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BIOLOGICAL STATUS OF FISH AND INVERTEBRATE ASSEMBLAGES IN A BREACHED-DIKE WETLAND SITE AT SPENCER ISLAND, WASHINGTON

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Key Words

benthic invertebrates, juvenile salmon, insects, Snohomish River estuary, wetland restoration

Biological Status of Fish and Invertebrate Assemblages in a Breached-Dike Wetland Site at Spencer Island, Washington

J.R. CORDELL, H. HIGGINS, C. TANNER, AND J.K. AITKIN

INTRODUCTION

The purpose of this study was to conduct the first post-breach sampling of juvenile salmon prey attributes at southern Spencer Island and an appropriate reference site, and to continue monitoring juvenile salmon access to the site. While the habitats associated with this site supported a variety of waterfowl and other wildlife (Shapiro and Associates 1989), they had not been accessible to juvenile salmonids (*Oncorhynchus* spp.) or other fishes since the early 1900s. Because tidal brackish and other marshes have been greatly decreased in the Snohomish River estuary (Bortelson et al. 1980) and because they provide direct support for fish and wildlife and indirectly supply organic material into the estuary, Spencer Island was chosen as a pilot wetland restoration site under the Puget Sound Water Quality Management Plan by a partnership of federal, state, and local agencies.

BACKGROUND

Spencer Island is located in the Snohomish River estuary near the city of Everett, Washington. It lies just off the main channel of the Snohomish River at approximately river mile 3.8 and is separated from the mainland by Union and Steamboat sloughs (Fig. 1). Prior to 1994, the perimeter of Spencer Island had been diked in the early 1900s to prevent inundation of the interior by tidal water from the sloughs. The island was used for agriculture until it was purchased in 1989 by Snohomish County and the Washington State Department of Wildlife. At this time, the area was a freshwater wetland habitat dominated by dense, monotypic stands of the exotic reed canary grass, *Phalaris arundinacea*, with lower areas containing patches of cat-tails (*Typha* spp.) and soft rush (*Juncus effusus*). The vegetation on the higher parts of the island consisted of wetland scrub-shrub assemblages predominantly made up of blackberries and rose (*Rubus* and *Rosa* spp.) grading into

mixed stands of Sitka spruce (*Picea sitchensis*), alder (*Alnus rubra*), willow (*Salix* spp.), and black cottonwood (*Populus trichocarpa*) near the dike edges.

The largest construction element of the restoration project was a cross levee (Fig. 1). The purpose of the levee is to restrict tidal activity to the south part of the island and decrease surface water fluctuations in the north part of the island, which is managed for waterfowl. In November 1994, after construction of the cross levee, the dikes surrounding the south section of Spencer Island were breached in several places, allowing natural tidal inundation of the interior of the island (Fig. 2).

Pre-breach baseline monitoring of Spencer Island consisted of topographic and vegetation mapping surveys and limited, unsuccessful fish surveys (Tear et al. 1996; C. Tanner, USFWS, Olympia, Washington, unpubl. data). Despite the development of comprehensive post-breach protocols and schedules for monitoring many biological habitat attributes (Shreffler and Thom, Battelle Northwest Marine Laboratories, Sequim, Washington, unpubl. report), the only parameters monitored in 1995–96 were fish access and vegetation (monitoring protocols and monitoring results through 1995 are summarized by B. Feist, L. Tear, and C. Simenstad, Univ. Washington Fish. Res. Inst., Seattle, Washington, unpubl. rep.).

Previous fish sampling at Spencer Island was designed to document fish access to the restoration site. Data from 1995–96 suggest that project goals related to increasing fish access to the breached portion of the island have been met (C. Tanner and J.K. Aitken, U.S. Fish and Wildlife Service, unpubl. data).

The specific objective of the study described in this report was to conduct systematic biological sampling at reference and breached-dike restored sites as follows:

1. Sample benthic invertebrates and fallout insects known to be important juvenile salmon prey in different strata (i.e., mudflat, wetland vegetation, wooded edge) at the breached-dike restored and reference sites.

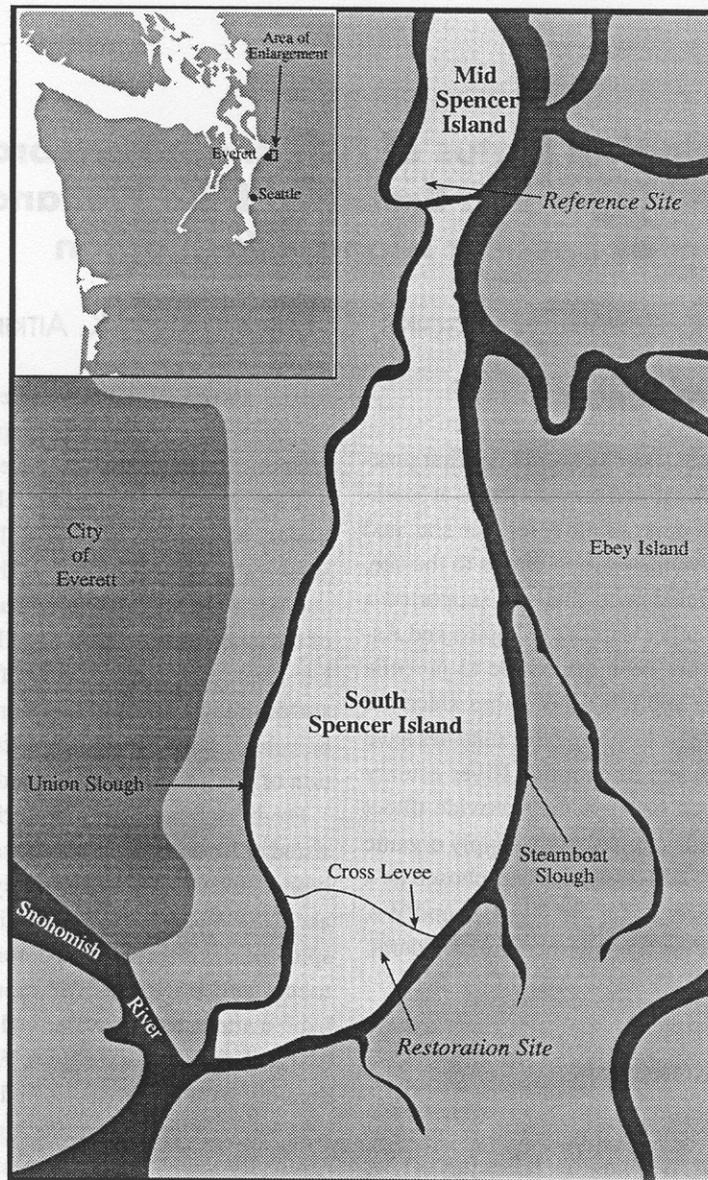


FIGURE 1. Location of restoration and reference study sites at Spencer Island, Washington.

2. Monitor juvenile salmon access to the restoration site using established (channel traps) and new (gillnets) methods.
3. Analyze diets of juvenile salmon captured within the restoration site.

The goal of this study was to provide data that will help to answer the following questions:

1. Are juvenile salmon able to access the inner portion of south Spencer Island?
2. Within south Spencer Island, does juvenile salmonid use vary by habitat strata?
3. Are the habitats inside south Spencer Island producing prey resources typical of those found in juvenile

salmon diets, and how do these resources compare with those at reference sites?

STUDY SITES

Breached Dike Restoration Site

We chose three habitat strata for sampling fish and invertebrates in the tidally influenced interior of the breached dike restoration site in south Spencer Island (referred to henceforth as the "restoration site") (Fig. 2). The first stratum consisted of an expanse of unvegetated mudflat adjacent to the cross levee separating north and south Spencer

