C. Powell

B544

Variations in Success of Eelgrass Transplants over a Five-years' Period

by

PAUL G. HARRISON, PhD (Dalhousie)
Department of Botany, University of British Columbia, 3529–6270 University Boulevard,
Vancouver, British Columbia V6T 2B1,
Canada.

RECEIVED
JUL 30 1992
HABITAT [illegible]

INTRODUCTION

Seagrass 'meadows' are among the most productive of coastal ecosystems, with beds of the common temperate Eelgrass (*Zostera marina* L.) exhibiting high productivity at both the primary (seagrass and attached Algae) and secondary (associated animals) levels... (Thayer *et al.*, 1975; Orth, 1977; Harding & Butler, 1979). The presence of Eelgrass greatly modifies the physical environment, because both the aboveground shoots and the belowground rhizomes and roots help to stabilize sediments (Wilson, 1949; McRoy & Helfferich, 1980), while the plants as a whole provide a three-dimensional habitat with many surfaces for attachment and sites of refuge for other biota (Kikuchi, 1980). For these and other reasons — including the very wide distribution of seagrass 'meadows' — their restoration and enhancement is of considerable environmental importance.

Eelgrass beds are often disrupted by the construction of marinas and port facilities, and by various other human activities, while numerous attempts have been made to transplant Eelgrass as a means of habitat enhancement and restoration. Some success has been reported on the Atlantic coast of North America (Fonseca *et al.*, 1982) and also on the Pacific coast (Phillips, 1982), but many other transplants, especially on the Pacific coast, have had only limited, if any, success (Robilliard & Porter, 1976; Goforth & Peeling, 1980; Walton & Wirt, 1986; Fredette *et al.*, 1987). Estimates of success of seagrass transplants have, in most cases, been based on data on shoot density or bottom coverage as observed up to two years after transplanting (Phillips & Lewis, 1983; Thorhaug, 1985), although some studies in subtropical waters have been monitored for longer periods (McLaughlin *et al.*, 1983). Fonseca *et al.* (1982) clearly point out that the choice of the time-period for monitoring is arbitrary; but it is likely that, for the establishment of a 'natural' community of productive plants and animals in temperate habitats, the seagrasses must persist for several years.

Phillips (1980), and Phillips & Lewis (1983), discussed several methods of transplanting Eelgrass. The research described in the present paper was an attempt to test some of those ideas in a shallow-subtidal sandflat ecosystem in southwestern British Columbia, on the Pacific coast of Canada. The opportunity to monitor the transplants frequently in the first two years, and then annually for up to three more years, led to the comparison of short- and long-term success rates that is presented here.

METHODS

Study Site

The Roberts Bank intercauseway Eelgrass bed (49°2'N; 123°8'W) has been described by Harrison (1987). Currently having an area of vegetation of over 400 ha, the bed has been subject to two episodes of dredging and filling — in 1969 and 1982–83 — for the construction and expansion of a causeway and coal-handling port. Alterations of water-flow patterns led to increased erosion in dendritic channel-systems (Fig. 1). Altogether, from 1969 to 1984, about 30% of the original Eelgrass bed was lost. At the same time, part of the sand-flats landward of the *Zostera marina* bed was colonized by a smaller seagrass, *Z. japonica* (Fig. 2*b*).

Transplant experiments were conducted in two areas of the intercauseway bed (Fig. 2). Site *C*, which included erosion channels and their banks, was largely devoid of vegetation. Site *L* was higher in elevation by up to 1 m, and was just landward of the upper edge of the existing vegetation in 1982. Site *L* was never exposed to the air, however, because of drainage of water from the vast area of intertidal sandflat situated to the landward of the Eelgrass, and because of the retardation of water-flow caused by the plants themselves. All the plants used were of the ecotype *Zostera marina phillipsi* as defined by Backman (1984), and were salvaged from an area at the seaward edge of the Eelgrass bed before dredging occurred (Fig. 2).

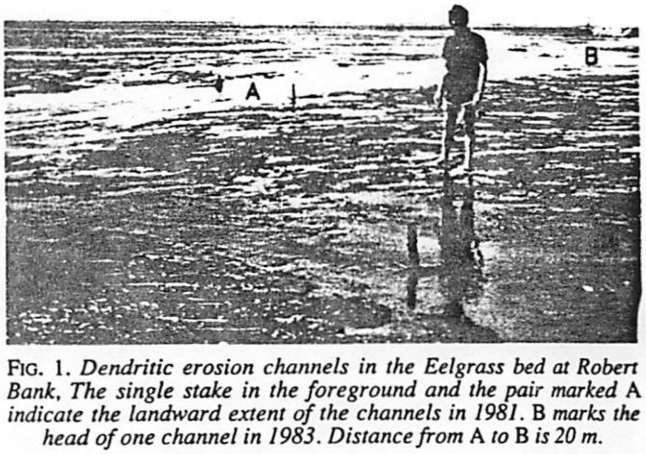

FIG. 1. *Dendritic erosion channels in the Eelgrass bed at Robert Bank. The single stake in the foreground and the pair marked* A *indicate the landward extent of the channels in 1981.* B *marks the head of one channel in 1983. Distance from* A *to* B *is 20 m.*

