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Distribution and Food Habits of Juvenile Salmonids in the Duwamish Estuary, Washington, 1980

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Olympia, Washington

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Chinook (Oncorhynchus tshawytscha), chum (O. keta) and coho salmon (O. kisutch) and steelhead (Salmo gairdneri) and cutthroat trout (S. clarki) are the salmonid species which we found present in the Duwamish estuary. Juvenile salmonids occurred in greatest numbers from mid-April to early June. Chum were oriented toward shoreline areas while other species utilized near and offshore areas. Chinook tended to move inshore at night, although they tended to move offshore with increasing size. Few cutthroat were encountered.

Much of the salmon diets were composed of dipteran insects (particularly Chironomidae) and gammarid amphipods (particularly Corophium salmonis, C. spinicorne and Eogammarus confervicolus). Calanoid and harpacticoid copepods were important to some salmon. Steelhead trout diets consisted largely of the mysid Neomysis mercedis. In general, epibenthic crustaceans were consumed more at nighttime in the nearshore estuary zone by smaller sized predators in the earlier months of the study. Pelagic crustaceans and insects were consumed more during the daytime, offshore by larger predators in later months. Predation of juvenile fish occurred primarily during the day, near shore by larger sized predators.

Epibenthic plankton organisms which are important in salmonid diets were abundant in areas of sand and silt and among gradually sloping riprap which contains much sand and gravel. The pelagic zone and an area of steeply sloping riprap shaded from direct sunlight by a concrete apron had lower abundances of organisms important in salmonid diets.

UNITED STATES DEPARTMENT OF THE INTERIOR
Fisheries Assistance Office
U. S. Fish and Wildlife Service
Olympia, Washington

DISTRIBUTION AND FOOD HABITS OF
JUVENILE SALMONIDS IN THE DUWAMISH ESTUARY
WASHINGTON, 1980

March 1981

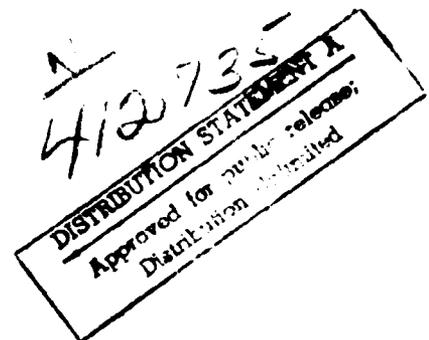
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ABSTRACT

Juvenile salmonid and plankton samples were collected from several stations in the Duwamish River estuary, Washington, from April to July, 1980 in a study to examine food habits and distribution of juvenile salmonids, and prey distribution.

Chinook (Oncorhynchus tshawytscha), chum (O. keta) and coho salmon (O. kisutch) and steelhead (Salmo gairdneri) and cutthroat trout (S. clarki) are the salmonid species which we found present in the Duwamish estuary. Juvenile salmonids occurred in greatest numbers from mid-April to early June. Chum were oriented toward shoreline areas while other species utilized near and offshore areas. Chinook tended to move inshore at night, although they tended to move offshore with increasing size. Few cutthroat were encountered.

Much of the salmon diets were composed of dipteran insects (particularly Chironomidae) and gammarid amphipods (particularly Corophium salmonis, C. spinicorne and Eogammarus confervicolus). Calanoid and harpacticoid copepods were important to some salmon. Steelhead trout diets consisted largely of the mysid Neomysis mercedis. In general, epibenthic crustaceans were consumed more at nighttime in the nearshore estuary zone by smaller sized predators in the earlier months of the study. Pelagic crustaceans and insects were consumed more during the daytime, offshore by larger predators in later months. Predation of juvenile fish occurred primarily during the day, near shore by larger sized predators.

Epibenthic plankton organisms which are important in salmonid diets were abundant in areas of sand and silt and among gradually sloping rip-rap which contains much sand and gravel. The pelagic zone and an area of steeply sloping rip-rap shaded from direct sunlight by a concrete apron had lower abundances of organisms important in salmonid diets.

TABLE OF CONTENTS

	<u>Page</u>
ABSTRACT	ii
INTRODUCTION	1
METHOD AND MATERIALS	3
RESULTS AND DISCUSSION	11
Fish Distribution	11
Food Habits	23
Chinook	23
Coho	26
Chum	28
Steelhead	30
Prey Availability	32
SUMMARY AND CONCLUSIONS	35
Fish Distribution	35
Food Habits.	36
Prey Availability	36
LITERATURE CITED	38
APPENDIX	40

LIST OF FIGURES

<u>Figure No.</u>		<u>Page</u>
1	Lower Duwamish River study area and sampling stations	4
2	Substrate typical of plankton pump sample site DP1 . .	6
3	Plankton pump sample site DP5.	7
4	Rip-rap typical of much of the Duwamish estuary. . . .	8
5	Rip-rap similar to that found at plankton pump sample site DP4	9
6	Mean weekly catch of juvenile chum per beach seine set in the lower Duwamish River during April - July, 1980	13
7	Mean weekly catch of juvenile chinook per set by beach seines and purse seines in the lower Duwamish River during April - July, 1980.	14
8	Mean weekly catch of juvenile coho per set by beach seines and purse seines in the lower Duwamish River during April - July, 1980.	15
9	Mean weekly fork length of juvenile chum captured in the lower Duwamish River during April - July, 1980 . .	20
10	Mean weekly fork length of juvenile chinook captured in the lower Duwamish River during April - July, 1980. .	21
11	Mean weekly fork length of juvenile coho captured in the lower Duwamish River during April - July, 1980 . .	22
12	IRI diagram and table showing major prey of juvenile chinook in the lower Duwamish River, April - July, 1980	24
13	IRI diagram and table showing major prey of juvenile coho in the lower Duwamish River, April - July, 1980 .	27
14	IRI diagram and table showing major prey of juvenile chum in the lower Duwamish River, April - July, 1980 .	29
15	IRI diagram and table showing major prey of juvenile steelhead in the lower Duwamish River, April - July, 1980	31

LIST OF TABLES

<u>Table No.</u>		<u>Page</u>
1	Fish species caught in the lower Duwamish River with beach seines and purse seines April - August, 1980 . . .	11
2	Salmonids planted in the Green-Duwamish watershed during 1980.	12
3	Abundance (No.) and percent frequency of occurrence of salmonids in beach seine catches in the lower Duwamish River during April - July, 1980	16
4	Abundance (No.) and percent frequency of occurrence of salmonids in purse seine catches in the lower Duwamish River during April - June, 1980	17
5	Mean fork length (\bar{X}) and standard deviation (S) of juvenile salmonids captured in purse seines and beach seines in the lower Duwamish River in April - July, 1980	18
6	Mean (\bar{X}) beach seine catch per set, standard deviation (S), coefficient of variation (CV), and number of sets (N) for juvenile salmonids during night, day, and overall in the lower Duwamish River in April - July, 1980	18
7	Mean (\bar{X}) purse seine catch per set, standard deviation (S), coefficient of variation (CV), and number of sets (N) for juvenile salmonids during night, day and overall in the lower Duwamish River in April - July, 1980	19
8	Relative abundance and percent species composition of invertebrates sampled in the lower Duwamish River. . .	33

INTRODUCTION

The Seattle District, Corps of Engineers has reactivated study of the Duwamish Navigation Improvement Project at the request of the Port of Seattle and the City of Seattle. The proposed project would deepen and widen the existing navigation channel in the lower Duwamish River to accommodate larger ships and reduce navigational hazards. Deepening and widening of the existing channel coupled with anticipated industrial development will result in changes in the substrate characteristics amount of shallow water habitat and water quality characteristics in the project area. These changes could in turn impact the fishery resources utilizing this estuary. In February, 1980, resource protection agencies reviewing this project requested additional baseline biological information needed to assess environmental impacts. Three basic questions were asked regarding juvenile salmonids in the project area; 1) what is their distribution, 2) what do they eat, and 3) what is the availability of food resources?

The Green-Duwamish River contains fall chinook, coho and chum salmon plus steelhead and cutthroat trout. Recent estimates by the Washington Department of Fisheries (WDF) indicate that Green River fall chinook are one of the largest naturally spawning stocks of this species in Puget Sound (Ames and Phinney, 1977). Present plans of WDF require management of commercial fisheries to allow for full escapement needed to meet natural spawning requirements of fall chinook. Coho and steelhead smolts are heavily planted in the Green River drainage and commercial and sport fisheries target on these hatchery stocks. The number of chum salmon returning to the Green River is depressed and probably far below historic levels. Johnson (1973) notes that Green River chum have "virtually disappeared in recent years". Reasons for the decline are unclear but probably involve over-fishing, habitat degradation, and, possibly, predation by introduced stocks of salmonids. Native Green River chum remain at a very low level. Management and restoration efforts for this species are currently directed toward rebuilding a naturally spawning run.

Environmental impacts resulting from the Duwamish Navigation Improvement Project will probably occur primarily in the estuary and lower river (between river mile 0 and 5.0). A recent body of literature has begun to reveal the role of estuaries in the early life history of salmonids. Studies by Reimers (1971), Mason (1974), Dunford (1975), Sibert *et al.* (1977), Congleton (1978), and Healey (1979), have documented juvenile salmonid residence and feeding in estuaries, particularly by chinook and chum. Important prey during estuarine residence are epibenthic invertebrates and aquatic insects. Residency in the estuary is variable but can extend up to several months for chinook. Other studies have documented use of intertidal and shallow shoreline areas by salmonids after leaving the area of the river mouth. There appears to be a gradual offshore movement and an associated shift in diet from primarily epibenthic invertebrates in nearshore shallow waters to pelagic organisms (Fresh *et al.*, 1979; Bax *et al.*, 1978; Simenstad and Kinney,

1978). This transition is probably related to a number of factors including fish size.

Work by Weitkamp and Campbell (1979) indicates use of both shallow and deeper water habitat in the lower Duwamish River by juvenile salmonids. An earlier study by Matsuda et al. (1968) also indicated utilization of shallow nearshore areas in the Duwamish estuary.

Because of the importance of Green-Duwamish River salmon and steelhead stocks and utilization of shallow estuarine areas by salmonids, it is critical that future development of the Duwamish estuary be directed so as to have the least impact on the fishery resource. In order to provide for this protection, it will be necessary to have additional information on some basic questions such as what areas of the estuary salmonids are utilizing, how long they remain there, what they are eating, and where food resources are available. Because of the limited amount of time and funding available, primary emphasis in this study was directed toward the two latter objectives. Another investigator, Weitkamp (in press), will be conducting a more thorough examination of fish distribution and residence time in the Duwamish estuary. This report will provide some fish distribution information supplemental to that reported by Weitkamp (in press), particularly diel effects on distribution.

METHODS AND MATERIALS

Fish and plankton samples were collected at sites between river miles one and four in the lower Duwamish River from early April to late July, 1980. Daily catches are presented in the appendix. Fish sampling was conducted by beach and purse seining. The beach seine measured 30.5 meters (m) (100 feet) in length and 3.0 m (10 feet) in depth. Mesh size was 6 millimeters (mm) (1/4 inch) in the wings and 5 mm (3/16 inch) in the center panel. Beach seine sampling was limited to the few areas with a smooth bottom. The purse seine was 61.0 m (200 feet) long, 2.1 m (7 feet) deep in the body, and 4.6 m (15 feet) deep at the bunt. Mesh size measured 6 mm (1/4 inch) throughout the net. Sampling occurred along the east shore of Kellogg Island and at the intersection of South Kenyon Street and Duwamish River (Figure 1). The Kellogg Island site (D1), one of the few remaining tidal marsh habitats in the Duwamish estuary and Elliott Bay, is characterized by a steep slope at the upper intertidal level with a more gradual slope below this. The bottom is composed of a thin upper layer of fine silt and mud over compacted sand. There is little intertidal vegetation although some marsh plants grow down into the upper intertidal zone. Logs are stored directly offshore from this site. The site at South Kenyon Street (D2) has a more gradual slope with sand in the upper intertidal zone giving way to silt in the lower portion of the zone. Again, there is little intertidal vegetation.

At each site, two replicate beach seine sets were made in the intertidal zone at or near high slack tide. Seining could not be conducted effectively at low tides because of numerous snags. Purse seine sets were made directly offshore from each site in mid-channel well away from any shoreline structure. A complete set of samples was collected at each site during daylight and again after sunset in order to examine diel effects on distribution and food habits. Our sampling schedule was weighted toward the expected period of peak outmigration (mid-April through early June). During this period, sampling was conducted weekly; at other times it occurred bi-weekly.

All juvenile salmonids caught at a particular site up to a maximum of 50 of each species were measured (fork length) to the nearest millimeter and at least 7 were retained for stomach analysis. Those sacrificed for stomach content analysis were preserved in 10% formalin. The abdominal cavity of individuals larger than 100 mm was opened to allow rapid entrance of formalin slowing the rate of digestion in the stomach. Occasionally, potential salmonid predators were preserved for stomach analysis. No special effort was made to capture hatchery fish which had been tagged with coded-wire tags and marked by removal of the adipose fin. Those fish that were retained were examined for tags. Due to time constraints and the large numbers of fish caught, stomach analysis was performed on chinook samples taken every other week after May 17, 1980. All preserved specimens of other salmonid species were examined.

