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

Phase I Report: Construction and Initial Monitoring,
July 1985-December 1986

by

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TABLE OF CONTENTS

	Page
LIST OF TABLES.....	iii
LIST OF FIGURES.....	v
ACKNOWLEDGMENTS.....	vi
EXECUTIVE SUMMARY.....	vii
INTRODUCTION.....	1
CHRONOLOGY OF PHASE I ACTIVITIES.....	5
MATERIALS AND METHODS.....	7
Transplanting.....	7
System Monitoring.....	10
Parameter Selection.....	10
Habitat Distributions.....	12
Monitoring Methods.....	12
RESULTS.....	23
Habitat Distributions.....	23
Transplanting.....	23
System Monitoring.....	25
Water Chemistry.....	25
Sediments.....	25
Vegetation.....	30
Infauna.....	43
Epibenthic Crustacea.....	43
Planktonic Zooplankton.....	51
Fish.....	56
Birds.....	62
Habitat Comparisons.....	66
DISCUSSION.....	68
RECOMMENDATIONS.....	75
System Maintenance Recommendations.....	75
Monitoring Recommendations.....	75
Permit-related Monitoring Program.....	77
Additional Research Recommendations.....	79
Reference Systems.....	81
LITERATURE CITED.....	83

LIST OF TABLES

Table	Page
1. <u>Carex lyngbyei</u> transplanting results.....	11
2. Fish collections (no. beach seine sets) made in Lincoln Street wetland, Puyallup River estuary, during initial six months of marsh establishment.....	20
3. Areal coverage of habitats at the Lincoln Street wetland system.....	24
4. Water chemistry values at the Lincoln Street wetland in early spring (March 1986) and late summer (August 1986).....	26
5. Changes in ground elevation in early spring (March 1986) at stations on Flat 4.....	27
6. Summary of regression analysis of plant shoot length (Y) versus shoot dry wt (X).....	39
7. Biomass and net primary production (NPP) of <u>Carex lyngbyei</u> and <u>Typha</u> sp. in the Lincoln Street wetland.....	42
8. Total infauna densities pre-breach (October 1985) and post-breach (March 1986).....	44
9. Combined taxonomic composition and standing stock of epibenthic organisms sampled in the Lincoln Street Wetland, October 1985 and March 1986.....	45
10. Density (den.) and standing crop (s.c.) composition (%) and diversity of epibenthic organisms on littoral flat in Lincoln Street Wetland before and after breaching (four transect locations) of the Puyallup River dike, February 1986.....	48
11. Combined taxonomic composition and standing stock of pelagic organisms sampled in the Lincoln Street Wetland, October 1985 and March 1986.....	52
12. Density and standing crop composition (%) and diversity of pelagic organisms sampled in the Lincoln Street Wetland pre- (October 1985) and post-breach (March 1986).....	54
13. Fish density (no. per 100 m ²) of fishes captured in Lincoln Street wetland, Puyallup River estuary, during initial six months of marsh establishment.....	57

Table	Page
14. Fish standing crop (g per 100 m ²) of fishes captured in Lincoln Street wetland, Puyallup River estuary, during initial six months of marsh establishment.....	60
15. Maximum observed number of individuals of each bird species in the wetland system.....	63
16. Percent each bird type comprised of the total number of individuals observed on each date.....	64
17. Areal coverage of habitat types at the Parcel 5 and Lincoln Street wetland systems.....	67
18. The schedule of monitoring studies in 1987.....	78

LIST OF FIGURES

Figure	Page
1. Location of parcel 5 and the Lincoln Street wetland.....	2
2. Aerial view of the Lincoln Street wetland system taken 31 March 1986.....	6
3. Location of flats, channels and sampling sites.....	8
4. Trace of water temperature in channel 3 16-26 March 1986.....	28
5. Grain size distributions.....	29
6. Photograph of vegetation on flat 4 on 22 August 1986.....	31
7. Profile of <u>Carex</u> parameters along transect 4.....	32
8. Plant densities on 22 August 1986.....	34
9. <u>Carex</u> shoot-length dry-weight relationship for plants on flat 3.....	35
10. <u>Carex</u> shoot-length dry-weight relationship for plants on flat 4.....	36
11. <u>Carex</u> shoot-length dry-weight relationship for Big Beef Creek plants.....	37
12. <u>Typha</u> shoot-length dry-weight relationship for plants on flat 4.....	38
13. <u>Carex</u> shoot-length frequency for plants on flats 3 and 4.....	40
14. Bird abundance in habitats over time in 1986.....	65

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EXECUTIVE SUMMARY

The present report summarizes the construction of a 9.6 acre wetland system adjacent to the tidally influenced portion of the Puyallup River near Lincoln Street. The report covers Phase I of the work which spans the period July 1985-December 1986, and includes a chronology of construction, marsh transplanting, and results of the first year of environmental monitoring. The Lincoln Street wetland was constructed, in part, to mitigate for filling of wetlands at Parcel 5 located approximately 1 mile downstream. Parcel 5 contained habitats that were relatively high in quality with regard to support of wetland-associated birds. Parcel 5, due to a very restricted connection with the river (i.e., a small conduit through the river levee affixed with a faulty tidegate), did not provide appreciable support for salmonid fish populations.

Construction of the wetland included building of a new dike to surround the system, excavation of fill material to form intertidal flats and channels, rerouting of a buried oil pipeline, breaching of the dike to connect the river to the wetland, and transplanting sedge plants onto the flats. Construction began in July 1985, the dike was breached in February 1986, and marsh plants were planted in March-July 1986.

The system that resulted consisted of 5.38 acres of wetland and 4.19 acres of upland habitats. This mix of habitats was designed to, and the results of the environmental monitoring showed that it did, attract the variety of target species designated by resource agencies. The target groups included juvenile salmon, shorebirds, waterfowl,

raptors and small mammals. In particular, the Lincoln Street wetland system provided far superior support for outmigrating juvenile salmonids as compared to Parcel 5. Prey resources for the salmon were abundant in the system, and the channels and deeper portions of the tidally influenced portion of the system provided rearing habitat for the juvenile fish. Monitoring also showed that shorebirds and waterfowl inhabited the system in relatively high numbers. Thirty-four species of birds were noted in the system during spring and summer, and individuals of several species were observed to be feeding within the marsh. Siting of a Bar-tailed Godwit in the wetland constituted a new distributional record for this species.

Initial survival of 37,150 transplanted sedge shoots was approximately 100%. Growth of the sedge and new shoot initiation was strong during the first growing season, and resulted in a four-fold increase in the number of plants by the end of summer.

It is concluded that the system supported target resources, and therefore did serve as mitigation for Parcel 5. The wetland system is in the initial stages of development, and it is anticipated that full development of the system will proceed during the next several years. A monitoring program will document the development process. Marsh establishment will be enhanced through transplanting.

INTRODUCTION

In spring of 1984, the Port of Tacoma filled a 9.6 acre parcel of land containing wetland and upland habitats known as Parcel 5, located adjacent to the Puyallup River near the 11th St. Bridge (Figure 1). The section 404 permit allowing the fill was granted provided two conditions were satisfied: (1) the environmental impacts of the fill be mitigated through construction of a comparably sized or larger wetland, and (2) the ecological "performance" of the new wetland be monitored and the wetland be maintained in perpetuity.

The general area including Parcel 5 was originally part of the Puyallup River estuarine wetlands. During the late 1940s, a levee was constructed by the U.S. Army Corps of Engineers which separated the wetland from the Puyallup River. Subsequently, the site was used for dredged material disposal. A faulty tidegate through the levee provided intermittent flooding of the lower elevations within Parcel 5 and resulted in the maintenance of some wetland habitats. Boulé and Dybdahl (1981) described Parcel 5 as a freshwater tidal wetland with cattails, spike rush, bulrush, redtop, and occasional saltgrass. Biologists for the Puyallup Tribe had observed the site on several occasions over the years and noted a variety of wildlife species. The species include marsh hawks, Canada geese, great blue heron, and California quail (Albright et al. 1984). A Habitat Evaluation Procedure (HEP) analysis performed just prior to filling of Parcel 5 in 1984 indicated that Parcel 5 contained 2.08 acres of wetland habitat (Albright et al. 1984). The HEP analysis showed that the area had a low (<1) habitat suitability

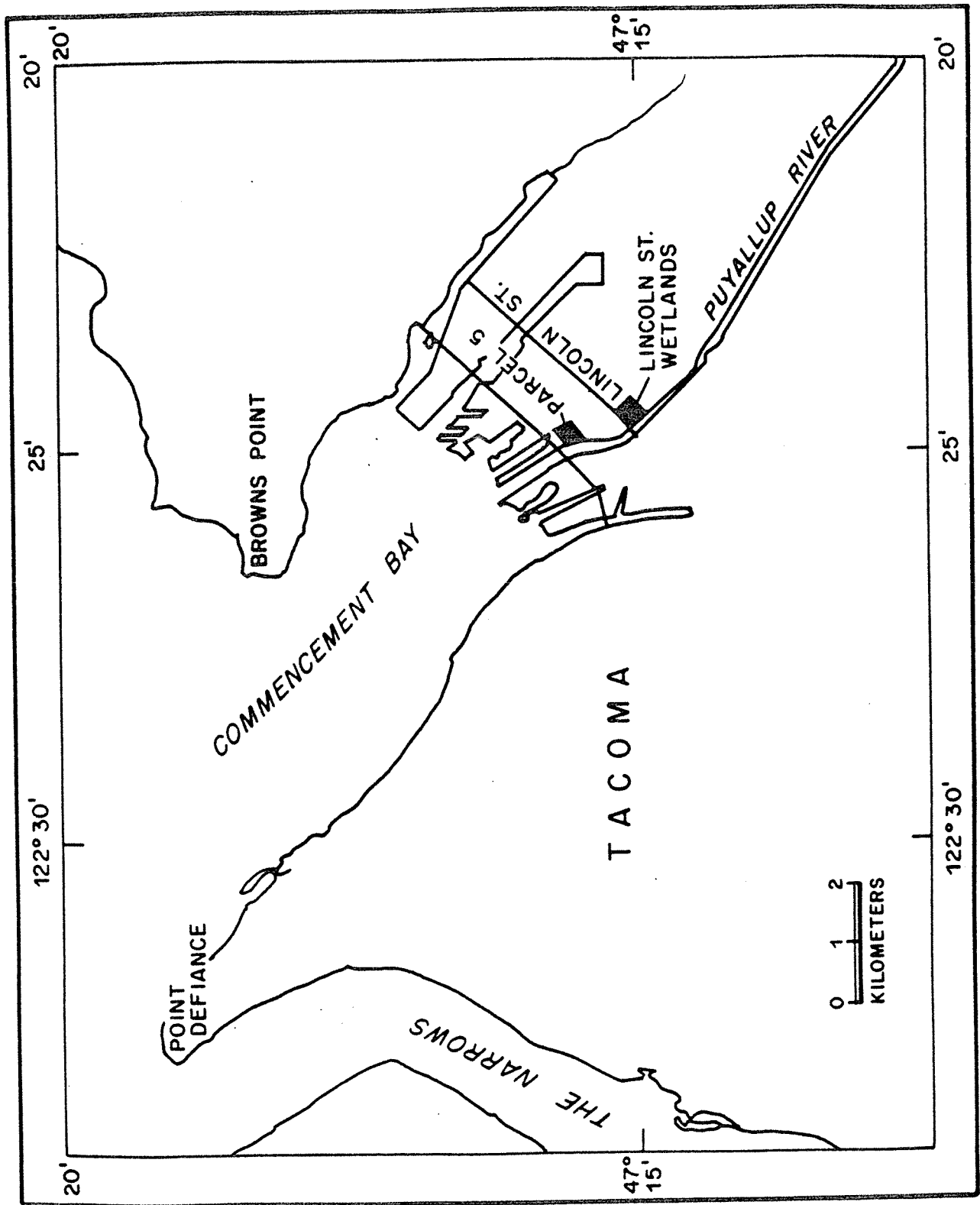


Figure 1. Location of parcel 5 and the Lincoln Street wetland.

for three selected salmonid taxa and a high suitability for seven selected wetland associated bird species.

The site selected for the mitigation wetland was located 3/4 mile upstream from Parcel 5, at the junction of Lincoln Street and the Puyallup River (Figure 1). The site was chosen primarily due to its proximity to Parcel 5 and the Puyallup River estuary, and the fact that the land was owned by the Port. Our work included development of a conceptual design for the wetland system at Lincoln Street, establishment of a marsh, and ecological monitoring of the system. The conceptual design and recommended wetland establishment methodology was reported previously (Thom et al. 1985). The criteria for the design included establishment of habitats, based on areal extent, to support several target resource groups. The groups, and the percentage of surface area of the wetland devoted to these resources, were designated by resource agencies to be 50% for juvenile salmonids, 20% for waterfowl, 10% for shorebirds, 10% for raptors and 10% for small mammals. The conceptual design for the wetland included mudflats, tidal channels, marshes, trees, grassland, and shrubland. These habitats were included in the design based on the current understanding of habitat preferences of the various target resources. Considerable habitat overlap occurs among the target resources, a fact that minimized the problem of assuring that design criteria were met.

The system that was constructed at Lincoln Street consisted of a total of 5.38 acres of wetland habitat which included a sedge marsh, a cattail marsh, and unvegetated mudflats and channels. The system also

contained 4.19 acres of upland habitat. These latter habitats included grasslands, shrubs, trees, and a berm. This mix of habitats was designed to, and we found that it did, attract the variety of target species as required by the resource agencies.

The present report summarizes wetland construction and results of the first phase of wetland system monitoring. Phase I, which spanned the period July 1985-December 1986, included wetland construction and the first year of monitoring. The purpose of monitoring was to test whether the construction of the Lincoln Street wetland successfully mitigated for the loss of wetland habitats at Parcel 5. Due to the fact that constructed wetlands generally require several years to reach full functioning potential, the monitoring program is a multiyear effort. The objectives of the Phase I work were to:

- 1) establish a sedge marsh on intertidal flats in the system;
- 2) sample the transplanted marsh plants to evaluate survival, spread, and growth of the plants;
- 3) sample selected physical, chemical, and biological parameters to evaluate the functioning of the system with regard to target resources;
- 4) evaluate the stage of development of the Lincoln Street wetland plants with reference to Parcel 5 and one natural wetland; and,
- 5) make recommendations on how to maintain a functioning wetland system.

CHRONOLOGY OF PHASE I ACTIVITIES

Ground breaking took place on 9 July 1985. Excavation and dike construction commenced approximately 1 week later, and continued through August. On 30 August, a pocket of soil containing very high concentrations of polychlorinated biphenyls (PCB's) was uncovered near the mouth of the wetland. Soils testing determined that the spatial extent of the contamination was limited. Excavation was halted while contaminated soil was removed from the site. Pre-breach biological and sediment grain size sampling was conducted on 24 October. Delays in moving an oil pipeline and gaining final approval for the new flood control dike delayed dike breaching until 20 February 1986. Two days after dike breaching, flooding deposited extensive amounts of wood debris onto the flats. Virtually all of this material was flushed out of the wetland within a week. The first post-breach monitoring studies were conducted on 5 March 1986. Transplanting operations were conducted over the period of 10 April-3 July 1986. Monitoring continued periodically through December.

The major construction and transplanting events were recorded on videotape and 35 mm color slides. Vertical aerial 9 x 9-in color photographs with a scale of 1 in = 200 ft were taken on 31 March 1986 (Fig. 2). Poor weather conditions in fall prevented similar photographs from being taken until 25 November.

