

A Study of the Downstream Migrations of Anadromous Fishes in the Taku River, Alaska

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ABSTRACT

A modified scoop trap was designed and constructed to sample downstream-migrant juvenile salmon in the Taku River, a turbid river in southeastern Alaska. A sampling program was designed to determine the behavior of these migrants with respect to their seasonal and daily timing, the size and age composition of the various species, and the correlation between certain of these biological measurements and the physical characteristics of the environment. The length-weight relationships and condition factors of chinook, coho, and sockeye smolts were determined; differences in these relationships by week and by time of day are discussed.

INTRODUCTION

Many of the larger salmon-producing rivers of southeastern Alaska are glacial or partly glacial in origin, are swift and turbid, fluctuate greatly and often rapidly in level, and at these times are heavily laden with debris. The Taku River is typical of these conditions. It originates in the high plateau country of northwestern British Columbia, and empties into Taku Inlet about 30 miles south of Juneau, Alaska (Figure 1). Because of these characteristics, the Taku was selected as the study area for an investigation of the behavior of downstream-migrant salmon, and a modified scoop trap was designed and constructed to sample these smolts. The site chosen for the study was the Canyon Island Research Station, located about 14 miles upriver from the mouth of the Taku, where previous studies were concerned with the evaluation of a fishwheel as a sampling gear for adult salmon (Meehan, 1961).

The river at the Canyon Island site funnels down through a narrow canyon, and at this point is extremely deep and swift. The river at the narrowest point in the canyon is approximately 120 feet wide, and preliminary geological survey work has shown it to be at least 40 feet deep. During high-water conditions a whirlpool is established at the downstream exit from the canyon and adjacent to the right bank.

During the winter and spring of 1960 a scoop trap was constructed, designed after the Washington Department of Fisheries' most recent model, with several modifications to

facilitate its use under the particular conditions encountered on the Taku River.

SAMPLING PROCEDURE

During the spring of 1960 the finished trap was transported from Juneau to Canyon Island, where it was cabled to trees on the left bank about 50 yards upstream from the lower end of the canyon. In this location most of the floating trees and other trash were deflected away from the left bank, and hence the danger of damage to the trap from this source was lessened considerably. It is, of course, conceivable that this current deflection might have guided away from the trap some smolts which otherwise would have been taken.

During the 1960 field season various conditions were altered in an attempt to determine the most efficient method to fish the trap and at the same time decrease the number of variables which were present, such as fishing time and depth of screen entrance. The results of the 1960 season's testings showed that most of the smolts migrated downstream within 2 feet of the river surface. Further, it was demonstrated that the trap could be fished at a 2-foot depth for 2 hours under any water conditions without appreciable loss of efficiency.

The general timing of the downstream migration of chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*O. kisutch*), sockeye salmon (*O. nerka*), and chum salmon (*O. keta*), was ascertained. Also, an external characteristic for differentiating between chi-