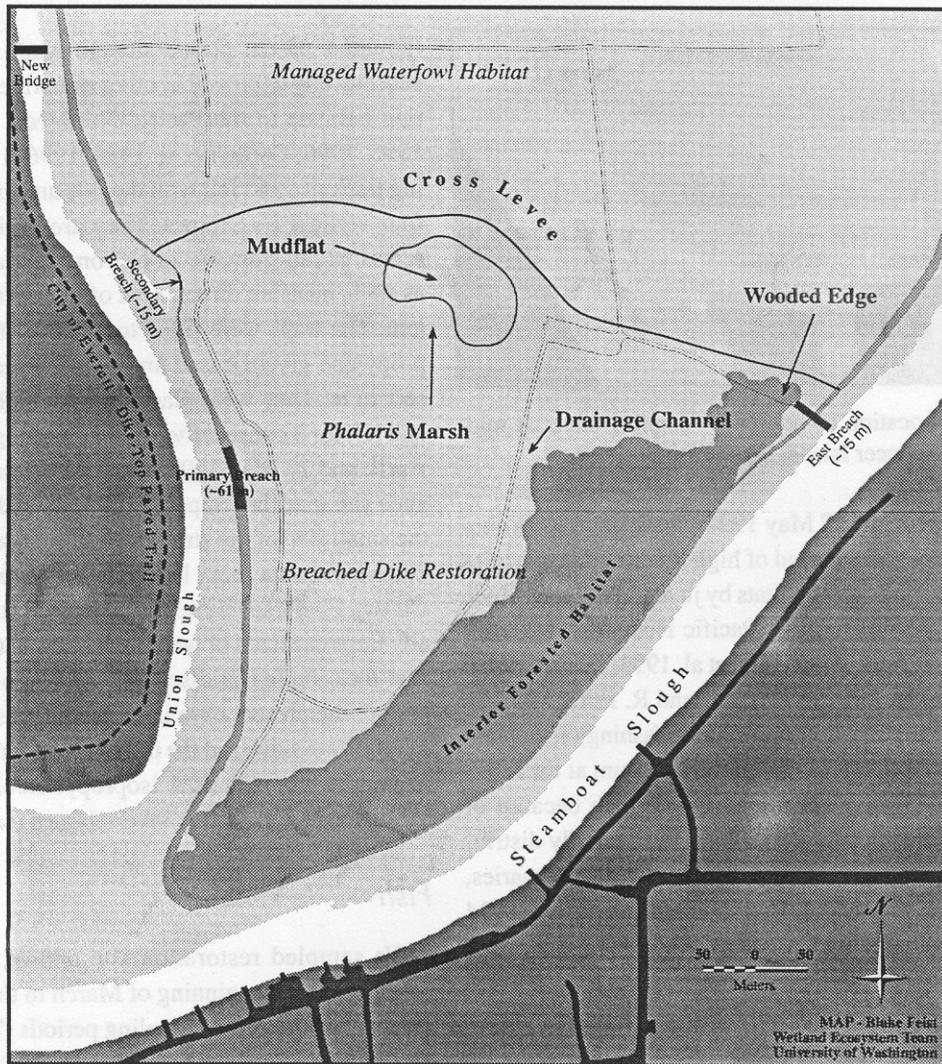


FIGURE 2. Location of sampling strata within breached dike restoration site at southern Spencer Island, Washington.

Island. The second stratum was inside the *Phalaris arundinacea* meadow that still dominates the interior of the southern island. The third sampling stratum was inside the forested edge near the juncture of the cross levee and the pre-existing dike along Steamboat Slough.

Reference Site

Our reference site was located on a part of Spencer Island that was cut off from the main, southern part of the island in the late 1950s or early 1960s when a channel was dredged to connect Union Slough and Steamboat Slough (Fig. 1). This section, which has been previously designated as "mid-Spencer Island," was breached around 1969, and the interior now consists mainly of stands of the native plants *Carex lyngbyei*, *Scirpus acutus*, and *Typha*

latifolia (Cunningham and Polayes-Wien 1995). The site consists of a small intertidal channel at the extreme southern end of mid Spencer Island with an associated mudflat, *Carex lyngbyei* stand, and wooded fringe (Fig. 3). This site was not affected by the late-1960s dike breach and appears in aerial photographs to have been unchanged since at least 1945. We established sampling strata in the mudflat, *Carex* stand, and wooded edge to correspond with the strata sampled at south Spencer Island. Fish were not sampled at the reference site.

METHODS

Benthic Invertebrates

Benthic sampling was conducted three times: on 31

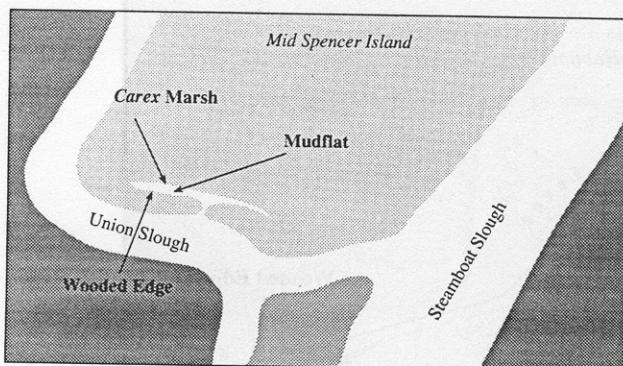


FIGURE 3. Location of reference sampling strata at mid-Spencer Island, Washington.

March, 14 April, and 27 May 1997. These dates were chosen to encompass the period of high invertebrate densities and use of tidal brackish habitats by juvenile salmon, which have been observed in other Pacific Northwest estuaries (Shreffler et al. 1992; Simenstad et al. 1993, 1996; Cordell et al. 1994, 1996, 1997; E. Warner and R. Fritz, Muckle-shoot Indian Tribal Fisheries, Auburn, Washington, unpubl. rep.). One exception was the mudflat stratum at the reference site, which was not sampled in March because of high water. At each site, we took 10 haphazardly distributed samples. As in previous samplings in other estuaries, we used a PVC plastic core that sampled an area of 0.0024 m² as recommended by Cordell et al. (1994). Cores were taken to a depth of 10 cm and were fixed in the field in a 5% buffered formaldehyde solution.

After approximately 1 week of fixation in the formaldehyde solution, benthic core samples were washed through two sieve sizes: 0.5 mm and 0.106 mm. Samples were then transferred to 50% isopropanol. All organisms in the larger fraction were identified using dissection and, when necessary, compound microscopes. Taxa occurring as attributes in the Estuarine Habitat Assessment Protocol (Simenstad et al. 1991—referred to henceforth as “the Protocol”) were identified to species level or to the level identified in the Protocol. Taxa not listed as attributes in the Protocol were not identified to species unless they had been identified or hypothesized as being prey for juvenile salmon. Representative samples of the smaller fractions were qualitatively scanned under a dissecting microscope to determine whether any juvenile salmon prey invertebrates were present. Because none of these taxa was found in the scans, the smaller fraction was not further processed.

Insects

Fallout insects were collected in rectangular fallout traps

(55-cm x 38-cm plastic storage bins), which have been successfully deployed in other estuarine emergent vegetation habitats in the Pacific Northwest (Simenstad et al. 1993, 1996; Cordell et al. 1994, 1996, 1997). These floating traps rise and fall with the tide and are kept in place by four vertical PVC pipes. They are designed to catch insects that fall from the air or from riparian vegetation and, as such, measure direct input of insects to the aquatic system. The traps were filled to a depth of about 4 cm with propylene glycol-based antifreeze, which acted as a preservative. They were placed haphazardly at each stratum and left for 3 consecutive days beginning on 31 March, 14 April, and 27 May 1997. One exception was at the reference site mudflat: traps were not placed there because of the small size of the stratum and its close proximity to the other two strata (e.g., less than 1 m from the edge of the *Carex*). Five traps were placed at each stratum. Occasionally traps capsized or were inundated with water, in which case the sample was discarded. At the end of the sampling period, the preservative in each trap was drained through a 0.106-mm sieve and the insects were removed and placed in sample jars with 50% isopropyl alcohol. Insects were identified as for benthic invertebrates (see previous text).

Fish

We sampled restoration site approximately every 3 weeks from the beginning of March to the middle of June 1997 for a total of six sampling periods (Table 1). In addition to the habitat strata defined in Study Sites (page 2), we sampled a main channel that drains the interior of the island on ebbing tides (Fig. 2).

The habitat strata were sampled with two horizontal floating gillnets consisting of two mesh sizes each. The nets have been successfully used to capture juvenile salmon and other fish in marshes at Willapa Bay, Washington (K. Fresh, Washington Dep. Fish and Wildlife, Olympia, Washington, unpubl. data). The “small mesh” net was 6.0-m long and 1.25-m deep, with two 3.0-m-long panels; one panel was composed of 15-mm stretch measure mesh and the other panel of 20-mm stretch measure mesh. The “large mesh” net had the same dimensions of the small mesh net, but one panel was composed of 25-mm stretch measure mesh and the other panel of 35-mm stretch measure mesh. The gillnets were hung between two 2.4-m garden stakes.

We also sampled at the mudflat site and at the largest of the dike breaches on 17 April with a beach seine in order to test the effectiveness of the other nets. The seine was 5.5 m long, 1.25 m deep, and was composed of 2.5-mm mesh. The drainage channel was sampled with a modified fyke trap.

TABLE 1. Tides and fish sampling periods for 1997 south Spencer Island sampling.

