# FRED Reports

GROWTH OF WILD AND HATCHERY
JUVENILE COHO SALMON IN AN
INTERIOR ALASKA STREAM

by
J.A. Raymond

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**Alaska Department of Fish & Game**
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ABSTRACT

Wild and hatchery juvenile coho salmon, Oncorhynchus kisutch, were studied in Wood Creek in interior Alaska. Survival of wild fish over a 19-month period from egg deposition to yearling was 6.0%, 3.7% and 5.2% for the 1981-1983 brood years, respectively. Wild coho juveniles grew to about 50 mm by the end of the first summer and to about 80 mm by the end of the second summer. Most wild juvenile coho salmon appeared to begin their downstream migration sometime before May of their third year in fresh water. Nearly all (98.5%) of the wild fish spent one winter in salt-water. These results indicated that juvenile coho salmon grow more slowly and begin their migration earlier and at a smaller size in interior Alaska than in most other parts of Alaska.

In years when 59,700, 82,500 and 83,000 hatchery fish were released, growth of wild and hatchery fingerlings in Wood Creek appeared about normal. In 1983 when 167,700 hatchery fish were released, growth was depressed for both the wild fry and the hatchery fish. In 1985, adult returns from this release were very low (0.18%). Small differences in size of juvenile wild and hatchery fish at the beginning of the growing season appeared to be magnified by competition. Recoveries of marked hatchery fish indicated that in the years 1982-85, the wild yearling population remained in the range 76,000-86,000. Returns of hatchery and wild adults in 1984 indicated that fingerling-to-adult survival was between 4.0% to 8.5% for hatchery fish and 13.4% for wild fish.

KEYWORDS: wild coho salmon, hatchery-produced coho salmon, Oncorhynchus kisutch, juvenile salmon, growth, competition, population, survival, carrying capacity, emigration, marking mortality, CWT, coded-wire tagging, ventral finclipping, Wood Creek, Clear Creek, Yukon River, Clear Hatchery, interior Alaska

# INTRODUCTION

Coho salmon, Oncorhynchus kisutch, are the basis of small commercial and subsistence fisheries on the Yukon River, with total catches averaging about 33,000 fish per year. In 1982 the Alaska Department of Fish & Game began releasing hatchery-produced coho salmon into Wood Creek, a small stream located in interior Alaska approximately 1400 km upstream from the mouth of the Yukon River. Although several studies have been done on juvenile coho salmon in other parts of its range (Drucker 1972; Crone and Bond 1976; McMahon 1983), little was known about the growth and migratory behavior of coho salmon in Alaska's Interior, where long migration distances and a cold climate would be expected to modify that behavior.

Pearse (1974) found that in one location in interior Alaska, juvenile coho salmon spent 2 years in fresh water and began migrating in May (or earlier) at a size of about 81 mm. Catches reported by Francisco (1977) and Tarbox and Scott (1979) were in general agreement with Pearse's observations. These data indicated that coho salmon migrate earlier and at a smaller size in interior Alaska than they do in most other parts of their range.

To improve the hatchery release program, further studies were made of wild and hatchery coho juveniles in Wood Creek. This report presents the results of studies that were designed to determine (1) the growth rate and migration timing of wild and hatchery stocks and (2) the degree of competition between the two stocks.

## MATERIALS AND METHODS

Portions of each hatchery release of coho salmon were marked with either coded-wire tags and adipose finclips or ventral finclips. Marking was done according to the methods described by Moberly et al. (1977).

Juvenile coho salmon were usually captured with a 10- by 2-m beach seine that had a 6-mm mesh. Occasionally minnow traps and dipnets were used. A few samples were collected with an inclined-plane trap described elsewhere (Raymond and Skaugstad 1986).

Samples were fixed in 10% formalin for approximately 4 days, measured, and transferred to a 70% isopropyl alcohol solution. Before 1984, samples were usually separated into different size groups if a natural separation appeared to occur. The groups were then usually weighed as a whole to obtain average weights. Also before 1984, samples were occasionally placed in alcohol for up to 24 h before measurements were made. An examination of other samples exposed to alcohol for different periods indicated that the alcohol exposure would have caused the samples to shrink by as much as 5% in weight and 1% in length. Beginning in 1984, samples were measured individually with a Mettler PE400 digital balance and then transferred to alcohol.

Occasionally juvenile scales were read to distinquish between different year classes. Scales were placed between two glass microscope slides and read with a dissecting microscope. Adult scales were imprinted on plastic cards and read with a microfiche projector.

In this report, wild coho juveniles are called 'fry', 'yearlings', or 'smolts', depending on whether they are in their first, second, or third year in freshwater, respectively. Hatchery coho juveniles were released at approximately the same size as the wild yearlings, but because they were reared at an accelerated pace, they were 1 year younger than the yearlings. In this report, mixed populations of hatchery fish and wild yearlings are called 'fingerlings'.

The age classes of adult salmon are reported here in the European notation. For example, an age-2.1 coho salmon is one whose scales have two freshwater annuli and one saltwater annulus. This indicates two winters spent in freshwater and one winter in saltwater.

The number of hatchery fish in a sample ($n_h$) was estimated as

$$n_h = \frac{n_m}{f}$$

where $n_m$ is the number marked in the sample and f is the fraction of the release that was marked. The number of wild fish was thus

$$n_w = N - n_h$$

where N is the total number in the sample.

The average length and weight of the hatchery fish (both marked and unmarked) in a sample were assumed to be the same as those of the marked fish. To obtain the average length of the wild fish, the average length of a sample containing both wild and hatchery fish (L) was assumed to equal the weighted average of the average lengths of the hatchery fish ($L_m$) and wild fish ($L_w$):

$$L = \frac{(n_h * L_m) + (n_w * L_w)}{n_h + n_w} .$$

The preceding equations can be solved for $L_w$:

$$L_w = \frac{(N * L) - (n_h * L_m)}{n_w} .$$

A similar expression was used for the average weight of the wild fish.

Estimates of the of total fingerling population and wild yearling population were based on the Petersen method (Ricker 1975, equations 3.5 and 3.6).

## THE STUDY AREA

Collections were made at 12 sites in the Wood Creek area (Figure 1, Table 1). Wood Creek is a spring-fed, clear-water tributary of Clear Creek. The stream substrate is composed mostly of gravel in the main channel and organic debris in calmer areas (where most of the collections were made). The flow in the creek is approximately 13,000 lpm (30 cfs) and remains relatively constant throughout the year. The temperature of the springs is about $1^{\circ}$ to $2^{\circ}$C, which keeps the upper 1.5 km of the creek ice-free in winter.

Clear Creek is also spring-fed, but above the mouth of Wood Creek, it has a flow about half that found in Wood Creek. This upper portion of Clear Creek usually has about 10 beaver dams, ranging in height from 60 to 120 cm. About 60% of the course of the upper creek is composed of beaver ponds. Below a dam where the flow is swift, the bottom is typically composed of gravel; where the beaver ponds are found, the bottom is typically composed of mud. Numerous leaks in the dams appeared to provide outlets for emigrating juveniles, but the leaks appeared too small to allow the upstream passage of adults.

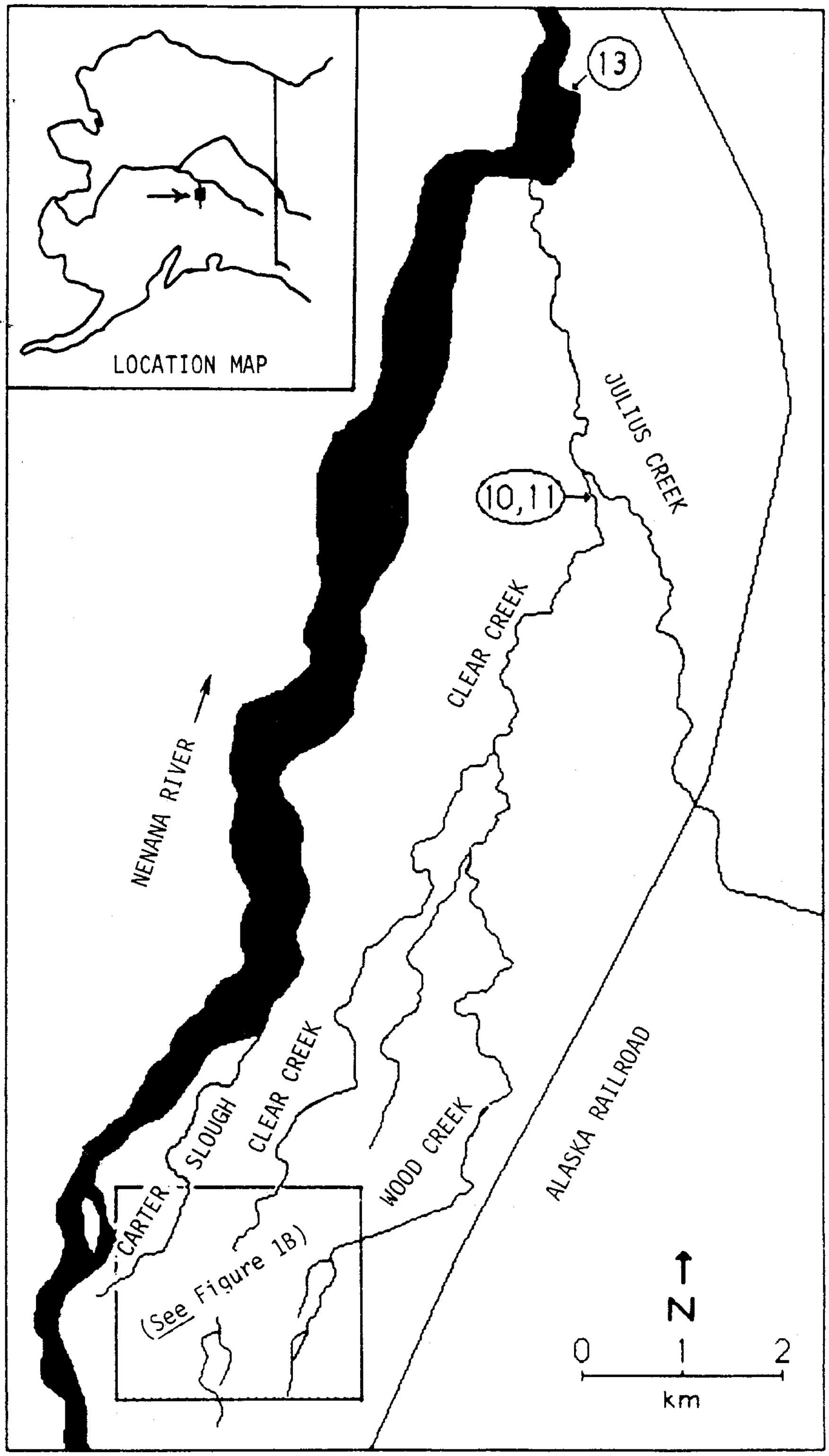


Figure 1A. Map of the Wood Creek area. Numbers indicate collection sites (see Table 1).

