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FOOD AND GROWTH PARAMETERS OF JUVENILE CHINOOK
IN THE CENTRAL COLUMBIA RIVER

**RECORD
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Running Head: Parameters of Juvenile Chinook

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ABSTRACT

Juvenile chinook salmon (Oncorhynchus tshawytscha) in the Hanford area of the free-flowing central Columbia River, Washington consume almost entirely adult and larval stages of aquatic insects. The diet is dominated by midges (Diptera: Chironomidae). By numbers, adult midges provided 64 and 58% of the diet and larval midges 17 and 18% of the diet, in 1968 and 1969, respectively. The families Hydropsychidae (Trichoptera), Notonectidae (Hemiptera) and Hypogastruridae (Collembola) are of minor numerical importance with a combined utilization of 7% in 1968 and 15% in 1969.

Distinctive features of food and feeding activity of juvenile chinook at Hanford are fourfold: 1) the fish utilize relatively few insect groups, predominantly Chironomidae; 2) they depend largely upon autochthonous river organisms; 3) they visually select living prey drifting, floating or swimming in the water; and 4) they are apparently habitat opportunists to a large extent. Analyses were made of variations in diet and numbers of insects consumed between six sampling stations distributed along a 38 km section of the river. Data are provided on feeding intensity, fish lengths, length-weight relationships, and coefficients of condition. Seasonal changes in river temperature and discharge, as well as variations in regulated flow levels, are environmental features influencing feeding, growth, and emigration of fish in the Hanford environs.

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INTRODUCTION

Food habits of juvenile chinook salmon, Oncorhynchus tshawytscha (Walbaum), have been reported from various habitats including the Sacramento River, California (Rutter 1904); lower Sacramento - San Joaquin system, California (Sasaki 1966); lower Chehalis River and upper Grays Harbor system, Washington (Herrmann 1970); middle Willamette River, Oregon (Breuser 1954); and tributaries of the central Columbia River, Washington (Chapman and Quistorff 1938). Initial observations on feeding bionomics of juvenile chinook in the central Columbia River, Washington were conducted in 1968 (Becker 1970a). The study was expanded in 1969. The objectives of this report are to present quantitative and qualitative data based on the more extensive 1969 investigation, and to discuss the influence of environmental features.

The mainstem Columbia River above Bonneville Dam has been ecologically altered during recent decades into a near consecutive series of artificial impoundments arising from hydroelectric development. Only one section

¹ This study was supported by contract AT(45-1)-1830 with the United States Atomic Energy Commission.

of the main channel now survives in its natural, free-flowing condition. This section extends from Richland, Washington some 93 km upriver to Priest Rapids Dam, where it forms the northern and northeastern boundaries of the Atomic Energy Commission's Hanford Reservation (Fig. 1).

Most spawning grounds for salmonids throughout the mainstem Columbia have now been inundated by the reservoir complex (Fulton 1968). Maintenance of salmonid resources is due largely to propagating young fish in hatcheries and spawning channels, protecting spawning and rearing areas in available tributaries, and providing access over otherwise impassable dams. The free-flowing Hanford section, however, still supports a sizeable population of fall chinook spawners that has been increasing each year since 1960 (Watson 1970). The annual contribution of the Hanford spawning population to the combined production of seaward migrants from the Columbia and Snake Rivers is not known. Due to extensive alteration of pristine river habitat elsewhere, the Hanford population of fall chinook has acquired considerable importance in sustaining natural salmonid runs within the Columbia River Basin.

ENVIRONMENTAL CONDITIONS

River temperatures and discharges are two ecological factors potentially influencing the availability of food organisms, feeding activity, and growth of juvenile chinook in the central Columbia River. The annual cycles of temperature and discharge (Fig. 2) are essentially similar from year to year. Temperatures are lowest in January and February when eggs of fall

chinook are buried in the gravel, rise during the spring as fry emerge, and peak during August and September. From the standpoint of known thermal requirements (Brett 1952), temperatures are well below the thermal preferendum of juvenile chinook (12-14C) in March and April, enter the preferred range in May and June -- when conditions are presumably optimum for feeding and growth -- and extend into the upper zone of thermal tolerance during July and August.

Temperatures at Priest Rapids Dam (above Hanford) were somewhat lower than those at Richland (below Hanford) in 1969 because of thermal discharges from operating plutonium production reactors on the Hanford reservation.² Solar radiation also contributes heat to the free-flowing river during the summer (Moore 1968). Maximum daily temperatures recorded in 1969 at Priest Rapids and Richland were 19.7 and 20.6C, respectively. These peaks were well below the apparent upper incipient lethal level of 25.1C for juvenile chinook, experimentally determined (Brett 1952).

