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Utilization of the Columbia River Estuary by Subyearling Chinook Salmon

Abstract

Subyearling chinook salmon (*Oncorhynchus tshawytscha*) were sampled in various habitats of the Columbia River estuary (Oregon and Washington) for 18 consecutive months in 1980 and 1981. Although present throughout the year, they were most numerous from May through September. Subyearlings captured in pelagic habitats from May through August were significantly larger than those collected in intertidal areas. The diet of subyearling chinook salmon included a variety of food, primarily invertebrates. The amphipod *Corophium salmonis* was an important prey; other important prey included *Daphnia* spp. and adult dipterans. Generally, subyearlings fed more intensively in intertidal areas than in pelagic areas.

Introduction

Various investigators (Reimers 1973, Healey 1980, Kjelson *et al.* 1982, Levy and Northcote 1982, Myers and Horton 1982) have observed that estuaries are important rearing areas for some subyearling chinook salmon (*Oncorhynchus tshawytscha*). The Columbia River estuary, the largest estuary in Washington and Oregon, contains millions of subyearling chinook salmon during the spring and summer. Adult returns from these juveniles make the Columbia River system an important producer of chinook salmon; in 1979 the estimated minimum run of fall chinook salmon was 355,500 adults (Bohn and Stockley 1981). Although subyearling chinook salmon are an important part of the fish community of the Columbia River estuary, little has been published about their use of the estuary. McCabe *et al.* (1983) described relationships between juvenile chinook salmon and other fish species in the Columbia River estuary, but important specific information on subyearling chinook salmon was not presented.

The purpose of this paper is to provide information on the utilization of the estuary by subyearling chinook salmon. Specific objectives include determinations of (1) primary habitats utilized, (2) spatial and temporal distributions, (3) size characteristics, and (4) feeding habits, including comparisons of feeding intensities in different habitats.

Methods

Sampling

Bottom trawls, purse seines, beach seines, and trapnets were used to sample various habitats of the estuary. An 8 m semiballoon shrimp trawl was used in benthic areas of channels. Trawl mesh size was 38.1 mm, and a liner of knotless 12.7 mm mesh was inserted in the cod end. Mesh size for all gear types is given as stretched size. The trawl was towed for five minutes, generally upstream during flood tide. Pelagic areas were sampled with a 200 x 9.8 m variable mesh purse seine; mesh sizes were 19.0 mm and 12.7 mm. The bunts of the purse and beach seines were constructed of knotless mesh to reduce scaling of fish. The purse seine was set upstream for five minutes during various tide stages. Intertidal areas (and often adjacent subtidal regions) were sampled with two 50 m variable mesh beach seines. Although both nets had the same mesh sizes (19.0, 12.7, and 9.5 mm), one was 4.0 m deep at its deepest point, whereas the other was 3.4 m. We beach seined during various tidal stages, using a method similar to that of Sims and Johnsen (1974). Collapsible trapnets were used to sample fish in tributaries, sloughs, and coves. The trapnet leads were 15.2 m long by 0.9 m high and were attached to an object on or near the shoreline. Mesh size in the leads was either 44.4 mm or 19.0 mm. The body of the net was 4.9 m long and constructed of 19.0 mm mesh netting. Trapnets were fished for about 24 hours per set.

The estuary was divided into upper and lower zones (Figure 1); the two zones were then subdivided into pelagic and intertidal habitats. In the upper estuary, pelagic and intertidal areas were considered fresh water, whereas in the lower estuary these habitats were classified as mixed. Salinity in the lower estuary varies widely, depending on tidal stage and river flow, and in some places may exceed 30 ppt during flood

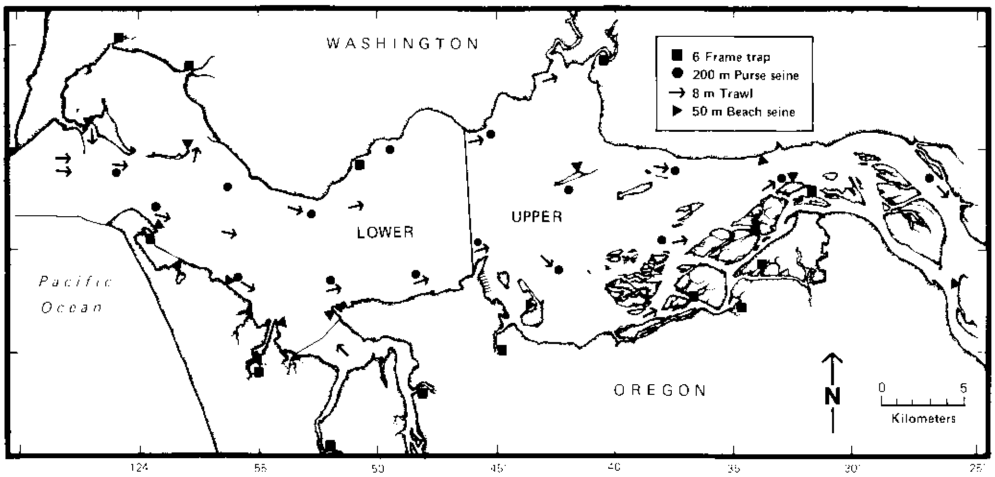

Figure 1. Locations of 63 stations in the Columbia River estuary sampled monthly from February 1980 through July 1981.

tide. Usually there is a vertical salinity gradient in the lower estuary, with highest salinity near the bottom. Saline water enters at times along the bottoms of channels in the upper estuary; however, the pelagic and intertidal sampling was generally conducted in fresh water.

