IMPORTANCE OF INSECTS AND ZOOPLANKTON IN THE DIET OF 0-AGE CHINOOK SALMON (ONCORHYNCHUS TSHAWYTSCHA) IN THE CENTRAL COLUMBIA RIVER

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Importance of Insects and Zooplankton in the Diet of 0-Age Chinook Salmon (*Oncorhynchus tshawytscha*) in the Central Columbia River

Abstract

Feeding habits of 0-age chinook salmon (*Oncorhynchus tshawytscha*), collected in the Hanford Reach of the Columbia River, were evaluated from March through July, 1976. Food items in chinook guts were compared to potential food organisms in the Columbia River.

Aquatic insects formed the bulk of the diet. Midge fly (Chironomidae) larvae and pupae accounted for 78 percent by number and 59 percent by volume of the total ingested items. Consumption of immature insects was greatest during March-June, whereas caddisfly adults were important food items in June and July. The cladoceran, *Daphnia schødleri*, was numerically and volumetrically important during the latter part of the study period. There was little size-related difference in diet, although chinook fry longer than 66 mm (FL) preyed mainly on caddisfly adults (7 percent number, 64 percent volume) and cladocerans (70 percent number, 13 percent volume). Chironomidae larvae dominated benthic samples in April and June with Trichoptera larvae in lesser abundance. Midstream zooplankton tows collected primarily Copepoda.

Introduction

Several studies (Gerke and Kaczynski, 1972; Carlson, 1976; Craddock *et al.*, 1976) indicated the importance of crustacean zooplankton in the diet of juvenile Pacific salmon (*Oncorhynchus* spp.) residing in semi-estuarine or marine environments. In contrast, studies in freshwater lotic environments showed that although zooplankters are sometimes abundant in river drift, insects formed the bulk of juvenile chinook salmon diet (Chapman, 1938; Becker, 1970, 1973; Sasaki, 1976). Although Becker (1970, 1973) previously described feeding habits of fall chinook salmon fry at Hanford, additional studies w..e needed to compare chinook diet to potential food organisms present in the Columbia River. This paper describes seasonal and size-related feeding differences in the diet of chinook salmon fry captured in nearshore habitats of the Columbia River. Data on relative abundance of zooplankton and benthos during the period of fall chinook fry residence are included.

Methods

Newly emergent fall chinook salmon fry reside in the Hanford stretch of the Columbia River from March through July. During the 1976 outmigration, fish were collected weekly by beach seine at eight stations between Columbia River kilometer 557 and 613. Collected fish were immediately preserved in 10 percent Formalin. Fork length (FL) and weights of preserved fish were recorded in the laboratory. Stomachs were later removed and contents were washed into shallow dissecting pans. Food organisms were sorted using a binocular microscope, identified to the lowest practical taxon, characterized by developmental stage, and enumerated. Food items were distributed to a uniform depth and visual volume estimates were made using grids (Windell, 1970). The number of stomachs containing each food item was recorded and expressed as a percentage of the total number of stomachs examined. Relative importance of food items was analyzed by month and by size of fish.

Samples of macrobenthic fauna were obtained using rock-filled baskets. Baskets were placed on the river bottom in 2-4 m depths and later ($\geqq$ 90 days) collected by SCUBA divers after organism colonization. Each basket contained 14 rocks, 5 to 8 cm diameter, and covered about 200 cm^2 of bottom substrate. Previous studies indicated similar populations of benthic organisms occurred in samples from baskets and grab samples of natural substrate (Page and Neitzel, 1976a). Benthic samples were taken to the laboratory and organisms were removed from rocks by scrubbing. Organisms retained by a 0.5 mm mesh screen were preserved in 70 percent isopropyl alcohol, identified and counted. Benthic populations were expressed as number of organisms per m^2.

Duplicate stepped-oblique zooplankton tows (Page and Neitzel, 1976b) were taken from depths of 2-4 m in March and June, 1976 with a 153μ metered plankton net, 30 cm in diameter. After each 3 min tow, the net was retrieved and the sample washed into a jar. Samples were preserved in 10 percent Formalin and taken to the laboratory for species identification and enumeration.

