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FISH ASSEMBLAGES AND JUVENILE SALMON DIETS AT A BREACHED-DIKE WETLAND SITE, SPENCER ISLAND, WASHINGTON 1997-98

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Key Words

fish assemblages, juvenile salmon diet, Snohomish River estuary, wetland restoration

FISH ASSEMBLAGES AND JUVENILE SALMON DIETS AT A BREACHED-DIKE WETLAND SITE, SPENCER ISLAND, WASHINGTON 1997–98

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Introduction

In 1997 we studied the biological status of a breached-dike restored wetland site on South Spencer Island, which is located in the Snohomish River estuary near the city of Everett, Washington (Fig. 1, Cordell et al. 1998). One of the components of this study was sampling fish presence and salmonid diets at the site. Fish were captured with small gillnets in several habitats, a fyke trap in a main drainage channel, and on one date, a small two-person pole seine (see Cordell et al. 1998 for descriptions of sampling sites and gear). Because these techniques proved relatively unsuccessful, we sampled fish at Spencer Island beginning in April 1998 using beach seines. The purpose of this report is to present the 1998 fish sampling and diet results and compare these results to data from the 1997 fish collections.

Methods

Sampling Sites

We chose three areas for sampling fish at the South Spencer Island restoration site (Fig. 2). The first was located just inside the primary breach connecting the restoration site with Union Slough. The other two areas were located on a mudflat adjacent to the cross levee that separates the restoration site from managed waterfowl habitat: the west mudflat site abutted an extensive *Typha* and *Phalaris arundinacea* marsh that dominates the restoration site.

Fish Sampling

We sampled the south Spencer Island restoration site approximately every 2 weeks from 3 April to 12 June 1998 for a total of six sampling periods (Table 1). Samples were taken with a 37-m floating beach seine. The net consisted of two 18-m panels made of 3-cm mesh with a 2-m x 2.4-m x 2.3-m bag made of 6-mm mesh. Sets were made within 1 hour of high tide to maximize the amount of water over the sites. The net was deployed from a small inflatable boat parallel to shore and was pulled in by two 2-person teams.

Captured fish were anesthetized in a plastic bucket in which water with a small amount of MS-222 (tricaine) had been added. All fish were then identified to species and counted. Salmonids were measured (fork length) and a subsample of 10 salmon from each 10-mm size class was preserved immediately in a 10% formaldehyde solution. All other fish were placed in freshwater until they recovered, and then were released.

Diet Analyses

In the laboratory, individual fish were measured (fork length) and weighed damp (excess water was blotted off with tissue) to the nearest 0.01 g. Stomachs were removed and opened, and each stomach was assigned a fullness rank (1 = empty, 6 = full) and digestion rank (1 = no prey identifiable, 6 = all prey identifiable). The contents were then weighed damp in their entirety, placed on a plastic petri dish, and separated into individual taxa under a dissecting microscope. Prey were identified to species level for crustaceans and to family level for insects. Each taxon was enumerated and weighed to the nearest 0.001 g. All data were entered on standard NODC (National Oceanographic Data Center) forms and analyzed using the University of Washington Fisheries Research Institute's GUTBUGS program. This program provides summary data for each group of fish analyzed; data were taken from this summary for further graphical analysis.

Results

Fish Catches

Twelve species of fish were captured during the course of this study (Table 2). Threespine stickleback *(Gasterosteus aculeatus)* dominated the overall catch (507 individuals): most of these (340) were caught in a single beach seine haul at the west mudflat site on 17 April. Peamouth chub *(Mylocheilus caurinus)* were also relatively abundant (145 individuals). Juvenile chum *(Oncorhynchus keta)* (174 individuals) and chinook *(O. tschawytscha)* (148 individuals) salmon were the most abundant salmonids (Tables 3, 4). Coho salmon *(O. kisutch)*were the third most numer-

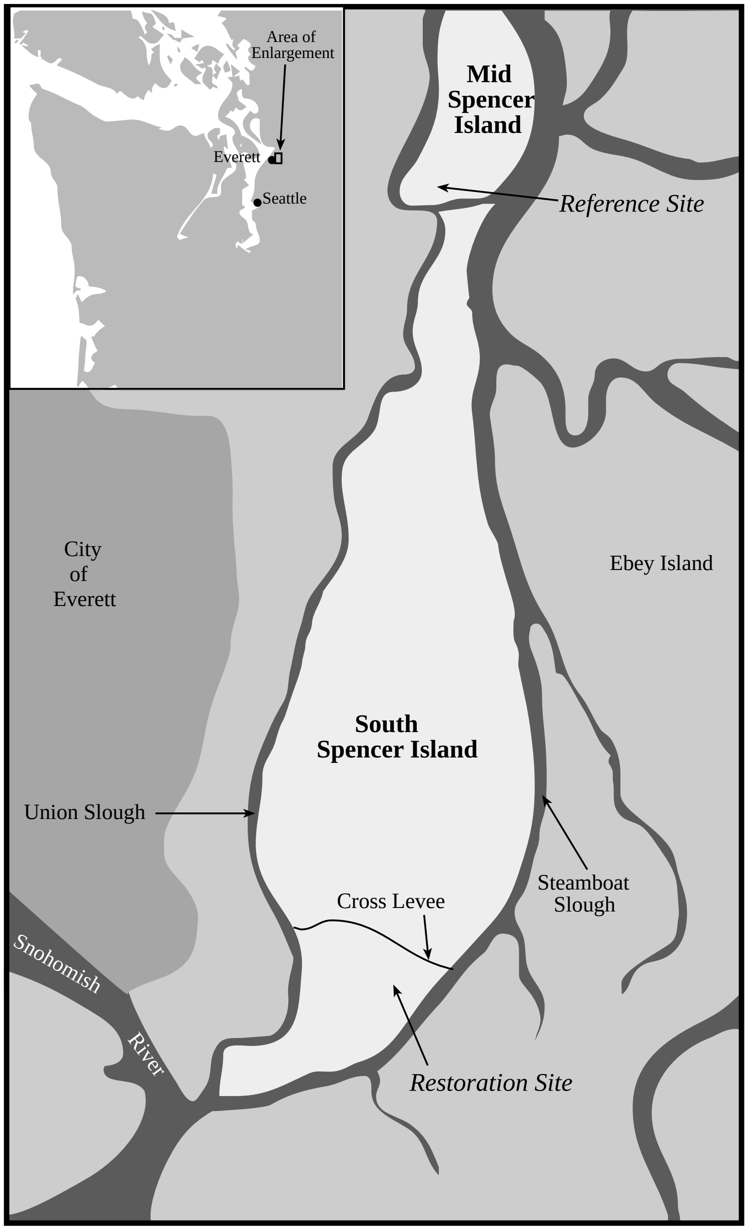

FIGURE 1. Location of breached-dike restoration site at Spencer Island, Washington.

