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DUWAMISH RIVER COASTAL AMERICA RESTORATION AND REFERENCE SITES:
RESULTS FROM 1997 MONITORING STUDIES

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WETLAND ECOSYSTEM TEAM

Acknowledgments

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Key Words

avifauna, benthic invertebrates, Duwamish River, emergent vegetation, insects, reference sites, wetland restoration

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Introduction

In this report, we present the results of 1997 biological monitoring at three wetland restoration sites in the Duwamish River estuary, Seattle, Washington. Restoration at these sites was originally facilitated by the federal Coastal America program and was carried out by a partnership of the City of Seattle, U.S. Fish & Wildlife Service, the U.S. Army Corps of Engineers, and the U.S. Environmental Protection Agency. Two of these sites are in the middle portion of the Duwamish Waterway, in a region dominated by tidal influence and mixed fresh- and marine water. The first of these sites consists of the General Service Administration (GSA) site located adjacent to the Federal Center South, which is a long, narrow intertidal strip running parallel to the east bank of the Duwamish Waterway adjacent /to the Seattle District Corps of Engineers. Restoration at this site included removal of rock riprap and a large overwater wharf structure to allow natural colonization by existing wetland plants, construction of a sediment "bench" at 0.0-m elevation to promote use by juvenile salmon (*Oncorhynchus* spp.), and planting of upland riparian vegetation. The second site is at Terminal 105 (T-105); this site originally consisted of a vacated street end and a large pipe that drained a small degraded wetland area. Restoration included removal of debris and replacement of the pipe with an estuarine channel that restored tidal flow to the area. The third Coastal America restoration site is at the upper Turning Basin at the head of the Duwamish Waterway. This site /comprises an upland riparian buffer planted with native vegetation and a small regraded upper intertidal basin planted with fringing native sedge, *Carex lyngbyei*, and rush, *Scirpus maritima*.

Initial baseline and pilot studies of benthic invertebrates, insects, emergent vegetation, and sediment grain size took place in 1993, prior to restoration (Cordell et al. 1994). During these baseline studies, appropriate reference sites in the vicinity of the restoration sites were also chosen and sampled. In late 1993 and early 1994, construction and planting of restoration sites took place. Using information gained from the initial pilot studies, post-restoration sampling was conducted in May 1995 and in April, May, and June 1996 at the restoration and reference sites (Cordell et al. 1996, 1997). The purpose of this study was to continue post-restoration sampling of the restoration and reference sites, and to compare the data with previous results. The specific objectives of this study were to conduct systematic biological sampling of long-term reference and restored sites using methods and protocols from previous samplings:

1. Sample benthic meio- and macroinvertebrates and fallout insects associated with mud and sandflats and at restored and reference sites.
2. Compare attribute species, as defined by the Estuarine Habitat Assessment Protocol (Simenstad et al. 1991; henceforth referred to as the "Protocol") and important non-attribute species among sites and years.
3. Analyze diets of juvenile salmon captured within or near restoration sites to compare with invertebrate sampling data and previous salmon diet data.
4. Continue monitoring bird numbers, use, and behavior at restoration and reference sites.
5. Continue sampling transplanted and naturally recruiting vegetation at restored sites and natural vegetation at reference sites.
6. Evaluate and summarize our current understanding of the status of restored habitats at the Coastal America sites.

Specific Tasks and Methods

Benthic Invertebrates

In 1993 (pre-restoration) and 1995, benthic sampling was conducted at lower intertidal reference mudflats and relatively fine sediments associated with or near restoration sites. In 1996, sampling was concentrated on upper intertidal vegetated habitats, with pilot sampling occurring on several sandflats on restoration sites. In 1997, we conducted benthic sampling at sand or mud benches or flats at restoration sites, and at reference mudflat sites that were sampled in 1993 and 1995. The reference sites included 0.0-m elevation mudflats at the Turning Basin and near the northeast tip of Kellogg Island (Fig. 1). Benthic samples were also taken at the following habitats at restoration sites: (1) the small sandflat encompassed by trans-

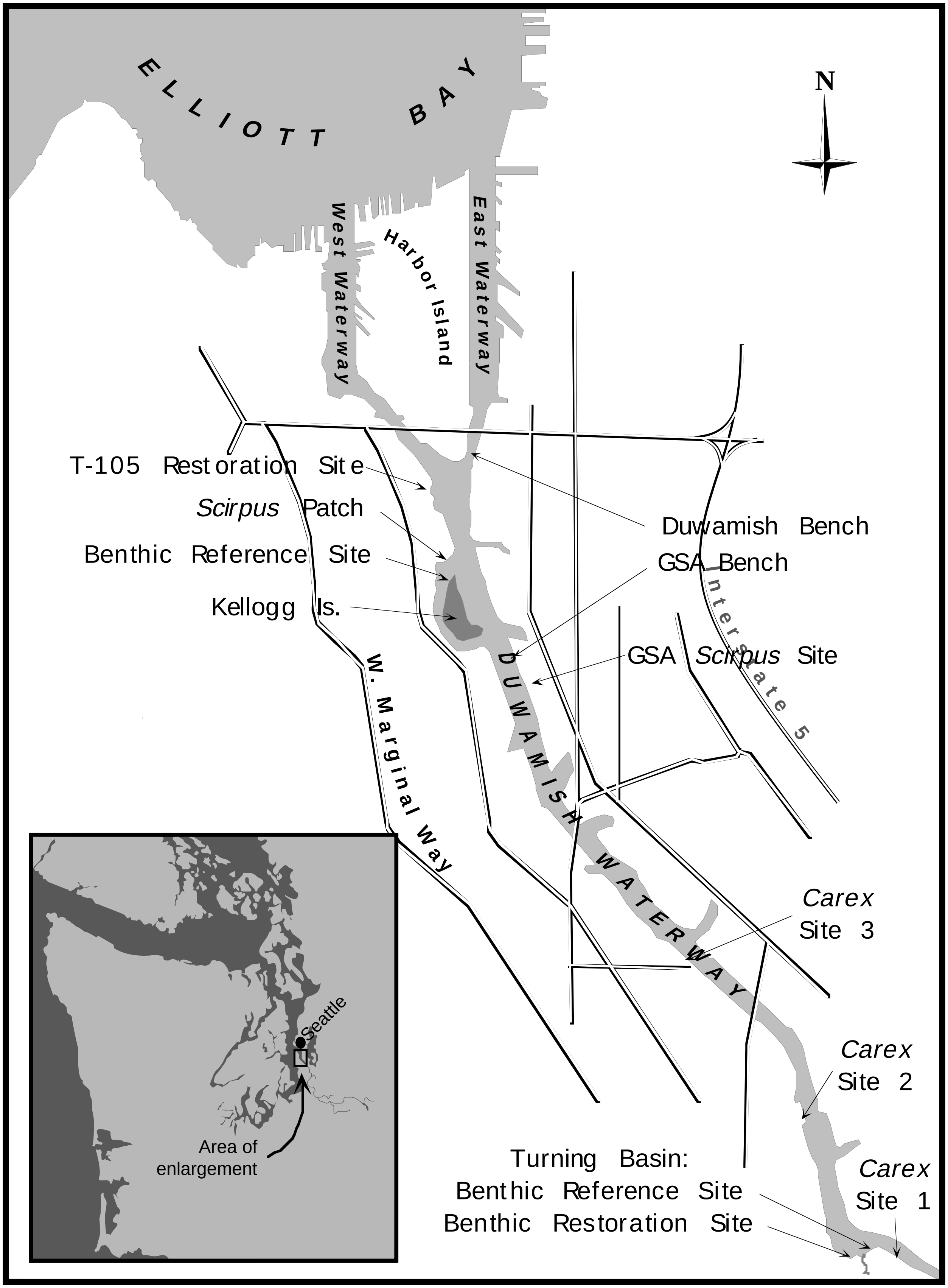

FIGURE 1. Location of 1997 sampling sites in the Duwamish Waterway.

planted *Carex* at and *Scirpus* at the Turning Basin, (2) the 0.0-m elevation mudflat at the base of the restoration area, (3) the constructed sediment bench at the 0.0-m elevation at the GSA site, (4) in the sediment along the center of the constructed channel at the T-105 site, and 5) at the "delta" or widened area at the terminus of the constructed channel at the T-105 site (Fig. 1).

Benthic sampling was conducted three times—22 April, 20 May, and 25 June 1997—to correspond with sampling dates in previous sampling years. At each site, we took 10 samples located haphazardly. As in previous samplings, we used a PVC core that sampled an area of 0.0024 m^2 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: macrofauna was retained on a 0.5-mm sieve, and meiofauna on a 0.153-mm sieve. Samples were then transferred to 50% isopropanol. If subsampling was necessary, samples were split to manageable fractions. Macrofauna samples were split in a Folsom plankton splitter until at least 100 organisms were obtained. Meiofauna samples were subsampled as for the macrofauna using a Hensen's Stemple pipette. All organisms were identified using dissection, and when necessary, compound microscopes. Taxa occurring as attributes in the Protocol were identified to the 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 were particularly abundant or have been identified or hypothesized as being prey for fishes or birds.

Insects

Insects were sampled at the two reference vegetation patches and three restoration sites that have been previously sampled. The reference sites included *Carex* site 1 and the small *Scirpus* patch across the channel from the northeast tip of Kellogg Island. The three restoration sites were (1) the *Carex* transplanted area at the Turning Basin (2) the small naturally recruiting patch of *Scirpus* at the GSA site, and (3) along the margins of the constructed channel at the T-105 site (Fig. 1).

Fallout insects were collected beginning 22 April, 20 May, and 25 June, 1997, using the rectangular fallout traps (55 cm x 38 cm plastic storage bins) that have been previously used. 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 measure direct input of insects to the aquatic system. The traps were filled to about 4 cm depth with propylene glycol-based antifreeze, which acted as a preservative. They were placed haphazardly in the vegetation at each site and left for 3 consecutive days. Five traps were placed at each site. 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 0.153-mm sieve and the insects were removed and placed in sample jars with 50% isopropyl alcohol. Insects were identified as for benthic invertebrates.

Juvenile Salmon Diets

Juvenile salmon for stomach analyses were collected on 22 April, 23 May, and 25 June, 1997 at three sites: (1) the upper Duwamish waterway near the Turning Basin (the sites designated as "Turning Basin" in Warner and Fritz 1996), (2) the waterway near Kellogg Island, and (3) at the T-105 created channel (Fig. 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. At the first two sites, the net was deployed from an outboard motor boat, parallel to shore and was pulled in by two 2-person teams. At the T-105 site, fish were captured by blocking the entrance of the created channel on a falling tide with the seine. 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 they 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 as a whole. 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 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, and for this study prey weight data were taken from this summary for further graphical analysis.

Avifauna

Observations were continually made from September 1996 through September 1998 at four sites on the east side of the Duwamish River. Two of the sites have undergone restoration treatment—Terminal 105 and the Turning Basin restoration site—and two have not (control sites)—Kellogg Island and Turning Basin South (called the Turning Basin reference site) (see Cordell et al. 1997 for site descriptions).

Using 10- x 40-mm binoculars, scan samples were taken in half-hour periods during daylight hours from 0700 to 1900 PST. This involved observing the site for a fixed period of time and recording all birds using the site by species, abundance, and behavior. Scan sampling was chosen because birds tended to display one primary behavior when at a site, making focal animal sampling (recording the behaviors of a single animal over a period of time) unnecessary. Observation times were concentrated primarily in early morning and late afternoon hours and, when possible, during low tide events. In order to concentrate observer effort during periods of increased migratory activity, we varied the number of visits to each site by season (Fig. 2). During the winter 1997–98 season, we were able to nearly double our effort compared with winter 1996–97 with the help of two independent research undergraduates.

An initial survey of species present, the number of each species, and the behavior of individuals was made. As new individuals arrived, their presence was recorded and classified by behavior. Behaviors were classified as foraging, resting, transit, breeding, and other. Transit birds in flight were not counted unless they landed and made contact with the intertidal area (summer 1995), but they were recorded for all subsequent seasons. Birds on the water were included when they were within a rectangle bounded by the extent of the site shorelines and the midline of the river. Tides, wind speed, direction, and general weather conditions were also recorded. Notes were made of obvious disturbances, such as boat traffic that caused birds to move or change behaviors.

Most of the data were collected from a location on the bank of the river or upper part of the intertidal area where birds could be seen with minimal disturbance. To minimize the impact of observer presence on the bird count, observers approached the site ready to note all the birds at the site immediately, then remained in the upland area for the first 15 minutes of observation. If the tide was so low that the water line was not visible, observers moved toward the water's edge to spot any birds otherwise out of sight, then returned to the upland location. All species that landed on the intertidal region were recorded, as well as those on pilings and posts set in the region. The tally of birds present was sorted by species and primary behavior (e.g., for mallard ducks: "MALL resting: 5, foraging: 4, transit: 2, other: 0").

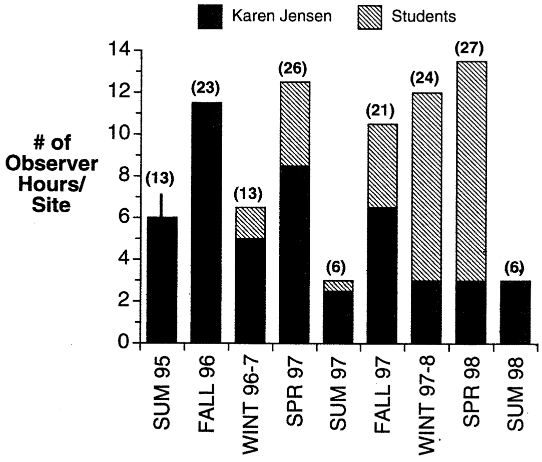

FIGURE 2. Observer effort for 9 seasons of avifauna data collection at four sites on the Duwamish Waterway; (n) = number of visits per site.

Data were sorted by species, abundance, and behavior. Abundance was graphed as the mean number of birds present across all observation periods within each season (i.e., summer 1995, fall 1996, etc.) for each site. In addition to calculating the total numbers of birds present, we compared the abundance without 14 species that were considered either introduced or native/human-associated (Table 1). Introduced species were defined as known exotics, and native/human-associated species were defined as resident birds whose populations have grown as a consequence of their interaction with humans (e.g., barn swallows nest only in man-made structures, glaucous-winged gulls forage in garbage dumps). Richness, or the mean number of species present across all observations, was also calculated by site and season. Richness was calculated with the full dataset, as well as without the introduced and human-associated species. Behavioral observations are presented as a percentage of all sightings, within site, to compare relative use patterns regardless of species.

Because the success of restoration depends not only on values such as abundance and richness, but on the particular type of species observed, data were further subdivided into three conservation categories: indigenous/native species, defined as resident birds of western Washington; non-native species, defined as known exotics; and native/human-associated species (defined above). Then pair-wise comparisons of the percentage of overlap for the three species categories at the four monitoring sites were done for each year of data. For T-105 and the Turning Basin restoration site, data were also plotted as percent occurrence of all species observed across the two sites as a function of the total number of half-hour observation periods within an observation season. Species were either grouped by guild—passerines, raptors, shorebirds, waterfowl, and seabirds—or as introduced or native/human-associated.

Emergent Vegetation

Six sites included in previous studies were sampled for emergent vegetation shoot density. Reference sites included the three *Carex* benches (sites 1-3) and the *Scirpus* patch across the channel from the northeast end of Kellogg Island (Fig. 1). These sites were references for (1) transplanted and recruiting *Carex* and *Scirpus* at the Turning

TABLE 1. List of species observed on the Duwamish Waterway. Species are grouped loosely by guild. Introduced and native, but human-associated species are categorized separately.

Guild	Species	
PASSERINES:	Fox Sparrow	FOSP
(23 Species)	Golden-crowned Sparrow	GCSP
	Savannah Sparrow	SASP
	Song Sparrow	SOSP
	White-crowned Sparrow	WCSP
	Cliff Swallow	CLSW
	Tree Swallow	TRSW
	Violet-green Swallow	VGSW
	American Goldfinch	AMGO
	Anna's Hummingbird	ANHU
	Bewick's Wren	BEWR
	Black-capped Chickadee	BCCH
	Bushtit	BUSH
	Dark-eyed Junco	DEJU
	House Wren	HOWR
	Northern Flicker	NOFL
	Northern Shrike	NOSH
	Orange-crowned Warbler	OCWA
	Pine Sisken	PISI
	Red-winged Blackbird	RWBL
	Ruby-crowned Kinglet	RCKI
	Rufous-sided Towhee	RSTO
	Swainson's Thrush	SWTH
RAPTORS:	Bald Eagle	BAEA
(7 Species)	Cooper's Hawk	COHA
	Merlin	MERL
	Osprey	OSPR
	Red-tailed Hawk	RTHA
	Sharp-shinned hawk	SSHA
	Swainson's Hawk	SWHA
SHOREBIRDS/	Dowitcher	DOWI
WADERS:	Dunlin	DUNL
(8 Species)	Great Blue Heron	GBHE
	Green-backed Heron	GBHE
	Killdeer	KILL
	Lesser Yellowlegs	LEYE
	Sanderling	SAND
	Spotted Sandpiper	SPSA
WATERFOWL:	American Coot	AMCO
(19 Species)	American Wigeon	AMWI
	Barrow's Goldeneye	BAGO
	Common Goldeneye	COGO
	Bufflehead	BUFF
	Cackling Goose	CAGO
	Canvasback	CANV
	Green-winged Teal	GWTE
	Gadwall	GADW
	Horned Grebe	HOGR
	Eared Grebe	EAGR
	Pied-billed Grebe	PBGR
	Red-necked Grebe	RNGR
	Western Grebe	WEGR
	Pacific Loon	PALO
	Red-throated Loon	RTLO
	Common Merganser	COME
	Hooded Merganser	HOME
	Red-breasted Merganser	RBME
SEABIRDS:	Caspian Tren	CATE
(4 Species)	Double-crested Cormorant	DCCO
	Mew Gull	MEGU
	Pigeon Guillemot	PIGU
	Ring-billed Gull	RBGU
INTRODUCED:	Brown-headed Cowbird	BHCO
(7 Species)	California Quail	CAQU
	Domestic Duck	DODU
	Domestic Goose	DOGO
	English Sparrow	ENSP
	European Starling	EUST
	House Finch	HOFI
NATIVE, BUT	Barn Swalow	BASW
HUMAN ASSOC.	American Robin	AMRO
(7 Species)	Rock Dove	RODO
	Northwestern Crow	NOCR
	Mallard	MALL
	Canada Goose	CAGE
	Glaucous-winged Gull	GWGU

Basin site (sampled by Caren Crandell, Center for Urban Horticulture, University of Washington), (2) recruiting *Scirpus*-dominated vegetation at the GSA site, and (3) the *Atriplex*-dominated channel margins at the T-105 site.

Field Methods. In each patch, a tape measure was placed parallel to shore, through the center of the patch. The length of the patch and locations of any breaks in vegetation were recorded. Ten 0.25- x 0.25-m quadrats were placed at random distances along the tape. In each quadrat, we counted the number of shoots of *Carex* and *Scirpus*, measured the height of the tallest shoot of each species, and noted any other species present in the quadrat.

At the T-105 site, we made additional measurements of vegetation along the upper 220-m of the created channel, which encompassed the area from the head of the channel to the *Atriplex*-dominated area near the channel mouth. We listed the species present in quadrats placed every five paces from the head of the slough to the mouth of the slough on both the up- and downstream sides of the channel. We also measured the distances from the head of the slough to individual patches of recruiting species along the north side of the channel.

At the Turning Basin, we noted species present in 10 quadrats distributed randomly through an area of the site from which Canada geese had been excluded.

Statistical Methods

Scirpus and *Carex* shoot height and shoot density: Mean maximum shoot height and mean shoot density in

1995, 1996, and 1997 were plotted for each of the three *Carex* and *Scirpus* sites. For both *Carex* and *Scirpus*, mean maximum shoot height and mean shoot density in 1997 were compared among sites using one-way analysis of variance (ANOVA). Statistical comparisons were not made between years. As we continue to develop a time series of shoot height and density data, our analysis will shift from comparing means for individual years to investigating temporal patterns in the mean and variance and hypotheses about the relationship between shoot density, shoot height, and selected environmental factors.

We also plotted the distribution of individual height and density data values at each site. The distribution of individual data values can provide visual understanding of how mean values vary over time and help to generate hypotheses about why distributions might be changing.

Other species: For the *Scirpus* and *Carex* patches, we summarized the frequency of understory species at each patch from 1995 to 1997. For T105, we listed the species found in systematic quadrats along the upstream and downstream sides of the channel, and the number of recruiting patches of each species along the length of the channel. For the Turning Basin, we summarized the percent frequency of species found in quadrats in the ungrazed center area.

Results

Benthic Macrofauna

Taxa Richness: In 1997 benthic samples, numbers of invertebrate taxa ranged from 11–29 taxa per site/date (Fig. 3, top panel). Taxa richness exhibited a downward trend between April and June at all sites except at the T-105 delta. For each sampling date numbers of taxa were similar among the sites, except at the T-105 delta and GSA bench, one of which always had the highest number of taxa. Number of taxa at each site were similar to those found in 1995 samples (see Cordell et al. 1996), with the exception of the T-105 site, which had higher numbers of taxa than in 1995 and the Kellogg Island reference mudflat, which had fewer.

