Experimental Transplants of Brackish and Salt Marsh Species on the Fraser River Estuary

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EXPERIMENTAL TRANSPLANTS OF BRACKISH AND SALT MARSH SPECIES ON THE FRASER RIVER ESTUARY

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ABSTRACT

Pomeroy, W.M., D. K. Gordon and C. D. Levings. 1981. Experimental transplants of brackish and salt marsh species on the Fraser River estuary. Can. Tech. Rep. Fish. Aquat. Sci. 1067: iv + 35 p.

In winter 1979, rhizome plugs of three species of brackish marsh plants (*Carex lyngbyei*, *Scirpus americanus* and *S. maritimus*) were transplanted to three different habitats at the Fraser estuary. One foreshore location, Iona, was characterized by relatively high salinities (>13$^{o}/_{oo}$ during freshet) and wave focussing due to jetties. Survival at this location was negligible, and observations were limited. A second foreshore location, Albion, was somewhat more sheltered and of lower salinity being closer to the mouth of the river. At this location plug success was 69% and 65% for *S. americanus* and *C. lyngbyei* in 1979. Shoot density peaked in late August to mid-September in both 1979 and 1980. In both years, *C. lyngbyei* transplants attained shoot heights of about 25% the height of donor site plants. *S. americanus* shoot heights were about the same as those at donor sites. Fifty-two percent of *C. lyngbyei* plugs produced seeds at Albion compared to 39% for *S. americanus*. A third location, Steveston Island, was a site on the south arm of the Fraser. At this location, plug success was 71% and 84% for *S. americanus* and *C. lyngbyei*, respectively. Shoot densities of *S. americanus* at Steveston Island were significantly higher than at Albion (peak mean of 9.2 *vs* 5.1 shoots per plug, respectively). For *C. lyngbyei*, differences were not significant (peak mean of 14.4 *vs* 11.0 shoots per plug). In 1979, *S. americanus* at Steveston achieved a maximum height of only about 50% of the donor site. *C. lyngbyei* plants were heavily grazed by waterfowl. More *C. lyngbyei* plants bore seeds at Steveston (80%) compared to Albion (53%). *S. americanus* showed the opposite pattern of seed production (39% vs 48%). Rhizome extension in 1979 for *C. lyngbyei* and *S. americanus* was about the same at both locations, about 20 cm for *C. lyngbyei* and 36 cm for *S. americanus*. Most plugs of both species were coalesced by 1980.

An additional transplant of 2 salt marsh species, *Salicornia virginica* and *Distichlis spicata* into the Iona area in 1980 was unsuccessful.

There was no significant difference in grain size of surficial sediments inside the transplant quadrats compared to non-vegetated habitats outside. Water content of sediment increased during freshet at Albion and Steveston. There was no significant difference in the organic content of sediments inside and outside the quadrats at either location. Sediment chlorophyll *a* values were approximately the same inside and outside transplant quadrats reflecting natural substrate colonization by microalgae, but with no increase attributable to the presence of vegetation. Filamentous forms such as *Enteromorpha* were trapped by the transplanted marsh, and subsequently colonized by invertebrates.

RÉSUMÉ

Pomeroy, W. M., D. F. Gordon, and C. D. Levings. 1981. Experimental transplants of brackish and salt marsh species on the Fraser River estuary. Can. Tech. Rep. Fish. Aquat. Sci. 1067: iv + 35 p.

Au cours de l'hiver 1979, des sections de rhizomes de trois espèces de plantes (Carex lyngbyei, Scirpus americanus et S. maritimus) de marais saumâtres ont été transplantées dans trois différents habitats de l'estuaire de Fraser. Iona, un emplacement d'estran, aviat des salinités élevées (>13‰ pendant la crue) et une convergence de vagues provoquée par des jetées. La survie à cet endroit a été négligeable et les observations, restreintes. Un deuxième emplacement d'estran, Albion, était un peu plus protégé; la salinité y était moins élevée, cet endroit étant plus près de l'embouchure du fleuve. La transplantation y a connu un succès allant de 69 % pour S. americanus à 65% pour C. lyngbyei en 1979. La plus forte densité de pousses s'est produite de la fin d'août à la mi-septembre en 1979 et en 1980. Au cours de ces deux années, les pousses de transplants de C. lyngbyei ont atteint une hauteur d'environ 25 % de la hauteur des plantes du site natal. La hauteur des pousses de S. americanus était sembable à celle des plantes du site natal A Albion, 52 % des sections de C. lyngbyei et 39 % des sections de S. americanus ont produit des graines. Le troisième emplacement, Steveston Island, est situé sur le bras sud du Fraser. À cet endroit, le succès de la transplantation de S. americanus et C. lyngbyei a été de 71 % et 84 %, respectivement. La densité des pousses de S. americanus à Steveston était plus élevée qu'à Albion (moyenne maximale de 9,2 vs 5,1 pousses par section, respectivement). Les différences n'étaient pas significatives pour C. lyngbyie (moyenne maximale de 14,4 vs 11,0 pousses par section). En 1979, les transplants de S. americanus à Steveston ont atteint une hauteur maximum d'environ 50 % de celle des plantes du site natal. Les plants de C. lyngbyei ont été fortement broutés par les oiseaux aquatiques. Les plants de C. lyngbyei ont produit des graines en plus grand nombre à Steveston (80 %) qu'à Albion (53 %). Le contraire s'est produit pour S. americanus (39 % vs 48 %). En 1979, le prolongement des rhizomes était presque le même pour C. lyngbyei (20 cm) et S. americanus (36 cm) aux deux endroits. La plupart des sections des deux espèces s'étaient fusionnées en 1980.

Une autre transplantation en 1980 dans la région d'Iona de deux espèces de marais salant, Salicornia virginica et Distichlis spicata, n'a pas réussi.

La grosseur des particules des sédiments superficiels n'accusait pas de différence significative entre les cadrats transplantés et les habitats sans végétation. Le volume d'eau contenu dans les sédiments a augmenté au moment de la crue à Albion et à Steveston. Il n'y avait pas de différence significative dans le contenu organique des sédiments entre l'intérieur et l'extérieur des cadrats aux deux endroits. Les valeurs de chlorophylle a du sédiment étaient semblables à l'intérieur et à l'extérieur des cadrats transplantés, démontrant la colonisation naturelle du substrat par les algues microscopiques, sans augmentation imputable à la présence de végétation. Les formes filamenteuses, dont Enteromorpha, ont été retenues par le marais transplanté et colonisées par des invertébrés.

INTRODUCTION

Alienation of the brackish marshes of the Fraser River estuary has become an important issue in recent years, since valuable habitat for fish and wildlife has been lost through dyking, filling, dock construction and sewage pollution (Anon 1978). Restoration of these habitats is one option open to the habitat manager, but there are few local data available on techniques. Experience elsewhere, primarily transplant efforts using sediments from dredging, has shown promise for this strategy. For example Heilman et al. (1978) successfully transplanted marsh species onto an artificial island in the lower Columbia River.

The present report deals with transplant experiments and technique development conducted with 3 species of brackish marsh plants: Carex lyngbyei, Hornem (Lyngbey's sedge), Scirpus americanus, Pers. (three-square bulrush), S. maritimus L. and 2 salt marsh species, Salicornia virginica L. and Distichlis spicata (L.) Greene. Transplant locations on Sturgeon and Roberts Bank and on the lower part of the Fraser River were used. Donor sites were at similar locations for brackish species and at Boundary Bay for saltmarsh plants. Preliminary results were presented in a workshop report (Pomeroy and Levings 1980) and complete tabulations of observations have been given in a data report (Pomeroy et al. 1981).

MATERIALS AND METHODS

Three sites, representing a range of habitat types, were selected on the Fraser River estuary (Fig. 1) for transplant during 1979/80. The Steveston Island transplant site (Fig. 1) is exposed to strong river current (>200 cm/sec) and moderate wave action from passing ships. Sediments are composed of loosely compacted, coarse sand typical of newly deposited dredge spoil. Marshes dominated by Scirpus americanus and Eleocharis palustris exist along the south side of the island. A 40 x 15 m transplant quadrat was established at this site, on a moderately sloping beach, where elevation ranged from about 1.4 to 3.2 m over chart datum.

The Albion site (Fig. 1) is a foreshore area open to wave and tidal currents. Sediments consist of coarse to fine sand either compact or loosely deposited. Extensive adjacent marshs of Scirpus americanus, S. validus, and Carex lyngbyei exist at this site. A 35 x 15 m transplant quadrat was established at the Albion site, at an uniform elevation of approximately 2.4 m above chart datum (determined by orthophotography, on June 12, 1979, courtesy Hugh Hamilton Ltd.).

The third transplant, approximately 7 km to the north of Albion, is the Iona intercauseway area representing high energy foreshore with wave focussing (Fig. 1). Sediments are composed of compacted coarse to fine sand. An area of sand waves exists along the length of the two jetties but not in the central area. Two transplant quadrats, one being peripherally located and 50 x 50 m in size, the other being central and 40 x 15 m in size, were established. The topography of the Iona intercauseway area was surveyed using transits in September 1978, and by boat, using an echo sounder, in February 1979. Detailed contour maps of these surveys are available from one of us (C.D.L.).

