NOTE

On the occurrence of hypersaline sediments in James Bay coastal marshes

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Measurements of soil salinity, soil moisture, and specific yield, along with depth to the water table, explain the occurrence of a band of hypersaline sediments, ubiquitous along James Bay coastal marshes, that profoundly affects vegetation development. The salinity of the hypersaline zone ranges from 8 g/kg Cl in a southern James Bay marsh, to 28 g/kg in the north, nearly an order of magnitude more than local sediments outside this zone. This common, yet previously unexplained, feature restricts the vegetation development to salt-tolerant species such as *Salicornia maritima, Puccinellia phryganodes*, and *Triglochlin maritimum*. The hypersaline zone is rarely inundated by tides, but frequent inundation of the seaward zone maintains a high water table there, with soil salinity, hence vegetation patterns that reflect the ambient tidewater salinity. At sites inland of the hypersaline band the development of an organic layer with a high moisture content supplied by meteoric water and high specific yield maintains relatively fresh water near the surface, imposing minimal salinity restrictions to vegetation. Intermediate to these zones of high water table is the hypersaline band, which has no organic layer and whose surface is not wetted by tides. Its depressed water table causes flow convergence, and the only water sink is through evaporation, which concentrates the salt imported in groundwater.

Key words: James Bay, marsh, salinity, hydrology, vegetation.

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Les données de la salinité du sol, de l'humidité du sol et du rendement spécifique, ainsi que de la profondeur de la nappe phréatique, expliquent la présence d'une bande de sédiments hypersalins ubiquistes le long des marais côtiers de la Baie James, ce qui affecte grandement le développement de la végétation. La salinité des zones hypersalines va de 8 g/kg Cl dans les marais du sud de la Baie James, à 28 g/kg dans le nord, ceci étant presque un ordre de grandeur plus élevé que celle des sédiments locaux à l'extérieur de cette zone. Cette caractéristique commune mais jusqu'ici inexpliquée, limite le développement de la végétation aux espèces tolérant le sel, telles que la *Salicornia maritima*, le *Puccinellia phryganodes* et le *Triglochlin maritimum*. La zone hypersaline est rarement inondée par les marées, mais l'inondation fréquente de la région du côté de la mer maintient une nappe phréatique élevée ainsi que la salinité du sol, d'où les patrons de végétation, ce qui reflète la salinité des eaux ambiantes. Dans les sites situés à l'intérieur des terres par rapport à la bande hypersaline, le développement d'une couche de matière organique possédant une humidité élevée, irrigée par l'eau de pluie et montrant un rendement spécifique élevé, maintient l'eau relativement fraîche près de la surface, ce qui minimise l'effet de la salinité sur la végétation. Dans la situation intermédiaire par rapport à ces zones, où la nappe phréatique est élevée, se trouve la bande hypersaline qui ne possède aucune couche de matériel organique, et dont la surface est couverte par les marées. Sa nappe phréatique basse entraîne la convergence de l'écoulement, et le seul sink provient de l'évaporation, ce qui concentre le sel importé par la nappe phréatique.

Mots clés : Baie James, marais, salinité, hydrologie, végétation.

[Traduit par la rédaction]

Introduction

Salinity and water flow conditions strongly affect the distribution of vegetation in James Bay salt marshes (Ewing and Kershaw 1986). Local hydraulic gradients near beach ridges and streams recharge freshwater (Price and Woo 1988*a*) that reduces surface salinity (Price and Woo 1988*b*), allowing vegetation with lower salt tolerance to establish (e.g., *Potentilla egedii, Juncus balticus*, and *Aster juncifolium*) (Price *et al.* 1988). On the backshore where hydraulic gradients are small, species composition reflects a somewhat more saline environment (Price *et al.* 1988), supporting mostly *Carex paleacea*. In general, northern James Bay marshes are more saline than those of southern James Bay (Price *et al.* 1989), and this is reflected in the species composition. A ubiquitous feature of northern and southern marshes is a hypersaline zone, which in one southern James Bay marsh (Price *et al.* 1988) is a 10- to 20-m band of sediments approximately 150 m inland of the mean high water (MHW) line, supporting halophytic plants like *Salicornia maritima, Puccinellia phryganodes*, and *Triglochlin maritimum*. The hypersaline band seems anomalous in that it appears well within the backshore zone and does not represent a topographic discontinuity. The objective of this paper is to explain the physical processes that produce this distinctive but previously unexplained feature. This is important in understanding the vegetation patterns in this coastal ecosystem.

