An Account of a Workshop on Restoration of Estuarine Habitats

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May 1980

Canadian Manuscript Report of Fisheries and Aquatic Sciences No. 1571

Government of Canada Fisheries and Oceans
Gouvernement du Canada Pêches et Océans

Canadian Manuscript Report of Fisheries and Aquatic Sciences

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Cat. no. Fs 97-4/1571 ISSN 0706-6473

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* Summaries not available

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ABSTRACT

Levings, C. D. (compiler). 1980. An account of a Workshop on restoration of estuarine habitats. Can. MS Rep. Fish. Aquat. Sci. 1571: 29 p.

Summaries, abstracts and preliminary results from talks given at a workship on restoration of estuarine habitats are presented. Topics include choosing sites for marsh and eel grass restoration in the Fraser estuary, preliminary results of two pilot projects for marsh transplants at the Fraser estuary, preliminary results of eel grass transplants at the Nanaimo River estuary, tidal re-activation of a portion of the Englishman River estuary, and the possibility of sand/mud flat restoration.

Key words: Marshes, eel grass, tidal flat, habitat improvement, estuaries, dredging.

RÉSUMÉ

Levings, C. D. (compiler). 1980. An account of a Workshop on restoration of estuarine habitats. Can. MS Rep. Fish. Aquat. Sci. 1571: 29 p.

Le rapport présente des sommaires, des résumés scientifiques et les résultats provisoires d'entretiens qui ont eu lieu lors d'un colloque sur le rétablissement des habitats estuariens. Les thèmes en sont le choix d'emplacements pour le rétablissement de marécages et le développement de la zostère dans l'estuaire du Fraser, les résultats provisoires de deux projets pilotes de transplantation de marécages dans cet estuaire, les résultats provisoires de transplantations de zostère dans l'estuaire de la rivière Nanaimo, le rétablissement de l'activité des marées dans une partie de l'estuaire de la rivière Englishman et la possibilité de reconstituer des battures et des vasières.

Mots clés: marécages, zostère, batture, amélioration de l'habitat, estuaires, dragage.

INTRODUCTION

One of the more insidious aspects of the degradation of coastal ecosystems has been the frequent loss of shoreline habitat. In the Fraser estuary, for example, approximately 100 incidents of habitat loss have been recorded in the past 5 years, ranging from the loss of 10 m of upriver marsh due to disposal of rubble to large scale disruption for construction activities on the foreshore. These losses destroy useful habitat for fish and wildlife.

One technique to slow or reverse the problem of habitat loss involves the concept of habitat restoration. In terrestrial (e.g. Cairns et al 1977) and freshwater (e.g. SEP 1978) ecosystems this strategy seems to be well-developed but there are few documented attempts at corrective measures in estuarine or marine ecosystems. Because of an increased awareness of the importance of near-shore habitat for the growth and survival of juvenile salmonids, the Salmonid Enhancement Program in B.C. has funded studies related to estuarine habitat restoration. Some of this work has been done with the collaboration of Habitat Protection Division personnel.

Habitat restoration techniques were discussed at a Workshop held on October 19 and 23 1979 at the West Vancouver Laboratory and the Pacific Biological Station, Nanaimo, respectively. These abstracts, preliminary results, and summaries report on the deliberations of the Workshop.

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Cairns, J., K. L. Dickson, and E. E. Herricks, (Ed.). 1977. Recovery and Restoration of Damaged Ecosystems. Univ. Press of Virginia, Charlottesville. 531 p.

Salmonid Enhancement Program (SEP). 1979. Annual Report 1978 (coedited by M. Glover and J. Barnetson). Dept. Fisheries and Oceans, Vancouver, B.C. 92 p.

Choosing sites for marsh and eelgrass restoration in the Fraser estuary

by

S. Boyd,[1] E. White,[1], J. Readshaw[2] and A. Tamburi[2]

The objective of the habitat development program was to develop and implement criteria for the selection and construction of fish and wildlife (wetland) habitat in the Fraser River estuary using dredge spoil as a substrate. Ten potential sites (Fig. 1) and three species of tidal macrophytes were selected by Public Works Canada, Fisheries and Oceans and Canadian Wildlife Service for investigation.

Recent studies have shown that tidal wetlands are important to the survival and growth of fish and wildlife in the Fraser River estuary. It has been estimated, however, that since the turn of the century up to 70% of these wetlands have been alienated due to various man-initiated activities. Public Works Canada dredge annually throughout the lower Fraser River, and dredge spoil could be utilized as substrate upon which to transplant marsh or eelgrass communities.

The major factors influencing the growth and distribution of the designated transplant species plus those controlling dredge spoil stability at each site, were used as the criteria for selecting the most appropriate site(s) at which to develop wetland habitat.

The designated marsh transplant species, *Scirpus americanus* and *Carex lyngbyei*, are good choices due to their wide elevation ranges, growth in pure stands, relatively high productivities, extensive root and rhizome structures and their utilization as a food source by various fish and wildlife. The major factors influencing the growth and distribution of these species appear to be substrate elevation (and its associated submergence/emergence ratio) and salinity. Although the exact significance of these factors are difficult to delineate, the foreshore and upstream extent of these species are limited by one or a combination of these factors. Substrate slope, substrate nutrients, substrate particle size, wave and current action, competition and grazing are other secondarily important factors influencing plant growth and distribution and, since these are manageable, they are used as the prime marsh design criteria. Based on submergence/emergence, salinity and other criteria, the following ranking order (from a biological point of view) resulted: from most to least appropriate - Sites 3, 2, 8, 7, 6 and 5. Site 9 and 10 were recommended for pilot-scale transplanting only.

With respect to spoil stability, none of the eight potential marsh development sites are suitable for both local current and wave regimes. Using these criteria, the 1980 DPW dredging schedule, and the above biological selction criteria, the following recommendation was made: to relocate Site 3 (Steveston North Jetty) to a (possible) low wave regime area adjacent to the bend in the jetty.