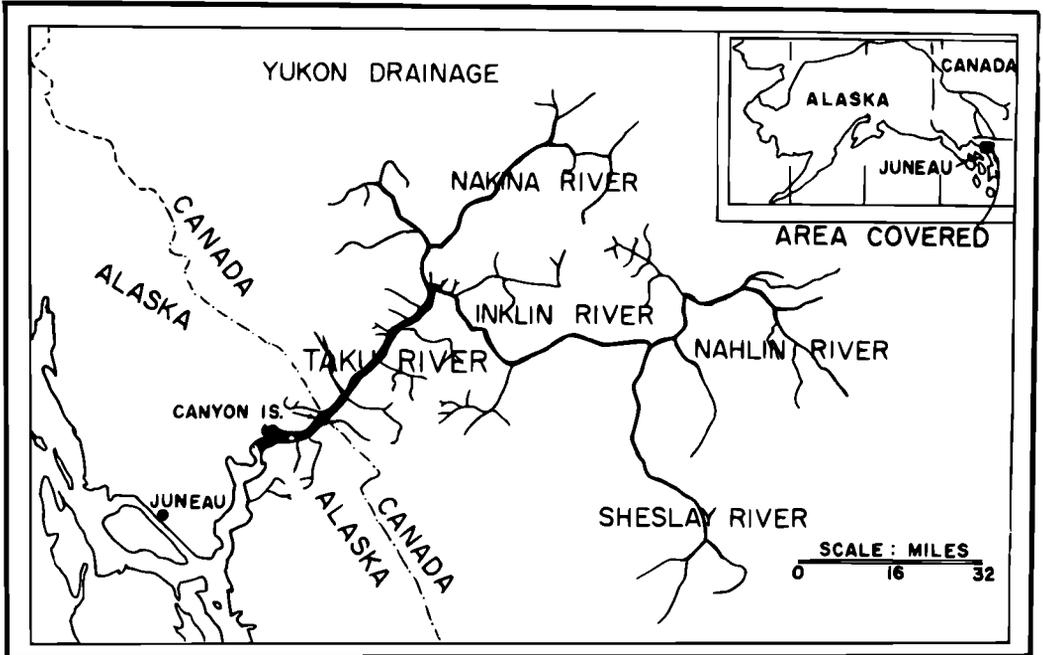


FIGURE 1.—Taku River area map.

nook and coho juveniles was discovered (Meehan and Vania¹).

The trap was secured on a sandbar over the winter of 1960–61 so that it would be possible to begin fishing it the following spring before water and ice conditions at the mouth of the river would allow upriver travel.

With the information obtained from the 1960 testings, a sampling program was designed for 1961 which would eliminate many of the variables. The trap was fished 24 hours a day from April 13 through June 15 at a depth of 2 feet, and was cleaned every 2 hours. Ten minutes was the maximum amount of time needed to clean the screen and live box assembly during periods of high water, so the assembly was held out of water for the full 10 minutes at the end of each fishing period. Therefore, the trap was actually fishing 1 hour and 50 minutes out of every 2-hour fishing period. Time periods were numbered 1

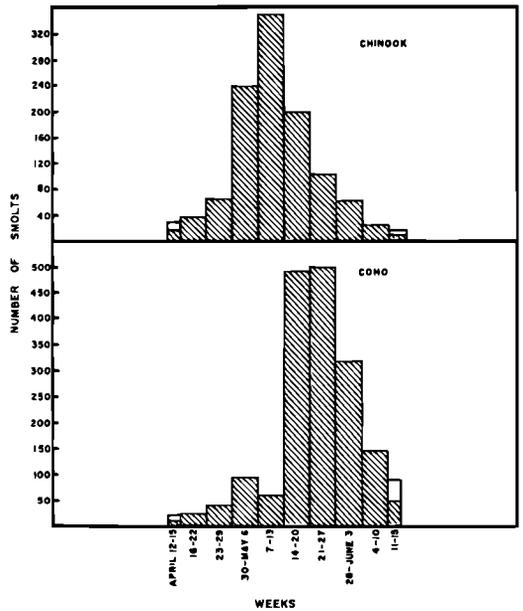


FIGURE 2.—Downstream migration patterns of chinook and coho salmon smolts sampled by Taku scoop trap during 1961. (Areas not shaded for first and last partial weeks show data expanded to a full 7-day week.)

¹ Meehan, William R., and John S. Vania. (1961) An external characteristic to differentiate between king and silver salmon juveniles in Alaska. Alaska Department of Fish and Game, Info. Leaf. 1, 6 pp. (Mimeo.)

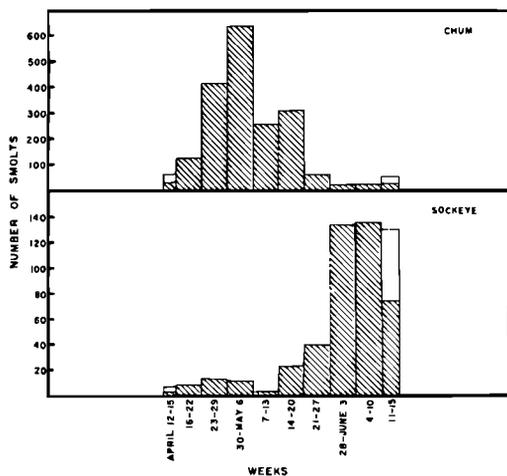


FIGURE 3.—Downstream migration patterns of chum and sockeye salmon smolts sampled by Taku scoop trap during 1961. (Areas not shaded for first and last partial weeks show data expanded to a full 7-day week.)

through 12 with period 1 beginning at 12:00 p.m. (2400 hours) and ending at 2:00 a.m. (0200 hours); and period 12 beginning at 10:00 p.m. (2200 hours) and ending at 12:00 p.m. Only one 24-hour period was not fished during the entire sampling program because of injuries sustained by one of the field men when he was attacked by a brown bear near the station.

