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THE LINCOLN AVENUE WETLAND SYSTEM IN THE PUYALLUP RIVER ESTUARY, WASHINGTON

Phase II Report: Year Two Monitoring, January - December 1987

by

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WETLAND ECOSYSTEM TEAM

ANNUAL REPORT

to

Port of Tacoma

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R. C. Fran
Director

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ACKNOWLEDGMENTS

Funding for this work was provided by the Port of Tacoma. We sincerely thank Leslie Sacha of the Port of Tacoma for her continuing assistance, support and comments on the draft report. The following people helped carry out the transplanting effort in 1987: LoAnn Hallum, Markku Kaukoranta, Ron Burnett, Sarah Cassatt, Margaret Pfitzer, John Kornstein, Ann Shaffer and Bill Meyer. Help in the field sampling program was provided by Tim Dalton, Jose Obra, Jim Bolger, John Stadler, Alan Olson, Mary Ruckelshaus, Richard Davis, Christine Andrews, Tom Quinn, Theresa Armetta, Mike Grossmann, Fran Yeatts, Debbie Olden and Jay Orr. Juvenile chum salmon for experiments were graciously provided by the Washington Department of Fisheries hatchery at Minter Creek. Puyallup Indian tribal biologists Joseph Miyamoto and Thomas Demming, and hatchery manager Herman Dillan kindly provided logistical support for fish studies and for the water chemistry sampling as well as juvenile chum salmon fry. Richard Davis, Bob Lauth and Ken Adkins provided a great deal of computer assistance. Amy Unthank conducted the bird sampling. We sincerely appreciate the interest of the Tahoma Audubon Society in the wetland. Audubon Society member Jon R. Jensen made bird counts in the system on 53 occasions in 1987; a noteworthy effort. His data sheets were kindly provided to us, along with additional sitings, by Thais Bock of the Society. We are grateful to Marcus Duke (FRI Publications) for manuscript production and editorial suggestions.

EXECUTIVE SUMMARY

In 1987, the monitoring program for the Lincoln Avenue wetland system included sampling of water chemistry, sediment characteristics, vegetation, benthic fauna, fish and birds. In addition, approximately 10,000 shoots of Lyngbye's sedge (*Carex lyngbyei*) were transplanted onto flats where over-winter survival of 1986 transplants was poor. The findings of the 1987 monitoring program were as follows:

1. Sediment algae appear to be abundant at times and highly productive, and may be contributing significantly to the food web in the wetland and the river.
2. The total abundance and biomass of sedge plants approximately doubled between 1986 and 1987. The lower ends of the flats showed poor or no survival, which indicates that these areas are either too low or are otherwise unsuitable for the establishment of a vegetated marsh at the present time.
3. Upland vegetated habitats, including the grassland, swamp and cattail (*Typha* spp.) marsh, appeared viable.
4. Infauna and epibenthic populations increased in density and standing stock on the order of 10-25 times as compared to 1986. A shift from freshwater to estuarine faunal assemblages was apparent. The types of organisms present indicated that the system was in a state of early development.
5. Juvenile salmonids were the most abundant fish group caught in the system. Abundances of juvenile salmonids in 1987 appeared to be higher than measured in 1986. Birds continued to occupy the system in relatively high numbers.
6. By November 1987, 89 species of birds had been observed in the system. There was a slight increase in the number of bird species in the system in 1987 as compared to 1986.
7. Considerable sedimentation had taken place in the channels and mid-bay, whereas the flats showed only minimal deposition of fine material.

8. A limited, 1-day study of water properties indicated that the wetland was affecting temperature, dissolved oxygen, salinity and nutrients as would be expected in a natural wetland system.

We conclude that the system was serving the target resources for which it was designed. The system is undergoing rapid and dramatic physical, chemical and biological changes, and is presently in an early stage of development. Maintenance recommendations include control of trash and illegal dumping. We recommend that development of the site as a nature preserve be pursued. Monitoring recommendations for 1988-1990 are as were previously given in Thom et al. (1987). This work includes sampling of sedimentation, vegetation, fish and birds. Studies of salmonid residence time and food resources are recommended to further verify the functional performance of the system.

INTRODUCTION

As mitigation for filling a 9.6-acre parcel of land (Parcel 5; Fig. 1) containing wetland and upland habitats, the Port of Tacoma constructed a similarly sized wetland system. Construction included establishment of a sedge (*Carex lyngbyei*) marsh through initial transplantings. The new wetland system, located at the intersection of the Lincoln Avenue bridge and the Puyallup River (Fig. 1), was connected to the Puyallup River estuary via a breach in the river dike in February, 1986. The first report (Thom et al. 1987) on the project details the construction and first-year monitoring results. This initial monitoring work showed that approximately 100% of the transplanted sedge survived through the first growing season. In addition, target resources including juvenile salmonids, shorebirds and waterfowl occupied and apparently utilized the system. Based on these findings, it was concluded that the wetland system satisfied ecological performance criteria established as part of the mitigation agreement (Thom et al. 1987). However, the system was in an early stage of development and, similar to any new ecological system, changes were expected in subsequent years.

The maintenance and monitoring work in 1987 included: (1) replanting certain areas of the intertidal flats where survival of sedges over the winter was poor; and (2) intensive biological and physical monitoring studies to evaluate the functional performance of the system relative to target resources. Wetland evaluation in 1987 entailed sedimentation, vegetation, infauna, epibenthic zooplankton, fish and birds. All components were sampled over several months in 1987 to document the seasonal peaks (e.g., end of the vegetation growing season). This information can be used to design a more limited, but ecologically meaningful, future monitoring effort. In addition, a limited study of water chemistry was carried out in the Puyallup River estuary on one day in June for the purposes of determining the location of the salt wedge and to provide an indication of the effects of the wetland system on water chemistry in the estuary.

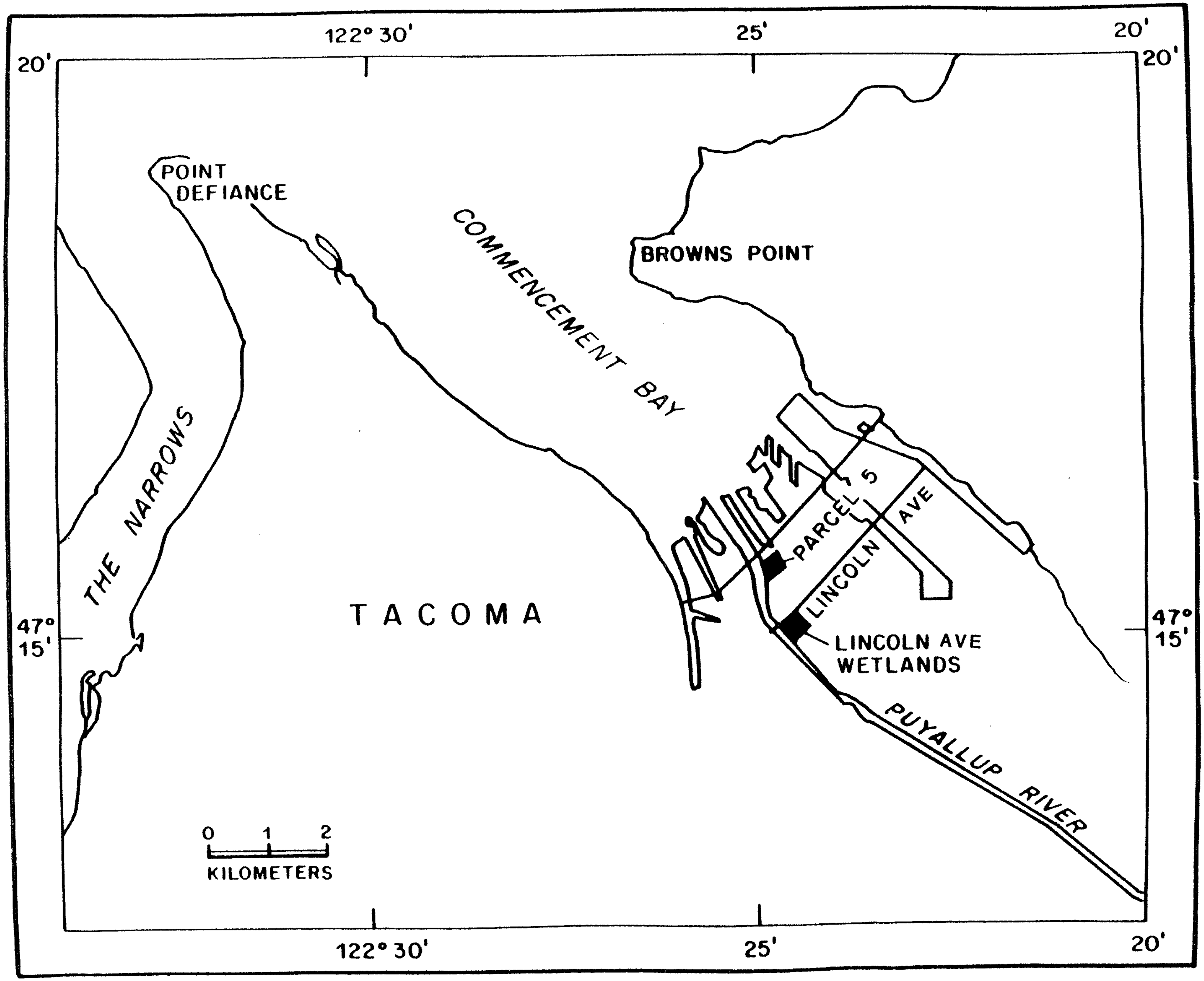


Figure 1. Location of Parcel 5 and the Lincoln Avenue wetland system

STUDY SITES

The wetland system contains an upland area with a grassland, cattail marsh and swamp, and an intertidal area consisting of mudflats and channels (Fig. 2). Sampling in 1987 of vegetation, infauna, epibenthos and fish was carried out in the newly constructed intertidal area. Birds were sampled in all habitats. A total of forty sampling sites (30 on the flats, five in channel 4 and five in the mid-bay) were established for sampling (Fig. 3) and were marked with wooden stakes to facilitate relocation during subsequent visits. All flats except flat 5 were planted with *Carex*, and flat 5 served as an unplanted reference area.

MATERIALS AND METHODS

Sediment Characteristics

Sediment characteristics monitored in 1987 included grain size, volatile solid and surface sediment height. Grain size and volatile solid concentration measure the particle size distribution and organic matter content, respectively, of the sediment. These conditions affect the benthic animal assemblages and help explain changes seen in animal assemblages. Sediment surface height indicates the amount of sedimentation or erosion that has occurred at a particular site. Cores of surface sediments 10-cm deep were collected using a PVC coring tube with a 5.1 cm inside diameter. The 20 sites sampled were located as follows: 12, 28, 44, 60 and 76 m along the transect on flat 4; 5, 14, 23, 32 and 41 m along the flat 5 transect; 25, 35, 45, 55 and 65 m along the transect in channel 4; and at five sites located between channel 4 and the mouth of the wetland (referred to as the mid-bay sites; Fig. 3). In addition, small core (2.1 cm inside diameter x 2 cm deep) samples were taken of sediments at the 20 sites for volatile solids analysis. Grain size was determined using standard sieve and pipette analysis. Volatile solids were measured at the percent loss of weight of a sample of sediment due to ashing at 500°C for 4 hours in a muffle furnace (Thom et al. 1987). Sampling was conducted on 26 August in conjunction with infauna sampling.

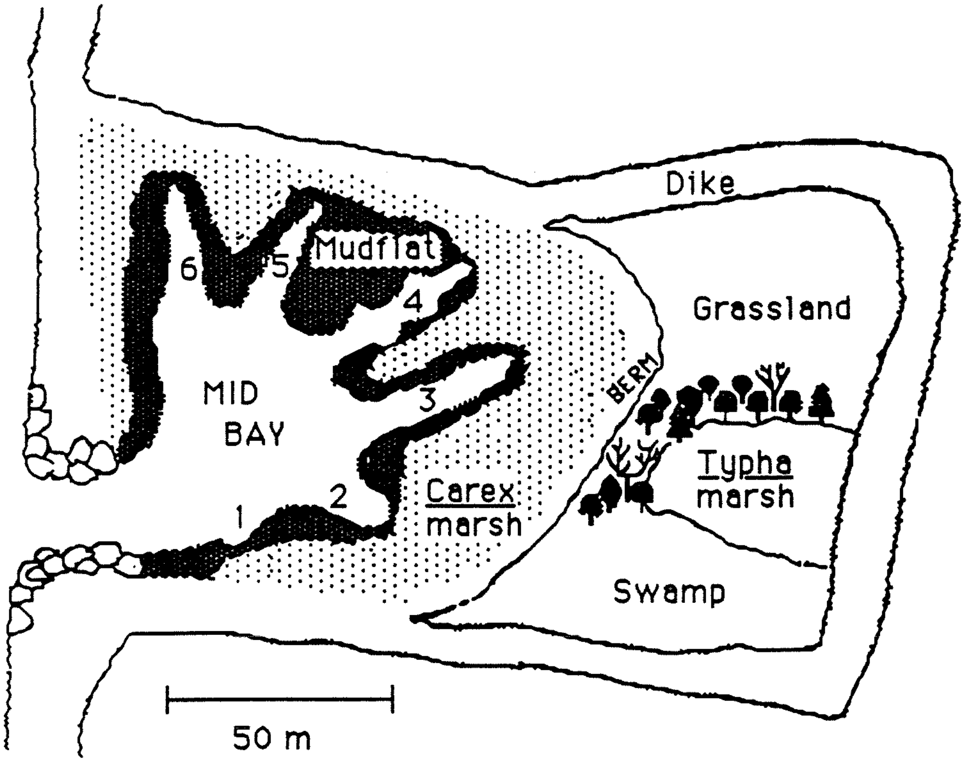


Figure 2. Distribution of the various habitat types within the Lincoln Avenue wetland system.

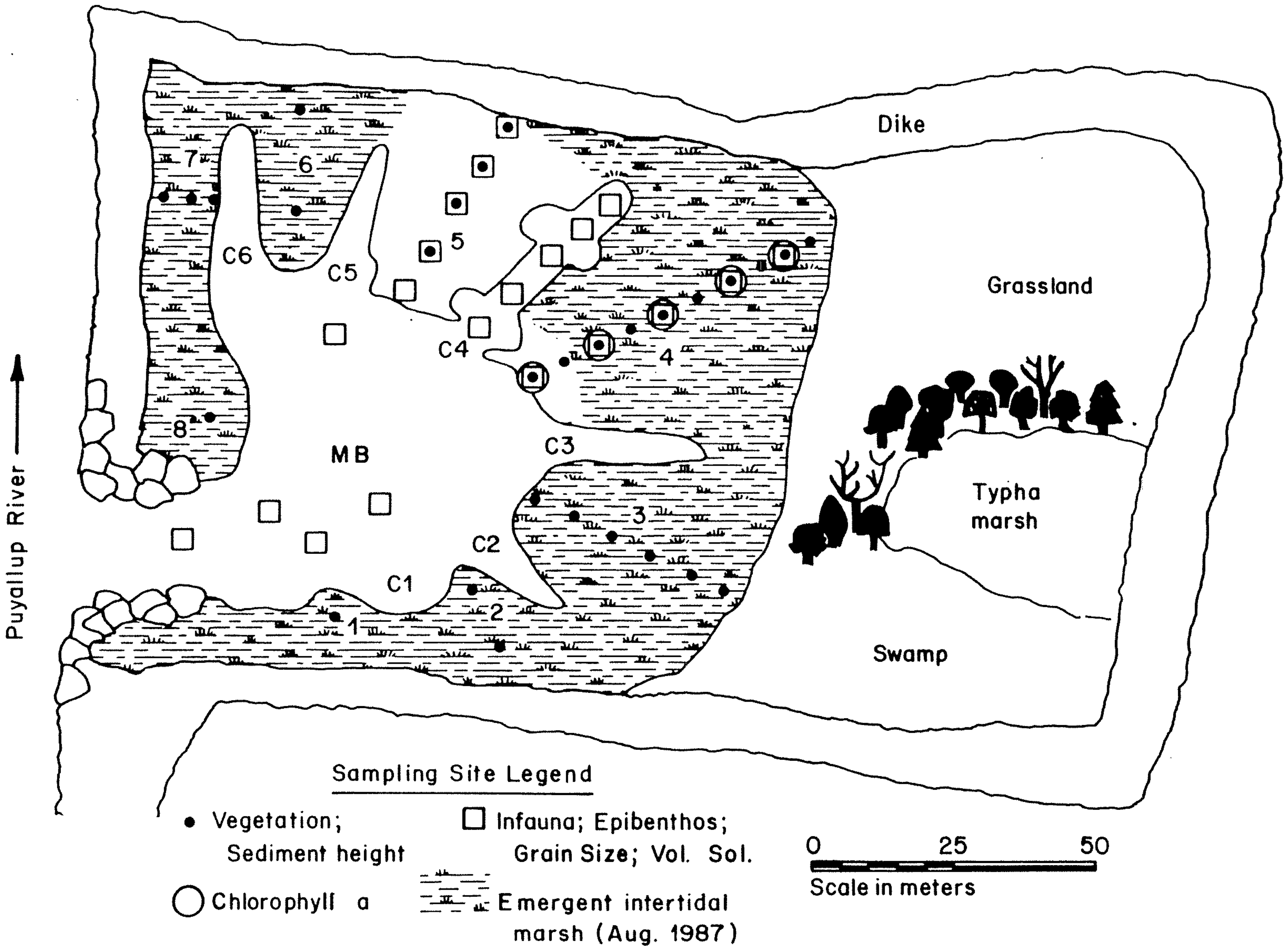


Figure 3. The wetland system showing sampling sites on intertidal flats numbered 1-8, channels numbered C1-C6, mid-bay (MB), and adjacent grassland, cattail marsh and swamp habitats.

Sedimentation on the flats was monitored using 29 permanent markers. The markers consisted of wooden stakes driven to a depth such that the top of the stake was 20 cm above the sediment surface. At monthly intervals, from February-November, the distance from the top of the stake to the ground surface was recorded.

Vegetation

Areas showing very low over-winter transplant survival were planted again in 1987. Individual shoots of *Carex* with attached roots and rhizomes were carefully collected by hand from the Big Beef Creek estuary on Hood Canal, and placed in groups of 50 in plastic bags for transporting to the Lincoln Avenue wetland system. Ten thousand shoots were collected on 27 April and were planted onto flats 6, 7 and 8 on the next day. On 11 May, an additional 1,650 shoots were collected and were planted the following day. Two to three shoots were planted by hand in holes spaced 0.5-0.75 m apart on the flats (Thom et al. 1987). These plantings covered areas (i.e., flats 6-8) that showed less than 10% over-winter survival of 1987 plantings. In total, 48,800 shoots were planted in the system during 1986 and 1987.

Chlorophyll *a* and phaeopigment concentrations were determined as a measure of important sediment-associated microalgal biomass from sediment cores (1-cm diameter x 1-cm deep) taken at five sites (12, 28, 44, 60, 76 m) along the flat 4 transect. Samples were collected in January and monthly from March-November. Sample processing followed the methodology of Thom et al. (1987).

Emergent macrophyte (i.e., rooted plants) percent cover, density and above ground biomass was sampled monthly from January-November at the 29 intertidal sites located on flats 1-8 (Fig. 3); the lowest site on flat 5 was not included. Macrophyte percent cover was estimated from photographs taken from directly above the center of each 1-m^2 area within a quadrat positioned at each site. The four corners of each 1-m^2 area were permanently marked with wooden stakes to facilitate repositioning of the quadrat during subsequent samplings. Percent cover of each macrophyte within the quadrat was estimated from the color slides using the point intercept method. The number of shoots of *Carex* and *Typha* occurring within each quadrat was counted in the field. Two shoots, cut at ground level, were taken immediately adjacent to each quadrat and were placed in a labelled plastic bag. The length of the longest leaf of each plant was measured, and the dry weight for each shoot was recorded. *Carex* biomass was estimated by multiplying the shoot density by mean shoot biomass for each sampling.

To document the distribution of plants, vertical color aerial photographs were taken from an airplane on 26 July 1987. The negatives were 9 x 9 in, and the scale for color prints made from the negatives was 1 in = 200 ft. The distribution of major plant assemblages and bottom types was traced from the photographs. These tracings were compared to identical photographs of the system taken on 31 March 1986. Both sets of photographs were taken near noon, when the predicted tide level was at or below MLLW.

Infauna

Infauna, as an indicator of biological assemblage development in the sediment, were sampled on 17 March and 26 August at the same 20 sites where grain size and volatile solids samples were collected (Fig. 3). The core sampler used for grain size collections was used for infauna sampling. The infauna cores were also 10-cm deep. The samples were placed in labelled plastic jars and preserved in 10% buffered formalin. Following preservation for at least 48 hours, the samples were gently washed on a 0.5-mm mesh sieve, and the animals and other material retained on the screen were stained with rose bengal and preserved in 70% alcohol. The animals retained on the screen were identified to major taxonomic levels (e.g., nematode, oligochaete, insect larva) and enumerated.

Epibenthos

Epibenthic animals, as a measure of biological assemblage development on the sediment surface and as an indicator of potential fish prey resources, were sampled using the epibenthic suction pump technique employed in the 1986 monitoring effort (Thom et al. 1987). The sampler collects animals from within a 0.016 m^2 area, and animals are collected on a 150 μ mesh screen. Epibenthos samples were collected at the 20 sites used for infauna sampling (see above). Epibenthic sampling was conducted on 17 March, 13 April, 19 May and 16 June. This time frame was the estimated period of peak juvenile salmonid outmigration. Samples were preserved in 10% buffered formalin. In the laboratory, the samples were placed in 50% alcohol, identified to species where possible, enumerated, and the wet weight recorded to the nearest 0.1 mg. All five samples from each area were processed except for the 19 May channel and mid-bay samples. Because of time constraints, only three randomly selected samples were processed from this latter collection.

Fish

Fish sampling was targeted at estuarine-dependent outmigrating juvenile chum salmon (*Oncorhynchus keta*) and chinook salmon (*O. tshawytscha*), but records were kept on all fish that were captured. Fish were collected on 12 occasions between 17 February and 16 June 1987. Collections were made using a 9.2-m floating net beach seine with a 6-mm mesh bag. Because of difficulties in pulling a seine over the flats during high tide, samples were collected at slack ebb tide when only the mid-bay and channels were submerged. The sampling effort varied on different dates depending upon the amount of time required to capture, sort and preserve each sample. Since sampling was restricted to ebb slack tide, the amount of time before the water level in the channels was too low for sampling limited the number of samples that could be taken. The seine was equipped with a solid core lead line that kept the net on the bottom while the float line kept the top of the net at the surface. Prior to sampling each channel, the surface water temperature, salinity, wind speed and direction, visibility, percent cloud cover, amount of precipitation, air temperature and time of day were recorded. At each channel, the seine was stretched across the width of the channel at the basin end, and then pulled up the the length of the channel to the upland end where the net was drawn completely out of the water. Mud clogging the bag of the seine was washed through the mesh with water before the sample was sorted. Captured fish were then placed in buckets of water, rinsed to remove most of the mud, and sorted to species. Differentiation between the various salmon species was made with the aid of several reference guides (McConnell and Snyder n.d., Trautman 1973, Phillips 1977). Subsamples of at least 10 individuals of each species were placed in labelled 1-qt glass jars and preserved in 70% isopropyl alcohol. Fish that were not part of the subsample were enumerated and released. Large fish which could not be easily preserved were identified in the field, the life history stage and length were noted, and then the fish were released.

In the laboratory, all preserved fish were identified, enumerated, measured (nearest 1-mm fork length or total length), weighed (damp weight to nearest 0.01 g) and checked for reproductive status. Species identifications followed Hart (1973) and Wydoski and Whitney (1979); they were verified using the University of Washington synoptic fish collection. Stomachs were removed from a subsample of 10 individuals of each salmon species. Gut contents were identified to the lowest possible taxon using a dissecting microscope.

Fish data were recorded on NODC format #100, type 3 (catch summary), type 4 (individual fish examination), and type 5 (stomach analysis) computer forms. These data were then stored on the University of Washington's Cyber mainframe computer and analyzed using the catch summary analysis program (CSRUN) and stomach analysis programs (PREYRUN, IRIRUN) adapted specifically for NODC coded fish data.

Birds

Bird counts followed the methodology employed previously (Thom et al. 1987). Nine visits were made to the wetland between 16 February and 4 August. During each visit, the numbers of each species of bird were recorded along with their location. The locations used were (1) the dike surrounding the wetland, (2) the intertidal zone (i.e., in the planted marsh or on the mudflats), (3) water, (4) the upland cattail marsh, or (5) in the air above the wetland. On each visit, observations were made twice during high tide and twice during low tide. All observations were made during daylight hours. In addition, 53 visits were made between 1 January and 27 September by Jon R. Jensen of the Tahoma Audubon Society. The data sheets, kindly supplied by Thais Bock of the Tahoma Audubon Society, included records of species observed in the wetland during each visit.

Water Chemistry

To locate the salt wedge in the estuary and begin to develop and understanding of the effects of the wetland system on water properties, a limited suite of water samples were collected at seven sites in the Puyallup River estuary on 18 June 1987. The sites were located between the Interstate Highway bridge (I-5) upstream of the wetland to the buoy anchored approximately 400 m seaward off the mouth of the river. Two sites were located in the wetland; one immediately inside the mouth and the other at the upland end of channel 4. Sites in the river were located at the I-5 bridge, the railroad bridge, and at the 11th Street bridge. These sites spanned the estuarine portion of the Puyallup River channel.

The water properties sampled were: water clarity, dissolved oxygen, temperature, salinity, and inorganic nutrients. Samples were collected between 09:53 and 11:50 hours, which covered the high tide period (max. +8.1 ft MLLW at 11:12 hours). A surface sample and a near-bottom water sample were collected at the five river sites from a boat using a Van Dorn water sampler. Only mid-depth samples were collected at the two wetland sites. The dissolved oxygen concentration in each sample was determined immediately upon collection using a polarographic oxygen probe (YSI mod. 58, corrected for salinity based on readings using a refractometer). Water temperature was recorded using the temperature probe affixed to the dissolved oxygen probe. Samples for nutrient analysis was placed in plastic bottles and frozen. These samples were analyzed for nitrate, nitrite, ammonium, orthophosphate and silicate at the School of Oceanography routine water chemistry laboratory. Salinity samples were placed in citrate bottles and were analyzed using a conductance salinometer. Water clarity was recorded using a Secchi disk, and depth was measured using a weight and marked line. A series of water samples were taken during low tide also. The low flow, low tide conditions prevented use of a boat. Therefore, samples were collected by wading from the north bank of the River. Samples were collected between 14:12 and 16:32 hours (min. tide level +2.2 ft MLLW at 17:05 hours). Secchi depth readings were not taken during the low tide series.

