Occurrence and Utilization of Zooplankton by Juvenile Chinook Salmon in the Lower Columbia River

DONOVAN R. CRADDOCK, THEODORE H. BLAHM, AND WILLIAM D. PARENTE

Made in United States of America
Reprinted from TRANSACTIONS OF THE AMERICAN FISHERIES SOCIET
Vol. 105, No. 1, January 1976
pp. 72–76

Occurrence and Utilization of Zooplankton by Juvenile Chinook Salmon in the Lower Columbia River

DONOVAN R. CRADDOCK, THEODORE H. BLAHM, AND WILLIAM D. PARENTE

Northwest Fisheries Center
National Marine Fisheries Service
2725 Montlake Boulevard East
Seattle, Washington 98112

ABSTRACT

The stomachs of juvenile chinook salmon, *Oncorhynchus tshawytscha*, taken in the Prescott-Kalama area of the Columbia River during July–November 1968 and March–December 1969 were examined to obtain information on their contents. Zooplankton, especially *Daphnia*, were the major item in the diet of the young salmon from July through October, whereas insects were the most important constitutents of the diet during spring and fall.

The zooplankton in the area was sampled from January 1968 to November 1969 and examined in relation to the relative abundance of juvenile chinook salmon and their stomach contents. *Daphnia*, *Bosmina*, and cyclopoid copepods were major zooplankters in the area, and their periods of highest abundance were associated with high water temperatures of summer. Samples taken during daylight hours indicated *Bosmina* were most numerous at the surface, *Daphnia* were most numerous below 5 m, and cyclopoid copepods were relatively uniform in their vertical distribution. The zooplankton populations were generally increasing during the season of juvenile chinook abundance (April–July). Juvenile chinook were selective in their feeding habits and consistently consumed *Daphnia* in a much higher percentage than it was found in the zooplankton samples.

Previous studies of the food habits of young chinook salmon in tributaries and upper river locations indicated that insects (adults and larvae) constituted a major portion of their diet (Clemens 1934; Chapman and Quistorff 1938; Hanson et al. 1940; Sasaki 1966; Becker 1973). Most food habit studies of young chinook have been in tributaries and other areas of rapid flows whereas this study was done in a semi-estuarine environment through which they must pass during their early development and seaward migration. The relative importance of insects and zooplankton to their diet was not known for the lower Columbia River. The study area is downstream from most of the spring, summer, and fall chinook spawning areas (Fulton 1968) and all but six of the chinook hatcheries on the river (Atkinson et al. 1967). Columbia River chinook salmon, hatchery reared or naturally spawned, spend an important part of their early life passing through this portion of the river.

The objectives of this study were to: (1) determine the importance of zooplankton and insects in the diet of juvenile chinook salmon sampled in the Prescott-Kalama reach of the Columbia River; (2) determine the seasonal abundance of zooplankton in the area; and (3) examine seasonal variations in relative abundance of selected zooplankters in relation to water temperature.

METHODS

Chinook salmon juveniles were collected weekly from purse and beach seining catches made to evaluate fish occurrence in the Prescott-Kalama reach of the Columbia River, 63 km down river from Portland, Oregon. A total of 207 stomach samples was collected from July to November 1968 and March to December 1969. Fish for stomach samples were selected from purse seine catches at mid-river, on the Washington side of the channel, on the Oregon side of the channel, and from beach seine catches on both sides of the river. Each week 1–10 fish were sampled, depending on availability. This food study was based on these stomach samples.

