DIET OF JUVENILE AND SUBADULT WHITE STURGEON IN THE LOWER COLUMBIA RIVER AND ITS ESTUARY

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November 1986

ABSTRACT

The diet of white sturgeon, Acipenser transmontanus, collected in the lower Columbia River (Washington and Oregon) from 1980 to 1983 is described. White sturgeon were captured by bottom trawl, purse seine, and hook and line and ranged from 49 to 1,289 mm in total length. Diet varied with size. The amphipod Corophium salmonis was primary prey for white sturgeon >800 mm long but not white sturgeon <800 mm. Larger white sturgeon consumed fish and large invertebrates. In general, diet diversity increased with sturgeon size.

INTRODUCTION

White sturgeon, Acipenser transmontanus, occur in large rivers and their estuaries and in marine waters on the Pacific coast of North America from the Aleutian Islands of Alaska to Monterey, California, (Scott and Crossman 1973). They are anadromous, but are landlocked in the upper Columbia and Snake Rivers by hydroelectric dams (Haynes and Gray 1981).

The Columbia River has the highest commercial and sport catches of white sturgeon on the Pacific coast; the commercial catch peaked in 1892 at more than 5 million pounds. This peak was followed by a rapid decline in landings (due to overfishing); by 1899 less than 100,000 pounds were landed (Craig and Hacker 1940). Commercial and sport fishermen have recently targeted on white sturgeon because of the decline of Pacific salmon, Oncorhynchus spp., and the availability of white sturgeon. In 1969 only 13,000 white sturgeon were captured (total sport and commercial) in the lower Columbia River below Bonneville Dam; in 1984 over 59,000 were captured (King 1985). Despite the monetary value of white sturgeon, limited life history information is available, especially for juveniles. This report provides information on food habits of juvenile and subadult white sturgeon in the lower Columbia River and its estuary.

MATERIALS AND METHODS

Sampling and Laboratory Procedures

White sturgeon were collected primarily during a comprehensive study of Columbia River estuarine fishes in 1980-1981 (McConnell et al. 1983). Sturgeon were collected with an 8-m semiballoon shrimp trawl, 200-m

purse seine, and hook and line. Overall mesh size in the trawl was 38.1 mm (stretched), with a knotless 12.7-mm (stretched) liner inserted in the net's cod end. The purse seine had mesh sizes of 19.0 and 12.7 mm (stretched). Trawling and purse seining were conducted monthly at 38 stations [River Kilometer (RKm) 3 to 62] for 18 consecutive months (Figure 1). In addition, diel sampling (bottom trawling and purse seining every 2 h for 24 h) was conducted once a month for 6 months (April-September 1980) at RKm 21. All trawling and purse seining were 5 min in duration. Hook and line sampling was conducted at RKm 22 on 25-26 June 1981 to increase sample size of white sturgeon >600 mm total length (TL).

White sturgeon were also collected in July-September 1983 using a 5-m trawl with a 4-mm (stretched) mesh liner in the cod end. A total of 80 trawls (5 min duration) were made between RKm 47 and 161.

During the 1980-81 survey, all specimens were retained for stomach analysis; during 1983, a subsample of white sturgeon stomachs was taken and the remaining fish were measured and released. Stomachs were initially preserved in the field with a buffered 20% formaldehyde solution, and in the laboratory they were transferred to vials containing 70% ethyl alcohol. Stomach and esophageal contents were examined with a 10X binocular dissecting microscope. Food organisms were identified to the lowest practical taxon (usually species), blotted, air-dried for 10 min, and weighed to the nearest 0.0001 g.

Data Analysis

We used an Index of Relative Importance (IRI), modified from Pinkas, Oliphant, and Iverson (1971), to evaluate diet:

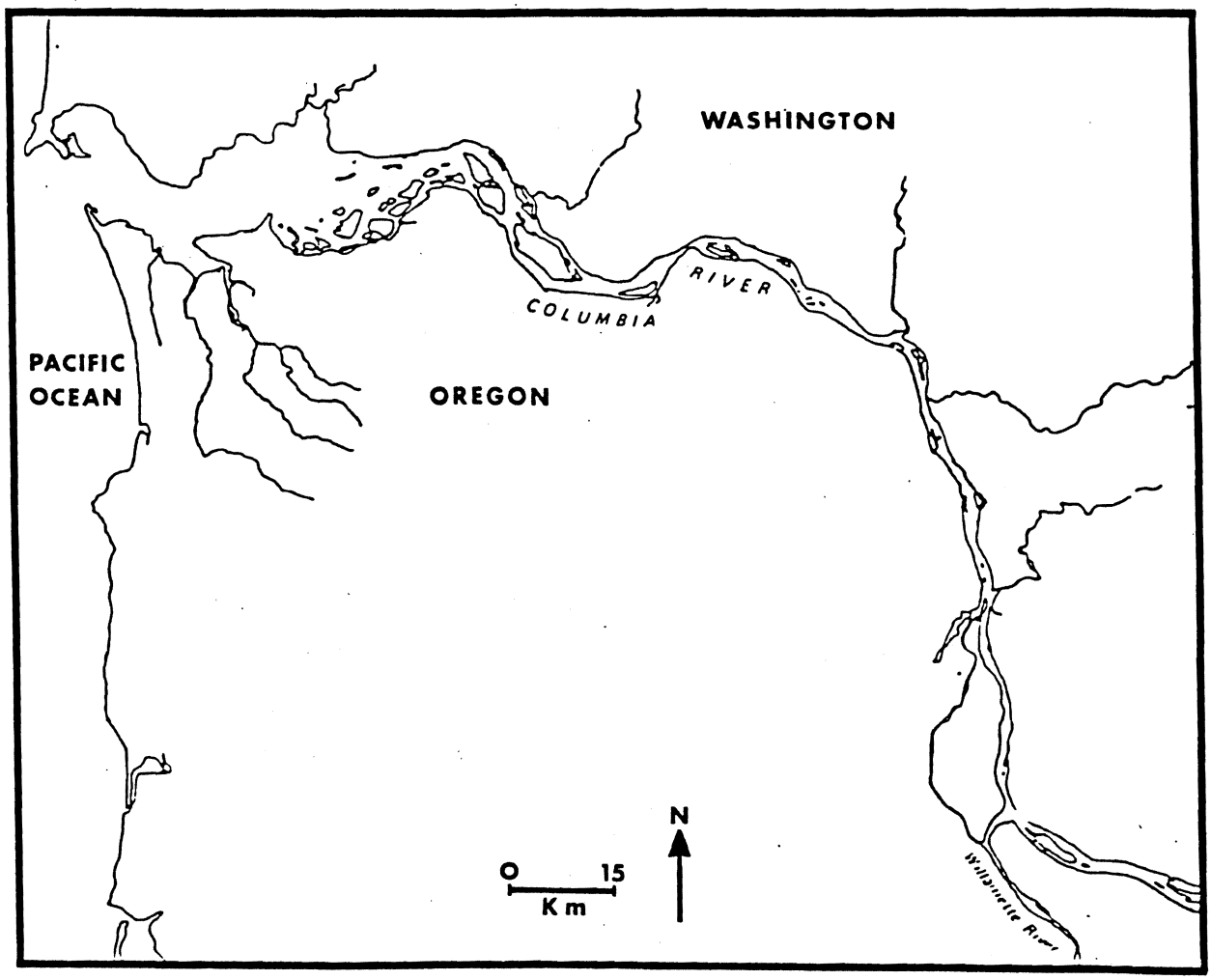


Figure 1. The lower Columbia River and its estuary.

$$IRI = (N * W)F$$

where N = numerical percentage of prey item,

W = weight percentage of prey item, and

F = percentage frequency of occurrence of prey item.

Data were combined for analysis and sorted by size range to identify the effect of this variable on white sturgeon feeding habits. White sturgeon <800 mm were divided into 200-mm size increments; those >800 mm were combined into one group. IRI values were converted to percentages to more easily describe the diet.

The Shannon-Weaver Diversity Index (Shannon and Weaver 1963) was used to compare diet diversity by size range. The formula is $H' = - \Sigma Pi (\log_2 Pi)$ where Pi = %IRI of a food item. The H' index provides a diversity value, ranging from 0.0 (low diversity) to 6.0 (high diversity). Since diet is poorly described by just prey number or weight, we used %IRI in the formula.