RESULTS AND DISCUSSION

Sediment Characteristics

Since construction in 1985, sediments from the Puyallup River have been deposited in the wetland, which has resulted in changes in sediment grain size and bottom contours. Figure 4 illustrates that the primary location for sediment build-up was in the mid-bay and channels. The net result has been to decrease the depth of these areas and reduce the area that contains water during all stages of the tide. Although surveys have not been conducted since dike breaching, we estimate that, on average, 1-3 ft of sediment has deposited in the channels and mid-bay. This deposition has occurred largely along the edges of the channels and immediately inside the mouth of the system (Fig. 4). It must be noted, however, that the illustration of 1987 conditions is based on aerial photographs taken in August—a period of extreme low river flow. In comparison, the March 1986 conditions reflect a period of relatively high river flow. Our observations in spring (April) of 1988 showed that during high river flows, the water depth in channel 4 and mid-bay averaged approximately 2-3 ft at a predicted tide level of -0.6 ft MLLW. These observations, along with recent collections (1988) of fish, indicate that adequate water remains in the system during the period of salmonid outmigration.

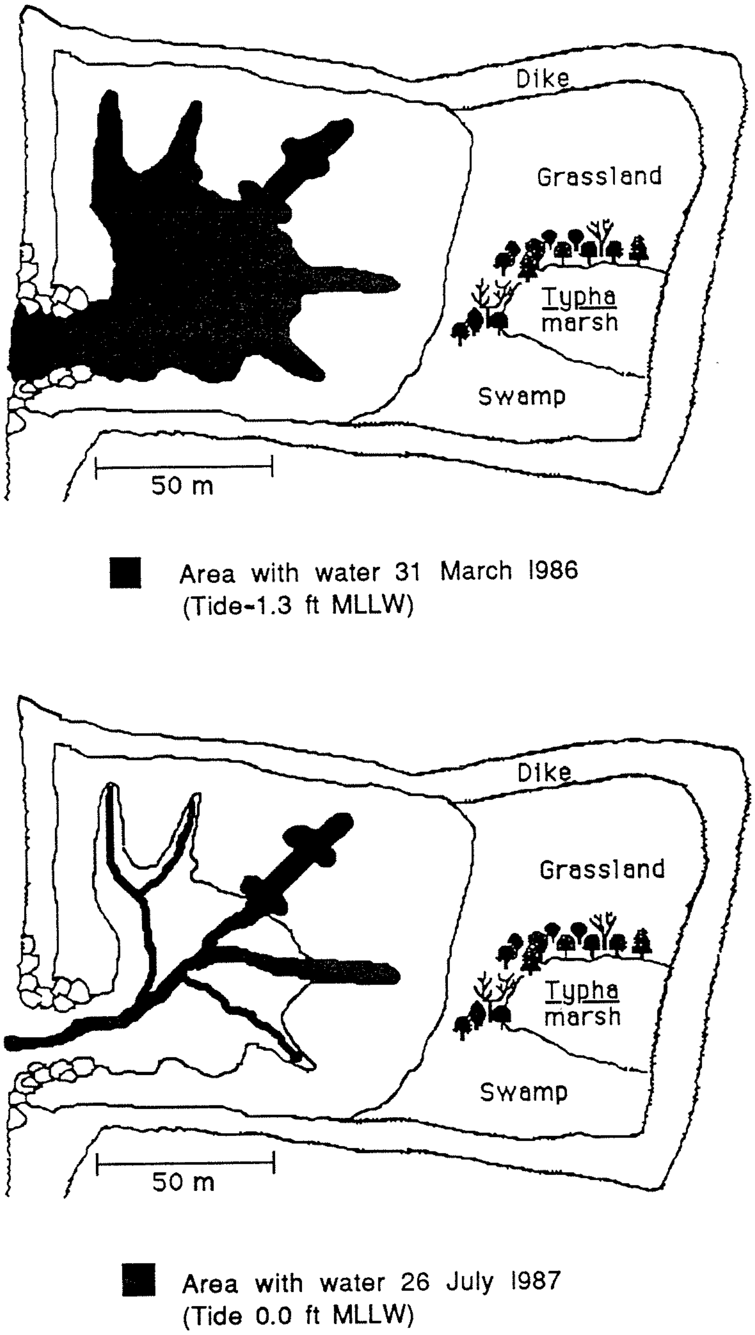


Figure 4. Areas of sediment accretion in mid-bay and channels in March 1986 and July 1987. Note that March 1986 conditions were during extreme high river flows and August 1987 conditions were during an extreme drought. The areas of the mid-bay where accretion has been most pronounced are accurately represented.

Grain size of surface sediments shows a shift from pre-breach conditions. On flat 4, sediments have changed from a very fine sand to a silt-clay mixture (Fig. 5). Sediments in the middle of channel 4 have become coarser (Fig. 6), and have changed from silt to medium-fine sand. The sediments in the mid-bay (Fig. 7) and near the mouth (Fig. 8) have changed from medium to fine sand, with some finer material, to a complete dominance by fine sand. With the exception of the flats, the data suggest that the sediments have become coarser following dike breaching. The material present in the system prior to dike breaching was exposed through excavation and was the result of historical processes. Not knowing the composition of sediments transported by the river and potentially deposited in the wetland allowed no *a priori* predictions of changes in sediment grain size. We would have expected that the sediments would have become finer over time. However, the data simply show that the system is trapping sediments that are generally coarser than the historical sediments in the region. The data from 1988 and subsequent years will allow predictions regarding the dynamics of change due to physical processes of the river.

In general, median phi size decreased along a depth gradient toward the mouth of the wetland (Fig. 9). Flat 4 (site serial nos. 1-5) had the finest sediments, followed by flat 5 (site serial nos. 6-10), channel 4 (site serial nos. 11-15) and the mid-bay (site serial nos. 16-20). The deposition of fine sediments on the flats was spatially variable (Fig. 10). Eighty-three percent of the samples of sediment height (i.e., the total number of observations made in the combined samplings conducted in March and August) showed sedimentation had occurred. Most sedimentation had occurred on flat 4 (site serial nos. 10-19). In contrast, sediment scouring was evidenced on flat 3 (site serial nos. 4-9) (Fig. 10). Frequency histograms of sediment height indicate that sedimentation had occurred between March and August (Fig. 11), with the number of sites showing at least 2 cm of deposition increasing from 3 to 11 cm between the two samplings.

Volatile solids, indicating the organic content of sediments, were greatest in the *Typha* and *Carex* marsh at the upper edge of flat 4 (site serial nos. 1-2) and at the three sites in the middle of

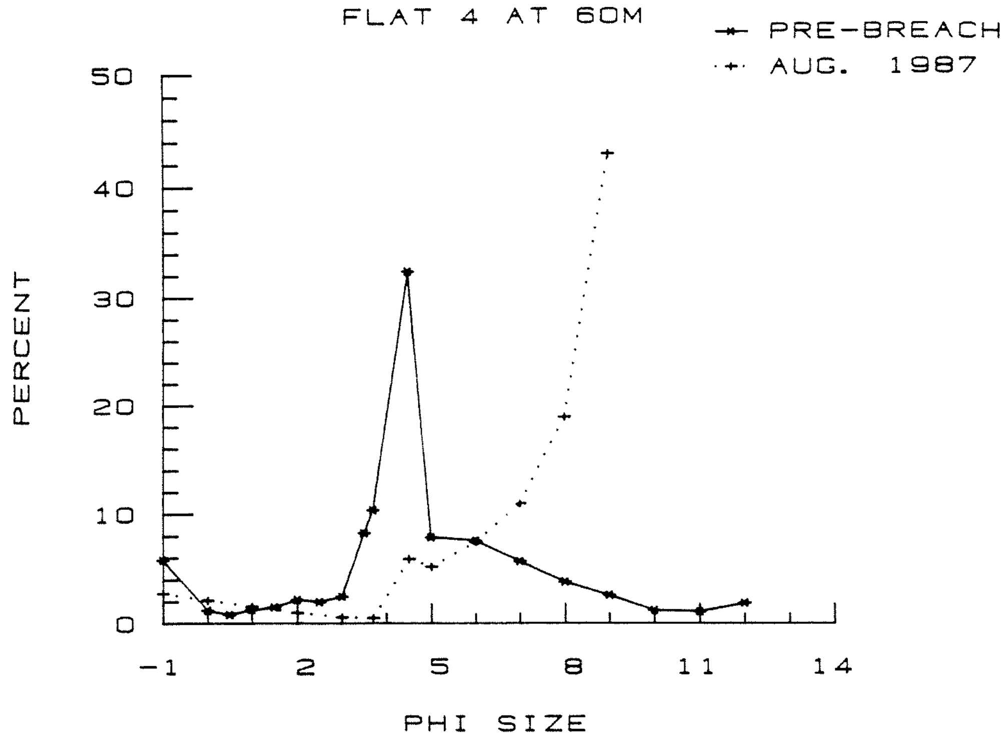


Figure 5. Sediment phi size on flat 4 in 1985 and 1987.

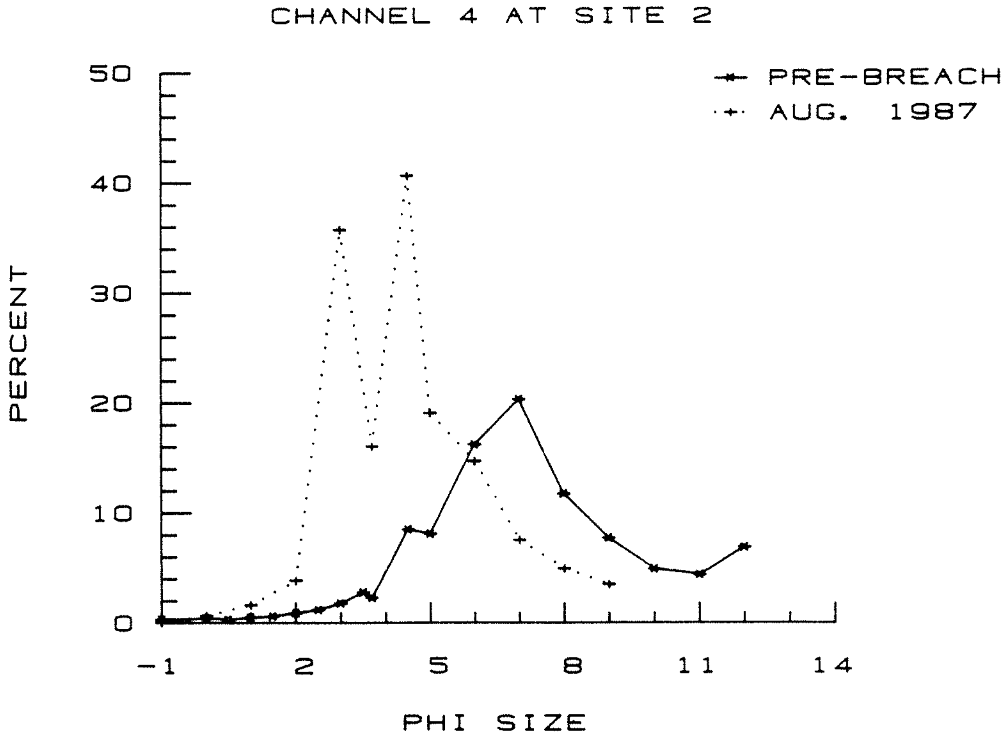


Figure 6. Sediment phi size in channel 4 in 1985 and 1987.

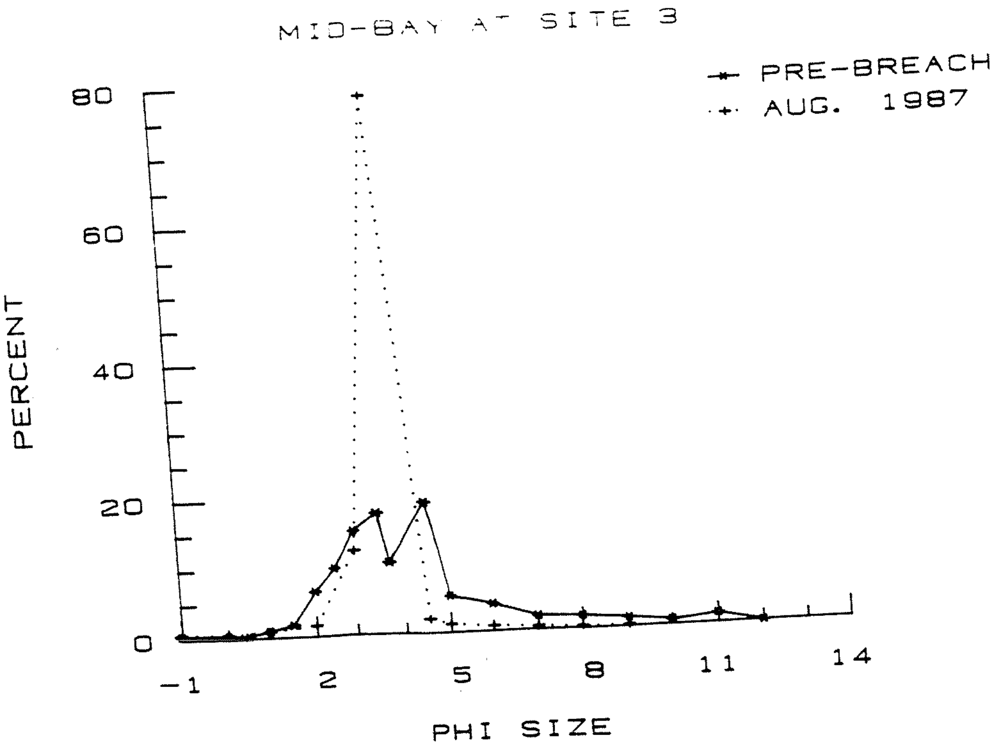


Figure 7. Sediment phi size in mid-bay in 1985 and 1987.

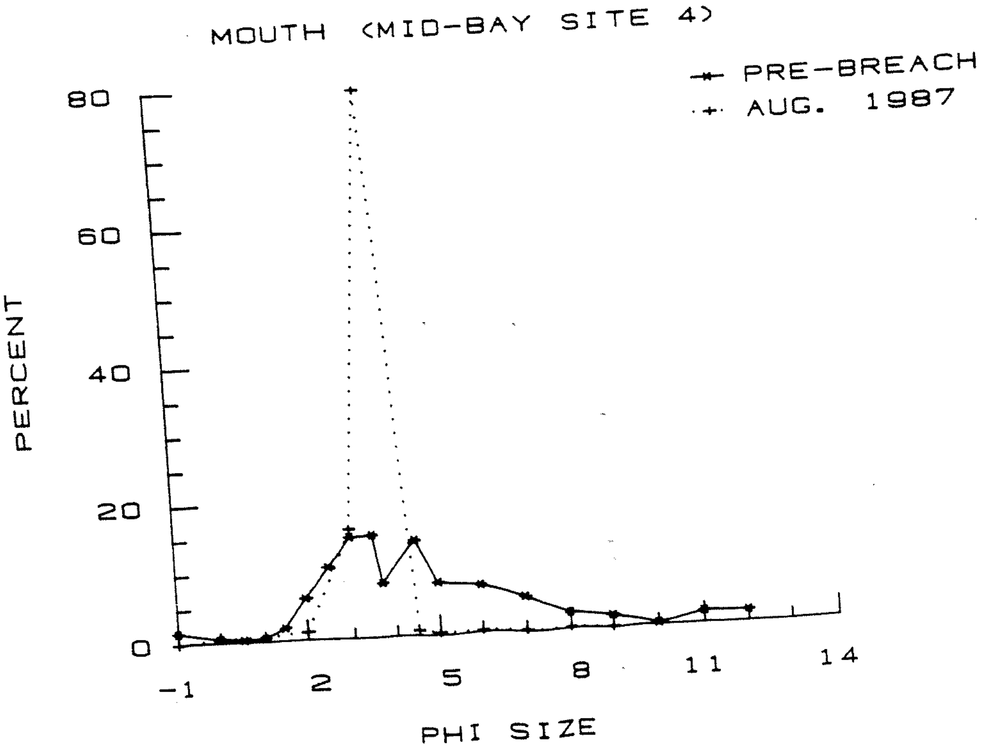


Figure 8. Sediment phi size at the mouth of the wetland in 1985 and 1987.

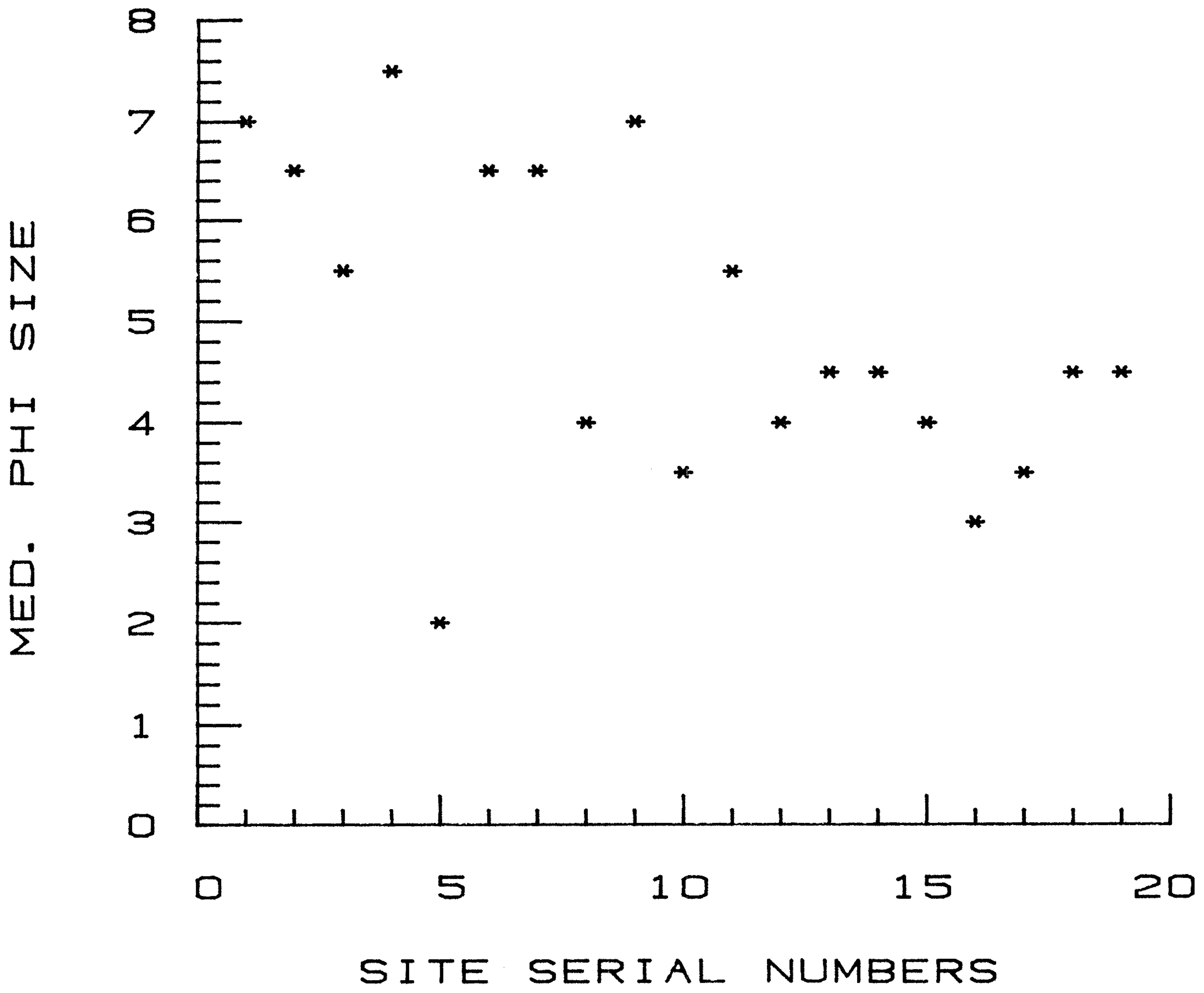


Figure 9. Median sediment phi size at the 20 sediment sampling sites in August 1987. Site locations: 1-5 on flat 4; 6-10 on flat 5; 11-15 in channel 4; 16-20 in mid-bay. Serial numbers within each area progress from landward (lowest serial number) to wetland mouth (highest number).

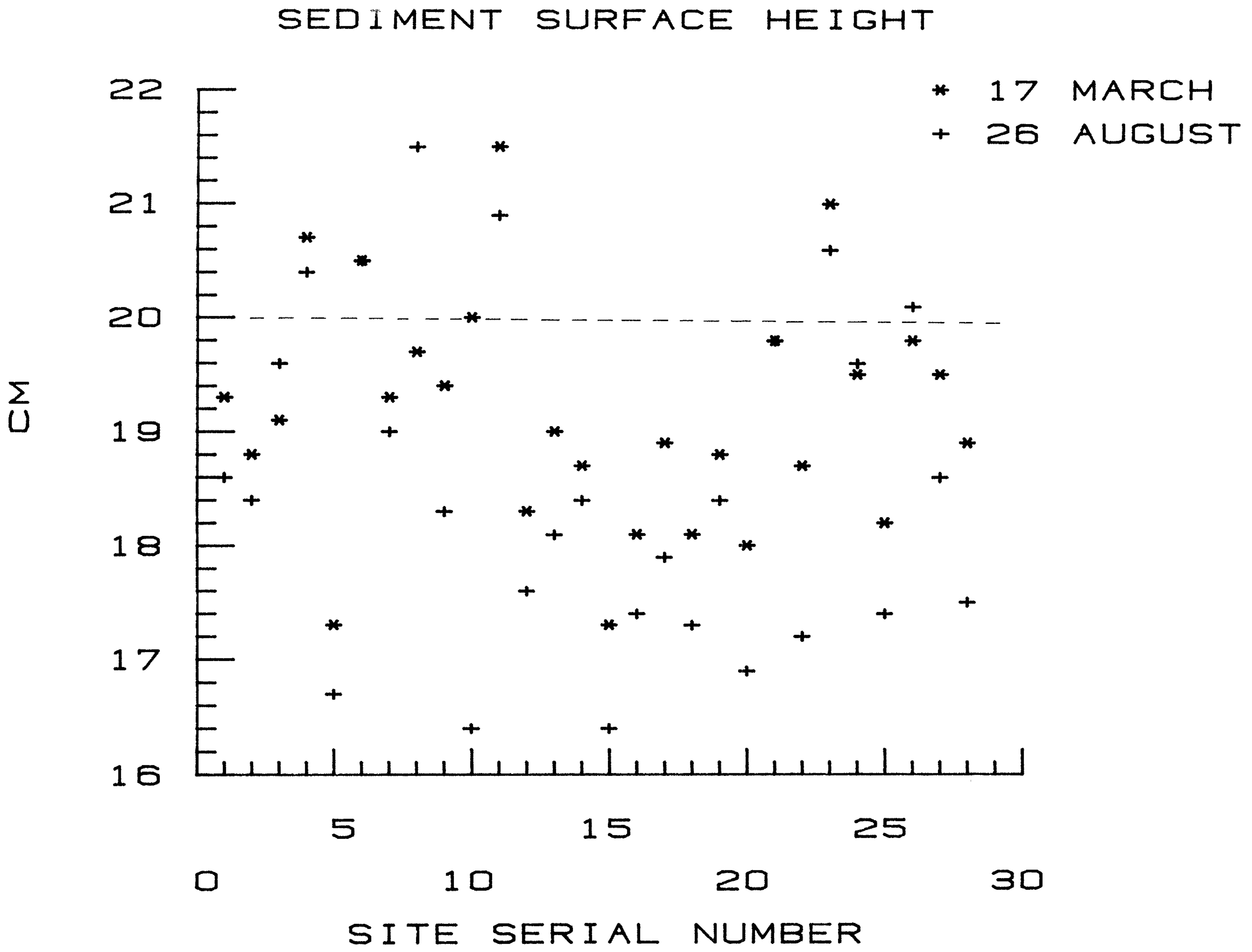


Figure 10. Sediment surface height in March and August 1987 relative to the tops of permanent stakes at 28 sites on flats 1-7. Tops of stakes were set at 20 cm (indicated by dashed line) above the sediment surface on 17 February 1987. Site locations: 1 on flat 1; 2-3 on flat 2; 4-9 on flat 3; 10-19 on flat 4; 20-23 on flat 5- 24-25 on flat 6; 26-28 on flat 7.