Study area

Two areas on the Ontario coast were selcted, one at southern James Bay and one at Ekwan Point in the north. These two sites have previously been described by Ewing and Kershaw (1986) and Price *et al.* (1988, 1989). The waters of James Bay are diluted by freshwater from rivers on its western flank producing a gradient of tidewater salinity from 23 g/kg in northern James Bay to about 1 g/kg in southern James Bay.

The regional topographic gradient is approximately 0.001 at southern James Bay and 0.0015 at Ekwan Point. The intertidal zone rises

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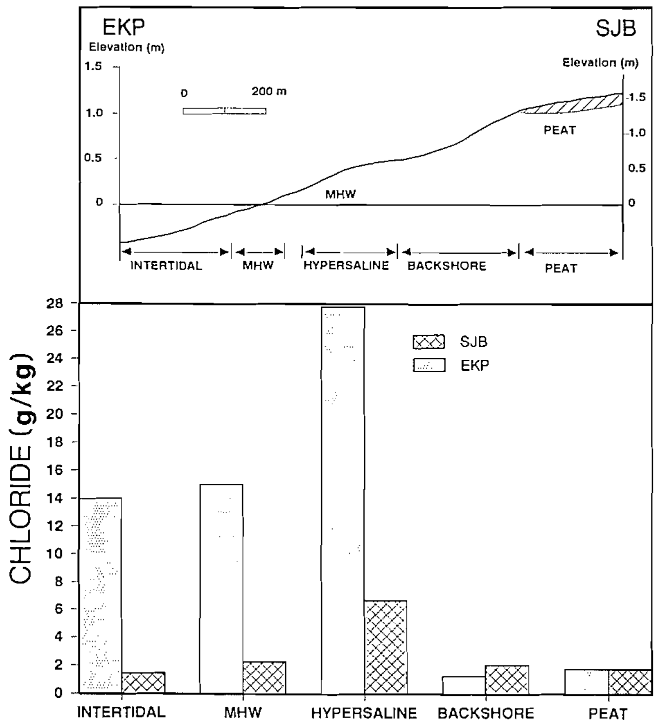

FIG. 1. Topographic cross sections along transects at both sites (top) and chloride concentration (bottom) at five typical zones along each transect. EKP, Ekwan Point, SJB, southern James Bay.

gradually to low (0.5–0.6 m), broad, emerged beach ridges formed of reworked sand and silt (Martini 1981) that define the upper limit of this study. At each site, a transect was made perpendicular to the shoreline, from just below mean high water (MHW) to the first beach ridge. Sampling points were selected along each transect to include different marsh environments, i.e., the intertidal zone, MHW, a hypersaline zone above MHW, the upper backshore, and the peat-covered first beach ridge.

Methods

An agricultural sampler was used to retrieve 0.3-m soil cores at southern James Bay in July 1985 and at Ekwan Point in July 1988. Chloride concentration from water extracted by the method described in Price *et al.* (1988) was determined using a specific ion electrode. Because samples were taken in different years, comparison of salinity data from southern and northern sites must be considered in a general rather than an absolute manner, although intrasite comparisons are not so restricted. Gravimetric soil moisture was measured from the samples, and groundwater wells were installed at each point.

Results

The generalized position of the intertidal, MHW, hypersaline, backshore, and peat-covered ridge sites are shown in the upper part of Fig. 1, and the chlorinity of each site is plotted below. The chlorinity of the intertidal and MHW zones at each site closely reflect the average concentration of the local tidewater (Price *et al.* 1989). In the intertidal zone the tides are semidiurnal, but inundation by tidal water is less frequent near MHW, allowing for more evaporative drying and a slightly higher chlorinity there. At both sites the chloride concentration rises dramatically at the hypersaline zone, then drops to a common low value at points inland. The lower salinity at