To identify diet differences with increasing length, diet overlap was calculated (Horn 1966) utilizing IRI values (Wallace 1981):

$$C = \frac{2 \sum_{i=1}^{s} XiYi}{\sum_{i=1}^{s} Xi^2 + \sum_{i=1}^{s} Yi^2}$$

where

C = overlap value,

s = food categories (lowest possible taxa),

Xi = %IRI contributed by food item i for sturgeon of length X, and

Yi = %IRI contributed by food item i for sturgeon of length Y.

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

RESULTS

A total of 174 white sturgeon stomachs were examined--135 from purse seine/trawl catches and 39 from hook and line catches. White sturgeon ranged in size from 49 to 1,289 mm TL. The mean TL for white sturgeon collected by purse seine and trawl was 422 mm; hook and line captures averaged 850 mm.

Overall, Amphipoda (71.4% IRI) was the most important food group (Table 1). Amphipods had a frequency of occurrence of 80.8%, a numerical composition of 62.0%, and a gravimetrical composition of 14.7%. This food group consisted primarily of the gammarid amphipod *Corophium salmonis*; the amphipods *Corophium spinicorne* and *Eogammarus* spp. were frequently eaten but in small quantities. Amphipods were most important in sturgeon <800 mm (Figure 2).

Fishes were the second highest overall prey (18.1% IRI) because of their weight; northern anchovy, *Engraulis mordax*, was the principal fish consumed overall (Table 1) and was the primary prey for white sturgeon >800 mm (Figure 2).

Insects, primarily chironomid and heleid larvae, and the mysid *Neomysis mercedis* had high frequencies of occurrence (Table 1) but were found primarily in white sturgeon <600 mm (Figure 2) and were not consumed in large quantities. Bivalvia, Crangonidae, and Isopoda were eaten principally by white sturgeon >400 mm (Figure 2). Copepods have a high percent number because one white sturgeon consumed 17,088 calanoid copepods (primarily *Eurytemora affinis*).

Table 1.--Summary of Food Habits of White Sturgeon in the Columbia River and Its Estuary [n = 174 (18 empty): $\bar{x}$ length = 507.3 mm, SD = 288.5mm. Prey Items that had Percent Frequency of Occurrence <1.0 % are not Shown. IRI = Index of Relative Importance.

Prey	Percent frequency of occurrence	Percent number	Percent weight	IRI	Percent IRI
Corbicula manilensis	12.82	0.17	0.26	5.6	0.09
Macoma balthica	1.92	0.17	3.44	6.9	0.11
Macoma (digested)	1.92	<0.01	0.83	1.6	0.02
BIVALVIA (TOTAL)	16.67	0.34	4.53	81.3	0.94
Neomysis mercedis	51.92	1.92	1.20	162.1	2.50
Archaeomysis grebnitzkii	1.28	<0.01	<0.01	<0.1	<0.01
Mysidacea (unidentified)	8.33	0.06	0.02	0.7	0.01
MYSIDACEA (TOTAL)	60.26	1.99	1.22	193.0	2.22
Corophium salmonis	73.08	59.95	13.47	5365.7	82.69
Corophium spinicorne	19.23	0.18	0.03	0.1	0.06
Corophium spp.	1.28	0.05	<0.01	0.1	<0.01
Eogammarus spp.	33.97	0.84	0.18	34.6	0.53
Eohaustorius estuaris	5.77	0.09	0.01	0.6	0.01
Eobrolgus milleri	3.85	0.91	0.77	6.4	0.10
AMPHIPODA (TOTAL)	80.77	62.02	14.68	6195.0	71.36
Saduria entomon	10.26	0.12	1.33	14.9	0.23
Gnorimosphaeroma oregonensis	1.28	0.03	<0.01	<0.1	<0.01
ISOPODA (TOTAL)	11.54	0.15	1.33	17.0	0.20
Cyclopoida	5.77	0.11	<0.01	0.6	0.01
Calanoida	3.21	33.59	0.02	107.7	1.66
Harpacticoida	2.56	0.16	<0.01	0.4	0.01
COPEPODA (TOTAL)	9.62	33.85	0.02	325.7	3.75
Crangon franciscorum	17.95	0.21	2.81	54.1	0.83
Crangon spp.	1.92	<0.01	0.01	<0.1	<0.01
Cancer magister	5.13	0.01	5.28	27.2	0.42
Cancer magister (megalops)	1.28	0.01	0.02	<0.1	<0.01
Unidentified Decapoda	1.28	<0.01	<0.01	<0.1	<0.01
DECAPODA (TOTAL)	19.23	0.22	2.85	59.0	0.68
Chironomidae larvae	23.72	0.24	<0.01	5.9	0.09
Heleidae larvae	23.72	0.50	<0.01	12.0	0.19
Diptera larvae	8.97	0.30	0.01	2.8	0.04
Diptera pupae	7.05	0.03	<0.01	0.2	<0.01
Ephemeroptera	3.85	0.01	0.01	0.1	<0.01
INSECTA (TOTAL)	48.08	1.09	0.04	54.2	0.62