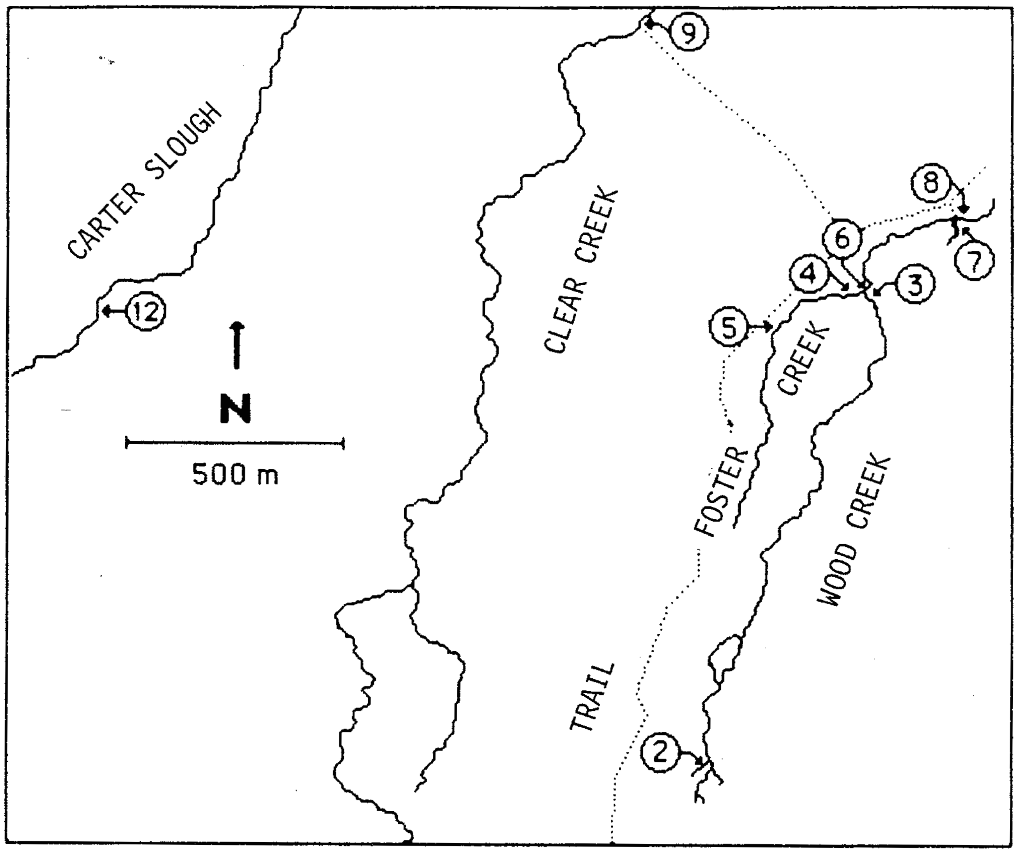


Figure 1B. Detail of the upper Wood Creek area.

Table 1. Juvenile coho salmon collection sites.[1/]

| No. | Location | Habitat type |
|---|---|---|
| 1 | Clear Hatchery | |
| 2 | Wood Creek headwaters | spring-fed backwaters |
| 3 | Wood Ck above Foster CK | main current |
| 4 | mouth of Foster Creek | sheltered backwater |
| 5 | Foster Creek | 1.5-m-wide spring-fed creek |
| 6 | Wood Creek | main current |
| 7 | Wood Creek spring | spring-fed backwater |
| 8 | Wood Creek | main current |
| 9 | Upper Clear Creek | slow-moving side channel |
| 10 | Lower Clear Creek | slow-moving sloughs |
| 11 | Lower Clear Creek | main current |
| 12 | Carter Slough | spring-fed trib. of Nenana R. |
| 13 | Nenana River | calm backwater |

[1/] see Figures 1A and 1B for locations.

Wood Creek has a natural run of coho salmon that spawns in the upper 1.5 km of the creek. Clear Creek has a run of a few hundred chinook salmon, _O. tshawytscha_, that spawns in a 3-km section below the mouth of Wood Creek. Each year in July, approximately 10 to 20 chum salmon, _O. keta_, are seen in this area, but it is not known if they spawn. No salmon have been observed in the portion of Clear Creek that is obstructed by beaver dams.

# RESULTS

A summary of collections of wild and hatchery-produced juvenile coho salmon made in the study area is given in Appendix Table 1. Water temperatures are given in Appendix Table 2.

## Wild Coho Juveniles

Average sizes of wild coho salmon collected in the Wood Creek area before the release of hatchery coho salmon are plotted in Figure 2. The approximate normal growth curve, which is based on these points, is shown as a dashed line. The curve is approximate because, in general, the populations that were sampled were different.

Figure 2 shows that coho fry typically grow from about 30 mm in length in May to about 50-55 mm at the end of their first summer. Little or no growth occurs in winter. During the second summer the yearlings grow to about 80-90 mm in length. Small catches of coho smolts in an outmigrant trap in lower Clear Creek in May (Raymond and Skaugstad 1986) indicated that most of the emigration from Wood Creek occurs sometime before May. This agrees with a scale analysis of adult coho salmon that showed that all had spent 2 years as rearing juveniles in fresh water (Table 2).

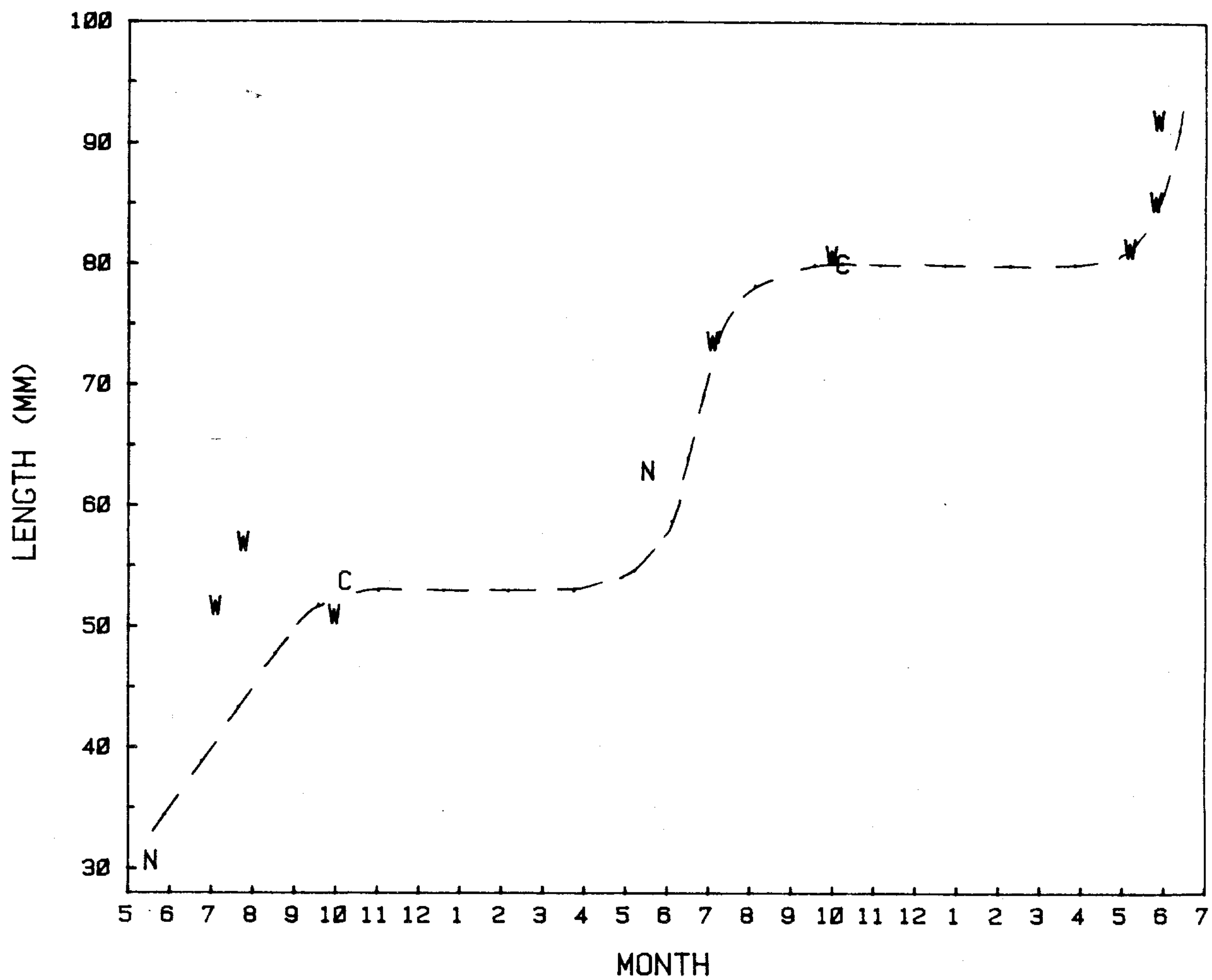


Figure 2. Length of wild juvenile coho salmon as a function of date in Wood Creek and nearby streams. Symbols refer to collection sites: W = Wood Creek, C = Carter Slough, N = Nenana River. Dashed line is the estimated normal growth curve based on the points shown.

Table 2. Age distribution of Wood Creek wild coho salmon adults, 1981-1983. During this period, no adult hatchery-produced coho salmon were in the creek.

| Return year | n[a] | Percent in age class 2.1 | 2.2 |
|---|---|---|---|
| 1981 | 50 | 100 | 0 |
| 1982 | 20 | 95 | 5 |
| 1983 | 65 | 98.5 | 1.5 |
| 1981-83 | 135 | 98.5 | 1.5 |

[a] number of fish sampled that had readable scales.

## Mixed Wild and Hatchery Coho Juveniles

Coho salmon produced in the Clear Hatchery were first released into Wood Creek in 1982 (Table 3). Chum and chinook salmon smolts were also released in most years. However, outmigrant trapping in lower Clear Creek (Raymond and Skaugstad 1986) indicated that most chum and chinook salmon left the creek within 2 weeks and, therefore, probably wouldn't have had an important effect on the growth of wild and hatchery coho juveniles.

1982 Release:

Growth. In 1982, 59,700 hatchery coho salmon were released into Foster Creek, a tributary of Wood Creek, and another 66,200 were released into Clear Creek. The growth curves of both the hatchery fish (Figure 3, points marked H) and the 1980-brood wild yearlings (points marked W) were roughly similar to the estimated normal growth rate (upper dashed line, replotted from Figure 2). Nine unmarked smolts that were collected in the outmigrant trap in lower Clear Creek in May 1983 (points marked X) could have been either hatchery or wild fish. The hatchery cohos may have grown at a slightly faster rate than the wild fish, but the sample sizes were not large enough to confirm this.

The hatchery fish did not appear to affect the growth of the 1981-brood wild coho fry (points marked F) whose growth was similar to the normal growth rate (lower dashed line, replotted from Figure 2).

Because none of the marked hatchery fish from the 1982 release was caught in the outmigrant trap in 1982 or seine catches in 1983, it appeared that the hatchery fish emigrated from Wood Creek before collections began in May 1983.

Population. The estimated fingerling population (wild yearlings and hatchery releases) in Wood Creek on 14 May 1982, the day of

Table 3. Releases of coho salmon from the Clear Hatchery.

| Release date | No. (1000s) | Average weight (g) | Marks: No. (1000s) | Marks: Type[a] | Marks: Fract. marked | Release site[b] |
|---|---|---|---|---|---|---|
| 14-May-82 | 59.7 | 1.94 | 11.9 | CWT1 | .1993 | 5 |
| 14-May-82 | 66.2 | 1.94 | 13.2 | CWT1 | .1993 | 9 |
| 5-May-83 | 167.7 | 1.73 | 18.1 | LV | .1121 | 5 |
| 3-May-84 | 82.5 | 2.2 | 12.5 | RV | .1516 | 8 |
| 3-May-84 | 82.5 | 2.2 | 12.5 | RV | .1516 | 9 |
| 2-May-85 | 83.0 | 2.08 | 15.12 | CWT2 | .1821 | 5 |
| 2-May-85 | 83.0 | 2.04 | 11.26 | CWT3 | .1357 | 9 |

[a] CWT = coded-wire tag and adipose finclip. CWT1, CWT2 and CWT3 refer to different tag lots. LV and RV = left and right ventral finclip.