ous salmon species (59 individuals). Overall catches of other salmonids were small, consisting of 15 pink salmon *(O. gorbuscha)*, one steelhead trout *(O. mykiss)*, and one cutthroat trout *(O. clarki)*. Numbers of fish caught per date were relatively consistent across the sampling period for chum and chinook salmon and for peamouth chub (Table 2). Coho salmon were relatively abundant only on the two May sample dates.

Chum Salmon Diets

A total of 68 juvenile chum salmon were analyzed for diet composition. Stomach fullness and instantaneous ration (the percent ratio of stomach contents weight to fish weight) were similar throughout the 1998 study period, averaging 3.4 and 1.32, respectively (Fig. 3). These values were lower in 1998 than in 1997.

Larvae and pupae of chironomid flies dominated the prey weight in juvenile chum salmon at every site and date analyzed except for two individuals from the 29 May sample taken near the large dike breach (Fig. 4). Prey in these fish consisted of adult dipteran flies, ceratopogonids, and larval fish. Diet from juvenile chum salmon captured at the two mudflat sites was especially dominated by chironomids, which constituted about 80% of prey weight.

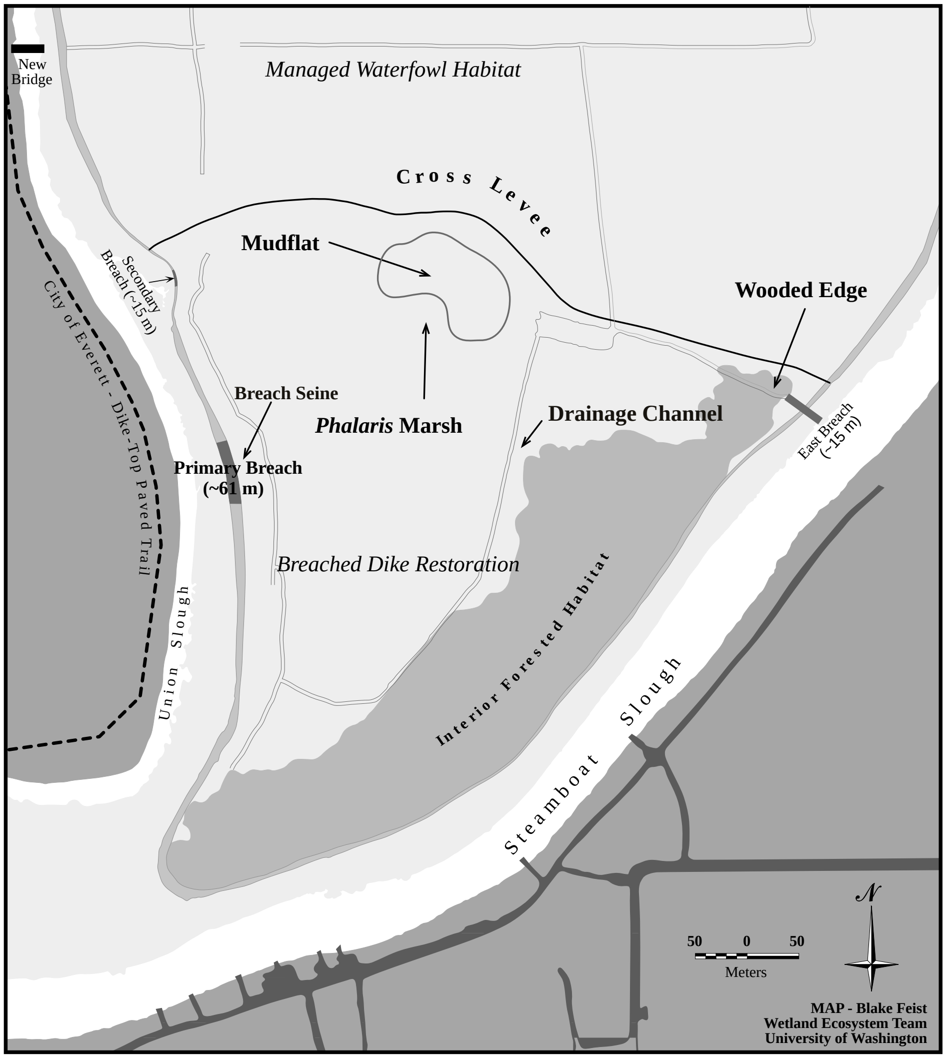

FIGURE 2. Spencer Island breached dike restoration site showing fish sampling locations in 1997 and 1998.

Chinook Salmon Diets

We analyzed the diets of a total of 71 juvenile chinook salmon, all of which were caught in 1998. Stomach fullness was similar throughout the study period, with an overall average of 4.3 (Fig. 5). Instantaneous ration was somewhat more variable than for chum salmon, ranging from 0.53–1.93, with an average of 1.21.