Assemblage Compositions: The composition of benthic macrofauna in April was numerically dominated by two or three invertebrate categories: in May and June invertebrates were distributed more evenly, usually into three or four categories (Fig. 4). Several taxa were nearly unique to one or two sites, including (1) the spionid polychaete worm *Pygospio elegans* at the T-105 delta and GSA bench sites, (2) the polychaete worm *Capitella capitata* at the T-105 delta, (3) ceratopogonid fly larvae and Ostracoda at the Turning Basin sandflat, and (4) the exotic cumacean crustacean *Nippoleucon hinumensis* at the Kellogg Island mudflat site. Several other taxa were present at many sites but were particularly dominant at one site. These included oligochaete worms at the T-105 channel, nematode worms at the Turning Basin restoration mudflat, and *Corophium* spp. at the Turning Basin reference mudflat.

Densities: For all benthic macrofaunal invertebrates combined, densities ranged from ~6.8 x 10^4 (GSA bench in May) to >3 x 10^5 individuals m^{-2} (Kellogg Island reference mudflat in May and June) (Fig. 5, top panel). At five of the seven sites , benthic invertebrate densities were highest in June.

Oligochaete worms were most abundant at the T-105 channel and Kellogg Island reference sites, with peak June abundances of ~12 x 10^4 individuals m^{-2} (Fig. 5, middle panel). These were similar to density peaks for this taxon in previous sampling years, which fell between ~10–15 x 10^4 individuals m^{-2} in May 1996 and 1997 (Appendix 1). At the T-105 channel site, oligochaetes were about three times more abundant in 1997 than they were in 1996 for each month sampled (Appendix 1).

Nematode worms reached peak density at the T-105 channel site in June, with an abundance of ~7 x 10^4 individuals m^{-2} (Fig. 5, bottom panel). This was higher than density peaks for this taxon at T-105 in previous sampling years, but were much lower than the peak densities of almost 5 x 10^5 individuals m^{-2} reached in May 1993 at the Kellogg Island reference mudflat (Appendix 1).

The terebellid polychaete worm *Hobsonia florida* occurred at all of the benthic sampling sites (Fig. 6, top panel). It was most abundant at the GSA bench in May and the T-105 delta in June, reaching peak densities of approximately 10^3 individuals m^{-2}. Abundances of this species were generally higher than in previous years (Appendix 1).

Manayunkia aesturina, a sabellid polychaete worm, was also widespread across the sampling sites, and was absent only from the GSA bench site (Fig. 6, middle panel). Highest densities of this species always occurred at the Kellogg Island reference mudflat, where densities peaked in May at approximately 10^4 individuals m^{-2}. This peak also represented the highest densities seen for *M. aesturina* in our studies to date (Appendix 1).

The predominant spionid polychaete worm *Pygospio elegans* was relatively abundant at the lower waterway sites (except for the T-105 channel), but was absent from sites at the Turning Basin (Fig. 6, bottom panel). The highest densities of *P. elegans*, approximately 4–5 x 10^4 individuals m^{-2} (T-105 delta and GSA bench sites) were also the highest densities for this species to date (Appendix 1).

The only \relatively abundant insect larvae in 1997 benthic samples were those of ceratopogonid flies (Fig. 7, top panel). They were rare at all sites except for the upper sandflat site at the Turning Basin. This taxon was 2–3 times more abundant in 1997 than in 1996 (Appendix 1).

Corophium spp. amphipods occurred at all sites except the Turning Basin upper sandflat (Fig. 7, middle panel). This was the only prominent taxon to consistently exhibit increases in density from April to June. Highest

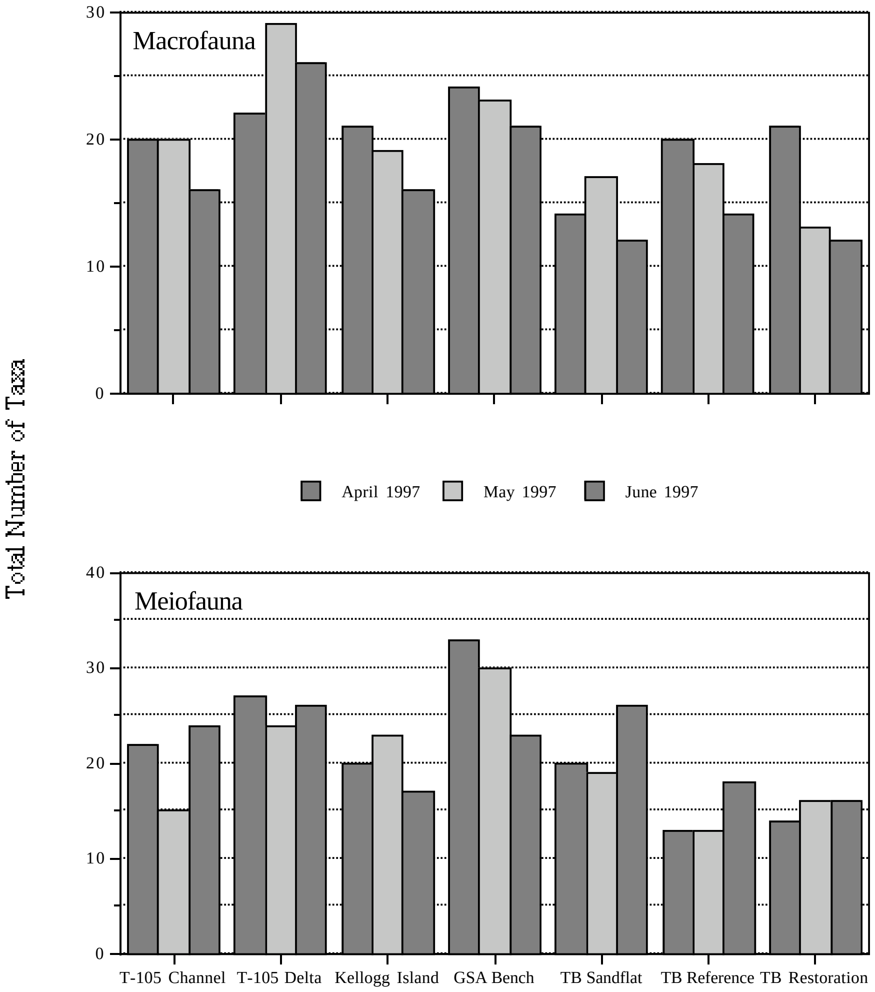

FIGURE 3. Taxa richness of benthic macrofauna (top) and meiofauna (bottom) from Coastal America restoration and reference sites, April–June 1997.

densities of *Corophium* occurred in June at the T-105 delta and Turning Basin reference mudflat sites, with approximately 4 x 10^4 individuals m^{-2}. The range of densities found in 1997 was similar to that found in previous sampling years (Appendix 1).

Another prominent gammarid amphipod, *Eogammarus confervicolus*, was most abundant at the T-105 channel and delta sites and at the Kellogg Island reference mudflat (Fig. 7, bottom panel). The only site at which this species did not occur was at the upper sandflat at the Turning Basin. Densities of *E. confervicolus* reached about 5 x 10^3 individuals m^{-2}, very similar to peak densities observed in previous years (Appendix 1).

Benthic Meiofauna

Taxa Richness: Numbers of meiofaunal taxa from 1997 benthic samples ranged from 13–33 taxa per site/date (Fig. 2, bottom panel). Highest taxa richness occurred in April and May at the GSA intertidal bench. As with meiofauna data from 1995 (see Cordell et al. 1996), lowest numbers of taxa were usually found at the Turning Basin mudflat sites. Meiofauna taxa richness was generally lower in 1997 than in previous samplings (Cordell et al. 1994, 1996).

Assemblage Compositions: Harpacticoid copepods and nematode worms usually dominated the meiofauna, comprising between 50 and 90% of the numerical composition (Fig. 8). Foraminifera were also numerically important at the T-105 channel and delta sites and Ostracoda were important at the Turning Basin sandflat. Harpacticoid copepods were especially dominant in April and May at the GSA bench, where they made up over 50% of the meiofauna numbers.

In most cases, each site was characterized by the harpacticoid copepod assemblages that occurred there (Fig. 9, Table 2). Several taxa were unique to a site, including *Coullana canadensis* and *Pseudobradya* sp.at the Turning Basin mudflats, *Mesochra rapiens* and *Onychocamptus mohammed* at the Turning Basin sandflat, *Tachidius triangularis* at the T-105 channel and delta, and *Stenhelia asetosa* at the Kellogg Island mudflat.

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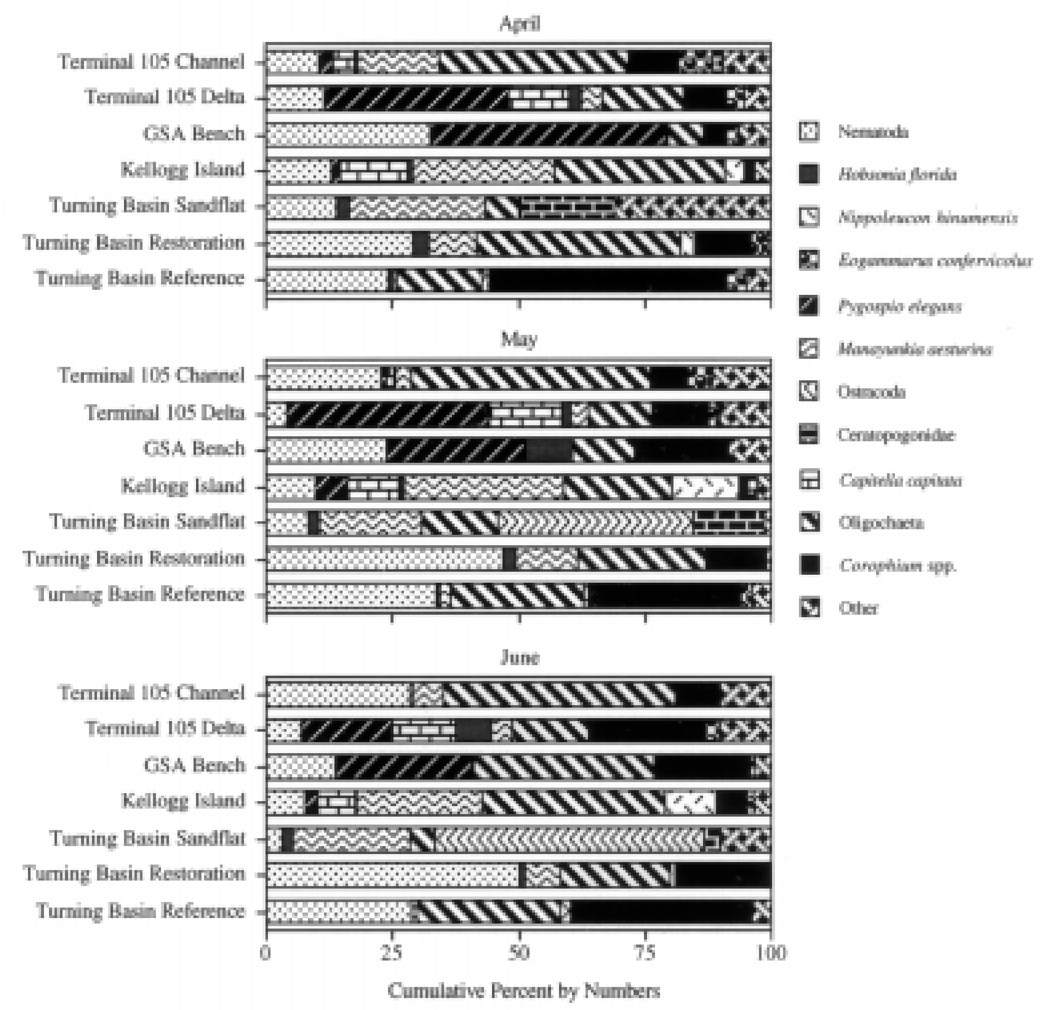

FIGURE 4. Percent numerical composition of macroinvertebrates from benthic core samples taken at Coastal America restoration and reference sites, April–June 1997.

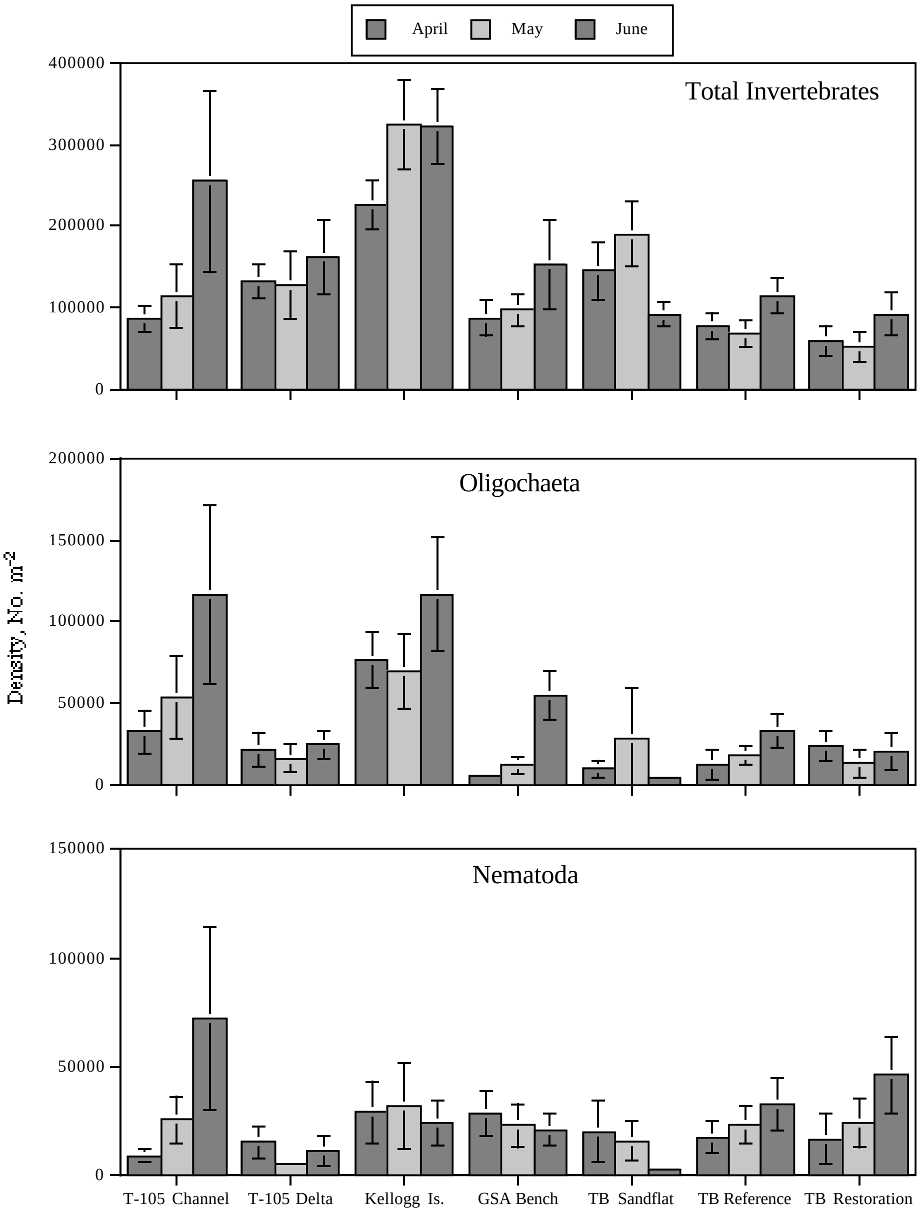

FIGURE 5. Densities of total macroinvertebrates and oligochaete and nematode worms from benthic core samples taken at Coastal America restoration and reference sites, April–June 1997. Vertical lines are 95% confidence intervals.

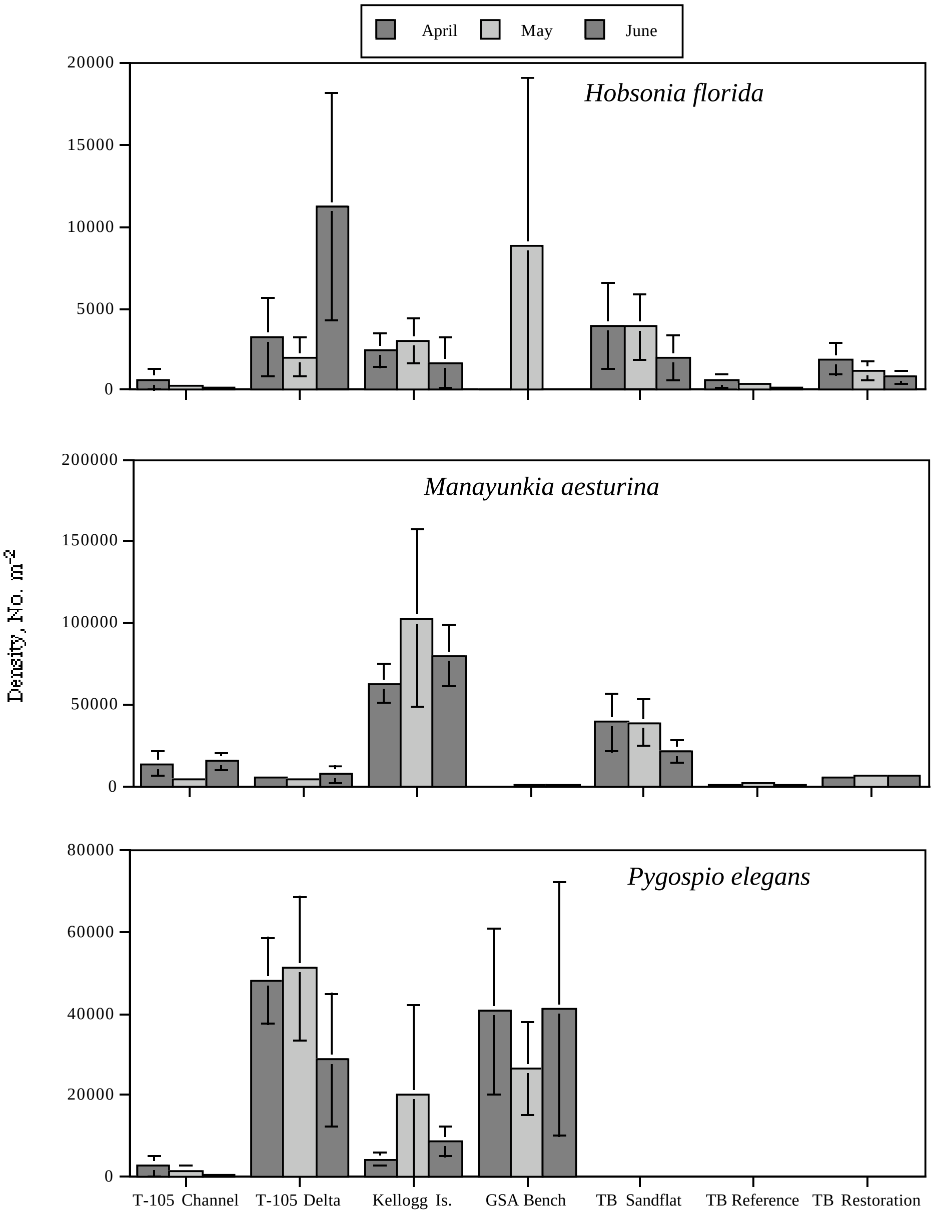

FIGURE 6. Densities of prominent polychaete worms from benthic core samples taken at Coastal America restoration and reference sites, April–June 1997. Vertical lines are 95% confidence intervals.

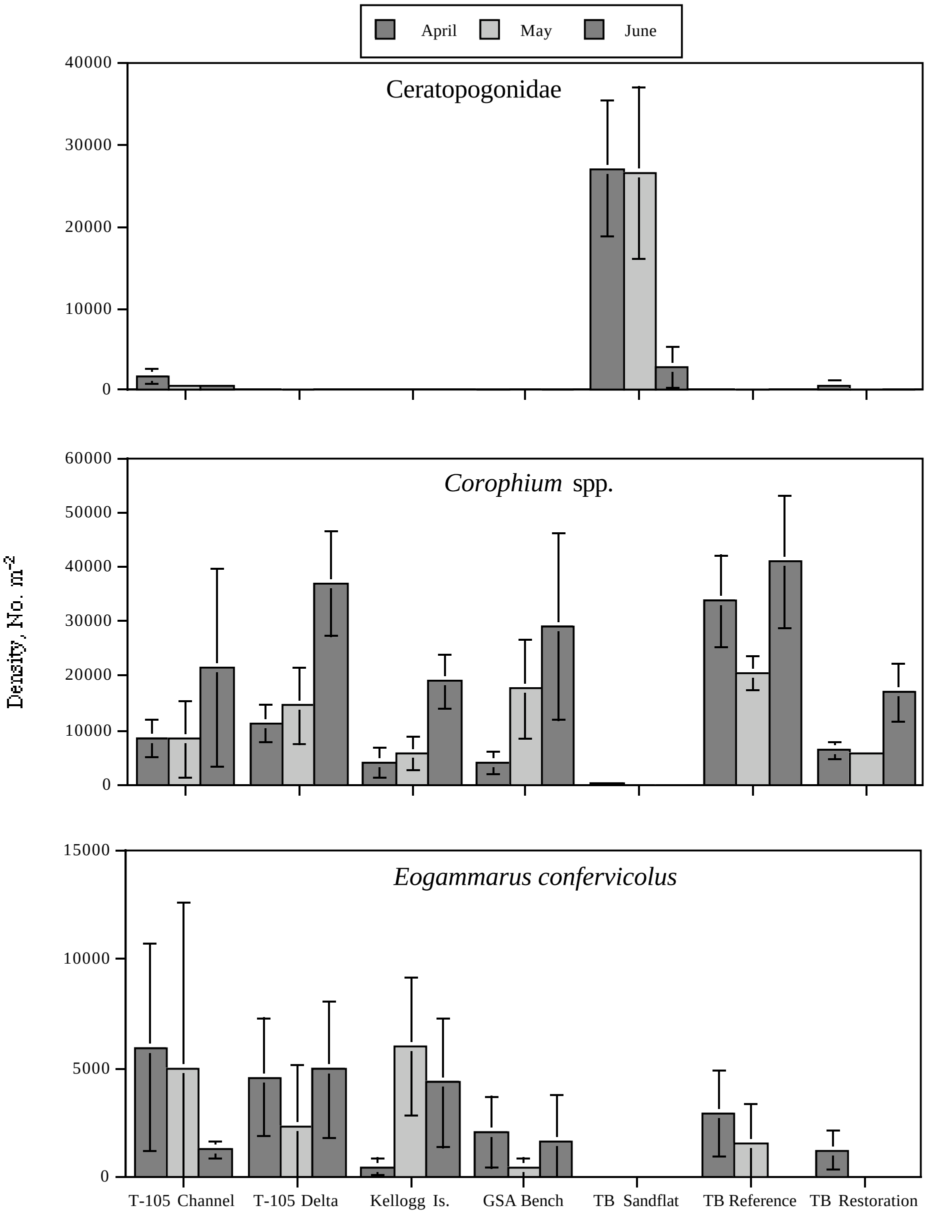

FIGURE 7. Densities of prominent amphipod crustaceans and ceratopogonid fly larvae from benthic core samples taken at Coastal America restoration and reference sites, April–June 1997. Vertical lines are 95% confidence intervals.