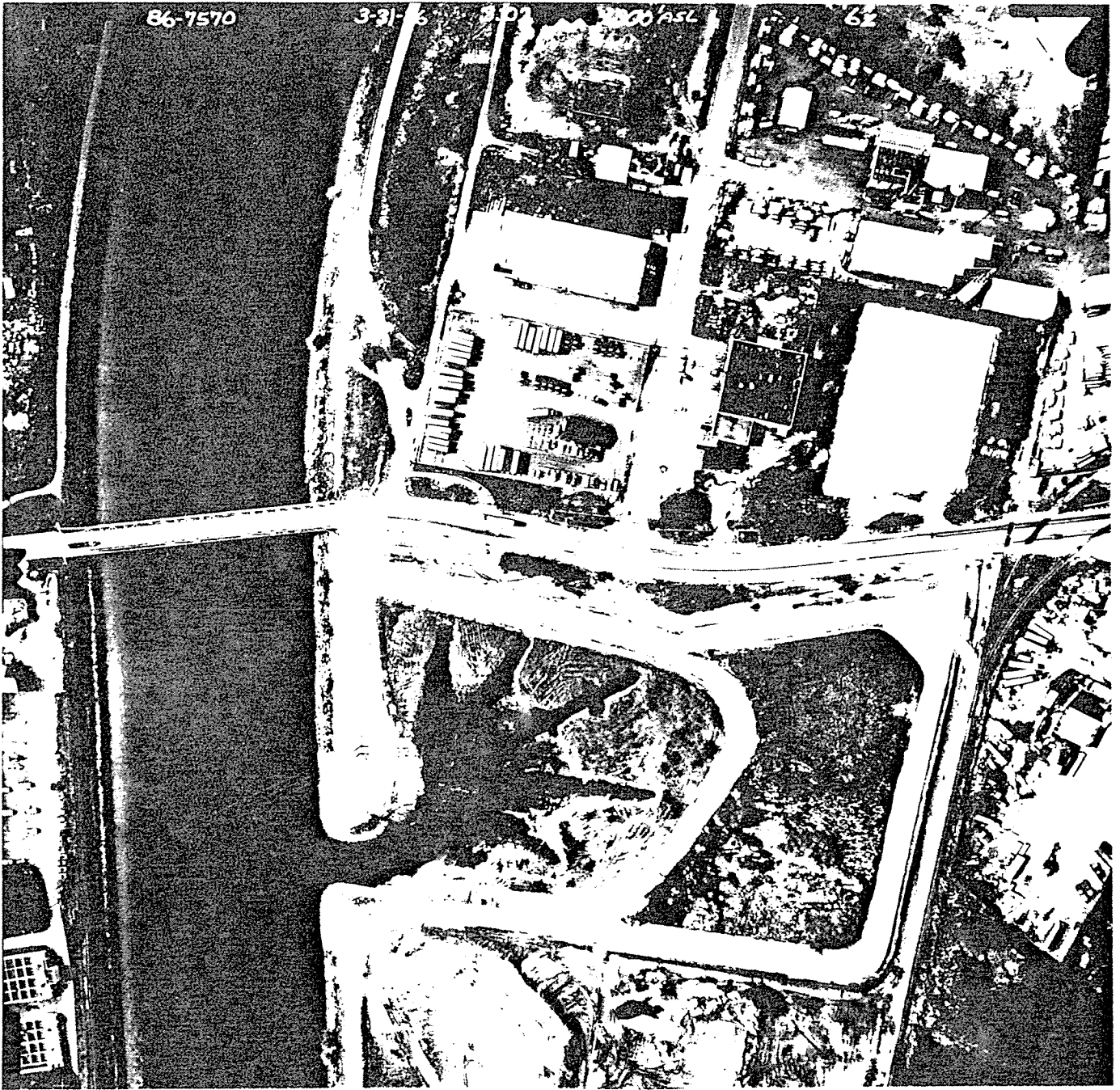


Figure 2. Aerial view of the Lincoln Street wetland system taken 31 March 1986.

MATERIALS AND METHODS

Transplanting

Based on a review and analysis of wetland construction techniques conducted earlier, we chose to concentrate on construction of a sedge marsh at Lincoln Street (Thom et al. 1985). Culms (a shoot) with attached roots and rhizomes of Lyngby's sedge, Carex lyngbyei Hornem., were transplanted by hand onto the flats. Fifteen-thousand culms were obtained from the Wave and Beach Grass Nursery (Florence, Oregon). These plants were planted onto flat 4. Twenty-two thousand one-hundred fifty culms were obtained from the marsh at Big Beef Creek estuary (122°47'W, 47°39'N) near Seabeck, located on Hood Canal, and were transplanted onto flats 1, 2, 3, 6, 7 and 8 (Fig. 3). Part of our sampling was conducted to test for differences in success of transplants from different source areas. The decision was made not to plant flat 5 in order to evaluate natural colonization by plants and other organisms with colonization enhanced by transplanting. This information is of basic importance when determining the optimal strategy for constructing wetlands, and can be used to better estimate the overall effort and cost of a wetland construction project.

The procedure used to collect transplant material at Big Beef Creek was as follows. Plants located at the leading edge of the marsh were extracted by inserting a shovel immediately next to a clump of plants, and raising the plants and attached sediments with the aid of the shovel. The clump was carefully removed from the ground, shaken to remove loose sediment, and placed in a 133-L (30 gal.) plastic bag. In

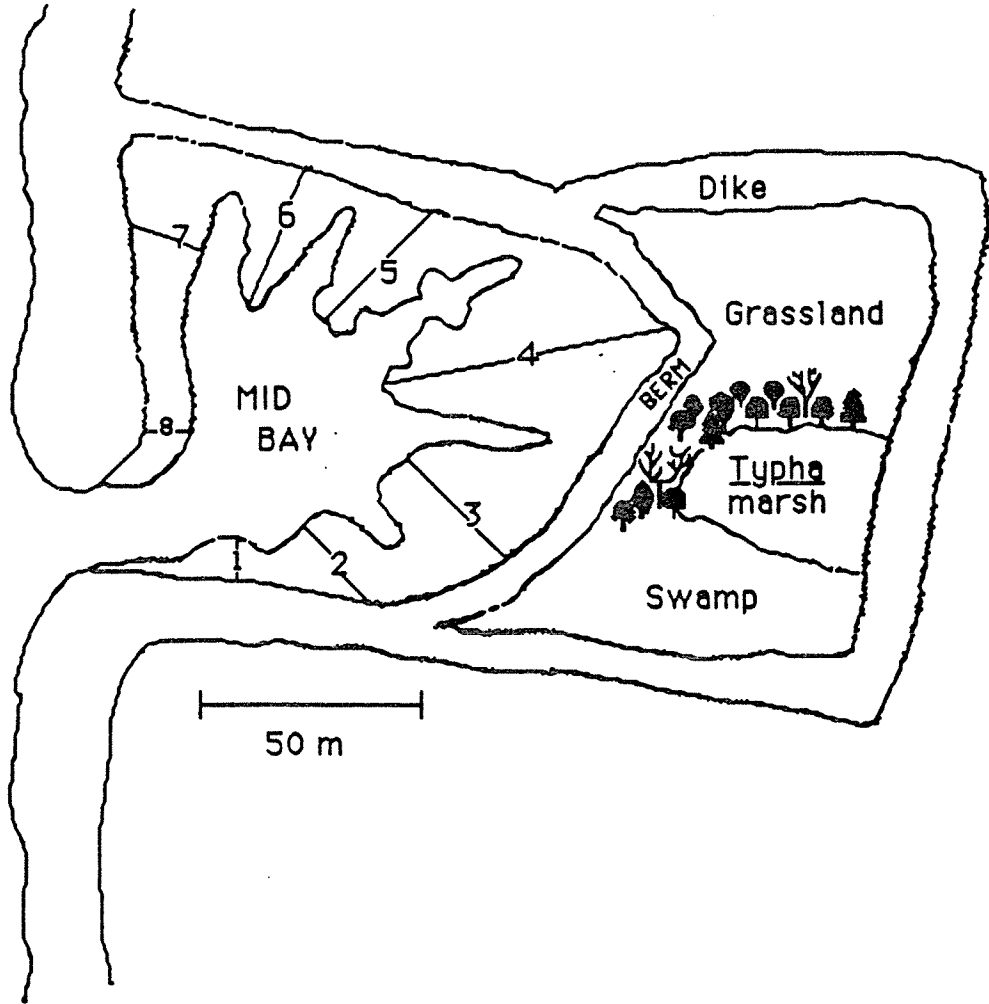


Figure 3. Location of flats, channels and sampling sites.

areas where plants were growing in loose sandy sediments, individual shoots were removed from the sediment by grasping the shoot near its base and pulling upward with a slow and steady motion. A total of fifty culms was placed in each bag. The plants and sediments were kept moist over night and transplanted the next day. In general, 5,000 culms were collected on one day and transplanted the next day.

The planting technique consisted of simply inserting a shovel to maximum blade depth (approximately 25 cm) into the sediment, creating a wedge-shaped hole by pushing the shovel sideways at a right angle to the face of the shovel blade, placing the culms into the wedge-shaped hole to a depth that covered the below ground segment of the plant, removing the shovel, and gently tapping the hole closed around the shoots. The initial planting density for the first 10,400 culms was 3 culms per hole, with a distance between holes of 0.5 m. Plantings at this density were carried out at the lower perimeter of flats 3 and 4, in a band approximately 10 m wide. Observations made approximately 2 weeks and again 1 month following the first transplanting indicated that culm survival was 100% and below ground spreading was occurring. As this initial success was above expected levels, we subsequently planted at a density of 2 culms per hole with 0.75-m spacing between holes. Uneven grading on the flats resulted in pools of standing water at low tide. These pools were not planted due to the fact that Carex does not occur naturally in areas of standing water. Transplanting was carried out approximately every 2 weeks until all flats were planted. Transplanting at 2-week intervals allowed us to evaluate the success of each previous transplanting effort with regard to survival of the plants. Areas that

showed poor survival were replanted during the next transplanting operation. The average collection rate at Big Beef Creek was 361 plants/person/hour (range = 300-400 plants/person/hour). The average transplanting rate was 167 plants/person/hour (range = 150-200 plants/person/hour). Most of the transplanting was conducted during cloudy, relatively cool weather, which may have reduced desiccation stress on the plants. Initial transplanting densities and dates of transplant operations are shown in Table 1.

System Monitoring

Parameter Selection

Chemical, physical, and biological parameters were selected to provide information on the performance of the system. The areal cover of the various habitats was mapped in order to calculate total areas of each habitat, and to quantify an increase or decrease in habitat distribution over time. Water chemistry data was taken to evaluate nutrients available to the plants, and the salinity and temperature regimes. Sediment sampling was conducted to determine sedimentation characteristics within the tidally influenced portion of the system. Marsh vegetation parameters included those that would allow us to evaluate the survival, spread, and growth of the transplanted plants. Benthic and planktonic invertebrate sampling was conducted to determine prey resources available to juvenile salmonids and other fish species. Fish and bird assemblage parameters were chosen to document the numbers, kinds, and temporal aspects of occurrences in the system.

Table 1. Carex lyngbyei transplanting results.

Flat no.	Transplanting dates	Total no. shoots transplanted	Starting average shoot density (no./m ²)	Total no. shoots 22 Aug 86	Average shoot density		Density change
					22 Aug 86 (no./m ²)	22 Aug 86 (no./m ²)	
1	5 June	1,500	6.9	3,924	18.0		+2.6X
2	15 May, 5 June	3,250	4.2	13,446	17.6		+4.1X
3	10 April, 15 May	6,750	2.6	51,858	20.1		+7.7X
4	11, 23, 24 April	14,900	3.5	63,705	15.0		+4.3X
5	-	0	0	0	0		
6	5 June, 20 June	3,750	4.1	5,278	5.8		+1.4X
7	20 June, 3 July	5,000	3.7	10,116	7.4		+2.0X
8	3 July	2,000	6.5	2,855	9.3		+1.4X
Over all flats				37,150	151,182	14.5	+4.1X

Habitat Distributions

A polar planimeter was used to determine the surface area of habitats within the system. The planimeter was calibrated and the areal measurements were made on the wetland creation grading plan produced by Whitacre Engineers, Inc., for the Port of Tacoma (dated 28 May 1986).

Monitoring Methods

Water Chemistry. Salinity and inorganic nutrient (phosphate, silicate, nitrate, nitrite, ammonia) concentrations were analyzed in early spring (5 and 18 March 1986) and in late summer (25 August 1986) for the purpose of characterizing water chemistry conditions. Samples were collected from stations located at the mouth, mid-bay, and in selected channels (Figure 3). Samples were collected by hand in polyethylene bottles at a depth of approximately 0.3 m, and were placed on ice and kept in the dark until analysis. Salinity was analyzed using a calibrated refractometer. Nutrients were analyzed by autoanalyzer in the routine chemistry laboratory at the School of Oceanography. pH was determined for water samples collected in August using a pH meter.

The dynamics of water temperature was studied using a Ryan TempMentor recording thermometer. The instrument was anchored at approximately +4 ft relative to mean lower low water (MLLW) in channel 3. Temperature was recorded by the instrument at 10-min intervals between 1115 hrs on 16 March to 1333 hrs on 26 March 1986.

Sediments. Sediment grain size was analyzed for collections made prior to dike breaching (29 October 1985). We felt that disturbance by breaching activities, transplanting operations, and post-breach dredging

in the mid-bay hampered the analysis of sedimentation during 1986. Therefore, subsequent sediment grain size analyses were postponed until 1987. The pre-breach (i.e., post-excavation but prior to connecting the wetland to the Puyallup River) samples provide a baseline with which sedimentation can be studied. The samples were collected in several locations in the system by using a hand held van Veen grab (0.05m^2), and analyzed using sieve and pipette analysis in the chemistry laboratory at the School of Fisheries. The wetland, prior to dike breaching, consisted of unvegetated newly uncovered river sediments. Water from rainfall and local runoff had filled the excavated portion of the wetland to an elevation of approximately +8 ft MLLW.

Information on sedimentation on the flats was gathered using permanent markers on flat 4. Because this flat was located farthest from the the region of greatest flow rates (i.e., the mouth), we felt that sedimentation would be relatively high as compared to the other flats, and therefore indicate the maximum sedimentation rates for the system. On 24 October 1985, wooden stakes were driven into the sediment at 15-m intervals along a transect running from the base of the berm to the outer edge of the flat (Figure 3). A total of 6 stakes were placed between 0 and 75 m along the transect. The top of the stakes protruded 20 cm from the surface of the sediment. Subsequently, measurements of the distance from the top of the stakes to the sediment surface were made on 5 March, 18 March, and 12 December 1986. Incidental observations were made at various intervals throughout the summer at some of the stakes.

Vegetation. Vegetation parameters included shoot density, shoot length-weight relationships, above ground biomass, below ground biomass, species composition and species percentage cover. These parameters were recorded for the vegetation in the wetland near the end of the first growing season, when vegetation standing stock is typically highest in Northwest estuaries (Selisker and Gallagher 1983). Data on biomass and shoot density from the Lincoln Street wetland were compared with data from Big Beef Creek (the source area for most of the transplants). The marsh at Big Beef Creek is well developed. Although several modifications have been made to the creek system, including fish screens and a new road dike across the mouth of the estuary, the Big Beef Creek estuary is relatively pristine.

Shoot density was assessed on each flat along transects running from the base of the berm to the edge of the flat (Figure 3). Each transect was divided into 5-m long by 0.5-m wide contiguous strips (quadrats). The number of shoots of C. lyngbyei and cattails (Typha sp.) were recorded for each quadrat. In addition, the number of patches (i.e., clumps of Carex shoots that were obviously associated with the initial transplanted culms) and the length of the longest shoot were recorded. Sampling occurred on 22 August 1986.

Species composition and percentage cover were assessed along transect 4 using a line-intercept method. This involved recording the species of plant at each 10-cm mark along a tape measure suspended at a height of 20 cm above the sediment surface along the transect. The number of 10-cm marks at which each species occurred within each 5-m

interval was recorded. Bare substrata was scored similarly. Specimens of plants, for which field identification was difficult, were collected for later identification in the laboratory. Sampling was conducted on 9 September 1986.

To estimate biomass with limited destruction of the marsh, random C. lyngbyei shoots were collected by harvesting the shoots, chosen at random, at ground level from flats 3 (n = 30) and 4 (n = 30). The length and dry weight (to the nearest mg) of each shoot was measured. Shoots were dried for 24-48 hours at 90°C prior to weighing. In addition, the length and dry weight of 100 shoots collected in June at Big Beef were recorded. A regression equation relating shoot length to dry weight was developed for plants from each flat and for the Big Beef Creek plants. Finally, all above-ground plant material was collected from within random 0.1 m² quadrats on flats 1 (n = 1), 2 (n = 1), 3 (n = 5), 4 (n = 5), and from Big Beef Creek (n = 5). The quadrats that were sampled at Lincoln Street were placed such that a patch of C. lyngbyei was located in the center. As new shoot production was largely confined to the original shoot mass, the measurement of biomass could be used to estimate biomass production associated with transplanting units (i.e., 1 hole). The data from Big Beef Creek indicates the average standing stock for a mature sedge marsh. Prior to drying, the number of shoots were recorded for each sample.

Below ground biomass was measured by extracting a core from the middle of each 0.1 m² quadrat following shoot harvesting. The core was 10 cm in diameter and 30-cm deep. Cores were placed in plastic bags and

kept cool until analysis. The live below-ground material retained on a 2mm mesh screen was dried and weighed to the nearest mg.