Diet composition of juvenile chinook salmon was also more variable than for chum (Fig. 6). In early April, diet was gravimetrically dominated by the amphipods *Corophium* spp. and larval fish at the east mudflat site. In late April, chironomid fly larvae, larval fish, and *Corophium* spp. were the predominant prey taxa. From chinook captured at the mudflat sites on May sample dates, chironomid larvae and pupae dominated the diets (50–75% of prey weight). In chinook from the breach site on 15 May, prey were distributed into relatively more taxa, including the mysid shrimp *Neomysis mercedis*, ceratopogonid fly larvae and pupae, and cercopid insects (leaf hoppers). In the 12 June sample, ceratopogonid fly larvae and pupae were dominant, constituting 83% of prey weight.

Coho Salmon Diets

We analyzed a total of 40 juvenile coho salmon stomachs taken from three sampling dates. Stomach fullness was similar throughout the 1997–98 study period, averaging 4.5 (Fig. 7). Instantaneous ration was more variable, ranging from 0.5–1.35, with an average of 0.9.

Compared with the chum and chinook salmon diets, which consisted mainly of chironomids and larval fish, prey weight in coho salmon was dominated by crustaceans (Fig. 8). One or two crustacean taxa dominated the diet at each site and date: *Neomysis mercedis* at the breach site on 17 April; *Corophium* spp. at both mudflat sites on 15

Text continues on p. 12

TABLE 1. Tides and fish sampling periods for 1998 south Spencer Island sampling.

Date	Everett tides						Beach seine (30 m)									Crew A	Notes
	low		high		low		east mudflat			west mudflat			breach				
	time	feet	time	feet	time	feet	start	end	total time	start	end	total time	start	end	total time		
3-Apr	3:49	6.1	9:05	9.5	16:10	0.4	9:30	10:30	1:00	10:30	11:30	1:00	8:30	9:30	1:00	KA, JC, AH, LT & AG	Two hauls were made at the breach site, but no fish were captured.
17-Apr	3:19	6.1	8:19	9.3	15:25	0.2	8:45	9:15	0:30	9:30	9:50	0:20	10:30	11:00	0:30	KA, JC, CT, AG & KO	
1-May	3:33	6.0	8:35	9.4	15:34	-0.5	9:00	9:30	0:30	9:40	10:05	0:25	11:00	12:00	1:00	KA, JC, CT & JT	Two hauls were made at the breach site, but fish were captured only on the first haul.
15-May	2:17	6.3	7:03	9.5	14:11	-1.0	7:30	7:45	0:15	7:50	8:10	0:20	8:45	9:15	0:30	KA, JC, AG & DL	
29-May	2:22	6.1	7:14	9.7	14:15	-1.6	7:30	7:45	0:15	8:15	8:30	0:15	8:45	9:00	0:15	KA, JC, SH & JK	
12-Jun	1:15	6.6	5:56	9.8	13:07	-1.8	7:35	7:50	0:15	8:15	8:30	0:15	9:10	9:25	0:15	JC, CT, PR & ER	

[A]Crews consisted of Kevin Aitkin (KA), Jeff Cordell (JC), Ayesha Gray (AG), Andy Haas (AH), Steve Hager (SH), James Kim (JK), Dave Low (DL), Kate O'Keefe (KO), Eric Reeder (ER), Paul Renaud (PR), Curtis Tanner (CT), Lucinda Tear (LT), Jason Toft (JT).

TABLE 2. Summary of 1998 south Spencer Island fish abundance data.

Species	Gear (30 m beach seine)																	
	Date																	
	3-Apr			17-Apr			1-May			15-May			29-May			12-Jun		
	Collection Sites																	
	east mudflat	west mudflat	breach	east mudflat	west mudflat	breach	east mudflat	west mudflat	breach	east mudflat	west mudflat	breach	east mudflat	west mudflat	breach	east mudflat	west mudflat	breach
										100								
Chum salmon	1	21		15	52	19		37			21	5	1	2				
Pink salmon	6			4	2	1					1	1						
Chinook salmon	24	2		7	21	1	5	10		4	7	14	6	1	12	32		2
Coho salmon						2			2		31	7	8	5	4	2		
Steelhead / rainbow trout								1										
Cutthroat Trout													1					
Threespine stickleback	4	4		4	340			113			10		5	20		1	6	
Peamouth				1	14		7	11	19		22	21	13	3	12	8	14	
Bluegill / pumpkinseed					1			1									1	
Staghorn Sculpin						2												
Prickly Sculpin														1				
Sculpin spp.																1	1	11
Starry Flounder								2				1					1	1
Subtotal	35	27	0	31	430	25	12	175	21	4	92	49	34	32	28	44	23	14
Total		62			486			208			145			94			81	

TABLE 3. All fish caught (top) and those retained for diet analyses (bottom) at Spencer Island, Snohomish County in 1998.

Date	Chum	Pink	Chinook	Coho	Steel-head	Cut-throat	Threespine stickleback	Peamouth chub	Bluegill / pumpkinseed	Staghorn sculpin	Prickly sculpin	Sculpin spp.	Starry flounder	Frog spp.
3-Apr	22	6	26	0	0	0	8	0	0	0	0	0	0	0
17-Apr	86	7	29	2	0	0	344	15	1	2	0	0	0	0
1-May	37	0	15	0	1	0	113	37	1	0	0	0	2	1
15-May	26	2	25	38	0	0	10	43	0	0	0	0	1	0
29-May	3	0	19	17	0	1	25	28	0	0	1	0	0	0
12-Jun	0	0	34	2	0	0	7	22	1	0	0	13	2	0
TOTAL	174	15	148	59	1	1	507	145	3	2	1	13	5	1

Date	Chum	Pink	Chinook	Coho	Bluegill/ Pumpkinseed
3-Apr	13	6	12	0	0
17-Apr	35	7	18	2	0
1-May	20	0	10	0	1
15-May	15	1	24	17	0
29-May	3	0	19	17	0
12-Jun	0	0	34	2	0
TOTAL	86	14	117	38	1

TABLE 4. Salmonid fork lengths from 1998 south Spencer Island sampling.