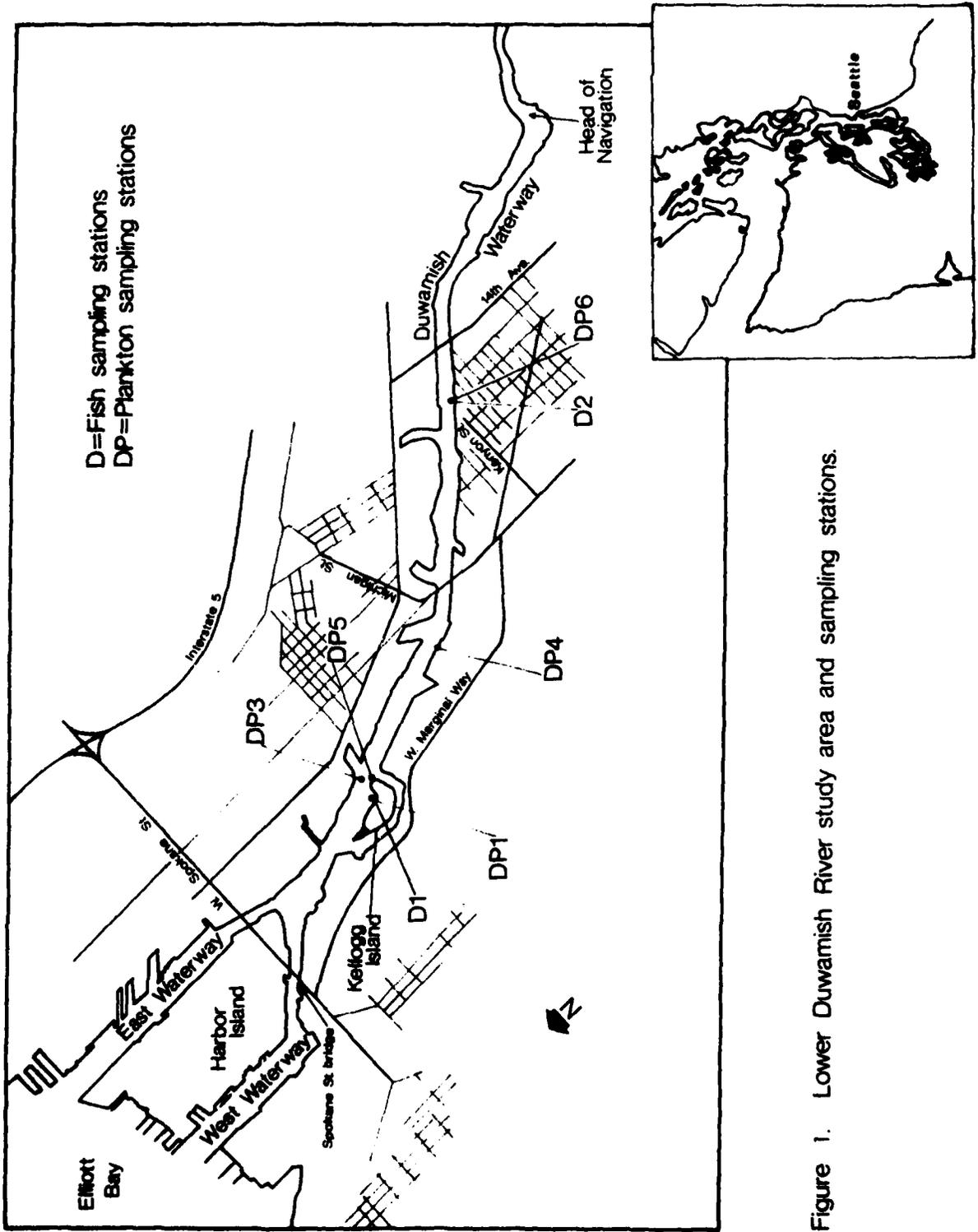


Figure 1. Lower Duwamish River study area and sampling stations.

Laboratory procedures consisted of severing the stomach at the esophagus and intestine and removing it from the fish carcass. Adhering tissue was cut away, the stomach blotted dry, and weighed to the nearest milligram. The stomach was then opened and percent fullness estimated. The weight of the empty stomach sac was subtracted from the weight of the full stomach to give an estimate of the biomass of the stomach contents.

Stomach contents were sorted and identified to the lowest taxonomic category practicable considering the stage of digestion, the state of the taxonomic literature, time constraints, and ease of identification (ie. extensive micro-dissection techniques were not employed). The number, weight and life history stage of the prey in each taxonomic category was recorded. Prey weights in milligrams were determined using a toploading Mettler PC 440 balance. The percent digestion of the stomach contents was also estimated. Hatchery fish food (Oregon Moist Pellet) remains were noted but not quantified.

Predator and prey information was recorded on keypunch forms using the Marine Ecosystems Analysis Program format. The data was then analyzed using the Index of Relative Importance (IRI) developed by Pinkas *et al.* (1971) and modified by Simenstad and Kirney (1978). IRI diagrams and tables simultaneously display the frequency of occurrence of important items, their percent of the total weight, and percentage contribution to the total number of individual items in the diet. IRI figures were computed using a computer program developed by Larry Gales and Charles Simenstad of the University of Washington, Fisheries Research Institute (FRI).

Epibenthic and pelagic plankton samples were collected at five sites (Figure 1) selected to represent the substrate types found in the project area and/or fish sampling site. These samples were collected to provide qualitative data regarding prey availability found in association with the various substrate types. Site DP1 coincided with fish sampling site D1 and was representative of a soft fine sediment substrate with much organic debris (Figure 2). Site DP3 was located in the surface water of the main channel offshore from DP1. Station DP5 was chosen to represent prey organisms found in association with a rock rip-rap substrate. However, the site chosen contains significant amounts of sand and gravel and has a gradual slope throughout much of the intertidal zone. Samples from this site are probably not representative of rip-rapped areas in which there are few or no sand/gravel patches and where the slope is much steeper. Figures 3 through 5 are illustrative of the rip-rap types found at DP5 and two other areas of the Duwamish estuary, respectively. DP4 was located under a long concrete apron where no direct natural light penetrates. Substrate composition at this site was steeply sloping rip-rap as shown in Figure 5. Long concrete aprons, such as those found at this site, could become the predominant shoreline structure under full scale development. Site DP6 is located adjacent to fish sampling station D2, which exhibited a soft sandy substrate. All plankton sampling stations except DP6 were chosen in the lower river within close proximity to each other so as to avoid significant changes in salinity.



FIGURE 2. Substrate typical of plankton pump sample site DP1.



FIGURE 3. Plankton pump sample site DP5. Rip-rap at this site contained moderate amounts of sand and gravel.

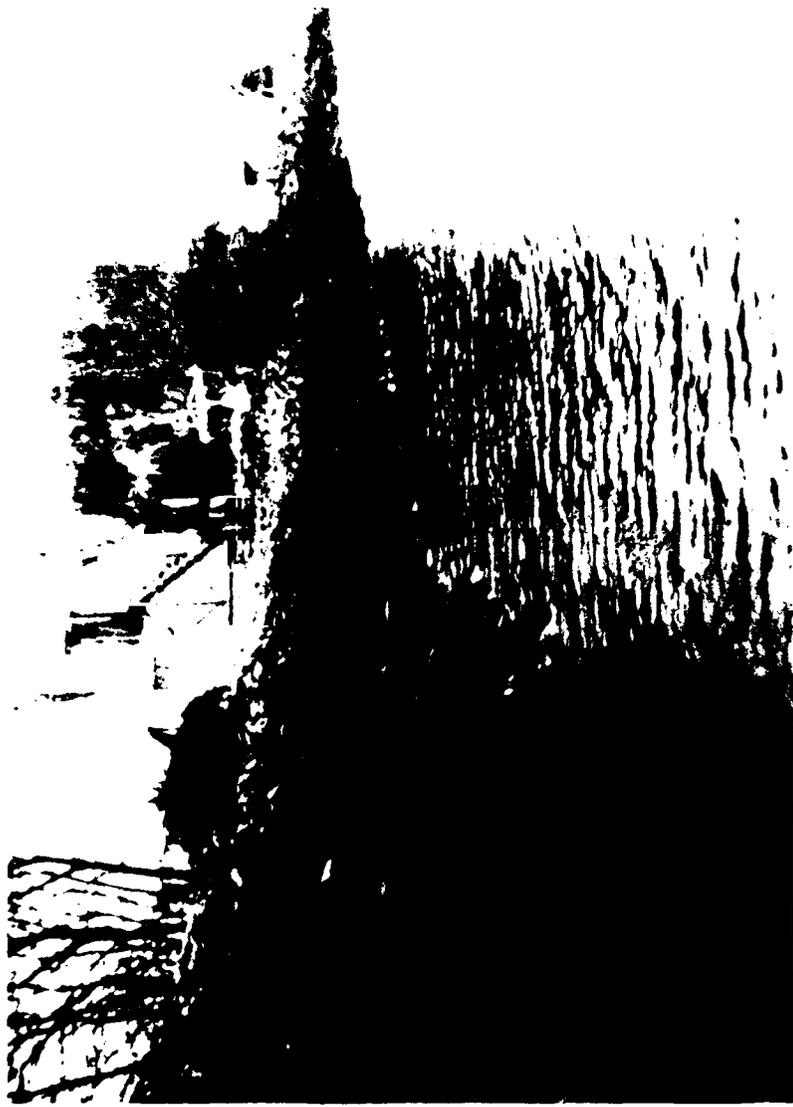


FIGURE 4. Rip-rap typical of much of the Duwamish estuary.



FIGURE 5. Rip-rap similar to that found at plankton pump sample site DP4.

Samples were collected monthly at or near high slack tide. Two replicate samples were collected at approximately one meter above mean low water. This tidal level was chosen as a compromise as there is significant tidal zonation among intertidal invertebrates. Smith (1977) examined the distribution of estuarine invertebrates in the Snohomish estuary and found insects in the upper portion of the intertidal zone while amphipods were located throughout the intertidal zone and subtidally.

Epibenthic and pelagic invertebrates were sampled with a suction pump system similar in design to one developed by FRI (Simenstad and Kinney 1978). This type of sampler was used because it could be utilized over various substrates and is designed to sample organisms available to salmonids. The sampling head was attached to a wooden pole and passed along the bottom until two hundred liters of water were pumped through two nested plankton nets of 0.500 mm and 0.209 mm mesh size. Because of the manner in which the sampling head was passed along the bottom, the area sampled could not be quantified. Material retained by the plankton nets was washed into sample jars, labeled and preserved in 10% formalin. Fifty liters of water were pumped through the sampling apparatus at each new site to flush the system of material from the previous sampling site. The system was not flushed between replicates at the same site. The presence of some benthic organisms in samples from a pelagic site suggests that 50 liters was not adequate to flush the system thoroughly between sampling sites. However, insufficient flushing does not appear to have significantly affected results in most cases. Because it was not possible to sample a known area of substrate, quantitative comparisons were not made between sampling sites although relative abundances were compared.

Rose bengal stain was added to all samples to dye organisms in order to facilitate sorting plankton organisms from other debris in the samples. Samples containing large amounts of sand were stirred and decanted several times until the supernatant liquid appeared free of suspended material. The sand remaining in two samples after decanting was examined to check the efficiency of the decanting process, and no organisms were found. The decanted material was passed through a piece of 0.1 mm mesh plankton net cloth to remove excess liquid. The material retained by the cloth was subdivided if necessary and examined under a dissecting microscope. Organisms were sorted from debris in the sample and were identified, enumerated and weighed to the nearest milligram.

RESULTS AND DISCUSSION

Fish Distribution

Twenty-one species of fish were captured during beach seine and purse seine sampling (Table 1). Species composition was similar to that reported by Weitkamp and Campbell (1979) and Matsuda et al. (1968). Juvenile chum and chinook salmon, snake pricklebacks, shiner perch and staghorn sculpins were the most prevalent species caught in beach seines. Juvenile chinook and coho salmon and herring were the most commonly caught species in purse seines.

Weekly mean salmonid catches are listed in Appendix A.

Table 1. Fish species caught in the lower Duwamish River with beach seines and purse seines April - August, 1980.

<u>Common Name</u>	<u>Scientific Name</u>
Western brook lamprey	<u>Lampetra richardsoni</u>
Pacific herring	<u>Clupea harengus pallasii</u>
Pink salmon	<u>Oncorhynchus gorbuscha</u>
Chum salmon	<u>Oncorhynchus keta</u>
Coho salmon	<u>Oncorhynchus kisutch</u>
Chinook salmon	<u>Oncorhynchus tshawytscha</u>
Cutthroat trout	<u>Salmo clarki</u>
Steelhead (Rainbow trout)	<u>Salmo gairdneri</u>
Dolly Varden	<u>Salvelinus malma</u>
Surf smelt	<u>Hypomesus pretiosus</u>
Largescale sucker	<u>Catostomus macrocheilus</u>
Pacific cod	<u>Gadus macrocephalus</u>
Pacific tomcod	<u>Microgadus proximus</u>
Walleye pollock	<u>Theragra chalcogramma</u>
Three spine stickleback	<u>Gasterosteus aculeatus</u>
Pacific staghorn sculpin	<u>Leptocottus armatus</u>
Shiner perch	<u>Cymatogaster aggregata</u>
Pile Perch	<u>Rhacochilus vacca</u>
Snake prickleback	<u>Lumpenus sagitta</u>
Pacific sandlance	<u>Ammodytes hexapterus</u>
Starry flounder	<u>Platichthys stellatus</u>

Two peaks in chum abundance were noted (Figure 6). The first, in late April, occurred prior to any plants of hatchery chum in the system (Table 2). The second peak occurred in mid-May, shortly after the Muckleshoot Tribe released 750,000 chum fry in Crisp Creek, a tributary to the Green River. Bostick (1955) reported a peak in his chum catches in the Duwamish estuary on May 6 and Weitkamp and Campbell (1979) found chum peaking in late April. We found chum present from early April through early July.