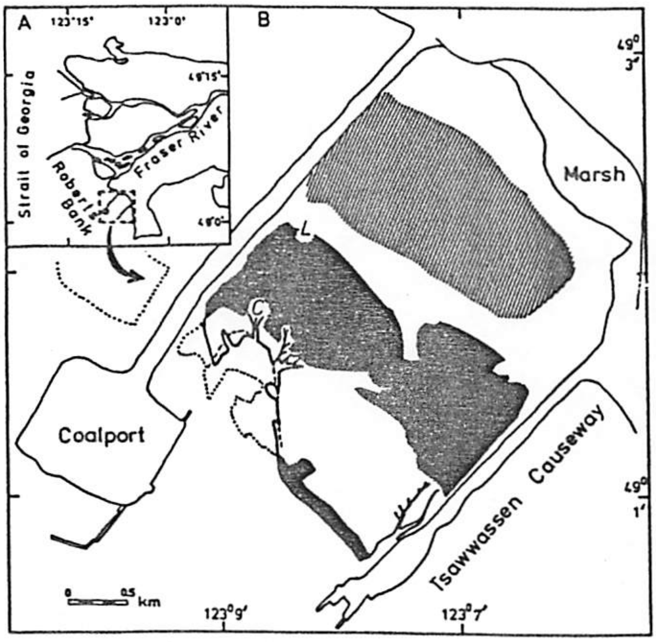

FIG. 2. A, *The location of Roberts Bank on the Pacific coast of Canada. The box indicates the extent of the intercauseway area shown in* B. B, *The intercauseway seagrass beds in 1984, showing the locations of the transplant sites (C, L), the Eelgrass* (Zostera marina) *bed (seaward) and the* Zostera japonica *bed (hatched). Within the Eelgrass bed, shading indicates areas that were not vegetated in 1969, and areas lost after 1969 are outlined with a dotted line.*

Transplants were initiated in summer (August 1982), winter (December 1982–January 1983), and spring (April–May 1983). Three methods of transplanting were employed: intact plants with sediment (cores), unanchored bare plants (sprigs), and plants anchored in the sediment by means of 50-cm lengths of iron rod (0.5 cm diameter) to each of which were attached the rhizomes of 5 shoots by means of elastic bands, the rods then being buried to a depth of 5 cm (anchors or 'rebars'). The plots were monitored until July 1987.

Core Transplants

Coffee cans (10 cm in diameter) were used to excavate intact cores containing plants with sediment around the rhizomes and roots (Fig. 3). At the transplant site, plots (1 x 2 m) were subdivided into 32 sections, and a hole was dug in each section to accommodate one core. The core was gently shaken out of the can into a hole, and packed securely in place with the excavated sediment (Fig. 4).

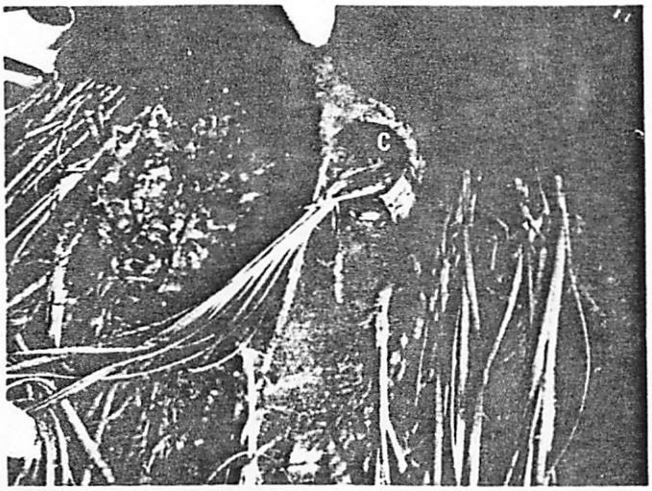

FIG. 3. *A core of intact Eelgrass plants being extracted from the sediment with the aid of a metal can* (C) *having a diameter of 10 cm.*

FIG. 4. *A newly-established transplant plot marked by four posts* (P). *Distance between adjacent posts is 2 m.*

Sprig Transplants

Shoots were gently dug up by hand from the donor area with as much attached rhizome as possible (5–20 cm). Side-shoots were removed, and the sprigs were planted at the desired depth in five parallel rows — each consisting of five sprigs and situated within a 1 x 2 m plot.

Anchored (Rebar) Transplants

Shoots were removed by hand from the donor beds, care being taken to leave attached as much rhizome as possible. Plants were not trimmed for the summer transplants of which the rhizomes were at most 30–40 cm long. Rhizomes were trimmed to lengths of 10–20 cm for the winter and spring plantings. By means of string or elastic bands, five shoots were attached to each piece of rebar (50 cm long, 0.5 cm in diameter). Most plots consisted of four or five pieces of iron rod (rebar), each of which was buried in its own trench in a 1 x 2 m plot.

Planting Variables

The three basic methods — core, sprig. and 'rebar' anchors — were modified to investigate the effects of:

i) The depth at which the rhizome was buried, *i.e.* 3–5 cm below the surface (the normal depth), 5–10 cm below the surface, or at 15–20 cm. Deeper burial may anchor the plants more firmly, but it may also reduce their photosynthetic capacity by covering the leaf-bases;

ii) The length of the rhizome, *i.e.* 5–8 cm *versus* 12–16 cm. The food reserves in a longer rhizome may increase the ability of a transplanted shoot to establish itself;

iii) The orientation of the plants in relation to currents associated with the ebbing and flooding tide, *i.e.* parallel *versus* perpendicular to the current;

iv) The addition of fertilizer (Jobe's 16-8-8 [N-P-K] solid fertilizer spikes) at 1-m intervals on days 0, 26–27, and 40, after planting;

v) Planting within a few hours of collection *versus* storage of shoots up to 24 hours prior to planting (covered with Algae, clear plastic, or black plastic);

vi) The density at which cores were planted (32 in plots 1 x 2 m *versus* 0.5 x 0.5 m *versus* 2 x 4 m);

vii) Season of planting (spring, summer, or winter);

viii) Transplant method (rebar anchors, cores, and sprigs); and

ix) The elevation of the transplant plots.