3-Apr			17-Apr				1-May			15-May				29-May				12-Jun	
Chum	Pink	Chinook	Chum	Pink	Coho	Chinook	Chum	Chinook	Steelhead	Chum	Pink	Chinook	Coho	Chum	Chinook	Coho	Cutthroat	Chinook	Coho
42	35	176	46	37	180	63	45	48	195	50	33	75	61	28	92	97	182	79	86
47	34	158	51	35	200	54	42	45		50	34	76	59	51	56	92		98	93
43	43	174	50	36		56	43	122		52		75	53	51	70	101		88	
44	37	146	55	35		55	48	67		53		76	55		77	105		89	
43	37	162	51	39		56	61	67		55		54	60		83	98		88	
45	36	129	57	36		48	42	45		48		55	53		72	104		71	
41		126	53	33		48	45	49		62		44	96		77	97		88	
39		151	50			57	44	76		55		81	86		86	70		93	
50		103	48			69	45	42		46		54	93		91	105		71	
42		166	53			66	41	61		41		55	57		71	100		88	
45		161	54			60	42	71		42		57	59		75	83		93	
45		141	57			48	54	53		41		65	60		66	131		87	
43		131	50			54	44	112		40		87	43		90	93		85	
40		134	43			57	41	56		53		54	49		72	91		84	
41		158	51			50	51	42		46		71	107		64	90		92	
47		154	50			49	46			44		65	98		82	95		88	
52		154	46			50	44			44		61	40		77	106		89	
29		128	48			63	46			56		68	97		81			80	
		106	46			55	56			50		62	53		62			76	
		165	51			51	43			52		65	52					82	
		102	43			55	54			52		63	50					79	
		134	49			55	45			43		63	55					68	
		140	51			56	46			49		63	101					82	
		161	45			56	45			60		57	59					92	
		150	43			50	50			36		60	104					86	
		135	47			57	44			41			54					85	
			47			45	42						52					79	
			52			62	43						56					93	
			47			56	43						54					83	
			48				54						103					92	
			53				41						56					83	
			46				46						105					83	
			52				44						115					75	
			52				46						99					83	
			51				49						77						
			48				47						124						
			45				44						97						
			54										57						
			53																
			56																
			50																
			49																
			50																

TABLE 4—cont.

	Sample date																			
	3-Apr			17-Apr				1-May			15-May				29-May				12-Jun	
	Chum	Pink	Chi-nook	Chum	Pink	Coho	Chi-nook	Chum	Chi-nook	Steel-head	Chum	Pink	Chi-nook	Coho	Chum	Chi-nook	Coho	Cut throat	Chin-nook	Coho
				43																
				46																
				46																
				54																
				43																
				55																
				49																
				45																
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n	18	6	26	60	7	2	29	37	15	1	26	2	25	38	3	19	17	1	34	2
mean	43.222	37	144.0	49.4	35.9	190.0	55.2	46.1	63.7	195.0	48.5	33.5	64.2	72.3	43.3	76.0	97.5	182.0	84.5	89.5
max	52	43	176	57	39	200	69	61	122	195	62	34	87	124	51	92	131	182	98	93
min	29	34	102	43	33	180	45	41	42	195	36	33	44	40	28	56	70	182	68	86
SD	4.8816	3.162	20.59219	3.8	1.9	14.1	5.7	4.6	24.3		6.5	0.7	10.0	24.1	13.3	10.1	12.5		7.0	4.9
median	43	36.5	148	50	36	190	55	45	56	195	49.5	33.5	63	59	51	77	97	182	85	89.5

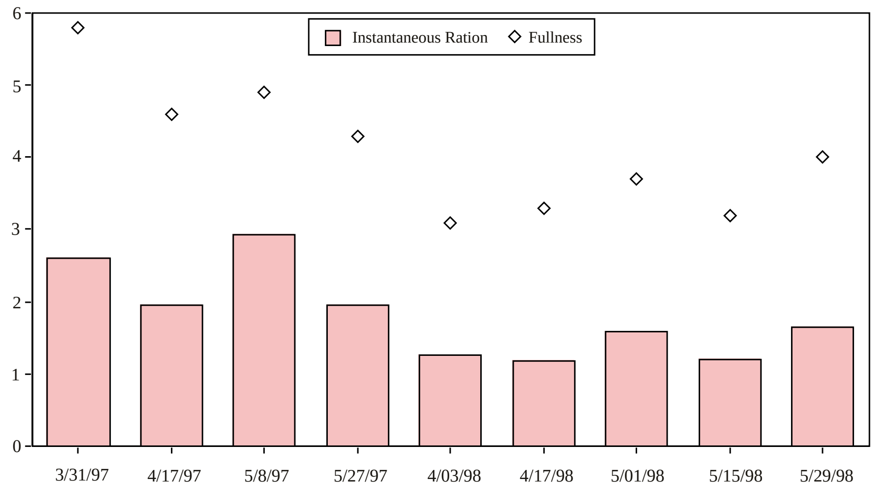

FIGURE 3. Stomach fullness factor (1 = empty, 6 = full) and index of percent ratio of stomach contents weight of fish weight for juvenile chum salmon captured by several methods at Spencer Island, Washington in 1997 and 1998. Vertical lines represent standard deviations.