[b] Release sites are shown in Figure 1B.

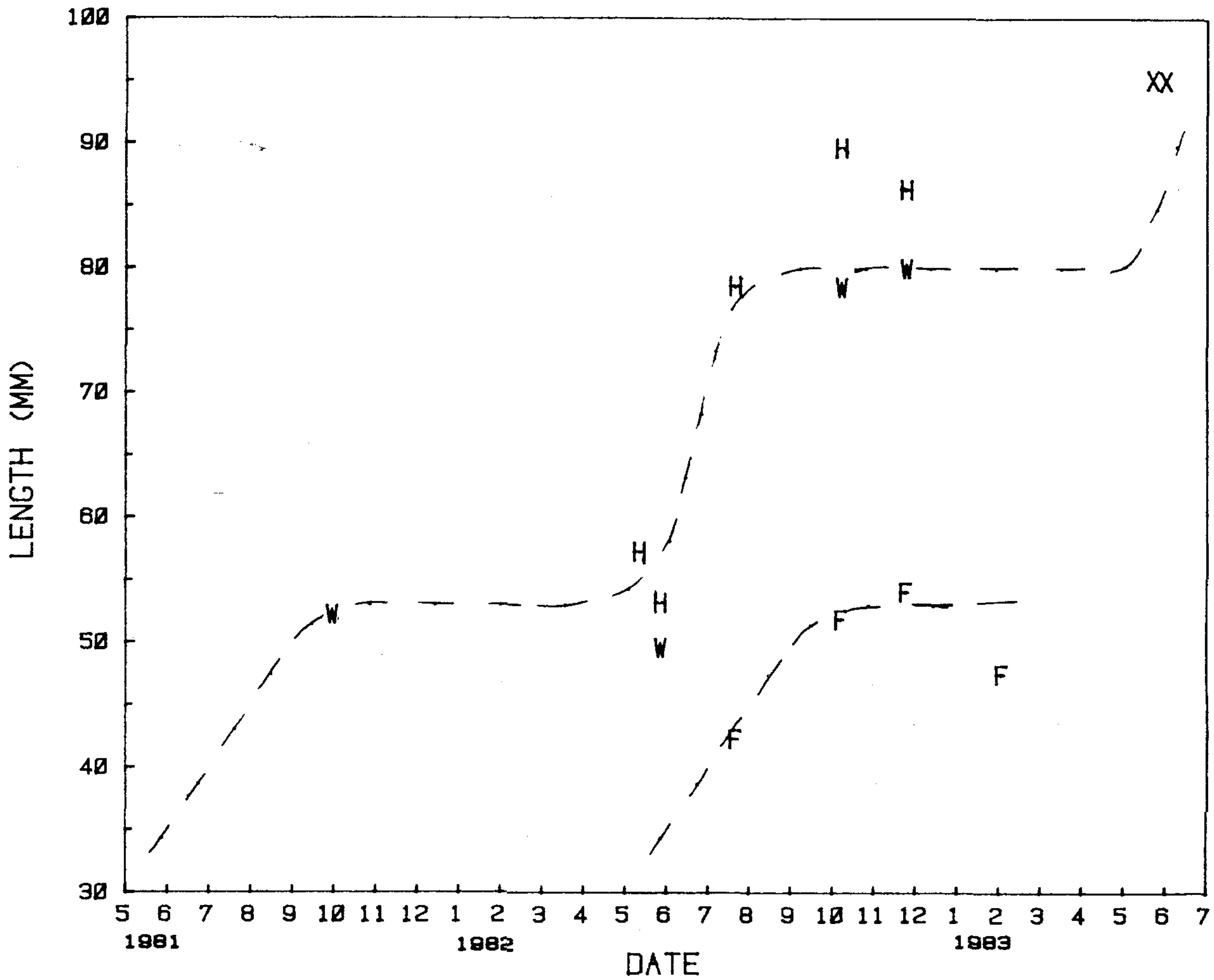


Figure 3. Length of juvenile coho salmon in Wood Creek, May 1981 to July 1983. The upper and lower dashed curves are the estimated normal growth curves (from Figure 2) plotted for the 1980- and 1981-brood wild coho salmon populations, respectively. Points marked H (hatchery 1981 brood), W (wild 1980 brood), and X (either wild or hatchery fish) should be compared to the upper dashed curve. Points marked F (wild 1981-brood coho fry) should be compared to the lower dashed curve.

the release, was 136,000 (80% confidence interval: 104,000 - 168,000) (Table 4). Thus, the estimated wild yearling population was 136,000 - 59,700 = 76,000 (80% confidence interval: 44,000 - 109,000). The fingerling population might have decreased over the summer because of natural mortality or emigration. However, emigration did not appear to be a factor during the period 7 May to 20 June 1982. The outmigrant trap, operated intermittently in lower Clear Creek during this period, caught a few age-2 coho smolts but no fingerlings.

<u>Fingerling-to-Adult Survival</u>. The 1982 wild and hatchery fingerling populations and the 1984 adult returns to the Wood Creek weir indicated fingerling-to-adult survivals of 7.7% for the wild yearlings and 2.3% for the hatchery fish (Table 5). The 2.3% hatchery return is based on the assumption that beaver dams on Clear Creek forced all adults returning to that creek to migrate up Wood Creek. However, if the none of the returning adults were from the Clear Creek release, then the return on the Wood Creek release would have been 4.9%. To obtain the approximate ocean survivals (Table 5), these percentages were multiplied by 1.74, which is the average run-to-escapement ratio for Yukon River coho salmon[1].

Scale analyses (Table 2) indicated that virtually all of the wild coho adults were from the 1980 brood year (age class 2.1). Thus, the higher return of wild adults could not be attributed to a return of more than one brood year. Also, only one marked hatchery fish from the 1982 release was recovered in 1985, which indicated that the relatively low hatchery return in 1984 was not due to a delay in the return by some of the hatchery fish.

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[1] Based on Commercial Fisheries Division records of catches and escapements of coho salmon between the mouth of the Yukon River and the Nenana River for the years 1977-1982.

Table 4. Petersen population estimates of total fingerling and wild yearling coho salmon in Wood Creek at the time of the hatchery releases.

| Release year | No. marked (M) | Sample (C) | No. marks recovered (R) | Population total (T=MC/R) | Population hatchery (H) | Population wild (T-H) | Half-width 80% conf. int. a/ |
|---|---|---|---|---|---|---|---|
| 1982 | 11,900 | 309 | 27 | 136,000 | 59,700 | 76,000 | 32,000 |
| 1983 | 18,800 | 445 | 33 | 254,000 | 167,700 | 86,000 | 54,000 |
| 1984 | 12,500 | 106 | 8 | 166,000 b/ | 82,500 | 83,000 | 72,000 |
| 1985 | 15,120 | 291 | 26 | 169,000 | 83,000 | 86,000 | 41,000 |

a/ The half-widths of the 80% confidence intervals apply to both the total population and the wild population since the hatchery population is a constant. Values are obtained from the expression $1.282 \sqrt{\text{variance}}$ where the variance = $M^2C(C-R)/R^3$.

b/ Excludes 1983 holdovers.

Table 5. Approximate fingerling-to-adult survival for wild and hatchery coho salmon originating from Wood Creek.

| Group | Fingerling population | Weir count[a] | Percent survival ocean[b] | Percent survival weir[c] |
|---|---|---|---|---|
| 1982 | | 1984 | | |
| wild | 76,500 | 5,902 | 13.4 | 7.7 |
| hatchery[d] | | | | |
| Wood & Clear Cks. | 125,900 | 2,900 | 4.0 | 2.3 |
| Wood Ck. only | 59,700 | 2,900 | 8.5 | 4.9 |
| 1983 | | 1985 | | |
| wild | 86,000 | 4,403 | 8.9 | 5.1 |
| hatchery[e] | | | | |
| Wood Ck. only | 167,700 | 178 | 0.18 | 0.11 |

[a] Based on the recovery of marked hatchery fish.

[b] Survival to the mouth of the Yukon River, based on a run-to-escapement ratio of 1.74 (see text).

[c] Survival to the Wood Creek weir.

[d] In 1982, hatchery fish were released in both Wood and Clear creeks. Survivals are calculated for two cases: (1) returns to the weir came from both releases and (2) returns came from the Wood Creek release only.

[e] In 1983, hatchery fish were released only in Wood Creek.

The average lengths of returning marked and unmarked coho salmon (56.9 and 57.5 cm, respectively) were not significantly different. The difference was less than the range in average lengths of wild coho salmon (54.8 to 60.8 cm) in the years 1981-1983 (Table 6).

The hatchery return of 2,900 adults was based on a return of 578 marked fish and an original fraction marked of 0.1993. This value could be underestimated if either 1) the marked hatchery fish had a higher mortality than the unmarked fish or 2) some of the clipped adipose fins were regenerated. Scale patterns of the returning adults, which identified many of the hatchery fish because of their accelerated rearing, indicated a hatchery return of 2,890 adults (80% confidence interval: 1,410 - 4,370) (Appendix B). Although this estimate was similar to the original estimate which assumed no mark losses, the upper confidence limit corresponds with a mark loss of 34%. Thus, mark losses may have occurred.

1983 Release:

Growth. In 1983, 167,700 coho juveniles--nearly three times the quantity released in 1982--were released into Wood Creek through its tributary, Foster Creek. These fish were 11% smaller in weight than those in the 1982 release. On two of the sampling dates (1 June and 13 October 1983), the hatchery fish (Figure 4A, points marked H) were considerably smaller than the wild yearlings (points marked W). These data indicated a substantial decrease in growth during the 1983 summer, compared to the expected normal growth (dashed curve). The growth of wild fry in the summer of 1983 (Figure 4B, points marked F) also appeared to be retarded compared to the expected normal growth.

In contrast to the low growth rates found in Wood Creek, normal growth rates were observed in nearby Carter Slough, where the resident population of wild coho juveniles was not affected by

Table 6. Average lengths of wild and hatchery coho salmon returning to the Wood Creek weir.

| Return year | Group | Males n | Males length[a] | Females n | Females length | Total n | Total length |
|---|---|---|---|---|---|---|---|
| 1981 | wild | 16 | 56.8 | 40 | 55.8 | 56 | 56.1 |
| 1982 | wild | 0 | | 20 | 60.8 | 20 | 60.8 |
| 1983 | wild | 31 | 53.2 | 35 | 56.2 | 66 | 54.8 |
| 1984 | marked[b] | 22 | 55.0 | 27 | 58.4 | 49 | 56.9 |
| | unmarked | 48 | 57.1 | 48 | 57.8 | 96 | 57.5 |
| 1985 | marked[c] | 1 | 48.9 | 9 | 56.8 | 10 | 56.0 |
| | unmarked | 35 | 57.7 | 40 | 56.0 | 75 | 56.8 |

a/ All lengths are in centimeters.

b/ Lacking an adipose fin.

c/ Lacking a left ventral fin.