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If the construction program is implemented, the basic design of the marsh, with respect to slopes, substrates, etc., will follow those found under natural conditions. Maximum diversity for elevations, slopes, transplant spacings, channels, etc., will be implemented. Because of the inherent advantages over sprigs, seeds and seedlings, plugs (cores of material) will be used for transplanting purposes. This method has already been used successfully (Pomeroy and Levings, this volume) in a transplant study in the Fraser River estuary.

The designated eelgrass transplant species, *Zostera marina*, is ecologically very important in terms of providing shelter and attachment sites for animals, acting as a stabilizer of sediments and as a source of food via the detritus pathway. The major factors influencing this species growth and distribution in the Fraser River estuary are depth range (with respect to dessication and turbidity effects), sediments, salinity and nutrients. Propagation techniques are similar to the plug method for marsh transplants.

In a comparison of two potential sites for eelgrass transplanting, the borrow pit at the Roberts Bank superport (Site No. 1) has distinct advantages over Iona (Site No. 4). These are; physical/chemical conditions conducive to growth, adjacent transplant material and the ability for sand spoil to stabilize at the site. If spoil transportation and disposal is found to be feasible at Site 1, eelgrass transplanting is recommended.

At Iona, on the other hand, high turbidity and sedimentation rates, low summer salinities, and a relatively high wave regime would substantially limit transplant establishment and growth.

The site conditions and criteria summary report is available from the Scientific Authority for the project, namely C.D. Levings, Fisheries and Oceans, West Vancouver Laboratory, West Vancouver, B.C.

Development of Eelgrass Transplanting Techniques for the Nanaimo River Estuary.

by

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In preparation for a full-scale program of eelgrass transplants during the winter of 1979-1980, a limited number of test plots were established in February and June 1979. These were designed to test a variety of techniques to determine the most suitable for mass transplanting.

Sites

Two sites were chosen: Jack Point and Holden Channel. The former was on a slight rise in the lower intertidal. The latter was along the bank of an inlet stream in the upper intertidal. Both were chosen to provide a number of plots in which conditions were as similar as possible. Proximity to existing eelgrass beds were also important to obviate the transportation problem. In addition a small number of plants were moved into side channels with rapid flow to test retention under these conditions.

Techniques

We concentrated on techniques that could be done on the flats at low tide because of the expense of diving and our interest in the intertidal area.

a. Tin can cores. Using 48 oz. juice cans with both ends removed small cores with shoot, root and associated sediment were taken. The cores were kept in the cans in dishpans until planting. At the planting site another can was used to take plugs and the cores were dropped in the holes. We attempted to have the surface of the transplanted core fractionally lower (approximately 0.5 cm.) than the surrounding sediment surface to minimize washout. Mud from the hole was used to level off the surface. The cross sectional area of the cores was 87 cm^2.

b. P.V.C. pipe cores. A corer was constructed from a 1.5 m length of P.V.C. pipe with a cross sectional area of 182 cm. Cores were taken and dropped into dishpans. Planting was as above.

c. Turf cutters. A rectangular sheet metal cutter with an area of 352 cm^2 was used to obtain "turfs" lifted with a shovel (Ranwell et at. 1974). Again the turfs were held in dishpans and transplanted as above.

d. Sprig transplants. Individual pieces of rhizome with associated shoots and roots were uprooted and replanted in groups of three by hand.

Cores, turfs and groups of sprigs were planted 0.75 m. apart, in square plots of 49.

Retention and Establishment of Transplants

On the basis of the work of Phillips (1976) it was felt that winter transplants would have a better change of taking than summer ones. The opposite has been the case however. The winter transplants showed 100% loss (no visible shoots) by mid-July, five months after being moved. In contrast the summer transplants showed at least 40% survival, with many transplants having new shoot growth and rhizomes extension on November 3, 1979.

The generally low success rate is attributed to lack of sediment saturation at low tide. Extremely minor variations in elevation had a major effect on survival.

With respect to techniques, the tin can cores and sprig transplants represented the extremes. Tin can summer transplants showed no loss in the first month, but had the highest loss rate, 24.5%, after three months. In contrast, the sprig transplants had a relatively high initial loss, 6.1% in the first month but once established appeared to hold better, with a 16.3% loss rate after three months. In terms of condition of surviving transplants, the sprigs also fared better. 61.2% of these showed new shoot growth as compared to 46.9% of the tin can transplants. The better condition of the sprig transplants is most likely due to a bias in choosing plants in good condition for stock. Taking stock with the tin cans is a more arbitrary procedure.

Erosion Control

Two plots were covered with 5 cm wire mesh to reduce erosion and anchor transplants. Work in other areas has indicated some value in some form of protection (Phillips 1974). This particular technique proved detrimental however, the mesh acting as a sediment trap and substrate for algal growth. Rapid and complete loss of transplants occurred.

Relevant Environmental Factors

On the basis of the transplant results, as well as investigations into the growth and development of eelgrass in the Nanaimo delta, a number of factors have been identified as relevant to decisions in transplent sites.

a. Exposure. *Zostera marina* is limited to below the 2 m datum level in the Nanaimo delta, except where surface water remains at low tide in streams or pools. This is presumably a direct function of the time of exposure at low tide, subjecting the plants to desiccation and frost damage.

b. Sediment water content. The water retention capacity of exposed flats appears to exert a considerable influence on the distribution of eelgrass below the 2 m level. Extensive sampling of sediment water content on flats exposed for approximately one hour showed an overall mean water content of 27.7% while samples from eelgrass patches had a mean value of 29.8%. While this may reflect local modification of sedimentation regime by the plants, the poor survival of transplants in drier sediments suggests a requirement for continuous saturation around the rhizomes and root system.

c. Sediment texture is important. In the Nanaimo delta eelgrass grows mainly in sandy sediments. Coarser texture does not provide for adequate attachment while finer sediments may inhibit nutrient exchange. We have not defined the absolute limits in either direction, but as a rule of thumb in transplanting we always move plants from coarser to finer texture.

d. Currents. The current regime plans an important role, particularly in the upper intertidal. Growth is much more luxuriant in channels with high current flow than where there is little flow. Where the substrate is suitable there appears to be no problem with maintaining attachment in the velocities attained here. We have done tranplants into maximum current situations and there appears to be no serious problem with retention.

