AN ABSTRACT OF THE THESIS OF

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Title: FACTORS AFFECTING THE SMOLT YIELD OF COHO SALMON
(ONCORHYNCHUS KISUTCH) IN THREE OREGON STREAMS

Abstract approved: Redacted for privacy
James D. Hall

Data from the coho salmon migration were examined from three streams of the Alsea Watershed Study, conducted on tributaries to Drift Creek, Oregon, from 1959 through 1973. With the migration season defined as November 1 through May 31, the mean seasonal smolt count was 2022 fish in Deer Creek, 665 in Flynn Creek, and 277 in Needle Branch. A general decline in numbers in the later years of the study was countered by a significant increase in mean length. The peak migration time was in late March and early April in each stream.

A general approach to correlate physical and biological factors to the total seasonal smolt count in each stream through single regression analyses was mostly unsuccessful. A hypothesized positive relationship between summer discharge and smolt yield could not be supported, either by using mean monthly or mean maximum flows. A negative relationship between winter discharge and smolt count was hypothesized, due to increased mortality from higher flows. This hypothesis was supported by significant regressions that included mean January flows and mean highest flows. Summer temperatures (mean monthly and mean maximum for

7, 15, and 30 days) showed little correlation with the smolt output. Suspended sediment concentrations were negatively correlated with the number of smolts, as expected from the close relationship between sediment and streamflow. September biomass of juveniles in Flynn Creek was significantly related to the smolt output, though the relationships were weaker in the other two streams. The number of spawning females was positively related to the resulting smolt count but the correlations were not significant. Cutthroat trout biomass showed very little correlation with the coho smolt output.

Combinations of variables in multiple regression analyses proved generally more successful than the single correlations with smolt count, but interpretation of the variables that proved significant was not always clear. For Deer Creek, 63.9% of the variability in smolt yield could be explained by the regression with September biomass and mean May maximum temperatures. September biomass, January discharge, and mean sediment concentration accounted for 80.7% of the variability in Flynn Creek smolt output. Only 53.8% of the variability in Needle Branch smolt count could be adequately explained (from January discharge and timing of the mean lowest discharge for 15 days), perhaps due to changes in stream variables following logging. When total smolt weight (biomass) was used as the dependent variable instead of count, only the Flynn Creek regression was significant ($R^2=0.888$, with September biomass, mean lowest discharge for 15 days, and spawning female count). It is evident from these analyses that the juvenile populations in each stream have different relationships with various physical and biological factors.

Other studies have shown strong positive relationships between commercial catch of coho salmon off Oregon and Washington and streamflow two years previously, corresponding to the freshwater residence period of the juveniles. In this study, however, negative relationships between winter discharge and smolt output were found. It seems that this negative correlation is masked by downstream, estuary, or ocean factors that are inherent in the relationships between catch and flow.

Factors Affecting the Smolt Yield of Coho Salmon (Oncorhynchus kisutch) in Three Oregon Streams

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INTRODUCTION

There has been considerable concern expressed recently about the status of coho salmon (_Oncorhynchus kisutch_) along the Pacific Coast of North America. General declines in natural spawning stocks have sparked interest in factors that may be responsible. Although many workers have examined fluctuations in commercial catch and escapement (Gunsolus 1978; Scarnecchia 1978), few have investigated factors that may affect juveniles during their freshwater period of residence.

The purpose of this study was to examine data on the smolt yield from three small tributaries to Drift Creek, Oregon, where populations were inventoried during the Alsea Watershed Study from 1959 through 1973. Aspects of the smolt migration, including magnitude, length, weight, and timing, were investigated. In addition, physical and biological factors that may cause some of the variability in smolt output were analyzed.

A brief freshwater sketch of coho in the study streams begins with adult spawning, generally taking place from late fall through mid-winter. Fry migration occurs soon after emergence, from late winter through spring. Very few fish move downstream in the summer, but increasing numbers of juveniles (smolts) move downstream beginning late fall, peaking in the next spring. Variations in this temporal pattern, particularly in freshwater age and timing of migration, have been shown (Drucker 1972), but variability in the magnitude of adult, fry, and smolt yields has been little studied.

In most studies along the Pacific Coast of North America, variability in smolt output has been generally less than the variability in escapement or fry output (Table 1), as seen from lower coefficients of variation. Exceptions to this pattern were in Gnat Creek, Oregon (Willis 1962) and in Waddell Creek, California (Shapovalov and Taft 1954), with a slightly higher variability in smolt output than in female escapement.

Juvenile coho salmon populations in the Alsea Watershed Study streams were previously studied in an attempt to determine the influence of behavior on migration and population regulation (Chapman 1961; Au 1972). My study was an attempt to extend this earlier work by analysis of physical and biological factors that may be partly responsible for determining the level of smolt production. Physical factors studied included streamflow, temperature, and suspended sediment. Biological factors examined included in-stream biomass, adult migrations, and possible interactions with other species.

Table 1. Magnitude of adult and resulting fry and smolt migrations of some North American coho salmon stocks, arranged geographically from north to south ($\bar{X}$=mean; S.D.=standard deviation; C.V.=coefficient of variation).

Location	Years of Study	Stage[a]	$\bar{X}$	Range	S.D.	C.V.(%)	Reference
Sashin Cr., Alaska	1955-63	adult[b]	128	37-271	74.8	58.4	Crone and Bond 1976
		fry	2645	218-9923	3369	127	
		smolt	1713	928-2865	490	40.3	
Hooknose Cr., British Col.	1948-57	smolt	4987	2982-7959	1618	32.4	Hunter 1959
Minter Cr., Wash.	1938-53	adult[c]	629	98-1393	382	60.8	Salo and Bayliff 1958
		smolt	28,455	17,839-41,848	7337	25.8	
Gnat Cr., Oregon	1954-59	adult	41.4	26-67	16.3	39.4	Willis 1962
		smolt	2028	1013-3226	1045	51.5	
Spring Cr., Oregon	1950-57	adult	22.7	6-57	16.1	70.9	Skeesick 1970
		smolt	1385	816-1946	462	33.3	
Deer Cr., Oregon	1959-73	adult	27.2	8-56	13.6	50.0	
		fry	4656	44-12,382	3440	73.9	Present Study
		smolt	1944	738-2775	563	29.0	
Flynn Cr., Oregon	1959-73	adult	18.5	2-55	16.8	90.8	
		fry	7323	22-29,828	9529	130	Present Study
		smolt	620	140-1354	334	53.8	
Needle Br., Oregon	1959-73	adult	12.5	1-28	9.32	74.6	
		fry	6759	0-19,777	6399	94.7	Present Study
		smolt	285	76-470	128	44.9	
Waddell Cr., Calif.	1933-42	adult	109	22-287	82.8	76.0	Shapovalov and Taft 1954
		smolt	2040	152-4911	1594	78.1	

[a] The adult stage includes females only, except where noted.
[b] Partial counts of both males and females.
[c] Includes only those females allowed to spawn naturally above the weir.

STUDY AREA

The three streams are located in Lincoln County, approximately 16 km south of Toledo, Oregon (Moring and Lantz 1975). All three streams eventually flow into Drift Creek, and ultimately into Alsea Bay (Fig. 1). The watersheds lie between 140 and 490 m above sea level. They have average slopes between 34 and 40 percent (Table 2).

Table 2. Physical characteristics of Deer Creek, Flynn Creek, and Needle Branch watersheds (from Chapman 1961 and Moring and Lantz 1975).

Characteristic	Deer	Flynn	Needle
Watershed area	304 ha	202 ha	75 ha
Stream length studied	2324 m	1433 m	966 m
Mean summer width	1.80 m	1.74 m	1.10 m
Mean summer depth	11 cm	13 cm	7 cm
Mean surface area	4720 m^2	2660 m^2	1060 m^2
Stream gradient	0.018 m/m	0.025 m/m	0.014 m/m

These tributaries were selected for a study of the effects of clearcut and patchcut logging on the aquatic resources. The Needle Branch watershed was clearcut and later slash burned in 1966. No buffer strip was left along the streambank. No effort was made to protect the stream from logging activity, except eventually to clear debris from the channel (Moring and Lantz 1975). The Flynn Creek watershed was not logged and served as a control for the study. The Deer Creek watershed was partially clearcut in 1966. Three patches comprising about 25 percent of the watershed were cut, with buffer strips of vegetation left bordering the stream along the lower two patchcut units.

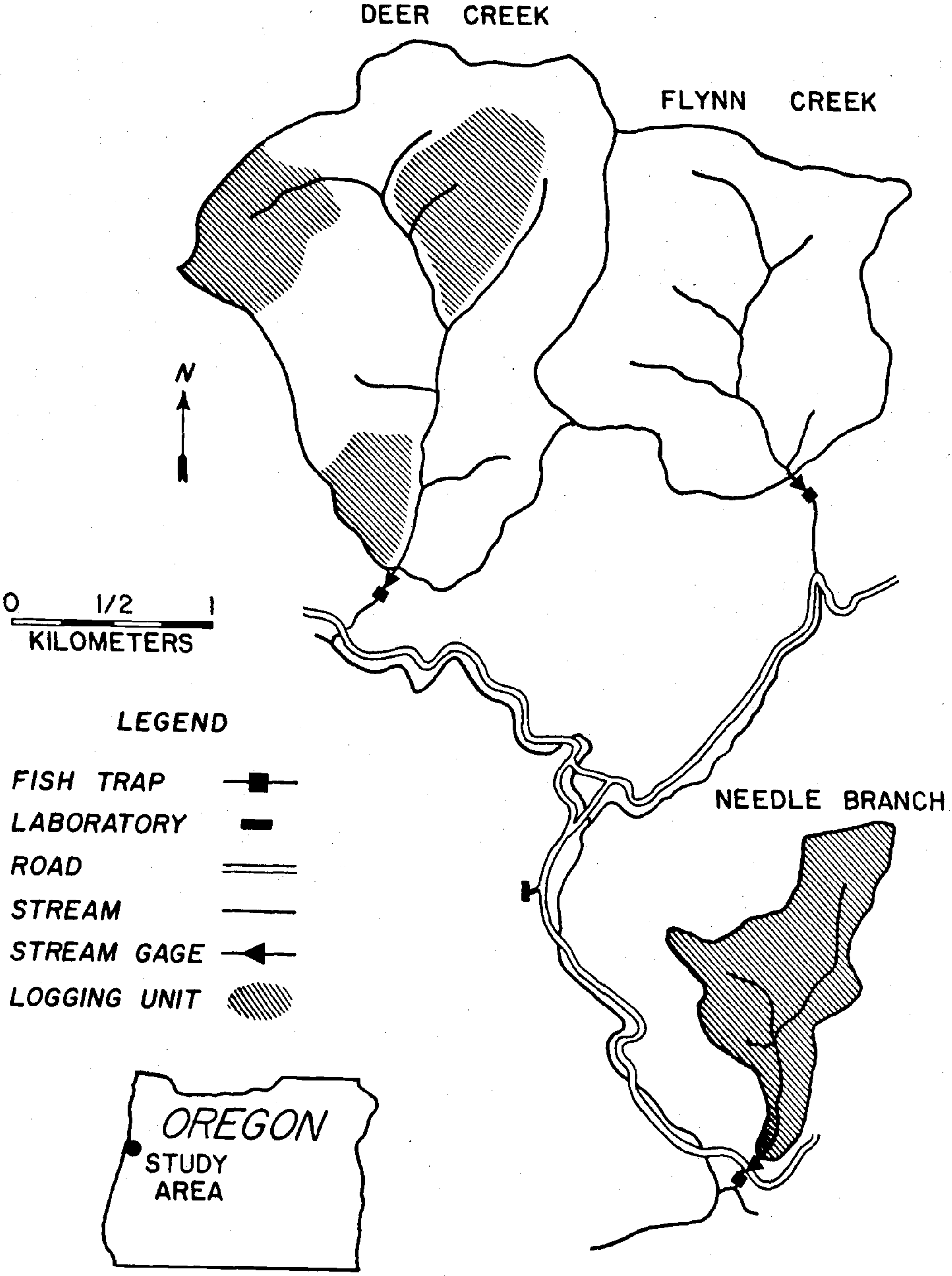

Figure 1. Map of the study watersheds.

The climate of the area is Pacific maritime. Mean annual precipitation is 244 cm (Hall and Lantz 1969). Most of this precipitation occurs as rain from October through March. Air temperatures range from about -7°C in winter to 32°C in summer (Au 1972).

A detailed description of the soil and vegetational characteristics of the area is given by Corliss and Dyrness (1965), but in general, forests of Douglas-fir predominate with an understory of vine maple, sword fern, and salal. Salmonberry and red alder are common along the streambanks. The stream substrate is sandstone (Au 1972).

Salmonid species present in the streams include coho salmon, chinook salmon (*Oncorhynchus tshawytscha*), coastal cutthroat (*Salmo clarki clarki*), and steelhead trout (*S. gairdneri gairdneri*). Steelhead trout and chinook salmon are rare and are found only in Deer Creek (Moring and Lantz 1975). Other fish species are the reticulate sculpin (*Cottus perplexus*), Pacific lamprey (*Entosphenus tridentatus*), and western brook lamprey (*Lampetra richardsoni*).

METHODS

Data for this study were available from several sources. Large fish traps constructed across all three streams allowed all adults moving upstream to be measured and weighed. Sex and condition were recorded. All juveniles moving downstream were measured and some were weighed in later years of the study. All other fish were enumerated (Moring and Lantz 1975). In addition, estimates of the biomass of juvenile coho in the stream in September are presented. Cutthroat trout biomass for 1962 and 1963 was estimated by Lowry(1964). For 1964 through 1973, estimates were made by the Oregon Department of Fish and Wildlife in September only. Data on daily temperature, streamflow, and sediment are presented in annual summary publications of the U.S. Geological Survey. Unpublished data of the Oregon Department of Fish and Wildlife and Oregon State University Department of Fisheries and Wildlife were used for smolt counts, lengths, and weights.

The timing of the smolt run is analyzed in terms of the median date of migration through the downstream trap on each stream. These dates are expressed in a modified Julian calendar, where each day is numbered consecutively, beginning with November 1 as day 1.

Mean smolt lengths are based on live fish only, yet because the smolt counts are based on live and dead fish, the differences between live and total fish need to be examined. This mortality was found to be 5 percent or less in all three streams. Another consideration is that only 76-83% of all smolts counted through the downstream traps were measured in the early years of the study. I assumed that the mean live lengths are fairly representative of the mean lengths of all the smolts counted.

Measurement of smolt weight at the downstream traps was begun in April 1968 in Needle Branch, April 1969 at Deer Creek, and February 1970 at Flynn Creek (Appendix Tables 1-3). However, because these weights are just a sample of all smolts measured for length, it cannot be assumed that these mean monthly smolt weights are representative for the entire migration. The value of these data is to develop length-weight regressions from which mean weights can be predicted from mean monthly smolt lengths.

Au (1972) found that slopes of the linear regressions of log weight on log length differed significantly between years. He therefore computed different regressions for each year class of fish. This method has been continued through the 1972-73 season. These regressions were calculated from a sample of 40 smolts each season, selected to represent the range of weights in each month. Correlations between log W and log L are all high (Appendix Table 4) and significant at $p=0.01$. Computed values of a and b in $W = aL^b$ from the 1963-64 through 1972-73 seasons (Appendix Table 5) are a combination of data from Au (1972) and more recent unpublished data. There is, however, a slight overlap in years in which regressions have been computed. Weight measurements were taken on both smolts and in-stream fish in 1967-68 and 1968-69 in Needle Branch and 1968-69 in Deer Creek. Differences in weight predictions between the two sets of regression results range from 0.01 to 0.42 g (Appendix Table 6). The mean percent differences are 6.25% and 4.56% in Needle Branch and 2.79% in Deer Creek. Because the percent differences are low and in both directions, Au's regressions could be used to predict smolt weights in the seasons when trap data were not available.

Mean monthly condition factors ($K = W/L^3 \times 10^5$) have been calculated only for those months with measured weight data. Total weight (biomass) of smolts has also been computed, on a seasonal basis from the product of mean seasonal weight per individual and the total seasonal smolt count. Prior to 1963, when no weight data are available, Au's (1972) 1963 length-weight relationships were used to estimate mean weights from mean seasonal lengths.

Stream gauging stations were set up near the outlets of the three watersheds in 1958 by the U.S. Geological Survey. Each station housed a continuous streamflow recorder and a recording themograph. Suspended sediment records are available throughout the study, from samples collected at the weirs in each stream (Moring 1975). Data were recorded in mean concentration (mg/l) and yield (tons/day).

Streamflow is first described in terms of mean monthly discharge. Although monthly flows may be important, the magnitude and timing of the lowest flow of the year may be more critical in affecting the smolt yield. Scarnecchia (1978) developed a FORTRAN program that read daily discharge for several years and computed the lowest flow for 60 consecutive days each year. Several modifications have been incorporated into this program (Appendix Table 7). This particular program calculates the lowest mean discharge for 30 consecutive days, and also prints the starting date (in Julian days with June 1 as day 1) for the lowest flow period each year. In this case, 60 consecutive days may not be sensitive enough in determining critically low flows. Mean flows would be lower, of course, in shorter time spans, so the program was modified to compute lowest flows for 30, 15, and 7 consecutive days as well. In addition, a simple alteration of the program permitted computation of mean highest discharges for the same time intervals during winter.

The initial temperature analysis utilizes mean monthly maximum temperatures. Another type of temperature regime is the mean maximum temperature during the warmest period each year. The 60-day interval was thought to be too long a period to include here. Mean maximum temperatures would not be as high as for shorter time periods and would have less of an effect on the ensuing smolt migration. Therefore, only the 30-, 15-, and 7-day intervals were used. The mean temperatures in these time periods were generally higher than those during times of lowest discharge, indicating solar radiation appears to be more important than discharge in influencing stream temperatures.

Most of the suspended sediment is carried downstream from November through March (Harris and Williams 1971). Thus data from these months have been used in this analysis. Mean suspended sediment concentration in mg/l is used because this is what might directly affect the juveniles in the stream. It is well known that sediment concentration is closely related to streamflow (Brown and Krygier 1971; Harris and Williams 1971). If sediment is a limiting factor to the smolt migration, then during times of higher streamflow the effects may be more pronounced. Therefore, in addition to monthly means, mean daily sediment concentrations were calculated during the 30, 15 and 7 consecutive days of highest discharge each season. As with the temperature analysis, the 60-day interval does not appear to be sensitive enough for illustrating the effects of sediment concentration on the juveniles.

Estimates of coho biomass in the streams in September are presented by Moring and Lantz (1975). In addition, monthly biomass data from June through May (end of smolt migration) are available from June 1959 through April 1969 (Chapman 1965; Au 1972). Data on mean biomass of cutthroat trout in September (beginning in 1962) are used as a measure of the abundance and influence of that species.

The migration of adult coho and its influence on the subsequent smolt migration is described by the number of spawning females counted through the upstream traps each season. Entry of spawning females into the study streams generally occurred from mid-November to early February in all three streams (Moring and Lantz 1975).

In addition to single regression analyses of these factors on the smolt count, multiple regressions are investigated to determine what may be the best combination of factors accounting for the variability in smolt output. Stream-specific variables are used corresponding to the highest single regression correlations with total seasonal smolt count. The best, most significant models ($p=0.05$) were determined from F tests of the differences in the residual sums of squares (Neter and Wasserman 1974). Single and multiple correlation coefficients significant at $p<0.05$ (Snedecor and Cochran 1967) will be designated with one asterisk, whereas two asterisks will be used for those significant at $p<0.01$.

RESULTS AND INTERPRETATION

Smolt Migration

Magnitude

Juvenile coho move downstream in some numbers in every month of the year, so it is necessary to define the length of time in which the smolt run takes place each year in order to determine the number of juveniles to consider as smolts. The fry migration begins in late February or early March and continues through June. Very few fish move downstream in the summer, but there are increasing numbers of juveniles counted as fall progresses. Chapman (1965) used November 1 to May 31 as the standard time framework for the smolt migration. However, his data were from the early years of the project, so a reevaluation is necessary. There is a wide variability in monthly and seasonal juvenile counts from September to June each year (Appendix Tables 8-10). However, fish moving downstream in September, October, and June contribute very little to the seasonal total (Fig. 2), so Chapman's time framework would still be appropriate.

Deer Creek had the largest November-May smolt count ($\bar{X}$=2022; range=738-3045). Flynn Creek had a mean of 665 (range=140-1354). In Needle Branch the mean was 277 (range=76-470). The trap in Needle Branch was not operational during certain months from 1961 through 1965 (Appendix Table 10). Consequently, a method for estimating monthly totals during these closure periods is needed. There were unusually high numbers of smolts in October and November 1966, 1967, and 1968 (Appendix Table 10). This may be partly due to the logging

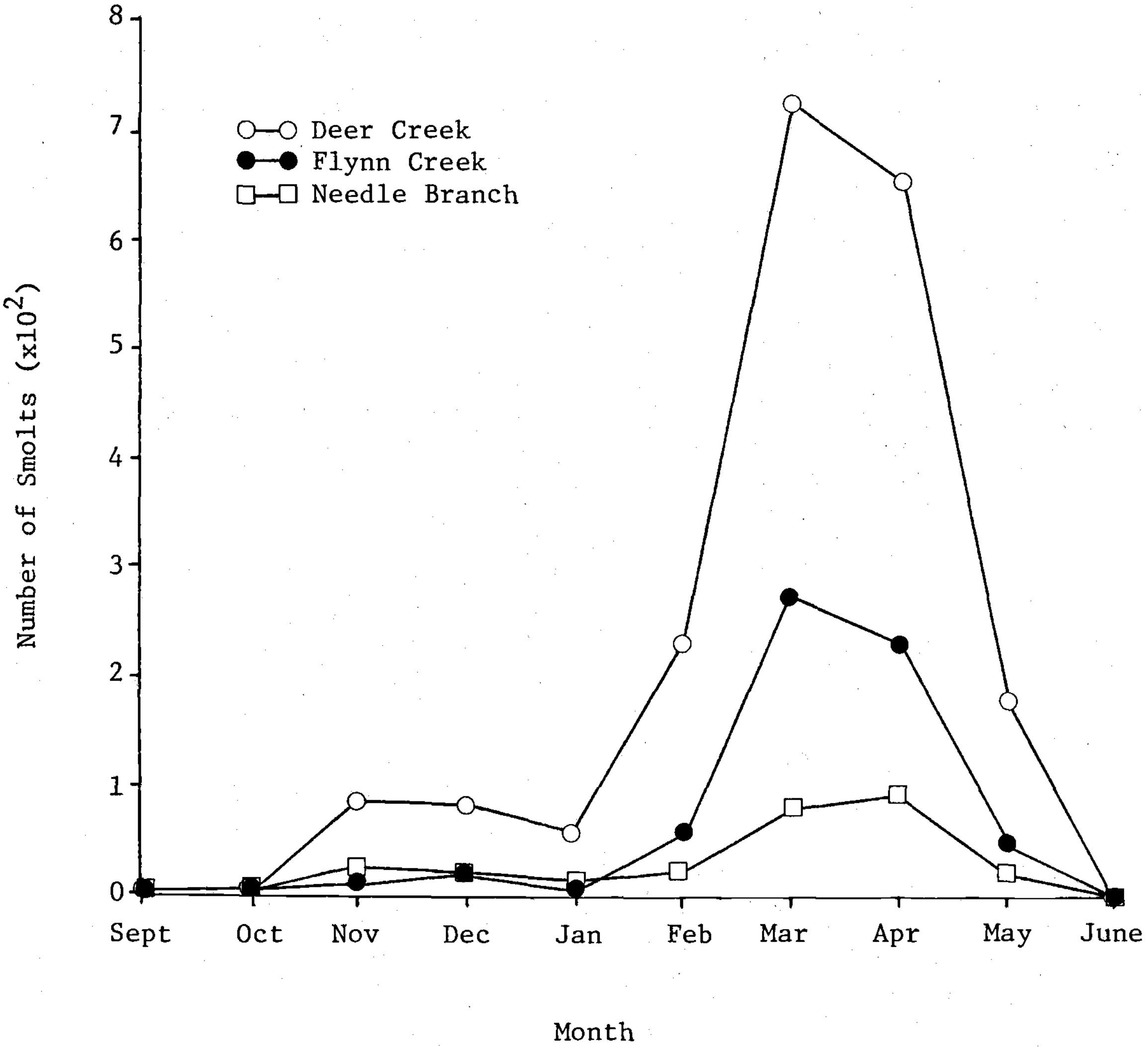

Figure 2. Mean monthly smolt counts. Data based on live and dead fish.

that occurred in 1966. Therefore, monthly totals for only the 1959-61 and 1969-73 seasons were used in obtaining means for the months with missing data. These were expressed as percentages of the total run (Nov. - 3.6%, Dec. - 5.2%, Jan. - 1.5%) and then with the partial totals of 1961-65, monthly counts and seasonal totals were estimated. Mortality of smolts in the downstream traps was 5 percent or less of the total run in all three streams (Table 3).

Table 3. Percent mortality in the downstream traps, based on mean monthly smolt counts, November-May. Needle Branch data exclude years when trap was not operational (Appendix Table 10).