Each time the trap was cleaned (every 2 hours) a sample of the chinook, coho, and sockeye smolts was measured and weighed, and scales were periodically taken for future age determination. Samples were chosen by the following systematic procedure in an attempt to adequately represent each time-period catch regardless of its magnitude: (1) For each species, if less than three fish were caught, all were processed; or (2) If more than three fish were caught, the first three dipped out plus every fifth fish thereafter were processed.

Each time the trap was cleaned, the water temperature, water level, turbidity, and air temperature were measured. Air temperature was recorded with a Taylor maximum-minimum thermometer. Water temperature was determined by means of a thermometer permanently attached to the smolt trap. A water level gauge had been constructed for use

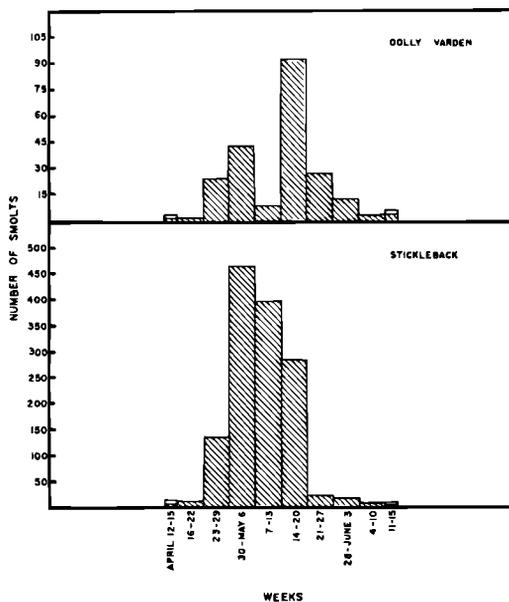


FIGURE 4.—Downstream migration patterns of juvenile Dolly Varden and sticklebacks sampled by Taku scoop trap during 1961. (Areas not shaded for first and last partial weeks show data expanded to a full 7-day week.)

in previous investigations at the study site, and this gauge was sufficient for the present study. Turbidity was determined with a Jackson candle turbidimeter, and the readings were made in centimeters (light path distance), as well as in parts per million.

TIMING

Figures 2, 3, and 4 represent the seasonal timing of the downstream migrations of chinook, coho, chum, and sockeye salmon, Dolly Varden char (*Salvelinus malma*), and three-spine stickleback (*Gasterosteus aculeatus*).

There is much evidence for the nocturnal downstream migration of smolts, e.g., Burgner,² Neave (1955), MacKinnon and Brett (1955). Our study demonstrated that this dominant nocturnal movement held true in most cases. Figure 5 represents the downstream migrations of the salmon and stickle-

² Burgner, Robert Louis. (1958) A study of fluctuations in abundance, growth, and survival in the early life stages of the red salmon (*Oncorhynchus nerka* Walbaum) of the Wood River Lakes, Bristol Bay, Alaska. Ph.D. thesis, University of Washington, Seattle. (Typewritten.)