Date	Everett tides			Low Time	Low Feet	Modified fyke trap distribution channel			Experimental gillnets												Crew ^a	Notes
	Time	Feet	Time			Feet	Set	Pull	Time	Mudflat		Marsh		Forest edge								
										Set	Pull	Set	Pull	Set	Pull	Set	Pull					
4 Mar	6:37	7.0	11:40	9.8	0.1	19:01	0.1	11:50	15:30	3:40	12:10	14:50	2:40	12:30	14:30	2:00	KA & CT	A small mesh gillnet was used at each site.				
31 Mar	3:56	6.5	9:01	9.4	0.5	16:15	0.5	7:50	13:30	5:40	8:00	13:00	5:00	8:10	12:45	4:35	KA & CT	A small mesh gillnet was used at each site.				
17 Apr	9:02	4.6	14:25	8.0	2.7	20:30	2.7	12:20	17:59	5:39	12:30	17:35	5:05	12:40	18:25	5:45	JC & CT	A small and large mesh gillnet were used at the mudflat site. The remaining sites were sampled only with a small mesh gillnet. The mudflat site and large breach were also beach seined.				
8 May	0:29	5.0	5:51	10.9	-1.8	12:45	-1.8	3:15	10:40	7:25	3:45	10:15	6:30	4:00	9:55	5:55	KA & DL	A small and large mesh gillnet were used at the mudflat site. The remaining sites were sampled only with a small mesh gillnet.				
27 May	3:39	5.9	8:25	9.0	-0.7	15:21	-0.7	6:15	12:15	6:00	6:25	11:55	5:30	6:40	11:30	4:50	KA & CT	A small and large mesh gillnet were used at the mudflat site. The remaining sites were sampled only with a small mesh gillnet.				
18 Jun	10:06	-0.7	17:26	10.1	6.5	22:20	6.5	14:35	21:30	6:55	14:40	20:30	5:50	15:05	21:05	6:00	CT	A small mesh gillnet was at each site.				

^aCrews consisted of Kevin Aitkin (KA), Jeff Cordell (JC), David Low (DL), and Curtis Tanner (CT).

The sites were sampled from low tide to the following low tide (Table 1). We attempted to sample when low tide was less than +6 ft MLLW and the following high tide was greater than +9 ft MLLW to use the full depth of the gillnets. Consequently, sampling occurred during both day and night.

Captured fish were identified to species and counted. All salmonids were measured (fork length) and preserved immediately in a 10% formaldehyde solution. The only exception was when numerous salmon were caught in the beach seine: in this case, 10 individuals from each 5-mm size-class were retained and preserved, and the others were released.

In the laboratory, individual fish were measured (fork length) and weighed to the nearest 0.01 g. Stomachs were removed and opened, and the contents were weighed in their entirety. The contents were examined under a dissecting microscope and separated into individual taxa. Prey were identified to species level for crustaceans and to the level designated in the Protocol for other taxa. Each prey taxon was enumerated and weighed to the nearest 0.0001 g. All data was 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; for this study, prey weight data were taken from the GUTBUGS summary for further graphical analysis.

RESULTS

Benthic Invertebrates

Taxa Richness and Diversity

Benthic invertebrate diversity as measured by both taxa richness and Shannon-Weiner indices peaked in April samples from the restoration site strata (Fig. 4). There was no pattern of diversity peaks across sampling times at the reference site. Compared with their reference site strata, the restoration site habitats had (with one exception) lower taxa richness (e.g., the wooded edge samples in May had six taxa as compared to the reference site wooded edge, which had 12 taxa—Fig. 4, bottom). For Shannon-Weiner diversity indices, which account for densities as well as total number of taxa, this trend was also present but was not as pronounced (Fig. 4, top).

Assemblage Compositions

The composition of benthic macrofauna at all strata and

on all dates was numerically dominated by nematode and oligochaete worms, which together always made up 50% or more of the numbers (Fig. 5). These two taxa were particularly dominant in samples from the restoration site *Phalaris* and mudflat habitats (more than 75% of the abundance). In contrast, the reference site *Carex* and mudflat strata had relatively higher proportions of dipteran larvae. Dipteran larvae, which consisted mainly of chironomids and ceratopogonids, were also particularly prominent (30–50%) in the wooded edge samples from both sites.

Densities

For all benthic macrofauna invertebrates combined, densities ranged from 4.2×10^3 to over 1.8×10^5 individuals m^{-2} for the restoration site wooded edge in April and the restoration site *Phalaris* marsh in May, respectively (Fig. 6). Overall invertebrate densities were always highest at either the mudflat or *Phalaris* restoration site strata, and

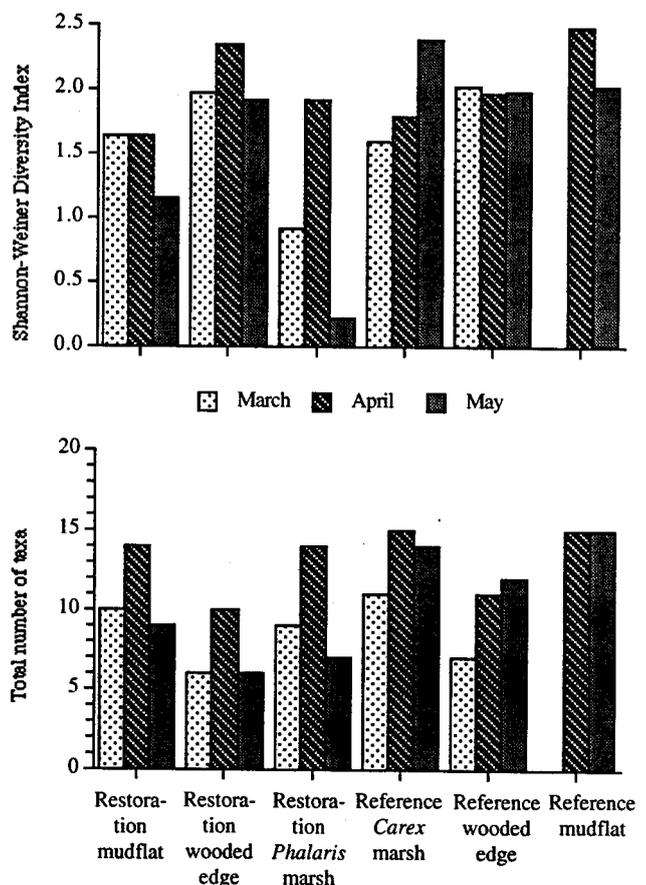


FIGURE 4. Taxa richness (bottom) and Shannon-Weiner diversity indices (top) for benthic invertebrates collected in several strata at breached-dike restored wetland and reference sites on Spencer Island, Washington, March–May 1997.

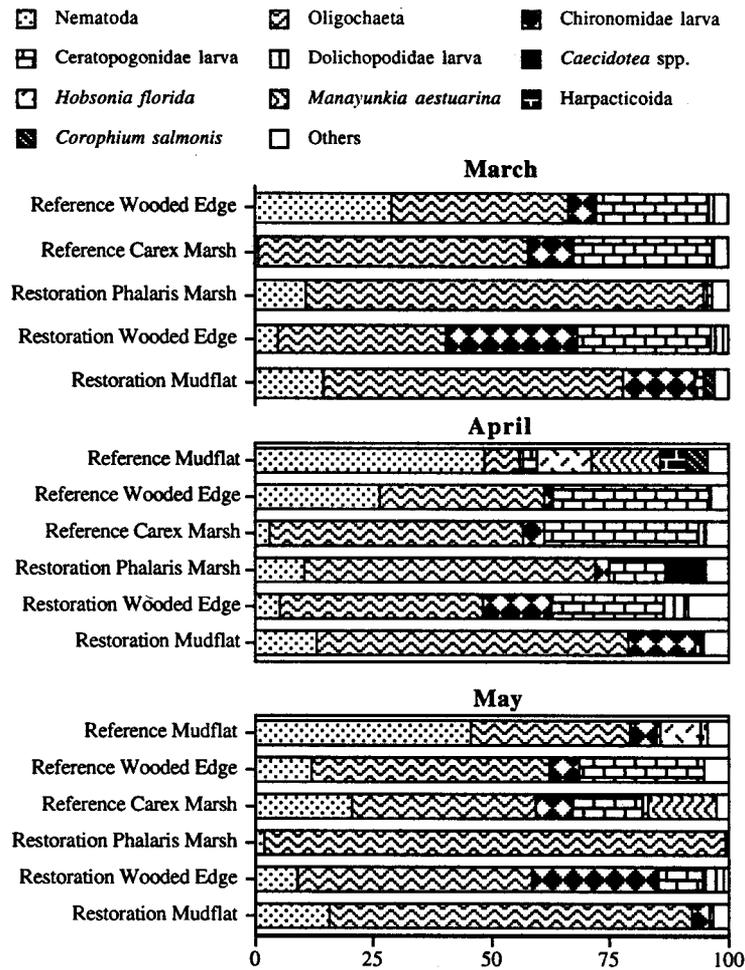


FIGURE 5. Percent numerical composition of invertebrates from benthic core samples collected in several strata at breached-dike restored wetland and reference sites on Spencer Island, Washington, March–May 1997.