The annual volume of river flow in the central Columbia River ranges from about 40,000 to over 280,000 cfs. Flows are low during the fall and winter, but increase and peak during April, May and June due to the seasonal runoff of the spring freshet. In 1969, flows increased about 6 weeks

² Four reactors were discharging heated water in 1968 and the spring of 1969. The effluents issued as point discharges from subsurface locations in midriver at depths exceeding 6 meters, and the mixing zones extended downstream in narrow bands prior to dispersal. Juvenile salmonids feeding in inshore areas below the reactors were not directly exposed to thermal increments.

earlier than normal because of operational releases at Grand Coulee Dam on the upper Columbia. High flows were sustained about three months, decreased sharply in July, and minimum summer flows occurred in late August and September.

The discharge data illustrated in Fig. 2 are based on weekly means and fail to reveal the extent of either weekly or daily fluctuations in river levels that occur from flow regulation at Priest Rapids Dam. Flows are generally reduced on weekends and increased during the week in response to consumer demands for hydroelectric power (Fig. 3). Similar but less extreme variations are induced daily. Water in excess of reservoir capacity is discharged over spillways at Priest Rapids Dam during the spring spate. At other seasons, weekly fluctuations in river volumes are more variable because greater need exists to conserve reservoir water supplies for hydroelectric production. At these times, such as in March and August 1969, flow regulation on weekends may result in changes of water level in the Hanford area of up to 2 m in 24 hours.

Juvenile fall chinook occur in the Hanford area of the Columbia River from late March to mid-July (Fig. 2) (Mains and Smith 1964, Becker 1970b). During this span the eggs hatch, fry leave the gravel of the riverbed, and juvenile fish occupy inshore feeding areas for indeterminate periods of feeding and growth before departing seaward. Most juveniles lingering at Hanford emigrate by the end of July. The short resident span is a historical characteristic of juvenile fall chinook originating in the central Columbia River. However, the timing of the seaward migration of juvenile salmonids passing

through the upper and lower Columbia River system is now delayed by the reservoir complex (Park 1969, Raymond 1969).

METHODS

Juvenile chinook of the 0-age group, produced by adults spawning during the fall of 1968, were collected by seines at stations along the river banks from March 4 to July 29, 1969. The sampling span corresponded to the annual presence of fish following emergence from the gravel and preceding seaward migration. Stomach analyses of 769 fish were made from samples collected at roughly weekly intervals, when available. All samples were collected between 0900 and 1500 hours, and preserved in 10% buffered formalin immediately after capture to stop digestive action. The fish were later measured (fork length, FL) and eviscerated. All measurements were taken after 7 days of preservation to obtain consistency, since formalin causes some initial shrinkage. Organisms in the stomachs were identified individually to the lowest practical category under a dissecting microscope with the aid of appropriate taxonomic texts, classified according to their developmental stage, and enumerated. Insects represented by chitinous head capsules, particularly larval Chironomidae, were counted as complete organisms whereas fragmented body parts were excluded.

The 1968 study quantified only the food organisms consumed. Methods in 1969 were modified to provide data on fish length-weight relationships and dry weight (biomass) of the stomach contents. Fish were individually blotted with adsorbent paper to remove excess fluid prior to weighing.

After identification and enumeration of food organisms, the entire stomach content of each fish was placed in a miniature watch glass, air dried at least 24 hours in a controlled atmosphere, and weighed.

Collecting stations were distributed along a 38 km section of the Columbia River extending downstream from the Highway 240 bridge at Vernita. Six primary stations, shown in Fig. 1 (A, B, C, D, E, F), and four supplementary stations were used. Samples from all ten stations were combined in summations of food organisms utilized (Tables 1 and 2) but only data from the six primary stations were used for subsequent statistical treatment.

RESULTS

Food Organisms Utilized

Throughout their sojourn at Hanford, over 95% of the diet of juvenile chinook consisted of insects. The forms utilized included adult, subadult, and larval stages of semi-aquatics, various developmental stages of aquatics, and winged adults of terrestrials (Table 1). Comparison of the 1968 and 1969 data in Table 1 reveals that the organisms consumed were essentially similar in two successive years.

The Chironomidae (midges) were the dominant insect group utilized. Emerging subadults and adults were captured in abundance (64% in 1968, 58% in 1969). Midge larvae were taken less extensively (17% in 1968, 18% in 1969). Few midge pupae and no pupal exuviae were noted.

The order Diptera, dominated by the Chironomidae, provided 83% and 78% of all insects utilized in 1968 and 1969, respectively. Other insect

orders were of less importance in terms of numbers, but not necessarily in volume (or nutritional value) since sizes of different species vary considerably. The relatively large Trichoptera or caddisflies, consisting primarily of Hydropsyche cockerelli (Hydropsychidae), were numerically the second most important order. Like the midges, most caddisflies eaten were recently emerged adults associated with the water-surface interface. Other orders of secondary importance were the Hemiptera, primarily small Notonecta nymphs (Notonectidae), and the Collembolla (Hypogastruridae).