All the above transplant quadrats are within the tidal range 2.5 to 3.5 m above chart datum. This elevation range has been suggested as having optimum submergence/emergence ratios for the species selected for transplanting (Moody 1978, Kistritz 1978, Envirocon 1980). Two slightly higher elevation quadrats (32 x 12 m and 32 x 10 m) were chosen as transplant sites for Salicornia virginica and Distichlis spicata, as these plants occur naturally in the upper intertidal.

Donor sites (Fig. 1) for the transplant experiments were chosen carefully to match the transplant site as closely as possible with respect to sediment grain size, salinity, organic content, water content, and elevation. Carex lyngbyei was obtained from the north side of Steveston Island and transplanted to all three sites. Scirpus americanus was obtained from the south side of Steveston Island then transplanted to Steveston and Albion. A site off the end of Francis Road was used for transplants to Iona. Scirpus maritimus was also obtained from the Francis Road site. Salicornia virginica and Distichlis spicata was obtained from a donor site in Boundary Bay for transplants to Iona.

Transplanting of Carex lyngbyei, Scirpus americanus, and S. maritimus was carried out between January and early March of 1979 when the plants were dormant and new shoots had not yet broken the surface. Salicornia virginica and Distichlis spicata were transplanted during February, 1980. A 'Par A cup cutter',used at golf courses, was used to obtain sediment plugs, containing plant shoots, 10 cm in diameter, 15 cm deep. Plugs containing rhizomes and shoots were taken at low tide at roughly 1 m intervals. When planting, the 'cup cutter' was used to make holes in the substrate at 1 m intervals into which the transplant plugs were placed.

The mean number of shoots per transplant plug, from the Steveston and Francis Road donor sites, at the time of transplanting was determined to be: Carex lyngbyei - 3 per core; Scirpus americanus - Steveston donor site - 4 per core, Francis Road donor site - 18 per core; and Scirpus maritimus - 4 per core.

The growth and development of C. lyngbyei and S. americanus transplants at Albion and Steveston was monitored at roughly monthly intervals. The success rate of of transplant plugs was determined by recording presence/absence over the entire quadrat in 1979. Changes in shoot density, mean shoot height and rhizome extension length and the presence/absence of seed heads (1979 only) were determined for a number of randomly selected plugs at each site in 1979 and 1980. Surface (to 2 cm depth) and subsurface (10 cm depth) sediment samples (2.0 cm^3) were also collected at randomly chosen locations within the quadrats immediately adjacent to a plug, and also from outside of the transplant quadrats to act as controls. Sediment material was subsampled immediately upon return to the laboratory. Analyses were performed to determine the active chlorophyll a and phaeopigment concentrations of surface samples and organic content, water content, grain size and intertidal salinity of surface and subsurface samples. Transplant monitoring procedures and sediment analytical procedures are described in detail in Pomeroy et al.(1981). Both the 1979 and 1980 transplants to Iona were initially monitored at roughly monthly intervals. However, due to poor growth results, monitoring was discontinued before the end of the growth season each year.

RESULTS

A. STEVESTON and ALBION

I. Transplant Monitoring

a. Plug Success

The number of transplanted plugs growing at the Albion and Steveston sites during 1979 reached a mid-summer maximum for both species. Plug success of *Scirpus americanus* and *Carex lyngbyei* at Albion peaked at 69% and 65%, respectively in late June (Table 1). However, a marked difference in growth was found between the outermost (row 2) and innermost (row 7) rows of *S. americanus*. Observation revealed that unsuccessful plugs tended to be located at the ends of the inner rows but at any point along the outer rows (Pomeroy et al. 1981). This edge effect became evident in late May and persisted through the rest of the monitoring period. Plug success at the Steveston quadrat (Table 1) showed a maxima of 71% for *S. americanus* and 84% for *C. lyngbyei* in late June - early July. No edge effects were obvious for either species at this site.

b. Shoot Density

Transplant plugs of *S. americanus* on Steveston Island had significantly greater ($F = 17.40$; $df = 1,227$; $P<0.05$) shoot densities per plug in 1979 than those at Albion after an initial similar growth phase (Fig. 2). The between site differences in density for *C. lyngbyei* were not significant ($p>0.05$). *S. americanus* increased from an initial planting density of 4 shoots per plug to a peak mean of 9.2 (max. = 24) at Steveston and 5.1 (max. = 11) at Albion. *C. lyngbyei* plugs reached a peak mean of 14.4 (max. = 29) at Steveston and 11.0 (max. = 16) at Albion, increasing from an initial planting density of 3 shoots per plug. Seasonal growth patterns for both species were similar with shoot density peaking in late August to mid-September, followed by a rapid decline.

The 1980 density values are expressed on a 1/4 m^2 basis, due to plug coalescence, and thus are not directly comparable with the 1979 data. The basic 1979 pattern of increasing shoot density to late summer was evident in all cases except *S. americanus* at the Albion site (Fig. 3). The initial shoot density for C. lyngbyei at the start of monitoring in May 1980 was at least 2-3 times that recorded for S. americanus. This condition persisted throughout the growing season at both sites. No significant (p>0.05) density differences between sites were determined for either species.

c. Shoot Height

Seasonal patterns of shoot growth differed between transplant sites during 1979. At Albion both C. lyngbyei and S. americanus exhibited an increase in shoot height through to late August, followed by a decrease in September (Fig. 2). At Steveston, however, these species reached a peak in early July followed by a slight decrease in shoot height for S. americanus, while C. lyngbyei showed a more marked reduction over the following months due to grazing by birds. C. lyngbyei transplants at both sites attained similar heights, about 25% of the height of plants at the donor site (180 cm) (Fig. 4). Transplants of S. americanus at Albion reached the approximate height of donor site plants while S. americanus at Steveston reached a maximum height of only about 50% of the donor site value (49 cm).

Both sites showed a similar pattern of seasonal shoot growth during 1980 with both species reaching a maximum height in early July and decreasing thereafter (Fig.2,3). The C. lyngbyei donor site also displayed an August height reduction similar to the transplants but plants at the S. americanus donor site continued to increase as of the August sampling (Fig. 4). Growth maxima at Steveston were approximately the same as those recorded during the 1979 season. Maximum mean shoot heights at Albion were somewhat less than those at Steveston with C. lyngbyei and S. americanus reaching 30.5 cm and 39.0 cm respectively, versus heights of 44 cm and 43 cm at Steveston. Grazing by waterfowl was evident at Albion. C. lyngbyei and S. americanus plants at the donor sites showed respective maximum mean shoot height values of 3 and 2 times those of the transplants (Fig. 4).

d. Seed Production

During the summer of 1979 a large proportion of the C. lyngbyei and S. americanus plugs produced seeds. At both sites, C. lyngbyei was observed to produce seeds over a much shorter period (late May to July) than did S. americanus (late May to mid October) (Pomeroy et al. 1981). Late May appeared to be the period of maximum seed production by both species at both sites. At Albion, a larger proportion of C. lyngbyei plugs (52.9%) produced seeds at this time compared to S. americanus (38.5%). Seed production in late May was higher at Steveston. About 80% of the C. lyngbyei plugs produced seeds compared to 48% for S. americanus.

No quantitative seed data were collected in 1980 due to the inability to identify individual plugs. However, field observations did indicate heavy seed production in early to late May.

e. Rhizome Extension

Rhizome extension, as evidenced by shoot appearance for C. lyngbyei was about one half that recorded for S. americanus (Table 2) and Eleocharis palustris (a contaminant species in the plugs). Extensions were fairly comparable at the two sites by the end of the 1979 growth period with C. lyngbyei reaching 19-20 cm and S. americanus 35-37 cm, for Albion and Steveston, respectively. S. americanus and E. palustris had such an extensive network of rhizomes extending from them that in many cases the interplug areas were filling in rapidly after the first season of growth. With this pattern re-appearing early in the 1980 growth season, it was not considered practical nor was it possible to identify the source of inter-plug rhizome extensions. Thus data were not collected.

Judging from a few C. lyngbyei plugs dug up at the Steveston quadrat in August 1980, rhizomes were also well developed vertically, penetrating approximately 20 cm from the bottom of the core.

II. Sediment Monitoring

a. Grain Size

Surface sediment samples from inside and outside the quadrat at Albion and from within the quadrat at Steveston showed a significant (Albion: $F = 28.41$: df = 5, 92; $p<0.01$; Steveston: $F = 6.44$; df = 3, 69; $p<0.01$) seasonal variation in 'per cent fines' during 1979 (Fig. 5). However, comparison of the trends exhibited at the two sites (Fig. 5) shows little similarity. A significant ($F = 6.69$; df = 1, 92; $p<0.05$) difference was determined between trends exhibited inside and outside of the Albion quadrat.

