Revegetation of bare peat substrates: the case of a saline bog, New Brunswick

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Summary

Harvested peatlands affected by salt contamination present an ensemble of complicating factors concerning their revegetation / rehabilitation, including salt toxicity, frost heaving, flood water control and perhaps most importantly lack of a viable seed bank. This study involves the identification of methods that may be used in the rehabilitation of a coastal post-harvest peatland on Pokesudie Island, New Brunswick. During a storm in January 2001 a large volume of seawater was washed onto the peatland. Despite mitigation efforts the peat resource has remained too saline for horticultural use and rehabilitation methods are being sought. These involve the use of various salt marsh species to establish a vegetal cover of the peat surface to first help stabilize the substrate. Various re-introduction techniques such as plug transfer at various densities and the use of hay transfer were tested. The use of fertiliser was also examined. Highest revegetation rates were achieved using hay transfers taken from swards of *Juncus buffonius* and salt marsh vegetation dominated by *Spartina pectinata*. Fertiliser use did not significantly increase plant establishment. This research may be applicable to other coastal peatland rehabilitation projects.

Key index words: peatland, salt toxicity, rehabilitation, restoration, hay transfer, plug transfer

Introduction

In recent years, coastal harvested peatlands that have been inundated with sea water, such as Pokesudie Bog, New Brunswick, have presented those responsible for their rehabilitation with an ensemble of complicating factors including salt toxicity, poor nutrient status, low pH, frost heaving, summer desiccation, spring and autumn flood water control, anoxia, wind erosion and perhaps most importantly lack of a viable seed bank.

The revegetation of bare peat substrates following disturbances such as fire or peat harvesting has been well studied in recent years (Price *et al.*, 2003; Rochefort *et al.*, 2003). Despite the difficulties encountered in the rehabilitation of harvested peatlands, much success has been achieved by the Peatland Ecology Restoration Group (PERG) with the development of a cost effective, paludifying restoration approach (Ferland and Rochefort, 1997). This approach focuses on the active reintroduction of typical peatland plants, particularly the *Sphagnum* mosses, onto the restoration site, and has proven to be a very successful means of rehabilitating disturbed peatlands.

The presence of high concentrations of salts following sea water incursion means that the plants normally used for peatland restorations cannot be used to rehabilitate Pokesudie Bog. Typical peatland plants, such as the Sphagnum mosses, have narrow tolerance ranges of chemical conditions (Clymo and Hayward, 1982; Wilcox, 1984; Wilcox, 1986a; Wilcox and Andrus 1987). They also lack the mechanisms necessary to deal with elevated salt levels and thus are not suitable for restoration programs in such areas. The plants to be used in the rehabilitation of saline peat substrates will have to be able to contend with all the factors typical of peatland rehabilitation, plus that of salt toxicity.

Damaged salt marshes are ecosystems where conditions similar to those encountered at Pokesudie Bog exist. Salt marsh plants have evolved to be tolerant of similar conditions and would therefore be likely to be capable of establishing on saline peat substrates. Plug transplants of mature plants and hay transfers of aboveground vegetation taken from plant communities dominated by typical salt marsh plants were tested along with fertiliser applications.

Site description

The site where the research was carried out is located on Pokesudie Island, New Brunswick, Canada (47°49'N; 64°49'W). The site is a former Atlantic coastal raised bog. Average yearly precipitation is 1,059 mm, 314 mm of which falls as snow. Average January temperature is -11.1°C and average July temperature is 19.3°C (Bathurst NB station; Environment Canada, 2008). It is surrounded by the sea on its northern, western and eastern sides. The peatland is bordered by areas of forestry and salt marsh. An access road crossing the site limited sea water incursion to the southern area of the study zone, resulting in a severely affected and a negligibly affected area with differing salinities of 2.1 ‰ and 0 ‰ respectively.

Materials and methods

Experiment 1: hay transfer with fertilisation. Negligibly affected area by salt.

