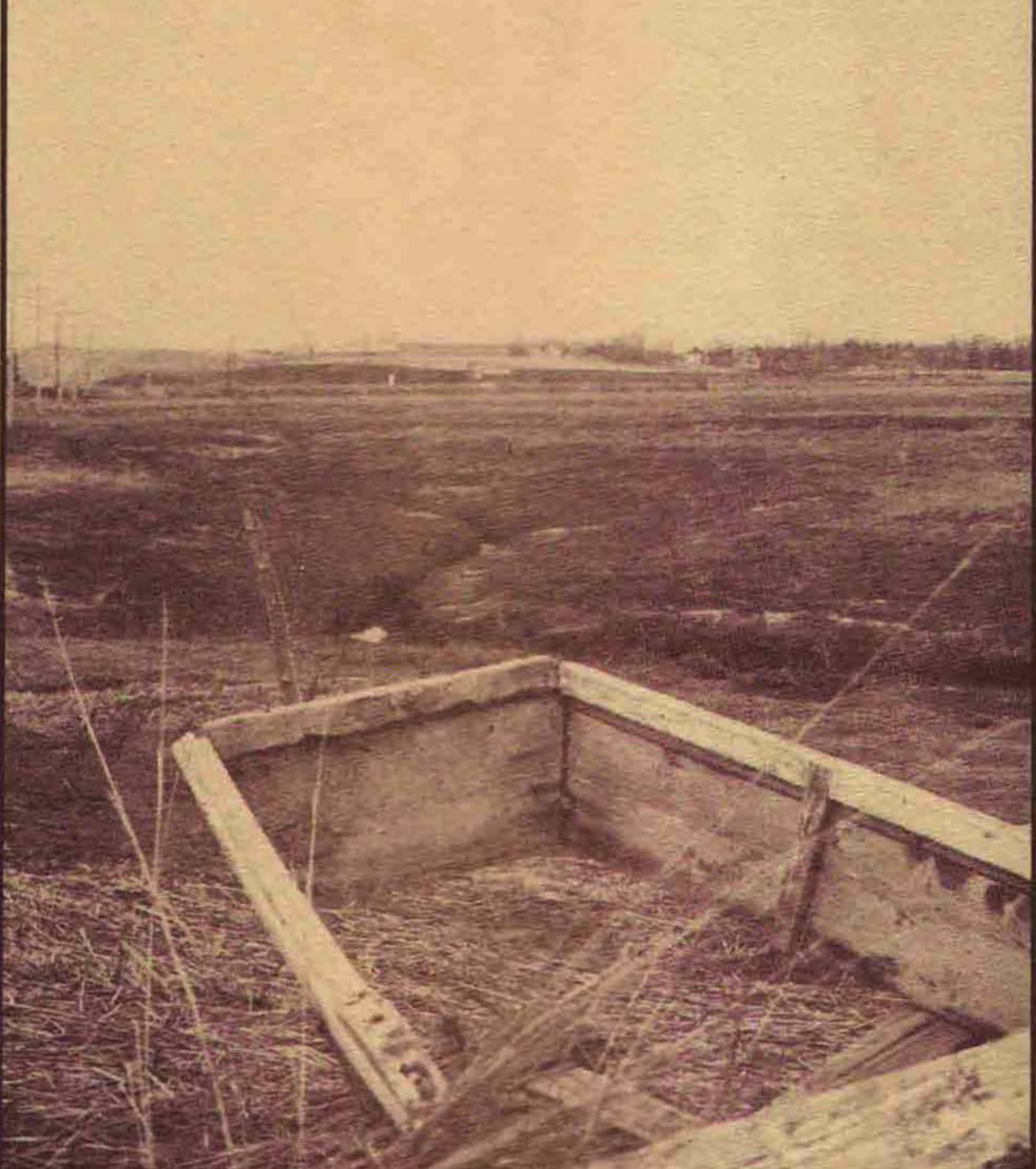
SALT MARSHES IN NOVA SCOTIA



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SALT MARSHES
IN NOVA SCOTIA

A STATUS REPORT OF
THE SALT MARSH WORKING GROUP

Edited by

A. Hatcher, David G. Patriquin,
with the assistance of Y. F. Fern,
A. J. Hanson and Judy Reade

Institute for Resource and Environmental Studies

and

Department of Biology

Dalhousie University
Halifax, Nova Scotia
1981

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INTRODUCTION

There are approximately 80,000 acres of salt marsh land in Nova Scotia of which approximately 43,000 acres have been dyked for agricultural use. Salt marsh lands have served as major producers of food in estuarine regions. Increasing demands are being placed on these lands for recreation, waterfowl impoundments, wild rice cultivation and aquaculture. At the same time, some of these areas are being eroded by dredging and filling operations. Questions concerning the agricultural versus pristine values of the marshes are raised whenever storm damage occurs and expensive repairs of dykes are required, or when these dykelands are simply left in a state of ill-use. Unfortunately, there is no comprehensive legislation dealing with these marshlands, and thus, as management problems arise, they are dealt with piece-meal or not at all.