Few Ephemeroptera, often important dietary items of salmonids in other streams, and no Plecoptera were detected in the stomach contents. Unpublished data from limited bottom samples, sporadic drift samples, inspection of stones, and trapping of adult insects by light attraction at night indicate that populations of mayflies and particularly stoneflies are low in the central Columbia. Zooplankton, originating primarily from the Priest Rapids reservoir and present in the river drift, were utilized in small quantities by only a few fish.

Seasonal Changes in Diet

Some change occurs in the diet of juvenile chinook from March to July (Table 2). The Chironomidae accounted for the greatest proportion of food organisms each month on a numerical basis, with the most larval and adult midges being consumed in March and April. Hemiptera and Collembola, both consisting of small forms, received maximum utilization in April, May and June when rising river volumes inundated shoreline areas. Adult

Trichoptera were consumed primarily in June and July, in association with summer emergence of the univoltine caddisfly populations. Adult Lepidoptera, consisting primarily of the semiaquatic Pyralidae, were taken most heavily in June.

Some correlation of diet with fish size was evident. Chinook fry were relatively small (35-40 mm FL) and contained incompletely absorbed yolk sacs when they emerged from the gravel and commenced feeding in March and April (Fig. 4). Food organisms selected by fry were predominantly small forms, primarily midges but also some Notonecta nymphs and Collembola. Adult Trichoptera in June and July were selected primarily by large fish (>50 mm FL) capable of capturing and swallowing these larger insects.

Use of Drift Organisms

The developmental stages of insects ingested by juvenile chinook reveal that most were floating, drifting, or swimming in the water when captured. This was apparently the situation for selection of most Chironomidae, Hydropsychidae, Notonecta nymphs, and Hypogastruridae, the four main insect forms utilized. Relatively few insect stages normally adhering to epibenthic substrates or living within gravel interstices were represented in the stomach contents.

Although autochthonous insects predominated, some allochthonous terrestrial forms were ingested. The orders Homoptera, Hymenoptera, and Thysanoptera are almost entirely of terrestrial origin, and other true terrestrials occur among the adult Diptera, Coleoptera, and Lepidoptera,

other than the Pyralidae (Table 1). The terrestrials were probably seized while drifting, either submerged or on the surface film. Since the river drift of allochthonous insects contributed less than 4% of the total food organisms by number, they were of relatively low value to the diet of juvenile chinook in this study.

Variability in Diet

On a proportional basis, some differences in feeding occurred between the six primary stations and some intersite influences were evident (Table 3). Adult midges were highly utilized at Station D (70.1%), a shallow, semi-enclosed backwater area with somewhat warmer temperatures than other stations, but not larval midges (6.1%). Notonecta nymphs were captured primarily at Stations A (7.3%) and E (7.4%), both with extensive areas of marginal vegetation. Adult Hydropsyche were taken primarily at Stations B (9.2%) and C (7.2%), both with rubble substrates and partially exposed to flow of the main channel. Larval caddisflies were captured primarily at Station C (9.0%). Collembola were taken most extensively at Stations A (16.5%) and D (6.0%), where extensive mud-water interfaces existed. Proportional variations between stations were probably influenced by numerous intersite features including type of substrate, exposure to current flow, changes in seasonal and regulated water levels, and possibly feeding preferences of individual fish.

Although juvenile chinook at all primary stations appeared to consume the same general types of food, Table 3 indicates some differences on the

basis of relative proportions. To explore these differences more fully, the percentages of major food organisms in seven categories (adult and larval Chironomidae, Hemiptera, adult and larval Hydropsychidae, Collembola and "all other insects") consumed within and between stations were retabulated on a monthly basis. Additionally, the samples were arbitrarily separated into "upper" (A, B, C,) and "lower" (D,E,F) stations because of the distance separating them. Analysis by percent similarities (Whittaker and Fairbanks 1958) was then applied with the formulae:

$$PS_c = 100 - .5 \sum [a-b] = \sum \min (a, b)$$

where PS_c = percent similarity of community samples at different stations, and a and b are, for a given species (or group), the percentages of samples A and B which that species (or group) represents. This method, as adapted for food organisms, permits comparison of diets within stations being studied. It quantitatively measures the relative similarity in terms of species numerical composition, in this case, occurrence in the stomach contents of juvenile chinook.

Percent similarities for all possible monthly combinations of samples were compiled and entered in a diamond matrix (Fig. 5). Values of combined samples for all Upper and Lower stations ranged from a low 58.5 in May, 68.8 in April, 70.4 in June, to 75.5 in July (dark areas).

Monthly computed figures within and between individual stations ranged above and below these values. No consistent pattern was evident.