Table 2. Salmonids planted in the Green-Duwamish watershed during 1980.

Species	Number	Size (No./Lb.)	Date	Site	Agency
Fall Chinook	199,120	1000	January 2	Soos Cr.	WDF
Fall Chinook	328,750	8	February 28	Crisp Cr.	WDF
Coho	51,790	1500	March 5	Soos Cr.	WDF
Coho	182,000	1300	March 11	Hill Cr.	WDF
Coho	620,000	1300	March 18	Soos Cr.	WDF
Coho	185,300	1300	March 27	Spring Brook Cr.	WDF
Steelhead	5,481	7	April 1	Mainstem	WDG
Fall Chinook	1,079,218	125	April 21	Soos Cr.	WDF
Coho	698,116	18-25	April 23	Soos Cr.	WDF
Steelhead	23,998	5-7	April 27-30	Mainstem	WDG
Steelhead	10,578	6	May 1-2	Mainstem	WDG
Fall Chinook	2,457,548	106	May 2	Soos Cr.	WDF
Steelhead	1,250	6	May 4	Mainstem	WDG
Chum	745,580	776	May 6	Crisp Cr.	Muckleshoot Tribe
Steelhead	9,295	6-8	May 6-9	Mainstem	WDG
Fall Chinook	183,341	167	May 9	Crisp Cr.	Muckleshoot Tribe
Fall Chinook	502,350	150	May 12	Mainstem	WDF
Coho	62,197	325	May 14	Soos Cr.	WDF
Coho	140,000	207	May 31	Soos Cr.	WDF
Coho	549,984	17	June 2	Crisp Cr.	WDF
Coho	24,276	28	October 15	Soos Cr.	WDF

Chinook exhibited the longest residency in the sampling area and were present on the first (April 8) and last (July 31) sample dates (Figure 7). Peak catches occurred during the first week of May and continued at high levels into June. Bostick (1955) and Weitkamp and Campbell (1979) both reported chinook numbers peaking in late May. Four chinook bearing coded wire tags were taken 5 to 48 days after their release. None of these four contained Oregon Moist Pellet (OMP) remains. However, of all chinook stomachs examined, 22% contained OMP remains and are undoubtedly from artificial enhancement facilities. Bostick (1955) and Weitkamp and Campbell (1979) both reported chinook numbers peaking in late May.

Two peaks in coho abundance were observed, in early May and early June (Figure 8). Both peaks occurred shortly after plants of over a half million coho smolts into Soos Creek, a tributary of the Green River 50 kilometers above our sampling sites on April 23 and June 2. Our own data plus that of Bostick (1955) and Weitkamp and Campbell (1979) suggest that coho probably

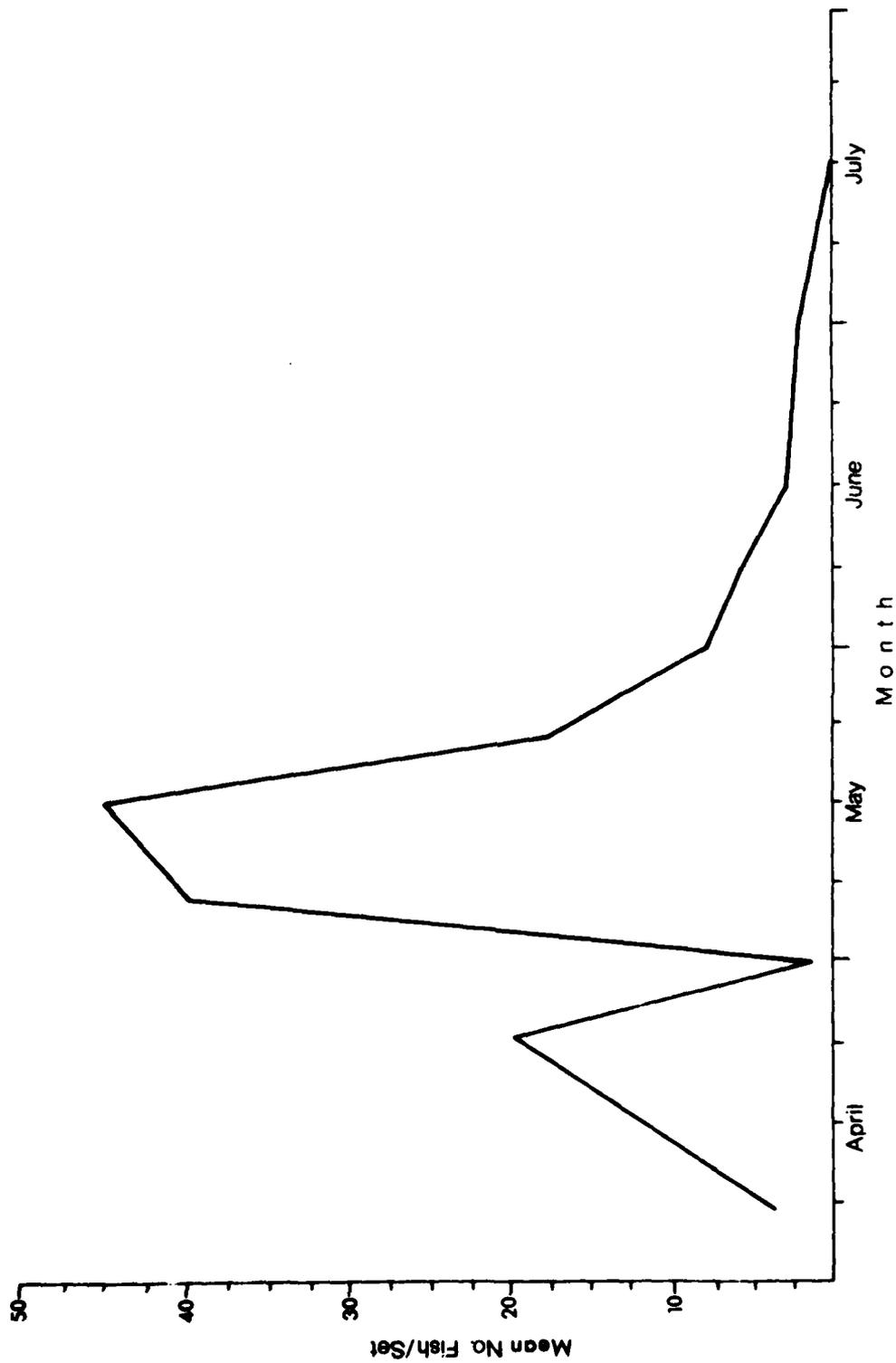


FIGURE 6. Mean weekly catch of juvenile chum per beach seine set in the lower Duwamish River during April - July, 1980.

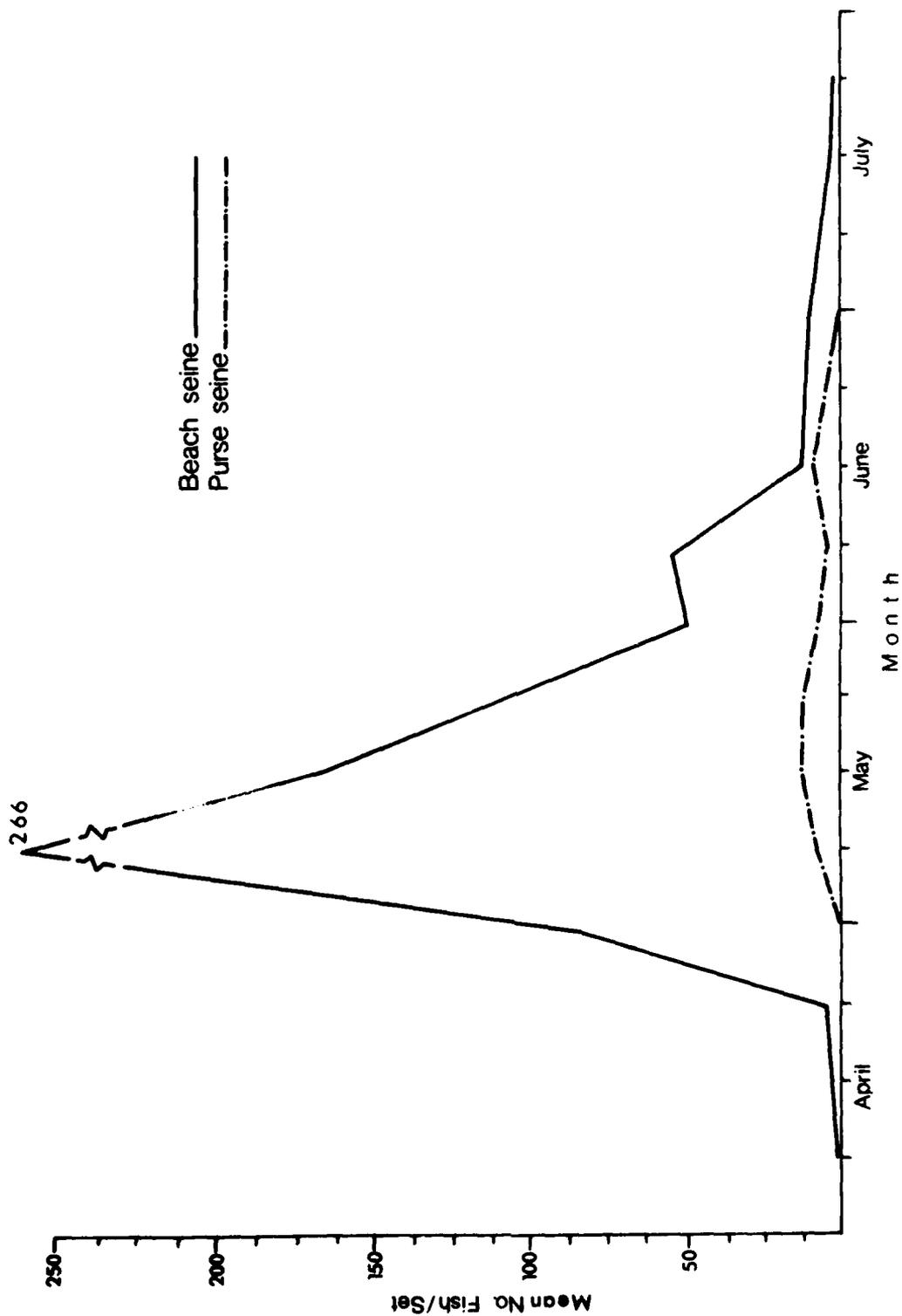


FIGURE 7. Mean weekly catch of juvenile chinook per set by beach seines and purse seines in the lower Duwamish River during April - July, 1980.

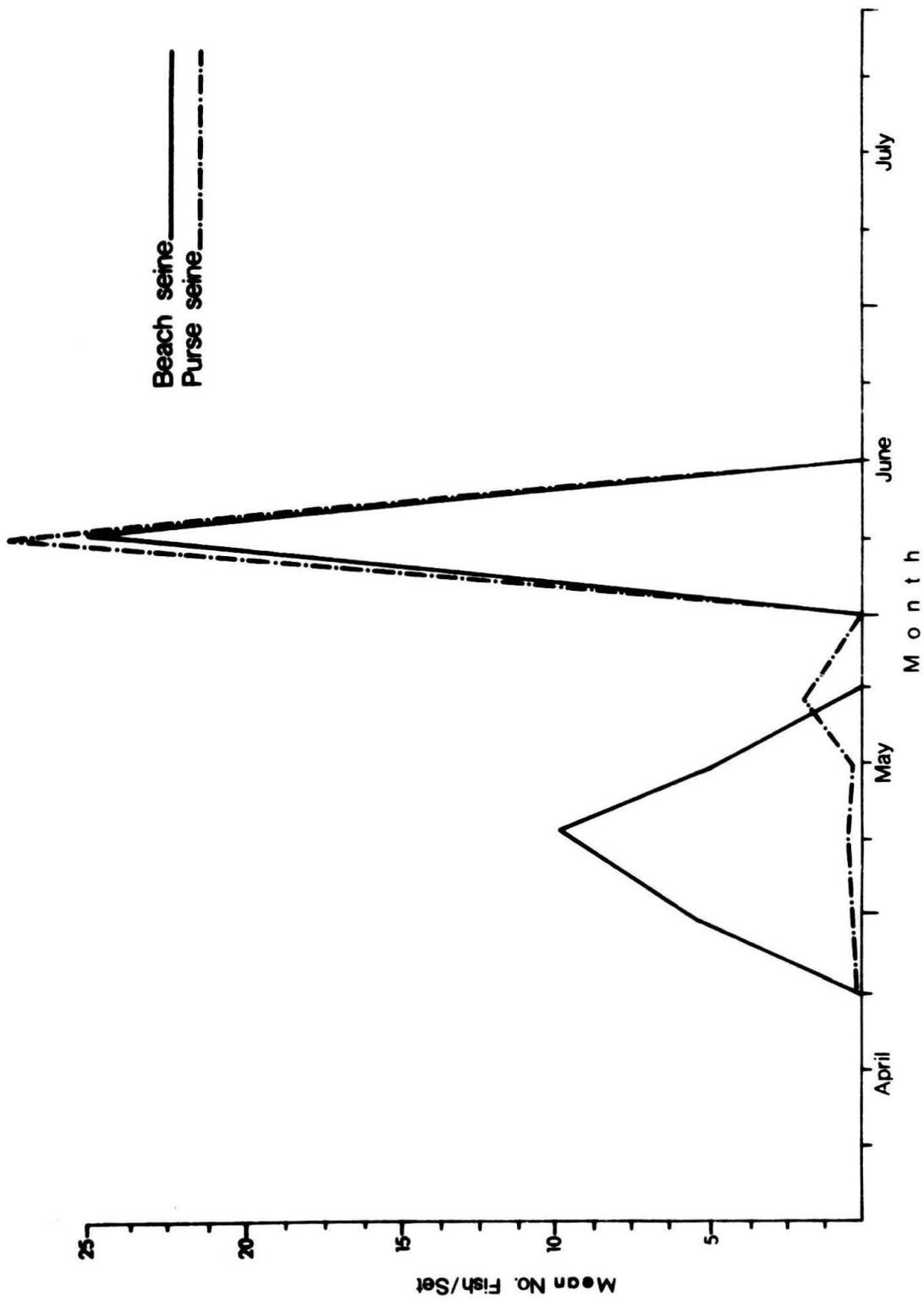


FIGURE 8. Mean weekly catch of juvenile coho per set by beach seines and purse seines in the lower Duwamish River during April - July, 1980.

move rapidly through the estuary in schools as evidenced by the rapid increase and decrease in abundance. Dawley et al. (1979) estimated the travel time of coho through the Columbia River estuary as one day. The available data also reveal few coho present in the estuary after early June.