A distinctive feature of salt marshes is their regional character. The secondary (animal) production in marshes, the nutrient and material exchanges with the adjacent estuarine and coastal waters, the soil types, the vegetation and so on, vary according to the regional climatic and physiographic regimes. Thus, it is essential to understand and appreciate these regional characteristics if the multiple value of the marshlands is to be realized. Unfortunately, little information on these regional characteristics is readily available in printed, circulated form. Further, there appear to be few, perhaps no, 'experts' on the subject of Nova Scotia salt marshes. On the other hand, there are considerable isolated pieces of available information in the form of uncirculated reports, statistical digests, and the personal familiarity of many individuals with some aspect of salt marsh biology, development or use, or with some specific, though unofficial, knowledge of a particular salt marsh.

The Salt Marsh Working Group was formed in an effort to bring together this body of information and to encourage the development of a salt marsh management policy which gives fair consideration to multiple demands. Three one-day public seminars were held during the winter of 1976-77 which dealt successively with Geology and Biology, Agricultural Usage, and Recreational and Waterfowl Usage of Nova Scotian salt marshes. Finally, there was a day in which the group attempted to reach some concensus on the status of present knowledge of the Nova Scotian salt marshes; in particular, to determine if we now have the scientific basis required for formulation of an effective management policy, and if not, the sort of information that is required. The publication of this report represents the culmination of this work by the Salt Marsh Working Group.

Special thanks are extended to the contributors of the papers in this volume; to Cathy Keddy and Charlene van Raalte (Dalhousie University) for their help in organizing sessions and reproducing presentations; and to Don MacDougall, Dalhousie University Chaplain at the time, who was the prime mover in coordinating this group.

The report has been prepared and printed by the Institute for Resource and Environmental Studies in the hope that it will inform a general audience and stimulate further management discussions. As Nova Scotia moves towards tidal power development and continues to emphasize agricultural land redevelopment, the need for more detailed strategies of wetland use will become apparent. The Salt Marsh Working Group provided an informal means of information exchange. In future years, others may wish to carry on this discussion in relation to their local ecosystems and management practises.

ECOLOGY. GEOLOGY AND HYDROLOGY

The General Biology of Salt Marshes

Dr. D. G. Patriquin
Department of Biology
Dalhousie University
Halifax, N. S.

INTRODUCTION

There is an enormous literature on salt marshes, but very little published information on Nova Scotian salt marshes. Salt marsh development is very much a local phenomenon and it is difficult to apply the body of literature available on other salt marsh systems to a local situation. This very brief review of general biology of salt marshes is intended only to serve as a reference point for beginning investigation into Nova Scotian salt marshes, so it can be said that "Fundy marshes differ from others in these respects . . . . ." Reference material is given in only a few places and a general bibliography follows.

DISTRIBUTION

Salt marshes are generally restricted to subtropical and higher latitudes. In the tropics, mangroves usually occupy the comparable niche. North American salt marshes commonly develop in one of three different situations on stable or emerging shore lines. These three situations are represented by:

i) estuaries;
ii) shelters of spits, offshore bars or islands;
iii) protected bays.

They develop under comparable situations on submerging coasts only if sedimentation rates exceed the rate of submergence. Salt marshes rarely occur on open coasts, or where land comes down steeply to the sea, as in lochs and fjords. Estuaries and enclosed bays are particularly suitable, with full marsh development where there is a coastal plain and a shallow sea bed offshore.

SUCCESSION AND PHYSIOGRAPHIC DEVELOPMENT

The exact nature of salt marsh development varies from place to place. The two most important features in this development are:

i) the part played by the vegetation;

ii) the supply of silt to build up the surface.

A generalized scheme of the stages in salt marsh development is outlined in Figure 1. Note that when sediments have accumulated to the level of mean high water (MHW) no further development will take place unless there is some disturbing factor. Where there is an input of fresh water, a fresh water reed swamp may develop, initiating a terrestrial sere.