	Deer			Flynn			Needle		
Month	Live	Total	Mort.%	Live	Total	Mort.%	Live	Total	Mort.%
Nov.	70.4	87.9	19.9	14.2	15.8	10.1	28.5	29.2	2.40
Dec.	78.3	84.0	6.79	18.6	19.9	6.53	19.3	21.1	8.53
Jan.	57.3	59.1	3.05	10.7	11.4	6.14	9.90	14.0	29.3
Feb.	228	233	2.06	60.9	62.6	2.72	22.1	23.1	4.33
Mar.	709	724	2.03	265	273	2.71	72.6	78.0	6.92
Apr.	649	655	0.95	229	231	0.95	93.7	94.8	1.16
May	177	180	1.33	50.6	51.4	1.56	24.5	24.9	1.61
Total	1969	2023		649	665.1		270.6	285.1	
$\bar{X}$			2.67			2.42			5.09

The greatest number of smolts passed through the traps during March and April in all three streams (Fig. 2). Peaks in smolt yield occurred in the 1962-63 season (Fig. 3). Low numbers of smolts were counted in the 1963-64, 1965-66, and 1970-71 seasons. Counts in other seasons did not show any definite trends common to all three streams, except a general decline in Flynn and Deer creeks. The smolt counts in these two streams did seem to vary proportionately, however, as

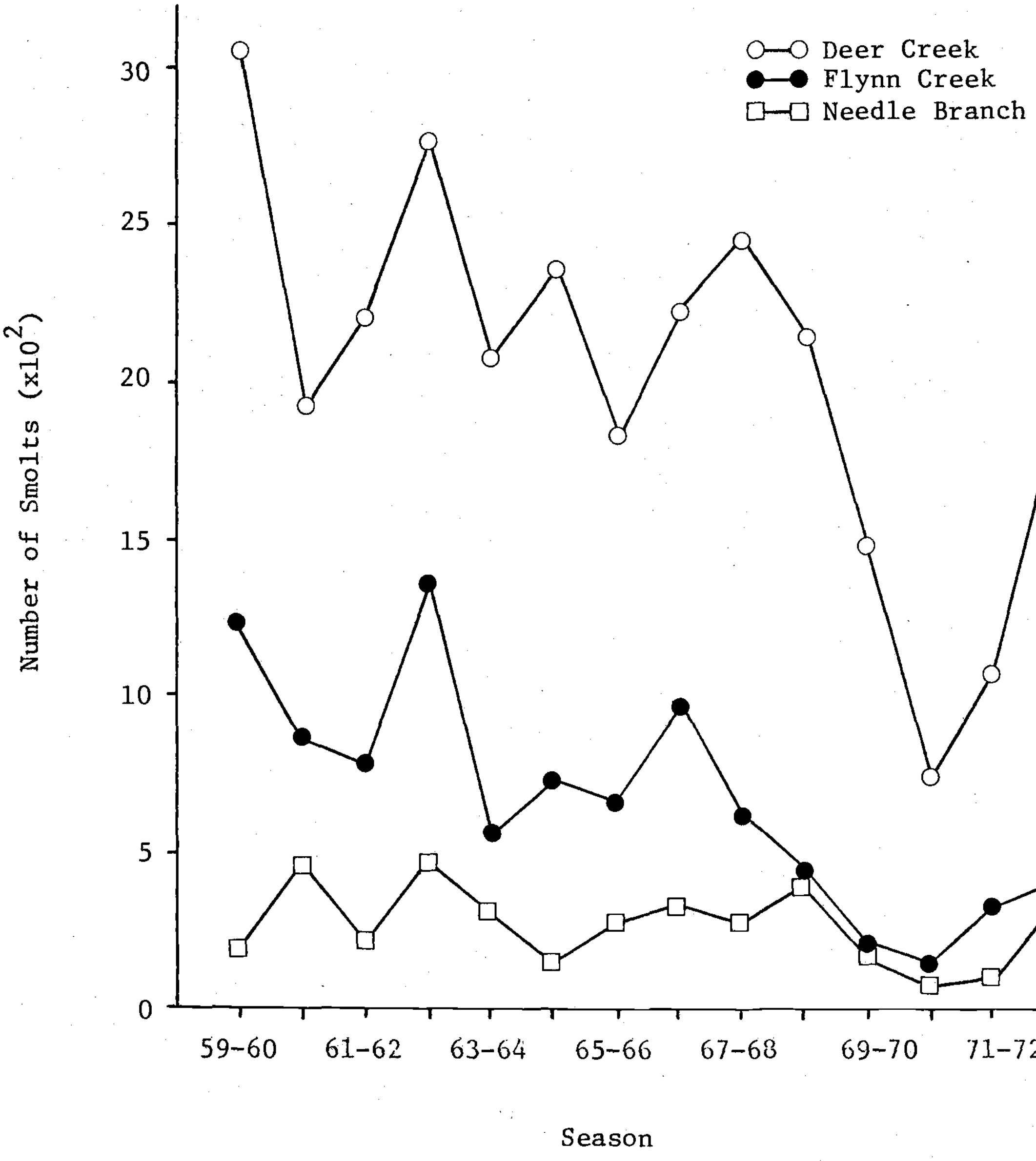

Figure 3. Total November-May smolt counts, 1959-60 to 1972-73.

evidenced by a high correlation coefficient (r=0.832**). Correlations were considerably lower, however, between Needle Branch and Flynn Creek (r=0.441) and between Needle Branch and Deer Creek (r=0.463).

In the rest of this report, a season will be defined as November 1 through May 31 and will be designated with two years, such as the 1961-62 season. A year will be defined as a calendar year, and will be used primarily with respect to events in the summer preceding the smolt migration, such as low streamflow and high temperatures, where the time intervals do not carry over two calendar years.

Length and Weight

Smolt lengths generally increased during the course of each migration season (Fig. 4) though there was some variability in mean monthly lengths between years (Appendix Tables 11-13). The mean seasonal smolt lengths were fairly close among the streams (DC - 84.3 mm; FC - 84.2 mm; NB - 82.1 mm). The mean length in Needle Branch is based on March lengths, because data are not available for those years in which the trap was closed for some months. March lengths were chosen because they had the highest correlation (r=0.847**) with mean seasonal lengths in those years for which complete length data were available. Interstream correlation coefficients for mean seasonal lengths are all significant (NB-FC - r=0.713**; NB-DC - r=0.641*; FC-DC - r=0.574*).

Generally, smolt lengths seemed to be somewhat greater after the 1965-66 season (Fig. 5). Although this season coincided with the logging activity in 1966, the fact that lengths in Flynn Creek (unlogged) also increased would seem to negate the possibility that

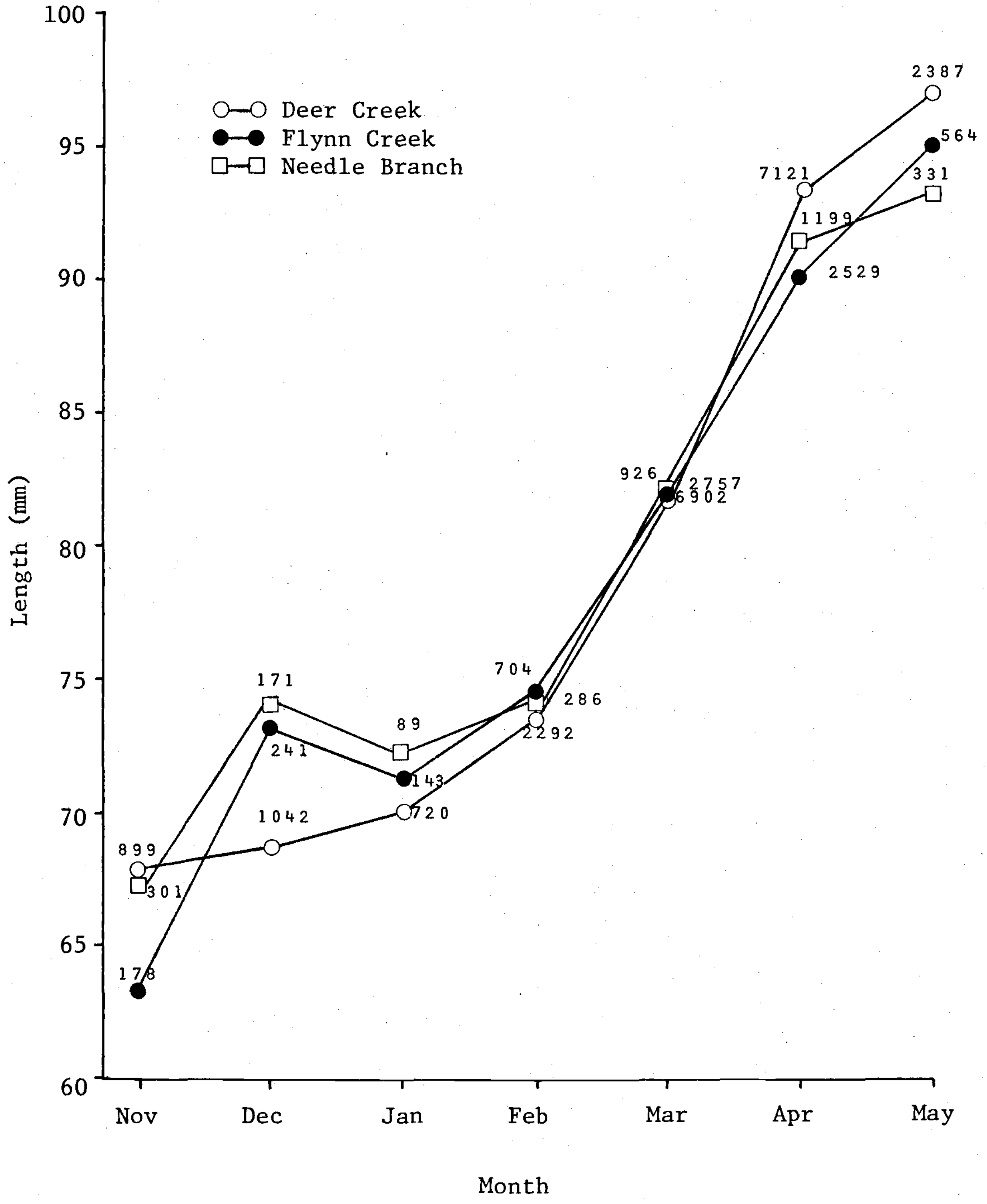

Figure 4. Mean monthly smolt lengths (mm). Data for live fish only. Total number of fish measured each month is indicated.

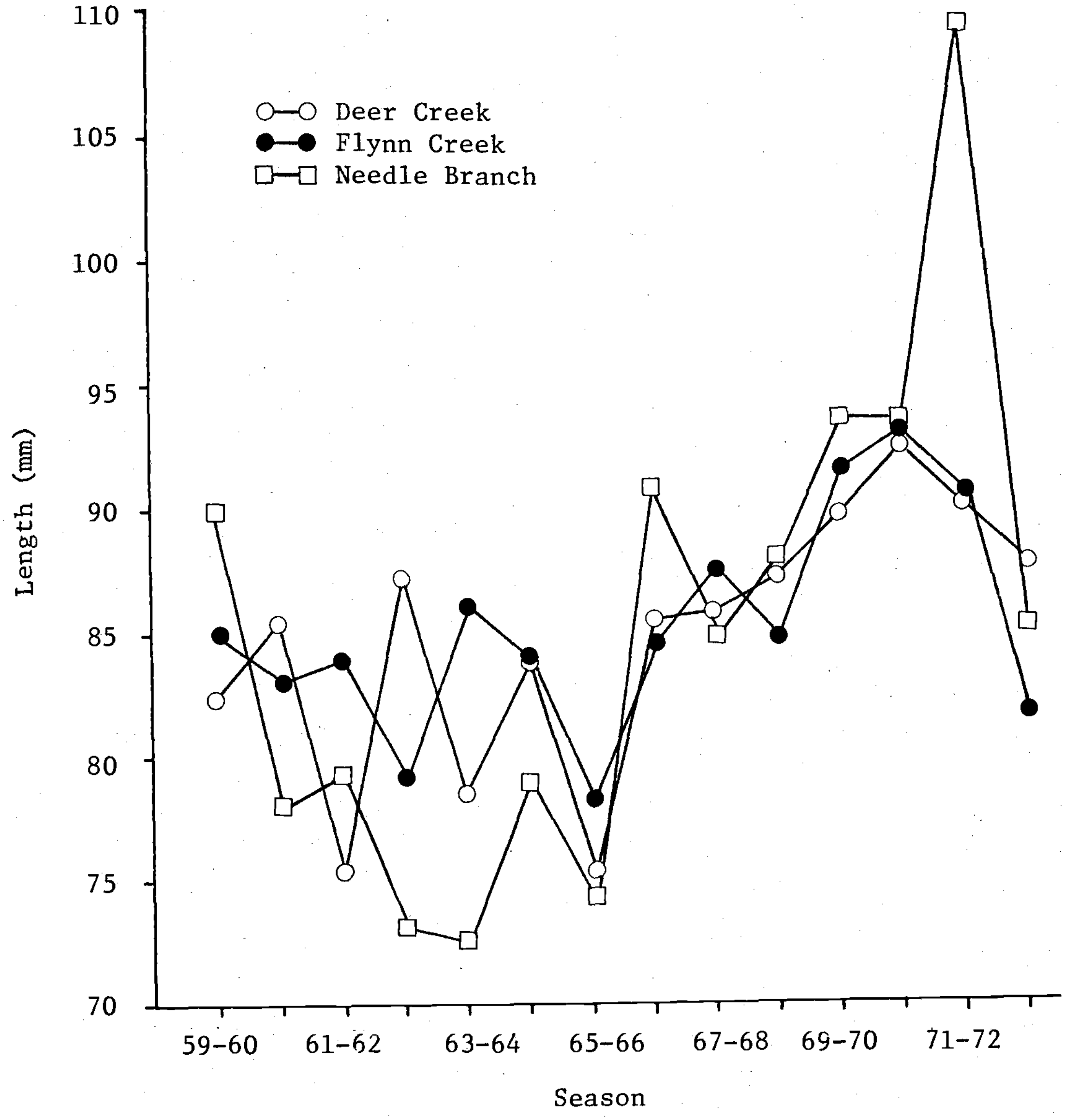

Figure 5. Mean November-May smolt lengths (mm), 1959-60 to 1972-73. Needle Branch data based on March lengths only. Data for live fish only.

this increase was a response to the logging activity. In fact, the mean lengths in all three streams were significantly greater in the period 1967-73 compared to 1959-66 (Table 4). It should be noted, however, that the percentage increase in Needle Branch was substantially greater than that in the other two streams.

Table 4. Mean November-May smolt lengths (mm) from 1959-60 to 1965-66, and 1966-67 to 1972-73, with calculated t values for the differences.

	Deer	Flynn	Needle
1959-60 to 1965-66	80.4	82.8	78.2
1966-67 to 1972-73	87.7	87.6	92.2
Percentage increase	9.05%	5.80%	18.0%
t value	3.52	2.48	3.62

Trends in mean smolt weights estimated from mean monthly smolt lengths for the 1963-64 through 1972-73 seasons are closely parallel to the mean lengths (Appendix Tables 14-16). Mean monthly condition factors in all three streams increased from March to April and then declined in May (Appendix Tables 1-3). The low numbers of fish weighed from November through February are responsible for the high interstream variability in that period.

Total seasonal smolt weight (Appendix Table 17) and smolt count are closely correlated, as would be expected (DC - r=0.857**; FC - r=0.957**; NB - r=0.698**). Because these correlations are high, total weight will also be used in the modeling as well as the count.

Timing

Most of the median dates of smolt migration occurred in a 20-day interval (March 20-April 9), although there is considerable interstream variability (Appendix Table 18). This general observation is supported by very low insignificant correlations between median dates in Needle Branch and Flynn Creek (r=0.191), Needle Branch and Deer Creek (r=-0.046), and Flynn and Deer Creeks (r=0.327). In Deer Creek the mean median date is 144 (March 24) with a range of 107 to 168. Flynn Creek has a mean of 149 (March 29) and a much smaller range of 140 to 157. In Needle Branch the mean is 140 (March 20), with a large range of 22 to 162. The 22 (Nov. 22) date occurred in the 1968-69 season when 52 and 202 smolts were counted in October and November, respectively, both unusually high numbers for those months (Appendix Table 10). This may be related to the high temperature and sediment yield following logging. The early date in the 1965-66 season in Deer Creek may be due to the road construction with resulting high sediment yield.

Interrelations

A hypothesis is proposed that the greater the smolt count, the smaller the mean length. In a given stream area, more fish competing for the same food resource and habitat space should show a slower growth rate and smaller size when they migrate. Conversely, fewer fish should exhibit faster growth rates and larger sizes at migration. This hypothesis is supported by negative correlation coefficients obtained from the regressions of mean length on count. The relationships are statistically significant (Fig. 6) for Flynn Creek and Needle Branch (DC - r=-0.444; FC - r=-0.647*; NB - r=-0.545*).

It is also hypothesized that a greater number of fish in a stream would result in greater competition for food and space, and this could cause fish to move downstream sooner. Aggressive behavior of juveniles could also be a factor here (Chapman 1962). Consequently, a negative relationship would be expected between the timing and magnitude of the migration (Fig. 7). The correlation coefficients, although negative, are insignificant (DC - r=-0.191; FC - r=-0.137; NB - r=-0.408).

Another hypothesis is that the later the timing of the migration, the greater the average smolt length would be. Smolts that move downstream later in the season would have a longer period of growth in the stream and should show greater lengths at the downstream traps. Thus one would predict a positive relationship between the median date of migration and mean seasonal length. The correlation is highly significant from Deer Creek data (Fig. 8), but no trend is evident from the other two streams (DC - r=0.726**; FC - r=0.164; NB - r=-0.009).

Logging Impacts

There were several impacts of the 1965-66 logging activities in Needle Branch and Deer Creek, to both physical and biological variables in the streams. There were significant increases in stream temperature in Needle Branch following clearcutting and removal of riparian vegetation. This has been documented by several workers (Brown and Krygier 1967, 1970; Moring 1975; Ringler and Hall 1975). Minimal

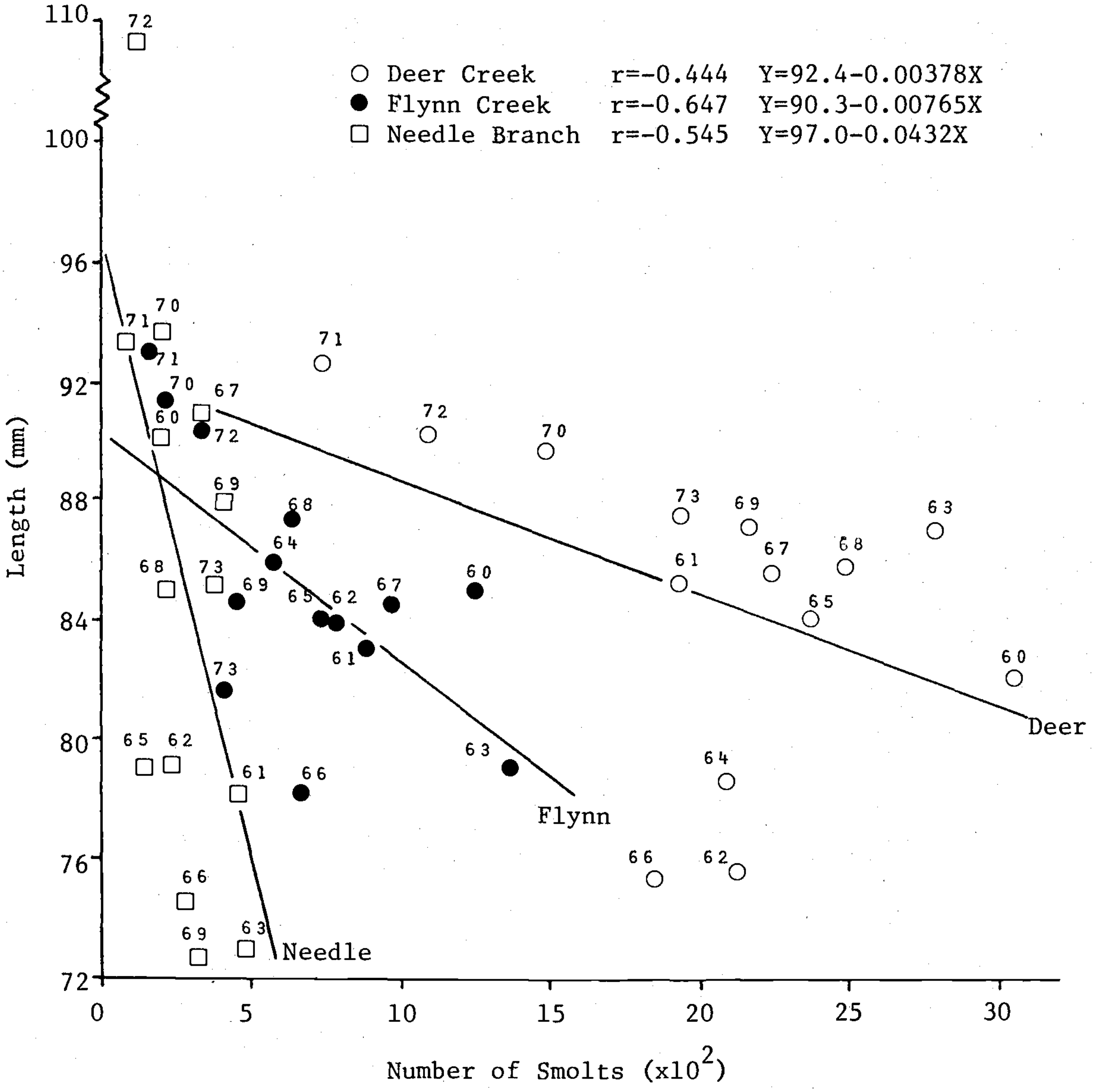

Figure 6. Total November-May smolt count versus mean November-May smolt length. Second year of smolt run is indicated. Needle Branch data based on March lengths only.

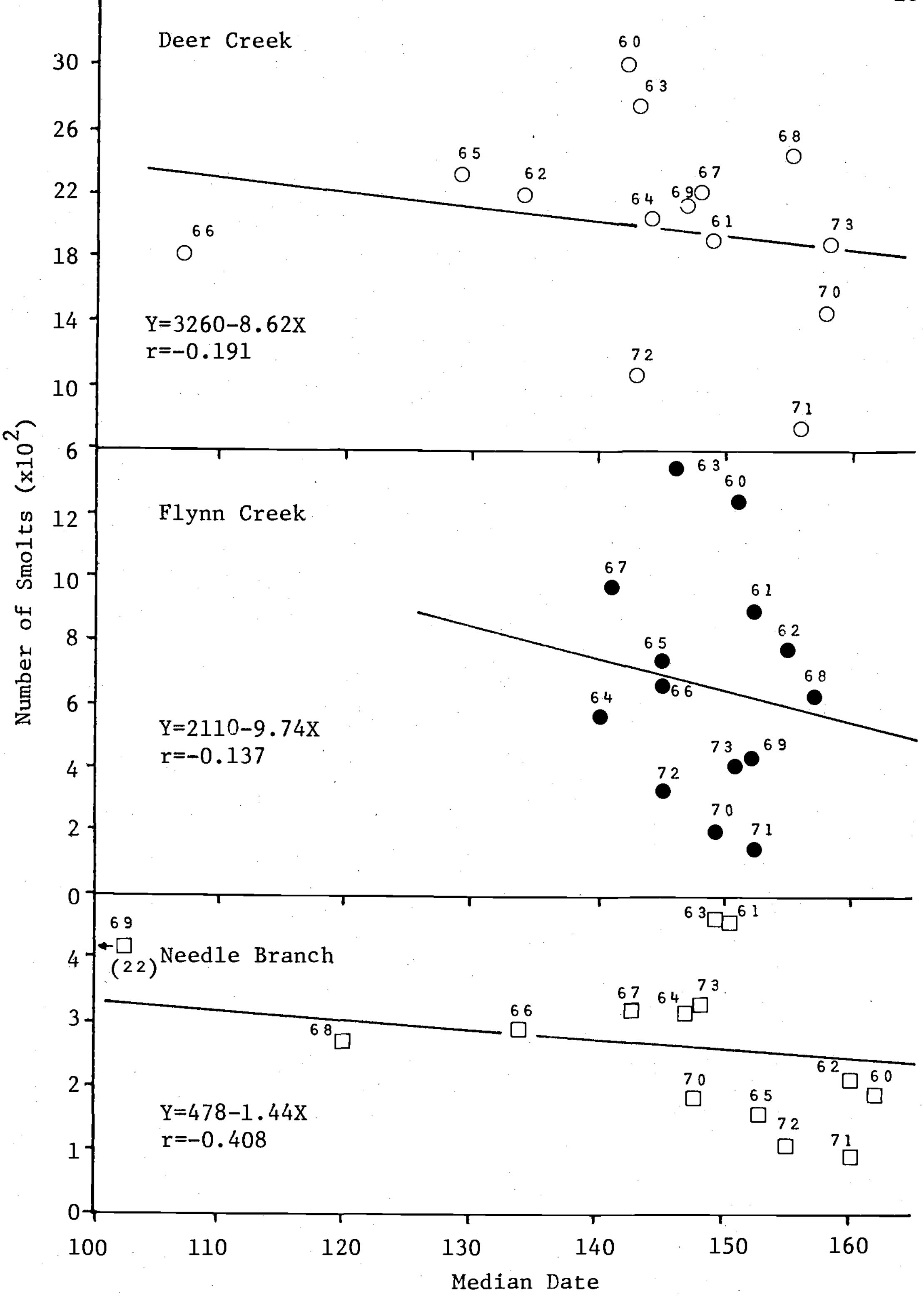

Figure 7. Median date of smolt migration (in Julian days with November 1 as day 1) versus total November-May smolt count. Second year of smolt run is indicated.

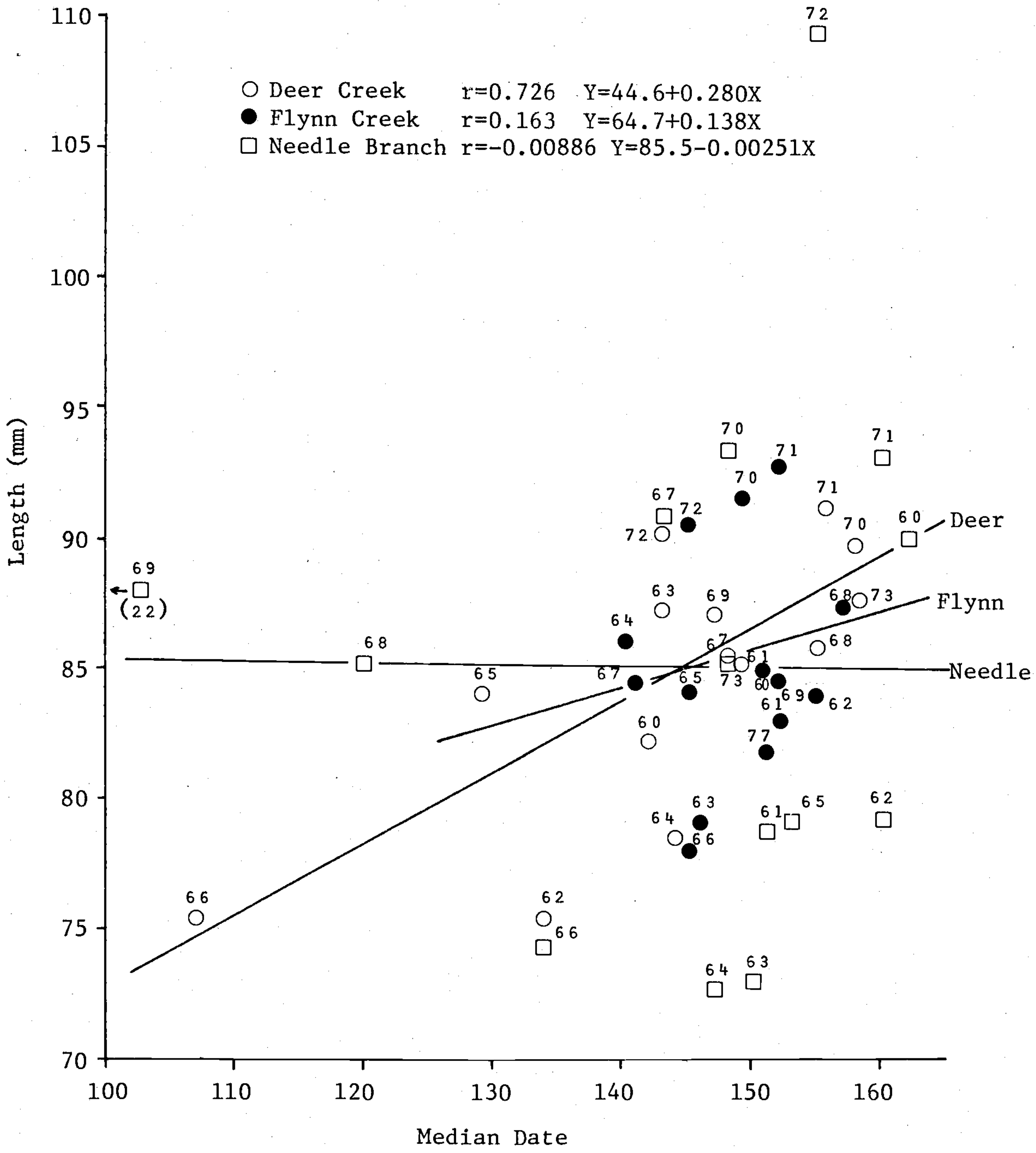

Figure 8. Median date of migration (in Julian days with November 1 as day 1) versus mean November-May smolt length (mm). Needle Branch data based on March lengths only. Second year of smolt run is indicated.

changes in temperature where buffer strips were left along the streambank were shown by Brazier (1972) and Brazier and Brown (1973).