Full-Scale Transplants

We are now into the full-scale program during which transplanting will be done on 40 low tides. Based upon the results of the experimental transplants we are using the tin can method. While relatively less successful than other methods, it appears to provide adequate survival and the ease of doing it more than compensates. Initial experience has shown that we can take 400 cores in about one hour if we get the barge to drop right at the donor site at low tide. These are planted on the following low tide in about two or three hours.

To protect source areas transplant material is taken only from areas of dense growth. Cores and rhizomes are removed from squares 3 m x 3 m., separated by distances of at least 15 m. A single path is used from a square to the barge, to minimize trampling. With care 400 cores can be obtained from a single square.

Phillips, R.C. 1974. Transplantation of seagrasses with special emphasis on eelgrass, *Zostera marina* L. Aquaculture 4: 161-176.

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Ranwell, D.S., D.W. Wyer, L.A. Boorman, J.M. Pizzey and R.J. Waters. 1974. *Zostera* transplants in Norfolk and Suffolk, Great Britain. Aquaculture 4: 185-198.

Conditions favouring the growth of eelgrass (*Zostera marina* L.)

by

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The establishment and growth of eelgrass (*Zostera marina* L.) is affected by many physical, chemical and biological factors but physical factors appear to be the most critical in the intertidal zone. Desiccation at low tide may limit the upper extent of eelgrass although the amount of water loss which can be tolerated is unknown. Grain size of the sediment may modify the response of the plant because mud retains water longer than does sand when the sediment is exposed at low tide. Deposition or erosion of sediment around the plants may occur quickly and may bury or wash out an established bed of eelgrass in a matter of hours or days. High currents may prevent seedlings from establishing in otherwise suitable habitats. A high sediment load in the water column may reduce light penetration at high tide and thus limit photosynthesis. Chemical factors such as concentrations of nutrients in the sediment and water may affect growth of eelgrass, but few pertinent data exist. Biological factors such as grazing are of minor importance to eelgrass, but competition with a recently introduced species (*Zostera americana* den Hartog) may be important in the future. In general, conditions on southern Roberts Bank are suitable for eelgrass in terms of temperature, salinity, and sediment type, but more information is needed on the factors outlined above before firm predictions can be made about the possibility of success in transplanting eelgrass to now barren areas.

Recommended Techniques for Transplanting Eelgrass Habitat in the Fraser River Estuary

The conditions for seed germination and seedling growth are poorly known, therefore attempts to seed barren sediment are not recommended. The following program using "plugs" or "turfs" is recommended instead,

a. *Z. marina* should be planted only in areas of suitable substrate, water motion, exposure/submergence regime, and combined water depth and clarity as determined by studies of natural beds. Alterations to the existing environment should bear in mind the requirements of the plant.

b. Eelgrass should be moved as turfs or plugs consisting of several vegetative shoots and the undisturbed sediment around the rhizomes and roots to a depth of 10 to 15 cm.

c. Plugs should be taken from natural eelgrass beds of high density. To minimize subsequent damage by erosion to the donor beds, plugs should be removed at least 1 m from the edge of the bed and 1 m from other plugs.

d. Use of a corer or a posthole digger is recommended for removing plugs cleanly. Use of shovels as well as excessive trampling underfoot may severely damage the beds.

e. If plugs must be transported to a distant site they should be placed in plastic bags, pails or trays and kept moist. Loss of sediment, exposure to air, and bright sunlight must be avoided.

f. Plugs should be placed in holes and the surrounding sediment should be packed around the plugs. One arrangement could have the plugs in rows with the position of plugs in adjacent rows alternating. Other arrangements are also possible.

g. Protective structures such as baffles or plastic screens may be used initially to prevent erosion while the transplants are rooting. Such structures may cause excessive sedimentation or erosion over the long run.

h. Transplanting should be conducted when the plants are semi-dormant or growing slowly (perhaps in February or March - by April the plants are growing quickly and may be intolerant of the stress involved in transplanting). Phillips (1976) found that transplants in June took nine months before growth was visible, whereas transplants in late winter or spring took only one or two months to become established.

Deas Slough March Transplant Project

Initiated by R. Higgins: presented and summarized by M. Pomeroy

This study was directed at developing a marsh habitat of 1115 m^2 downstream from Deas Harbour marina to replace an equal area undergoing development. The donor site is described as the Sunbury area of Delta. Sediment containing root and rhizome material was scraped from the surface of the donor area in January 1979 using a front end loader and stored on land for several months prior to being placed at the transplant site in Deas slough. Plants were beginning to grow at the time the sediment was put in place May 3, 1979 using a loader. No attempt was made to return the material to the original elevation from which it was taken nor to ensure shoots were pointing upwards.

A very diverse marsh appeared soon after planting with a species being distributed throughout the intertidal range. Four transects have been established to monitor changes in species composition from high to low intertidal. The dominant species after the first year's growth is *Juncus articulatus*, being found at most levels. Some indication of zonation patterns is present even at this point.

Slumping and erosion around clumps or clods of transplanted material does seem to be a potential problem with this type of transplant technique.

Attributes of marshes important for fish

by

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Fish populations in tidal channels (TC's) of the Fraser River estuary were surveyed with inter-tidal fish traps over the period of 10-17 May 1979. Eighteen sampling stations were established on Ladner Marsh, Woodward Island, Barber Island and Roberts Bank. Each site was sampled on at least 3 occasions prior to the survey to ensure a consistent sampling effort at different locations. A total of 22 environmental (habitat) variables were measured after the survey including: width of the TC mouth, the distance of the sampling station to the TC mouth, the depth of the TC, the length of the TC, the height of the surrounding marsh plants, the mean sediment particle size, the distance to the nearest sub-tidal refuge, the angular deflection of the TC to the prevailing flowing tide, the total sub-channel length, the turbidity of the water at low tide, the area of the TC, the relative elevation of the TC's, etc. The catches of the dominant fish species were used as dependent variables in a stepwise multiple regression analysis. Habitat variables were used as independent variables.

Regression equations were generated for the dominant fish species for both the first (10-13 May) and second (14-17 May) sampling dates. Results showed that a small number of habitat variables (1-3) accounted for a large proportion of the variation in fish catch numbers (R^2 values between 0.48 and 0.93). The most significant variables were occasionally consistent between sampling dates.