The 1980 data (Fig. 5) also show seasonal variation in 'per cent fines' at both sites. This variation was significant ($F = 10.63$; df = 3, 48; $p<0.01$) at Albion but not Steveston. No significant difference was determined between samples taken from inside or outside of the quadrat at either site.

b. Interstitial Water Content

The 'per cent water content' was determined for both surface and subsurface (approximately 10 cm depth) sediment samples from inside and outside the transplant quadrats at Albion and Steveston (Fig. 3). The 1979 data displayed only minor fluctuations, averaging 12 to 15% water content between May and September.

A different pattern existed in 1980 with considerable temporal fluctuations in sediment water content (Fig. 6). There was generally a marked increase between late May and late June followed by a period of lower values through to early August. Water content at Steveston was somewhat lower compared to Albion. Surface sediment water content at both sites exhibited a wider range of volume than did subsurface samples, reflecting duration of tidal exposure.

Donor sites showed minor fluctuations in sediment water content over the 1979 season (Fig. 4). Values at the Scirpus americanus donor site on Steveston Island were only slightly higher than those recorded at the transplant sites. However, at the Carex lyngbyei donor site sediment water content values were generally 5-8% higher than transplant site values. Limited data on 1980 donor site sediment water content indicate that the Steveston Island S. americanus donor site exhibited only slight fluctuations over the summer months while the C. lyngbyei donor site exhibited sediment water content values more than twice those recorded at the transplant sites during May and June.

c. Interstitial Sediment Salinity

Sediment salinities at both Albion and Steveston exhibited a rapid decrease during May 1979, from greater than $10^{o}/_{oo}$ to about $2^{o}/_{oo}$ in June - July, coinciding with freshet (Fig. 6). Higher values were noted at Albion in August and September compared to those at the Steveston quadrat. Surface and subsurface values were similar at each site. A parallel pattern was evident outside of the quadrats.

Salinity patterns for the summer of 1980 were comparable to those described for 1979 (Fig. 6), with values being somewhat lower. Subsurface salinities were similar inside and outside of the quadrat at each site.

Sediment salinities at the Steveston Island donor sites showed a marked decrease during May 1979 (Fig. 4). Summer values at the S. americanus donor site were similar to those at the transplant sites while values at the C. lyngbyei donor site were somewhat higher. The Francis Road donor site also showed a decrease over the early months of 1979 (Fig. 4) which reached a minimum in early July. Due to inadequate sampling little can be said about the 1980 Steveston Island donor site sediment salinities except that the mid-summer values are lower than in the previous year and much lower than those at the Albion transplant site.

d. Sediment Organic Content

Surface sediment organic values (LOI) from inside and outside of the Albion quadrat and inside of the Steveston quadrat showed a general increase over the 1979 growth season (Fig. 7). Subsurface organic values decreased dramatically over the same period (Fig. 7). The maximum surface sediment organic value recorded at Steveston was 8.7 mg/cc, less than one half the peak mean value recorded at Albion, 17.8 mg/cc. The temporal variation of surface sediment organic content from inside the quadrats at the two sites was found to be statistically significant ($F = 8.33$; df = 3, 87; $p<0.01$) as were the between site differences ($F = 28.04$; df = 1, 87; $p<0.01$).

Sediment organic content values recorded during 1980 are in the same range as those for 1979 (Fig. 7). Summer mean maxima of 10.1 mg/cc and 16.0 mg/cc were recorded for surface sediments from inside the Steveston and Albion quadrats, respectively. Surface values from inside the quadrat at Albion were consistently higher than those at Steveston. Surface organic values from outside of the quadrats exhibit roughly the same trend as those within (Fig.7). The temporal variation in surface organic content ($F = 38.31$; df = 3, 94; $p<0.01$) and between site differences ($F = 12.70$; df = 1, 94; $p<0.01$) were found to be significant at the two sites during 1980. However, no significant difference existed between surface samples from inside and outside of the quadrats. The data available suggest a trend towards increasing organic content over the summer months (Fig. 7), with values being higher inside the quadrat at Albion and the reverse being true at Steveston.

The surface sediment organic content values for the Scirpus americanus donor site on Steveston Island during 1980 show large fluctuations from month to month (Fig. 4). The pattern of these fluctuations corresponds with temporal changes occurring at the transplant quadrats at both sites, however, the magnitude of the changes is more pronounced. Subsurface organic values, while sampled less frequently, showed a general increase over the same period and in the same range as subsurface values from inside and outside the Albion quadrat and outside the Steveston quadrat. A mean surface sediment organic value of 41.3 mg/cc for July 1980 is the only datum available for the Steveston Island Carex lyngbyei donor site. This is 2 and 4 times larger than corresponding inside quadrat surface values at Albion and Steveston, respectively.

c. Sediment Chlorophyll Content

Surface sediment chlorophyll a values increased from 1.27 µg/cc in early March 1979 to 15.63 µg/cc in late August 1979 inside the Albion quadrat (Fig. 8). Surface sediment chlorophyll a values from outside the quadrat peaked at 17.35 µg/cc a month later in mid-September. Although only sparse data exist for the Steveston transplant quadrat during 1979, much lower levels are indicated (Fig. 8).

Phaeopigment concentrations at both sites during 1979 were lower than chlorophyll a (Fig. 8). A trend towards increasing levels through October was recorded inside and outside the Albion quadrat. Available data from Steveston show much lower concentrations than those present at Albion.

The ratio of chlorophyll a to phaeopigments, reflecting the photosynthetic activity of the microalgal community in the sediment, rose from 1.32 in March to 3.62 in August inside the Albion quadrat during the 1979 season (Fig. 8). Similar values were recorded outside the quadrat.

Surface sediment chlorophyll a and phaeopigment concentrations recorded at both sites during 1980 proved to be lower than in 1979. Chlorophyll a ($F = 43.80$; df = 3, 43; $p<0.05$) and phaeopigment ($F = 3.83$; df = 3, 43; $p<0.05$) concentration from inside and outside the Albion quadrat showed significant increases over the sampling period. Chlorophyll a from inside and outside the Steveston quadrat showed only a slight change, which was not statistically significant, while phaeopigment concentrations showed a significant ($F = 15.69$; df = 3, 41; $p<0.05$) decrease.

Chlorophyll a to phaeopigment ratios were generally higher at the Steveston site, both inside and outside the quadrat, than at Albion during the 1980 sampling period (Fig. 8). A notable feature is the opposite pattern for Albion and Steveston during May and June. A large increase in the ratio occurred at Steveston accompanied by a smaller decrease at Albion.

Surface sediment chlorophyll a and phaeopigment concentration from the Steveston Island Scirpus americanus donor site showed a decrease over the sampling period in 1980 (Fig.4). Values are in the same range as concentration values determined at the transplant sites. Available data for the Carex lyngbyei donor site on Steveston Island shows July 1980 mean values of 23.3 µg/cc for chlorophyll a and 37.5 µg/cc for phaeopigment, greater than 20 times higher than corresponding values recorded at the transplant sites.

B. IONA

Only very minimal short term growth was observed for S. americanus, S. maritimus and Carex lyngbyei transplants at Iona during 1979. Interstitial salinities showed a decrease over the summer months but values never dropped below $13^{o}/_{oo}$ (Fig. 4). Interstitial sediment salinities recorded at the Francis Road and Steveston Island donor sites dropped much lower over the summer months (Fig. 4). Monitoring was discontinued at the end of the summer due to lack of growth.

The success of transplant plugs of Salicornia virginica and Distichlis spicata at Iona decreased steadily from mid April through July of 1980. Monitoring of plug success was discontinued after July 7 because of the high mortality. In August 1981 the plugs were still intact but only two showed evidence of growth.

DISCUSSION

A. Survival and Performance of Transplants

Since only two other transplant experiments, to our knowledge, have been performed with estuarine Carex spp. or Scirpus spp., we have few data with which to compare our survival results. Heilman et al. (1978) and McVay et al. (1980) transplanted C. lyngbyei and C. obnupta onto dredged sand in the lower Columbia River, above the influence of salt water, but in an area affected by tides. They used sprigs and seeds for C. obnupta but the latter technique was completely unsuccessful. Sprig survival was 80% and 69% in "upper and middle tiers", respectively, and 0% in "lower tiers". Because of the differences in water level data points between the Fraser and the Columbia it is difficult to relate the elevation of these tiers to our study areas. Nevertheless, these findings emphasize the importance of elevation in any transplant work in an intertidal area. Moody (1978) transferred a few small plugs (20 cm^3) of C. lyngbyei from the Brunswick Point marsh, Fraser Estuary (est. 5 km south of our Albion site) in March 1976. A site north of the Westshore causeway was the only location where plants survived, achieving a height of 40 cm in the second growing season. Two other transplant locations, both between the Tsawwassen and the Westshore causeways, were completely unsuccessful. Moody (1978) suggested that higher salinities were responsible for the mortalities, supporting our results at Iona.