To test the suitability of a hay transfer technique, an experiment was carried out over two growing seasons (2004-2005). Three blocks of two experimental units (4 m x 6 m) were put in place using a completely randomized block design. Hay from communities dominated by more than 60% cover of either *Juncus buffonius* or *Carex brunesscens* were used. The hays were harvested at Pokesudie peatland in areas where spontaneous revegetation has occurred in the negligibly affected area. Plant material from the previous year and the current season growth was harvested by hand using a scythe. Seeds from the previous year's growth were contained in this material. The harvest : spread ratio was 1:1. Boundary walls of peat approximately 30 cm high were constructed around the receiving parcels in order to prevent spring and autumn flood waters spreading the hay treatments. A custom formula of di-ammonium orthophosphate $[(NH_4)_2\ HPO_4]$ 15-25-0 fertiliser was broadcast spread on all experimental units at a rate of 15 $g.m^{-2}$ at the time of hay application in August 2005.

Experiment 2: plug transfer technique with different densities. Negligibly affected area by salt.

In order to test the suitability of the plug transfer technique and the influence of different planting densities using *Spartina pectinata* and *J. buffonius*, a 13 month experiment was started in June 2004. Three blocks comprising four experimental units (4 m x 6 m) were put in place using a completely randomized block design. Each species was planted at high and low densities. Both species were harvested from the salt marsh of Pokesudie Island. Cores of 2 cm in diameter were used to harvest *J. buffonius*. Each *J. buffonius* core contained an average of 4 plants. These cores were planted at low (70 cores per unit) and high (280 cores per unit) densities. *S. pectinata* were harvested individually and planted at low (3 plants m^{-2}) and high (12 plants m^{-2}) densities. Slow release rock phosphate was broadcast spread on all experimental units at a rate of 25g per m^{-2} in early June 2005.

Experiment 3: plug transfer technique with sanding. Severely affected area by salt.

The effect of the application or absence of a layer of sand (~2-3 cm deep) on the growth of 3 species, *Juncus balticus*, *J. buffonius* and *Spartina patens* transplanted by plugs was tested in an one year trial. Three blocks of six experimental units (4 m x 6 m) were put in place using a completely randomized block design. Planting densities of *J. balticus*, *J. buffonius*, and *S. patens* were 12 $plants.m^{-2}$, 48 $plants.m^{-2}$ and 21 $plants.m^{-2}$ respectively. Slow release rock phosphate was broadcast spread on all experimental units at a rate of 25g per m^{-2} in early June 2005.

Experiment 4: hay transfer technique with and without fertiliser. Severely affected area by salt.

The suitability of hay transfers and fertiliser application was tested in a 12 month experiment begun in August 2005. The *Spartina* hay came from an area of the peatland unaffected by flooding where spontaneous revegetation by *S. pectinata* has occurred. The *Juncus* hay came from the lesser affected area of the peatland which has spontaneously revegetated mainly by *Juncus buffonius*. The marsh hay came from the adjoining salt marsh in the mid-upper marsh zone. The harvest : spread ratio was 1:1. Four blocks comprising of eight experimental units (4 m x 6 m) were put in place using a completely randomized block design. Boundary walls of peat approximately 30 cm high were constructed around each experimental unit in order to prevent spring and autumn flood waters spreading the hay treatments. Any vegetation present within the boundary walls was removed before any treatments were applied. Each hay transfer treatment was fertilised or not. A commercially available di-ammonium orthophosphate $[(NH_4)_2\ HPO_4$, (10-25-10)] fertiliser was broadcast at a dose of 20g m^{-2} in June 2006.

Plant establishment success was measured based on density, percent cover, height and health scale (Table 1). Experiments 1, 2 and 3 were assessed in July 2005, and experiment 4 in August 2006. Although more than one species was often found growing in the experimental units, generally only the growth of the dominant species were

Table 1. List of parameters used to describe the health of plants.

5 : No stress apparent	Over 90% of the stem is green. Presence of many new stems. Strong growth of existing stems. No necrosis of plant tissue. Presence of seeds.
4 : Signs of stress hardly apparent	75% to 90% of the stem is green. Presence of many new stems. Strong growth of existing stems. Little or no necrosis of plant tissue.
3 : Weak signs of stress	50% to 75% of the stem is green. Presence of new stems. Evidence of growth of existing stems. Low levels of necrosis of plant tissue.
2 : Signs of moderately elevated stress	25% to 50% of the stem is green. A few new stems growing. Annual growth weak or zero. Significant levels of necrosis of plant tissue.
1 : Signs of elevated stress	Less than 25% of the stem is green. No new stems growing. No indications of growth. High levels of necrosis of plant tissue.

assessed as other species were limited usually to single occurrences. A buffer area of 1 m from the perimeter wall was excluded from sampling so as to avoid edge effects. Six quadrats of 50 cm x 50 cm were selected at random within each experimental unit.