Significant increases in sediment production in Deer Creek and Needle Branch from road construction and clearcut logging were noted by Brown and Krygier (1971), Harris (1973), and Beschta (1978). However, as with stream temperature, little analysis has been done on the effects of sediment on the fish populations in these three streams.

The coho populations proved to be fairly resilient in comparison to a significant decline in the Needle Branch cutthroat trout population (Moring and Lantz 1975).

Although this study is not intended as an assessment of impacts of logging activities, these changes should be kept in perspective for the following analyses. A few anomalies appear in comparisons of results between Needle Branch and the other two streams that may be partly due to logging effects.

Factors Affecting the Migration

Physical Factors

Streamflow

It is hypothesized that streamflow in the summer months would be positively correlated with the smolt count. The lower the flow, the less habitat would be available for the juveniles. This would result in greater competition, increased aggressive behavior (Chapman 1962), and a greater mortality during the low flow period, with fewer fish remaining for the smolt migration. It could also be hypothesized that the shorter the time interval, the lower the mean flow, and the greater the correlations would be. Another hypothesis is that the later the starting date of the lowest flow period, the lower the total smolt count would be. The later in the season the lowest flow occurs, the larger the juveniles would be and the greater would be the competition for food and space. Mortality would be greater, resulting in a lower number of smolts the next winter. Therefore, one might expect a negative correlation between the timing of the lowest flow and the total seasonal smolt count.

In addition, it is hypothesized that discharge in the winter months would be negatively correlated to smolt count. This could be due to a higher mortality from higher flows, particularly freshets.

For the summer flow analysis, there is almost no correlation between mean monthly discharge and total smolt count (Table 5).

Table 5. Correlation coefficients for mean monthly discharge versus total November-May smolt count.

Month	Deer	Flynn	Needle
May	0.095	0.318	0.404
June	-0.025	-0.115	0.295
July	-0.252	-0.277	-0.209
August	0.174	0.036	0.186
September	-0.352	-0.338	0.015
October	0.400	0.381	0.058
November	-0.107	0.120	0.182
December	-0.277	-0.360	-0.451
January	-0.644*	-0.647*	-0.521
February	0.246	0.373	0.296
March	-0.424	0.053	0.027
April	-0.067	0.388	-0.356
January-April	-0.571*	-0.120	-0.354
June-September	-0.117	-0.189	0.154

The direct effects of mean monthly flows in summer cannot be seen here, probably due to other interacting factors. Although monthly flows may be important, the magnitude and timing of the lowest flow of the year may be more critical than monthly flow in affecting the smolt output. The lowest flows occurred in 1960, 1965-67, 1970, and 1972. The annual trends between streams are fairly close in each time interval (Appendix Table 19). Yet there does not seem to be any significance in the relationship between the lowest flow and total smolt count (Table 6).

Table 6. Correlation coefficients between mean lowest discharge for 60, 30, 15, and 7 consecutive days and total November-May smolt count.

Time Interval	Deer	Flynn	Needle
60 days	0.071	-0.081	-0.060
30 days	0.219	0.005	-0.076
15 days	0.253	0.088	0.132
7 days	0.300	0.056	0.042

Also there is no significant improvement in the relationship when flow is regressed against total smolt weight instead of count. The plots of mean lowest discharge for 30 consecutive days against smolt count (Fig. 9) show the data are fairly scattered, yet most of the outliers occur in the later years of the study. If data from the 1959-60 through 1965-66 seasons only are examined, the relationships are significantly improved for Deer Creek and Flynn Creek (DC - r=0.857*; FC - r=0.486; NB - r=-0.666). Thus mean summer discharge showed strong relationships with smolt count in the early years of the study, but these correlations were nullified in the later years.

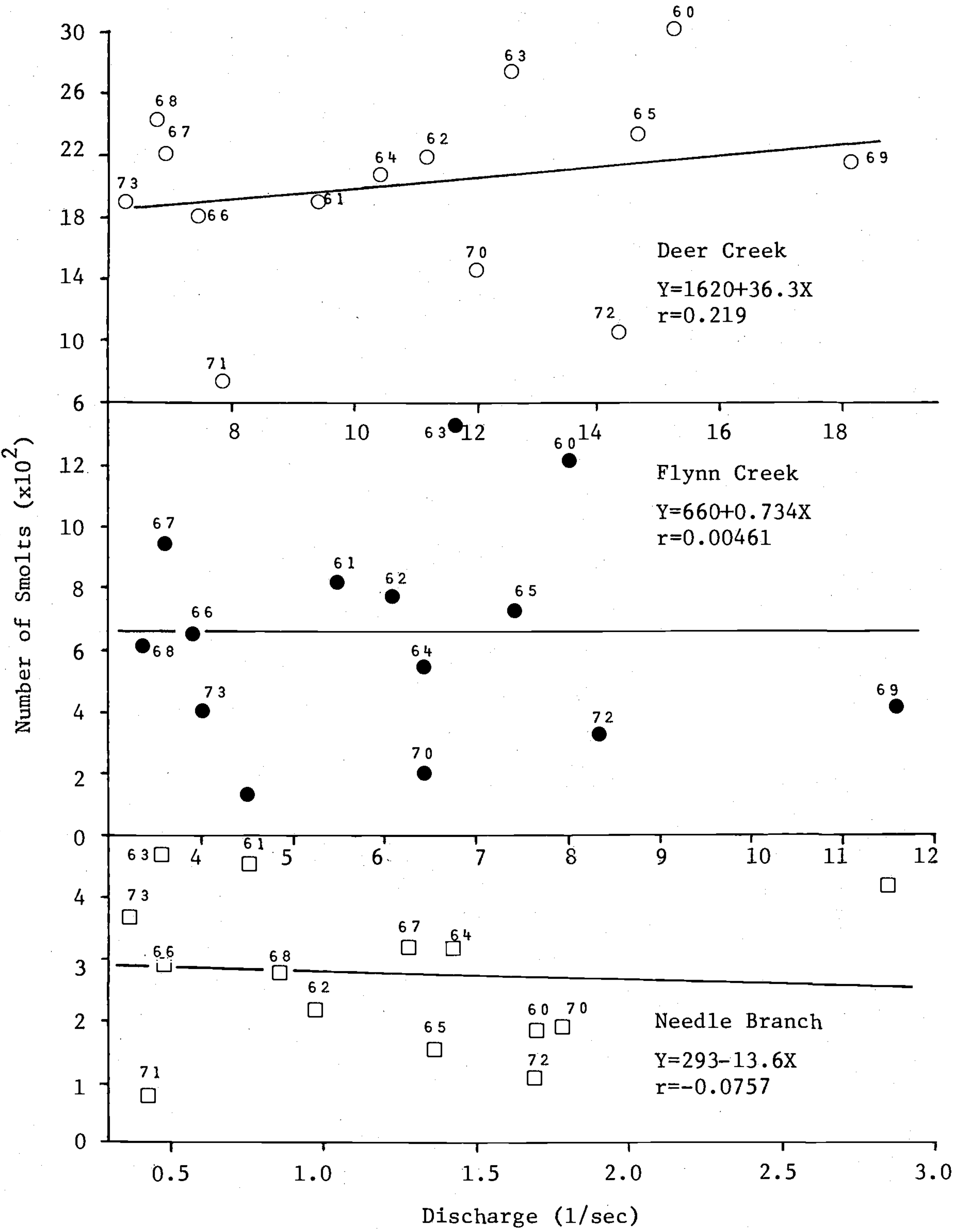

Figure 9. Mean discharge (1/sec) for 30 consecutive days of lowest flow versus total November-May smolt count. Second year of smolt run is indicated.

The starting dates for the lowest flow periods in each stream are fairly close to each other in each time interval (Appendix Table 20). Yet there is considerable variability from one year to the next. For example, in Flynn Creek the starting date for the 7 consecutive days of lowest flow was September 28 in 1960 and August 9 in 1961. However, no relationship is apparent between timing of the lowest flow and smolt yield, with the r values all less than 0.2 in absolute value. Thus the hypothesis advanced cannot be supported.

The winter discharge-count hypothesis is supported by significant negative correlations (Fig. 10) between mean January discharge and total smolt count (DC - r=-0.644*; FC - r=-0.647*; NB - r=-0.521). A clearer representation of this relationship is seen in a plot of discharge in l/ha versus smolt abundance in no./m^2 (Fig. 11).

The winter flow hypothesis is supported by the negative correlations in Table 7, and the results are significant for Deer Creek (Fig. 12).

Table 7. Correlation coefficients between mean highest discharge for 60, 30, 15, and 7 consecutive days and total November-May smolt count.

Time Interval	Deer	Flynn	Needle
60 days	-0.532*	-0.404	-0.242
30 days	-0.619*	-0.437	-0.402
15 days	-0.608*	-0.397	-0.401
7 days	-0.268	-0.206	-0.318

Peak flows occurred in the 1960-61, 1964-65, and 1971-72 seasons (Appendix Table 21). Reduced high flows were in 1961-62 and 1967-68.

Starting dates for the consecutive days of highest flow are extremely close in all three streams for the 60- and 30-day intervals

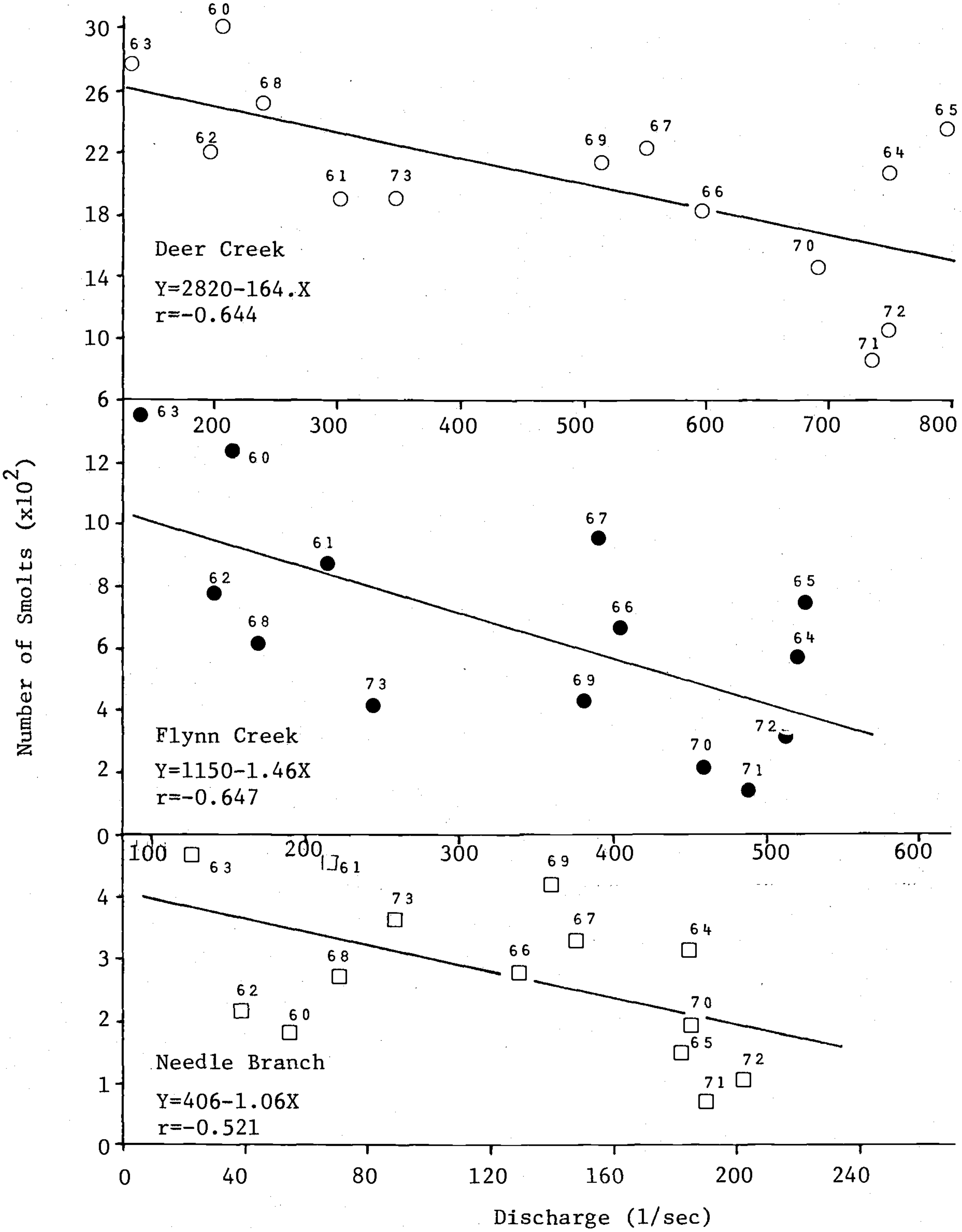

Figure 10. Mean January discharge (1/sec) versus total November-May smolt count. Second year of smolt run is indicated.

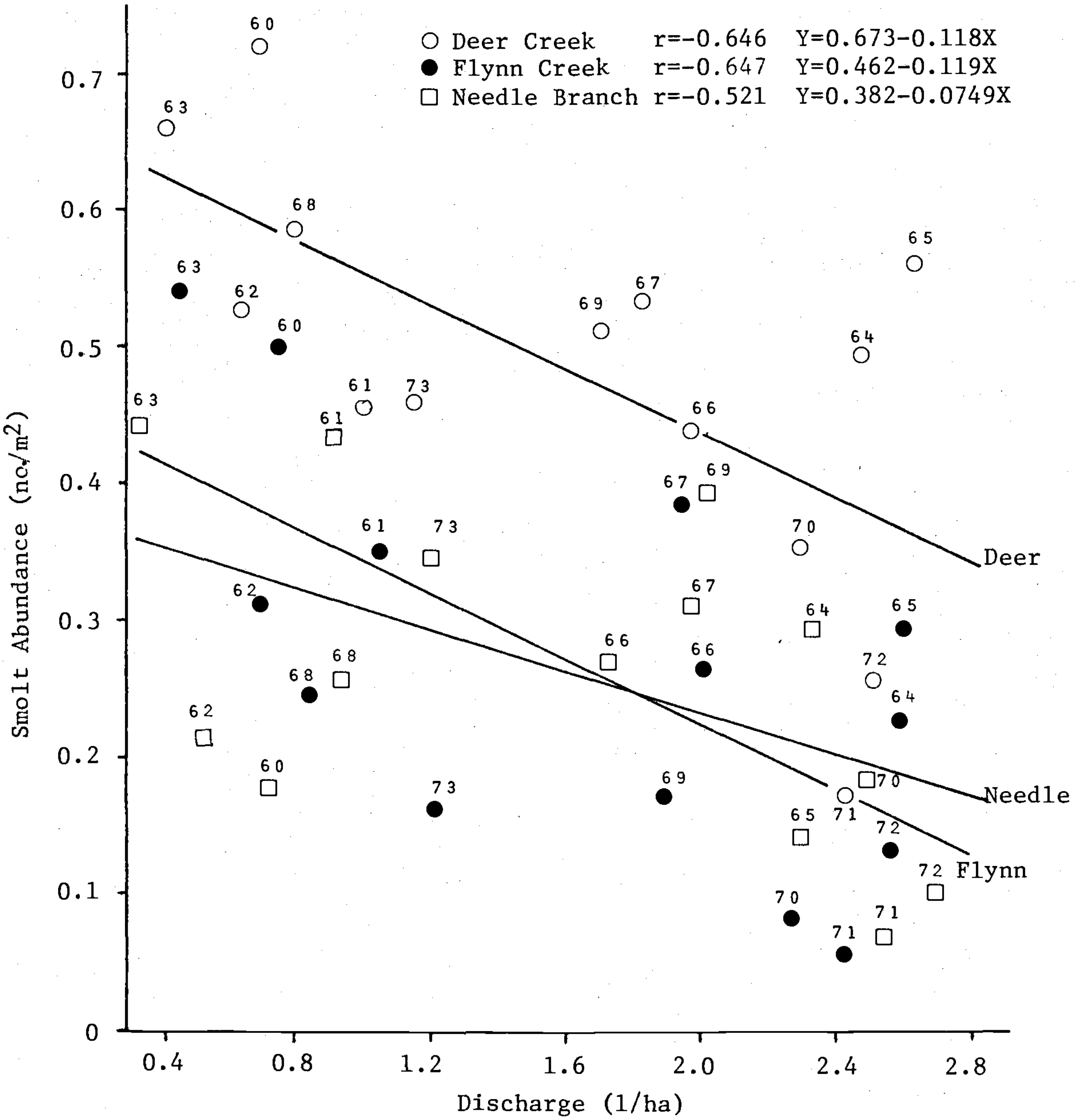

Figure 11. Mean January discharge (1/ha) versus total November-May smolt abundance (no./m^2). Second year of smolt run is indicated.

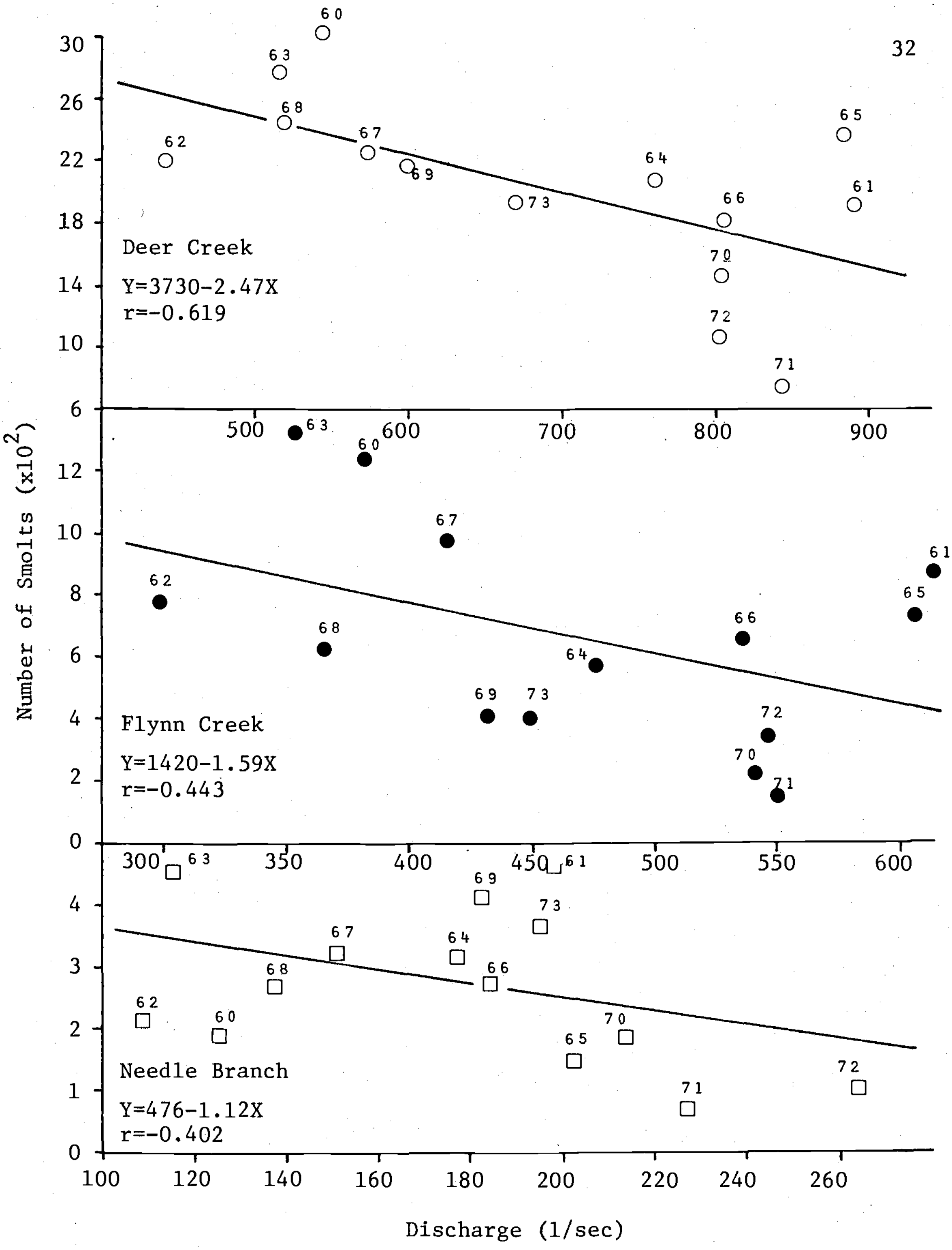

Figure 12. Mean discharge (l/sec) for 30 consecutive days of highest flow versus total November-May smolt count. Second year of smolt run is indicated.

(Appendix Table 22). But some variability shows up in the shorter intervals, particularly in 1964-65 and 1967-68. As in the lowest flow analysis, there is a substantial variability between years. Correlation coefficients for the relationships between starting dates of the highest flow and smolt count, however, are all low and insignificant.

One additional streamflow regime to examine is the peak instantaneous discharge that occurs each season. Perhaps very short-term peak discharges may have a more pronounced effect on the smolts than mean highest flows over several days (Appendix Table 23). The correlations with seasonal smolt count, however, are insignificant (DC - r=-0.346; FC - r=-0.079; NB - r=-0.366). These correlations are lower than the correlations with mean highest discharge and mean January discharge. Thus these fish populations seem less affected by peak instantaneous flows than they are by high flows over a longer period of time.

Temperature

Mean maximum monthly temperatures generally occur in August (Appendix Tables 24-26). Significant increases in Needle Branch and slight increases in Deer Creek temperatures following logging are evident. Correlations with the total smolt count, however, are quite variable (Table 8), with only one significant relationship (FC - July) that may be due to chance.

Table 8. Correlation coefficients between mean maximum monthly temperatures and total November-May smolt count.

Month	Deer	Flynn	Needle
May	-0.388	-0.161	-0.120
June	-0.217	0.279	-0.298
July	-0.039	0.632*	-0.106
August	0.027	0.352	0.109
September	0.278	0.379	0.294
October	0.332	0.495	-0.177

The second type of temperature regime is the mean maximum temperature each year, for 30-, 15-, and 7-day intervals (Appendix Table 27). Effects of logging can be seen here also. In correlating this variable with total smolt output, the resulting regression coefficients are quite low in Deer Creek and Needle Branch (Fig. 13), though positive and nearly significant in Flynn Creek (Table 9). This is a similar pattern to the one observed for mean monthly temperatures. However, it is difficult to ascribe any biological significance to this trend in view of the fact that post-logging temperatures were coolest in Flynn Creek compared to those in the other two streams.

Table 9. Correlation coefficients between mean maximum temperatures for 30, 15, and 7 consecutive days and total November-May smolt count.

Time Interval	Deer	Flynn	Needle
30 days	0.020	0.443	0.043
15 days	-0.028	0.474	0.043
7 days	0.018	0.436	0.004

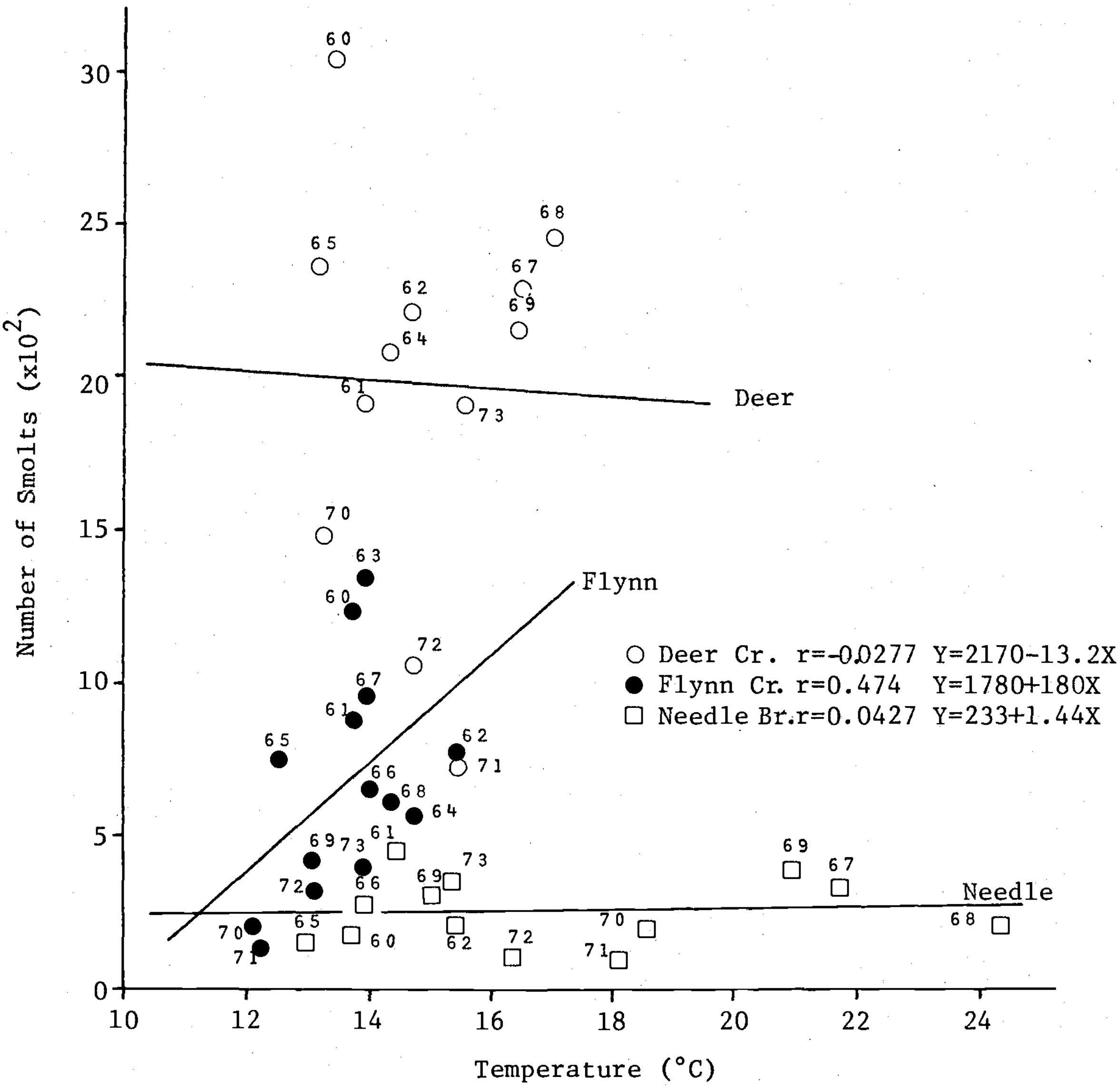

Figure 13. Mean maximum temperature (°C) for 15 consecutive days versus total November-May smolt count. Second year of smolt run is indicated.