Transplanted C. lyngbyei and S. americanus did not achieve the final shoot heights shown by plants at the donor sites, except for S. americanus at Albion. In the case of C. lyngbyei this was probably attributable to physical conditions, as both the Steveston and Albion transplants were in areas subject to increased river flow and/or wave action compared to the donor site on the inside of Steveston Island (Cannery Channel). As pointed out above, waterfowl grazing probably reduced shoot lengths of the transplant locations, making direct comparisons with natural stands difficult. Moody's (1978) relationship between shoot length and elevation for C. lyngbyei on Roberts Banks (Westham Island) was used to predict August shoot lengths at the Albion site (elevation 2.4 m above chart datum). C. lyngbyei should have reached maximum heights of 60 cm whereas lengths of 45 cm and 32 cm were reached in 1979 and 1980, respectively. Heilman et al. (1978) found that transplanted C. lyngbyei in the Columbia River estuary reached a height of 26 cm in August 1977, 13 months after transplanting. This length was clearly much less than adjacent natural sites, and indeed was only about 50% of the length of the original transplant sprigs (44 cm). Thus, 'natural' shoot height should not be expected for at least the first few seasons following transplanting. The cause and duration of height suppression remains to be determined.

B. Salinity and Sediment Effects

In a preliminary publication we attributed the total mortality of C. lyngbyei and S. americanus at Iona to salinity effects (Pomeroy and Levings 1980), and more thorough interpretation reaffirms this. Sediment salinity at Iona was not significantly reduced by freshet, but this effect was clear at Steveston and Albion (Fig. 6), where plants survived.

Sediment stablity at one of the quadrats at Iona (north site) was also strongly implicated as a major factor influencing the success of transplants, as shown by several other authors elsewhere (e.g. Heilman et al. 1978). Adjacent to the North Arm jetty, sand and mud is in motion due to wave-generated currents (Luternauer 1980). Over the period September 1978 to February 1979 an increase in elevation of approximately 30 cm was observed in the north quadrat, closest to the jetties (Levings 1980). This was responsible for the burial of many cores. In the middle sector, where the other quadrat was located, no change in elevation was observed, but plant survival was still negligible, implicating salinity as a major effect.

Laboratory experiments (Gordon,unpublished) show conclusively that salinity influences C. lyngbyei and S. americanus. Optimum survival growth and growth for both species was at 0 $^{o}/_{oo}$.

The transplant sites at Iona could be supplied with fresh water from the North Arm via a culvert. A preliminary engineering study (Seaconsult 1980) showed that a 61 cm diameter pipe could deliver a maximum flow of 7.6 m^3 min^{-1}. This would occur near the end of an ebb tide. During freshet flows would probably be greater because of the enhanced hydraulic head in the North Arm. Further engineering studies are required to determine if soil conditions in the vicinity of the jetty would permit construction of the culvert.

It is not clear why the transplants of Salicornia virginica and Distichlis spicata did not survive. Salinities at Iona are not too high for these species as salinities at the donor site range between 24-29$^{o}/_{oo}$ judging from the few data available (Swinbanks and Murray 1981). Conversely, the suggestion that consistently high salinities are required to maintain these species is not supported by Barbour and Davis' (1970) results. They found that both S. virginica and D. spicata appear to be intolerant halophytes, showing a negative growth response to increasing salinity. In light of the above information, and since Kamps (1962) has shown that Salicornia sp. can be successfully transplanted, one would suggest that some other factor or interaction of factors is responsible for the failure of S. virginia and D. spicata transplants.

C. Prognosis for Fish Use

Field observations showed that both species of marsh plants began to trap drift algae, especially Enteromorpha spp., when shoots were tall and robust enough to hold this material against water flows. The drift algae was colonized by invertebrates, notably the gammarid amphipod Eogammarus sp., suggesting the transplants were becoming food production sites similar to natural marshes. Juvenile salmonids would be expected to use the food items accumulating in the transplanted marsh. No site specific data were obtained in this study, but juvenile chum are known to be more abundant at Steveston Island on shorelines characterized by vegetation (Anderson et al. 1981. Further data are required to determine if a transplanted marsh and its associated fauna would attract fish.

D. Donor Sites

Periodic observations of the donor sites, in the months following transplanting, revealed that holes formed by plug removal filled in almost immediately in the soft, sandy substrates found at the Steveston Island S. americanus donor site. In areas of soft, fine sediments, such as those found at the Steveston Island C. lyngbyei and Francis Road Scirpus sp. donor sites, the effects of plug removal were evident for 1 - 2 months. After this time no sign of the disturbance could be found. Signs of plug removal from firm hummocks, also found at the Francis Road *Scirpus* sp. donor site, were still evident after 6 months with the plug holes only being about 3/4 filled with sediment. There were even a few cases of plug holes joining to form small pools at this time. However, after 7 months the plug removal holes had filled in and the few small pools which has been created did not get any larger.

ACKNOWLEDGMENTS

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FIGURE CAPTIONS

Figure 1. Chart of the study areas showing donor sites and transplant locations on the Fraser estuary.

Figure 2. Mean shoot height (cm) and mean number of shoots per core for tranplants in the first growing season (1979) at Steveston (upper panel) and Albion (lower panel). ●-indicates data for C. lyngbyei and ▲-S. americanus.

Figure 3. Mean shoot height (cm) and mean number of shoots per core for transplants in the second growing season (1980) at Steveston (upper panel) and Albion (lower panel). ●-indicates data for C. lyngbyei and ▲-S. americanus.

Figure 4. Temporal changes in sediment and botanical parameters at the C lyngbyei and S. americanus donor sites on Steveston Island: (a) surface salinity ($^o/_{oo}$) (data for S. americanus donor site at Francis Road also given); (b) chlorophyll a and phaeopigments (ug cc^1); (c) loss-on-ignition of sediment (ug cc^{-1}); (d) loss-on-ignition of sediment (%); (e) mean shoot height (cm); (f) water content of subsurface sediment (%); (g) water content of surface sediment (%).

Figure 5. Temporal differences in percent fine sediment (material <63 m) at Steveston (upper panel) and Albion (lower panel) transpant sites. Δ-indicates samples from inside the transplant quadrat; ●-indicates samples from outside.

Figure 6. Temporal changes in water content (%) and salinity ($^o/_{oo}$) at subsurface sediments at the Albion (left panel) and Steveston (right panel) transplant sites.

Figure 7. Temporal changes in sediment organic matter (loss-on-ignition; mg cc^{-1} and %) at the Steveston (right panel) and Albion (left panel) transplant sites. ● - indicates samples from inside transplant quadrat; O - indicates outside.

Figure 8. Temporal changes in algal pigment concentrations at the Albion (left panel) and the Steveston (right panel) transplant sites: (a) chlorophyll a (ug cc^{-1}); (b) phaeopigment (ug cc^{-1}); (c) chlorophyll (%); (d) chlorophyll a/phaeopigment. ●-indicates samples from inside the transplant quadrat; O - indicates samples from outside.

TABLES

Table 1. Number of transplant plugs growing at the Steveston and Albion quadrats during 1979. (n = number of plugs planted per row)

Table 1.

Steveston

Row	May 9	May 23	June 7	June 22	July 9	Aug. 22	Sept. 18	Oct. 17
Scirpus americanus								
2 (n = 39)	16	21	21	26 (67)[a]	26	18	16	16 (41)[a]
3 (n = 39)	19	31	27	28 (72)	28	25	25	24 (62)
4 (n = 39)	22	28	27	27 (69)	27	21	18	18 (46)
5 (n = 39)	26	30	28	28 (72)	27	26	26	26 (67)
6 (n = 39)	23	26	25	25 (64)	25	21	21	20 (51)
7 (n = 39)	28	35	37	34 (87)	32	30	30	30 (77)
8 (n = 39)	25	28	28	27 (69)	28	25	25	24 (62)
9 (n = 39)	22	26	26	25 (65)	24	23	21	21 (54)
Per cent plug growth	58	72	71	71	70	61	58	57
Carex lyngbyei								
10 (n = 16)	11	10	12	13 (81)	13	12	10	11 (69)
11 (n = 21)	15	14	16	16 (76)	16	16	18	20 (95)
12 (n = 39)	32	32	31	33 (85)	33	33	32	32 (82)
13 (n = 39)	29	31	31	31 (79)	32	30	31	30 (77)
14 (n = 39)	33	33	34	34 (87)	35	33	33	34 (87)
Per cent plug growth	77	78	81	82	84	81	81	82

[a] per cent growing in each row on the date indicated.

N.B. A row 1 was originally planned for this quadrat but was never planted.

Table 1 (continued)

Albion

Row	May 14	May 23	June 7	June 22	July 9	Aug. 22	Sept. 18	Oct. 17
Scirpus americanus								
2 (n = 26)[b]	13	13	15	14 (54)[a]	10	6	6	5 (19)[a]
3 (n = 24)[b]	6	10	13	12 (50)	10	9	8	8 (33)
4 (n = 25)[b]	12	15	11	11 (44)	11	10	10	10 (40)
5 (n = 33)[b]	13	22	27	27 (82)	24	19	19	18 (55)
6 (n = 33)[b]	14	22	26	26 (79)	25	21	20	20 (61)
7 (n = 33)[b]	12	21	27	30 (91)	31	28	27	24 (73)
Per cent plug growth	40	59	68	69	64	53	52	49
Carex lyngbyei								
8 (n = 36)	19	20	23	21 (58)	25	22	19	20 (56)
9 (n = 36)	19	21	26	28 (78)	28	25	25	25 (69)
10 (n = 36)	23	25	24	24 (67)	23	21	21	21 (58)
11 (n = 36)	15	21	16	15 (42)	15	16	18	18 (50)
12 (n = 36)	23	29	27	27 (75)	26	25	24	23 (64)
13 (n = 36)	28	26	26	26 (72)	26	26	26	26 (72)
14 (n = 36)	17	20	22	22 (61)	22	22	22	22 (61)
Per cent plug growth	57	64	65	65	65	62	62	62

[a] per cent growing in each row on the date indicated.