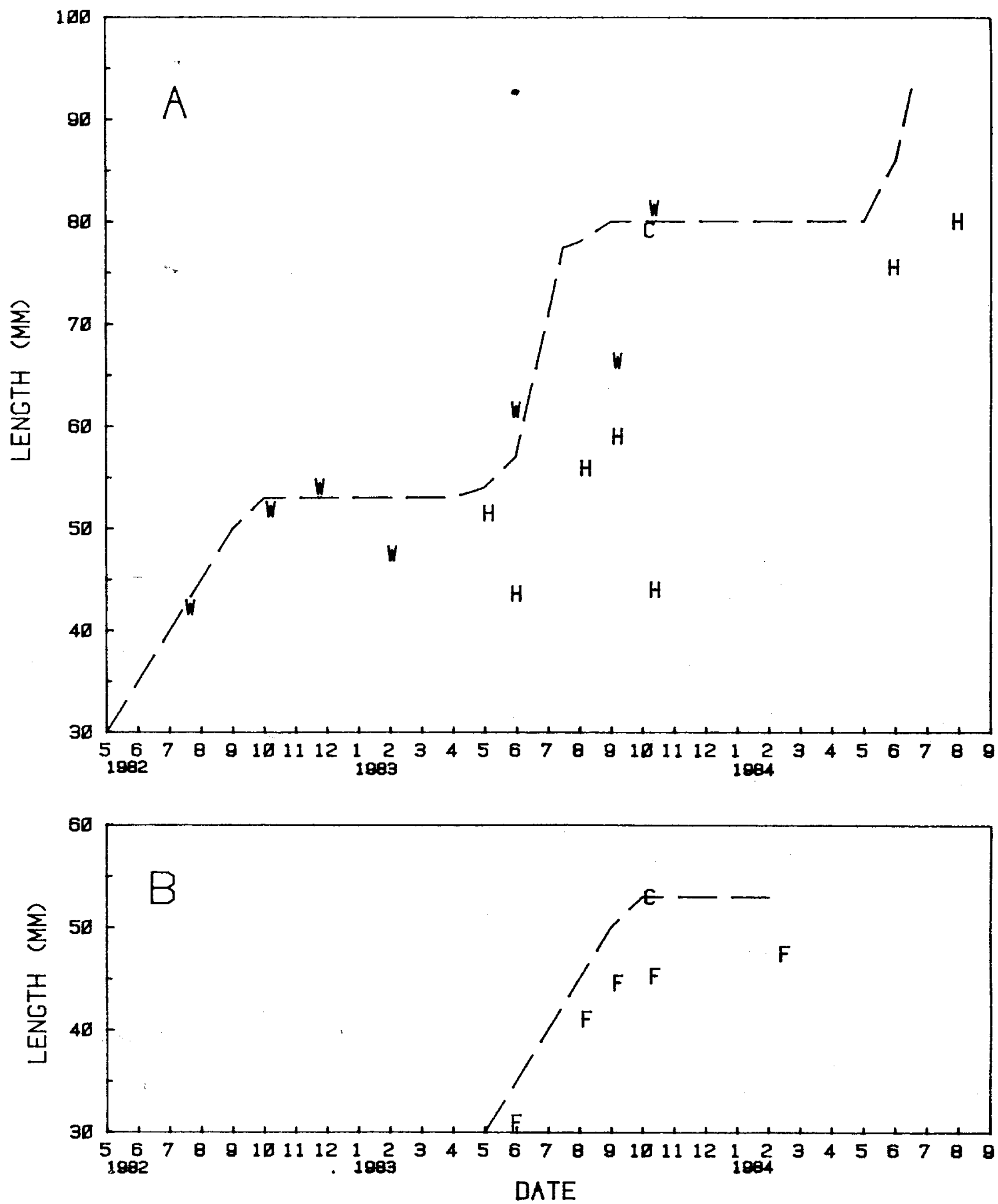


Figure 4. Length of juvenile coho salmon in Wood Creek and Carter Slough, May 1982 to September 1984. (A) W = Wood Creek wild 1981 brood, H = Wood Creek hatchery 1982 brood, C = Carter Slough wild 1981 brood. The dashed curve is the estimated normal growth curve shown in Figure 2, plotted for 1981-brood wild coho salmon. (B) F = Wood Creek wild 1982 brood, C = Carter Slough wild 1982 brood. The dashed curve is the same as in (A) but plotted for 1982-brood wild coho salmon.

hatchery releases. In October, the sizes of the wild yearlings and fry (points marked C in Figures 4A and 4B, respectively) were close to the normal values (dashed curves) for that time of year.

Many of the hatchery fish appeared to be too small to emigrate in the spring of 1984. Recoveries of marked fish indicated that about 31% or 52,000 (see below) remained in the creek for the first half of the 1984 summer. During this period, these hatchery "holdovers" were larger than the wild yearlings in the creek. The holdovers appeared to emigrate in late summer or early fall of 1984, since none was found in samples taken in October 1984 or February 1985. The size at emigration appeared to be about 80 mm, which was approximately the same size attained by coho smolts at the time of the normal migration in the spring.

Population. On the date of the hatchery release (5 May), the estimated fingerling population in Wood Creek (hatchery fish plus wild yearlings) was 254,000 (80% confidence interval: 199,000 - 308,000) and the wild yearling population was 86,000 (80% confidence interval: 31,000 - 140,000) (Table 4). The wild and hatchery fingerlings probably remained in the stream at least through the end of May, since none was caught in the outmigrant trap that was operated intermittently during the period 3-26 May 1983.

Fingerling-to-Adult Survival. Of the approximately 86,000 wild yearlings in Wood Creek in 1983, 4,403, or 5.1%, returned in 1985 (Table 5). Scale analyses (C. Skaugstad and J. Raymond, unpublished data) indicated that all the wild adults had originated from the 1983 yearling population. Because of the poor growth and late migration of many of the hatchery fish, a low return was expected. Only 178 or 0.11% of the hatchery fish released in 1983 returned to the Wood Creek weir in 1985. However, those that did return were similar in size to the unmarked fish (Table 6).

1984 Release:

Growth. In 1984, 82,500 hatchery fish were released into Wood Creek and another 82,500 were released into Clear Creek. The Wood Creek release, which was smaller in number than the 1983 release, resulted in a growth rate (Figure 5, points marked A) that was higher than that observed in 1983 and closer to the normal value (upper dashed curve).

However, the growth of fry in 1984 (Figure 5, points marked F), when compared to the expected growth (lower dashed curve), appeared to be retarded. The poor growth of the fry may have been due to a larger-than-normal fingerling population that, in addition to the wild yearlings and the 1984 hatchery release, included the 1983 holdovers.

The hatchery fish in Wood Creek appeared to grow at a higher rate than both the hatchery fish in Clear Creek and the wild yearlings in Wood Creek.

Population. In May and July 1984, only 3 marked fish from the 1984 release were recovered out of a sample of 227. This indicated either a large population of wild yearlings or a non-random distribution of the 1984 release in the sampling area. The latter explanation seemed more probable because in 1984 the hatchery fish were released at a site on Wood Creek about 700 m downstream from the former release site on Foster Creek and about 400 m downstream from the main sampling area. This may have resulted in a distribution that was centered outside the main sampling area. In addition, the large number of relatively large-sized holdovers from the 1983 release in the sampling area probably discouraged the upstream movement of the 1984 release until late summer when the holdovers were gone. Therefore, only the later samples taken in October 1984 and February 1985 were included in the population estimate. The resulting population estimates on 3 May 1984, the day of the release, were 166,000

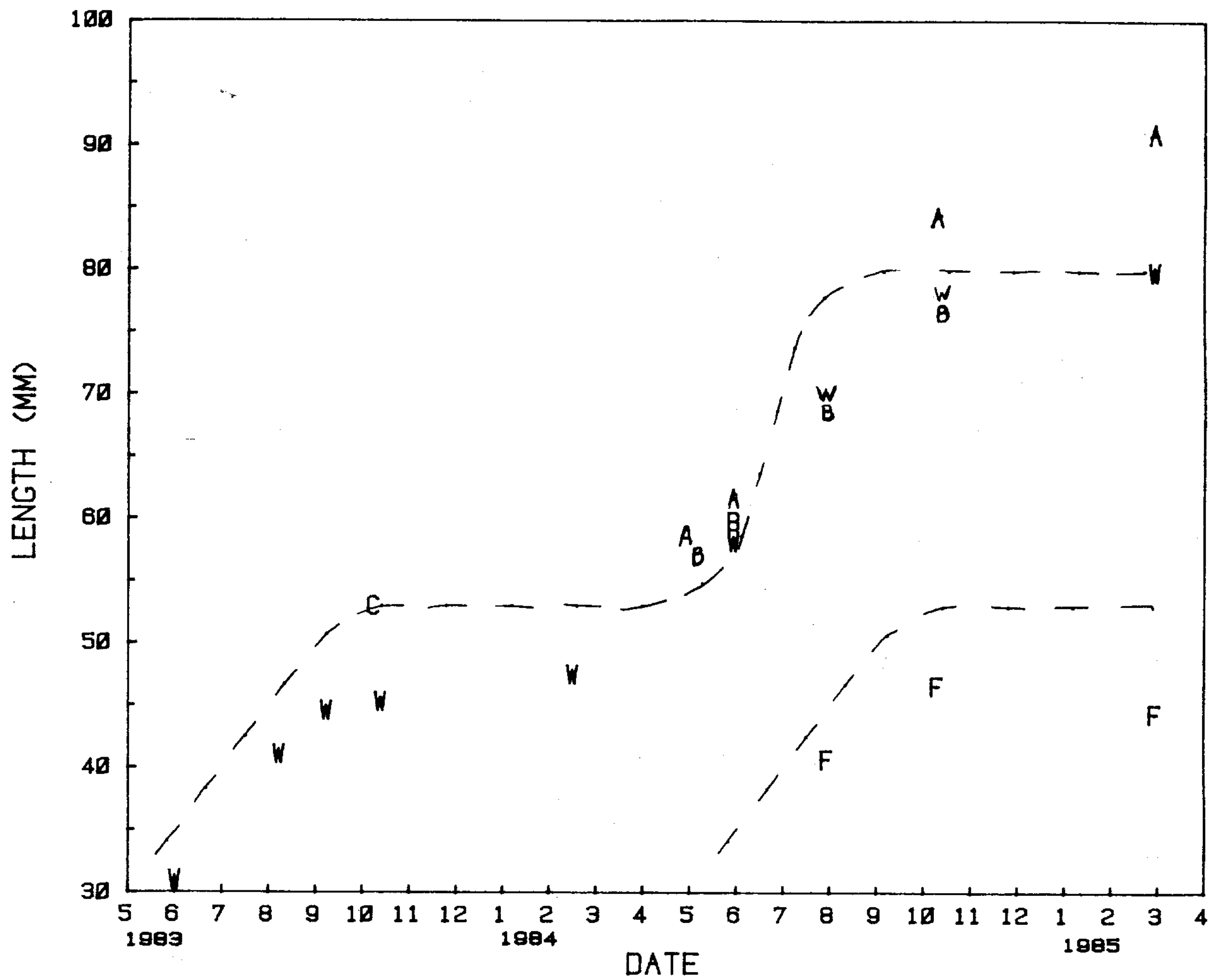


Figure 5. Length of juvenile coho salmon in Wood Creek and Clear Creek, May 1983 to February 1985. W = wild 1982 brood in Wood Creek, A = hatchery 1983 brood in Wood Creek, B = hatchery 1983-brood in Clear Creek, F = wild 1983 brood in Wood Creek. The upper and lower dashed curves are the estimated normal growth curves (obtained from Figure 2) for the 1982-brood and 1983-brood wild coho salmon populations, respectively.

fingerlings (excluding 1983 holdovers) and 83,000 wild yearlings (Table 4).

Although the holdover population is difficult to estimate because of emigration, a rough estimate can be obtained for the end of May when the first collection was made. In the 30 May sample, 36 of 115 fingerlings were identified as holdovers. If it is assumed that the fingerling population estimate of 166,000 for early May hadn't changed significantly by the end of May and that for every 115 fingerlings there were 36 holdovers, then the number of holdovers would be (36/115)(166,000) = 52,000. Thus, about 31% of the 1983 release appeared to be in Wood Creek on 30 May 1984.