Sampling was done monthly from February 1980 through July 1981; each month's effort consisted of 22 trawls, 16 purse seine sets, 11 beach seine sets, and 14 trapnet sets (Figure 1). Eleven to sixteen days were required to complete monthly sampling, depending on weather, tidal conditions, catches, and available personnel and boats. Before each set, water temperature and salinity were measured with a Beckman Model RS5-3 salinometer and probe (Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA).

Processing of Fish

Juvenile chinook salmon were measured to the nearest mm (fork length). Subyearling chinook salmon were separated from yearling chinook salmon using length-frequency histograms. When more than 50 subyearlings were caught in a set, a sample of 50 was taken and the remaining fish were counted and weighed as a group.

Five individuals from each set were kept for stomach analysis. These fish were injected with 8 percent buffered formaldehyde solution soon after capture to preserve stomach contents (Emmett *et al.* 1982). In the laboratory we removed the stomachs and placed them in individual labeled vials containing 70 percent ethanol. Food organisms were identified to the lowest practical taxon with the aid of a 10X binocular dissecting microscope, blotted, air-dried for 10 minutes, and weighed to the nearest 0.0001 g.

Food Data Analysis

Two equations were used to evaluate the food habits of juvenile chinook salmon. The importance of a prey item was assessed using a modification of the Index of Relative Importance described by Pinkas *et al.* (1971);

$$IRI = (N + W)\,F,$$

where

IRI = Index of Relative Importance of a prey item,
N = percent number of a prey item,
W = percent weight of a prey item, and
F = percent frequency of occurrence of a prey item.

IRI values were then converted to percentages.

The value of a particular estuarine habitat for subyearling chinook salmon feeding was measured by an Index of Feeding:

$$IF = \frac{Ws}{Wf} \times 100\%,$$

where

IF = Index of Feeding,

Ws = weight of the stomach contents of a fish, and

Wf = weight of a fish.

The Mann-Whitney U statistic (Elliott 1977) was used to determine if there were significant differences in IF values between various habitats.

Results

Spatial and Temporal Distributions

Subyearling chinook salmon were collected throughout the estuary, but their distribution was not uniform. More than 95 percent of the subyearling chinook salmon were captured in intertidal (beach seines) and pelagic areas (purse seines). Catches in channel bottoms, tributaries, sloughs, and coves were small and were not further analyzed. Subyearling chinook salmon were captured in every month; however, they were most abundant from May through September (Figure 2).

Pelagic catches were lower in 1981 (prior to August) than in 1980; whereas those in intertidal areas were higher in 1981 than in 1980 (Figure 2). In 1980, peak abundance was bimodal (May and July) in pelagic areas of the upper estuary, but peak catches occurred in June in the lower pelagic habitat. In 1981, highest catches in pelagic areas occurred in July in both zones of the estuary. During June 1980 and 1981, peak catches occurred in intertidal areas of both the upper and lower estuary.

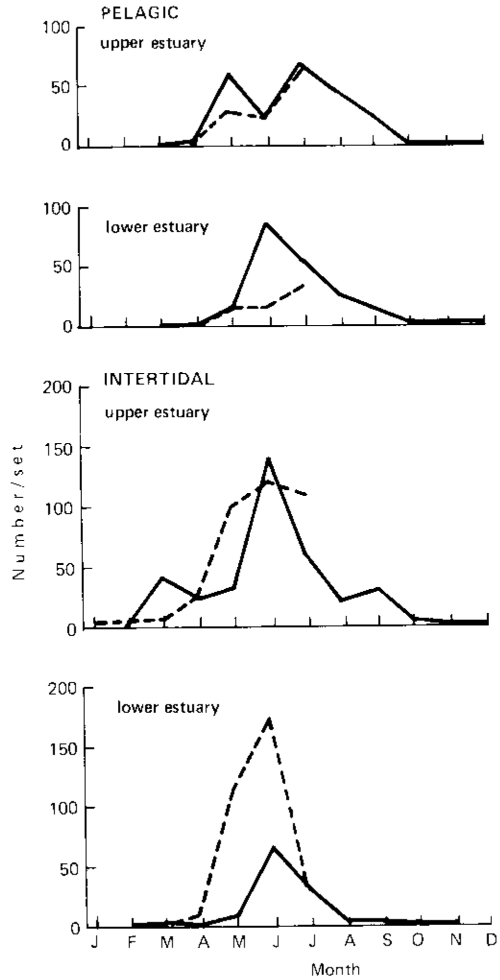

Figure 2. Catch per unit of effort of subyearling chinook salmon in four habitats of the Columbia River estuary. The solid line represents 1980 data and the dashed line represents 1981 data. Comparisons should not be made between pelagic and intertidal areas because of the use of different gear types.