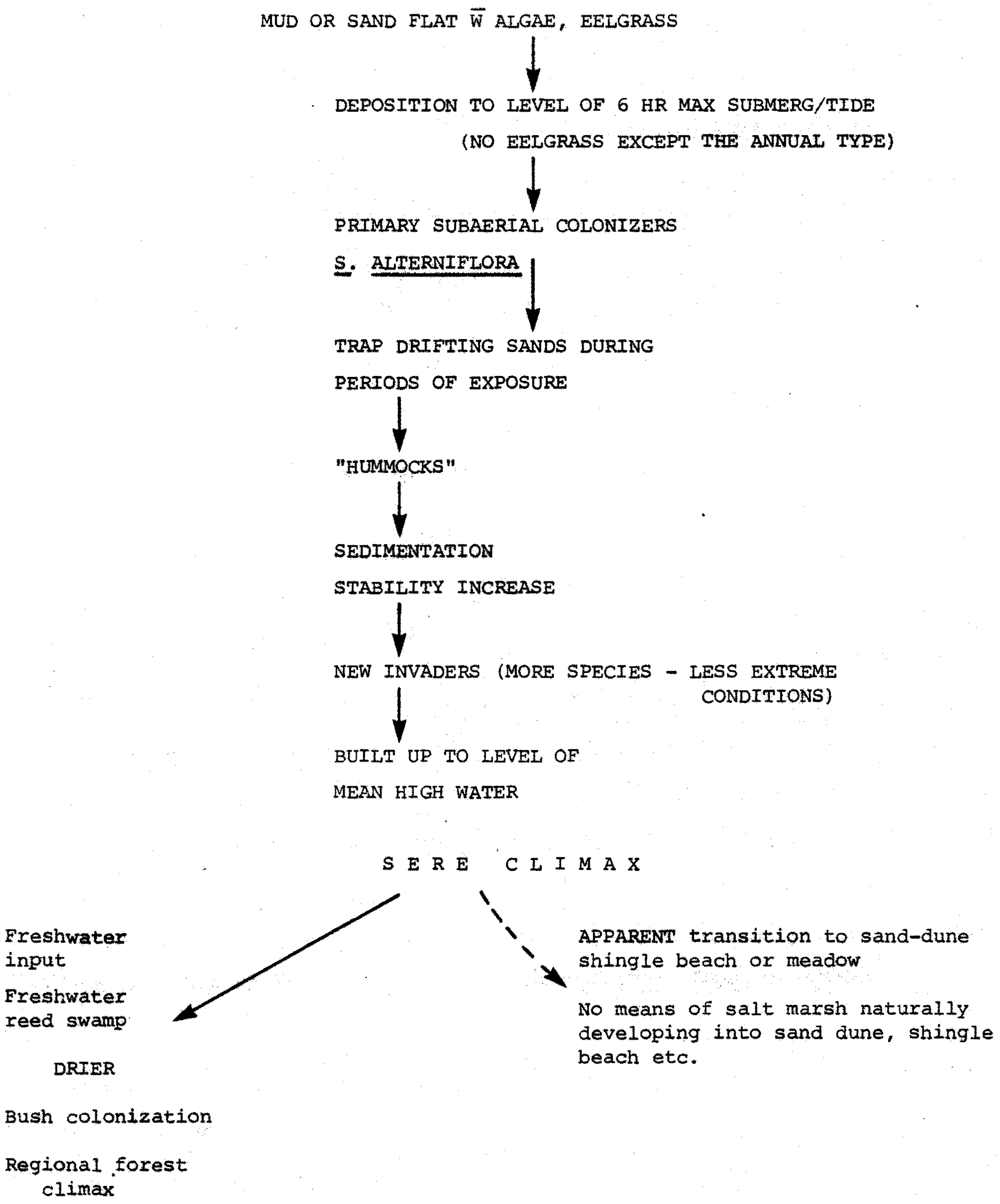
Redfield (1972) distinguishes between *intertidal marsh* and *high marsh* in the New England marshes, and such a distinction is probably appropriate for Nova Scotian marshes as well.

Intertidal marsh - Stands of Spartina alterniflora growing below mean high water.

High marsh - Marsh in the mature stage of development in which an essentially flat surface lies at approximately mean high water level.

Redfield describes the following physiographic stages in the development of New England marshes:

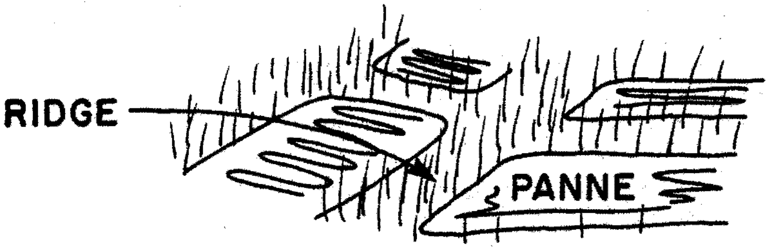
Figure 1. Stages in salt marsh formation.