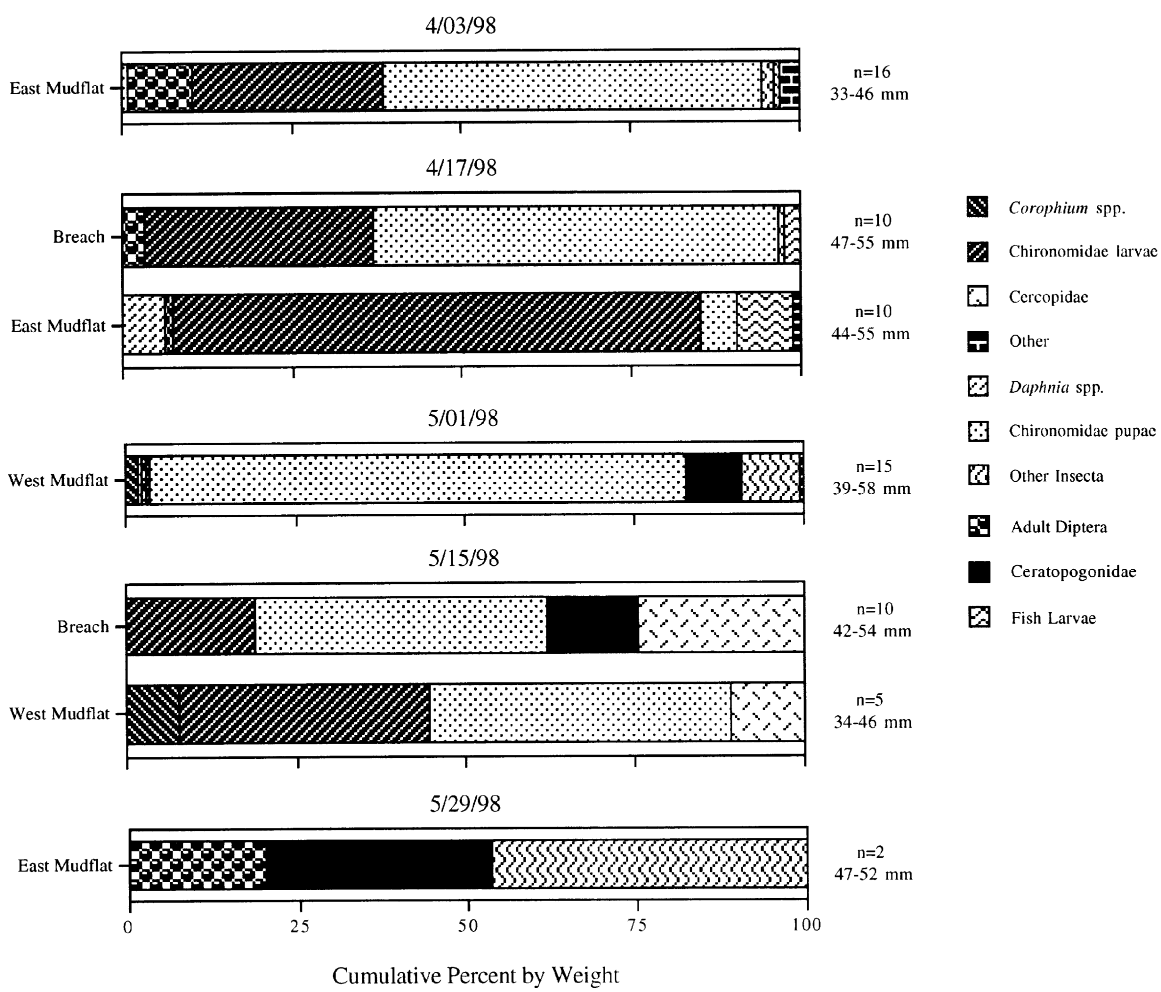

FIGURE 4. Percentage composition by weight of prey from juvenile chum salmon on five dates at several stations at Spencer Island, Washington, 1998.

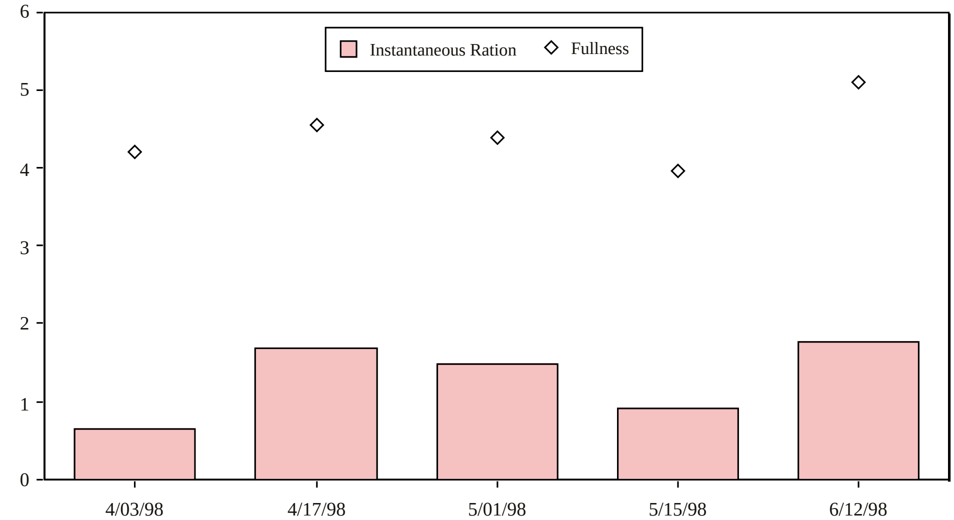

FIGURE 5. Stomach fullness factor (1 = empty, 6 = full) and index of percent ratio of stomach contents weight of fish weight for juvenile chinook salmon captured by beach seine at Spencer Island, Washington in 1998. Vertical lines represent standard deviations.