Length Characteristics

During June, July, and September 1980, and in June and July 1981, subyearlings captured in pelagic areas of the lower estuary were significantly longer ($P \leq 0.05$) than subyearlings captured in pelagic areas of the upper estuary (Table 1). Comparisons were not made when $n \leq 20$ fish in a particular habitat. In intertidal areas of the lower estuary, juvenile chinook salmon were significantly longer than subyearlings in the intertidal upper estuary during May and July 1980, and May through July 1981.

From March to October the mean lengths of subyearling chinook salmon increased (Table 1). Mean lengths remained the same or declined in June. From May through August subyearlings collected in pelagic areas were significantly

TABLE 1. Lengths ($\bar{x}$ and 2SE; in mm) of subyearling chinook salmon collected in four habitats of the Columbia River estuary during 1980 and 1981.

Year and month	Pelagic						Intertidal					
	Upper estuary			Lower estuary			Upper estuary			Lower estuary		
	No.	$\bar{x}$	2SE	No.	$\bar{x}$	2SE	No.	$\bar{x}$	2SE	No.	$\bar{x}$	2SE
1980												
Feb	0	---	---	0	---	---	16	40.4	1.4	3	37.3	1.4
Mar	3	73.3	4.0	7	72.7	1.6	154	64.9	1.8	18	67.2	2.8
Apr	31	79.4	2.0	4	76.0	4.2	128	71.6	2.4	4	68.8	6.8
May	422	92.6	0.8	138	93.6	1.4	158	78.4	2.2	58	85.1	2.4
Jun	205	87.3	1.8	304	94.3	1.0	235	68.7	1.4	283	68.6	1.0
Jul	303	91.3	1.4	384	94.8	1.4	186	74.2	1.2	190	77.4	2.0
Aug	316	119.1	1.8	215	115.3	2.4	111	88.8	1.8	28	86.6	3.8
Sep	177	107.2	1.4	116	113.0	2.4	145	113.0	2.6	25	106.8	5.4
Oct	17	130.1	12.0	29	113.1	6.6	20	102.9	5.2	10	99.8	7.0
Nov	9	184.7	14.2	12	129.9	11.8	3	112.3	20.4	1	113.0	0.0
Dec	24	170.4	11.2	13	180.5	19.6	6	132.5	19.4	0	---	---
1981												
Jan	0	---	---	0	---	---	18	41.2	1.6	0	---	---
Feb	0	---	---	0	---	---	10	43.9	5.4	2	42.5	11.0
Mar	0	---	---	0	---	---	17	50.9	6.4	7	51.1	4.8
Apr	7	78.9	8.6	3	79.7	6.0	132	73.8	1.8	51	75.5	1.6
May	235	90.0	0.8	119	90.9	1.4	221	82.6	1.2	239	85.8	0.8
Jun	175	84.5	1.4	137	89.4	1.8	249	72.2	1.2	319	74.6	1.0
Jul	284	94.8	1.4	214	100.6	2.4	220	80.6	1.4	190	82.4	1.2

longer than those collected in intertidal habitats. In pelagic catches, there was an absence or paucity of subyearlings < 69 mm. In addition, subyearlings > 99 mm were not abundant in intertidal catches from May through August; yet they were common in pelagic catches.

Food Habits

A variety of food was consumed by juvenile chinook salmon (Table 2). Few subyearling chinook salmon were captured from October to February, so diet information from these months is not provided. Stomach analyses for 1981 were not completed due to financial constraints. The benthic amphipod *Corophium salmonis* was an important prey from March through July; however, in July, *C. salmonis* was only important in the intertidal habitat of the upper estuary. *Daphnia* spp. were important prey from July through September in pelagic habitats. In the intertidal habitat of the lower estuary, adult dipterans were important prey during April, May, August and September. Fish were important prey only in lower estuarine habitats (April and June).

Of the 762 stomachs examined from subyearlings collected from March through September, 12.3 percent were empty. The highest percentage of empty stomachs was found in the lower pelagic area (29.0 percent); the pelagic and intertidal habitats of the upper estuary had fewer empty stomachs (≤ 6.7 percent).

