SPACE AND FOOD UTILIZATION BY SALMONIDS IN MARSH HABITATS OF THE FRASER RIVER ESTUARY

by

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B.A., The University of Toronto, 1972

A THESIS SUBMITTED IN PARTIAL FULFILMENT OF
THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF SCIENCE

in the Department
of
Zoology

We accept this thesis as conforming to the required standard

THE UNIVERSITY OF BRITISH COLUMBIA

JANUARY, 1975

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ABSTRACT

The temporal utilization of space and food by juvenile Pacific salmon was studied in selected marsh habitats of the Fraser River Estuary. Two types of marginal habitat were examined- slough habitat (exposed to main current) and channel habitat (backwaters). Chum salmon fry (*Oncorhynchus keta*) and chinook salmon fry (*O. tshawytscha*) were the most abundant species present in both habitats, with peak densities occurring in late April. Chum and chinook exploited many similar food sources, and the size of prey selected was examined to show a size segregation of the diet. Chum tended to select a greater proportion of smaller, planktonic prey, while chinook ingested a greater proportion of larger, benthic prey. The divergence in types of prey and prey size selected was greatest during maximum density in late April and early May. The density of chinook was greater than chum, except in early April. Few chum were taken after early June, while chinook were present until late July, showing a steady increase in length throughout the season. It is suggested that chinook may reside in the estuarine marsh habitats temporarily each spring and summer. The chum fry utilize the habitats for feeding, during migration, but disperse to marine habitats in a shorter time period than chinook.

TABLE OF CONTENTS

LIST OF FIGURES

Figure | Page

LIST OF TABLES

ACKNOWLEDGEMENTS

I wish to express my appreciation of the advice and criticism, given me by my thesis supervisor Dr. T.G. Northcote. I also wish to thank Ms. Marg Fisher and Mr. Kanji Tsumura for their technical assistance and encouragement. Finally, I wish to thank my wife, Larcy Dunford, for her support and assistance at all times during the development of this study.

INTRODUCTION

The progeny of all species of Pacific salmon (genus *Oncorhynchus*) begin life as eggs buried deep in the gravel of cool, clean streams or occasionally lakes. The incubation of the eggs, the development of alevins, and the emergence of the fry, together with the environmental factors influencing these events have been well documented (eg. Bams, 1969). Upon emergence from the gravel, the salmon fry will eventually make a downstream migration to river estuaries and the sea, the timing depending upon the species.

On departure from their natal streams or rearing lakes and in their movement toward the ocean, very little is known of the ecology of the Pacific salmon, until they reach commercial size at sea. The survival rate for most species (specifically sockeye) is measured as the ratio of enumerated adults (catch plus escapement) to the number of smolts estimated at the time they leave the lake (Ricker, 1966). At present, there are no quantitative estimates of losses during the downstream migration of the juveniles. Yet losses during this segment of their life history may be considerable.

During the downstream migration, it is generally accepted that the juvenile of all species are carried by, and may swim with the current of the river system. Upon reaching tidal water, the activities and final dispersal of juvenile Pacific salmon remain relatively unknown.

An estuary, in biological terms, may be defined as a region of a river with a variable salinity due to the sea (Day, 1951). The term "variable salinity" implies both a diel variability due to tidal influence, and a seasonal variability due to discharge of the river. During the period of juvenile salmon migration, the Fraser River discharge reaches its peak, and the surface waters of the estuary are essentially freshwater throughout the freshet. A salt wedge intrusion, typical of a stratified estuary such as the Fraser, only penetrates to the mouth of the river during the freshet. (Hoos & Packman, 1974).

Feeding of juvenile Pacific salmon in river estuaries and adjacent waters has only recently been studied for pink and chum (Kaczynski et al., 1973, and Manzer, 1969), for chum (Mason, 1974, and Sparrow, 1968), for chinook (Reimers, 1973, Stein et al., 1972, and Kask, 1972) and for coho (Parker, 1971). The importance of the feeding period in the estuary was first emphasized by Henry, 1961, who suggested:

> that a deficiency of food for a few weeks could cause serious mortality, but still have only a rather small effect on the total first year growth of the survivors.

Growth of juvenile salmon before they encounter sea water most probably will enhance their marine survival, and for this reason the estuarine feeding is of great importance.

Over three hundred million juvenile Pacific salmon migrate into the Fraser River estuary during certain years (Northcote,

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K.A. Henry, Racial identification of Fraser River sockeye salmon by means of scales and its application to salmon management. Internat. Pac. Salm. Fish. Comm. Bull. 12: 97 p.

1974). This phenomenon is assumed to occur between the months of February and July, with the greatest abundance occurring in the months of April and May. In spite of the magnitude of the number of fishes involved, and the importance of this stage in their life cycle, virtually nothing is known about the feeding and possible residence of the salmon in the Fraser estuary.

The Fraser River estuary is divided into two main branches, a North Arm and a South Arm. Near the mouth of the river, marshes are a significant feature, with the largest marshes in the South Arm. Two types of habitat are present in the marsh areas, slough habitat and side channel habitat. Only slough habitat is present in the small marsh area in the North Arm. A large marsh area exists in the South Arm, including both slough and side channel habitat.

These habitats were studied to determine the spatial and temporal use by fishes from early March until early August. The most abundant fish present in the habitats were juvenile salmonids. The food resource exploitation by juvenile salmonids was examined in relation to habitat type and prey size selection. The food sources of other species utilizing the habitats were also determined, and these results are recorded in the Appendix.

STUDY AREA

A. South Arm

The principal study area was located in the South Arm of the Fraser River, in the Duck - Barber - Woodward Island complex, located approximately 6 Km. from the mouth of the river (Figure 1). This area is composed of approximately 485 hectares (1200 acres) of undisturbed marshland. The characteristic vegetation of this marshaland is bulrush (*Scirpus americanus*), sedge (*Carex lyngbyei*) , and cattail (*Typha latifolia*). The substrate is very soft, composed of alternating layers of fine silt and detritus.

Two types of habitat predominate in the South Arm study area. The first type is termed slough habitat, which refers to an area exposed to the flow of the river (Figure 2a). The second is termed side channel habitat, referring to the blind channels branching off of the main current into the marsh (Figure 2a, b). The flow of water into and out of these narrow channels is determined largely by the river height and the tide cycle.

B. North Arm

The south branch of the North Arm of the Fraser River is composed almost totally of the slough type of habitat (Figure 3). The only area of undisturbed marshland remaining is the

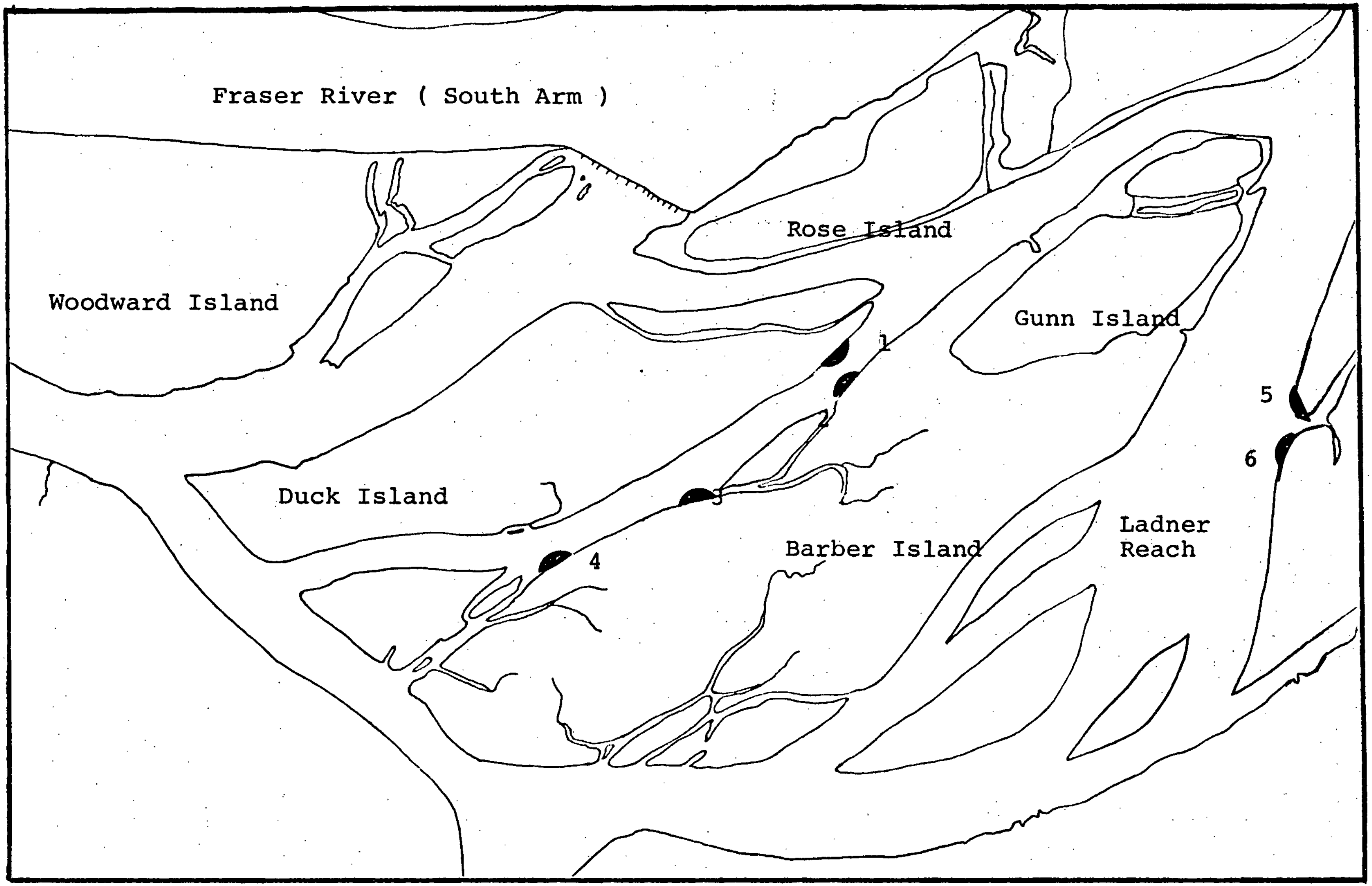


Figure 1: Six slough habitat sites sampled by beach seine in the South Arm of the Fraser River, approximately 6 km from the mouth. (See Figure 3 b)
Scale: 1 cm = 200 m

Figure 2 (a): Typical slough habitat (left) and channel habitat (right) in the South Arm of the Fraser River.

Figure 2 (b): Typical channel habitat approximately 600 m from the confluence of channel and slough habitat shown in Figure 2 (a).

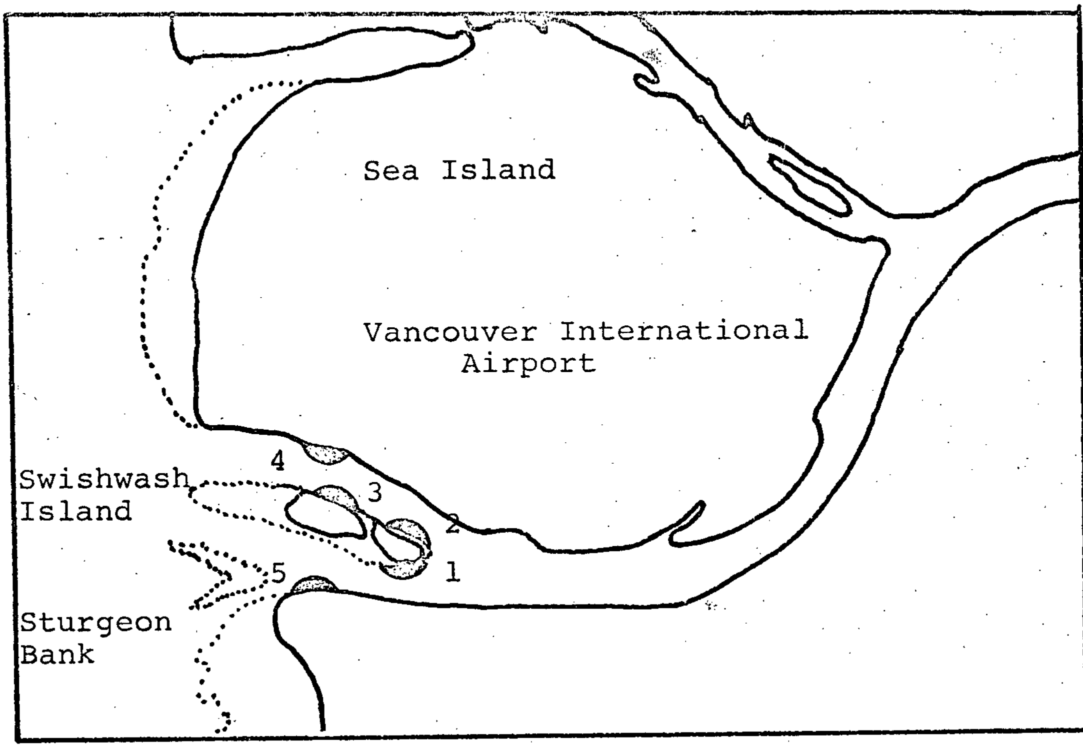


Figure 3 (a): Five slough habitat sites sampled by beach seine in the North Arm of the Fraser River. (See Figure 3 (b)).
Scale: 1 cm = 630 m

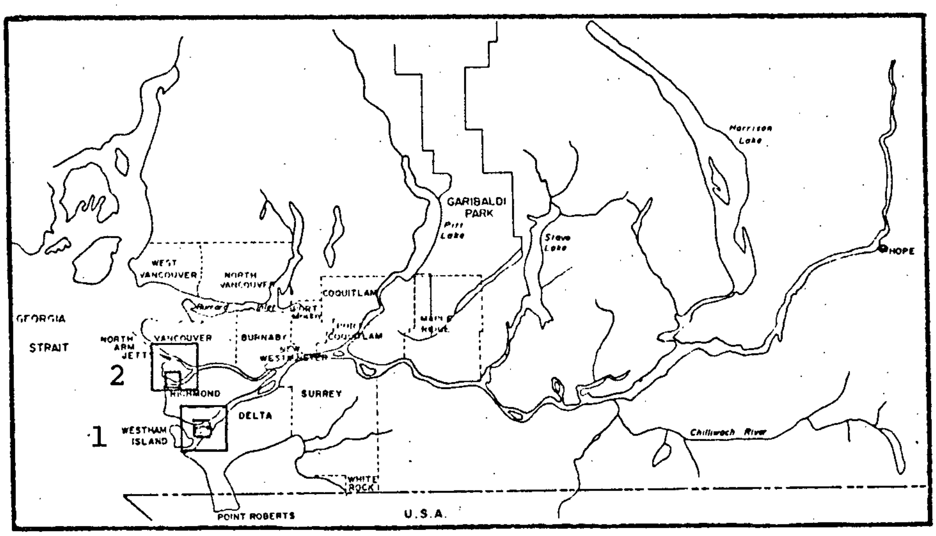


Figure 3 (b): The lower Fraser River system, including the South Arm marsh habitat (1) and the North Arm marsh habitat (2).
Scale: 1 cm = 14 km

small island (Swishwash Island) at the mouth of this arm. The vegetation on this island is composed of bulrush (*Scirpus americanus*) at the lowest levels, sedge (*Carex lyngbyei*) at intermediate levels, and cattail (*Typha latifolia*) at the higher points (Forbes, 1972).

Most of the habitat along the main banks of the North Arm is a modified slough habitat, having steeper banks on the north side due to the development of Vancouver International Airport, and steep rocky banks on the south side due to elaborate dyking by the Municipality of Richmond. The side channel habitat so prevalent in the South Arm has been virtually eliminated from the North Arm due to these developments.

C. Fraser River Discharge

The discharge of the Fraser River will have a measurable effect on the current speed and the river height in the estuary. Over the two seasons that the habitats were studied, the discharge of the river varied considerably (Figure 4). The total volume of discharge from mid March to mid August increased from 5.427 billion cubic meters in 1973 to 7.031 billion cubic meters in 1974, an increase of approximately 30% (Water Survey Canada). This discharge is measured at Hope, B.C., approximately 137 Km upstream from the mouth of the Fraser River.

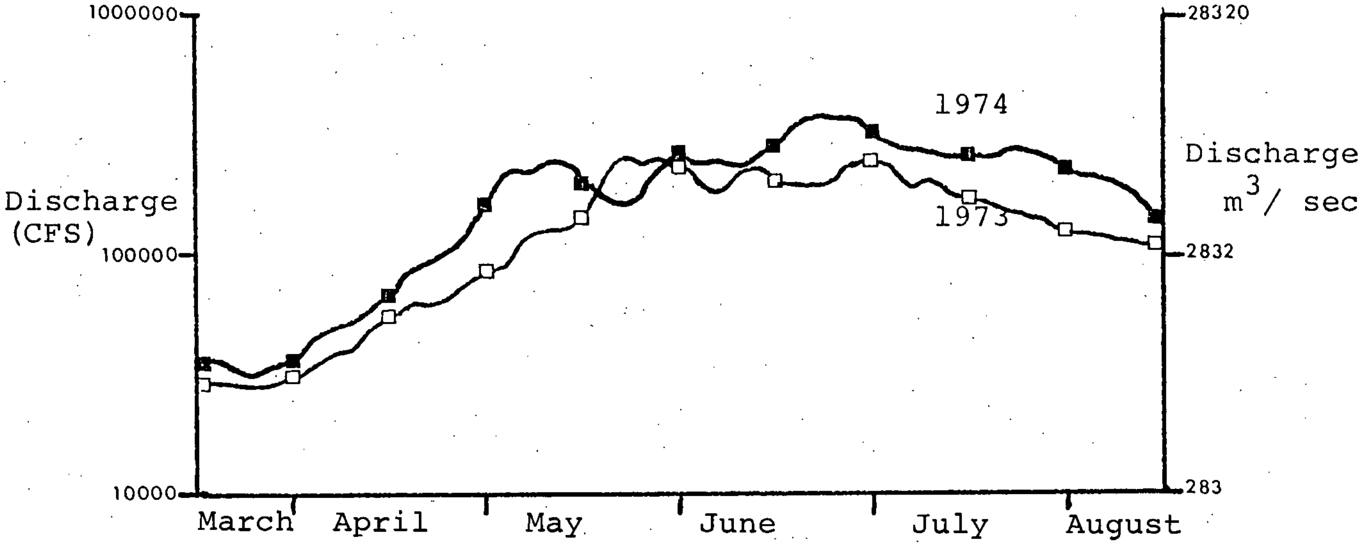


Figure 4: Daily discharge of Fraser River at Hope, from mid March to mid August, 1973 and 1974.