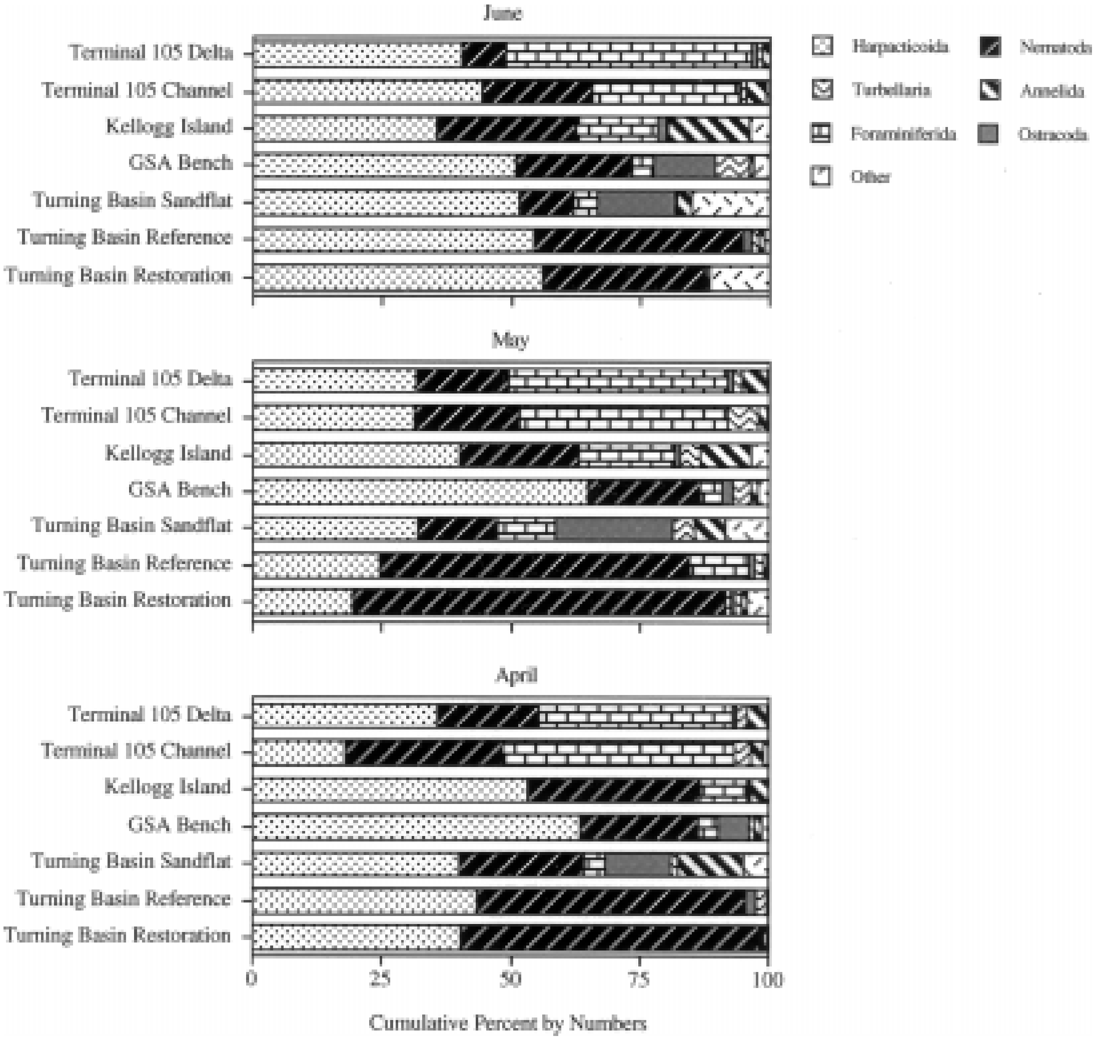

FIGURE 8. Percent numerical composition of meiofaunal invertebrates for major taxonomic groups from benthic core samples taken at Coastal America restoration and reference sites, April–June 1997.

Densities: Total meiofauna densities ranged from ~8 x 10^5 (GSA bench in April) to ~5.5 x 10^6 individuals m^{-2} (Turning Basin restoration mudflat in June) (Fig. 10, bottom panel). At all of the sites except the Kellogg Island reference mudflat, meiofauna density increased between April and June. The range of meiofauna densities was similar to that found in 1995 (Appendix 2).

Harpacticoid copepod nauplius larvae, turbellarian flatworms, and nematode worms were relatively abundant at all sites (Figs. 10–11). However, harpacticoid nauplii and nematodes reached particularly high peak densities at the Turning Basin mudflat reference and restoration sites. Several other taxa were relatively numerous only at one site. These included ostracodes at the Turning Basin high intertidal sandflat (Fig. 10, top panel) and Foraminiferans at T-105 (Fig. 11, upper panel).

Several of the prominent harpacticoid copepod species were also mainly restricted to one or two sites. These included *Coullana canadensis* and *Pseudobradya* sp. at the Turning Basin restoration and reference mudflats (Fig. 12): the distribution of these species was similar to that observed for them in 1995 (Appendix 2). *Microarthridion littorale* was relatively abundant only at the Kellogg Island mudflat in 1997 (Fig. 12, bottom panel), but was also abundant at the Turning Basin mudflats in 1995 (Appendix 2). *Harpacticus uniremis* group were present only at the GSA intertidal bench (Fig. 13, top panel); however their numbers at this site in 1997 were very low compared with those found at another intertidal bench in 1995 (Appendix 2). The upper intertidal sandflat was the only site at which *Mesochra rapiens* was abundant (this site was not sampled in 1995) (Fig. 13, bottom panel). *Tachidius triangularis* occurred only at T-105 in 1997 (Fig. 14, top panel) (this site was not sampled for meiofauna in 1995).

Other harpacticoid copepods were relatively numerous at a number of sites. *Tachidius discipes* was abundant at sites in both upper- and lower waterway sites in 1997 (Fig. 13, middle panel), but was rare in samples taken in

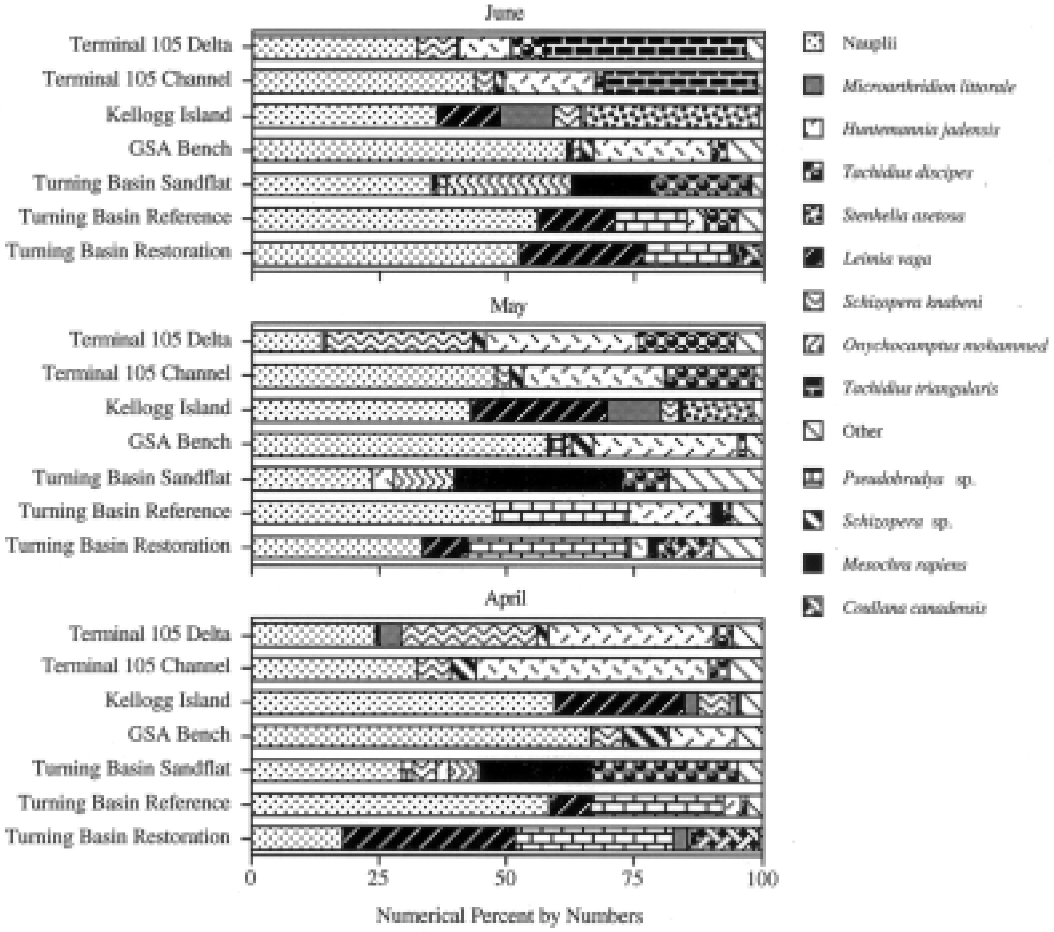

FIGURE 9. Percent numerical composition of meiofaunal harpacticoid copepods from benthic core samples taken at Coastal America restoration and reference sites, April–June 1997.

TABLE 2. Dominant harpacticoid copepods at benthic sampling sites in the Duwamish Waterway, April–June, 1997. †Juvenile salmon prey taxa; *juvenile flatfish prey taxa.

Site(s)	Dominant harpacticoid taxa
Terminal 105 channel and delta	*Tachidius triangularis*†, *Huntemannia jadensis*†, *Schizopera knabeni*
Kellogg Island reference mud flat	*Stenhelia asetosa*, *Microarthridion littorale*†*, *Leimia vaga*†*
GSA intertidal bench	*Huntemannia jadensis*†, *Schizopera* spp.
Turning Basin high intertidal mud flat	*Mesochra rapiens*, *Tachidius discipes*†*
Turning Basin reference and restoration mud flats	*Leimia vaga*†*, *Pseudobradya* sp.†, *Coullana canadensis*†*

1995 (Appendix 2). *Huntemannia jadensis* was also relatively numerous at most of the sites, but exhibited density peaks at the T-105 sites (Fig. 13, middle panel). This species was relatively rare in 1995 meiofauna samples, except at the Turning Basin restoration mudflat (Appendix 2). Another species that was abundant at both lower- and upper waterway sites was *Leimia vaga*, which occurred at the Kellogg Island reference mudflat and at the Turning Basin mudflats (Fig. 14, bottom panel). Densities observed in 1997 for this species at Kellogg Island were similar to those found in 1995, but *L. vaga* 1997 densities at the Turning Basin were much lower than in 1995 (Appendix 2).

Insects

Assemblage Compositions: At the Turning Basin transplanted *Carex* site in 1997, insects were distributed into relatively numerous taxa in April; in May and June, insect composition was dominated by juvenile Homoptera with adult aphids also being relatively important in May (Fig. 15, top panel). In contrast, 1996 insect trap samples at this site were dominated in April and May by ephydrid flies, and in June and July by chironomid flies (Fig. 15, top panel). At the

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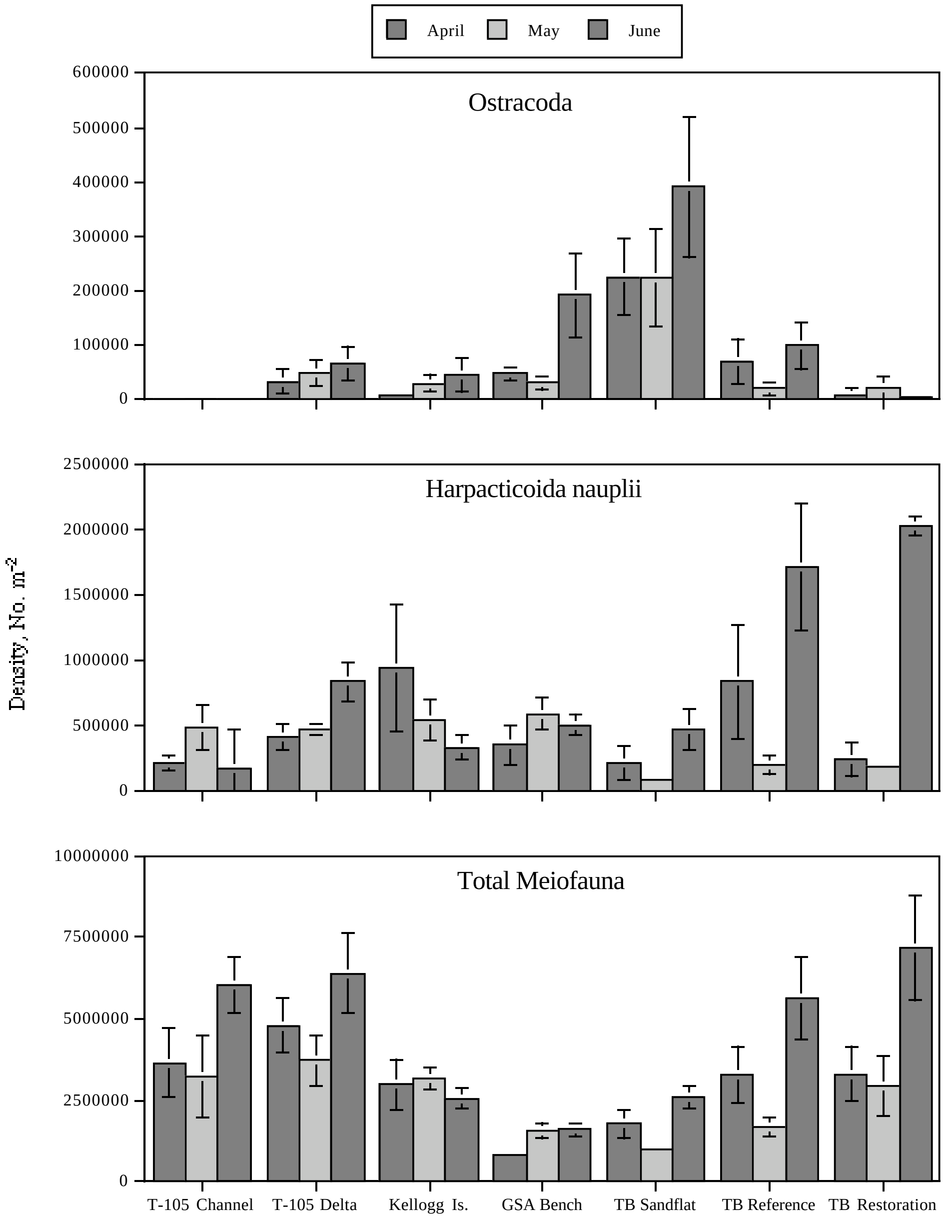

FIGURE 10. Densities of total meiofauna, Ostracoda, and harpacticoid copepod nauplii from benthic core samples taken at Coastal America restoration and reference sites, April–June 1997. Vertical lines are 95% confidence intervals.

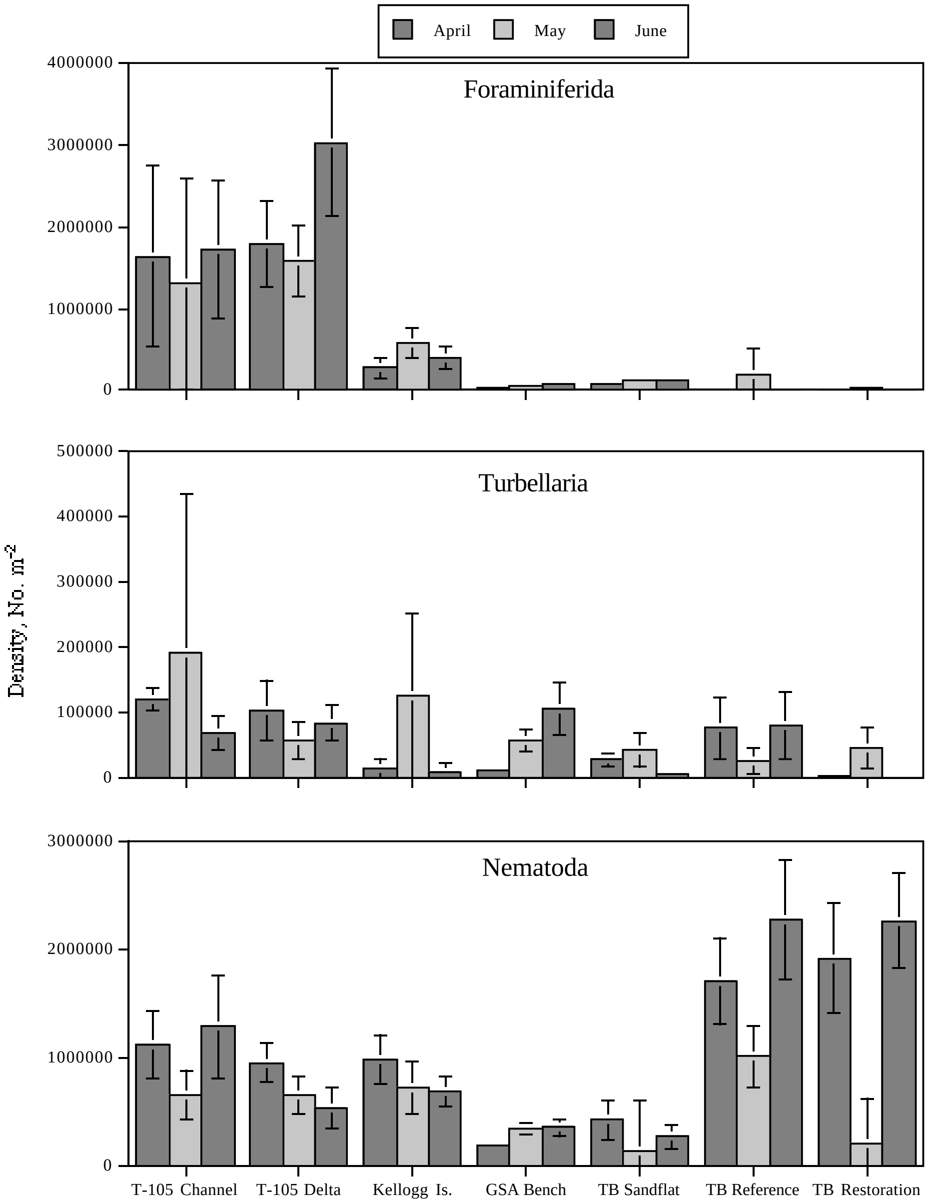

FIGURE 11. Densities of Nematoda, Turbellaria, and Foraminifera from benthic core samples taken at Coastal America restoration and reference sites, April–June 1997. Vertical lines are 95% confidence intervals.