[b] these rows were originally planted with 36 plugs however, encroachment by the surrounding natural marsh made it impossible to tell the transplant plugs from the 'natural' plants.

N.B. A row 1 was originally planned for this quadrat but was never planted.

Table 2. Mean rhizome extension (cm) for transplants at Albion and Steveston during the 1979 growth season.

Species	Site	June	July	August	September
Scirpus americanus	Albion	5	14	31	35
	Steveston	6	21	35	37
Carex lyngbyei	Albion	nil	9	17	19
	Steveston	nil	11	18	20
Eleocharis palustris	Albion	7	12	29	36
	Steveston	5	14	30	37

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Fig. 1.

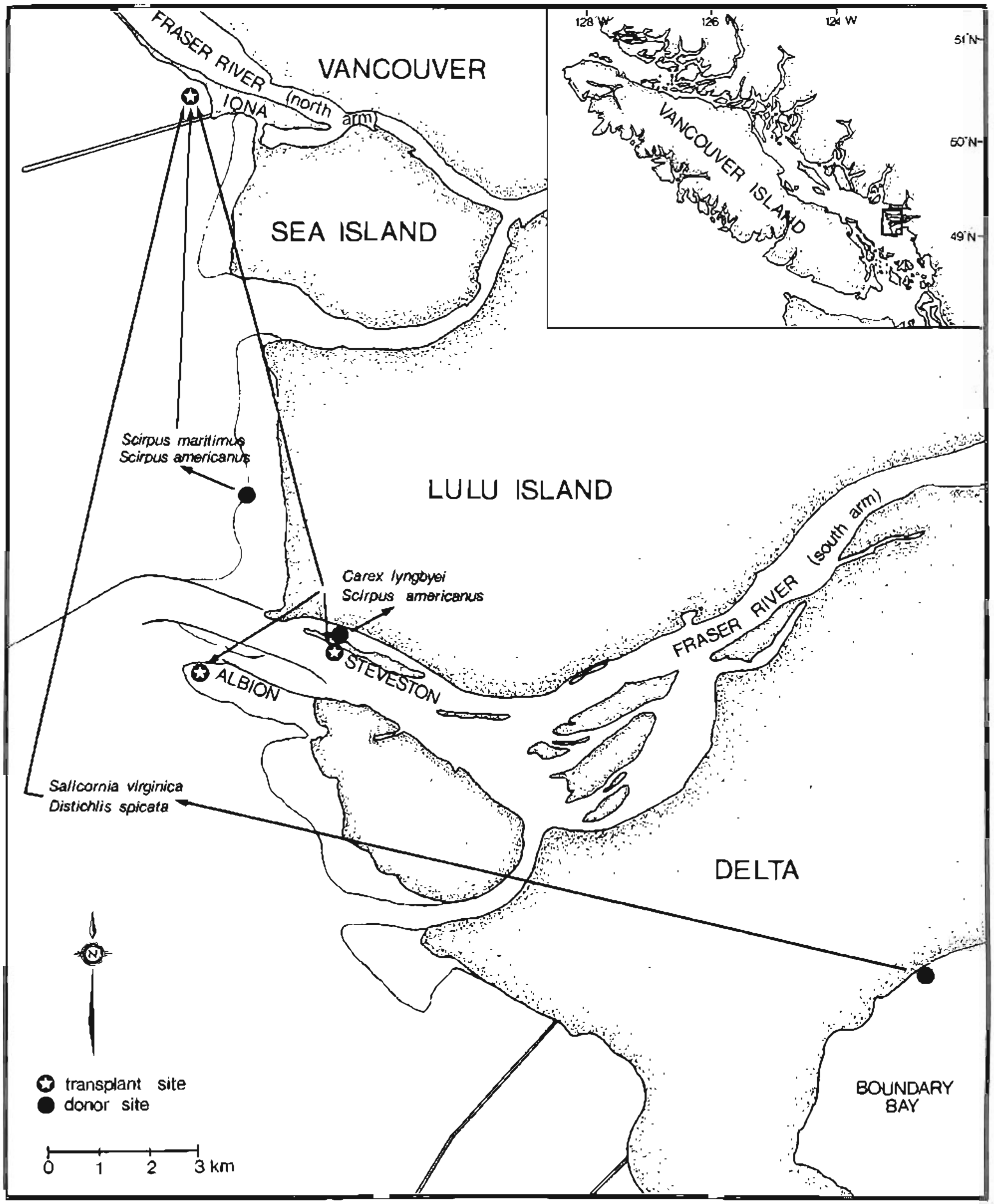
FRASER RIVER (north arm)
VANCOUVER
IONA
SEA ISLAND
LULU ISLAND
Scirpus maritimus
Scirpus americanus
Carex lyngbyei
Scirpus americanus
STEVESTON
ALBION
FRASER RIVER (south arm)
Salicornia virginica
Distichlis spicata
DELTA
BOUNDARY BAY
N
transplant site
donor site
0 1 2 3 km
128°W
126°W
124°W
51°N
50°N
49°N
VANCOUVER ISLAND

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Fig. 2.

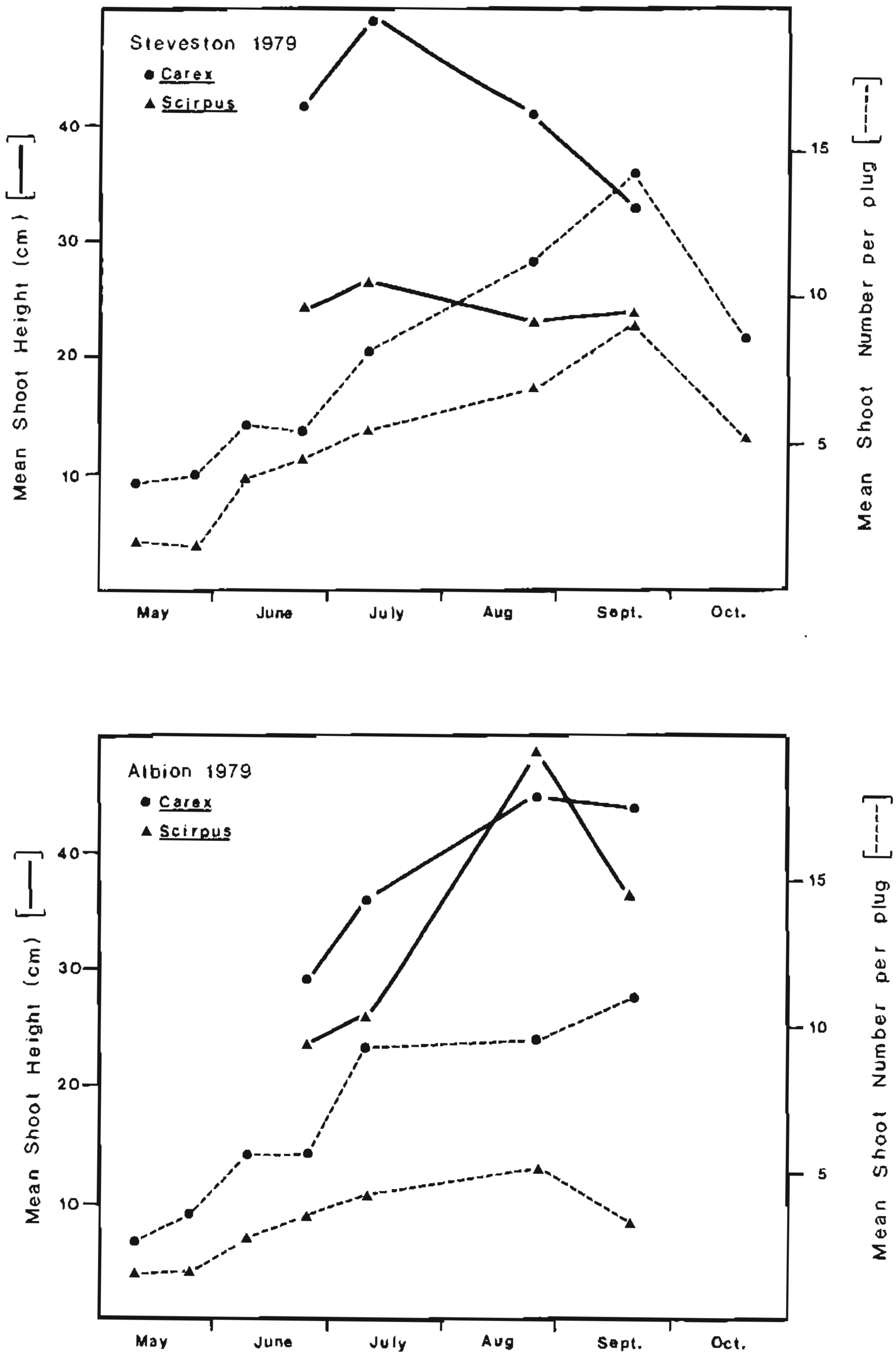
Steveston 1979
Carex
Scirpus
Mean Shoot Height (cm)
Mean Shoot Number per plug
10
20
30
40
5
10
15
May
June
July
Aug
Sept.
Oct.
Albion 1979
Carex
Scirpus
Mean Shoot Height (cm)
Mean Shoot Number per plug
10
20
30
40
5
10
15
May
June
July
Aug
Sept.
Oct.