Results

Experiment 1: hay transfer with fertilisation. Negligibly affected area.

C. brunesscens did not establish well and was generally limited to 1-5 stems per experimental unit. *J. buffonius* established very well in both hay treatments, leading to *J. buffonius* being evaluated for both hay treatments. Healthy carpets of *J. buffonius* were recorded within all experimental units with average cover >15%. Health of *J. buffonius* plants was also good (Fig. 1).

Experiment 2: plug transfer technique with different densities. Negligibly affected area.

Neither *J. buffonius* nor *S. pectinata* outperformed the other and vegetal groundcover was low for all treatments: <9% (Fig. 2). No biological advantage was observed for high initial planting density over low initial planting density for either species. Experimental units were largely empty with only occasional clumps of vegetation scattered throughout. Signs of stress were apparent in all experimental units, as shown by the poor plant health levels. Evidence of frost heaving was apparent on bare peat. Once the floodwater retreated away from the experimental units, the peat surface dried up very quickly and cracked.

Experiment 3: plug transfer technique with sanding. Severely affected area.

Vegetal cover was low for all treatments: <7% (Fig. 3). *J. balticus* had the highest percentage cover, followed by *S. patens* and then *J. buffonius*. In all experimental units, vegetation was concentrated around small clumps and was not uniformly spread over the peat surface. Sand application resulted in significantly more groundcover; however, since the highest achieved groundcover was so low this is not biologically significant. Evidence of frost heaving was apparent in all units. Once the floodwater retreated away from the experimental units, the peat surface dried up very quickly and cracked.

Experiment 4: hay transfer technique with and without fertiliser. Severely affected area.

The highest total groundcover was achieved using the marsh hay, followed by the *Juncus* hay (Fig. 4). The *Spartina* hay and the control treatments resulted in the lowest total ground cover. These treatments did not differ significantly. Non-target species were found growing in experimental units where they were not initially introduced. *J. buffonius* was present in all units and *S. pectinata* was present in all but the control units. When the results for *J. buffonius* and *S. pectinata* were analyzed separately for each of the hay treatments, both were observed to perform better in the marsh hay plots than in any of the other treatments.

A significant hay x fertiliser interaction on the health of *J. buffonius* and *S. pectinata* was detected; however, when this was sliced by hay it only proved to be significant for the