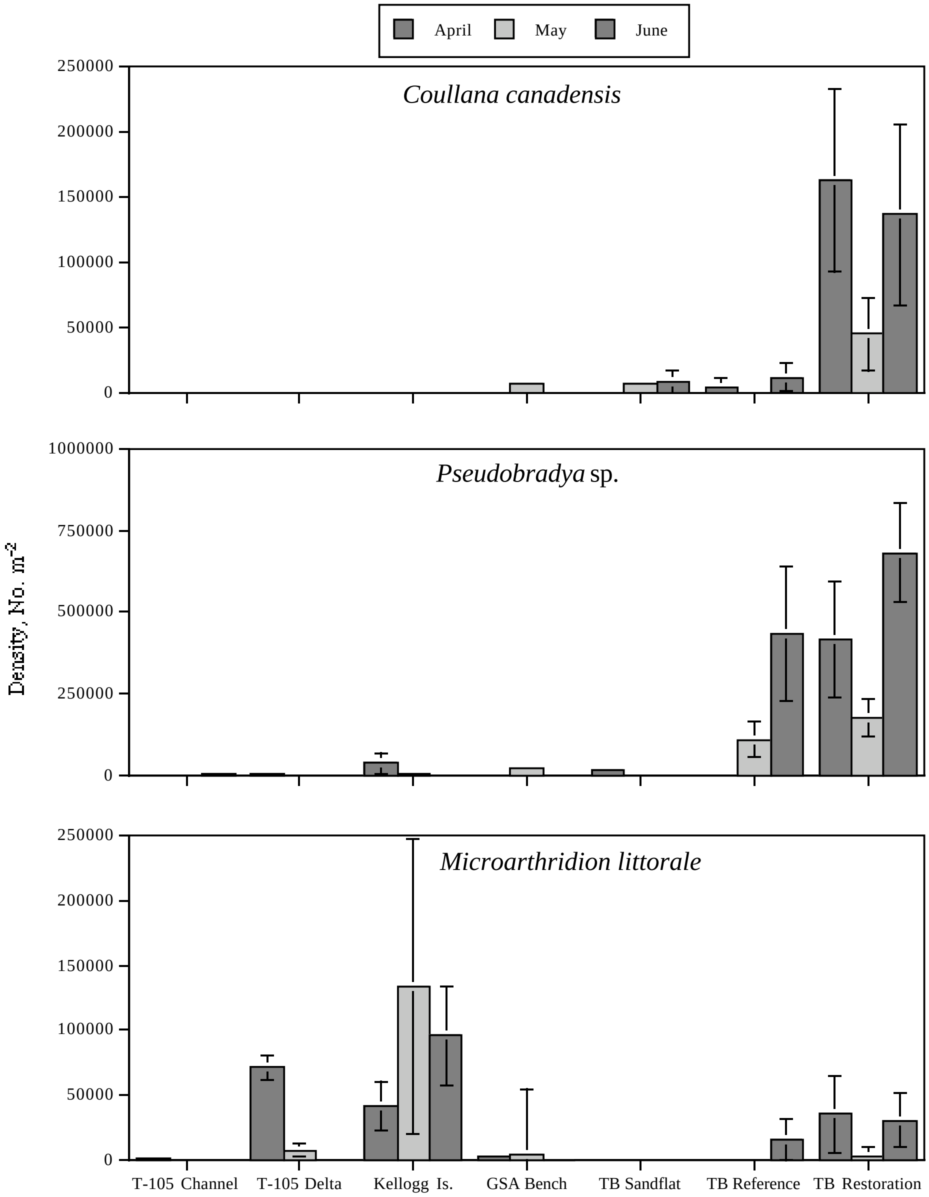

FIGURE 12. Densities of prominent harpacticoid copepods from benthic core samples taken at Coastal America restoration and reference sites, April–June 1997. Vertical lines are 95% confidence intervals.

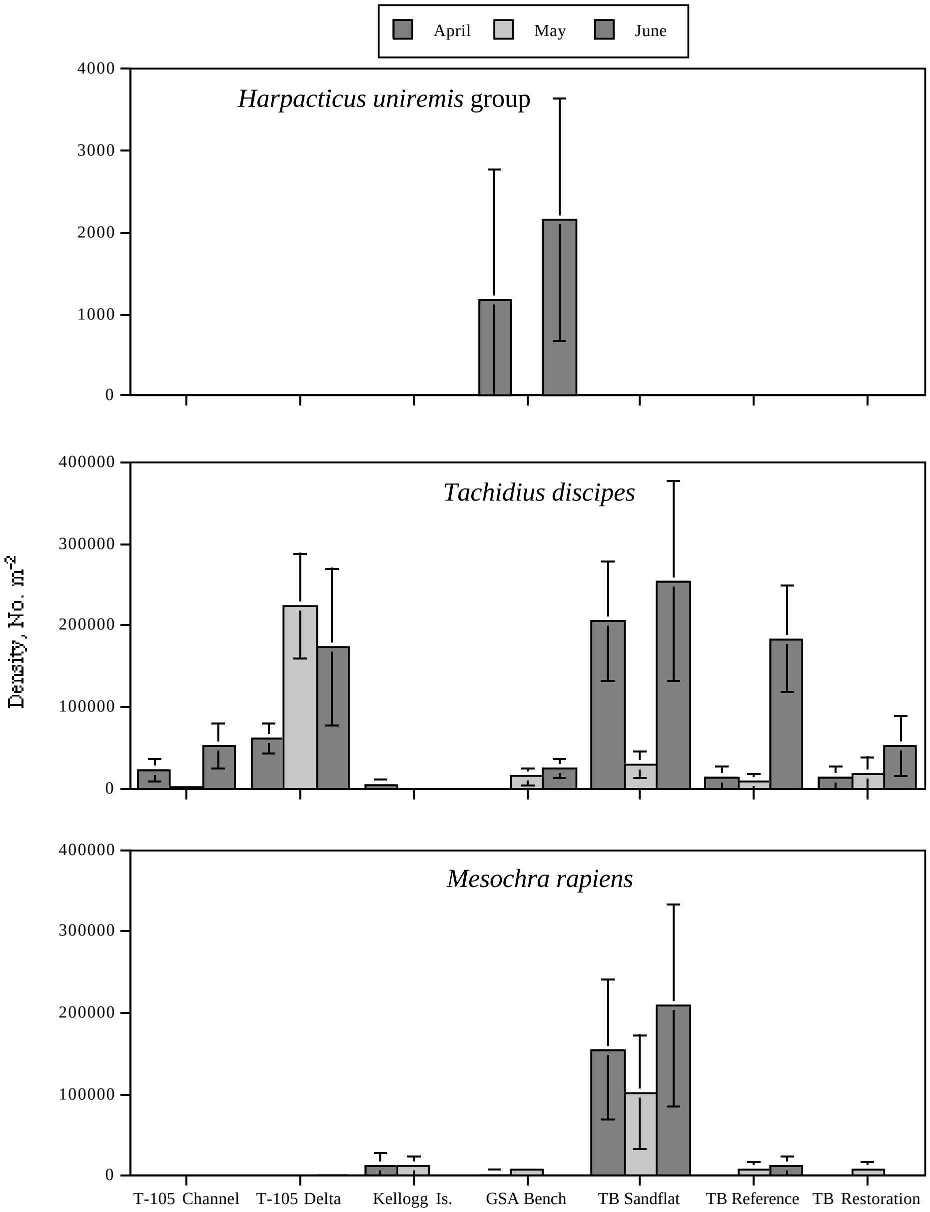

FIGURE 13. Densities of additional prominent harpacticoid copepods from benthic core samples taken at Coastal America restoration and reference sites, April–June 1997. Vertical lines are 95% confidence intervals.

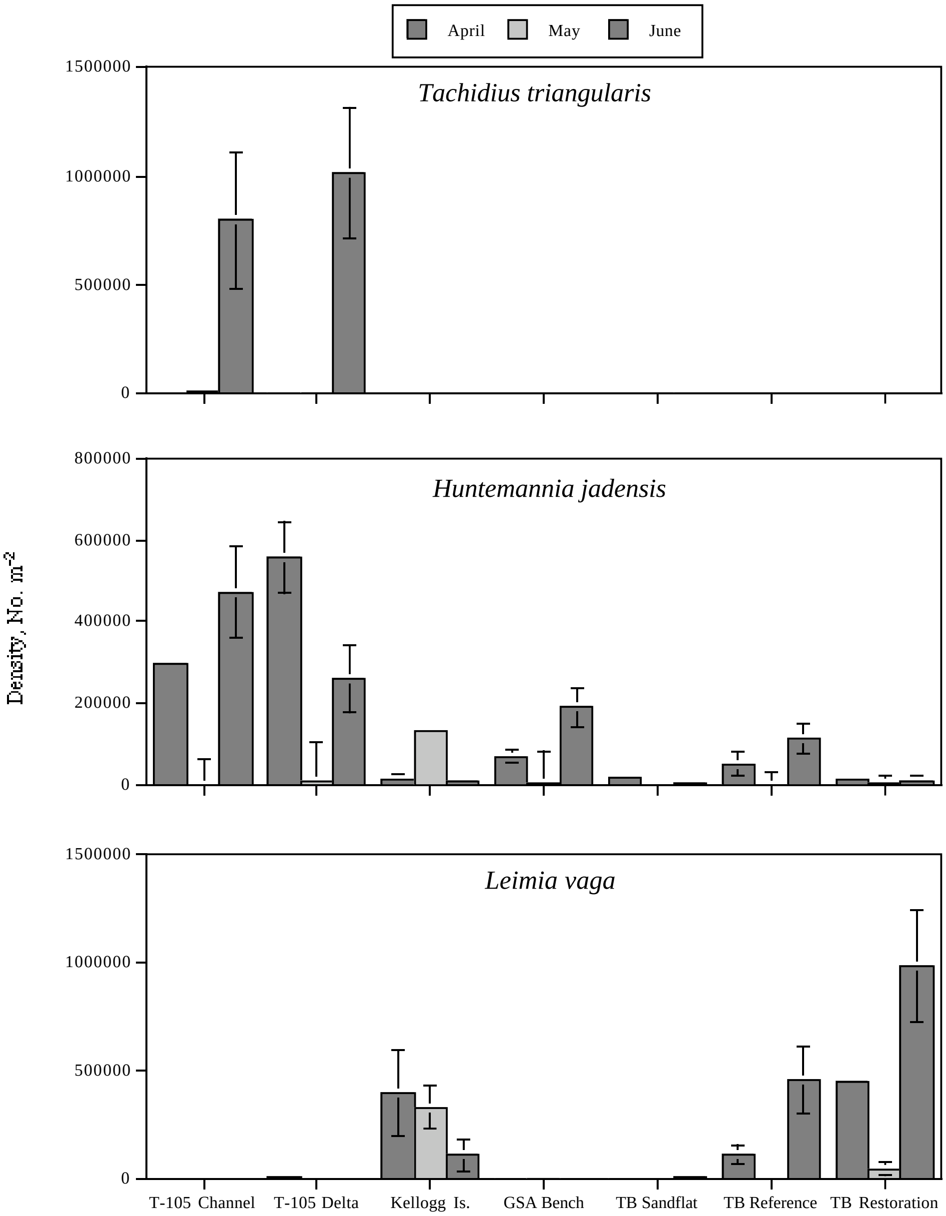

FIGURE 14. Densities of additional prominent harpacticoid copepods from benthic core samples taken at Coastal America restoration and reference sites, April–June 1997. Vertical lines are 95% confidence intervals.

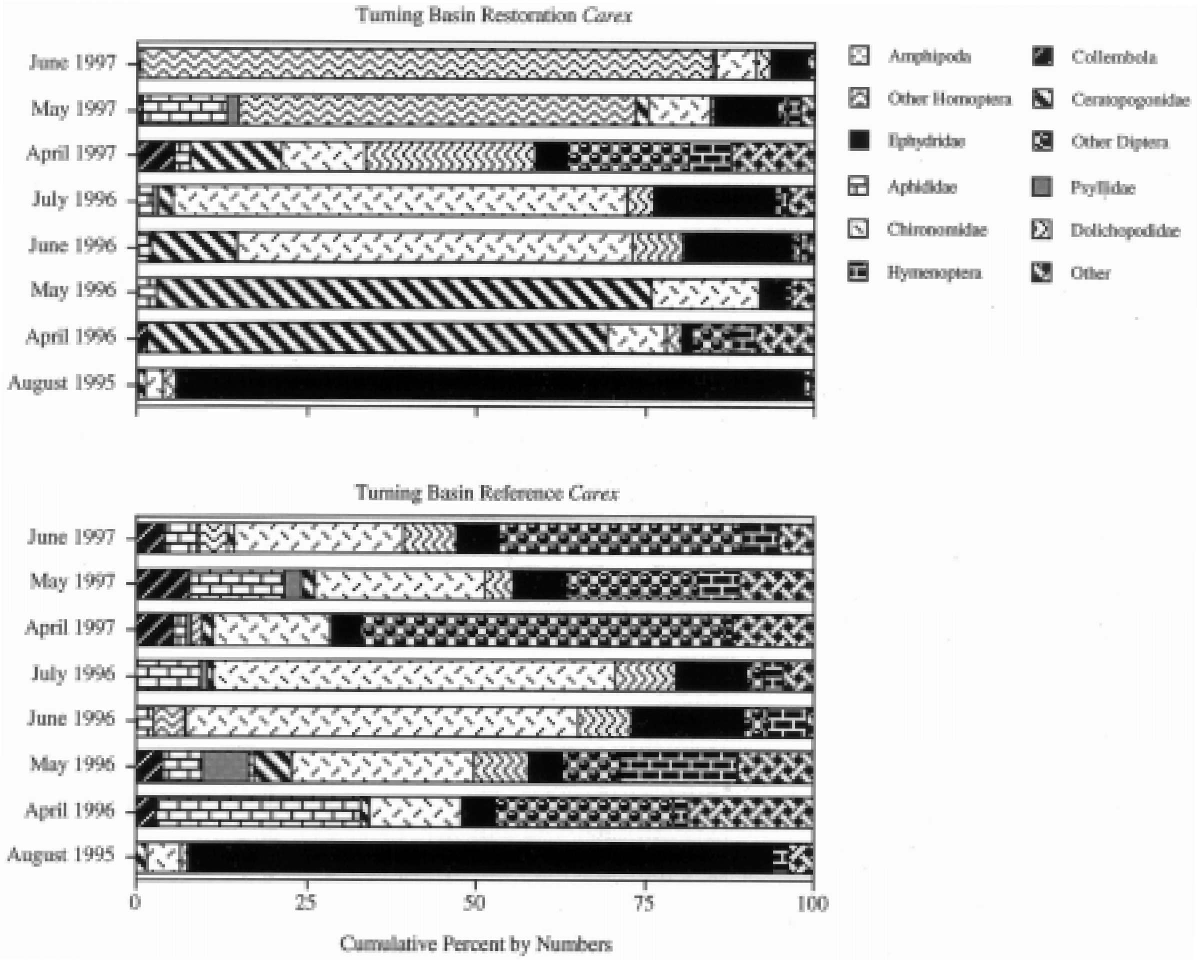

FIGURE 15. Percent numerical composition of invertebrates from insect fallout traps deployed at Coastal America restoration and reference *Carex lyngbei* sites, April–June 1997.

reference *Carex* bench, 1997 insect samples consisted mainly of chironomids and a variety of other dipteran flies (Fig. 15, bottom panel). As at the transplant site, aphids were also relatively important in May at this site. Insects at the reference site in 1996 were distributed into a relatively large number of categories in April and May (including aphids, chironomids, other dipterans, hymenopterans, and other insects), and were characterized by high proportions of chironomids in June and July (Fig. 15, bottom panel).

At the Kellogg Island reference and GSA restoration *Scirpus* patches, there was a large difference in insect assemblage structure both amongsites and amongsampling years. In April 1997 samples, chironomid, dolichopodid, and ephydrid flies were dominant at the GSA site; at the Kellogg Island site, amphipods, collembolans (springtails), and “other” dipterans were the main components (Fig. 16, top and middle panels). In May and June 1997 samples, insects from the GSA *Scirpus* patch consisted mostly of dolichopodid and ephydrid flies whereas at the Kellogg Island site, insects were distributed into a larger number of taxa. Insect assemblages at these sites in 1996 were characterized by proportionally many more chironomid (both sites) and ceratopogonid flies (GSA) and hymenopterans (Kellogg Island).

The margins of the created channel at T-105 that were vegetated by *Atriplex patula* had different insect assemblages in each of the three sampling periods in 1997. In April, Collembola made up 50% of the numbers with the remainder consisting of a variety of taxa (Fig. 16, bottom panel). In May, aphids and psyllids (homopteran relatives of aphids) were the most abundant taxa. The dominant insect group in June was “other” homopterans, consisting mainly of juveniles. In contrast, 1996 samples had relatively few aphids, psyllids, or other homopterans but were dominated by several families of dipteran flies (Fig. 16, bottom panel).

Densities: Total fallout trap insect densities were higher at every site in 1997 as compared with 1996 samples in April and May (Fig. 17). This difference was especially marked in May samples, for which densities in 1997 were up to five times greater than they were in 1996 (Fig. 17, middle panel). In April, the highest overall insect density

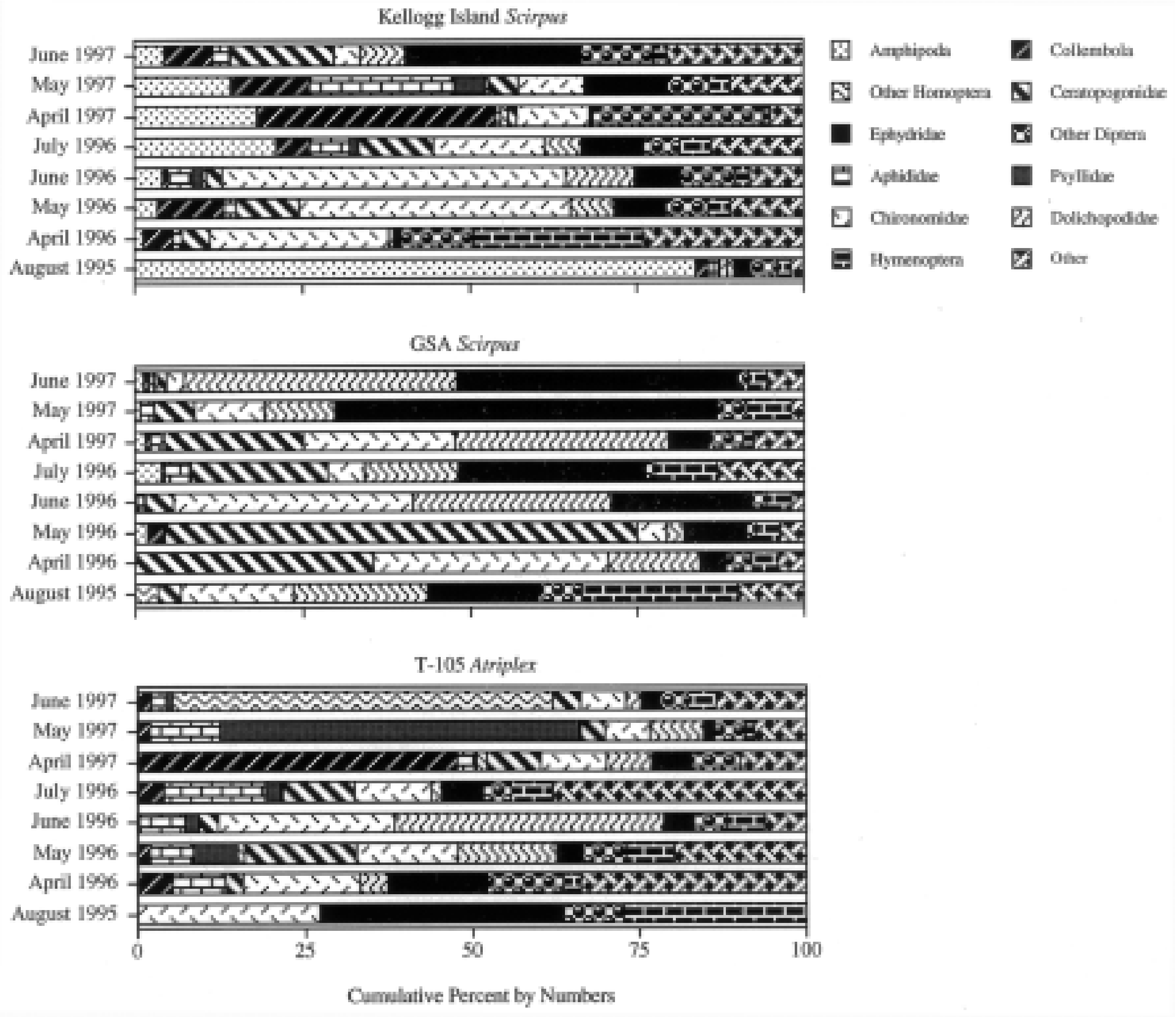

FIGURE 16. Percent numerical composition of invertebrates from insect fallout traps deployed at Coastal America restoration and reference *Scirpus maritimus* sites, April–June 1997.

was found at the Kellogg Island *Scirpus* patch, and in May and June the highest density occurred in the transplanted *Carex* at the Turning Basin restoration site.

The following results were found for densities of Protocol attribute insect taxa:

1. Collembola were much more abundant in 1997 than in 1996 and were always most abundant at the Kellogg Island *Scirpus* patch (Fig. 18);
2. aphids were much more numerous in 1997 than in 1996 in May samples, when overall highest densities of this taxon were observed, but in April and June aphids were usually most abundant in 1996 (Fig. 19);
3. Psyllidae reached their highest densities in May 1997 at the T-105 channel, when they were over 10 times more abundant than at any other site and date (Fig. 20);
4. ceratopogonid flies were most abundant at the Turning Basin transplanted restoration site and were more numerous in 1996 than in 1997 at this site (Fig. 21);
5. chironomids were relatively abundant at all sites: in April and May they were more numerous in 1997 than in 1996, but in June 1996 they reached their highest overall densities (Fig. 22);
6. dolichopodid flies, which were usually most abundant at the GSA *Scirpus* patch, were much more numerous in 1997 than in 1996 in April and May, but had similar densities in both years when they reached their peak numbers in June (Fig. 23);
7. ephydrid flies were also most dense at the GSA *Scirpus* patch, where they reached their peak densities in 1997 May and June samples (Fig. 24).

Juvenile Salmon Diets

Chum Salmon: In chum (*Oncorhynchus keta*) salmon captured on 22 April near the Turning Basin and Kellogg Island sites, prey consisted primarily of *Corophium* spp. amphipods (Fig. 25, top panel). At Kellogg Island, the fish analyzed were also consuming the amphipod *Eogammarus confervicolus*, and at the Turning Basin site the mysid shrimp *Neomysis mercedis* and several kinds of insects also occurred in the diets.