1. *Colonization of bare sand flats by S. alterniflora through seeding, consolidation of clumps and expansion of margins.* Initial colonization takes place when sand flats have accumulated to the level where they are not submerged for more than 55% of any one tidal cycle. At Barnstable marsh (mean tidal range 9.6 ft.), this level is at about 6 ft. below MHW (max. submergence 6.8 h). Expansion at the margins takes place at the rate of about 1.2 ft. per year.

2. *Juvenile marsh - characterized by a uniform stand of S. alterniflora.* Where sediments are at a suitable level for colonization by *S. alterniflora*, about 5 years are required for this stage to be attained (New England). I have estimated that a comparable period was taken to establish a new juvenile marsh stand at Conrad Beach, Nova Scotia.

3. *Panne marsh - characterized by localized bare areas in which shallow water does not drain off at low tide, and where previously standing vegetation has been killed.* Such pannes are observed in Atlantic coast Nova Scotian marshes; frequently, they are colonized secondarily by eelgrass (*Zostera marina*) and widgeon grass (*Ruppia maritima*). The pannes result from unequal distribution of sediment in the juvenile marsh, resulting in poor drainage, and death of vegetation (*S. alterniflora*).



4. *Slough marsh - characterized by narrow ridges of turf that separate pannes and rise abruptly 1 - 2 ft. above the surface of pannes.* The ridges are areas of exceptionally good growth of *S. alterniflora*.

At Barnstable marsh where the mean tidal range is 9.6 ft, maximum development of the slough marsh occurs at levels where the tops of the ridges are 3-4 ft below MHW. I have not observed slough marsh development in Atlantic coast Nova Scotian marshes.

5. *Transition to high marsh* - When the elevation of the vegetated ridges separating pannes becomes less than 3 ft (Barnstable) below MHW, the ridges broaden, reducing the size of the pannes, and many pannes become colonized by "dwarf" S. alterniflora.

6. *High marsh* - While not always clearly distinguished from the intertidal marsh (stages 1 to 4), in general, this stage has a flat surface at about MHW level and has a more varied vegetation than the intertidal marsh. In the New England marshes, the high marsh is drained by a tortuous system of creeks and is spotted by "pond holes". The pond holes may have several origins, e.g., as relics of intertidal pannes from blocking of creeks, or from decay of surface turf. In the St. Lawrence estuary salt marshes, ice rafting is believed to be the main origin of pond holes.

Vegetational development of Fundy marshes (Chapman 1974, after Ganong) is outlined in Figure 2. The high marsh is characterized by a Spartinetum patensis association. Nova Scotia is near the northern limit of Spartina alterniflora and Spartina patens distribution. On the Atlantic coast, Carex paleacea is commonly the dominant species of the high marsh.

The lateral extent of marsh development depends on the local topography, and on the relative changes in sea level. On emerging coastlines, salt marshes generally occupy a narrow fringe (Figure 3a). On stable coastlines, the marshes may develop progressively over the sea bed (Figure 3b).

Figure 2. Succession: Fundy marshes.