An Upper station (A, B, or C) sometimes showed a high similarity value when compared with a Lower station (D, E, or F) and sometimes a low value. For example, values for Station A versus F were high in April (77.7), June (74.8), and July (78.3) but low in May (49.2). The calculations were consistent with the conclusion that, despite the general similarity in diet (PS_c above 50% in most cases), proportional variations between stations occurred randomly in response to site habitat features and the feeding activity of individual fish.

Variability in Feeding Intensity

Mean numbers of insects in the stomach contents revealed an increasing trend from March to July in correlation with increasing fish size and water temperature (Fig. 6). During March and April, when fish were small and temperatures were low (3-9C), mean numbers of insects consumed were minimum, about 10 per fish. Mean numbers increased to 38 in May and decreased to 28 in June. A peak of 47 was reached in July when the fish were large and temperatures ranged from 16-20°C. The May samples were influenced by high consumption of Hypogastruridae at Station A on May 20, and the July samples by adult midges at Station F on July 29, the last time fish were available. If these samples were excluded, mean numbers of insects contained in May and July did not differ greatly from those in June. Yet a slight increase throughout the season was evident.

High variations within and between samples, related to feeding of individual fish, preclude meaningful comparison between stations on the basis of number of insects per stomach. Number of insects contained under field situations is, at best, a rough index to nutrition and subsequent growth. There are several reasons. First, insects vary widely in size from minute midges to large caddisflies; a large number of small insects in a stomach is not necessarily equivalent to few large insects in terms of energy supplied. Second, the relative nutritional value may vary between like amounts of different kinds of food organisms. Third, stomach contents reveal only feeding at the approximate time a sample was taken and not the preceding meals responsible for growth. Fourth, digestion rates, metabolism, and energy consumption that result in growth are highly temperature dependent, particularly over the March to July range of 2 to 20C that occurs in the central Columbia. Fifth, changes in water levels influence current patterns, availability of food supply and, more or less, expenditure of energy required for a fish to obtain a "full meal".

Total stomach biomass provides better information on daily rations from natural river ecosystems. Feeding intensity on the basis of the relationship between fish size and stomach biomass was calculated as:

$$FI = \frac{w}{W} \times 100$$

where FI = feeding intensity, w = dry weight of stomach contents in grams,

and W = weight of juvenile chinook in grams (Olmsted and Kilambi 1971).

Amounts of food in the stomachs of individual fish varied widely. To minimize random sample variations, feeding intensities were tabulated on the basis of combined samples for each collection date at all primary stations (Table 4). The few fish taken in March were available only at Station C, where water temperatures were somewhat higher than in the main channel. These fish revealed a relatively high feeding intensity compared to fish at all primary stations in April.

FI values from grouped samples generally increased as the season progressed and the river water warmed. The highest feeding intensity in June and July reflects primarily an increase in the size of food organisms consumed, particularly by inclusion of adult Trichoptera (Table 2).

Variability in Fish Lengths

Growth of juvenile chinook was relatively slow and uniform at each station during April and early May when recruitment to shoreline zones was initiated and temperatures were low. Variations in mean fish lengths within and between stations appeared with further growth in late May, as temperatures increased, and these variations became extreme in June and July (Fig. 4).

Apparently considerable turnover of fish took place along the shore during the period of high river discharge and thereafter. The inference is that groups of fish at each station were composed largely of transitory groups. Interstation turnover probably resulted from irregular movements

of fish along the shoreline and seaward migration, in response to such factors as physiological stimuli, high river discharge, rising water temperature, and daily and weekly fluctuations in regulated water levels.

The combined mean lengths of fish collected at Upper and Lower stations provide a clearer picture of growth in relation to season (Fig. 7). The slight curvilinear relationship reveals an increase in growth rates under warming temperature regimes in June and July.

Length-Weight Relationship

Although lengths of juvenile chinook varied randomly between and within samples, the length-weight relationship for fish of equal size is a relatively constant parameter. Furthermore, the relationship is characteristic of a given habitat and may indicate the adequacy of all synecological conditions leading to fish growth and development in that environment.

The length-weight relationship of juvenile chinook at Hanford, based on the standard regression equation $\text{Log } Y = \text{Log } A + b \text{ Log } X$, was slightly curvilinear throughout the 40 - 80 mm size range (Fig. 8). The computed values transform the equation to $\text{Log } \hat{Y} = -12.52 + 3.31 \text{ Log } X$.

Coefficients of Condition

In fisheries biology, the coefficient of condition is used primarily as an aid in determining the general physical status of fish stocks in different environments. The equation is:

$$Q = \frac{W (10^5)}{L^3}$$

where Q is the coefficient of condition, W is the weight of the fish in grams, L is the length of the fish in mm, and the factor 10^5 brings the value of Q near unity (Fraser 1969).