RESULTS

In the short term (*i.e.* the first two years after planting), changes in shoot numbers in some plots were correlated with many of the planting variables tested, but the results were not consistent. First, the extra anchorage provided by burying rhizomes more deeply than normal was beneficial only for shoots that were attached to iron rods and planted in the erosion channel (Site *C*); shallowly-buried iron rods were often exposed by the current and the transplants were lost. Unanchored shoots in the channel did equally well at all burial depths. Second, bare sprigs with a long rhizome were more successful than sprigs with a short rhizome, but no effect of rhizome length was seen when the shoots were anchored. Third, little difference was measured in the shoot-counts between plots oriented parallel *versus* perpendicular to the flow of the incoming and outgoing tides. Fourth, fertilization led to increased shoot-counts in core and sprig plots but not in rebar (anchor) plots (Fig. 5). Fifth, storage of plants for a day before transplanting them did not affect the outcome as long as the plants were protected from the summer sun by a layer of Algae or black plastic (Fig. 6). Plants stored under clear (water-white) plastic remained moist but died soon after being planted, probably because of excessive temperatures that were reached under the cover. The following year some shoots were growing in these plots, but they were the results of seed germination and were not the remains of the transplants. Sixth, initial planting density did not affect the results.

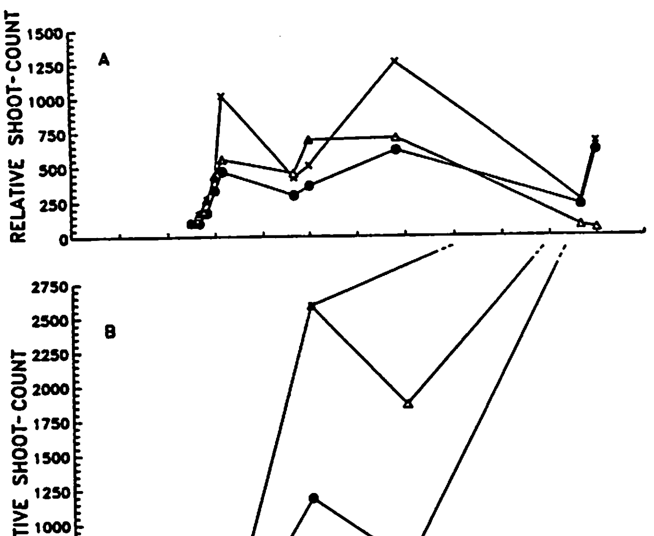

FIG. 5. *Changes in relative shoot-counts in transplant plots initiated in spring 1983, showing the effect of application of a slow-release inorganic fertilizer to the sediment.* A, *Site L: stars = control core plot, triangles = fertilized cores; crosses = control anchored plants, circles = fertilized, anchored.* B, *Site C: stars = control sprig plot, triangles = fertilized sprigs; crosses = control anchored, circles = fertilized anchored.*

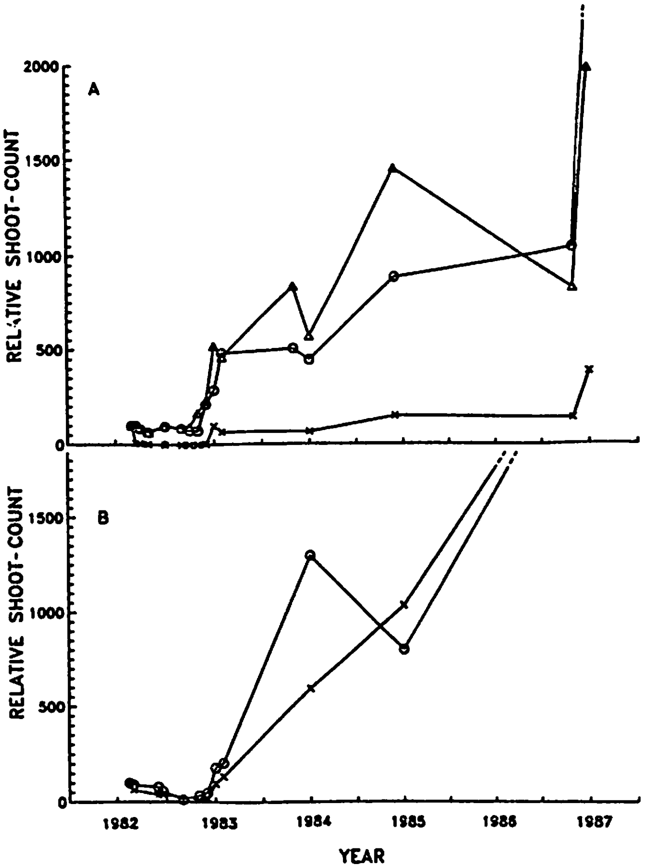

FIG. 6. *Changes in relative shoot-counts in core transplant plots initiated in summer 1982, showing the effect of storing the plants for 24 hr under various conditions before planting them.* A, *Site L: circles = control, i.e. planted immediately; triangles = covered with Algae; crosses = covered with clear water-white plastic.* B, *Site C: circles = control; crosses = covered with black plastic.*

In the longer term, *i.e.* up to five years after planting, the beneficial effect of fertilization disappeared (Fig. 5), and no long-term effect of storage appeared (Fig. 6). The other planting variables discussed above also had no effect.

The season in which Eelgrass was planted did not affect the outcome significantly. Plots begun in summer or winter remained unchanged until the following spring, when the summer, winter, and spring, plantings all began to expand at similar rates (Figs 7, 8). By 1987 at Site *L* it appeared (Fig. 7) that only some summer and the winter plantings continued to show expansion, but the poor showing of the other treatments was more a result of unfavourable elevations (as discussed later) than season of planting.