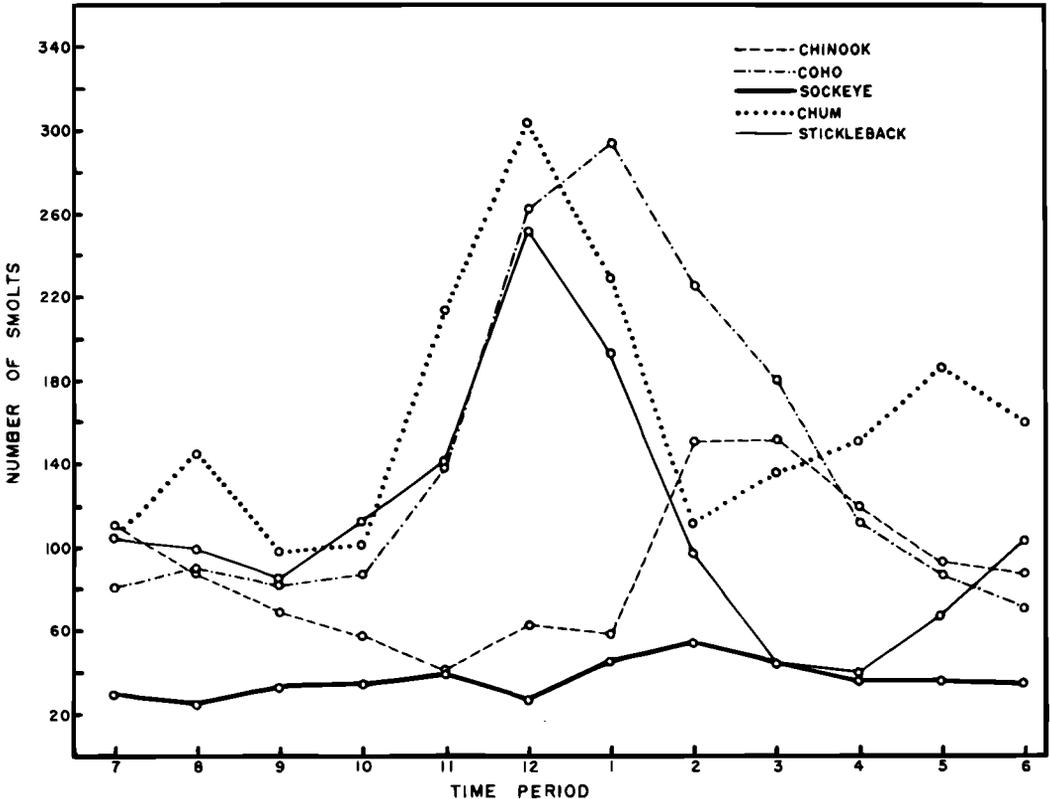


FIGURE 5.—Downstream migration of salmon and sticklebacks represented by total catch per time period over the season of 1961.

backs by time period. The average seasonal observations for each time period were tested by analysis of variance to determine whether the differences observed between time periods were actual, or could be considered random fluctuations. Coho, chum, and sticklebacks were found to exhibit differences (0.05 probability level) between time periods, but chinook and sockeye did not exhibit time-period differences at this probability level. The peak activity of chinook smolts was during the early morning hours (0200–0600); peak sockeye activity was between 0200–0400 hours, but this was only a minor increase over other time periods. It is possible that as the season progressed and water turbidity increased the tendency for smolts to move more at night decreased and was correlated with the decrease in light penetration during the daylight hours as a result of turbidity.

SIZE AND AGE OF MIGRANTS

The length–frequency distributions of coho, sockeye, and chinook salmon smolts are shown in Figure 6. Scales from a small random sample of coho and chinook smolts were aged. Approximately 46 percent of the coho smolts were found to be 1-check (2-year) fish, and the remainder were 2-check (3-year) fish ($n = \text{sample size} = 26$, $s_p = \text{standard error} = 0.098$). Approximately 94 percent of the chinook smolts were 1-check fish, and the remainder were 2-check smolts ($n = 80$, $s_p = 0.026$). Because of insufficient sample size and questionable age analysis, no age data for sockeye smolts are presented, although it would appear from the length–frequency graph (Figure 6) that two age groups are present. The limited scale analyses which were made bear out this assumption, and the dominant year class is apparently composed of 1-check fish.