Ventral Finclips. The effect of a ventral finclip on growth and mortality was studied in upper Clear Creek where only hatchery fish were present (Table 7). The ventral finclip appeared to have little effect on growth. The marked fish might have been slightly smaller than the unmarked fish in the October sample, but the sample size was too small to confirm this. The occurrence of marks was greater than expected in the May and July samples but less than expected in the October sample. However, a chi-square test indicated that the decrease in frequency of marked fish during the sampling period was not significant. Thus, these data were insufficient to conclude whether or not finclipping affected growth rate or mortality.

1985 Release:

Growth. In 1985, 83,000 hatchery fingerlings were released in Wood Creek through its tributary, Foster Creek, and another 83,000 were released in Clear Creek. The hatchery fish appeared to grow at an approximately normal rate both in Wood Creek (Figure 6, points marked A) and in Clear Creek (points marked B).

Table 7. Frequency of mark occurrence and growth comparison of marked and unmarked hatchery coho juveniles collected in Clear Creek in 1984.

| Date | Sample | No. marks | | Length (mm) | |
|---|---|---|---|---|---|
| | | Observed | Expected[a] | marked | unmarked |
| 30 May | 175 | 37 | 27 | 59.3 | 59.8 |
| 30 July | 53 | 10 | 8 | 70.1 | 69.3 |
| 10 Oct. | 38 | 3 | 6 | 73.7 | 77.2 |

[a] Based on a fraction marked of 0.1516 (see Table 3).

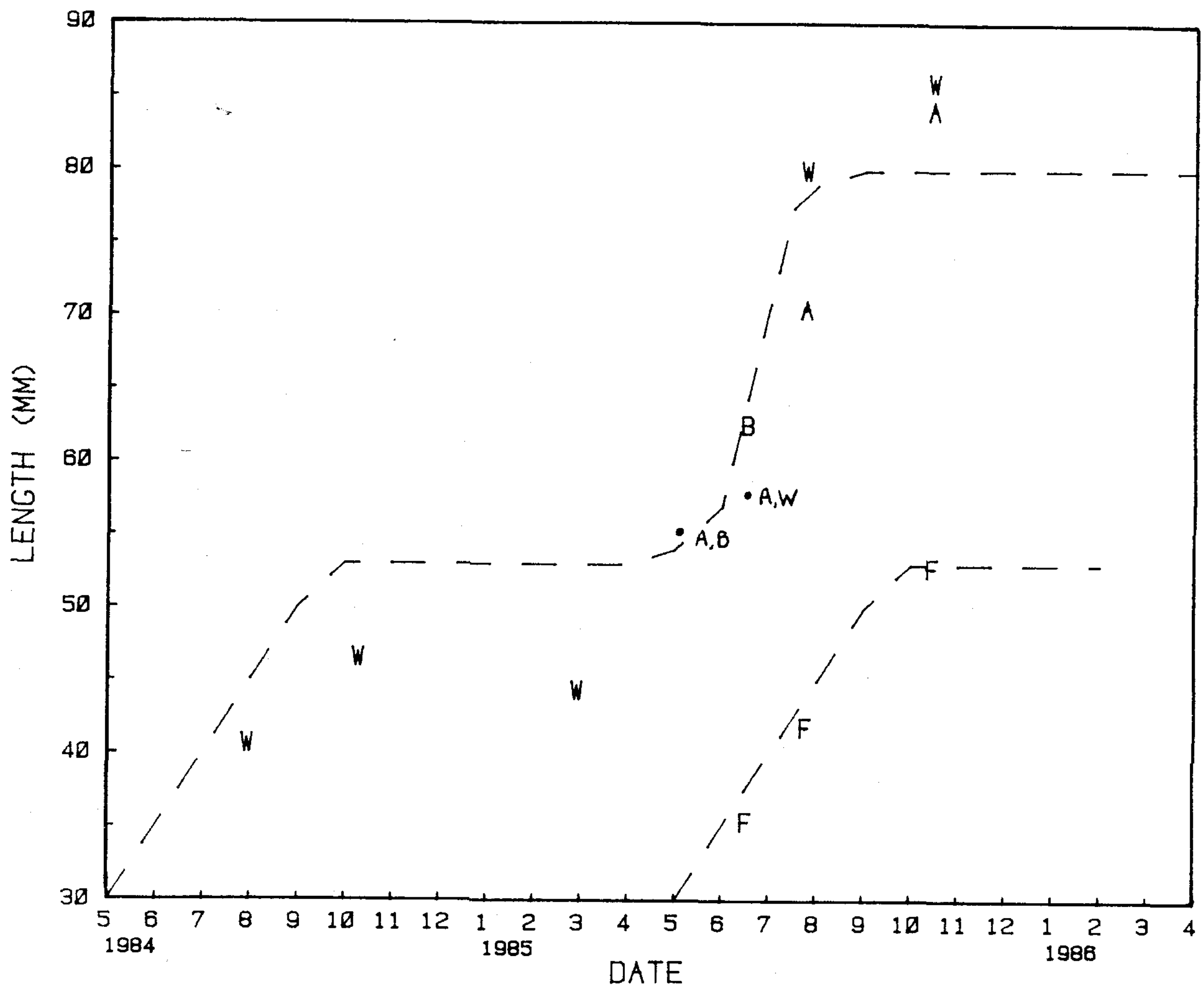


Figure 6. Length of juvenile coho salmon in Wood Creek and Clear Creek, May 1984 to July 1985. W = wild 1983 brood in Wood Creek, A = hatchery 1984 brood in Wood Creek, B = hatchery 1984 brood in Clear Creek, F = wild 1984-brood in Wood Creek. The upper and lower dashed curves are the estimated normal growth curves (obtained from Figure 2) for the 1983-brood and 1984-brood wild coho salmon populations, respectively.

In Clear Creek where only hatchery fish were present, the unmarked fish were slightly larger in length and weight than the fish marked with an adipose finclip (Appendix Table 3). However, t-tests showed that these differences were not significant ($P \simeq .1$).

The wild 1983-brood fish (Figure 6, points marked **W**), which appeared to have a poor growing season as fry, appeared to have recovered and to have attained normal growth as yearlings in 1985. The 1984-brood fry (points marked F) also showed normal growth.

Population. The estimated fingerling population (wild yearlings and hatchery releases) in Wood Creek on 2 May 1985, the day of the release, was 169,000 (80% confidence interval: 129,000 - 210,000) (Table 4). Thus, the estimated wild yearling population was 86,000 (80% confidence interval: 46,000 - 127,000).

Green Egg-to-Yearling Survival:

The potential egg deposition for coho salmon in Wood Creek can be estimated from female escapements and fecundities (Table 8). Using the estimated wild yearling populations (Table 4), survival rates for the wild population from egg deposition to yearlings 19 months later were estimated at 6.0% for the 1981-brood year, 3.7% for the 1982-brood year, and 5.2% for the 1983-brood year (Table 8).

Habitat Preference:

The catch of fry as a fraction of the total catch of juveniles in Wood Creek is summarized by location and month in Table 9. The fry usually outnumbered fingerlings in sheltered areas, such as the headwaters of the creek and a backwater near the weir site. Coho fingerlings were more abundant than fry at the mouth of Foster Creek and in the main current at the weir site. In the

Table 8. Female escapement, fecundity, potential egg deposition (P.E.D.), yearling population, and green-egg-to-yearling survival in Wood Creek, 1981 and 1982 brood years.

| Brood year | Female escape-ment[a] (E) | Fecundity[a] (F) | P.E.D (millions) (P=E*F) | Yearling population[b] (Y) | Survival (%) (Y/P) |
|---|---|---|---|---|---|
| 1981 | 364 | 3920 | 1.43 | 86,000 | 6.0 |
| 1982 | 544 | 4140 | 2.25 | 83,000 | 3.7 |
| 1983 | 391 | 4237 | 1.66 | 86,000 | 5.2 |

[a] Dave Parks, Alaska Dept. of Fish & Game, unpublished data.

[b] *See* Table 4.

Table 9. Distribution of coho fry in Wood Creek.[a]

| Location | Month: May | June | July | Aug. | Sept. | Oct. | Nov. | Feb. |
|---|---|---|---|---|---|---|---|---|
| 2. Head-waters | | 55/55 | | | | | | 85/94<br>23/53[b] |
| 3. Above Foster | | 44/50 | | | | | | 0/1 |
| 4. Mouth Foster | 0/151<br>3/92 | 51/84<br>0/218 | 105/114<br>0/79 | 28/73 | 63/113 | 142/148<br>120/187[c] | | 10/33<br>48/48 |
| 5. In Foster | | | | | | | 66/184 | 1/2 |
| 6. Below Foster | | | 34/34 | | | | | |
| 7. Back-water | | 0/13 | 1/30<br>61/82 | | 25/35 | 95/116 | 19/22 | |
| 8. In current | | | | | 19/56 | 140/352<br>8/78<br>2/51 | | |

[a] Catches are expressed as (no. fry)/(total catch). Each entry is an individual catch. Data are from Appendix Table 1. Location numbers are the same as those given in Table 1.

[b] Fry and fingerlings were for the most part caught in separate but adjacent areas.

[c] Locations 4 and 6 combined.

fall, however, larger numbers of fry seemed to move into the area at the mouth of Foster Creek. Although mixing was usually present, in about 60% of the samples one size group accounted for at least 80% of the catch.

## DISCUSSION

### Wild Coho Juveniles

Growth Rate:

A comparison of growth rates of different stocks of coho salmon juveniles in Alaska is shown in Figure 7. The growth rate of coho juveniles in Wood Creek is consistent with sizes of coho juveniles reported for two other streams in interior Alaska: the Delta Clearwater River (Pearse 1974) and the Delta River (Francisco 1977)[1]. However, in another interior stream, Lignite Creek, sizes of juvenile coho salmon (Tarbox and Scott 1979) indicated a higher growth rate. South of the Alaska Range, growth rates appear to be substantially higher. By the end of their first summer, coho juveniles typically reach a length of 80 mm in the Deshka River (Delaney et al. 1981) and 71 mm in the upper Susitna River (Roth and Stratton 1985). The relatively low rate of growth observed in Sashin Creek in southeastern Alaska (Crone and Bond 1976) indicates that factors other than climate

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[1] Francisco reported an age of 1.0 ($2_2$ Gilbert Rich) for coho juveniles that were caught between 12 April and 25 May because their scales had a single annulus. However, in interior Alaska, the second annulus is not formed until June (Ken Alt, Alaska Department of Fish & Game, personal communication). Consequently, the Delta River coho juveniles are shown in Figure 7 as being at the beginning of their third spring.