Index of Feeding (IF) values for subyearlings collected in intertidal areas were significantly greater ($P \leq 0.05$) than those for subyearlings captured in pelagic habitats during all months except April (Table 3). Comparisons also were made between IF values for subyearling chinook salmon in intertidal habitats of the upper and lower estuary and in upper and lower pelagic habitats. The only significant differences were in June and September, when IF values were significantly higher in the upper pelagic habitats than in the lower pelagic habitats.

Effects of the Eruption of Mount St. Helens

Mount St. Helens erupted on 18 May 1980, resulting in the deposition of tremendous amounts of ash and mud in the Columbia River estuary. Turbidities in the estuary [River Kilometer (Rkm) 21] increased dramatically—1120 Nephelometric

TABLE 2. Food of subyearling chinook salmon captured in four Columbia River estuary habitats from March through September 1980. The importance of a particular food is estimated as percent Index of Relative Importance (n = sample size; values <1.0 are not shown).

Prey items	MARCH 1980				APRIL 1980				MAY 1980				JUNE 1980			
	Lower pelagic n=3 0 empty	Upper pelagic n=3 0 empty	Lower intertidal n=11 0 empty	Upper intertidal n=20 3 empty	Lower pelagic n=4 1 empty	Upper pelagic n=20 1 empty	Lower intertidal n=4 1 empty	Upper intertidal n=19 0 empty	Lower pelagic n=30 5 empty	Upper pelagic n=33 0 empty	Lower intertidal n=20 1 empty	Upper intertidal n=21 0 empty	Lower pelagic n=45 20 empty	Upper pelagic n=45 2 empty	Lower intertidal n=30 2 empty	Upper intertidal n=25 0 empty
Mysidacea	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Neomysis mercedis	—	3.4	14.2	9.1	—	—	9.6	—	—	—	2.7	4.9	—	—	2.5	6.4
Cumacea	—	—	—	—	—	—	1.5	—	—	—	—	—	—	—	1.1	—
Amphipoda	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Eogammarus spp.	—	—	8.0	—	—	—	—	—	—	—	—	—	7.9	—	3.2	3.3
Eogammarus oclari	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3.4	—
Ampithoe spp.	—	—	—	—	—	—	—	—	—	—	—	—	2.6	—	—	—
Corophium spp.	27.6	—	—	—	—	—	—	—	—	—	—	—	5.3	—	—	—
Corophium salmonis	—	4.5	73.7	88.8	37.2	84.0	11.5	52.4	81.7	74.9	9.5	90.4	5.7	4.6	48.8	68.5
Corophium spinicorne	—	—	—	—	—	10.1	—	3.1	1.1	10.7	—	—	7.7	—	—	—
Eohaustorius estuaris	—	—	—	—	—	—	—	—	—	—	3.1	—	—	—	—	—
Decapoda	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Crangon franciscorum	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2.5	—
Cancer magister (megalops)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Cladocera	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Daphnia spp.	60.6	—	1.2	—	—	—	—	—	—	3.4	—	1.1	1.2	4.2	2.1	2.2
Copepoda	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Calanoida	—	—	—	—	—	—	—	—	—	—	—	—	1.4	—	20.5	—
Cyclopoida	—	—	—	—	—	—	—	—	—	—	—	—	2.4	—	—	—
Harpacticoida	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1.2	—
Insecta	—	—	—	—	—	—	16.0	—	—	—	—	—	—	—	—	—
Diptera (adult)	—	5.1	1.8	—	—	—	72.8	4.7	1.9	7.7	71.0	3.1	15.2	81.2	3.6	6.2
Heleidae (larvae)	—	—	—	—	—	—	—	—	—	—	—	—	3.0	—	—	4.6
Chironomidae (larvae)	—	—	—	—	—	1.4	1.4	—	—	—	—	—	—	1.2	—	7.5
Chironomidae (pupae)	—	55.0	—	—	—	2.1	—	13.5	—	—	—	—	—	—	—	—
Isoptera	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Coleoptera	—	1.7	—	—	—	—	—	1.6	—	—	—	—	—	1.1	—	—