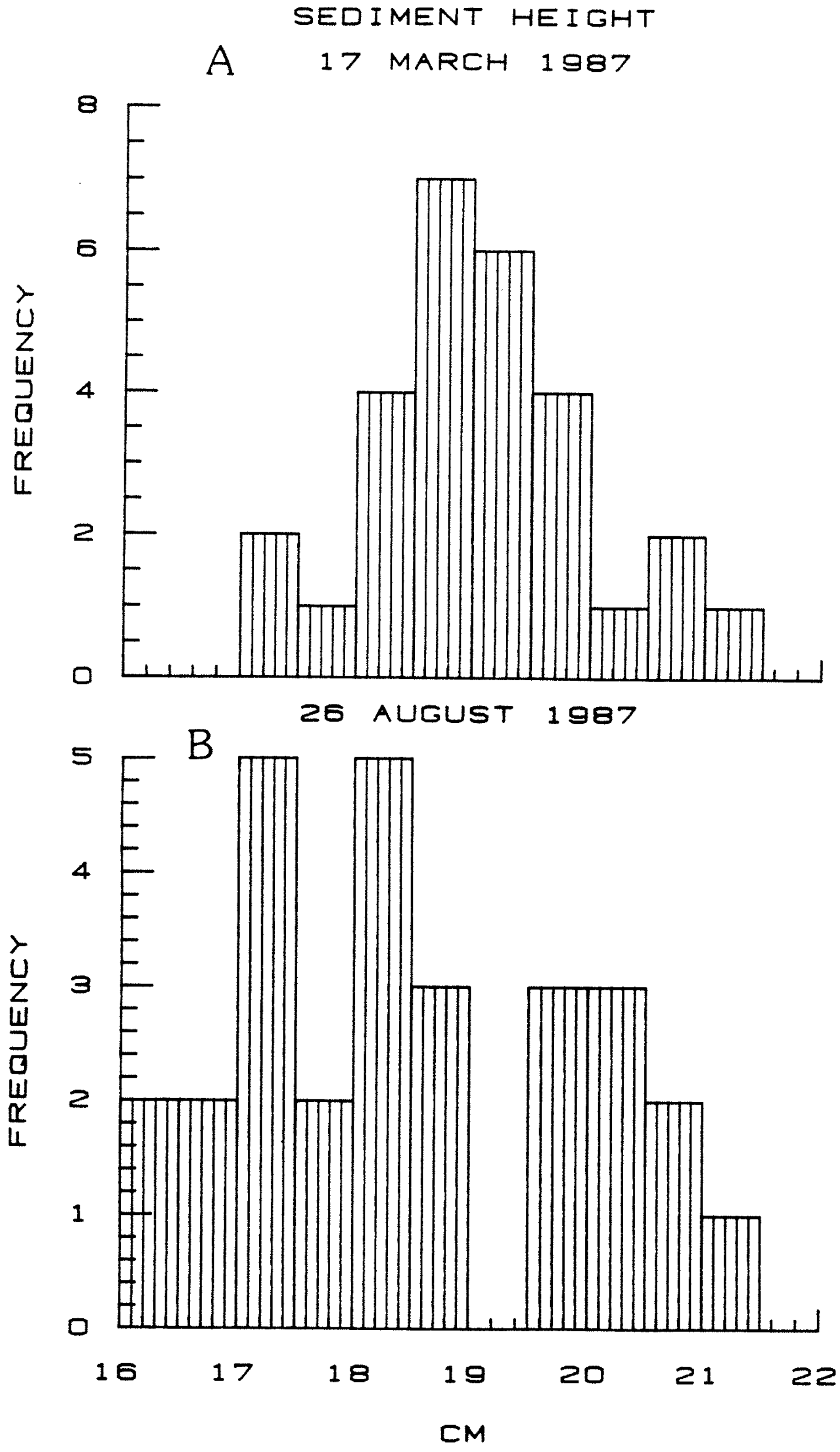


Figure 11. Histogram of sediment heights relative to stakes in March (A) and August (B) 1987.

channel 4 (site serial nos. 12-14; Fig. 12). While volatile solids tended to increase with increasing phi size (i.e., decreasing sediment grain size; Fig. 13), there was considerable variability in this relationship. The ratio of volatile solids to median phi size at the 20 sites indicates that sites at the outer end of the transect on flat 4 (site 5) and the three mid-channel 4 sites (12-14) were relatively enriched in organic content (Fig. 14). In addition, we encountered plant debris in the bottom of channel 4 during our sampling, which would explain the higher values there. However, a high relative volatile solid value for site 5, in an area with no macroscopic vegetation is difficult to explain. The data may indicate that the leading edge of the flat receives deposits of finer-grained organic debris. In general, sediments in a wetland system are enriched in organic content.

Vegetation

Benthic algae were present and at times abundant in the system. Sediment-associated algal assemblages were present on flat 4 as indicated by sediment chlorophyll samples (Fig. 15). However, spatial variation in the values was high (mean CV = 112%) during all months. The highest average concentrations occurred in January (462 mg chl *a*/m^2), April (618 mg chl *a*/m^2) and October (516 mg chl *a*/m^2). Lowest concentrations were detected in May (40 mg chl *a*/m^2), June (59 mg chl *a*/m^2) and August (91 mg chl *a*/m^2). The May (2312 mg/m^2) and June (3715 mg/m^2) samplings also had the highest average phaeopigment concentrations, indicating that breakdown of chlorophyll was taking place relatively rapidly during these times. The breakdown may be due to natural degradation of chlorophyll in the gut of small animals (e.g., copepods) that normally feed on microflora. Phaeopigment concentration was generally less than 1 mg/l in all other samplings (Fig. 16). Heavy mats of the filamentous green alga *Spirogyra* sp. developed primarily on flats 5, 6 and 7 in May and June. The mats were so thick at some sites that they clogged both the epibenthos pump during collections of samples and the bag of the beach seine during fish collections. Bubbles of what was presumably oxygen generated from photosynthesis were trapped below the thick mat. In addition, thick clumps of the alga were floating free in the

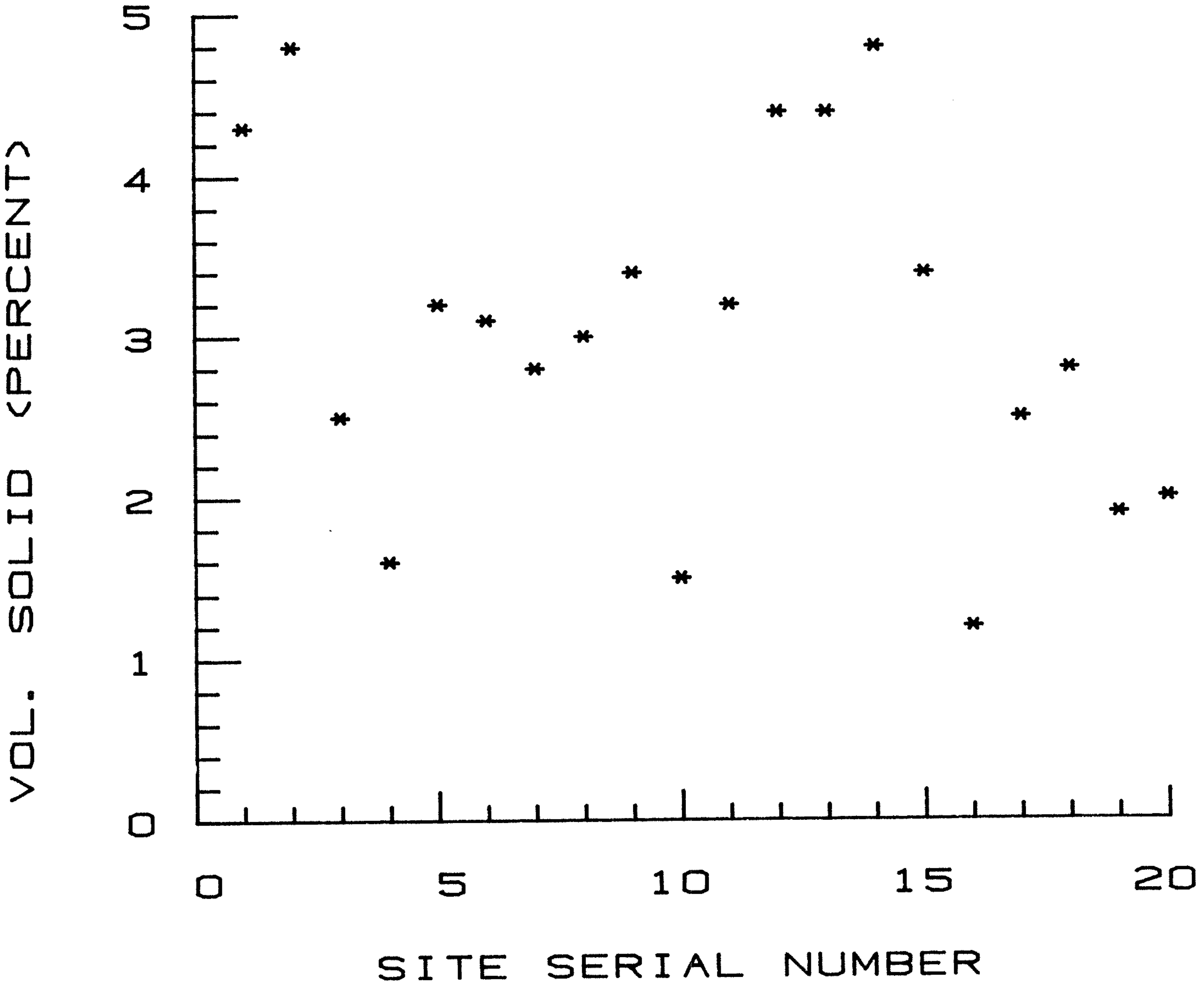


Figure 12. Volatile solids in sediments at the 20 sediment sampling sites. See Figure 26 for site locations.

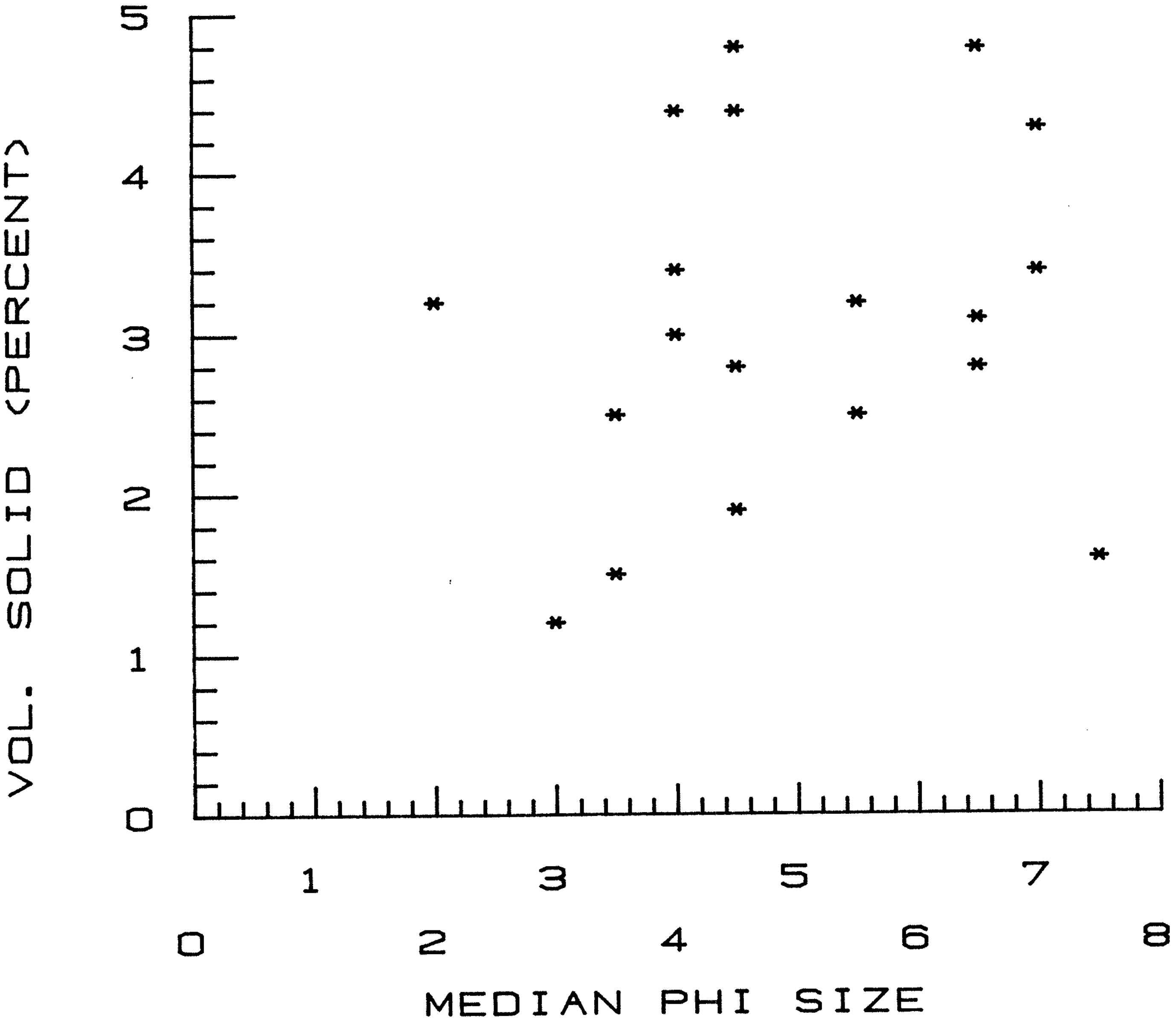


Figure 13. Volatile solids versus median phi size in August 1987 at the 20 sediment sampling sites.

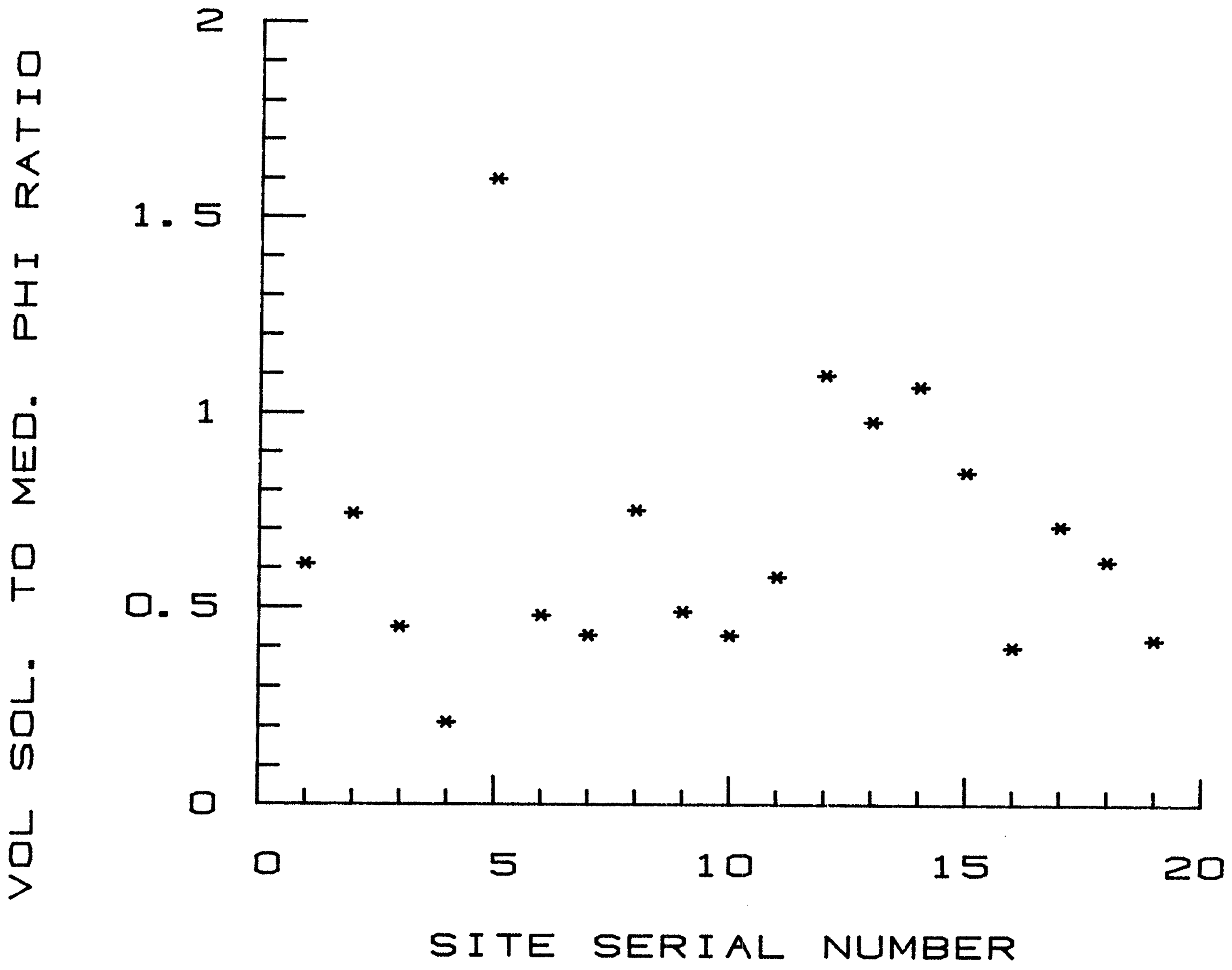


Figure 14. Volatile solids to median phi size ratio at the 20 sediment sampling sites in August 1987.

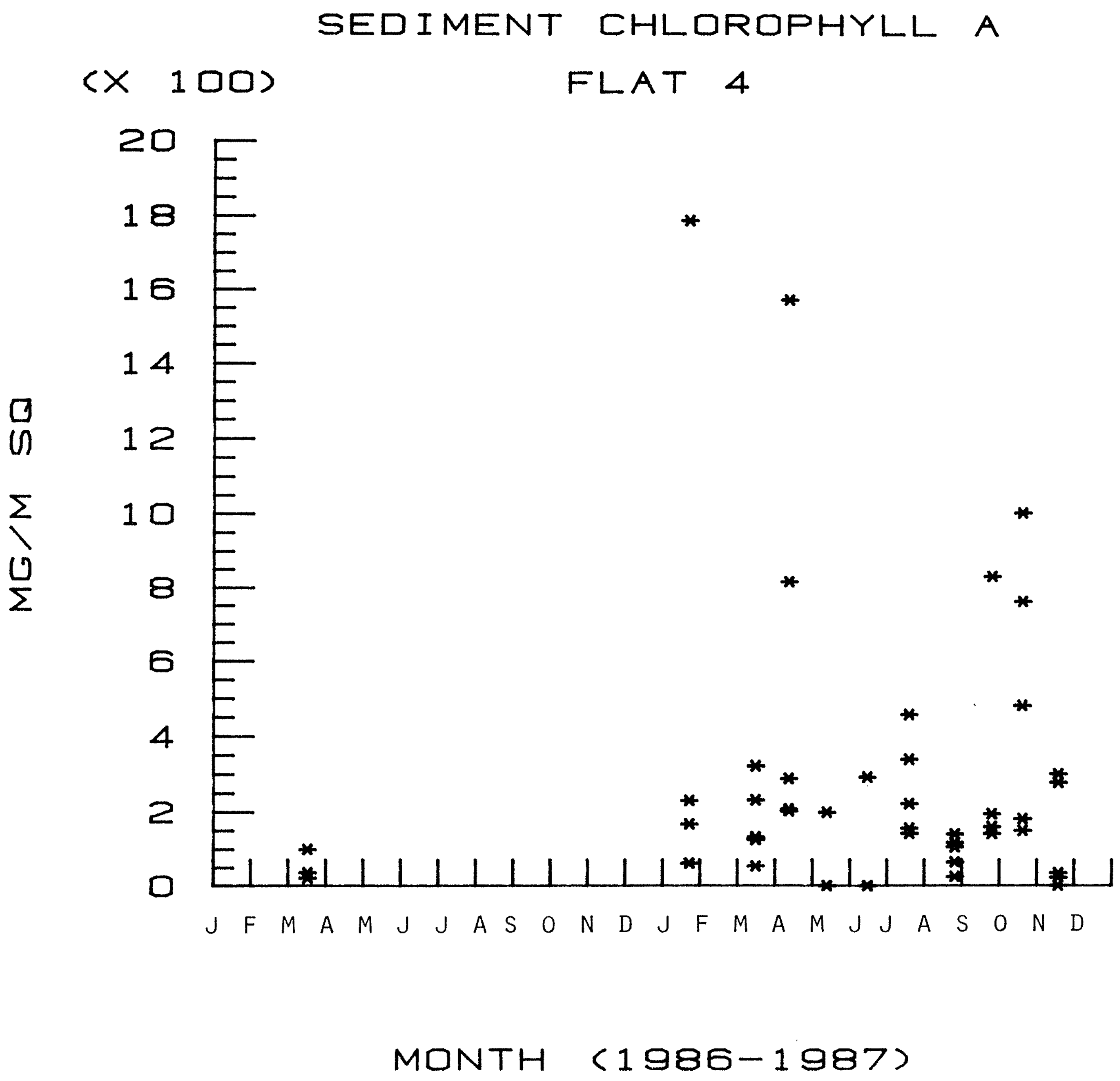


Figure 15. Sediment chlorophyll a concentration on flat 4 over time.

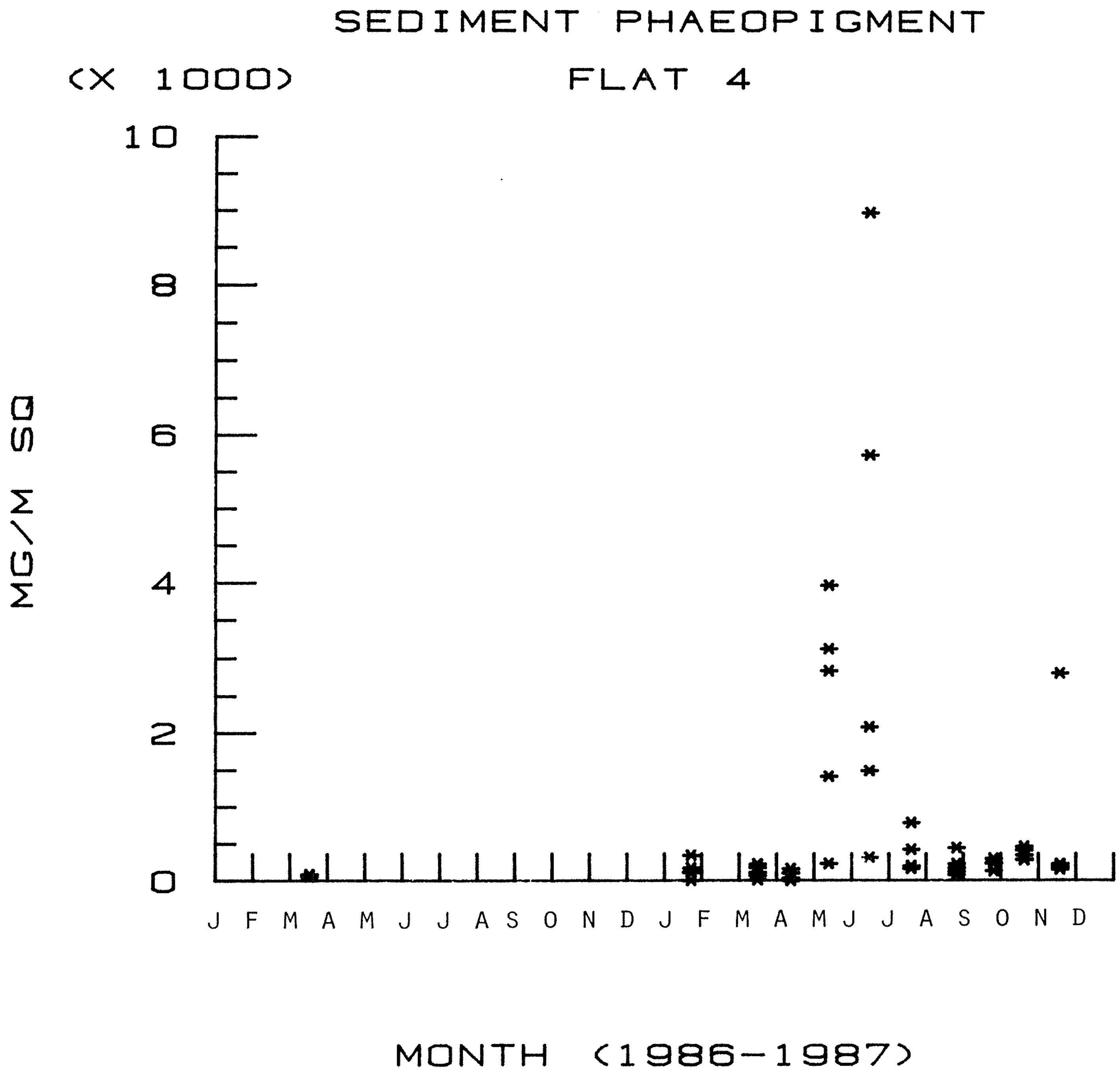


Figure 16. Sediment phaeopigment concentration on flat 4 over time.

system and were being exported to the river. The yellow-green alga *Vaucheria* occurred in patches on the upper portion of flat 5 and in smaller isolated areas on the upper ends of most other flats. *Vaucheria* is common in tidally influenced estuarine systems in the northwest.

The planting effort in terms of numbers of *Carex* shoots planted each day in 1986 and 1987 is shown in Fig. 17. The total number of shoots planted in the wetland was 48,800. Total shoot abundance in the system showed a seasonal pattern, with peak abundance of ca. 271,810 shoots in August 1987 (Fig. 18). In comparison, the shoot abundance in the system at the end of the 1986 growing season (i.e., August) was 151,182. Therefore, shoot abundance increased in the system by a factor of 1.8 between the two years. Total *Carex* standing crop also showed a dynamic seasonal pattern with a low point of 6.5 kg dry wt. in April and a peak in July of 548.4 kg dry wt. (Fig. 19). The July 1987 standing crop exceeded the August 1986 standing crop (271.8 kg dry wt.) by a factor of 2.02.

The total area of the flats with rooted macrophyte vegetation decreased by about 30% between August 1986 (6730 m^2) and July 1987 (4736 m^2) (Fig. 20). Peak *Carex* cover declined from 3736 m^2 to 3472 m^2 (-7%). *Typha* and *Eleocharis* actually occupied more area than *Carex* during August-November 1987. In August 1987, the peak area covered by *Typha* was 2568 m^2 compared to 2994 m^2 in August 1986. Therefore, although the total area covered by *Carex* decreased between 1986 and 1987, the standing crop and abundance increased by approximately twofold. The increases are due to increases in shoot density caused primarily by shoot production from below ground root systems. Where *Carex* appeared to be doing well, new shoots were dense between the original planting clumps. In some areas it was difficult to delineate the original planting clumps from new shoot production.

The decline in marsh area resulted in an increase in mudflat area. On the basis of chlorophyll *a* measurements, and infauna and epibenthos data (see below), it appears that the mudflats (and channels) are at least as important as the marsh in terms of benthic community development.