Infauna. Sediment-dwelling macroinvertebrates were sampled on 24 and 29 October 1985, and on 18 March 1986. We did not analyze any samples collected after March due to extensive amount of sediment disturbance by various activities as mentioned above. Samples on the flats were collected with a cylindrical core sampler (2.75-cm inside diameter x 10-cm deep) at 0, 30 and 60 m along the transect on flat 4. The samples were placed in labelled jars and preserved in buffered 10% formalin. In the laboratory, the samples were gently sieved on a 0.5 mm mesh screen and the animals retained on the screen were placed in 70% alcohol. Sediment in many of the samples consisted of clay which prevented easy screening. In these cases, the samples were placed in a funnel with water in it through which air was bubbled from the bottom. The air gently mixed the sample and broke up the chunks of clay prior to screening. The animals were separated into to major taxonomic groups (e.g., insect larvae, oligochaete) and enumerated. Samples were also collected at the mouth, mid-bay, and in channel 4 from a small boat using a 0.05 m² van Veen grab. Samples from these latter areas were treated as above.

Epibenthic Crustacea. Organisms, primarily small crustaceans (large meiofauna-small macrofauna; 0.250 to ~5 mm), which occupy the sediment-water column interface, were sampled using an epibenthic suction pump sampling technique modified from a previous methodology used to evaluate juvenile salmonid prey resources in Pacific Northwest

estuaries (Thom et al. 1984; Simenstad et al. 1980; Simenstad and Cordell 1985). The modification, described in Thom et al. (1985), involved primarily a smaller sampling cylinder (0.016 m^2) than was used in the previous studies, and was designed to specifically sample non-evasive prey of juvenile pink (Oncorhynchus gorbuscha), chum (O. keta), and chinook (O. tshawytscha, fry) salmon. The modified epibenthic pump is also battery powered, which increased its utility and mobility.

Five replicate samples were suctioned from 0.016 m^2 of the marsh surface and channel bottom during ebbing and ebb slack tides, respectively. Tidal flat samples were taken from random distances, as determined by a random numbers table, from along the principal flat 4 transect (Fig. 3). Intake screens on the sampling cylinder are composed of 0.253-mm mesh screen, thus limiting contamination by large meiofauna and small macrofauna outside the sampling area. In the field, each suction sample was filtered directly through a 150- μm mesh sieve and preserved in 5% buffered formalin.

In the laboratory, each sample was sorted under an illuminated dissecting microscope and identified to the lowest taxonomic/life history level possible. The samples were enumerated and weighed (damp weight) to the nearest 0.1 mg. If necessary, samples were split further by taking 1% incremental subsamples with a Henson-Stempel pipette until sufficient animals (at least 100 of the most common taxa) were represented in the subsample.

Epibenthos data were entered and stored as data files on the University's Cyber mainframe computer in modified National Oceanographic

Data Center (NODC) computer formats and codes (including the NODC taxonomic and life history codes). Epibenthos (and zooplankton, see below) data were recorded in NODC format #410, record type #6, computer format. These files were tabulated and summarized statistically using the FRI computer program SUPERPLANKTON (FR 363), which is specifically designed to address NODC-formatted data. Subsequently, more detailed analysis of the summary data was performed using the Statgraphics software installed on IBM PC-compatible microcomputers.

All density and standing crop values for epibenthic organisms are reported as per unit area (m^2). These values may be transformed to volumetric (m^3) data for the epibenthic portion of the water column within 10 to 15 cm of the bottom substrate by multiplying the areal estimates by 8.42 to convert to the $0.0019 m^3$ volume of the epibenthic sampling cylinder.

Planktonic Zooplankton. Triplicate samples of pelagic zooplankton were obtained using the battery-powered epibenthic pump as a water column sampler. The pump drew water and zooplankters from within 0.5 m of the surface at random points distributed in the tidal basin and tidal channels during ebb slack tide. The pump was operated for 30 sec. for each sample, filtering ~32 L samples at the estimated pumping rate of $1.07 L s^{-1}$.

All pelagic zooplankton samples and data were treated identically to epibenthic sample analysis and data processing.

Fish. Fishes were sampled on eight occasions between March 5 and July 15, 1986 (Table 2), initially on the tidal flats and in the tidal basin, but standardized later in tidal channels 2 and 3 (Fig. 3).

Fish were captured during the 5 and 17 March samplings with a 37-m beach seine equipped with 18-m wings with a 3-cm mesh joined to a 0.6-m x 2.4-m x 2.3-m bag of 6-mm mesh. We employed a smaller seine for the remaining six samplings. The net was 9.2 m in length with a bag mesh of 6 mm. The smaller net was much easier to handle in tidal channels and was equally as efficient as the larger net. The net was equipped with a solid core leadline to keep the net on the bottom and prevent rolling, and floats to maintain the top of the net at the surface; however, given the shallow depths of the waters in the wetland at the time of sampling, the seine effectively sampled the entire water column and the benthic region. During the initial two sampling periods, collections were made during flood tides when water covered the tidal flats; thereafter, all collections were made during ebb slack tide, when only the tidal basin and tidal channels were submerged.

In the tidal basin and over the tidal flats, where the seine could be fully deployed, the net was set 30 m from shore, i.e., sampling 590 m². In contrast, sampling of the tidal channels involved sweeping the net down the length of the channel; thus, the sampling effort was considered to include the total area of the channel, i.e., 1682 m² and 949 m² for channels 4 and 5, respectively. It should be recognized, however, that collections were made in the tidal channels when fish were forced from the tidal flats and other high intertidal areas they would

Table 2. Fish collections (no. beach seine sets) made in Lincoln Street wetland, Puyallup River estuary, during initial 6 months of marsh establishment (1986).

	Date							
	3/5	3/17	3/28	4/25	5/30	6/13	6/17	7/15
Tidal flats:								
#3			1					
#5			2					
Tidal basin:								
		1	2	1				
Tidal channels:								
#4			1	2	2	2	2	2
#5			1	2	2	2	2	2
Total no. sets								
	4	2	3	4	4	4	4	4
Total area sampled (m ²)								
	2360	1180	3221	5262	5262	5262	5262	5262

normally occupy during higher tidal elevations, suggesting that the tidal channel fish density and standing crop estimates are inflated (i.e., overestimates) compared to the distribution of fish standing stock over the fully-inundated wetland.

In the field, the fish samples were labeled immediately and preserved in 10% buffered formalin; in the case of exceptionally large fish, however, these were processed for species, life history, length, weight, and reproductive status data at the time of capture and either released live or dissected for stomach and gonad samples. In the laboratory, all preserved fish were allowed to remain in formalin for several weeks, then identified, enumerated, weighed (damp weight to nearest 10 mg), and reproductive status noted.

Fish data were recorded on modified NODC format #100, type #3 (catch summary) and #4 (individual fish examination), computer format. As with the epibenthic and zooplankton data, these were stored on the University's Cyber mainframe computer. The catch was analyzed therein using FRI's catch summary analysis program CATCHSUM adapted specifically for NODC-coded fish data.

Birds. Quantitative bird observations were made on six dates between 2 April and 6 July 1986. Two surveys, approximately 1 hour apart, were made at high tide and again at low tide during each visit, for a total of four surveys per visit. A spotting scope, positioned on top of the berm above flat 4, was used first to make initial counts and identifications (Figure 3). Then, a walking survey was made that included the entire dike and berm. The abundance of the species occurring

in five habitats was recorded during each survey. The habitats were dike, open water, cattail marsh, C. lyngbyei marsh, and aerial. Because water covered the flats during high tide surveys, the sediment surface within the C. lyngbyei marsh habitat was not exposed.

RESULTS

Habitat Distributions

The areal coverages of various habitats within the wetland system are given in Table 3. The total area planted with C. lyngbyei was 10,393 m². The low marsh/mudflat subsystem accounted for the majority of the area within the system. A total of 64% of the system was aquatic (i.e., Carex marsh/mudflat/cattail marsh). Elevation measurements made using a hand level from benchmarks placed in the berm at the transect head on flat 4 showed that the planting was carried out over an elevation span of +10 ft (at 0m) to +9 ft (at 85 m) MLLW.

Transplanting

Average planting density was 3.6 shoots/m² (Table 1). The late August surveys showed that mean shoot density had increased to approximately four times the planting density (Table 1). Areas that were planted earliest (i.e., April and May) showed greater shoot production than those planted later. Initial shoot density was not correlated (Spearman's Rank Correlation Coefficient, $r_s = -0.05$) with ending shoot density. No individuals of any species were recorded on the transect located on flat 5. A few scattered plants of unidentified weedy species found commonly on the steep slopes of the dike were noted at the interface between all flats and the dike base.

Table 3. Areal coverage of habitats at the Lincoln Street wetland system.

Habitat	Area		Percent of total	Resource use
	m ²	acres		
Upland:				
trees	679	0.17	1.8	raptors; upland birds
grassland/ shrubland	11,908	2.94	30.7	small mammals; raptors; upland birds
Cattails	2,962	0.73	7.6	marsh birds
Berm	1,412	0.35	3.6	waterfowl; upland birds
Flats (+8 to +10 ft MLLW):				
1	218	0.05	0.6	shorebirds; juvenile salmonids; waterfowl; raptors
2	764	0.19	2.0	"
3	2,580	0.64	6.7	"
4	4,247	1.05	11.0	"
5	1,581	0.39	4.1	"
6	910	0.22	2.3	"
7	1,367	0.34	3.5	"
8	307	0.08	0.8	"
Total flats	11,974	2.96	30.9	"
Channels (+4 to +8 ft MLLW):				
1	343	0.08	0.9	waterfowl; juvenile salmonids
2	883	0.22	2.3	"
3	1,398	0.35	3.6	"
4	1,682	0.42	4.3	"
5	949	0.23	2.4	"
6	836	0.21	2.2	"
Total channels	6,091	1.51	15.7	"
Open water (includes channels)	9,808	2.42	25.3	waterfowl; juvenile salmonids
Wetland (includes flats and open water)	21,782	5.38	56.2	shorebirds; waterfowl; juvenile salmonids; raptors
SYSTEM TOTAL	38,743	9.57	100.0	-

System Monitoring

Water Chemistry

Salinities measured during early spring and late summer were zero, indicating that the excavated portion of the system is a tidally influenced freshwater wetland (Table 4). Nutrient concentrations were typical of freshwater streams tributary to Puget Sound, with high nitrogen to phosphorus ratios (N:P = 53.9 in March). The late summer data suggest that nitrogen was in much shorter supply (N:P = 8.2). Ammonia concentration was notably high during both samplings. A t-test comparing the two samplings indicated that mean phosphate, nitrate, and nitrite concentrations were significantly different between the two samplings.

Water temperature varied between about 7.2 and 14.6°C over the 10-day sampling period in March (Fig. 4). The highest temperatures occurred during daytime low tides. Periods of low tidal amplitude had correspondingly low daily ranges in temperature. There appeared to be an increase in daily minimum temperatures over the measurement period.

Sediments

Pre-breach grain size data indicate that the channels and flats contained relatively large proportions of medium to fine sands (Fig. 5). The mid-bay and mouth region sediments were dominated by silt and clay. Sediment surface level changes between pre-breach and early post-breach were evident only in the mid portion of flat 4 (Table 5). Maximum sediment height increase was 8 cm, which was recorded at the 30 m site. Measurements made on 18 March indicated that some sediment export had occurred at this site. Measurements made in December, after a period of

Table 4. Water chemistry values at the Lincoln Street wetland in early spring (March 1986) and late summer (August 1986).

Parameter	Early spring			Late summer			Students _{t_s} value ¹
	N	\bar{X}	SD	N	\bar{X}	SD	
Salinity (ppt)	9	0.0	-	6	0.0	-	-
Phosphate (μM)	9	0.50	0.11	6	1.36	0.29	8.07
Silicate (μM)	9	193.48	26.16	6	169.60	13.08	2.07
Nitrate (μM)	9	20.41	0.97	6	5.95	0.50	33.66
Nitrite (μM)	9	0.20	0.04	6	0.35	0.07	5.27
Ammonia (μM)	9	6.34	2.31	6	4.91	2.46	1.14
pH	0	-	-	6	7.633	0.075	-

¹Critical value of $t_s = 2.16$ for $\alpha = 0.05$.

Table 5. Changes in ground elevation at stations on flat 4. Values are distance from ground surface to top of stake.

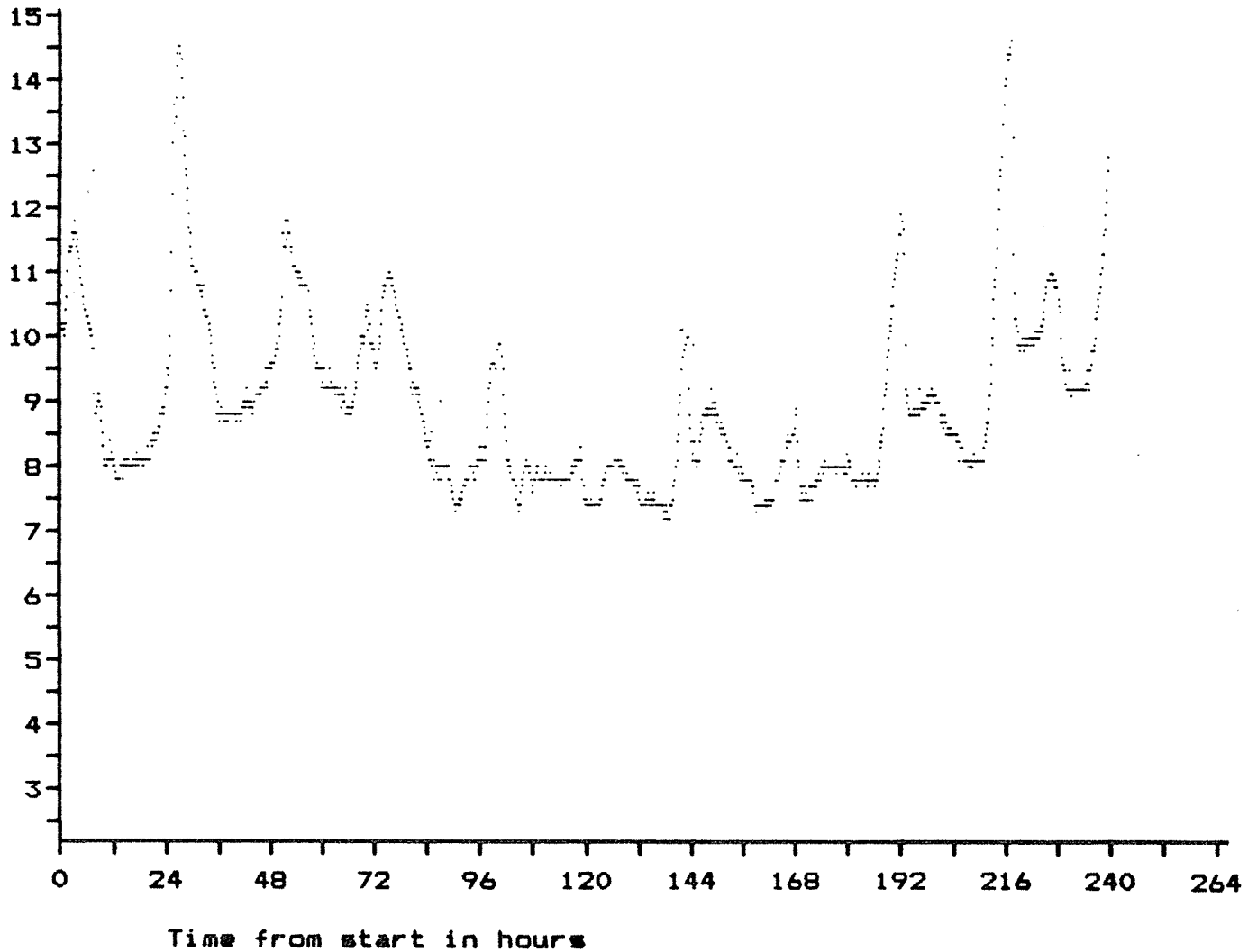
Station ¹	24 Oct 85	5 March 86	18 March 86	12 Dec 86 ²
0 m	20 cm	20	20	Covered by wood debris
15	20	20	19.5	17.2
30	20	12	14.0	12.9
45	20	15	16.5	Not measured
60	20	16	17.5	16.5
75	20	20	20.0	18.9

¹These distances refer to the distance between the stake and the base of the berm.

²Values are means of four measurements made at each stake. One measurement was made on each side of a stake.

Ryan TempMentor

SN900212 #001



03/16/86 11:15:00 Start Sample 300 End Sample 1782

LINCOLN ST. WETLANDS DEPLOYMENT STARTING 18 MARCH 1986
at 1:35pm and ending at 1:33pm on 28 March 1986.
Instrument was in mid portion of channel

Figure 4. Trace of water temperature in channel 3, 16-26 March 1986.