TABLE 2. Continued

	MARCH 1980				APRIL 1980				MAY 1980				JUNE 1980			
Prey items	Lower pelagic n=3 0 empty	Upper pelagic n=3 0 empty	Lower intertidal n=11 0 empty	Upper intertidal n=20 3 empty	Lower pelagic n=4 1 empty	Upper pelagic n=20 1 empty	Lower intertidal n=4 1 empty	Upper intertidal n=19 0 empty	Lower pelagic n=30 5 empty	Upper pelagic n=33 0 empty	Lower intertidal n=20 1 empty	Upper intertidal n=21 0 empty	Lower pelagic n=45 20 empty	Upper pelagic n=45 2 empty	Lower intertidal n=30 2 empty	Upper intertidal n=25 0 empty
Hymenoptera	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Plecoptera	—	—	—	1.0	—	—	—	—	—	—	—	—	—	—	—	—
Hemiptera	—	—	—	—	—	—	2.4	—	—	—	—	—	—	—	—	—
Homoptera	—	—	—	—	—	—	—	—	11.3	—	—	—	4.0	1.5	—	—
Collembola	—	6.4	—	—	—	—	—	18.6	—	—	—	—	2.2	—	—	—
Insect parts	11.8	19.0	—	—	—	—	—	4.4	—	1.3	—	—	—	—	—	—
Arachnida	—	1.7	—	—	—	—	—	—	—	—	—	—	—	3.2	—	—
Teleostei	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Engraulis mordax	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Allosmerus elongatus	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Spirinchus thaleichthys	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ammodytes hexapterus	—	—	—	—	—	—	—	—	—	—	2.0	—	—	—	7.5	—
Digested fish	—	—	—	—	19.1	—	—	—	3.6	—	9.2	—	22.4	—	—	—
Larval fish	—	—	—	—	43.7	—	—	—	—	—	—	—	—	—	—	—
Plant material	—	3.2	—	—	—	—	—	—	—	—	—	—	16.4	—	—	—

TABLE 2. (Continued)

Prey items	JULY 1980 Lower pelagic n=47 9 empty	JULY 1980 Upper pelagic n=57 6 empty	JULY 1980 Lower intertidal n=33 1 empty	JULY 1980 Upper intertidal n=22 1 empty	AUGUST 1980 Lower pelagic n=60 22 empty	AUGUST 1980 Upper pelagic n=58 8 empty	AUGUST 1980 Lower intertidal n=20 3 empty	AUGUST 1980 Upper intertidal n=22 0 empty	SEPTEMBER 1980 Lower pelagic n=32 7 empty	SEPTEMBER 1980 Upper pelagic n=36 0 empty	SEPTEMBER 1980 Lower intertidal n=18 1 empty	SEPTEMBER 1980 Upper intertidal n=24 0 empty
Mysidacea	—	—	—	—	—	—	—	—	—	—	—	—
Neomysis mercedis	—	—	—	—	—	—	—	19.6	—	—	—	1.0
Cumacea	—	—	—	—	—	—	—	—	—	—	—	—
Amphipoda	—	—	—	—	—	—	—	—	—	—	—	—
Eogammarus spp.	—	—	2.5	—	—	—	—	—	—	—	—	—
Eogammarus oclari	—	—	—	—	—	—	—	—	—	—	—	—
Ampithoe spp.	—	—	—	—	—	—	—	—	—	—	—	—
Corophium spp.	—	—	—	—	—	3.3	—	—	—	—	—	—
Corophium salmonis	—	—	13.2	78.1	—	—	—	—	—	—	—	3.2
Corophium spinicorne	—	1.0	2.4	—	—	—	—	—	—	—	—	—
Eohaustorius estuaris	—	—	—	—	—	—	2.7	—	—	—	—	—
Decapoda	—	—	—	—	—	—	—	—	—	—	—	—
Crangon franciscorum	—	—	—	—	—	—	—	—	—	—	—	—
Cancer magister (megalops)	—	—	—	—	2.6	—	—	—	—	—	—	—
Cladocera	—	—	—	—	—	—	—	—	—	—	—	—
Daphnia spp.	90.4	43.0	5.1	8.9	74.1	95.4	7.9	79.1	72.6	99.7	—	6.0
Copepoda	—	—	—	—	—	—	—	—	—	—	—	—
Calanoida	—	2.2	24.3	1.2	—	—	1.0	—	—	—	—	—
Cyclopoida	1.6	3.0	—	—	—	—	3.3	—	—	—	—	—
Harpacticoida	—	—	—	—	—	—	—	—	—	—	—	—
Insecta	—	—	—	—	—	—	—	—	—	—	—	—
Diptera (adult)	1.2	7.5	11.3	4.3	—	—	26.6	—	1.7	—	21.8	13.5
Heleidae (larvae)	—	15.5	—	—	—	—	—	—	—	—	—	—
Chironomidae (larvae)	—	5.2	—	—	—	—	—	—	—	—	—	—
Chironomidae (pupae)	—	—	—	—	—	—	—	—	—	—	—	—
Isoptera	—	—	—	—	—	—	—	—	—	—	—	3.6
Coleoptera	—	16.7	—	—	—	—	—	—	—	—	—	—