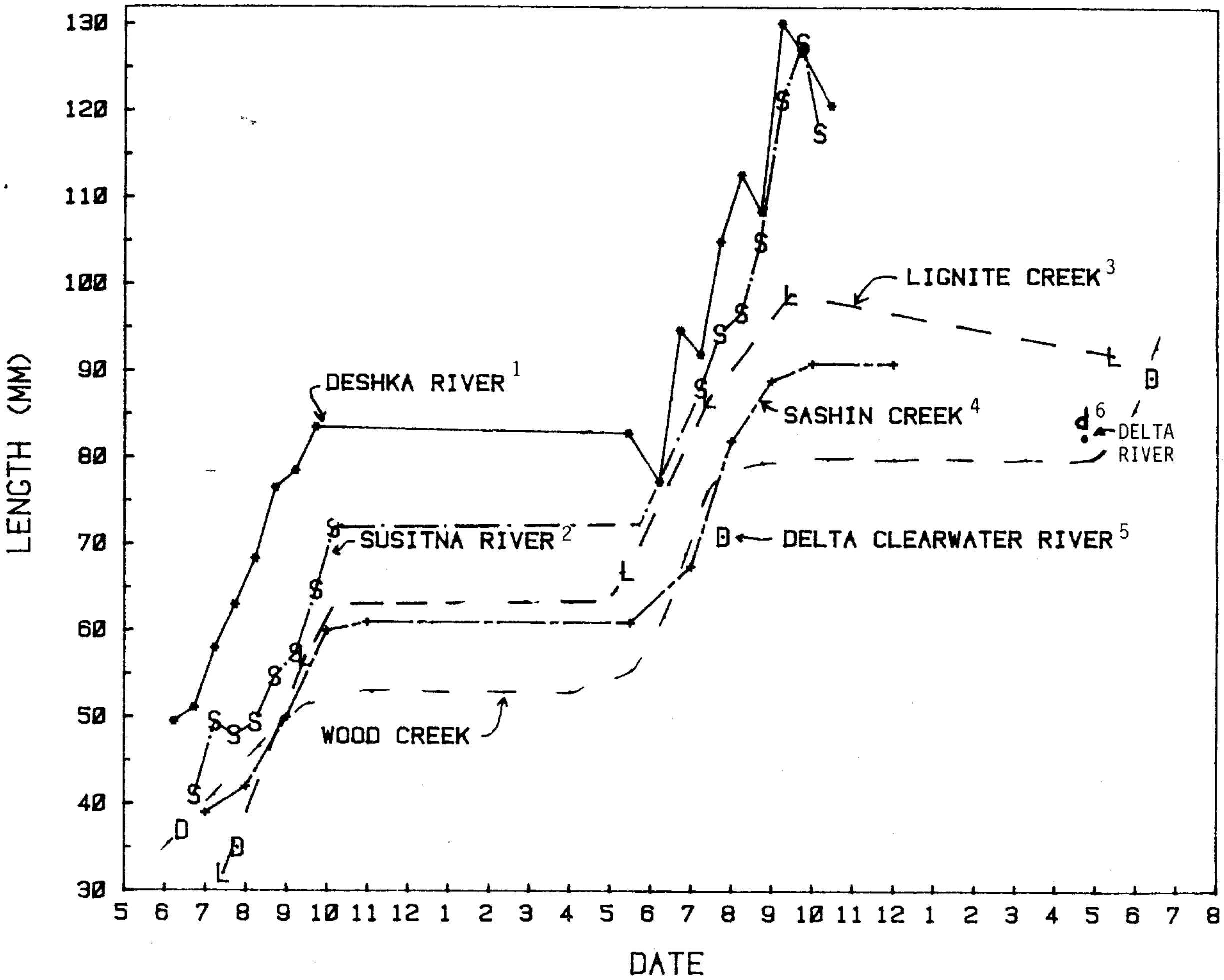


Figure 7. Length of wild juvenile coho salmon as a function of date in Alaska. Sources: 1, Delaney et al. (1981); 2, Roth and Stratton (1985); 3, Tarbox and Scott (1979); 4, Crone and Bond (1976); 5, Pearse (1974); 6, Francisco (1977). Data points are lacking for lengths in the Susitna River and in Lignite Creek early in the second growing season. In this figure, it is assumed that no growth occurred during the first winter in these streams.

affect the growth of juvenile coho salmon. This is also reflected in the different growth rates observed in pairs of streams that are closely located, such as Lignite and Wood creeks in interior Alaska and the Susitna and Deshka rivers in south central Alaska.

Migration Timing:

A summary of salmon smolt catches in the Yukon River drainage is given in Table 10. These data indicate an early start of emigration for coho salmon compared to chum and chinook salmon. Pearse (1974) concluded from his capture rate that most coho smolts had left the Delta Clearwater River sometime before late May. Furthermore, he collected some coho smolts in the Tanana River near the mouth of the Delta River in late March. These fish appeared to be migrating downstream since they were captured in the current (Gary Pearse, personal communication). Francisco (1977) collected coho smolts leaving the Delta River between 14 April and 25 May. However, these fish probably emigrated from the Delta Clearwater River at an earlier time and had entered the Delta River to feed on chum fry, which are abundant there in the spring. Gissberg and Benning (1965) and Barton (1978) collected salmon smolts in the Yukon River. In neither of these studies were coho smolts collected during periods when chum and chinook smolts were present. Similarly, smolt trapping in Clear Creek and in the Tanana River in May and June resulted in the capture of only small numbers of coho smolts in May (Raymond and Skaugstad 1986).

The apparent early start of migration for interior Alaska coho salmon appears to contradict the observation of Drucker (1972, see Figure 8) that coho smolt migration starts progressively later at higher latitudes. The probable explanation for the early start of migration in the Interior, as well as the smaller size at the start of the migration, is the long migration distance. If the times at which coho smolts arrived in salt-water,

Table 10. Collections of salmon smolts in interior Alaska.[1]

| Location | | Dist.[2] (km) | Sampling period | Catch chum | Catch chinook | Catch coho | Ref[a] |
|---|---|---|---|---|---|---|---|
| Yukon River | | 101 | 7 Jun- 7 Jul | 275 | 14 | 0[b] | 1 |
| Tanana R. | 1983 | 1373 | 9 May-23 Jun | 274 | 131 | 5 | 2 |
| | 1984 | | 14 May- 6 Jul | 201 | 26 | 1[c] | 2 |
| Clear Ck. | 1981 | 1390 | 30 Apr- 4 Jun | 842[d] | [e] | [e] | 2 |
| | 1982 | | 6 May-20 Jun | 717[d] | 103[f] | 12 | 2 |
| | 1983 | | 2 May-26 May | 159[d] | 63 | 9 | 2 |
| Yukon River | | 1440 | 6 May-24 Aug | 474 | 57 | 0 | 3 |
| Delta River | | 1655 | 1 Apr-25 May | 1426 | 22[g] | 104[g] | 5 |
| Tanana R. | 1973 | 1660 | 27 Mar-30 Mar | 0 | 0 | ~10 | 2,6 |
| Delta Clearwater | | 1690 | 25 May-27 Jun | 0 | 0 | 16 | 4 |

[1] Excluding studies on streams with no known coho salmon populations.

[2] Distance from the Yukon River mouth.

[a] 1: Barton (1978); 2: Raymond and Skaugstad (1986); 3: Gissberg and Benning (1965); 4: Pearse (1974); 5: Francisco (1977); 6: Gary Pearse (personal communication).

[b] Plus 4 fingerlings (average length 50 mm).

[c] Plus 3 fingerlings (average length 46 mm).

[d] Hatchery chum release.

[e] Combined catch of chinook and coho smolts was 532. Identifications were unreliable, but most were believed to be chinook.

[f] Mixed hatchery and wild smolts.

[g] Probably entered river to feed on chum fry.

instead of the times of the start of migration, were compared, the migration of interior coho salmon would be more consistent with Drucker's observation of later migrations at higher latitudes.

Our observation that Wood Creek wild coho salmon spend 2 years in freshwater before emigrating is in general agreement with other reports on Yukon River coho salmon. However, others have found that some Yukon River coho juveniles spend only 1 year in freshwater, while others spend 3 years (Table 11). Gilbert (1922) and Sato (1961) reported relatively large percentages of coho salmon in the 1.1 age class. However, Gilbert cautioned that his results may be unreliable because of the small sample size. Sato's results may also be unreliable for this reason.

Yearling Population:

During the 4-year study period, estimates of the wild yearling population in Wood Creek ranged from 76,000 to 86,000 at the time of the hatchery releases in early May. This apparently stable population does not seem to be a result of the stream's carrying capacity for yearlings because the 1982, 1984 and 1985 hatchery releases approximately doubled the yearling population without strongly affecting growth. It seems more likely that fry production in Wood Creek exceeds the stream's carrying capacity for fry. This would result in a relatively constant fry population at the end of the first summer and, therefore, a relatively constant yearling population in the following spring. This is in agreement with the findings of Crone and Bond (1976), who studied coho salmon in Sashin Creek in southeastern Alaska. They found a relatively constant yearling population despite variations in escapement.

Table 11. Age classes of Yukon River wild coho salmon adults.

| Location | n | Age Class 1.1 | 2.1 | 2.2 | 3.1 | Ref.[a] |
|---|---|---|---|---|---|---|
| Yukon River (mouth?) | 31 | 38.7 | 58.1 | | 3.2 | 1 |
| Yukon River (mouth?) | 18 | 55.6 | 44.4 | | | 2 |
| Yukon River mouth | 619 | 13 | 75 | | 12 | 3 |
| Wood Creek | 135 | | 98.5 | 1.5 | | 4 |
| Delta Clearwater River | 58 | | 100 | | | 5 |
| Delta Clearwater River | 250 | 4 | 75 | | 21 | 3 |

[a] 1: Gilbert (1922); 2: Sato (1961); 3: Buklis and Wilcock (1985); 4: this report; 5: Pearse (1974).

## Mixed Wild and Hatchery Coho Juveniles

Growth:

When 59,700 hatchery fish were stocked in Wood Creek in 1982, little effect on the growth of wild yearlings or fry was observed. When the release was increased to 167,700 in 1983, substantial decreases in growth rate were observed in both the wild fry and the hatchery fish. The wild yearlings may have also experienced a reduced growth rate, but the data were inconclusive. When the stocking was decreased to 82,500 in 1984, a small decrease in the growth rate of wild yearlings and a larger decrease in the growth of fry were observed. However, holdovers from the 1983 release may have been partly responsible for these decreases. In 1985, when a similar number of fish was released and when no holdovers were present, normal growth rates were observed for both fingerlings and fry.

It appears from these data that Wood Creek is capable of supporting a total fingerling population of approximately 160,000 (80,000 wild yearlings plus 80,000 hatchery fingerlings) without a significant decrease in growth.

The low growth rates observed in Wood Creek in 1983 appeared to be the result of insufficient food or habitat caused by overpopulation. Growth did not appear to be limited by low temperatures or low food production, since normal growth was simultaneously observed in a nearby area (Carter Slough) that was unaffected by the hatchery fish.

Competition:

Apparent differences in growth rate between wild and hatchery fingerlings in Wood Creek were observed in three of the four growing seasons covered in this study. Usually the group with the smaller fish at the beginning of the growing season showed a lower growth rate than the group with the larger fish. In 1983 when hatchery fish were released at a size that was probably smaller than the size of the wild yearlings, the hatchery fish appeared to experience poor growth (Figure 4). On the other hand, in 1982 and 1984 the hatchery fish were released at a size that was slightly above the expected size of wild yearlings. In those years, the growth of the wild yearlings appeared to be slightly depressed (Figures 3 and 5). In 1985, the size of the wild and hatchery fingerlings were about the same at the beginning and the end of the growing season (Figure 6). It is not clear why the size of the wild yearlings was near normal in June 1985, when their growth appeared to be retarded in 1984.

The appearance of growth rate differences during the 1982-1984 growing seasons may have been the result of sampling errors. However, it is also possible that an initial size difference between two groups of fish can be magnified by competition when food supplies are not abundant (Moav and Wohlfarth 1974). This can occur because the larger fish will become dominant, grow faster and repress the growth of smaller fish. Chapman (1962), found that social dominance among coho fry was determined by very small differences in size, and Mason and Chapman (1965), found that early emergent coho fry increased their initial size advantage over late emerging fry during the summer. Other examples of magnification of size differences through competition have been reported for carp, Cyprinus carpio, (Wohlfarth and Moav 1972; Moav and Wohlfarth 1974), a Cyprinodont fish, Orysias latipes, (Magnuson 1962), and a sunfish, Lepomis cyanellus, (Greenberg 1947).