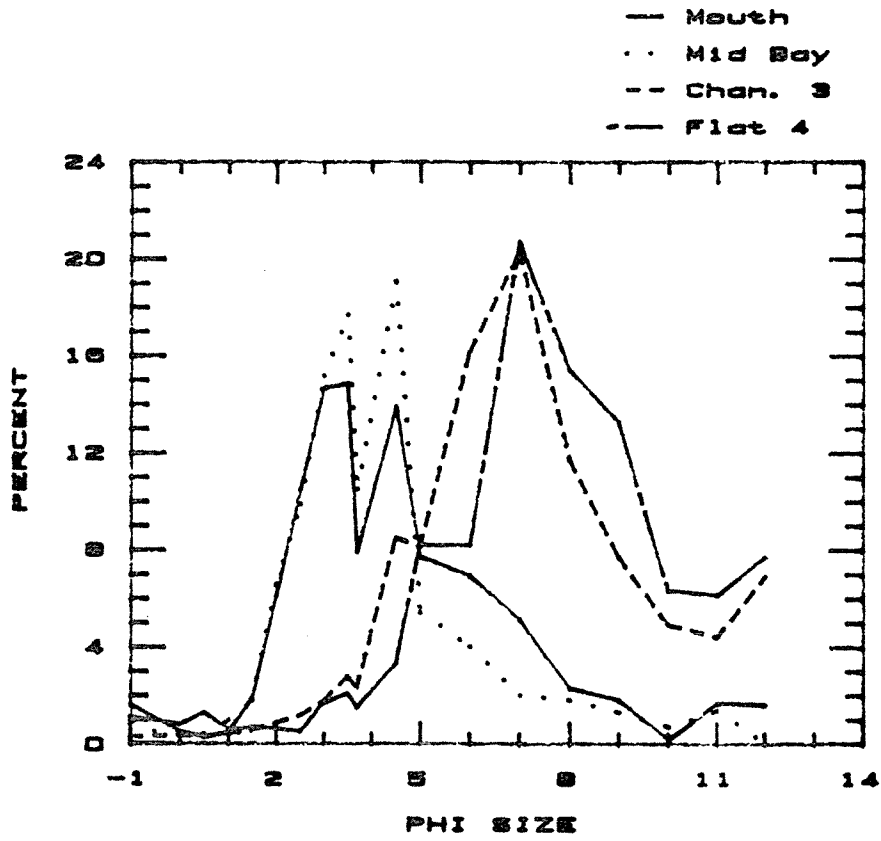


Figure 5. Grain size distributions.

heavy runoff, showed that between 1- and 7-cm of sediment had accumulated at the stakes. It appeared that sedimentation had stabilized at sites located in the mid portion of the flat (30 m, 60 m) since measurements made in March. In contrast, sites at the upper and lower ends of the transect showed some sediment accumulation between March and December. During the December sampling trip, a thin (<1-cm thick) layer of newly deposited fine grained sediment appeared to cover all flats. Observations made in vicinity of the stakes indicated that data taken at the stakes reflected the general condition within approximately 5 m of the stake. The stake was not affecting sediment accumulation.

Sediments collected for infaunal analysis prior to dike breaching showed that a dark black layer, indicating anoxic conditions, existed a few centimeters below the sediment surface throughout the flats and channels. Post-breach samples indicated that the anoxia was generally restricted to deeper portions of the channels and in the mid-bay.

Vegetation

The data for the transect on flat 4 (Figs. 3 and 6) are plotted as an example of vegetation structure in the marsh (Fig. 7). Shoot and patch density varied along the transect, with the highest density recorded at the lower end of the transect, where planting density was highest (Fig. 7B, C). The greatest density of 36 shoots/m² was recorded within the last quadrat on the transect. No plants were found in the quadrats located in a pool between approximately 50 and 60 m along the transect (Fig. 7). In general, areas of pooling were not planted because it was known that C. lyngbyei does not normally occur in pools.



Figure 6. Photograph of vegetation on flat 4 on 22 August 1986.

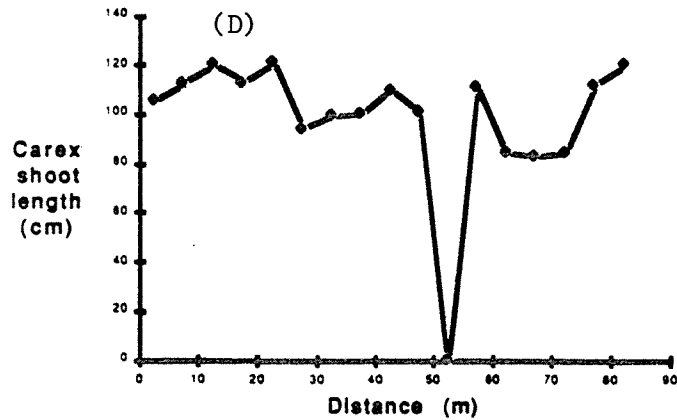
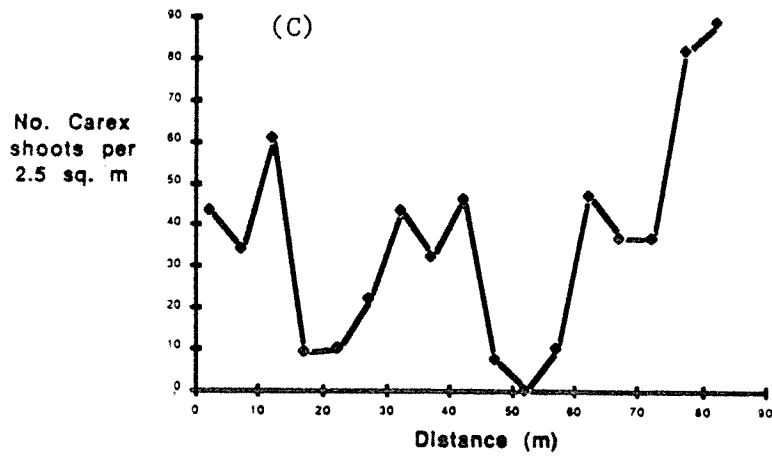
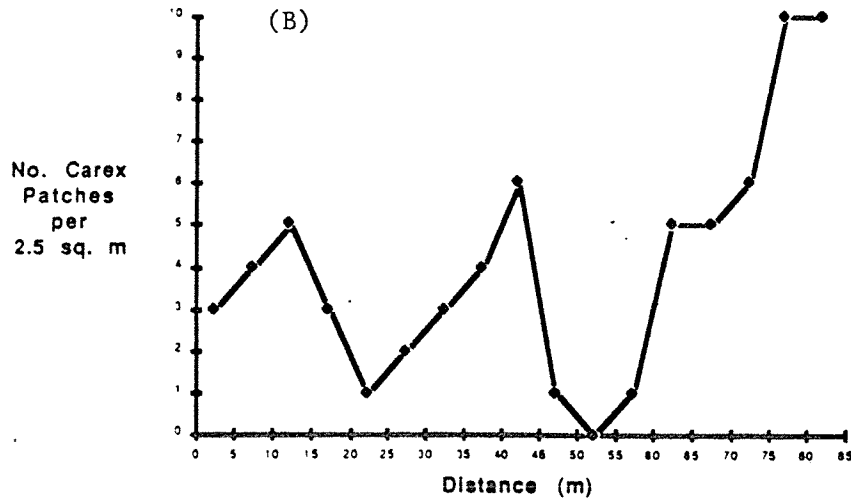
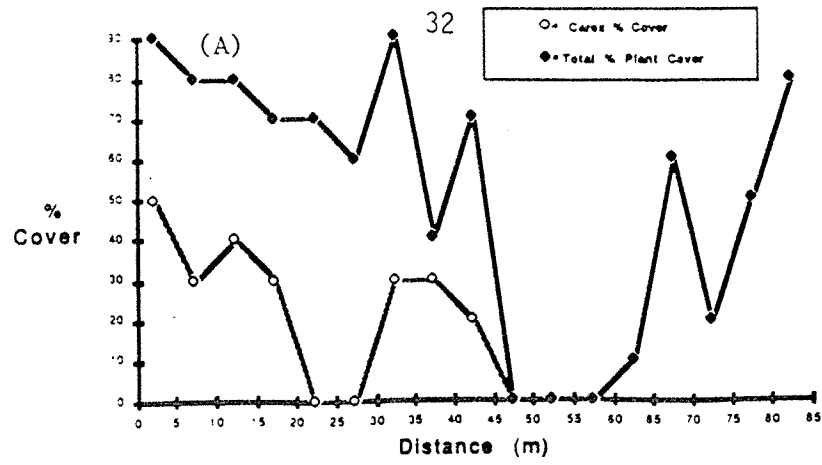


Figure 7. Profile of Carex parameters along transect 4.

Maximum shoot length did not vary appreciably between the upper and lower ends of the transect. The percent cover of Carex was greatest at the lower end of the transect (Fig. 7A). Average percent cover of Carex for the entire transect was 31.2%. Other species that co-occurred with Carex at the upper end of the transect were Typha sp. (cattails) and Eleocharis sp. (spike rush). Typha sp. reached a maximum cover at 10-15 m of 40%, and Eleocharis sp. reached maximum cover at 5-10 and 15-20 m of 20%. Typha was distributed between 0 and 45 m along the transect. Eleocharis was recorded as far out as 25 m. Plant densities on all flats are shown in Fig. 8.

Length-weight relationships were fit best by an exponential model for Carex plants from Big Beef Creek, and flats 3 and 4 (Figs. 9, 10, and 11). This suggests that older plants are heavier per unit length as compared to younger plants. This general relationship applies to Typha also (Figure 12). Correlation coefficients for the relationships were high and ranged from 0.77 to 0.84. The parameters for the models are given in Table 6, and these results are used for calculating biomass estimates from density and shoot length information below.

Flat 3 plants did not differ from flat 4 plants with regard to mean shoot length and weight. The mean shoot length of plants on flat 4 was 87.99 cm (sd = 21.52) as compared to a mean shoot length of 90.27 cm (sd = 22.05) for flat 3 plants. Mean shoot weights for flat 3 and flat 4 plants were 2.557 g (sd = 1.708) and 2.755 (sd = 1.788), respectively. Length frequency plots illustrate the similar distribution of plant sizes between the two flats (Figure 13).

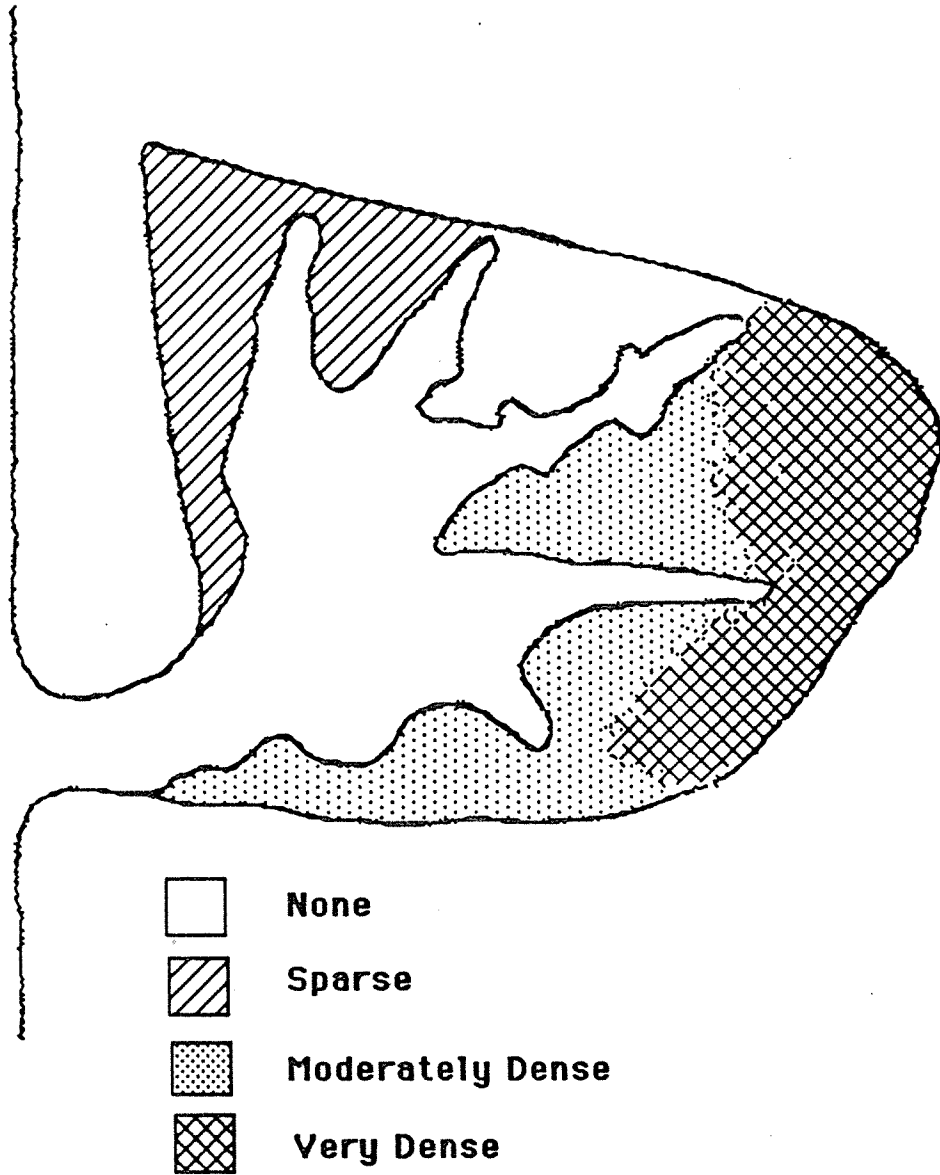


Figure 8. Plant densities on 22 August 1986.

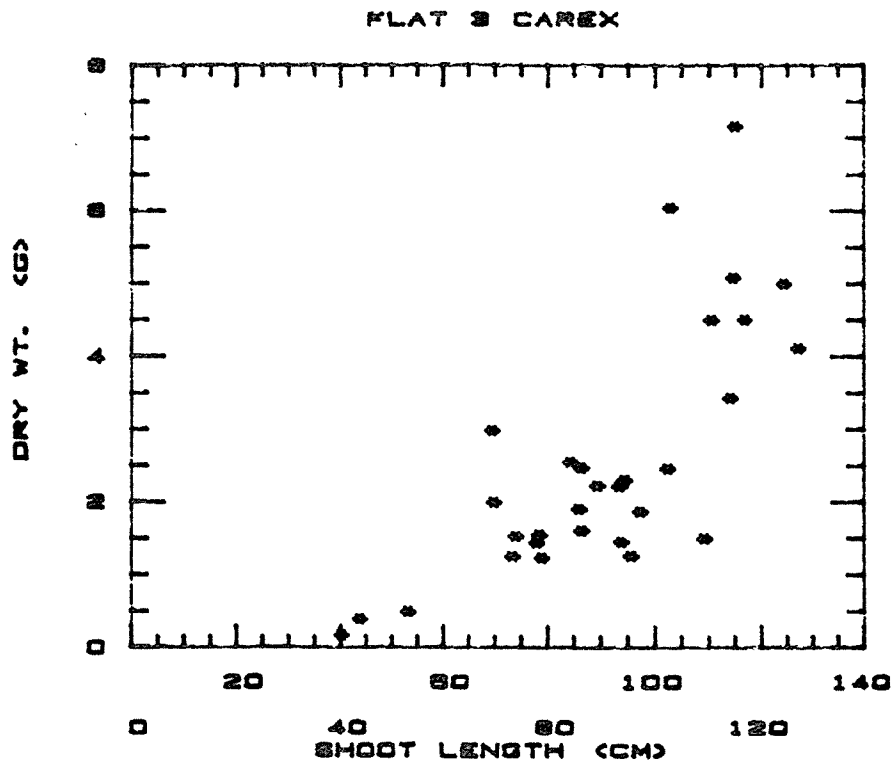


Figure 9. Carex shoot-length dry-weight relationship for plants on flat 3.