The three planting methods used — cores, anchored, and sprigs — gave similar results. This was especially true at Site *C* (Fig. 8); but even at Site *L*, the differences among methods were minor (Fig. 7).

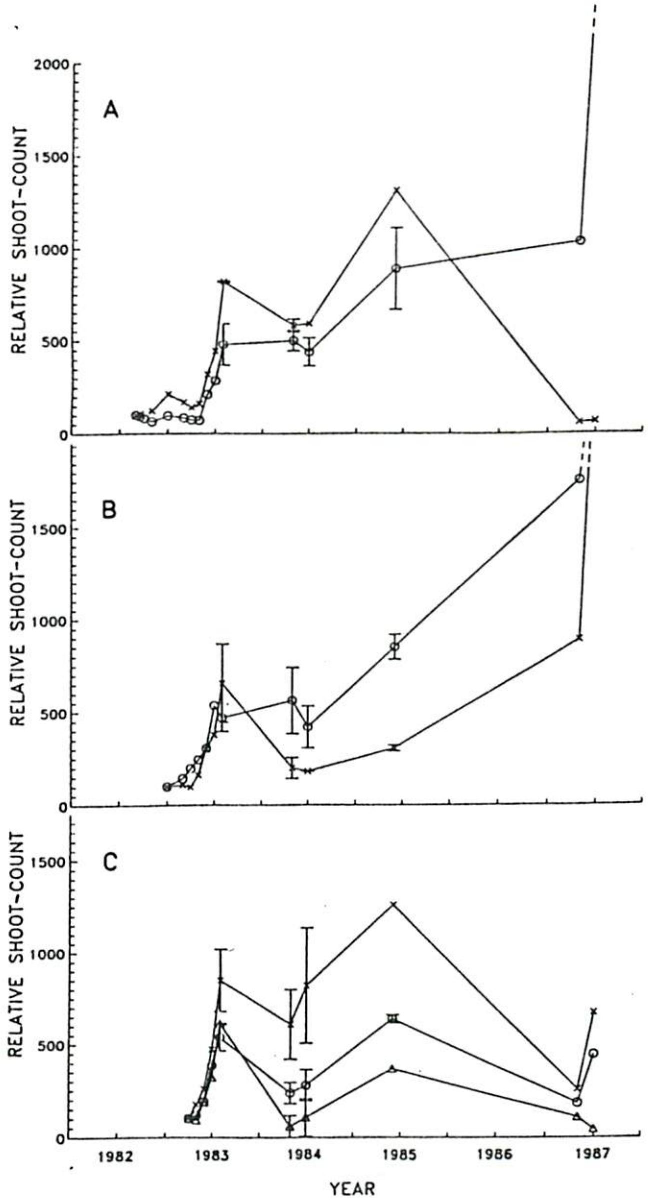

FIG. 7. *Changes in relative shoot-counts in the most successful transplant plots at Site L, showing the effect of season of planting.* A, *Summer.* B, *Winter.* C, *Spring. Key: cross = anchored, circle = core, triangle = sprig. Standard errors are shown for some means.*

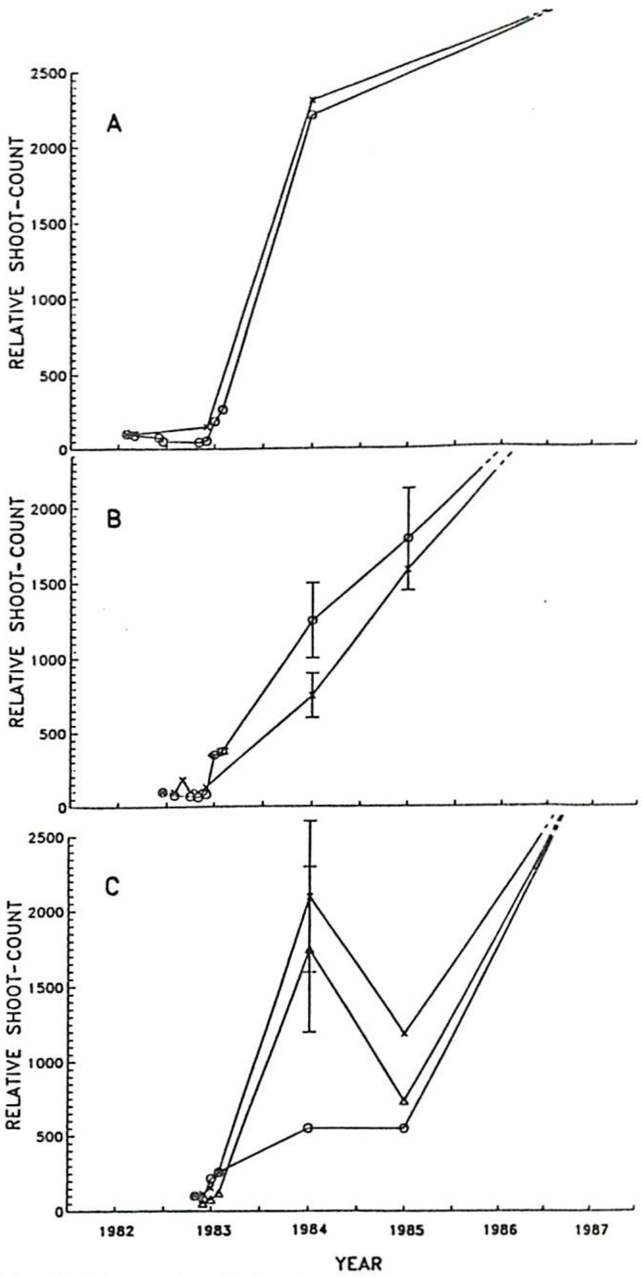

FIG. 8. *Changes in relative shoot-counts in the most successful transplant plots at Site C, showing the effect of season of planting.* A, *Summer.* B, *Winter.* C, *Spring. Key: cross = anchored, circle = core, triangle = sprig. Standard errors are shown for some means.*