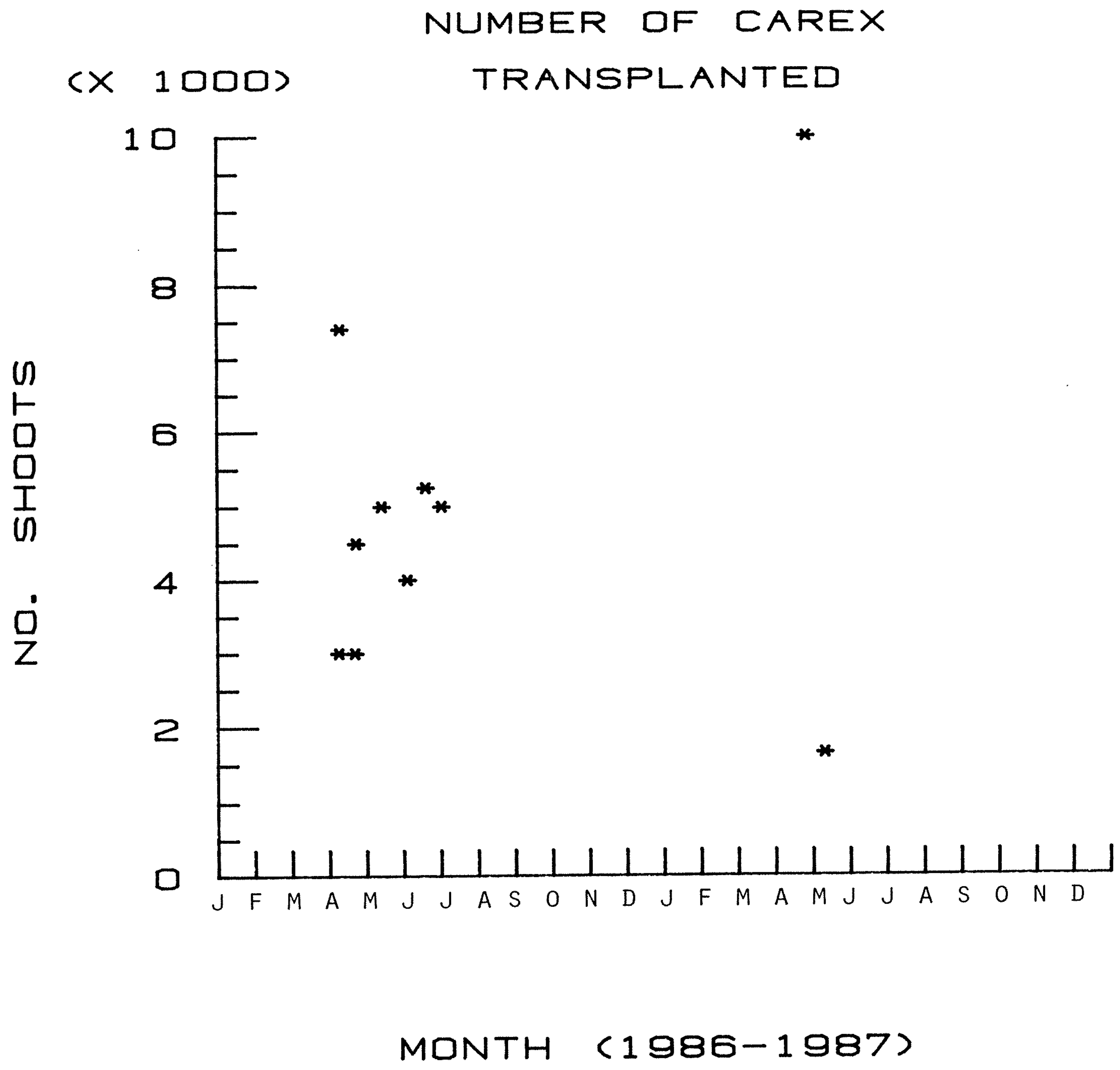


Figure 17. Number of shoots of *Carex lyngbyei* planted versus time.

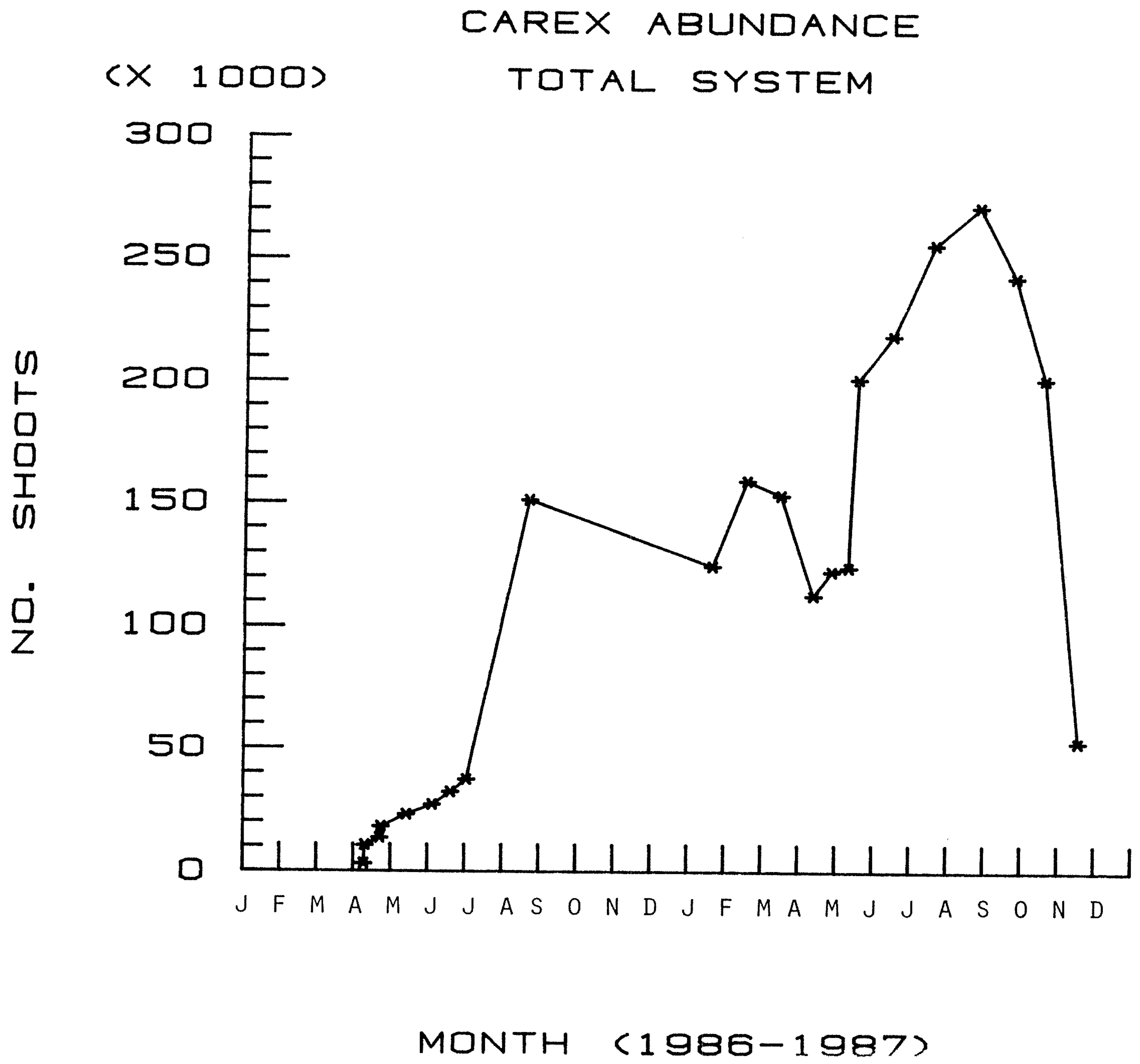


Figure 18. Total *Carex* shoot abundance in the system versus time.

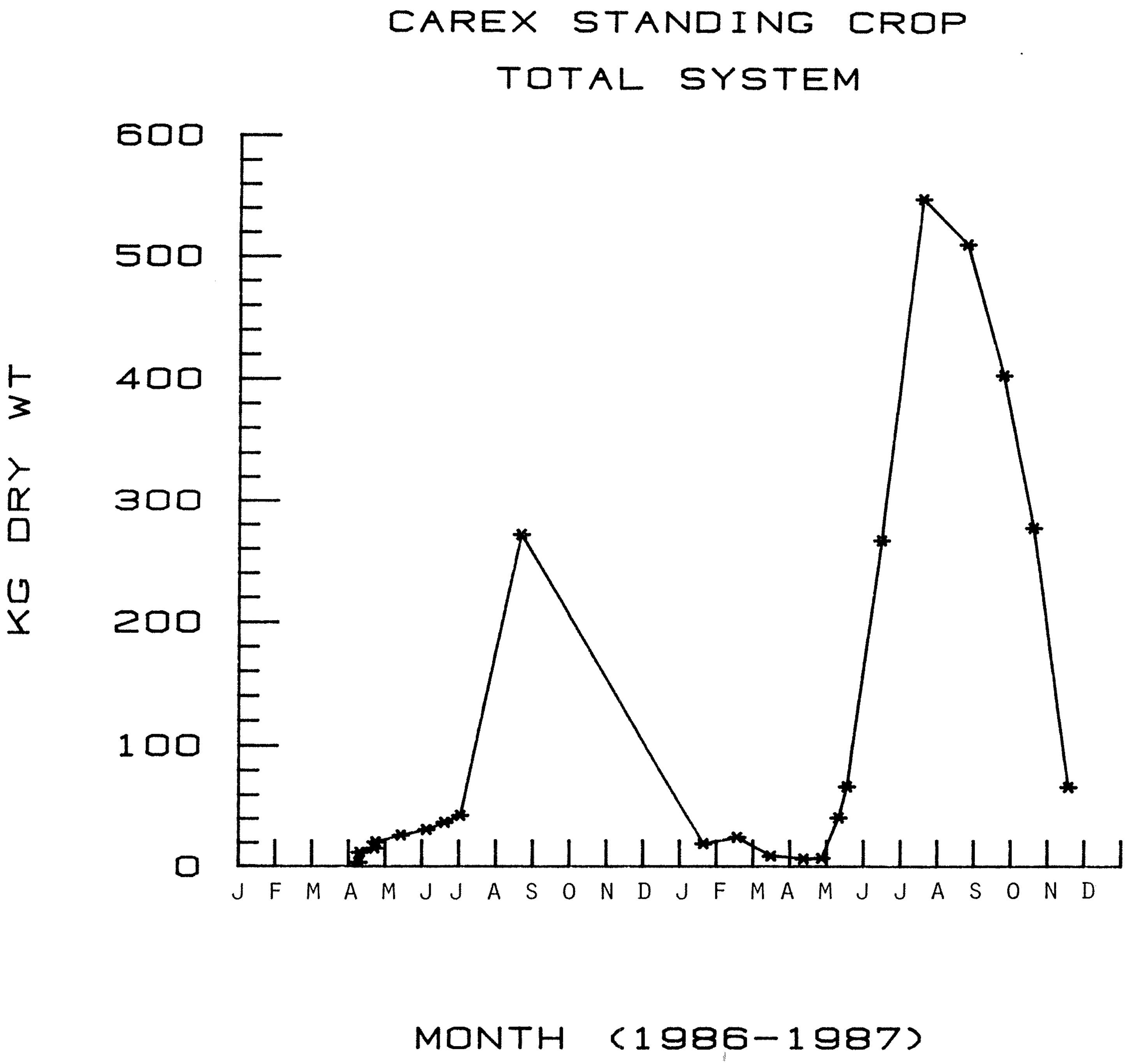


Figure 19. Total *Carex* standing crop in the system versus time.

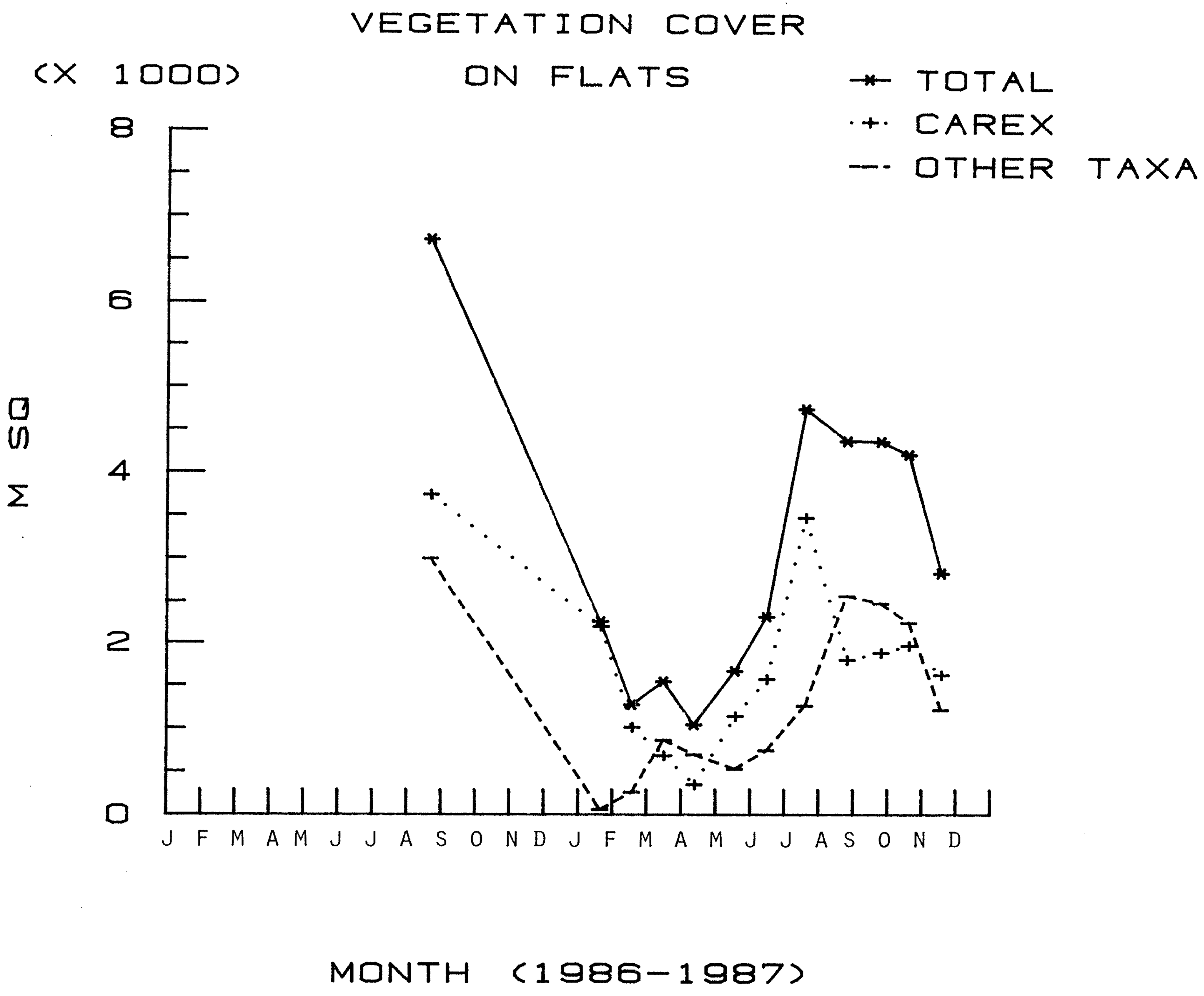


Figure 20. Total vegetation cover on the flats versus time.

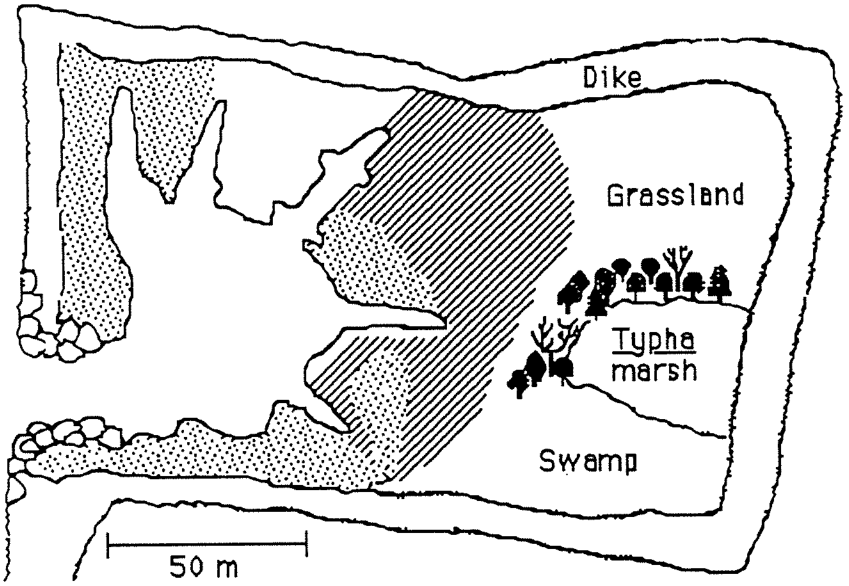
Hence, loss of marsh habitat area does not necessarily reflect a decline in the ability of the system to support target resources. Furthermore, plant density and standing stock increased since 1986, which suggests that the marsh that remains is becoming increasingly better established.

Plant density plotted on tracings of the aerial photographs illustrates the spatial changes in vegetation distribution (Fig. 21). In general, the upper portions of the flats have the greatest shoot densities. Between 1986 and 1987, plant density increased in these areas. Plantings directly onto flats 6-8 accounted for the increased densities there. Physical, biological and chemical factors continue to actively determine the distribution of plants in the system. For example, we noted evidence of physical scouring around the base of clumps of plants and grazing by waterfowl on the erect shoots. In addition, sediment characteristics are undergoing rapid changes. All of these factors may be influencing the survival of marsh plants.

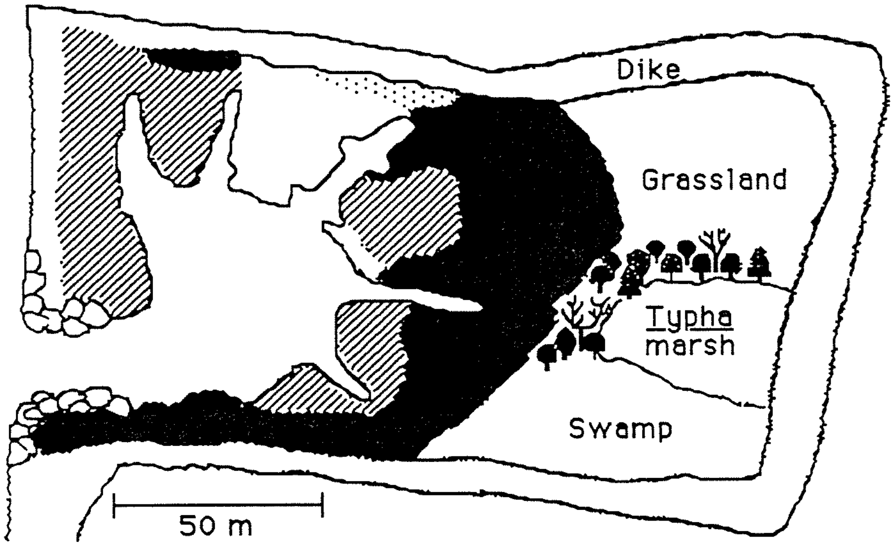
The upland habitats, which include the grassland, cattail marsh and swampy area, showed very little change in the aerial photographs or from observations made on the ground. Bird data (see below) in particular show that the marsh continues to function as an important bird habitat. Incidental samples of water in the marsh had very high densities of insect larvae and other invertebrates, which indicated a thriving system. Water was present in the marsh throughout the year.

Infauna

Total infauna abundance increased on the order of 2.7 times between March 1986 and March 1987 (Table 1). The largest proportional increase occurred on the flats (7.0 x), followed by the mid-bay (4.2 x) and the channels (1.8 x). Total abundance increased between spring and late summer samplings in 1987, primarily due to a substantial (6.3 x) increase in abundance on the flats. The infaunal abundances in the channels and mid-bay decreased between these two samplings. The relative abundance of taxa groups also changed substantially between spring samplings in 1986 and 1987 (Table 2). This change was primarily due to a shift in dominance of the system by insects in 1986 to oligochaetes in 1987. The wetland was very new in March 1986,



Vegetation Cover 22 August 1986



Vegetation Cover 26 July 1987

☐ < 4 shoots/ sq. m
▒ 4-15 shoots/ sq. m
▨ 15-50 shoots/ sq. m
■ > 50 shoots/ sq. m

Figure 21. Comparison of vegetation distribution and cover in 1986 and 1987.

Table 1. Total system abundance and density (no./m^2) of infauna in the wetland system . Areas of habitats used for calculations were: flats = 11,974 m^2; channels = 6,091 m^2; mid-bay - 3,717 m^2 (Thom et al. 1987).

Habitat	March 1986		March 1987		August 1987	
	Total	No./m^2	Total	No./m^2	Total	No./m^2
Flats	9.4 x 10^6	785	65.9 x 10^6	5,504	416.1 x 10^6	34,667
Channels	103.7 x 10^6	17,025	232.5 x 10^6	38,171	165.5 x 10^6	27,171
Mid-bay	57.8 x 10^6	15,550	242.8 x 10^6	65,321	107.5 x 10^6	28,921
Total	197.9 x 10^6	9,085	541.2 x 10^6	24,846	688.1 x 10^6	31,590

Table 2. Relative abundance of taxa collected in infauna samples. Values are the percentage of total number of individuals collected each date.

Taxon	March 1986	March 1987	August 1987
Insect	78%	1%	<1%
Harpacticoid	9	3	0
Oligochaete	8	89	99
Nematode	4	6	6
Ostracod	1	0	0
Corophium	0	2	0
Gammarid	0	<1	<1
Polychaete (neried)	0	0	<1
Mysid	0	0	<1
Gastropod (juv.)	0	0	<1

and the shift may reflect the development of estuarine infauna during the first 13 months as compared to the terrestrial insect fauna, which initially colonized the system. Physical factors, including sediment grain size changes, bottom depth changes and changes in organic matter, are probably interacting in structuring the infaunal assemblage. The fact that the total infauna abundance is increasing suggests that food resources (i.e., detritus in the sediment) are probably increasing over time. A plot of the August 1987 data indicates that the greatest densities occurred at sites with coarse sand and silt and volatile solid concentrations between ca. 1.5-4.0% (Fig. 22).

The samples from the flats (sites 1-10) contained far fewer infauna as compared to the channels (sites 11-15) and mid-bay (sites 16-20) in March 1986 (Fig. 23) and March 1987 (Fig. 24). The August sampling in 1987 showed that abundances increased substantially on the flats and decreased slightly in the deeper habitats (Fig. 25); this may be due to changes in several factors, including food availability, predation pressure or reproductive behavior. The data do prove that major seasonal shifts are occurring in the benthos, and that these shifts must be considered in interpreting the long-term changes in the system.

Epibenthos

Significant changes occurred in the epifaunal assemblage since the March 1986 post-breach sampling. Faunal composition shifted toward a dominance by estuarine taxa and standing stock increased significantly. In addition, the prey of juvenile salmonids were more common, although they still were not a prominent component of the epibenthos.

During the immediate post-breach collections in 1986, the epibenthos standing stock was dominated by nauplii and copepodids of cyclopoid and other pelagic copepods, and adults of the cyclopoids *Cyclops vicinus* and *Eucyclops speratus*; only two epibenthic harpacticoid copepods were identified (*Bryocamptus* sp., *Maraenobiotus* sp.), and no amphipods nor mysids were evident (see Table 10 in Thom et al. 1987). One year later, in comparison, nematodes and oligochaetes tended to dominate the epibenthos, eight harpacticoid copepod taxa were present, most of

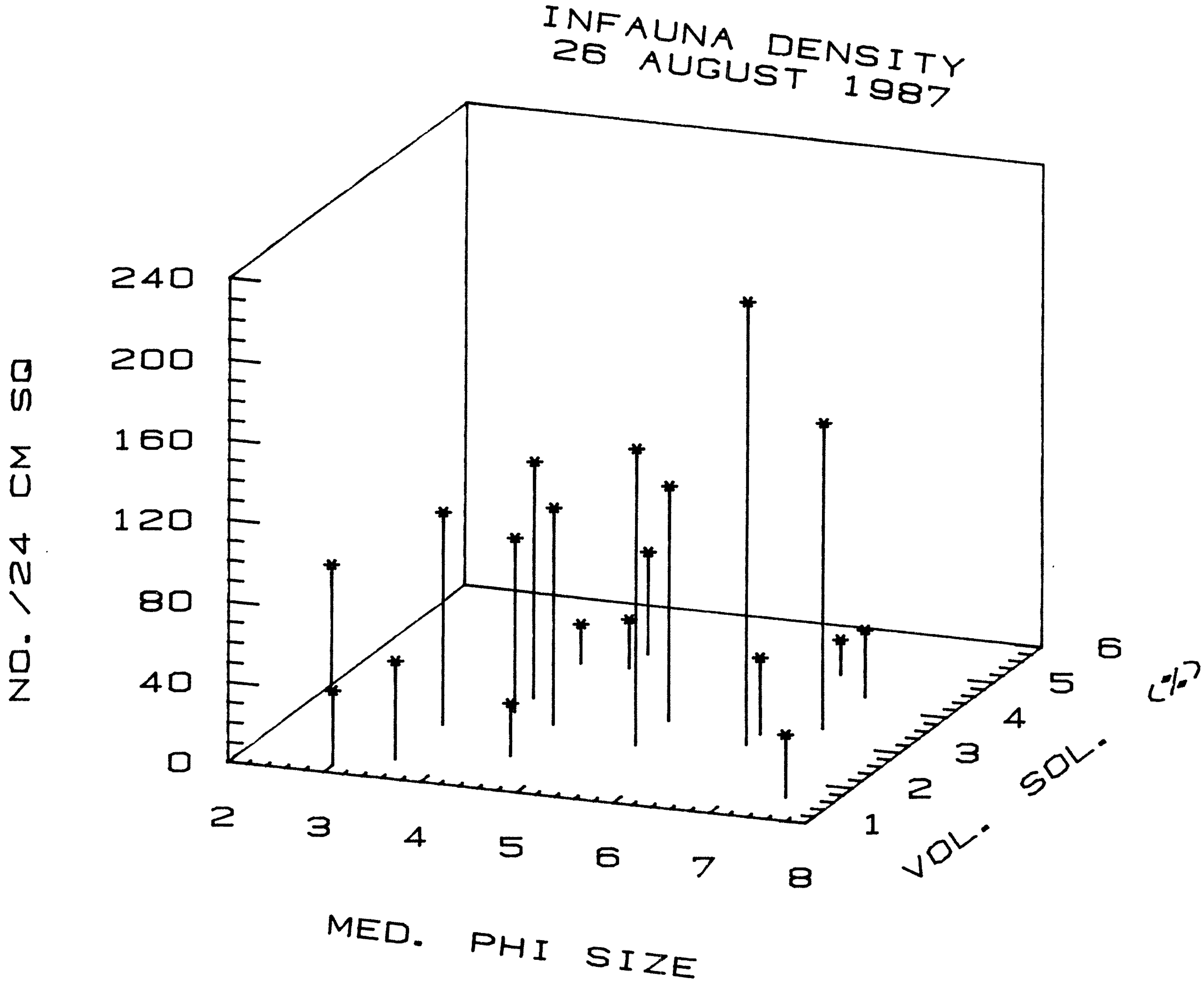


Figure 22. Infauna density versus median phi size and volatile solids in August 1987.