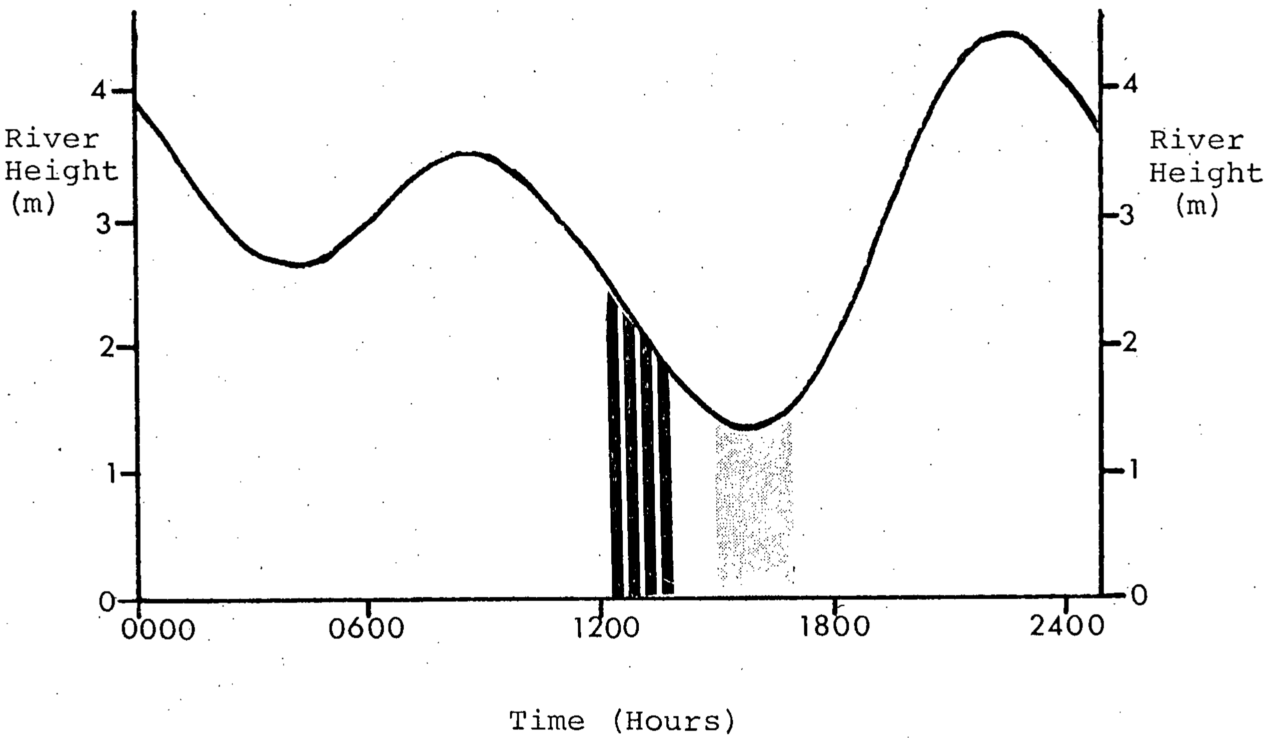


Figure 5: A typical biweekly tide cycle, measured at the mouth of the Fraser River (South Arm). Shaded areas indicate the timing of sampling in the slough (light area) and side channel (dark area) habitat.

MATERIALS AND METHODS

A. Slough Habitat

1. South Arm

Fish were collected at bi-weekly intervals from mid March until early August at six sites in the South Arm (Figure 1). The beach seine used for these collections was 14 m. long and 2 m. deep, having heavy lead line (3Kg/m) along the bottom. The stretched mesh size was 6 mm in the centre of the seine, and 12 mm in a 2.8 m. segment on both ends.

Beach seining was conducted within one hour of the low point of the bi-weekly tide cycle (Figure 5). The beach seine was set using a 5 m aluminum boat powered with a 10 h.p. motor, starting from shore and cutting a semicircle, returning to the same shore approximately 8 to 10 m. upstream. The approximate area covered by each beach seine was 30 m^2, and the maximum distance from shore seldom exceeded 2 meters.

The number of juvenile chum and chinook taken by beach seine are expressed in numbers per 100 m^2. Since six beach seines covered 187 m^2, the actual number caught are multiplied by a factor of 0.531 to make the estimate per 100 m^2. These estimates only refer to this marginal slough habitat, and cannot be extrapolated to the total wetted area.

Drift organisms were collected using a 0.5 m diameter tow net with a mesh size of 0.242 mm. Tows were made slightly upstream approximately 6 meters from the shore. The approximate volume of water filtered by the tow nets were 21.6 m^3 for the large net (0.5 m in diameter) and 5.0 m^3 for the small net (0.24 m in diameter). The organisms collected were preserved in 4% formalin.

2. North Arm

Five sites in the North Arm were used for beach seining at bi-weekly intervals from mid May until early August (Figure 3). The beach seine and technique was identical to that used in the South Arm slough habitat.

Drift organisms were collected in the North Arm, using the same tow nets employed in the South Arm slough habitat.

B. Side Channel Habitat

1. South Arm

Fish were collected from four stations in the South Arm at bi-weekly intervals, on the day before or the day after the slough habitat sampling (Figure 6). A pole net was used to catch the fish in the narrow side channels. This hand held device was constructed of two poles 1.8 meters in height, joined by a band of fine nylon mesh (3 mm stretched) 1 m wide and 1 m deep. The bottom edge of the netting was fitted with heavy

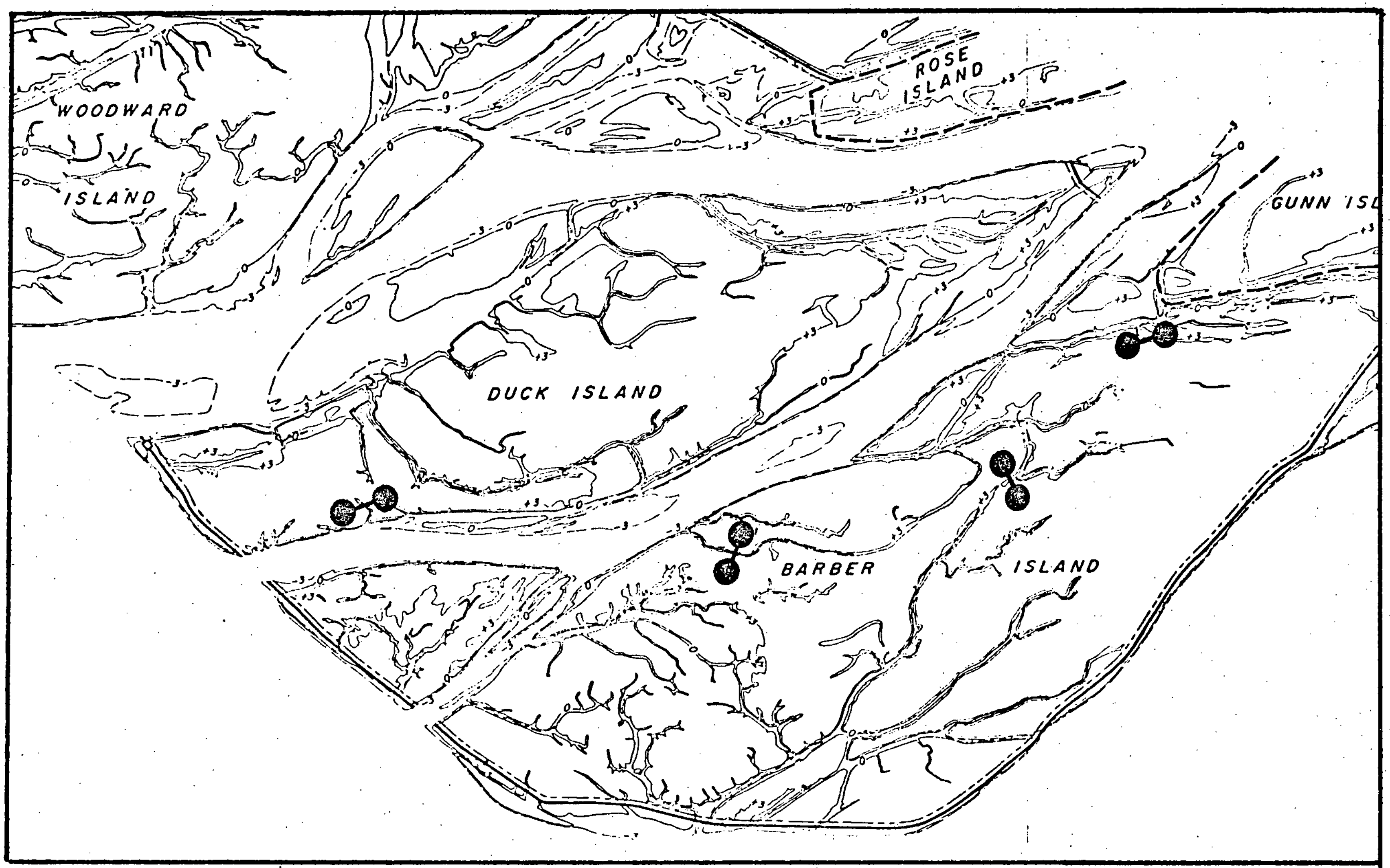


Figure 6: Four side channel habitat sites sampled by pole net in the South Arm of the Fraser River. Scale: 1 cm= 140 m (approximately)

lead line. The approximate distance sampled by pole nets at the four stations was 50 m, covering an area of about 37 m^2. The number of juvenile chum and chinook caught by pole net on each date are expressed in numbers per 100 m^2, by multiplying the actual number caught by 2.7.

Pole netting was conducted approximately two to three hours before low tide (Figure 5), when the water would be running out of the side channels. The upper reaches of many of these channels would be exposed at the lowest point in a tide cycle.

Drift organisms in the side channel habitat were collected with a nylon mesh (.242 mm) plankton net, 24 cm in diameter. The net was towed approximately 50 m for each sample, filtering 2.3 cubic meter m^3 of water. Samples were preserved in 4% formalin.

C. Physical Characteristics

Water temperatures were recorded at all sampling sites in both habitats to the nearest 0.5C°, using a mercury filled thermometer.

Light penetration was measured in slough habitat using a standard Secchi disc, held in the current by a meter stick.

D. Laboratory Methods

All fish were initially preserved in 10% formalin, and after two weeks transferred to 37% isopropyl alcohol. Fork length and maxillary length (length of upper jaw) were measured to the nearest 0.1 mm using dial calipers. Weights of fish and weights of the food bolus (stomach contents) were made to the nearest milligram using a Sauter Balance, Model 160/0.001.

Prey items in every stomach were identified and counted. The largest diameter of each prey type was measured, and the means of these dimensions were used to rank all prey items by size. A large number of each prey item were weighed, and a mean weight determined. The initial biomass was calculated by multiplying the number of each prey type by the mean weight of the prey (Jensen, 1974). Then a corrective factor was applied, by comparing the calculated total biomass of the food items in each stomach with the actual measured weight of the stomach contents. The calculated biomass for each prey category would be scaled up or down according to the difference between calculated biomass and measured biomass.

Drift organism samples were filtered, then thoroughly mixed in 100 ml of water before five one ml sub-samples were drawn. Each sub-sample was counted using a Sedgewick Rafter cell. The number of organisms per cubic meter of water were calculated.

E. Laboratory Feeding Experiments

The experimental apparatus was a closed system using Fraser River water taken near the sites of the fish collections. The turbidity of the water was maintained by the circulating pumps and agitation in the temperature control tank. Periodically, fine silt would be added to the system to maintain the light penetration to about 20 cm, as measured with a standard Secchi disc in the control tank. The water temperature was controlled between 10 and 11 degress centigrade using a small refrigeration unit in the control tank (Figure 7a).

Juvenile chum and chinook were collected in the field using a beach seine, and transported to the lab in large (100 liter) plastic containers. No mortality occurred during transport. Upon reaching the lab, the chum and chinook were poured into the holding tanks (Figure 7b) and kept for three days without food before testing.

The feeding aquaria were supplied with a controlled flow of water from the large observation tank (Figure 7c), and the input was allowed to overflow the aquaria into the surrounding water bath. An air stone was also placed in each aquarium to maintain the circulation and to maintain the dissolved oxygen at the saturation level. Aeration also occurred in the large holding tank, using two air stones in each tank.

The prey items were also maintained in aquaria in the laboratory. Chironomid larvae (genus Chironomus) and Neomysis were collected from the sites of fish collection in the Fraser Estuary. Some of the Daphnia used as prey species in the experiments were collected from channel habitat in the field, (Daphnia pulex- 1.2 mm), and a larger species of Daphnia (3 mm) was collected in small ponds on the University of British Columbia campus. The prey items were placed into the feeding aquaria approximately ten minutes before the addition of the

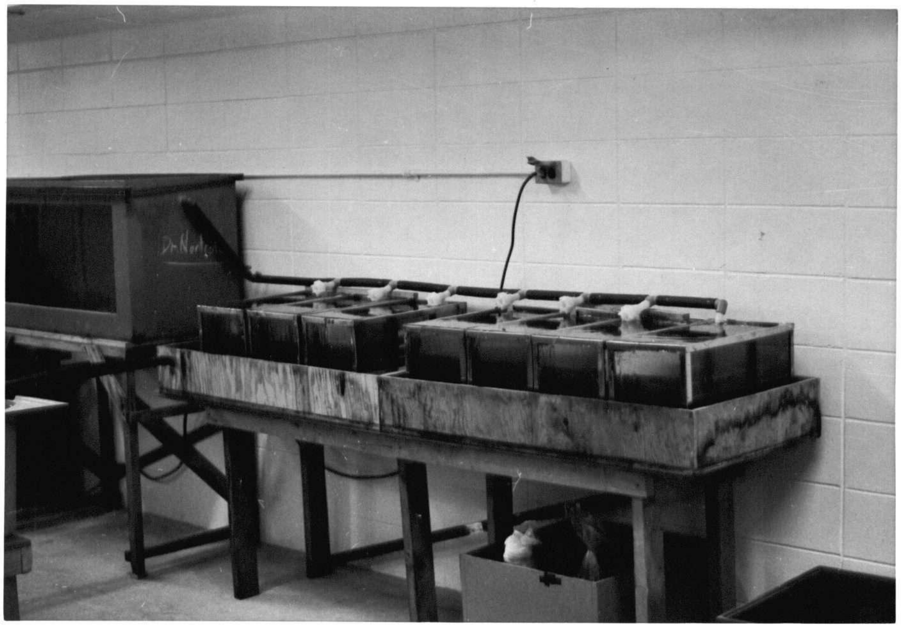


Figure 7 (a): Laboratory experimental apparatus, with temperature control tank on left.

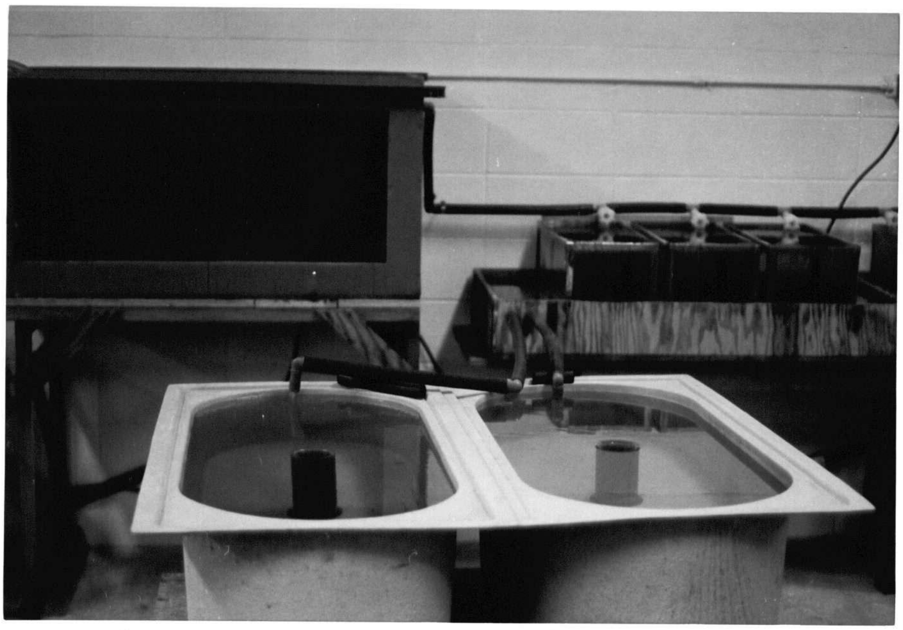


Figure 7 (b): Large holding tanks in foreground were used to maintain chum and chinook juveniles for three days, without food, prior to testing.

Figure 7 (c): Fish were transferred from large holding tank to seven small aquaria for feeding tests.

fish. The bottom of each aquarium was covered with a fine layer of silt (2 mm depth). Prior to the addition of the prey, the inflow of water was diverted directly into the surrounding water bath, to prevent the circulation of the chironomid larvae during the feeding.

Chinook and chum were transferred by dip net from the holding tank to the smaller testing tanks to commence each experiment. A fine mesh nylon screen was then placed over the top of each testing tank to prevent escape, and the predators and prey were left undisturbed for fifty minutes. At the end of this time period, the fish were caught with dip nets, anaesthetized using MS 222, and put into a 10% formalin solution for later stomach content analysis. The feeding tanks were then drained through a fine mesh screen to remove any remaining prey before the next test run.

RESULTS

A. Physical Characteristics

Water transparency was highly variable, dependent on the turbidity and mainstem river discharge. The transparency in the slough habitat and the side channel habitat was very similar. Transparency decreased markedly in early April, and remained quite low until mid July (Figure 8). This time period corresponds with the peak abundance of juvenile salmon in the Fraser estuary.

