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FOOD OF JUVENILE CHINOOK, *ONCORHYNCHUS TSHAWYTSCHA*, AND COHO, *O. KISUTCH*, SALMON OFF THE NORTHERN OREGON AND SOUTHERN WASHINGTON COASTS, MAY–SEPTEMBER 1980 [1]

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The food of juvenile chinook, *Oncorhynchus tshawytscha*, and coho, *O. kisutch*, salmon captured in the northern Oregon and southern Washington coastal zones during three cruises, May-September 1980, is described. Fishes were primary prey for both species during the first cruise. Although diets overlapped, fishes and crab larvae were primary prey for chinook salmon in the second cruise, while fishes and the euphausiid *Thysanoessa spinifera* were important prey for coho salmon. During the third cruise, hyperiid amphipods were primary prey for both species. There were relatively few empty stomachs during any cruise. Fullness values are used to discuss possible food limitations.

INTRODUCTION

Individuals and resource agencies interested in the perpetuation of Pacific salmon, *Oncorhynchus* spp., in the Pacific Northwest are becoming more aware of the need to understand the ecology of salmon in the marine environment. Fewer adult returns of coho salmon, *O. kisutch,* even though hatchery production has been increasing, has recently stimulated interest in this species habits (Gunsolus 1978). Biologists have concluded that reduced upwelling off the Pacific Northwest coast has lowered primary production and thus the carrying capacity for salmonids (Oregon Department of Fish and Wildlife 1982).

Adequate early marine feeding is apparently a critical factor in determining the resultant number of adult salmon returns (Healey 1980), and yet there are only limited data concerning the food of juvenile salmon in marine waters. Previous food studies of salmonids in coastal waters of Oregon and Washington (Reimers 1964) and other Pacific areas (Silliman 1941, Merkel 1957, Andrievskaya 1957, Allen and Aron 1958, Ito 1964, LeBrasseur 1966) have been concerned primarily with adults. Recently, Healey (1978, 1980) described the food habits of juvenile chinook, *O. tshawytscha,* and coho salmon collected in British Columbia marine waters during spring and summer. Peterson, Brodeur and Pearcy (1983) presented food habit data of juvenile chinook and coho salmon captured in coastal waters of Oregon and southern Washington in June 1979.

This paper provides additional information on the feeding of juvenile salmon in the coastal waters of northern Oregon and southern Washington during the spring and summer of 1980.

METHODS

Fishes for this study were collected with a purse seine (495 x 30 m) from 10

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five-station, east-west transects between Tillamook Bay, Oregon, and Copalis Head, Washington, (Figure 1). The net was constructed of 32-mm knotted nylon web with 30 meshes of 127-mm nylon hung along the bottom above the lead line. The bunt was made of 18-mm knotted nylon web. Three cruises were conducted beginning 27 May 1980, 4 July 1980, and 28 August 1980; one day of sampling time was allotted per transect during each cruise. Descriptions of the sampling vessel, equipment, water quality measurements, fish processing, and overall catch, along with distribution, abundance, and growth of juvenile salmonids during the cruises can be found in Miller, Williams, and Sims (1983).

The first 10 individuals of each species (if available) from each seine set were taken for stomach analysis. All salmonids having a coded wire tag (CWT), recognized by the absence of an adipose fin, were also sampled. Fish selected for feeding analysis were measured (fork length, mm) and their stomachs were removed and fixed in a 4% formaldehyde solution. In the laboratory, stomachs were transferred to 70% ethyl alcohol. Approximately 600 stomachs were collected; however, not all the stomachs could be analyzed because of time and funding constraints. All CWT salmon were examined first and a random subsample of the remaining fish was selected to provide at least 50 stomachs from each salmon species from each cruise, except Cruise 2 where all stomachs collected were examined because so few fish were caught. Twenty-one percent of the fish analyzed were CWT fish.

Stomach contents were identified to the lowest possible taxa with the aid of a 10X binocular microscope. Food items were counted, blotted, air dried for 10 min, and weighted to the nearest 0.1 mg.