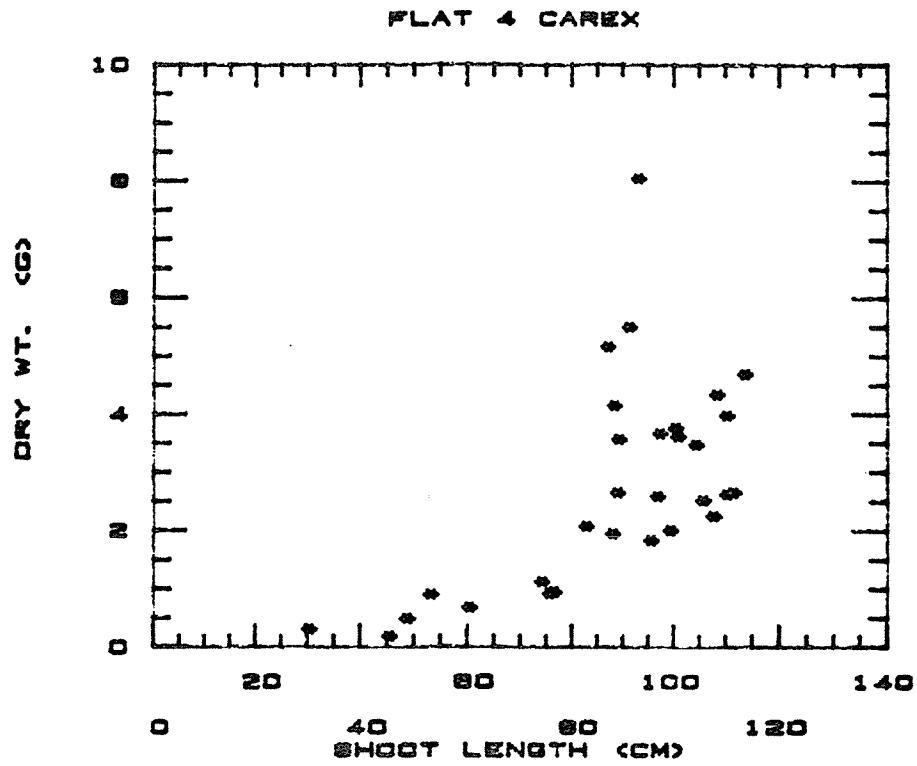


Figure 10. Carex shoot-length dry-weight relationship for plants on flat 4.

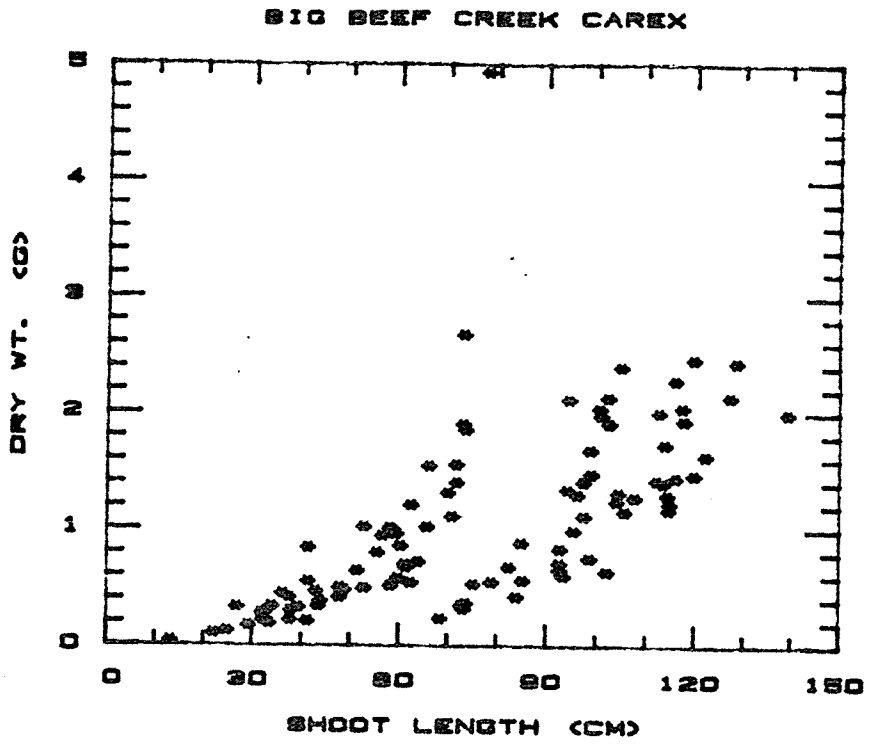


Figure 11. Carex shoot-length dry-weight relationship for Big Beef Creek plants.

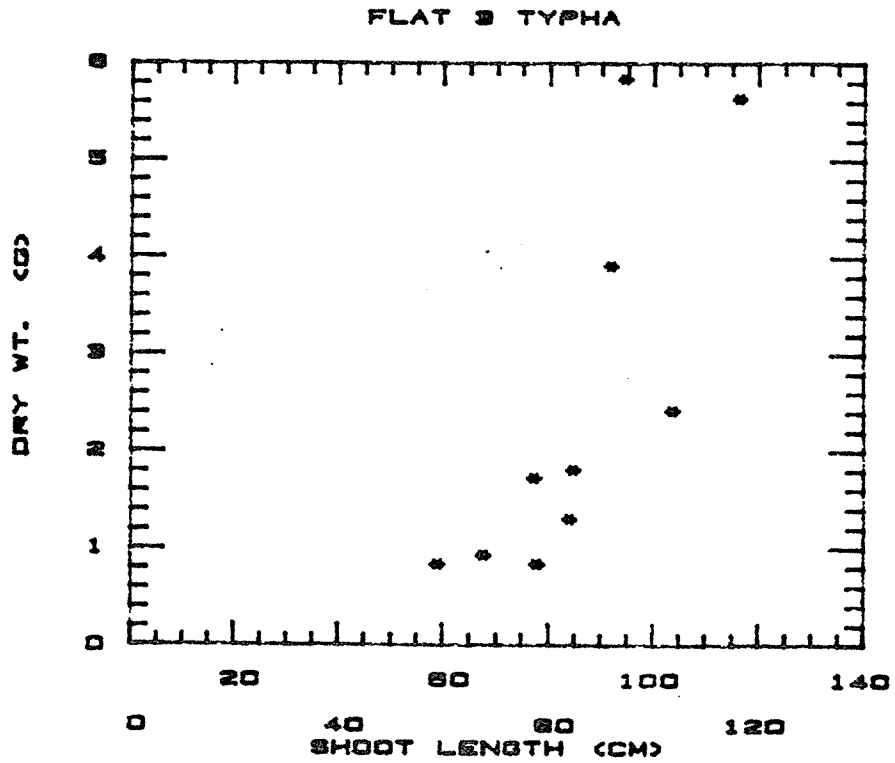


Figure 12. Typha shoot-length dry-weight relationship for plants on flat 4.

Table 6. Summary of regression analysis of plant shoot length (Y) versus shoot dry wt (X). The model is of the form $Y = e^{(a+bx)}$. R = correlation coefficient.

Source area and species	Model parameters		Model	R
	a	b	probability level	
Big Beef - <u>Carex</u>	-1.83	0.021	<0.0001	0.77
Flat 3 - <u>Carex</u>	-2.12	0.031	<0.0001	0.85
Flat 4 - <u>Carex</u>	-2.30	0.034	<0.0001	0.84
Flat 3 - <u>Typha</u>	-2.50	0.037	0.0026	0.84

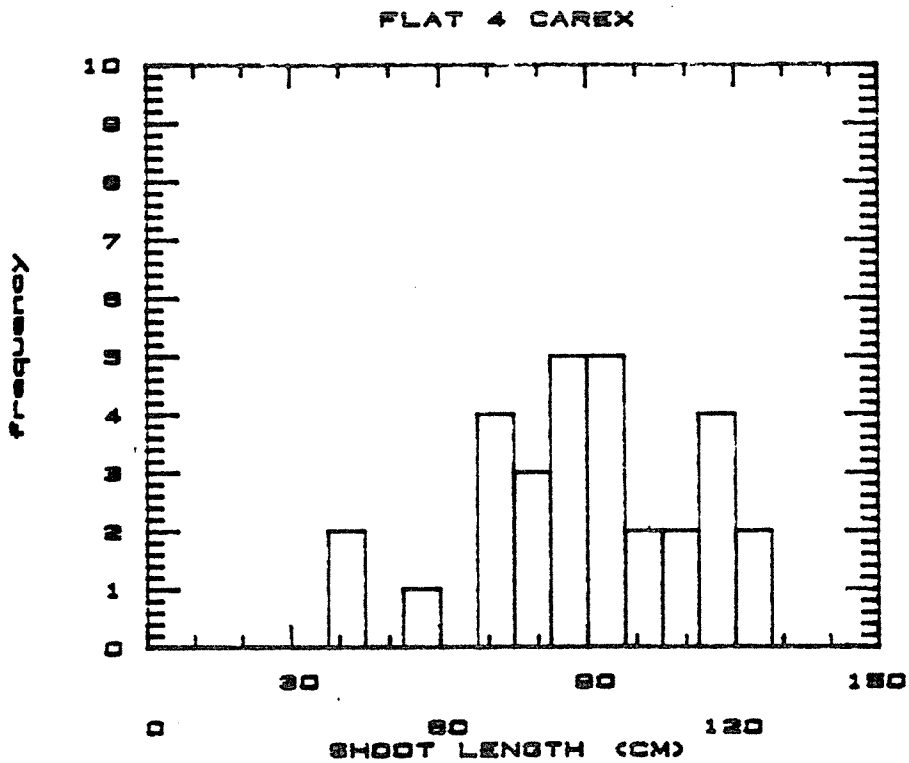
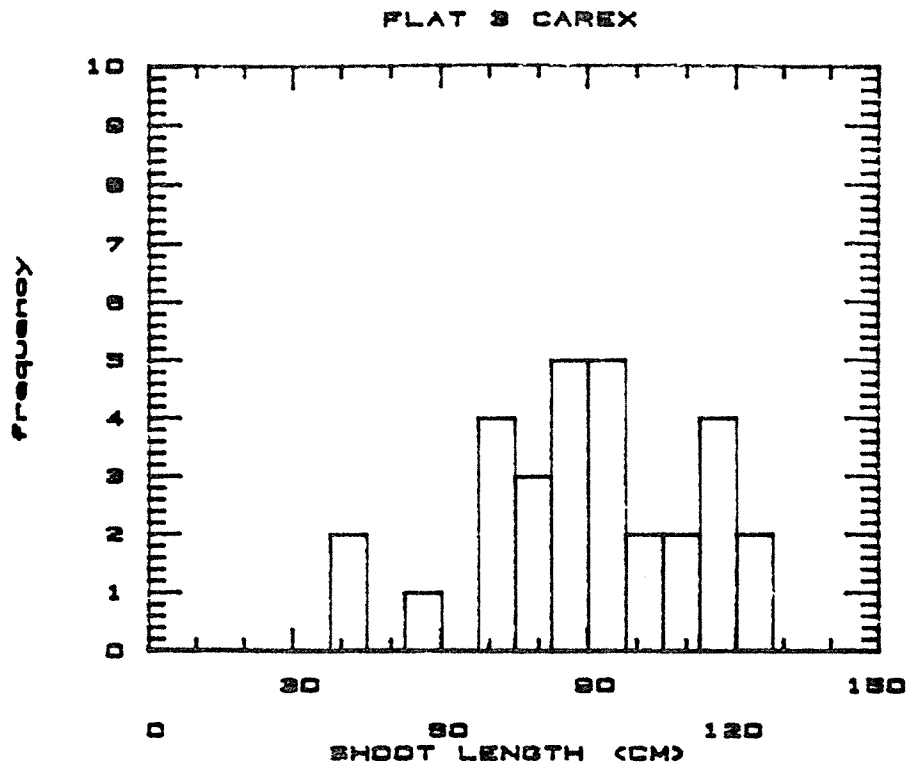


Figure 13. Carex shoot-length frequency for plants on flats 3 and 4.

Biomass and net primary production for the planted flats are summarized in Table 7. By 22 August, Carex biomass had increased over six times that of the initial transplant biomass. The greatest increase occurred on flats 3 and 4 (the flats planted earliest in the year). Although shoot density increased on flats 6, 7 and 8 (Table 1), biomass decreased following transplanting. The natural colonization by Typha, especially on flats 3 and 4, was substantial in terms of biomass.

Net primary production (NPP) as measured by the change in biomass between transplant levels and data taken in late August was greatest on flat 2. If NPP is measured as an increase in biomass starting from zero at Lincoln Street, the value for the site of 57 g dry wt/m²/growing season is approximately 8% of that measured in terms of maximum standing crop (mean = 744 g dry wt/m²/growing season) for the Carex marsh at Big Beef Creek. A total of 272 kg dry wt of Carex roughly converts to 2,720 kg wet wt., which equates to approximately 3.0 tons of live standing crop at the end of summer. If Typha is included, the standing crop estimate is raised to 3.5 tons. The standing crop of other vegetation (e.g., Eleocharis sp.) was not measured, but probably was significant although less than the value for Typha. Production for a similarly sized area at Big Beef Creek would yield 7,732 kg dry wt of Carex, which converts to approximately 85 tons wet wt. Based on these estimates, production within the mature Carex marsh was approximately 24 times greater than in the Lincoln Street marsh.

Maximum (i.e., in the center of the patch of plants) below-ground mean biomass at Lincoln Street was determined by multiplying average

Table 7. Biomass and net primary production (NPP) of Carex lyngbyei and Typha sp. in the Lincoln Street wetland.

Flat no.	Carex		Typha biomass		NPP			Total (kg dry wt/flat)	
	transplant biomass (kg dry wt)	biomass 22 Aug 86 (kg dry wt)	biomass 22 Aug 86 (kg dry wt)	biomass 22 Aug 86 (kg dry wt)	Carex		Typha		
					(kg dry wt/flat)	(g dry wt/m ²)	(kg dry wt/flat)		(g dry wt/m ²)
1	1.594	6.843	0	0	+5.249	24.1	0	0	5.249
2	3.455	36.815	0	0	+33.360	43.7	0	0	33.360
3	7.175	103.094	4.052	4.052	+95.919	37.2	4.052	1.6	99.971
4	15.838	117.982	42.568	42.568	+102.144	24.1	42.568	10.0	144.712
5	0	0	0	0	0	0	0	0	0
6	3.986	2.945	0.082	0.082	-1.041	-1.1	0.082	0.1	-0.959
7	5.315	4.997	0	0	-0.318	-0.2	0	0	-0.318
8	5.315	1.000	0	0	-4.315	-14.1	0	0	-4.315
Total for flat		42.678	271.830	47.055	230.998	-	46.702	-	277.700
Average (excl. Flat 5)		6.097	38.833	6.722	33.000	16.2	6.672	1.671	39.671

biomass per core (74.0 g dry wt), which approximates patch below-ground biomass, by average patch density ($1.6/\text{m}^2$). The value of $118.4 \text{ g dry wt}/\text{m}^2$ was substantially less than the mean value of $12,678 \text{ g dry wt}/\text{m}^2$ (sd = 4,196; n = 5) for Big Beef Creek. A maximum average density of $20.1 \text{ shoots}/\text{m}^2$ was measured on flat 3 in the Lincoln Street marsh. This compares to a mean density of $238 \text{ shoots}/\text{m}^2$ (sd = 87.0; n = 5) at Big Beef Creek.

Infauna

Mean total infauna density in the channels and mid-bay samples showed a marked increase between pre- and post-breach samplings (Table 8). In contrast, infaunal populations decreased on the flats between the two samplings. The most abundant taxa during both samplings were insect larvae (chironomid). Oligochaetes were the second most abundant taxonomic group in the post-breach samples. This latter group was not represented in the pre-breach samples.

Epibenthic Crustacea

Delay in the breaching of the Puyallup River dike reduced the time and funds available for processing of epibenthic samples to two dates, the pre-breach sampling of 29 October 1985 and the post-breach collections of 5 March 1986.

Over all collections, epibenthic crustacean densities across littoral flat #4 averaged $8,823.12 \pm 9,334.04 \text{ organisms } \text{m}^{-2}$; standing crop averaged $219 \pm 233 \text{ mg wet weight } \text{m}^{-2}$ (Table 9). These estimates were widely variable, suggesting patchy distributions of animals, in

Table 8. Total infauna densities pre-breach (October 1985) and post-breach (March 1986). Deep = unvegetated areas in channels and in mid-bay; Flat = on the flats.

	Deep		Flat	
	Pre	Post	Pre	Post
\bar{X} (no./m ²)	4,042	15,710	3,875	833
SD	4,292	7,167	6,376	750
N	3	6	3	8

Table 9. Combined taxonomic composition and standing stock of epibenthic organisms sampled in the Lincoln Street Wetland, October 1985 and March 1986.