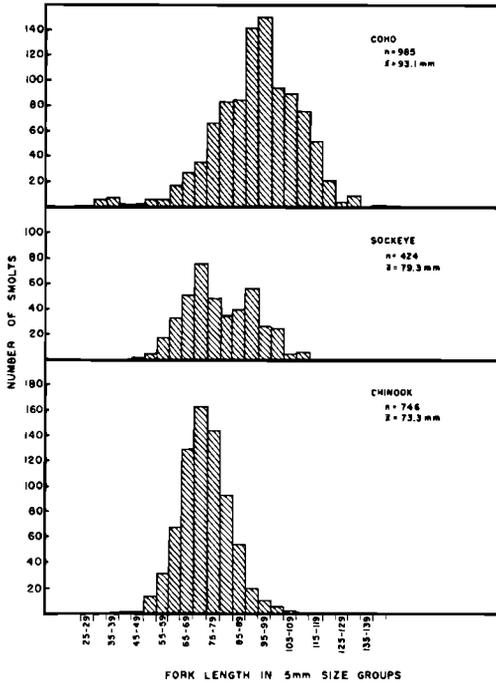


FIGURE 6.—Length-frequency distributions of coho, sockeye, and chinook salmon smolts sampled by the Taku scoop trap.

LENGTH FREQUENCY BY TIME PERIOD

The rationale for examining length frequencies by time period is primarily twofold: (1) To determine if there exists any avoidance reaction to the trap because of light influence—larger fish may avoid the trap during the daylight hours and display a greater tendency to be captured at night; and (2) To determine any size differences by time period that may exist in the migrant population. The average lengths for sockeye, coho, and chinook are presented by time period with their accompanying 95-percent confidence limits in Figure 7. These data are presented in this manner so that the relative variances may be examined visually. Any comparisons between individual means should be avoided, or, if these comparisons are desired, they should be carried out by means of some multiple-comparison test.

The hypothesis being tested by the analysis of variance is whether differences exist in mean length from time period to time period. By examining the analysis of variance tables it

is seen that chinook is the only species to exhibit time-period differences at the 0.05 probability level. Chinook were further examined by use of the least-significant-difference multiple-comparison test. The method is outlined in Steel and Torrie (1960). The results of this analysis showed that the mean for time period 12 differed (0.05 level of significance) from time periods 2, 3, 6, 7, 8, and 9. Time periods 4, 5, 10, 11, and 1 were not different from any of the others. Therefore there is a tendency for larger fish of this species to migrate during the nighttime hours.

For coho and sockeye the evidence was not in favor of length differences from time period to time period. The wider confidence limits exhibited in sockeye and coho may be at least partly due to the occurrence of two age groups in each of these species, while the chinooks, composed primarily of a single age group, manifest a smaller variance. On the basis of the preceding evidence, the authors feel that the scattering of these means without any apparent pattern lends credence to the assumption that the trap was not biased to size of fish due to an avoidance reaction which would result from varying light intensities between time periods.

LENGTH-WEIGHT RELATIONSHIP

A random sample was drawn each week from the length-weight data collected on chinook, coho, and sockeye, and regression lines plotted. Preliminary examination of these data revealed a general tendency for the average length and weight to increase as the season progressed. Each of the three species exhibit this increase; however, it is more pronounced in chinook and coho. This trend can probably be attributed to growth. It is hypothesized that some consistent change in the slope or intercept of the regressions may exist, and these factors could assist in analysis of these data. Therefore, for each weekly sample, a length-weight regression equation and the associated standard error of the slope were computed.

Generally with data of this type there are three hypotheses which are of interest and which may be tested by the use of covari-

TABLE 1.—Results of covariance analysis for weekly differences in the length-weight regression equations

Hypothesis being tested	F-ratios		
	Chinook	Coho	Sockeye
(1) One regression line can be used to represent all weeks.	8.11*	5.73*	2.12*
(2) The slopes of the weekly regression equations are the same.	2.67*	3.99*	0.62
(3) The intercepts of the weekly regression equations are the same (i.e., are there differences in elevation?).	**	**	4.12*

* Significant at 0.05 probability level; thus reject hypothesis as stated; evidence is in favor of alternative.

** Since the hypothesis of equal slopes (2) was rejected, there is no need to test hypothesis (3).

ance analysis. These hypotheses are stated in Table 1. The first hypothesis to be tested is whether all data (in this case all data regardless of week) can be properly described by one regression line. For all species this hypothesis must be rejected, indicating that there are larger weekly differences than can be attributed to sampling variation.