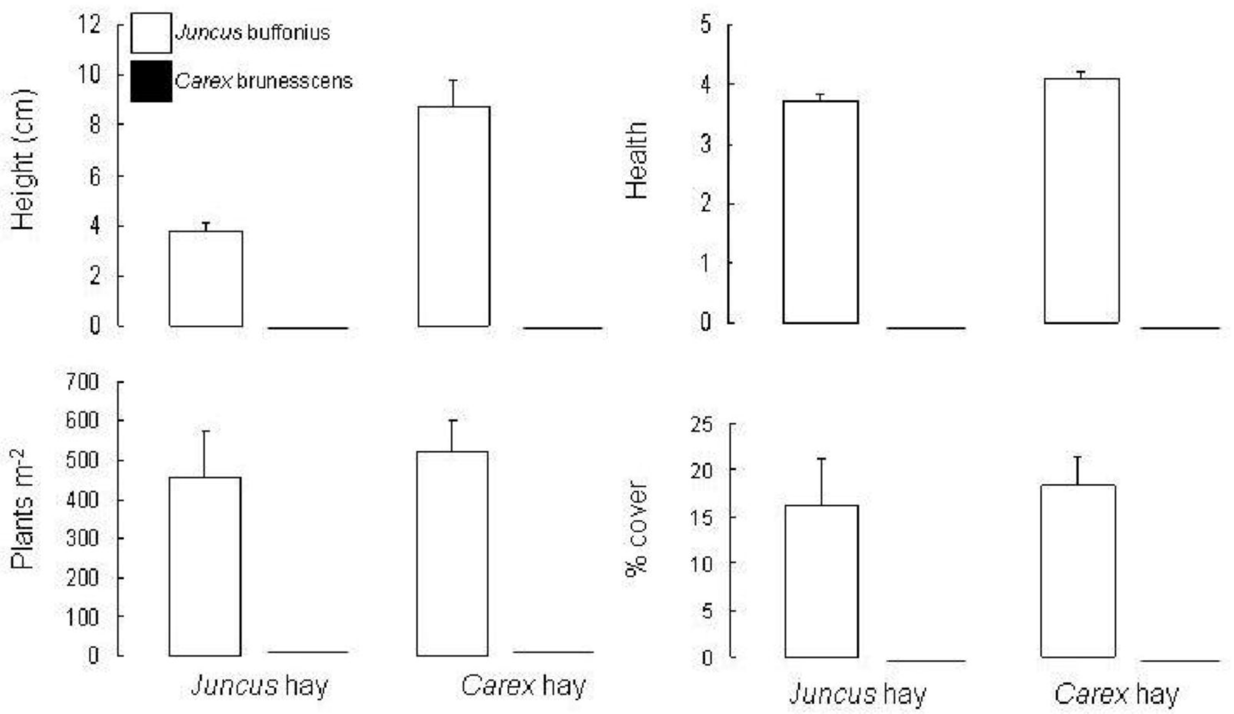

Figure 1. Plant establishment success of two wetland species (*Juncus buffonius* and *Carex brunesscens*) introduced by the hay transfer technique from communities dominated by >60% *Juncus buffonius* for the Juncus hay and >60% *Carex brunesscens* for the Carex hay. Mean values (± SD) after 14 months.

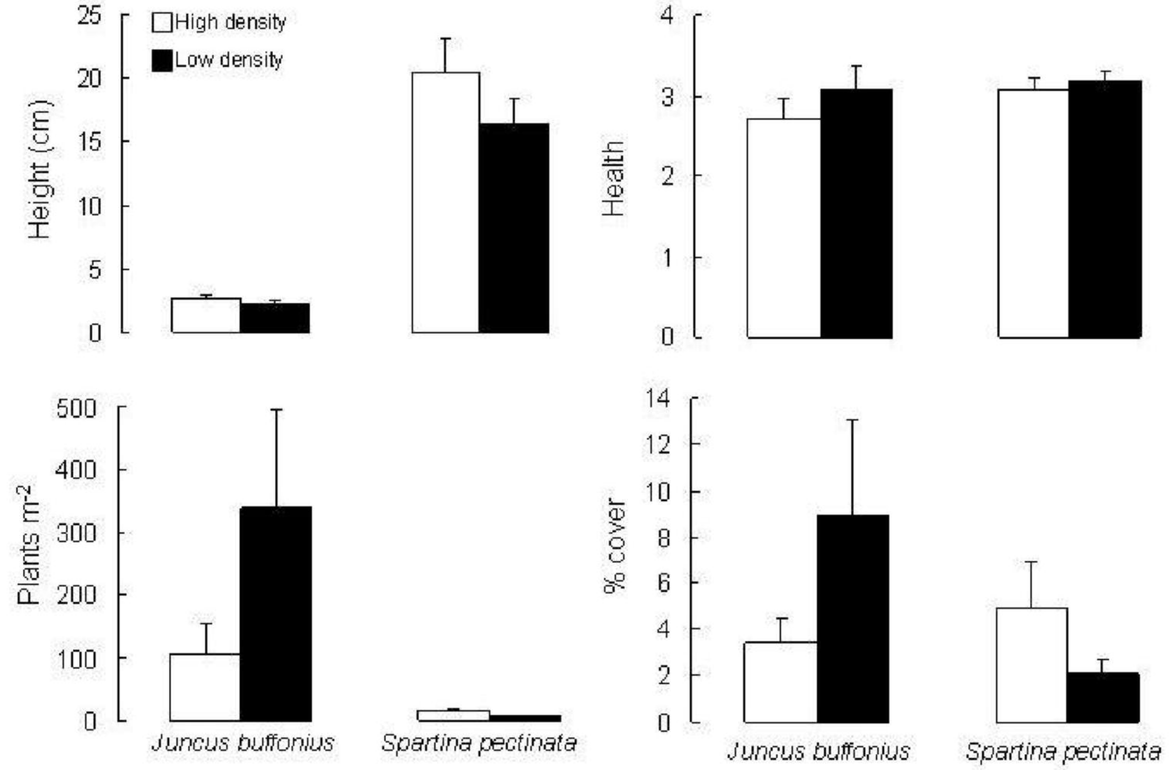

Figure 2. Revegetation parameters assessed for plug transplants of Juncus buffonius and *Spartina pectinata* at low and high initial planting densities. Mean values (± SD) after 11 months.