Taxa	Life History Stages	Density (mean no.m ⁻²)	Standing Crop (mean mg m ⁻²)	Percentages	
				numerical	gravimetric
Platyhelminthes	J/A	2.2	*	0.03	0.10
Rotifera	J/A	216.7	2	2.46	0.82
Nematoda	J/A	77.9	3	0.88	1.35
Oligochaeta	J/A	4.5	*	0.05	0.20
Acarina	J/A	2.2	*	0.03	0.10
Cladocera	EC	9.4	1	0.11	0.43
Daphnidae	J	25.7	1	0.29	0.26
<u>Daphnia</u> sp.	J	191.4	4	2.17	1.76
" "	EC	2.2	*	0.03	0.10
<u>D. pulex</u>	J	4.5	*	0.05	0.10
" "	J/A	151.4	13	1.72	6.13
" "	ECF	9.4	7	0.11	3.11
<u>Bosmina</u>					
<u>longirostris</u>	A	2.2	*	0.03	0.10
" "	ECF	2.2	*	0.03	0.10
<u>Chydorus</u>					
<u>sphaericus</u>	A	13.4	1	0.15	0.31
" "	J/A	6.7	*	0.08	0.20
Podocopa	J/A	46.1	2	0.52	0.88
Copopoda	N	3168.8	8	35.92	3.43
Calanoida	C	2.9	*	0.03	0.13
Harpacticoida	A	2.2	*	0.03	0.10
" "	C	2.2	*	0.03	0.10
<u>Bryocamptus</u> sp.	A	4.5	*	0.05	0.20
<u>Maraenobiotus</u> sp.	A	2.2	*	0.03	0.10
Cyclopoida	N	17.9	*	0.20	0.10
" "	A	32.7	1	0.37	0.47
" "	C	2655.2	16	30.09	7.08
" "	ECF	8.9	*	0.10	0.10
Corycaeidae	A	35.7	1	0.40	0.41
" "	ECF	4.5	*	0.05	0.10
Cyclopidae	A	22.3	1	0.25	0.31
<u>Cyclops vernalis</u>	A	4.5	*	0.05	0.10
<u>C. vicinus</u>	A	601.7	37	6.82	16.69
" "	J/A	41.4	2	0.47	1.11
" "	C	26.8	2	0.30	0.71
" "	ECF	41.6	6	0.47	2.94
<u>Acanthocyclops</u> sp.	A	49.1	2	0.56	1.02
" "	" ECF	6.7	1	0.08	0.31
<u>Eucyclops speratus</u>	A	459.9	20	5.21	4.51
" "	J/A	462.9	8	5.25	3.84
" "	C	60.3	1	0.68	0.51
" "	ECF	238.3	7	2.70	2.97

Table 9. Combined taxonomic composition and standing stock of epibenthic organisms sampled in the Lincoln Street Wetland, October 1985 and March 1986 - cont'd.

Taxa	Life History Stages	Density (mean no.m ⁻²)	Standing Crop (mean mg m ⁻²)	Percentages	
				numerical	gravimetric
Cyclopidae - cont'd.					
<u>Microcyclops</u>					
<u>varicans</u>	A	6.7	*	0.08	0.10
Insecta	L	4.5	*	0.05	0.20
Chironomidae	L	86.3	57	0.98	1.82
"	A	1.4	4	0.02	1.82
"	P	2.9	18	0.03	8.28
Total		8823.12 ± 9334.04	218 ± 252		

Life History Codes:

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

that densities ranged between 250 and 33,600 m^{-2} (coef. var. = 106% of mean) and standing crops, <1 to 948 $mg m^{-2}$ (116%).

Including discrete life history stages, 47 taxonomic categories of organisms were collected epibenthically on the flat (Table 9). These included nine major (subclass or higher level) groups: (1) platyhelminthes; (2) rotifera; (3) nematoda; (4) oligochaeta; (5) acarina; (6) cladocera; (7) podocopa (ostracods); (8) copepoda; and, (9) insecta. Among these taxa, copepoda was the most taxa rich group, with seven recognizable species, followed by cladocera, with three.

As anticipated, composition and standing stock changed between pre- and post-breach collections; density and standing stock generally declined, while both numerical and gravimetric diversity increased. It must be remembered, however, that the pre- and post-breach samples occurred in two different seasons and many of these differences may simply reflect seasonality in the occurrence and life histories of the organisms. Total epibenthic crustacean densities in late October 1985 averaged $15,670.00 \pm 11,371.46$ organisms m^{-2} , and the standing crop averaged 423 ± 351 $mg m^{-2}$; densities in early March, after the dike breach, averaged $6,084.38 \pm 6,966.59$ organisms m^{-2} , and the standing crop averaged 136 ± 141 $mg m^{-2}$ (Table 10).

The pre-breach epibenthic assemblage was numerically dominated by freshwater cladocerans, copepod larvae, and cyclopoid copepods, and gravimetrically by dipteran fly (chironomid) larvae. Daphnia pulex dominated (3.5% of total density, 16.5% of total standing crop) the cladocera, although unspecific Daphnia juveniles were the most abundant

Table 10. Density (den.) and standing crop (s.c.) composition (%) and diversity of epibenthic organisms on littoral flat in Lincoln Street Wetland before and after breaching (four transect locations) of the Puyallup River dike, February 1986.

Taxa	Life History Stage	Pre-Breach		Post-Breach, February 1986									
		October 1985 den.	October 1985 s.c.	0 m den.	0 m s.c.	15 m den.	15 m s.c.	30 m den.	30 m s.c.	60 m den.	60 m s.c.		
Platyhelminthes	J/A					0.10	0.64						
Rotifera	J/A	4.69	1.33			0.29	0.64						
Nematoda	J/A	0.10	0.24	15.79	14.81	0.98	1.92	0.33	1.14	5.21	3.26		
Oligochaeta	J/A									0.69	2.17		
Acarina	J/A			2.63	3.70								
Cladocera	EC	0.16	0.60							0.35	1.09		
Daphnidae	J	0.57	0.48										
<u>Daphnia</u> sp.	J	4.28	3.25										
"	EC					0.10	0.64						
<u>D. pulex</u>	J			5.26	3.70								
"	J/A	3.38	11.33										
"	ECF	0.16	5.18	2.63	11.11								
<u>Bosmina longirostris</u>	A							0.17	0.57				
"	ECF					0.10	0.64						
<u>Chydorus sphaericus</u>	A							0.17	0.57	1.74	2.17		
"	J/A					0.29	1.28						
Podocopa	J/A	0.03	0.12			0.49	1.28	1.84	1.70	1.39	3.26		
Copopoda	N	54.28	2.77	31.58	18.52	19.16	3.21	11.37	2.27	19.10	5.43		
Calanoida	C	0.06	0.24										
Harpacticoida	A			2.63	3.70	0.10	0.64						
"	C												
<u>Bryocamptus</u> sp.	A			2.63	3.70	0.10	0.64						
<u>Maraenobiotus</u> sp.	A									0.35	1.09		
Cyclopoida	N							1.34	0.57				
"	A	0.03	0.12			1.08	1.28			1.04	2.17		
"	C	18.92	3.49	13.16	14.81	45.65	12.18	44.31	11.93	25.35	7.61		
"	ECF					0.39	0.64						
Corycaeidae	A							2.68	2.27				
"	ECF							0.33	0.57				
Cyclopidae	A					0.98	1.92						
<u>Cyclops vernalis</u>	A					0.20	0.64						
<u>C. vicinus</u>	A	0.13	0.36	2.63	3.70	8.60	29.49	21.40	50.57	17.36	28.26		
"	J/A	0.93	2.05										
"	C							2.01	3.98				
"	ECF	0.03	0.36			0.29	1.92	2.34	13.07	0.35	1.09		
<u>Acanthocyclops</u> sp.	A					0.49	1.28	2.01	2.84	1.74	3.26		
"	ECF					0.29	1.92						

Table 10. Density (den.) and standing crop (s.c.) composition (%) and diversity of epibenthic organisms on littoral flat in Lincoln Street Wetland before and after breaching (four transect locations) of the Puyallup River dike, February 1986 - cont'd.

Taxa	Life History Stage	Pre-Breach		Post-Breach, February 1986								
		October 1985	den.	s.c.	0 m		15 m		30 m		60 m	
		den.	s.c.	den.	s.c.	den.	s.c.	den.	s.c.	den.	s.c.	
Cyclopidae - cont'd.												
<i>Eucyclops speratus</i>	A	0.35	0.24	15.79	14.81	11.83	16.03	6.52	3.98	11.46	7.61	
"	J/A	10.34	7.11			2.44	2.56	0.33	0.57			
"	C											
"	ECF	0.29	0.60	2.63	3.70	5.08	7.69	2.68	2.84	11.11	8.70	
<i>Microcyclops varicans</i>												
	A					0.29	0.64					
	L					0.20	1.28					
Insecta	L											
Chironomidae	L	1.18	41.45	2.63	3.70	0.49	8.97	0.17	0.57	2.78	22.83	
"	A	0.03	3.37									
"	P	0.06	15.30									
Shannon-Wiener Diversity		2.15	2.90	2.94	3.26	2.55	3.48	2.56	2.59	2.96	3.16	
Mean density (no.m ⁻²)		15670.00		475.00		12787.50		7475.00		3600.00		
		± 11371.46		± 180.06		± 8994.75		± 6351.77		± 1903.23		
Mean standing crop (mg m ⁻²)		423 ± 351		8 ± 10		221 ± 118		220 ± 184		94 ± 77		

Life History Codes:

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

(7.7%). Copepod (presumably calanoid) nauplii were overwhelmingly the most abundant organism overall, accounting for 54.3% of the total density; due to their small biomass, however, they comprised only 2.8% of the total standing stock. Cyclopoid copepodids (life history stages between nauplii and adult) were second most abundant, at 18.9% of the total density. There were two identifiable cyclopoids, Cyclops vicinus (1.1%, 2.8%) and Eucyclops speratus (11.0%, 8.0%). Although chironomids comprised only 1.3% of the total density of the assemblage, the larvae alone accounted for 41.5% of the total standing stock, pupa 15.3%, and adults 3.4%.

Post-breach, Daphnia all but disappeared and were found only at the upper edge of the littoral flat (0 m transect position) adjacent to the drainage from the freshwater, Typha marsh. On the other hand, Bosmina longirostris and Chydorus sphaericus appeared, presumably advected into the wetland from the river. Harpacticoids, principally Bryocamptus sp. and Maraenobiotus sp., also appeared in low abundance in the upper elevations of the flat. Cyclopoids such as Cyclops vicinus and Eucyclops speratus were equally or more prominent after the dike breaching, but several new taxa (C. vernalis and Acanthocyclops sp.) also appeared. Egg-carrying female cyclopoids of most species were present after the dike breach, suggesting that reproduction was occurring within the wetland or in an adjacent habitat (Typha marsh, river) and transported into viable waters of the wetland. Only larval chironomids were present post-breach, as compared to pupae and adults at the time of the pre-breach sampling. Cyclopoids continued to dominate the numerical composition, but also (in particular C. vicinus) became prominent

gravimetrically with the decline in the standing crop of chironomid adults and pupae.

Planktonic Zooplankton

Organisms collected in the water column of the wetland's tidal channels and basin were slightly less taxa rich (38 taxa/life history categories) but included epibenthic/benthic forms as well as pelagic zooplankton (Table 11). Notable differences included the lack of harpacticoid (Maraenobiotus sp.) and cyclopoid copepod species (Cyclops vernalis, Microcyclops varicans) and the inclusion of two other harpacticoid genera (Attheyella sp., Moraria sp.).

Compositional differences in the pelagic assemblages sampled pre-versus post-breach reflected those described for the epibenthos, while standing stocks were measurably different (Table 12). Densities of pelagic zooplankton in the pre-breach waters of the wetland in October 1985 averaged $3,936,400 \pm 3,673,020$ organisms m^{-3} , and standing crop 201.0 ± 249.0 g m^{-3} ; post-breach in early March 1986, densities were more than six time less, $659,333.3 \pm 334,416.0$ organisms m^{-3} , and standing crop averaged 25.0 ± 15.8 mg m^{-3} . Two of the more probable explanations for these differences are: (1) the low volume, stable freshwater mass in the wetland pre-breach, as compared to the higher volume (except at extreme low tides) estuarine water mass subjected to frequent fluvial and tidal flushing; and, (2) seasonal aspects of the population abundances and reproductive periodicities of the zooplankters.

Table 11. Combined taxonomic composition and standing stock of pelagic organisms sampled in the Lincoln Street Wetland, October 1985 and March 1986.

Taxa	Life History Stages	Density (mean no.m ⁻³ x 10 ³)	Standing Crop (mean mg m ⁻³)	Percentages	
				numerical	gravimetric
Rotifera	J/A	337.8	1244	7.02	0.50
Nematoda	J/A	26.4	244	0.55	0.10
Oligochaeta	J/A	2.9	111	0.06	0.04
Cladocera	EC	3.8	356	0.08	0.14
Daphnidae	J	117.8	1556	2.45	0.63
<u>Daphnia</u> sp.	J	963.3	17978	20.01	7.27
<u>D. pulex</u>	J/A	>1000	158800	36.47	64.25
"	ECF	51.1	36889	1.06	14.93
<u>Bosmina</u>					
<u>longirostris</u>	A	0.4	44	0.01	0.02
Chydoridae	A	0.2	22	<0.01	0.01
"	J/A	0.4	22	0.01	0.01
<u>Chydorus</u>					
<u>sphaericus</u>	A	2.4	67	0.05	0.03
Podocopa	J/A	0.2	22	<0.01	0.01
Copopoda	N	512.9	1556	10.66	0.63
"	EC	10.7	978	0.22	0.40
<u>Bryocamptus</u> sp.	A	0.4	44	0.01	0.02
"	J/A	0.7	22	0.01	0.01
"	C	0.2	22	<0.01	0.01
<u>Attheyella</u> sp.	A	0.2	22	<0.01	0.01
<u>Moraria</u> sp.	A	0.2	22	<0.01	0.01
Cyclopoidea	A	2.7	111	0.06	0.04
"	C	620.0	7200	12.88	2.91
"	EC	14.0	311	0.29	0.13
Cyclopidae	ECF	0.2	22	<0.01	0.01
<u>Cyclops</u>					
<u>bicuspidatus</u>	A	0.2	22	<0.01	0.01
<u>C. vicinus</u>	A	68.7	5800	1.43	2.35
"	J/A	62.2	2222	1.29	0.90
"	C	65.1	2867	1.35	1.16
"	ECF	13.1	2400	0.27	0.97
<u>Acanthocyclops</u> sp.	A	2.2	111	0.05	0.04
"	J/A	1.8	89	0.04	0.04
<u>Eucyclops</u> <u>speratus</u>	A	48.0	1022	1.00	0.41
"	J/A	91.1	1778	1.89	0.72
"	C	5.1	89	0.11	0.72
"	ECF	24.7	1333	0.51	0.54

Table 11. Combined taxonomic composition and standing stock of pelagic organisms sampled in the Lincoln Street Wetland, October 1985 and March 1986 - cont'd.

Taxa	Life History Stages	Density (mean no.m ⁻³ x 10 ³)	Standing Crop (mean mg m ⁻³)	Percentages	
				numerical	gravimetric
Collembola	J/A	0.2	22	<0.01	0.01
Chironomidae	L	6.0	1711	0.12	0.01
"	P	0.2	22	<0.01	0.01
Total			239489 ± 544256		

Life History Codes:

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

Table 12. Density and standing crop composition (%) and diversity of pelagic organisms sampled in the Lincoln Street Wetland pre- (October 1985) and post-breach (March 1986).

Taxa	Life History Stages	Standing Stock Composition (%)			
		Pre-Breach		Post-Breach	
		Density	Standing crop	Density	Standing crop
Rotifera	J/A	7.72	0.54		
Nematoda	J/A			6.02	1.48
Oligochaeta	J/A			0.66	0.67
Cladocera	EC	0.05	0.10	0.35	0.81
Daphnidae	J	2.69	0.67		
Daphnia sp.	J	22.02	7.78	0.05	0.13
D. pulex	J/A	40.14	68.84		
" "	ECF	1.17	15.99		
Bosmina					
longirostris	A			0.10	0.27
Chydoridae	A			0.05	0.13
" "	J/A			0.10	0.13
Chydoru s					
sphaericus	A			0.56	0.40
Podocopa	J/A			0.05	0.13
Copopoda	N	9.86	0.58	18.60	1.35
" "	EC	0.24	0.42	0.10	0.27
Bryocamptus sp.	A			0.10	0.27
" "	J/A			0.15	0.13
" "	C			0.05	0.13
Attheyella sp.	A			0.05	0.13
Moraria sp.	A			0.05	0.13
Cyclopoida	A			0.61	0.67
" "	C	11.73	2.62	24.37	7.01
" "	EC			0.05	0.13
Cyclopidae	ECF			0.05	0.13
Cyclops					
bicuspidatus	A			0.05	0.13
C. vicinus	A			15.62	35.18
" "	J/A	1.42	0.96		
" "	C	0.04	0.02	14.41	17.12
" "	ECF			2.98	14.56
Acanthocyclops sp.	A			0.51	0.67
" "	J/A			0.40	0.54
Eucyclops speratus	A	0.41	0.19	6.88	3.50
" "	J/A	2.08	0.77		
" "	C			1.16	0.54
" "	ECF	0.43	0.50	1.37	1.08

Table 12. Density and standing crop composition (%) and diversity of pelagic organisms sampled in the Lincoln Street Wetland pre- (October 1985) and post-breach (March 1986) - cont'd.