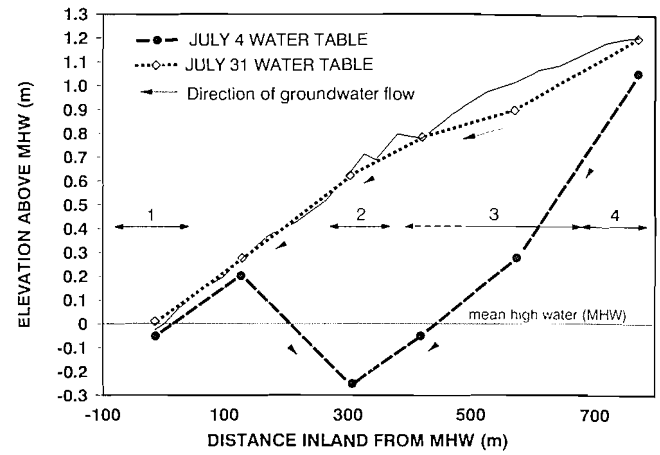

FIG. 2. Water table along Ekwan transect immediately following rain (July 31) and between events (July 4). Zones 1–4 correspond to the characteristic zones delineated by vegetation pattern. Zone 1, MHW; zone 2, hypersaline; zone 3, backshore; and zone 4, peat-covered ridge.

TABLE 1. Specific yield (S_y) and soil moisture at Ekwan Point (0–0.1 m)

Zone	S_y	Soil moisture (%)
Intertidal	—	28.7
MHW	—	31.7
Hypersaline	0.04	30.3
Upper backshore	0.12	40.1
Peaty ridge	0.23	40.1

the inland sites reflects the longer period since isostatic emergence from the Bay, during which meteoric water has leached salt from the surface.

At the hypersaline zone the elevation is 0.4 to 0.7 m above the MHW level, and based on a probability analysis of James Bay tides (Price *et al.* 1988), there is only a 0.5–1% chance of being inundated by any given tide. Thus the elevated salinity here is not due to salt import by present day tidal processes. The high salinity is due to the convergence of saline groundwater resulting from a locally depressed water table (Fig. 2), which persists in the summer except following rain (e.g., 31 July). A similar pattern was observed at southern James Bay, with the water table at the hypersaline zone typically 0.4 m deeper than in the backshore or at MHW. The lowest water table was consistently found at the hypersaline zone.

Druing drying periods, frequent inundation of tidewater maintains a high water table near the coast. Positions inland of the hypersaline zone have an organic mat that retains moisture (see Table 1). Furthermore, the high specific yield (S_y) (Freeze and Cherry 1979) (Table 1) of the top layer at the upper backshore and peat-covered ridge dampens change in water table height (dh) for a given change in water storage (dS). This follows from the relation

$$[1] \qquad dh = \frac{dS}{S_y}$$

Thus a 1-cm decline in water storage will produce a drop of 25 cm in the water table at the hypersaline zone but only

4 cm at the peaty site. The exaggerated water table drawdown that occurs at the hypersaline zone induces deeper groundwater to flow towards it from landward and seaward sides. The convergence of groundwater coupled with evaporative drying has produced elevated salinity. Microtopographic variations were small at both sites and did not correspond well to the position of the hypersaline zone, so were unlikely to be important to the salinization process.

Conclusion

The limited sampling of this study may not encompass the full range of spatial and temporal variation in salinity, which is an important feature of these marshes (Glooschenko and Clarke 1982; Price *et al.* 1988). Such variations, however, are superimposed on the general trends described herein. In particular, the high salinity of the hypersaline zone has been demonstrated to be a function of the hydrological processes that control the water level regime of the marsh. In the zone near and below MHW, salinity reflects the local tidal water concentration; at inland locations it more closely reflects meteoric conditions. However, high salinity occurs in an intermediate zone because the relatively high water table at MHW blocks the coastward transport of groundwater (and salts therein). The convergence of groundwater from MHW with that from further inland (which also contains salt; from deeper underlying sediments; Price and Woo 1988*c*) prohibits the export of salt. Evaporative drying then elevates the concentration to the observed values. The higher values at the hypersaline zone of the Ekwan Point site compared with the southern James Bay site reflect the high local tidewater salinity, which introduced salts in a previous era (i.e., before it was uplifted to its present position).

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