Sediment

Mean monthly sediment concentrations (Appendix Tables 28-30) varied similarly between streams and appeared to be related to streamflow. Since these concentrations do not begin to approach toxic levels (Cordone and Kelley 1961), fish would be little affected by changes of this low magnitude. Therefore, no relationship would be expected between sediment concentrations and total smolt count. This hypothesis is supported by insignificant correlations between the two variables (Table 10).

Table 10. Correlation coefficients between mean monthly sediment concentration and total November-May smolt count.

Month	Deer	Flynn	Needle
November	0.009	0.307	0.258
December	-0.217	-0.268	-0.079
January	-0.436	-0.340	-0.070
February	0.370	0.226	-0.066
March	-0.216	-0.098	0.023
November-March	-0.391	-0.270	-0.038

Mean sediment concentration in periods of highest discharge may have more pronounced effects on juveniles in the streams than monthly sediment concentrations. These concentrations during 30, 15, and 7 consecutive days of highest discharge showed peaks in the 1964-65 and 1971-72 seasons (Appendix Table 31), corresponding to unusually large storms in those winters. There are negative but insignificant relationships between mean sediment concentrations in these time intervals and total seasonal smolt count (Table 11; Fig. 14).

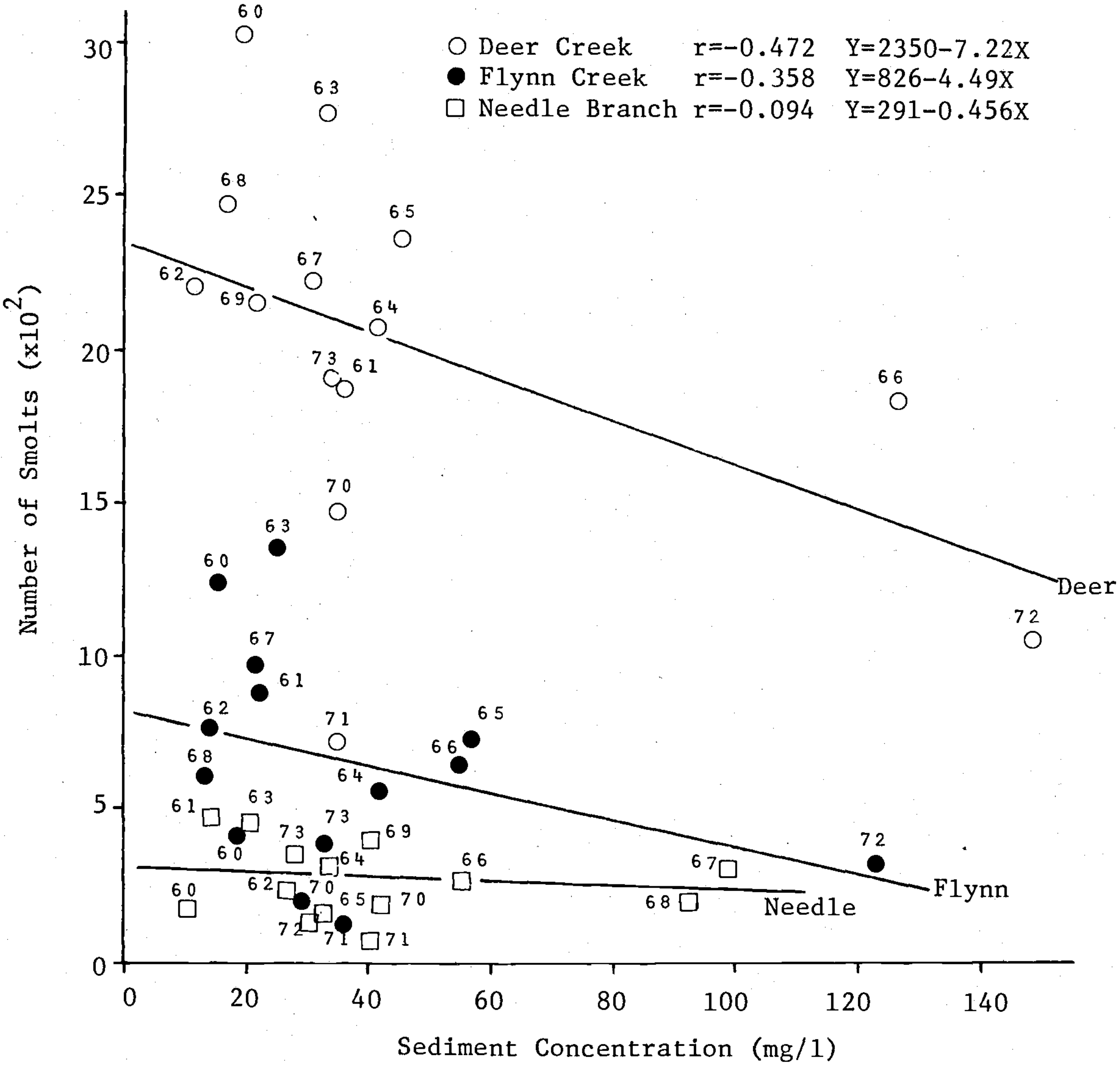

Figure 14. Mean sediment concentration (mg/1) during 30 consecutive days of highest discharge versus total November-May smolt count. Second year of smolt run is indicated.

Table 11. Correlation coefficients between mean sediment concentration during 30, 15, and 7 consecutive days of highest discharge and total November-May smolt count.

Time Interval	Deer	Flynn	Needle
30 days	-0.472	-0.358	-0.094
15 days	-0.344	-0.282	-0.028
7 days	-0.060	-0.053	0.116

Biological Factors

Biomass

Mean September in-stream biomass (Appendix Table 32) showed peaks in 1962 and 1967 in Deer Creek and Needle Branch, and in 1966 in Flynn Creek. Following 1967 there was a substantial decline in biomass in all three streams. Relatively low levels were still evident in 1972 (Fig. 15). Generally, throughout the years of the study, biomass ranged from 0.4 to 6.8 g/m^2. Mean June-October biomass seemed to vary in a similar pattern between streams (Fig. 16). Peaks occurred in 1962 and 1967, as before, but most values were between 1.5 and 4.0 g/m^2. Biomass generally decreased in the summer, increased in the fall, peaking out in October or November, and then decreased through the smolt migration the following spring (Fig. 17; Appendix Tables 33-35).

The time of the year that biomass may have a regulatory effect on the magnitude of the smolt output is an important consideration. It is hypothesized that the period of increasing biomass, specifically in late summer and fall, would have the most influence on the smolt output. Also, if biomass could be a general indicator of smolt abundance, then

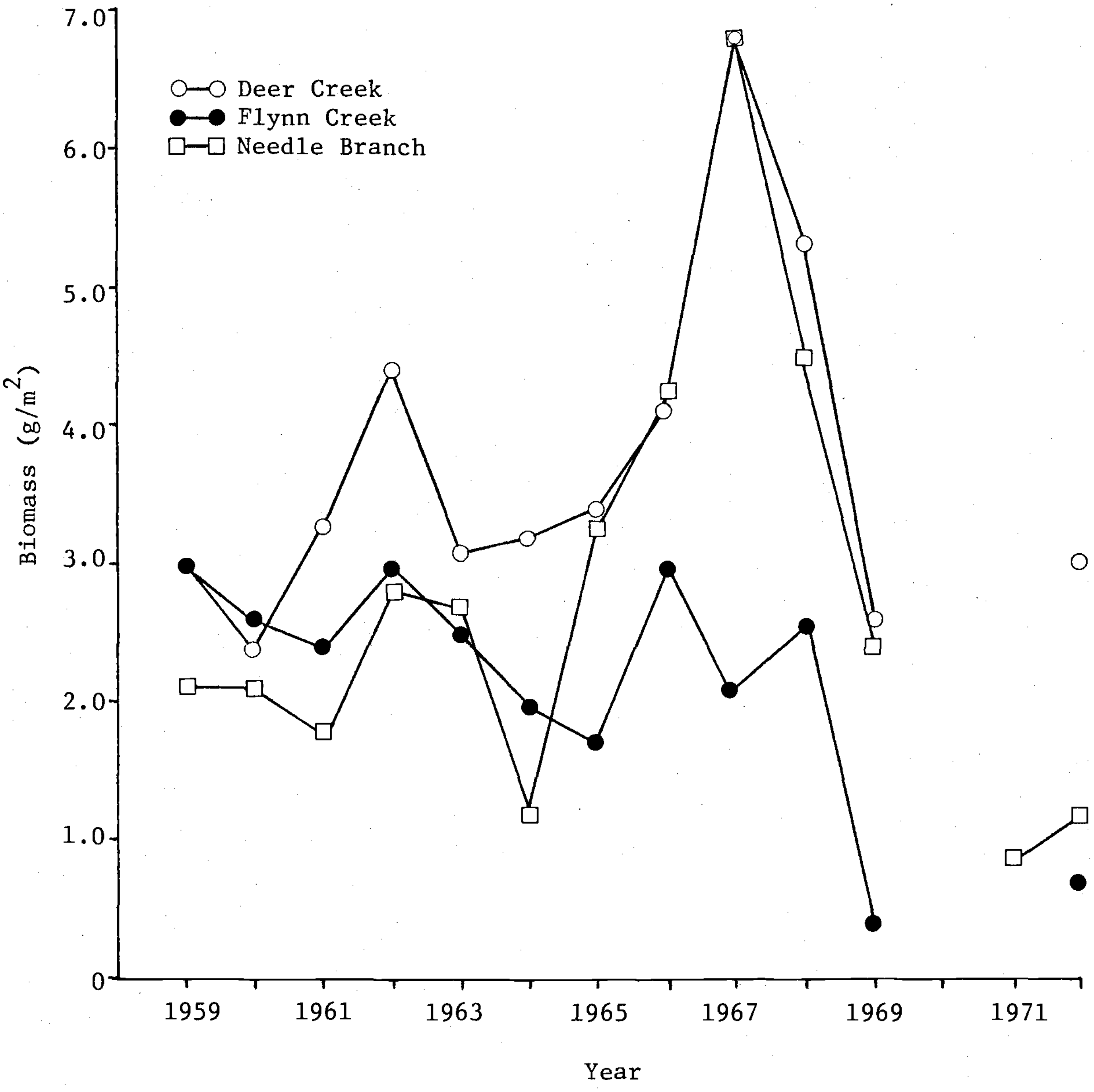

Figure 15. Mean September in-stream biomass (g/m^2), 1959-72.

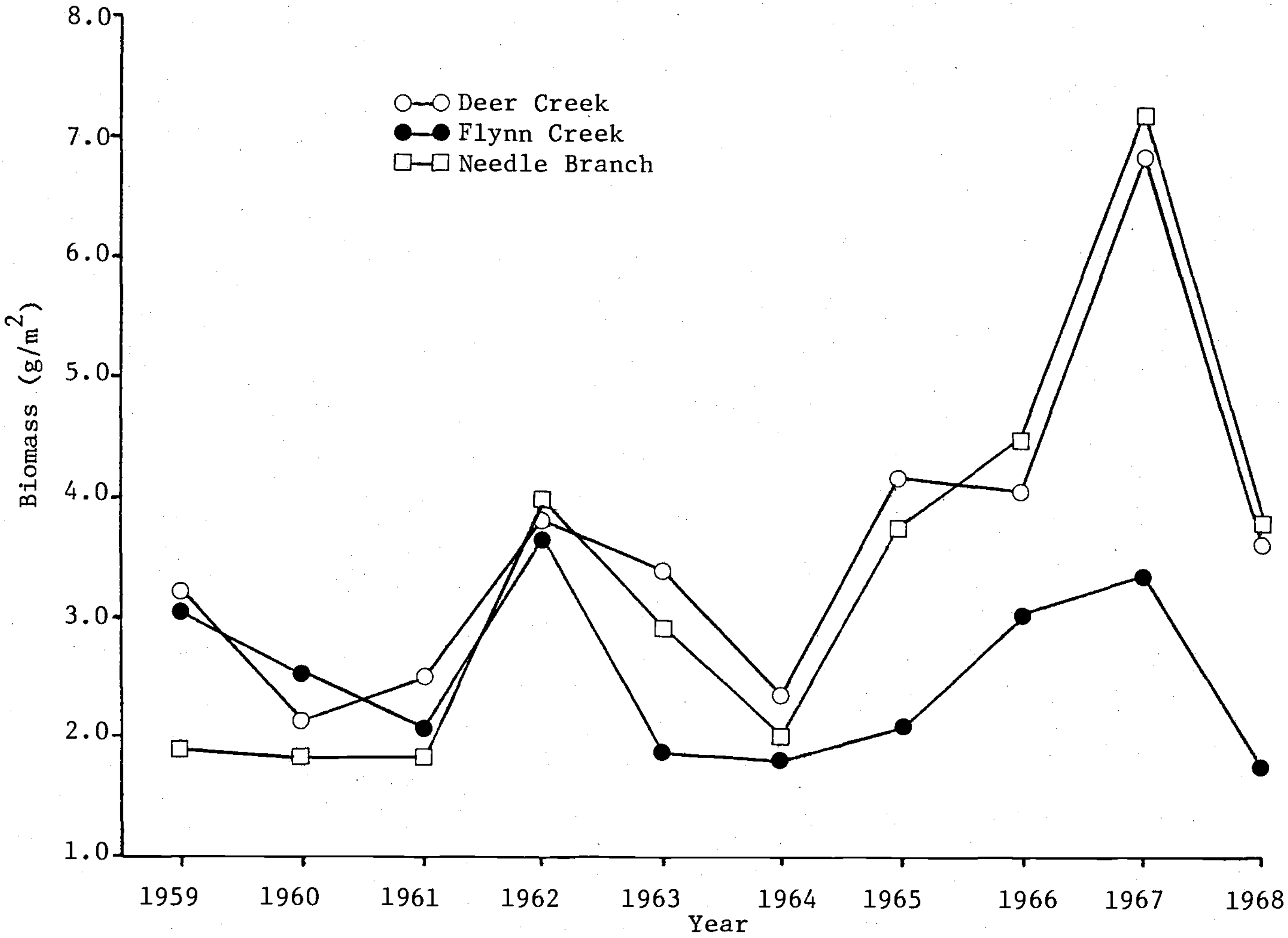

Figure 16. Mean June-October biomass (g/m^2), 1959-68.

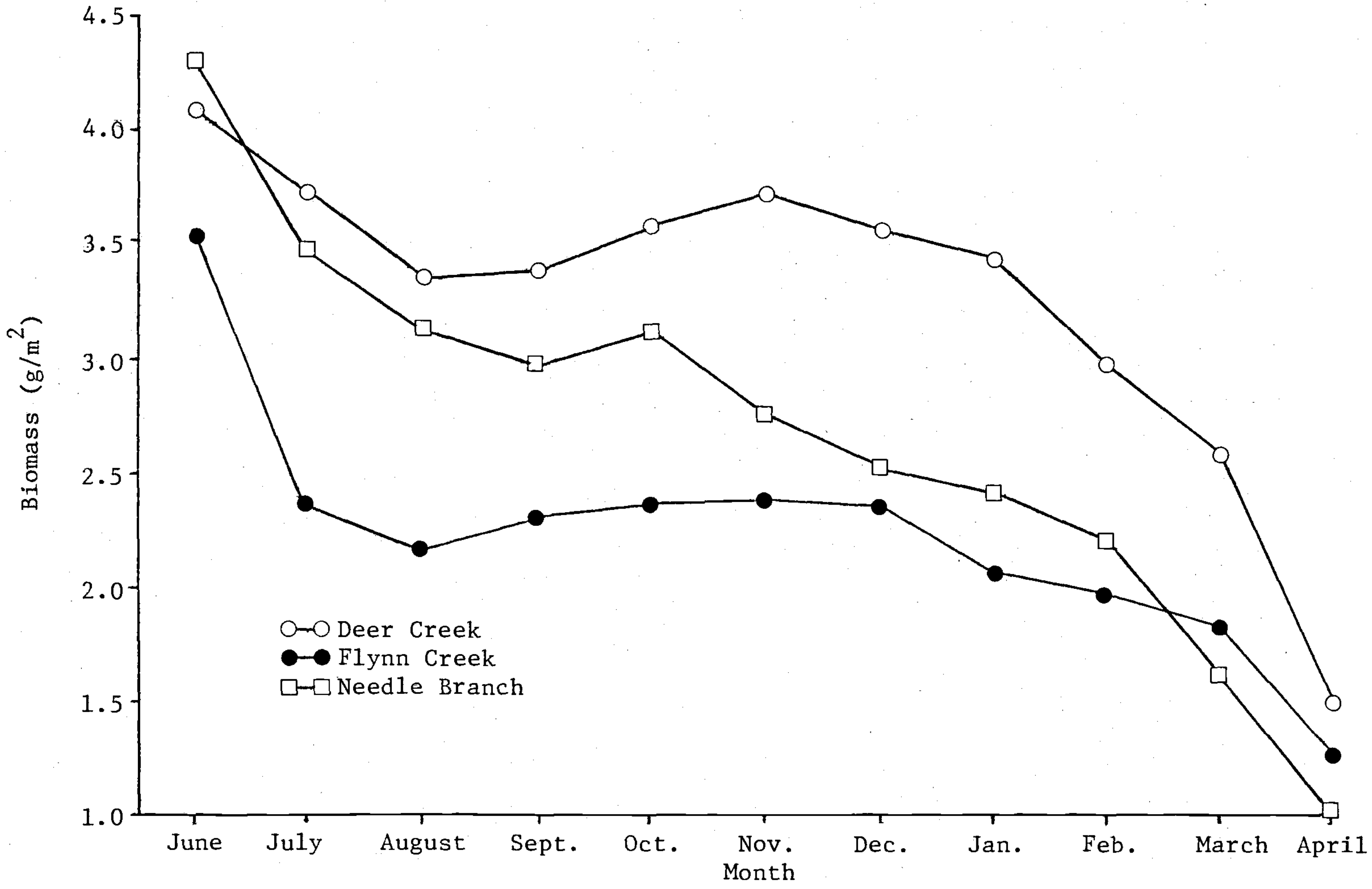

Figure 17. Mean monthly biomass (g/m^2), June-April, based on data from June 1959 through April 1969.

a positive relationship between mean monthly biomass and total smolt yield would be expected, and this hypothesis is supported by highly significant correlations for Flynn Creek (Sept., Oct., and June-Oct.) but not for the other two streams (Table 12). September biomass in Flynn Creek and Needle Branch correlate best with count. For Deer Creek fish, the second highest correlation is in September. Thus this month may influence the smolt count the most (Fig. 18). In addition, if an accurate prediction of smolt count can be obtained from biomass measurements, then costly stream trapping facilities for counting fish would not have to be constructed. Although the correlation coefficients are not high enough to allow accurate prediction of smolt counts, the September correlations are well worth including in the model-building process.

Table 12. Correlation coefficients between mean monthly biomass and total November-May smolt count.

Month	Deer	Flynn	Needle
June	0.286	0.619	0.153
July	0.472	0.510	0.065
August	-0.080	0.403	0.154
September	0.345	0.777**	0.345
October	0.228	0.719**	0.282
June-October	0.091	0.725**	0.182

Adult Migration

Spawning female escapement was highest in Deer Creek and lowest in Needle Branch. Freshwater survivals (egg potential to smolt yield) showed the greatest range in Flynn Creek (0.446-12.2%), but most values

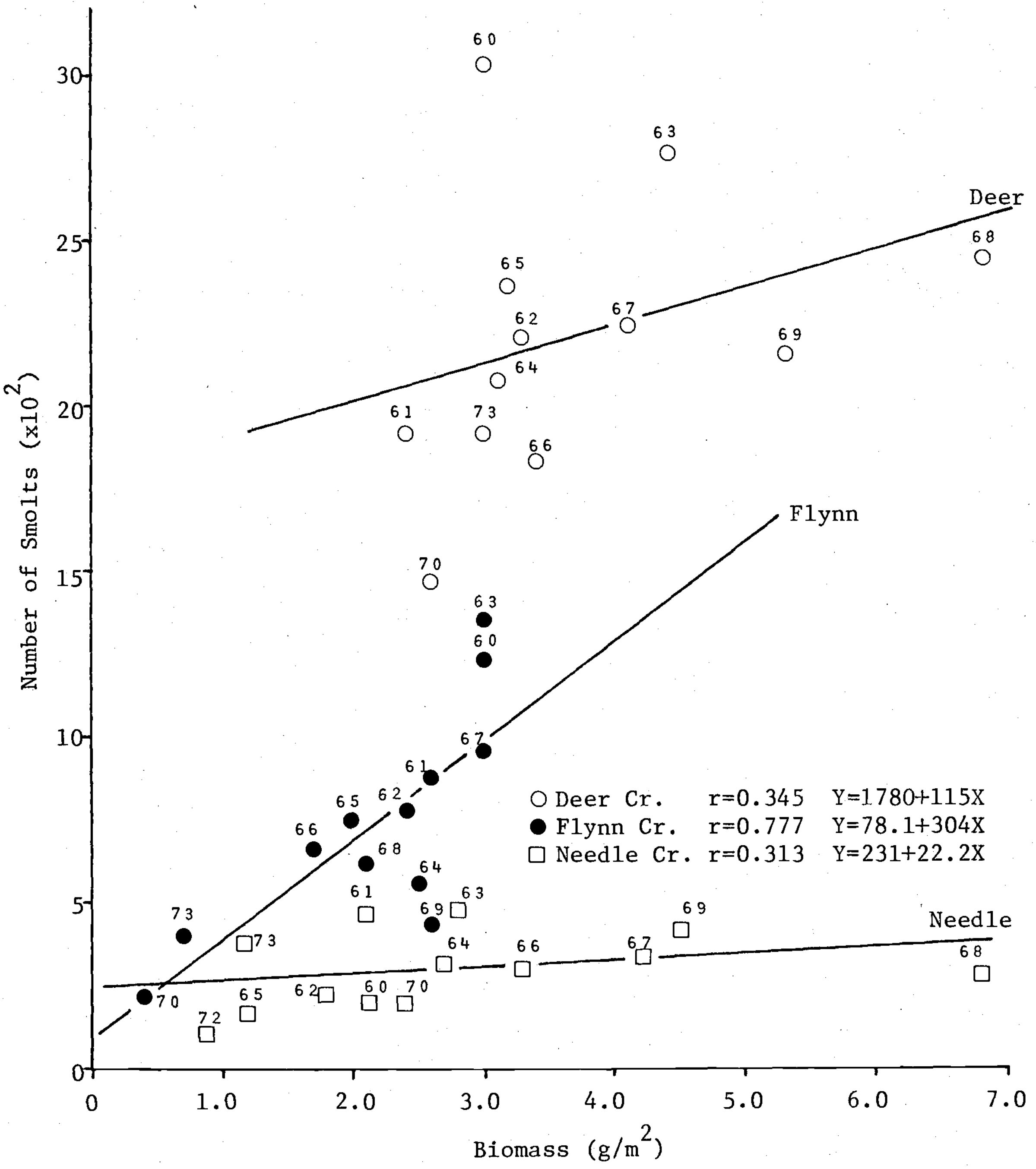

Figure 18. Mean September biomass (g/m^2) versus total November-May smolt count. Second year of smolt run is indicated.

were between 1 and 5 percent (Tables 13-15). The mean number of smolts per female was highest for Deer Creek, 82.6, lower for Flynn Creek, 63.2, and lowest for Needle Branch, 53.4 (Table 16).

Table 13. Escapement, egg potential, and freshwater survival, Deer Creek, 1959-60 to 1971-72.

Brood Season	Female Escapement	Egg Potential[a]	Smolt Count	Freshwater Survival(%)
1959-60	21	43,197	1917	4.43
1960-61	19	44,156	2210	5.00
1961-62	28	67,620	2775	4.10
1962-63	18	42,030	2082	4.95
1963-64	27	62,964	2368	3.76
1964-65	44	104,940	1836	1.75
1965-66	24	55,176	2245	4.07
1966-67	56	141,798	2461	1.74
1967-68	23	52,815	2160	4.09
1968-69	39	80,301	1484	1.85
1969-70	8	15,484	738	4.77
1970-71	10	22,119	1072	4.85
1971-72	36	73,134	1923	2.63
$\bar{X}$	27.2	61,979.5	1943.9	3.691
S	13.6	33,737.8	563.02	1.254

[a] Calculated from regression equation (Koski 1966), Y=-3,184+7.81X, where X= average length in mm (from unpublished data) and Y= individual fecundity. Total egg potential then equals Y times the number of female spawners.

Table 14. Escapement, egg potential, and freshwater survival, Flynn Creek, 1959-60 to 1972-73.

Brood Season	Female Escapement	Egg Potential[a]	Smolt Count	Freshwater Survival (%)
1959-60	8	17,368	875	5.04
1960-61	26	66,742	776	1.16
1961-62	51	131,427	1354	1.03
1962-63	2	4,644	565	12.2
1963-64	20	44,220	736	1.66
1964-65	10	24,020	663	2.76
1965-66	11	26,565	968	3.64
1966-67	55	138,050	616	0.446
1967-68	10	23,130	430	1.86
1968-69	19	38,931	207	0.532
1969-70	5	9,625	140	1.45
1970-71	5	13,745	330	2.40
1971-72	18	37.404	404	1.08
$\bar{X}$	18.5	44,297.8	620.2	2.712
S	16.8	43,366.7	333.6	3.131

[a] Calculated from regression equation (Koski 1966), Y=-3,184+7.81X, where X= average length in mm (from unpublished data) and Y= individual fecundity. Total egg potential then equals Y times the number of female spawners.