Immediately after capture, the abdominal wall of each fish to be examined was slit open and the fish placed in 10% formalin. The fish was weighed and measured; the entire alimentary canal was removed and weighed to the nearest 0.01 gram; the contents were removed by splitting the gut and washing with

TABLE 1.—*Percentage (based on dry weight of stomach contents) of different types of food items in stomachs of juvenile chinook salmon taken in the Columbia River near Prescott, Oregon, 1968–69.*

	Chinook sampled			Food items in stomachs			
Year and month	Number of fish	Average weight (g)	Average length (mm)	Stomach contents weight (g)	% Zooplankton	% Insects	% Miscellaneous
1968							
July	6	8.8	79.6	0.455	23	13	64
Aug.	8	14.3	101.6	0.179	53	5	42
Sept.	4	18.8	110.0	0.269	81	0	19
Oct.							
Nov.	6	12.9	97.3	0.169	0	27	73
Total	24			1.072	39	11	50
1969							
Mar.	13	47.8	153.2	1.283	0	12	88
Apr.	1	23.6	137.0	0.029	0	41	59
May	2	18.6	117.5	0.045	0	36	64
June	17	6.6	76.4	0.692	4	26	30
July	25	8.2	83.6	0.395	5	17	78
Aug.	36	12.7	96.0	1.479	66	8	26
Sept.	31	18.7	106.6	1.635	77	17	6
Oct.	35	14.6	100.1	1.162	51	32	17
Nov.	17	11.4	95.9	0.250	0	28	72
Dec.	6	10.9	95.0	0.102	5	17	78
Total	183			7.072	41	18	41

distilled water into 50 ml of 10% formalin; the empty gut was weighed to obtain wet weight of the contents; the contents were separated (using a binocular microscope) into three component groups, i.e., insects (adult and larvae), zooplankton (cladocerans and copepods), and miscellaneous items (fish, algae, sand, rocks, unidentifiable material, etc.); zooplankton were separated and counted by species (cladocerans) or genus (copepods); the contents were dried by vacuum filtration through a HA 0.45 micromillipore filter and baked overnight in an oven at 37.8 C; and the three component groups were weighed individually to the nearest 0.001 gram.

Zooplankton populations were sampled (during daylight, normally 1000–1400 hours) in mid-river, offshore from the Trojan Nuclear Power Plant (river kilometer 118). This approximated the area of the purse seine fishing. In 1968, samples were taken biweekly from April through October and once every 3 weeks during November through March. Weekly samples were collected during 1969.

Two types of sampling gear were used: (1) a 0.5-m Nansen type net constructed with number 10 bolting cloth and (2) a 127-mm Clarke-Bumpus sampler with number 10 cloth. Mesh opening of both nets was 150 microns.

The Nansen gear was used for all samples taken during the period April 1968 through June 1969; the Clarke-Bumpus was used July through December 1969. During 1968 each sampling operation included two vertical hauls from 10 m. In 1969 the procedure was changed to include vertical hauls from 5-, 10-, and 15-m depths (vertical hauls were at a speed of 20 m/min). Also during July through December, horizontal tows at the surface and at 5-, 10-, and 15-m depths were taken with the Clarke-Bumpus. The samples were preserved in 5% formalin; the zooplankters were later identified and enumerated in terms of organisms per m^3. Volume of water strained by the 0.5-m Nansen net was calculated from the area of the opening and the distance hauled, whereas the volume of water strained by the Clarke-Bumpus sampler was monitored by a flow meter which is a part of the gear.

Water temperatures were monitored and recorded with a thermistor thermometer system in the fishing area both years.

RESULTS

Juvenile chinook salmon were captured during the entire year (26,000 were captured during 1968 and 1969); however, the peak of downstream chinook salmon migration occurs in June or July. The size of chinook captured

TABLE 2.—*Occurrence of zooplankton in stomachs of juvenile chinook salmon taken in the Columbia River near Prescott, Oregon, 1968–69.*

Year and month	Number of stomachs	*Daphnia* No.	*Sida* No.	Cyclopoids No.	All others No.
1968					
July	6	6	15		3
Aug.	8	2,073	22	16	5
Sept.	4	3,886	17	52	7
Nov.	6	5			
Total	24	5,970	54	68	15
1969					
Mar.	13				
Apr.	1				
May	2				
June	17	538		5	3
July	25	76	93		
Aug.	36	23,280	209	4	19
Sept.	31	29,795	170		
Oct.	35	7,805			
Nov.	17	12			
Dec.	6	36		1	
Total	183	61,542	472	10	22

ranged from 49–218 mm, but the average was 100 mm.

