the fall chinook population in Elk River. Oregon Dept. Fish and Wildlife. Info. Rep. 78-5.
Ricker, D.E. 1981. Changes in the average size and average age of Pacific salmon. *Can. J. Fish. Aqua. Sci.* 38:1636–1656.
Roni, P. and T.P. Quinn. 1995. Geographic variation in size and age of North American chinook salmon. *N. Amer. J. Fish. Mgmt.* 15:325–345.
Snyder, J.O. 1931. Salmon of the Klamath River, California. Calif. Dept. Fish and Game. *Fish. Bull.* 34. 130 pp.
Voight, H. and J. Waldvogel. 2002. Smith River anadromous fish action plan. Smith River Advisory Council. 78 pp.
Waldvogel, J.B. 1981. Statistical analysis of adult chinook salmon spawned at Rowdy Creek Hatchery, 1980. Univ. Calif. Coop. Ext. (UCSG-MAP-11). 9 pp.
Waldvogel, J.B. 1983. A report on marked salmon caught in the Smith River sport fishery in 1982. Univ. Calif. Coop. Ext. Rep. 6 pp.
Waldvogel, J.B. 1984a. A report on chinook salmon straying into the Smith River, California in 1983. Univ. Calif. Coop. Ext. (UCSG-MAP-19). 11 pp.
Waldvogel, J.B. 1984b. Statistical analysis of adult fall chinook salmon spawned at Rowdy Creek Fish Hatchery, 1981–83. Univ. Calif. Coop. Ext. (UCSG-MAP-20). 9 pp.
Waldvogel, J.B. 1985. Fall chinook salmon spawning escapement estimate for a tributary of the Smith River, California: Interim report. Univ. Calif. Coop. Ext. (UCSG-MAP-23). 17 pp.
Waldvogel, J.B. 1988. Fall chinook salmon spawning escapement estimate for a tributary of the Smith River, California: Second interim report. Univ. Calif. Coop. Ext. (UCSGEP-88-5). 22 pp.
Zhou, S. 2002. Size-dependent recovery of chinook salmon in carcass surveys. *Trans. Amer. Fish. Soc.* 131:1194–1202.

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