At Site *L* the elevation differences (max. 8 cm) did not affect the growth of transplants over the short term, *i.e.* through 1984 (Fig. 9A); but elevation appeared to be the main factor controlling the long-term success. Four to five years after transplanting, most of the plots located at or below 1.73 m above Chart Datum (CD) had expanded to the extent that individual plots were no longer distinguishable from surrounding vegetation. The density of plants in these plots (mean of seven = 107.7 per m^2) far exceeded that where natural colonization had occurred (20.1 per m^2) (Fig. 10). The density of plants at intermediate elevations (1.71–1.73 m) was less than in the lower plots, but greater than in the highest ones (Fig. 9A).

Slight differences in elevation of Site *C* plots also caused little difference in transplant success in the first year, but after two years the plots at the highest elevations (>0.81 m above CD) expanded more slowly than those at lower elevations (Fig. 9B). After three years (*i.e.* in 1985) the plots situated deepest in the channel were also not growing well. Apparently, plants in the high plots suffered from excessive exposure to air at low tide, while plants in the low plots may have been subject to excessive current-flow.

A factor complicating this analysis was the changing pattern of drainage at particular plots associated with changes in the location, depth, and water velocities, of channels. After the crest protection wall — a rock dyke on the seaward perimeter of the Eelgrass bed — was constructed in 1982, the smallest branches of the channels began to disappear as plants colonized them from the adjacent vegetated areas. Year by year, the channel outlines became less distinct.

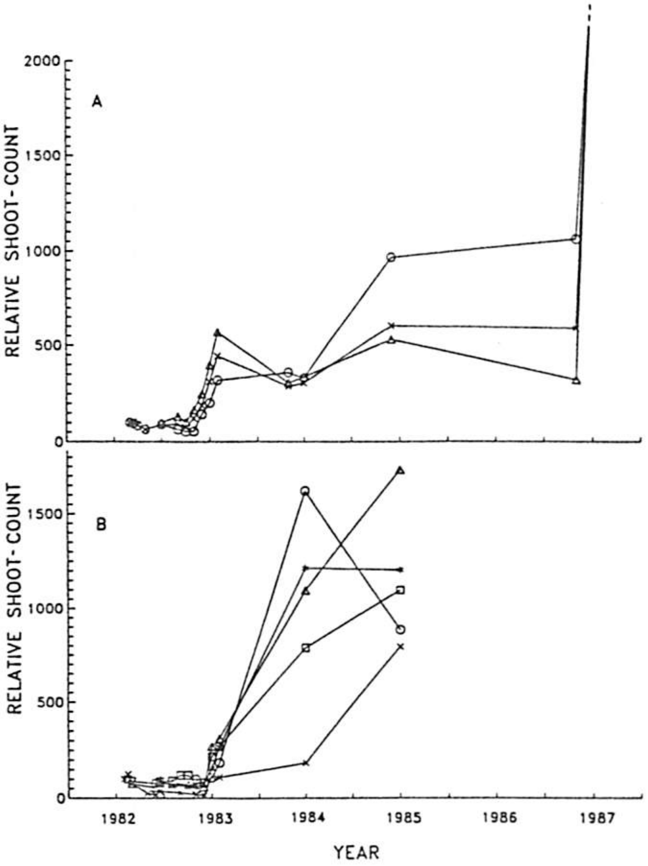

FIG. 9. *Changes in relative shoot-counts in transplant plots initiated in summer 1982, showing the effect of elevation.* A, *Site L: circles = low elevation (<1.71 m above Chart Datum); crosses = mid (1.71-1.73 m); triangles = high (>1.73 m).* B, *Site C: circles = below 0.51 m; stars = 0.51–0.65 m; triangles = 0.66–0.80 m; squares = 0.81–0.95 m; crosses = 0.96–1.10 m.*

By 1987, the entire area of the channels (Site *C*) was vegetated. Some areas which had offered less favourable habitat when the study began (*e.g.* channel banks and higher elevations) were densely populated (50–90 shoots per m²) with Eelgrass (Fig. 11). It was impossible to distinguish the transplants and their progeny from plants which had colonized naturally. During the field work, it became obvious that major changes had occurred in the physical environment, and specifically that the currents were much reduced as compared with those at the time of transplanting.

DISCUSSION

These transplants were performed adjacent to Site *L* and within Site *C*, an existing Eelgrass bed. Hence, many of the limiting environmental factors discussed by Fonseca *et al.* (1982) were known to be suitable for growth of the plants; these include temperature, salinity, sediment texture, and light regime. In the short term (up to two years after planting), many of the variables studied were correlated with differences in the numbers of shoots growing in experimental transplant plots; but few variables had a detectable effect after four or five years. The depth at which rhizomes were buried, within the range which we examined, had little long-term effect — although initially, shallowly-buried anchor rods tended to get uncovered by erosion, with subsequent loss of shoots. Also, in some areas, deep burial led to poor initial results. In the longer term, however, these initial differences were masked by the vigorous growth of those shoots which did survive. Variations in length of rhizome, in orientation in relation to currents, in fertilization, and in initial density, likewise had no lasting effect.