Calculations were made on the basis of juvenile chinook in 10 mm size groups from all primary stations combined (Table 5). Q was lowest (1.08) for the 36-45 mm size group, i.e. the smallest fish emerging from the gravel in early spring and beginning to feed at low river temperatures. Q values increased to the range of 1.3 to 1.4 for the larger size groups. Indices of feeding intensity (FI) for the various size groups, included in the Table, show that the ratio of stomach food biomass to fish weight generally increases as the fish became larger. The FI value was low for the eight fish in the largest (76-85 mm) size group collected in late July.

DISCUSSION

Food Organisms

Distinctive features of feeding activity for juvenile chinook in the central Columbia River appear to be fourfold: first, the fish utilize relatively few insect groups, predominantly Chironomidae; second, they depend largely upon autochthonous river organisms; third, they visually select living prey drifting, floating or swimming in the water; and

fourth, they are apparently habitat opportunists to a large extent. These features are not necessarily unique among young salmonids in lotic environments. Here, in the free-flowing Columbia River, they demonstrate a close relationship with existing ecological conditions.

Chironomids are of variable importance to the diet of juvenile chinook in other streams. An early study conducted in the Sacramento River, California indicated that young chinook consumed midges only to a limited extent, although floating and drifting insects did form the greatest portion of their diet (Rutter 1904). Young chinook in tributaries of the central Columbia above Hanford in 1938 utilized few if any midges, although the fish fed almost exclusively on insects and the order Diptera was of greatest numerical importance (Chapman and Quistorff 1938); these fish were relatively large, up to 152 mm, and were probably young spring chinook. The food of juvenile chinook in the middle Willamette River, Oregon in 1958 was 39% Diptera, primarily midges, and 40% Ephemeroptera (Breuser 1954). Emigrating chinook in the lower Sacramento---San Joaquin system, California consumed primarily insects (90%) in 1964 but only 16% were midges (Sasaki 1966). Adult and immature midges were a major dietary item of juvenile chinook in the lower Chehalis River, Washington, along with other Diptera, Trichoptera, Plecoptera and Ephemeroptera in 1965 (Herrmann 1970).

Perusal of numerous published records dealing with food habits of young salmonids other than chinook (i.e. salmon, trout, and charr) reveal that insects, primarily aquatic but also some terrestrial forms, are the

major food organisms selected in various river habitats. Clearly, the taxonomic composition of food organisms will differ between and even within various lotic systems because the existence and production of insect taxa is influenced by diverse edapic factors.

Determination of preference for a particular food organism depends on the ratios of ingredients making up the food complex and their occurrence in the stomach of fish (Allen 1942; Ivlev 1961). Although I obtained some invertebrate drift samples in the central Columbia River, which demonstrated an abundance of chironomid larvae, the data were inadequate for accurate determination of ratios over the entire season. Feeding apparently corresponded roughly to food organisms occurring free in the water, but not necessarily in proportion to the food actually available. Some selectivity was evident in that benthic stages of aquatic insects and zooplankton were relatively unutilized. Also, fry consumed small midges most extensively whereas fingerlings tended to include larger insects in their diet. The relationship of increasing fish size to increasing food size in young salmonids has been recognized (Lindstrom 1955, Hartman 1958). Foods utilized by small salmonids are subject to limitations imposed by the size of the fish whereas food utilized by larger fish can be very diverse (Mundie 1969). However, diversity is clearly limited to what is available in a given ecosystem.

Juvenile chinook at Hanford exhibited a high degree of selection for living food organism, presumably as a result of prey movement that evoked the feeding response. Visual stimulation is an important factor involved in the feeding of young salmonids (Chapman 1966).

Ecological Aspects

The central Columbia remains a large flowing river with a relatively vast water mass, rapid current velocities, and minimum shoreline habitat in relation to discharge volume. Living in stream environments requires considerable expenditure of energy that must be balanced by food consumption. Growth occurs only when energy provided by food exceeds energy expended in feeding and other activities. Energy can apparently be conserved by juvenile salmonids in three ways: (1) leaving stream conditions to enter a lake or sea; (2) living in the stream below the main impact of the current; or (3) living predominantly in slack water, in pools, and in marginal back eddys (Mundie 1969).

Examples of habitat selection associated with energy conservation can be noted. Young chinook and steelhead (Salmo gairdneri) in Idaho streams are associated with velocities and depths in relation to body size, shifting to faster and deeper water as body growth occurs (Chapman and Bjornn 1969; Everest and Chapman 1972). Similarly, chinook fry in the Big Qualicum River, British Columbia occupy marginal areas while the larger fish move into habitats of progressively higher velocity (Lister and Genoe 1970). Since my samples were obtained entirely from shoreline areas that could be effectively seined, they reflect feeding in these habitats and a possible shift of larger fish to deep water would remain undetected.