TABLE 2. Continued

Prey items	JULY 1980 Lower pelagic n=47 9 empty	JULY 1980 Upper pelagic n=57 6 empty	JULY 1980 Lower intertidal n=33 1 empty	JULY 1980 Upper intertidal n=22 1 empty	AUGUST 1980 Lower pelagic n=60 22 empty	AUGUST 1980 Upper pelagic n=58 8 empty	AUGUST 1980 Lower intertidal n=20 3 empty	AUGUST 1980 Upper intertidal n=22 0 empty	SEPTEMBER 1980 Lower pelagic n=32 7 empty	SEPTEMBER 1980 Upper pelagic n=36 0 empty	SEPTEMBER 1980 Lower intertidal n=18 1 empty	SEPTEMBER 1980 Upper intertidal n=24 0 empty
Hymenoptera	—	3.3	14.9	—	—	—	27.9	—	—	—	2.6	22.6
Plecoptera	—	—	—	—	—	—	—	—	—	—	—	—
Hemiptera	—	—	—	—	15.3	—	1.2	—	—	—	—	—
Homoptera	—	—	—	—	—	—	10.0	—	11.9	—	33.2	4.1
Collembola	—	—	—	—	—	—	—	—	—	—	—	—
Insect parts	—	—	2.6	3.0	—	—	17.0	—	1.1	—	37.2	45.1
Arachnida	—	—	—	1.7	—	—	—	—	—	—	—	—
Teleostei	—	—	—	—	—	—	—	—	—	—	—	—
Engraulis mordax	—	—	18.9	—	—	—	—	—	—	—	3.3	—
Allosmerus elongatus	2.4	—	—	—	—	—	—	—	—	—	—	—
Spirinchus thaleichthys	2.7	—	—	—	3.5	—	—	—	—	—	—	—
Ammodytes hexapterus	—	—	—	—	—	—	—	—	—	—	—	—
Digested fish	—	—	—	—	2.3	—	—	—	11.8	—	—	—
Larval fish	—	—	—	—	—	—	—	—	—	—	—	—
Plant material	—	—	—	—	—	—	—	—	—	—	—	—

TABLE 3. Comparisons of Index of Feeding (IF) values, using the Mann-Whitney U statistic, for subyearling chinook salmon *Oncorhynchus tshawytscha* captured in two habitats in the Columbia River estuary, 1980 (* $P < 0.05$, *** $P < 0.001$).

Month	Habitat	Sample size	IF median (%)	U
Mar	Pelagic	6	.050	64.5*
	Intertidal	31	.260	
Apr	Pelagic	24	.250	587.0
	Intertidal	23	.140	
May	Pelagic	63	.260	2842.5***
	Intertidal	41	.780	
Jun	Pelagic	90	.070	5961.5*
	Intertidal	55	.130	
Jul	Pelagic	104	.030	6864.0***
	Intertidal	55	.180	
Aug	Pelagic	118	.020	7871.5***
	Intertidal	42	.300	
Sep	Pelagic	68	.135	3220.0***
	Intertidal	42	.440	

Turbidity Units (NTU) on the surface 3 days after the eruption. Normal turbidity is <10 NTU. Subyearling chinook salmon catches in pelagic areas of the upper estuary decreased substantially in June. This large decline was not repeated in 1981, suggesting that the eruption may have been responsible for the 1980 change; however, other factors such as timing of large hatchery releases may have influenced catches. The eruption probably had little effect on the 1980 feeding habits of subyearling chinook salmon, except in June. May sampling in pelagic and intertidal habitats was completed prior to the eruption of the volcano.

Discussion

Distribution

Because we sampled monthly at each station, our catches indicate only general trends in relative abundance of subyearling chinook salmon in the Columbia River estuary. Large groups of hatchery fish migrate through the estuary during the spring and summer. Sampling only monthly at each station increases the probability of not collecting large numbers of subyearling chinook salmon from particular hatchery releases. Intensive sampling at a particular site(s) is necessary to define migrational peaks and timing (Dawley *et al.* 1981, 1982).

The relative abundance of subyearling chinook salmon in areas (i.e., tributaries, sloughs, and coves) sampled with trapnets may have been underestimated. Some subyearling chinook salmon may have swum over or under the narrow stationary leads of the trapnets. In addition, some subyearling chinook salmon may have swum through the leads of the trapnets, particularly those that contained 44.4 mm mesh netting.

Residence Time

Other researchers observed that juvenile subyearling chinook salmon have extended residences in estuaries. In the Sixes River estuary in southern Oregon, Reimers (1973) found that subyearling fall chinook salmon remained in the estuary for up to about three months. Healey (1980) estimated an average residency of 25 days for individual fish in the Nanaimo River estuary, British Columbia.

It is difficult to ascertain how long individual subyearling chinook salmon remain in the Columbia River estuary because of the various groups of wild and hatchery fish that enter the estuary in the spring and summer. Releases of hatchery subyearling chinook salmon into the Columbia River system exceeded 91 million fish in both 1980 and 1981. Juveniles enter the estuary primarily from the Columbia River, but significant numbers also enter through tributaries of the estuary.