Having rejected hypothesis 1, further inquiry is made to determine in what particular manner these data fail in this quality. The hypothesis of equal slopes is tested, and it is seen (Table 1) that for coho and chinook this second hypothesis is also rejected; however, for sockeye the evidence is not in favor of rejection. Rejections in the case of chinook and coho are perhaps not surprising, but there is some question as to why sockeye should exhibit a different behavior. In the case of sockeye the existence of small samples at the beginning of the season is obvious (Figure 3). Also, from the magnitude of the standard errors of the slopes, the sockeye data are more variable than those of the other two species. Naturally the small size of the samples of these early weeks contributes to the increased variance. Thus the total contribution of these early weeks is minimized by these factors, and any biological interpretation based upon the different behavioral characteristics of sockeye should be scrutinized carefully.

Since the hypothesis of equal slopes was rejected in the cases of coho and chinook, there was no need to examine these species further. However, following the assumption that no differences in slopes existed for sockeye, the analysis was continued to test for differences in elevation (intercept). As seen from Table 1, the evidence is in favor of a difference in intercept from week to week.

The biological interpretation of these results is difficult because of the inconsistencies en-

countered. The differences in slope (in the cases of chinook and coho) and in intercept (in sockeye) are probably not due to sampling variation. However, if these measures are examined for consistent trends which exhibit themselves in relation to seasonal growth, there seems to be no tendency for either an increase or a decrease with the seasonal increase in length and weight. These variations may be attributable to racial influences if it can be assumed that separate races migrate during the same general time period, causing heterogeneous groups to be captured during these weekly periods. Also, environmental influences acting upon the downstream migrants as a group may cause such variations. Certainly further investigation is required to interpret more completely the biological significance of such evidence, although from these data it is evident that a single length-weight equation for each species will not satisfactorily describe this stage in their life cycles.

CONDITION FACTORS

In chinook, coho, and sockeye there is evidence that length-weight relationships are not consistent from week to week. However, some measure was needed to examine the weekly changes in weight and length, and the cube-law condition factor was chosen. The relative condition factor proposed by LeCren (1951) was considered, but, as pointed out by Lagler (1956), "An obvious difficulty lies in the impossibility of comparing indices based on different regression equations." This objection is certainly applicable in the case at hand.

Condition factors based on the cube law were calculated for each specimen collected. These indices were then grouped by week and tested for differences by analysis of variance