Results

Diptera, primarily Chironomidae (midge fly), were the dominant food item, both numerically and volumetrically. Figure 1 shows percent number and percent volume of dominant food items by month and by size class of chinook fry. Since size of food organisms varied, examination of both numerical and volumetric values provided the best indication of an item's importance. Either value by itself may be misleading, especially when large (caddisfly adults) or small (zooplankton, chironomid larvae) food items are consumed. For example, chironomid larvae were numerically dominant in June yet ranked third by volume. Caddisfly adults were lowest numerically but ranked second volumetrically in June and July.

Midge fly pupae were heavily utilized and were numerically dominant in April and May when numbers of chinook fry were at peak abundance in the study area (Gray and Dauble, 1977). Midge fly larvae were important only in March and July when few fish were collected. Trichoptera adults were ingested in greatest numbers in June and July. Twenty-two percent of all chinook samples in June contained > 80 percent caddisfly adults by volume. A terrestrial insect, Homoptera, family Cicadellidae, was present in large numbers in May. Zooplankters, mainly the cladoceran *Daphnia schødleri*, were consumed in all months except March. *D. schødleri* was of greatest importance in July. All other food items were usually present in trace (< 1 percent) amounts only.

Ingestion of dominant food items by four size classes of chinook fry is shown in Figure 1. Midge fly pupae and larvae were most important numerically and volumetrically in the diet of fish 34-55 mm. Fish longer than 56 mm fed mainly on midge fly pupae and larvae (90 percent by number, 48 percent by volume). Caddisfly adults (2 percent by number, 39 percent by volume) were also important. Caddisfly adults were the most important food item (7 percent by number, 64 percent by volume) for chinook