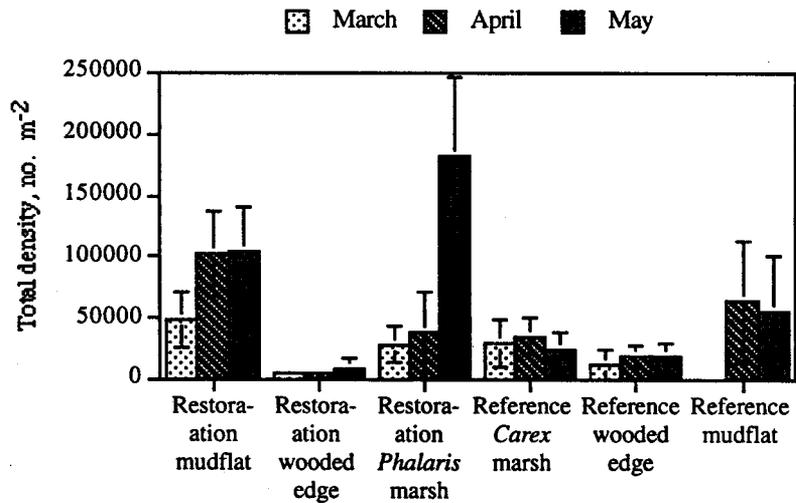


FIGURE 6. Densities (\pm SD) of total invertebrates from benthic core samples collected in several strata at breached-dike restored wetland and reference sites on Spencer Island, Washington, March–May 1997.

lowest at the restoration site wooded edge stratum. At the three breached dike habitats, invertebrate abundance increased from April to May; this trend was particularly marked at the *Phalaris* stratum. No temporal trend was evident in overall invertebrate densities at the reference site.

Some benthic taxa were absent or rare at a site: (1) the polychaete worms *Manayunkia aesturina* and *Hobsonia florida* occurred only at the reference site *Carex* and mudflat strata (Fig. 7), (2) tipulid fly larvae were relatively numerous only in the *Carex* and wooded edge samples at the reference site (Fig. 8), (3) the amphipod *Corophium salmonis* was prominent only at the reference site mudflat in April (Fig. 9), and (4) the isopod crustaceans *Caecidotea* spp. (which also occurred in coho salmon stomachs—see page 8) were found only at the restoration site mudflat and *Phalaris* strata (Fig. 9). Other taxa—nematode and oligochaete worms and ceratopogonid, dolichopodid, and chironomid fly larvae—were relatively abundant at one or more strata at both sites.

None of the taxa showed consistent increases in abundance over time or peaked in the same month across sites and strata. However, several taxa showed marked peaks in density at individual strata and sampling periods. These included nematodes at the reference site mudflat in May, oligochaetes at the restoration site *Phalaris* marsh in May, and chironomid larvae at the restoration site mudflat in April.

Insects

Taxa Richness and Diversity

Fallout insect diversity as measured by both taxa richness and Shannon-Weiner indices increased from March to May at the restoration site strata (Fig. 10). This trend was most dramatic at the mudflat and *Phalaris* marsh habitats, where the number of taxa approximately doubled between March and May. At the reference site, diversity measures among the strata were similar across the sampling period except in May at the *Carex* stand, which had a slightly lower diversity of insects compared with the other dates. In March and April, insect diversity was markedly lower in the restoration site *Phalaris* marsh compared with the reference site *Carex* stand. A similar trend was found in the wooded edge samples—Shannon-Weiner diversity index numbers were lower at the restoration site than at the reference site in March and April (although taxa richness was similar). On each sampling date, the lowest taxa richness was always found at the restoration site unvegetated mudflat.

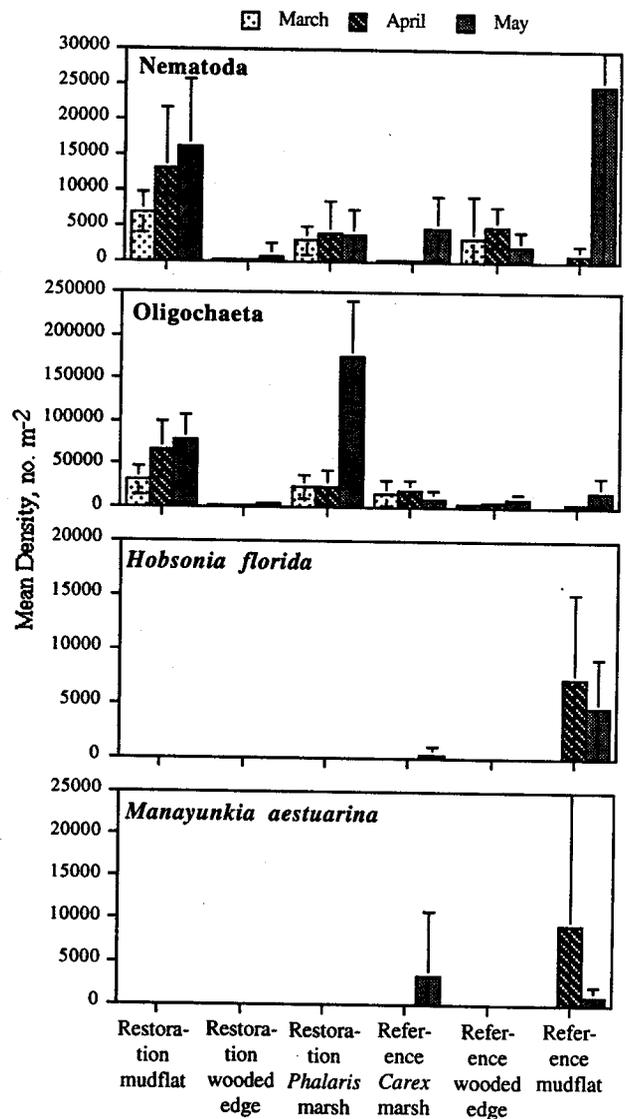


FIGURE 7. Densities (\pm SD) of prominent annelid worms and nematodes from benthic core samples collected in several strata at breached-dike restored wetland and reference sites on Spencer Island, Washington, March–May 1997.

Assemblage Compositions

In March, insect numbers at the reference site were distributed among three to four taxa, whereas at the restoration site, composition consisted almost entirely of only one or two taxa (Fig. 11, top panel). Chironomid flies represented over 50% of the numerical insect composition at all sites. They were particularly prominent at the restoration site *Phalaris* marsh and wooded edge strata, where they represented over 80% of the insect numbers. Other dipteran fly taxa were of secondary importance in March at both reference site strata (Ephydriidae) and at the resto-

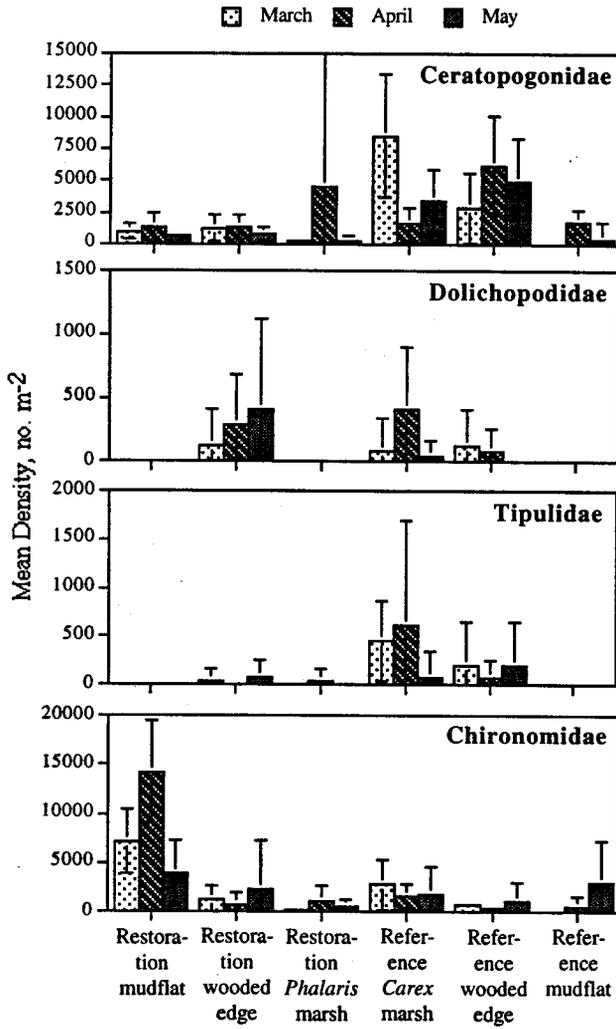


FIGURE 8. Densities (\pm SD) of prominent insect larvae from benthic core samples collected in several strata at breached-dike restored wetland and reference sites, Spencer Island, Washington, March–May 1997.

ration site unvegetated mudflat (Pyschodidae).

In April, the difference in distribution of taxa between the reference and restoration sites was more marked: in the reference site strata, insects were distributed among six or more taxa whereas at the restoration site, chironomid flies continued to dominate (approximately 65-85% of the numbers) (Fig. 11, middle panel). At the reference site, other prominent insect taxa included dipteran flies (Sciaridae, Ephydriidae, Tipulidae) and Collembola (spring-tails). At the restoration site, the only other prominent insect taxon was ephyrid flies at the mudflat and *Phalaris* strata.