Fish containing coded wire tags were taken 2 to 28 days after release and 58% of these tagged coho contained OMP remains. OMP remains were present in coho 2 to 24 days after release. Of all coho examined, 32% contained OMP remains indicating that a significant proportion of the population is probably of hatchery origin.

A total of 7729 salmonids were captured in beach seines in the Duwamish estuary (Table 3). Most of these were chinook (6084) which were caught in 75.0 and 87.5 percent of all beach seine sets at stations D1 and D2, respectively. Chums were next in abundance (1221) and were captured in 70.8 and 79.2 percent of the beach seine hauls at D1 and D2, respectively. Coho were third in abundance followed by steelhead and cutthroat. There was relatively little difference in the frequency with which each species occurred at the two sites although chinook and coho were caught in greater numbers at D2.

Table 3. Abundance (No.) and percent frequency of occurrence of salmonids in beach seine catches in the lower Duwamish River during April - July, 1980.

Species	SITE				TOTAL	
	D1		D2		No.	%
	No.	%	No.	%		
Chum	601	70.8	620	79.2	1221	79.2
Chinook	1229	75.0	4855	87.5	6084	91.7
Coho	58	33.3	307	33.3	365	45.8
Steelhead	32	25.0	18	20.8	50	33.3
Cutthroat	2	8.3	7	20.8	9	25.0
Total	1922		5807		7729	

Only 511 salmonids were captured in purse seine sets (Table 4). Again, chinook were caught in greater numbers than other salmonids followed by coho and steelhead. Overall, chinook were captured in 62.5% of our purse seine sets, coho in 37.5%, and steelhead in 12.5% of all sets. On two occasions, a single chum was caught in purse seine sets. The apparent minor utilization of the mid-channel by chums is consistent with information collected from Hood Canal (Bax et al., 1978) and the Nisqually Reach (Fresh

et al., 1979) where it was determined that chums migrate along shallow shorelines, gradually moving offshore with time and increasing size. No quantitative comparison could be made as to the relative use of the near-shore and offshore habitats by chinook and coho. However, the number of chinook captured in beach seines was 19 times greater than that captured in purse seines while the number of coho captured in beach seines was only twice as large as the number captured in purse seines. This suggests that chinook are more shoreline oriented than coho.

Table 4. Abundance (No.) and percent frequency of occurrence of salmonids in purse seine catches in the lower Duwamish River during April - June, 1980.

Species	SITES					
	D1		D2		TOTAL	
	No.	%	No.	%	No.	%
Chinook	72	75.0	245	54.2	317	62.5
Coho	160	20.8	22	16.7	182	37.5
Steelhead	5	8.3	5	12.5	10	12.5
Chum	1	4.2	1	4.2	2	4.2
Total	238		273		511	

Notable differences in total numbers of chinook and coho caught at the two sampling stations were evident from the purse seine catch data. For chinook, this difference could not be explained although it is interesting that they were caught with greater frequency at D1, the station at which fewer total chinook were caught. Coho were captured with comparable frequencies at the two stations but in much greater numbers at D1. This is probably attributable to a single large catch on June 5, the period of peak coho abundance in the study area. At other times, catch per set was comparable to station D2.

Because of the low numbers of fish being captured in the purse seine, some concern was raised as to its ability to retain fish. We tested the net's catch efficiency by releasing 55 juvenile chinook and 40 juvenile chums into the net after it had been set but before it was pursed. The net was then pursed and retrieved in the usual manner. Fifty-five chinook and 39 chum were re-captured leading us to believe that the net would retain fish upon which it was set.

Mean length of chinook and coho captured in purse seines was larger than that of beach seine caught fish of the same species (Table 5). Steelhead

exhibited the opposite pattern with beach seine caught fish having a greater mean length. The statistical significance of these differences was tested with a two-way analysis of variance (ANOVA). The ANOVA test indicated that the differences between weekly mean lengths of chinook caught in beach seines and purse seines was significant at the 0.001 level. Differences in mean length between coho and steelhead were not significantly different according to the ANOVA. This analysis indicates greater utilization of offshore areas by chinook with increasing size.

Table 5. Mean fork length (\bar{X}) and standard deviation (S) of juvenile salmonids captured in purse seines and beach seines in the lower Duwamish River in April - July, 1980.

Species	Beach Seine		Purse Seine	
	\bar{X}	S	\bar{X}	S
Chinook	76.7	9.56	82.8	12.83
Coho	129.0	14.05	134.1	14.84
Steelhead	183.6	32.67	159.3	29.70

Average catch per beach seine set of juvenile chums was greatest during daylight hours while mean catches of chinook and steelhead appeared to be greatest during the hours of darkness (Table 6). Magnitude of beach seine catches of coho showed little difference between daylight and darkness.

Table 6. Mean (\bar{X}) beach seine catch per set, standard deviation (S), coefficient of variation (CV), and number of sets (N) for juvenile salmonids during night, day, and overall in the lower Duwamish River in April - July, 1980.

Species	Day				Night				Overall			
	\bar{X}	S	CV	N	\bar{X}	S	CV	N	\bar{X}	S	CV	N
Chum	15.24	33.41	219%	59	8.94	17.81	199%	36	12.85	28.63	223%	95
Chinook	43.36	77.53	179%	59	97.94	204.52	208%	36	64.04	142.43	222%	95
Coho	3.90	15.85	406%	59	3.75	11.06	295%	36	3.84	14.22	370%	95
Steelhead	0.07	0.25	357%	59	1.28	3.62	283%	36	0.53	2.31	438%	95

Differences in mean catch per set were not statistically significant except for steelhead. This is probably attributable to the high variability among catches as evidenced by large standard deviations. Average purse seine catches of chinook, coho and steelhead were higher during daylight hours than at night but were not statistically significant (Table 7).

Table 7. Mean (\bar{X}) purse seine catch per set, standard deviation (S), coefficient of variation (CV), and number of sets (N) for juvenile salmonids during night, day and overall in the lower Duwamish River in April - July, 1980.

Species	Day				Night				Overall			
	X	S	CV	N	X	S	CV	N	X	X	CV	N
Chinook	6.58	15.73	239%	40	1.93	2.49	129%	28	4.66	12.38	266%	68
Coho	4.38	23.05	526%	40	0.29	0.60	207%	28	2.69	17.80	662%	68
Steelhead	0.18	0.77	428%	40	0.11	0.31	282%	28	0.15	0.62	413%	68

Further examination of diel distribution was investigated using chi-square analysis. Comparisons were made between the ratio of the average catch per set during daylight to the average catch at night for beach seines and purse seines. The diel ratio of beach seine and purse seine chinook catches were significantly different at the 0.005 level. Coho and steelhead diel ratios were not significant although they also exhibited approximately the same pattern of larger nighttime beach seine catches and larger daytime purse seine catches. These results indicate a possible inshore movement at night by chinook, coho, and steelhead with a shift in the other direction during daylight hours.

Fresh et al. (1979) utilized coefficients of variation (Coefficient of Variation (CV) = (Standard Deviation/Mean) X 100%) to examine diel schooling behavior of juvenile salmonids in the Nisqually reach. They found increased schooling during the day as evidenced by larger CV values compared to those calculated for nighttime catches. We also utilized this statistic and found a similar schooling pattern except for chinook. In this study, beach seine catches of chinook exhibited higher CV values at night than during the day (Tables 6 and 7).

Length data for chum, chinook and coho showed an increasing trend in the size of fish captured during the course of this study (Figures 9-11, respectively). Chum revealed the greatest increase in mean length. These increases may be attributable to growth while residing in the study area or immigration of larger fish from upstream areas. Without mark/recapture data it is difficult to determine which of these factors is causing the observed increases in size.

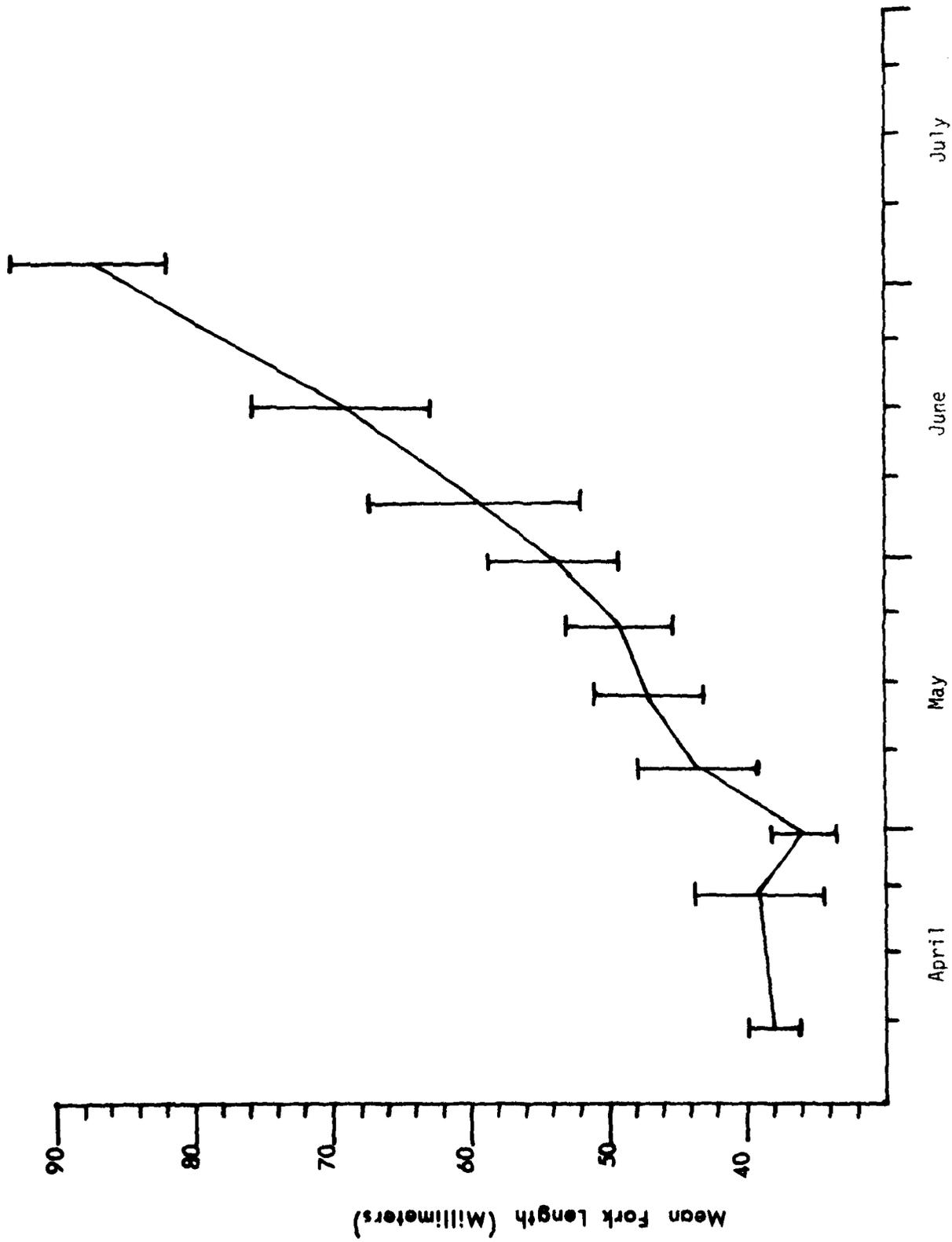


FIGURE 9. Mean weekly fork length of juvenile chum captured in the lower Duwamish River during April - July, 1980. Vertical bars represent \pm one standard deviation.