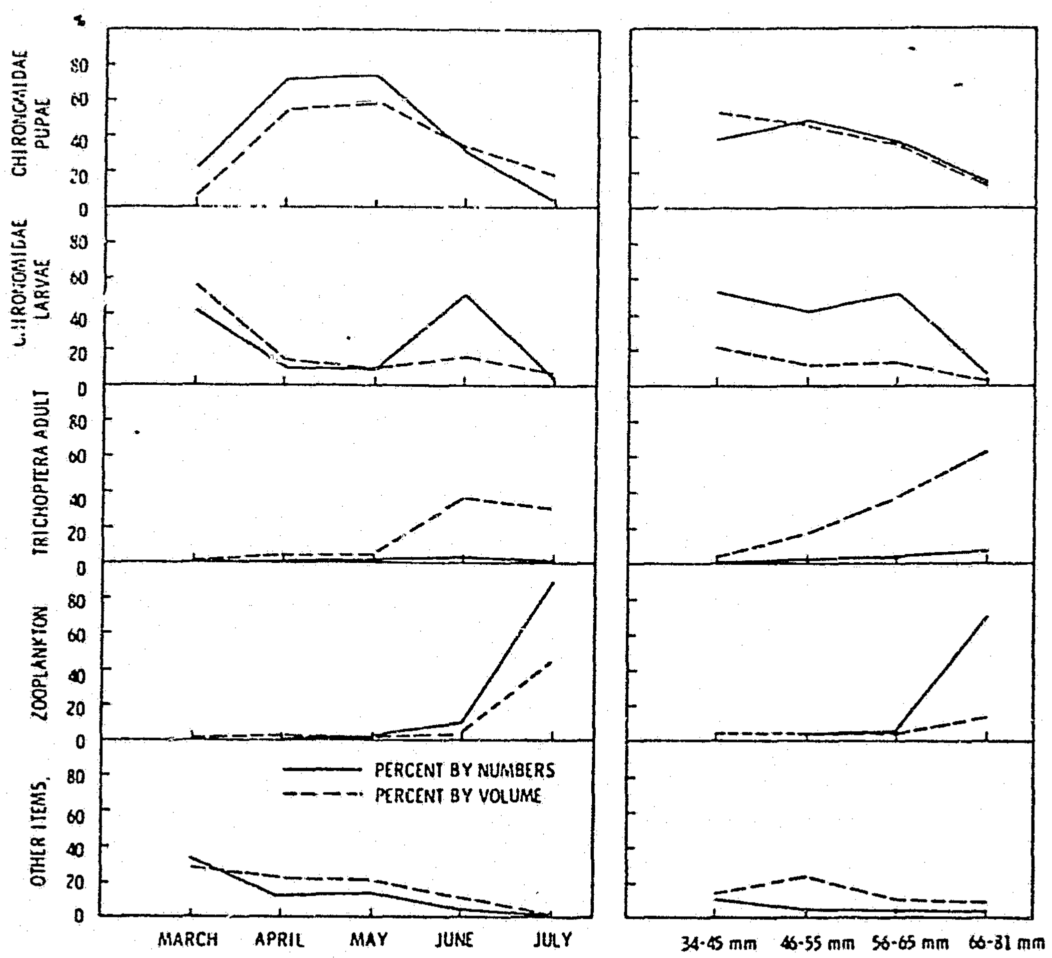

Figure 1. Relative importance of major food items by month and by size class of juvenile chinook salmon collected at Columbia River kilometer 557-613 in 1976.

fry longer than 66 mm. Crustacean zooplankton (70 percent by number, 13 percent by volume) and midge fly pupae (13 percent by number, 12 percent by volume) were also important food items for larger fish.

Table 1 summarizes the diet of all fish examined. Dipterans were clearly the dominant food item. Autochthonous food sources provided > 97 percent of the diet by number and > 90 percent by volume. These results differ from previous studies (Becker, 1973) which showed lack of zooplankton and greater consumption of Collembola by 0-age chinook fry in this section of the Columbia River.

TABLE 1. Summary of food items consumed by 0-age chinook salmon (N=260) collected in the central Columbia River, March through July, 1976.

Food Category	Percent Number	Percent Volume	Percent Occurrence
Diptera larvae	37	15	53
pupae	41	44	80
adult	2	4	21
Trichoptera larvae	<1	6	2
pupae	<1	1	2
adult	3	17	27
Terrestrial Insects	2	7	22
Zooplankton	14	4	13
Arachnida	<1	<1	8
Other	<1	2	3

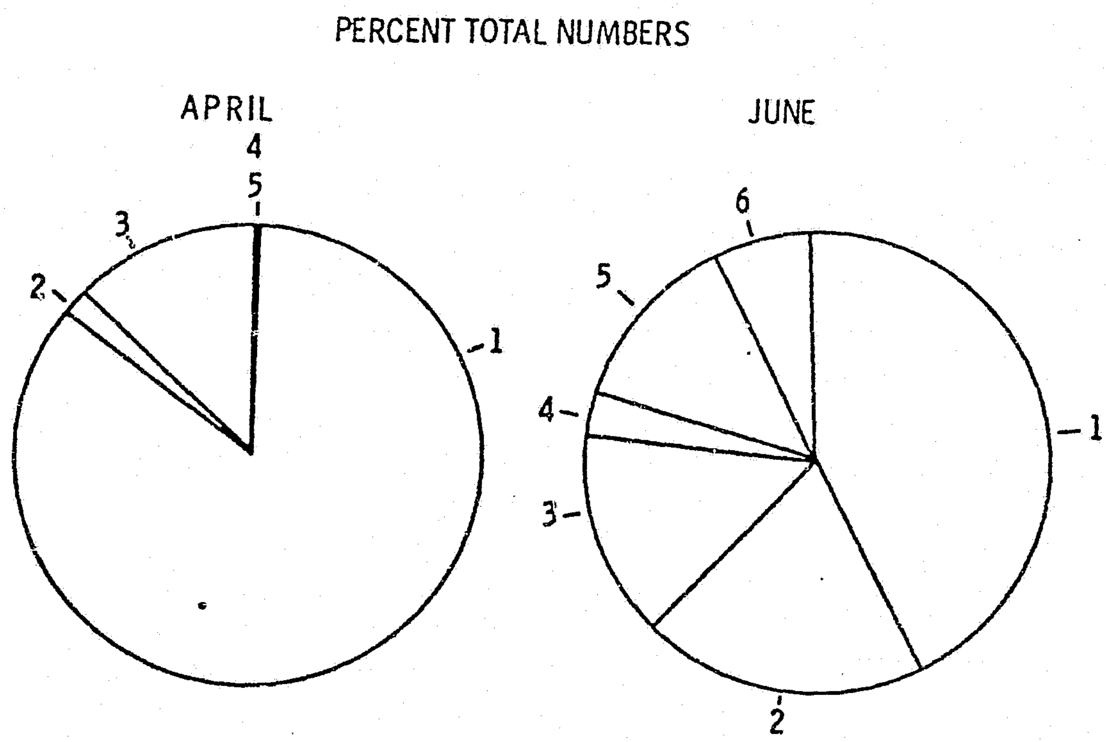

Figure 2. Relative abundance of major aquatic insect groups collected in rock-filled baskets from the benthic community in the central Columbia River, 1976. Key: 1. Chironomidae larvae; 2. Chironomidae pupae; 3. Trichoptera larvae; 4. Trichoptera pupae; 5. Simulidae larvae; 6. other insects.