Further statistical analysis of the results is currently underway.

Factors in Sand/Mud Flat Restoration

by

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In terms of autotrophic production, sand and mud flats may equal or exceed contribution from marshes. Recent data from the Fraser estuary shows that juvenile salmonids may use "pits" in sand flats as low tide refuges. Rehabilitation of these important habitats should therefore be considered. Schemes to create sand flat habitats should consider the submergence/emergence aspect of sites, as algal biomass, invertebrate abundance, and sediment type all change with elevation. Salinities may be manipulated through culverting to bring fresh water, and sea water distribution can be modified by changing elevations and hence salt wedge penetration. The surface area at specific elevations is an important index to judge the merit of rehabilitation schemes in general (Gonor 1979). Islands of sand with beaches colonized by algae and invertebrates may be feasible, recognizing that open water habitat for fish is lost.

Literature Cited

Gonor, J.J. 1979. An evaluation of the ecological basis of mitigation requirements in Oregon statewide estuarine resources planning. p. 93-102 in The Mitigation Symposium. Gen. Tech. Rep. RM-65. Rocky Mountain Forest and Range Experiment Station, Forest Service, U.S. Dept. of Agriculture, Fort Collins, Colorado. (Held July 16-20 1979, Colorado State University, Fort Collins, Colorado).

Current activities of the Geological Survey of Canada in the Nanaimo estuary/delta

by

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1. Preparing a detailed map of substrate types/depositional environments on the intertidal zone and subtidal area adjacent to the delta.

2. Obtaining photographs of subtidal sedimentary-biological environments adjacent to the delta.

3. Compiling all airphotos obtained of the tidal flats at low tide from which historical morphologic changes can be mapped.

4. Preparing for publication a B.Sc. thesis by J. Leroux (prepared under supervision by GSC and UBC) titled "Evaluation of the morphosedimentologic character of a section of the Nanaimo River Delta tidal flats using photogrammetric techniques".

Marsh Rehabilitation on the Fraser River Estuary: A Pilot Project

by

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Introduction

Transplantation of marsh vegetation as a means of habitat stabilization and rehabilitation has been carried out in estuaries and rivers of the United States for some time. However, little use has been made of this technique of estuarine rehabilitation in Canada. The present pilot study was undertaken to:(1) determine the best method for collecting, transporting and planting marsh vegetation; (2) identify the best species to transplant into an area and; (3) identify factors (physical, chemical and/or biological) which may influence the success of transplantation. This report presents some preliminary findings after one season's growth in 1979.

Methods

Three sites were selected on the estuary representing different habitat types within the range of 2.5-3.5 m above chart datum (Table 1, Fig. 2). This elevation is suggested as having optium submergence/emergence ratios for marsh vegetation selected as transplant species (*Carex lyngbyei, Scirpus americanus* and *S. maritmus*) common on the marsh.

Donor sites were matched as closely as possible to transplant sites with respect to sediment grain size, salinity and organic content, percent water content as well as elevation. The donor site for Iona posed the greatest problem in trying to find an area of high enough salinity. An area off Lulu Island at the foot of Francis Street was selected, having the highest salinity in the *Scirpus* zone on the foreshore (Fig. 2).

Carex was taken from Steveston Island for Iona as a trial in long distance, wide salinity range transplants. Transplant material for the other 2 sites came from Steveston Island, requiring short distance transport (Fig. 1).

Transplants were carried out in January and February when marsh vegetation was dormant. Sediment plugs 10 x 15 cm (1 kg) were taken at low tide at 1 m intervals, placed in herring skiffs and towed to the transplant site at high tide. On the following low tide, the plugs were planted at 1 m intervals. Snow fence was initially placed around the quadrats to stop washout of the newly planted plugs. However, the fence was removed by wave action and as few plugs washed out, was considered unnecessary.

Monitoring of donor and transplant sites is continuing as outlined in Table 2.

Results and Discussion

Donor Sites

It is very apparent that in order to minimize any adverse effects of plug removal, donor sites must be selected carefully. Soft, sandy substrates such as on the river side of Steveston Island make excellent donor sites, the holes filling almost immediately after plug removal. However, there is some problem with maintaining the cores intact during transportation. The next preferred type of donor site is one of soft sediment away from hummock areas. The inside of Steveston Island (*Carex*) and the Francis Road site (*Scirpus*) are representative. In these areas the effects of plug taking and tramping in the soft, fine sediments were evident for about 1½ - 2 months after which no signs were present that plugs had been removed from the area.

The least desirable area for plug removal is firm hummocks (i.e. foreshore of Lulu Island). On these areas the plug holes were still evident 6 months after plug removal, only being about 3/4 filled by sediment. There were even a few cases of plug holes joining to form small pools (ca. 0.25 m across) at this time. However, 9 months after plug removal holes on the hummocks had filled in and pools which had been created were not getting larger.

Transplant Sites

At the Steveston Island and Albion sites growth of transplants was very successful while at Iona only minimal short term growth occurred. Lack of growth in the latter is attributed to high energy (waves), compact sediments and high salinity (> $15^{o}/oo$). Of these, salinity appears to be a major factor with shoots of *Carex lyngbyei* and *Scirpus* spp. requiring a low salinity period for initiation of growth. The seasonal salinity patterns at Steveston Island donor site and the Steveston and Albion transplant sites were quite similiar (Fig. 3). Salinity at Albion began to rise in July - early August with an accompanying decrease in growth and health of the plants. The Francis Road donor site off Lulu Island with a high salinity during the transplant period in January had a significant salinity drop during the summer growth period. Iona did not have this salinity drop. These results suggest that salinity is important in initiating and determining the duration of growth.

The number of transplanted plugs growing continued to increase, reaching a mid-summer maximum of both transplant species (Table 3). At the Albion site success of *Scirpus* and *Carex* plugs were about the same, reaching 75 and 71%, respectively in July. Little elevation effect was evident aside from September when *Scirpus* plug growth increased from 27% in the lowest elevation row to 82% at mid quadrat. Plug success on Steveston Island was comparable, with maxima of 71% for *Scirpus* and 67% for *Carex* in July (Table 3). Elevation effects were clear for *Carex* (31% to 87% per row at the highest elevation).