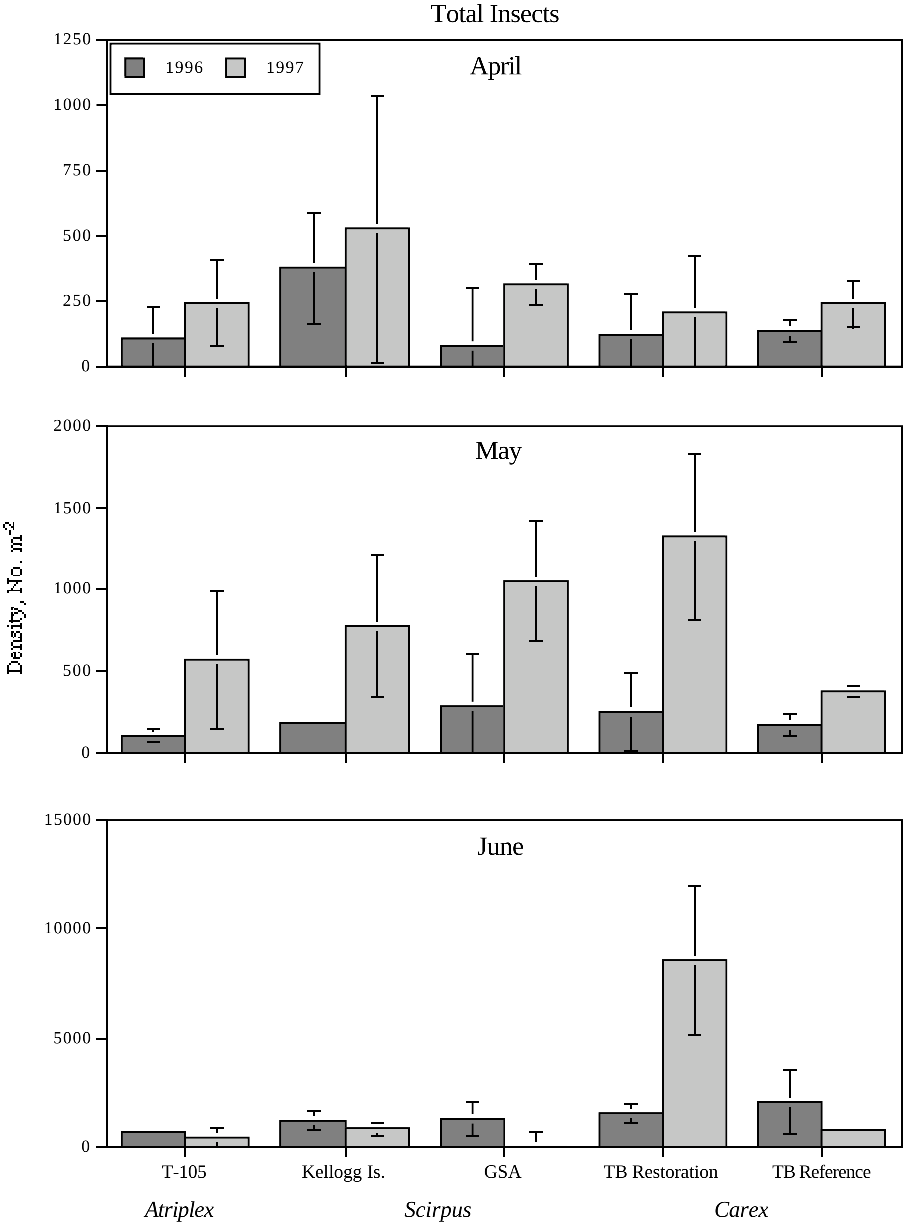

FIGURE 17. Densities of total insects from insect fallout traps deployed at Coastal America restoration and reference sites, April–June 1996 and 1997. Vertical lines are 95% confidence intervals.

Juvenile chum salmon were captured only once at the T-105 channel, on 23 May. Diet of the 10 chum analyzed consisted almost entirely of psyllid homopterans (85% of the prey weight) (Fig. 25, middle panel). The prey of chum salmon from this sampling date captured near Kellogg Island consisted entirely of adult dipteran flies.

In June, we caught chum salmon only at the Turning Basin sampling site. Diets from this site and date were dominated by aphids but also contained a variety of other insects (Fig. 25, bottom panel).

Chinook Salmon. In juvenile chinook (*O. tshawytscha*) salmon from the 22 April sample, diets at Kellogg Island consisted of about 75% dipteran flies by weight with the other 25% consisting of the cumacean crustacean *Cumella vulgaris* and *Corophium* spp. (Fig. 26, top panel). At the Turning Basin on this date, *Corophium* spp. were the most abundant prey item, with *E. confervicolus*, *N. mercedis*, and dipteran flies constituting the remainder.

In May, as with the chum salmon, the diets of chinook salmon at the T-105 channel site and at Kellogg Island were dominated by psyllids (Fig. 26, middle panel). At the Turning Basin site, chinook diets were very similar to those from the April sample.

In June samples, juvenile chinook salmon consumed mainly hymenoptera (wasps and their relatives) and other insects at Kellogg Island (Fig. 26, bottom panel). In

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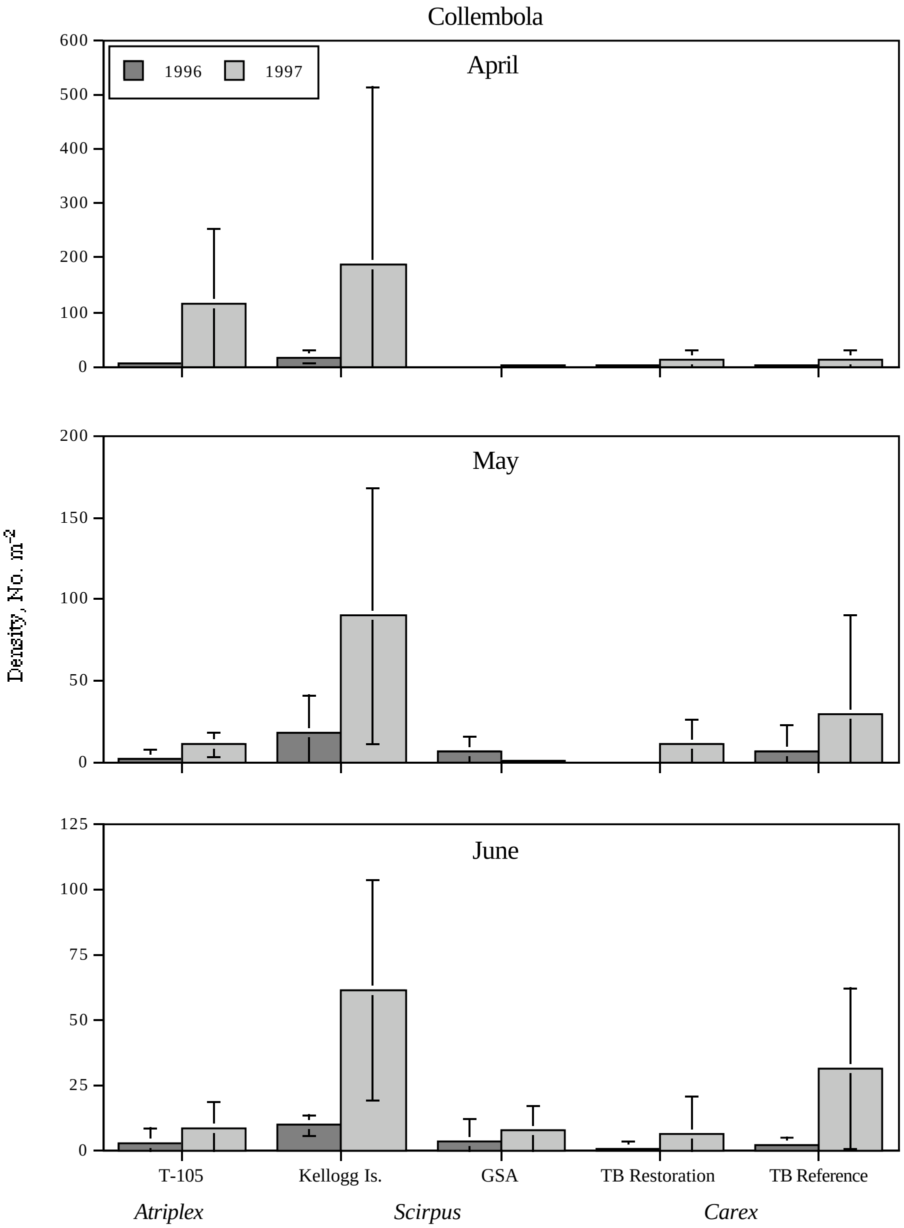

FIGURE 18. Densities of Collembola from insect fallout traps deployed at Coastal America restoration and reference sites, April–June 1996 and 1997. Vertical lines are 95% confidence intervals.

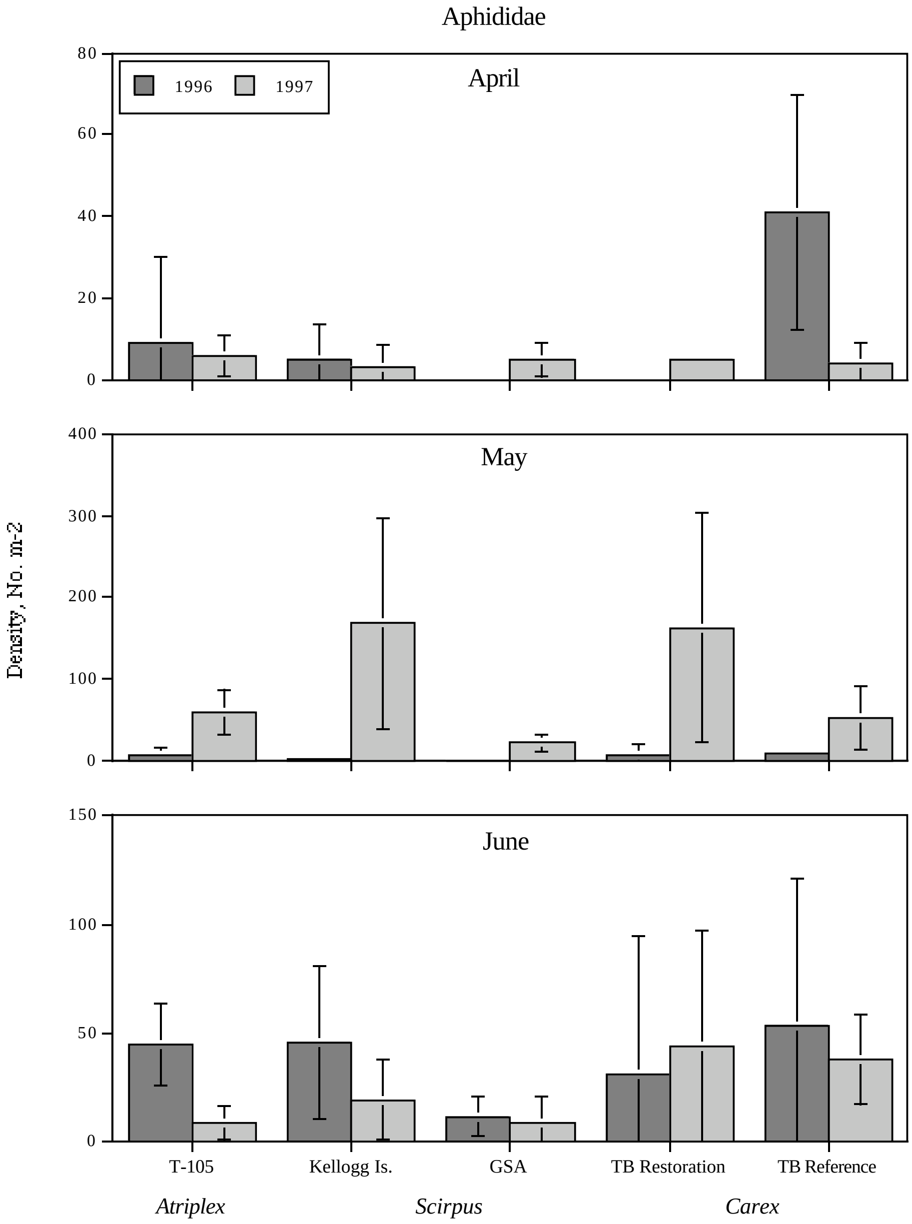

FIGURE 19. Densities of Aphididae from insect fallout traps deployed at Coastal America restoration and reference sites, April–June 1996 and 1997. Vertical lines are 95% confidence intervals.

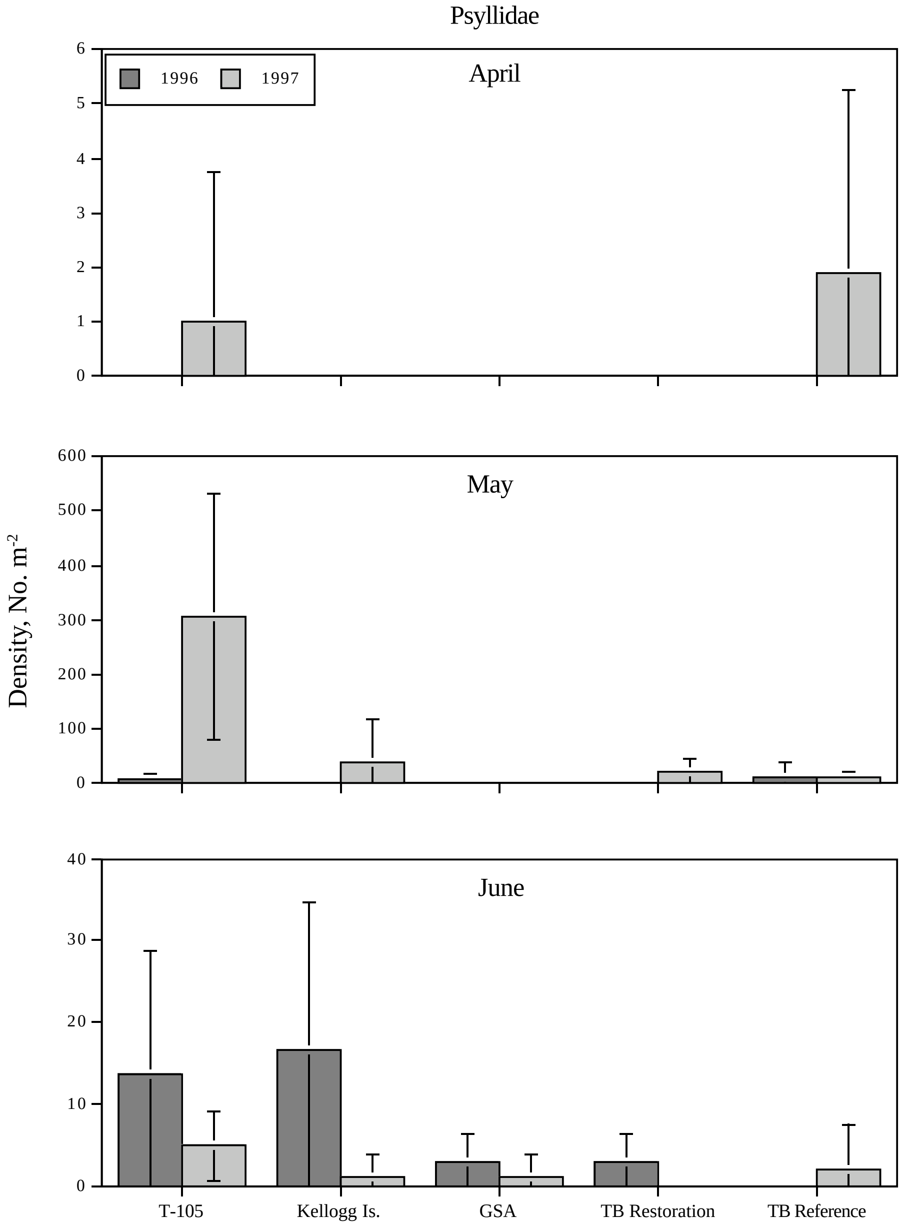

FIGURE 20. Densities of Psyllidae from insect fallout traps deployed at Coastal America restoration and reference sites, April–June 1996 and 1997. Vertical lines are 95% confidence intervals.

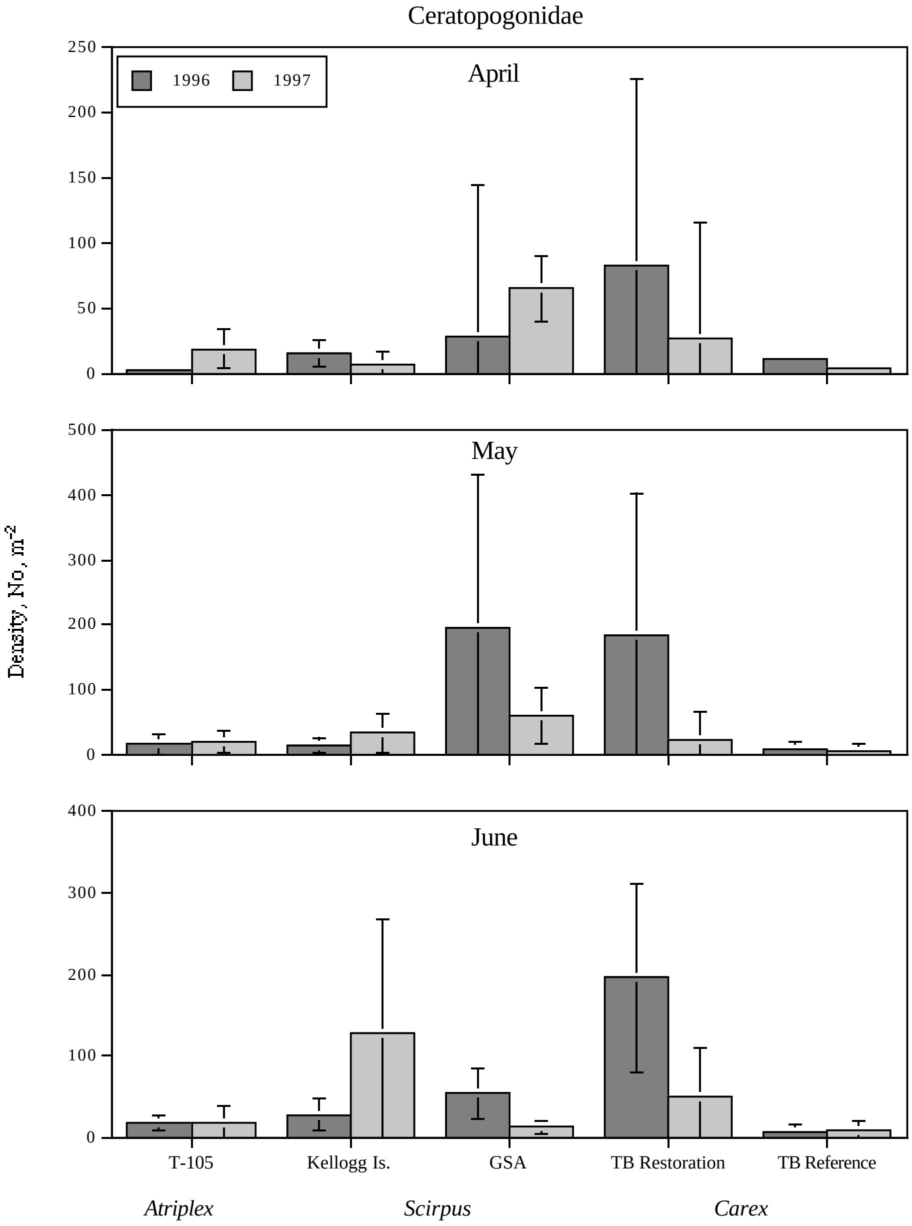

FIGURE 21. Densities of Ceratopogonidae from insect fallout traps deployed at Coastal America restoration and reference sites, April–June 1996 and 1997. Vertical lines are 95% confidence intervals.