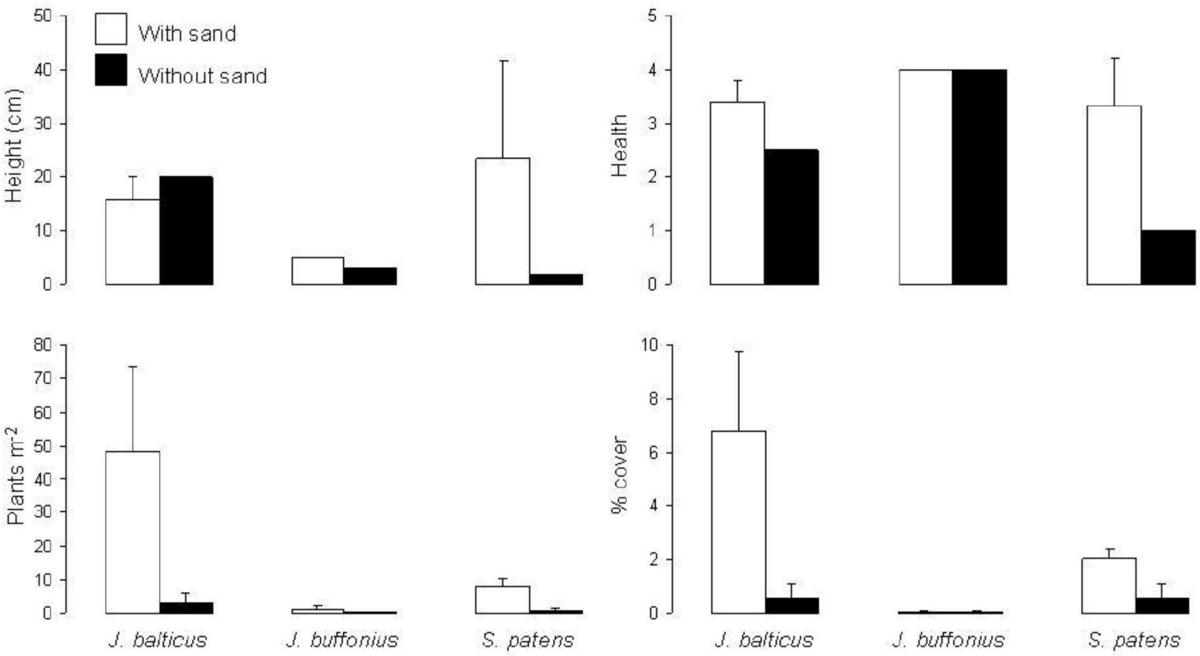

Figure 3. Revegetation parameters assessed for plug transplants using *Juncus balticus*, *Juncus buffonius* and *Spartina patens* reintroduced with sand and without sand. Mean values (± SD) after 12 months.

control and *Spartina* hay treatments. When the interaction was sliced for fertiliser its effects were only significant on the health of *J. buffonius* and *S. pectinata* when no fertiliser was applied.

Discussion

The establishment rates of plants at Pokesudie Bog were low compared to studies of conventional peatland rehabilitations (Ferland and Rochefort, 1997) however; vegetation