Transplant plugs of *Carex* and *Scirpus* on Steveston Island had greater shoot density per plug compared to those at Albion (Fig. 4). *Carex* rose from an initial planting density of 3 to a mean of 14 at Steveston and 11 at Albion. *Scirpus* plugs had a mean of 9 shoots at Steveston and 5 at Albion during the period of maximum growth. Although the plug success at both sites was about the same, as previously noted, there does appear to be a restriction of growth at Albion. A salinity increase beginning in July when shoot density levelled off may be responsible.

Mean shoot height for *Carex* (40 cm) was ca. 1/3 - 1/4 that recorded at the donor site. A similar reduction in height was noted for *Scirpus*, about ½ that in the donor site. This is to be expected as the plants are acclimating to a new environment, putting a greal deal of energy into rhizome and root growth. The mean shoot height for both transplant species appears to be higher at Albion (Fig. 4). This, however, may not be the true situation since waterfowl appeared to be grazing the plants at Steveston much more than at Albion.

Rhizome extension is an indicator of good growth and potential for stabilization and cover. Extension by *Carex* was about half that recorded for *Scirpus* and *Eleocharis palustris*, a "contaminant" species in the plugs (Table 4). The latter two plants had such extensive rhizome growth that the 1 m area between plugs was filling in rapidly after one season. In view of extension rates, *Scirpus* and *Eleocharis* would appear to be good for stabilizing substrates initially. *Carex* with its lower rhizome extension and greater above surface biomass would be less valuable for stabilization but of greater importance as a source of organics and detritus. *Carex* also acts as low tide refugia for amphipods with none being recorded from around *Scirpus* within the same quadrat. Benthic algae (filamentous forms) became entangled in the *Carex* shoots and began extensive growth around the plugs.

As yet the data on sediment chlorophyll, organic and C/N content and microalgal colonization have not been worked up. These and a more detailed discussion of results presented above will appear in a future publication. To date, results indicate that it is feasible to carry out transplants on the Fraser estuary using techniques outlined. Good growth can be expected by selecting donor and transplant sites carefully.

Tidal re-activation and salmonid utilization of a portion of the Englishman River Estuary, Vancouver Island, British Columbia

by

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The knowledge of the importance of estuarine habitat for rearing fry of the chum salmon, (*Oncorhynchus keta*), has gradually evolved (e.g. Mason 1974; Healey 1979; Sibert 1979). Delayed seaward movement from spawning streams may be of adaptive value to chum fry if associated with sufficient epibenthic food prey items and covering habitat in estuaries. The Englishman River estuary located at Parksville, Vancouver Island, B.C. was the location of a rehabilitation program to tidally re-activate a previously dyked and alienated estuarine slough habitat in the northern portion of the Englishman River flats. In 1969 a sea dyke had been constructed that cut off 218 acres (88 ha) from tides $\geq$ 16 ft (4.9 m) over chart datum. On March 27, 1979 a 10 meter breach was excavated in the sea dyke so that tidal inundation would once again occur.

The main purpose of this study was to rehabilitate the estuary and ascertain whether any juvenile salmonids would gain access and utilize this new habitat. Also the succession of epibenthic and benthic invertebrate communities was measured inside and adjacent to the breached dyke so that dietary selection by salmonids captured during the study could be better understood. A series of fish trapping and benthic sampling surveys were completed to assess whether salmonid rearing occurred in the re-activated estuary. Significant rearing by chum fry did occur during April and May 1979 and the prey found in their stomach contents appeared to be most representative of invertebrates found in the epibenthos of the re-activated estuary.

LITERATURE CITES

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Table 1. Description of transplant sites at the Fraser estuary.

Area	Characteristics
Steveston Island (south side)	- river site with strong current and wave action - soft coarse sand typical of newly deposited dredge spoil - salinity 3-15°/oo - existing adjacent marsh of *Eleocharis* and *Scirpus* - 40 x 15 m quadrat
Albion	- foreshore site open to wave and currents - coarse to fine sand similiar to settled dredge spoil - salinity 3-25°/oo - extensive existing adjacent marshes of *Scirpus* - 35 x 15 m quadrat
Iona Flats	- high energy foreshore area with wave focusing and moving sand waves - bounded by two jetties - salinity 10-25°/oo - very small existing marsh of *Scirpus* - 50 x 50 m and 40 x 15 m quadrats

Table 2. Outline of sampling at donor and transplant sites at the Fraser estuary.

DONOR SITE

Fill in of plug holes
Erosion of holes
Shoot height and number
Rhizome extension into plug holes
Salinity, percent water content of sediment at surface and 1 m
Surface grain size and algal species composition

TRANSPLANT SITE

A. Plants
Plug success
Shoot height and number (also in natural adjacent vegetation)
Seed production
Grazing effect
Rhizome extension
Effect of sand coverage

B. Substrate (within quadrat and outside controls)
1. Surface and rhizome level
Salinity, organic content and percent water

2. Surface
Algal colonization and chlorophyll content
Organic and carbon/nitrogen content
Colonization by invertebrates
Grain size

Table 3. Number of transplant plugs growing in Steveston and Albion quadrats. n = plug number per row.

Plug growth over time - STEVESTON QUADRAT (n = 39)

	Row	May 19	May 23	June 7	June 22	July 9	Aug.22	Sept.18	Oct.17
Scirpus americanus	2	16	21	21	26 (67)[a]	26	18	17 (44)	17 (44)
	3	19	31	27	28 (72)	29	26	27 (69)	23 (60)
	4	22	28	27	27 (69)	27	21	19 (49)	18 (46)
	5	26	29	28	28 (72)	27	26	26 (67)	26 (67)
	6	23	26	25	24 (63)	25	20	22 (56)	21 (54)
	7	28	35	37	34 (87)	33	31	30 (77)	30 (77)
	8	25	28	28	29 (76)	29	26	25 (64)	25 (64)
	9	22	25	26	25 (65)	25	24	23 (59)	21 (54)
Percent plug growth		58	71	70	71	71	62	61	58
Carex lyngbyei	10	11	10	12	11 (28)	11	12	12 (31)	12 (31)
	11	15	14	16	18 (46)	19	21	19 (49)	21 (49)
	12	32	31	31	33 (85)	34	33	32 (82)	32 (82)
	13	28	31	31	30 (77)	32	29	30 (77)	30 (77)
	14[b]	33	33	34	35 (90)	35	34	34 (87)	34 (87)
Percent plug growth		61	61	64	65	67	66	65	66

[a] percent growing in each row on date indicated.