Stomach content data were presented graphically using a method similar to that of Pinkas, Oliphant, and Iverson (1971), where percent number and percent weight of prey items are represented on the vertical axis and percent frequency of occurrence of prey items on the horizontal axis. To evaluate the importance of each prey item we calculated an Index of Relative Importance (IRI) (Pinkas et al. 1971):

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

where

IRI = Index of Relative Importance,
F = percent frequency of occurence of a prey item for a fish species,
N = percent number of a prey for a fish species, and
W = percent weight of a prey item for a fish species.

The relative importance of a particular prey item can be more easily identified by expressing IRI values as percents. Percent IRI was calculated using the formula

$$\%\,IRI_i = \frac{IRI_i}{IRI_t} \times 100$$

where

$\%\,IRI_i$ = Percent Index of Relative Importance for prey item i,
IRI_i = Index of Relative Importance for prey item i, and
IRI_t = total of all Indexes of Relative Importance values for prey items of predator.

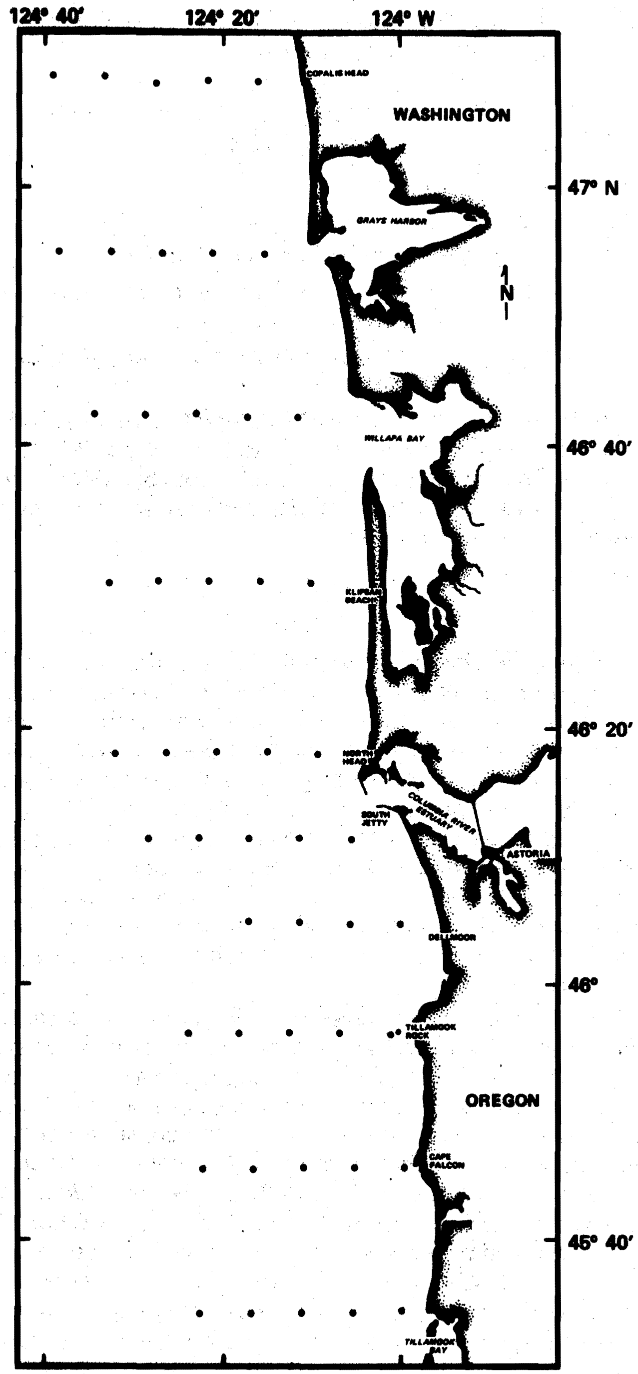

FIGURE 1. Transects and stations sampled during offshore purse seining for juvenile salmonids, May–September 1980.