Length Characteristics

Many subyearling chinook salmon enter the Columbia River estuary at a larger size than those entering other estuaries, such as the Nanaimo River estuary in British Columbia (Healey 1980) and the Sacramento-San Joaquin estuary in California (Kjelson *et al.* 1982). The mean length of subyearlings in the Columbia River estuary increased from March to October; however, size variation cannot be attributed solely to growth in the estuary. Subyearlings continually enter the estuary throughout the year. Hatchery releases of different sized fish were responsible for some of these length changes. The decline, or at least lack of increase, in the mean length of subyearlings in June was probably due to a large hatchery release(s) of smaller juvenile chinook salmon.

Dawley *et al.* (1979) observed that subyearling chinook salmon collected in beach seines at Rkm 6-8 (April-August) were only slightly larger than those collected at Rkm 75. We observed a similar size pattern between the upper and lower estuary intertidal sites from May through July.

Length differences between subyearlings collected in intertidal and pelagic habitats (Table 1) indicated that larger subyearlings preferred pelagic areas. The scarcity of subyearlings < 69 mm in pelagic catches could have been caused by gear selectivity and/or by avoidance of pelagic areas by smaller fish. Although mesh sizes in the purse seines and beach seines were similar, the purse seine contained a larger percentage of mesh through which smaller subyearlings could escape. However, gear selectivity did not account for the reduced beach seine catches of subyearlings > 99 mm during the late spring and summer, since they were captured in purse seines. A logical explanation is that, in general, larger subyearlings prefer open water to the shallow intertidal habitats of the estuary. Myers (1980) observed that the mean length of juvenile chinook salmon collected in channel areas was greater than that of those collected in intertidal areas. Dawley *et al.* (1982) observed similar size distributions at Jones Beach (Rkm 75), Columbia River.

Food Habits

The food habits of subyearling chinook salmon in other Pacific Northwest estuaries have been studied by Sasaki (1966), Herrmann (1971), Levy and Levings (1978), Levy *et al.* (1979), Healey (1980), Myers (1980), Meyer *et al.* (1981), and Pearce *et al.* (1982). The amphipod *Corophium salmonis* was an important prey in the lower San Joaquin River, California (Sasaki 1966); Grays Harbor, Washington (Herrmann 1971); Duwamish estuary, Washington (Meyer *et al.* 1981); and the Columbia River estuary (this study).

The Columbia River estuary is an important foraging area for subyearling chinook salmon. Although subyearlings feed in pelagic areas, intertidal areas are used more intensively. The higher IF values for subyearling chinook salmon in intertidal habitats are probably related to prey distributions and abundances. Large populations of *Corophium salmonis* occur in many intertidal areas of the Columbia River estuary (Durkin and Emmett 1980). Commonly eaten insect species, such as chironomids, may also be found in the tidal flats and/or marsh areas. The IF differences between intertidal and pelagic subyearling chinook salmon in July through September were apparently related to the importance of *Daphnia* spp. as a prey item in pelagic habitats. *Daphnia* spp. are relatively small zooplankters; consequently, many have to be consumed to equal the biomass of one larger invertebrate.

Differences in IF values for subyearling chinook salmon feeding in intertidal and pelagic habitats could also be caused by fish behavior. Subyearling chinook salmon in pelagic habitats may be actively migrating to the ocean, spending little time pursuing prey. This could explain the high percentage of empty stomachs found in the lower pelagic habitat. Subyearling chinook salmon in the intertidal zones are generally shorter in mean length than those in the pelagic zones, and may not be migrating as rapidly and spending more time searching for food.

Why subyearling chinook salmon switched from feeding primarily on *C. salmonis* during the spring and early summer to other prey in later months is unclear. Possibilities include changes in *C. salmonis* behavior and/or abundance, or increases in the relative abundances of other prey. For example, *Daphnia* spp. populations peak in

July-August (Haertel and Osterberg 1967). The dietary importance of *C. salmonis* coincided with the spring freshet. Information regarding the effects of the spring freshet on *C. salmonis* populations is lacking and needs to be studied.

The Columbia River estuary is important in the life history of subyearling chinook salmon. Intertidal areas are especially important feeding habitats. Unfortunately, it is these intertidal areas that have the greatest potential for alteration or are already threatened by development. These areas must be preserved to maintain suitable habitat for subyearling chinook salmon in the Columbia River estuary.

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Literature Cited

Bohn, B. R., and C. E. Stockley. 1981. Columbia River fish runs and fisheries 1957-1979. Oregon Dept. Fish Wildl. and Wash. Dept. Fish.

Dawley, E. M., C. W. Sims, R. D. Ledgerwood, D. R. Miller, and F. P. Thrower. 1979. A study to define the migrational characteristics of chinook and coho salmon and steelhead trout in the Columbia River estuary. Annual Rept. to Pac. Northwest Reg. Comm. by U.S. Nat. Mar. Fish. Serv., Seattle, Washington.

Dawley, E. M., C. W. Sims, R. D. Ledgerwood, D. R. Miller, and J. G. Williams. 1981. A study to define the migrational characteristics of chinook and coho salmon in the Columbia River estuary and associated marine waters. Annual Rept. to Pac. Northwest Reg. Comm. by U.S. Nat. Mar. Fish. Serv., Seattle, Washington.