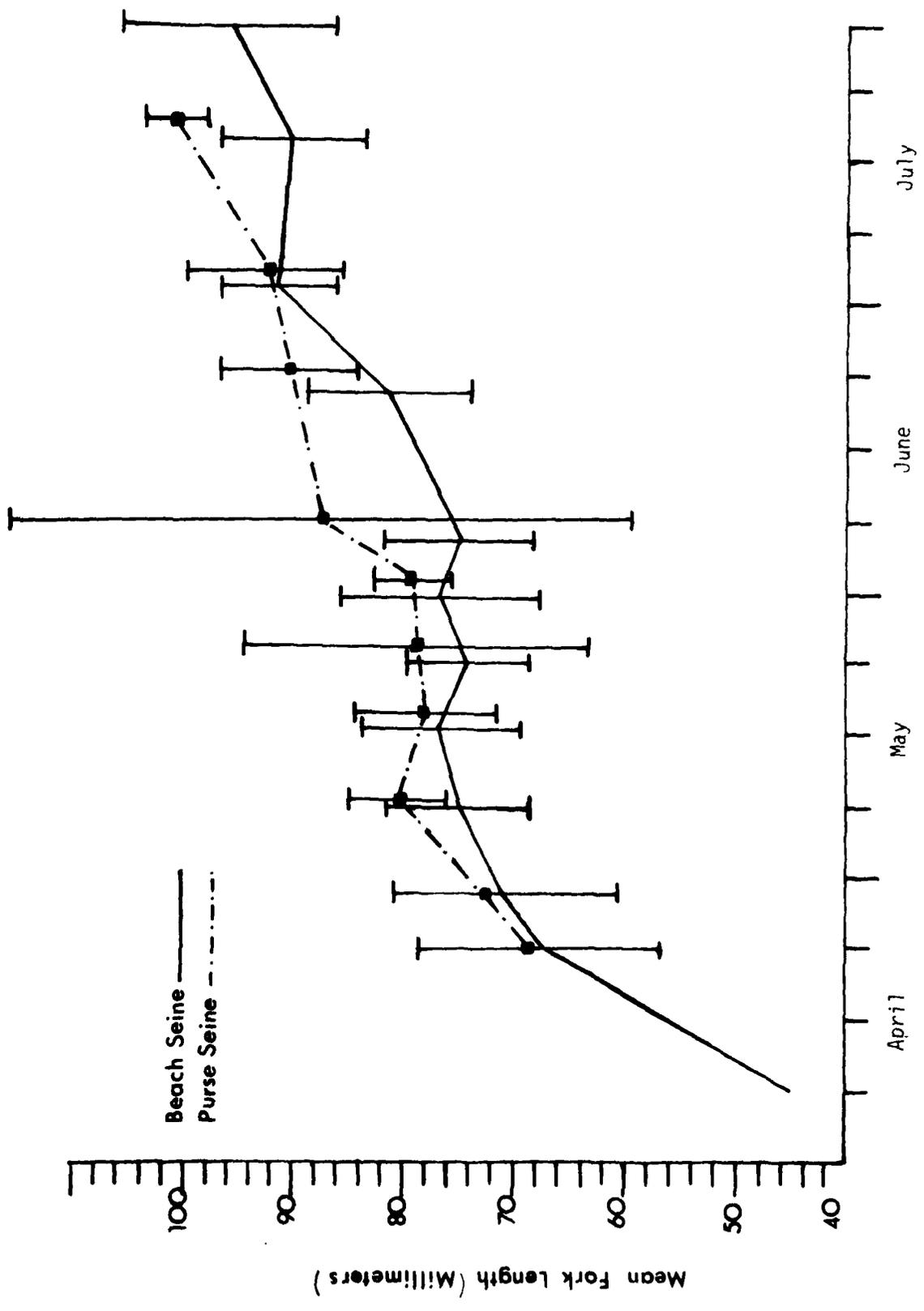


FIGURE 10. Mean weekly fork length of juvenile chinook captured in the lower Duwamish River during April - July, 1980. Vertical bars represent \pm one standard deviation.

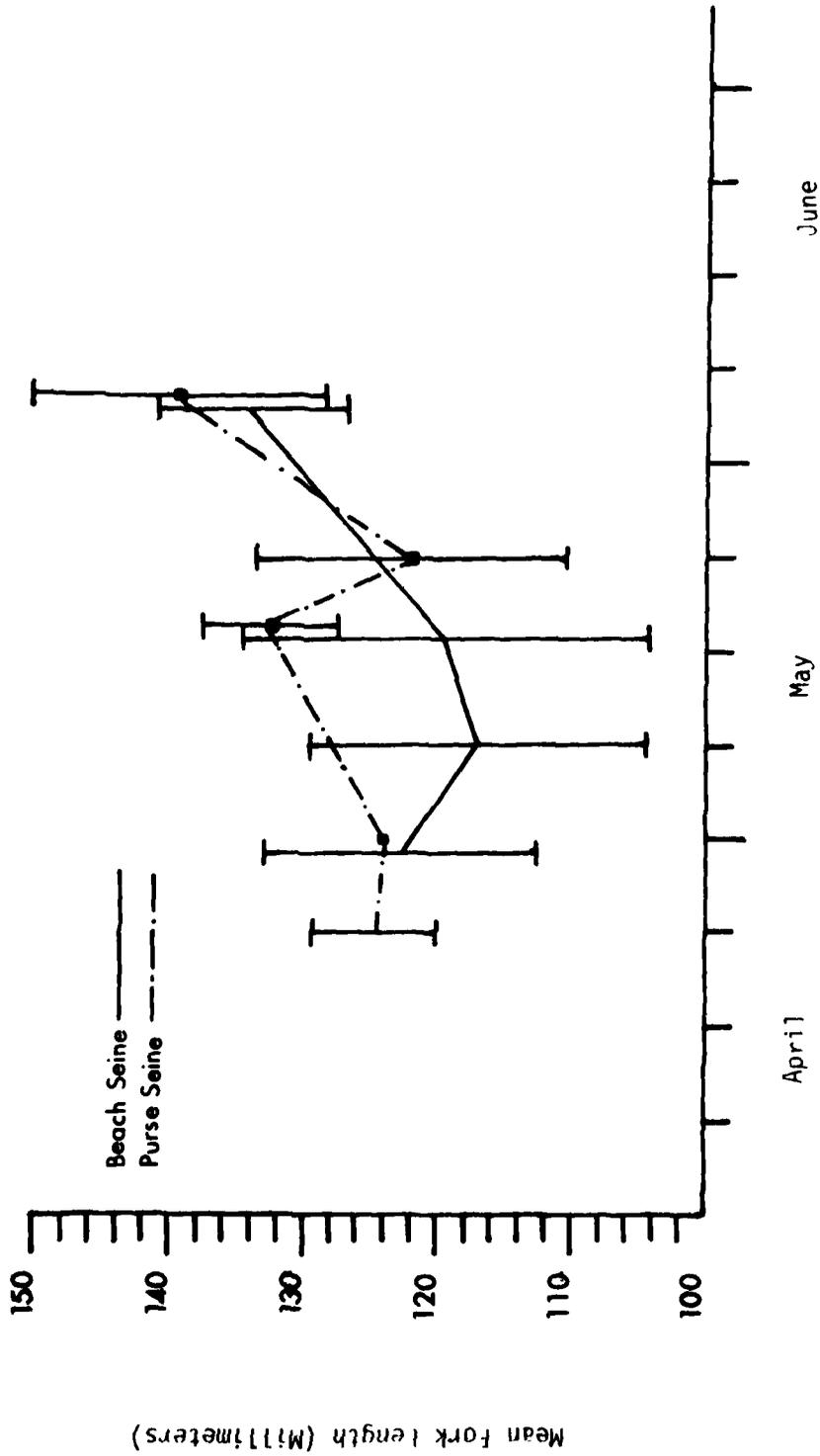


FIGURE 11. Mean weekly fork length of juvenile coho captured in the lower Duwamish River during April - July, 1980. Vertical bars represent \pm one standard deviation.

Food Habits

Food habits of juvenile salmonids varied over time, size of predator, and among sampling stations. Two hundred fifty-two chum, 305 chinook, 97 coho, 49 steelhead and 4 cutthroat stomachs were analyzed. Very few empty stomachs were noted and a wide variety of prey items were identified. Variability in salmonid diets was investigated by comparing the influence of the following factors: day versus night feeding, shallow littoral versus mid-channel zone, lower salinity upstream station versus more saline downstream station, size of predator, and month.

We consider it unlikely that fish consumed food at one station or in one estuary zone and then were caught at another station or zone. Elliot (1972) found the rate of digestion in brown trout to vary with food type and water temperature, but in general over 50% of stomach contents were digested after several hours. It would be possible for a fish to move from a nearshore to an offshore site in several hours, but it would not be likely for a fish to move from the upstream to the downstream station in this amount of time. Furthermore, some of the prey items found in the fish stomachs suggest that the fish had been feeding where they were caught. For instance, crab zoea, which are marine and pelagic, were found almost exclusively in chinook and coho taken offshore (in purse seines) at the more saline downstream station.

Chinook. Gammaridean amphipods, calanoid copepods, and dipteran flies are prey categories which seem to be important in the diets of juvenile chinook salmon from the Duwamish River estuary (Figure 12). Of the gammarids, Corophium salmonis, and C. spinicorne were consumed by 41% of the chinook. Eogammarus confervicolus was also a major contributor to juvenile chinook diets. Most of the dipteran flies are aquatic; the midge family Chironomidae was found in 37% of the chinook and is the most important dipteran eaten, while the biting midge family Heleidae (also known as Ceratopogonidae) is of less importance. The adult stage of chironomids was consumed most frequently while the pupa stage of heleids was more important in chinook diets than adults or larvae. Calanoids were found in 21% of chinook stomachs.

In examining diel differences in chinook feeding behavior, we found that gammaridean amphipods, particularly Corophium salmonis, were consumed more at nighttime than in the day. Corophium salmonis comprised 32% of the total Index of Relative Importance (IRI) at night and 6% in the day. Calanoid copepods were eaten during the day and at night but primarily at dusk. Chironomid flies made a greater contribution to chinook diets in the day-time than at night, comprising 30% of the total IRI in the day and only 11% at night.

Chinook feeding in the nearshore shallow littoral zone (sampled by beach seine) tended to eat more epibenthic prey, particularly gammaridean amphipods and especially C. salmonis. Purse seine caught chinook ate more pelagic prey. Corophium salmonis, which are epibenthic, made up 14% of the total IRI for chinook feeding near shore, and less than 1% in those feeding off-shore. Planktonic crab zoea (juveniles), particularly in the pea crab family Pinnotheridae, occurred almost exclusively in chinook caught off-shore contributing 18% of the IRI of those caught in purse seines and less than 1% in beach seined chinook. A very small amount of predation on non-salmonid juvenile fish was indicated in 2% of chinook in the near-shore zone.

Marine species of prey tended to be more important in the diets of chinook feeding at station D1 than D2. Gammaridean amphipods, particularly C. salmonis, and brachyura crab zoea, largely Pinnotheridae, are marine crustaceans which were eaten primarily by fish collected at the downstream station. Corophium salmonis made up 26% of the total IRI at station D1 and 1% at D2. Brachyurans made up 12% of the total IRI at D1 and 2% at D2. It is curious that calanoid copepods, which are generally marine, were consumed in largest numbers at the upstream station. Calanoids made up 51% of the total IRI upstream and 15% downstream. Chironomid flies were consumed more at the upstream site, comprising 19% of the total IRI at D2 and 7% at D1, while heleid flies made up 5% of the total IRI at the downstream site and were essentially absent from fish stomachs at the upstream site.

There was a slight trend for smaller chinook to consume more epibenthic prey while larger chinook ate more pelagic food. Gammaridean amphipods, particularly Corophium species, contributed 44% of the total IRI to diets of small chinook 60 to 69 mm long, becoming less important to larger chinook (20% of total IRI in chinook 90 to 99 mm long and 6% in chinook 100 to 109 mm). Harpacticoid copepods (epibenthic in habitat), particularly in the family Cletodidae, were important to smaller chinook from 40 to 69 mm long as were chironomid flies. Chironomids decreased in importance as predator size increased, from 59% of the total IRI in chinook 50 to 59 mm long, to 15% total IRI in chinook 70 to 79 mm. Calanoid copepods (pelagic in habitat) were important to larger chinook 70 to 99 mm long, making up 34 to 47% of the total IRI. The largest chinook we sampled, 100 to 109 mm long, consumed non-salmonid juvenile fish and the pelagic larvacean Oikopleura, which made up 31% and 36% of the total IRI, respectively. These results suggest that smaller chinook are feeding in shallow nearshore areas while larger chinook make greater use of the mid-channel.

Monthly differences in chinook diets are related to differences in size of the chinook, since fish size increased with time, although monthly diet trends are not as clear cut as diet trends by predator size. Gammaridean amphipods were most important early in the year in April (66% total IRI), but were also important in June (31% total IRI), and of some importance in July (19% total IRI). Calanoid copepods were of primary importance later in the year in July (45% total IRI), although they were also important in May (25% total IRI).

Coho. Gammaridean amphipods and insects were found to be important prey of juvenile coho in the Duwamish River estuary (Figure 13). Small rocks or sand grains were also found in appreciable quantities in coho stomachs. Of the gammarids, Corophium salmonis was the most important species in coho diets, comprising 32% of the total IRI, although Eogammarus confervicolus was also an important contributor to the diet (9% of the total IRI). Of the insects, the most important were adults and larvae of the aquatic midge family Chironomidae which contributed 13% of the total IRI. There was a small amount of predation on juvenile fishes (3% of the total IRI). However, only one out of 97, or 1% of the coho, had preyed on chum salmon.