Diet overlap values were calculated between the two species for each cruise to determine the potential for competition.

$$C = 2 \sum_{i=1}^{s} X_i Y_i \Big/ \sum_{i=1}^{s} X^2 + \sum_{i=1}^{s} Y^2$$

where

C = overlap coefficient,
s = food categories (lowest possible taxa),
X_i = % weight contributed by food item i for fish species X (chinook salmon), and
Y_i = % weight contributed by same food item i for fish species Y (coho salmon).

C ranges from 0 (no diet overlap) to 1 (complete overlap). Values ≥ 0.6 are believed to indicate significant overlap (Zaret and Rand 1971).

An index of fullness was used to identify possible differences in feeding intensity. Fullness was evaluated by subjectively rating stomachs 1 to 7, with 1 being empty and 7 distended (Terry 1976).

RESULTS

Food

The food of juvenile chinook salmon sampled during the three cruises comprised six major prey groups (Figure 2). For chinook salmon captured during Cruise 1, fishes were the most important prey with crab larvae secondary. In Cruise 2, fishes were again the most important prey, although crab larvae were more important than in Cruise 1. During Cruise 3, hyperiid amphipods replaced fishes as chinook salmon primary prey. For coho salmon captured during Cruise 1, fishes were the primary prey with crab larvae, calanoid copepods, the gammarid amphipod *Atylus tridens,* and other invertebrates being secondary (Figure 2). In Cruise 2, fishes were still primary prey for juvenile coho salmon, but the euphausiid *Thysanoessa spinifera* was also important. In Cruise 3, hyperiid amphipods were primary prey for coho salmon, with the pelagic gastropod *Limacina* sp. secondary.

Besides differences in the IRI values of major prey groups (fish, crab larvae, etc.) between cruises, there were also changes in the species composition within prey groups for both species of salmon (Figures 3 and 4). For example, in Cruise 1, sand lance, *Ammodytes hexapterus;* rockfish, *Sebastes* spp., unidentified Osmeridae, and digested fish constituted most of the consumed fish; but in Cruise 2, *Sebastes* spp. alone constituted most of the consumed fish. In Cruise 3, northern anchovy, *Engraulis mordax,* and Pacific herring, *Clupea harengus pallasi,* were the fish primarily consumed. The species composition of crab larvae consumed also changed between surveys. In Cruise 1, chinook and coho salmon fed on Dungeness crab, *Cancer magister* (megalops); hermit crab, *Pagurus* spp. (megalops); and porcelain crab, Porcellanidae (megalops); whereas, in Cruise 2, crab larvae were primarily Oregon cancer crab, *Cancer oregonensis* (megalops).

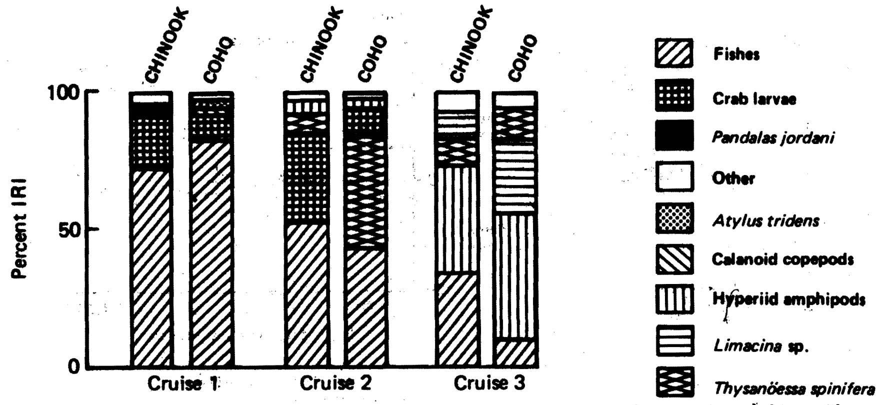

FIGURE 2. The food of juvenile chinook salmon, *Oncorhynchus tshawytscha*, and juvenile coho salmon, *O. kisutch*, captured by purse seine off northern Oregon and southern Washington during three cruises in 1980. Food is represented by Percent Index of Relative Importance (%IRI).