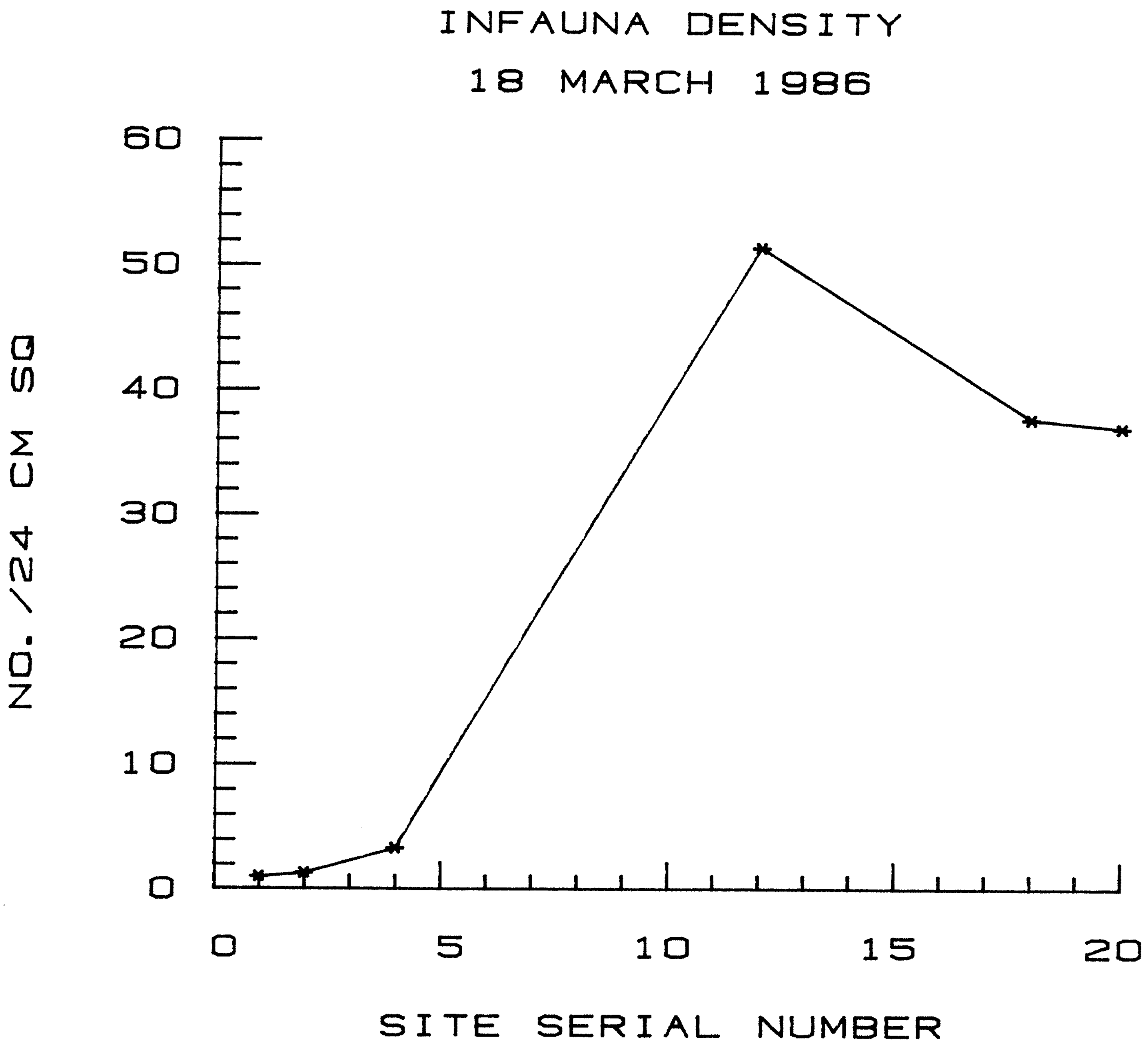


Figure 23. Infauna density at sampling sites in March 1986. See Figure 3 for site locations.

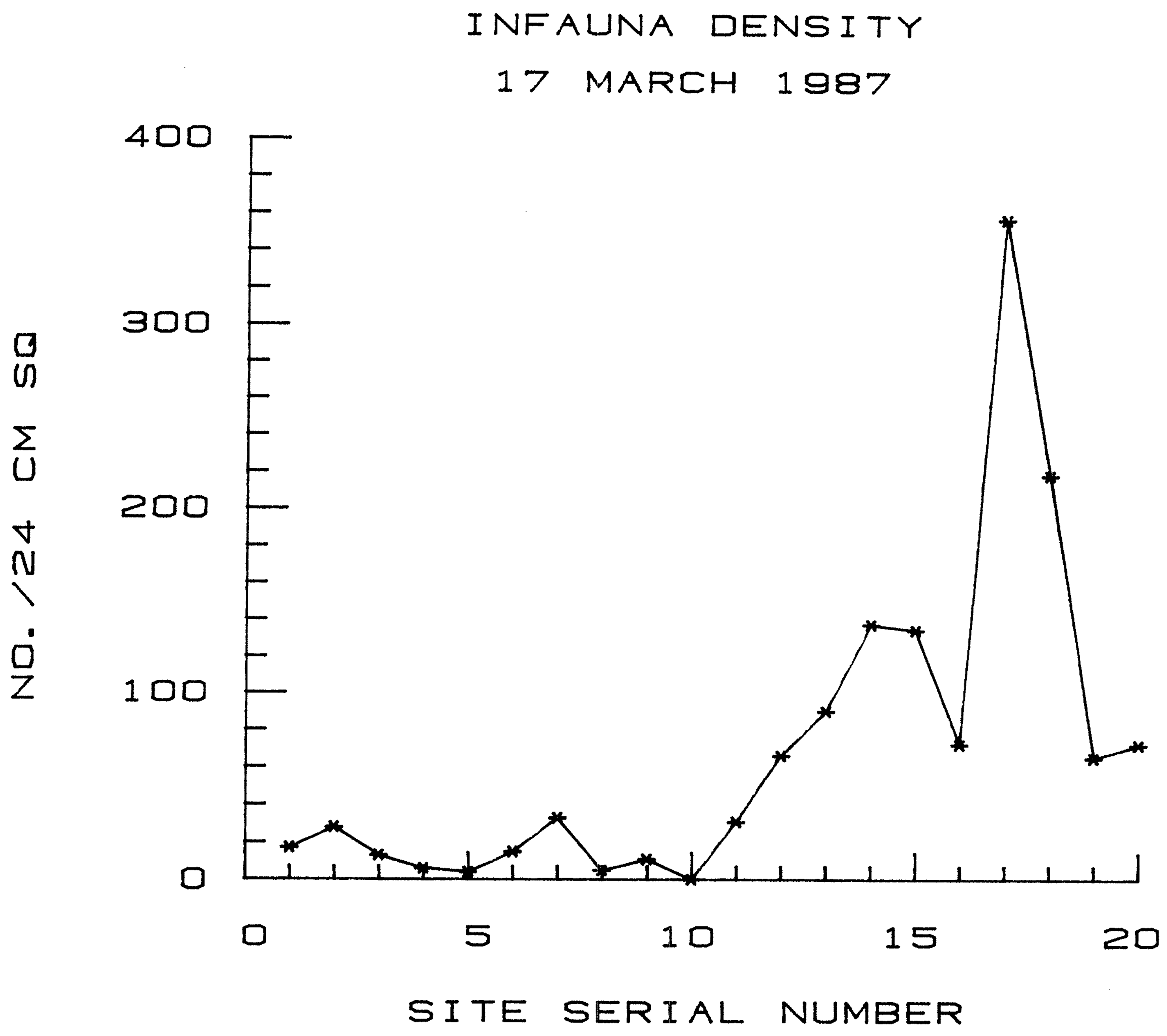


Figure 24. Infauna density at sites in March 1987. See Figure 3 for site locations.

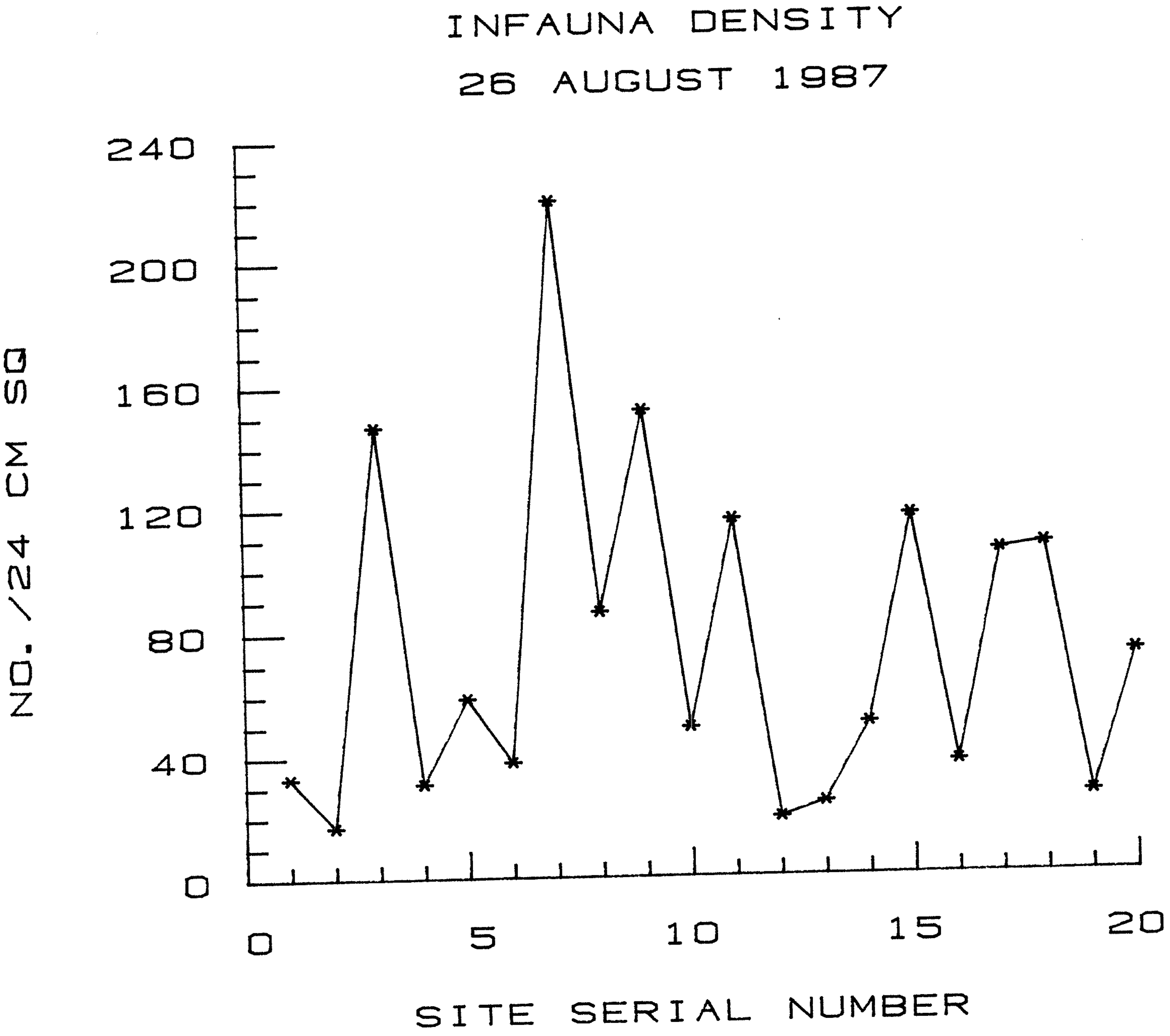


Figure 25. Infauna density at sites in August 1987. See Figure 3 for site locations.

the freshwater cladocerans (e.g., *Daphnia pulex, Microcyclops* sp.) had disappeared, and both amphipods and mysids were present (Appendix Tables A-D). Quantitative comparison of the epibenthos assemblage on flat 4 illustrates the shift between 1985-1986 and 1987 from a cyclopoid-dominated fauna to one numerically dominated by tartigrades, harpacticoids and nematodes, and gravimetrically dominated by oligochaetes, tartigrades and harpacticoids (Table 3). The harpacticoid fauna had shifted from *Bryocamptus* and *Maraenobiotus*, which were not found in 1987, to four very common taxa (*Microarthridion littorale, Tachidius discipes, Leimia vaga, Mesochra rapiens*) and four less prominent taxa (an unidentified species of Ectinosomatidae, *Huntemannia jadensis, Nitocra* sp., *Mesochra lilljeborgi*). In general, these species are representative of marsh and tideflat habitats in freshwater dominated oligohaline estuaries (Hicks and Coull 1983, Simenstad and Cordell 1985). While appearing only in June collections, juvenile gammarid amphipods and a tubiculous gammarid (*Corophium* sp.) were also recorded for the first time; mysids (*Neomysis mercedis*) also appeared in the June collections and were reported as incidental catch in the beach seines during the sampling throughout 1987. Both amphipods and mysids are characteristic of intertidal estuarine habitats throughout the Pacific Northwest region.

The mean density and standing stock of epibenthic organisms increased significantly from 6,084/m^2 (sd = 5,307) and 193.2 g wet wt/m^2 on flat 4 in spring 1986 to 154,273/m^2 (sd = 212,543) and 1,998.8 g/m^2 (sd = 2,932.2) in spring 1987. These changes in density and standing stock represent a 25- and 10-fold increase, respectively. On flat 5, density and standing stock increased to 124,908/m^2 (sd = 194,554) and 1,775.5 g/m^2 (sd = 2,694.7) in 1987. These changes represented a 21- and 9-fold increase in density and standing stock, respectively, since 1986. Flat 5 was unvegetated, and this suggests that the emergent marsh on flat 4 accounted for a somewhat higher standing stock of epibenthos.

Numerical diversity of the epibenthos generally increased over the sampling period from 1.60-2.95 (H', Shannon-Weiner diversity index) in March to 3.0-3.5 in June (Fig. 26). The samples

Table 3. Faunal composition (% numerical, % gravimetric) of epibenthic organisms on flat 4 of the Lincoln Avenue Wetland in 1987 as compared to previous (1985-1986) collections (Thom et al. 1987).

	1985-1986		1987	
Taxa	Numerical	Gravimetric	Numerical	Gravimetric
Hydrozoa	0	0	<0.01	<0.01
Platyhelminthes	0.03	0.10	0.34	1.41
Rotifera	2.46	0.82	1.28	1.66
Nematoda	0.88	1.35	13.42	3.11
Oligochaeta	0.05	0.20	8.21	43.19
Acarina	0.03	0.10	0.01	0.05
Cladocera	4.77	12.17	0.58	1.56
Podocopa	0.52	0.88	0.15	0.55
Copopoda*	35.92	3.43	4.32	1.36
Calanoida	0.03	0.13	0.01	<0.01
Harpacticoida	0.14	0.50	29.72	17.88
Cyclopoida	54.13	43.38	0.68	2.41
Insecta	1.08	12.12	0.12	1.00
Tardigrada	0	0	48.09	25.72

*Undifferentiated larvae.

TOTAL EPIBENTHOS NUMERICAL AND GRAVIMETRIC DIVERSITY

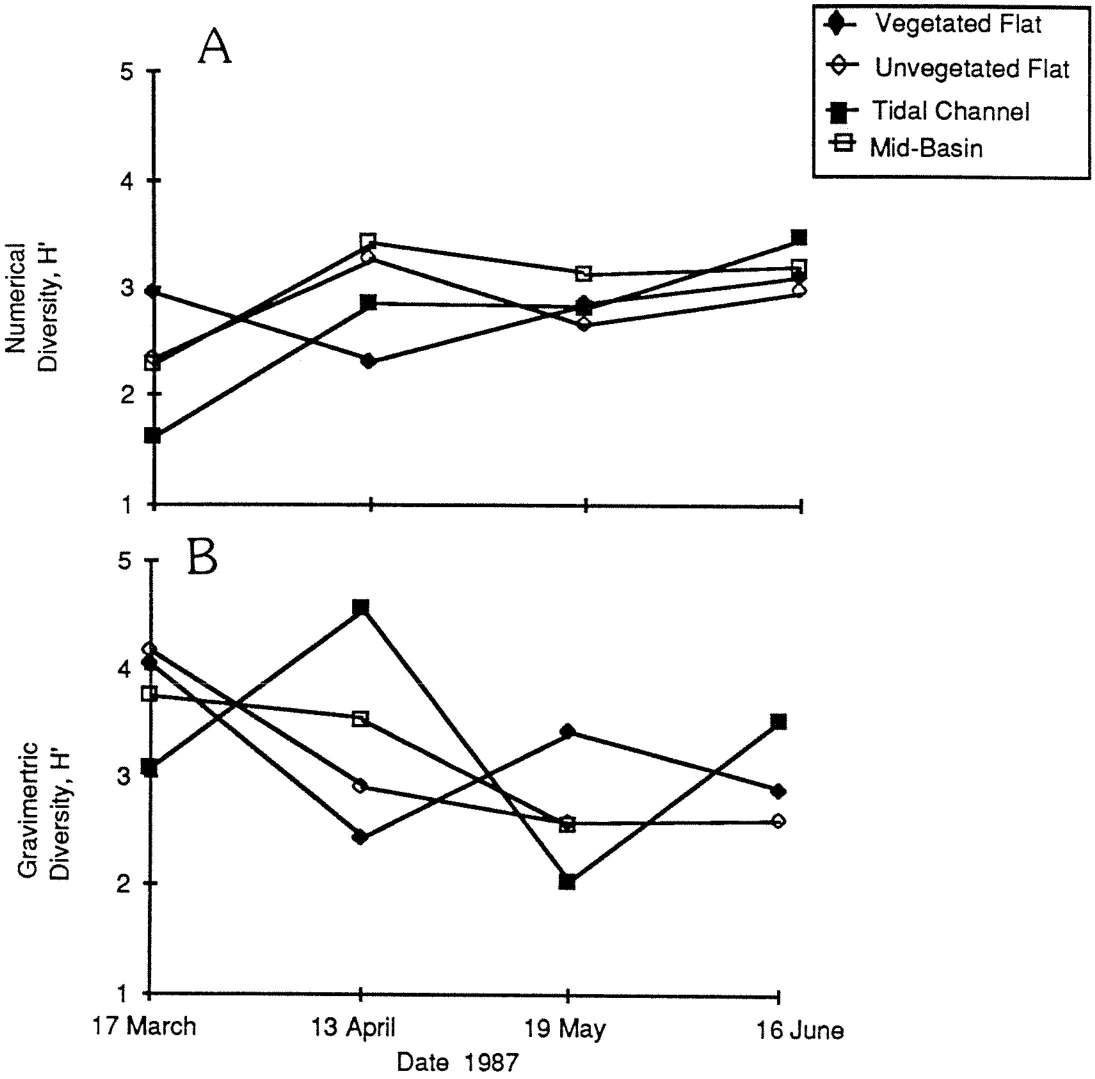


Figure 26. Numerical (A) and gravimetric (B) diversity (Shannon-Weiner, H') of epibenthic fauna for habitats in the wetland system.

on flat 4 were an exception, and these showed a decrease in diversity. These data compare to a post-breach diversity of 2.75 in March 1986. In contrast, gravimetric diversity declined over the same period (Fig. 26) from 3.15-4.20 in March to 2.50-3.55 in June. The unvegetated flat and mid-bay epibenthos followed similar trends, while the vegetated flat and the tidal channel epibenthos were more anomalous. This range and trend compares to the average gravimetric diversity of 3.12 for the unvegetated flat benthos in 1986. These comparisons indicate that the epibenthos assemblage had shifted from one composed of numerous species of relatively the same biomass to an assemblage in which different organisms of divergent sizes dominate over time, e.g, nematodes, oligochaetes, harpacticoid copepods, and tartigrades, during the late winter and early spring (Fig. 27).

Total epibenthos density was initially higher in both channel and mid-bay habitats (631,875 to 929,000/m^2) as compared to both flats (14,400 to 11,813/m^2) but declined through the remainder of the sampling period (Fig. 28). Epibenthos density on both flats increased between March and April (414,778 to 466,204/m^2) but declined to the same level (<200,000/m^2) as the channel and mid-bay by May and June, probably as a result of the decline in sediment microalgae (chl *a*) on the flats (Fig. 15). Total standing stock reflected similar patterns to density; declining from 5.0 to 7.5 g/m^2 to 0.5 to 2.2 g/m^2 (Fig. 28). The April increase in epibenthos on the flats was more pronounced in terms of standing stock, which reflected an increase in oligochaetes, rotifers, and nematodes (Table 3). Epibenthic copepod density followed the same temporal trend as did total epibenthos density (Fig. 29).

Previous information was used to categorize epibenthos taxa as potential fish prey, including chironomid larvae, mysids and all gammarid amphipods. None of the harpacticoids were considered viable prey organisms because of their small size and interstitial occurrence. Temporal trends in the total density of fish prey (Fig. 29) did not correspond to the patterns in density of the total epibenthos. All habitats had comparatively lower densities (0-650/m^2) in March; densities

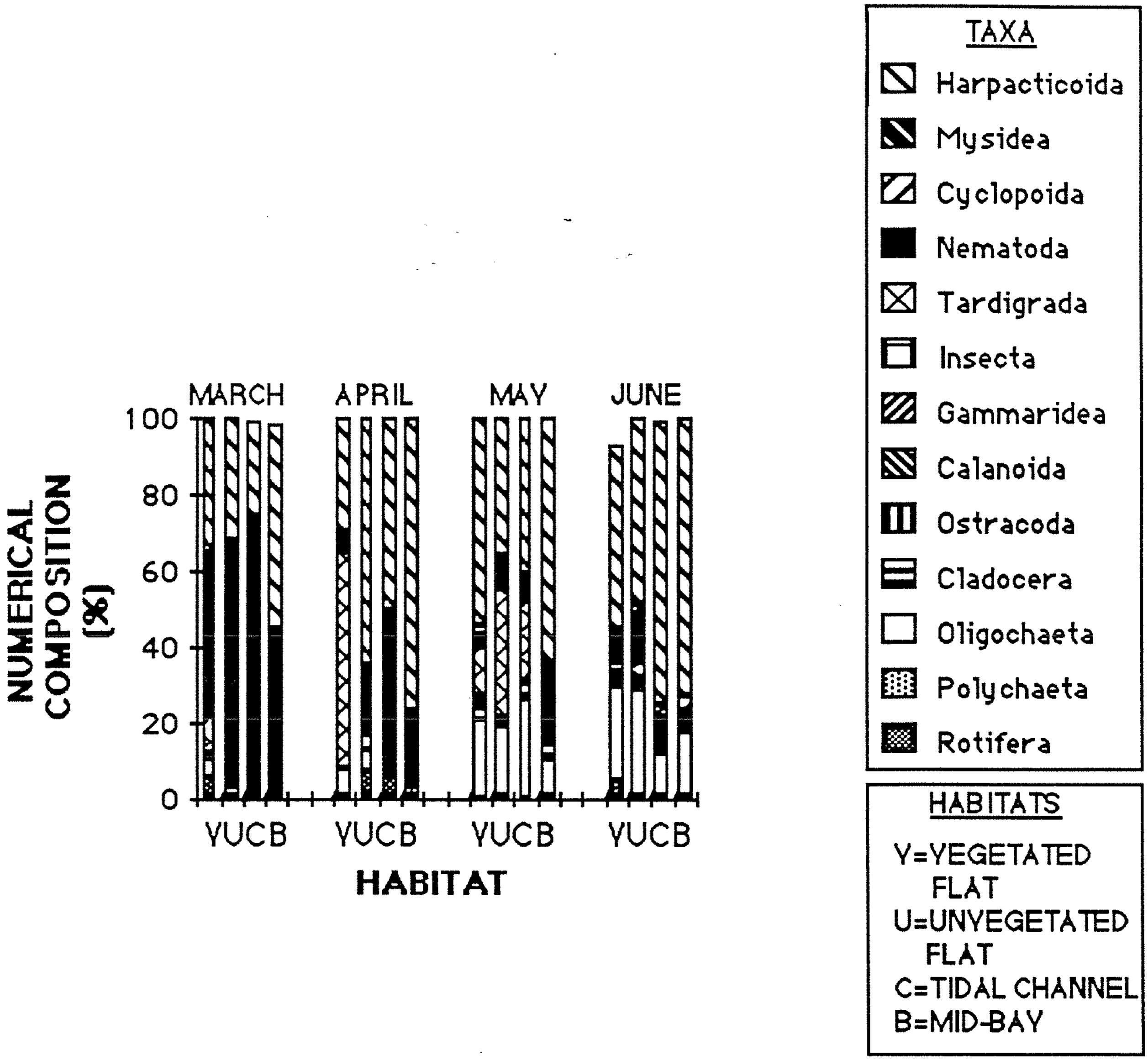


Figure 27. Lincoln Avenue wetland epibenthos community composition by density in March-June 1987.