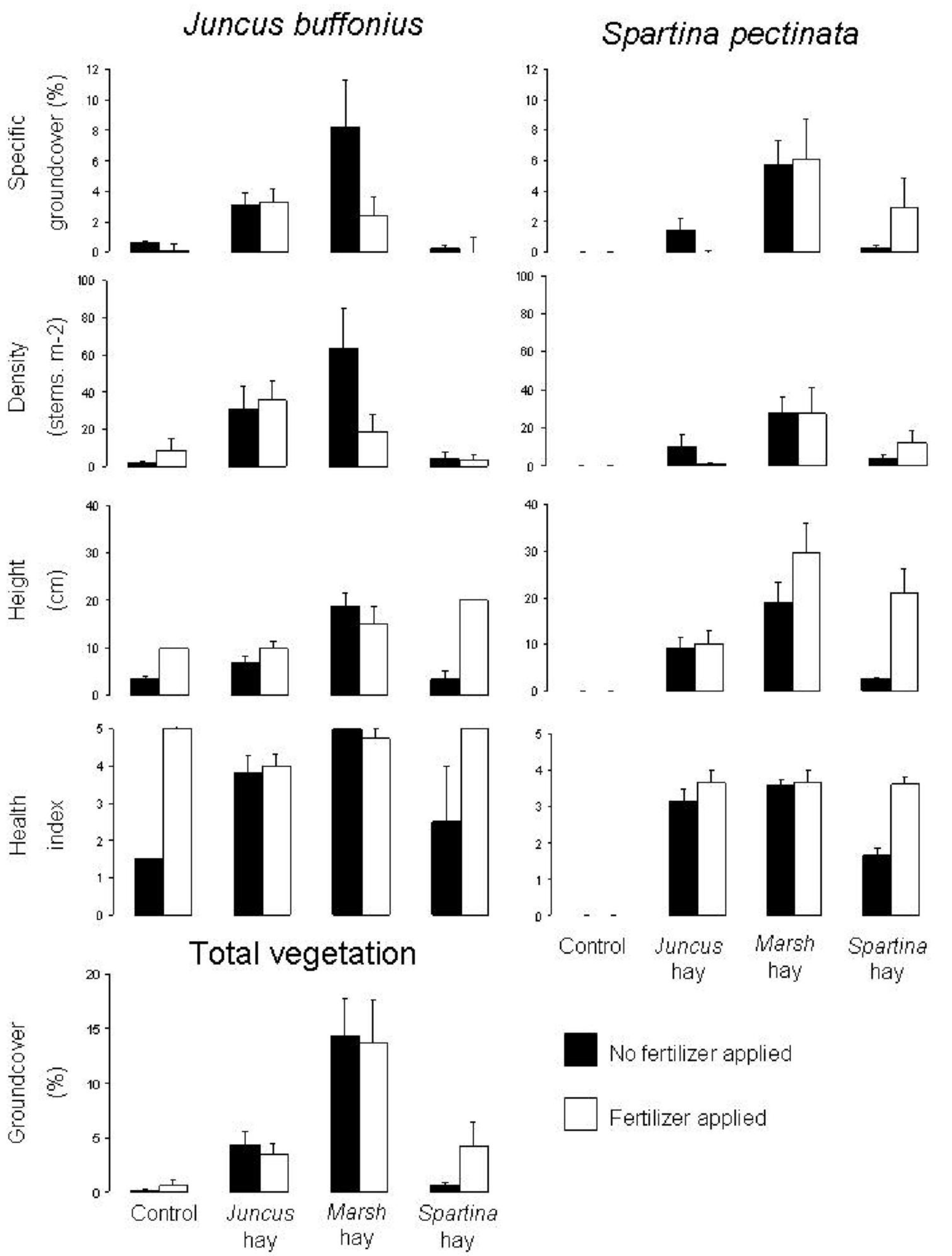

Figure 4. Revegetation parameters assessed after 11 months of transferring 3 hay communities which were dominated by more than 60% of *Juncus buffonius* for *Juncus* hay and more than 60% of *Spartina pectinata* for both marsh and *Spartina* hays. Mean values (± SD) after 12 months.

establishment on bogs affected by the same complicating factors as those at Pokesudie has only recently begun to be studied and thus comparison of these results is difficult, as little reference work exists with which to compare.

C. brunesscens was eliminated as a potential species for use in the rehabilitation of saline water affected peatlands as it failed to colonize at any ecologically significant rates. That *J. buffonius* established in and dominated units where no seeds of the former were thought to have been present shows that it is capable of arriving, most likely with the floodwaters, and taking advantage of improved local conditions, i.e. the presence of fertiliser. Within 5 months of growth the experimental units were seen to have a healthy carpet of *J. buffonius* growing within them. The lack of signs of frost heaving and dry cracked peat suggest also that the established carpets of vegetation provide ample insulation to negate these phenomena.

Planting at higher rather than lower initial planting density does not improve final vegetal groundcover rates for either *J. buffonius* or *S. pectinata.* The poor health of plants and lack of a biologically significant increase in groundcover suggests that low initial planting density would give similar results as if higher initial planting density were used.

Although sand application resulted in significantly higher groundcover, the overall appearance of the blocks in this experiment suggests that sand application does not aid the revegetation of saline peat substrates. Any positive effects shown by the effect of sanding were too discreet to merit the extra cost in time and money required and were far outweighed by the evidence of frost heaving and peat instability.