In examining diel differences in coho food habits, we found that more insects were eaten in the daytime. Some crustaceans, such as the mysid Neomysis mercedis and the cumacean Cumella were eaten exclusively at night (19, 2 and 9% of the total nighttime IRI, respectively). The gammaridean amphipod Eogammarus confervicolus was eaten primarily at dawn, while the gammarid Corophium salmonis was quite important to coho diets both day and night (31% total IRI in day, 43% total IRI at night). Predation on juvenile fish including chum occurred during the day.

Coho feeding nearshore consumed epibenthic crustaceans while those feeding offshore ate more insects. Gammarids were found almost exclusively in fish that had been feeding nearshore. Corophium salmonis contributed 33% of the total IRI in beach seine caught coho, and was absent from coho taken by purse seine. Eogammarus confervicolus comprised 9% of the total IRI in beach seined coho and 2% in purse seined coho. Juvenile fish, including chum salmon, made up 4% of the total IRI in diets of coho taken nearshore by beach seine but were absent in fish feeding offshore.

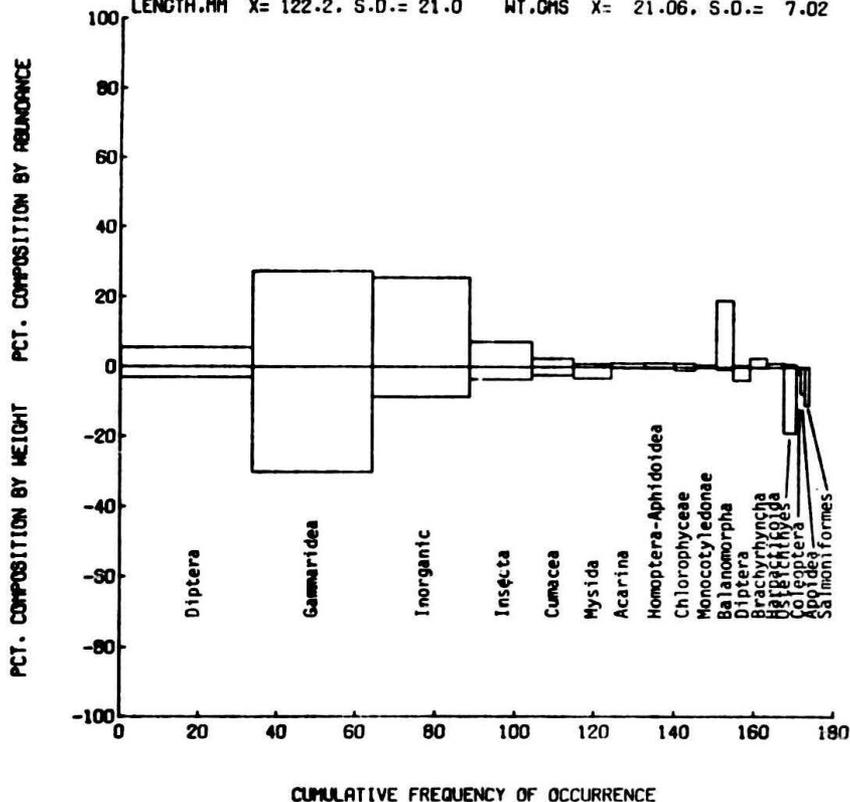
Marine crustaceans were more important in the diets of coho from the more saline downstream station (D1), while freshwater species and insects were consumed in greater quantities at the upstream station (D2). Of the gammaridean amphipods, which comprised 90% of the total IRI at station D1, Corophium salmonis contributed 61% of the total IRI at station D1, compared to 4% at D2, and Eogammarus confervicolus made up 27% of the total IRI at station D1 and was essentially absent from coho at station D2. The cumacean Cumella sp. was also consumed by coho only at the downstream station, comprising 3% of the total IRI. Insects, including the dipteran family Chironomidae, were found almost exclusively in coho from the upstream station (35% total IRI at D2 compared to 1% at D1). Predation on juvenile fish including chum occurred primarily at station D2.

There was a tendency for smaller coho to consume epibenthic crustaceans while those of a larger size tended to eat aquatic and terrestrial insects. The gammaridean amphipod Corophium salmonis made up 21 to 64% of the total IRI for coho 90 to 129 mm long. Eogammarus confervicolus was less important to smaller coho but did contribute 14% of the total IRI to those between 110 and 129 mm. Cumella cumaceans were also consumed by coho less than 129 mm long, comprising 2 to 3% of the total IRI. The mysid Neomysis mercedis, larger than Cumella, made up 2 to 3% of the total IRI for coho 110 to 150 mm

INDEX OF RELATIVE IMPORTANCE (I.R.I.) DIAGRAM
FROM FILE IDENT. DWAMSH. STATION D 123

PREDATOR 8755010203 - ONCORHYNCHUS KISUTCH
(COHO SALMON) ADJUSTED SAMPLE SIZE = 95

LENGTH,MM X= 122.2, S.D.= 21.0 WT,GMS X= 21.06, S.D.= 7.02



CUMULATIVE FREQUENCY OF OCCURRENCE

PREY ITEM	FREQ. OCCUR.	NUM. COMP.	GRAV. COMP.	PCT. I.R.I.	PERCENT TOTAL IRI
DIPTERA	33.66	5.52	3.05	266.6	8.57
GAMMARIDEA	30.23	27.14	30.16	1744.2	51.93
INORGANIC	24.21	25.27	6.64	626.4	24.37
INSECTA	15.75	7.12	3.74	171.5	5.04
CUMACEA	10.53	2.40	2.37	50.2	1.44
MYSIDA	9.47	.39	3.24	34.1	1.14
ACARINA	8.42	1.07	.24	14.0	.33
HOMOPTERA-APHIDOIDEA	7.37	1.10	.27	16.1	.31
CHLOROPHYCEAE	5.26	1.07	.41	16.4	.31
MONOCOTYLEDONAE	3.26	.53	.61	3.2	.10
BALANOMORPHA	4.21	15.04	.57	66.6	2.43
DIPTERA	4.21	.44	3.52	18.4	.55
EUCARIDA-DECAPODA-BRACHYRHYNCHA	4.21	2.55	.12	14.3	.34
HARPACTICIDA	4.21	1.07	.63	4.6	.14
OSTEICHTHYES	3.16	.80	16.66	64.1	1.84
COLEOPTERA-ADEPHAGA	1.05	.07	1.66	1.9	.06
APIDIA	1.05	.07	7.58	6.1	.24
SALMONIFORMES	1.05	.07	15.45	14.7	.35

PREY TAXA WITH FREQ. OCCUR. LESS THAN 5 AND NUMERICAL AND GRAV. PCT. IRI COMPOSITIONS BOTH LESS THAN 1 ARE EXCLUDED FROM THE TABLE AND PCT. IRI BUT NOT FROM CALCULATION OF DIVERSITY INDICES					
PERCENT DIVERSITY INDEX		.19	.17		.38
SHANNON-WIENER DIVERSITY		3.07	3.27		2.14
EVENNESS INDEX		.57	.61		.46

Figure 13. IRI diagram and table showing major prey of juvenile coho in the lower Duwamish River, April - July, 1980.

long. The aquatic chironomid flies contributed 15 to 30% of the total IRI for fish 110 to 150 mm long. Other insects such as terrestrial homopterans, including aphids and psyllids, made up 41% of the total IRI for larger fish 130 to 150 mm long. Juvenile fish including chum salmon were preyed upon by coho less than 129 mm in length.

Crustaceans were eaten by coho earlier in the season in April and May (36 to 78% total IRI), while insects became more important in June (75% total IRI). The gammaridean amphipods Corophium salmonis and Eogammarus confervicolus were eaten in large numbers only early in the season in April and May (33 and 49% total IRI, respectively). Predation on juvenile fish by coho occurred in May. Chironomid flies made up 43% of the total IRI in June, and other insects, including terrestrial aphids, comprised 32% of the total IRI for coho in June.

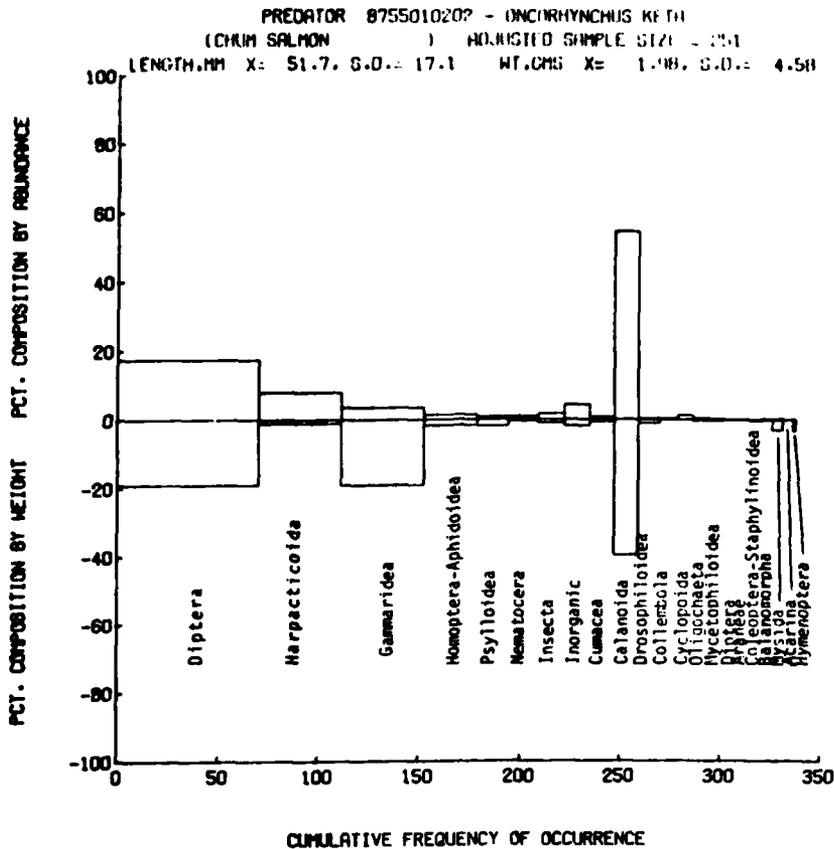
Chum. Juvenile chums preyed upon dipteran insects, particularly chironomids, harpacticoid copepods, gammaridean amphipods (primarily Corophium sp.), and calanoid copepods (Figure 14). Chironomids were consumed by 61% of all chums examined, harpacticoids by 41%, aphids by 26%, Corophium salmonis by 20%, and calanoid copepods by 12%. However, calanoids contributed 54% of all prey items enumerated and 40% of the total prey biomass.

The only notable differences in the stomach contents of chums caught at night and during the day was the occurrence of calanoids. At night, calanoids comprised 31% of the total IRI, while they contributed 0.02% during the day.

An examination of chum diets by size of the fish revealed some definite differences. Small chums preyed heavily on insects and epibenthic crustaceans. At 30 to 39 mm fork length, chironomids contributed 85% of the total IRI with harpacticoids making up 10% of the IRI. Calanoids contributed little to the diet. Chironomids and harpacticoids continued to be important with increasing predator size, but contributed less to the total IRI. At 50 to 59 mm, numbers of gammaridean amphipods, particularly Corophium salmonis, became more significant occurring in 28% of the fish, contributing 13% of the IRI. Large chum, 70 mm and above, preyed extensively on calanoids (IRI = 86 to 98%) and very little on insects.

The pattern of monthly prey preferences appears to be similar and related to that exhibited by increasing predator size. This is to be expected as the mean length of chums increased over the course of the study. Again, chironomids and harpacticoids were important in April and May, becoming insignificant or absent in July. The Heleidae became important in May (IRI = 13%). The gammaridean amphipods were prominent in May and June when Corophium salmonis made up 20% of the IRI. The calanoids increased in importance from April (IRI = 0.05%) to July (IRI = 99%) when all the chums sampled had consumed them. However, it should be pointed out that our July sample was relatively small and all chums taken during this month were caught at night. As stated earlier, diel food habits indicated greater utilization of calanoids at night.

INDEX OF RELATIVE IMPORTANCE (I.R.I.) DIAGRAM
FROM FILE IDENT. DWAMSH. STATION D 123



PREY ITEM	FREQ OCCUR.	NUM. CUMPL.	GRAV. CUMPL.	PREY I.R.I.	PERCENT TOTAL IRI
DIPTERA	70.12	17.45	19.04	2556.7	47.44
HARPACTICOIDA	41.43	7.46	1.12	376.2	7.03
GAMMARIDEA	41.04	3.44	14.10	425.7	17.30
HOMOPTERA-APHIDOIDEA	25.40	1.34	1.71	86.2	1.20
PSYLLIODEA	15.54	.86	1.64	42.0	.76
NEMATOCERA	14.73	.95	.56	26.5	.35
INSECTA	13.15	1.60	1.63	35.3	.66
INORGANIC	12.75	4.20	1.58	76.5	1.46
CUMACIA	12.15	.76	.07	17.4	.33
CALANOIDA	11.27	24.44	34.73	1155.4	21.04
DROSOPHILOIDEA	10.36	.31	1.07	14.3	.27
COLLEMBOLA	4.16	.22	.12	3.2	.06
CYCLOPOIDA	7.97	1.16	.14	16.7	.20
OLIGOCHAETA	7.27	.74	.24	2.2	.10
MYCETOPHILLOIDEA	7.57	.30	.31	4.6	.08
DIPTERA	6.37	.15	.15	2.1	.04
ARANEAE	6.37	.12	.23	2.3	.04
COLEOPTERA-STAPHYLINOIDEA	5.96	.12	.33	4.7	.08
BALANOMORPHA	5.76	.25	.05	1.6	.03
MYSTIA	5.16	.34	3.68	17.7	.33
ACARINA	5.15	.13	.63	.5	.01
HYMENOPTERA	1.26	.02	3.24	4.6	.07

PREY TAXA WITH P.P.C. OCCUR. LESS THAN 2 ARE NEGLIGIBLE AND GRAVITIMIC COMPOSITION BOTH LESS THAN 1 ARE EXCLUDED FROM THE TABLE AND PLOT (BUT NOT FROM CALCULATION OF DIVERSITY INDICES)

PERCENT DOMINANCE INDEX	.34	.63	.31
SHANNON-WIENER DIVERSITY	2.91	2.40	2.14
EVERNESS INDEX	.76	.46	.32

Figure 14. IRI diagram and table showing major prey of juvenile chum in the lower Duwamish River, April - July, 1980.