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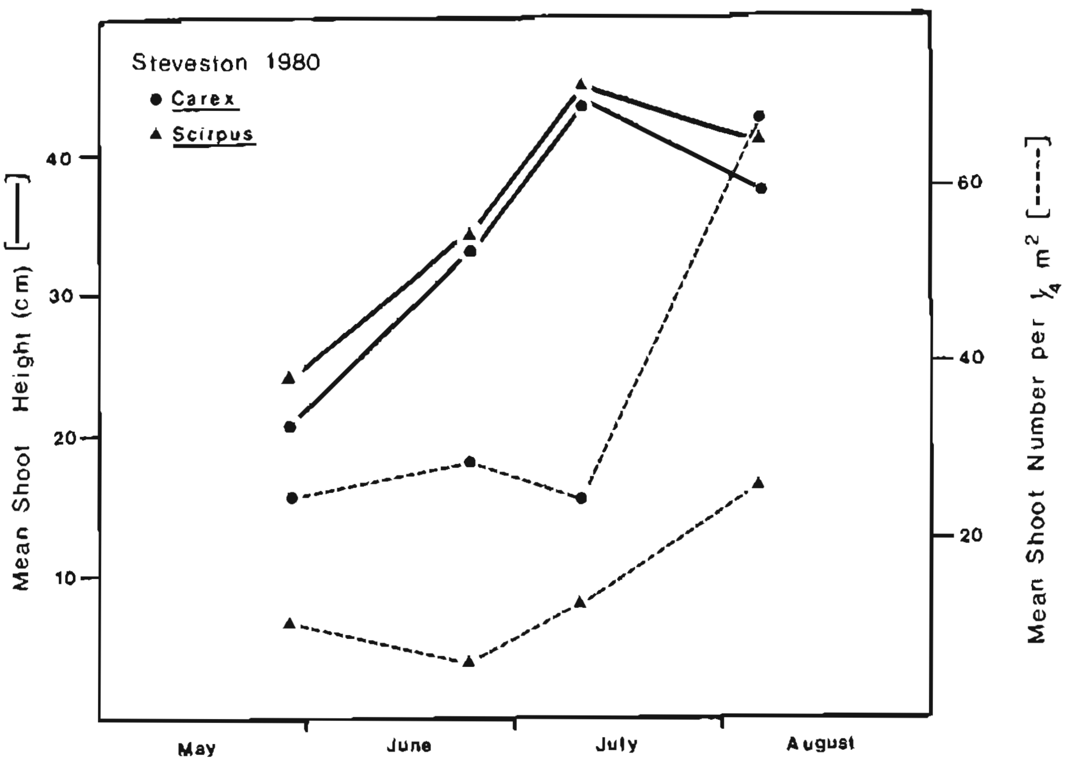
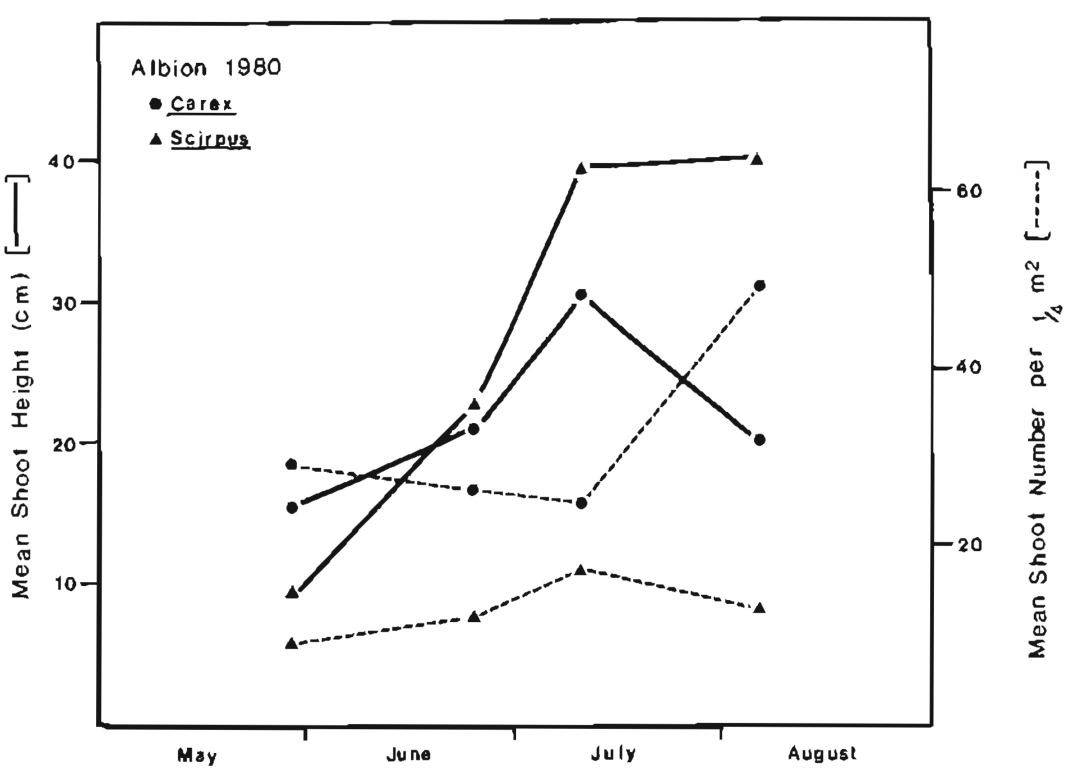
Fig. 3.



Steveston 1980
Carex
Scirpus
Mean Shoot Height (cm) [——]
40
30
20
10
Mean Shoot Number per 1/4 m² [-----]
60
40
20
May
June
July
August



Albion 1980
Carex
Scirpus
Mean Shoot Height (cm) [——]
40
30
20
10
Mean Shoot Number per 1/4 m² [-----]
60
40
20
May
June
July
August

Fig. 4.