Yearling-to-Adult Survival:

It is not clear why the survival to adulthood of the 1982 release of hatchery fish appeared to be lower than that of the wild fish. As previously mentioned, some or all of the hatchery fish released into Clear Creek may have failed to return to Wood Creek.

This could have been the result of limited availability of food or rearing habitat, obstruction to emigration by the beaver dams, or a reluctance of adults to migrate up Wood Creek (a separate marking program to evaluate the Clear Creek releases was begun in 1985). The hatchery fish also may have experienced a higher mortality than the wild fish, since they were entering an unfamiliar environment. Another possibility is that the wild yearling population was higher than the estimated 76,000 because of a sampling bias. Elsewhere in Alaska, losses of marked fish have frequently caused underestimation of hatchery returns (Ken Leon, Alaska Dept. of Fish & Game, personal communication). As previously mentioned, a scale analysis (Appendix B) was consistent with low losses of marked fish in the present study, but it didn't exclude the possibility that mark losses occurred.

Adult returns in 1985 indicated that the fingerling-to-adult survival of the 1983 release of hatchery fish was also lower than that of the wild fish. However, a weak return of hatchery fish was expected because of their retarded growth rate and delayed emigration from Wood Creek. The overall survival rate may increase if some of these fish return in 1986.

Because of the accelerated rearing program in the hatchery, the major difference between the hatchery and wild coho fingerlings was that the hatchery fish were 1 year younger. There is some evidence that accelerated rearing can lead to lower adult returns. Donaldson and Brannon (1976) reported adult returns of 0.39% to 6.42% (an average of 2.5%) on releases of 6- to 15-g smolts. Bilton and Jenkinson (1980) and Bilton (1982) reported returns of 0.6% to 2.48% on releases of 10-to 15-g smolts. These returns were lower than the returns of normally reared coho smolts (Bilton and Jenkinson 1980; Bilton 1982). Bilton was unsure of the reason for the low survival, but he suspected that the fish were not physiologically ready for the transition to salt water. This explanation should not apply to the present study because the hatchery fish were released at a smaller size (approximately 2 g) and remained in freshwater for a full year before emigrating. However, some other undetermined effect of accelerated rearing may be present.

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# APPENDIX A

Appendix Table 1. Juvenile coho salmon catches near Clear Hatchery, 1978-1985. The total catch was separated into wild fry, and wild and hatchery fingerlings primarily according to size. The fingerlings were then separated into wild and hatchery fish based on the occurrence of marked fish in the samples (see Materials and Methods).

| | | | Wild fry | | | | | Wild yearlings | | | | | Hatchery fingerlings | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Length (mm) | | Weight (g) | | | Length (mm) | | Weight (g) | | | Length (mm) | | Weight (g) | | |
| Date | Loc[1/] | N | n | ave | range | ave | range | n | ave | range | ave | range | no.[2/] | ave | range | ave | range | % of fing.[3/] |
| 25-Jul-78 | 10 | 15 | 9 | 56.3 | 47-66 | 1.95 | 0.96-3.27 | | | | | | 0 | | | | | |
| 04-Jul-79[a/] | 10 | 20 | 17 | 51.2 | 41-59 | 1.55 | 0.81-2.35 | 3 | 73.0 | 66-80 | 4.65 | 3.41-6.17 | | | | | | 0 |
| 07-May-81[b/] | 11 | 3 | 0 | | | | | 0 | | | | | | | | | | |
| | | | | | | | age 2 | 3 | 81.4 | 81-83 | 4.26 | 3.67-5.24 | | | | | | |
| 30-Sep-81 | 7 | 35 | 25 | 52.2 | 44-58 | 1.64 | 0.96-2.25 | 10 | 82.2 | 74-91 | 6.27 | 4.76-7.8 | | | | | | 0 |
| 12-May-82 | 1 | 12 | 0 | | | | | 0 | | | | | 12 | 57.3 | 51-64 | 2.07 | | |
| 18-May-82 | 13 | 5 | 3 | 30.7 | 29-32 | | | 2 | 63 | 60-66 | | | 0 | | | | | 0 |
| 26-May-82[c/] | 11 | 4 | 0 | | | | | 0 | | | | | | | | | | |
| | | | | | | | age 2 | 4 | 85.3 | 76-93 | 6.05 | 3.9-7.6 | | | | | | |
| 28-May-82 | 4 | 92 | 3 | 34 | 30-37 | | | 58 | 49.6 | 38-69 | 1.14[d/] | | 6AD(30) | 53.2 | 48-59 | 1.14[d/] | | 34 |
| | | | | | | | age 2 | 1 | 92 | | | | | | | | | |
| 21-Jul-82 | 7 | 82 | 61 | 42.3 | 32-50 | 0.71 | | 0 | | | | | 5AD(25) | 81.0 | 77-89 | | | 100 |
| | | | | | | | | | | | | | 21 | 78.6 | 69-94 | 4.65 | | |
| 07-Oct-82 | 7 | 116 | 95 | 51.8 | 43-61 | 1.48 | | 21 | 72.3 | 63-82 | 4.15 | | 0 | | | | | 0 |
| 08-Oct-82 | 8 | 51[e/] | 2 | 56.5 | 55-58 | 2.17 | | 14 | 87.7 | 70-99 | 7.84 | | 7AD(35) | 89.6 | 82-102 | 7.49 | | 71 |
| 7+8-Oct-82 | 7,8 | 167 | 97 | 51.9 | 43-61 | 2.17 | | 35 | 78.5 | | 5.75 | | --------same as loc 8-------- | | | | | 50 |
| 24-Nov-82 | 5 | 184 | 66 | 54.8 | 41-67 | 1.63 | 0.6-3.0 | 73 | 80.1 | | 5.15 | | 9AD(45) | 86.3 | 76-101 | 6.73 | 4.0 -10.4 | 38 |
| 24-Nov-82 | 7 | 22 | 19 | 51.4 | 45-62 | 1.25 | 1.1-2.2 | 3 | 76.0 | 73-79 | 4.1 | 3.6 -4.7 | 0 | | | | | 0 |
| 24-Nov-82 | 5,7 | 206 | 85 | 54.1 | 41-67 | 1.54 | 0.6-3.0 | 76 | 80.0 | 68-95 | 5.11 | | -------------same as loc 5------------- | | | | | 37 |
| 03-Feb-83 | 4 | 48 | 48 | 48.3 | 40-56 | 0.85 | | 0 | | | | | 0 | | | | | |
| 03-Feb-83 | 2 | 94 | 85 | 47.0 | 36-61 | 0.88 | | 9 | 74.2 | 67-84 | 3.48 | | 0 | | | | | 0 |
| 03-Feb-83 | 2,4 | 142 | 133 | 47.5 | 36-61 | 0.87 | | -----same as loc 2----- | | | | | 0 | | | | | 0 |
| 05-May-83 | 1 | 33 | 0 | | | | | 0 | | | | | 4LV(36) | 51.0 | 42-60 | 1.62 | 0.82-2.62 | 100 |
| | | | | | | | | | | | | | 33 | 51.5 | 39-69 | 1.76 | 0.71-4.21 | |
| 22-May-83[f/] | 11 | 9 | 0 | | | | | 0 | | | | | | | | | | |
| | | | | | | | age 2[g/] | 9 | 95.1 | 76-113 | 9.75 | 4.9 -14.45 | | | | | | |

(continued)

Appendix Table 1. (Continued)

| Date | Loc[1/] | N | Wild fry n | Wild fry Length (mm) ave | Wild fry Length (mm) range | Wild fry Weight (g) ave | Wild fry Weight (g) range | Wild yearlings n | Wild yearlings Length (mm) ave | Wild yearlings Length (mm) range | Wild yearlings Weight (g) ave | Wild yearlings Weight (g) range | Hatchery fingerlings no.[2/] | Hatchery fingerlings Length (mm) ave | Hatchery fingerlings Length (mm) range | Hatchery fingerlings Weight (g) ave | Hatchery fingerlings Weight (g) range | % of fing.[3/] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 01-Jun-83 | 4 | 218 | 0 | | | | | 56 | 61.6 | | 2.57 | | 18LV(161) | 43.6 | 36-49 | 0.86 | 0.49-1.26 | 74 |
| | | | | | | | age 2? | 1 | 95 | | 9.75 | | | | | | | |
| 01-Jun-83 | 3 | 50 | 44 | 31.0 | 27-33 | 0.26 | 0.16-0.36 | 6 | 37.2 | 34-47[d/] | 0.53 | 0.35-1.15[d/] | 0 | | | | | 0 |
| 01-Jun-83 | 3,4 | 268 | ----------same as loc 3------------ | | | | | 62 | 59.2 | 46-70[d/] | 2.38 | 0.5 -3.77[d/] | --------------same as loc 4-------------- | | | | | 72 |
| | | | | | | | age 2? | -----same as loc 4------ | | | | | | | | | | |
| 08-Aug-83 | 4 | 73 | 28 | 41.1 | 30-48 | 0.78 | 0.20-1.26 | 0 | | | | | 6LV(54) | 58.5 | 52-65 | 2.19 | 1.42-2.83 | 100 |
| | | | | | | | | | | | | | 45 | 55.9 | 49-69 | 2.01 | 1.23-3.67 | |
| 07-Sep-83 | 4 | 113 | 63 | 44.5 | 36-51 | 0.81 | 0.41-2.21 | 5 | 84.6[h/] | | 3.98[h/] | | 5LV(45) | 56.8 | 52-68 | 1.64 | 1.22-2.56 | 90 |
| 09-Sep-83 | 8 | 56 | 19 | 45.2 | 39-51 | 1.00 | 0.58-1.44 | 28 | 63.5 | | 3.14 | | 1LV(9) | 70 | | 3.09 | | 24 |
| 7+9-Sep-83 | 4,8 | 169 | 82 | 44.6 | 36-51 | 0.85 | 0.41-2.21 | 33 | 66.4 | | 3.26 | | 6LV(54) | 59.0 | 52-57 | 1.88 | 1.22-3.09 | 62 |
| 08-Oct-83 | 12 | 203 | 170 | 53.0 | 36-68 | 1.42 | 0.31-3.19 | 33 | 79.2 | 69-104 | 4.85 | 2.68- 9.61 | 0 | | | | | 0 |
| 13-Oct-83 | 4,6 | 187 | 120 | 45.6 | 33-57[i/] | 0.86 | 0.29-1.79[i/] | 40 | 81.3 | 60-116 | 5.24 | 1.85-14.48 | 3LV(27) | 44.0 | 40-50 | 0.74 | 0.59-1.00 | 40 |
| 05-Feb-84 | 4 | 33 | 10 | 47.5 | 44-50 | 0.81 | 0.58-0.94 | 23[g/] | 71.2 | 56-87 | 2.95 | 1.16-5.07 | 0 | | | | | 0 |
| 03-May-84 | 1 | 29 | 0 | | | | | 0 | | | | | 29 | 58.0 | 44-67 | 2.44 | 0.80-3.70 | |
| 30-May-84 | 9 | 175 | 0 | | | | | 0 | | | | | 37RV(244) | 59.3 | 49-71 | 2.26 | 1.22-4.05 | 100 |
| | | | | | | | | | | | | | 175 | 59.8 | 46-72 | 2.37 | 1.22-4.48 | |
| 30-May-84 | 4 | 151 | 0 | | | | | 95 | 58.2 | 43-95[d/] | 2.35 | 0.79-9.05[d/] | 4LV(36) | 75.5 | 65-88 | 4.82 | 2.84-7.79 | |
| | | | | | | | | | | | | | 3RV(20) | 61.7 | 59-64 | 2.57 | 2.22-2.94 | 17 |
| 30-Jul-84 | 9 | 53 | 0 | | | | | 0 | | | | | 10RV(66) | 70.1 | 62-80 | 3.95 | 2.90-6.02 | 100 |
| | | | | | | | | | | | | | 53 | 69.3 | 54-85 | 3.79 | 1.69-6.48 | |
| 30-Jul-84 | 4 | 79 | 0 | | | | | 49 | 70.1 | 57-88[d/] | 4.05 | 2.27- 8.81[d/] | 3LV(27) | 80.0 | 76-82 | 6.92 | 5.27-7.93 | |
| | | | | | | | age 2? | 3 | 93.3 | 92-96 | 9.79 | 9.01-11.18 | | | | | | |
| 30-Jul-84 | 6 | 34 | 34 | 40.7 | 34-49 | 0.82 | 0.45-1.48 | 0 | | | | | 0 | | | | | 0 |
| 10-Oct-84 | 4 | 148 | 142 | 46.0 | 34-58 | 1.17 | 0.44-2.24 | 6 | 68.2 | 64-72[d/] | 3.73 | 2.94- 4.63[d/] | 0 | | | | | 0 |
| 10-Oct-84 | 8 | 78 | 8 | 57.0 | 52-59 | 2.26 | 1.46-2.76 | 37 | 78.9 | 62-97[d/] | 6.39 | 2.90-11.66[d/] | 5RV(33) | 84.4 | 78-91 | 7.71 | 6.04-10.73 | 47 |
| 10-Oct-84 | 4,8 | 226 | 150 | 46.6 | 34-59 | 1.23 | 0.44-2.76 | 43 | 77.5 | 62-97[d/] | 6.01 | 2.90-11.66[d/] | -------------same as loc 8------------- | | | | | 43 |
| 10-Oct-84 | 9 | 38 | 0 | | | | | 0 | | | | | 3RV(20) | 73.7 | 70-79 | 4.41 | 3.82- 5.48 | 100 |
| | | | | | | | | | | | | | 38 | 77.2 | 62-90 | 5.07 | 2.46- 7.78 | |