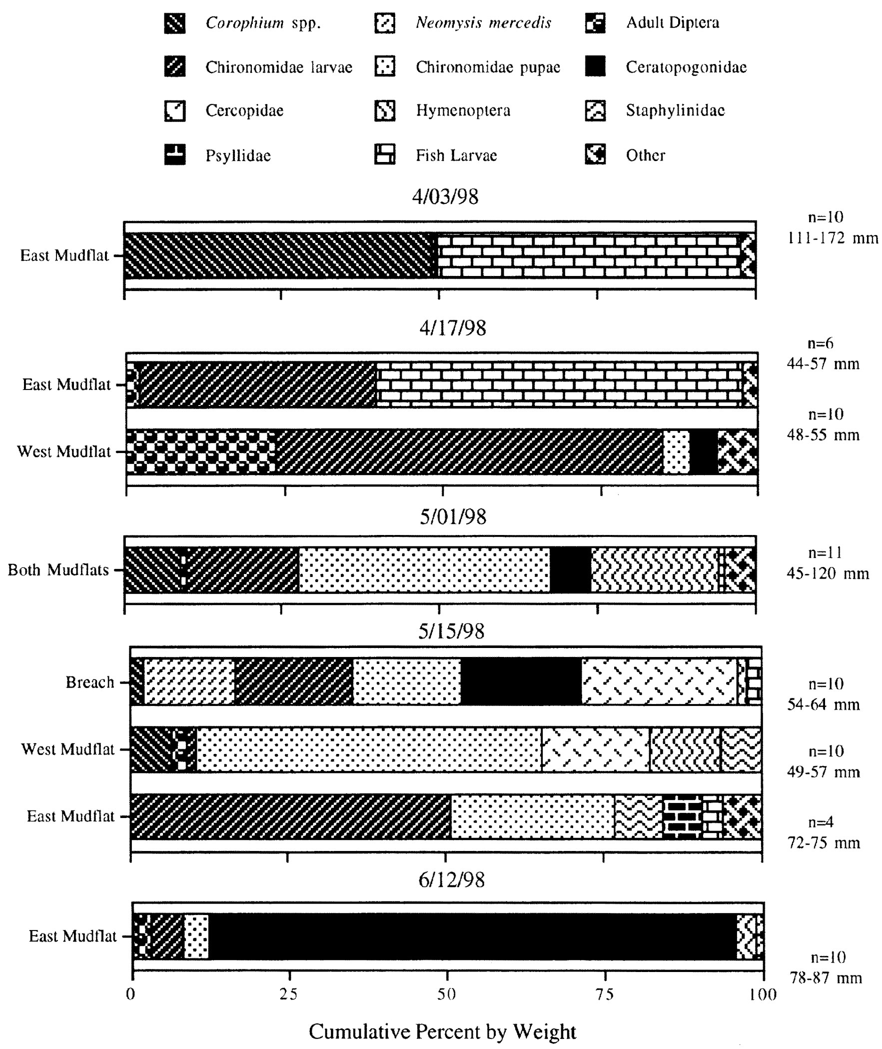

FIGURE 6. Percentage composition by weight of prey from juvenile chinook salmon on five dates at several stations at Spencer Island, Washington, 1998.

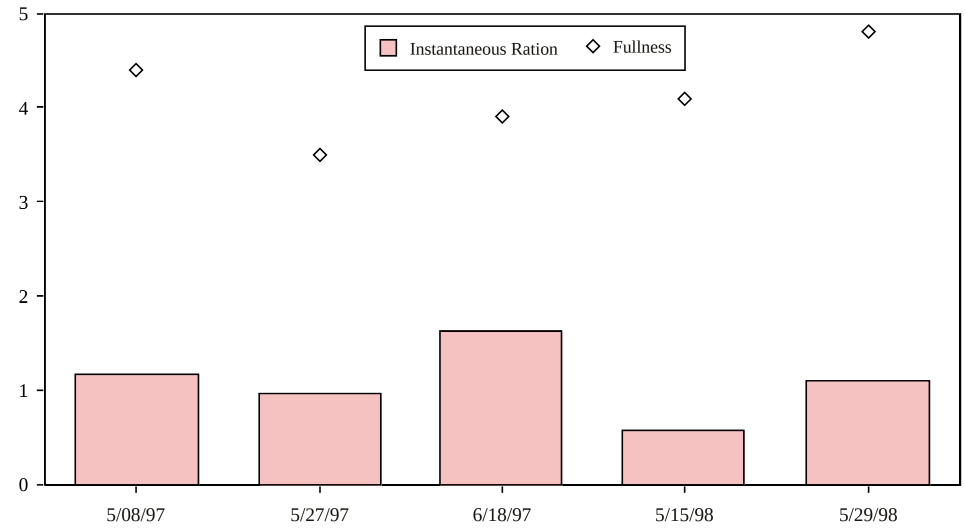

FIGURE 7. Stomach fullness factor (1 = empty, 6 = full) and index of percent ratio of stomach contents weight of fish weight for juvenile coho salmon captured by several methods at Spencer Island, Washington in 1998. Vertical lines represent standard deviations.