In May, chironomid flies were much less dominant than they had been in the previous two sampling periods (Fig.

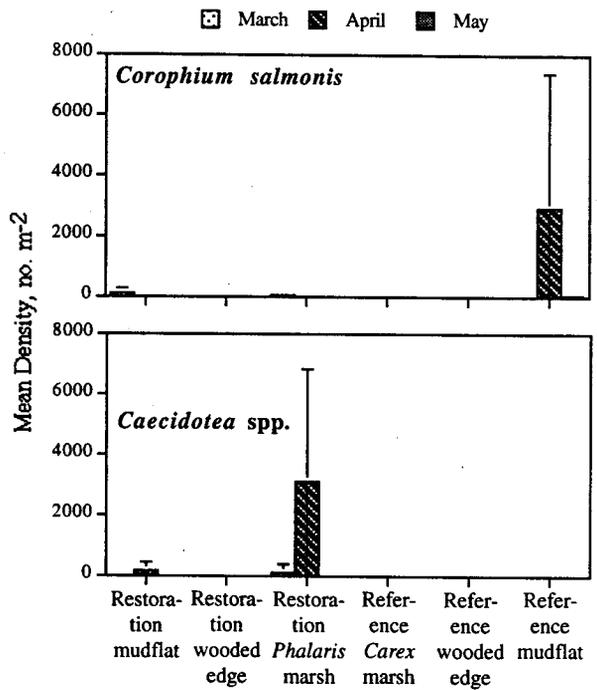


FIGURE 9. Densities (\pm SD) of prominent crustaceans from benthic core samples collected in several strata at breached-dike restored wetland and reference sites, Spencer Island, Washington, March–May 1997.

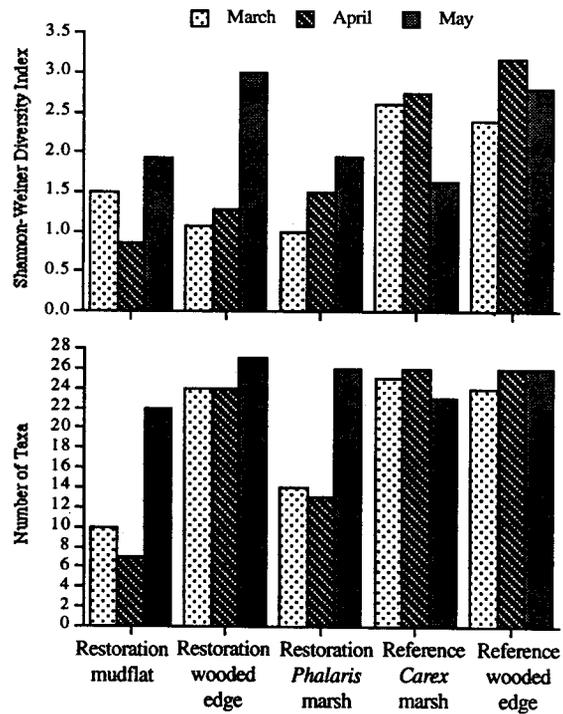


FIGURE 10. Taxa richness (bottom) and Shannon-Weiner diversity indices (top) for fallout insects collected in several strata at breached-dike restored wetland and reference sites on Spencer Island, Washington, March–May 1997.

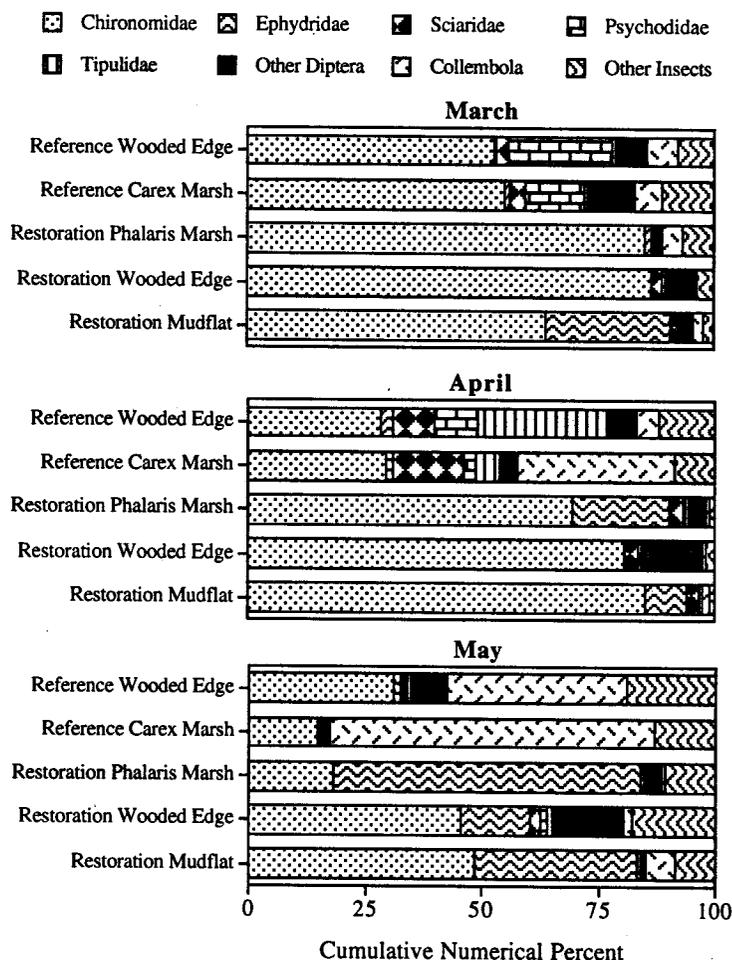


FIGURE 11. Percent numerical composition of insects from fallout traps deployed in several strata at breached-dike restored wetland and reference sites on Spencer Island, Washington, March–May 1997.

11, bottom panel). However, they still made up nearly 50% of the insect abundance at the restoration site mudflat and wooded edge strata. At the restoration site *Phalaris* marsh, the dominant insect taxon was ephydrid flies (about 60% of the numbers). Ephydriids were also prominent in the restoration site wooded edge and mudflat strata (about 15% and 30%, respectively). In contrast, the reference site was dominated by Collembolans, which comprised about 40% and 60% of the insect numbers at the wooded edge and *Carex* strata, respectively. Chironomids were of secondary importance at the reference site.

Densities

For all fallout insects combined, there was a trend of increasing densities between March and May at all but one site (Fig. 12). The exception was at the restoration site wooded edge stratum, where insect density peaked in April. This site and date also had the highest overall den-

sities found in this study, with mean numbers exceeding 6.0×10^3 individuals m^{-2} . Total insect densities at all other sites and dates ranged between 0.2 and 2.5×10^3 individuals m^{-2} .

Chironomid flies showed no consistent trends in density among the sites and strata (Fig. 13, top panel). On every sampling date, they were most abundant at the restoration site wooded edge, where they reached a peak density of approximately 5.0×10^3 individuals m^{-2} in April. Chironomid density at this site and time was approximately five times higher than at any other site and time; this was the highest density of any single fallout insect taxon recorded in this study.

Ephydrid flies occurred almost exclusively at the three restoration site strata (Fig. 13, middle panel). At all three of these strata, abundance of ephydriids peaked dramatically in May.

In contrast, while psychodid flies were present in relatively high numbers at both restoration and reference sites

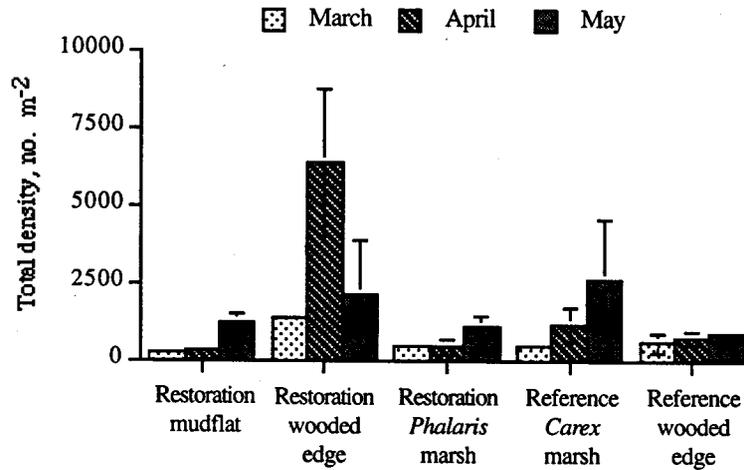


FIGURE 12. Densities (\pm SD) of total insects from fallout traps deployed in several strata at breached-dike restored wetland and reference sites on Spencer Island, Washington, March–May 1997.