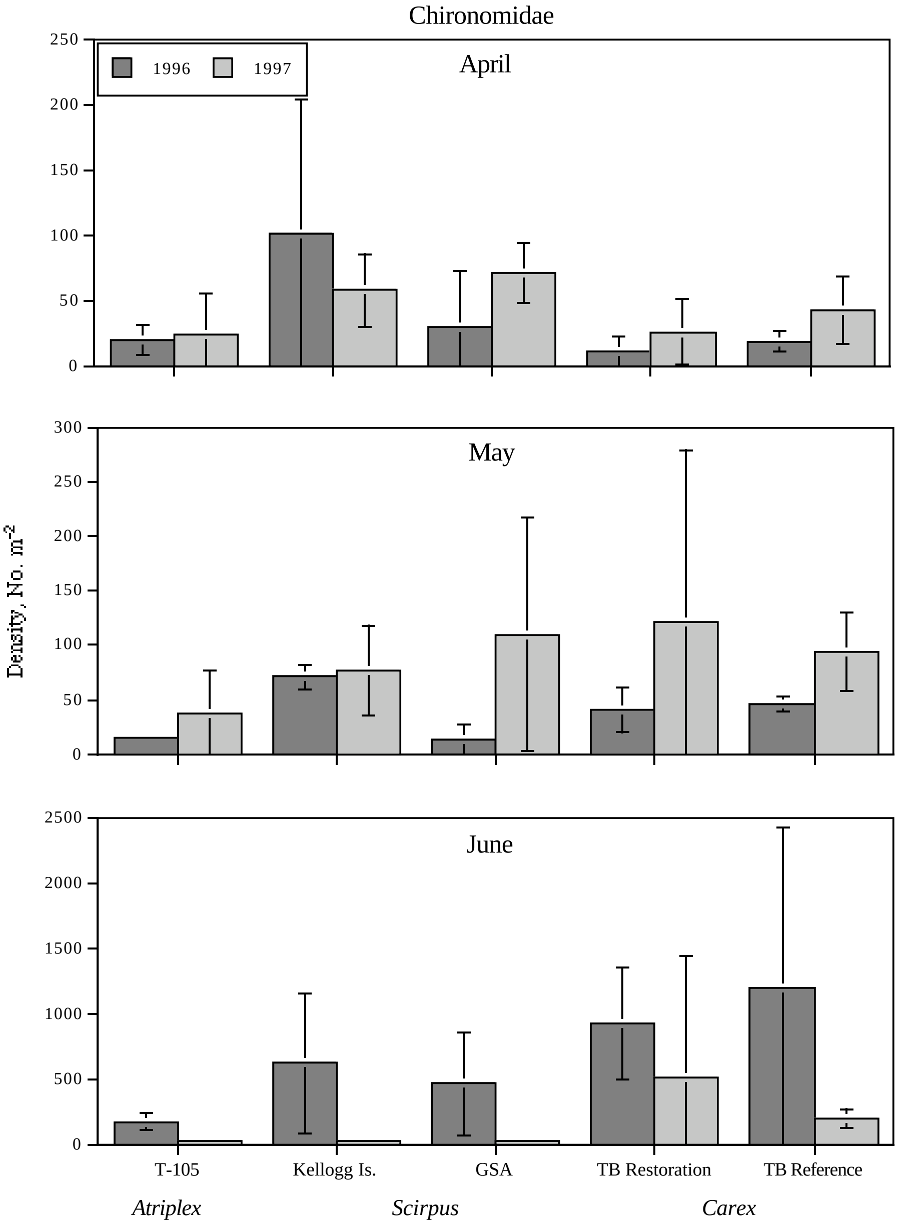

FIGURE 22. Densities of Chironomidae from insect fallout traps deployed at Coastal America restoration and reference sites, April–June 1996 and 1997. Vertical lines are 95% confidence intervals.

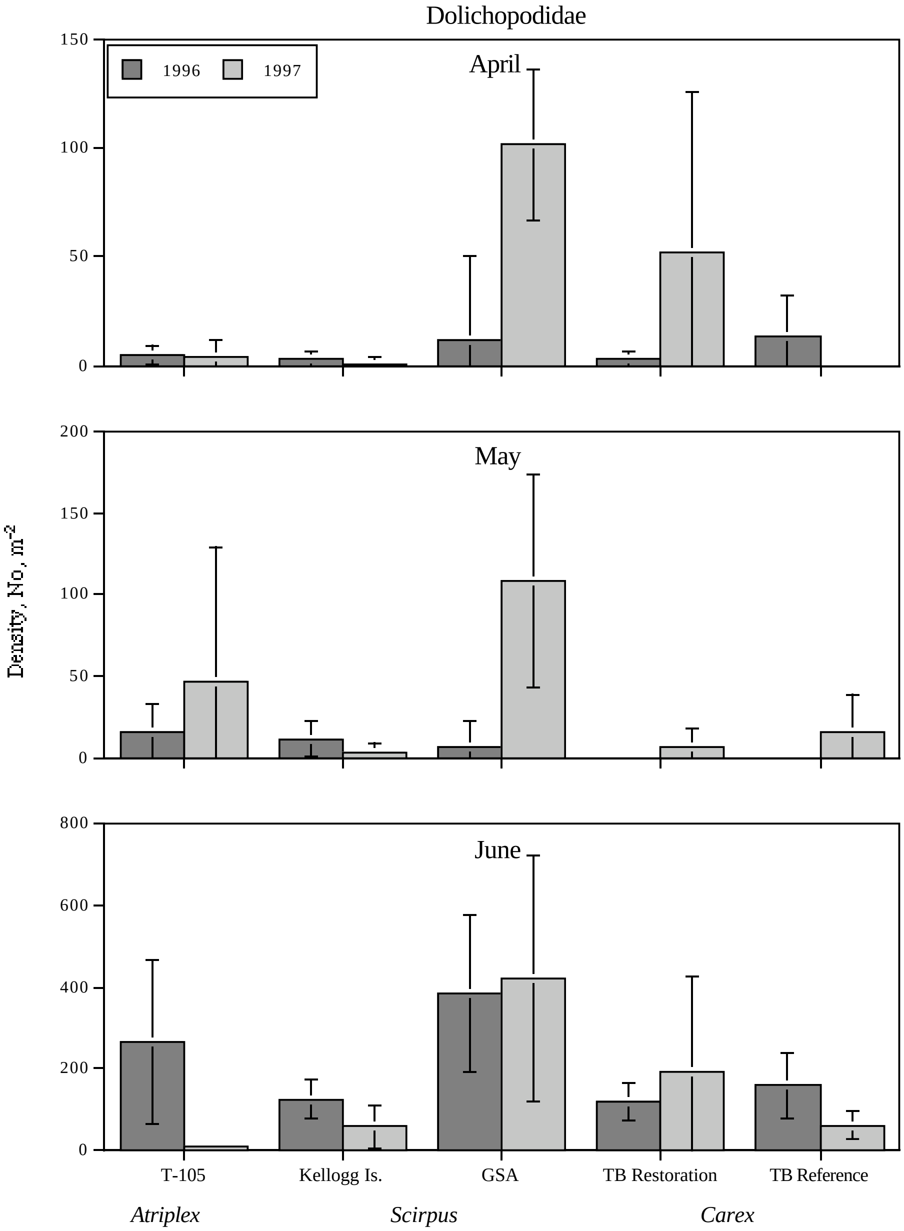

FIGURE 23. Densities of Dolichopodidae from insect fallout traps deployed at Coastal America restoration and reference sites, April–June 1996 and 1997. Vertical lines are 95% confidence intervals.

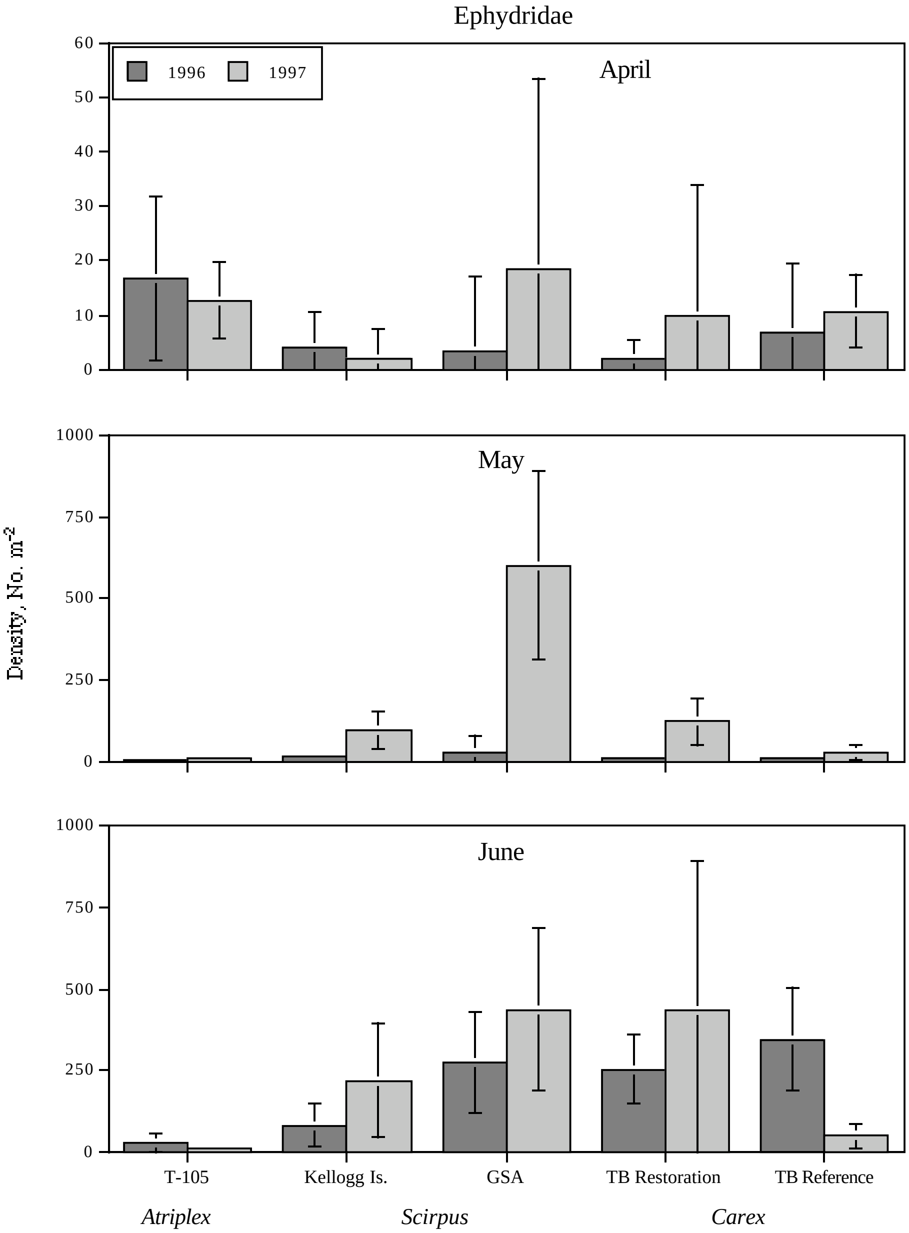

FIGURE 24. Densities of Ephydridae from insect fallout traps deployed at Coastal America restoration and reference sites, April–June 1996 and 1997. Vertical lines are 95% confidence intervals.

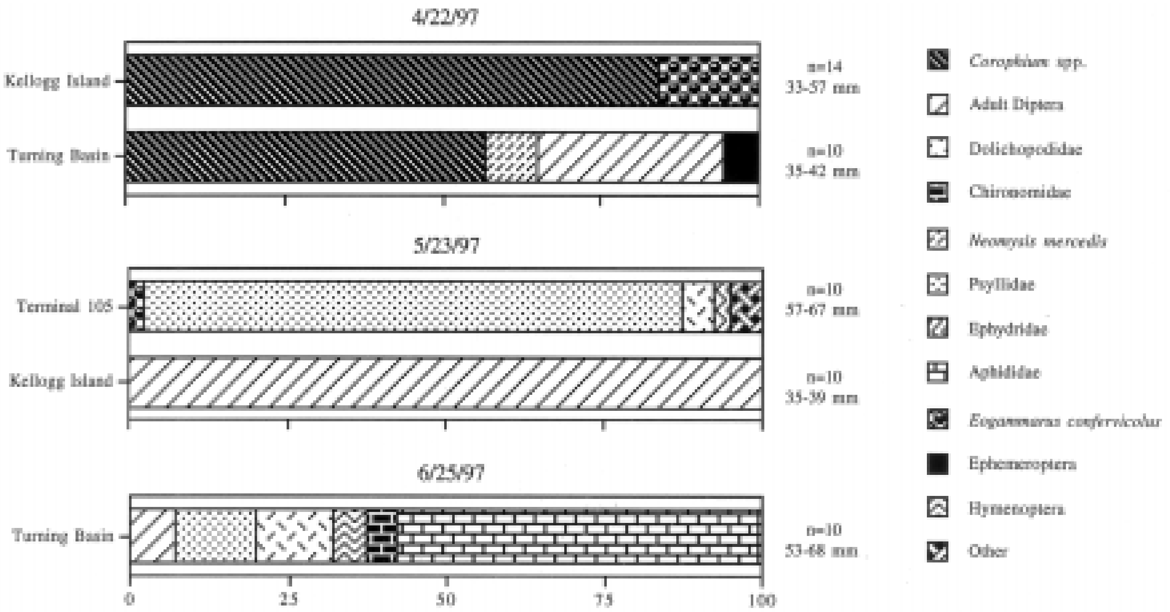

FIGURE 25. Percentage composition by weight of prey from juvenile chum salmon on three dates at several stations in the Duwamish Waterway, 1997.

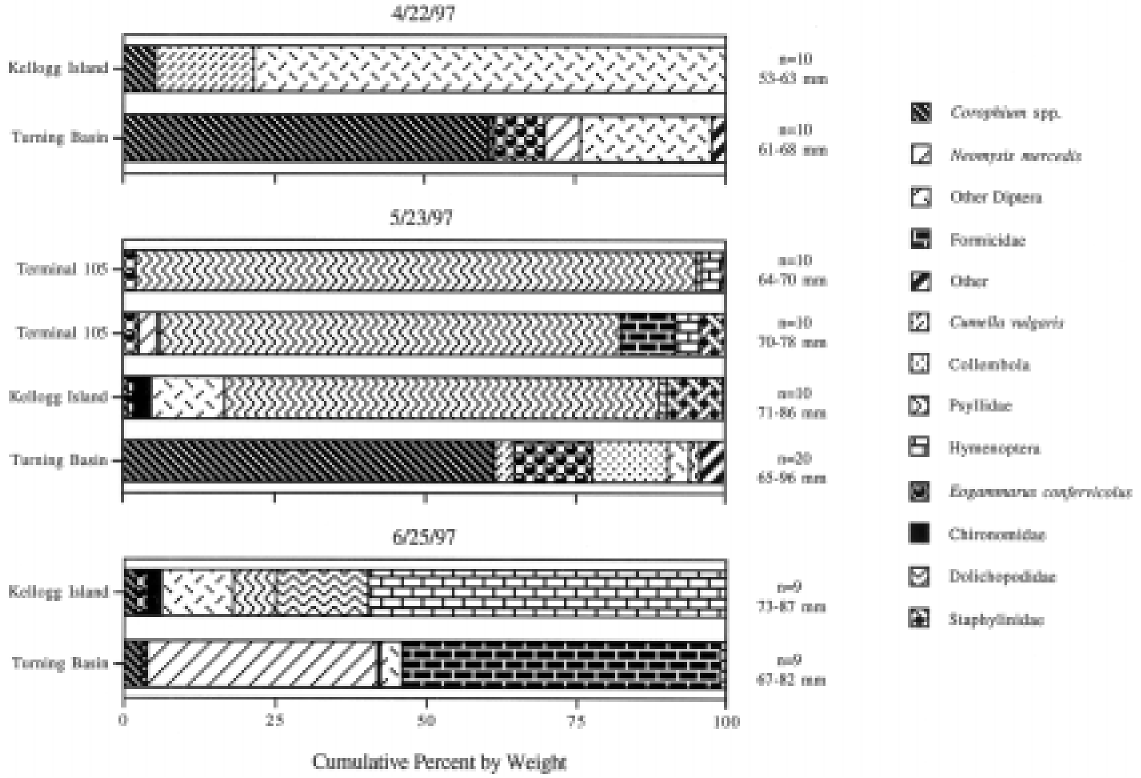

FIGURE 26. Percentage composition by weight of prey from juvenile chinook salmon on three dates at several stations in the Duwamish Waterway, 1997.

chinook from the Turning Basin sample on this date, diet consisted almost entirely of formicidae (ants) and *N. mercedis* .

Avifauna

During nine seasons of monitoring, 87 bird species have been observed on the Duwamish waterway (Table 1). Seasonally, the greatest number of species were seen during the spring months (58 species in spring '97 and 48 species in spring '98), and the fewest species were sighted during the summer months (27 species in summer '95, 38 species in summer '97 and 34 species in summer '98).

Site-specific abundance continued to vary tremendously (Fig. 27). Mean abundance was always highest at Kellogg Island (78–171 birds/30-min observation). For every site except T-105, mean abundance was higher but more variable in the 1998 season (September 1997–August 1998, Table 1) than in the 1997 season (September 1996–August 1997, Table 1). At T-105 a decline in abundance began during the latter part of the summer 1997 season (June 1–August 30), and this trend continued through the next four seasons of data collection (Fig. 2). The timing of the downward trend in abundance at T-105 was closely tied to the construction and operation of the rendering plant to the west of the T-105 site. For example, during initial construction, a vacant lot was cleared of trees and brush where 15–20 white-crowned sparrows had previously been observed foraging and exhibiting territorial behavior. Since then, no more than one male white-crowned sparrow has ever been seen at T-105. In 1997, killdeer nested in the shrub roses above the slough at T-105 as evidenced by chick vocalizations and broken-wing displays by parents: however, in 1998 there was no sign of nesting activity and killdeer were seen less frequently than in 1997. In 1998, an increase in human activity at T-105 was also observed. People were present during almost every visit and frequently were accompanied by dogs. With over 2 years of data collection, seasonal trends in abundance have become less clear, but the highest mean number of birds for every site, except T-105, was recorded during the 1998 summer season.

When mean abundance for all nine seasons is calculated without the 14 species classified as introduced or native/human-associated (Table 1), total abundance still drops dramatically (52–63%, Fig. 28), but the range is less than it was with only three seasons of data (see Cordell et al. 1997). When 1997 is compared with 1998, two sites—Kellogg Island and T-105—show a decline of 7–8% in the abundance of introduced and human-associated species relative to indigenous species. At theTurning Basin reference site, the proportion of introduced and human-associated species remained the same in 1997 and 1998 whereas at the Turning Basin restoration site, the proportion of these "undesirable" species relative to indigenous species increased by 13%.

For the two restored sites, species were grouped loosely by guild with the exception of the 14 species categorized as either introduced or native/human-associated to show seasonal presence/absence and within-season frequency (Appendix 3). At T-105, waterfowl diversity and frequency were greatest during the winter and spring months whereas during the summer months waterfowl were almost nonexistent (Appendix 3). In 1998, the osprey pair that nested south of T-105 was the only species of raptor seen (Appendix 3). The frequency of shorebird and wader sightings at T-105 also declined in 1998 even though presence/absence patterns were relatively unchanged (Appendix 3). For seabirds at T-105, only mew gull sightings remained the same while the other three predominant species, ring-billed gulls, belted kingfisher, and double-crested cormorants, declined in 1998 (Appendix 3). The number of introduced species sighted at T-105 declined slightly in 1998; however the overall frequency of introduced species sightings was higher in 1998 than in 1997 (Appendix 3). Sightings of native/human-associated species at T-105 has changed little over nine seasons of data collection (Appendix 3).

At the Turning Basin restoration site, passerines continued to be a strong presence, especially in the fall and spring (Appendix 3). In 1998, red-winged blackbirds bred successfully in the cattail marshes and American goldfinch exhibited territorial behavior all season and foraged with their fledglings in and around the *Carex* cages. The pattern of waterfowl presence at the Turning Basin restoration site was generally the same as at T-105; however the sighting frequency was greater. Fewer species of seabirds were seen at this site than at T-105, probably as a result of being further upstream from Elliot Bay. Raptors were observed more often at this site than at T-105 but less often in 1998 than in 1997. Shorebirds and waders were regularly observed at the Turning Basin restoration site at all times of the year. This site consistently had the greatest shorebird diversity of all four sites. Both introduced and human-associated species continued to be prevalent at the Turning Basin. However, one such species, the rock dove, was seen much less frequently after a derelict ferry where they perched and nested was removed.

Similar to abundance, overall mean species richness was greatest during the summer 1998 season at every site except T-105 (Fig. 29). At T-105 richness peaked during the spring 1997 season. Seasonally, richness was variable across sites with no clear seasonal pattern. Mean richness for all nine seasons declined by 40–57% when calculated without the 14 introduced and human associated species (Fig. 30). Mean richness at Kellogg Island and the Turning Basin restoration site declined the least, 42% and 45%, respectively while T-105 and the Turning Basin reference site showed the greatest decline, 55% and 57%, respectively. Also, as for abundance during 1998, mean richness

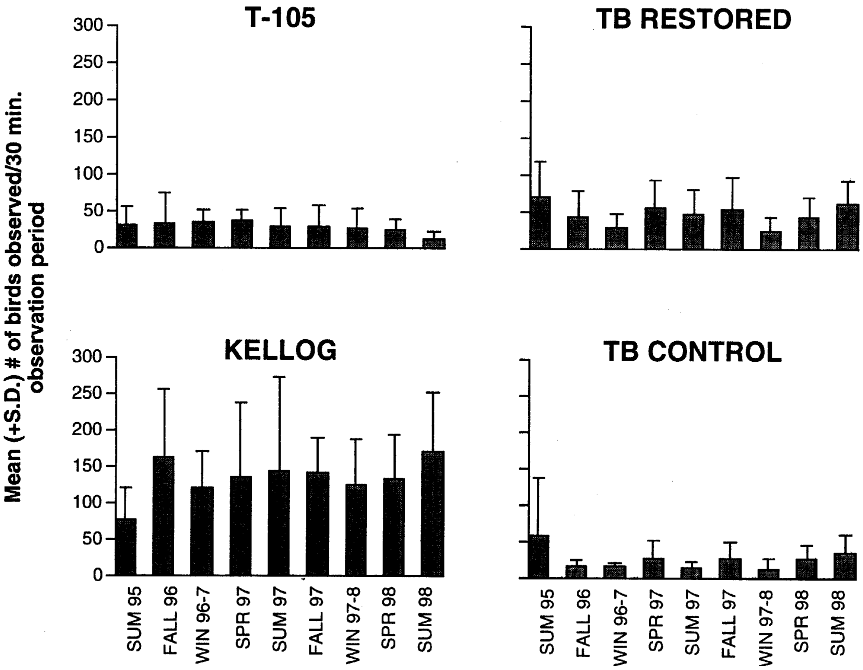

FIGURE 27. Overall mean abundance (+ SD) by season and site at four sites on the Duwamish Waterway.