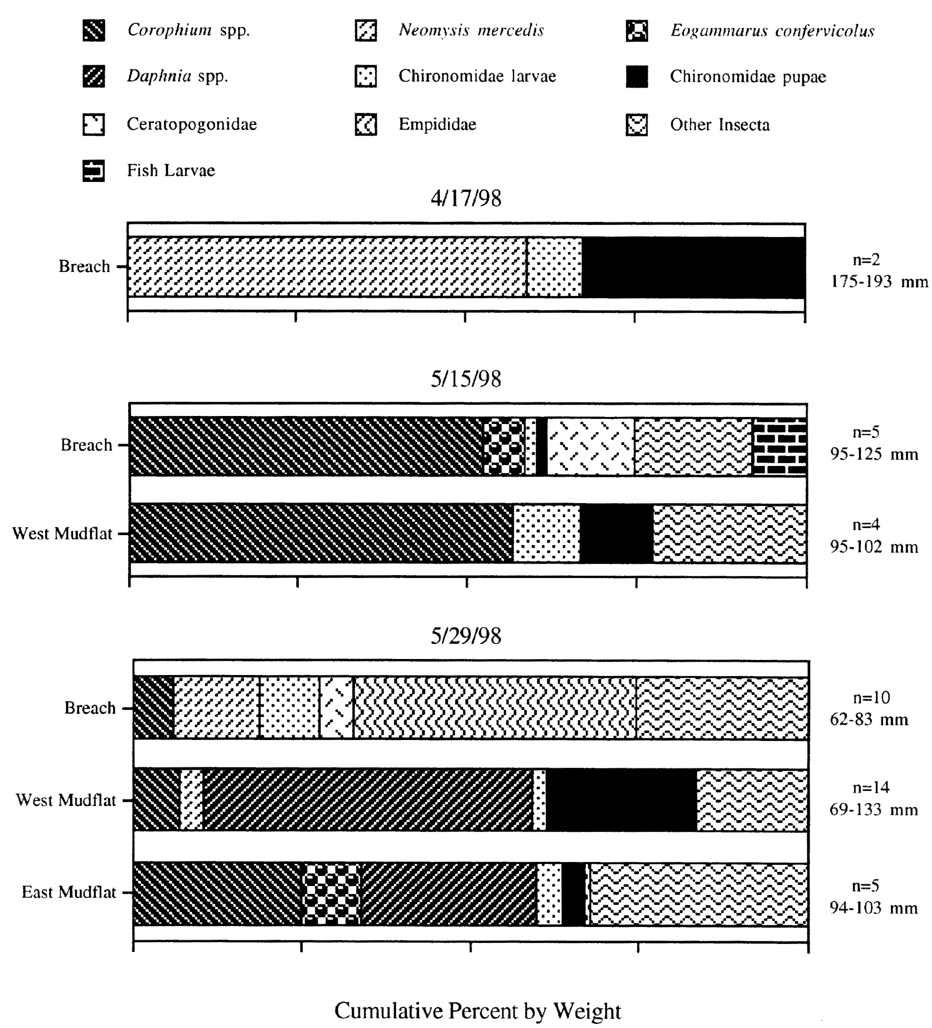

FIGURE 8. Percentage composition by weight of prey from juvenile coho salmon on five dates at several stations at Spencer Island, Washington, 1998.

May; and *Corophium* spp., the gammarid amphipod *Eogammarus confervicolus*, and *Daphnia* spp. cladocerans at the mudflat sites on 29 May. Insects dominated coho diets only at the breach site on 29 May, in which case prey consisted of mostly empidid fly larvae and a variety of other insects.

Discussion

In 1998 we caught almost five times as many salmonids as were caught in 1997, and five additional fish species on the same number of sampling dates. In addition, we caught 148 chinook salmon in 1998 and none in 1997. This difference may be due to between-year differences in amounts and patterns of use by juvenile salmon at the site. However, we believe that increased catches in 1998 were due to better catches by the 37-m beach seine compared with the gillnets and channel traps previously used (see Cordell et al. 1998 for a discussion of the problems using these gear types). Our 1998 catches were also much more consistent than in 1997, when nearly half of the juvenile salmon were caught in a single, small two-person pole seine sample on one date (Cordell et al. 1998). The consistency of our catches of chum and chinook salmon across the sampling period in the interior regions of the site suggests that these species regularly access the breached-dike restoration site.

With respect to the predominance of chironomid flies, the diets of chum salmon captured at the restoration site in 1998 were similar to those in 1997. This dominance by chironomids is similar to results from diet analyses of chum salmon from other estuarine sites (Congleton 1978, Northcote et al. 1979, Shreffler et al. 1992, Cordell et al. 1997), including freshwater tidal creeks in the Fraser river estuary (Levings et al. 1995). This finding is not surprising; given the dominance of that taxon in the benthic core and fallout trap samples collected at Spencer Island in 1997 (Cordell et al. 1998) and in emergence traps from marsh habitats in the Fraser river estuary (Whitehouse et al. 1993). As in diets from chum salmon sampled at Spencer Island in 1997, crustaceans such as harpacticoid copepods represented only a minor percentage of prey weight. This result differed from earlier studies in the lower Fraser and Nanaimo river estuaries, in which harpacticoid copepods and other crustaceans were relatively important prey items (Levy and Northcote 1981, Levings and Nishimura 1997, Sibert et al. 1997). The scarcity of harpacticoid copepods in chum salmon diets from Spencer Island may be due to the lack of harpacticoid prey of sufficient size at this site. For example, typical chum salmon harpacticoid prey species are rare in similar habitats in the Chehalis and Puyallup river estuaries (Shreffler et al. 1990; Thom et al. 1990, 1991; Simenstad et al. 1992, 1993, 1997), and our qualitative scans of meiofauna fractions of benthic samples taken at Spencer Island in 1997 revealed very few harpacticoids (Cordell et al. 1998).

The diets of juvenile chinook salmon in our study, which were usually dominated by chironomids (*Corophium* spp.) and larval fish, were also very similar to diets of chinook from other restored and natural habitats in the Pacific Northwest. Shreffler et al. (1992) found that juvenile chinook residing in a restored wetland on the Puyallup River estuary were highly selective for chironomids, and Cordell et al. (1997) found that *Corophium* spp. and larval fish were prominent diet components in the Duwamish river estuary. At created and natural channels in the Chehalis river estuary, Miller and Simenstad (1997) found that chironomids and aphids were the most important prey items for juvenile chinook; chironomids were also an important prey item for chinook in tidal creeks in the Fraser river estuary (Levings et al. 1995). The above-cited studies found that aphids are rare in the diet of juvenile salmon captured in habitats that have little or no native vegetation (e.g., Duwamish, Spencer Island), but are common to abundant in the diets of fish that have been caught in habitats where such vegetation (mostly *Carex lyngbei*) is naturally occurring or replanted. As native vegetation becomes established at the Spencer Island restoration site, aphids and other plant-dependent insects may become more important prey items for juvenile chinook salmon.

Data on the feeding habits of juvenile coho salmon in tidal fresh and oligohaline reaches of estuaries are scarce, and the results of our diet analysis of 29 coho are based on one of the largest samples for this species in this habitat type. In having diets composed of insects and a relatively large proportion of benthic and epibenthic crustaceans, our results are similar to those of Miller and Simenstad (1997), who found that the mysid shrimp *Neomysis mercedis* is an important prey component at a created channel in the Chehalis river estuary. Crustaceans were also prominent in the diets of juvenile coho at Spencer Island in 1997, and in the Duwamish River estuary (Cordell et al. 1997, 1998). The isopod *Asellus* (= *Caecidotea*) was prominent in the diets of a small sample of coho presmolts from tidal creeks in the Fraser river estuary (Levings et al. 1995) and from the coho captured at Spencer Island in 1997 (Cordell et al. 1998).