Table 15. Escapement, egg potential, and freshwater survival, Needle Branch, 1959-60 to 1971-72.

Brood Season	Female Escapement	Egg Potential[a]	Smolt Count	Freshwater Survival (%)
1959-60	2[b]	4,471[b]	462	10.3
1960-61	2	4,192	223	5.32
1961-62	15	33,135	470	1.42
1962-63	4	9,632	314	3.26
1963-64	15[c]	33,530[d]	160	0.477
1964-65	25[c]	55,884[d]	286	0.512
1965-66	28[c]	62,590[d]	333	0.532
1966-67	19	46,664	277	0.594
1967-68	15	40,460	421	1.04
1968-69	17	35,088	194	0.553
1969-70	1	2,666	76	2.85
1970-71	2	5,386	113	2.10
1971-72	18	35,604	369	1.04
$\bar{X}$	12.5	28,407.8	284.5	2.308
S	9.32	20,919.4	127.6	2.798

[a] Calculated from regression equation (Koski 1966), Y=-3,184+7.81X, where X= average length in mm (from unpublished data) and Y= average individual fecundity. Total egg potential then equals Y times the number of female spawners.

[b] Estimated equivalents from 1627 planted fry.

[c] Estimated from redd surveys.

[d] Estimated from mean female length ($\bar{X}$=693.9 mm) from the other years of the study.

Table 16. Number of smolts per female, 1959-60 to 1971-72.

Brood Season	Deer	Flynn	Needle
1959-60	91.3	109	231[a]
1960-61	116	29.8	112
1961-62	91.1	26.5	31.3
1962-63	115	283	78.5
1963-64	87.9	36.8	10.7
1964-65	41.8	66.3	11.4
1965-66	93.5	88.0	11.9
1966-67	43.9	11.2	14.6
1967-68	93.9	43.0	28.1
1968-69	38.1	10.9	11.4
1969-70	92.3	28.0	76.0
1970-71	107	66.0	56.5
1971-72	53.4	22.4	20.5
$\bar{X}$	82.62	63.15	53.38
S	28.18	72.43	62.53

[a] Based on a plant of 1627 fry.

The hypothesis is advanced that there is no relationship between adult escapement and smolt yield based on previous studies of Au (1972) and Crone and Bond (1976). However, the correlation coefficients between the two variables (Fig. 19) are positive, though not quite significant (DC - r=0.448; FC - r=0.477; NB - r=0.447). With the low number of spawners, the data may comprise part of the ascending limb of a general spawner-recruit curve (Ricker 1975), a potential explanation for the observed relationship.

Other Species

The only other fish species in the study streams that might have an effect on coho salmon smolts are cutthroat trout and reticulate sculpin.

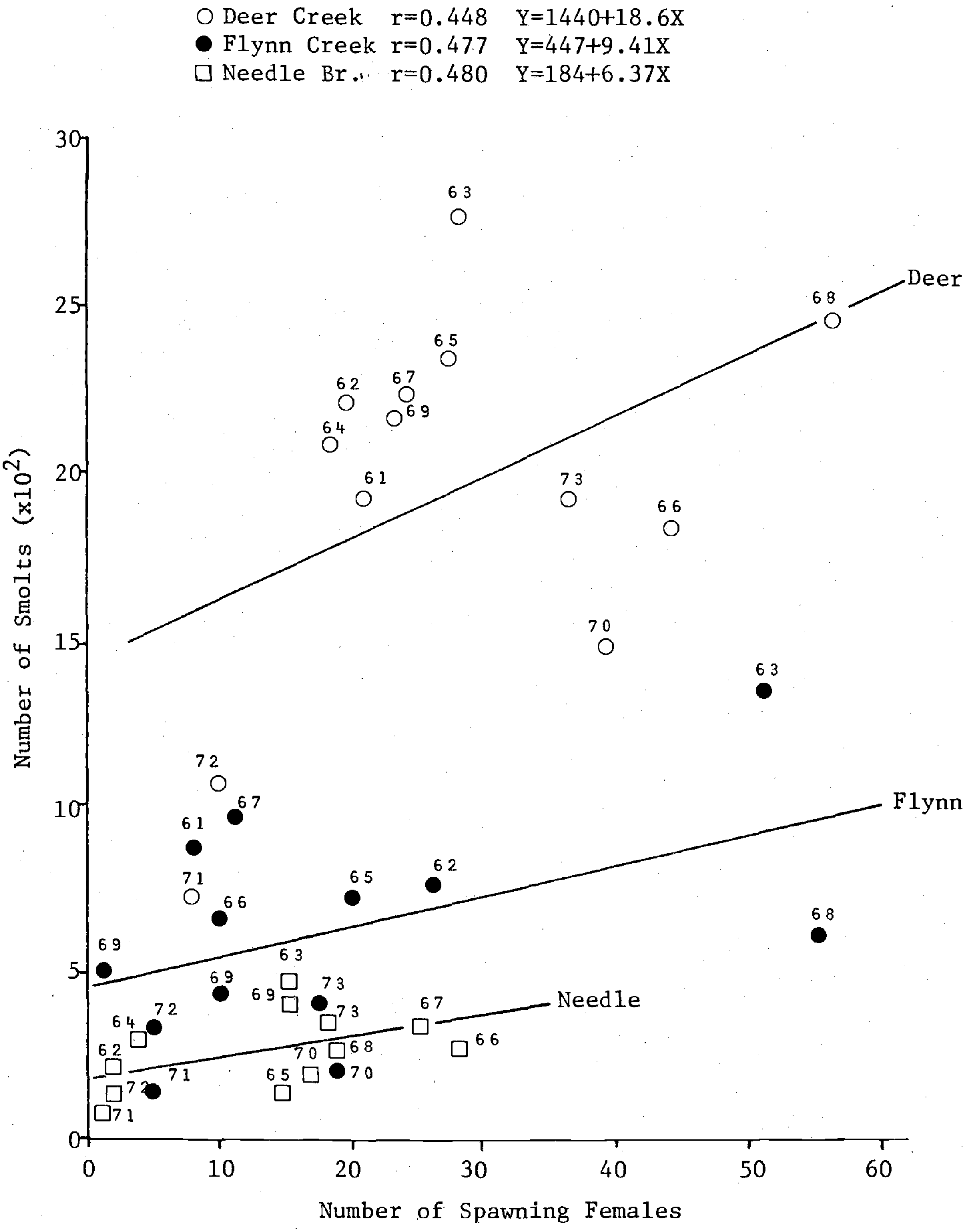

Figure 19. Number of spawning females versus total November-May smolt count. Second year of smolt run is indicated.

The substantial decline in the cutthroat population in Needle Branch following logging is clearly seen from September biomass estimates (Fig. 20; Appendix Table 36).

If there were significant interactions between the species (Glova 1978), then one might expect a negative relationship between cutthroat biomass and total smolt count. That is, cutthroat biomass should be inversely related to coho biomass, and because coho biomass and smolt count are directly related, one would expect a negative correlation between those two variables. This is only slightly evident in Deer Creek, however, whereas the relationship seems to be positive in the other two streams (DC - r=-0.163; FC - r=0.328; NB - r=0.323). For the relationship between cutthroat biomass and total seasonal smolt weight (biomass), only the Flynn Creek correlation is positive (DC - r=-0.153; FC - r=0.251; NB - r=-0.298). Some other factor in Flynn Creek may be masking this interaction. Perhaps food availability may be partly responsible. Years of higher food availability could be beneficial to both species, with a resulting positive correlation between the two variables. Biomass estimates of both coho and cutthroat in September (Fig. 21) are not well correlated, although the relationship is negative in Needle Branch, as expected (DC - r=0.062; FC - r=0.036; NB - r=-0.345).

In-depth study of the sculpin populations occurred only during 1965-66 (Krohn 1967). Consequently, there are insufficient data to determine any relationships with the total seasonal coho smolt yield.

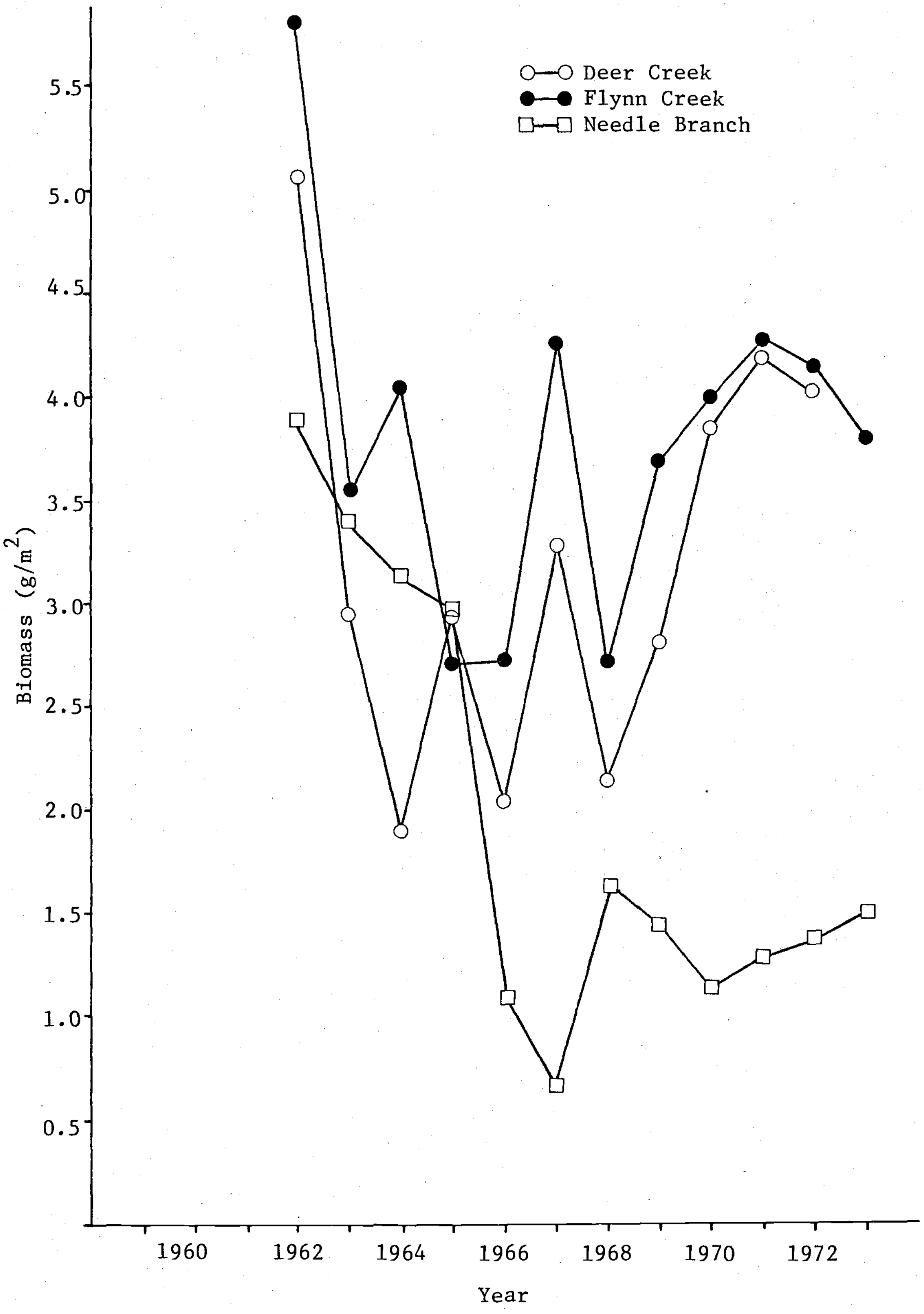

Figure 20. Mean September biomass (g/m^2) of cutthroat trout, 1962-1973.

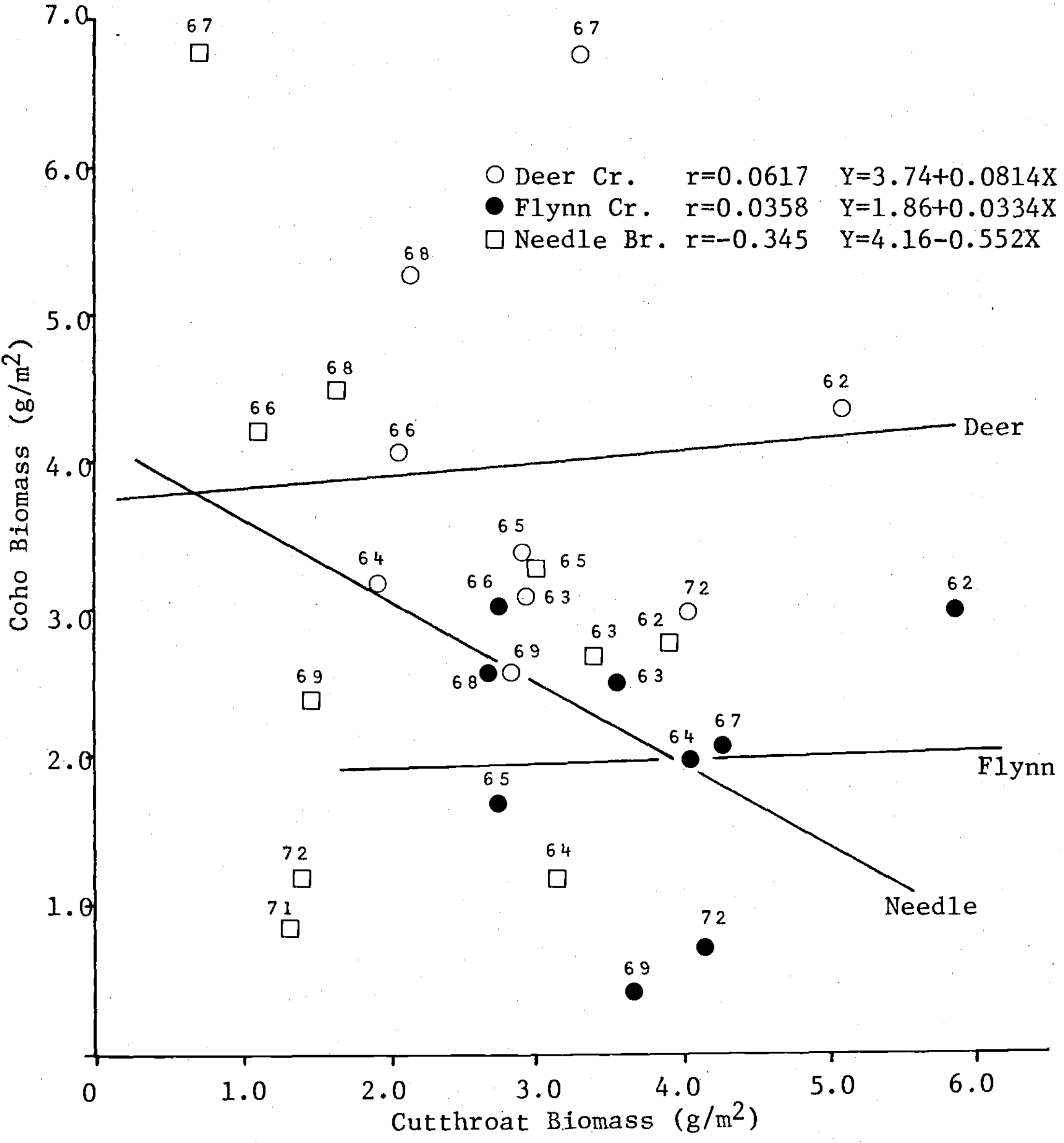

Figure 21. Mean cutthroat biomass (g/m^2) in September versus mean coho biomass (g/m^2) in September.

Multiple Regression Models

The preceding regression analyses lead to the conclusion that no one factor can adequately explain the variability in smolt output over the entire study period. If high stream temperatures and low streamflows have similar effects on the smolt migration, then a combination of these two factors might explain more of the variability in smolt counts than would either factor singly. Multiple regression analysis was employed with smolt counts as the dependent variable and mean lowest discharge and mean maximum temperature for 30-, 15-, and 7-day intervals as independent variables. An underlying assumption in multiple regression analysis is that the independent variables are not related or interacting with each other. Table 17 shows all the correlation coefficients to be insignificant between mean maximum temperature and mean lowest discharge. For comparative purposes, the original single correlation coefficients between streamflow and count and between temperature and count are presented as well as the square root of the coefficients of multiple determination (Table 18). However, none of the resulting multiple correlations is substantially higher than the original correlations, and none is significant.

Table 17. Correlation coefficients between mean maximum temperature and mean lowest discharge.

Time Interval	Deer	Flynn	Needle
30 days	-0.417	-0.306	0.226
15 days	-0.429	-0.209	0.232
7 days	-0.426	-0.208	0.241

Table 18. Correlation coefficients for mean lowest discharge, mean maximum temperature, and the combination versus total November-May smolt count.

Time Interval	Deer	Flynn	Needle
	Discharge		
30 days	0.178	0.005	0.060
15 days	0.234	0.088	0.099
7 days	0.279	0.095	0.134
	Temperature		
30 days	0.020	0.443	0.153
15 days	-0.028	0.474	0.147
7 days	0.018	0.436	0.107
	Combination		
30 days	0.205	0.467	0.155
15 days	0.248	0.514	0.161
7 days	0.317	0.476	0.154

Consequently, in this case the streamflow-temperature combination does not account for any more of the variability in seasonal smolt count than either variable did separately. Also, there were no significant improvements in the model by using total smolt weight instead of smolt count.

One additional step was to combine sediment concentration and mean highest discharge for the three time intervals in multiple regressions with smolt count. For Deer Creek the negative relationship is stronger and more significant than with either variable alone (Table 19). For the other two streams, however, the correlations are little better than those obtained with highest discharge alone. No improvements in the correlations were found by using total smolt weight instead of count.

Table 19. Correlation coefficients for mean highest discharge, mean sediment concentration, and the combination versus total November-May smolt count.

Time Interval	Deer	Flynn	Needle
	Discharge		
30 days	-0.618*	-0.440	-0.360
15 days	-0.608*	-0.398	-0.362
7 days	-0.268*	-0.211	-0.294
	Sediment		
30 days	-0.472	-0.358	-0.094
15 days	-0.344	-0.219	0.028
7 days	-0.060	-0.053	0.116
	Combination		
30 days	-0.651*	-0.467	-0.383
15 days	-0.620*	-0.398	-0.379
7 days	-0.378	-0.318	-0.312

However, there is a strong relationship between sediment concentration and mean highest discharge in the same time intervals for Deer and Flynn creeks (Table 20), so the results of this multiple regression analysis may be tenuous. The low correlations in Needle Branch are likely due to a change in the sediment-discharge relationship following logging. Higher sediment yields and concentrations following logging

Table 20. Correlation coefficients between mean sediment concentration and mean discharge for 30, 15, and 7 consecutive days of highest discharge.

Time Interval	Deer	Flynn	Needle
30 days	0.471	0.505	-0.104
15 days	0.708**	0.712**	0.222
7 days	0.808**	0.849**	-0.034

associated with similar discharge patterns before and after logging would result in a regression line with a nearly horizontal slope and a low correlation coefficient.

The most important regression analyses consist of several variables on smolt count and total smolt weight for the populations in each stream. Stream-specific variables used in the full model are shown in Table 21. For the Deer Creek smolt count, the best model for the entire study period was with January discharge, spawning female count, and mean lowest discharge, respectively (R^2=0.501**). When biomass was added, two years of data had to be deleted because September biomass estimates were not made in 1970 or 1971 (Appendix Table 32). With 11 years of data remaining, the best model (Appendix Table 37) was with September biomass and mean May maximum temperatures, respectively (R^2=0.639**). However, with a nearly significant relationship between spawning female count and September biomass (r=0.460), a third model

Table 21. Stream-specific variables used for the full model in multiple regression analyses against total November-May smolt count and total November-May smolt weight.

Variable	Deer	Flynn	Needle
Spawning female count	seasonal	seasonal	seasonal
Mean maximum monthly temperature	May	July	June
Mean maximum temperature	15 days	15 days	15 days
Timing of lowest discharge	15 days	30 days	15 days
Mean lowest discharge	7 days	15 days	30 days
Mean monthly biomass	September	September	September
Mean monthly discharge	January	January	January
Mean highest discharge	30 days	30 days	60 days
Sediment concentration in highest discharge	30 days	30 days	30 days

was tried with female count deleted, yet there was no change in the results. Note the importance of January discharge in contributing to smolt count variability, but when the biomass variable is added, this streamflow variable is no longer a significant contributor to the model. No significant relationships were found when modeling against total seasonal smolt weight (biomass) for Deer Creek fish. Although the correlation between count and weight is high (r=0.833**), there are apparently enough differences between the two variables to nullify any significance in the model by regressing against weight instead of count.

Abundance of smolts in Flynn Creek was associated most highly with September biomass. In the absence of this variable, only January discharge contributed significantly to the model (R^2=0.348*). With biomass, however, the model (Appendix Table 38) was substantially improved (R^2=0.805**). In addition to September biomass and January discharge, mean sediment concentration in the highest discharge was also important in this model. The R^2 value was not significantly affected by the presence or absence of the female spawner count. In the regression against total smolt weight, the model with biomass alone was just as significant (R^2=0.807**), but here the mean lowest discharge was the only significant contributor to the model in addition to biomass. When female spawners were added (Appendix Table 39), the model improved significantly (R^2=0.888**). A close correlation between smolt count and total weight (r=0.950**) may be partly responsible for this improvement.

For the Needle Branch smolts, January discharge and timing of the lowest mean discharge contribute significantly to the model (R^2=0.538**). Neither the presence, absence, or combination of biomass or spawning female count improved the model significantly, although the correlation was slightly higher (Appendix Table 40) with only 11 years of data (R^2=0.572**). All of the models regressed against total weight were insignificant. This could be partly due to the relatively low correlation (r=0.673**) between smolt count and total smolt weight.

The low final R^2 value for Needle Branch may be partly due to changes in stream variables following logging. These changes may have been substantial enough to lower the overall relationship with smolt count such that very few of those variables were significant additions to the model.

To summarize this preliminary model-building process, 63.9% of the variability in Deer Creek smolt count could be explained by the multiple regression with September biomass and mean May maximum temperatures. September biomass, January discharge, and mean sediment concentration explained 80.5% of the variability in Flynn Creek smolt counts. Only 53.8% of the variability in Needle Branch smolt counts was explained, by January discharge and timing of the mean lowest discharge. When regressing these variables against total smolt weight (biomass) instead of count, the model was improved only for Flynn Creek fish.

These results should be regarded cautiously because of the small number of data points compared to the number of variables in the full model. Ideally, more data would define the relationships better. There is also difficulty in interpretation of some of the specific results. For example, the May temperatures in the Deer Creek model are not high enough to be biologically significant. Also, use of the sediment concentration variable in the Flynn Creek model may be tenuous. As is, these preliminary results are useful only in highlighting approaches and trends.

DISCUSSION

Definition of the time period for the smolt migration was essential for determining the magnitude of the run. Because the number of fish checked through the downstream traps in September and October was very low compared to later months, the migration season was defined as beginning November 1 and continuing through May 31. In addition, juveniles moving downstream in September and October probably do not migrate directly to the ocean. They may rear further downstream before undergoing the parr-smolt transformation. This behavior could be a response to sea-water survival being a function of fish size, as opposed to age (Conte _et_ _al_. 1966). From laboratory experiments, only juveniles over 6 cm in length showed 30 day survivals in sea water over 50 percent. Consequently, a high mortality of early migrants (Sept.-Oct.) might be expected if they descended directly to the ocean. Therefore, most early migrants probably remained above the estuary until they reached a size at which they could tolerate the increase in salinity. At the Minter Creek, Washington downstream trap, fish that still had parr marks (primarily in February and March) were placed upstream (Salo and Bayliff 1958). The main smolt migration period there was from mid-April through May. Fish moving downstream out of the Alsea Watershed Study streams from November through February also may not migrate directly to the ocean. Conceivably, if a trap were installed further downstream, such as on Drift Creek just before it enters Alsea Bay, then a much shorter and later time interval of downstream migration may be seen. This would correspond better to the roughly two-month interval of smolt migration observed from studies in California, Washington, and Alaska (Shapovalov and Taft 1954; Salo and Bayliff 1958; Meehan and Siniff 1962; Drucker 1972; Crone and Bond 1976). However, with respect to the number of fish checked through the downstream traps in these three tributaries, there is a relatively smooth increase in magnitude during those four months (Nov.-Feb.) such that these early migrants cannot really be separated from the total seasonal migration (Fig. 2). These early migrants may not be smolts in the physiological sense, yet for the operational purpose of this analysis, they were considered as such.

There is evidence from previous studies that fluctuations in smolt output may be correlated to streamflow. In Cowichan Bay, British Columbia, a lower availability of coho to the sport fishery was noted for year classes that experienced low summer streamflows in their juvenile stages (Neave 1949). Two years of low summer rainfall, in the period 1946 to 1949, had two low counts of coho smolts in Nile Creek, British Columbia (Wickett 1951). A significant correlation between annual coho catch in the Siletz River, Oregon and low summer flows two years previously was reported by McKernan et al. (1950). In Waddell Creek, California (Shapovalov and Taft 1954), streamflow had a greater effect on the timing of migration than the number of smolts. There were earlier smolt migrations in years of low flow, and unusually high flows resulted in late downstream migrations.

Two of the more important studies relating streamflow to coho salmon production have been done by Smoker (1955) and Scarnecchia (1978). Smoker (1955) found very high correlations between annual and summer streamflow values for a combination of 23 western Washington watersheds and the commercial catch two years later, from 1935 through 1954. Scarnecchia (1978) found significant correlations between annual and winter streamflows on five Oregon coastal rivers and commercial catch two years later, from 1942 through 1962. These streamflows in both works, therefore, corresponded to periods of freshwater residence of the juveniles. Because the correlations from these studies are significant and span broader time periods of streamflow than used here so far, comparisons with the Alsea Watershed Study streams seemed in order (Table 22). On an individual stream basis, nearly all the correlations were negative, except for low positive correlations in August. A significant negative relationship (r=-0.55*) was found in Deer Creek between November-May (7 month) flow and smolt count. This time interval corresponds to the smolt migration period. In addition, significant negative relationships were found in Deer Creek (r=-0.59*) and Needle Branch (r=-0.54*) for the 17-month period corresponding to the beginning of the upstream adult migration period through the end of the smolt migration. When discharges from the three streams were combined (in acre-feet) and regressed against total smolt count of the three streams, none of the relationships improved significantly over any of the individual stream regressions.