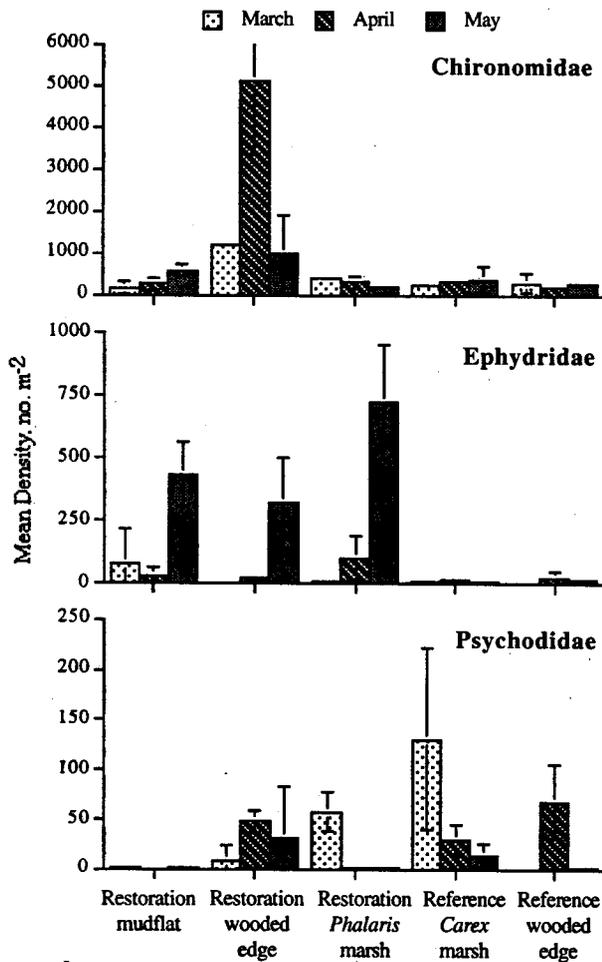


FIGURE 13. Densities (\pm SD) of prominent dipteran flies from fallout traps deployed in several strata at breached-dike restored wetland and reference sites on Spencer Island, Washington, March–May 1997.

(excepting the mudflat, where they were rare), they were usually most abundant at one of the two reference site strata, where they reached their peak densities (Fig. 13, bottom panel). They were most abundant in March or April (or both), and decreased in May.

Similarly, tipulid flies (craneflies) occurred at both the restoration site wooded edge stratum and the two reference site strata, but were much more abundant at the reference site (Fig. 14, top panel). Tipulids showed a strong peak in densities in April, and had negligible numbers on the other sampling dates.

Another dipteran fly taxon, Sciaridae, had large peaks in density in May at both the restoration site wooded edge and the reference site *Carex* marsh strata (Fig. 14, middle panel).

Collembola occurred almost exclusively at the reference site, where they were mainly found in the *Carex* stratum (Fig. 14, bottom panel). Collembolans peaked markedly in the May samples. In this month, their density at the reference site *Carex* marsh (approximately 1.7×10^3 individuals m^{-2}) was the second highest for any single fallout insect taxon.

Fish

Seven species of fish were captured during the course of this study (Table 2). Juvenile chum salmon (*O. keta*) dominated the overall catch (Table 3). All chum salmon were caught either in the drainage channel trap net or in the beach seine that was deployed on 17 April. Overall catches of other salmonids were small, consisting of 18 coho salmon (*O. kisutch*), one pink salmon (*O. gorbuscha*), three steelhead trout (*O. mykiss*), and one Dolly Varden/bull trout (*Salvelinus* sp.).

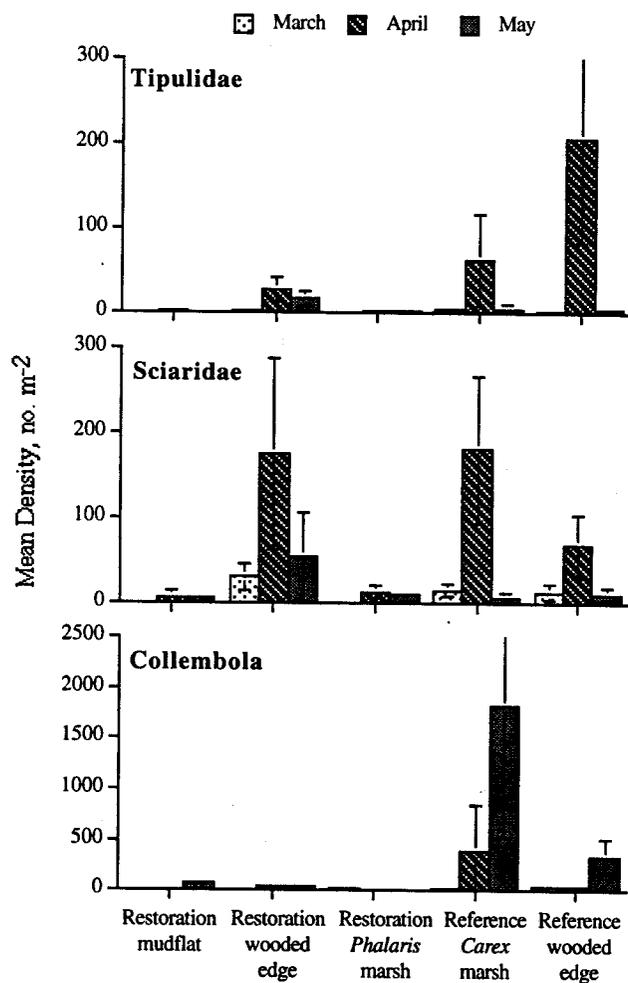


FIGURE 14. Densities (\pm SD) of other prominent insects from fallout traps deployed in several strata at breached-dike restored wetland and reference sites on Spencer Island, Washington, March–May 1997.

Chum Salmon Diets

Emergent adults and pupae of chironomid flies dominated the prey weight in juvenile chum salmon at every site and date analyzed except one (Fig. 15). The diet of the 16 juvenile chum from the 17 April beach seine sample taken near the large dike breach consisted mainly of the mysid shrimp *Neomysis mercedis* (about 85% of the prey weight). Secondary prey taxa, which comprised 5–25% of the prey weight, consisted of chironomid larvae, other dipteran flies, spiders, the amphipod crustaceans *Crangonyx* and *Corophium* spp., and the freshwater isopod crustaceans *Caecidotea* spp.

On 17 April, we captured enough chum salmon to analyze diets from three areas. In these samples, diets from

TABLE 2. List of fish species trapped at Spencer Island, March–June 1997.

Family	Common name	Scientific name ^a
Cyprinidae	Peamouth	<i>Mylocheilus caurinus</i>
Salmonidae	Pink salmon	<i>Oncorhynchus gorbuscha</i>
	Chum salmon	<i>O. keta</i>
	Coho salmon	<i>O. kisutch</i>
	Rainbow trout/steelhead	<i>O. mykiss</i>
	Dolly Varden/bull trout	<i>Salvelinus</i> sp.
Gasterosteidae	Threespine stickleback	<i>Gasterosteus aculeatus</i>

^aFish nomenclature taken from *Common and Scientific Names of Fishes from the United States and Canada*, Fifth ed., 1991, Am. Fish. Soc. Spec. Publ. 20.

the beach seine at the mudflat and from the drainage channel trap were similarly dominated by chironomid fly larvae and pupae/emergent adults. The only difference between these two groups of fish was in the secondary prey composition: in the fish from the mudflat this consisted primarily of other dipteran flies and *Corophium* amphipods, and in those from the channel trap it was made up mainly of spiders and *Caecidotea* isopods. As mentioned above, prey of chum salmon captured near the large dike breach on this date were predominantly *Neomysis mercedis*.

Coho Salmon Diets

We did not capture enough coho salmon in the gillnets to analyze diets by strata (see Table 2). On one date, we caught coho only in the mudflat stratum, and on the other two dates on which coho were captured we combined the data from the strata (Fig. 16).

Compared with the chum salmon diets, prey in coho salmon on the first two of the three dates analyzed (8 and 26 May) were distributed into a relatively large number of taxa. Chironomid flies were still the dominant taxon at about 50% of the prey weight, but the remainder of the prey weight was distributed into a variety of other insect categories, the most abundant of these being Tipulidae (craneflies), Ephemeroptera (mayfly) nymphs, and Coleoptera (beetles). In contrast, the diets of the seven coho salmon analyzed from 18 June were completely dominated by the isopods *Caecidotea* spp.