Because the breaches at the Spencer Island restoration site were open during our sampling, we cannot say definitively that the prey in the salmon stomachs were acquired on site: they may have fed in adjacent waters and entered the site just before capture. However, we attempted to control for this by sampling near high slack tide when the fish captured had presumably been inside the restoration site for the longest time. We also believe that much of the prey from salmon captured in the interior of Spencer Island had been acquired there; because the type of prey in these fish was often qualitatively different than that from fish caught near the large breach: in particular, the channel-dwelling mysid *Neomysis mercedis* occurred almost exclusively in prey from fish caught near the breach. We found relatively high stomach fullness indices (averaging about 50–75% full) for all three species of juvenile salmon that were abundant at Spencer Island. Along with our findings from benthic and insect fallout samples taken in 1997—that the restoration site was producing juvenile salmon prey organisms in densities that equaled or exceeded those at a reference site—these results suggest that juvenile salmon are able to successfully forage at this site.

References

Congleton, J.L. 1978. Feeding patterns of juvenile chum in the Skagit River salt marsh. Page 141-150 *in* C.A. Simenstad and S.J. Lipovsky (eds.), Fish Food Habits Studies. 1st Pacific Northwest Technical Workshop. Workshop Proceedings, Washington Sea Grant, WSG-WO-77-2. Univ. Washington, Seattle.

Cordell, J.R., L.M. Tear, K. Jensen, and V. Luiting. 1997. Duwamish River Coastal America restoration and reference sites: results from 1996 monitoring studies. Univ. Washington School of Fisheries, Fish. Res. Inst. FRI-UW-9609. Seattle.

Cordell, J.R., H. Higgins, C. Tanner, and J.K. Aitken. 1998. Biological status of fish and invertebrate assemblages in a breached-dike wetland site at Spencer Island, Washington. Univ. Washington School of Fisheries, Fish. Res. Inst. FRI-UW-9805. Seattle.

Levings, C.D., D.E. Boyle, and T.R. Whitehouse. 1995. Distribution and feeding of juvenile Pacific salmon in freshwater tidal creeks of the lower Fraser River, British Columbia. Fish. Manag. Ecol. 2:299-308.

Levings, C.D. and D.J.J. Nishimura. 1997. Created and restored marshes in the lower Fraser River, British Columbia: summary of their functioning as fish habitat. Wat. Qual. Res. J. Can. 32:599-618.

Levy, D.A. and T.G. Northcote. 1981. The distribution and abundance of juvenile salmon in marsh habitats of the Fraser River estuary. Westwater Research Centre, Tech. Rep. 25. Univ. British Columbia, Vancouver, British Columbia.

Miller, J.A. and C.A. Simenstad. 1997. A comparative assessment of a natural and created estuarine slough as rearing habitat for juvenile chinook and coho salmon. Estuaries 20(4):792-806.

Northcote, T.G., N.T. Johnston, and K. Tsumura. 1979. Feeding relationships and food web structure of lower Fraser River fishes. Westwater Research Center Tech. Rep. 16. Univ. British Columbia, Vancouver, British Columbia.

Shreffler, D.K., C.A. Simenstad, and R.M. Thom. 1992. Juvenile salmon foraging in a restored estuarine wetland. Estuaries 15:204-213.

Shreffler, D.K., R.M. Thom, C.A. Simenstad, J.R. Cordell, and E.O. Salo. 1990. The Lincoln Avenue wetland system in the Puyallup River estuary, Washington: Phase III report; Year three monitoring, January-December 1988. Univ. Washington School of Fisheries, Fish. Res. Inst. FRI-UW-8916. Seattle.

Sibert, J., T.J. Brown, M.C. Healey, B. Kask, and R.J. Naiman. 1977. Detritus-based food webs: exploitation by juvenile chum salmon (*Oncorhynchus keta*). Science 196:649-650.

Simenstad, C.A., J.R. Cordell, J.A. Miller, W.G. Hood, and R.M. Thom. 1992. Ecological status of a created estuarine slough in the Chehalis River estuary: Assessment of created and natural estuarine sloughs, January-December 1991. Univ. Washington School of Fisheries, Fish. Res. Inst. FRI-UW-9206. Seattle.

Simenstad, C.A., J.R. Cordell, J.A. Miller, W.G. Hood, and R.M. Thom. 1993. Ecological status of a created estuarine slough in the Chehalis River estuary: Assessment of created and natural estuarine sloughs, January-December 1992. Univ. Washington School of Fisheries, Fish. Res. Inst. FRI-UW-9305. Seattle.

Simenstad, C.A., J.R. Cordell, W.G. Hood, B.E. Feist, and R.M. Thom. 1997. Ecological status of a created estuarine slough in the Chehalis River estuary: Assessment of created and natural estuarine sloughs, January-December 1995. Univ. Washington School of Fisheries, Fish. Res. Inst. FRI-UW-9621. Seattle.

Thom, R.M., C.A. Simenstad, J.R. Cordell, and L.A. Hamilton. 1991. The Gog-Li-Hi-Ti wetland system in the Puyallup River estuary, Washington: Phase V report: Year five monitoring, January-December 1990. Univ. Washington School of Fisheries, Fish. Res. Inst. FRI-UW-9108. Seattle.

Thom, R.M., C.A. Simenstad, J.R. Cordell, D. K. Shreffler, and E.O. Salo. 1990. The Lincoln Street wetland system in the Puyallup River estuary, Washington: Phase IV report; Year four monitoring, January-December 1989. Univ. Washington School of Fisheries, Fish. Res. Inst. FRI-UW-9004. Seattle.

Whitehouse, T.R., C.D. Levings, and J.S. MacDonald. 1993. Chironomid (Diptera) insects from natural and transplanted estuaries marshes in British Columbia. Pages 499-524 *in* Proceedings of the 1993 Canadian Coastal Conference May 4-7, 1993, Vancouver, British Columbia. Coastal Zone Engineering Program of the National Research Council, Ottawa.