The mean water temperature in the slough habitat was quite consistent over two sampling seasons, increasing from about 5° C. in mid March to 13-14° C. in early July (Figure 9).

The mean water temperature in the side channel habitat varied from 0 - 2 Centigrade degreees warmer than the slough habitat, (Figure 9). The diel water temperature in a shallow side channel fluctuated greatly, with the highest temperature generally corresponding to the minimum water volume (at low tide). In June or July, side channel temperatures occasionally reached 18 - 20° C. Few salmon were taken at temperatures greater than 15° C. The only species present in side channels at these elevated temperatures were threespine stickleback and peamouth chub.

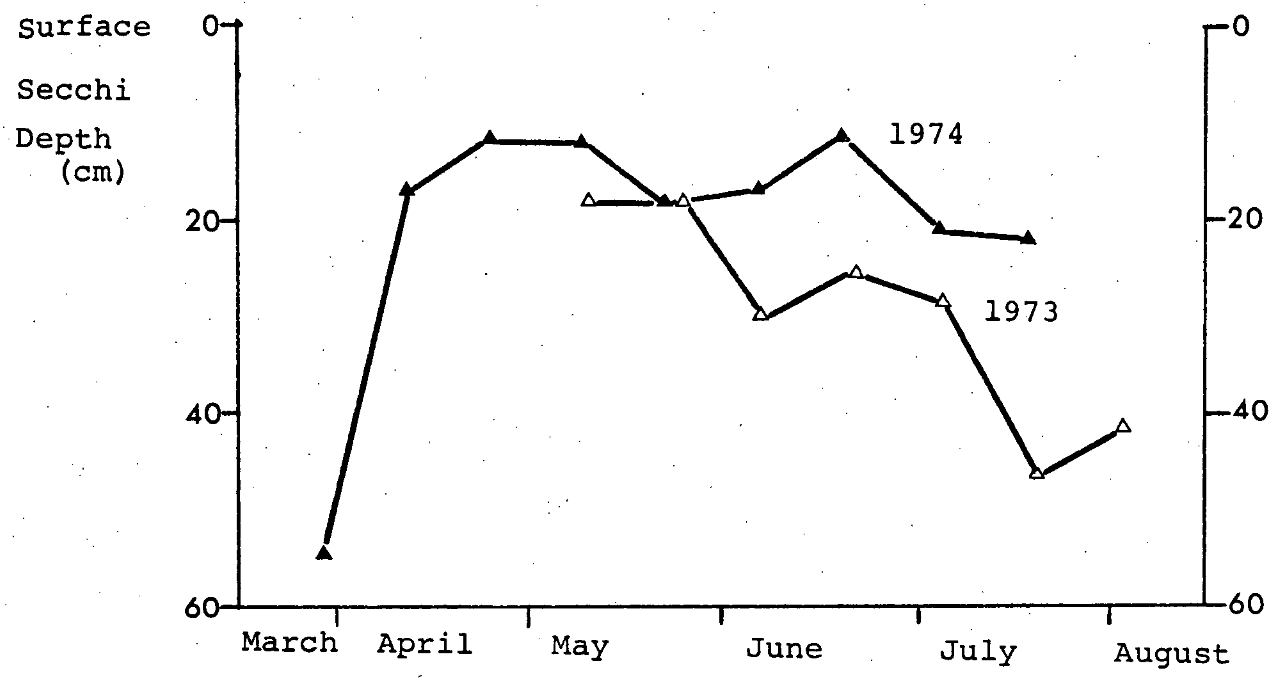


Figure 8: Seasonal changes in water transparency in slough habitat of the South Arm of the Fraser River.

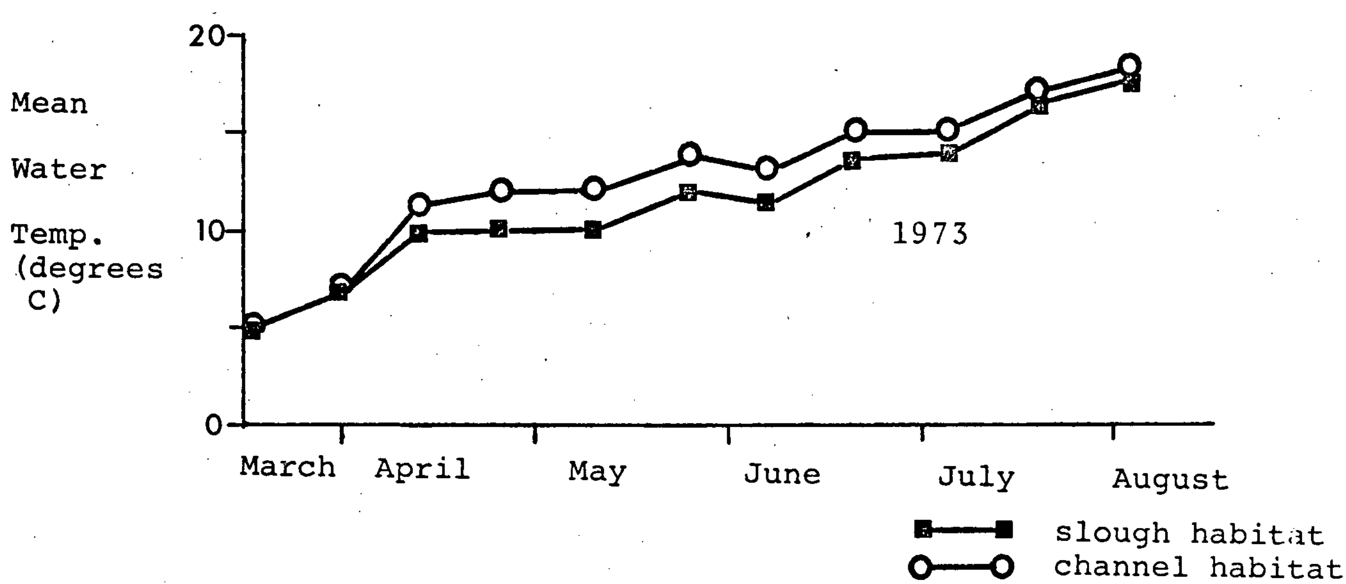


Figure 9: Seasonal changes in mean water temperature of slough habitat and side channel habitat.

B. Drift Organisms

1. Slough Habitat

Cyclopoid, calanoid, and harpacticoid copepods were the most frequent organisms present in plankton tows from the slough habitat in the South Arm (Table 1). Very few other organisms were present in the samples. Cyclopoid copepods reached a maximum density of 188 per cubic meter of water filtered in late April. The virtual absence of *Neomysis* from these surface samples taken in the main current, compared to the great numbers observed in every beach seine in the slough habitat, suggests a near shore, possibly benthic association of these opossum shrimp.

Copepods were also dominant in most plankton tows from slough habitat in the North Arm (Table 2). Eulachon larvae were very abundant ($56/m^3$) in the tows in late May. These larvae are carried by the current through the estuary in approximately a two week period in late May and early June. Oligochaetes, Nematodes, and the motile *Volvox* were represented in the samples from the slough habitat in the North Arm, but were not present in similar tows in the South Arm. The low density of drift organisms in the North Arm slough habitat is similar to densities observed in the South Arm (Table 1).

2. Side Channel Habitat

A greater diversity and greater density of organisms were

TABLE 1

Estimated number of drift organisms per cubic meter of surface water in slough habitat of the South Arm of the Fraser River.

	March 28[a]	April 24[a]	May 25[a]	June 8[a]	July 4[a]
Bosmina		4			4
Calanoid copepods	40	24		8	
Cyclopoid copepods	40	188	4	4	
Harpacticoid copepods	8	8	4		
Copepod nauplii	32		4		
Ostracods		12			
Neomysis		1			
Anisogammarus		4			
Corixids					4
Chironomid larvae					

a - samples collected using a nylon mesh tow net, 0.5 m in diameter, mesh size 0.32 mm.

TABLE 2

Estimated numbers of drift organisms per cubic meter of water in slough habitat of the North Arm of the Fraser River.

	b	a	a	a	b	a	a	a
	May 1	May 17	May 31	June 28	July 2	July 11	July 25	Aug. 2
Oligochaetes	2	2	2	5		1		
Nematodes	4							
Alona	2				8			
Daphnia	4					1	11	5
Bosmina					50			
Calanoid copepods	2		1	2	28	1	2	1
Cyclopoid copepods	10			1	74		4	3
Harpacticoid copepods	8							
Nauplii	2							
Leptodoridae								1
Rotifers					18			
Neomysis				1				
Anisogammarus		2		1				
Corophiam								
Chironomid larvae		1			1	1		
Eulachon larvae		1	56					
Volvox					1000			

a - taken by surface tow net, 0.5 m in diameter, 1973, mesh size 0.32 mm

b - taken by surface tow net, 0.24 m in diameter, 1974, mesh size 0.2 mm present in plankton tows in side channel habitat than in slough habitat (Table 3). Cyclopoid copepods and Daphnia pulex were the most abundant organisms, reaching densities of 322 and 870 animals/m^3 respectively. Harpacticoid copepods, calanoid copepods, and Bosmina were frequently present. Neomysis and chironomid larvae and pupae were only occasionally taken. The only organism more numerous in the slough habitat compared to the side channel habitat were calanoid copepods.

C. Temporal and Spatial Use

1. Slough habitat

Juvenile salmon were first taken in the slough habitat in mid to late March (Figure 10). Juvenile chum (*Oncorhynchus keta*) and juvenile chinook (*Oncorhynchus tshawytscha*) were the most abundant salmon in the slough habitat (Table A1, Appendix A).

In both years, the juvenile chum salmon preceded the juvenile chinook salmon into the area, and were initially more abundant. However, by late April, the chinook were much more numerous than the chum and were present in the area over a longer time period.

In 1973, the peak density for both species occurred in late April, after which time both species declined in abundance, the number of chum dropping off at a greater rate than chinook. By that time most of the chinook salmon smolts were taken. In 1974, a different pattern occurred. Since the sampling dates in 1974

TABLE 3

Estimated numbers of drift organisms per cubic meter of water in side channel habitat of the South Arm of the Fraser River.

	Mar. 28	April 11	April 24	May 8	May 22	June 19	July 4
Daphnia	4	26	13	148	70	113	870
Bosmina	4	9	17		9	52	
Calanoid copepods	9	17	4	4		9	17
Cyclopoid copepods	109	322	117	48	296	130	148
Harpacticoid copepods	1	43	65	4	26	4	17
Nauplii	2						
Rotifers							
Ostracods	4		160				
Neomysis		1		3	9		
Anisogammarus				4			
Collembola	4						
Ephemeroptera				2			
Chironomid larvae						4	
Chironomid pupae		4	3		11		1

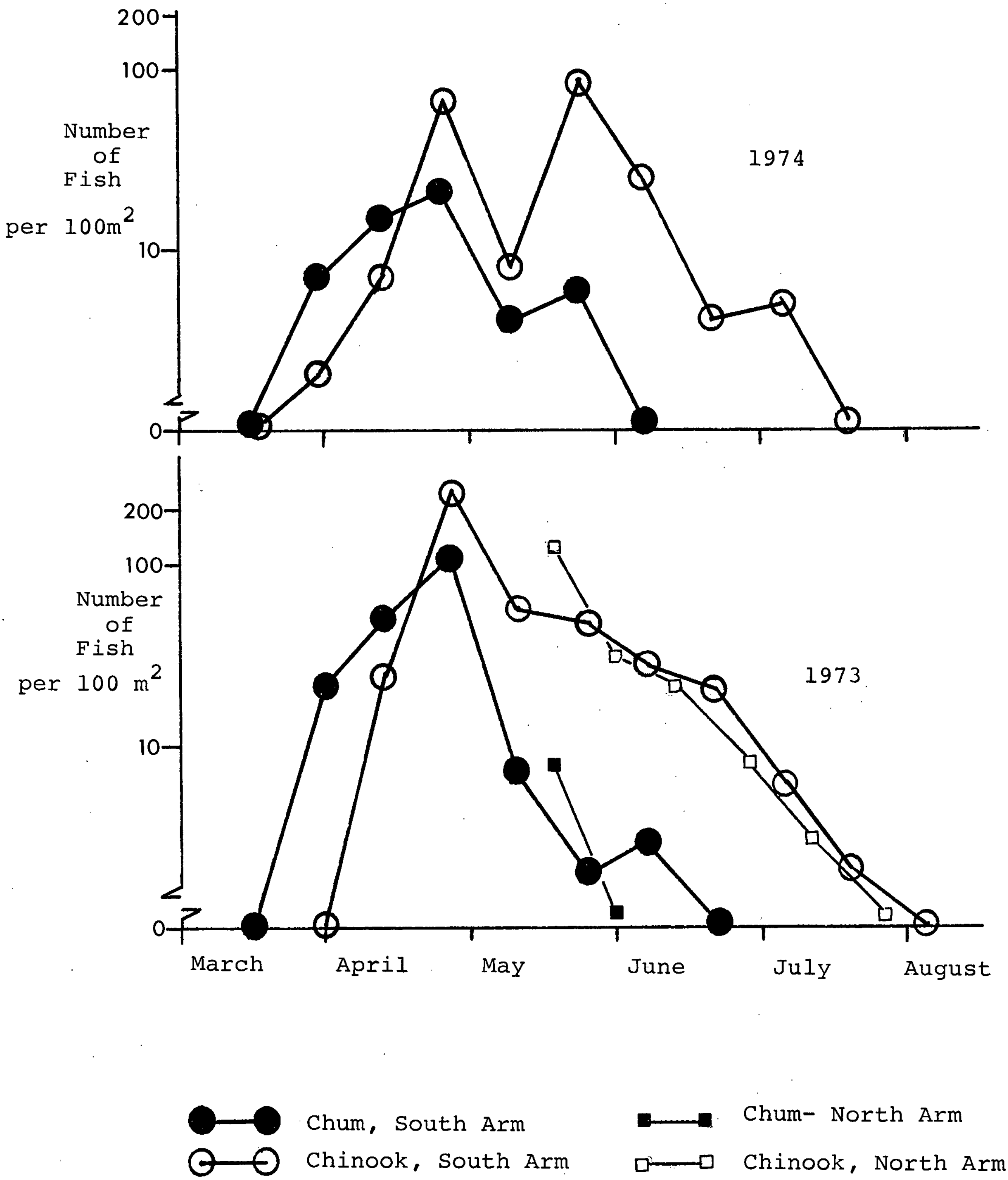


Figure 10: Seasonal change of density of juvenile chum and chinook salmon in slough habitat of the Fraser River Estuary.

were almost identical to those of 1973, it is reasonable to compare the density of fish taken on each date in each year. In 1974, the peak density of juvenile chum salmon again occurred in late April, but were only one fifth of the density of 1973. The juvenile chinook, however, exhibited a different pattern between the two years. In 1974, a bimodal peak in abundance occurred, the first peak in late April and the second in late May. Each of these peaks is about one third of the magnitude of the 1973 peak. It should be noted, however, than a thick layer of silt and fine detritus, freshly laid down by the river, made sampling very difficult in early May, and many fish were lost.

In 1974, the chinook salmon smolts (yearlings) exhibited a broader migration period through the study area and many remained in the area during June and July.

In the slough habitat of the North Arm, chum and chinook were also the most abundant juvenile salmon present (Table A2, Appendix A). The density of chum and chinook was very similar to the density observed in slough habitat of the South Arm over the same time period (Figure 10).

Relatively few juvenile sockeye salmon were taken in the slough habitat, but the individuals present are of interest. In 1973, 26 very small (mean length 28-31 mm) sockeye fry were taken from late May to mid June. Some of the fry had not yet fully absorbed their yolk sac, yet all had been feeding to some extent. These fry were taken only in slough habitat, on the South bank of the estuary. Two fry of the same type were also taken in the North Arm during the same time period. In 1974, three of these very small sockeye fry were taken in early June (Table A3, Appendix A).

Larger juvenile sockeye fry were also captured in slough habitat in 1973. These juveniles were of intermediate size (48-65 mm), and were taken from early July until the termination of sampling in early August.

Juvenile sockeye salmon smolts were present in slough habitat in late April and Early May, 1974 (Table A3, Appendix A). The mean length of eleven sockeye taken on these dates was 95.4 mm. An examination of the scales from these sockeye smolts indicated they were yearling smolts.

Only one coho juvenile was taken in slough habitat in 1973 and 1974. This single specimen, taken in the South Arm in late May, 1974, was 99.1 mm in fork length and weighed 11.25 grams. The coho smolts migrating through the estuary probably remain in deeper water, passing directly through the estuary to Sturgeon and Roberts Banks. Recent sampling at various sites on the Sturgeon and Roberts Banks indicate the coho may remain and feed in this area for several weeks (Anonymous, 1975).

Only three juvenile pink salmon were taken in slough habitat in 1974 (Table A3, Appendix A). Since pink fry migrate down the Fraser River at the same time as chum fry (Vernon, 1966), the utilization of slough habitat by this species appear negligible.

2. Side channel habitat

Juvenile chinook and chum were the only salmon taken in the side channel habitat (Table A4, Appendix A). The density of chum and chinook in this habitat corresponds fairly closely to the density observed in the slough habitat (Figure 11). In early April, the density of chum in the side channel habitat is greater than the density in the slough habitat. The reverse is true for the chinook. In late April, at peak densities, the chum and chinook are evenly distributed in both habitats. Throughout May, the density of both chum and chinook is greater in the slough habitat.

D. Estimation of the Total Seasonal Use of Marginal Habitats

An attempt was made to develop an "order of magnitude" approximation of the total number of juvenile chum and chinook utilizing the slough and side channel habitats of the Duck - Barber - Woodward Island complex. These estimates are based on the four beach seine and four pole net catches at bi-weekly intervals between Duck Island and Barber Island (Figure 6).