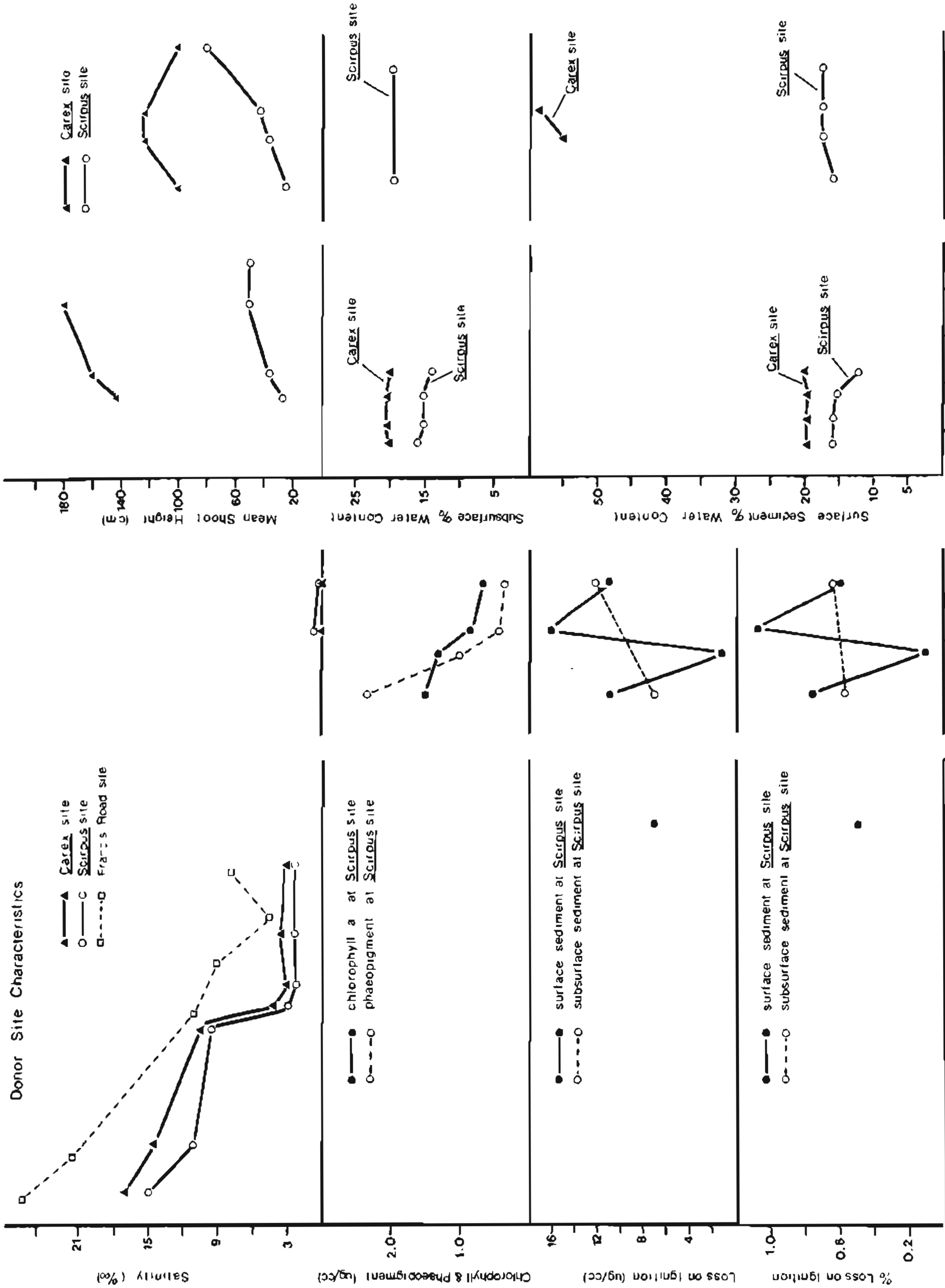

Donor Site Characteristics
Carex site
Scirpus site
Salinity (‰)
chlorophyll a at Scirpus site
phaeopigment at Scirpus site
Chlorophyll & Phaeopigment (ug/cc)
surface sediment at Scirpus site
subsurface sediment at Scirpus site
Loss on Ignition (ug/cc)
% Loss on Ignition
Mean Shoot Height (cm)
Subsurface % Water Content
Surface Sediment % Water Content
1979
1980

Fig. 5.

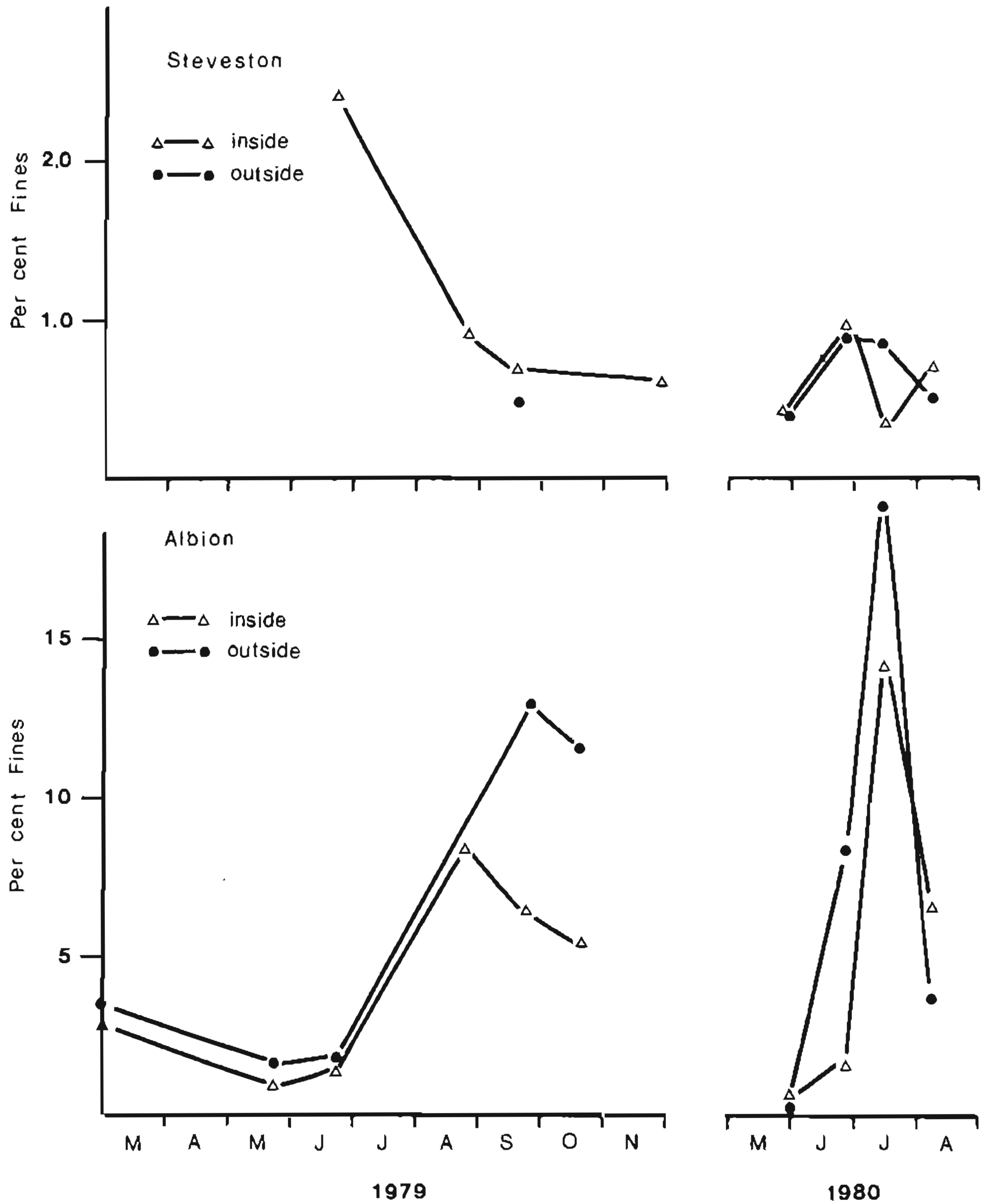

Steveston
inside
outside
2.0
1.0
Per cent Fines
Albion
inside
outside
15
10
5
Per cent Fines
M
A
M
J
J
A
S
O
N
1979
M
J
J
A
1980

Fig. 6.

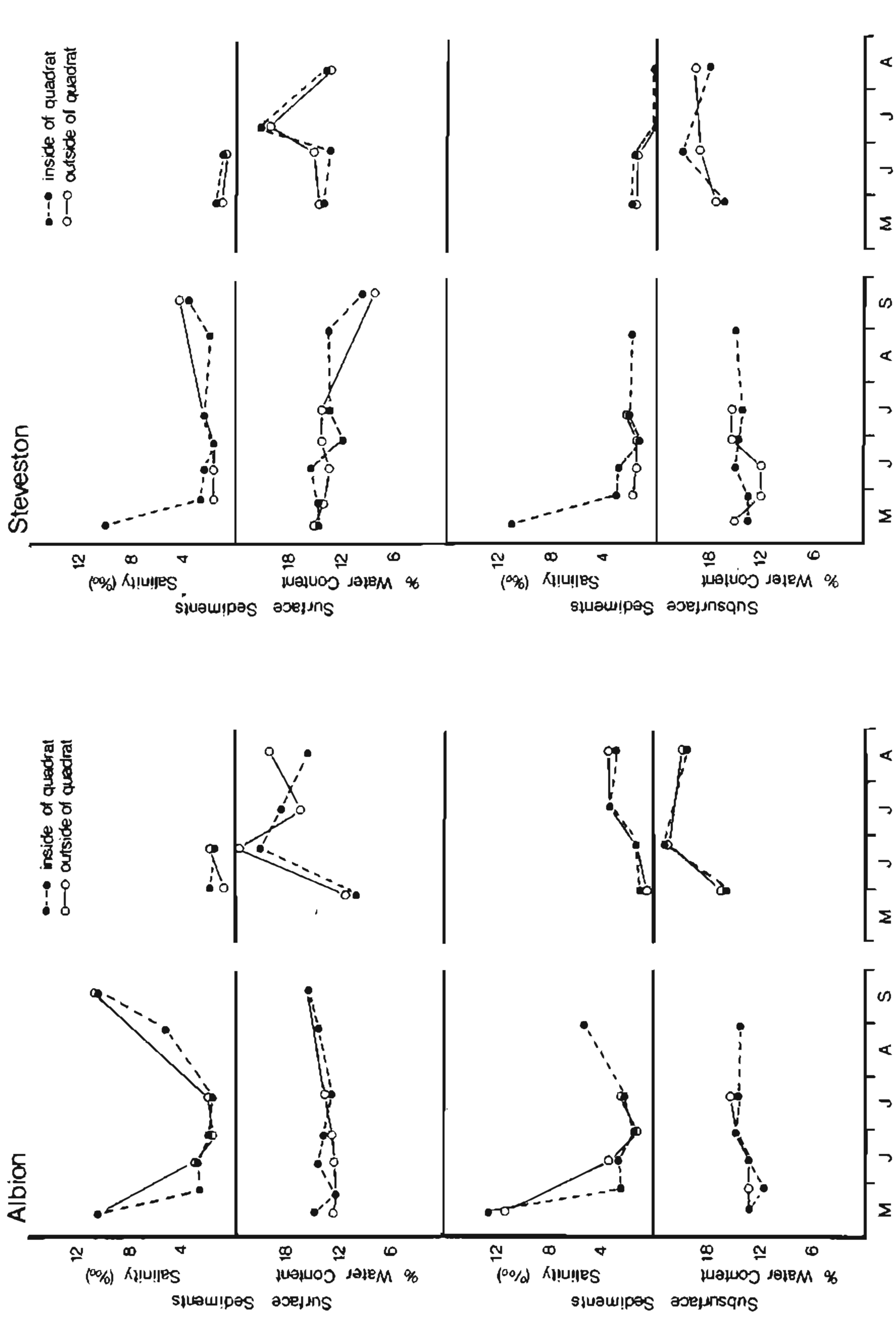

Albion
Steveston
inside of quadrat
outside of quadrat
Surface Sediments
Subsurface Sediments
Salinity (‰)
% Water Content
M J J A S
1979
M J J A
1980

Fig. 7.