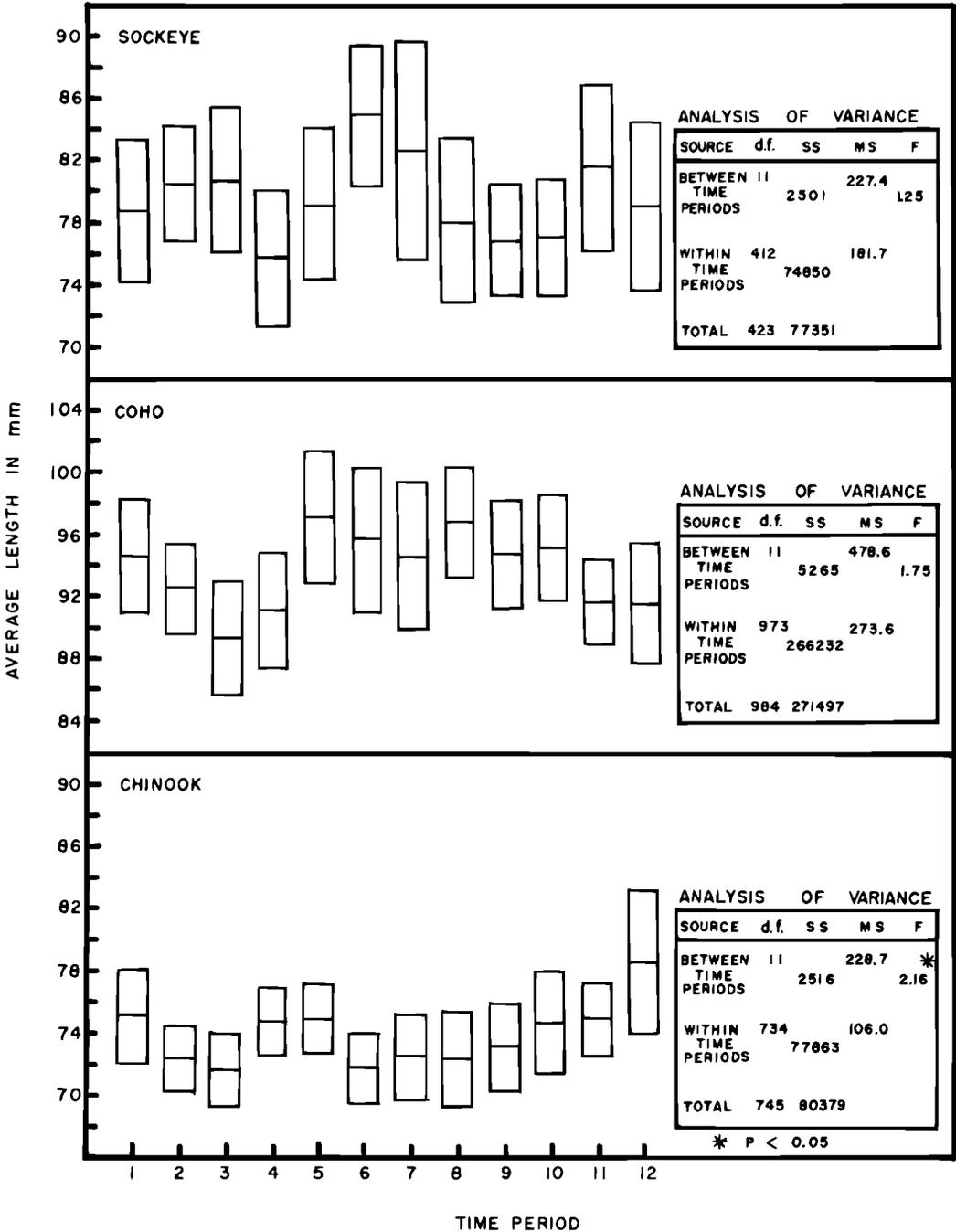


FIGURE 7.—Average fork length of sockeye, coho, and chinook salmon smolts determined from the average catch of the Taku scoop trap by time period (± 2 standard errors). Time-period 1 began at midnight, and each period was 2 hours long.