The area covered by four beach seines (125 m^2) was extrapolated to the total area of similar slough habitat available (76,128 m^2). This total area available was calculated by multiplying the total length of shoreline available (17,069 m) by the average maximum distance from shore (4.5 m) sampled by the beach seine. The estimated numbers of salmon for each sampling

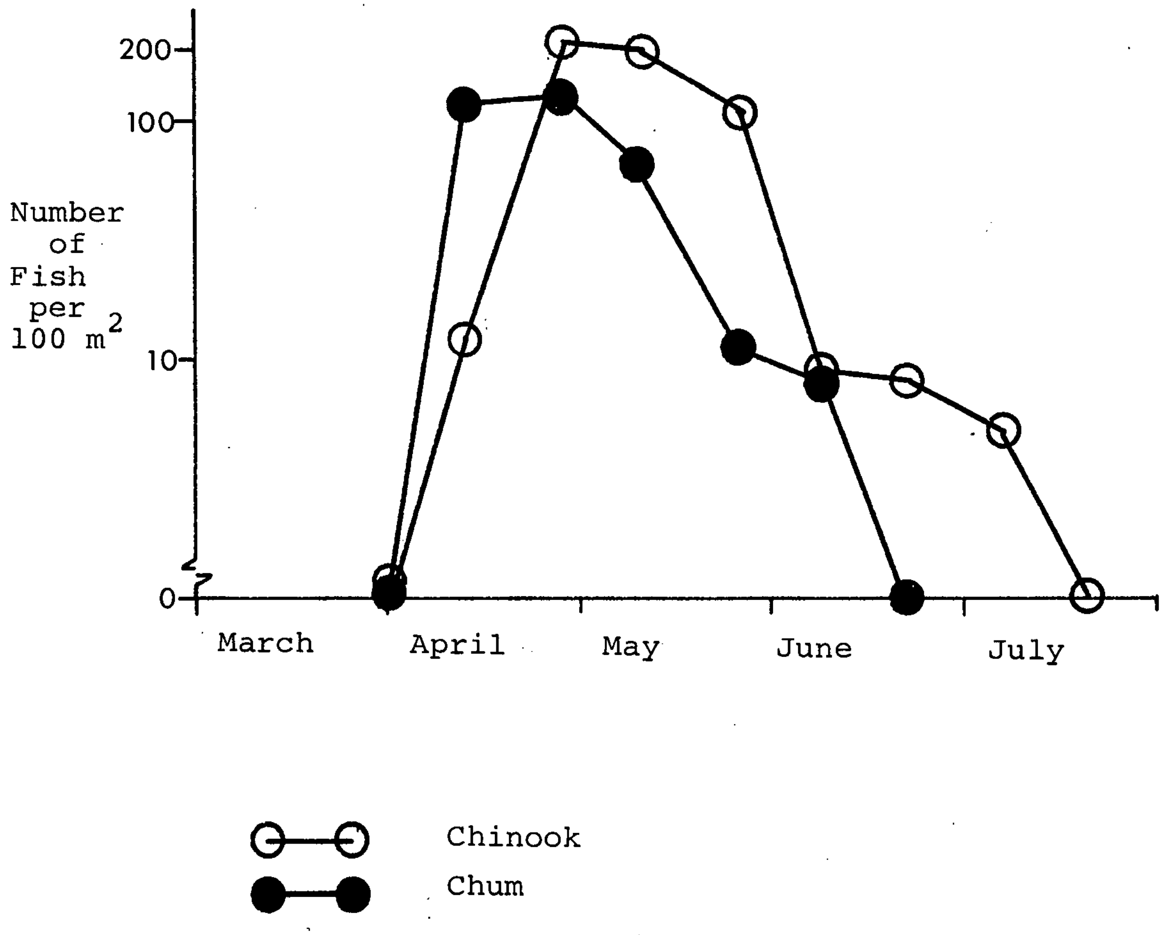


Figure 11: Seasonal change in density of juvenile chum and chinook salmon in side channel habitat of the Fraser River Estuary, 1973.

date (total number X 76,128/125) were then plotted over the whole time period. Assuming that the daily number of salmon passing through the habitat area between any two sampling dates is equal to the average number taken on those two dates, then the area under the plotted curve will yield an estimate of the total number of salmon utilizing the habitat (Table 4).

In the channel habitat, the estimated length of side channels sampled at four pole net sites was approximately 50 m. The total length of channel habitat available was 12,195 m (probably a low estimate). The number of juvenile salmon taken on each sampling date was multiplied by 244, and plotted over the whole time period. Using the same assumptions as the slough estimate, the area under the curve yields the total number of salmon utilizing the channel habitat. (Table 4).

These estimates indicate that a larger proportion of chinook salmon fry utilize these habitats than chum salmon fry. It is also apparent that in 1974 a lesser proportion of chum and chinook fry utilized the slough habitat than in 1973.

E. Seasonal changes in size of juvenile chum and chinook salmon

1. Fork length

The mean fork length of the chum salmon fry from their first arrival in March until late May remained between 37 and 38 mm, with a maximum standard deviation in any sample of 2.31 (Figure 12). The few chum taken after this date were larger (47 mm),

TABLE 4

A comparison of the total pink, chum, and chinook salmon fry migrating population in the Fraser River at Mission, with an estimate of the total numbers utilizing slough and side channel habitats of a marsh area.

1973	Chum	Chinook
Total Migrating Population[a]	109,477,344	13,500,390
Slough habitat estimate	1,900,000	2,600,000
Channel habitat estimate	412,000	732,000
TOTAL ESTIMATE	2,312,000	3,332,000
% of Total population	2.1%	24.6%
1974	**Chum**	**Chinook**
Total Migrating Population[a]	130,777,696	16,427,324
Slough habitat estimate	434,000	1,440,000
% of Total population	0.3%	8.8%

a - Fraser & Bailey, 1975

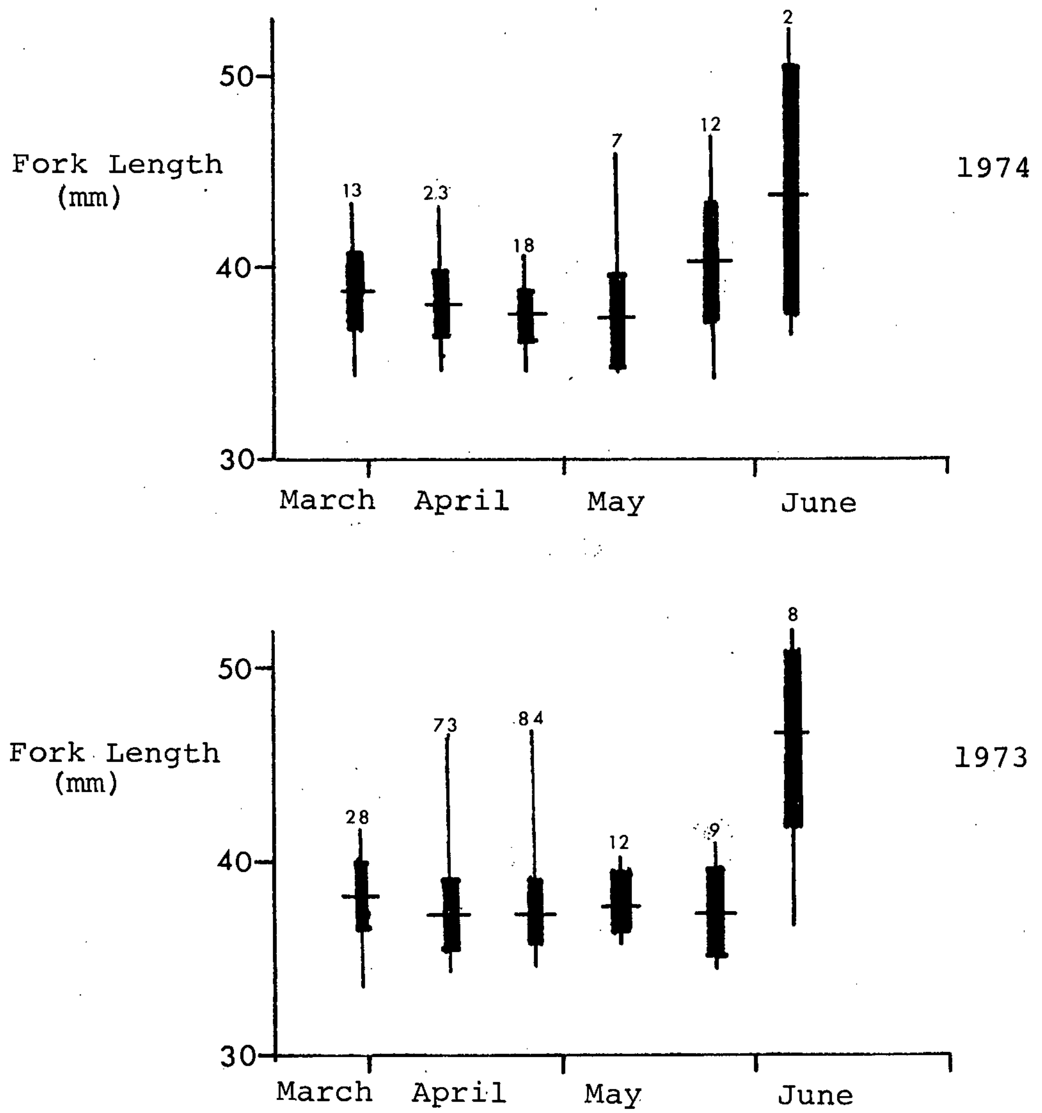
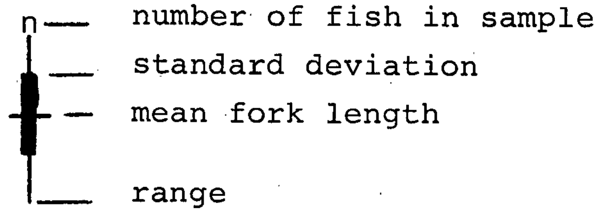


Figure 12: Seasonal change in length of juvenile chum salmon from combined slough and side channel habitat in the South Arm of the Fraser River.



indicating a small proportion of chum would delay their seaward migration to some extent, attaining a greater size before reaching salt water. The fact that there was no increase in length of the chum during the peak migration period (March 15 to May 31) sugggests that any delays in the estuary for feeding are very brief for the majority of the population. However, the feeding data will show that the marsh areas are utilized by the chum for feeding, rather than strictly used for migratory passage.

The mean fork lengths of both chum and chinook fry from slough and channel habitats were identical, and both habitats have been combined for analysis.

The mean fork length of the juvenile chinook salmon in 1973 remained between 39 and 40 mm throughout the April sampling dates (Figure 13). After this point, the mean length increased steadily until the chinook migrated out of the estuary. Two individuals taken on July 18 were greater than 80 mm in length, indicating a doubling of size over a three month period.

Since the downstream migration of juvenile chinook in the Fraser River, as determined at Mission, terminates about the beginning of June (Todd, 1966), it is clear that the juvenile chinook salmon delay their seaward migration in the Fraser River Estuary. It is also evident from Figure 13, that they experience a rapid growth rate during residence there. The relationship between estuarine residence and early marine survival is an important, but as yet unknown factor.

In 1974, the initial mean length of the chinook juveniles (41-42 mm) in April was slightly greater than that observed in

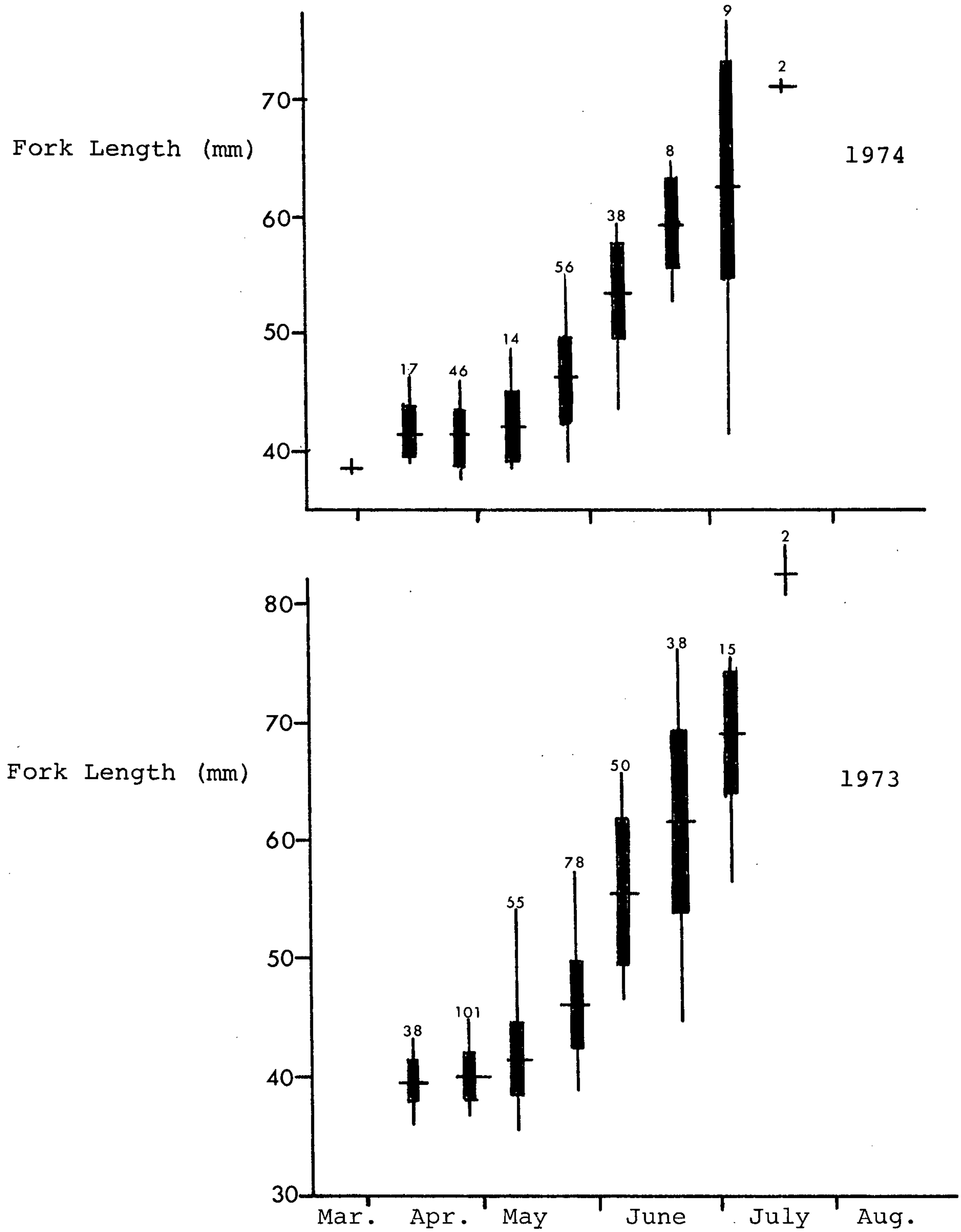
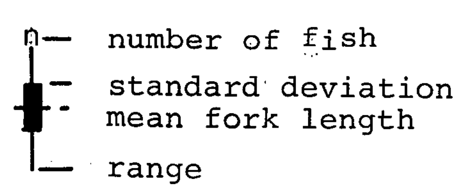


Figure 13: Seasonal change in length of juvenile chinook salmon from combined slough and side channel habitats in the South Arm of the Fraser River.



1973 (Figure 13). A rapid growth rate was also observed in 1974, although the increases were not as dramatic as 1973. In spite of the initial larger size of the juvenile chinook in 1974, the final lengths and weights attained were below those reached in 1973.

2. Mouth Size

Juvenile chinook had a significantly larger mouth (premaxillary length) than juvenile chum of the same fork length (Figure 14). The premaxillary length of chinook 40 mm in fork length was approximately 20% larger than that of a 40 mm chum. The size of food items consumed by these two species may be segregated by their different mouth sizes.

F. Food and Feeding

Thirteen food categories (prey items) were most frequently found in the stomachs of juvenile chinook and chum salmon (Table 5). The prey ranged in size from 0.3 mm in mean width (Harpacticoid copepods) to 1.9 mm (*Neomysis*). The measurements of prey listed are from the stomachs of juvenile salmon, rather than from prey available. A much greater size range of prey occurred in the stomachs of other species, such as starry flounder and prickly sculpin. The code numbers assigned to each prey type (Table 5) will be referred to in all following figures.