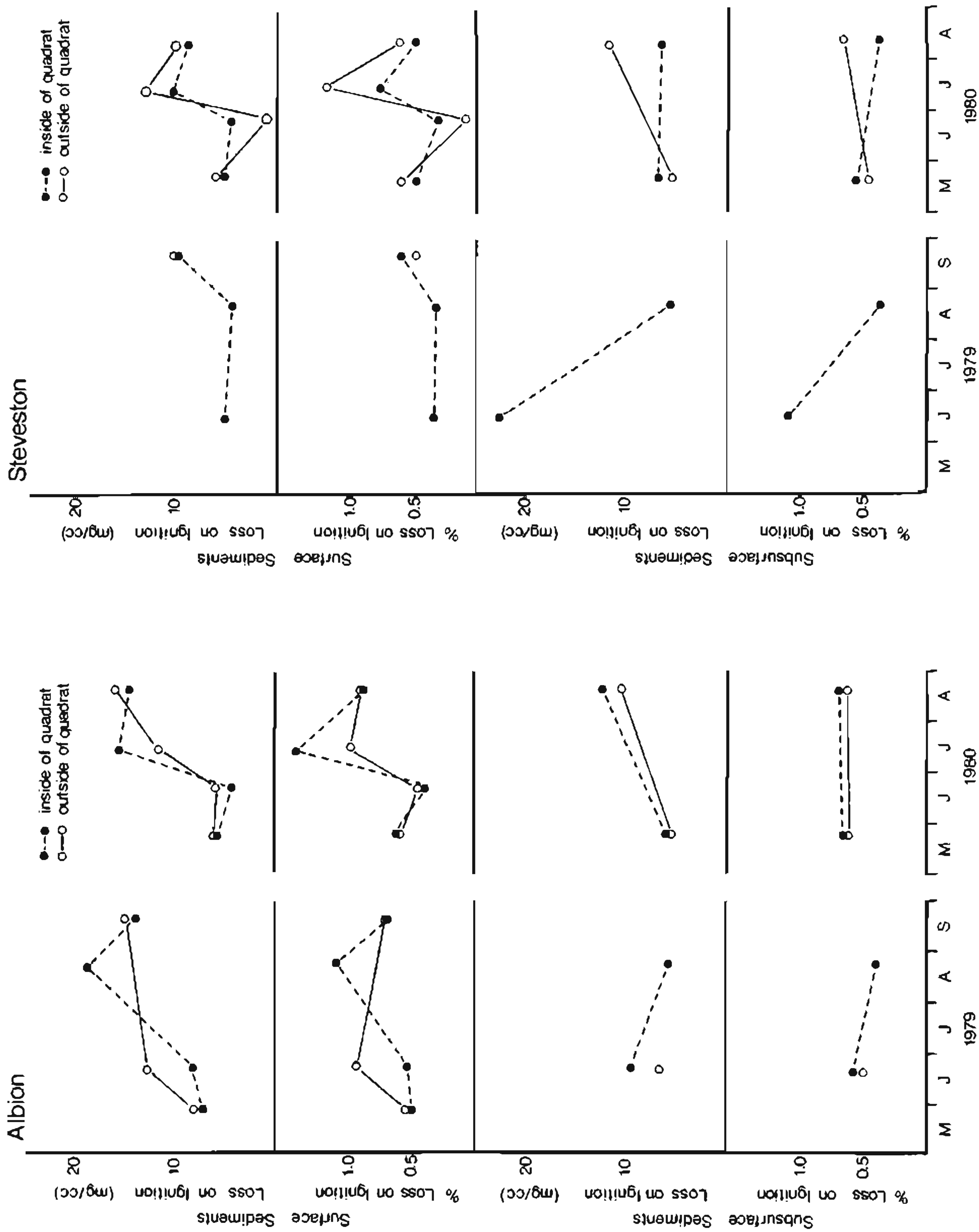
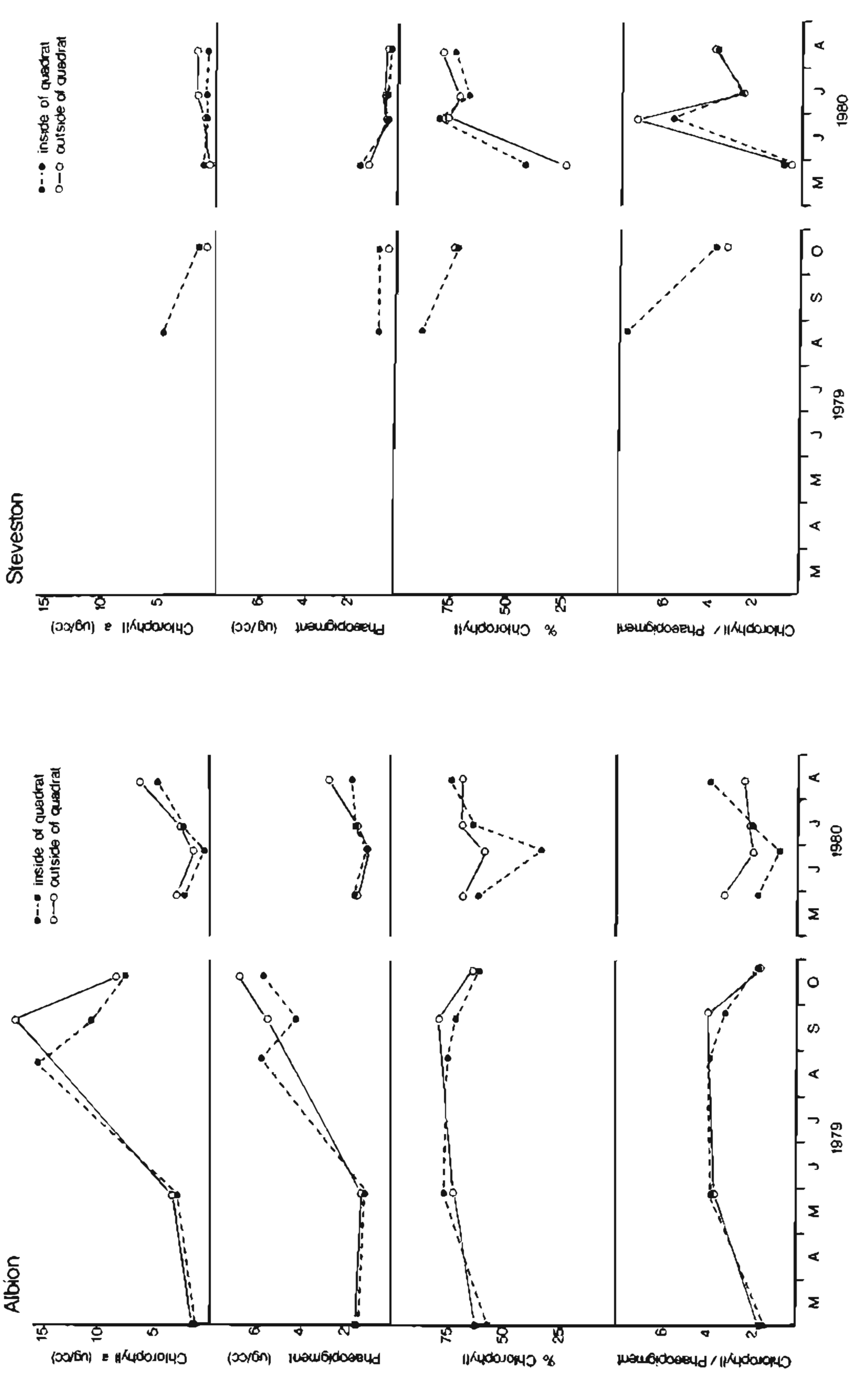

Albion
Steveston
inside of quadrat
outside of quadrat
Surface Sediments
Subsurface Sediments
Loss on Ignition (mg/cc)
% Loss on Ignition
M J J A S
1979
M J J A
1980
20
10
1.0
0.5

Fig. 8.


Albion
Steveston
inside of quadrat
outside of quadrat
Chlorophyll a (ug/cc)
Phaeopigment (ug/cc)
% Chlorophyll
Chlorophyll / Phaeopigment
M A M J J A S O
M J J A
1979
1980