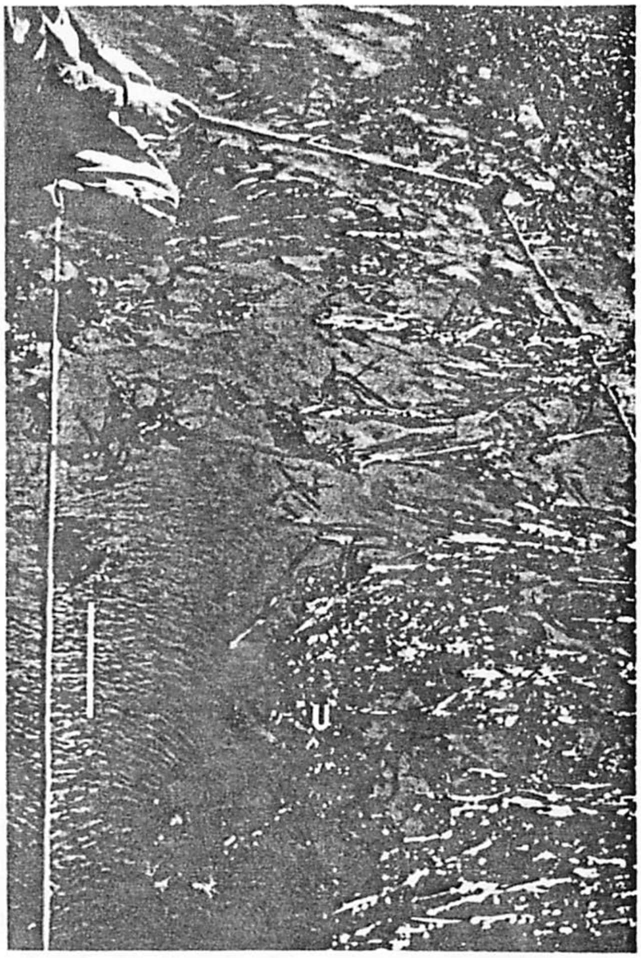

FIG. 10. *Patchy low-density Eelgrass vegetation resulting from natural expansion of the Eelgrass bed in the vicinity of Site L. White scale-bar = 50 cm.* U = *green Algae (mainly* Ulva *sp.) caught among Eelgrass leaves.*

It is possible to store Eelgrass shoots for up to 24 hours before planting them but only as long as the plants are thoroughly shaded. Storage under a layer of moist Algae gave the best short-term survival and growth, but the results were just as good in the longer term (after 3–5 years) when shoots had been stored under black plastic. It is often not practicable to collect and plant shoots on the same day, so it is important to learn more about suitable storage conditions.

In the longer term, only elevation of the transplant site was critical in determining the outcome of the Eelgrass transplants. Elevation affected transplant success in different ways at the two sites. The higher site (*L*) was established in 1982, just landward of the leading edge of the vegetation which had been extending landwards at a rate of some tens of metres a year since 1969 (Harrison, 1987). This expansion ceased around 1982, most probably because of changes in the patterns of water drainage on the ebb tide caused by construction activities associated with the expansion of the coalport next to the Eelgrass bed

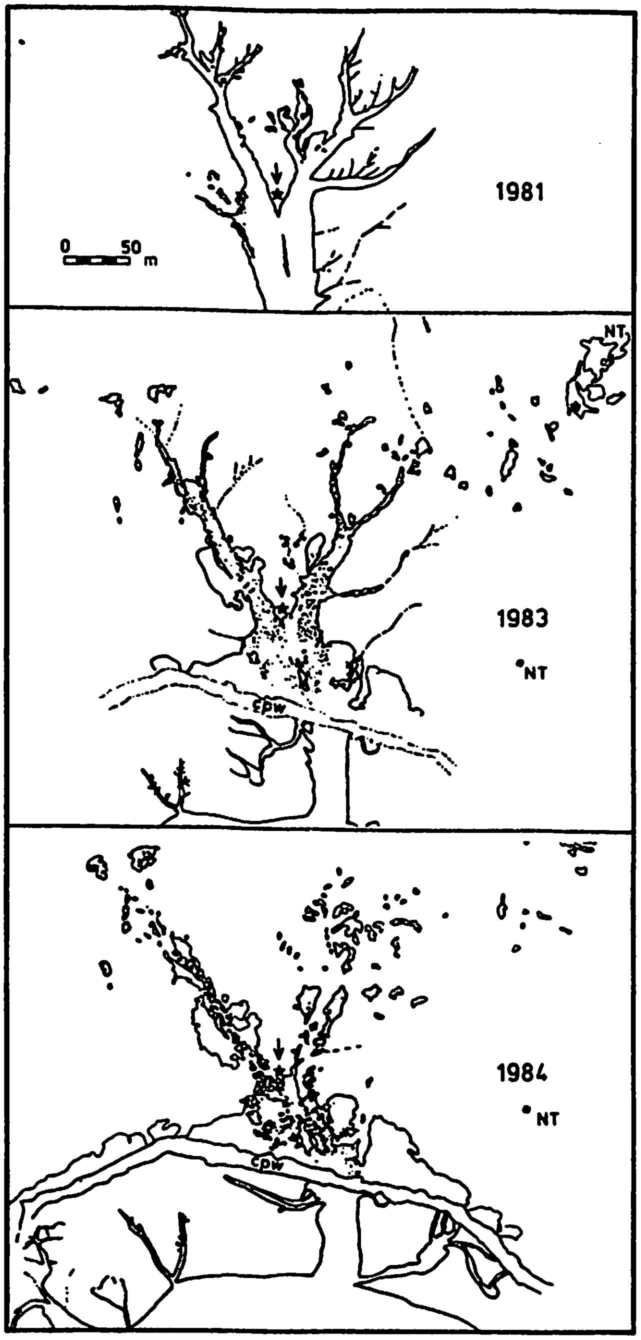

FIG. 11. *Map of Site C drawn from aerial photographs, showing progressive colonization of erosion channels by transplants and natural vegetation. (A common geographical reference-point is provided by the star.) Key:* cpw = *crest protection wall constructed in 1982,* NT = *navigation tower. Irregular patches away from the channels are bare sediment within the Eelgrass bed. In the 1983 and 1984 maps, irregular patches adjacent to channels and the cpw are sediment dumped during construction of the cpw. Dots and patches within channels indicate Eelgrass.*

(Duggan & Luternauer, 1985; Harrison, 1987). Site *L*, although encompassing a narrow range of elevations (8 cm), was at a critical level on the shore, where a change of only a few centimetres could make the whole difference between an exposure/submergence regime that was suitable for Eelgrass and one that was not. Thus, although other factors may have caused some of the short-term differences in success at Site *L*, elevation was the long-term determinant.