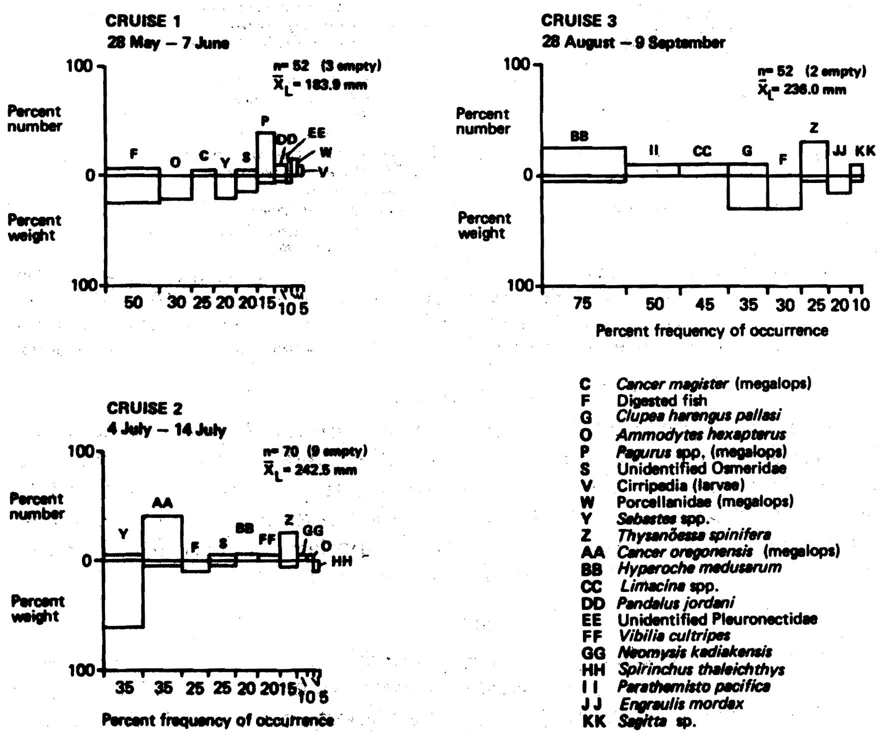

FIGURE 3. Food of juvenile chinook salmon, *Oncorhynchus tshawytscha*, captured by purse seine off northern Oregon and southern Washington during three cruises in 1980. Food is represented by numeric and gravimetric composition and by frequency of occurrence (n = sample size, $\overline{X}$ = mean fork length). Prey items less than 3% are omitted.