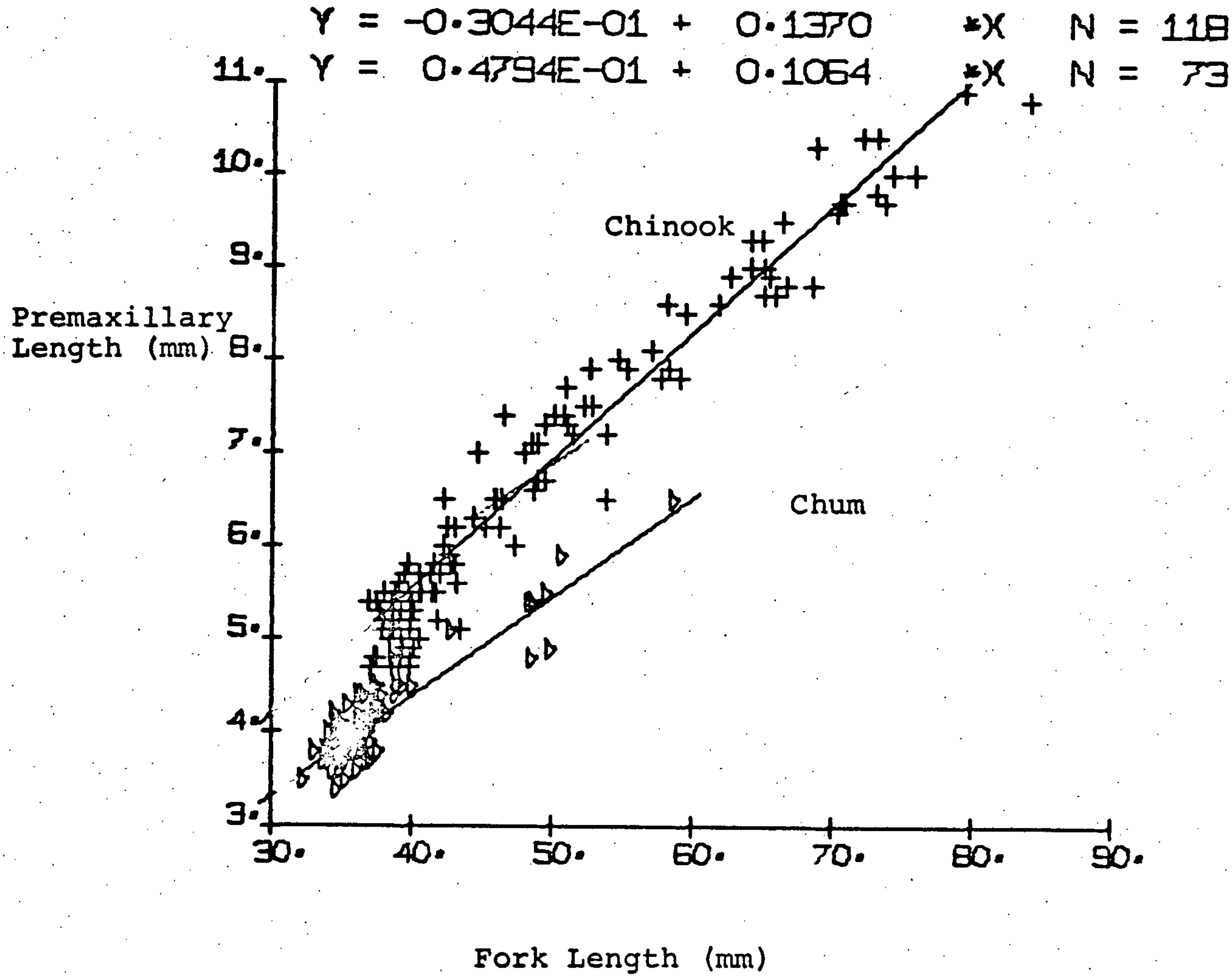


Figure 14: Change of mouth size (premaxillary length) with body size (fork length) of juvenile chum and chinook salmon.

TABLE 5

Size of common prey items found in the stomachs of Juvenile Chum and Chinook from both Slough and Channel Habitats.

Code	Prey Items	mm Mean Width	mm Range	Sample Size
1	Copepoda	0.3	0.2-0.4	50
2	Cladocera	0.5	0.4-0.8	50
3	Collembola	0.6	0.4-0.8	25
4	Chironomid larvae	0.7	0.5-0.8	25
5	Chironomid pupae	0.9	0.8-1.0	25
6	Adult Diptera	1.1	0.9-1.3	25
7	Homoptera[a]	1.2	0.9-1.6	25
8	Ephemeroptera & Plecoptera	1.4	1.1-1.7	15
9	Eulachon larvae	1.4	1.0-1.5	50
10	Anisogammarus	1.5	0.9-1.8	25
11	Corophium	1.6	1.0-2.0	25
12	Tabanid larvae	1.7	1.4-2.2	15
13	Neomysis	1.9	1.2-2.5	25

a - This category includes about 5% of other terrestrial insects.

1. Slough Habitat

In late March 1973, the predominant organisms consumed by chum were chironomid pupae (65%), the amphipods *Anisogammarus* (20%), and *Corophium spinicorne* (10%), the opossum shrimp *Neomysis* (9.5%), and chironomid larvae (7%) (Figure 15). These chum salmon were feeding without the influence of juvenile chinook salmon in the area, and this is reflected in the composition of their diet. Two weeks later, as indicated below, a proportion of their diet had shifted to the smaller prey items.

In late March 1974, the few chum and chinook present were both feeding heavily on Chironomid pupae and a *Anisogammarus*. Under these conditions of low density, there seemed to be a merging of both diets to the same prey types.

By early April, a slightly different pattern of prey selection was evident (Figure 15). Both species utilized Chironomid pupae and Amphipods (*Anisogammarus* and *Corophium*) as common food sources, but the chum consumed greater amounts of prey smaller than chironomid pupae (Copepoda and Cladocera), while the chinook consumed greater amounts of larger prey (tabanid larvae and *Neomysis*).

Cladocera (primarily *Daphnia pulex*) became very important components of both chum and chinook diets by late April (Figure 16). The chum consumed proportionately more *Daphnia* than the chinook, and the remainder of the diet was composed principally of copepods and chironomid pupae. The chinook, in addition to Cladocera, consumed more of the larger prey such

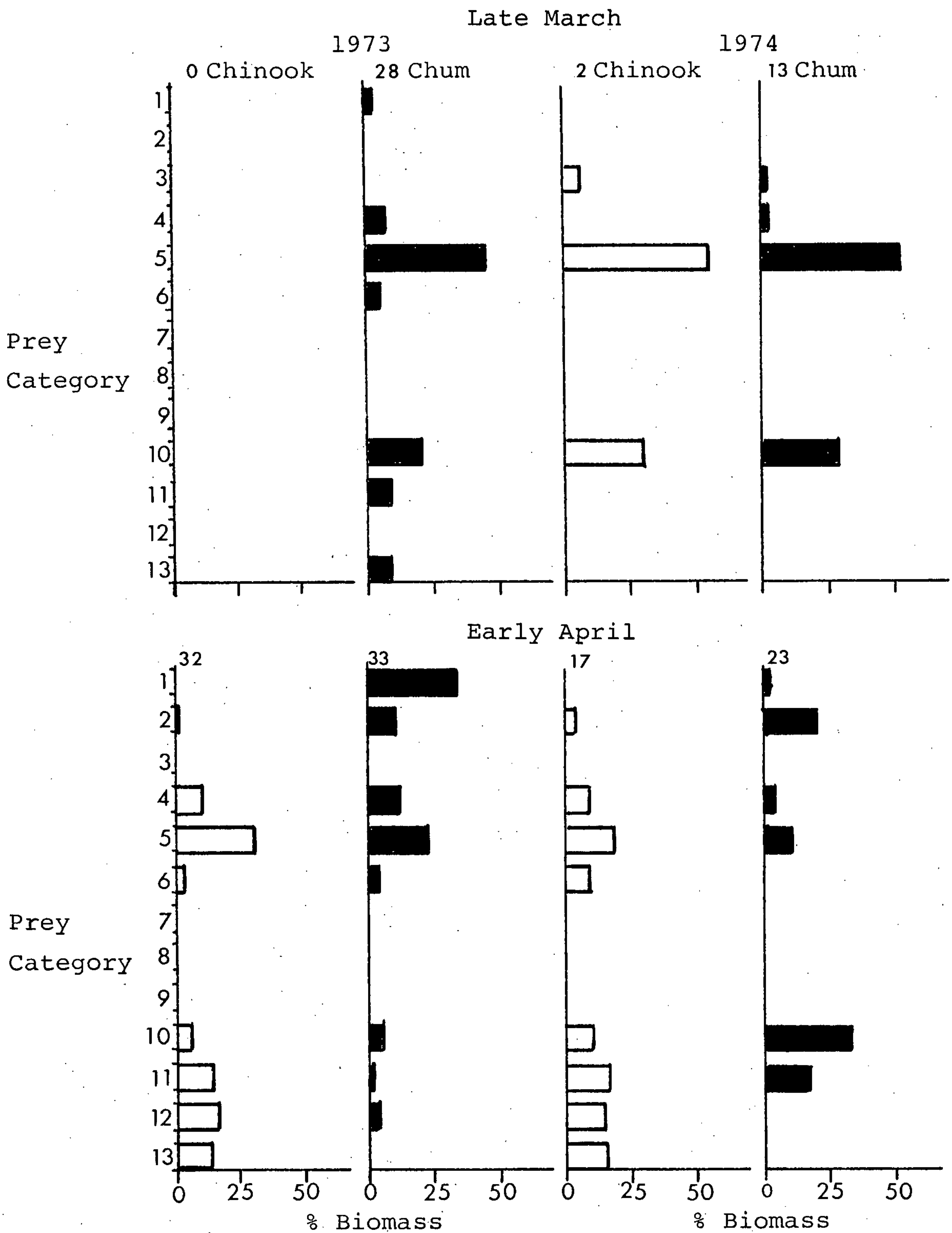


Figure 15: Percentage biomass of major food categories of juvenile chinook and chum salmon in slough habitat late March and early April, 1973 and 1974.

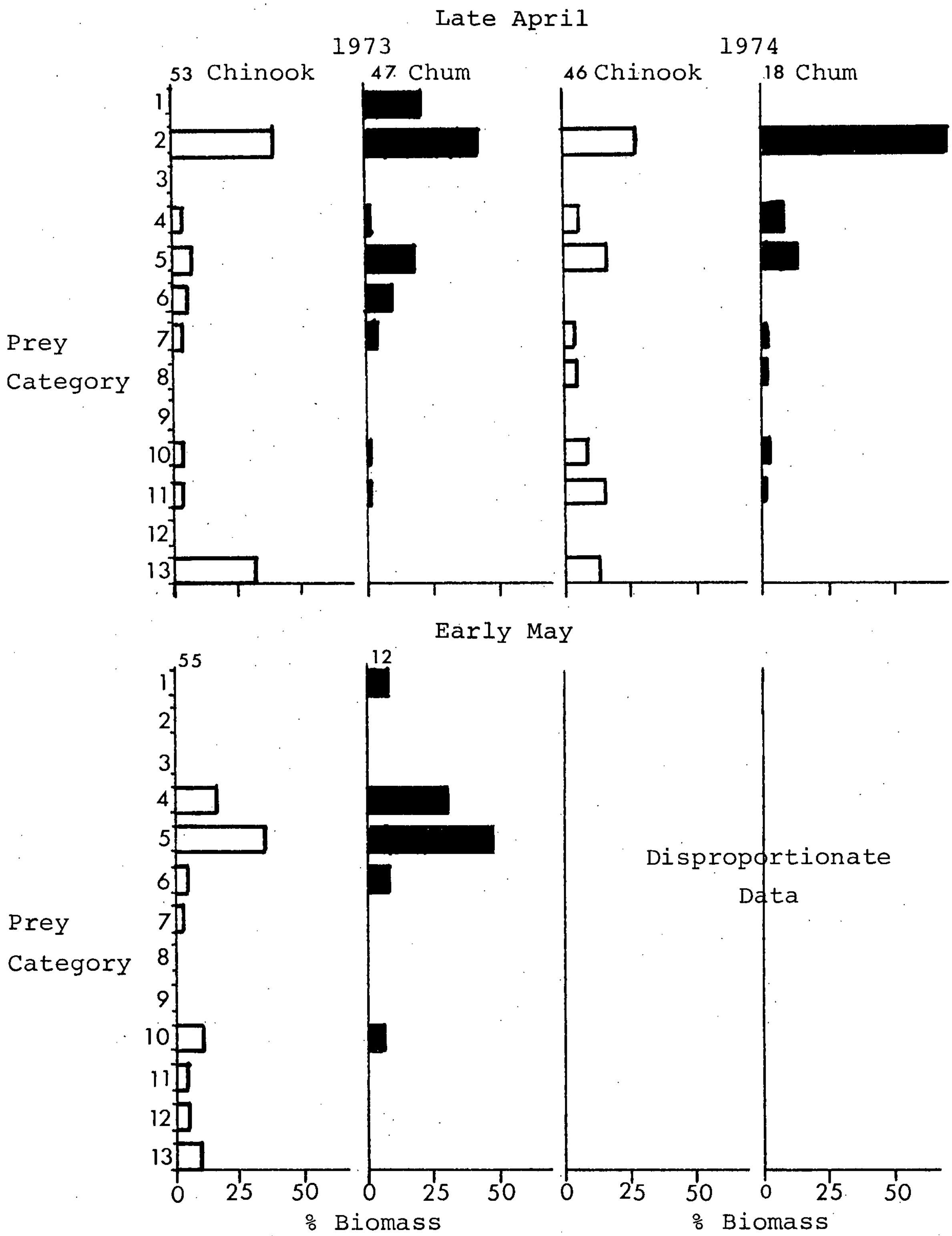


Figure 16: Percentage biomass of major food categories in the stomachs of juvenile chum and chinook salmon in the slough habitat in late April, early May, 1973 and 1974.

as *Anisogammarus*, *Corophium*, and *Neomysis*.

In early May, chironomid larvae and pupae formed the dominant portion by biomass of both chum and chinook diets. The chum consumed proportionately more of these insects, with the remainder of the biomass consisting of copepods and terrestrial insects. The chinook, however, preyed upon larger organisms as well, with *Anisogammarus*, *Corophium*, tabanid larvae, and *Neomysis* forming about 30% of the stomach content biomass.

The stomach contents of the chum and chinook taken in late May (Figure 17) were similar to those of early May. Greater than 70% of the food biomass of the chum consisted of chironomid larvae and pupae, with the remainder made up of larger prey items such as terrestrial insects, Ephemeroptera and Amphipoda. Approximately forty per cent of the chinook stomach content biomass was composed of the chironomid larvae and pupae, with more than fifty per cent of the remainder made up of larger prey. Terrestrial insects, specifically the family Homoptera, became an important component of the diet (> 39%) and were common in all stomachs. These insects are probably washed off the lush emergent vegetation of the marsh on the rising tide and then are concentrated in the sloughs as the tide ebbs.

A comparison of the biomass of food categories present in the stomachs of chum and chinook from late May until early August indicates an increasing similarity in the diets. (Figure 17). The density of both species, especially the chum, has been much reduced by this time.

The results of the examination of chinook stomachs after

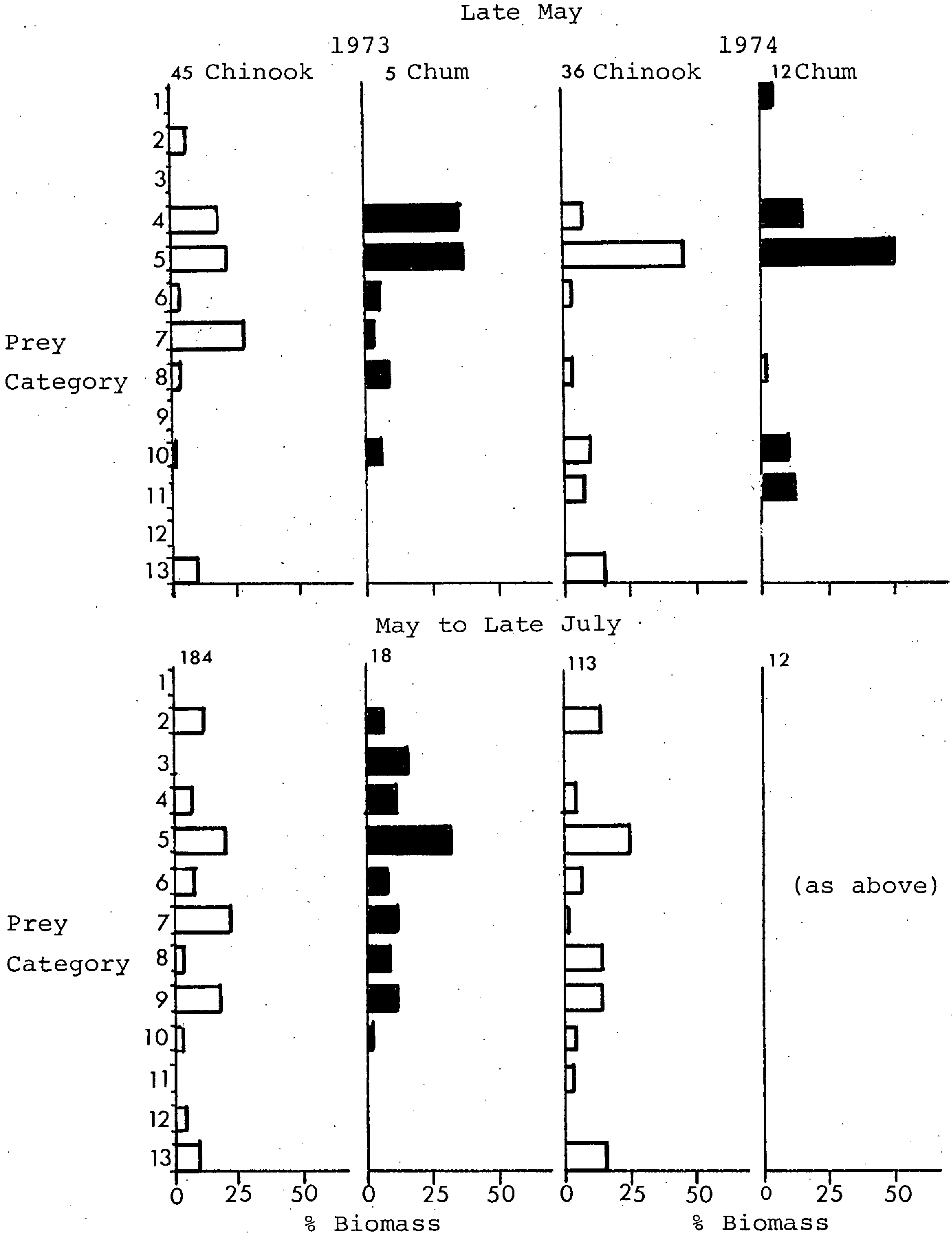


Figure 17: Percentage biomass of stomach contents of juvenile chum and chinook in slough habitat, late May and from May to late July.

late May suggests the lack of dominance of a single food category. On any given sampling date, a single food category could predominate in the stomach content biomass, but over an extended period of time (8 weeks), this dominance could be reduced due to the increasing availability of other prey items. For example, many chinook juveniles taken in July fed exclusively on eulachon larvae. These larvae were only available for about a two week period, and chinook taken before and after this time contained no larvae. Chironomid pupae were the most consistent prey source available to the chinook, forming about 25% of the consumed biomass. Other planktonic prey commonly taken were *Daphnia* and eulachon larvae. The semi-planktonic opossum shrimp *Neomysis* also formed an important component of the diet, together with several benthic invertebrates, such as the nymphs of Ephemeroptera and Plecoptera, the amphipods *Anisogammarus* and *Corophium*, and chironomid larvae.

Fourteen chum salmon juveniles examined from mid May in the slough habitat of the North Arm relied heavily on *Anisogammarus* as a food source (Figure 18). These amphipods formed more than 70% of the food biomass. The next most common food category was chironomid pupae, forming 14% of the biomass.