One important distinction between these two studies and the present one is that Smoker and Scarnecchia have downstream, estuary, and ocean factors inherent in their relationships. One or several variables in those environments may be influencing the fish before they are caught by commercial fishermen. Also, these downstream variables must be

Table 22. Comparisons of correlation coefficients between streamflow and coho salmon production obtained by Smoker (1955), Scarnecchia (1978), and the present study.

Author:	Smoker	Scarnecchia	Knight				
Location:	W. Washington	5 W. Oregon Rivers	Alsea Bay Tributaries				
Years of Study:	1935-54	1942-62	1959-73				Combined
Streams:	Combined	Combined	Deer	Flynn	Needle	Combined	Female
Regressed Against:	Comm. Catch	Comm. Catch	Smolts	Smolts	Smolts	Smolts	Escapement
Annual	0.912**	0.56**	-0.24	-0.15	-0.39	-0.48	0.06
July	0.861**	0.20	-0.25	-0.28	-0.21	-0.20	0.30
August	0.825**	0.11	0.17	0.04	0.19	0.14	0.16
June-Sept.	0.795**		-0.12	-0.19	0.15	0.07	0.05
Lowest 60 days		0.28	0.07	-0.08	-0.06		
Nov.-May (7 month)		0.59**	-0.55*	-0.11	-0.38	-0.46	-0.17
Nov.-May (19 month)		0.68**	-0.59*	-0.26	-0.50	-0.59*	0.01
March-May		0.53*	-0.22	0.27	-0.14	-0.02	-0.19
Jan.-Sept.		0.52**	0.13	-0.05	-0.43	-0.16	0.09

somehow associated with streamflow. In the present study, however, the relationships have exclusively upstream headwater variables influencing the smolts. The negative relationships obtained here could conceivably be masked by one or more factors in the downstream or ocean environment. One method of testing this is to examine relationships between streamflow and the number of returning adults. Because the Oregon commercial catch is composed of several stocks of coho and since the number of smolts from these streams is small, this analysis needs to be restricted to adult escapement, specifically for spawning females. An important assumption here, which allows comparisons with the results of Smoker and Scarnecchia, is that catch:escapement ratios remain relatively constant throughout the study period. The resulting correlations are very low, yet all are positive except the November-May (7 month) and March-May relationships (Table 22).

The low relationship between discharge in the summer and smolt count is partly substantiated by research conducted by the Oregon Department of Fish and Wildlife at Elk Creek, a tributary to the Rogue River, Oregon. A 90 percent drop in streamflow reduced pool volume by only 25 percent (personal communication, T. E. Nickelson, Oregon Department of Fish and Wildlife, Corvallis, Oregon). Pool volume was the stream variable that correlated best with coho biomass (Nickelson and Hafele 1978), so the biomass (and to a certain extent, smolt yield) was not significantly affected by the wide fluctuation in discharge.

Very little work has been done on the effects of temperature regimes on fish populations in the Alsea Watershed Study stream. In experimental feeding studies, Iwanaga (1971) found higher growth rates in juveniles from cooler temperatures of Flynn Creek than the warmer temperatures from the clearcut Needle Branch. However, in the streams where the fish were feeding on natural food, this trend was reversed.

Interaction between fish species in streams has been studied in detail only recently. Habitat utilization by coho salmon and cutthroat trout was investigated by Bustard and Narver (1975) and Glova (1978) in British Columbia streams. Both species demonstrated a strong preference for clean rubble substrates as opposed to silted rubble. Glova (1978) found that in streams where both species occurred, coho salmon made up a greater percentage of the salmonid biomass in pools (53.1-90.8%) than did the trout (9.2-46.9%), while in riffles trout were predominant (63.4-88.0%). Cutthroat utilized pools more than riffles in streams where coho were absent. He postulated a greater niche plasticity among the socially subdominant cutthroat, due to their difficulty in obtaining an adequate share of available resources. Because cutthroat emerged much later in the year than did coho, they may emerge into a stream environment filled near capacity by coho fry. The trout would thus be largely restricted to riffle areas in summer and early fall. Based on Glova's findings, a negative relationship between abundance or biomass of the two species would be expected. In the Alsea Watershed Study streams, however, little relationship between the species was found.

Chapman (1966) reviewed the importance of food and space in regulating salmonid population numbers in streams. Interactions between the two, specifically density increases with increases in food supply, were discussed. He speculated that the physical environment only set the framework within which density was governed. In summer, each species was regulated by a space-food or sometimes a space-shelter mechanism. If density was regulated in the winter, it was probably related to space necessary to escape downstream displacement or damage by streamflow.

Mason (1976) attempted supplemental feeding of coho fry during their summer of stream residence in a study of food limitation in Sandy Creek, on Vancouver Island, British Columbia. He observed a seven-fold increase in biomass, yet the smolt yield the following spring was the same as before the experiment. The natural over-winter carrying capacity of the stream was thought to be the limiting factor.

In the present study, characteristics of the smolt migration were examined in terms of magnitude, length, weight, and timing of the downstream migrating fish. Then factors influencing the magnitude of the smolt migration were investigated. Physical factors, including streamflow, temperature, and sediment, had varying effects on the smolts, as summarized earlier. Other factors, such as stream measurements and changes therein, could have an important effect on the smolts, if adequate data were available. Biological factors analyzed include intracohort biomass, female escapement, and the influence of other species in the streams.

Limitations in available data prevented detailed analyses of the possible roles of food and space as regulators of the smolt production. The only data available on food consumed by coho salmon are from the early years of the study (Chapman 1961). Infrequent measurements of stream width, depth, and pool-riffle ratios are insufficient for anything better than conjecture. However, measurements of changes in pool volume relative to changes in streamflow could still be done now after termination of the study. These relationships may be useful in determining factors in the summer that could affect the subsequent smolt output, particularly in view of the Elk Creek, Oregon study.

Predation by fish-eating birds may also be an important factor regulating the smolt production. Elson (1962) showed a significant increase in Atlantic salmon (*Salmo salar*) smolts with merganser (*Mergus merganser*) control. Au (1972) noted the presence of the belted kingfisher (*Megacerle alcyon*) and the great blue heron (*Ardea herodias*), both predatory on small fish, at the three study streams. However, no data are available on the amount of predation, so the impact cannot be assessed.

As seen in the previous sections, the results obtained are highly variable among the streams. Even though the watersheds are adjacent to each other and have similar climatic and hydrologic regimes, their fish populations seem to show different relationships to various physical and biological factors. This variability prevents one from making any general conclusions about specific effects of certain variables on coho salmon smolts that could be extended or applied to other stream systems. The principles and methods may be applicable elsewhere, but this variability emphasizes the need to examine each stream location separately and completely.

The multiple regression analysis allows a partial model-building process incorporating those variables that were related to smolt counts by single regressions. A foundation has also been laid to test this approach on other aspects of the smolt migration, such as timing and mean length. However, interactions between variables in the model can often produce questionable results. If these interactions can be sorted out and separated, then this approach has the potential of yielding improved explanations or predictions of the variability encountered in the coho salmon smolt output.

LITERATURE CITED

Au, D.W.K. 1972. Population dynamics of the coho salmon and its response to logging in three coastal streams. Ph.D. Thesis. Oregon State University, Corvallis. 245 pp.

Beschta, R.L. 1978. Long-term patterns of sediment production following road construction and logging in the Oregon Coast Range. Water Resour. Res. 14:1011-1016.

Brazier, J.R. 1972. Controlling water temperatures with buffer strips. M.S. Thesis. Oregon State University, Corvallis. 65 pp.

Brazier, J.R., and G.W. Brown. 1973. Buffer strips for stream temperature control. Res. Paper 15. Forest Research Laboratory, Oregon State University, Corvallis. 9 pp.

Brown, G.W., and J.T. Krygier. 1967. Changing water temperatures in small mountain streams. J. Soil and Water Cons. 22:242-244.

Brown, G.W., and J.T. Krygier. 1970. Effects of clear-cutting on stream temperature. Water Resour. Res. 6:1133-1139.

Brown, G.W., and J.T. Krygier. 1971. Clear-cut logging and sediment production in the Oregon Coast Range. Water Resour. Res. 7:1189-1198.

Bustard, D.R., and D.W. Narver. 1975. Preferences of juvenile coho salmon (Oncorhynchus kisutch) and cutthroat trout (Salmo clarki) relative to simulated alteration of winter habitat. J. Fish. Res. Board Canada 32:681-687.

Chapman, D.W. 1961. Factors determining production of juvenile coho salmon, Oncorhynchus kisutch, in three Oregon streams. Ph.D. Thesis. Oregon State University, Corvallis. 214 pp.

Chapman, D.W. 1962. Aggressive behavior in juvenile coho salmon as a cause of emigration. J. Fish. Res. Board Can. 19:1047-1080.

Chapman, D.W. 1965. Net production of juvenile coho salmon in three Oregon streams. Trans. Amer. Fish. Soc. 94:40-52.

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

Conte, F.P., H.H. Wagner, J. Fessler, and C. Gnose. 1966. Development of osmotic and ionic regulation in juvenile coho salmon Oncorhynchus kisutch. Comp. Biochem. Physiol. 18:1-15.

Cordone, A.J., and D.W. Kelley. 1961. The influences of inorganic sediment on the aquatic life of streams. Calif. Fish and Game 47:189-228.

Corliss, J.F., and C.T. Dyrness. 1965. A detailed soil-vegetation survey of the Alsea area in the Oregon Coast Range. Pages 457-483 in C.T. Youngberg, ed. Forest-soil relationships in North America. Oregon State University, Corvallis.

Crone, R.A., and C.E. Bond. 1976. Life history of coho salmon, Oncorhynchus kisutch, in Sashin Creek, southeastern Alaska. N.M.F.S. Fish Bull. 74:897-923.

Drucker, B. 1972. Some life history characteristics of coho salmon of the Karluk River System, Kodiak Island, Alaska. N.M.F.S. Fish Bull. 70:79-94.

Elson, P.F. 1962. Predator-prey relationships between fish-eating birds and Atlantic salmon. Bull. Fish. Res. Board Can. 133. 87 pp.

Glova, G.J. 1978. Pattern and mechanism of resource partitioning between stream populations of juvenile coho salmon (Oncorhynchus kisutch) and coastal cutthroat trout (Salmo clarki clarki). Ph.D. Thesis. University of British Columbia, Vancouver, B.C. 185 pp.

Gunsolus, R.T. 1978. The status of Oregon coho and recommendations for managing the production, harvest, and escapement of wild and hatchery-reared stocks. Oregon Dept. Fish and Wildlife, Portland, Oregon. 59 pp.

Hall, J.D., and R.L. Lantz. 1969. Effects of logging on the habitat of coho salmon and cutthroat trout in coastal streams. Pages 355-375 in T.G. Northcote, ed. Symposium on salmon and trout in streams. H.R. MacMillan Lectures in Fisheries. University of British Columbia, Vancouver, B.C.

Harris, D.D. 1973. Hydrologic changes after clear-cut logging in a small Oregon coastal watershed. U.S. Geol. Surv. J. Res. 1:487-491.

Harris, D.D. 1977. Hydrologic changes after logging in two small Oregon coastal watersheds. U.S. Geol. Surv. Water Supply Paper 2037. 31 pp.

Harris, D.D., and R.C. Williams. 1971. Streamflow, sediment-transport, and water temperature characteristics of three small watersheds in the Alsea River Basin, Oregon. U.S. Geol. Surv. Circ. 642. 21 pp.

Hunter, J.G. 1959. Survival and production of pink and chum salmon in a coastal stream. J. Fish. Res. Board Can. 16:835-886.

Iwanaga, P.M. 1971. Effects of logging on the growth of juvenile coho salmon. M.S. Thesis. Oregon State University, Corvallis. 44 pp.

Koski, K V. 1966. The survival of coho salmon (Oncorhynchus kisutch) from egg deposition to emergence in three Oregon coastal streams. M.S. Thesis. Oregon State University, Corvallis. 84 pp.

Krohn, D.C. 1967. Production of the reticulate sculpin (Cottus perplexus) and its predation on salmon fry in three Oregon streams. M.S. Thesis. Oregon State University, Corvallis. 78 pp.

Lowry, G.R. 1964. Net production, movement, and food of cutthroat trout (Salmo clarki clarki Richardson) in three Oregon coastal streams. M.S. Thesis. Oregon State University, Corvallis. 72 pp.

Mason, J.C. 1976. Response of underyearling coho salmon to supplemental feeding in a natural stream. J. Wildl. Mgmt. 40:775-788.

McKernan, D.L., D.R. Johnson, and J.I. Hodges. 1950. Some factors influencing the trends of salmon populations in Oregon. Trans. N. Amer. Wildl. Conf. 14:427-448.

Meehan, W.R. and D.B. Siniff. 1962. A study of the downstream migrations of anadromous fishes in the Taku River, Alaska. Trans. Amer. Fish. Soc. 91:399-407.

Moring, J.R. 1975. The Alsea Watershed Study: Effects of logging on the aquatic resources of three headwater streams of the Alsea River, Oregon. Part II: Changes in environmental conditions. Oregon Dept. Fish and Wildlife, Fish. Res. Rep. No 9 (Part 2). 39 pp.

Moring, J.R.,and R.L. Lantz. 1975. The Alsea Watershed Study: Effects of loggins on the aquatic resources of three headwater streams of the Alsea River, Oregon. Part I: Biological studies. Oregon Dept. Fish and Wildlife, Fish. Res. Rep. No. 9 (Part 1). 66 pp.

Neave, F. 1949. Game fish populations of the Cowichan River. Fish Res. Board Can.Bull. 84. 32 pp.

Neter, J.,and W. Wasserman. 1974. Applied linear statistical models. Richard D. Irwin, Inc. Homewood, Illinois. 842 pp.

Nickelson, T.E.,and R.E. Hafele. 1978. Streamflow requirements of salmonids. Proj. AFS-62. Oregon Dept. Fish and Wildlife, Portland, Oregon. 26 pp.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Fish. Res. Board Can. Bull. 191. 382 pp.

Ringler, N.H., and J.D. Hall. 1975. Effects of logging on water temperature and dissolved oxygen in spawning beds. Trans. Amer. Fish. Soc. 104:111-121.

Salo, E.G., and W.H. Bayliff. 1958. Artificial and natural reproduction of silver salmon, Oncorhynchus kisutch, at Minter Creek, Washington. Wash. Dept. Fish. Res. Bull. 4. 76 pp.

Scarnecchia, D.L. 1978. Factors affecting coho salmon production in Oregon. M.S. Thesis. Oregon State University, Corvallis, 100 pp.

Shapovalov, L., and A.C. Taft. 1954. The life history of the steelhead rainbow trout (Salmo gairdneri gairdneri) and silver salmon (Oncorhynchus kisutch) with special reference to Waddell Creek, California, and recommendations regarding their management. Calif. Dept. Fish Game Fish Bull. 98:1-375.

Skeesick, D.G. 1970. The fall immigration of juvenile coho salmon into a small tributary. Ore. Fish Comm. Res. Rep. 2(1):90-95.

Smoker, W.A. 1955. Effects of streamflow on silver salmon production in western Washington. Ph.D. Thesis. University of Washington, Seattle. 195 pp.

Snedecor, G.W., and W.G. Cochran. 1967. Statistical methods. Sixth Ed. Iowa State University Press. Ames, Iowa. 593 pp.

U.S. Geological Survey. 1958-65. Water Supply Papers No. 1518, 1638, 1645, 1718, 1745, 1885, 1935. Washington, D.C. Superintendent of Documents.

U.S. Geological Survey. 1961-1973. Water resources data for Oregon. Washington, D.C. Superintendent of Documents.

Wickett, W.P. 1951. The coho salmon population of Nile Creek. Fish. Res. Board Can., Progr. Rep. (Pac.). 89:88-89.

Willis, R.A. 1962. Gnat Creek weir studies. Final Report. Ore. Fish. Comm., Portland, Ore. 71 pp. (mimeo).

APPENDIX

Appendix Table 1. Mean monthly smolt weight (gr-W), corresponding mean length (mm-L), and mean condition factor (K), Deer Creek downstream trap, 1968-69 to 1972-73.

		Season					
Month		68-69	69-70	70-71	71-72	72-73	Mean
Nov.	W			6.00			6.00
	L			83.0			83.0
	K			1.048			1.048
	N			3			3
Dec.	W			4.25	4.80	3.52	3.617
	L			73.5	77.5	68.8	69.45
	K			1.070	1.031	1.013	1.016
	N			1	2	31	34
Jan.	W		5.85	4.10		3.25	3.403
	L		81.5	73.8		67.5	68.40
	K		1.077	1.012		1.029	1.030
	N		2	2		41	45
Feb.	W		6.32	6.02	4.74	3.75	5.110
	L		83.6	83.8	77.4	72.5	78.75
	K		1.053	1.010	1.005	0.978	1.014
	N		43	13	55	32	143
Mar.	W		7.48	7.25	7.38	5.17	7.053
	L		89.1	88.9	88.6	79.3	87.33
	K		1.029	1.009	1.033	0.998	1.025
	N		41	47	269	61	418
Apr.	W	8.29	8.50	9.98	9.79	8.23	9.271
	L	91.8	93.8	97.4	97.8	92.4	95.66
	K	1.038	1.020	1.064	1.023	1.020	1.032
	N	116	12	46	208	17	399
May	W	10.03		9.63	11.42	10.16	10.71
	L	99.2		98.3	102.7	99.1	100.8
	K	1.006		1.001	1.038	1.035	1.025
	N	64		9	94	26	193
Mean	W						7.886
	L						89.94
	K						1.026
	N						1235

Appendix Table 2. Mean monthly smolt weight (gr-W), corresponding mean length (mm-L), and mean condition factor (K), Flynn Creek downstream trap, 1969-70 to 1972-73.

		Season				
Month		69-70	70-71	71-72	72-73	Mean
Nov.	W					
	L					
	K					
	N					
Dec.	W				2.77	2.77
	L				59.7	59.7
	K				1.117	1.117
	N				7	7
Jan.	W	5.16			5.05	5.087
	L	78.0			79.0	78.67
	K	1.087			1.018	1.041
	N	1			2	3
Feb.	W	6.65	4.68	5.75	3.31	5.247
	L	86.5	77.5	82.3	69.7	79.73
	K	1.017	1.089	1.015	0.974	1.014
	N	4	4	28	9	45
Mar.	W	8.16	8.21	7.47	4.55	7.195
	L	91.2	91.9	88.7	76.7	87.52
	K	1.059	1.029	1.015	0.985	1.035
	N	58	36	125	48	267
Apr.	W	11.87	9.13	9.55	6.73	9.547
	L	102.9	94.5	96.4	87.0	96.23
	K	1.065	1.075	1.047	1.010	1.049
	N	11	15	116	7	149
May	W			9.94	6.57	9.435
	L			98.0	86.0	96.20
	K			1.042	1.018	1.038
	N			17	3	20
Mean	W					7.746
	L					89.35
	K					1.039
	N					491

Appendix Table 3. Mean monthly smolt weight (gr-W), corresponding mean length (mm-L), and mean condition factor (K), Needle Branch downstream trap, 1967-68 to 1972-73.

Month		Season						
		67-68	68-69	69-70	70-71	71-72	72-73	Mean
Nov.	W							
	L							
	K							
	N							
Dec.	W						3.53	3.53
	L						69.3	69.3
	K						1.018	1.018
	N						23	23
Jan.	W						3.10	3.10
	L						67.5	67.5
	K						1.009	1.009
	N						2	2
Feb.	W			9.97			4.30	7.135
	L			93.3			74.3	83.80
	K			1.222			1.032	1.127
	N			3			3	6
Mar.	W			8.63	9.27	14.42	5.96	9.619
	L			93.6	93.3	109.4	82.1	94.52
	K			1.043	1.130	1.062	1.007	1.048
	N			26	18	44	49	137
Apr.	W	8.74	9.11	9.71	11.56	17.74	11.61	11.74
	L	92.7	95.1	97.3	101.1	117.1	105.3	101.6
	K	1.074	1.030	1.041	1.102	1.062	0.981	1.060
	N	59	32	42	31	59	7	230
May	W	9.06	6.92		13.47	13.22	9.23	9.214
	L	93.6	88.2		108.7	106.4	96.0	94.76
	K	1.091	0.978		1.038	1.095	1.028	1.048
	N	20	13		3	5	7	48
Mean	W							10.29
	L							96.63
	K							1.053
	N							446

Appendix Table 4. Correlation coefficients for log W versus log L, 1967-68 to 1972-73, based on seasonal samples of 40 smolts measured at the downstream traps.

Season	Deer	Flynn	Needle
1967-68	-	-	0.963
1968-69	0.979	-	0.993
1969-70	0.984	0.988	0.959
1970-71	0.992	0.988	0.963
1971-72	0.966	0.994	0.975
1972-73	0.996	0.985	0.995

Appendix Table 5. Statistics for the relationship between length (L) in mm and weight (W) in grams of the form $W=aL^b$ (from Au, 1972 and unpublished data). Values from Au (1972) are based on data from in-stream fish, whereas more recent values are based on downstream trap data.

	Deer[a]		Flynn[b]		Needle[c]	
Season	a[d]	b	a[d]	b	a[d]	b
1963-64	13.26	2.958	14.31	2.946	5.59	3.162
1964-65	5.04	3.189	6.48	3.127	22.97	2.854
1965-66	42.64	2.693	87.96	2.523	249.23	2.255
1966-67	59.24	2.645	36.23	2.748	8.05	3.079
1967-68	122.33	2.396	3.40	3.303	26.06	2.804
1968-69	16.11	2.910	6.48	3.129	11.43	2.977
1969-70	10.35	3.000	14.09	2.936	60.95	2.615
1970-71	7.534	3.067	12.88	2.951	26.42	2.812
1971-72	8.630	3.035	13.40	2.943	7.047	3.087
1972-73	13.58	2.933	32.81	2.730	16.33	2.894

[a] From Au (1972) through 1967-68.

[b] From Au (1972) through 1968-69.

[c] From Au (1972) through 1966-67.

[d] Multiply these values by 10^{-6}.

Appendix Table 6. Comparison of weight prediction from mean monthly smolt length between in-stream sampling and downstream trap data, 1967-68 and 1968-69 (from Au 1972 and unpublished data).

Location	Season	Month	Length (mm)	Stream Weight	Trap Weight	Diff.	%Diff.
Needle Br.	1967-68	Nov	54.8	1.65g	1.96g	+0.31	15.8%
		Dec	68.9	3.37	3.72	+0.35	9.41
		Jan	73.2	4.07	4.41	+0.34	7.71
		Feb	75.0	4.39	4.72	+0.33	6.99
		Mar	85.0	6.49	6.70	+0.21	3.13
		Apr	91.8	8.25	8.31	+0.05	0.602
		May	93.6	8.77	8.78	+0.01	0.114
Needle Br.	1968-69	Nov	66.3	3.16	3.02	-0.14	4.64
		Dec	68.2	3.44	3.29	-0.15	4.56
		Jan	70.1	3.74	3.57	-0.17	4.76
		Feb	73.0	4.21	4.03	-0.18	4.47
		Mar	88.1	7.37	7.05	-0.32	4.54
		Apr	96.0	9.52	9.10	-0.42	4.62
		May	86.8	7.05	6.75	-0.30	4.44
Deer Cr.	1968-69	Nov	72.0	3.98	4.09	+0.11	2.69
		Dec	74.9	4.47	4.59	+0.12	2.61
		Jan	77.5	4.93	5.07	+0.14	2.76
		Feb	79.0	5.21	5.36	+0.15	2.80
		Mar	83.6	6.14	6.32	+0.18	2.85
		Apr	92.1	8.14	8.38	+0.24	2.86
		May	98.0	9.74	10.04	+0.30	2.99

Appendix Table 7. FORTRAN program for computation and output of 30 consecutive days of mean lowest discharge and starting date, 1959-1972, with June 1 as day 1.

```
      PROGRAM LOFLO (INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
      DIMENSION MTH(24), SUMFLO(15,185), DATAFLO(15,185),
     1FLS(15,185), FINVAL(15), IM(15)
      DATA (MTH=8,8,8,6,8,8,8,7,8,8,8,7,8,8,8,6,8,8,8,7,8,8,8,6)
      WRITE (6,2)
    2 FORMAT ("STREAMFLOW VALUES - LOWEST 30 DAYS",/)
      DO 50 LYR=1,14
      IX=1
      IY=6
      DO 20 LP=1,24
      IF (MTH(LP).EQ.6) GO TO 12
      IF (MTH(LP).EQ.7) GO TO 8
      IY=IY+2
      READ (5,6) (FLS(LYR,LM),LM=IX,IY)
    6 FORMAT (25X,8F7.2)
      GO TO 16
    8 IY=IY+1
      READ (5,10) (FLS(LYR,LM),LM=IX,IY)
   10 FORMAT (25X,7F7.2)
      GO TO 16
   12 READ (5,14) (FLS(LYR,LM),LM=IX,IY)
   14 FORMAT (25X,6F7.2)
   16 IX=IY+1
      IY=IY+6
   20 CONTINUE
      DO 25 J=1,154
      K=J+29
      STRFLO=0.
      DO 22 I=J,K
      SUMFLO(LYR,I)=STRFLO+FLS(LYR,I)
      STRFLO=SUMFLO(LYR,I)
   22 CONTINUE
      DATAFLO(LYR,J)=STRFLO
   25 CONTINUE
      COMPVAL=DATAFLO(LYR,2)
      DO 40 M=1,154
      IF (DATAFLO(LYR,M).LT.COMPVAL) GO TO 30
      GO TO 40
   30 COMPVAL=DATAFLO(LYR,M)
      IMS=M
   40 CONTINUE
      FINVAL(LYR)=COMPVAL/30.
      IM(LYR)=IMS
      COMPVAL=0.
      IMS=0
   50 CONTINUE
      WRITE (6,60)
   60 FORMAT ("YEAR",4X,"START",5X,"VALUE",/)
      DO 80 LYR=1,14
      WRITE (6,70) LYR, IM(LYR), FINVAL(LYR)
   70 FORMAT (1X,I2,6X,I3,5X,F7.4)
   80 CONTINUE
      END
```

Appendix Table 8. Monthly smolt counts, Deer Creek, 1959-60 to 1972-73.