Table 1.--Continued.

Prey	Percent frequency of occurrence	Percent number	Percent weight	IRI	Percent IRI
Engraulis mordax	11.54	0.11	54.50	630.1	9.71
Clupea harengus pallasi	1.28	<0.01	2.83	3.6	0.06
Spirinchus thaleichthys	3.85	0.01	4.13	15.9	0.25
Thaleichthys pacificus	1.92	<0.01	2.07	4.0	0.06
FISH (TOTAL)	23.08	0.15	68.09	1574.8	18.14
Polychaeta	4.49	0.01	0.02	0.1	<0.01
Neanthes limnicola	1.92	0.10	0.11	0.4	0.01
Daphnia spp.	3.85	0.01	<0.01	0.1	<0.01
Cumacea	2.56	0.01	<0.01	<0.1	<0.01
Lithoglyphys virens	2.56	0.02	<0.01	<0.1	<0.01
Arachnida	1.28	<0.01	<0.01	<0.1	<0.01
Ostracoda	1.28	<0.01	<0.01	<0.1	<0.01
OTHER (TOTAL)	24.36	0.19	7.25	181.2	2.09

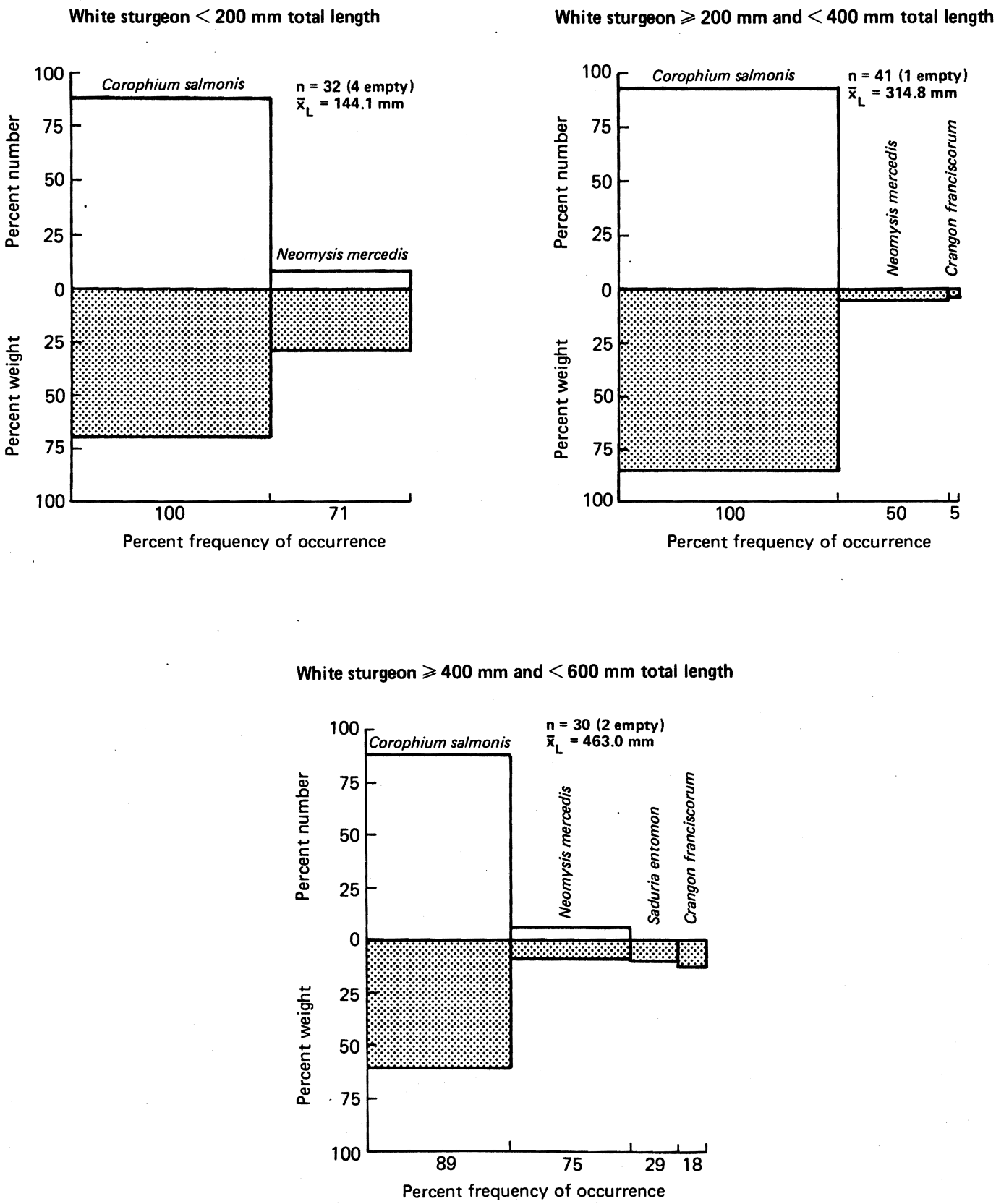
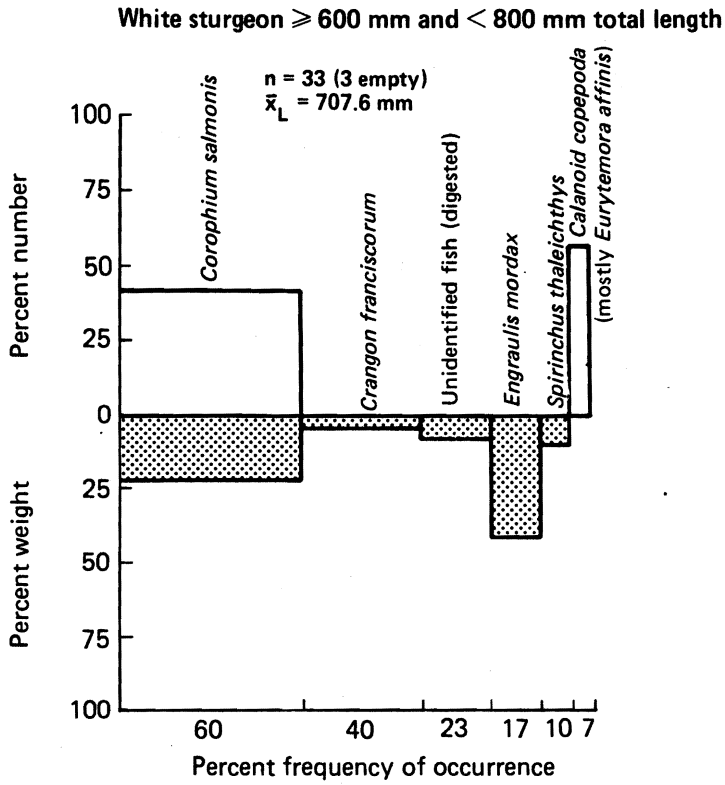


Figure 2. Food of different size groups of white sturgeon, Acipenser transmontanus, in the lower Columbia River. Food is represented by % composition by abundance and weight and by frequency of occurrence. Prey items that had number and weight comprising less than 3.0% are not shown.