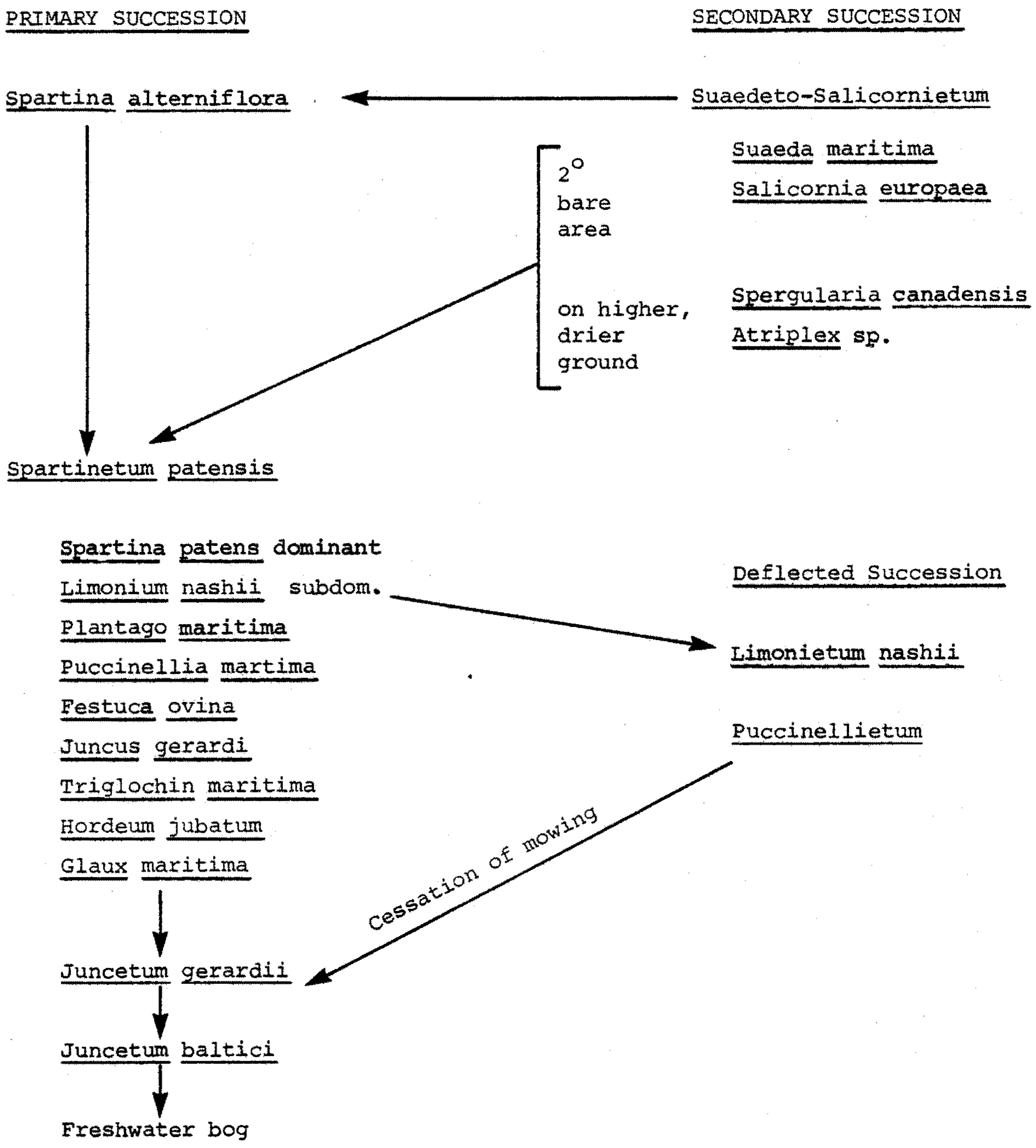


Figure 3. Lateral extent of marsh development (after Chapman).

3a

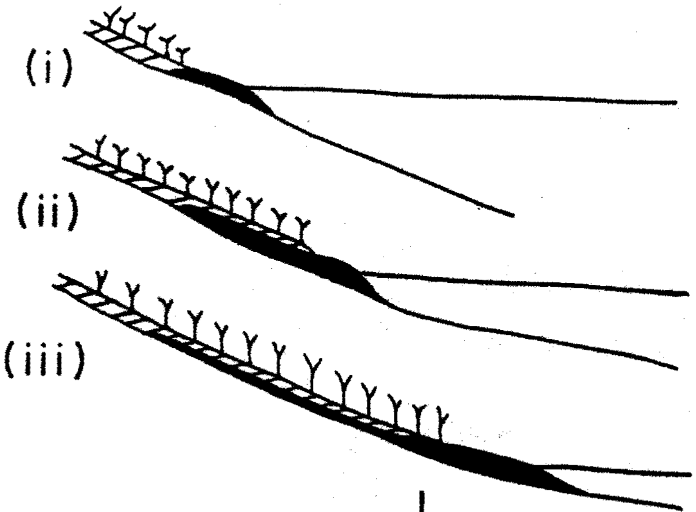


Fig. 3a. Development of salt marsh on a rising coastline. Marsh silt (black) eventually becomes covered by normal soil (hatches). Marsh develops more extensively where sea bed becomes less deep and shelving.

3b

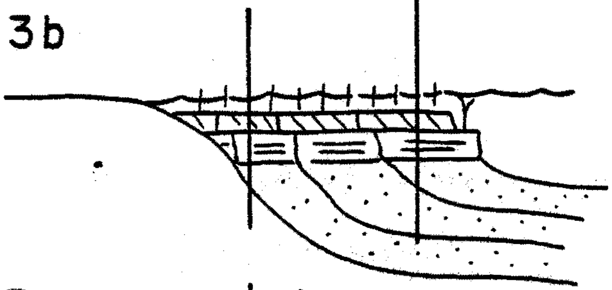


Fig. 3b. Shaler hypothesis. Constant sea level; seaward extension of marsh; cores reveal uniform thickness of HM peat over LM peat over basement sediment.