(continued)

Appendix Table 1. (Continued)

| | | | Wild fry | | | | | Wild yearlings | | | | | Hatchery fingerlings | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Length (mm) | | Weight (g) | | | Length (mm) | | Weight (g) | | | Length (mm) | | Weight (g) | | % of |
| Date | Loc[1] | N | n | ave | range | ave | range | n | ave | range | ave | range | no.[2] | ave | range | ave | range | fing.[3] |
| 27-Feb-85 | 2 | 53 | 23 | 44.4 | 34-65 | 0.97 | 0.37-3.14 | 10 | 79.9 | 76-98[d] | 5.11 | 4.68-10.49[d] | 3RV(20) | 91.0 | 89-94 | 8.07 | 7.68-8.77 | 67 |
| 03-May-85 | 1 | 56 | 0 | | | | | 0 | | | | | 56 | 55.5 | 47-63 | 2.11 | 1.24-3.26 | 100 |
| 17-Jun-85 | 2 | 55 | 55 | 33.1 | 29-39 | 0.35 | 0.16-0.67 | 0 | | | | | 0 | | | | | 0 |
| 17-Jun-85 | 4 | 84 | 51 | 37.8 | 33-45 | 0.60 | 0.32-1.10 | 28 | 53.9 | 46-65 | 1.90 | 0.74-3.32 | 1AD(5) | 53 | | 1.72 | | 15 |
| 17-Jun-85 | 7 | 13 | 0 | | | | | 7 | 73.3 | 71-78 | 5.01 | 4.25-6.30 | 1AD(5) | 63 | | 2.96 | | 42 |
| | | | | | | | age 2? | 1 | 88 | | 8.29 | | | | | | | |
| 17-Jun-85 | 2,4,7 | 152 | 106 | 35.4 | 29-45 | 0.47 | 0.16-1.10 | 34 | 57.7 | 46-78 | 2.52 | 0.74-6.30 | 2AD(11) | 58.0 | 53-63 | 2.34 | 1.72-2.96 | 24 |
| 17-Jun-85 | 9 | 68 | 0 | | | | | 0 | | | | | 10AD(74) | 60.2 | 51-69 | 2.59 | 1.37-3.78 | 100 |
| | | | | | | | | | | | | | 68 | 62.6 | 51-71 | 2.89 | 1.37-4.51 | |
| 25-Jul-85 | 4 | 114 | 105 | 41.8 | 30-51 | 0.87 | 0.27-1.65 | 0 | | | | | 3AD(16) | 68.3 | 63-72 | 3.89 | 2.95-4.64 | 100 |
| | | | | | | | | | | | | | 9 | 64.2 | 54-81 | 3.47 | 2.02-6.84 | |
| 25-Jul-85 | 7 | 30 | 1 | 53 | | 1.94 | | 24 | 77.8 | 62-98 | 6.00 | 2.86-10.98 | 1AD(5) | 77 | | 5.36 | | 17 |
| 25-Jul-85 | 4,7 | 144 | 106 | 41.9 | 30-53 | 0.88 | 0.27-1.94 | 16 | 80.0 | 74-98 | 6.78 | 2.86-10.98 | 4AD(22) | 70.5 | 63-77 | 4.26 | 2.95-5.36 | 58 |
| 15-Oct-85 | 8 | 352[k] | 140 | 52.8 | 38-68 | 1.90 | 0.51-5.91 | 102 | 86.0 | 69-122 | 8.25 | 2.58-21.63 | 20AD(110) | 84.1 | 78-90 | 7.32 | 5.18-10.10 | 52 |

1/ Locations are shown in Figure 1.

2/ The lengths and weights of hatchery fish are expressed in two ways. One set of measurements is based on marked fish only, in which case the number of fish in the sample is expressed as xM(n) where x is the number of marked fish, M is the mark type (AD = adipose clip, LV = left ventral clip, RV = right ventral clip), and (n) is the expected number of hatchery fish in the sample. Lengths and weights on the same line refer to the marked fish only. If the expected number of hatchery fish exceeded the number of fingerlings caught, then it is assumed that all fingerlings were of hatchery origin. In that case, the catch and average lengths and weights of all the fingerlings is also given.

3/ Percent of the fingerlings that are of hatchery origin.

a/ Combination of catches made in period 2-6 July.

b/ Combination of catches made on 2 and 12 May.

c/ Combination of catches made in period 20 May-1 June.

d/ Wild yearlings and hatchery fish combined.

e/ Non-random sample. Total catch was 500 of which about 450 unmarked were released.

f/ Combination of catches made in period 19-25 May.

g/ Sample may not include hatchery fish.

h/ Unreliable due to small sample size.

i/ Wild age 0 and hatchery fish combined.

k/ Approximately 1500 captured in one seine haul. All but 352 were released.

Appendix Table 2. Water temperatures in the Wood Creek area.

| Date | Location[a/] | Temperature (°C) |
|---|---|---|
| 25-Jul-78 | 10 | 9.5 |
| 7-May-81 | 11 | 7.0 |
| 26-May-82 | 11 | 9 |
| 7-Oct-82 | 7 | 4.0 |
| 8-Oct-82 | 8 | 0.5 |
| 24-Nov-82 | 7 | 1.8 |
| 22-May-83 | 11 | 7.0 |
| 8-Aug-83 | 4 | 6.7 |
| 7-Sep-83 | 4 | 5.0 |
| 13-Oct-83 | 4 | 3.0 |
| 30-May-84 | 4 | 5.0 |
| 30-May-84 | 9 | 4.0 |
| 30-Jul-84 | 4 | 4.7 |
| 30-Jul-84 | 9 | 5.8 |
| 27-Feb-85 | 2 | 1.5 |
| 17-Jun-85 | 2 | 10.6 backwaters |
| 17-Jun-85 | 2 | 7.2 in current |
| 17-Jun-85 | 4 | 7.65 |
| 17-Jun-85 | 7 | 10.8 |
| 17-Jun-85 | 9 | 6.9 |
| 25-Jul-85 | 8 | 9.5 |

[a/] Locations are shown in Figure 1.

Appendix Table 3. Lengths and weights of marked and unmarked hatchery-produced coho salmon collected in Clear Creek, 17 June 1985.

| Group | Sample size | Length (mm) ave. | Length (mm) s.d. | Weight (g) ave. | Weight (g) s.d. |
|---|---|---|---|---|---|
| marked[a] | 10 | 60.20 | 6.01 | 2.59 | 0.78 |
| unmarked | 58 | 62.98 | 4.15 | 2.94 | 0.56 |

[a] Lacking an adipose fin.

APPENDIX B

# CALCULATION OF THE NUMBER OF HATCHERY-PRODUCED COHO SALMON RETURNING TO THE WOOD CREEK WEIR BASED ON SCALE PATTERNS

The age classes of adult coho salmon returning to the Wood Creek weir are shown in Appendix Table 4. The expected age class of the hatchery fish was 1.1, but about half of the marked salmon with readable scales were in the 2.1 age class. Thus, the age-2.1 hatchery fish at some point acquired a false freshwater annulus. This may have occurred while the fish were undergoing accelerated growth in the hatchery.

Since previous scale analyses of wild fish (Table 2) failed to find age-1.1 fish, the four unmarked fish in the age-1.1 group were probably all unmarked hatchery fish. Since marking shouldn't affect the age class or scale readability, the fraction of the fish that are age 1.1 should be the same for both marked and unmarked hatchery fish:

$$\frac{\text{No. age-1.1 fish}}{\text{No. marked hatchery fish}} = \frac{\text{No. age-1.1 fish}}{\text{No. unmarked hatchery fish}},$$

or,

$$\frac{16}{45} = \frac{4}{x}$$

where x is the number of unmarked hatchery fish. The fraction of the 40 unmarked fish that are of hatchery origin is thus

$$\frac{x}{40} = \frac{(4)(45)}{(16)(40)} = 0.281$$

Because of the small sample size, the standard deviation for the above estimate, 0.14, is rather large (Kit Rawson, Alaska Department of Fish & Game, personal communication).

This fraction can then be applied to the entire run:

$$\frac{\text{number of unmarked hatchery fish}}{\text{total number of unmarked fish}} = 0.281$$

The numerator is equal to $H - n_m$, where H is the number of hatchery fish in the return and $n_m$ is the number of marks recovered (578). The denominator is equal to $N - n_m$ where N is the total return (8,805). Solving for H, we have

$$H = 578 + 0.281\ (8{,}805 - 578) = 2{,}890$$

with a standard deviation of 0.14 (8,805-578) = 1,152. Thus, the 80% confidence interval is 2,890 $\pm$ 1.282 (1,152) = 1,410 - 4,370. The expected value for H is close to the value of 2,900 obtained using adipose finclips, but the precision with which it is known is low.

A loss of marked fish could result from either mortality due to marking or to regeneration of clipped adipose fins. The above results are consistent with, but not proof of, the absence of such losses.

Appendix Table 4. Age classes of adult coho salmon collected at the Wood Creek weir in 1984.

| | | Age | | |
|---|---|---|---|---|
| Type | n | 1.1 | 2.1 | unread-able |
| MALE | | | | |
| unmarked | 20 | 3 | 11 | 6 |
| marked | 20 | 7 | 7 | 6 |
| FEMALE | | | | |
| unmarked | 20 | 1 | 15 | 4 |
| marked | 25 | 9 | 11 | 5 |
| MALE & FEMALE | | | | |
| unmarked | 40 | 4 | 26 | 10 |
| marked | 45 | 16 | 18 | 11 |