At Site *C*, elevation was important initially but not in the long term. Channel beds were the most suitable transplant sites in 1982 and 1983; channel edges were subject to erosion and channel banks drained too quickly at low tide, exposing the plants to excessive desiccation. The channel flow-regime changed, however — most probably because of the construction of a rock dyke around the seaward perimeter of the vegetation, to prevent further erosion (Duggan & Luternauer, 1985). Maximum flow-rates were reduced in the channel system at Site *C* after 1983, at the same time as more water was impounded behind the dyke at low tide. Overall, the site became more suitable than formerly for Eelgrass, and the transplants and natural vegetation flourished.

The season of planting seemed to have an effect on the success of transplants at Site *L* only; but local site differences, mainly in elevation, were partly responsible for this apparent success. After one and two growing-seasons, all three sets of transplants at Site *L* had similar ranges of shoot increases; but even in 1984, spring transplants began to lag behind the others, so that by 1987 it was clear that spring had not been the best season for planting. This conclusion is contrary to that of Phillips (1976), who suggested that 'late winter or spring, *i.e.* when the plants were close to or in the active vegetative growth phase', is the best time for planting, because plants start to root and grow soon after being planted, thus avoiding a long period of dormancy that could result in higher losses. The results of the present study confirm Phillips' observations in that summer and winter transplants did not show any net increase in shoot numbers until the following spring.

Recent field studies on Roberts Bank have revealed that Eelgrass does branch during the fall of the year, but such growth was not detected in the transplants. The explanation for the poor long-term results with spring transplants at Site *L* most probably lies in the elevation differences of the plots. It is unfortunate (in hindsight) that many of the plots chosen for spring transplants were at or above 1.73 m above Chart Datum, the level later determined empirically to be the upper limit for rapid expansion of Eelgrass at the site. Thus what appears to be an effect of season is most likely another effect of elevation.

Transplantation is a viable technique for replacing lost Eelgrass beds. Eelgrass will grow in a wide range of environmental conditions, but it takes several years for transplants to achieve 'natural' shoot densities. In the interval, which may be 4–5 years, ecosystem productivity is much reduced, and habitats for many other biota — especially animal types — are unavailable. Even when the Eelgrass itself recovers, there is no guarantee that the ecosystem will be re-established; the fauna in transplanted Eelgrass beds may differ quantitatively and qualitatively from the original suite of animals (Fonseca, 1987). Further study is required on the relationships between transplanted Eelgrass and animals. In the meantime, *transplantation* should be used cautiously, and only after all possibilities for mitigating damage to existing Eelgrass beds have been explored — through consideration of alternative sites for development, and modifications of design to reduce the detrimental effects of construction.

ACKNOWLEDGEMENTS

The research reported in this paper was supported mainly by the Port of Vancouver (Ports Canada Corporation), and also by the Summer Canada Works Programme of Employment and Immigration Canada, the Natural Sciences and Engineering Research Council of Canada, and the International Development Research Centre of Canada. Field and laboratory assistance was provided by F. Bishay, D. Carter, D. Connelly, J. Cryder, C. Durance, J. Elvidge, J. Francis, S. Khanna, B. Ko, A. Listrum, D. Miyake, P. O'Hara, and K. Vasarhelyi.

SUMMARY

An Eelgrass (*Zostera marina* L.) bed in a very shallow subtidal habitat adjacent to a busy port in southwestern British Columbia, Canada, was the site of experimental transplants. Eelgrass populations were successfully established, using a variety of transplanting techniques, namely cores (plants with the sediment retained around the rhizomes and roots), sprigs (plants from which the sediment had been washed), and sprigs anchored to buried lengths of iron rod. Transplants took place in two sites — (1) a shallow channel that had eroded from the sea into the Eelgrass bed, and (2) at the landward edge of the existing vegetation.

In the short term, *i.e.* up to two years after planting, treatment variables which affected success of some transplant plots included depth of rhizome burial, orientation to current, fertilization, storage of shoots before planting, elevation, season of planting, and use of cores, sprigs, or anchored shoots. In the longer term, *i.e.* up to five years after planting, only elevation and local drainage-patterns had marked effects on transplant success. The critical upper elevation varied between sites, depending on the rate at which water drained at low tide. At the landward-edge site, the only transplants that flourished were those which were covered by a shallow layer of water throughout the tidal cycle. Among the transplant plots, some Eelgrass plants colonized naturally but the expansion of those patches which contained natural invaders was much slower than that of the transplants themselves.

Changes in the pattern of water-flow during the course of the study contributed to a high success-rate at the erosion channel site. Construction of a rock dyke around the seaward perimeter of the Eelgrass bed reduced the velocity of the ebbing tidal flow, eliminated sediment erosion, and led to such rapid natural recolonization that many of the transplant plots could not be distinguished after five years. The need to monitor transplants over several years to assess their success was demonstrated.