Dawley, E. M., R. D. Ledgerwood, T. H. Blahm, and A. L. Jensen. 1982. Migrational characteristics and survival of juvenile salmonids entering the Columbia River estuary in 1981. Annual Rept. to Bonneville Power Admin. by U.S. Nat. Mar. Fish. Serv., Seattle, Washington.

Durkin, J. T., and R. L. Emmett. 1980. Benthic invertebrates, water quality, and substrate texture in Baker Bay, Youngs Bay, and adjacent areas of the Columbia River estuary. Final Rept. to U. S. Fish Wild. Serv. by U.S. Nat. Mar. Fish. Serv., Seattle, Washington.

Elliott, J. M. 1977. Some methods for the statistical analysis of samples of benthic invertebrates. Freshwater Biol. Assoc. Sci. Pub. 25.

Emmett, R. L., W. D. Muir, and R. D. Pettit. 1982. Device for injecting preservative into the stomach of fish. Prog. Fish-Cult. 44:107-108.

Haertel, L., and C. Osterberg. 1967. Ecology of zooplankton, benthos and fishes in the Columbia River estuary. Ecology 48: 459-472.

Healey, M. C. 1980. Utilization of the Nanaimo River estuary by juvenile chinook salmon, *Oncorhynchus tshawytscha*. Fish. Bull., U.S. 77:653-668.

Herrmann, R. B. 1971. Food of juvenile chinook and chum salmon in the lower Chehalis River and upper Grays Harbor. *In* Grays Harbor cooperative water quality study 1964-1966. Wash. Dept. Fish., Tech. Rept. 7. Pp. 59-82.

Kjelson, M. A., P. F. Raquel, and F. W. Fisher. 1982. Life history of fall-run juvenile chinook salmon, *Oncorhynchus tshawytscha*, in the Sacramento-San Joaquin estuary, California. *In* V. S. Kennedy (ed.) Estuarine comparisons. Academic Press, New York. Pp. 393-411.

Levy, D. A., and C. D. Levings. 1978. A description of the fish community of the Squamish River estuary, British Columbia: relative abundance, seasonal changes, and feeding habits of salmonids. Can. Fish. Mar. Serv. Manuscr. Rep. 1475.

Levy, D. A., and T. G. Northcote. 1982. Juvenile salmon residency in a marsh area of the Fraser River estuary. Can. J. Fish. Aquat. Sci. 39:270-276.

Levy, D. A., T. G. Northcote, and G. J. Birch. 1979. Juvenile salmon utilization of tidal channels in the Fraser River estuary, British Columbia. Westwater Res. Cent. Univ. Brit. Col., Tech. Rep. 23.

McCabe, G. T., Jr., W. D. Muir, R. L. Emmett, and J. T. Durkin. 1983. Interrelationships between juvenile salmonids and nonsalmonid fish in the Columbia River estuary. Fish. Bull., U.S. 81:815-826.

Meyer, J. H., T. A. Pearce, and S. B. Patlan. 1981. Distribution and food habits of juvenile salmonids in the Duwamish estuary Washington, 1980. U.S. Fish Wildl. Serv., Olympia, Washington.

Myers, K. W. W. 1980. An investigation of the utilization of four study areas in Yaquina Bay, Oregon, by hatchery and wild juvenile salmonids. Oregon State University. Thesis.

Myers, K. W., and H. F. Horton. 1982. Temporal use of an Oregon estuary by hatchery and wild juvenile salmon. *In* V. S. Kennedy (ed.) Estuarine comparisons. Academic Press, New York. Pp. 377-392.

Pearce, T. A., J. H. Meyer, and R. S. Boomer. 1982. Distribution and food habits of juvenile salmon in the Nisqually estuary, Washington, 1979-1980. U.S. Fish Wildl. Serv., Olympia, Washington

Pinkas, L., M. S. Oliphant, and I. L. K. Iverson. 1971. Food habits of albacore, bluefin tuna, and bonito in California waters. Calif. Dept. Fish Game, Fish. Bull. 152.
Reimers, P. E. 1973. The length of residence of juvenile fall chinook salmon in Sixes River, Oregon. Fish Comm. Oregon, Res. Rept. 4:1-43.
Sasaki, S. 1966. Distribution and food habits of king salmon, *Oncorhynchus tshawytscha,* and steelhead rainbow trout, *Salmo gairdnerii,* in the Sacramento-San Joaquin Delta. *In* Ecological studies of the Sacramento-San Joaquin Delta (Part II). Calif. Dept. Fish Game, Fish. Bull., 136.
Sims, C. W., and R. H. Johnsen. 1974. Variable-mesh beach seine for sampling juvenile salmon in Columbia River estuary. Mar. Fish. Rev. 36:23-26.

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