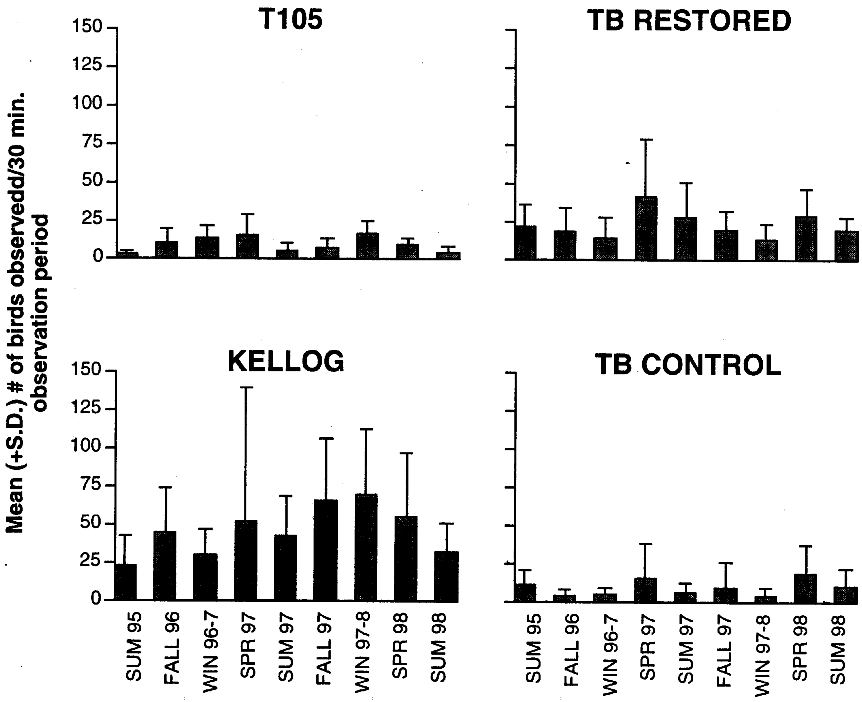

FIGURE 28. Mean abundance (+ SD) by season and site calculated without the 14 species classified as introduced or human-associated.

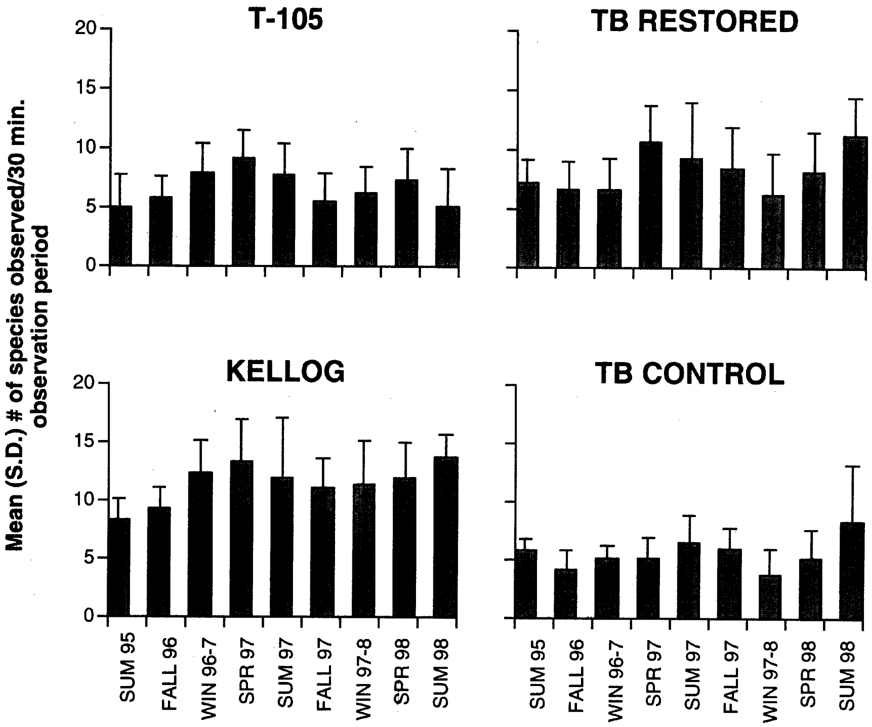

FIGURE 29. Overall mean richness (+ SD) by season and site at four sites on the Duwamish Waterway.

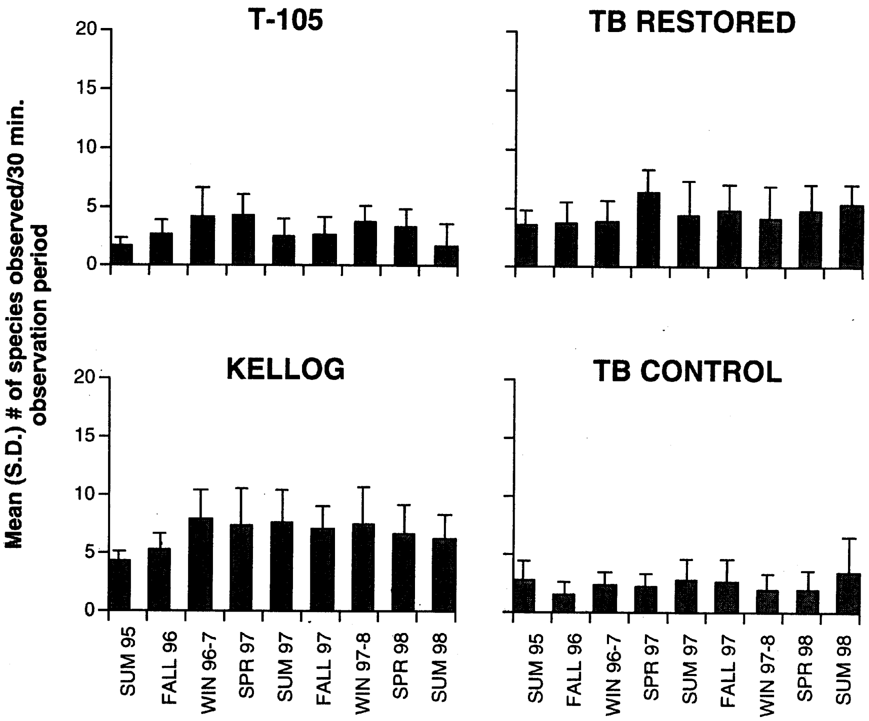

FIGURE 30. Mean richness (+ SD) by season and site calculated without the 14 species classified as introduced or human-associated.

was higher at every site except T-105 than it was in 1997 (Table 1). At T-105 mean richness declined in 1998 compared with 1997 (Table 3).

Birds continued to use each site differently (Appendix 4). Birds in transit continued to be observed most frequently at T-105 while direct site use (e.g., foraging and resting) occurred primarily at Kellogg Island and the Turning Basin restoration site. Foraging activity across sites was generally greater in the summer months. Both Kellogg Island and the Turning Basin restoration site had the most consistent year-to-year patterns of habitat use.

In order to rank "effectiveness" of the restored sites relative to each other as well as the control areas, a pairwise index of association was calculated (Table 4): species present at both sites/species present at either site for both 1997 and 1998. With respect to native/indigenous species, the Turning Basin restoration site most closely resembled Kellogg Island, and that relationship remained the same in 1997 and 1998. The T-105 and Turning Basin reference sites became more similar to each other in 1998 than they were in 1997 owing to the decline in native/indigenous species recorded at T-105. In 1998, fewer non-native species were seen at the Turning Basin reference site than in 1997. Native/human-associated species were seen nearly evenly across sites with a 75% overlap in 1998 (as a resulting of not seeing barn swallows at T-105).

Emergent Vegetation

Carex lyngbyei *Benches*. In 1997, shoot density was lower than in the previous 2 years at each site (Table 5) and was not significantly different among sites (p = 0.52). Findings were similar for mean maximum shoot height (except at site 3). At sites 1 and 2, mean maximum shoot height was lower in 1997 than in 1995 and 1996, but at site 3 in 1997, it was equal to or greater than in the previous two years. In 1997, mean maximum shoot height did not differ among the three *Carex* sites (p = 0.133).

TABLE 3. Mean (± SD) annual abundance and richness at four sites on the Duwamish Waterway. 1997 = 9/1/96–8/31/97 and 1998 = 9/1/97–3/31/98.

Mean/range	T-105	Kellog	TB restored	TB control
Annual mean abundance				
1997				
Mean ± SD	35±4	141±17	45±11	19±6
Range	29–38	122–163	29–56	15–27
1998				
Mean ± SD	24±7	143±20	47±16	26±10
Range	13–29	125–171	25–62	13–36
Annual mean richness				
1997				
Mean ± SD	7.7±14.	11.8±1.8	8.4±2.0	5.3±0.9
Range	5.8–9.2	9.3–13.4	6.7–10.7	4.2–6.5
1998				
Mean ± SD	6.1±1.0	12.1±1.2	8.6±2.1	5.8±1.9
Range	5.2–7.4	11.1–13.8	6.3–11.3	3.7–8.3

The distribution of individual data values shows that each site may be distinct (Fig. 31). For example, the variance in shoot density was greatest at site 3 in 1995 and 1996, site 2 in 1996, and site 1 in 1997. The increase over time in variance at site 1 was due to an increase in the number of low density and bare patches. At site 2, the variance increased from 1995 to 1996, and then the population seemed to split into two more homogeneous groups in 1997. At site 3, the process was the reverse of site 2. What appeared to be a bimodal population in 1995 became more consistent by 1997.

Variance in shoot height appeared to increase over time at sites 1 and 3 while staying constant and relatively low at site 2. At site 1, the increase in variance may have been due, in part, to the increase in bare and low density patches.

TABLE 4. Pairwise comparisons (% overlap) for three species categories of birds at four sites in the Duwamish Waterway. 1997 (9/1/96 - 8/31/97) = plain text, 1998 (9/1/97 - 8/31/98) = bold text.

Category	TBcont/TBrest	TB cont/Kell	TB rest/Kell	TB cont/T-105	TB rest/TB-105	Kell/T-105
Native/ indigenous	61	54	89	66	93	83
Non-native BNCO ENSP CAQU EUST DODU HOFI DOGO	80 **50**	100 **50**	80 **80**	80 **50**	100 **100**	80 **80**
Native/human-associated BASW RODO AMRO NWCR	100 **100**	100 **100**	100 **100**	100 **75**	100 **75**	100 **75**
CAGE MALL GWGU	100 **100**	100 **100**	100 **100**	100 **100**	100 **100**	100 **100**

TABLE 5. Summary statistics for *Carex lyngbyei* sites 1, 2, 3.

		Site								
Year	Shoot density	1	2	3	1	2	3			
1995	Average	32.0	46.8	38.1	0.4	0.3	0.5	CV		
	StdDev	13.9	14.8	19.6	3.5	2.7	3.8	max/min		
	Max	60	76	75	0.7	1.2	1.2	site1/site2	site2/site3	site3/site1
	Min	17	28	20	0.8	1.5	0.8	site1/site3	site2/site 1	site3/site2
1996	Average	43.7	40.5	29.1	0.3	0.7	0.6	CV		
	StdDev	12.9	26.9	16.2	2.3	10.9	8.5	max/min		
	Max	63	87	68	1.1	1.4	0.7	site1/site2	site2/site3	site3/site1
	Min	28	8	8	1.5	0.9	0.7	site1/site3	site2/site 1	site3/site2
1997	Average	25.7	29.7	26.7	0.9	0.6	0.4	CV		
	StdDev	22.3	17.4	10.7		4.8	4.9	max/min		
	Max	62	63	44	0.9	1.1	1.0	site1/site2	site2/site3	site3/site1
	Min	0	13	9	1.0	1.2	0.9	site1/site3	site2/site 1	site3/site2

		Site								
Year	Shoot density	1	2	3	1	2	3			
1995	Average	91.0	93.7	123.6	0.3	0.2	0.2	CV		
	StdDev	24.0	14.4	25.5	3.0	1.5	2.0	max/min		
	Max	138	120	158	1.0	0.8	1.4	site1/site2	site2/site3	site3/site1
	Min	46	78	81	0.7	1.0	1.3	site1/site3	site2/site 1	site3/site2
1996	Average	140.0	100.0	136.1	0.2	0.2	0.2	CV		
	StdDev	32.7	21.9	31.1	2.3	1.8	2.1	max/min		
	Max	177	138	191	1.4	0.7	1.0	site1/site2	site2/site3	site3/site1
	Min	76	77	89	1.0	0.7	1.4	site1/site3	site2/site 1	site3/site2
1997	Average	47.9	89.0	136.9	0.9	0.2	0.4	CV		
	StdDev	42.2	18.5	60.7		2.1	4.3	max/min		
	Max	131	125	280	0.5	0.7	2.9	site1/site2	site2/site3	site3/site1
	Min	0	59	65	0.4	1.9	1.5	site1/site3	site2/site 1	site3/site2

Low-density patches tended to have shorter shoots at this site in 1997 (correlation of shoot height with shoot density = 0.87, but this was the only site and year with a significant correlation between the two variables). At site 3, the increase in variance was due to the extreme height of at least one shoot in a few quadrats. The increase in variance in shoot height at site 3 occurred simultaneously with a decrease in variance in shoot density.

Between 1995 and 1997, the coefficients of variation (CV) in both shoot height and shoot density varied between 30% and 90% at the three *Carex* sites. These are relatively low CVs for environmental data and, in this dataset, correspond with a ratio of maximum to minimum values of 2.3 to 10.9. Shoot densities at the sites have fallen within 70% to 120% of one another. Shoot heights have varied more among sites and have fallen between 50% and 300% of heights at the other sites (Table 5).

Scirpus validus. At the Kellogg Island reference site, the variance in shoot density remained quite low and constant while variance in shoot height increased over the 3 years (Table 6, Fig. 31) so that the population seemed to become bimodal. At the GSA restoration site, shoot height has tended to increase in mean and variance while shoot density has decreased (fewer quadrats with high numbers of shoots).

The CVs in shoot height have ranged from 30% to 40%. The CVs of shoot density were slightly greater, 40% to 70%. These CVs represent ratios between maximum and minimum values of 3.8 to 11.4 for shoot height and 2.4 to 3.9 for shoot density. Shoot density at the GSA has been 1.4 to 2.3 times as great as shoot density at the Kellogg Island reference site. Shoot height at the GSA, on the other hand, has been only 0.5 to 0.7 times the shoot height at the reference site.

Additional Species

Scirpus sites. Four species have been present at both *Scirpus* sites: *Spergularia marina* (more abundant at the GSA site), *Scirpus cernuus, Plantago maritima*, and *Potentilla palustris* (more abundant at the Kellogg Island reference site) (Table 7). In 1997, understory at the GSA site was dominated by *S. marina, Cotula coronopofila*, and *Lilaeopsis* sp.; understory species were found in every quadrat, and 3 to 6 species were found in each quadrat. At the Kellogg Island reference site, 3 to 4 species were found in each upstream quadrat and the understory was dominated by *C. lyngbyei, Potentilla. palustris, Plantago maritima*, and *Distichlis spicata*. *Carex* has begun to recruit to this site, and the distributions of shoot density and height of the *Carex* recruits were both quite skewed (Table 8). The Kellogg Island reference site had little or no *C. coronopofila, Salicornia virginica*, or *Grindelia integrifolia*. The GSA site had no *C. lyngbyei, D. spicata, R. repens*, or *Triglochin maritimum*.

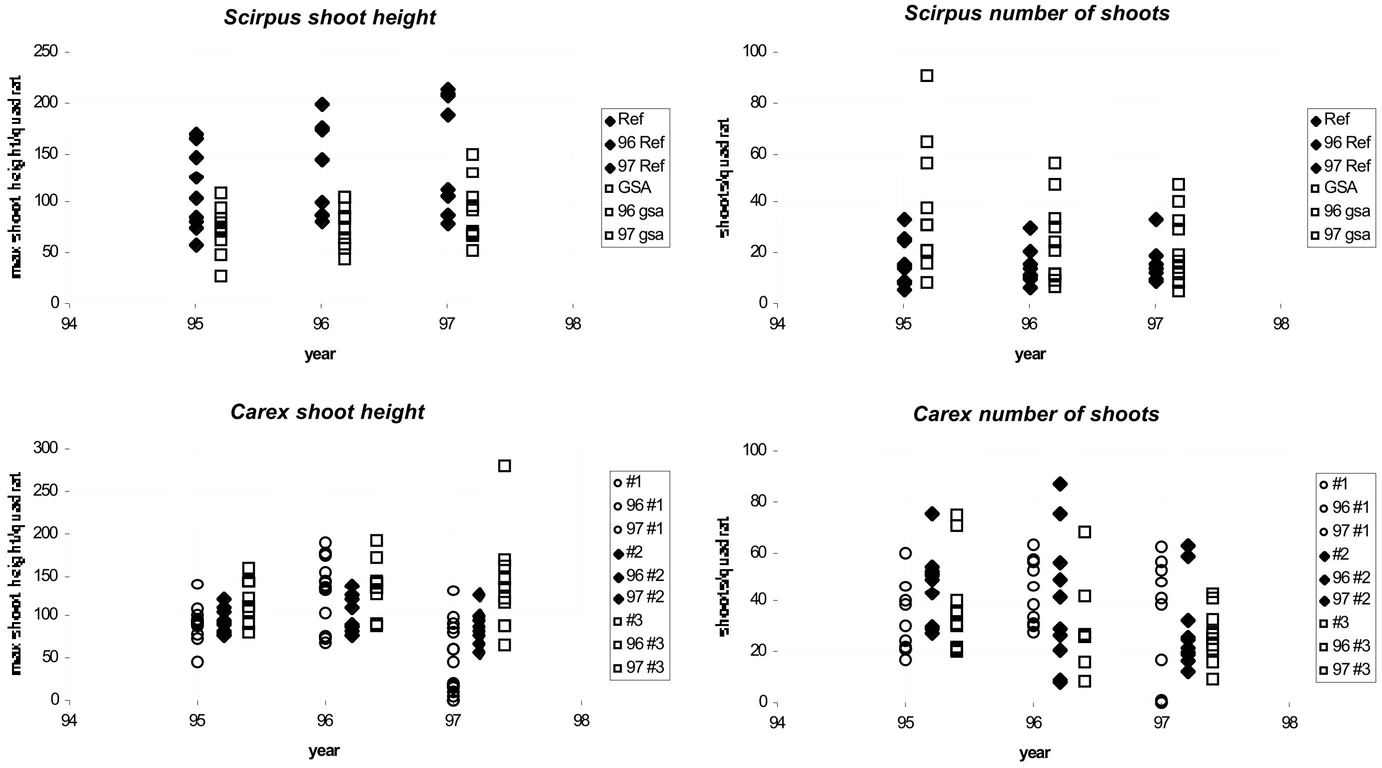

FIGURE 31. Distribution of replicate *Carex* and *Scirpus* data showing changes in mean and variance at Coastal America restoration and reference sites.

TABLE 6. Summary statistics for *Scirpus* GSA and reference sites.

	Shoot	Site				
Year	density	GSA	Ref	GSA	Ref	
1995	Average	37.8	16.2	0.7	0.6	CV
	StdDev	25.7	9.3	11.4	5.7	max/min
	Max	91	34	2.3		GSA/Ref
	Min	8	6		0.4	Ref/GSA
1996	Average	25.2	14.9	0.7	0.4	CV
	StdDev	16.6	6.6	8.0	4.3	max/min
	Max	56	30	1.7		GSA/Ref
	Min	7	7		0.6	Ref/GSA
1997	Average	22.4	15.9	0.6	0.4	CV
	StdDev	14.1	7.0	9.4	3.8	max/min
	Max	47	34	1.4		GSA/Ref
	Min	5	9		0.7	Ref/GSA

.	Shoot	Site				
Year	density	GSA	Ref	GSA	Ref	
1995	Average	73.2	118.4	0.3	0.4	CV
	StdDev	23.0	42.7	3.9	2.9	max/min
	Max	110	171	0.6		GSA/Ref
	Min	28	58		1.6	Ref/GSA
1996	Average	77.3	129.1	0.3	0.3	CV
	StdDev	21.3	44.5	2.4	2.4	max/min
	Max	106	200	0.6		GSA/Ref
	Min	44	82		1.7	Ref/GSA
1997	Average	90.2	140.8	0.3	0.4	CV
	StdDev	31.0	57.2	2.9	2.7	max/min
	Max	150	215	0.6		GSA/Ref
	Min	52	79		1.6	Ref/GSA

TABLE 7. Number of understory species found at each *Carex* and *Scirpus* site in the Duwamish River, 1995–97.