Warmer water temperatures increase the metabolic rates of fish. A greater amount of food must be consumed for growth to be maintained as the season advances and temperatures rise. My data show that feeding intensity,

on the basis of both number of insects and total stomach biomass, tended to increase from March to July in correlation with increasing fish size and rising river temperatures. Although chironomids are small and individually low in nutritional value, they are utilized throughout the season by juvenile chinook at Hanford and their abundance compensates for size deficiency. The adult caddisflies appearing in June and July are large and provide greater nutritional value per individual at a time when temperatures are high and more energy is required for fish growth. By dry weight, one adult Hydropsyche cockerelli is equal to 35 adult midges. However, the calories available per gram of dry weight for chironomids (5424) and hydropsychids (5386) is nearly equal (Cummins and Wuycheck 1971).

Invertebrate drift is important to the feeding of stream fish, and particularly so at Hanford. The significance of the drift phenomenon is that of increasing the availability of food and supplementing possible interstation limitations on insect production; moreover, under conditions of high discharge, the quantity of drift organisms passing downriver per unit of time is higher than under low flow conditions (Waters 1969). The Columbia's annual spring spate presumably increases the availability of food organisms to juvenile chinook at Hanford during their period of maximum abundance.

Changes in river water levels, both seasonal and regulated, appear to have unique significance to the Hanford situation by influencing populations of aquatic insects and juvenile chinook in inshore areas. The influence is apparent in four ways..

First, the annual increase in seasonal discharge in April and May (Fig. 2) inundates barren shoreline areas that are exposed to air during the preceding winter. Recolonization of recently flooded inshore areas by aquatic insects depends upon organisms in the drift, which may occur rapidly, or upon the deposition of eggs by adults. There are no available data on recolonization rates of recently inundated areas at Hanford, but detached animals presumably spend only a short time in the drift and re-attach as soon as possible (Elliott 1967).

Second, weekly and daily variations in water level resulting from flow regulation at Priest Rapids Dam (Fig. 3), which periodically floods and exposes vast stretches of shoreline areas, restricts insect recolonization and incorporates marginal dwellers into the river drift. On this basis, it is not surprising that the diet of juvenile chinook includes food organisms that normally live along the shoreline such as Notonecta nymphs, adult Hypogastruridae, Collembola and terrestrial Arachnida (spiders).

Third, station occupation by juvenile chinook appears to be temporality limited. Young salmonids commonly occupy relatively small home areas (ecological niches) for a period of feeding and growth prior to seaward migration (Chapman 1966, Chapman and Bjornn 1969, Edmondson, Everest and Chapman 1968). Analysis of length frequency distributions of fish collected at the primary stations reveals considerable variation in sizes from week to week after mid May (Fig. 4). At least part of this variation must be due to flow regulation at Priest Rapids Dam. I interpret the groups of fish feeding along the shore as being unstable and existing

in dynamic equilibrium with recruitment from the gravel, irregular shoreline movements, and direct seaward migration.

Fourth, the great difference in river discharge volume between the annual spring spate ($>280,000$ cfs) and the summer period of low flow ($\approx 40,000$ cfs) suggests that juvenile chinook lingering at Hanford are prompted seaward by falling water levels. At any rate, increasing then decreasing river flows accompanied by rising temperatures (Fig. 2) are the main environmental factors correlated with normal seaward migration. These factors, which have occurred annually throughout recorded history, may well have played an evolutionary role in the development of the spring migration characteristic for young fall chinook in the Columbia River ecosystem.

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Table 1. Organisms consumed by juvenile chinook (0-age group) in the central Columbia River. (435 and 769 fish examined in 1968 and 1969, respectively).

Food Organism	1968 ⁽¹⁾		1969	
	Number	%	Number	%
DIPTERA				
<u>Adults</u>				
Chironomidae ⁽²⁾	5,973	63.5	11,062	58.2
Dolichopodidae	31	0.3	6	--
Empididae	13	--	4	--
Simuliidae	4	--	52	0.3
Culicidae	0	--	6	--
Ephydriidae	1	--	3	--
Heleidae	0	--	1	--
Stratiomyidae	0	--	1	--
Dixidae	0	--	1	--
Unidentified	82	0.9	193	1.0
<u>Larvae</u>				
Chironomidae	1,596	17.0	3,450	18.1
Dolichopodidae	18	--	4	--
Empididae	0	--	1	--
Simuliidae	55	0.6	54	0.3
Ephydriidae	1	--	1	--
Heleidae	3	--	0	--
Muscidae	3	--	0	--
Unidentified	7	--	9	--
<u>Pupae</u>				
Chironomidae	7	--	18	0.1
Tipulidae	5	--	0	--
Heleidae	0	--	2	--
Unidentified	5	--	4	--
TOTAL DIPTERA	7,804	82.9	14,872	78.2

Table 1 (Continued)