3c

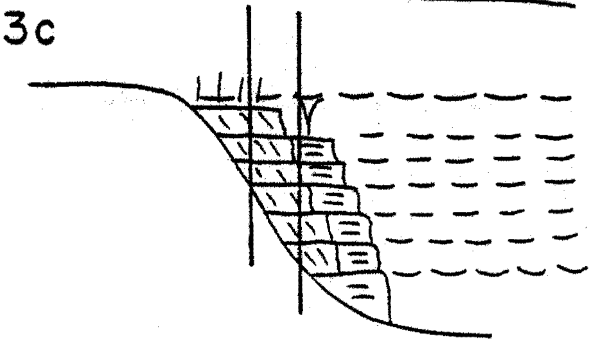


Fig. 3c. Mudge hypothesis. Rising sea level; no seaward extension of marsh. Cores reveal a great depth of HM peat.

3d

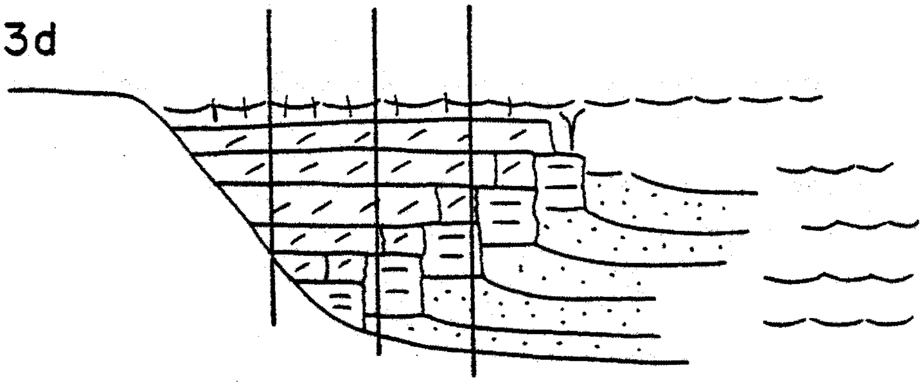
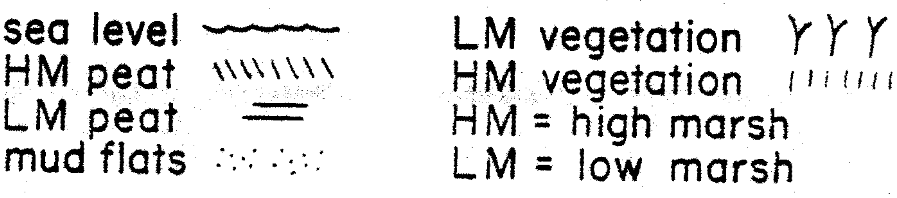


Fig. 3d. Chapman-Redfield hypothesis. Rising sea level with seaward extension of marsh. Cores reveal wedge of HM peat towards the land and uniform thickness of LM peat. This structure has been confirmed for the Barnstable (Mass.) marsh.



On submerging coastlines, the marshes may become drowned, and more restricted or, if sedimentation is sufficient, may extend seaward (Figures 3c and 3d). Rates of vertical accretion of salt marshes are greatest in the early stages of salt marsh formation; as MHW level is approached, the controlling factor is the rate of sea level rise. At Barnstable, an average of about 600 years was required for the development of high marsh from the lowest level of intertidal marsh (about 6 ft below MHW), and high marsh is currently accreting at a rate comparable to sea level rise (3 ft per 1000 years in Cape Cod region c.f., 1.5 ft per century in Fundy region).

BIOLOGY OF THE PRIMARY COLONIZER SPARTINA ALTERNIFLORA

This plant is a "facultative halophyte", that is, it is capable of growing in fresh waters as well as in brackish situations. Generally, however, it is restricted to areas with salinities of 20 to 30 parts per thousand. S. alterniflora is adapted to grow in waterlogged, poorly aerated soils by virtue of an air space ("lacunal") system in its tissue. The spaces allow movement of air into the roots. This grass also possesses several mechanisms for dealing with high salt concentrations.

S. alterniflora has a "C4" type photosynthetic pathway which is believed to be highly efficient. Many of the most highly productive plants in tropical latitudes (e.g. sugar cane) are "C4" species. Although Spartina alterniflora exhibits exceptionally high productivities in more southern areas, its productivity in this region is not unusually high in comparison to other ("C3" type) salt marsh species noted in Table I.

The main nutrients required for growth of S. alterniflora are carbon (CO_2), phosphorus and nitrogen. "C4" plants are not generally carbon limited at ambient (approximately 300 ppm) atmospheric CO_2 levels.

Table I. Annual production of dry matter by marsh angiosperms.