The highest groundcover in experiment four was achieved using the marsh hay. That non-target species were found to have established in hays which did not contain individuals or seeds of the non target species would seem to suggest that both *J. buffonius* and *S. pectinata* are capable of spreading to new areas in floodwater and then of successfully establishing. The presence of boundary walls seems to have had an influence on this also as individuals of these species were rare outside of the experimental units.

Fertiliser application did not seem to have an ecologically significant effect. This may be due to the restrictions imposed by experimental design which did not permit for the testing of different amounts and types of fertiliser. Fertiliser application is often used in salt marsh restorations and is likely to be essential in the restoration of saline peat substrates if salt marsh plants are to be used.

The species most suited for the restoration program at Pokesudie Bog seems to be *J. buffonius*, followed closely by *S. pectinata*. Overall, these two species had rates of percentage groundcover that were superior to those achieved using the other species; *J. balticus*, *S. patens* and *C. brunesscens*. *J. buffonius* was used in all experiments, two of which were in the severely and negligibly affected areas respectively, and was observed to perform best when introduced using the hay transfer technique. It also established quickly from the high number of seeds in the area and the established plants produced seeds to provide for the next season's population.

The ability to produce and establish from seed appears to be a very important aspect to consider for the restoration of saline peat substrates, as it seems plants establishing by this means are able to colonize the site quicker than those spreading only through rhizomatous growth. Therefore, the introduction method most likely to be successful is the hay transfer method of mid-upper salt marsh communities. Introduction of seeds of *J. buffonius* through hay transfers from communities dominated by *J. buffonius* may also aid in vegetation establishment. Community diversity appeared higher in hay transfer treated parcels. While only the target species were found growing in experimental units that contained plug transfers, species such as *Eriophorum vaginatum*, *Agrostis capilliaris*, and *Festuca rubra* were found growing in experimental units that received hay transfers.

The machinery necessary for carrying out rehabilitations using these methods are commonplace on most farms. Hays can be harvested and gathered using agricultural hay harvesters. To replicate the boundary walls on a large scale, an agricultural plough could be used to make criss-cross patterns over the peat surface. This means that large areas can be rehabilitated in a short period of time and at low cost.

Acknowledgements

We thank the Canadian Peat Moss Association, ASB Greenworld Ltd., Cie de Tourbe Fafard ltée, Fafard et frères ltée., La Mousse Acadienne (1979) ltée., Les Tourbes Nirom Peat Moss Inc., Les Tourbières Berger Inc., Modugno-Hortibec, Premier Horticulture ltée., Sun Gro Horticulture Inc., Tourbières Lambert Inc. and the Ministry of Natural Resources of New Brunswick for financially supporting this project within an industrial research chair program from the Natural Sciences and Engineering Research Council, granted to L. Rochefort.

References

Clymo, R.S. and Hayward, P.M. (1982). The ecology of *Sphagnum*. In A.J.E. Smith (ed.), *Bryophyte Ecology*, 229-289. Chapman Hall, London.

Environment Canada. (2008). 'Canadian Climate Normals, 1971 – 2000' (http://www.climate.weatheroffice.ec.gc.ca/climate_normals/index_e .html).

Ferland, C. and Rochefort, L. (1997). Restoration techniques for *Sphagnum*-dominated peatlands. *Canadian Journal of Botany* **75**, 1110-1118.

Price, J.S., Heathwaite, A.L. and Baird, A.J. (2003). Hydrological processes in abandoned and restored peatlands: An overview of management approaches. *Wetlands Ecology and Management* **11**, 65-83.

Rochefort, L., Quinty, F., Campeau, S., Johnson, K. and Malterer, T. (2003). North American approach to the restoration of *Sphagnum* dominated peatlands. *Wetlands Ecology and Management* **11**, 3-20.

Wilcox, D.A. (1984). The effects of NaCl deicing salts on *Sphagnum recurvum*. *Environmental and Experimental Botany* **24**, 295-304.

Wilcox, D.A. (1986). The effects of deicing salts on vegetation in Pinhook Bog, Indiana. *Canadian Journal of Botany* **64**, 865-874.

Wilcox, D.A. and Andrus, R.E. (1987). The role of *Sphagnum fimbricatum* in secondary succession in a road-salt impacted bog. *Canadian Journal of Botany* **65**, 2270-2275.