Food Organisms	1968 ⁽¹⁾		1969	
	Number	%	Number	%
HEMIPTERA				
Notonectidae	248	2.6	918	4.8
Mesoveliidae	34	0.4	2	--
Macroveliidae	1	--	0	--
Corixidae	1	--	1	--
Saldidae	4	--	8	--
Hebridae	1	--	0	--
Unidentified	11	--	27	0.1
TOTAL HEMIPTERA	300	3.2	957	5.0
COLEOPTERA				
<u>Adults</u>				
Unidentified	4	--	23	0.1
<u>Larvae</u>				
Dytiscidae	26	0.3	13	--
Noteridae	1	--	0	--
Hydrophilidae	1	--	1	--
Elmidae	0	--	1	--
Ptilodactylidae	1	--	0	--
Unidentified	1	--	16	0.1
TOTAL COLEOPTERA	34	0.4	54	0.3
LEPIDOPTERA				
<u>Adults</u>				
Unidentified ⁽³⁾	3	--	187	1.0
<u>Larvae</u>				
Unidentified ⁽³⁾	0	--	21	0.1

Table 1 (Continued)

Food Organism	1968 ⁽¹⁾		1969	
	Number	%	Number	%
TRICHOPTERA				
<u>Adults</u>				
Hydropsychidae	277	2.9	948	5.0
Psychomyiidae	0	--	3	--
Calamoceratidae	0	--	6	--
Hydroptilidae	0	--	12	--
Unidentified	1	--	44	0.2
<u>Larvae</u>				
Hydropsychidae	18	0.2	93	0.5
Psychomyiidae	13	0.1	5	--
Phryganeidae	1	--	0	--
Rhyacophilidae	0	--	2	--
Unidentified	13	0.1	27	0.1
TOTAL TRICHOPTERA	415	4.4	1,140	6.0
EPHEMEROPTERA				
<u>Adults</u>				
Subimagos	0	--	0	--
Unidentified	8	0.1	0	--
<u>Nymphs</u>				
Baetidae	1	--	24	0.1
Unidentified	0	--	4	--
TOTAL EPHEMEROPTERA	9	0.1	28	0.1
HYMENOPTERA				
<u>Adults</u>				
Unidentified	26	0.3	27	0.1

Table 1 (Continued)

Food Organism	1968 ⁽¹⁾		1969	
	Number	%	Number	%
HOMOPTERA				
<u>Adults</u>				
Aphididae	49	0.5	245	1.3
Aleyrodidae	1	--	0	--
Unidentified	40	0.5	28	0.1
TOTAL HOMOPTERA	90	1.0	273	1.4
COLLEMBOLA				
Hypogastruridae	115	1.2	974	5.1
OTHER INSECTS				
Thysanoptera	35	0.3	11	0.1
Megaloptera	1	--	1	--
Unidentified Adults	0	--	98	0.5
Unidentified Larvae	0	--	11	0.1
Unidentified	165	1.8	51	0.3
TOTAL INSECTS	8,997	95.6	18,704	98.4
OTHER FOOD ITEMS				
Fish Larvae	0	--	18	0.1
Acari	276	2.9	169	0.9
Zooplankton	30 ⁽⁴⁾	0.3	15 ⁽⁴⁾	0.1
Algae	1 ⁽⁵⁾	--	0	--
Arachnida	93	1.0	97	0.5
Plant Seeds	5	--	1	--
TOTAL OTHER FOOD ITEMS	405	4.4	300	1.5

1. 1968 data from Becker (1970a).
2. Primarily emerging subadults.
3. Primarily Parargyractis sp. (Pyrallidae)
4. Number of fish containing small quantities of Cladocera, Ostracoda, Copepoda, or Amphipoda.
5. A quantity of Anacystis.

Table 2. Monthly changes in diet of juvenile chinook in 1969,
all sampling stations combined.

Food Organism	Consumption per Month (Percent)				
	March	April	May	June	July
*Diptera	99.5	88.8	70.2	77.2	84.8
Chironomidae, adults	67.1	62.4	50.4	52.4	77.2
Chironomidae, larvae	31.8	24.6	17.4	22.8	6.3
*Hemiptera	--	3.2	13.2	2.6	T
Coleoptera	T	T	T	T	T
Lepidoptera	--	T	T	3.3	T
*Trichoptera	--	T	T	10.2	13.0
Ephemeroptera	--	T	--	T	T
Homoptera	--		T	3.4	T
Hymenoptera	--	T	T	T	T
*Collembola	T	5.6	13.8	1.4	--
Unknowns	--	--	T	T	--
All Other Insects	--	T	T	1.3	T
Total Insects (%)	99.5	97.6	97.2	99.4	97.8

Note: "T" = "Trace", or less than 1% by number in stomach contents.

* = Major insect groups utilized.

Table 3. Proportions of main insect groups utilized by juvenile chinook salmon at six primary station, combined 1969 data.