Month		Season															
		59-60	60-61	61-62	62-53	63-64	64-65	65-66	66-67	67-68	68-69	69-70	70-71	71-72	72-73	x̄	s
Sept.	Live	0	0	4	0	4	0	0	0	29	6	8	5	3	0		
	Dead	0	0	0	0	1	0	0	1	4	0	0	0	0	0		
	Total	0	0	4	0	5	0	0	1	33	6	8	5	3	0	4.64	8.61
Oct.	Live	116	0	4	1	4	0	0	0	11	5	2	1	3	0		
	Dead	0	0	2	0	0	0	0	0	0	1	0	0	0	0		
	Total	116	0	6	1	4	0	0	0	11	6	2	1	3	0	10.7	30.5
Nov.	Live	27	66	121	53	95	181	124	85	25	119	34	24	31	1		
	Dead	0	2	18	0	5	134	68	5	2	5	0	0	5	0		
	Total	27	68	139	53	100	315	192	90	27	124	34	24	36	1	87.9	84.5
Dec.	Live	16	9	244	14	30	138	309	32	85	86	48	15	38	32		
	Dead	0	0	0	2	0	4	25	0	2	17	1	1	2	26		
	Total	16	9	244	16	30	142	334	32	87	103	49	16	40	58	84.0	96.4
Jan.	Live	31	7	20	3	174	66	242	39	24	116	26	4	9	41		
	Dead	0	2	0	0	5	6	0	0	1	6	2	1	1	2		
	Total	31	9	20	3	179	72	242	39	25	122	28	5	10	43	59.1	72.4
Feb.	Live	261	132	261	584	218	332	338	305	234	237	134	28	96	30		
	Dead	5	4	1	5	0	1	1	0	15	21	3	0	10	2		
	Total	266	136	262	589	218	333	339	305	249	258	137	28	106	32	232.7	145.0
Mar.	Live	1695	804	735	1218	730	647	260	722	803	554	410	238	440	670		
	Dead	34	2	36	9	2	86	0	0	3	5	0	3	14	12		
	Total	1729	806	771	1227	732	733	260	722	806	559	410	241	454	682	723.7	385.1
Apr.	Live	817	780	730	676	597	622	342	709	1003	647	650	324	285	907		
	Dead	9	2	1	3	6	2	0	0	1	10	0	15	20	17		
	Total	826	782	731	679	603	624	342	709	1004	657	650	339	305	924	655.4	209.9
May	Live	150	107	43	207	220	134	125	348	263	334	176	83	121	172		
	Dead	0	0	0	1	0	15	2	0	0	3	0	2	0	11		
	Total	150	107	43	208	220	149	127	348	263	337	176	85	121	183	179.8	89.2
June	Live	5	0	1	8	10	4	1	6	1	2	1	0	1			
	Dead	0	0	0	0	0	0	0	0	0	0	0	0	0	-		
	Total	5	0	1	8	10	4	1	6	1	2	1	0	1		3.08	3.25
Nov.-May	Live	2997	1905	2154	2755	2064	2120	1740	2240	2437	2093	1478	716	1020	1853		
	Dead	48	12	56	20	18	248	96	5	24	67	6	22	52	70		
	Total	3045	1917	2210	2775	2082	2368	1836	2245	2461	2160	1484	738	1072	1923	2022.0	615.3

Appendix Table 9. Monthly smolt counts, Flynn Creek, 1959-60 to 1972-73.

		Season															
Month		59-60	60-61	61-62	62-63	63-64	64-65	65-66	66-67	67-68	68-69	69-70	70-71	71-72	72-73	$\bar{X}$	s
Sept.	Live	0	3	4	23	0	0	1	2	0	0	0	1	0	0		
	Dead	0	2	0	1	0	0	0	5	0	0	0	0	0	0		
	Total	0	5	4	24	0	0	1	7	0	0	0	1	0	0	3.00	6.46
Oct.	Live	1	4	6	20	0	1	0	3	4	2	1	0	1	0		
	Dead	0	0	0	32	0	0	0	0	0	0	0	0	1	0		
	Total	1	4	6	52	0	1	0	3	4	2	1	0	2	0	5.43	13.5
Nov.	Live	1	24	3	62	6	28	3	13	5	30	19	0	5	0		
	Dead	0	2	1	0	0	11	0	3	0	3	1	0	1	0		
	Total	1	26	4	62	6	39	3	16	5	33	20	0	6	0	15.8	18.4
Dec.	Live	1	0	4	7	97	14	13	67	6	23	7	1	10	10		
	Dead	0	1	1	0	0	5	2	0	5	2	0	0	2	1		
	Total	1	1	5	7	97	19	15	67	11	25	7	1	12	11	19.9	27.8
Jan.	Live	11	9	16	1	9	18	51	8	2	13	8	1	1	2		
	Dead	0	2	0	0	0	0	0	0	2	5	1	0	0	0		
	Total	11	11	16	1	9	18	51	8	4	18	9	1	1	2	11.4	12.9
Feb.	Live	61	72	43	189	20	123	148	79	34	27	6	14	28	9		
	Dead	9	10	0	0	0	0	0	0	2	0	0	2	0	1		
	Total	70	82	43	189	20	123	148	79	36	27	6	16	28	10	62.6	56.2
Mar.	Live	714	297	272	617	261	159	197	449	220	113	66	48	135	165		
	Dead	0	1	2	5	2	64	0	8	1	0	0	3	2	15		
	Total	714	298	274	622	263	223	197	457	221	113	66	51	137	180	272.6	197.4
Apr.	Live	383	390	312	380	131	267	209	223	272	174	90	64	122	188		
	Dead	4	3	0	1	0	10	0	1	0	0	0	3	5	4		
	Total	387	393	312	381	131	277	209	224	272	174	90	67	127	192	231.1	109.7
May	Live	60	64	122	93	39	28	40	117	67	40	9	4	17	9		
	Dead	0	0	0	0	0	9	0	0	0	0	0	0	2	0		
	Total	60	64	122	93	39	37	40	117	67	40	9	4	19	9	51.4	38.2
June	Live	0	1	0	5	2	2	0	0	0	0	0	0	0			
	Dead	0	0	0	0	0	0	0	0	0	0	0	0	0	-		
	Total	0	1	0	5	2	2	0	0	0	0	0	0	0		0.769	1.48
Nov.- May	Live	1231	856	772	1348	563	637	661	956	606	420	205	132	318	383		
	Dead	13	19	4	6	2	99	2	12	10	10	2	8	12	21		
	Total	1244	875	776	1354	565	736	663	968	616	430	207	140	330	404	664.8	361.2

Appendix Table 10. Monthly smolt counts, Needle Branch, 1959-60 to 1972-73. Numbers in parentheses are estimates.

		Season															
Month		59-60	60-61	61-62[a]	62-63[b]	63-64[c]	64-65[d]	65-66[e]	66-67	67-68	68-69	69-70	70-71	71-72	72-73	$\bar{x}$	s
Sept.	Live	0	0	3	4	0	0	0	0	5	1	6	0	0	0		
	Dead	0	0	0	0	0	0	0	0	5	0	0	0	0	0		
	Total	0	0	3	4	0	0	0	0	10	1	6	0	0	0	1.71	3.05
Oct.	Live	22	21	0	7	1		4		44	51	2	0	2	0		
	Dead	0	0	0	0	0		0		0	1	0	0	1	0		
	Total	22	21	0	7	1	(10)	4	(11)	44	52	2	0	3	0	12.6	16.7
Nov.	Live	0	38		6		1	23	58	6	198	9	1	2	0		
	Dead	0	0		1		0	0	0	0	4	0	2	0	1		
	Total	0	38	(8)	7	(11)	1	23	58	6	202	9	3	2	1	26.4	53.2
Dec.	Live	0	3						13	38	49	47	1	0	23		
	Dead	0	0						1	2	10	1	0	0	2		
	Total	0	3	(12)	(25)	(16)	(9)	(15)	14	40	59	48	1	0	25	19.1	18.5
Jan.	Live	2	6	0					20	39	26	4	0	0	2		
	Dead	0	2	0					5	15	13	2	2	0	2		
	Total	2	8	0	(7)	(5)	(3)	(4)	25	54	39	6	2	0	4	11.4	16.4
Feb.	Live	2	55	4	18	29	27	70	52	37	9	3	1	0	3		
	Dead	0	0	0	0	0	0	0	0	10	1	2	1	0	0		
	Total	2	55	4	18	29	27	70	52	47	10	5	2	0	3	23.1	23.8
Mar.	Live	52	143	31	151	120	28	104	59	39	30	29	18	45	168		
	Dead	3	3	4	49	1	0	0	0	1	4	0	0	2	8		
	Total	55	146	35	200	121	28	104	59	40	34	29	18	47	176	78.0	60.3
Apr.	Live	80	173	156	167	87	78	59	73	70	51	72	46	59	141		
	Dead	0	0	1	5	0	0	0	3	0	6	0	0	0	0		
	Total	80	173	157	172	87	78	59	76	70	57	72	46	59	141	94.8	45.2
May	Live	50	39	7	37	44	14	11	49	20	19	25	4	5	19		
	Dead	0	0	0	4	0	0	0	0	0	1	0	0	0	0		
	Total	50	39	7	41	44	14	11	49	20	20	25	4	5	19	24.9	16.6
June	Live	2	0	2	1	0	3	1	0	0	0	1	0	0	1		
	Dead	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
	Total	2	0	2	1	0	3	1	0	0	0	1	0	0	1	0.786	0.975
Nov.-May	Live	186	457							249	382	189	71	111	356		
	Dead	3	5							28	39	5	5	2	13		
	Total	189	462	(223)	(470)	(314)	(160)	(286)	(333)	277	421	194	76	113	369	277.1	125.5

[a] Trap closed October 26, opened February 14.

[b] Trap closed November 21, opened February 9.

[c] Trap closed November 7, opened February 9.

[d] Trap closed November 23, opened February 4.

[e] Trap closed November 12, opened February 2.

Appendix Table 11. Mean monthly smolt lengths (mm), Deer Creek, 1959-60 to 1972-73. Data for live fish only.

Month		Season														$\bar{X}$
		59-60	60-61	61-62	62-63	63-64	64-65	65-66	66-67	67-68	68-69	69-70	70-71	71-72	72-73	
Nov.	$\bar{X}$	64.4	66.5	69.1	70.9	63.5	71.7	63.1	62.1	60.5	72.0	77.5	79.3	66.1	64.0	67.9
	N	27	45	120	50	85	137	121	81	24	119	28	23	31	1	892
Dec.	$\bar{X}$	67.9	65.4	68.6	68.5	63.3	75.2	63.8	70.1	64.5	74.9	79.9	69.1	72.3	68.6	68.8
	N	14	8	233	19	28	129	295	26	75	85	45	13	37	32	1039
Jan.	$\bar{X}$	67.7	67.8	66.2	73.0	68.7	73.4	66.7	72.0	62.2	77.5	76.6	81.5	71.8	67.5	70.2
	N	31	8	17	2	170	66	188	38	15	113	20	4	9	41	722
Feb.	$\bar{X}$	71.7	75.8	71.5	71.3	70.3	76.7	71.5	75.5	71.1	79.0	68.5	81.1	78.0	71.9	74.1
	N	235	148	254	238	211	332	337	297	222	116	105	28	95	30	2617
Mar.	$\bar{X}$	79.2	84.0	76.0	78.5	77.5	82.1	78.7	81.6	82.5	83.6	86.9	88.6	88.7	80.8	81.9
	N	827	371	239	260	532	642	247	714	799	533	402	239	440	670	6915
Apr.	$\bar{X}$	89.8	91.9	87.0	97.1	85.8	92.1	89.8	90.9	91.4	92.1	95.6	96.5	97.3	93.1	92.1
	N	550	325	319	210	340	619	335	708	992	646	642	324	285	909	7204
May	$\bar{X}$	94.9	95.2	94.2	94.2	88.9	102.4	92.6	99.8	96.6	98.0	100.8	99.4	102.5	95.9	97.1
	N	143	92	43	202	156	123	126	348	262	334	183	83	120	172	2387
Nov.-May	$\bar{X}$	82.2	85.3	75.8	83.4	77.5	84.1	75.4	85.6	85.8	87.2	90.7	92.6	90.3	87.6	84.3
	N	1827	997	1225	981	1522	2048	1649	2212	2389	1946	1425	714	1017	1855	21806

Appendix Table 12. Mean monthly smolt lengths (mm), Flynn Creek, 1959-60 to 1972-73. Data for live fish only.

Month		Season														$\bar{X}$
		59-60	60-61	61-62	62-63	63-64	64-65	65-66	66-67	67-68	68-69	69-70	70-71	71-72	72-73	
Nov.	$\bar{X}$	84.0	65.6	60.7	60.6	72.7	70.8	60.0	62.3	60.4	65.2	58.2	78.0	60.2		63.4
	N	1	11	3	62	6	22	3	10	5	30	19	1	5	0	178
Dec.	$\bar{X}$	74.0		73.2	62.9	82.8	72.9	59.9	65.7	62.8	71.1	84.3		67.9	56.8	73.3
	N	2	0	4	7	95	9	11	59	5	22	7	0	10	10	241
Jan.	$\bar{X}$	70.3	69.2	65.4	70.0	82.0	74.9	68.4	71.8	57.5	74.5	78.7	84.0	102.0	79.0	71.2
	N	11	8	17	1	8	15	49	9	2	13	6	1	1	2	143
Feb.	$\bar{X}$	73.4	71.4	68.8	69.5	77.7	78.8	71.9	77.4	75.7	77.9	86.5	80.1	82.3	69.7	74.5
	N	61	29	10	126	19	120	146	78	33	27	4	14	28	9	704
Mar.	$\bar{X}$	82.3	78.4	78.0	77.2	83.6	83.5	77.7	83.2	84.2	82.0	91.8	91.1	88.7	78.4	82.1
	N	466	164	148	224	244	156	164	445	220	113	66	48	134	165	2757
Apr.	$\bar{X}$	90.6	87.7	90.0	92.5	91.7	88.2	84.4	89.3	90.9	90.2	98.5	97.0	96.3	86.1	90.0
	N	277	204	186	141	126	262	209	222	272	172	89	63	122	184	2529
May	$\bar{X}$	94.5	95.7	96.0	90.8	97.0	92.3	89.2	97.4	94.5	98.3	105.1	100.5	98.0	91.1	95.0
	N	58	38	30	78	39	15	40	117	67	40	9	4	17	9	561
Nov.-May	$\bar{X}$	84.9	83.1	84.0	79.1	86.0	84.1	78.2	84.5	87.4	84.7	91.4	92.9	90.5	81.7	84.2
	N	876	454	398	638	537	498	622	940	604	417	200	131	317	379	7114

Appendix Table 13. Mean monthly smolt lengths (mm), Needle Branch, 1959-60 to 1972-73. Data for live fish only.

Month		Season														
		59-60	60-61	61-62[a]	62-63[a]	63-64[a]	64-65[a]	65-66[a]	66-67	67-68	68-69	69-70	70-71	71-72	72-73	X̄
Nov.	X̄		59.8		73.0	65.5	93.0	52.3	73.2	54.8	66.3	79.8	72.0	86.5		67.4
	N	0	25	0	3	2	1	3	56	6	193	9	1	2	0	301
Dec.	X̄		62.7						79.1	68.9	68.2	85.7	79.0		69.4	74.1
	N	0	3	-	-	-	-	-	13	35	49	47	1	0	23	171
Jan.	X̄	70.5	69.3						76.3	73.2	70.1	85.0			67.5	72.5
	N	2	10	-	-	-	-	-	14	34	25	2	0	0	2	89
Feb.	X̄	76.5	72.0	75.0	68.2	69.1	81.1	69.7	83.4	75.0	73.0	93.3	79.0		74.3	74.2
	N	2	55	1	18	23	27	66	41	37	9	3	1	0	3	286
Mar.	X̄	90.1	78.3	79.2	73.1	72.7	79.1	74.6	90.9	85.0	88.1	93.6	93.3	109.4	85.2	82.4
	N	52	127	26	79	119	27	95	58	37	28	26	18	44	168	904
Apr.	X̄	95.2	86.3	86.1	84.0	81.0	85.7	83.5	99.2	91.8	96.0	98.7	101.6	117.0	96.7	91.6
	N	80	134	140	119	86	78	58	72	70	46	72	44	59	141	1199
May	X̄	102.2	89.9	97.7	86.0	83.9	89.8	88.0	99.0	93.6	86.8	97.0	104.0	106.5	95.0	93.2
	N	47	39	7	33	42	12	11	49	20	19	25	3	5	19	331
Nov.-May	X̄	96.1	79.8						88.7	81.4	73.4	93.3	98.4	112.9	89.1	
	N	181	393	-	-	-	-	-	303	239	369	184	68	110	356	

[a] Trap not operational during certain months (Appendix Table 10).

Appendix Table 14. Mean monthly smolt weight (gr), Deer Creek, 1963-64 to 1972-73. Estimated from mean lengths in Appendix Table 11 and length-weight relationships in Appendix Table 5. N values are the same as those in Appendix Table 11.

		Season										
Month		63-64	64-65	65-66	66-67	67-68	68-69	69-70	70-71	71-72	72-73	$\bar{X}$,N
Nov.	$\bar{X}$	2.85	4.17	3.00	3.28	2.27	4.09	4.82	5.04	2.89	2.69	3.579
	N	85	137	121	81	24	119	28	23	31	1	650
Dec.	$\bar{X}$	2.83	4.85	3.09	4.51	2.65	4.59	5.28	3.30	3.79	3.30	3.724
	N	28	129	295	26	75	85	45	13	37	32	765
Jan.	$\bar{X}$	3.60	4.49	3.48	4.84	2.43	5.07	4.65	5.48	3.71	3.15	3.966
	N	170	66	188	38	15	113	20	4	9	41	664
Feb.	$\bar{X}$	3.85	5.16	4.20	5.49	3.35	5.36	3.33	5.40	4.77	3.79	4.515
	N	211	332	337	297	222	116	105	28	95	30	1773
Mar.	$\bar{X}$	5.14	6.42	5.44	6.75	4.78	6.32	6.79	7.08	7.04	5.34	5.999
	N	532	642	247	714	799	533	402	239	440	670	5218
Apr.	$\bar{X}$	6.95	9.26	7.76	8.97	6.11	8.38	9.04	9.20	9.33	8.09	8.158
	N	340	619	335	708	992	646	642	324	285	909	5800
May	$\bar{X}$	7.72	13.0	8.43	11.5	6.97	10.0	10.6	10.1	10.9	8.82	9.773
	N	156	123	126	348	262	334	183	83	120	172	1907
Mean	$\bar{X}$	5.288	7.158	5.063	7.852	5.333	7.294	7.922	8.185	7.651	6.900	6.740
	N	1522	2048	1649	2212	2389	1946	1425	714	1017	1855	16,777

Appendix Table 15. Mean monthly smolt weight (gr), Flynn Creek, 1963-64 to 1972-73. Estimated from mean lengths in Appendix Table 12 and length-weight relationships in Appendix Table 5. N values are the same as those in Appendix Table 12.

Month		Season										
		63-64	64-65	65-66	66-67	67-68	68-69	69-70	70-71	71-72	72-73	$\bar{X}$,N
Nov.	$\bar{X}$	4.36	3.95	2.70	3.09	2.60	3.08	2.14	4.94	2.31		3.115
	N	6	22	3	10	5	30	19	1	5	0	101
Dec.	$\bar{X}$	6.40	4.33	2.68	3.58	2.95	4.04	6.36		3.30	2.02	4.776
	N	95	9	11	59	5	22	7	0	10	10	228
Jan.	$\bar{X}$	6.22	4.71	3.75	4.57	2.21	4.67	5.19	6.14	10.9	4.97	4.420
	N	8	15	49	9	2	13	6	1	1	2	106
Feb.	$\bar{X}$	5.31	5.52	4.25	5.61	5.47	5.37	6.85	5.34	5.81	3.53	5.112
	N	19	120	146	78	33	27	4	14	28	9	478
Mar.	$\bar{X}$	6.58	6.62	5.17	6.85	7.78	6.31	8.16	7.81	7.24	4.87	6.636
	N	244	156	164	445	220	113	66	48	134	165	1755
Apr.	$\bar{X}$	8.65	7.85	6.37	8.32	10.0	8.50	10.0	9.39	9.22	6.29	8.292
	N	126	262	209	222	272	172	89	63	122	184	1721
May	$\bar{X}$	8.81	9.05	7.33	10.6	11.4	11.1	12.1	10.4	9.71	7.34	10.09
	N	39	15	40	117	67	40	9	4	17	9	357
Mean	$\bar{X}$	7.121	6.818	5.328	7.294	8.954	7.209	8.406	8.350	7.818	5.512	7.129
	N	537	599	622	940	604	417	200	131	317	379	4746

Appendix Table 16. Mean monthly smolt weight (gr), Needle Branch, 1963-64 to 1972-73. Estimated from mean lengths in Appendix Table 13 and length-weight relationships in Appendix Table 5. N values are the same as those in Appendix Table 13.

		Season										
Month		63-64[a]	64-65[a]	65-66[a]	66-67	67-68	68-69	69-70	70-71	71-72	72-73	$\bar{X}$,N
Nov.	$\bar{X}$	3.09	9.53	1.87	4.43	1.96	3.02	5.74	4.41	6.72		3.420
	N	2	1	3	56	6	193	9	1	2	0	273
Dec.	$\bar{X}$				5.63	3.72	3.29	6.91	5.73		3.48	4.614
	N	-	-	-	13	35	49	47	1	0	23	168
Jan.	$\bar{X}$				5.04	4.41	3.57	6.77			3.21	4.282
	N	-	-	-	14	34	25	2	0	0	2	77
Feb.	$\bar{X}$	3.66	6.45	3.57	6.62	4.72	4.03	8.63	5.73		4.24	4.860
	N	23	27	66	41	37	9	3	1	0	3	210
Mar.	$\bar{X}$	4.30	6.01	4.17	8.63	6.70	7.05	8.71	9.15	13.9	6.30	6.576
	N	119	27	95	58	37	28	26	18	44	168	620
Apr.	$\bar{X}$	6.05	7.55	5.37	11.3	8.31	9.10	10.00	11.6	17.1	9.10	9.307
	N	86	78	58	72	70	46	72	44	59	141	726
May	$\bar{X}$	6.77	8.63	6.05	11.2	8.78	6.75	9.56	12.4	12.7	8.64	8.834
	N	42	12	11	49	20	19	25	3	5	19	205
Mean	$\bar{X}$				8.337	6.158	4.374	8.703	10.71	15.43	7.317	6.891
	N				303	239	369	184	68	110	356	2279

[a] Trap not operational in December and January (Appendix Table 10).

Appendix Table 17. Total seasonal smolt weight (kg), 1959-60 to 1972-73, based on the product of total November-May smolt count and mean November-May smolt weight per fish.

Season	Deer	Flynn	Needle
1959-60	18.6	8.60	1.60
1960-61	13.1	5.66	2.51
1961-62	10.6	5.18	1.26
1962-63	20.3	7.57	2.06
1963-64	11.4	4.02	1.35
1964-65	17.0	5.01	0.925
1965-66	9.30	3.53	1.19
1966-67	17.6	7.06	2.78
1967-68	13.1	5.52	1.71
1968-69	15.8	3.01	1.84
1969-70	11.4	1.74	1.69
1970-71	6.04	1.17	0.814
1971-72	8.20	2.58	1.74
1972-73	13.3	2.22	2.70
$\bar{X}$	13.27	4.491	1.726
S	4.159	2.268	0.616

Appendix Table 18. Median dates of November-May smolt migration, 1959-60 to 1972-73. Expressed in Julian days with November 1 as day 1.

Season	Deer	Flynn	Needle
1959-60	142	151	162
1960-61	149	152	151
1961-62	134	155	160
1962-63	143	146	150
1963-64	144	140	147
1964-65	129	145	153
1965-66	107	145	134
1966-67	148	141	143
1967-68	155	157	120
1968-69	147	152	22
1969-70	158	149	148
1970-71	156	152	160
1971-72	143	145	155
1972-73	158	151	148
$\bar{X}$	143.8	148.7	139.5
S	13.6	5.08	35.6

Appendix Table 19. Mean discharge (l/sec) for 60,30, 15, and 7 consecutive days of lowest flow, 1959-72.

	Deer				Flynn				Needle			
Year	60	30	15	7	60	30	15	7	60	30	15	7
1959	20.53	15.20	15.20	15.13	12.05	7.958	7.553	7.442	3.257	1.691	1.492	1.416
1960	11.40	9.346	9.082	8.779	7.222	5.474	5.287	4.166	1.558	0.756	0.756	0.649
1961	12.27	11.14	10.38	10.07	6.655	6.041	5.854	5.664	1.606	0.971	0.793	0.688
1962	14.35	12.55	11.01	10.56	8.544	6.703	6.400	5.987	1.181	0.473	0.926	0.566
1963	12.33	10.38	9.439	8.740	7.219	6.409	5.871	5.619	1.946	1.416	0.983	0.890
1964	23.61	14.65	13.84	12.47	7.709	7.383	6.890	6.228	1.481	1.368	1.226	1.008
1965	8.955	7.468	6.853	6.638	4.543	3.888	3.701	3.557	0.779	0.462	0.320	0.280
1966	7.893	6.882	6.720	6.154	4.036	3.577	3.435	3.121	1.444	1.266	1.226	1.130
1967	7.581	6.777	6.004	5.426	3.857	3.362	2.945	2.671	0.969	0.858	0.717	0.606
1968	26.01	18.13	15.97	14.69	13.93	11.55	10.35	9.504	4.622	2.840	2.359	2.149
1969	18.33	12.04	10.31	9.954	9.130	6.372	5.401	5.219	3.197	1.793	1.396	1.249
1970	9.855	7.881	7.270	6.919	5.378	4.455	4.115	3.970	0.847	0.433	0.340	0.280
1971	22.87	14.34	13.42	11.77	13.40	8.354	7.457	6.519	3.186	1.699	1.323	1.093
1972	8.049	6.250	5.777	5.304	5.154	3.956	3.605	3.435	0.666	0.368	0.283	0.280
$\bar{X}$	14.574	10.931	10.091	9.472	7.773	6.106	5.633	5.222	1.910	1.171	1.001	0.877
S	6.453	3.711	3.435	3.230	3.340	2.268	2.037	1.891	1.191	0.697	0.558	0.519

Appendix Table 20. Starting dates for 60, 30, 15, and 7 consecutive days of lowest discharge, 1959-72. Expressed in Julian days with June 1 as day 1.