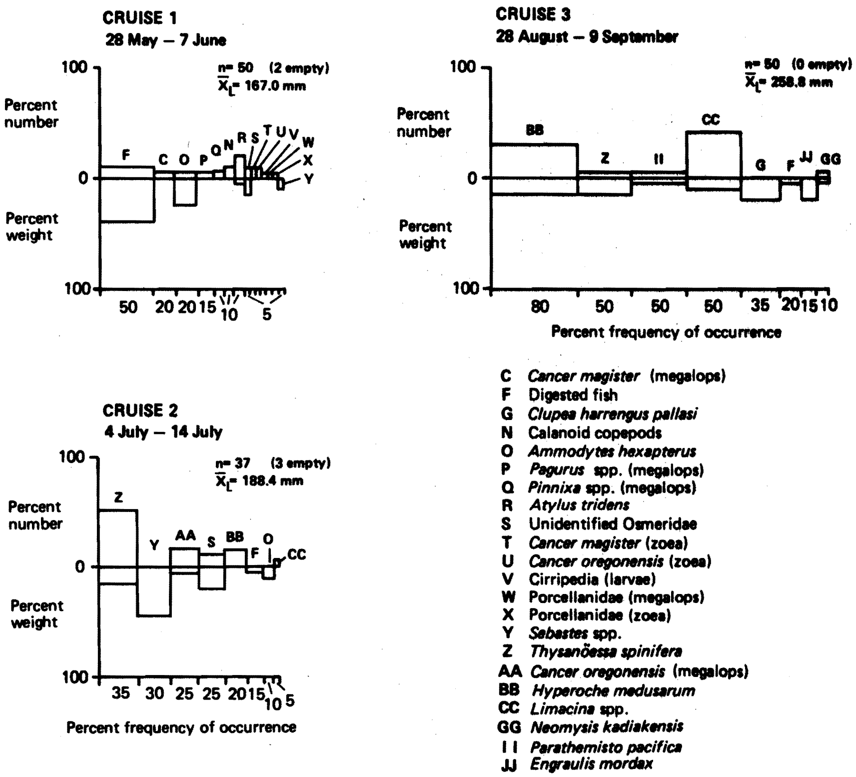

FIGURE 4. Food of juvenile coho salmon, *Oncorhynchus kisutch,* captured by purse seine off northern Oregon and southern Washington during three cruises in 1980. Food is represented by percent numeric and gravimetric composition and by frequency of occurrence (n = sample size, $\overline{X}$ = mean fork length). Prey items less than 3% are omitted.

Diet Overlap

Diet overlap for the two salmon species was highest in Cruise 1 (C = 0.91) and lowest for Cruise 3 (C = 0.71); Cruise 2 diet overlap value was 0.90. This indicated significant diet overlap for all three cruises. During Cruises 1 and 2, chinook and coho salmon utilized similar fish species for primary prey, whereas during Cruise 3, chinook salmon consumed proportionally more fish than did coho salmon, which ate more *Limacina* sp. (Figure 2).

Fullness

The intensity of feeding in juvenile chinook and coho salmon changed between cruises (Table 1). The lowest percentage of empty stomachs for both salmon species occurred during Cruise 3; the highest occurred in Cruise 2. The largest percentage of stomachs that were half full or better (percent index of fullness values of $\geq$4) occurred in Cruise 3 for both chinook and coho salmon. The lowest percentage of stomachs that were half full or better occurred in Cruise 2 for chinook salmon and Cruise 1 for coho salmon.

TABLE 1. Fullness of Juvenile Chinook, *Oncorhynchus tshawytscha,* and Coho, *O. kisutch,* Salmon Captured by Purse Seine During Three Cruises Off the Coasts of Northern Oregon and Southern Washington in Spring and Summer 1980. Fish Taken Were Divided into Categories of Fullness Ranging from 1 (Stomach Empty) to 7 (Stomach Fully Distended).

Species / *Cruise no. and date*	*Index of fullness values*							
	1 (%)	*2* (%)	*3* (%)	*4* (%)	*5* (%)	*6* (%)	*7* (%)	*≥ 4* (%)
Chinook salmon								
1 (28 May–7 June)	5.8	13.5	5.8	19.2	25.0	21.2	13.5	78.9
2 (4–15 July)	12.2	5.4	13.5	16.2	8.1	14.9	29.7	68.9
3 (28 August–9 September	3.8	3.9	5.8	11.5	11.5	19.2	44.2	91.7
Coho salmon								
1 (28 May–7 June)	3.8	21.2	17.3	21.2	13.5	9.6	13.5	57.8
2 (4–15 July)	7.9	7.8	2.6	7.9	5.3	28.9	39.5	81.5
3 (28 August–9 September)	0.0	6.0	2.0	18.0	12.0	24.0	38.0	92.0

DISCUSSION

Our data indicate that the food of juvenile chinook and coho salmon changes from spring to late summer off the northern Oregon and southern Washington coasts. This change is probably directly related to changes in prey availability and abundance. The importance of juvenile nonsalmonid fishes to juvenile chinook and coho salmon diets in the spring correlates closely with abundance of coastal fish larvae populations off Yaquina Bay, Oregon, from February through July (Richardson and Pearcy 1977). The importance of hyperiid amphipods in juvenile chinook and coho salmon diets in late summer is probably related to their relative abundance at this time. Lorz and Pearcy (1975) found that the hyperiid amphipod species commonly consumed in this study were most abundant in plankton off Newport, Oregon, in late summer and fall. There is evidence that many hyperiid amphipods species have parasitoid relationships to jellyfish and other gelatinous plankton (Laval 1980). Therefore, jellyfish population dynamics may be an important component of juvenile salmonid feeding at certain times.