The juvenile chinook in the North Arm exploited a wider variety of prey types, with *Neomysis*, *Anisogammarus*, and chironomid pupae forming about 60% of the biomass, (Figure 18). The chinook of the North Arm consumed greater proportions of *Neomysis* and amphipods than the chinook in the South Arm (Figure 20). They also consumed less *Daphnia*. A comparison of

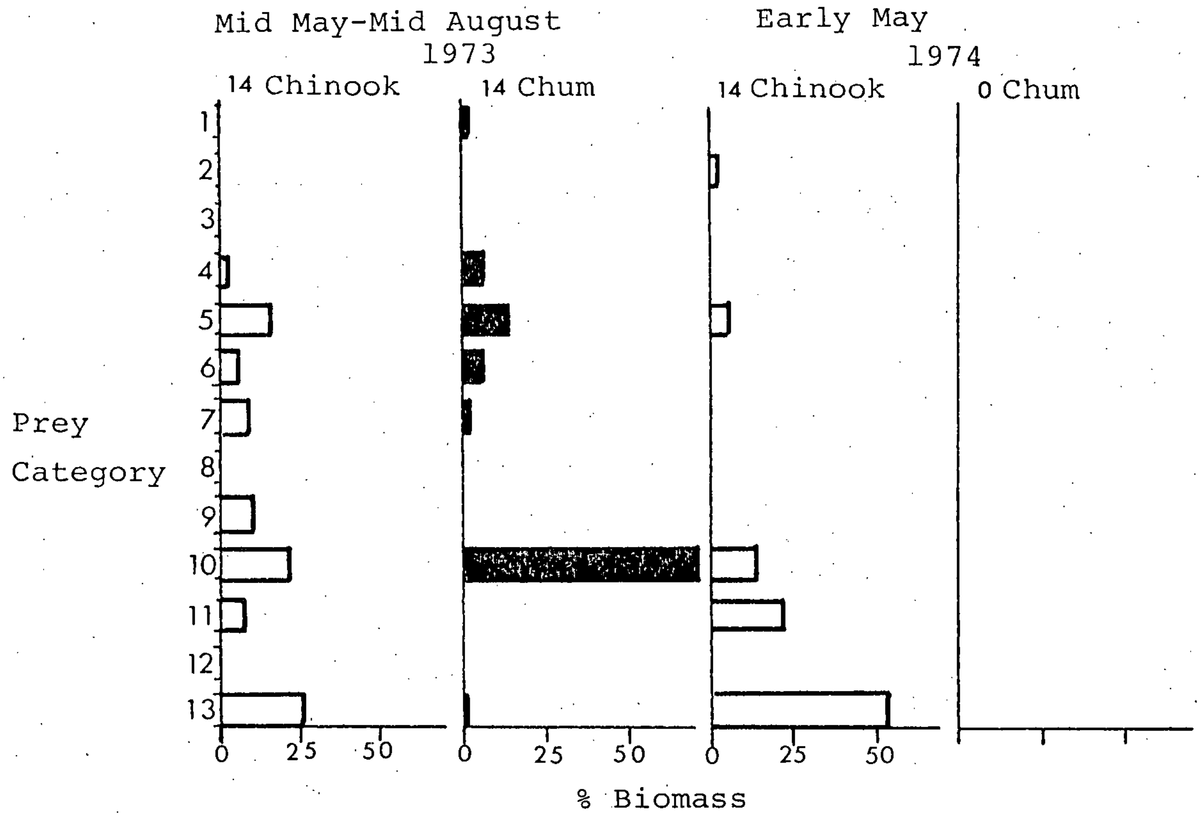


Figure 18: Percentage biomass of major food categories in the stomachs of juvenile chinook and chum salmon in slough habitat of the North Arm, Fraser River.

chinook of the North Arm with the chinook of the South Arm suggests that a greater array of prey types may be available to the chinook in the slough habitat of the South Arm.

2. Side Channel Habitat

Chironomid pupae formed over 60% of the stomach content biomass of chinook fry and over 40% of the stomach content biomass of chum fry in side channel habitat in early April (Figure 19). Most of the remainder of the chum diet was composed of harpacticoid copepods, whereas the chinook utilized chironomid larvae, and larger insects such as Hemiptera and Coleoptera.

Harpacticoid copepods, were dominant in the diet of the chum in channel habitat in late April, forming approximately 70% of the biomass (Figure 19). The remainder of the prey consumed consisted of Collembola, chironomid larvae and pupae, and terrestrial insects. The chinook consumed less copepods (16%), a greater proportion of chironomid pupae, terrestrial insects and amphipods, plus a large proportion (33%) of *Neomysis*. *Daphnia* were not present in the channel habitat sampled.

In late May, Collembola were an important component in the diet, forming about forty per cent of the chum stomach content biomass, and 13% of the chinook prey biomass. This small, semi-aquatic insect is restricted to the still backwaters where it hops about on the surface, clinging to debris or overhanging vegetation. Adult Diptera and other terrestrial insects (Homo-

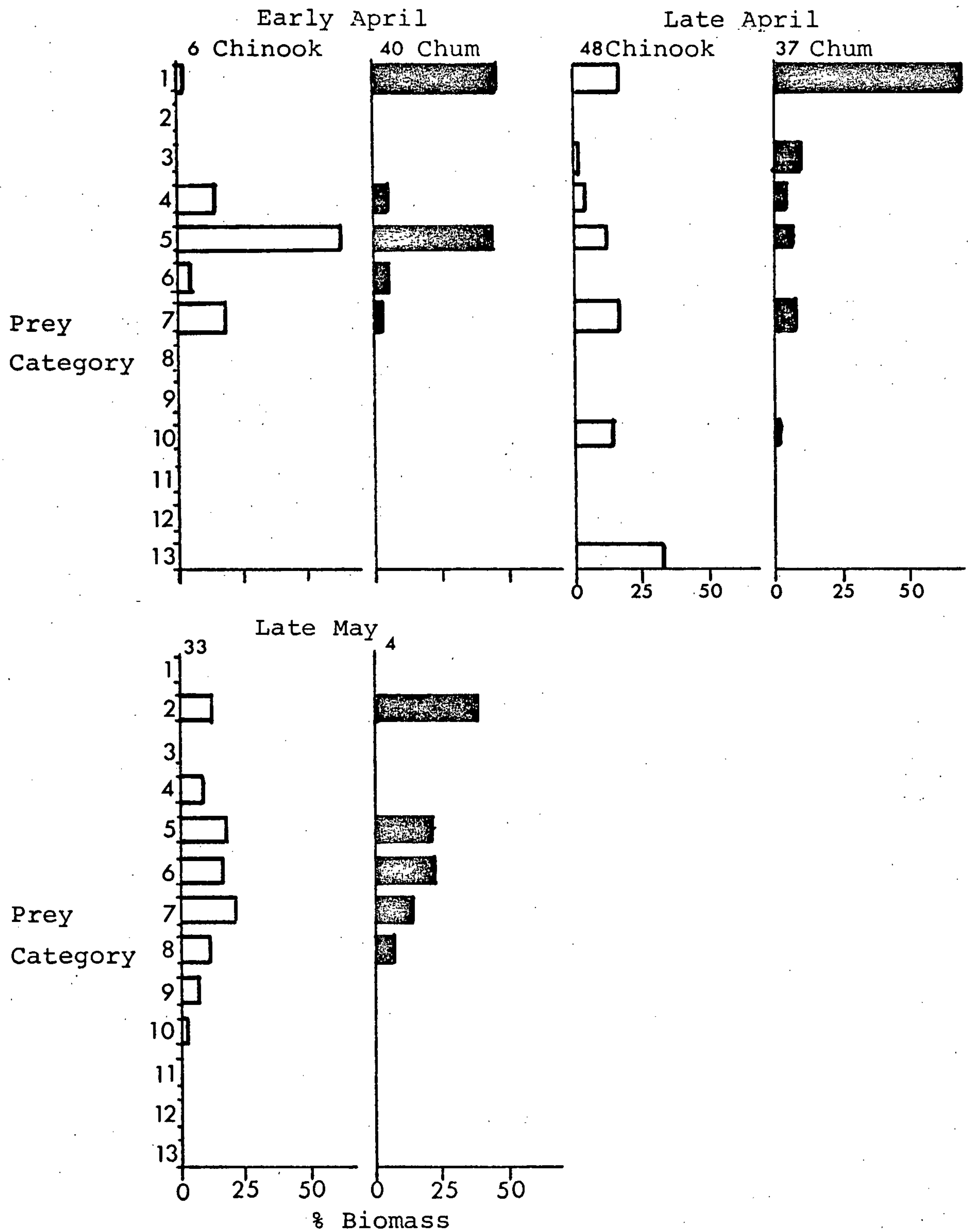


Figure 19: Percentage biomass of food categories occurring in the stomachs of chum and chinook in channel habitat, South Arm, 1973.

optera) were also important in the diet of both the chum and chinook. The chinook were also able to utilize the larger lepidopteran and coleopteran larvae, amphipods, and small fishes (eg. young *Gasterosteus*).

3. Similarity of diets of Chum and Chinook fry

The similarity of the diets of chum and chinook from slough and channel habitat were calculated, using the Spearman rank correlation coefficient (Table 6). The t value for this statistic was calculated and tested for significance. Only on one occasion (late March, 1974) was the test significant, indicating the independence of the diets on all other sampling dates.

4. Chinook smolts (yearlings)

In late April, chinook salmon smolts preyed heavily on the *Daphnia* in the slough adjacent to beach seine sites 6 and 7. The remainder of their diet (22%) was composed almost entirely of chum salmon fry (Figure 20). No chinook salmon fry were observed in the stomachs of the chinook salmon smolts, and it is possible that their slightly larger size could remove them from the size range open to predation by chinook smolts.

In late April 1974, chinook smolts also utilized *Daphnia*, but their principle prey was other juvenile salmon, primarily

TABLE 6

The Spearman rank correlation coefficients and t values, comparing the diet of chum and chinook fry on occasions when both were present in the same habitat.

Slough Habitat

	1973		1974	
Date	Correlation Coefficient	t value	Correlation Coefficient	t value
Late March			0.8303	4.214*
Early April	.1305	.437	0.0030	.009
Late April	.1923	.650	.5667	1.820
Early May	.3319	1.219	.4382	1.824
Late May	.1888	.608		
Early June	.4167	1.213		
	North Arm			
Mid May	.2381	.600		
	Side Channel Habitat, 1973			
Early April	.2440	.616		
Late April	.2473	.846		
Late May	.6000	2.121		

*significant at .05 level

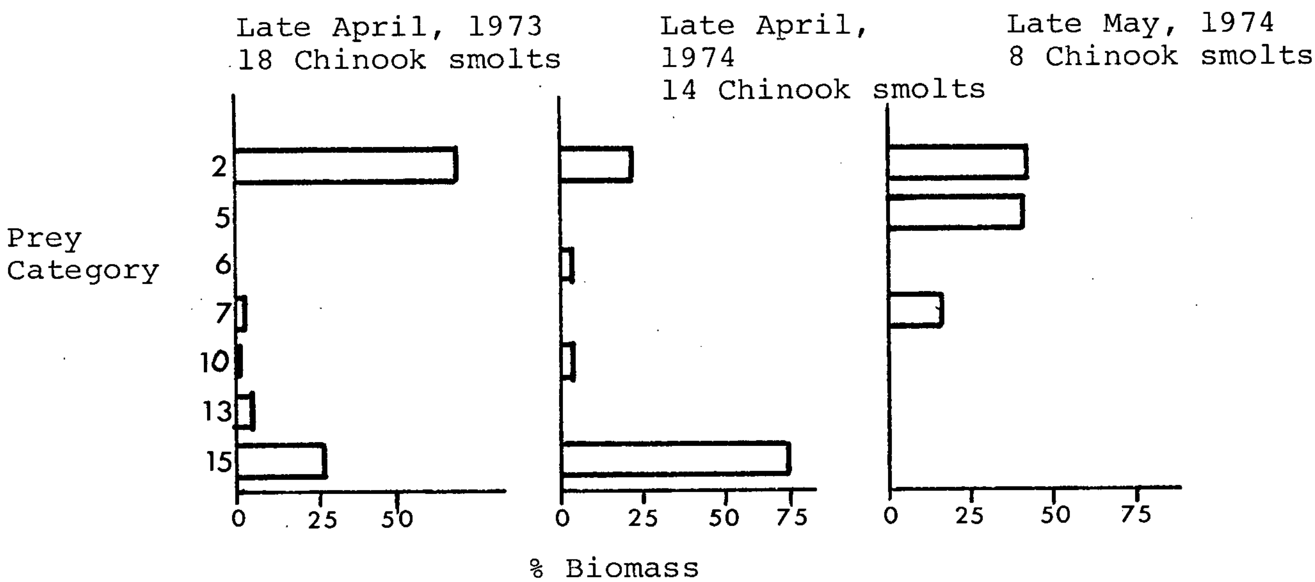


Figure 20: Percentage biomass of stomach contents of chinook salmon smolts in slough habitat, in the South Arm of the Fraser River. Prey Category 15: chum salmon fry.

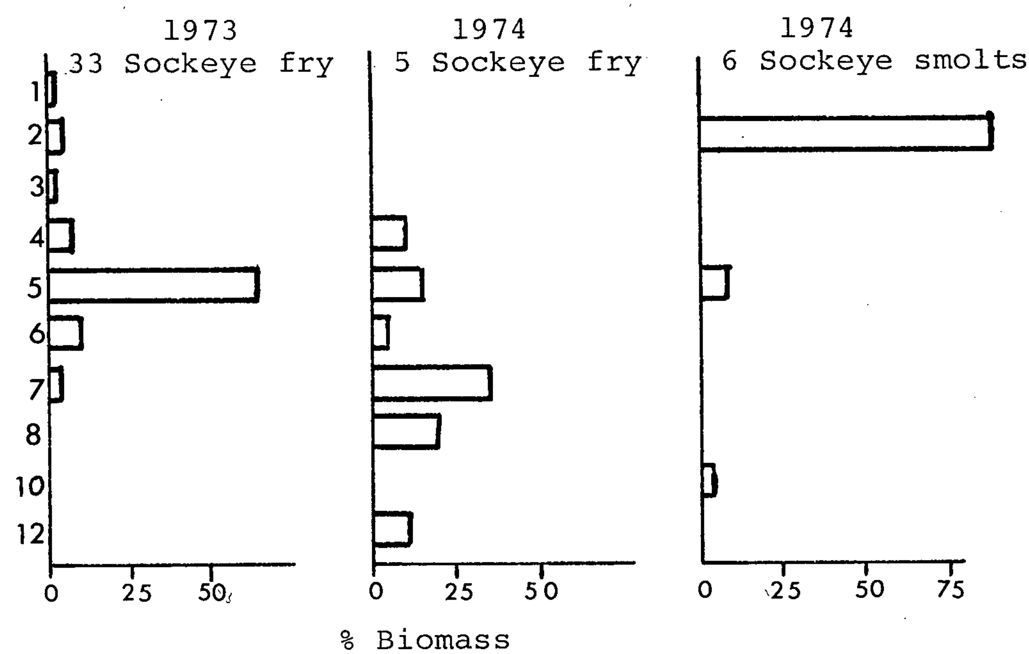


Figure 21: Percentage biomass of stomach contents of juvenile sockeye salmon in slough habitat, South Arm, Fraser River.

chum salmon fry. These salmon fry comprised about 65% of the biomass of the smolt diet (Figure 21). Eight chinook smolts captured in late May consumed primarily planktonic prey such as Daphnia and chironomid pupae (Figure 21). The most obvious difference in the diet of these chinook smolts is the absence of juvenile chum salmon, which comprised over 60% of the stomach content biomass before this date.

This is due to the emigration of the chum fry out of the estuary.

5. Juvenile Sockeye salmon

Chironomid pupae were the dominant food source of thirty-three sockeye salmon fry taken in slough habitat in 1973. These formed approximately 65% of the prey biomass consumed (Figure 20). Other surface or planktonic invertebrates taken were adult Diptera, Collembola, terrestrial insects (Homoptera), Cladocera, and Copepoda. Very few benthic invertebrates were taken, with the exception of chironomid larvae and Plecoptera.

The five juvenile sockeye fry (young of the year) taken in slough habitat in late May 1974, utilized a wide variety of food organisms (Figure 21). Terrestrial insects, of the families Homoptera and Coleoptera, comprised about 30% of the prey biomass consumed. Ephemeroptera nymphs, tabanid larvae, and chironomid larvae were common benthic organisms selected by these sockeye. Benthic invertebrates made up about 50% of the total biomass consumed. Noteably absent from all the stomach contents were Daphnia and other zooplankton commonly found in chinook stomachs examined over the same time period.

Six of the nine sockeye smolts taken in late April had food items in their stomachs. These fish were all taken in slough habitat on the south bank. The principal prey consumed was Daphnia, forming 90% of the stomach content biomass (Figure 20). Other prey consumed included chironomid pupae and Anisogammarus.

G. Laboratory feeding experiments

1. Behavioral observations

The chum salmon juveniles in the holding tank schooled and swam closer to the surface than the juvenile chinook fry. The chinook juveniles tended to remain in an aggregation near the bottom of the tank, with the intraspecific distance well defined and constant (about 6 cm). The chinook moved about much less than the chum, and in general were much more wary than the chum. When chinook and chum were placed together in the same tank, the chinook remained near the bottom, while the chum schooled and moved actively near the surface.

2. Experimental feeding results

Chinook and chum juveniles were first tested with single prey types (Table 7). The size of the prey types were larger than those normally found in the stomachs of fish collected in the field. Daphnia (type a) were 1.2 mm in mean length, ranging from 0.7 to 1.4 mm. Daphnia (type b) were 3.0 mm in mean length, ranging from 2.5 to 3.5 mm. Chironomus had a mean body width of 1.6 mm, ranging from 1.0 to 2.1 mm. A wide range of sizes of Neomysis were available, ranging from 1.8 to 4.0 mm in body width, with a mean size of 2.7 mm.