[b] most landward and highest in elevation.

Table 3. Continued

ALBION QUADRAT

	Row	May 14	May 23	June 7	June 22	July 9	Aug.22	Sept.18
Scirpus americanus	2 (n=26)	13	13	15	19 (73)	19	13	7 (27)
	3 (n=24)	6	10	14	14 (58)	13	14	11 (46)
	4 (n=25)	12	15	11	14 (56)	15	13	11 (44)
	5 (n=33)	13	22	26	25 (76)	27	21	17 (51)
	6 (n=33)	14	22	26	26 (79)	26	24	21 (64)
	7 (n=33)	12	21	27	30 (91)	31	28	27 (82)
Percent plug growth		40	59	68	74	75	65	54
Carex lyngbyei	8 (n=36)	19	20	23	21 (58)	25	22	20 (55)
	9 (n=36)	19	20	26	28 (78)	28	27	27 (75)
	10 (n=36)	23	24	24	24 (67)	24	24	24 (67)
	11 (n=36)	15	20	16	21 (58)	23	18	18 (50)
	12 (n=36)	23	23	27	25 (69)	27	26	25 (70)
	13 (n=36)	28	25	26	27 (52)	27	27	27 (75)
	14 (n=36)	17	20	22	22 (61)	26	23	22 (61)
Percent plug growth		41	60	65	67	71	66	65

Table 4. Mean rhizome extension in cm recorded for the 1979 growth period for transplants at the Fraser estuary.

SPECIES	JUNE	JULY	AUGUST	SEPTEMBER
Eleocharis				
Albion	7	12	29	36
Steveston	5	14	30	37
Scirpus				
Albion	5	14	31	35
Steveston	6	21	35	37
Carex				
Albion	Nil	9	17	19
Steveston	Nil	11	18	20

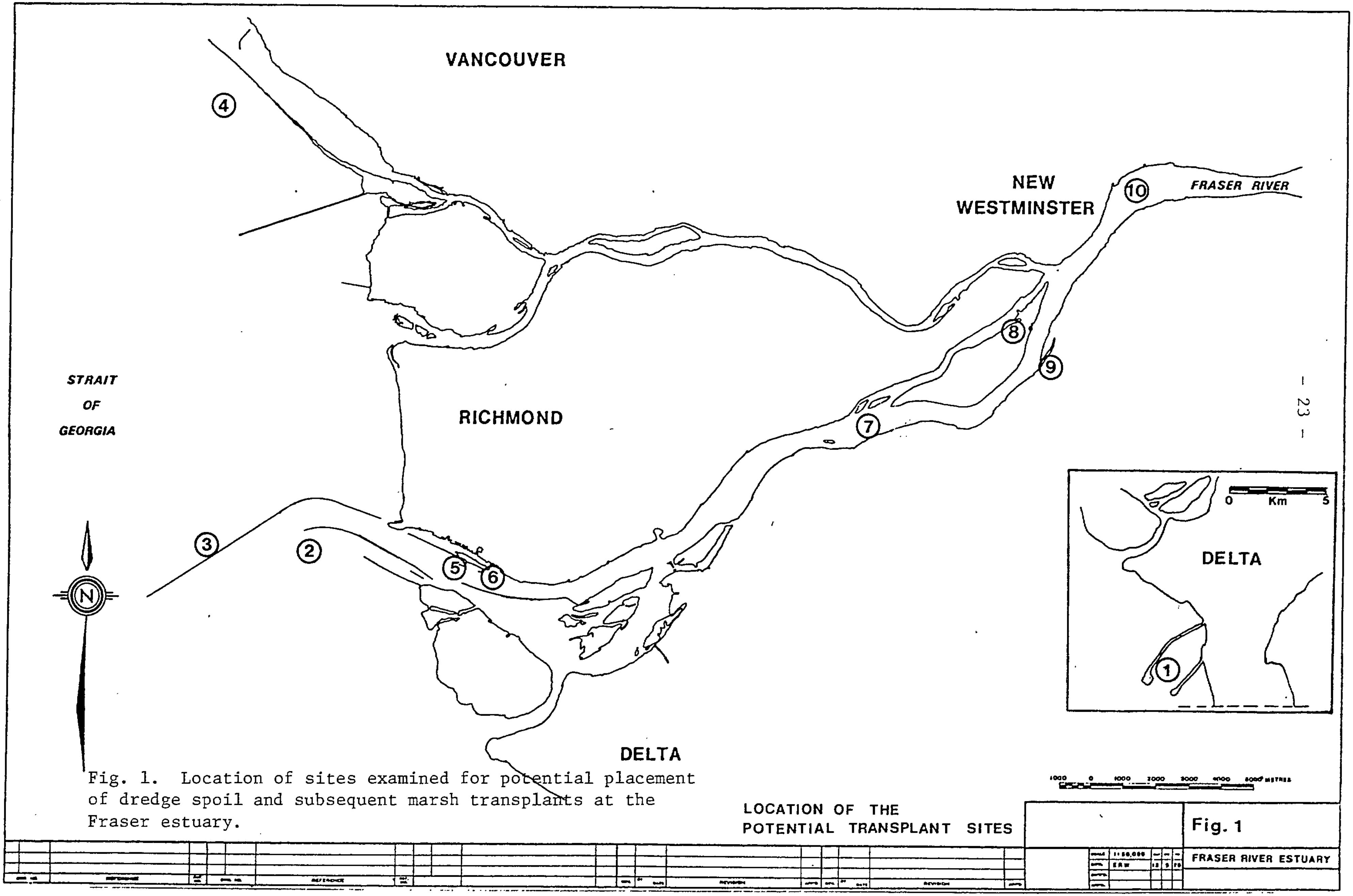

Fig. 1. Location of sites examined for potential placement of dredge spoil and subsequent marsh transplants at the Fraser estuary.