	1995	1996	1997
Scirpus			
Reference			
Carex lyngbyei	4	7	6
Spergularia marina	4	5	2
Potentilla palustris	2	4	6
Plantago maritima	0	0	4
Distichlis spicata	0	2	4
Atriplex patula	2	1	1
Ranunculus repens	2	0	0
Triglochin maritimum	0	2	0
Scirpus cernuus	0	2	0
Cotula coronopofila	1	0	0
GSA			
Spergularia marina	9	10	10
Cotula coronopofila	6	7	9
Lileopsis sp.	3	7	10
Potentilla palustris	0	0	1
Atriplex patula	1	0	1
Salicornia virginica	1	2	1
Plantago marina	0	0	2
Grindelia integrifolia	0	0	2
Scirpus cernuus	6	3	2
Carex lyngbyei			
# 1: Boeing			
Eleocharis parvula	0	0	4
Cotula coronopofila	0	0	1
Lemna minore	0	0	2
Scirpus validus	0	2	0
Spergularia marina	0	0	1
#2: DSB			
Lileopsis sp.	0	0	3
Eleocharis parvula	0	0	3
Lemna minore	0	0	2
Potentilla palustris	0	0	2
Polygonum hydropiperoides	0	0	2
Deschampsia caespitosa?	0	0	1
#3: Lombardi			
Spergularia marina	3	1	2
Scirpus cernuus	3	2	4
Plantago marina	0	2	3
Aster subspicatus	1	2	2
Atriplex patula	1	3	1
Potentilla palustris	0	1	1
Polygonum hydropiperoides	0	0	1
Triglochin maritimum	1	0	0

Carex sites. Understory species at the reference *Carex* benches have been present since 1995 at site 3, since 1996 at site 1, and in 1997 at site 2. In 1997, understory species at site 1 were found in 10 of the 15 sampling units and included *Spergularia marina, Cotula coronopofila, Eleocharis parvula*, and *Lemna minor*. *Scirpus validus* was noted in 1996. At site 2, 8 of the 10 quadrats had an understory species and 6 understory species were present at the site. Site 3 had 9 understory species and these species were found in 9 of the 10 quadrats.

Comparison of Scirpus *and* Carex *Sites*. Understory species have been present at both *Scirpus* sites and *Carex* site 3 since 1995. They appeared at site 1 in 1996 and at site 2 in 1997. More species have tended to be present in the *Scirpus* patches than the *Carex* patches. Eight species were found at both *Carex* and *Scirpus* sites (*Atriplex, Cotula, Lilaeopsis, Plantago, Potentilla, Scirpus cernuus, Spergularia*, and *Triglochin*). *Distichlis* and *Grindelia* were seen only at the *Scirpus* sites, while *Aster, Eleocharis parvula*, *Lemna*, and *Polygonum* were seen only at the *Carex* sites.

T-105 and Turning Basin. At the T-105 site, *Atriplex patula* was recruiting heavily to both sides of the channel. It was found in every systematic quadrat placed along the upstream and downstream sides of the channel. *D. spicata, P. maritima, S. virginica, S. validus*, and *Juncus effusus* were found in one quadrat each. Eleven patches of *Scirpus maritimus*, 7 patches of *S. virginica*, 5 patches of *S. maritimus*, 3 patches of *P. maritima*, and 1 patch each of *D. spicata, Cotula coronopofila, P. maritima, Atriplex patula, J. effusus*, and *Scirpus acutus* were counted along the 220-m downstream bank (Appendix 5).

At the Turning Basin, a diverse assemblage of species

TABLE 8. Shoot density and maximum shoot height of *Carex lyngbyei* recruits in *Scirpus* reference patch.

Replicate	Density	Height
1	19	79
2	89	44
3	0	0
4	3	61
5	1	69
6	5	45
7	15	170
8	0	0
9	0	0
10	0	0
mean	13.2	52
median	2	45
std. dev.	27.5	53.9

TABLE 9. Plant species found at Turning Basin and number of quadrats in which they were found.

Species	No. quadrats
Eleocharis palustris	7
Spergularia marina	7
Aster subspicatus	5
Gnapthalium ugliosum	5
Crab grass	4
Carex lyngbyei	3
Cotula coronopofila	3
Plantago maritima	2
Grass (unident)	2
Dandelion	1
Eleocharis parvula	1
Rumex crispus	1
Tanacetum bipinnatum	1
Conioselinum pacificum	1
Melilotus alba	1

has begun to develop in areas that have been protected from goose grazing (Table 9). Sixteen species were observed in the sampled area. Three to eight species were found in each quadrat.

Conclusions

Benthic Studies

Several of the Coastal America restored habitats appear to be experiencing increased benthic invertebrate abundances. In particular, at T-105, the channel and the "delta" region near the mouth have developed invertebrate densities similar to those found at the other restored and reference sites, especially for the Protocol amphipod taxa *Corophium* spp. and *Eogammarus confervicolus*. This is notable because the T-105 sites are at higher elevations than the benthic reference flats and might have been expected to have lower densities because of this difference. Our data also show that invertebrate densities have increased relative to previous sampling years. For example, the T-105 channel had much higher densities of total invertebrates and most of the Protocol taxa in 1997 than it did in 1996, and the GSA intertidal bench had higher total invertebrate density in 1997 than it did in 1995 (see Appendix 1).

Between-year comparisons must be interpreted with caution because we only have data from two or three sampling years for each site (see Appendix 1); nevertheless, some of the created habitats clearly are becoming colonized with ecologically important benthic invertebrates. In addition to *Corophium* and *Eogammarus*, the sand substrates at the T-105 site are populated by high densities of the Protocol attribute polychaete worm *Manayunkia aesturina* and the harpacticoid copepod *Huntemannia jadensis*, a prey species for juvenile flatfish. The high intertidal sandflat at the Turning Basin restoration site has had high numbers of ceratopogonid fly larvae (in two consecutive years), and *Mesochra rapiens*, a common oligohaline harpacticoid copepod and fish prey species (J. Cordell, unpubl. data, Snohomish and Chehalis river estuaries) was abundant in 1997. The important juvenile salmon prey taxon *Harpacticus* was found only at the GSA intertidal bench and another created bench in the lower waterway (see Appendix 2 and Cordell et al. 1996).

The created and restored habitats at the Coastal America sites are very young and probably at an early stage in their progression to ecological equilibrium. We cannot predict with certainty the end point of these trajectories, and several factors will be important in determining what invertebrate assemblages ultimately become established and persist.

1. The extent of both intertidal and riparian vegetation colonization and the subsequent input of organic matter will affect the amount and quality of food available for benthic invertebrates. Sites that become heavily vegetated by emergent marsh plants (e.g., Turning Basin upper flat) will probably be dominated by detritivores such as insect larvae and oligochaete worms whereas habitats that remain unvegetated (e.g., intertidal benches) will support proportionally more deposit and suspension feeders such as *Corophium* and certain polychaete worms.
2. Grain size, elevation, and accretion rates will be important in determining assemblage structure. Accretion may be particularly important at sites like the high intertidal flat at the Turning Basin, which appears to be accreting fined-grained sediments. Sites that now have relatively coarse sediments (e.g., T-105 channel and "delta," GSA intertidal bench) have characteristic species such as the polychaete worm *Pygospio elegans* and the harpacticoid copepod *Huntemannia jadensis* that will probably remain abundant at these sites if grain size does not change.
3. Some of the animals that occupy the sites now may be early colonizers, or "pioneering" species that will

give way to other species as the sites stabilize. Fourth, position within the estuary will continue to play an important part in defining benthic assemblage structure. Sites in the vicinity of the Turning Basin will be characterized by relatively large numbers of species that are tolerant of oligohaline conditions (*Corophium* spp. and the harpacticoids *Coullana canadensis*, *Pseudobradya* sp., and *Mesochra rapiens*) while those downstream will be more diverse.

4. As other restoration sites are constructed in the Duwamish Waterway, linkages among these new habitats may cause larger-scale off-site changes in benthic assemblage structure and densities coinciding with increasing levels of organic matter and changes in hydrographic characteristics of the estuary.

Fallout Insects

Insects sampled by fallout traps were characterized by large variations in assemblage structure among sampling dates, years, and sites. These variations occurred at reference and restoration sites. Therefore, determining if these differences are due to physical or biotic changes in the sites or to natural interannual and seasonal variation is difficult. However, one large and consistent shift in insect assemblages at the T-105 and Turning Basin restoration sites was probably not due to natural variation. At both sites, the populations sampled shifted from being dominated by various dipteran flies in 1996 to a large dominance by aphids, psyllids, and other homopterans in 1997. The predominance of these obligate plant feeders was probably due to the large increase in riparian and emergent vegetation at these sites between 1996 and 1997. We cannot predict what will happen as these sites continue to develop, but it is reasonable to predict that the ultimate outcome will be a natural seasonal progression in which homopterans predominate in the spring when tender new growth emerges, followed by increases in dipterans and other types of insects.

Densities of total fallout insects and most individual insect taxa were greater in 1997 than in 1996 both at reference and restoration sites (especially in May—see Figs. 17–24). Again, this finding suggests that differences may be the result of between-year variation. At the T-105 site, the densities of total insects and most Protocol attribute insect taxa fell below those at the Kellogg Island reference site, as they did in 1996. However, the differences were usually small, and some individual taxa such as psyllids were consistently more abundant at the T-105 site. As naturally recruiting and planted vegetation becomes established and stabilizes at this site, insect assemblages will also probably become more stable.

The GSA *Scirpus* site also had lower total fallout insect densities than the Kellogg Island reference *Scirpus* patch on two of three 1997 sampling dates. However, as in 1996, the GSA site had abundances of ephydrid, ceratopogonid, dolichopodid, and chironomid flies that were similar to or exceeded those at Kellogg Island. The higher abundances at the Kellogg Island reference *Scirpus* patch were due to other taxa such as collembolans, aphids, and a variety of other insects. The high density and diversity of insects at this site are probably the result of the setting, which is located adjacent to a shoreline with dense fringing riparian vegetation consisting of grasses, blackberries, and various trees and shrubs. It is also located in a quiet backwater area that appears to accumulate plant detritus that probably supports the relatively high densities of amphipods and collembolans observed there.

On May and June 1997 sampling dates, the Turning Basin restoration site had much higher total insect densities than did the reference *Carex* bench; densities were also 4–5 times greater in 1997 than on corresponding sample dates in 1996. For aphids, ephydrids, ceratopogonids, dolichopodids, and chironomids, the transplanted *Carex* area had abundances that were similar to or (usually) exceeded those at the reference *Carex* patch. Increased density of insects at the restoration site may be a result of much higher survival of transplanted and naturally recruiting vegetation after goose grazing exclosures were erected and maintained as part of a graduate student project (Caren Crandell, Center for Urban Horticulture, Univ. Washington).

Carex and *Scirpus* vegetation patches at the Coastal America restoration sites continue to produce juvenile salmon prey attribute insects. Insect assemblage structure and densities at these sites are probably not yet stable, however. As planted and recruiting vegetation continues through successional states toward a stable state, the types of insects inhabiting each site will change accordingly.

Juvenile Salmon Diets

Chum Salmon: As in 1996, *Corophium* spp. amphipods were important prey in juvenile chum salmon diets captured in April. However, other than *Corophium*, juvenile chum salmon collected in 1997 had qualitatively different diets than those captured in 1996. In particular, 1997 fish diets lacked harpacticoid copepods, chironomid flies, calanoid copepods, and cladocerans that were all quite important in 1996. Instead, fishes consumed relatively more of a variety of other dipteran flies, aphids, and psyllids in 1997. It is not possible to determine whether these differences are due to interannual variation, differences in timing of fishing effort between years, or small fish sample sizes.

On 23 May 1997 at the T-105 channel, the chum salmon diets and insect fallout trap samples overlapped remarkably. In the insect samples, psyllids made up over 50% of the numbers, and in the fish diets they constituted over 80% of the prey weight. This finding reinforces our previous assertion (Cordell et al. 1997) that the created channel at T-105 presents a unique opportunity to sample fish that have been using the actual restored habitat. It also shows that, at least at this stage in its development, the T-105 site is producing prey taxa that are being utilized by juvenile chum salmon.

Chinook Salmon: The juvenile chinook salmon captured in 1997 had similar diets to those caught in 1996, consisting primarily of benthic amphipods, mysid shrimp, and drift insects. However, the makeup of the insects consumed was different between the years. In 1996, dipteran flies predominated while in 1997, psyllids, hymenoptera (wasps and their relatives), and formicidae (ants) were more important. As for the results from juvenile chum, we cannot determine the source of these differences with our limited data. Similarly to the juvenile chum diets, psyllids dominated in both insect fallout traps and juvenile chinook diets on 23 May 1997. Such findings suggest that these and other riparian plant-dependent insects are beginning to be produced and utlized by fish in the vegetation at this site.

The results of 1996 (Cordell et al. 1997) and 1997 Duwamish Waterway juvenile salmon diet analyses an emerging pattern that is different than that for other natural and restored estuaries in the Pacific Northwest. The insect portion of juvenile chum and chinook diets has been dominated by chironomid flies (larvae, pupae, and emergent adults), and aphids in other studies (Congleton 1978; Cordell et al. 1998, 1999; Levings et al. 1995; Miller and Simenstad 1997; Northcote et al. 1979; Shreffler et al. 1992). In contrast, in the Duwamish Waterway insects in the diets were much more likely to consist of collembolans, psyllids, ants, wasps, a variety of adults flies, and other insects. These differences likely result from habitat differences between the Duwamish Waterway and other study areas. In most other estuaries studied, sites were dominated by emergent vegetation such as *Carex lyngbyei*, which supports associated populations of chironomids and aphids (Simenstad et al. 1993, 1996; Whitehouse et al. 1993) whereas in the Duwamish estuary such vegetation is rare. Whether or not recruitment and growth of emergent vegetation at Coastal America sites will be of sufficient magnitude to be reflected in the diets of juvenile salmon in the future is unkown.

Avifauna

With the end of the summer 1998 field season, 9 seasons (27 months) of data collection and monitoring of birds at 4 sites (described in Cordell et al. 1997) on the Duwamish waterway have been completed. In spite of being highly industrialized, the waterway hosts a diverse and often abundant bird population that uses the area for resting, foraging, and breeding. Relatively isolated patches of shoreline (e.g., Kellogg Island) consistently draw large numbers of birds. However, increased levels of human activity appear to have decreased bird abundance and diversity. Construction of a rendering plant west of T-105 and the dismantling and removal of the ferry at the Turning Basin were associated with a negative effect on bird populations compared with the previous year. At T-105, upland habitat loss and the continued disturbance related to the rendering plant may result in a permanent decrease in bird use of the site. Perhaps another way to evaluate T-105 is to consider the increasing level of human activity, over the course of the last 2 years as a positive increase in access for humans. Therefore, if one purpose of the created habitat at T-105 was to make the waterway more accessible to people, then this goal has to some degree been accomplished. The Turning Basin shows greater promise for birds inhabiting the Duwamish Waterway for several reasons: it is relatively more isolated and therefore was already a magnet for birds, and two new habitat restoration projects adjacent to this site will create additional habitat and linkages with existing habitat. Future monitoring plans should encompass old and new restoration sites to determine whether the increasingly linked sites have greater ecological value in aggregate than does each site alone. Continuing to measure changes in richness and abundance of avifauna will also allow us to determine which species are benefiting most from restoration.

Emergent Vegetation

The changes in variance and apparent bimodality in shoot height and density at some of the *Scirpus* and *Carex* sites may be caused by sampling that was insufficient to capture the full gradient of densities and heights. Alternatively, the cycles of increasing and decreasing variance may also indicate patterns of growth, die-back, and recruitment of individual plants within the patches. It may be of interest to tag and follow the fates of particular shoots to provide additional information about the cycles of recruitment and growth.

Of the *Carex* reference benches, site 3 has the lowest shoot density and seems to be frequently disturbed by wave action and large pieces of industrial and woody debris. The *Scirpus* patch at the GSA restoration site also continues to be profoundly disturbed by boat wakes and deposits of debris. The reference *Scirpus* near Kellogg Island remains a small, marginal patch. Understory species have been relatively numerous and diverse at these sites, and pioneering disturbance-tolerant species may be more able to recruit to these sites than to those with greater vegetation cover. Also, goose grazing of understory species may be restricted at these sites because of low biomass of optimal grazing species, physical and human disturbances or, in the case of *Carex* site 3, isolated location in an industrial area.

Substrate in the Duwamish is limited by riprapping of the shoreline and wind/wave action that transports large debris and erodes the shoreline. Promoting plant diversity in the Duwamish may require different policies in different parts of the Duwamish. For example, the main impediments to the spread of vegetation in upstream areas seems to be riprapping and goose grazing. In downstream areas, wave action and destruction by debris may be more limiting. Seed availability does not seem to be limiting given that many species germinate when protected from grazing (Caren Crandell, Center for Urban Horticulture, Univ. Washington).

Summary

1. Benthic macro- and meiofauna were collected in April, May, and June 1997 from 0.0-m elevation reference mudflat sites in the Duwamish Waterway at the Turning Basin, an upper waterway site, and at Kellogg Island in the lower waterway. Samples were also collected from the following Coastal America restoration sites: (1) an intertidal sediment bench at the GSA site across the waterway from Kellogg Island, (2) sand channel and "delta" sites at T-105, a created channel near Kellogg Island, and (3) a high intertidal sandflat encompassed by transplanted vegetation and a 0.0-m elevation mudflat at the Turning Basin restoration site. Insect fallout was sampled at the same time at the reference *Carex* and *Scirpus* sites, and at restored vegetation sites at the Turning Basin, along the margins of the created channel at T-105, and at the GSA site. Juvenile salmon for diet analyses were collected by beach seine near the Turning Basin and Kellogg Island sites, and by occluding the mouth of the created channel at T-105. Avifauna have been observed from June 1996 through September 1998 at Kellogg Island and Turning Basin reference sites and at Turning Basin and T-105 restoration sites. In August 1997, shoot density and height were measured from three *Carex lyngbyei* benches in the vicinity of the Turning Basin and from *Scirpus* patches at Kellogg Island and GSA sites. Recruitment of new vegetation at the T-105 channel was observed and recorded.
2. Several of the Coastal America restored habitats appear to be experiencing increased benthic invertebrate abundances. In particular, habitats at the T-105 site had densities similar to those found at reference sites. Some of the created habitats are becoming colonized with ecologically important benthic invertebrates, including amphipods, polychaete worms, insect larvae, and harpacticoid copepods.
3. Insects sampled by fallout traps were characterized by large variations in assemblage structure among sampling dates, years, and sites. These variations occurred both at reference and restoration sites. While it is difficult to determine if these differences are due to physical or biotic changes in the sites or to natural interannual and seasonal variation, a shift in dominance by dipteran flies in 1996 to a large dominance by aphids, psyllids, and other homopterans in 1997 at the T-105 and Turning Basin sites was probably not due to natural variation. This change was probably caused by the large increase in riparian and emergent vegetation at these sites between 1996 and 1997. *Carex* and *Scirpus* vegetation patches at the Coastal America restoration sites continue to produce juvenile salmon prey attribute insects.
4. Juvenile chum and chinook salmon collected in 1997 had qualitatively different diets than those captured in 1996. It is not possible to determine whether these differences are due to interannual variation, differences in timing of fishing effort between years, or small fish sample sizes. In data from both years, a pattern is emerging that indicates insect diet of juvenile chum and chinook salmon in the Duwamish Waterway is different than what has been found in other studies in the region. In the Duwamish, juvenile salmon consumed fewer chironomid flies and aphids, and more surface drift insects than in studies from other estuaries. These differences may result from a lack of emergent vegetation in the Duwamish that supports typical marsh-dwelling insects in other systems. On the May sampling date at the T-105 channel, there was a remarkable overlap between both chinook and chum salmon diets and insect fallout trap samples based on the dominance in both sample types by one taxon of plant-dwelling insect (psyllids). This finding reinforces our previous assertion that the created channel at T-105 presents a unique opportunity to sample fish that have been using the actual restored habitat. It also suggests that the riparian and emergent vegetation at the site is beginning to provide prey resources for juvenile salmon.
5. In spite of being highly industrialized, the Duwamish Waterway hosts 87 bird species that use the area for resting, foraging, and breeding. However, increased levels of human activity appear to have decreased bird abundance and diversity at the T-105 and Turning Basin sites. At T-105, upland habitat loss and the continued disturbance related to the operation of a new rendering plant may result in a permanent decrease in bird use of the site. The Turning Basin shows greater promise for bird use because it is relatively more isolated and is close to two new restoration projects that may provide additional habitat and linkages with existing habitat.
6. In 1997, reference *Carex* shoot density was lower than in the previous 2 years at each site, and shoot height was lower at two of three sites. At the *Scirpus* refer-

ence site, the variance in shoot density remained quite low and constant, while variance in shoot height increased over the 3 years so that the population seemed to become bimodal. At the GSA *Scirpus* site, shoot height has tended to increase in mean and variance while shoot density has decreased. Observed changes in variance and apparent bimodality in shoot height and density may be caused by sampling that was insufficient to capture the full gradient of densities and heights or by natural cycles of the plants within the patches. One of the *Carex* reference benches and the *Scirpus* patch at the GSA restoration site appear to be continuously disturbed by boat wakes and deposits of debris, and the reference *Scirpus* near Kellogg Island continues to be a small, marginal patch. Understory species have been relatively numerous and diverse at these sites, and pioneering disturbance-tolerant species may be more able to recruit to these sites than to those with greater vegetation cover. However, at the Turning Basin and T-105 restorations sites, exclosures that minimize goose grazing appear to increase natural recruitment and survival of emergent plants. Recognition of different limiting factors for vegetation in different parts of the estuary should be taken into account in future restoration efforts.

7. The created and restored habitats at the Coastal America sites are probably at an early stage in their progression to ecological equilibrium. We cannot predict with certainty the end point of these trajectories, and factors such as the extent and structure of intertidal and riparian vegetation colonization, grain size, elevation, accretion rates, natural successional processes, location in the estuary along the salinity gradient, and linkages with new restored habitats will be important in determining which plants and animals will ultimately benefit from the sites.

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