Insects (adults and larvae) were the major component of the identifiable stomach contents in the spring and fall, whereas zooplankton (small crustacea) were most utilized in July, August, and September of 1968 and August, September, and October of 1969 (Table 1). The miscellaneous or unidentifiable contents of the stomachs sampled normally accounted for the greatest percentage of the weight, except in months when zooplankton dominated.

Daphnia were the most prevalent zooplankter in juvenile chinook stomachs. In August and September of 1968, they constituted approximately 98% of the zooplankton; in 1969 they averaged over 95% for 6 of the last 7 months of the year (Table 2). The only other zooplankter utilized in quantity by juvenile chinook salmon was the cladoceron *Sida* (62.5% in July 1968 and 55.0% in July 1969).

Of 14 species of cladocerans collected, 2 were numerically dominant in both years. *Daphnia* and *Bosmina* were by far the most abundant cladocerans and occurred in almost equal abundance. They both exceeded the third most numerous cladoceran (*Ceriodaphnia*) by approximately 40 times in 1968 and by 80 times in 1969 (Table 3). The months of peak abundance coincided closely for the 2 years. Cyclopoids were the most common of the copepods, exceeding the calanoids by factors of 19 and 7 in 1968 and 1969, respectively. The time of peak abundance for copepods did not coincide for the 2 years.

Daphnia increased to peak abundance as water temperature peaked at 21 C in August of both years, then declined sharply. The density of *Daphnia* was greater than 100/m^3 from June through October 1968 and July through September 1969.

Bosmina increased in abundance with rising temperature in April or May and reached a maximum in June or July preceding the peak period of water temperature in August, and then decreased during the period of highest water temperature and returned to a second maximum as temperatures declined in October and November. The pattern of fluctuations in relative abundance of *Bosmina* was similar for the 2 years.

Two population peaks of cyclopoid copepods appeared in 1968: in May as water temperature was increasing and in September as water temperature decreased. The period of greatest density in 1969 was fairly uniform from June through September, the season of highest water temperature.

The population of calanoid copepods peaked in July 1968 before maximum water temperature and in September 1969 after maximum water temperature. The average monthly abundance of calanoids did not exceed 175/m^3 in the 2 years of sampling.

Cyclopoid copepods were uniformly dis-

TABLE 3.—*Zooplankton abundance (no./m³) as indicated by plankton sampling in the Columbia River near Prescott, Oregon, 1968–69.*

Zooplankton composition	1968				1969								
	July	Aug.	Sept.	Nov.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.
Cladocera													
Daphnia	227	2,548	824	40		2	22	94	406	1,722	825	66	12
Bosmina	1,212	48	64	800	1	5	54	560	461	338	304	609	700
Ceriodaphnia		68	24	8					20	22	1		
Monospilus											4	11	2
Alona				8						2	6	7	2
Chyderus	22			16			1	1	1	2	1	8	2
Sida	19								4		6	2	
Simocephalus									1	10			
Diaphanosoma									3	4			
Leptodora	3								4	2			
Ilyocryptus												3	2
Pleuroxus										2		1	
Macrothrix	3						2	1					
Leydigia	3	16										1	
Copepoda													
Cyclopoids	613	1,270	3,064	160	27	68	105	751	598	666	636	199	56
Calanoids	173	84	32	24	3	12	6	61	71	37	158	27	11
Harpacticoids			8	8		2	1	1	1	5			

tributed from the surface downward to 15 m. *Daphnia* were relatively scarce at the surface but increased with depth to a maximum density from 10 to 15 m. *Bosmina* were most abundant at the surface, nearly double that of their abundance at the other depths.