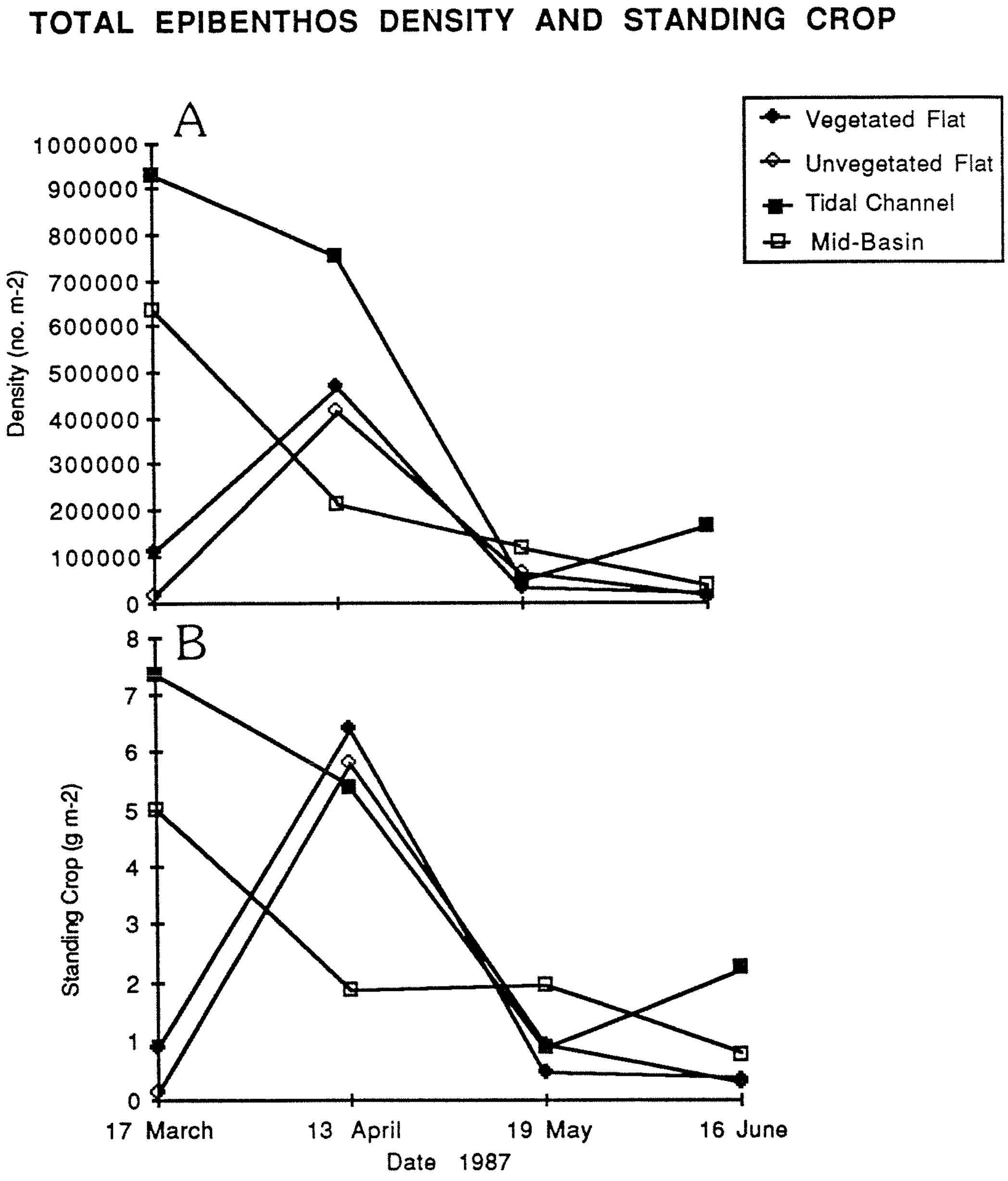


Figure 28. Total density (A) and standing crop (B) of epibenthic fauna for habitats in the wetland system March-June 1987.

HARPACTICOID COPEPOD AND JUVENILE SALMONID PREY DENSITY

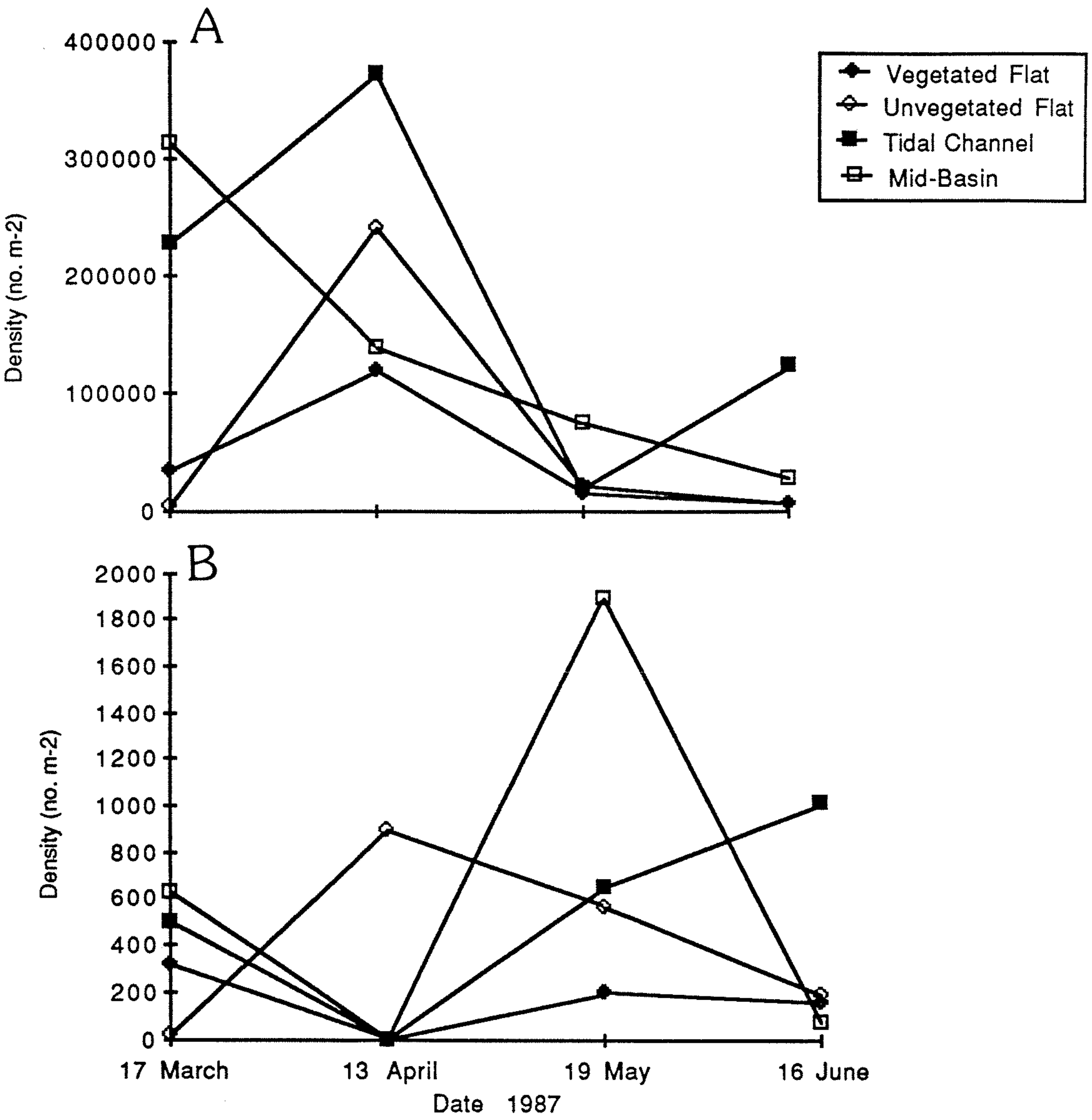


Figure 29. Densities of harpacticoid copepods (A) and preferred prey of juvenile salmonids (B) for habitats in the wetland system March-June 1987.

decreased further in all habitats except for the unvegetated flat in April. Populations in the mid-bay erupted to ca. 2,000/m^2 in May, while other habitats showed a decline or modest increase (channel 4). By June, all habitats except channel 4 had declined uniformly to 50-200/m^2. Except for the June collection, in which the mysids and gammarids occurred, all patterns were due to changes in chironomid larvae, which reflects metamorphosis to adult stages.

Fish

Eleven species within six families of fish were collected from the wetland during 1987 beach seine sampling (Table 4). In 1987, the family Salmonidae was the best represented of the six families with three species (mountain whitefish, chum salmon, and chinook salmon). The families Cyprinidae and Cottidae were each represented by two species, and the families Catostomidae, Pleuronectidae and Gasterosteidae by one species. The two species of Pacific salmon are common estuarine residents as juveniles during their migration to the Pacific Ocean. Five species are considered freshwater or oligohaline (mountain whitefish, redside shiner, largescale sucker, prickly sculpin and longnose dace). Three species are commonly reported to be euryhaline (threespine stickleback, Pacific staghorn sculpin and starry flounder).

Fish abundances, weights, densities, standing stocks and species richness from collections on each sampling date are summarized in Table 5. Fish densities (the number of fish caught divided by the tidal channel area) for the separate species varied markedly during the February-June 1987 sampling period (Table 6), primarily due to the immigration and emigration of juvenile salmon. Both chinook and chum salmon were present throughout the sampling period; a total of 696 chinook salmon (including fish released) with a preserved wet weight of 524.68 g and 44 chum salmon with a preserved wet weight of 59.79 g were collected. Chum salmon (31 to 58 mm) and chinook salmon (30 to 93 mm) accounted for 20 to 50% of the total density. Total fish density peaked on March 17 (6/100 m^2) and May 30 (8/100 m^2); chinook salmon density peaked in late March (0.6/100 m^2) and late May (3.3/100 m^2); and chum salmon density peaked on April 2

Table 4. Fishes collected in 1986-1987 beach seine samples at Lincoln Avenue wetland, Puyallup River estuary.

Family/Species/Common name	
1986	1987
Family Salmonidae *Prosopium williamsoni* (mountain whitefish)	Family Salmonidae *Prosopium williamsoni* (mountain whitefish)
Oncorhynchus gorbuscha (pink salmon)*	*Oncorhynchus keta* (chum salmon)
O. keta (chum salmon) (chum salmon)	*O. tshawytscha* (chinook salmon)
O. kisutch (coho salmon)*	Family Cyprinidae *Rhinichthys cataractae* (longnose dace)+
O. tshawytscha (chinook salmon)	*Richardsonius balteatus* (redside shiner)
Family Cyprinidae *Richardsonius balteatus* (redside shiner)	Family Catostomidae *Catostomus macrocheilus* (sucker)
Family Catostomidae *Catostomus macrocheilus* (largescale sucker)	Family Gasterosteidae *Gasterosteus aculeatus* (stickleback)
Family Gasterosteidae *Gasterosteus aculeatus* (three-spine stickleback)	Family Cottidae *Cottus asper* (prickly sculpin)
Family Cottidae *Cottus asper* (prickly sculpin)	*Leptocottus armatus* (staghorn sculpin)
Leptocottus armatus (Pacific staghorn sculpin)	Family Pleuronectidae *Platichthys stellatus* (starry flounder)
Family Pleuronectidae *Platichthys stellatus* (starry flounder)	

*only collected in 1986

+only collected in 1987

Table 5. Summary of 1987 beach seine fish collection data for Lincoln Avenue wetland, Puyallup River estuary. Abundance, wet weight, density, standing crop, and number of species are means of all beach seine hauls on the given sampling date. Standard deviations are given in brackets.

	Sampling date										
	2/17	3/3	3/17	3/31	4/2	4/3	4/14	5/19	5/30	6/8	6/16
No. of hauls	3	5	4	3	2	2	4	1	1	1	2
Fish abundance	20.33 [16.35]	8.25 [4.41]	61.5 [10.20]	20.67 [18.74]	29.5 [30.41]	12 [4.24]	11 [7.07]	19 [0]	130 [0]	72 [0]	26.5 [0]
Wet weight (g)	145.46 [152.54]	16.72 [11.46]	102.2 [51.70]	74.39 [81.10]	54.52 [58.46]	16.12 [3.85]	5.97 [2.74]	9.44 [0]	236.98 [0]	27.03 [0]	30.24 [10.83]
Density (no./100m^2)	2 [1]	1 [0]	6 [2]	1 [1]	2 [2]	1 [0]	1 [1]	1 [0]	8 [0]	5 [0]	2 [1]
Standing crop (wet g/100m^2)	9 [9]	1.8 [2]	8 [3]	5 [5]	3 [3]	1 [0]	0 [0]	1 [0]	14 [0]	2 [0]	2 [1]
No. of species	4 [0.71]	3.25 [0.99]	6.5 [1]	3.67 [2.68]	5.6 [2.83]	3 [0]	2.5 [0.71]	3 [0]	7 [0]	6 [0]	5 [2.83]

Table 6. Mean density (no./100 m^2) of fishes captured in Lincoln Avenue wetland, Puyallup River estuary, during 1987. Densities which appear in the table are means of all hauls on the given sampling date.

			Sampling date										
Species name	Common name	stage	2/17	3/3	3/17	3/31	4/2	4/3	4/14	5/19	5/30	6/8	6/16
Family Salmonidae													
Prosopium williamsoni	Mountain whitefish	Adults		0.4									
Oncorhynchus keta	Chum salmon	Juveniles				0.1	0.4	0.1			0.7		
Oncorhynchus tshawytscha	Chinook salmon	Juveniles	0.4	0.2	0.6	0.6	0.5		0.6	0.7	3.3	3.1	0.1
Family Cyprinidae													
Rhinichthys cataractae	Longnose dace	Juveniles	0.1	0.1	0.6								
Richardsonius balteatus	Redside shiner	Juveniles	0.5	0.1	0.2							0.1	
Family Catostomidae													
Catostomus macrocheilus	Largescale sucker	Juveniles		0.1	0.4		0.1			0.2	0.6	0.1	0.4
Family Gasterosteidae													
Gasterosteus aculeatus	Threespine stickleback	Adults		0.1							0.8		
		Juveniles								0.3	0.5	0.3	0.7
Family Cottidae													
Cottus asper	Prickly sculpin	Juveniles				0.1	0.2	0.1			0.2		0.1
Leptocottus armatus	Pacific staghorn sculpin	Juveniles	0.8	0.1	0.4	0.4	0.5	0.5	0.1		0.1	0.4	0.4
Family Pleurronectidae													
Platichthys stellatus	Starry flounder	Juveniles									1.2	0.1	0.1

(0.4/100 m^2) and May 30 (0.7/100 m^2). Mean total fish densities nearly doubled between 1986 and 1987 (Figure 30), and in both years peak densities were observed shortly after hatchery releases of juvenile salmon. Among the non-salmonid species, Pacific staghorn sculpins, prickly sculpins and largescale suckers were present in the greatest densities (0.4-0.8/100 m^2) throughout the 1987 sampling period. Relatively high densities of the two cyprinids, longnose dace and redside shiner, were observed in February and March; thereafter, these species virtually disappeared. In contrast, low densities of starry flounder and threespine sticklebacks were observed in the early sampling months followed by higher densities in May and June. Larval starry flounders, largescale suckers and prickly sculpins were collected in the wetland in May and June.

In general, trends in standing crop (the biomass of fish caught divided by the channel area) mimicked trends in density (Table 7). Notable exceptions were the influence of a few relatively large fish: one adult starry flounder on 17 February; several juvenile starry flounders on 17 February, 31 March and 2 April; and one adult mountain whitefish on 3 March. Excluding these exceptions, the mean total standing stock ranged from 1 to 14 g/m^2. The highest total standing crop recorded on 17 March (8 g/m^2) and 30 May (14 g/m^2) can be attributed to the abundance of chinook salmon on these dates.

Epibenthic organisms throughout the wetland were considered to be potential available prey to foraging juvenile chum and chinook salmon. The principal taxa among the epibenthos were Nematoda, Oligochaeta, Harpacticoida and Tartigrada. Midges (Chironomidae), stonefly nymphs (Plecoptera), two species of gammarid amphipods (*Corophium* spp.), flies (Diptera) and cladocerans (*Daphnia* spp.) were among the dominant prey found in both chum and chinook stomachs. The most important prey category overall in terms of percent total IRI (Index of Relative Importance) was midge larvae, pupae and adults (Chironomidae). A variety of other prey taxa (Arachnida, Chaoborus, Coleoptera, Collembolla, *Eogammarus confervicolus*, Harpacticoida, Homoptera, Hymenoptera, unidentified Insecta, *Neomysis mercedis*, Odonata and Osteichthys)

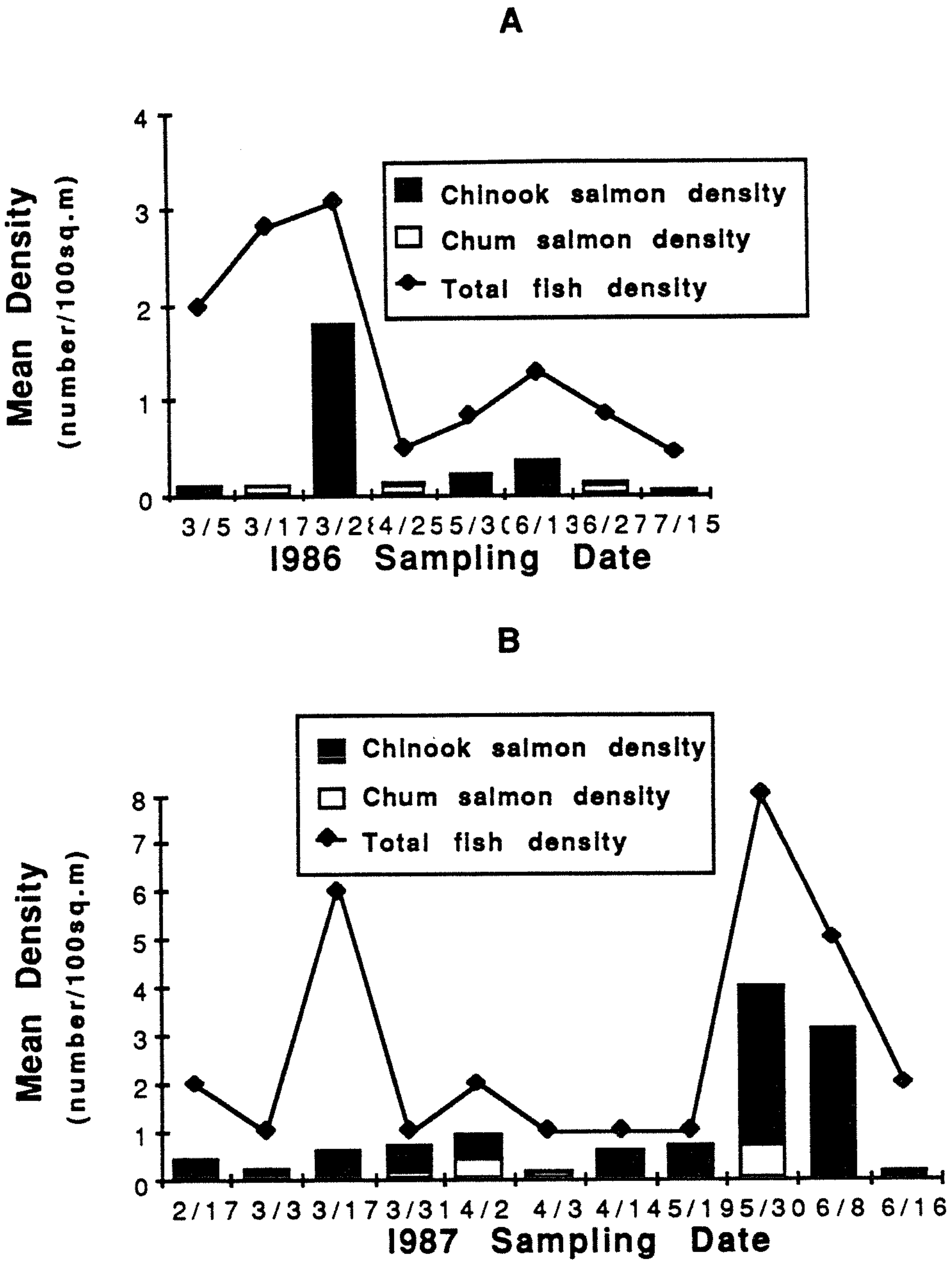


Figure 30. Chinook, chum and total fish density comparisons for Lincoln Avenue wetland, Puyallup River estuary: (A) 1986; (B) 1987.

Table 7. Mean standing crop (wet g/100 m^2) of fishes captured in Lincoln Avenue wetland, Puyallup River estuary, during 1987. Data which appear in the table are means of all hauls on the given sampling date.

			Sampling date										
Species name	Common name	stage	2/17	3/3	3/17	3/31	4/2	4/3	4/14	5/19	5/30	6/8	6/16
Family Osmeridae													
Thaleichthys pacificus	Eulachon	Adult		0.2									
Family Salmonidae													
Prosopium williamsoni	Mountain whitefish	Adults		70.2									
Oncorhynchus ketax	Chum salmon	Juveniles				0.1	0.3	0.1		0.4	0.5		
Oncorhynchus tshawytscha	Chinook salmon	Juveniles	0.4	0.5	5	1.8	1.2		0.4		10.5		0.3
Family Cyprinidae													
Rhinichthys cataractae	Longnose dace	Juveniles			0.2								
Richardsonius balteatus	Redside shiner	Juveniles	0.3	0.1	0.1								
Family Catostomidae													
Catostomus macrocheilus	Largescale sucker	Juveniles	0.1	0.1	0.5	0.1	0.1		0.1	0.1	0.6	0.1	0.5
Family Gasterosteidae													
Gasterosteus aculeatus	Threespine stickleback	Adults					0.2	0.1			1.3		
		Juveniles	0.1			0.1				0.1	0.2	0.4	0.4
Family Cottidae													
Cottus asper	Prickly sculpin	Adults					0.6						
		Juveniles	0.2			0.2	0.3	0.1					
Leptocottus armatus	Pacific staghorn sculpin	Juveniles	2.4	0.3		1	1.4	0.9	0.8		0.1	1.2	1.2
Family Pleuronectidae													
Platichthys stellatus	Starry flounder	Adults	15.2										
		Juveniles	7.8			9.4	1.8				0.7	0.2	0.2

were consumed infrequently or in small numbers. Comparisons of prey available and prey consumed during the 1987 outmigration period (March-May) indicated minimum overlap (Figure 31).

In the two years since the Lincoln Avenue wetland was constructed, eleven species of oligohaline and euryhaline fish have appeared in the new habitat. In 1987, the majority of the fish caught with a beach seine were collected in channels 3 and 4, the two deepest channels. Juvenile chum and chinook salmon showed the highest densities of the eleven species. The Puyallup River is dominated by hatchery releases and there are no current estimates of wild salmon escapement. Hence, a significant number of these juvenile salmon may have been released from the Puyallup Indian Tribal Hatchery or the Washington Department of Fisheries hatchery at Voight Creek. Both of these hatcheries are upriver of the Lincoln Avenue wetland and, hence, any juvenile salmon released into the Puyallup River could potentially have accessed the wetland during their outmigration to Commencement Bay. The range of observed salmon densities in the wetland (0.1-3.3/100 m^2) was low in comparison to densities of up to 77/100 m^2 in the Fraser River (Levy and Northcote 1982) or up to 178/100 m^2 in the Skagit River (Congleton et al. 1981). Hatchery fish, which dominate the Puyallup system, may have shorter residence times than naturally produced fish (Levings et al. 1986). The Fraser and Skagit rivers probably contain a smaller proportion of hatchery fish as compared to the Puyallup, which may explain some of the differences in densities among the systems. Changes in the bathymetry and morphology of the tidal channels due to sedimentation, the salinity regime, the composition and standing stock of prey resources, and the timing of hatchery releases may in part explain why juvenile salmon utilization of the wetland is still in a state of flux. As the system stabilizes over time, we expect variability in juvenile salmon utilization.