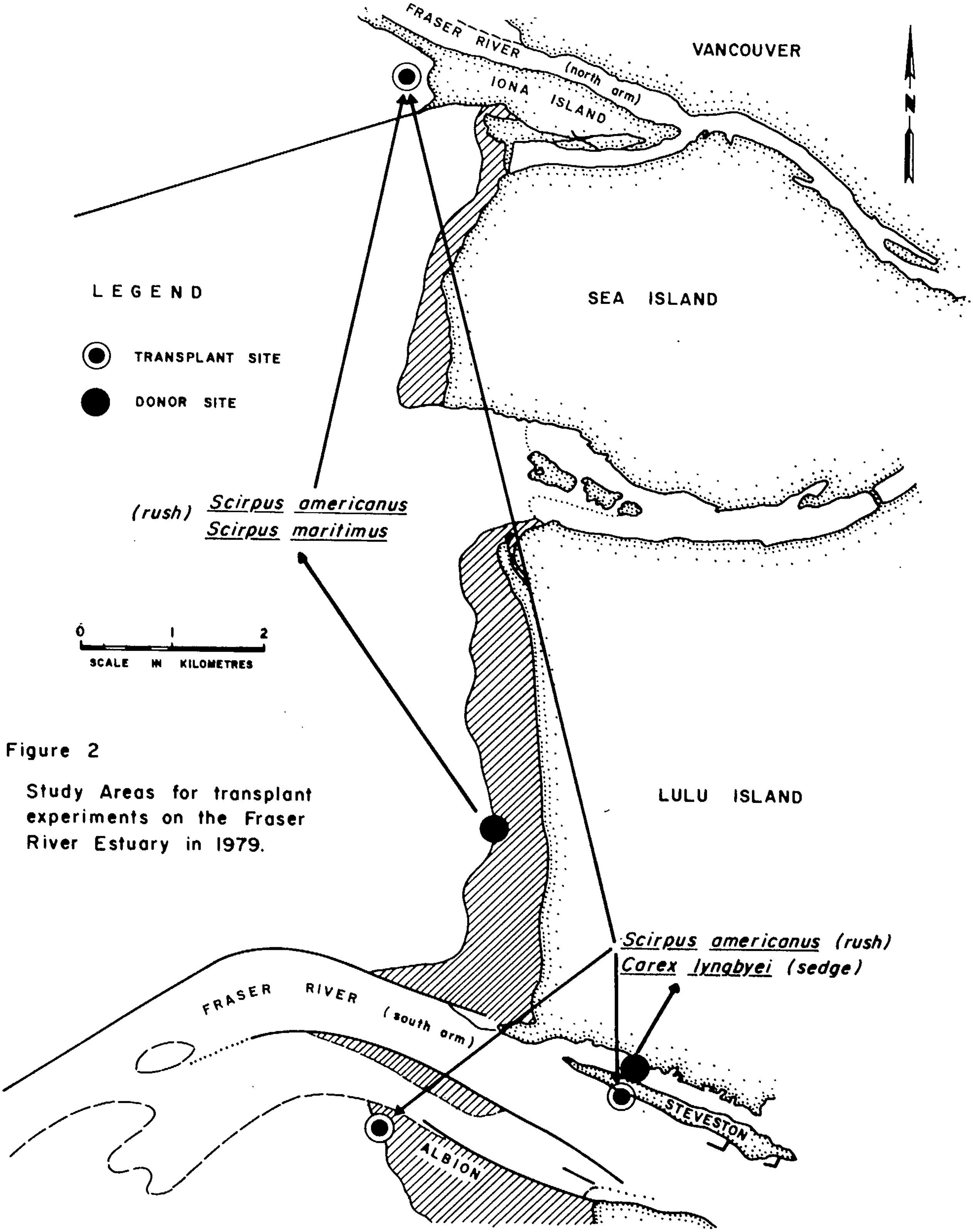

Figure 2

Study Areas for transplant experiments on the Fraser River Estuary in 1979.