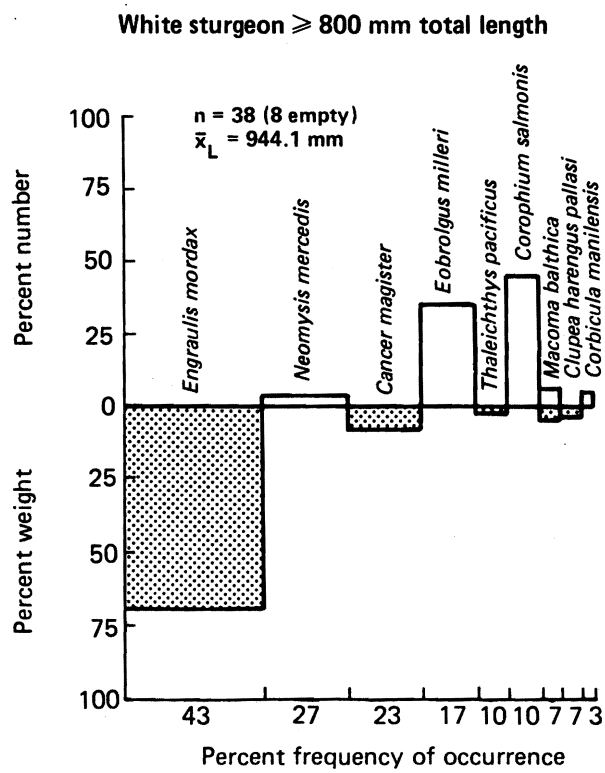


Figure 2. Continued.

Generally, diet diversity increased as white sturgeon increased in size (Figure 3). Trends in diet diversity were inversely related with the % IRI for Amphipoda, primarily Corophium salmonis, in the diets of white sturgeon. White sturgeon that did not feed intensively on C. salmonis consumed many different prey and were larger in size. Smaller white sturgeon concentrated their feeding on C. salmonis. It is important to note that 94% of the smaller white sturgeon (<600 mm) were captured above RKm 27, whereas only 7% of the white sturgeon >600 mm were captured above this RKm. Except for the largest size group (>800 mm), all sizes of white sturgeon had similar diets (Table 2). The low diet overlap between the largest size class and the others indicates a diet shift occurs at approximately 800 mm. At this length, white sturgeon alter their diet by concentrating on fishes (primarily northern anchovy in the estuary) and other prey larger than C. salmonis (Figure 2).

DISCUSSION

Stomach contents of white sturgeon captured in the Columbia River and its estuary revealed diets similar to those described by Schreiber (1962), Radtke (1966), and McKechnie and Fenner (1971). Semakula (1963) and Semakula and Larkin (1968) found white sturgeon collected primarily in a salmon gill-net fishery in the Fraser River, British Columbia, fed mostly on fishes. They found fish became increasingly important with increasing white sturgeon size, with eulachon, Thaleichthys pacificus, being seasonally dominant. Insect larvae, crayfish, mysids, Daphnia spp., and copepods were also important prey for Fraser River white sturgeon. Differences in food habits between this and other studies probably relates to the occurrence and abundance of prey in the different drainages. As in the Fraser River, eulachon are apparently