The utilization of the mitigation wetland by juvenile salmon is of particular interest since 50% of the habitat was designed to support this target resource group. Simple descriptive documenta

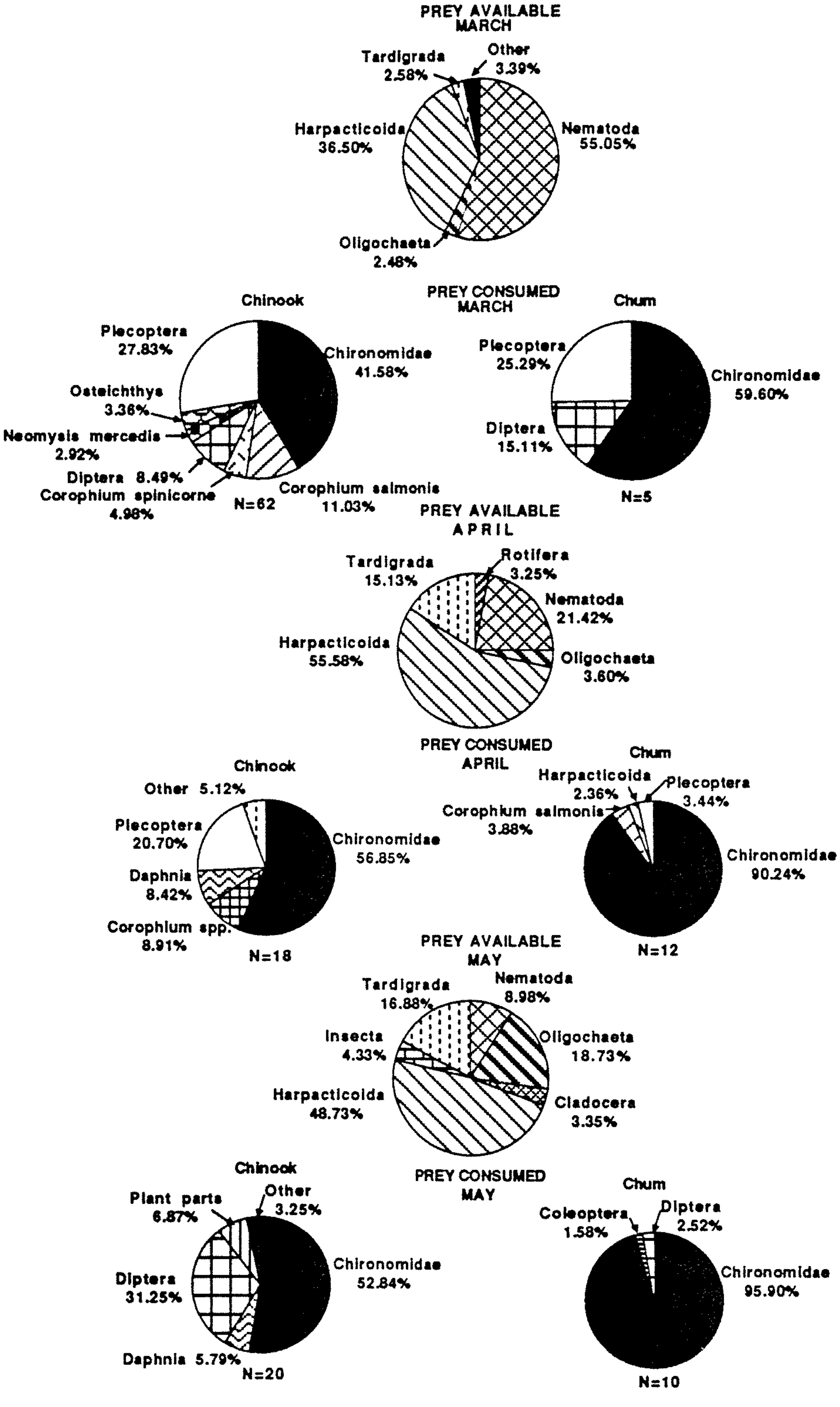


Figure 31. Prey availability (% composition of epibenthos) and rank importance (total %IRI) of items in the stomach contents of juvenile chum and chinook salmon collected in Lincoln Avenue wetland, Puyallup River estuary, March-May 1987. Sample sizes (n) are indicated below each pie.

tion of the incidence of juvenile salmon in the restored wetland does not test the benefit(s) (i.e., predation avoidance, seawater acclimation, foraging habitat) derived from their utilization of the habitat. One potential functional value of the wetland is as a foraging area for outmigrating juvenile salmon. Based on the epibenthic samples from 1987, we estimate that between 500 and 2,000 organisms/m^2 represented the potential prey resource for juvenile salmon in the wetland between March and June. However, direct comparison of epibenthic prey available in the wetland with prey found in chum and chinook stomachs indicated essentially no overlap (Fig. 31). Harpacticoid copepods were among the dominant prey available for consumption, yet midges were the dominant prey consumed by both chum and chinook salmon. Among a number of possible explanations for this discrepancy, two are most likely: (1) epibenthos sampling was not designed to assess the availability of the prey selected by the fish, which were predominantly emergent or drift insects and tubiculous gammarid amphipods; and (2) the selected prey originated outside the wetland and were either consumed in the river before the fry entered the wetland or advected into the wetland as drift. In order to verify the origins and quantities of food organisms available for consumption in the Lincoln Avenue wetland, we have expanded monitoring in 1988 to: (1) include emergent and drift insects and document the advection of drift prey from the river into the wetland; (2) obtain more precise estimates of juvenile chum and chinook salmon residence times; and (3) generate *in situ* consumption rate estimates for juvenile salmon residing in the wetland over diel foraging periods. If juvenile salmon growth in the wetland is more rapid than growth in the river, wetland foraging should correlate with increased survival of the outmigrants. At this time, however, we are constrained in our interpretation of the status of the Lincoln Avenue wetland system as a foraging area for outmigrating juvenile salmon because there are virtually no reference data available from emergent plant wetlands in the region that describe fish consumption rates and prey carrying capacity. In conjunction with our 1987 data, our 1988 (unpublished) findings of extended juvenile chinook salmon resident time in the wetland suggest that the wetland is utilized to some degree for foraging.

Birds

The wetland system continued to be utilized by a large number of bird species in 1987. A total of 37 species of birds were observed during 9 site visits in February-August 1987 (Table 8). This compares to 33 species observed in 1986 during six site visits conducted in April-July. A total of 80 species were observed by Jon R. Jensen of the Tahoma Audubon Society during 53 visits in October 1986-November 1987. Up to November 1987, a total of 89 species have been observed in the system (Table 8). Notable sitings, due to rare or uncommon occurrence in the region, included Snow Geese, Thayer's Gulls, Wood Ducks, American Kestrel, Merlin, Lesser Golden Plover, and Bar-tailed Godwit. Some of the most abundant species included Mallards, American Widgeons, and Gadwalls. Red-winged Black Birds were common in the upland cattail marsh. In April-May, Mallard ducklings were abundant in the system. In May-June, two pairs of Green Herons were observed nesting in the upland cattail marsh; they were photographed on 28 May 1987. One or two Great Blue Herons were observed on most visits in March-May, and these bird were obviously preying on fish in the system. More study would be required to fully evaluate the effect of predation by birds on fish in the system.

Between 50 and 110 individuals were recorded in the system during each visit in 1987, which was comparable to the range in 1986 of 55-135 (Fig. 32). The majority of individuals were generally observed in the intertidal (i.e., on the flats, or in the channels and mid-bay) during the visits. The lower range in abundance in 1987 was due to slightly lower numbers of waterfowl and shorebirds (Fig. 33). Total species richness ranged between 13 and 23 per site visit in 1987 as compared to 18 and 27 in 1986 (Fig. 34). The slight decline between the two years was primarily due to a drop in the number of waterfowl species. The maximum number of shorebird species present during a site visit was slightly greater in 1986 (6) in comparison to 1987 (4). There are a number of factors that could explain the differences in bird abundance and species richness between 1986 and 1987. These factors include internal (e.g., changes in the physical conditions and food resources in the wetland) and external (e.g., climatic differences, bird reproductive

Table 8. Bird species observed in the Lincoln Avenue wetland system. TA=Tahoma Audubon observations October 1986-November 1987; FRI=Fisheries Research Institute observations.

Common Name	TA 1986-1987	FRI 1986	FRI 1987	FRI 1986-1987
1. Common Loon		X		X
2. Pied-billed Grebe	X	X		X
3. Horned Grebe	X	X	X	X
4. Western Grebe	X	X		X
5. Double-crested Cormorant	X	X	X	X
6. Great Blue Heron	X	X	X	X
7. Green-backed Heron	X	X	X	X
8. Snow Goose	X			
9. Canada Goose	X	X	X	X
10. Wood Duck	X			
11. Green-winged Teal	X	X	X	X
12. Mallard	X	X	X	X
13. Cinnamon Teal	X			
14. Common Teal			X	X
15. Blue-winged Teal			X	X
16. Northern Shovelor	X		X	X
17. Gadwall	X	X	X	X
18. Eurasian Widgeon	X			
19. American Widgeon	X	X	X	X
20. Common Goldeneye	X			
21. Barrow's Goldeneye	X			
22. Bufflehead	X			
23. Hooded Merganser	X			
24. Common Merganser	X	X		X
25. Red-breasted Merganser	X		X	X
26. Cooper's Hawk	X			
27. Red-tailed Hawk	X	X		X
28. American Kestrel	X			
29. Merlin	X			
30. Red-necked Pheasant	X		X	X
31. California Quail	X	X		X
32. Sora	X			
33. American Coot	X	X	X	X
34. Lesser Golden-Plover	X			
35. Killdeer	X	X	X	X
36. Greater Yellowlegs	X		X	X
37. Lesser Yellowlegs	X			
38. Spotted Sandpiper	X			
39. Bar-tailed Godwit	X			
40. Western Sandpiper	X	X		X
41. Least Sandpiper	X	X	X	X

Table 8. Bird species observed in the Lincoln Avenue wetland system. TA=Tahoma Audubon observations October 1986-November 1987; FRI=Fisheries Research Institute observations - cont'd.

Common Name	TA 1986-1987	FRI 1986	FRI 1987	FRI 1986-1987
42. Pectoral Sandpiper	X			
43. Common Snipe		X	X	X
44. Long-billed Dowitcher	X		X	X
45. Short-billed Dowitcher	X			
46. Bonaparte's Gull	X	X	X	X
47. Mew Gull	X			
48. California Gull	X			
49. Western Gull		X	X	X
50. Herring Gull		X	X	X
51. Thayer's Gull	X			
52. Glaucous-winged Gull	X			
53. Morning Dove	X			
54. Rock Dove	X	X	X	X
55. Belted Kingfisher	X			
56. Northern Flicker	X			
57. Willow Flycatcher	X			
58. Tree Swallow	X			
59. Violet-green Swallow	X		X	X
60. Cliff Swallow	X	X	X	X
61. Barn Swallow	X	X	X	X
62. Rough-winged Swallow		X	X	
63. Stellar's Jay	X			
64. American Crow	X		X	X
65. Black-capped Chickadee	X		X	X
66. Bushtit	X			
67. Bewick's Wren	X			
68. Winter Wren	X			
69. Marsh Wren	X			
70. Ruby-crowned Kinglet	X			
71. American Robin	X	X	X	X
72. Cedar Maxwing	X			
73. Northern Shrike	X			
74. European Starling	X		X	X X
75. Orange-crowned Warbler	X			
76. Common Yellowthroat	X		X	X
77. Black-headed Grosbeak	X			
78. Rufous-sided Towhee	X			
79. House Sparrow		X		X
80. Savannah Sparrow	X	X	X	X
81. Fox Sparrow	X			

Table 8. Bird species observed in the Lincoln Avenue wetland system. TA=Tahoma Audubon observations October 1986-November 1987; FRI=Fisheries Research Institute observations - cont'd.

Common Name	TA 1986-1987	FRI 1986	FRI 1987	FRI 1986-1987
82. Song Sparrow	X		X	X
83. Lincoln's Sparrow	X			
84. Golden-crowned Sparrow	X			
85. White-crowned Sparrow	X			
86. Red-winged Blackbird	X	X	X	X
87. Brown-headed Cowbird			X	X
88. House Finch	X			
89. American Goldfinch	X	X	X	X
TOTAL NUMBER OF SPECIES	80	33	37	46

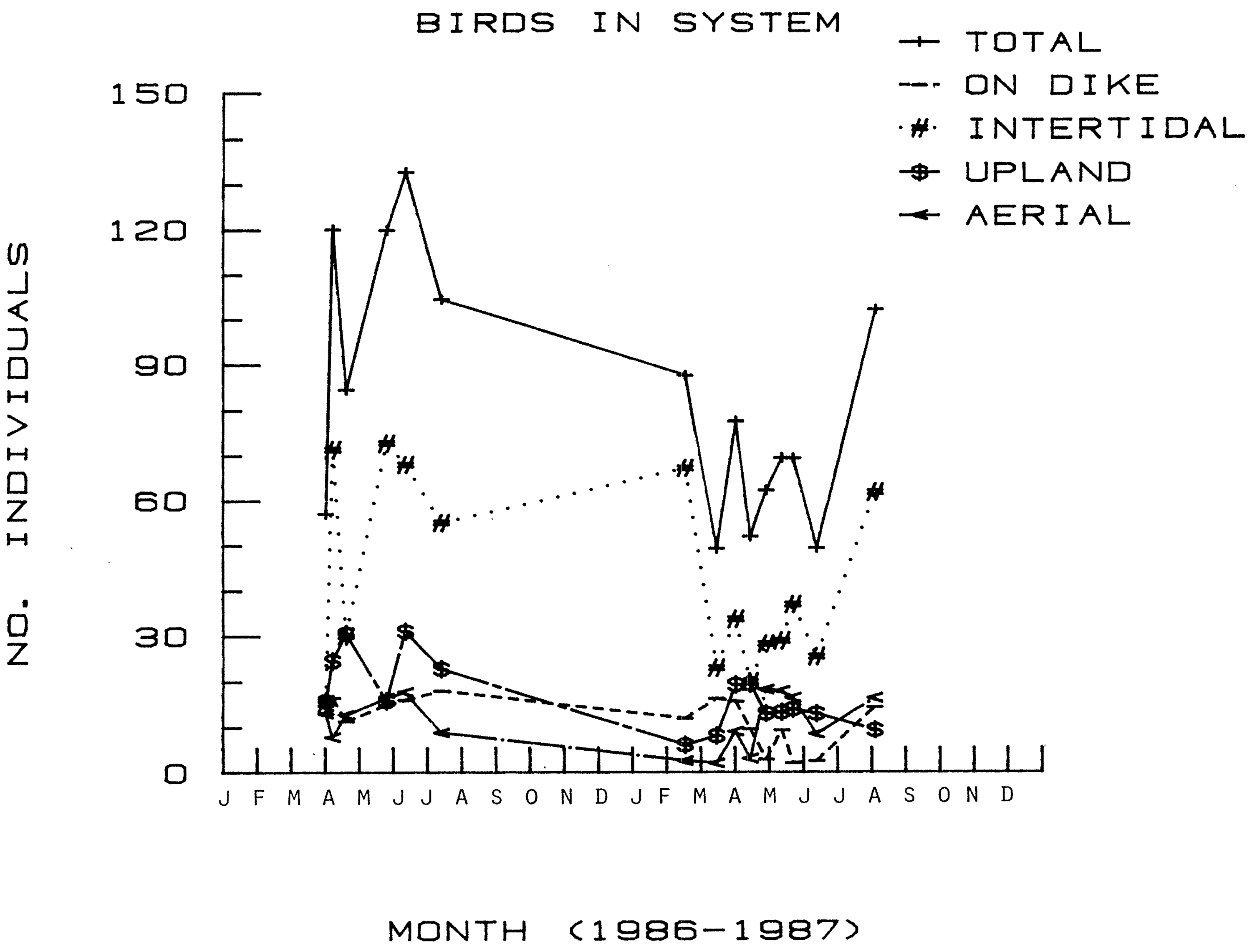


Figure 32. Maximum abundance of birds, and their distribution by habitat, observed in the wetland system on each sampling date.

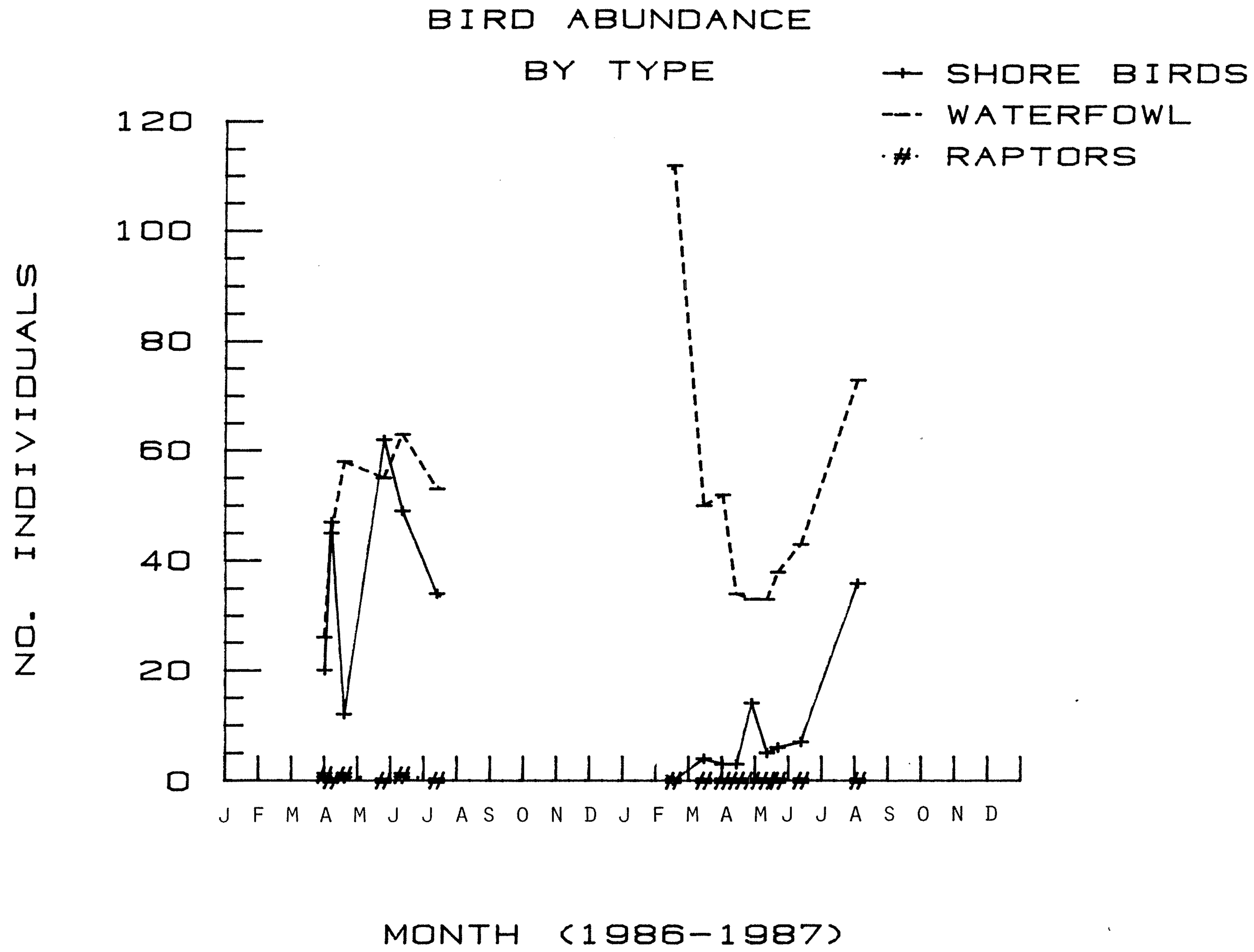


Figure 33. Maximum abundance of each bird type observed in the wetland system on each sampling date.

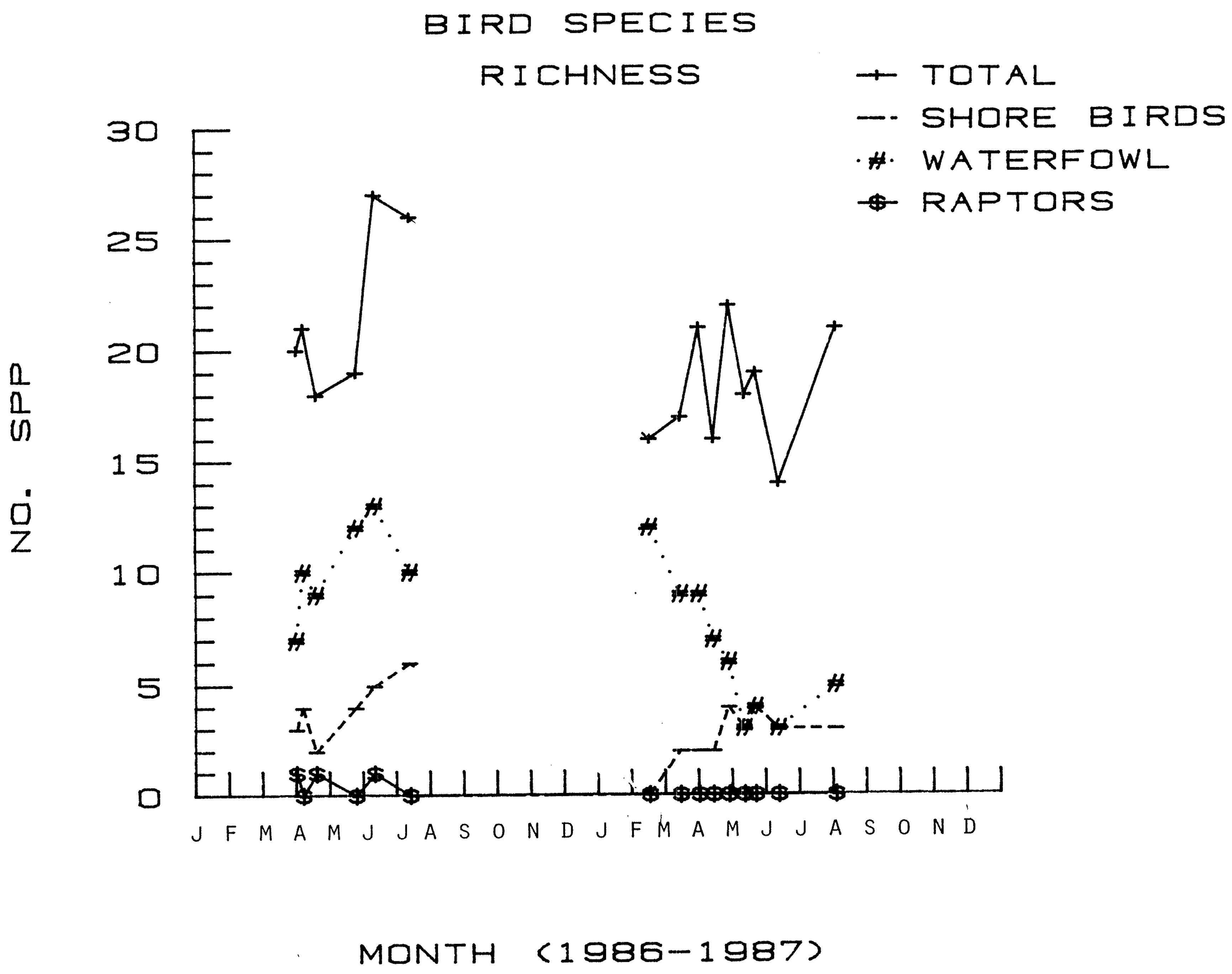


Figure 34. Maximum number of bird species observed in the wetland system on each sampling date.

success) causes. Our data show that marsh standing stock, benthic infauna density, epibenthos standing stock and fish abundance are all greater in 1987 as compared to 1986. This suggests that the system has more food resources available to the aquatic food web, and that food resources available to birds most probably were also greater in 1987. Although physical conditions are somewhat different in terms of basin morphometry, it is difficult to explain a slight decrease in bird abundance due to this change. A much longer-term data set is required to sort out short-term (i.e., annual) fluctuations in bird abundance and species richness.

Water Chemistry

Water temperature, recorded at various points in the intertidal portion of the wetland, varied from a low of 8°C in February to a high near 20°C in June (Fig. 35). However, considerable variation in water temperature occurs in channels and over the flat within a given date in summer. This variation was noted during intensive water temperature monitoring conducted in 1986, and is due to heating of waters during low tide and influxes of relatively cold water at high tide (Thom et al. 1987).

The salt wedge was detected at the 11th Street Bridge site, which is located very close to the mouth of the River (Table 9). Salinities at sites upstream from the 11th Street Bridge were generally below 1 ppt in both surface and bottom samples. Bottom water temperature was also low at the bridge and in Commencement Bay as compared to surface waters (Table 9). Water temperature was 1.5 to 3.0°C warmer in the wetland as compared to ambient river conditions during the high slack sampling, which suggests that heating of the water during slack tides is influenced by the shallow flats in the wetland. This type of heating is a natural process which occurs in nearshore systems dominated by shallow flats.

Dissolved oxygen (DO) also reflected the influence of the salt wedge (Table 9). Lowest DO occurred in bottom high salinity water. Greatest DO was measured at the furthest upstream site (I-5 bridge), in the wetland and at the Lincoln Avenue Bridge located immediately downstream of

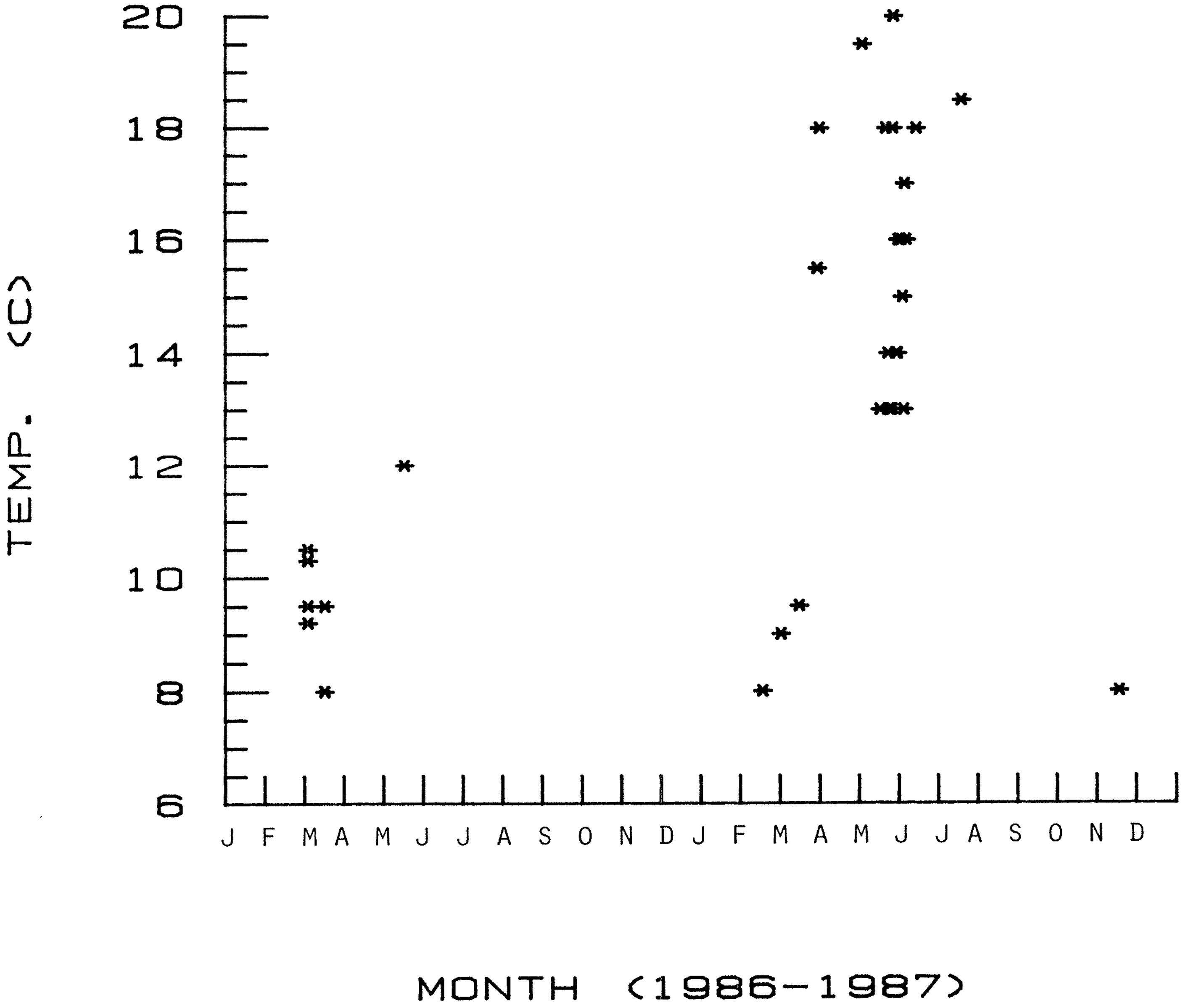


Figure 35. Water temperature in the system.