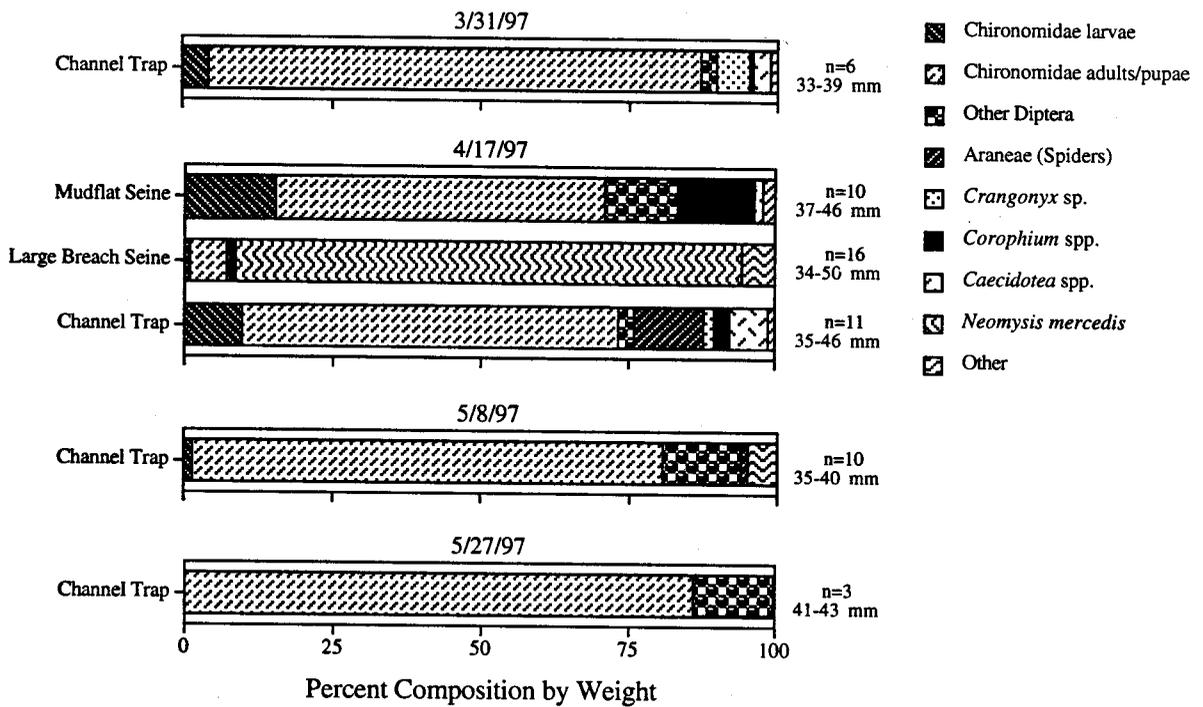


FIGURE 15. Composition of prey from juvenile chum salmon collected with beach seine and drainage channel traps at Spencer Island breached-dike restoration site, March–May 1997.

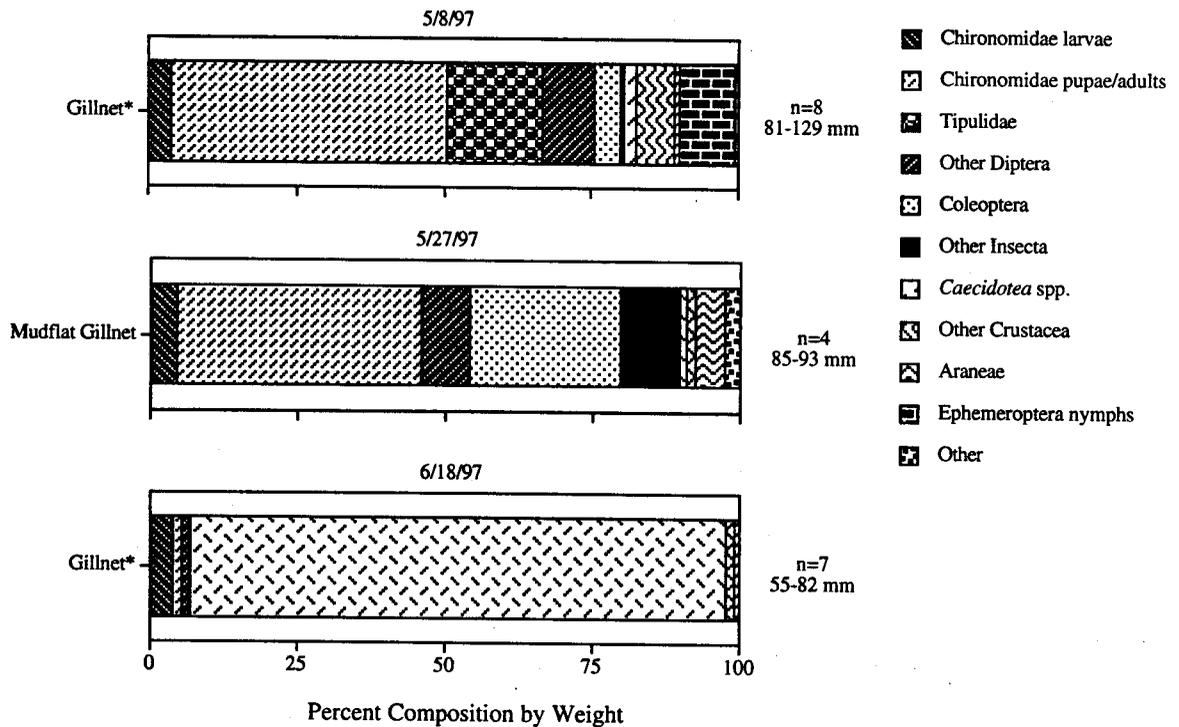


FIGURE 16. Composition of prey from juvenile coho salmon collected with gillnets at Spencer Island breached-dike restoration site, May–June 1997.

DISCUSSION

Benthic Invertebrates

Benthic estuarine polychaete worms and crustaceans (e.g., *Corophium* spp.) of the breached dike restoration site at south Spencer Island are far less abundant compared with other similar, recently sampled areas in Pacific Northwest estuaries (Simenstad et al. 1992, 1993, 1996; Cordell et al. 1994, 1996, 1997). These taxa occurred only at the mid-Spencer Island reference site. However, in lacking these taxa and being dominated by oligochaetes and nematodes, the restoration site is similar to the early phases of a constructed wetland on the Puyallup River estuary in Tacoma, Washington (Simenstad et al. 1997). Our data suggest that low salinity is why these typical estuarine taxa are lacking at the restoration site. The benthic invertebrate assemblage at the restoration site was dominated by taxa—nematodes, oligochaetes, and chironomid larvae—that can dominate freshwater as well as estuarine habitats. Also, the presence of the strictly freshwater isopods *Caecidotea* spp. (which were also abundant as prey in coho salmon caught at the site) further indicates that the restoration site does not experience regular salinity intrusions. Salinity measured in 1995 at the site during low-flow (and assumed high salinity intrusion) periods strengthens this hypothesis: the data showed that salinity entered the restoration site only rarely (B. Feist, L. Tear, and C. Simenstad, Univ. Washington Fish. Res. Inst., Seattle, Washington, unpubl. rep.). Another possibility is that estuarine taxa have not yet had time to colonize the restored habitats, especially if freshwater taxa are successful in excluding them by competing for resources. In time, however, some of the estuarine taxa may get a foothold and successfully colonize the changing habitat, even if salinity conditions do not change. The colonization of freshwaters by estuarine benthic invertebrates is exemplified in the Pacific Northwest by the amphipod *Corophium salmonis*, which has moved up the Columbia River from the estuary and become very abundant in the benthos of freshwater reservoirs (J. Cordell, unpubl. data).

Benthic insect assemblages of vegetated strata dominated by chironomids and ceratopogonids are very similar to those found in the Fraser and Duwamish River estuaries (Whitehouse et al. 1993, Cordell et al. 1997). Relatively high proportions and abundances of chironomid fly larvae at the restoration strata (see Figs. 5 and 8) may indicate the site is stressed by ongoing changes. Domination by chironomids is often used as a criterion for stressed or degraded freshwater habitats because many species in this family are tolerant of perturbation or pollution (Saether

1979, Wiederholm 1984, Ferrarese and Bertocco 1990, Kerans and Karr 1994). But this may not be true in estuaries: Whitehouse et al. (1993) found that in the Fraser River estuary, British Columbia, emergent chironomids were usually most abundant in reference natural marshes compared with transplanted restored marshes. Furthermore, these authors found a clear relationship between amount of vegetation and chironomid abundance—more were found in marshes with successfully transplanted vegetation relative to sites where transplants failed or relative to sand/mud locations. Therefore, the restored site at southern Spencer Island may also be producing high numbers of chironomids because of the persistence of the *Phalaris* on the site. Numbers of chironomids may actually decrease at the site after the *Phalaris* dies off and before natural plant assemblages become established.

The results from the restoration site—high numbers of relatively few taxa compared with the reference site—may be typical of disturbed or newly created habitats and may represent the first step in a succession of assemblages. In other systems, colonization of disturbed or newly created habitats by aquatic insects is sometimes dominated by a few taxa that are particularly suited to the new conditions (Sheldon 1984), and human-induced changes in the hydrology of estuarine habitats can cause a permanent shift in the benthic assemblage structure (Nienhuis and Smaal 1994). Thus, the developing habitats at the south Spencer Island restoration site may experience a fluctuating benthic assemblage structure as the system equilibrates, and the terminal faunal assemblage may differ from what we expected or observed in this study.