DISCUSSION

Juvenile chinook in the Prescott-Kalama reach of the Columbia River selectively fed on *Daphnia*. Both Brooks (1968) and Galbraith (1967) determined that trout were highly selective for *Daphnia*, especially for *Daphnia* over 1.3 mm in length. Size of zooplankters (as given by Edmondson 1966) may have an important bearing on the selection of *Daphnia* (1.3–2.2 mm) over *Bosmina* (0.5 mm). *Bosmina* were numerous during July and November of 1968 and during the summer and fall of 1969, but they made only a minor contribution to the stomach contents in 1968 and none at all in 1969. *Cyclops vernalis* (the dominant cyclopoid) overlaps *Daphnia* in the lower size range (0.99–1.8 mm), but was not utilized to any extent by juvenile chinook. The large size of *Sida* (3–4 mm) probably was a significant factor in determining its utilization by the juvenile chinook. *Sida*, which contributed very little to the total entomostracans in our zooplankton samples (1% or less in all months sampled), made a significant contribution to the stomach contents in some months, especially July of both years.

Cyclopoids were of equal or greater abundance than *Daphnia* at certain times during 1968, but they did not contribute significantly to the diet of juvenile chinook that were examined. In September of 1968 when the population of cyclopoids exceeded that of *Daphnia* by almost four times, *Daphnia* (1.3–2.2 mm) constituted 98% of the stomach contents of juvenile chinook while cyclopoids (0.99–1.8 mm) made up 1.3%.

Calculation of Ivlev's (1961) electivity indices for the important zooplankters in the area from July through November 1968 and June through November 1969 revealed that on the scale of −1 to +1 *Daphnia* and *Sida* were highly selected by chinook juveniles (average index 0.58 and 0.99, respectively), whereas *Bosmina* and cyclopoids were actively avoided (average index −0.97 and −0.99).

During May, June, and July, when most juvenile chinook moved through the study area, zooplankters comprised less than 23% of the food in the stomachs we examined. Fish which remained in or passed the study area in August or September fed selectively on *Daphnia*, which were at peak abundance at that time.

LITERATURE CITED

ATKINSON, C. E., J. H. ROSE, AND T. O. DUNCAN. 1967. Salmon of the North Pacific Ocean—Part IV. Spawning populations of North Pacific salmon. 4. Pacific salmon in the United States. Int. North Pac. Fish. Comm. Bull. 23:43–223.

BECKER, C. D. 1973. Food and growth parameters of juvenile chinook salmon, *Oncorhynchus tshawytscha*, in central Columbia River. Fish. Bull. 71:387–400.

BROOKS, JOHN LANGDON. 1968. The effects of prey size selection by lake planktivores. Syst. Zool. 17:273–291.

CHAPMAN, WILBERT MCLEOD, AND ELMER QUISTORFF. 1938. The food of certain fishes of north central Columbia River drainage, in particular, young chinook salmon and steelhead trout. Wash. St. Dep. Fish. Biol. Rep. 37A. 14 pp.

CLEMENS, W. A. 1934. The food of young spring salmon in Shuswap Lake, B.C. Can. Field Nat. 43(9): 142.

EDMONDSON, W. T., ed. 1966. Fresh-water biology. 2nd ed. John Wiley & Sons, Inc., New York 1248 pp.

FULTON, LEONARD A. 1968. Spawning areas and abundance of chinook salmon (*Oncorhynchus tshawytscha*) in the Columbia River Basin—past and present. U.S. Fish Wildl. Serv. Spec. Sci. Rep. Fish. 571. 26 pp.

GALBRAITH, MERLE G., JR. 1967. Size-selective predation on *Daphnia* by rainbow trout and yellow perch. Trans. Am. Fish. Soc. 96(1): 1–10.

HANSON, HARRY H., OSGOOD R. SMITH, AND PAUL R. NEEDHAM. 1940. An investigation of fish-salvage problems in relation to Shasta Dam. U.S. Fish Wildl. Serv. Spec. Sci. Rep. 10. 200 pp.

IVLEV, V. S. 1961. Experimental ecology of the feeding of fishes. Translated from the Russian by Douglas Scott. Yale Univ. Press, New Haven, Conn. 302 pp.

SASAKI, SHOKEN. 1966. Distribution and food habits of king salmon, *Oncorhynchus tshawytscha*, and steelhead rainbow trout, *Salmo gairdneri*, in the Sacramento-San Joaquin Delta. Calif. Dep. Fish Game Fish Bull. 136:108–114.