Table 9. Results of water property sampling at high slack tide on 18 June 1987. Site abbreviations are: I-5 = Interstate 5 bridge; RRB = railroad bridge; MTH = mouth of wetland; CH4 = landward end of channel 4 in wetland; LAB = Lincoln Ave. bridge; ESB = 11th St. bridge; CB = Commencement Bay. S = surface sample; B = bottom sample.

		Sites						
Water property		I-5	RRB	MTH	CH4	LAB	ESB	CB
Secchi depth	(m)	0.25	0.25	0.50	0.50	0.50	0.50	1.25
Salinity (°/₀₀)	S	0.043	0.125	0.377	0.144	0.102	0.096	20.779
	B	0.038	0.160	-	-	0.097	25.836	27.432
Temperature (°C)	S	14.6	14.3	15.6	17.1	14.3	14.4	14.4
	B	14.1	14.1	-	-	14.2	12.7	11.5
Dissolved oxygen (mg/l)	S	10.86	10.44	10.40	10.50	10.64	10.39	9.60
	B	10.80	10.30	-	-	10.56	9.01	9.03
Phosphate (µM)	S	1.58	1.65	2.06	2.22	1.77	2.03	1.95
	B	1.06	1.01	-	-	2.58	2.14	1.89
Nitrate (µM)	S	8.64	6.60	6.33	5.39	7.89	6.69	8.37
	B	8.38	6.63	-	-	11.50	10.70	13.52
Nitrite (µM)	S	0.59	0.57	0.67	0.89	0.62	0.68	0.71
	B	0.24	0.22	-	-	0.79	0.58	0.56
Ammonia (µM)	S	3.02	1.94	2.63	2.58	2.05	1.50	2.02
	B	2.81	2.14	-	-	7.34	5.93	2.97
Silicate (µM)	S	45.23	73.67	56.12	75.73	61.47	77.15	48.23
	B	105.70	82.22	-	-	135.57	43.54	27.55
Nitrogen:Phosphate	S	7.8	5.5	4.7	4.0	6.0	4.4	5.7
	B	10.8	8.9	-	-	7.6	8.0	9.0

the mouth of the wetland. In general, DO was relatively high in all samples, and areas of low DO were not encountered. The sites with highest DO were also high in dissolved inorganic nutrients (Table 9). All of these nutrients are required by plants, including phytoplankton, for growth, and the data indicate that phytoplankton growth is stimulated by higher nutrient concentrations in this portion of the estuary. The increased DO in the wetland may also be due to photosynthesis by benthic plants, including marsh angiosperms and algae. We noted an intense bloom of the filamentous green alga *Spirogyra* sp. on the flats during this period. Gas bubbles evident under the algal mat may have been trapped oxygen from algal productivity. Of note is the fact that all the nutrients we measured are generally in very high concentrations in sewage effluent. The data suggest that the sewage outfall from the Tacoma Treatment Plant, located ca. 100 m upstream of the mouth of the wetland, does have a significant effect (i.e., increased nutrients in the River) on water chemistry and plant productivity (i.e., high DO) in the immediate area. Runoff from agricultural land and streets may also be impacting water quality in the River. The area of influence may extend as far downstream as Commencement Bay, as indicated by the increased ammonium concentrations in bottom water (Table 9). Further study is required to evaluate effluent and runoff impacts on the Puyallup River. This is beyond the scope of the monitoring effort for the Lincoln Avenue wetland.

Sampling surface water at low tide indicated the effect of the wetland system on properties of water entering the intertidal portion of the system. Salinity was very high (ca. 7 ppt) at the site in channel 4 in the wetland relative to all other sites (Table 10). This suggests that water, which contains less than 1 ppt salt, enters the wetland and undergoes evaporation in pools on the flats during low tide. This process concentrates the salts, which then slowly drain into the channels and result in hypersaline conditions. The influence of tidal and evaporative processes causes salinity to vary widely during a tidal day. In order to survive in the system, the organisms living in the wetland must be adapted to withstand these wide fluctuations. This process occurs in natural wetland systems with a similar structure.

Table 10. Results of water property sampling at low slack tide on 18 June 1987. See Table 9 for site abbreviations. Only surface samples were collected during low tide.

	Sites						
Water property	I-5	RRB	MTH	CH4	LAB	ESB	CB
Salinity (°/₀₀)	0.032	0.032	0.668	7.195	0.358	0.267	1.985
Temperature (°C)	17.1	17.2	20.6	19.0	17.9	17.6	17.3
Dissolved oxygen (mg/l)	10.50	10.36	11.85	18.40	10.47	10.34	10.62
Phosphate (µM)	2.41	1.22	1.18	11.20	1.14	1.24	0.95
Nitrate (µM)	7.22	8.96	5.28	2.98	7.64	8.05	8.83
Nitrite (µM)	0.74	0.22	0.05	0.16	0.08	0.17	0.11
Ammonia (µM)	2.38	1.28	12.02	6.03	3.10	2.79	2.80
Silicate (µM)	79.89	32.93	112.20	251.30	110.78	122.93	149.09
Nitrogen:Phosphate	4.3	8.6	14.7	0.8	9.5	8.9	12.4

Water temperature, phosphate, nitrite, ammonium, silicate and DO showed pronounced peaks in the wetland (Table 10). Nitrate concentration, however, was substantially less in the wetland as compared to all other sites (Table 10). The very high DO value (ca. 18 mg/l) in channel 4 suggests again that productivity in the system, probably largely due to benthic autotrophs, was great. High nutrient concentrations indicate that these substances are either being trapped in the wetland and/or are being produced because of remineralization processes on the flats. Depletion of nitrate suggests that this nutrient is being utilized in the system, perhaps to a greater degree than the other nutrients. In addition, relatively low (i.e., <5) inorganic nitrogen to phosphate ratios indicated possible nitrogen limitation (Tables 9 and 10). The limited (i.e., 1 day) water chemistry data reveal the pervasive effect of the wetland system on the water column. This effect is in line with what occurs in natural wetland systems, which further proves that the Lincoln Avenue system is functioning in a manner similar to a natural system.

CONCLUSIONS

The general conclusion is that the Lincoln Avenue wetland system continues to serve the target resource groups for which it was designed. These resource groups include juvenile salmonids, shore birds, waterfowl and raptors. The relative ecological importance of the system to the resources appears, based on several quantitative measures, to have increased between 1986 and 1987. At present, the system provides superior ecological support of fish, fish prey and greater habitat diversity as compared to Parcel 5. The system continued to change dramatically in terms of basin morphometry, sediment characteristics, vegetation and benthic faunal assemblages. Smaller, but significant, changes were seen with fish use and bird use of the system.

The data in 1987 showed that the system is still in an early developmental stage. This is highlighted by the presence of a benthic fauna that is indicative of nascent environments. In addition, 2.5- to 25-fold increases in vegetation, infauna and epibenthos densities and/or standing stocks indicate that the system is undergoing a colonization process. These types of developmental patterns are typical of "new" environments (e.g., MacArthur and Wilson 1967).

The primary concerns regarding the fate of the system include sedimentation and water quality. The effects of the Tacoma Sewage Treatment Plant on water chemistry in the vicinity of the system suggest that the system is receiving significant quantities of effluent, but the impact of the effluent was not studied. Sedimentation was heavy during the 12 months following dike breaching. The main effects have been to decrease bottom depths in the mid-bay and reduce channel widths. These changes did not exclude salmonids from the system in spring because of high river flows. The intertidal portion of the system contained adequate water depths for fish during all stages of the tide in spring. During summer, especially during the major drought in 1987, water remained only in channels 3 and 4 during neap series low tides. This probably excluded all but small hardy fish from the system during summer low tides. Sedimentation was minimal on the flats. At Lincoln Avenue, sedimentation was expected to be substantial immediately after dike breaching. In natural systems, newly exposed to sediment sources, sedimentation is typically rapid for a period of time, after which the rate of sediment accrual declines. We expect that sediment accrual rate will decrease at Lincoln Avenue, and that it is premature at this time to conduct remedial action to remove sediments or reduce sedimentation. Monitoring over the next several years will allow the evaluation of the long-term effects of sedimentation on the system and facilitate the development of remedial action alternatives.

Finally, the system affects water chemistry, as shown by a limited study conducted in June 1987. These effects included the formation of hypersaline conditions, high dissolved oxygen, higher temperatures and either depletion or increases in inorganic nutrient concentrations. These effects on water chemistry follow, in direction of change but not necessarily magnitude, what would be expected to occur in natural systems. The data show that the system can uptake and produce nutrients, which is another important function common to natural wetland habitats.

RECOMMENDATIONS

System Maintenance Recommendations

The spatial patterns and general rate of sedimentation in the system should be monitored using the stakes we established on the flats and new stakes placed by surveyors in the channels and mid-bay. At the present time, we do not recommend sediment removal from the system. Trash that floats in from the river and is dumped from land accumulates in the intertidal and terrestrial habitats. The trash is unsightly and some materials may be toxic to the organisms. We recommend that illegal dumping be controlled by posting no-dumping signs in appropriate locations. Further, periodic clean up by local volunteers or paid workers may be necessary to keep the intertidal habitats free of trash. We strongly encourage developing the area as a nature preserve. This action will enhance the overall habitat quality of the system and may reduce illegal trash dumping.

Monitoring Recommendations

Permit-related Monitoring

Permit-related monitoring in 1988-1990 should follow the program outlined in the first report on the wetland (Thom et al. 1987). The program includes sediment, vegetation, salmonid prey, fish and bird sampling. The 1988 monitoring effort is presently underway and includes work designed to evaluate the functional performance of the system. The monthly samplings of vegetation in 1987 showed that the peak standing stock of plants occurred in July-August, which means that this period is the appropriate time to conduct sampling in the future to document peak standing stock. We found that juvenile salmon were preying principally on insects, and that the epibenthic pump sampler we used was not adequately sampling these latter organisms. We recommend that fish prey sampling include collections of insects that are either emerging from the sediment or are floating on the water surface. To evaluate whether fish (especially juvenile salmon) were actually residing for periods of time in the system, we recommend for 1988 that residence time experiments be conducted. These experiments can be carried out using traps placed at the mouth and fish marking techniques. These data will help interpret the functional performance of the wetland in terms of salmon prey production and juvenile salmon foraging and residence.

Additional Research Recommendations

Monitoring should be continued for as long as possible. It is difficult to presently predict when the system will be fully developed (i.e., when annual changes decrease substantially in degree). The Lincoln Avenue system is unique in size, design and many other features, and has thus far met functional criteria. As such, the system is valuable in advancing the understanding of wetland construction technology. Further, monitoring of functional aspects not considered as part of the design criteria (e.g., water processing) would be useful in technology development. The Port of Tacoma is required by permit to monitor the wetland through 1990. We strongly recommend that resource agencies jointly pursue a well-integrated and scientifically sound monitoring program beyond 1990. Furthermore, without data from reference sites, it is difficult to place the Lincoln Avenue system in perspective with regard to stage of development or functional performance relative to natural systems. Therefore, we strongly recommend that agencies develop reference areas and conduct sampling of sediment characteristics, vegetation, benthic invertebrates and fish in a manner comparable with the methodology employed at Lincoln Avenue.

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APPENDIX

Appendix Table A. Taxonomic composition and mean density (# m^{-2}), and standing crop (mg wet m^{-2}) of epibenthic organisms sampled in Lincoln Avenue Wetland, Puyallup River estuary, Washington, 17 March 1987.

Taxa	Life history stage	Vegetated Flat		Unvegetated Flat		Channel		Mid-Bay	
		#	mg	#	mg	#	mg	#	mg
Platyhelminthes	J/A	637.5	25			1500.0	50	125.0	38
Rotifera	J/A	5000.0	25	87.5	5	750.0	25	375.0	13
Nematoda	J/A	48312.5	69	8887.5	11	664000.0	1150	276875.0	500
Oligochaeta	J/A	5737.5	208	325.0	16	16750.0	3025	4250.0	650
Acarina	J/A	50.0	5					250.0	25
Cladocera									
Daphnidae	J	12.5	28	12.5	1				
Bosmina longirostris	A	112.5	6						
Chydorus sp.	A	12.5	1						
C. sphaericus	A	700.0	19	200.0	6	1250.0	75	1125.0	113
Podocopa	J/A	200.0	6					250.0	13
Copopoda	N	5587.5	25	600.0	8	7500.0	125	25500.0	175
Calanoida	C							250.0	25
Harpacticoida	A	175.0	18			250.0	25	1250.0	125
"	C	5225.0	25	500.0	6	4750.0	75	1750.0	150
"	ECF	125.0	13						
Ectinsomatidae	ECF							250.0	25
Microarthridion littorale	A	200.0	19	462.5	8	49000.0	625	98500.0	1163
"	C	600.0	6	119000.0	600	162125.0	575		
"	ECF	25.0	3	37250.0	575	36375.0	500		
"	MP	50.0	1	3500.0	25	1500.0	63		
Tachidius discipes	A	4787.5	50	287.5	5	1250.0	75	750.0	50
"	C	100.0	5	75.0	5				
"	ECF	4150.0	41	312.5	8	2750.0	100	1125.0	50
"	MP	25.0	1						
Huntemannia jadensis	ECF							250.0	25
Leimia vaga	A							1250.0	125
"	C					500.0	25	3125.0	113
"	ECF					500.0	50	2000.0	100
Mesochra rapiens	A	8400.0	45	737.5	6	5250.0	125	1500.0	50
"	ECF	10350.0	86	975.0	10	3500.0	125	1250.0	75
Cyclopoida	A					500.0	50		
"	C					250.0	25		
Cyclopidae	A	125.0	13			250.0	25	250.0	25
"	C	300.0	11	150.0	5	500.0	50		
Halicyclops sp.	A	412.5	11	12.5	1				
Cyclops bicuspidatus	A	12.5	1	12.5	1				
"	C					250.0	25		

Appendix Table A - cont'd.

Taxa	Life history stage	Vegetated Flat #	Vegetated Flat mg	Unvegetated Flat #	Unvegetated Flat mg	Channel #	Channel mg	Mid-Bay #	Mid-Bay mg
Insecta									
Thysanura	J/A	12.5	1						
Collembola	L	25.0	3						
Chironomidae	L	287.5	9	12.5	1	500.0	50	625.0	38
Tardigrada	J/A	10675.0	80	50.0	4	1750.0	75	750.0	25
Teleostei	E					250.0	25		
unidentified	EC	62.5	11	25.0	2	5250.0	125	8500.0	200
Total		111812.5	873	14400.0	120	929000.0	7350	631875.0	5000

Life History Codes:

A = adults
C = copepodids
EC = egg cases
ECF = egg-carrying female
J/A = juveniles and adults, undifferentiated
J = juveniles
L = larvae
MP = mating pair
N = nauplii
P = pupae
* = <1 mg

Appendix Table B Taxonomic composition and mean density (# m^{-2}), and standing crop (mg wet m^{-2}) of epibenthic organisms sampled in Lincoln Avenue Wetland, Puyallup River estuary, Washington, 13 April 1987; see Appendix Table A for list of life history codes.

Taxa	Life history stage	Vegetated Flat		Unvegetated Flat		Channel		Mid-Bay	
		#	mg	#	mg	#	mg	#	mg
Platyhelminthes	J/A	814.8	81	3777.8	111	5555.6	222	1355.6	46
Rotifera	J/A	2392.6	105	25533.3	109	32777.8	287	3911.1	31
Nematoda	J/A	27177.8	160	74800.0	131	323518.5	370	39044.4	77
Oligochaeta	J/A	32948.1	289421777.8	2964	3425.9	324	3266.7	571	
Cladocera									
Daphnidae									
Daphnia sp.	J			44.4	4	370.4	74		
Bosmina longirostris	A					1666.7	111	100.0	6
C. sphaericus	A	1122.2	57	1288.9	116	555.6	28	44.4	4
Podocopa	J/A	22.2	1						
Copopoda	N	19222.2	78	30377.8	127	6388.9	83	24133.3	27
Calanoida									
Diaptomus sp.	C	222.2	22						
Harpacticoida	A					925.9	93	222.2	22
	N			6933.3	4	67592.6	204	14888.9	28
	C	20588.9	79	75822.2	140	102777.8	259	19755.6	50
	EC			666.7	22				
Ectinsomatidae	A					925.9	93	233.3	23
	ECF							11.1	1
	MP					740.7	37	533.3	27
Microarthridion littorale	A	777.8	78	3022.2	93	40555.6	639	21866.7	324
	C			2000.0	98	90185.2	287	24855.6	86
	ECF					7685.2	231	5311.1	130
	MP			88.9	4	2222.2	83	377.8	10
Tachidius discipes	A	10081.5	161	31466.7	131	11851.9	398	7166.7	77
	C	55888.9	181	95800.0	220	22129.6	287	35233.3	137
	ECF	2177.8	123	9422.2	131	4444.4	222		
	MP			177.8	9				
Nitocra sp.	ECF	11.1	1						
Huntemannia jadensis	C					370.4	37	1688.9	49
"	J/A			1822.2	93				
Leimia vaga	A			888.9	89	1296.3	93	11.1	1
"	C					11666.7	148	6300.0	54
"	ECF					370.4	37	55.6	6
Mesochra lilljeborgi	A					370.4	37		
M. rapiens	A	20318.5	160	8844.4	109	3888.9	222		
"	ECF	8029.6	140	4822.2	131	555.6	56	311.1	27
Cyclopidae	C	1400.0	79	377.8	38			655.6	10
	ECF	11.1	1						
Halicyclops sp.	A	455.6	46			1111.1	111		
"	ECF	11.1	1						
Oithonidae	A					277.8	28		

Appendix Table B - cont'd.

Taxa	Life history stage	Vegetated Flat		Unvegetated Flat		Channel		Mid-Bay	
		#	mg	#	mg	#	mg	#	mg
Insecta									
Chironomidae	L			888.9	711				
Tardigrada	J/A	262751.9	1954	13911.1	173	2870.4	176	588.9	28
Teleostei	E					277.8	111		
Larvacea	J/A							11.1	1
Total		466203.7	6382	414777.8	5782	749351.9	5389	211933.3	1851

Life History Codes:

A = adults
C = copepodids
EC = egg cases
ECF = egg-carrying female
J/A = juveniles and adults, undifferentiated
J = juveniles
L = larvae
MP = mating pair
N = nauplii
P = pupae
* = <1 mg

Appendix Table C Taxonomic composition and mean density (# m^{-2}), and standing crop (mg wet m^{-2}) of epibenthic organisms sampled in Lincoln Avenue Wetland, Puyallup River estuary, Washington, 19 May 1987; see Table A for list of life history codes.

Taxa	Life history stage	Vegetated Flat		Unvegetated Flat		Channel		Mid-Bay	
		#	mg	#	mg	#	mg	#	mg
Platyhelminthes	J/A							333.3	26
Rotifera	J/A			111.1	11				
Nematoda	J/A	4988.9	14	4400.0	24	2648.1	9	22259.3	37
Polychaeta									
Nereis sp.	J							74.1	7
Oligochaeta	J/A	5611.1	167	11.1	1	12185.2	602	11000.0	1163
Cladocera	EC								
Daphnidae	J								
Daphnia sp.	J	55.6	11	88.9	3	92.6	6		
Bosmina longirostris	A	244.4	13	900.0	26	166.7	9	3370.4	30
Chydorys sphaericus	A	844.4	10	22.2	2	1388.9	15	1148.1	30
Podocopa	J/A	400.0	11	111.1	11				
Copopoda	N			11.1	1				
Calanoida	C								
Diaptomus sp.	A			11.1	1				
Harpacticoida	A	111.1	11			222.2	7		
	J/A							1481.5	30
Ectinsomatidae	A							407.4	22
	MP							148.1	7
Microarthridion littorale	A	111.1	11	133.3	12	333.3	7		
J/A								29407.4	181
	ECF							259.3	26
Tachidius triangularis	ECF	11.1	1						
Tachidius discipes	A	9733.3	60	13455.6	69	13018.5	72	20407.4	115
	C	455.6	12	4244.4	26	1166.7	9	5333.3	30
	ECF	466.7	12	266.7	12	518.5	9	1185.2	26
	MP			22.2	1				
Huntemannia jadensis	J/A			33.3	1	37.0	4	10703.7	52
Leimia vaga	A	111.1	11	111.1	11	203.7	9	407.4	26
	C	11.1	1	11.1	1				
Mesochra rapiens	A	3577.8	26	3166.7	29	3018.5	9	4185.2	30
	ECF	144.4	13	44.4	1	314.8	6	296.3	30
Cyclopoida									
Cyclopidae	A					18.5	2		
	C	244.4	13	733.3	26	370.4	9	185.2	11
Halicyclops sp.	A	77.8	2	11.1	1	92.6	6	111.1	11
Cyclops bicuspidatus	A	266.7	16	266.7	13	37.0	4	37.0	4
	J/A					425.9	6		
Eucyclops speratus	A	22.2	1						
Paracyclops fimbriatus	A	11.1	1			74.1	4	111.1	11
	ECF	11.1	1						

Appendix Table C - cont'd.

Taxa	Life history stage	Vegetated Flat		Unvegetated Flat		Channel		Mid-Bay	
		#	mg	#	mg	#	mg	#	mg
Insecta									
Diptera	L	22.2	1	11.1	1				
Chironomidae	L	166.7	11	555.6	1	648.1	26	1888.8	37
Tardigrada	J/A	3366.7	12	20288.9	93	9425.9	35	1148.1	11
Total		27077.8	434	60044.4	938	46407.4	865	115888.9	1952

Life History Codes:

A = adults
C = copepodids
EC = egg cases
ECF = egg-carrying female
J/A = juveniles and adults, undifferentiated
J = juveniles
L = larvae
MP = mating pair
N = nauplii
P = pupae
* = <1 mg

Appendix Table D. Taxonomic composition and mean density (# m^{-2}), and standing crop (mg wet m^{-2}) of epibenthic organisms sampled in Lincoln Avenue Wetland, Puyallup River estuary, Washington, 16 June 1987; see Table A for list of life history codes.

Taxa	Life history stage	Vegetated Flat		Unvegetated Flat		Channel		Mid-Bay	
		#	mg	#	mg	#	mg	#	mg
Hydrozoa	J/A	22.2	2	11.1	1	44.4	4		
Platyhelminthes	J/A	522.2	7	22.2	2	1155.6	96	66.7	7
Nematoda	J/A	844.4	6	1300.0	7	13111.1	42	1722.2	10
Polychaeta	L					22.2	2		
Oligochaeta	J/A	3011.1	170	2977.8	159	18688.9	871	6122.2	444
Cladocera									
Daphnidae									
Daphnia sp.	J	55.6	4	22.2	2			11.1	1
	J/A			11.1	1			11.1	1
Bosmina longirostris	A	22.2	2	11.1	1	1377.8	42	55.6	3
Chydorus sphaericus	A	166.7	4	66.7	4				
Podocopa	J/A	455.6	31						
Copopoda	N	55.6	3			977.8	27		
Calanoida	N							11.1	1
	C	11.1	1			22.2	2	11.1	1
Paracalanus sp.	A					22.2	2		
Diaptomus sp.	C			11.1	1				
	J/A	44.4	2						
Harpacticoida	A	11.1	1						
	J/A	66.7	2	111.1	2	7644.4	42	877.8	10
Ectinsomatidae	J/A					5177.8	38	588.9	9
	ECF					555.6	33	188.9	9
	MP					44.4	2		
Microarthridion littorale	A	22.2	1	22.2	1	111.1	11		
	J/A					20711.1	142	2033.3	16
	ECF					3844.4	24	1666.7	19
Tachidius discipes	A	1411.1	11	2866.7	17	34466.7	193	9688.9	64
	C	88.9	3	222.2	6	20800.0	53	555.6	9
	ECF	200.0	4	200.0	6	4177.8	64	4833.3	47
Huntemannia jadensis									
	J/A					1800.0	42	4400.0	67
	ECF					888.9	22	1166.7	22
Leimia vaga	A			11.1	1				
	J/A					22111.1	162	166.7	8
	ECF					688.9	24		
M. rapiens	A	3800.0	13	1211.1	6	177.8	13		
	J/A			211.1	1				
	C			55.6	1				
	ECF	200.0	4	200.0	4				
Cyclopoida	C							11.1	1
Cyclopidae									
	C	77.8	3	33.3	2	88.9	4		
	ECF					222.2	22		

Appendix Table D - cont'd.

Taxa	Life history stage	Vegetated Flat		Unvegetated Flat		Channel		Mid-Bay	
		#	mg	#	mg	#	mg	#	mg
Halicyclops sp.	A	44.4	2	77.8	3			11.1	1
	J/A					4244.4	42	1444.4	8
Cyclops bicuspidatus	J/A	144.4	3	122.2	6	466.7	20	66.7	3
Eucyclops agilis	J/A	244.4	2						
E. speratus	A	33.3	1						
Paracyclops fimbriatus	A			22.2	2			22.2	2
Oithonidae	A					22.2	2	11.1	1
Mysidacea									
Mysidae									
Neomysis mercidis	J					677.8	147		
Gammaridea									
Gammaridae	J			44.4	4				
Corophiidae									
Corophium sp.	J					222.2	22		
Insecta									
Diptera	L	11.1	1	11.1	1				
Chironomidae	L	144.4	14	133.3	16	111.1	11	66.7	3
Tardigrada	J/A	288.9	3	422.2	4				
Total		12000.0	306	10411.1	262	164677.8	2229	35822.2	796

Life History Codes:

A = adults
C = copepodids
EC = egg cases
ECF = egg-carrying female
J/A = juveniles and adults, undifferentiated
J = juveniles
L = larvae
MP = mating pair
N = nauplii
P = pupae
* = <1 mg