Changes in diet related to predator size and season could not be separated from one another. It is not known if the observed differences were attributable to the increasing size of the predator and, therefore, a change in preference or, if they result from seasonal changes in the abundance and availability of prey.

Some differences in chum food habits between stations D1 and D2 were noted which, again, are probably related to differences in salinity. Chironomids were very important at D2 contributing 50% of the total IRI and only 14% at D1. On the other hand, Corophium salmonis contributed 21% of the total IRI at D1 and only 3% at D2. However, the heleids were very important at D1 (35% of the IRI) but were not even eaten at D2.

Steelhead. Steelhead food habits were less diverse than other salmonid species and consisted primarily of epibenthic invertebrates, insects, and juvenile fish (Figure 15). Neomysis mercedis dominated the overall diet occurring in 38% of our fish samples and contributing 66% of the IRI. Insects and gammarid amphipods (principally Eogammarus confervicolus) also made significant contributions to the diet. Juvenile fish including salmonids occurred at lower frequencies but made substantial contributions to the gravimetric composition of the diet. A surprising amount of sticks, rocks, plant parts, etc. were found in the stomach contents.

When our data were broken down into groups of steelhead caught during the day and at night, N. mercedis increased even further in importance in fish caught after dark comprising 93% of the IRI. Other prey items contributed little to the nighttime samples. Steelhead caught during the day did not even contain N. mercedis. Juvenile fish were the dominant prey items during the day.

The steelhead samples were divided into two size categories based upon predator size. Steelhead under 200 mm preyed extensively on insects, N. mercedis, and gammaridean amphipods (Corophium spinicorne, C. salmonis, and Eogammarus confervicolus). Fish larger than 200 mm preyed on N. mercedis and juvenile fish. Ten steelhead over 200 mm were examined and had consumed 5 juvenile salmonids (3 chinook and 2 chum) plus 3 unidentified juvenile fish.

Beach seine caught steelhead contained 15 recognizable prey categories (does not include inorganic material and plant parts). They preyed principally on Neomysis mercedis, Eogammarus confervicolus, and juvenile fish. The prey spectrum of purse seine caught steelhead was much lower in diversity being comprised of 6 prey groups. Principal prey items were juvenile fish and insects.

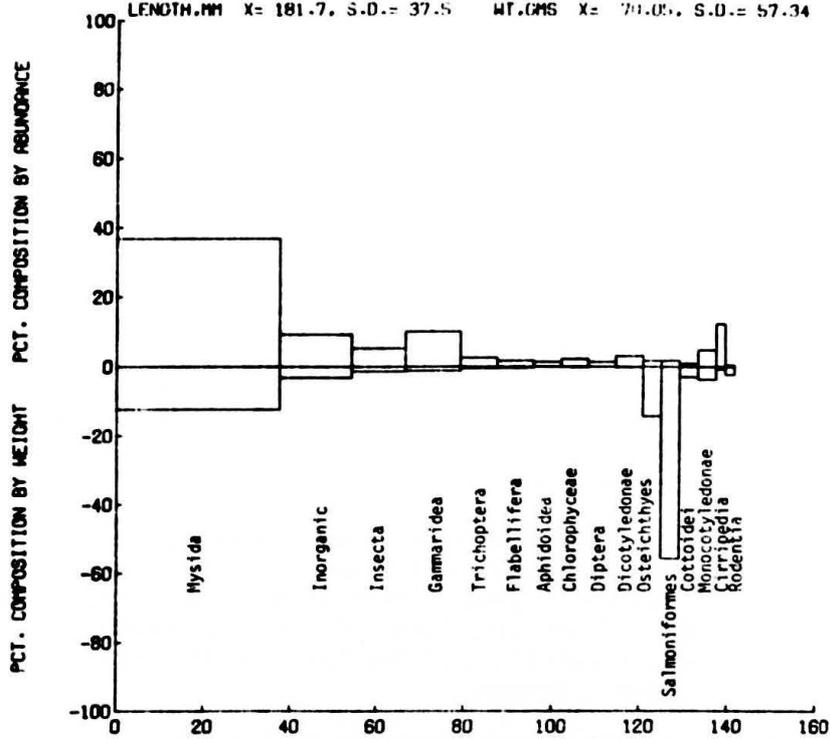
Food habits of juvenile steelhead captured at the upstream and downstream stations did not appear to exhibit significant differences.

Only four cutthroat trout were captured during our study and little can be said about their food habits. However, they have been identified in the

INDEX OF RELATIVE IMPORTANCE (I.R.I.) DIAGRAM
FROM FILE IDENT. DUWAMISH, STATION D 123

PREDATOR 8755010302 - SALMO GAIRDNERI
(RAINBOW TROUT) ADJUSTED SAMPLE SIZE = 48

LENGTH.MM X = 181.7, S.D. = 37.5 WT.GMS X = 70.05, S.D. = 57.34



CUMULATIVE FREQUENCY OF OCCURRENCE

PREY ITEM	FREQ OCCUR	NUM. COMP.	GRAV. CUM.P.	PREY I.R.I.	PERCENT TOTAL I.R.I.
MYSIDA	37.50	36.84	12.40	1096.6	60.46
INORGANIC	16.67	4.21	3.17	20.64	7.43
INSECTA	12.50	5.26	1.43	65.6	3.61
GAMMARIDEA	12.50	10.39	1.10	140.5	5.07
TRICHOPTERA	6.33	2.63	.46	25.8	.93
FLABELLIFERA	6.33	1.75	.26	17.6	.63
HOMOPTERA-APHIDOIDEA	6.25	1.32	.02	6.3	.30
CHLOROPHYCEAE	6.25	2.19	.11	14.6	.52
DIPTERA	6.25	1.32	.01	6.3	.30
DICOTYLEDONAE	6.25	3.37	.14	20.4	.73
OSTEICTHYES	4.17	1.75	14.43	64.6	2.91
SALMONIFORMES	4.17	1.75	55.10	43.6	1.97
SCORPAENIFORMES-COTTOIDEI	4.17	.69	3.03	12.3	.54
MONOCOTYLEDONAE	4.17	4.07	3.01	36.6	1.69
CIRRIPIEDIA	2.08	12.85	.70	27.6	1.27
RODENTIA	2.08	.49	2.35	5.8	.27
PERCENT DOMINANCE INDEX		1.13	.35		.49
SHANNON-WIENER DIVERSITY		3.29	2.69		1.99
EVENSNESS INDEX		.72	.43		.43

Figure 15. IRI diagram and table showing major prey of juvenile steelhead in the lower Duwamish River, April - July, 1980.

literature as potential salmonid predators (Fresh and Cardwell, 1979). Of the four cutthroat examined, one had preyed upon four juvenile fish. None of the fish consumed were identified as salmonids.

Eight Pacific staghorn sculpin, another potential salmonid predator, had their stomachs examined. Again, while they did contain juvenile fish, none were identified as salmonids.

Prey Availability

Epibenthic, benthic, and pelagic invertebrates captured with the plankton pump have been classified into 32 taxonomic groups (Table 8). Abundance of the various groups was highly variable between sampling periods. The high variability and lack of representative samples in April and May did not allow direct quantitative comparisons or estimates of monthly abundance. However, some trends are apparent.

Taxonomic richness was somewhat uniform among the various sampling stations. This may be partly attributable to contamination of the sampler from previous stations. Of the 32 taxonomic groups identified in our samples, the rip-rap site (DP5) and the upper river site (DP6) yielded representatives from 24 and 22 of these groups, respectively. Samples from the other sites contained between 17 and 19 taxonomic groups.

The Kellogg Island site (DP1) exhibited very high numbers of epibenthic and benthic organisms. Harpacticoid copepods were very abundant relative to other sites as were Foraminifera. In his study of the benthic community in the vicinity of Kellogg Island, Leon (1980) found harpacticoids in highest abundance at stations having fine-grained sediments and particularly those located adjacent to tidal marsh vegetation. Benthic nematodes, polychaetes (primarily Manayunkia aestuarine), and oligochaetes were also quite numerous in the fine organic sediment at this site. Because these animals occurred in such large numbers, other invertebrates such as Corophium amphipods comprised a relatively small percentage of the sample. However, more Corophium (primarily C. salmonis) were captured at DP1 than at any other site. Leon (1980) surmised that distribution of Corophium in the Duwamish estuary was related to sediment type and season. The sediment type preferred appeared to be "moderately oxygenated sediments, avoiding the black anoxic material, but also avoiding the sandy sediment where food is apparently sparse". Relatively few insects were detected in DP1 samples. To examine the diversity of epibenthic taxa in the substrate types found at Kellogg Island, several core samples were collected among the marsh vegetation near the mean high water mark. These samples contained high numbers of Heloidea.

Samples from the main channel (DF3) contained very few organisms relative to other sites. The presence of bottom oriented species in these samples probably resulted from animals not flushed from the sampler following sampling in shallow littoral areas. As expected, pelagic organisms dominated

Table 8. Relative abundance and percent species composition of invertebrates sampled in the lower Duwamish River.

	DP1		DP3		DP4		DP5		DP6	
	No.	%	No.	%	No.	%	No.	%	No.	%
Foraminifera	▲	20.6	○	18.6	○	○	○	○	○	○
Coelenterata	▲	22.0	○		○	○	○	○	○	○
Nematoda	■	0.7	○		○	2.5	○	○	○	○
Turbellaria	▲	8.1	○		○	8.8	○	○	○	○
Polychaeta	○	6.9	○		○	1.3	○	○	○	○
Oligochaeta	○		○		○		○	○	○	○
Gastropoda	○		○		○		○	○	○	○
Bivalvia	○		○		○		○	○	○	○
Acari (mites)	○	0.3	○		○		○	○	○	○
Ostracoda	▲	9.0	○		○		○	○	○	○
Calanoida	■	0.9	○	65.1	○	56.3	○	○	○	○
Harpacticoida	▲	30.4	○		○	1.3	○	○	○	○
Cyclopoida	■	0.4	○	7.0	○	5.0	○	○	○	○
Cirripedia	○		○	9.3	○	2.5	○	○	○	○
Mysidacea	○		○		○	17.5	○	○	○	○
Cumacea	○	0.1	○		○		○	○	○	○
Tanaidacea	○	0.1	○		○		○	○	○	○
Isopoda	○		○		○		○	○	○	○
Gammaridea	○		○		○		○	○	○	○
Corophium	■	0.4	○		○	2.5	○	○	○	○
Eogammarus	○		○		○	2.5	○	○	○	○
Hyperiidae	○		○		○		○	○	○	○
Euphausiacea	○		○		○		○	○	○	○
Caridea (juv. shrimp)	○		○		○		○	○	○	○
Anomura	○		○		○		○	○	○	○
Brachyura (juv. crab)	○		○		○		○	○	○	○
Coleoptera (beetles)	○		○		○		○	○	○	○
Diptera	○		○		○		○	○	○	○
Heleidae	○		○		○		○	○	○	○
Chironomidae (flies)	○		○		○		○	○	○	○
Hymenoptera (ants)	○		○		○		○	○	○	○
Chaetognatha	○		○		○		○	○	○	○

Key to symbols:

T Terrestrial
 B Benthic
 E Epibenthic
 P Pelagic

Symbol No./200 liters

▲ 1000
 ○ 500-1000
 + 200-499
 ■ 50-199
 - 10-49
 ○ presence

DP3 samples, particularly calanoid copepods. Calanoids comprised 65.1% of the animals collected at this site. Barnacle nauplii (larva) and cyclopoid copepods were also abundant in the main channel.

Station DP4, located under the concrete apron, also contained very few organisms. Calanoids again dominated samples at this site. The only other invertebrates occurring in appreciable quantities were mysids which comprised 17.5% of our samples. Smaller numbers of polychaetes and gammaridean amphipods (Eogammarus confervicolus) were also present.

Epibenthic, benthic and pelagic organisms occurred in samples from the rip-rap site (DP%). Most abundant were polychaetes, harpacticoids, foraminiferans and calanoids. Although our sampler did not capture appreciable numbers of insects, DP5 samples contained higher numbers of chironomids than other stations.

Samples from the upriver site (DP6) contained high numbers of organisms and ranked second to the Kellogg Island site in sheer numbers. DP6 samples were numerically dominated by harpacticoid copepods which made up 74.6% of the animals collected at this site. Benthic worms were also quite numerous. Again, the high numbers of harpacticoids, nematodes and oligochaetes overshadowed other species. Gammaridean amphipods contributed only 1.4% of the individuals in these samples but ranked just behind Kellogg Island samples in abundance. Mysids and cumaceans were also present in appreciable quantities relative to other sites. The location of this site upstream in lower salinity water probably influenced the species composition and abundance of certain organisms at this station.