Food Organism	Relative Proportions (Percent)						Total
	A	B	C	D	E	F	
All Diptera	67.4	78.2	75.7	79.5	77.5	84.9	76.4
Chironomidae, adults	38.1	44.3	49.8	70.1	60.0	60.6	54.5
Chironomidae, larvae	26.6	31.1	24.3	6.1	15.9	21.9	19.6
Hemiptera (Notonectidae)	7.3	4.6	2.6	4.2	7.4	1.1	5.0
All Trichoptera	6.3	9.6	16.6	6.6	6.0	3.3	6.8
Hydropsychidae, adults	5.9	9.2	7.2	6.1	4.8	2.5	5.7
Hydropsychidae, larvae	0.0	0.1	9.0	0.2	0.2	0.0	0.6
Collembola (Hypogastruridae)	16.5	2.2	0.0	6.0	2.7	1.2	6.5
All "Adults" (1)	73.0	67.3	64.4	91.5	82.7	76.1	78.4
All "Larvae" (2)	27.0	32.7	35.6	8.5	17.3	23.9	21.6

(1) Includes all winged forms, aquatic insects as well as terrestrials, plus Hemiptera and Collembola.

(2) Includes larvae, pupae, nymphs and other stages normally associated with benthic substrates.

Table 4. Feeding intensity (FI) of juvenile chinook salmon in the central Columbia River, 1969.
(Samples combined by collection date.)

Date	Number of Fish	Mean Fish		Feeding Intensity (FI)
		Length (mm)	Weight (gms)	
March 4	19	38.7	0.59	0.32
11	10	38.9	0.60	0.83
April 8	75	39.7	0.62	0.32
15	58	39.8	0.62	0.19
24	57	40.0	0.66	0.14
29	56	40.7	0.70	0.14
May 13	50	41.6	0.82	0.37
20	50	45.1	1.15	0.48
27	50	46.4	1.24	0.17
June 3	50	47.2	1.38	0.70
10	38	48.7	1.69	0.57
16	57	53.6	2.30	0.66
24	40	54.1	2.15	0.45
July 2	30	54.6	2.27	0.60
7	10	49.8	1.64	0.50
15	20	59.7	2.97	0.68
21	10	68.1	4.25	0.38
29	10	78.1	6.36	0.40

Table 5. Mean length, mean weight, coefficient of condition (Q) and feeding intensity (FI) for 10 mm size groups of juvenile chinook in the central Columbia River, March-June 1969.

Size Group ⁽¹⁾	Number of Fish	Length (mm)	Weight (gms)	Q	FI
36-45 mm	411	40.5	0.72	1.08	0.33
46-55 mm	177	50.1	1.63	1.30	0.51
56-65 mm	57	59.1	2.76	1.34	0.55
66-75 mm	27	70.1	4.68	1.40	0.63
76-85 mm	8	79.0	6.53	1.33	0.25

(1) The few fish < 36-85 > mm in fork length were omitted.

FIGURE LEGENDS

- Figure 1. The Hanford environs of the free-flowing Columbia River between Richland, Washington and Priest Rapids Dam.
- Figure 2. Temperature and flow conditions in the central Columbia River during the spring and summer of 1969, in relation to the presence and preferred temperatures of juvenile fall chinook salmon.
- Figure 3. Weekly and daily fluctuations in flow volumes in the central Columbia River due to regulation at Priest Rapids Dam, above Hanford, March-August 1969.
- Figure 4. Monthly length-frequency distributions of all juvenile chinook collected at Hanford in 1969. (Data smoothed by a moving mean of three's.)
- Figure 5. Diamond matrix comparison of percent similarities (PS_c) between and within Upper (A, B, C) and Lower (D, E, F) stations based on major food organisms consumed, April-July 1969.
- Figure 6. Number of insects in stomach contents of juvenile chinook at six primary stations, in relation to mean fish lengths and water temperature.
- Figure 7. Growth of juvenile chinook at Upper and Lower stations, March-July 1969, in relation to Columbia River temperatures.
- Figure 8. Length-weight relationship of juvenile chinook in the central Columbia River, March-July 1969.

Complete list of Parameters
- Food & Growth Parameters -

								A								
								B								
								C								
								D								
								E								
								F								
								US								
								LS								
								LS								
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								US								
								F								
								E								
								D								
								C								
								B								
								A								

- (1) NO SAMPLES AT STATION C IN MAY
- (2) NO SAMPLES AT STATION B IN JULY

FIGURE 6. MEAN NUMBERS OF INSECTS IN STOMACHS OF JUVENILE CHINOOK AT PRIMARY STATIONS IN RELATION TO FISH LENGTH AND WATER TEMPERATURE.

Fig. 7

FIGURE 8. LENGTH-WEIGHT RELATIONSHIPS OF JUVENILE CHINOOK