REFERENCES

BACKMAN, T.W.H. (1984). *Phenotypic Expressions of* Zostera marina *L. Ecotypes in Puget Sound, Washington*. Unpublished Ph.D. Thesis, School of Fisheries, University of Washington, Seattle, Washington, USA: xvi + 226 pp. (typescript).

DUGGAN, D.M. & LUTERNAUER, J.L. (1985). Development-induced tidal-flat erosion, Fraser River delta, British Columbia. Pp. 317–26 in *Current Research Part A*. Geological Survey of Canada Paper 85-1A, x + 802 pp., illustr.

FONSECA, M.S. (1987). Habitat development applications: use of seagrass transplanting for habitat development on dredged material. Pp. 145–50 in *Beneficial Uses of Dredged Material; Proceedings of the First Inter-agency Workshop, 7–9 October* 1986, Pensacola, Florida (Eds M.C. LANDIN & H.K. SMITH). USACE Technical Report D-87-1, v + 271 pp.

FONSECA, M.S., KENWORTHY, W.J. & THAYER, G.W. (1982). A low-cost transplanting procedure for sediment stabilization and habitat development using Eelgrass (*Zostera marina*). *Wetlands*, **2**, pp. 138–51.

FREDETTE, T.J., FONSECA, M.S., KENWORTHY, W.J. & WYLLIE-ECHEVERRIA, S. (1987). *An Investigation of Eelgrass* (Zostera marina *L.*) *Transplanting Feasibility in San Francisco Bay, California* Consultation for US Army Corps of Engineers, District of San Francisco, California, USA: 36 pp.

GOFORTH, H.W., jr. & PEELING, T.J. (1980). *Intertidal and Subtidal Eelgrass* (Zostera marina *L.*) *Transplant Studies in San Diego Bay, California*. Technical report for Naval Ocean Systems Center, San Diego, California, USA: NOSC TR 505, 25 pp., illustr.

HARDING, L.W. & BUTLER, J.H. (1979). The standing stock and production of Eelgrass, *Zostera marina*, in Humbolt Bay, California. *California Fish and Game*, **65**, pp. 151–8.

HARRISON, P.G. (1987). Natural expansion and experimental manipulation of seagrass (*Zostera* spp.) abundance and the response of infaunal invertebrates. *Estuarine, Coastal and Shelf Science*, **24**, pp. 799–812.

KIKUCHI, T. (1980). Faunal relationships in temperate seagrass beds. Pp. 153–72 in *Handbook of Seagrass Biology: An Ecosystem Perspective* (Eds R.C. PHILLIPS & C.P. MCROY). Garland STPM Press, New York, NY, USA: xiii + 353 pp., illustr.

MCLAUGHLIN, P.A., TREAT, S.-A.F., THORHAUG, A. & LEMAITRE, R. (1983). A restored seagrass (*Thalassia*) bed and its animal community. *Environmental Conservation*, **10**(3), pp. 247–54, illustr.

MCROY, C.P. & HELFFERICH, C. (1980). Applied aspects of seagrasses. Pp. 297–343 in *Handbook of Seagrass Biology: An Ecosystem Perspective* (Eds R.C. PHILLIPS & C.P. MCROY). Garland STPM Press, New York, NY, USA: xiii + 353 pp., illustr.

ORTH, R.J. (1977). The importance of sediment stability in seagrass communities. Pp. 281–300 in *Ecology of Marine Benthos* (Ed. B.C. COULL). University of South Carolina Press, Columbia, South Carolina, USA: xvii + 467 pp.

PHILLIPS, R.C. (1976). Preliminary observations on transplanting and a phenological index of seagrasses. *Aquatic Botany*, **2**, pp. 93–101.

PHILLIPS, R.C. (1980). Transplanting Methods. Pp. 41–56 in *Handbook of Seagrass Biology: An Ecosystem Perspective* (Eds R.C. PHILLIPS & C.P. MCROY). Garland STPM Press, New York, NY, USA: xiii + 353 pp., illustr.

PHILLIPS, R.C. (1982). Seagrass meadows. Pp. 173–201 in *Creation and Restoration of Coastal Plant Communities* (Ed. R.R. LEWIS III). CRC Press, Inc., Boca Raton, Florida, USA: vii + 219 pp., illustr.

PHILLIPS, R.C. & LEWIS III, R.L. (1983). Influence of environmental gradients on variations in leaf widths and transplant success in North American seagrasses. *Marine Technology Society Journal*, **17**, pp. 59–68.

ROBILLIARD, G.A. & PORTER, P.E. (1976). *Transplantation of Eelgrass* (Zostera marina) *in San Diego Bay*. Consultation for Naval Undersea Center, San Diego, California, USA: NUC TN 1701, 36 pp., illustr.

THAYER, G.W., ADAMS, S.M. & LACROIX, M.W. (1975). Structural and functional aspects of a recently established *Zostera marina* community. Pp. 518–40 in *Estuarine Research, Vol. 1: Chemistry, Biology and the Estuarine System* (Ed. L.E. CRONIN). Academic Press, New York, NY, USA: xiv + 738 pp., illustr.

THORHAUG, A. (1985). Large-scale seagrass restoration in a damaged estuary. *Marine Pollution Bulletin*, **16**(2), pp. 55–62.

WALTON, J.M. & WIRT, W. (1986). *Eelgrass Transplant Mitigation for the John Wayne Marina: One-year Assessment*. Fisheries Technology Program, Peninsula College, Port Angeles, Washington, USA: PCFRP 86-03, 6 pp.

WILSON, D.P. (1949). The decline of *Zostera marina* L. at Salcombe and its effects on the shore. *Journal of the Marine Biological Association of the United Kingdom*, **28**, pp. 395–412.