Taxa	Life History Stages	Standing Stock Composition (%)			
		Pre-Breach		Post-Breach	
		Density	Standing crop	Density	Standing crop
Collembola	J/A			0.05	0.13
Chironomidae	L			1.37	10.38
"	P			0.05	0.13

Total mean density (no. m ⁻³)		3,936,400.0 ± 3,673,020.0		659,333.3 ± 334,416.0	
Total mean standing crop (g m ⁻³)		201.0 ± 1244.0		25.0 ± 15.8	
Taxa richness		14		31	
Shannon-Weiner Diversity, H'		2.50	1.57	3.17	3.02

Life History Codes:

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

As inferred from the epibenthos collections, the expected supplement to and shift to fluvial and estuarine organisms from the freshwater marsh taxa occurred with the breaching of the dike. Rotifers and Daphnia pulex essentially disappeared, while some cladocerans (Chydorus sphaericus), ostracods, harpacticoids (Bryocamptus sp., Attheyella sp., Moraria sp.), cyclopoids (Cyclops bicuspidatus, Acanthocyclops sp.) and insects (Collembola) appeared or became more prominent. As a result, taxa richness and numerical and gravimetric diversity all increased 20% to ~100% in the shift from from freshwater marsh to estuarine assemblages.

Fish

Eleven species of six families of freshwater and estuarine fishes were collected from the wetland during the initial six months of marsh establishment (Table 13). Fourteen categories of fish were collected, which included general life history stages (i.e., juveniles, adults). Salmonids, including juveniles of both mountain whitefish and four of the five species of Pacific salmon, were the most speciose family; only one or two species represented the other families. Although all species have been reported from estuarine waters in the region, four species would be considered oligohaline or principally freshwater taxa (mountain whitefish, reidside shiner, largescale sucker, and prickly sculpin), three are common euryhaline taxa (three-spine stickleback, Pacific staghorn sculpin, and starry flounder), and the four juvenile Pacific salmon are common estuarine residents during their anadromous migrations to the North Pacific. No euhaline, or low-salinity intolerant, fishes had been collected by the middle of July. Species/life history stage

Table 13. Fish density (no. per 100 m²) of fishes captured in Lincoln Street wetland, Puyallup River estuary, during initial six months of marsh establishment.

Species/common name	Life history stage	Date								
		3/5	3/17	3/28	4/25	5/30	6/13	6/27	7/5I	
Family Salmonidae										
<u>Prosopium williamsoni</u> (Girard) Mountain whitefish	Juveniles	0.38								
<u>Oncorhynchus gorbuscha</u> (Walbaum) Pink salmon	Juveniles	0.51	0.14	0.20						
<u>O. keta</u> (Walbaum) Chum salmon	Juveniles	0.04	0.09		0.10	0.03		0.11	0.01	
<u>O. kisutch</u> (Walbaum) Coho salmon	Juveniles	0.13				0.21	0.01	0.03		
<u>O. tshawytscha</u> (Walbaum) Chinook salmon	Juveniles	0.04		1.79	0.01	0.16	0.36			
Family Cyprinidae										
<u>Richardsonius balteatus</u> (Richardson) Redside shiner	Juveniles			0.77	0.03	0.03			0.13	
Family Catostomidae										
<u>Catostomus macrocheilus</u> (Girard) Largescale sucker	Juveniles	0.81	0.68	0.34					0.03	
	Adults	0.34					0.01			
Family Gasterosteidae										
<u>Gasterosteus aculeatus</u> (Linnaeus) Threespine stickleback	Juveniles				0.02	0.03	0.05	0.10	0.01	0.06
	Adults		0.51			0.11	0.10	0.15	0.06	0.04

Table 13. Fish density (no. per 100 m²) of fishes captured in Lincoln Street wetland, Puyallup River estuary, during initial six months of marsh establishment - cont'd.

Species/common name	Life history stage	Date							
		3/5	3/17	3/28	4/25	5/30	6/13	6/27	7/5
Family Cottidae									
<u>Leptocottus armatus</u> (Girard) Pacific staghorn sculpin	Juveniles					0.03	0.05		0.01
<u>Cottus asper</u> (Richardson) Prickly sculpin	Juveniles Adults		0.59			0.03	0.19	0.36	0.13
		0.13	0.25						0.01
Family Pleuronectidae									
<u>Platichthys stellatus</u> (Pallas) Starry flounder	Juveniles	0.09	0.17			0.16	0.40	0.26	
Total species/life history stage richness									
Average total density (no./100 m ²)		8	7	5	6	9	8	6	8
		1.96	2.80	3.06	0.48	0.80	1.27	0.83	0.42

richness varied between 5 and 9 through the collection period, and showed no chronological trends indicating succession or incremental colonization. Basically, fish appeared in the wetland immediately or soon after the dike was breached. Juvenile salmonids were present in varying densities throughout the sampling period: pink salmon between mid-March and late April; chum salmon throughout the period; coho salmon between early March and later June; and, chinook salmon between late March and mid-June.

Fish density also varied considerably among sampling dates. The highest densities occurred in March, when 1.96 to 3.06 fish per 100 m² were captured in the tidal basin and tidal channels (Table 13). Much of these densities were due to the high abundance of largescale suckers and, during late March, juvenile chinook salmon. Maximum densities of juvenile salmonids differed among species: pink salmon in mid-March and declining thereafter; chum salmon between late April and late May; coho salmon in late April; and chinook salmon, as mentioned, in late March but also relatively dense again in mid-June.

Standing crop, the (wet weight) biomass of fish per unit area, generally followed the trends in fish density, with the exception of the influence of adult largescale sucker and prickly sculpin in early March (Table 14). Excluding the infrequent periods of abundance by large juvenile and adult fish, such as the mountain whitefish, largescale sucker, and prickly sculpin, the average standing crops of most were less than 1 g per 100 m². Similarly, the average total standing crop

Table 14. Fish standing crop (g per 100 m²) of fishes captured in Lincoln Street wetland, Puyallup River estuary, during initial six months of marsh establishment.

Species/common name	Life history stage	Date							
		3/5	3/17	3/28	4/25	5/30	6/13	6/27	7/51
Family Salmonidae									
<u>Prosopium williamsoni</u> (Girard) Mountain whitefish	Juveniles	4.67							
<u>Oncorhynchus gorbuscha</u> (Walbaum) Pink salmon	Juveniles		0.20	0.05	0.06				
<u>O. keta</u> (Walbaum) Chum salmon	Juveniles	0.03	0.08		0.05	0.04		0.64	0.08
<u>O. kisutch</u> (Walbaum) Coho salmon	Juveniles	0.63				1.26	0.03	0.06	
<u>O. tshawytscha</u> (Walbaum) Chinook salmon	Juveniles	0.79		3.46	0.13	1.34	1.63		
Family Cyprinidae									
<u>Richardsonius balteatus</u> (Richardson) Redside shiner	Juveniles			0.17	0.01	0.01			0.01
Family Catostomidae									
<u>Catostomus macrocheilus</u> (Girard) Largescale sucker	Juveniles	1.25	1.70	0.21					0.01
	Adults	260.81					0.05		
Family Gasterosteidae									
<u>Gasterosteus aculeatus</u> (Linnaeus) Threespine stickleback	Juveniles			0.01	0.01	0.14	0.02	0.01	0.02
	Adults		0.49		0.20	<0.01	0.21	0.09	0.06

Table 14. Fish standing crop (g per 100 m²) of fishes captured in Lincoln Street wetland, Puyallup River estuary, during initial six months of marsh establishment - cont'd.

Species/common name	Life history stage	Date							
		3/5	3/17	3/28	4/25	5/30	6/13	6/27	7/51
Family Cottidae									
<u>Leptocottus armatus</u> (Girard) Pacific staghorn sculpin	Juveniles					0.01	0.06		0.03
<u>Cottus asper</u> (Richardson) Prickly sculpin	Juveniles Adults		0.23			<0.01	0.04	0.13	0.11 0.43
		3.51	1.08						
Family Pleuronectidae									
<u>Platichthys stellatus</u> (Pallas) Starry flounder	Juveniles	1.30	1.80			0.08	0.16	0.51	
Average total standing crop		273.0	5.58	3.90	0.06	2.88	2.20	1.44	0.75

exclusive of the 5 March collections with adult largescale suckers typically ranged between 1 and 5 g per 100 m².

Birds

Thirty-four species of birds were recorded during the bird surveys (Table 15). Between 19 and 27 species were noted (mean = 21.8 species/survey day; sd = 3.8; n = 6) during each site visit that were associated with the system. One additional noteworthy species was observed in the marsh by Thais Bock of Tahoma Audubon Society. On 11 October 1986, a Bar-tailed Godwit was noted feeding and resting on the flats as the tide was flooding. This report represents the farthest west sighting of the species. Species observed on at least five visits to the site included Double-crested Cormorants, Mallards, Gadwalls, American Widgeons, Great Blue Herons, American Coots, Killdeers, Least Sandpipers, Common Snipes, Western Gulls, Barn Swallows, Rough-winged Swallows, Red-winged Blackbirds, and Savannah Sparrows. Of the three target resource bird types, waterfowl comprised the greatest percentage of observations (Table 16). The greatest number of birds were noted on the marsh flats on most days as compared to other habitats (Fig. 14). Bird species noted in the wetland that are potential predators on fish include the Common Loon, Western Grebe, Cormorant, Common Merganser, and Great Blue Heron.

General notes on birds were taken during a site visit in December. Approximately 50 gulls, 40 Mallards, and three geese were observed in the wetland. In addition, four pheasant were flushed from the dike bank immediately above flat 1.

Table 15. Maximum observed number of individuals of each bird species in the wetland system. Bird types: S = shorebird; W = waterfowl; R = raptor; 0 = other.

Name	Type	Date						Primary habitats of observations
		2 April	8 April	20 April	26 May	12 June	14 July	
Common Loon	W	0	0	1	0	1	0	Open water
Western Grebe	W	2	1	0	0	4	2	Open water
Horned Grebe	W	1	1	1	0	0	3	Open water
Pied-billed Grebe	W	0	1	0	3	1	0	Open water
Double-crested Cormorant	W	1	1	24	0	2	1	Open water
Canada Goose	W	0	0	0	15	14	14	Open water; dike
Mallard	W	12	18	14	19	15	18	Flats; open water
Gadwall	W	2	0	1	2	3	2	Open water
American Widgeon	W	6	3	0	1	4	0	Open water
Green-winged Teal	W	0	0	0	2	2	1	Open water
Common Merganser	W	0	1	1	0	1	0	Open water
Red-tailed Hawk	R	1	0	1	0	1	0	Aerial
California Quail	O	0	0	0	0	0	1	Cattails
Great Blue Heron	S	1	2	0	11	1	1	Cattails; flats
Green Heron	S	0	0	0	1	0	1	Flats
American Coot	W	0	5	4	2	4	8	Open water
Killdeer	S	8	12	10	0	12	12	Dike; flats; cattails
Least Sandpiper	S	0	31	0	35	11	6	Flats
Western Sandpiper	S	8	0	0	15	18	11	Flats
Common Snipe	S	3	2	2	0	7	3	Cattails
Western Gull	W	2	8	8	10	7	0	Dike
Herring Gull	W	0	6	0	0	5	2	Dike
Bonaparte's Gull	W	0	0	4	1	0	2	Aerial
Rock Dove	O	6	0	2	2	0	2	Dike
Barn Swallow	O	12	4	7	12	5	3	Aerial
Cliff Swallow	O	0	10	0	8	16	1	Aerial
Rough-winged Swallow	O	5	4	6	8	10	10	Aerial
Common Crow	O	3	0	0	9	1	1	Dike
Robin	O	0	1	0	0	5	6	Cattails
House Sparrow	O	4	0	25	0	8	6	Cattails
Red-winged Blackbird	O	8	8	10	11	10	8	Cattails
Savannah Sparrow	O	5	7	3	0	7	3	Cattails
American Goldfinch	O	0	1	0	0	0	0	Cattails
Starling	O	6	0	0	0	0	0	Cattails
Total no. species		20	21	18	19	27	26	\bar{x} 21.8 SD 3.8

Table 16. Percent each bird type comprised of the total number of individuals observed on each date.

Bird type	Sampling date (1986)						Mean
	2 April	8 April	20 April	26 May	12 June	14 July	
Shorebirds	22%	37%	10%	37%	28%	27%	26.8
Waterfowl	28	35	47	33	36	41	36.7
Raptors	1	0	1	0	1	0	0.5
Others	49	28	42	30	35	32	36.0

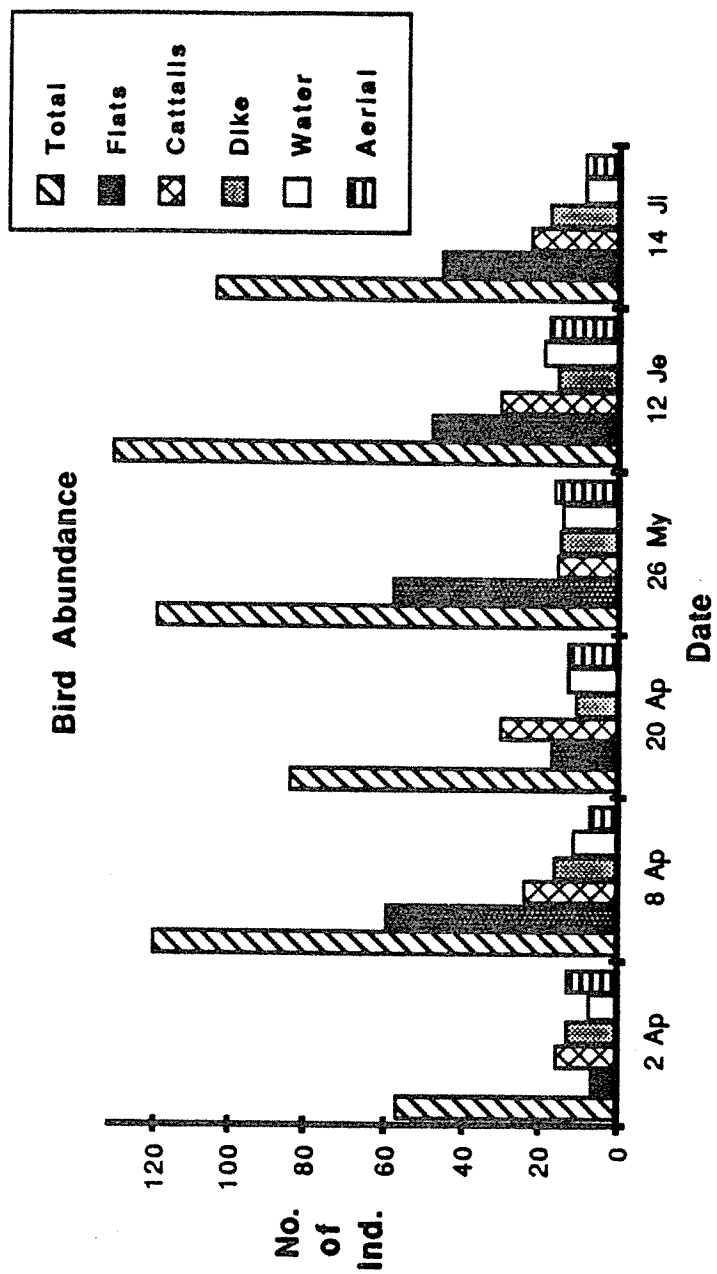


Fig. 14. Bird abundance in habitats over time in 1986.

Habitat Comparisons

The areal coverage of habitats in the system satisfied resource use criteria established for the project by resource agencies (Table 3). Most habitats were utilized by more than one target resource group. For example, waterfowl utilized dikes, vegetated wetlands and open water. Raptors sited in the wetland were assumed to be preying upon shorebirds and small mammals that occurred in several habitats and, therefore, areal habitat coverage for raptors included habitats utilized by prey species.

Primary production of sedge marshes in Parcel 5 can be roughly compared to Lincoln Street. If production at Parcel 5 is assumed to be equal to that at Big Beef Creek (i.e., 744 g dry wt/m²/growing season), then total production for Parcel 5 was 662 kg dry wt/growing season (7.3 tons wet wt). The value for Lincoln Street is approximately 41% of the Parcel 5 value, even though sedge marsh covers more area at Lincoln Street. The discrepancy is related to the fact that the Lincoln Street sedge marsh is in a development phase.