Fallout Insects

As in the benthic invertebrate samples, fallout insect abundance is distributed into relatively fewer taxa at the restoration strata, resulting in generally lower diversity. As discussed previously, this situation may not persist as the restoration site changes. Our finding of relatively low diversity and densities of insects at the unvegetated mudflat stratum at the restoration site is similar to that of Whitehouse et al. (1993) who found that, in the Fraser River estuary, more chironomid adults were produced in vegetated vs. nonvegetated habitats. As we also expected, the highest diversity of fallout insects was found in the wooded edge samples—the most heterogeneous habitat that we sampled.

One notable difference between the fallout insect data from this study and those from similarly vegetated habitats in other Pacific Northwest estuaries is the rarity of aphids.

Aphids were abundant in insect samples from the Duwamish River estuary (Cordell et al. 1997) and in insect and juvenile salmon prey samples from the Chehalis River estuary (Miller and Simenstad 1997, Simenstad et al. 1996). The lack of this taxon at the reference *Carex stratum* is particularly surprising given that aphids are a major constituent of the fauna collected from *Carex* benches in the Chehalis River estuary (Simenstad et al. 1997). The reasons for these differences are unknown but may be due to interannual or site variations.

Another interesting finding from the fallout trap data is the almost exclusive occurrence of ephydrid flies in strata from the restoration site. At a restoration site in the Duwamish River estuary, this taxon was dominant in 1995, 1 year after site was constructed, but was only a minor constituent of the fauna in 1996 (Cordell et al. 1997). It is possible that ephydrids are a transitory taxon that is abundant only early in site progression when disturbance is a large factor: this group of flies often is the dominant life form in physiologically stressed habitats (Foote 1995). However, we will not be able to further determine whether this is the case, or whether it is due to natural interannual variation or to some permanent change in the sites, until we obtain a sufficient time-series of data.

Juvenile Salmon

Our catches of juvenile salmon at the southern Spencer Island restoration site were small and probably not indicative of the actual access and use of the site by the fish. Sampling fish at the site using fyke nets and channel traps has been problematical in the past, mainly because of the multiple breaches and the large volume of water entering and leaving the site on each tide cycle. However, our individual visual observations of large numbers of juvenile salmon inside the breached dike area, plus our relatively large catches of juvenile chum salmon using a small beach seine on one date, suggest that juvenile salmon are successfully accessing the site. In addition, fish sampling using both beach seines and channel traps in 1995 suggest that juvenile salmon are entering the restoration site (K. Aitkin 1996¹). We recommend that several alternatives be considered in future sampling. First, a full-sized, 30-m beach seine could be successfully fished at both the largest breach and at the interior mudflat site. Second, the same beach seine could be set over emergent vegetation (such as *Phalaris* or *Carex*) at high tide as an "encirclement" seine, and fish could be removed as the tide recedes.

¹Copy of letter on file with J. Cordell.

Chum Salmon Diets

The predominance of chironomid pupae and emergent adults in juvenile chum salmon captured at the restoration site is not surprising given the dominance of that taxon in the benthic core and fallout trap samples. It is also very similar to results from diet analyses of juvenile salmon from other estuarine restoration sites. Shreffler et al. (1992) found that while residing in a restored wetland on the Puyallup River estuary, juvenile chum salmon selected chironomids over all other organisms, and Cordell et al. (1997) found that emergent or drifting dipteran flies, especially chironomids, dominated juvenile chum diets at a created channel in the Duwamish River estuary in Puget Sound, Washington. Chironomids are also important, often dominant prey for juvenile chum in natural estuarine habitats. For example, chironomid pupae and adults constituted 58% to 81% of the diet of juvenile chum captured in the Skagit River delta, Washington (Congleton 1978), and chironomid larvae dominated the diet of 29 species of fish collected in tidal marshes of the lower Fraser River (Northcote et al. 1979).

Crustaceans, especially harpacticoid copepods and gammarid amphipods, are important prey for juvenile outmigrating chum salmon, usually in nearshore marine waters but also in the oligohaline parts of some estuaries (e.g., the Duwamish River estuary; Cordell et al. 1997). Crustaceans were abundant only once in chum diets from southern Spencer Island: in the beach seine sample near the large breach taken in mid-April, chum diets were dominated by the mysid shrimp *Neomysis mercedis*. However, it is possible and perhaps likely that this prey was obtained outside the breach in the main channel of Union Slough. The lack of crustaceans in the chum diets from this study, plus our qualitative scans of meiofaunal fractions of the benthic samples, revealed that these types of prey were not present at the southern Spencer Island restoration site.

Coho Salmon Diets

On the first two of the three dates on which we analyzed juvenile coho salmon, the fish consumed mainly chironomid pupae and adults although in a lower proportion than was found in the chum diets. It appears that coho on these dates were more surface-oriented than the chum, feeding on a variety of other surface-drift insects (including coleopteran beetles, tipulid flies, and spiders). In contrast, diets of coho salmon captured on June 18 were completely dominated by the benthic freshwater isopod genus *Caecidotea*. This isopod has never been reported as a prey item

for juvenile salmon feeding in estuaries. Little published data exist on the diet of juvenile coho salmon in tidal oligohaline or freshwater estuaries. But diets of juvenile coho collected in the estuaries of Carnation Creek, British Columbia (Tschaplinski 1982, 1987), the Squamish River, B.C. (Ryall and Levings 1987), and the Chehalis River, Washington (Miller and Simenstad 1997), were similar to those in this study in that they consisted of a combination of surface-oriented insects and benthic/epibenthic crustaceans.

There is considerable overlap of prey types in benthic and fallout trap samples at the south Spencer Island restoration site and the diets of juvenile chum and coho salmon. This is especially true for chironomid flies, which generally dominated in both the diets and invertebrate samples. Also, our data clearly show that the restoration site was producing juvenile salmon prey organisms in densities that equaled or exceeded those at the reference site in spring 1997. However, equally clear is that the habitats within the breached dike restoration site are undergoing rapid and profound change. As the transition from a palustrine *Phalaris* meadow to an emergent estuarine marsh progresses, there will be radical changes and fluctuations in juvenile salmon invertebrate prey assemblages at the site.

CONCLUSIONS

At this juncture, approximately 2.5 years after breaching the dikes, the interior of southern Spencer Island is undergoing profound biotic changes. For example, both the forested area along the dike margins and the dense stands of *Phalaris arundinacea* in the area of restored tidal hydrology are dying off, resulting in increasing unvegetated patches. Also, some native plant species such as wapato (*Sagittaria latifolia*) and water plantain (*Alisma plantago-aquatica*) are beginning to colonize the area (L. Tear, Parametrix, Kirkland, Washington, unpubl. data). More importantly, large amounts of detritus from the senescing plants are entering the system. It is in this light—of a system in flux—that the results of our study should be interpreted. Large fluctuations in assemblage structure and densities of invertebrates at the site will be the rule in its short-term development. Pioneering species that can use the large input of detritus (mudflat and *Phalaris* strata) and decaying wood (wooded edge) may predominate early on and be replaced later by assemblages of more typical wetland species. It appears likely that juvenile salmon will continue to access the breached area, but the food resources that they find there will change as the site stabilizes, and

any future investigations of fish diet may reflect these changes.

The south Spencer Island restoration site currently contains several discrete habitats—wooded edge, *Phalaris* marsh, *Typha* sp., unvegetated mudflat, and tidal channels. We do not know which and to what extent any of these strata will remain intact. Development and stabilization of old and new species assemblages may require additional sampling strata in the future at this site. Our reference site appears to have been undisturbed at least since the late 1940s, is dominated by native plant species, is close to the restoration site, and is probably as good an example of relict natural habitats as can be found in the Snohomish River estuary. It also has a single discrete entrance channel that would lend itself well to experimental fishing with fyke-net or block-seine techniques. Therefore, comparison of juvenile salmon diets from both reference and restoration sites should be considered in any future biological monitoring at Spencer Island. Drainage and exit channels at both sites also present the opportunity to study the use of these habitats by mysid shrimp. In particular, the mysid *Neomysis mercedis*, which can be an important diet component in juvenile salmon feeding in estuaries (Cordell et al. 1997, Miller and Simenstad 1997, Simenstad et al. 1996), has been observed using similar channels in natural sloughs and channels in the Chehalis River (J. Cordell, pers. observations). The drainage channels at the Spencer Island restoration site may provide habitat for both the mysids and for the juvenile salmon that prey on them.

Because the site is changing, we recommend that biological sampling continue at the Spencer Island restoration site. If funding is not available to quantitatively sample the site at regular intervals throughout its development trajectory. The site should at least be monitored qualitatively but regularly to estimate when it reaches relative biological stability. This may be done through periodic observation of vegetation assemblages and development of discrete strata over time. At a minimum, comprehensive biological monitoring should take place again after stabilization of the site.

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