Figure 2 shows the relative percentage of major aquatic insect groups collected from removable substrates placed on the river bottom. During emergence of fall chinook salmon in April, Chironomidae larvae constituted 85.2 percent and Trichoptera larvae 12.8 percent of the total benthic fauna. Although June samples were also dominated by Chironomidae larvae (46.4 percent), Trichoptera larvae (15.1 percent) and Simulidae larvae (14.4 percent) were present in increased numbers. Pupal forms of Diptera and Trichoptera were more evident in June benthic samples and supported field observations on insect emergence times.

Zooplankton samples in the mid-river drift were dominated by Copepoda, primarily *Cyclops* sp. in March and June, 1976 (Table 2). Although *Daphnia* sp. was the most abundant zooplankter present in fish guts, it was rarely found in drift samples.

TABLE 2. Mean percentages of cladoceran and copepod zooplankton sampled in midstream at Columbia River kilometer 560.

Zooplankton	March Number/ℓ	March percent	June Number/ℓ	June percent
Cladocera				
Daphnia spp.	—		0.4	0.7
Bosmina sp.	0.3	0.6	6.9	12.0
Chydoridae	0.7	1.5	0.9	1.6
Copepoda				
Cyclops sp.	23.5	50.8	42.3	73.8
Diaptomus sp.	21.8	47.1	6.8	11.9
Totals	46.3	100.0	57.3	100.0
Sample Volume	3.54×10^4 ℓ		3.37×10^4 ℓ	

Discussion

The availability concept in fish feeding dynamics has been discussed for young salmonids (Hoag, 1972; Carlson, 1976). Seasonal changes in diet have been attributed to seasonal changes in availability of various food items in the fish's habitat. Qualitative and quantitative changes in food supply and behavioral changes associated with fish size may be reflected in an organism's diet.

Timing of adult insect abundance and trends in benthic prey organism density were reflected in the diet of juvenile chinook salmon. Increased surface feeding by juvenile chinook salmon was noted during periods of caddisfly emergence and reflected opportunistic feeding. Although the relative large size of adult caddisflies limits the size of their predators, guts from some chinook salmon fry as small as 46 mm contained only adult caddisflies.

The frequent occurrence of midge fly larvae and pupae in young chinook salmon guts coincided with high midge numbers in benthic areas. We calculated forage ratios (Hess and Swartz, 1941), which indicated that chironomid pupae were the only benthic organisms selected in April and June (ratios, 55.4 and 1.9, respectively, when a number > 1 indicates selectivity). However, absence of larval cases in examined stomachs indicated that most midges were consumed while the highly visible pupae moved to the surface before adult eclosion. Becker (1970) considered most insect forms to have been floating, drifting or swimming in the water column when captured by chinook fry. Mundie (1971) attributed utilization of various food items of coho fry to flotation and visibility and found that chironomid adult and pupal forms were selected from the drift.

Seasonal presence of zooplankton as a major component in the diet of young chinook salmon may reflect zooplankton population fluctuations resulting from high water inundations that persisted long enough for the zooplankters to reproduce and grow. Although spatial separation of zooplankton tows could lead to discrepancies in actual availability of food items, habitat characteristics of *Daphnia schødleri* (Brooks, 1957) indicate they may be concentrated at times in shallow slack areas. Concentration of this cladoceran could result in visual discrimination from other food items and increase predator food collecting efficiency. This event could explain the presence of this cladoceran in the diet of chinook salmon fry in contrast to Becker's (1973) study. Craddock *et al.* (1976) found zooplankton were the most common item in the diet of young chinook salmon collected from July through October in the lower Columbia River. However, midstream zooplankton abundance in the lower Columbia River sometimes exceeded 4500 organisms per m^3 during the summer, whereas our samples never exceeded 400 zooplankton per m^3. Nearshore sampling of insects and zooplankton drift would be necessary before selectivity of all available food organisms could be determined.

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