When exposed to a relatively high density of Daphnia (10/ litre), the chum juveniles proved to be more efficient predators, removing as much as 88% of the total number of Daphnia available. As few as two chum per tank could remove more than 50% of the Daphnia available, over a fifty minute period. The chinook juveniles were not as effective as the chum, consuming less than 30% of the Daphnia available. The variation between individuals was also greater for the chinook, with only one of every two chinook selecting any prey. This result conflicts with the field data, since the chinook in the estuary consumed greater numbers of Daphnia than the chum. The chinook juveniles in all the feeding experiments generally took prey less readily than the chum.

Chum salmon exposed to Neomysis as the only available food source did not feed on the Neomysis. On one occasion parts of one Neomysis were found in three different chum stomachs. These prey were generally too large for the chum to handle. The chinook juveniles consumed whole Neomysis when it was the only prey available. Observations of chinook attacks on Neomysis indicated that only one attempt in about ten was successful in capturing this prey. Neomysis is almost transparent, and possesses a darting escape behavior which would remove it 10-12 cm from the initial site of attack. In the turbid water, this movement would probably take the *Neomysis* out of the sight of the predator. *Chironomus* was the only prey tested which the chinook captured more frequently than the chum. These prey were larger than the chironomid larvae normally found in the stomachs of chum and chinook from the field collections. The benthic nature of these larvae, and the tendency of chinook (in the experimental situation) to remain near the bottom of the tank, could account for the increased selection by the chinook.

When the three prey types were presented at the same time, similar results were obtained as when presented individually, (Table 8). Both the chum and chinook consumed approximately the same number of *Daphnia* as in the previous experiment. With the *Daphnia* available, both the chum and chinook chose a lesser proportion of chironomid larvae, the chinook choosing slightly more of the larvae than the chum. Neither the chum or chinook preyed upon *Neomysis*, indicating that the other prey species were "preferred" or easier to obtain.

TABLE 7

Number of *Daphnia*, *Neomysis*, and *Chironomus* consumed by juvenile chum and chinook when presented with only one prey type per test.

	Number of fish per tank	Species	Mean Fork Length (mm)	Number of each prey available	Number of each prey consumed	Prey consumed per fish
	5	chum	38.1	200 *Daphnia*	176	35
	5	chum	39.4	200 *Daphnia*	144	29
	2	chum	40.9	200 *Daphnia*	111	56
Total	12	chum	38.8	600 *Daphnia*	431	36
	5	chinook	51.7	200 *Daphnia*	107	21
	5	chinook	54.3	200 *Daphnia*	69	14
	2	chinook	53.7	200 *Daphnia*	0	0
Total	12	chinook	53.3	600 *Daphnia*	176	16
	5	chum	40.2	10 *Neomysis*	0	0
	2	chum	38.0	10 *Neomysis*	0	0
	5	chum	40.0	50 *Neomysis*	1	0.2
Total	12	chum	39.8	70 *Neomysis*	1	0.08
	5	chinook	48.6	10 *Neomysis*	0	0
	2	chinook	45.8	10 *Neomysis*	2	1
	5	chinook	53.0	50 *Neomysis*	4	0.8
Total	12	chinook	50.0	70 *Neomysis*	6	0.5

(cont....)

TABLE 7 (cont....)

	Number of fish per tank	Species	Mean Fork Length (mm)	Number of each prey available	Number of each prey consumed	Prey consumed per fish
	4	chum	41.9	50 Chironomus	32	8
	3	chum	43.5	50 Chironomus	15	5
Total	7	chum	42.5	100 Chironomus	47	7
	5	chinook	52.7	50 Chironomus	41	8.2
	5	chinook	53.1	50 Chironomus	41	8.2
Total	10	chinook	52.9	100 Chironomus	82	8.2

TABLE 8

Number of *Daphnia*, *Neomysis*, and *Chironomus* consumed by the juvenile chum and chinook salmon when presented with the three prey types simultaneously.

	Number of fish per tank	Species	Mean Fork Length (mm)	Number of each prey available	Number of each prey consumed	Prey consumed per fish
	5	chum	47.8	200 *Daphnia*[b]	185	1.8
				50 *Chironomus*	9	37
				10 *Neomysis*	0	0
	4	chum	45.6	200 *Daphnia*	80	20
				50 *Chironomus*	24	6
				10 *Neomysis*	0	0
	5	chum	47.6	200 *Daphnia*	174	35
				50 *Chironomus*	30	6
				10 *Neomysis*	0	0
Total	14	chum	47.0	600 *Daphnia*	439	31
				150 *Chironomus*	63	4.5
				30 *Neomysis*	0	0
	5	chinook	55.6	200 *Daphnia*	45	9
				50 *Chironomus*	23	4.6
				10 *Neomysis*	0	0

(cont....)

TABLE 8 (cont....)

	Number of fish per tank	Species	Mean Fork Length (mm)	Number of each prey available	Number of each prey consumed	Prey consumed per fish
	5	chinook	59.6	200 *Daphnia*	158	32
				50 *Chironomus*	30	6
				10 *Neomysis*	0	0
	5	chinook	58.3	200 *Daphnia*	75	15
				50 *Chironomus*	20	4
				10 *Neomysis*	0	0
Total	15	chinook	57.8	600 *Daphnia*	278	18.5
				150 *Chironomus*	73	4.9
				30 *Neomysis*	0	0

b - All the *Daphnia* used in this set of experiments were the larger "b" type, 3.0 mm in mean length.

DISCUSSION AND CONCLUSIONS

The slough and side channel habitats of the Fraser River estuary have been shown to be important feeding areas for juvenile chum and chinook salmon. The greatest density of these species was recorded in late April, after which time the density of chum declined rapidly. Few chum were taken after early June. The chinook, however, were present in the habitats until late July. The chinook juveniles taken after their arrival in late April exhibited a steady increase in length until late July. This growth suggests that chinook may reside in the estuary for several months before final dispersal. The density of salmonids in the slough habitat was similar to the density in the side channels in late April (Figures 10 & 11). By early May, a greater density occurred in the side channels suggesting a possible increase in food availability in this habitat.

Chinook and chum from slough and side channels exhibited a differential prey selection, indicating possible differential availabilities in the two habitats. The surface insect Collembola formed about 13% of the prey biomass of the chinook and chum in the channels, but less than 1% in the stomach contents from the sloughs. Harpacticoid copepods comprised 43% of the consumed prey biomass of chum from the channels, but formed only 14% of the consumed prey biomass in the sloughs. Chironomid larvae and pupae, however, formed more of the total biomass in the fish from the slough habitat than in fish from side channel habitat. Chum and chinook utilized many common prey types, but chinook and chum taken together in the same habitat show a divergence in the prey sizes of the stomach contents. The tendency for the chinook to select larger prey than the chum, was in part related to the larger mouth size of the chinook. Both chinook and chum fed extensively on chironomid pupae and *Daphnia* when these prey were available in abundant supply. These prey could be termed the "preferred food item" for both species. The greatest divergence in the diet of the two fish occurs at the extremities of the size range of prey selected. Chum fry fed extensively on copepods and Collembola, especially the chum from channel habitats. Chinook fry ingested very few copepods and Collembola, but *Neomysis* often formed a large proportion of the biomass of their diet. *Neomysis* was too large a prey to be handled by the chum, as shown by the feeding experiments, and by the absence of this prey item in the stomach contents of field collected specimens.

The chum are capable of exploiting most of the same food sources as the chinook. In late March, when juvenile chum were not influenced by the presence of chinook, the biomass of the prey types in the stomach contents was remarkably similar to the chinook present in early April (Figure 18). As the density of juvenile salmon increased, the divergence in prey size selected increased. In late May, when the density of salmonids was reduced, the stomach content biomass of the chum again was more similar to the chinook (Figure 20). It is possible that under the conditions of reduced density (in late March and late

May), the feeding interactions between chinook and chum would be less frequent and less intense.

Juvenile chum salmon have been shown to feed in small coastal streams where they could normally reach the sea in one night. Mason (1974) reports chum fry remaining in a small estuary (Lymn Creek, Vancouver Island, B.C.) until June 3, feeding on amphipods (Anisogammarus and Corophium), copepods, and insects (Diptera). Observations are similar to results obtained in this study.

Feeding of juvenile salmonids in freshwater habitats prior to marine dispersal has been described for other coastal rivers, and the food sources utilized are consistent with the results obtained in this study. Sparrow (1968) reported chironomids and Daphnia very common in the stomachs of chum fry in Somenos Creek, a tributary of the Cowichan River, B.C. Sparrow also reports that chum fry as large as 67 mm in fork length were recorded, remaining in freshwater as late as June 9.

Juvenile chinook salmon fry in the Somass River Estuary, B.C., have been reported feeding on amphipods (Anisogammarus confervicolus), fish larvae, chironomid larvae, and terrestrial insects (Kask and Parker, 1972).

Residence and growth of juvenile chinook (young of the year) has been demonstrated in the Sixes River, Oregon (Reimers, 1973). Chinook fry in this system migrate down into the lower river in April, at a mean length of 43 mm, and reside here until as late as September, attaining lengths of 80 mm or more. The increasing temperature of the river was determined to be the controlling factor for the timing of final dispersal.

Goodman and Vroom (1972) found that juvenile chinook and chum in the Squamish River estuary (B.C.) consumed primarily amphipods and mysids. The chum were most abundant in mid May, and were abundant until mid June. The chinook were most abundant in mid June, and were present in early August when sampling terminated.

Goodman (1975) reports that Anisogammarus forms the greatest percentage biomass (31.6%) of food items, consumed by chinook salmon in early May in the Fraser River (South Arm). These fish were taken in slough habitat on the north shore of the river, due north of Woodward Island (Figure 1). Chironomid larvae and adult Diptera also formed a dominant portion of the prey biomass in early May and mid June. These results are similar to stomach content analysis of chinook taken in slough habitat in the Duck - Barber - Woodward Island complex in 1974.

The more frequent occurrence of benthic organisms in the diet of the chinook suggests that chinook juveniles are primarily benthic oriented. This conclusion is also supported by the laboratory feeding experiments. The chum fry, on the other hand, are more pelagic, utilizing primarily prey on the surface or in the water column. As previously discussed, the chinook are not restricted to benthic invertebrates, but will take advantage of a temporary or local abundance of pelagic prey such as Daphnia and chironomid pupae.

Differences in the feeding behaviour of chum and chinook probably contributes to some degree of spatial segregation. This could account for the vertical distribution of the species under laboratory conditions, where the chum remain near the surface, and the chinook near the bottom, whether in the same tank or in separate tanks. Due to the turbidity of the water in the study areas, it is not known whether this vertical distribution occurs in the field.

Other species utlizing the slough habitat were threespine stickleback, prickly sculpin, peamouth chub, staghorn sculpin, and starry flounder (Appendix B). Only the threespine stickleback and prickly sculpin utilized the side channel habitat. The threespine stickleback exploited a wide variety of food resources, with chironomid larvae being most important in the slough habitat. Copepods and amphipods formed over 70% of the prey biomass of the stickleback in the side channel habitat. The principal food sources of the prickly sculpins were isopods and chironomid larvae. Staghorn sculpin preyed upon isopods, amphipods and juvenile salmon. The peamouth chub taken in slough habitat were planktivorous, consuming chiefly Daphnia. Starry founders taken in slough habitat relied almost exclusively on benthic invertebrates, chiefly amphipods and isopods.

The arrival of juvenile Pacific salmon in the Fraser River estuary in late March corresponds with the initial presence of other species in the estuary. In this study, marginal habitat types in a marsh area have been examined. The habitat has been shown to be an important feeding area for at least three species of juvenile Pacific salmon and five other species. The diverse marsh areas in the Duck - Barber - Woodward Island complex and Ladner Marsh provide suitable habitat for the production of many terrestrial and aquatic invertebrates. These invertebrates in turn supply a vital food resource for many estuarine fishes, including the migrating juvenile salmon. Any further degradation of this habitat, by development or pollution, would further reduce the Fraser River salmon stocks.

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APPENDIX A

Table A 1: Number of juvenile salmon per 100 m^2 of slough habitat, in the South Arm of the Fraser River, 1973.

Date	pink	chum[a]	chinook fry a	chinook smolts b	coho	sockeye[a]
Mar. 15						
Mar. 29		22				
Apr. 12		50	24			
Apr. 25		105	257	11		
May 9		7	55	1		
May 24		2	46			3
Jun. 6		3	27			4
Jun. 20		1	20			7
Jul. 4			6			2
Jul. 18			2			4
Aug. 2			1			1

a) young of the year

b) smolts (yearlings)

Table A 2: Number of juvenile salmon per 100 m^2 of slough habitat in the North Arm of the Fraser River, 1973.

Date	pink	chum	chinook fry	chinook smolts	coho	sockeye
May 17		8	126			1
May 31		1	31			1
Jun. 13		1	24			
Jun. 28			8			
Jul. 11			3			1
Jul. 25			1			1
Aug. 7						

Table A 3: Number of juvenile salmon per 100 m^2 of slough habitat in the South and North Arms of the Fraser River, 1974.

South Arm

Date	pink[a]	chum[a]	chinook[a] fry	chinook[b] smolts	coho	sockeye
Mar. 14	1	1				
Mar. 28		7	1			
Apr. 11		14	7			
Apr. 24		21	68	7		5[b]
May 8[c]		4	8	3		1[b]
May 22		6	84	2	1	
Jun. 5		1	25	3		2[a]
Jun. 19	1		4			
Jul. 4			5			1[a]
Jul. 17			1			1[a]
Middle Arm						
May 1			22	1		
Jul. 2			1			

a) young of the year
b) smolts (yearlings)
c) thick layer of silt and fine organic material made seining very difficult on this date and many fish were probably lost.

Table A 4: Number of juvenile salmon per 100 m^2 of channel habitat in the South Arm of the Fraser River, 1973.

Date	pink	chum	chinook fry	chinook smolts	coho	sockeye
Mar. 14						
Mar. 28			3			
Apr. 11		111	13			
Apr. 26		121	208			
May 10		67	200			
May 25		11	105			
Jun. 8		8	8			1[a]
Jun. 21			8			
Jul. 4			5			
Jul. 19						1[a]
Aug. 3						

a) young of the year

APPENDIX B

Species other than salmonids in the Fraser Estuary

Five other species were frequently taken in the slough and channel habitat of the study area. These species were: threespine stickleback (Gasterosteus aculeatus), prickly sculpin (Cottus asper), peamouth chub (Mylocheilus caurinus) staghorn sculpin (Leptocottus armatus), and starry flounder (Platichthys stellatus). The latter two species are marine forms commonly found in estuarine or brackish waters. Other species taken infrequently by the sampling gear were: eulachon (Thaleichthys pacificus), longfin smelt (Spirinchus thaleichthys), mountain whitefish (Prosopium williamsoni), squawfish (Ptychocheilus oregonensis), redside shiner (Richardsonius balteatus), brassy minnow (Hybognathus hankinsoni), carp (Cyprinis carpio), and western brook lamprey (Lampetra richardsoni).

A. Temporal and spatial use

1. Slough habitat

The initial arrival of other species of fish into the slough habitat generally coincided with the arrival of the juvenile Pacific salmon (Figure B 1). Starry flounder were the most abundant species in the slough habitat, followed by threespine

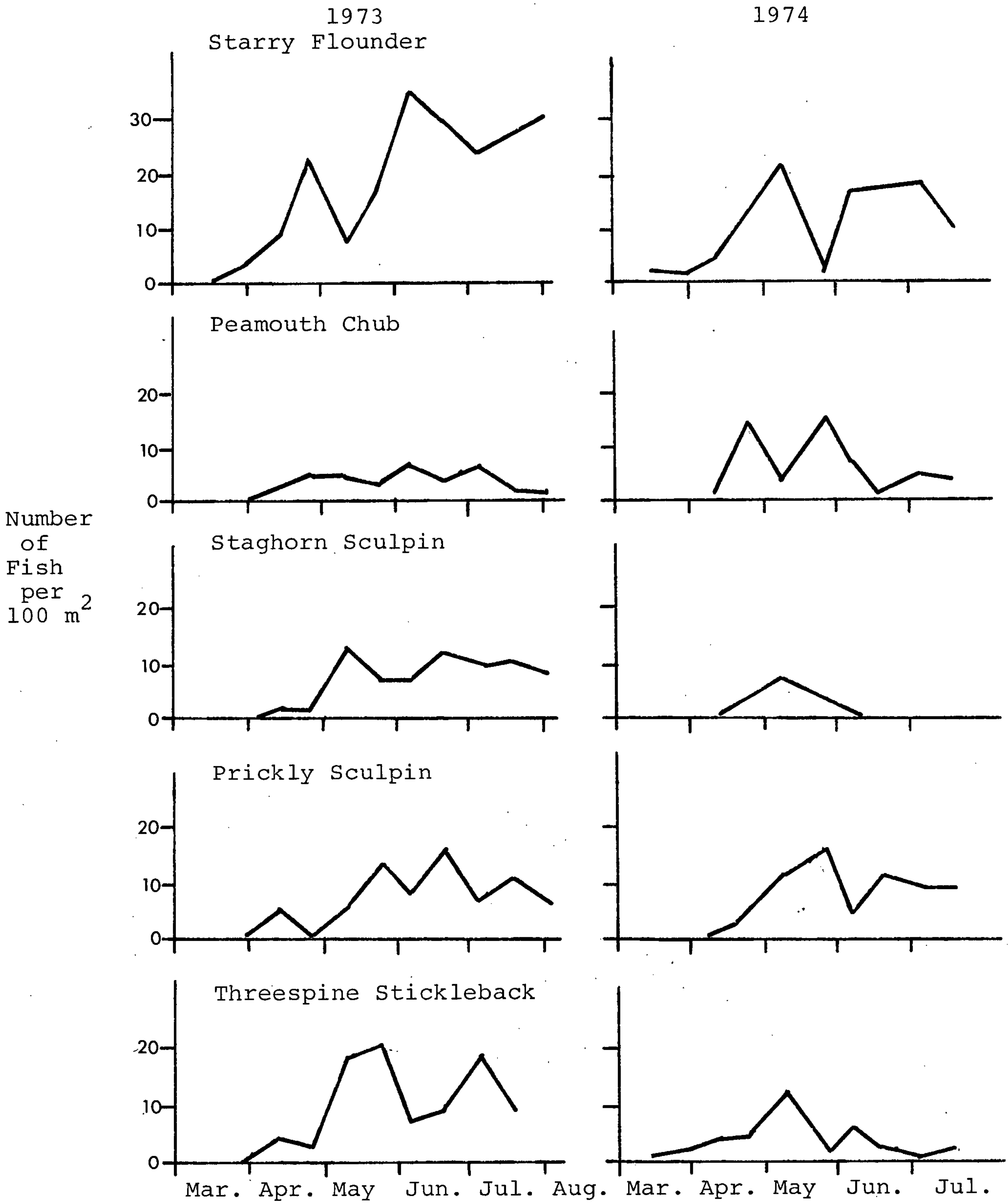

Figure B 1: Number of other species per 100 m^2 of slough habitat in the South Arm of the Fraser River.

stickleback, prickly sculpin, staghorn sculpin, and peamouth chub, respectively. The number of each of these species, after an initial increase in April, did not show any clear trends in abundance until sampling terminated in August.