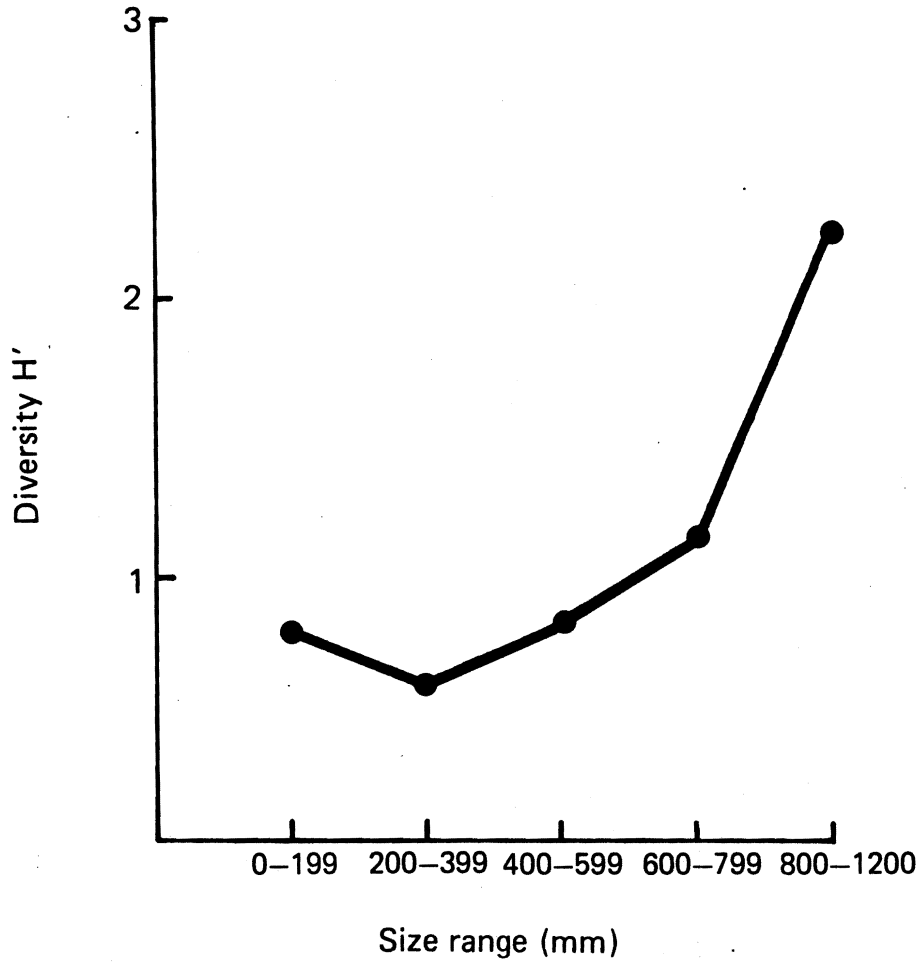


Figure 3. Shannon-Weaver Diversity Indices (H') for white sturgeon diets by size range in the Columbia River and its estuary.

Table 2.--Diet Overlap Between Different Size Groups (Total Length) of White Sturgeon in the Columbia River and Its Estuary.

Size group	Size group				
	<200 mm	>200 mm <400 mm	>400 mm <600 mm	>600 mm <800 mm	>800 mm
<200 mm	1.00	0.98	1.00	0.95	0.14
>200 mm <400 mm	0.98	1.00	0.99	0.94	0.13
>400 mm <600 mm	1.00	0.99	1.00	0.96	0.14
>600 mm <800 mm	0.95	0.94	0.96	1.00	0.31
>800 mm	0.14	0.13	0.14	0.31	1.00

seasonally important prey in larger white sturgeon in the Columbia River (Dees 1961). We did not find many eulachon in white sturgeon stomachs; however, we collected few large white sturgeon when eulachon were abundant (late winter).

The estuary appears to be a particularly important feeding area for large (>800 mm) white sturgeon. From 1979 to 1984, the estuary (RKm 1-61) was the most productive sport fishing area; in 1984, 55% (21,900) of the total white sturgeon sport catch occurred here (King 1985). Small white sturgeon (<800 mm) utilize primarily upriver areas (few were captured in the estuary) and concentrate their feeding on C. salmonis.

Due to the value and growing interest in white sturgeon by sport and commercial fishermen in the Columbia River, accurate sturgeon life history information is essential for resource managers. Small sturgeon, as well as juvenile salmonids and many other species (McCabe et al. 1983), feed extensively on Corophium salmonis in the Columbia River and its estuary. Although benthic invertebrates in the Columbia River have been well studied (Durkin and Emmett 1980; Higley et al. 1983), very little information is available concerning the benthic invertebrates of the Columbia River above the estuary to Bonneville Dam (RKm 233). We believe a more comprehensive study to determine the life history, distribution, and abundance of white sturgeon and C. salmonis in the Columbia River is essential for the proper preservation of white sturgeon resources of the lower Columbia River.

ACKNOWLEDGMENTS

We wish to express our thanks to personnel at the Hammond, Oregon, Field Station of the National Marine Fisheries Service's Northwest and Alaska Fisheries Center who helped collect data or assisted in the preparation of this paper. J. Peacock and his staff prepared our text figures. G. McCabe Jr., T. Blahm, and G. Monan reviewed the manuscript. Data collections for this study were in part supported by Columbia River Estuary Data Development Program funds.

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Diet of White Sturgeon in the Lower Columbia River and Its Estuary

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FIGURE CAPTIONS

FIGURE 1. The lower Columbia River and its estuary.

FIGURE 2. Food of different size groups of white sturgeon, *Acipenser transmontanus*, in the lower Columbia River. Food is represented by % composition by abundance and weight and by frequency of occurrence. Prey items that had number and weight comprising less than 3.0% are not shown.

FIGURE 3. Shannon-Weaver Diversity Indices (H') for white sturgeon diets by size range in the Columbia River and its estuary .