	Deer				Flynn				Needle			
Year	60	30	15	7	60	30	15	7	60	30	15	7
1959	36	66	81	89	36	66	81	81	36	66	79	81
1960	68	98	113	121	68	97	111	120	64	94	110	116
1961	68	98	114	121	63	62	114	70	71	99	116	122
1962	60	72	87	95	60	87	87	95	60	72	87	94
1963	66	75	90	98	82	112	127	135	83	75	90	98
1964	94	106	139	144	94	119	115	142	76	101	115	114
1965	76	96	111	119	66	96	111	119	66	96	110	115
1966	74	73	89	95	74	78	89	95	74	72	73	78
1967	62	91	106	114	62	91	106	114	61	91	106	114
1968	24	50	60	68	46	54	60	67	24	50	59	67
1969	55	79	94	102	63	79	94	102	63	79	94	98
1970	50	65	80	88	50	65	80	87	38	65	76	76
1971	33	62	77	85	57	62	77	85	57	62	77	85
1972	53	83	95	104	53	120	133	136	51	71	85	85
$\bar{X}$	58.5	79.6	95.4	103.1	61.4	84.9	98.9	103.4	58.9	78.1	91.2	95.9
S	18.6	16.4	19.8	19.3	14.7	22.0	21.0	24.6	16.6	15.7	17.8	17.8

Appendix Table 21. Mean discharge (l/sec) for 60, 30, 15, and 7 consecutive days of highest flow, 1959-60 to 1972-73.

Season	Deer				Flynn				Needle			
	60	30	15	7	60	30	15	7	60	30	15	7
1959-60	399.6	546.0	783.6	1088	283.5	382.0	543.7	732.4	90.57	126.2	181.2	251.2
1960-61	675.1	890.1	1102	1533	467.6	623.0	762.7	1048	149.4	197.6	244.9	350.3
1961-62	359.4	442.4	632.4	918.4	240.2	298.8	419.7	623.0	84.73	109.0	145.4	227.0
1962-63	339.6	516.8	806.3	995.2	229.5	354.6	550.5	683.6	71.42	113.8	185.4	235.1
1963-64	512.3	761.0	977.9	1173	352.6	526.2	672.0	793.0	119.8	176.6	227.5	273.5
1964-65	813.6	892.1	1244	2104	548.0	605.5	829.2	1335	182.3	202.4	283.2	473.8
1965-66	516.0	806.0	1170	1363	346.4	536.1	772.3	890.1	123.0	185.1	271.9	326.8
1966-67	496.7	576.3	745.7	1145	353.4	414.6	546.9	845.9	137.3	150.9	215.2	296.5
1967-68	381.2	520.2	604.3	1044	267.6	366.2	409.8	687.9	102.9	137.3	193.1	293.7
1968-69	577.2	600.4	783.6	1056	412.9	433.3	565.0	768.6	178.2	182.9	230.3	327.4
1969-70	571.8	804.0	1180	1444	376.4	539.8	783.6	942.8	162.1	212.9	315.8	386.9
1970-71	610.0	844.5	1074	1226	401.6	548.0	694.1	793.0	173.0	227.1	286.6	359.7
1971-72	759.0	797.2	1283	1517	537.2	546.6	874.8	1028	239.1	263.7	361.1	397.3
1972-73	435.3	671.5	938.2	1351	292.5	448.6	623.0	874.0	122.1	195.2	284.3	417.2
$\bar{X}$	531.91	690.61	951.79	1282.7	364.96	473.09	646.24	860.38	138.28	177.19	244.71	329.74
S	146.59	154.40	228.06	306.98	101.29	100.77	147.00	185.61	45.823	44.955	59.223	72.757

Appendix Table 22. Starting dates for 60, 30, 15, and 7 consecutive days of highest discharge, 1959-60 to 1972-73. Expressed in Julian days with November 1 as day 1.

Season	Deer				Flynn				Needle			
	60	30	15	7	60	30	15	7	60	30	15	7
1959-60	78	87	95	98	79	87	96	98	78	80	94	97
1960-61	92	101	101	102	92	102	101	102	92	101	101	101
1961-62	22	46	47	48	22	46	47	48	21	22	47	47
1962-63	11	19	20	20	12	20	20	25	11	17	20	25
1963-64	51	62	77	80	52	63	78	80	51	62	78	80
1964-65	31	30	84	86	31	30	51	86	31	29	50	51
1965-66	54	54	57	63	54	54	57	63	54	53	57	58
1966-67	34	65	80	87	34	65	81	88	32	64	32	86
1967-68	68	92	110	111	68	92	110	111	92	91	29	32
1968-69	21	34	62	68	22	52	62	68	21	30	34	68
1969-70	42	73	76	79	42	74	76	79	41	71	75	79
1970-71	31	59	76	76	31	60	76	76	28	59	73	76
1971-72	26	54	72	79	26	54	72	79	25	26	70	79
1972-73	47	49	48	51	47	50	49	51	35	49	47	51
$\bar{X}$	43.4	58.9	71.8	74.9	43.7	60.6	69.7	75.3	43.7	53.9	57.6	66.4
S	23.3	23.6	23.7	23.9	23.3	22.7	24.1	23.0	26.4	26.5	24.9	23.1

Appendix Table 23. Peak instantaneous discharge (l/sec), 1959-60 to 1972-73 (from Harris 1977).

Season	Deer	Flynn	Needle
1959-60	1900	1220	566
1960-61	3230	2210	935
1961-62	2290	1300	821
1962-63	2970	1840	793
1963-64	2720	1780	793
1964-65	5690	3880	1420
1965-66	3400	2070	821
1966-67	2970	1980	935
1967-68	2270	1270	708
1968-69	2040	1270	680
1969-70	2210	1420	708
1970-71	3230	1640	878
1971-72	5550	3940	1810
1972-73	3260	1590	1020

Appendix Table 24. Mean monthly maximum temperatures (°C), Deer Creek, 1959-1972 (data from U.S. Geological Survey).

	Month						
Year	May	June	July	Aug.	Sept.	Oct.	$\bar{X}$
1959	9.64	10.6	12.7	12.8	11.2	9.73	11.11
1960	9.46	11.7	13.4	13.2	12.5	10.7	11.83
1961	9.44	13.0	13.6	14.3	11.9	10.8	12.17
1962	9.34	12.1	13.5	-	-	11.0	-
1963	10.5	11.3	12.2	13.8	13.2	11.1	12.02
1964	10.3	11.0	12.5	12.7	11.6	10.2	11.38
1965	9.64	11.2	-	-	-	-	-
1966	11.4	13.2	14.4	14.6	13.8	10.9	13.05
1967	12.9	13.6	15.9	16.3	14.7	11.3	14.12
1968	11.2	13.0	15.5	14.9	13.9	11.4	13.32
1969	12.6	12.7	12.4	12.9	12.5	9.77	12.15
1970	12.2	13.8	14.9	14.1	11.6	10.1	12.78
1971	10.5	10.8	12.8	13.9	11.0	9.81	11.47
1972	11.7	12.8	14.6	15.1	13.5	11.3	13.17
$\bar{X}$	10.77	12.20	13.72	14.05	12.62	10.62	12.330
S	1.235	1.090	1.230	1.077	1.196	0.6220	

Appendix Table 25. Mean monthly maximum temperatures (°C), Flynn Creek, 1959-1972 (data from U.S. Geological Survey).

	Month						
Year	May	June	July	Aug.	Sept.	Oct.	X̄
1959	9.73	11.2	13.2	12.7	11.1	10.4	11.39
1960	9.89	11.5	12.7	13.2	12.5	10.7	11.75
1961	9.28	11.1	13.4	15.4	14.0	11.1	12.38
1962	9.30	11.0	12.9	13.4	13.2	11.0	11.80
1963	-	10.9	12.0	13.9	12.8	11.2	-
1964	9.23	10.6	11.9	12.2	11.4	10.1	10.91
1965	9.48	10.6	12.8	13.6	12.2	11.0	11.61
1966	9.32	11.1	12.6	13.4	12.8	10.2	11.57
1967	8.80	11.1	12.7	13.9	12.7	10.6	11.63
1968	10.4	10.6	12.4	12.4	12.4	10.1	11.38
1969	10.3	11.5	11.4	11.5	12.0	10.1	11.13
1970	9.21	11.0	12.1	12.1	10.7	10.0	10.85
1971	9.10	9.57	11.2	12.7	10.9	9.00	10.41
1972	9.73	10.6	12.9	13.5	12.1	9.97	11.47
X̄	9.521	10.88	12.44	13.14	12.20	10.39	11.429
S	0.468	0.486	0.647	0.974	0.927	0.594	

Appendix Table 26. Mean monthly maximum temperature (°C), Needle Branch, 1959-1972 (data from U.S. Geological Survey).

	Month						
Year	May	June	July	Aug.	Sept.	Oct.	X̄
1959	9.55	10.7	13.0	12.9	12.4	10.8	11.56
1960	9.69	11.7	13.2	14.0	13.2	11.3	12.18
1961	8.92	12.5	14.2	15.1	13.5	10.8	12.50
1962	10.4	10.8	12.3	-	-	10.9	-
1963	9.28	12.4	13.1	14.5	13.6	11.4	12.38
1964	9.39	10.7	12.4	12.7	11.2	10.0	11.07
1965	10.6	11.2	12.7	13.5	11.8	10.6	11.73
1966	-	13.2	14.9	20.4	19.1	13.8	-
1967	15.5	21.1	23.4	21.6	17.7	14.2	18.92
1968	15.8	17.4	21.0	18.0	16.8	12.5	16.92
1969	14.8	16.0	17.0	16.7	14.6	12.3	15.23
1970	13.7	17.0	16.6	15.3	13.0	15.2	15.13
1971	12.8	16.3	14.8	15.2	12.6	10.1	13.63
1972	13.0	13.9	14.9	14.5	12.5	10.2	13.17
X̄	11.80	13.92	15.25	15.72	14.00	11.72	13.735
S	2.551	3.172	3.318	2.760	2.405	1.648	

Appendix Table 27. Mean maximum temperatures (°C) for 30, 15, and 7 consecutive days, 1959-1972 (data from U.S. Geological Survey).

	Deer			Flynn			Needle		
Year	30	15	7	30	15	7	30	15	7
1959	13.2	13.4	13.9	13.5	13.7	13.9	13.5	13.7	14.1
1960	13.8	13.9	14.1	13.4	13.7	14.0	14.1	14.4	14.7
1961	14.5	14.7	15.0	15.4	15.4	16.0	15.2	15.4	15.6
1962	-	-	-	13.6	13.9	14.5	-	-	-
1963	13.9	14.3	14.6	14.2	14.7	15.2	14.6	15.0	15.3
1964	12.9	13.2	14.0	12.3	12.5	13.2	12.9	12.9	13.6
1965	-	-	-	13.6	13.9	14.1	13.7	13.9	13.9
1966	15.8	16.4	16.6	13.6	13.9	14.1	20.4	21.7	22.1
1967	16.7	17.0	17.6	14.0	14.3	14.4	23.8	24.3	25.3
1968	15.9	16.4	17.0	12.6	13.0	13.0	20.5	20.9	21.9
1969	12.9	13.2	13.7	11.9	12.0	12.6	17.7	18.5	19.4
1970	14.9	15.4	15.6	12.2	12.2	12.8	17.4	18.1	19.5
1971	14.2	14.7	15.2	12.8	13.0	13.5	16.1	16.3	16.6
1972	15.2	15.5	16.2	13.7	13.8	14.4	15.2	15.3	15.7
$\bar{X}$	14.49	14.84	15.29	13.32	13.57	13.98	16.55	16.95	17.52
S	1.239	1.312	1.315	0.958	0.949	0.933	3.284	3.512	3.753

Appendix Table 28. Mean monthly sediment concentration (mg/l), Deer Creek, 1959-60 to 1972-73 (data from U.S. Geological Survey).

	Month					
Season	Nov.	Dec.	Jan.	Feb.	Mar.	$\bar{X}$
1959-60	5.60	6.10	8.87	17.8	5.29	8.626
1960-61	33.9	2.10	6.13	30.5	13.3	16.80
1961-62	9.70	10.5	2.13	4.54	7.87	6.982
1962-63	30.6	5.81	3.32	9.82	7.97	11.41
1963-64	12.6	6.94	40.6	6.00	10.8	15.53
1964-65	10.4	41.8	84.3	8.82	2.81	30.17
1965-66	5.77	70.9	59.2	7.75	44.6	38.43
1966-67	13.4	35.2	29.8	10.2	10.3	20.01
1967-68	3.80	5.65	4.71	18.7	5.00	7.454
1968-69	16.4	20.4	13.9	10.6	2.58	12.80
1969-70	6.37	14.3	31.1	7.89	2.87	12.63
1970-71	12.8	19.0	21.4	4.36	9.42	13.58
1971-72	17.2	26.2	143	12.8	13.6	43.06
1972-73	3.13	28.1	8.19	2.39	12.4	11.06
$\bar{X}$	12.98	20.93	32.62	10.87	10.63	17.753
S	9.310	18.82	39.75	7.343	10.51	11.408

Appendix Table 29. Mean monthly sediment concentration (mg/l), Flynn Creek, 1959-60 to 1972-73 (data from U.S. Geological Survey).

	Month					
Season	Nov.	Dec.	Jan.	Feb.	Mar.	$\bar{X}$
1959-60	1.33	2.13	4.84	13.9	3.35	5.019
1960-61	31.9	1.52	7.16	23.2	10.1	14.50
1961-62	13.2	20.3	4.06	5.04	7.45	10.09
1962-63	26.2	1.84	1.77	3.43	4.26	7.457
1963-64	8.53	5.00	43.1	7.31	10.5	15.03
1964-65	12.0	52.4	98.3	6.64	4.71	35.52
1965-66	5.97	29.9	27.5	3.68	22.0	18.17
1966-67	5.27	13.0	20.6	6.11	6.19	10.34
1967-68	2.67	5.16	3.36	13.3	2.36	5.282
1968-69	15.2	15.6	15.2	5.14	4.00	11.12
1969-70	3.63	8.58	28.1	6.79	1.45	9.808
1970-71	11.1	17.4	23.9	5.64	7.39	13.26
1971-72	11.6	18.3	119	9.10	14.0	34.80
1972-73	2.00	25.4	11.8	2.29	4.55	9.393
$\bar{X}$	10.78	15.47	29.19	7.969	7.308	14.271
S	9.001	13.96	35.91	5.527	5.470	9.564

Appendix Table 30. Mean monthly sediment concentration (mg/l), Needle Branch, 1959-60 to 1972-73 (data from U.S. Geological Survey).

Season	Month					
	Nov.	Dec.	Jan.	Feb.	Mar.	$\bar{X}$
1959-60	0.867	1.16	1.87	9.38	2.55	3.099
1960-61	20.4	0.839	3.65	14.3	6.97	9.049
1961-62	17.7	18.6	1.45	8.54	6.00	10.44
1962-63	17.6	4.68	4.52	4.21	9.39	8.094
1963-64	8.60	2.90	33.4	4.69	9.48	11.93
1964-65	11.7	25.9	33.1	3.76	2.00	15.54
1965-66	7.60	32.3	26.0	4.50	22.7	18.97
1966-67	32.7	74.4	95.5	18.5	34.2	51.84
1967-68	9.10	22.7	15.9	91.6	8.16	28.81
1968-69	26.9	41.4	42.6	29.4	9.00	29.89
1969-70	10.9	25.2	35.4	21.6	8.06	20.27
1970-71	17.9	31.0	28.5	7.39	20.8	21.41
1971-72	19.6	22.4	34.3	8.03	9.26	18.85
1972-73	3.70	24.0	6.61	2.25	5.03	8.469
$\bar{X}$	14.66	23.39	25.91	16.30	10.97	18.333
S	8.822	19.36	24.80	23.05	8.897	12.439

Appendix Table 31. Mean sediment concentration (mg/l) in 30, 15, and 7 consecutive days of highest discharge, 1959-60 to 1972-73 (data from U.S. Geological Survey).

	Deer			Flynn			Needle		
Season	30	15	7	30	15	7	30	15	7
1959-60	19.5	28.7	50.6	14.9	22.9	41.1	10.1	16.5	29.4
1960-61	34.4	48.6	72.4	21.9	40.7	68.9	14.6	23.9	44.9
1961-62	11.4	19.0	37.0	13.8	20.6	32.4	26.8	28.3	52.7
1962-63	33.1	59.9	109	25.4	49.5	69.0	19.7	32.5	47.4
1963-64	41.6	60.4	98.6	41.6	64.3	101	34.3	41.1	62.9
1964-65	45.4	167	326	57.3	94.8	406	30.3	43.3	81.0
1965-66	126	232	196	54.4	96.3	89.4	54.7	97.3	92.9
1966-67	30.9	47.4	89.4	21.2	32.1	61.7	98.5	149	259
1967-68	17.2	22.1	38.6	13.1	14.0	26.0	92.1	47.9	75.9
1968-69	22.6	27.9	36.4	18.1	28.7	46.9	40.3	63.6	128
1969-70	35.5	55.7	79.1	29.0	52.2	77.0	42.4	58.3	69.3
1970-71	34.5	30.0	43.9	36.2	37.0	47.3	40.2	49.7	82.4
1971-72	148	289	201	123	238	195	29.3	65.1	50.1
1972-73	33.6	53.5	69.3	32.4	49.8	41.9	28.3	48.4	36.7
$\bar{X}$	45.26	81.51	103.4	35.88	60.06	93.83	40.11	54.64	79.47
S	40.21	84.75	83.22	28.78	56.98	99.07	26.11	33.89	57.72

Appendix Table 32. Estimated mean September biomass (g/m^2), 1959-72 (from Moring and Lantz 1975).

Year	Deer	Flynn	Needle
1959	3.0	3.0	2.1
1960	2.4	2.6	2.1
1961	3.3	2.4	1.8
1962	4.4	3.0	2.8
1963	3.1	2.5	2.7
1964	3.2	2.0	1.2
1965	3.4	1.7	3.3
1966	4.1	3.0	4.2
1967	6.8	2.1	6.8
1968	5.3	2.6	4.5
1969	2.6	0.4	2.4
1970	-	-	-
1971	-	-	0.9
1972	3.0	0.7	1.2
$\bar{X}$	3.72	2.17	2.77
S	1.26	0.861	1.63

Appendix Table 33. Mean biomass (g/m^2) at the beginning of the month, Deer Creek, June 1959-April 1969. Data extrapolated from curves placed through estimates made four to five times per year (from Chapman 1965 and Au 1972).

	Year											
Month	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	$\bar{X}$	S
June	4.3	2.4	1.9	5.3	4.2	2.1	4.8	5.0	8.7	2.3	4.10	2.08
July	3.6	2.2	2.2	3.2	3.7	2.0	5.9	4.3	7.2	2.9	3.72	1.69
August	2.8	2.0	2.7	2.7	3.4	2.1	4.3	3.7	6.2	3.7	3.36	1.24
September	2.6	2.0	2.8	3.6	3.1	2.6	3.2	3.6	6.0	4.4	3.39	1.13
October	2.8	2.2	3.0	4.2	2.5	3.1	2.9	3.8	6.1	5.1	3.57	1.24
November	3.2	2.4	3.0	4.5	2.4	3.5	2.8	4.0	6.2	5.3	3.73	1.27
December	3.2	1.8	2.8	3.6	2.5	3.6	2.8	4.2	6.1	5.1	3.57	1.28
January	3.4	1.8	3.4	4.0	2.5	3.6	3.0	4.2	4.5	4.1	3.45	0.833
February	3.6	1.8	1.5	4.0	2.5	2.8	2.9	4.2	3.5	2.9	2.97	0.884
March	3.7	1.8	1.5	3.2	2.4	1.9	2.4	3.7	3.2	2.1	2.59	0.803
April	1.6	1.2	1.2	1.9	1.6	1.5	0.8	2.0	2.0	1.3	1.51	0.393
May	0.4	0.4	0.5	0.4								
June-Oct $\bar{X}$	3.22	2.16	2.52	3.80	3.38	2.38	4.22	4.08	6.84	3.68		

Appendix Table 34. Mean biomass (g/m^2) at the beginning of the month, Flynn Creek, June 1959-April 1969. Data extrapolated from curves placed through estimates made four to five times per year (from Chapman 1965 and Au 1972).

Month	Year										$\bar{X}$	S
	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968		
June	3.9	2.7	2.0	7.8	1.3	2.3	4.1	4.0	6.1	1.1	3.53	2.13
July	3.1	2.6	1.9	2.8	1.7	1.7	1.7	2.8	3.9	1.3	2.35	0.817
August	2.8	2.5	2.0	2.2	2.1	1.5	1.4	2.6	2.9	1.8	2.18	0.520
September	2.9	2.4	2.2	2.4	2.3	1.8	1.6	2.9	2.2	2.4	2.31	0.409
October	2.7	2.4	2.4	3.2	2.4	2.0	1.7	2.8	1.8	2.4	2.38	0.459
November	2.7	2.4	2.4	3.6	2.3	2.0	1.7	2.6	1.8	2.4	2.39	0.536
December	2.3	1.9	3.3	4.2	2.1	2.0	1.8	2.4	1.7	1.8	2.36	0.792
January	2.1	1.8	2.0	3.9	1.8	1.9	1.7	2.5	1.8	1.1	2.06	0.735
February	2.1	1.6	1.9	3.9	1.7	1.8	1.7	2.5	1.7	0.9	1.98	0.786
March	2.4	1.7	1.7	3.6	1.4	1.7	1.1	2.2	1.6	0.8	1.82	0.780
April	1.4	1.6	1.5	2.4	1.1	1.3	0.5	0.8	1.4	0.6	1.26	0.554
May	0.5	1.2	0.6	1.3								
June-Oct. $\bar{X}$	3.08	2.54	2.07	3.68	1.94	1.84	2.11	3.05	3.37	1.80		

Appendix Table 35. Mean biomass (g/m^2) at the beginning of the month, Needle Branch, June 1959-April 1969. Data extrapolated from curves placed through estimates made four to five times per year (from Chapman 1965 and Au 1972).

	Year											
Month	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	$\bar{X}$	S
June	2.3	1.4	2.1	7.2	3.5	4.0	5.0	7.6	6.9	3.1	4.31	2.26
July	1.6	1.7	1.9	3.9	3.0	2.4	3.9	4.0	9.0	3.4	3.48	2.15
Aug.	1.8	2.0	1.8	3.2	2.9	1.5	3.5	3.1	7.8	3.8	3.14	1.82
Sept.	1.9	2.0	1.8	2.8	2.7	1.3	3.4	3.7	6.5	4.2	3.03	1.53
Oct.	2.2	2.2	1.7	2.8	2.8	1.2	3.3	4.3	6.2	4.6	3.13	1.52
Nov.	2.4	2.4	1.7	2.9	2.7	1.0	2.9	4.1	3.2	4.4	2.77	1.01
Dec.	2.0	2.2	1.8	2.8	2.6	0.7	2.2	4.4	3.1	3.7	2.55	1.04
Jan.	1.9	2.2	1.8	3.3	2.3	0.8	1.9	4.0	3.2	2.4	2.38	0.911
Feb.	1.9	2.4	1.7	3.1	2.3	0.9	1.3	3.1	3.9	1.7	2.23	0.921
March	2.4	1.5	1.4	3.1	1.5	1.0	0.8	1.5	2.6	0.4	1.62	0.843
April	2.4	1.1	1.8	2.1	1.0	0.8	0.4	0.4	0.2	0.1	1.03	0.818
May	0.9	0.3	0.7	0.9								
June-Oct $\bar{X}$	1.96	1.86	1.86	3.98	2.98	2.08	3.82	4.54	7.28	3.82		

Appendix Table 36. Mean September biomass (g/m^2) of cutthroat trout, 1962-1973 (from Lowry 1964 and unpublished data).

Year	Deer	Flynn	Needle
1962	5.07	5.82	3.89
1963	2.93	3.54	3.41
1964	1.90	4.04	3.16
1965	2.93	2.72	2.97
1966	2.05	2.73	1.09
1967	3.29	4.26	0.68
1968	2.15	2.71	1.65
1969	2.80	3.70	1.46
1970	3.83	4.01	1.14
1971	4.20	4.27	1.32
1972	4.03	4.13	1.39
1973	-	3.79	1.53
$\bar{\bar{X}}$	3.198	3.810	1.974
S	1.001	0.869	1.071

Appendix Table 37. Most significant multiple regression model with total November-May smolt count, Deer Creek (X(2)=mean May maximum temperature; X(6)= September biomass).

```
Y( 10)=
  3009.55      (CONSTANT)
 -159.102      X(  2)
  221.209      X(  6)


             ANALYSIS OF VARIANCE TABLE

SOURCE        DF    SUM OF SQUARES          MEAN SQUARE
TOTAL         10       .119736E+07          119736.
REGRESSION     2       765627.              382814.
RESIDUAL       8       431735.              53966.9

             R SQUARED =  .6394


VAR           S.E. OF REGR. COEF.           T
CONSTANT             622.74               4.833
     2               62.823              -2.533
     6               61.773               3.581
```

Appendix Table 38. Most significant multiple regression model with total November-May smolt count, Flynn Creek (X(6)= September biomass; X(7)=January discharge; X(9)= mean sediment concentration during 15 consecutive days of highest discharge).

```
Y( 10)=
  321.180      (CONSTANT)
  237.739      X(  6)
 -31.3897      X(  7)
  4.81829      X(  9)


             ANALYSIS OF VARIANCE TABLE

SOURCE        DF    SUM OF SQUARES          MEAN SQUARE
TOTAL         10       966340.              96634.0
REGRESSION     3       777679.              259226.
RESIDUAL       7       188661.              26951.6

             R SQUARED =  .8048


VAR           S.E. OF REGR. COEF.           T
CONSTANT             198.24               1.620
     6               62.264               3.818
     7               11.379              -2.758
     9               2.1728               2.218
```

Appendix Table 39. Most significant multiple regression model with total November-May smolt weight, Flynn Creek (X(1)= spawning female count; X(5)=mean lowest discharge for 15 consecutive days; X(6)=September biomass).

```
Y( 11)=
  1428.48      (CONSTANT)
  31.6797      X(  1)
 -7801.92      X(  5)
  1917.99      X(  6)


               ANALYSIS OF VARIANCE TABLE

SOURCE       DF   SUM OF SQUARES         MEAN SQUARE
TOTAL        10      .348965E+08         .348965E+07
REGRESSION    3      .309993E+08         .103331E+08
RESIDUAL      7      .389714E+07         556735.

                R SQUARED =  .8883

VAR          S.E. OF REGR. COEF.          T
CONSTANT            853.63              1.673
     1              14.014              2.261
     5              3395.0             -2.298
     6              288.07              6.658
```

Appendix Table 40. Most significant multiple regression model with total November-May smolt count, Needle Branch (X(4)=timing of mean lowest discharge for 15 consecutive days; X(7)=January discharge).

```
Y( 10)=
  795.380      (CONSTANT)
 -3.39830      X(  4)
 -41.3945      X(  7)


               ANALYSIS OF VARIANCE TABLE

SOURCE       DF   SUM OF SQUARES         MEAN SQUARE
TOTAL        11      149985.             13635.0
REGRESSION    2      85767.2             42883.6
RESIDUAL      9      64217.5             7135.28

                R SQUARED =  .5718

VAR          S.E. OF REGR. COEF.          T
CONSTANT            167.90              4.737
     4              1.4872             -2.285
     7              12.763             -3.243
```