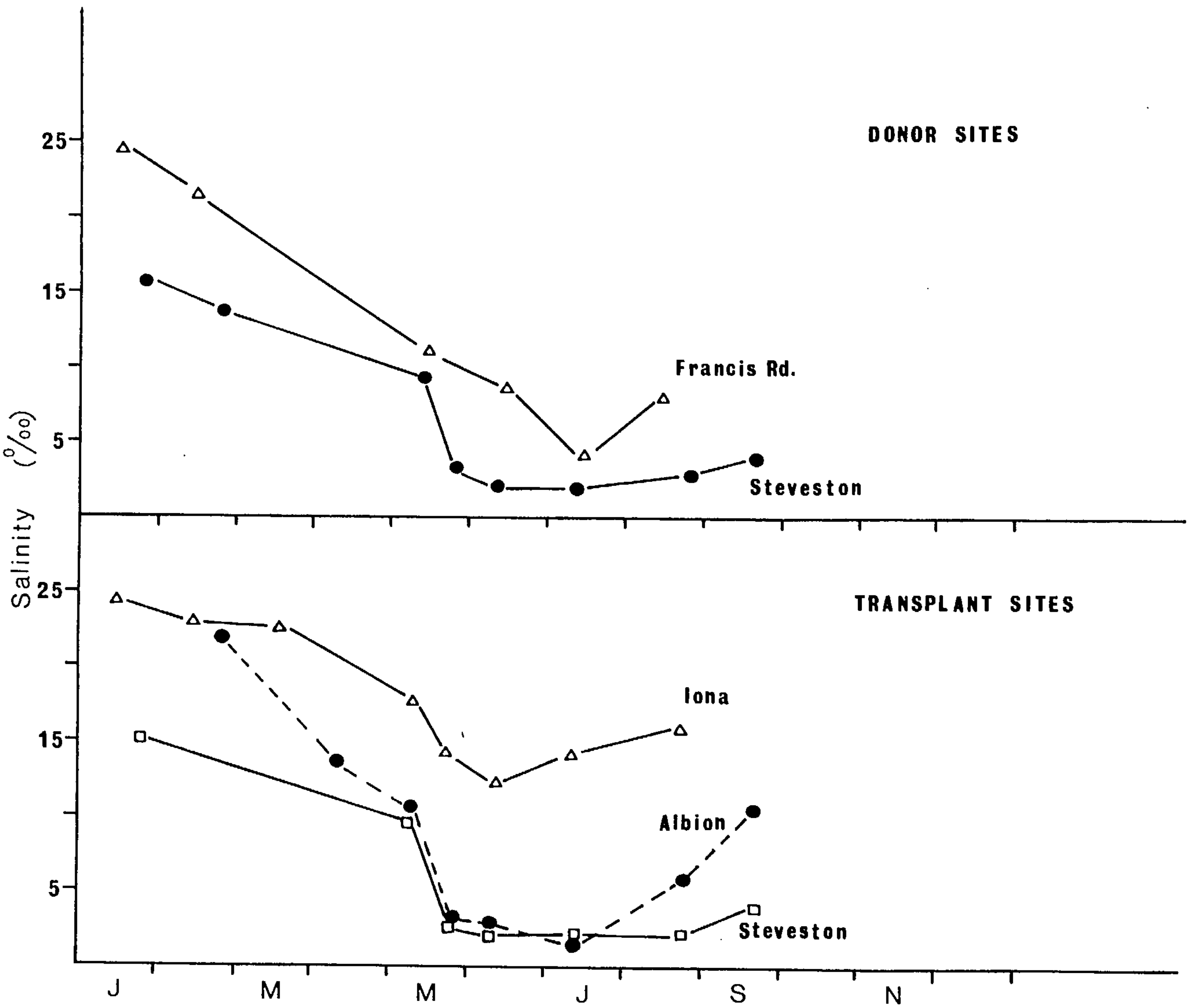

Figure 3. Mean sediment salinity to 10 cm depth, January to September 1979, at the donor and transplant sites at the Fraser estuary.

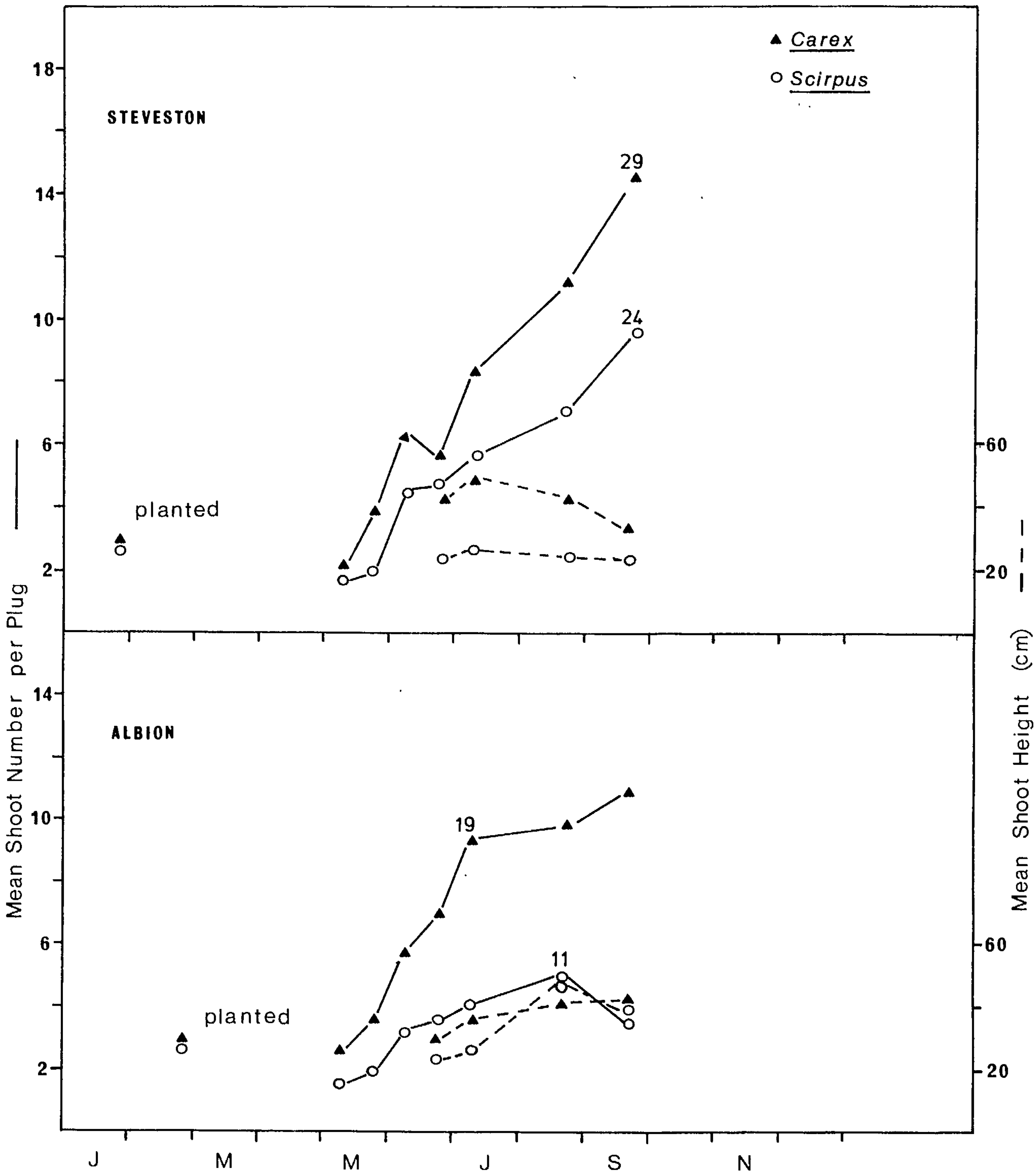

Figure 4. Mean shoot density and shoot height for *Carex* and *Scirpus*, January to September, 1979. Numbers on graph refer to maximum shoot density. Upper panel: Albion (Fraser estuary).