Previous studies of juvenile chinook and coho salmon marine feeding indicate simliar foods. Peterson et al. (1983) found fishes and invertebrates to be important prey in juvenile chinook and coho salmon collected off Oregon and southern Washington in June 1979, with euphausiids, amphipods, and crab larvae numerically important and fishes gravimetrically important. Their data most closely resemble our data from Cruise 2. Healey (1980) observed that fish (mainly Pacific herring) were an important prey of juvenile chinook and coho salmon in the Strait of Georgia, British Columbia. Our data indicate that herring were important only in late summer. The difference in herring consumption is probably a result of availability. Our observations, as did those of Healey (1980) and Peterson et al. (1983), showed that juvenile salmon fed on different prey in different geographic areas. For example, in Cruise 3, chinook and coho salmon captured north of the Columbia River consumed many anchovies; whereas, south of the Columbia River herring were an important prey and anchovies were rarely found in the diet. These diet differences may be due to patchy distributions of prey and to relative prey abundances. There also appeared to be a possible seasonal component to prey patchiness and/or relative abundance. For example, during Cruise 3, four prey items occurred in at least 50% of the coho salmon stomachs, but in Cruise 2, no item had a frequency of occurrence over 50%; in Cruise 1 only one item had a frequency of occurrence over 50%.

It is difficult to assess the time of poorest feeding, although data from Cruise 2 indicate a possible reduction in feeding. The largest percentage of empty stomachs for both species occurred during Cruise 2, and this was also when chinook salmon had the fewest stomachs that were at least half full. Also, in Cruise 2 the fewest juvenile salmonids were captured (Miller et al. 1983). High ocean temperature (surface water temperatures for Cruise 2 averaged 15.2°C) may have caused juvenile salmon to move into deeper water where they could not be captured by purse seine. Godfrey (1968) found poor juvenile salmonid captures at high ocean temperatures off British Columbia. Salmonids may also have migrated to better feeding areas; Healey (1980) found a direct correlation between coho salmon abundance and amounts of food in their stomachs.

Juvenile chinook and coho salmon showed a large degree of diet overlap for all three cruises. High diet overlap values may indicate abundant food supply and not competition (Zaret and Rand 1971). The high diet overlap along with the low percentage of empty stomachs and relatively high percentage of stomachs that were greater than half full are evidence that no food shortages occurred for juvenile chinook and coho salmon off the northern Oregon and southern Washington coasts in 1980. Growth rates derived from fishes caught in this study also do not suggest food limitations (Miller et al. 1983).

An important component of the feeding habits of many fish species is the time of day. Fish used in this study were collected at various times during daylight hours, yet many salmonid species have diel feeding behavior (Godin 1981). Prey species also have diel behavior patterns (Alton and Blackburn 1972, Youngbluth 1976) which may affect salmon feeding rates. Peterson et al. (1983) found no significant differences in the diets of salmon collected at different times of the day; however, their information was collected during 1 month in 1979, and they combined data from many different sampling stations.

To accurately assess potential limitations of salmonid prey in coastal waters will require a more rigorous study. Salmonid digestion rates, migration patterns, and feeding behavior, along with prey availability, prey distributions, predation rates, and prey population dynamics would be required. Of special need would be a sustained series of offshore collections of juvenile salmon, their prey, and other biological and physical data during both weak and strong upwelling years. These data could then be compared to assess the relationship of upwelling to salmonid feeding.

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