In comparison with Parcel 5, the Lincoln Street system contained more than twice the coverage of wetlands (Table 17). Also important is the fact that, unlike Parcel 5, the Lincoln Street system has a relatively large open connection with the Puyallup River that allows uninhibited access of fish and aquatic invertebrates to the system.

Table 17. Areal coverage of habitat types at the Parcel 5 and Lincoln Street wetland systems. Parcel 5 data are based on the vegetation map in Albright et al. (1984). * = habitats created by the project.

Habitat	Parcel 5	Lincoln St.	Difference ¹
Grassland/shrubland	3.76 ac.	2.94 ac.	-0.82 ac.
Trees	0.05	0.17	+0.12
Sedge marsh	0.22	2.57*	+2.35
Bentgrass marsh	1.56	0.00	-1.56
Cattail marsh	0.29	0.73	+0.44
Openwater/mudflat	0.01	2.81*	+2.80
Unvegetated upland/berm	3.71	0.35*	-3.36
Total area	<u>9.60</u>	<u>9.57</u>	<u>-0.03</u>
Wetland total (includes marshes and open water)	2.08	5.38 ²	+3.30

¹+ = more at Lincoln St; - = less at Lincoln St.

²The area for cattails was excluded from this total because the cattail marsh was existing at Lincoln Street prior to wetland construction.

DISCUSSION

The goal of the wetland construction project was to create habitats that are critical to juvenile salmonids, shorebirds, waterfowl, raptors, and small mammals in natural estuarine systems of the northwest. The wetland habitats include intertidal mudflats, sedge and cattail marshes, adjacent upland habitats including grass and shrublands, and trees. Wetland habitats have essentially been eliminated from the Puyallup River delta, and loss of marginal wetlands such as in the filling of Parcel 5 resulted in further losses. The Lincoln Street system contains 6.1 acres of wetlands, of which 5.4 acres are tidally influenced marsh and mudflat habitat. In comparison, Parcel 5 contained 2.1 acres of wetlands.

Sedge marsh establishment appears to be successful with a survival of the transplants of nearly 100%. By late summer, shoot production from the transplants resulted in a four-fold net increase in shoot density as well as an increase in shoot length. Transplant success was relatively poor in areas planted in early- to mid-summer as compared to those areas planted in spring. However, in the areas showing poorer results, sediments may be too hard for plants to establish and flourish. This will be evaluated further in spring and summer of 1987 by replanting these areas.

The method used for transplanting did not result in significant harm to the plants. We found that the 0.5-m as compared to 0.75-m spacing between holes resulted in higher densities of shoots at the end of the growing season. As plant survival was very high, and new shoot

production in the original hole and from rhizomes was occurring, we chose to use the lower planting density.

There appeared to be no difference in the survival, growth, and spread associated with plant material obtained from Oregon or from Big Beef Creek on Hood Canal. Carex showed good growth characteristics as measured by shoot production and shoot growth. The conclusion by other workers (Ternyik 1979, Colin Levings, personal communication 1985) that this species is an excellent choice for marsh establishment in tidally influenced riverine situations was borne out at Lincoln Street.

Sedimentation onto the flats occurred shortly after breaching and continued in some areas into December. The data suggest that predictions by hydrologists (D. G. Mutter, letter dated 19 October 1984) were correct in that sediment would accumulate in the tidally influenced portion of the system. Based on periodic measurements, it appeared that some areas showing early post-breach sediment accumulation stabilized later in the year. Areas that showed little sedimentation in spring accumulated some sediments by December. Sedimentation in the channels and mid-bay region was not assessed in the first year because of post-breach dredging activities. Sampling in 1987 will allow further evaluation of the sedimentation dynamics of the system. Based on observations on the input and subsequent removal within 1 week of wood debris and other floatable material from the wetland, it appears that the physical morphology of the system functions well to promote significant tidal flushing action.

How well did the system function in support of target biological resources? During these initial studies in 1986, we judged functional performance primarily in terms of plant production, benthic invertebrate abundance, salmonid presence, and bird presence. Monitoring proved that benthic invertebrates, fish (including juvenile salmonids), shorebirds, waterfowl and raptors utilized the system. Prior to dike breaching, the invertebrate assemblages were dominated by freshwater arthropods, and oligochaete worms in relatively low densities, as compared to literature values for natural systems (Selisker and Gallagher 1983). The assemblage changed considerably following dike breaching, and a riverine invertebrate assemblage appeared to colonize shortly following breaching. The colonization of new habitats by benthic invertebrates generally proceeds as a series of successional steps (Boyd 1982). We anticipate that densities and taxa diversity will change appreciably as succession proceeds. Oligohaline and euryhaline fishes appeared in the wetland immediately after its connection with the Puyallup River. In particular, four species of anadromous juvenile salmon were captured frequently throughout the initial 6 months of the wetlands development. Compared with Parcel 5, which was separated from the Puyallup River by a tide gate, the Lincoln Street wetland afforded juvenile salmonids freer access to more extensive wetland habitats.

The pre-breach collections of epibenthic and pelagic organisms represented a freshwater marsh assemblage due to the immigration of such animals from the Typha marsh at the higher elevations of the wetland, into the lower, "salt marsh" elevations via the small drainage stream (Fig. 2). Given this artificial "inoculation" of the wetland prior to

breaching of the dike, we cannot assume that the composition, density, and standing crop values are representative of a "natural" assemblage in vegetated, climax freshwater wetland such as that dominated by Typha. This information, however, did provide a benchmark as a comparison with fluvial (freshwater riverine) and estuarine taxa transported into and colonizing the wetland after the breach of the dike. For instance, it was apparent that the cladoceran Daphnia pulex was a dominant contribution of the freshwater marsh but functionally disappeared by the time of the breach, either due to the changes incurred in the shift to an estuarine wetland or, potentially, a resting (diapause) stage which reduced the influx to the wetland during the winter. Immigration through the breached dike was also the probable origin of Bosmina longirostris, Chydorus sphaericus, all the harpacticoids, Cyclops bicuspidatus, Acanthocyclops sp., and Microcyclops varicans. Some of these taxa will probably always be present in the wetland, particularly in the water column, due to fluvial transport from the river; others may eventually disappear or decline (as viable populations) on a seasonal basis due to variability in salinity intrusion.

Comparison of pre- and post-breach composition and standing stock of epibenthic and pelagic organisms indicated that: (1) organisms from the freshwater (Typha) marsh retained at the upper elevations of the wetland probably contributed most of the organisms found prior to the breaching of the dike, and continued to be a source of freshwater assemblages to the wetland after the dike breach, due to positive drainage

into the wetland; (2) taxa richness and numerical and gravimetric diversity increased with the immigration of fluvial and estuarine assemblages; (3) standing stock decreased between pre- and post-breach, probably due to the increased turnover and mixing of sediment with the initiation of fluvial and tidal flushing; and, (4) certain taxa of estuarine epibenthos (such as the harpacticoid copepods) appeared to have established populations immediately after connection to estuarine sources.

Shorebirds and waterfowl were attracted to the site, even prior to dike breaching. Shorebirds were noted on the shallow water mudflats and in the marsh, and appeared to be feeding in these habitats. Gulls, ducks, geese, heron and several other taxa of waterfowl were common in the system. It was difficult to evaluate the relative importance of the system to birds without data from reference areas. However, the general concentration of birds in numbers of individuals and numbers and types of species was high based on our general knowledge for Northwest estuaries.

The general picture with regard to bird assemblages in the system in spring was as follows. We noted waterfowl swimming in open water and in pools within the marsh. During lower tides, shorebirds were seen foraging on the flats at the edge of the marsh, and several herons were stalking prey at the water's edge. Swallows from the adjacent cattail marsh periodically swarmed over the marsh in search of insect prey. Raptors were noted hovering over the system, presumably in search of prey. We have not observed this general picture of the avian assemblage

species diversity, density, and behavior elsewhere in the Commencement Bay region.

The sedge marsh is in a phase of initial development. The transplants, besides providing immediate habitat, appeared to enhance the recruitment of other wetland plant species. The most dominant by size and distribution of these latter species included cattails and spike rush. Cover at the upper ends of two of the flats was dominated by these latter two species at the end of August. In comparison, the flat that was not planted had essentially no emergent plants.

Primary production, below- and above-ground biomass, and shoot density of sedge at the developing Lincoln Street site were low in comparison to the natural marsh at Big Beef Creek. Based on very limited long-term data (Broome et al. 1986, Colin Levings, personal communication 1986; Wilber Ternyk, personal communication 1987) from other artificially established marshes, development proceeds for 3-10 years. Two factors that could have significant impacts on the establishment and maintenance of the functional values of the wetland system are sedimentation and sewage treatment plant effluent. The Puyallup River is a major source of sediments, and it is anticipated that the wetland will be a sediment sink. Wetlands dominated by emergent vegetation do tend to trap sediments. At Lincoln Street, sedimentation may pose a threat to maintenance of fishery-related functions. Therefore, removal of sediments by dredging may be required periodically in the future. Primarily treated effluent is presently discharged about 100 m upstream of and on the side of the river opposite the mouth of the wetland. We have

noted floating sewage particulates in channels within the wetland, and nutrients, organic matter, and toxicants have had unknown but possibly significant impacts on the system. The situation will change in the near future when a new outfall is constructed in Commencement Bay.

RECOMMENDATIONS

System Maintenance Recommendations

As indicated in the Discussion section, areas showing poor transplant survival should be planted again in 1987 (this will be carried out). Substrata in these areas may be too hard. Should survival again be poor, coarser grained sediment should be mixed with existing sediment, and the area should be replanted.

The major threat to maintenance of the wetland system is sedimentation from the Puyallup River. Our observations and measurement show that significant sedimentation has taken place at the mouth of the wetland and in the channels. We expect that tidal action will maintain a channel at the mouth. However, channels between the flats should continue to accrete sediment. We strongly recommend that the Port survey elevations on the flats and in the channels, and that these data be compared with "as built" surveys. This information will define the location and indicate rates of sedimentation occurring in the system. A hydrologist familiar with wetland channel design should be consulted regarding options for maintaining open channel with minimal dredging requirements.

Monitoring Recommendations

Studies conducted at Lincoln Street in 1986 fulfill regulatory requirements regarding compensatory mitigation specific to Parcel 5, and provide valuable data that can be incorporated into the planning and design of future projects. Monitoring will aid our understanding of the long-term fate of an artificially established sedge marsh in a tidally

influenced riverine area in the Northwest. This understanding is critical when evaluating the length of time a constructed wetland takes to reach maximum sustainable performance, which is important to the maintenance and enhancement of biological resources resident within the system.

Permit-related Monitoring Program

Below, we recommend components of a monitoring program (tentatively proposed for 1988, 1989, and 1990) that address the regulatory requirements (i.e., proving establishment and success of the wetland as mitigation for loss of habitat due to filling of Parcel 5. The Port of Tacoma has funded 1986 and 1987 studies, and would fund a 3-year permit-related monitoring program described below. This proposed program is intended to form a starting point for discussions among agency representatives regarding specific requirements for 1988-1990 monitoring period at the Lincoln Street wetland. The 1987 monitoring schedule is shown in Table 18.

We recommend that the 1988-1990 monitoring program include five components. The program will result in a data set that will aid in work required to maintain a functioning wetland system in perpetuity. The recommendations are based on our understanding of the system and the requirements of the target resources. We have followed the general reasoning of Zedler (1984) in proposing the program. Zedler states that a monitoring program should include ". . . those features that ecologists find to be important indicators of ecosystem function plus those features which the public views as important assets."

The long-term program should include the following components:

- (1) sedimentation—Measure the location and amount of sedimentation in the wetland in order to evaluate when maintenance activities (e.g., dredging) should be carried out;
- (2) vegetation—Measure the distribution and quality (i.e., cover, density, standing stock) of emergent vegetation in order to assess the condition of dominant habitats, and the need for maintenance of these habitats;
- (3) juvenile salmonid prey resources—Measure the quantity and quality (i.e., species densities) of major prey items for juvenile salmonids as an indication that the wetland is providing adequate food for the resource for which the wetland was primarily designed;
- (4) fish—Measure the species abundances of fish, focusing on juvenile salmonids, occurring in the wetland in order to evaluate the functioning of the wetland with regard to the primary target resources; and,
- (5) birds—Measure the species density of birds occurring in the wetland system in order to assess the functioning of the system with regard to shorebirds, waterfowl, and raptors.

Additional Research Recommendations

The Lincoln Street wetland system presents a unique opportunity to advance wetland construction technology. The studies described below

are largely applied research designed to enhance the general understanding of wetland functions and to provide data needed to advanced wetland construction technology. We strongly recommend that these studies be funded by appropriate agencies other than the Port of Tacoma.

The data show that the system was functioning as a wetland within 1 year of construction initiation. However, the functional performance of the system can be fully evaluated only through comparison with other natural systems that are similar to the one being developed at Lincoln Street. The Lincoln Street wetland supports different target resource groups as compared to Parcel 5. In particular, juvenile salmonids are afforded free access to productive shallow flats and channels in contrast to no access to the wetlands of Parcel 5.

We conducted limited studies at Big Beef Creek to compare the production and other characteristics of the sedge marsh there with that at Lincoln Street. Other key parameters that require comparative data are juvenile salmonid prey density and fish diet in tidally influenced sedge marsh systems. Furthermore, the question regarding residence time of the salmonids in the Lincoln Street wetland system needs to be addressed to evaluate the performance of the wetland as rearing habitat. Salmonid feeding and residence time within the Lincoln Street wetland will be addressed by studies funded by the Port of Tacoma as part of the monitoring work in 1987.

Recommendations for continued studies of epibenthic and pelagic invertebrate assemblages include: (1) laboratory processing of archived samples collected between early March and June 1986, to map the con-

tinued succession of fluvial and estuarine assemblages introduced into, and potentially colonizing, the wetland; (2) continued sampling of epibenthic assemblages, with focus on the potential prey resources of juvenile salmon, in order to evaluate the "succession" of an estuarine community in the wetland; (3) examination of the stomach contents of fishes, particularly juveniles, utilizing the wetland to establish the relative contribution of epibenthic, pelagic, and benthic organisms in their diets; (4) depending upon the findings of (3), continue to monitor the composition, standing stock, and flux of pelagic zooplankton in order to separate the role of the wetland per se as compared to exogenous sources such as the freshwater marsh, the Puyallup River, and tidally introduced Commencement Bay waters; and (5) initiate a study of emergent insects in the developing (both planted and naturally colonizing) marsh habitats in the wetland in order to establish the rate and composition of the emerging assemblage.

It is recommended that subsequent studies in the Lincoln Street wetland be designed to address the latter two data gaps as the wetland continues to develop as a low marsh and tidal channel habitat. Specifically, we propose that an intense mark-recapture study be coupled with emigration-immigration monitoring at the mouth of the wetland in order to better understand the flux and residence rate of fish moving through the wetland. Subsequently, the relationship of these data may be related to physiochemical variables, such as tide and temperature, and to the composition and production of various prey resources in the wetland. In addition, food habits and growth information obtained concurrently should provide some relative indication of the contribution of the wet-

land's developing prey resources to the fishes' during their residence in the wetland.

Three concordant sets of information are needed: (1) reference data from a comparable, natural wetland which would provide a quantitative indication of the species, life history stages, and standing stock levels which might be expected in a fully developed low marsh wetland; (2) data on the residence time and growth of fish in the wetland, to better understand the magnitude and periodicity of feeding, growth, and protection from predation which the restored wetland may be affording these fishes; and (3) food habits data on the fishes during their residence in the wetland, in order to evaluate the restored, developing marsh habitat as foraging area. Points 2 and 3 will be investigated in 1987.

Reference Systems

We strongly recommend one or more reference sites be established, and that the above studies be carried out at these sites in conjunction with the monitoring program in the Lincoln Street wetland. The responsibility of the Port of Tacoma to fund studies at reference sites must, again, be viewed in a regulatory context. The Lincoln Street wetland is compensatory mitigation for filling of the Parcel 5 wetland only, and comparison of biological conditions at Lincoln Street with those at Parcel 5 only is necessary to evaluate whether the fill was adequately mitigated. We suggest that resource agencies jointly erect representative estuarine monitoring sites and pursue monitoring studies similar to those outlined above. These studies could be used to evaluate perform-

ance or success parameters such as expected salmonid prey densities, plant densities, sedimentation rates, and bird and fish use. The work would provide a unified data set upon which to base performance standards for constructed wetland systems.

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