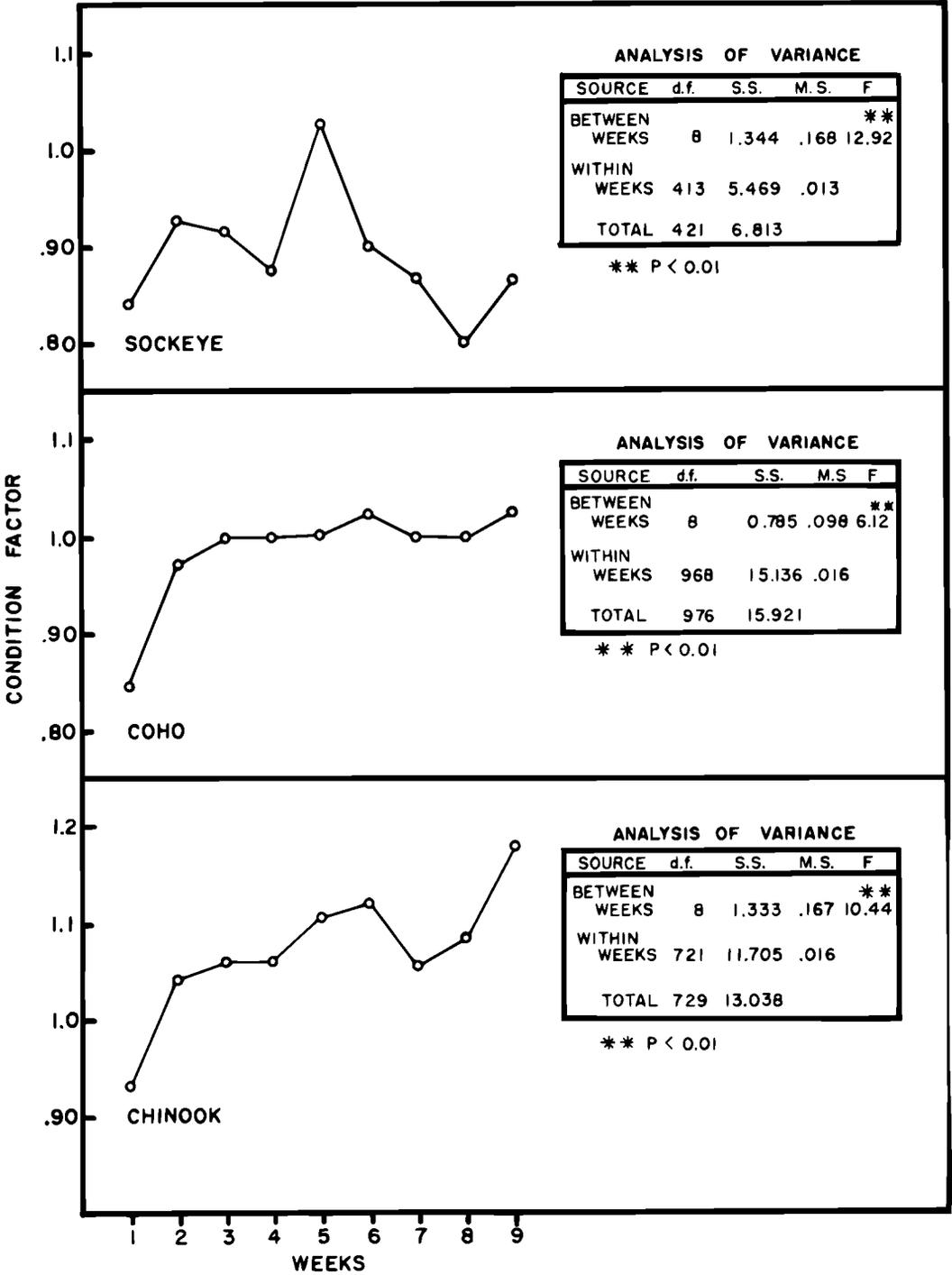


FIGURE 8.—Average condition factors of sockeye, coho, and chinook salmon smolts by week, showing differences tested by analysis of variance.

(Figure 8). The condition factors were computed from the following formula:

$$K = \frac{AW}{L^3}$$

where W = weight in grams, L = fork length in millimeters, A = a constant, and K = coefficient of condition.

It can be seen from Figure 8 that all three species exhibited a difference (0.01 level of significance) in condition factor by week. Chinook and coho show a general increase in the condition factor as the season progresses; however, sockeye show a rather erratic pattern. The general increase in condition factor in chinook and coho probably was not the influence of age groups migrating together, but is more likely attributable to the change of the length-weight association as these migrants initiate spring growth. Some questions which now arise are: (1) Does the increase in condition factor of the later migrants have an influence on the early marine survival of these species; (2) What influence does the additional time spent in fresh water have on the freshwater survival; and (3) Are these findings typical of other large river systems?

The different pattern of the sockeye smolt length-weight association is difficult to interpret. The most intensive downstream migration period for this species can be seen to have been in late May and early June when the water turbidity and water level were very high. Whether these environmental factors, racial influences, or other factors caused this species to react differently is interesting speculation; however, it is not possible at this time to suggest any concrete explanations.

ADDITIONAL OBSERVATIONS

Besides the fishes discussed in this paper, the scoop trap also picked up fair numbers of round whitefish (*Prosopium cylindraceum*),

sculpin (*Cottus* sp.), and Pacific lamprey (*Lampetra tridentata*). A few specimens of rainbow trout (*Salmo gairdneri*) were also captured. The cottids, lampreys, and rainbows exhibited a nocturnal migration pattern, while the whitefish that were captured were taken primarily during the late afternoon. The cottids and lampreys exhibited a rather short migration period from mid-May to early June, while the rather small samples of rainbow and whitefish were scattered over the entire study period.

An examination of the stomach contents of 10 coho smolts taken on May 17 showed a variety of food consumed. Only one stomach was empty, and the rest contained midge larvae (Tendipedidae), mayfly nymphs and adults (Ephemeroptera), caddis fly larvae (Limnephilidae), and stonefly nymphs (Plecoptera). Also, two unidentifiable salmonid fry were found. These were well-digested, and therefore had not been taken within the confines of the live box of the trap.

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