Distribution and availability of chironomid adults, pupae and larvae was of particular interest because of its importance as salmonid prey. Merritt and Cummins (1978) state that chironomids are found in fresh, marine, and brackish waters. We were not able to identify any chironomids to species and were not able to determine which of these groups was being preyed upon. Our plankton pump samples contained low numbers of chironomids except at the rip-rap site. Marine chironomids are found in association with algal vegetation in rocky beaches as well as muddy bottoms (Morley and Ring, 1972). In order to better define the distribution of chironomids and other important salmonid prey in the Duwamish estuary, additional invertebrate studies should be conducted. These studies should utilize various sampling techniques to define invertebrate distribution in relation to tidal height, salinity gradients, bottom composition, algal and marsh vegetation and season.

SUMMARY AND CONCLUSIONS

Fish Distribution

Juvenile salmonids were found to utilize the lower Duwamish River in appreciable numbers from mid-April through early June. Periods of peak abundance are probably related to releases from artificial enhancement facilities. Length of residency varies considerably between species with chinook and chum present for the longest period in the study area. Although we do not have residency estimates, these conclusions are collaborated by other studies which have documented chinook and chum rearing in estuarine areas for periods of up to two months (Reimers, 1971; Levy *et al.*, 1979; and Healey, 1979). Coho and steelhead appeared to spend much less time in the estuary, moving through fairly rapidly in schools.

Juvenile salmonids utilized both shallow nearshore and deeper water habitats of the lower Duwamish River. There are species differences in the use of these areas. As expected, chum were highly oriented toward shallow shoreline areas. They were rarely captured in the mid-channel (deep water habitat). Juvenile chum orientation toward shallow shorelines has been documented in Puget Sound and Hood Canal, Washington by Fresh *et al.* (1979) and Bax *et al.* (1978), respectively. However, we did not note the gradual offshore movement with increasing size or time which they reported. This may be due to differences in study area, sampling gear, or chum early life history strategies.

Chinook were captured frequently in both shallow and deep water habitats. Less can be said about their habitat preference from this study and from the existing literature. However, magnitude of beach seine catches relative to what was taken in purse seines indicates considerable use of shoreline areas. Chinook distribution is also influenced by size. Chinook captured in purse seines were significantly larger than those caught in beach seines indicating greater use of shallow shorelines by smaller fish. Chinook also appeared to move inshore at night.

Coho and steelhead were captured in both shallow and deep water habitats. Little can be said about their preferences although it is likely that these relatively large juveniles readily move between habitats.

Mean length of chum and chinook showed definite increases between April and July. We could not determine if these increases were due to growth while residing in the study area or immigration of fish from upstream areas. Some of the previously cited studies (Reimers, 1971; Levy *et al.*, 1979; and Healey, 1979) have documented appreciable growth in estuarine areas by these two species.

Food Habits

Juvenile salmonids preyed upon epibenthic and pelagic plankton, insects, and, to a small extent, on other fish. Principal prey items varied in importance for each species between daylight and darkness, nearshore and offshore habitats, upstream and downstream sites (greater salinity at the downstream station), predator size and season. In general, epibenthic crustaceans tended to be more important at night while pelagic crustaceans, insects and, to some extent, juvenile fish were more important to salmonid diets during the day. Salmonids which were caught nearshore had preyed on epibenthic invertebrates and, to a small extent, on juvenile fish, while salmonids caught in mid-channel preyed primarily on pelagic organisms. Marine species were the primary food items at the downstream station while chironomid flies and freshwater organisms made a greater contribution at the upstream site. Epibenthic invertebrates and chironomids were more important to smaller sizes of salmonids while larger individuals consumed more planktonic prey and showed minor predation on juvenile fish. Monthly food habits generally paralleled and were related to the food habits observed for increasing predator size.

Epibenthic organisms which were consumed in appreciable numbers by salmon are the gammaridean amphipods Corophium salmonis and Eogammarus confervicolus and harpacticoid copepods. Steelhead preyed heavily on the epibenthic mysid Neomysis mercedis. Calanoid copepods are pelagic organisms which were important to salmon diets. Chironomid flies are another very important prey to salmonids. The larvae of these insects would be epibenthic in habitat, while the adult insects are probably eaten from the water's surface.

Prey Availability

Availability of salmonid prey over various substrate types was highly variable not only between sites but also between sampling dates at the same site. Although quantitative comparisons were not made, it was evident that differences in abundance between sites was quite large.

The two soft bottom sites (DP1 and DP6) exhibited extremely high numbers of benthic and epibenthic invertebrates, particularly harpacticoid copepods. Corophium amphipods were also found in greatest numbers at these two sites. Insects, while not occurring in large quantities, were present. Samples from the rip-rap site also contained most of the other prey organisms consumed by salmonids, although in abundances apparently below those found at the soft bottom sites.

The mid-channel site (DP3) was low in abundance of all potential salmonid prey except pelagic calanoid copepods. The presence of pelagic stages of some juvenile crustaceans was unique to this site. The site located under the concrete apron was also relatively low in abundance of prey organisms except calanoid copepods and mysids. Some gammarid amphipods, such as Eogammarus confervicolus, were collected at this site.

Finally, the soft fine-grained sediment sites would appear to present the greatest abundance of preferred prey organisms. The rip-rap site sampled in this study did exhibit many prey organisms including chironomid flies which were a very important dietary item to chum and small chinook. Rip-rap differing from our rip-rap sample site by not containing moderate amounts of sand and gravel patches probably would not contain significant numbers of many of the epibenthic invertebrates, particularly harpacticoid copepods and Corophium amphipods. Areas under concrete aprons where little natural light penetrates do not appear to be productive feeding areas.

LITERATURE CITED

- Ames, J.A. and D.E. Phinney. 1977. 1977 Puget Sound summer-fall chinook methodology: Escapement estimates and goals, run size forecasts, and in-season run size updates. State of Wash., Dept. of Fish., Tech. Rept. No. 29, P. 71.
- Bax, N.J., E.O. Salo, B.P. Snyder, C.A. Simenstad, and W.J. Kinney. 1978. Salmonid outmigration studies in Hood Canal. Final Rept., Phase III, January to July 1977. Univ. of Wash., Fish. Res. Inst., FRI-UW-7819. pp. 128.
- Bostick, W.E. 1955. Duwamish River seining studies. In Puget Sound Stream Studies, Progress Rept. July - Nov. 1953. Wash. Dept of Fish.
- Congleton, J.L. 1978. Feeding patterns of juvenile chum salmon in the Skagit River salt marsh. Fish Food Habits Studies, Proceedings of the Second Pacific Northwest Tech. Workshop. Ed. by Lipovsky and Simenstad. p. 141-150.
- Dawley, E.M., C.W. Sims, R.D. Ledgerwood, D.R. Miller, 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. 1978, Project 712. National Marine Fish. Serv.
- Dunford, W.E. 1975. Space and food utilization by salmonids in marsh habitats of the Fraser River estuary. M.S. thesis, Univ. of British Columbia. p. 81.
- Elliott, J.M. 1972. Rates of gastric evacuation in brown trout, Salmo trutta L. Freshwater Biology 2:1-18.
- Fresh, K.L. and R. Cardwell. 1979. Salmon-herring predator/competitor interactions (Phase I). Report to Pacific Northwest Regional Commission. Wash. Dept. of Fish.
- Fresh, K.L., D. Rabin, C. Simenstad, E.O. Salo, K. Garrison, and L. Matheson. 1979. Fish ecology studies in the Nisqually Reach area of southern Puget Sound, Washington. Univ. of Wash., Fish. Res. Inst. FRI-UW-7904. p. 229.
- Healey, M.C. 1979. Detritus and juvenile salmon production in the Nanaimo Estuary: 1. Production and feeding rates of juvenile chum salmon. Pacific Biol. Sta., Fish. and Mar. Serv., Dept. of Fish, and the Environment, Journal of the Fish. Res. Bd. of Canada 36:488-496.
- Johnson, F.C. 1973. Potential interspecific problems between hatchery coho smolts and juvenile pink and chum salmon. Wash. Dept. Fish., Management and Research Division, p. 40.

- Leon, H. 1980. Terminal 107 environmental studies benthic community impact study for Terminal 107 (Kellogg Island) and vicinity. Prepared for Port of Seattle by Pacific Rim Planners, Inc. p. 98.
- 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. Ctr., Tech. Rept. No. 23, Nov., 1979. Univ. of B.C. p. 70.
- Mason, J.C. 1974. Behavioral ecology of chum salmon fry in a small estuary. Fish. Res. Bd. of Canada 31(1) p. 83.
- Matsuda, R.I., G.W. Isaac, and R.D. Dalseg. 1968. Fishes of the Green-Duwamish River. Water Quality Series No. 4, Municipality of Metropolitan Seattle. p. 38.
- Merritt, R.W. and K.W. Cummins. 1978. An introduction to the aquatic insects of North America. Kendall/Hunt Publishing Co. p. 441.
- Morley, R.L. and R.A. Ring. 1972. The intertidal Chironomidae (Diptera) of British Columbia. II. Life history and population dynamics. Can. Ent. 104:1099-1121.
- Pinkas, L., M.S. Oliphant and I.L.K. Iverson. 1971. Food habits of albacore, bluefin tuna, and bonita in California waters. Calif. Fish and Game, Fish. Bull. 152:1-105.
- Reimers, P.E. 1971. The length of residence of juvenile fall chinook salmon in Sixes River, Oregon. PH.D. Thesis, Ore. St. Univ. p. 99.
- Sibert, J., T.J. Brown, M.C. Healey, B.A. Kask, and R.J. Naimon. 1977. Detritus-based food webs: Exploitation by juvenile chum salmon (Oncorhynchus keta). Science, May 1977, p. 649-650.
- Simenstad, C.A. and W.J. Kinney. 1978. Trophic relationships of outmigrating chum salmon in Hood Canal, Washington, 1977. Univ. of Wash., Fish. Res. Inst. FRI-UW-7810. p. 75.
- Smith, J.E. 1977. A baseline study of invertebrates and of the environmental impact of intertidal log rafting on the Snohomish River delta. Univ. of Wash., Cooperative Fish. Res. Unit.
- Weitkamp, D.E. In press. 1980 juvenile salmonid study. Prepared for the Port of Seattle by Parametrix, Inc.
- Weitkamp, D.E. and R.F. Campbell. 1979. Port of Seattle Terminal 107 fisheries study. Draft report, Parametrix, Inc., Document No. 79-1120-034FD.

APPENDIX

Table 1. Salmonid catch per beach seine set by week at station D1 in the lower Duwamish River during April - July, 1980.

<u>Date</u>	<u>Chum</u>	<u>Chinook</u>	<u>Coho</u>	<u>Steelhead</u>	<u>Cutthroat</u>
April 8	0	0	0	0	0
April 21-24	8.8	1.0	0.3	0	0
April 28-29	1.3	3.0	1.8	0.3	0.3
May 7	66.3	80.3	2.3	1.3	0
May 15-16	47.0	150.8	9.3	6.0	0
May 21-22	11.3	24.8	0	0.5	0.3
May 28-29	7.8	18.5	0	0	0
June 4-5	4.0	7.0	0.5	0	0
June 18-19	3.0	7.0	0	0	0
July 2-3	1.0	11.0	0.3	0	0
July 16-17	0	1.5	0	0	0
July 30-31	0	2.5	0.3	0	0

Table 2. Salmonid catch per beach seine set at station D2 in the lower Duwamish River during April - July, 1980.

<u>Date</u>	<u>Chum</u>	<u>Chinook</u>	<u>Coho</u>	<u>Steelhead</u>	<u>Cutthroat</u>
April 8	5.5	0.3	0	0	0
April 21-24	28.8	7.3	0	0.3	0
April 28-29	1.3	178.0	10.0	0.3	0
May 6-7	1.0	517.0	29.5	3.5	0
May 15-16	48.5	204.5	1.5	2.3	0
May 21-22	29.8	204.0	0	0	0.8
May 28-29	14.8	84.8	0	0	0
June 4-5	13.3	103.5	50.0	0	0.3
June 18-19	5.5	27.8	0	0	0
July 2-3	4.3	13.8	0	0	0.3
July 16-17	0	1.3	0	0	0
July 30-31	0	.8	0	0	0

Table 3. Salmonid catch per purse seine set at station D1 in the lower Duwamish River during April - July, 1980.

<u>Date</u>	<u>Chinook</u>	<u>Coho</u>	<u>Steelhead</u>
April 8	0	0	0
April 21-24	0	0.5	0
April 28-29	0	0.3	0
May 6-7	17.0	0.5	0.5
May 15-16	4.0	0	0
May 21-22	1.0	0	1.3
May 28-29	2.5	0	0
June 4-5	3.7	52.0	0
June 18-19	1.5	0	0
July 2-3	0.3	0.3	0
July 16-17	0	0	0
July 30-31	0	0	0

Table 4. Salmonid catch per purse seine set at station D2 in the lower Duwamish River during April - July, 1980.

<u>Date</u>	<u>Chinook</u>	<u>Coho</u>	<u>Steelhead</u>
April 8	0	0	0
April 21-24	0.3	0	0
April 28-29	0	0	0
May 6-7	1.0	0.5	0.5
May 15-16	18.3	0.7	0
May 21-22	19.8	4.5	1.0
May 28-29	9.0	0	0
June 4-5	4.5	0.5	0
June 18-19	21.8	0	0
July 2-3	0	0	0
July 16-17	1.3	0	0
July 30-31	0	0	0