Larger numbers of prickly sculpin, staghorn sculpin, and starry flounder were present in the slough habitat of the North Arm (Figure B 2). The prickly sculpin exhibited a clear migratory pattern, with peak numbers occurring in mid June. The few threespine stickleback and peamouth chub in the NorthnArm could be indicative of a greater marine influence in this area.

2. Side channel habitat

Only two of the five common species other than juvenile salmonids were present in the channel habitat (Figure B 3). Threespine sticklebacks were the most numerous, utilizing these channels as a breeding and rearing area. Small numbers of prickly sculpin were consistently present in channel catches. Starry flounder and staghorn sculpin were absent in this habitat type.

B. Food and Feeding

1. Slough habitat

Longfin smelt (Spirinchus thaleichthys): Nine longfin

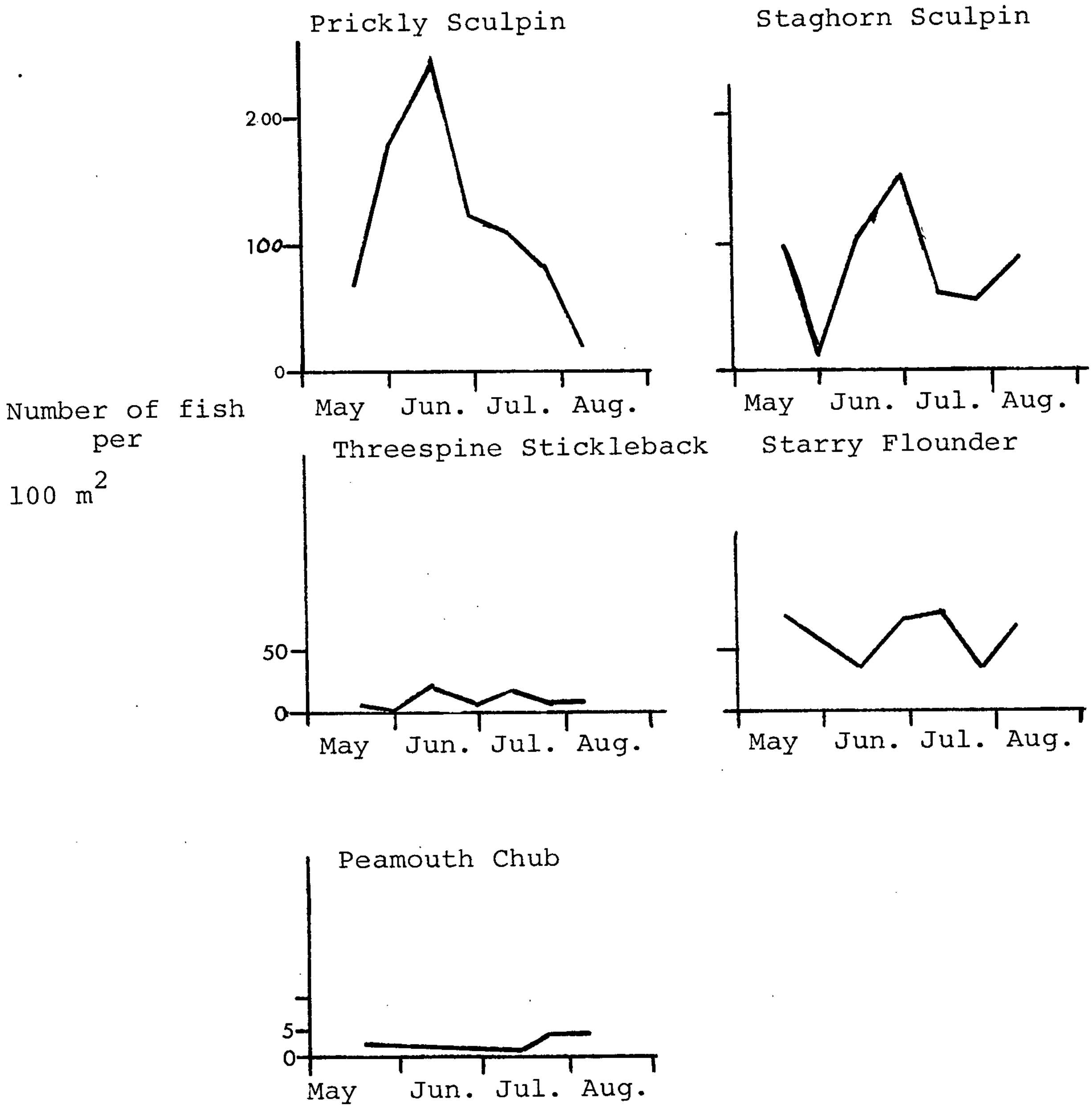

Figure B 2: Number of other species per 100 m^2 of slough habitat in the North Arm, Fraser River.

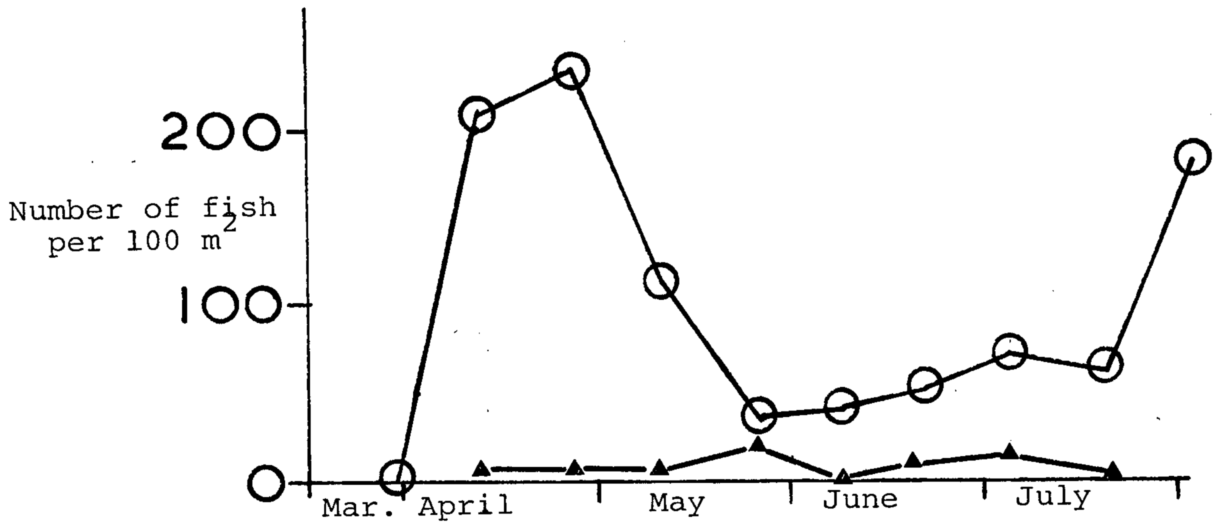

Figure B 3: Seasonal change in numbers per 100 m^2 of other species in side channel habitat, South Arm Fraser River.

smelt were examined from the slough habitat in 1973. Almost the entire biomass of the stomach contents (98.4%) consisted of the opossum shrimp (Neomysis mercedis) (Figure B 4). Although the sample size is small (9 stomachs), the longfin smelt was the only species taken who fed almost exclusively on the Neomysis. Since Neomysis were very abundant in the area, this fish species could possess a feeding behaviour or foraging characteristic which would enable it to capture this prey more efficiently than other species.

Peamouth Chub (Mylocheilus caurinus): Although the number of peamouth chub taken on any date was low, this species can become very concentrated in the larger backwaters of the estuary at low tides. The peamouth chub were primarily planktivorous, with 56% of the biomass of the stomach contents formed by Cladocera (primarily Daphnia pulex) (Figure B 4). Ostracods were also abundant in the stomach contents, comprising about 20 % of the biomass. Very few true benthic organisms were taken by the peamouth chub, except the chironomid larvae, forming 11% of the consumed biomass.

Starry Flounder (Platyichthys stellatus): Starry flounder were abundant in the slough habitat of the South Arm. Although a wide range of sizes were examined, the stomach content analysis yielded consistent results (Figure B 4). Benthic

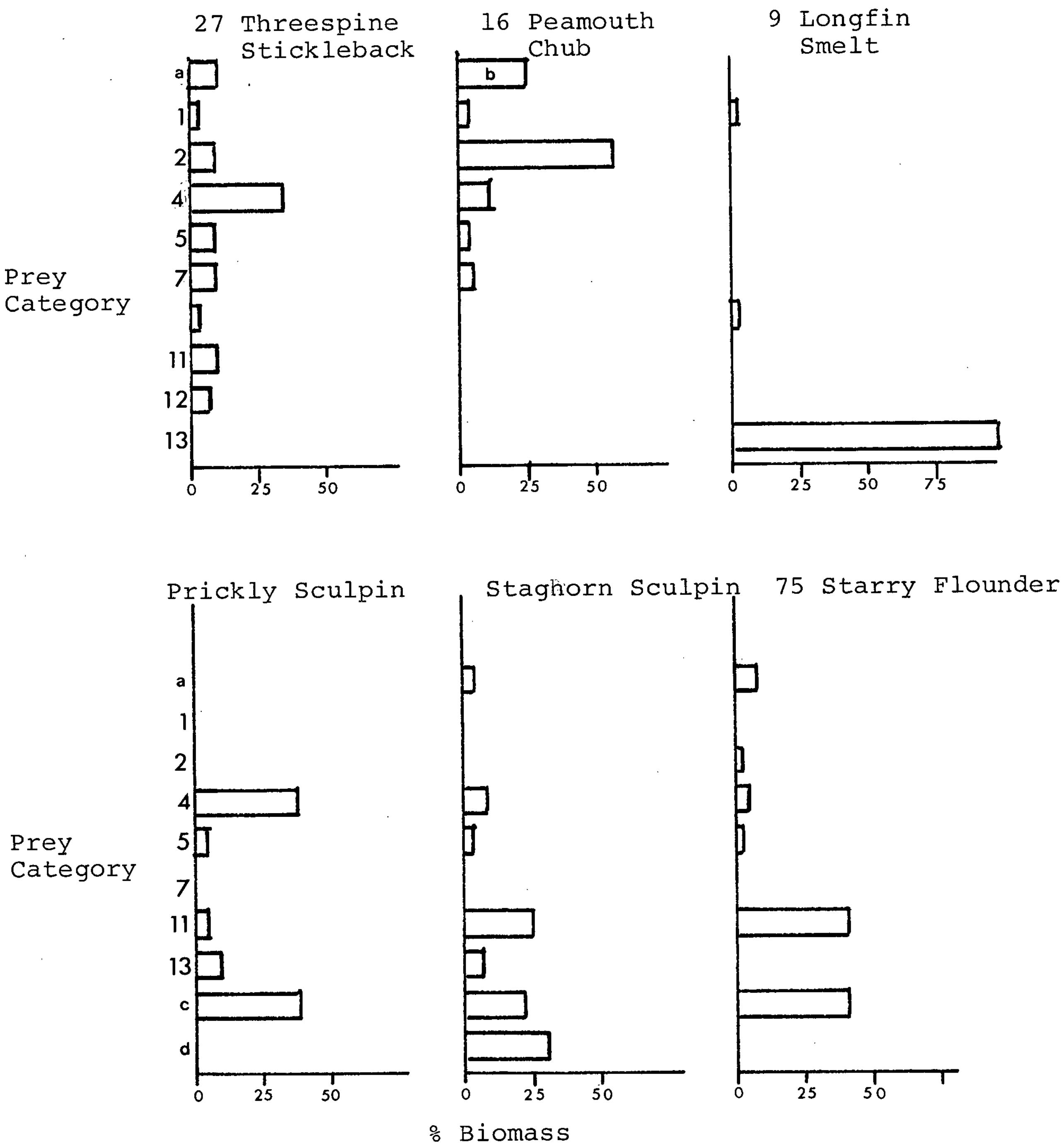

Figure B 4: Percentage biomass of major prey items from six fish species in slough habitat, South Arm.

a Oligochaetes
b Ostracods
c Isopods
d Juvenile salmon

organisms were taken almost exclusively by the flounder, with Isopods (Gnorimosphaeroma) and Amphipods (Corophium and Anisogammarus) comprising 40.5% and 41.5% of the consumed biomass, respectively. The starry flounder depended on the larger prey to a greater extent than any other species. The remainder of their diet consisted of ologochaetes, polychaetes, and chironomid larvae.

Prickly sculpin (Cottus Asper): Thirty three prickly sculpin from slough habitat were examined. Isopods (Gnorimosphaeroma) and chironomid larvae were predominant food categories, each forming 38% of the stomach content biomass (Figure B 4). Tabanid larvae and amphipods were also present in the stomachs.

Staghorn Sculpin (Leptocottas armatus): Thirty three staghorn sculpin were examined from the South Arm slough habitat. The mean size captured was approximately 70 mm in fork length, which is about 20 mm greater than the mean size of the prickly sculpin. This size difference is reflected in the results of the stomach content analysis (Figure B 4). The staghorn sculpin preyed heavily upon benthic organisms such as Isopods (22%) and Amphipods (24%). More importantly, they were of sufficient size to predate upon juvenile Pacific salmon. Juvenile salmon formed 30.5% of the biomass of the stomach contents of the staghorn sculpin. It is likely that larger sculpins, not sampled by the gear types used, are present and are an important predator of juvenile Pacific salmon in the

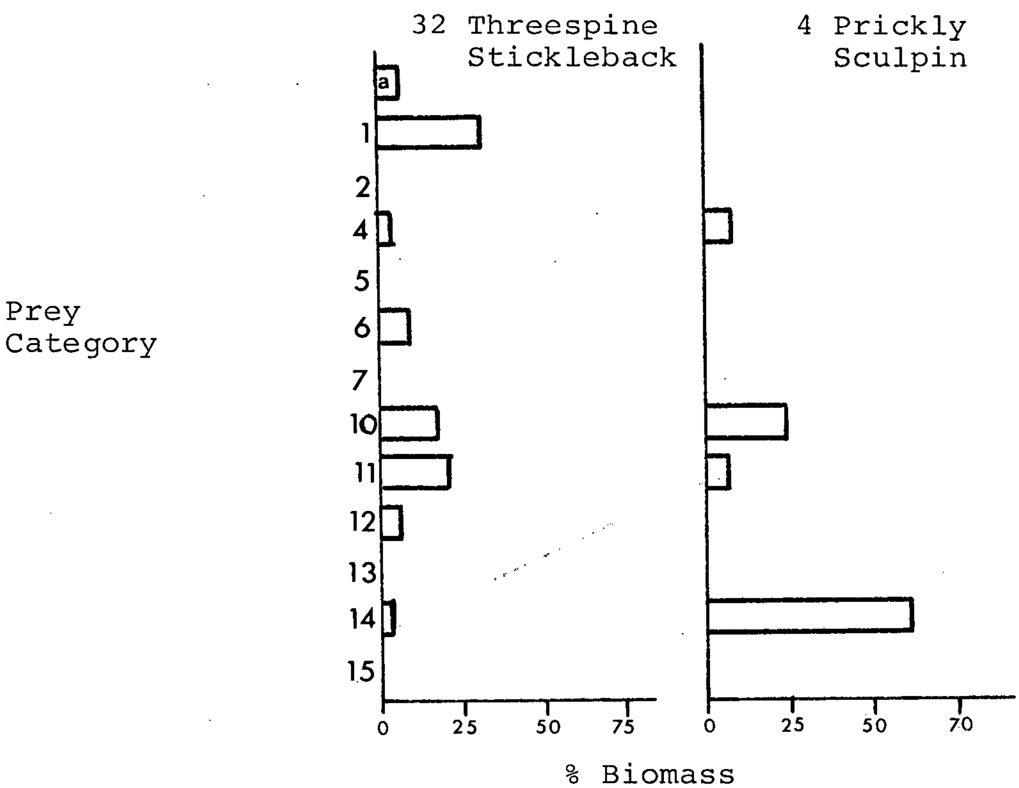

Figure B 5: Percentage of biomass of prey items consumed by two species in side channel habitat, South Arm, 1973.

[a] Oligochaetes

Fraser River Estuary.

Threespine stickleback (*Gasterosteus aculeatus*): Chironomid larvae comprised the largest portion of the biomass (35%) of the stomach contents of threespine stickleback (Figure B 4). Many other benthic prey were present in the stomachs, such as oligochaetes, amphipods, and tabanid larvae. Copepods, Cladocera, and terrestrial insects were also taken, indicating the lack of specialized feeding behaviour of *Gasterosteus*.

2. Side channel habitat

Threespine stickleback and prickly sculpin were the only species other than juvenile chum and chinook salmon taken in channel habitat in the South Arm. Of these stickleback were the most common.

Copepods and amphipods comprised the greatest portion of the stomach content biomass (70%) of the sticklebacks in the channel habitat (Figure B 5). These prey only formed 17% of the stomach biomass of sticklebacks taken in the slough habitat.

Four prickly sculpin were examined from the channel habitat. Isopods and *Anisogammarus* were the dominant prey found in the stomach contents of these fish (Figure B 5).