Species	Photosynthetic metabolism (C3 or C4)	Locale	Production (g dry leaves m^{-2} $annum^{-1}$)
Spartina alterniflora	C4	*Georgia*	2883
		Louisiana	2222
		Virginia	1143
		Rhode Island	668
		Nova Scotia:	
		Fundy	900
		Northumb. Str.	750
		Atlantic	710
Carex paleacea	C3	Atlantic	1307
Calamagrostis canadensis	C3	Atlantic	1319
Agrostis stolonifera	C3	Atlantic	430
Spartina patens	C4	Atlantic	577

Phosphorus does not appear to be limiting for growth of S. alterniflora. Iron and aluminum phosphates tend to be solubilized in the presence of sulfides in salt marsh sediments, and in fact there is evidence from U.S. studies that S. alterniflora acts as a "phosphorus pump", taking up phosphorus from the sediments and releasing it directly into flooding waters. Nitrogen is commonly the limiting factor for S. alterniflora growth. In spite of this, nutrient budget studies have shown salt marshes to be net sources of nitrogen in estuarine systems. Thus they are implicated as sites of N_2 fixation (conversion of atmospheric nitrogen into ammonia). Nitrogen fixation occurs mainly at two sites in the marsh:

i) on the mud surface, by or in association with blue-green algae and possibly photosynthetic bacteria, and

ii) around and in the roots, by N_2-fixing bacteria.

Rates of N_2 fixation in salt marshes may be very substantial. For Conrad Beach, I have estimated annual fixation to be 115 kg N per hectare per year. Of this total, 92 Kg N per hectare per year occurs below the mud surface. These rates are similar to those occuring in nodulated plants such as clover and provide an amount of nitrogen roughly equivalent to that applied as fertilizer on corn. The high nitrogen-fixation associated with S. alterniflora is undoubtedly a factor in the success of this plant in the intertidal zone.

SECONDARY PRODUCTIVITY IN THE SALT MARSH-ESTUARINE ECOSYSTEM

Most of the quantitative description of production processes has been done on systems in the U.S. The salt marsh-estuarine complex is highly productive at higher trophic levels, and directly, or indirectly, estuarine animals use the vegetal production of the salt marsh. But, few animals feed directly on the marsh plants. In southern marshes, grasshoppers may feed abundantly on the marsh grass. Aphids suck juices from the leaves, larvae of marsh flies live in stems and eat plant tissue, and nematodes feed on roots. However, most animals use the grass production only after it has been decomposed and converted into a more suitable form through a detrital food chain similar to the following sequence:

> *Dead Grass → Decomposed and Converted into Bacterial, Fungal and Yeast Biomass → Fed Upon by Ciliates →Small Crustaceans, Worms, etc. → Fish, Birds → Man.*

Because conversion takes place relatively slowly, the food supply based on the marsh grasses tends to be relatively uniform through the year (i.e. it is not subject to large fluctuations such as occur with plankton populations). This factor probably contributes to the seasonal and year to year stability of salt marsh-estuarine animal populations.

Exactly how much of the marsh grass production ends up in higher trophic levels (such as in species which can be harvested by man), and where this secondary production takes place varies greatly between different marsh-estuarine systems according to:

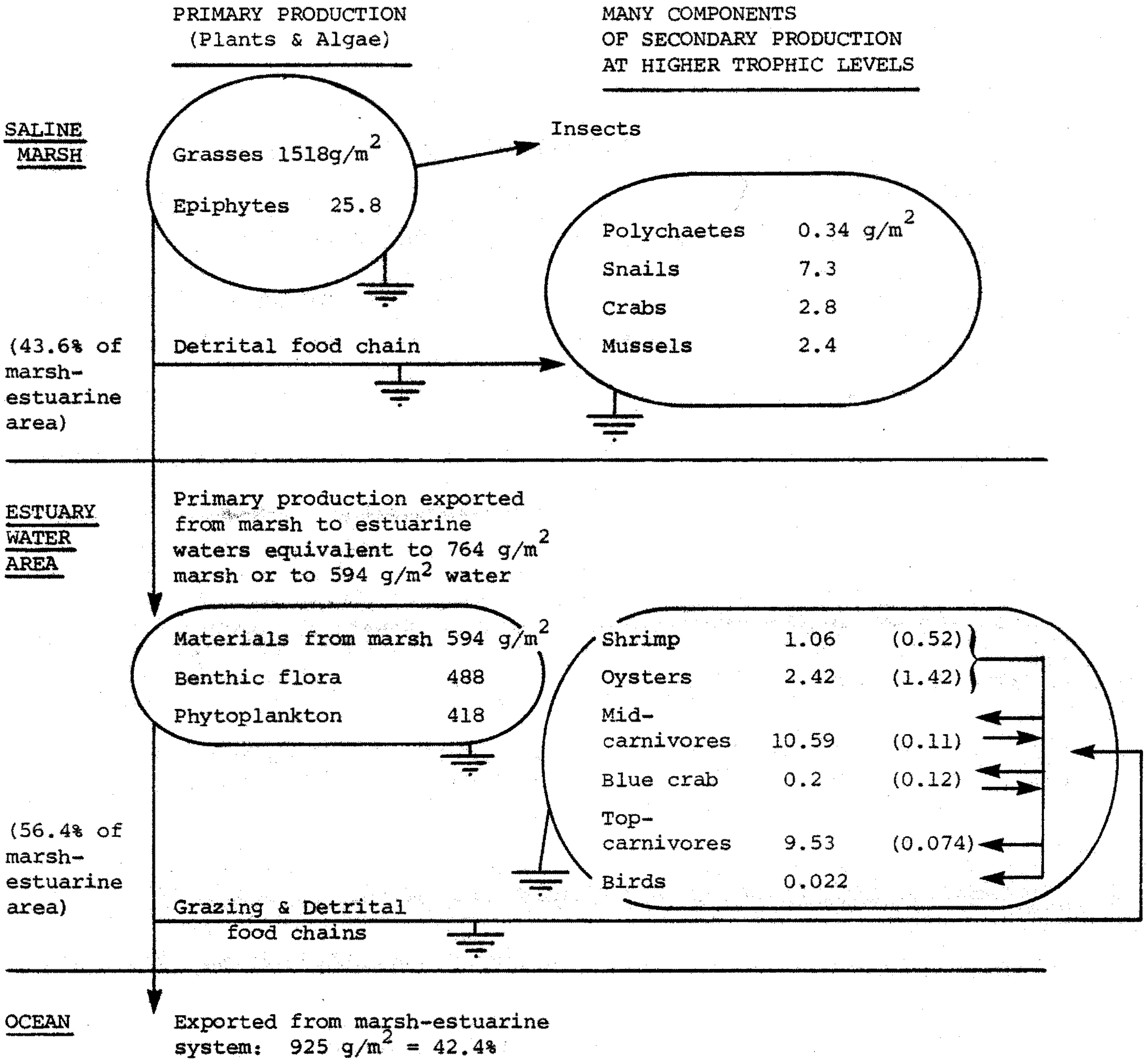
i) the qualitative and quantitative aspects of the fauna;
ii) the amount of exchange between the marsh and estuarine waters, and
iii) the amount of exchange between the estuarine waters and the open ocean.

The most detailed analysis of food chain tranfers in a marsh-estuarine system is that given by Day et al. (1973) for Barataria Bay, Louisiana. This is a highly complex system with many more species involved than in marsh-estuarine systems in Nova Scotia. However, the efficiencies of transfer of energy and materials between different levels in the Louisiana system are probably comparable to those in Nova Scotian systems, and examination of the Louisiana data serves at least as a reference system for considering production processes in Nova Scotian marsh-estuarine complexes.

A summary of the production processes leading to secondary production at higher trophic levels for Barataria Bay is given in Figure 4. The marsh grasses contribute very substantially to production in the estuarine waters, and ultimately, to export of materials from the marsh. An important point concerning secondary production in the marsh itself is that almost 100% of this occurs within 50 m of the water's edge. Thus marshes with many tortuous channels are probably more productive at higher trophic levels than are marshes with few or straight (e.g. man-made) channels. Further, such marshes will exchange more materials with the estuarine water. Day _et_ _al_. considered that only the saline (intertidal) marsh contributed substantially to the estuary water area production. The commercial harvests are indicated in brackets in Figure 4. Of the total harvest of 2.12 g/m^2, about half was in the form of molluscs. The mid- and top-carnivores included 113 species of fish, of which 44 species were relatively common. The authors noted that larvae and juveniles of many species move into the estuary at the time of the "spring detrital pulse". This is the time when the main pulse of detritus loss from the marsh occurs.

How might Nova Scotian marshes differ from this system? An overall difference is the much lower number of fish species in Nova Scotian estuarine systems — with probably not more than 15 to 20 species. It is likely that the marsh-estuarine primary production in Nova Scotian systems is not as efficiently utilized by fish as in the Louisiana system. In turn, we exploit

Figure 4. Summary of production data from Barataria Bay (Louisiana).



Note that main components of secondary production in marsh but not in water are at same trophic level. Numbers in brackets represent harvest by man. Units are g organic material produced per m^2 per year of net production available to water. ⏚ Represents respiratory losses.

few species that are highly dependent on the marsh-estuarine system as a food source. Figure 5 illustrates the spatial use of the Kouchibouguac estuarine system (New Brunswick) in the Gulf of St. Lawrence by edible species, and Figure 6 illustrates seasonal use. Of these species, only the flounder, eel, and striped bass obtain the major part of their food within the estuarine system. Striped bass populations, once large, are now small and are not exploited commercially in the Maritimes. Flounder are not taken, and eels are taken to a limited extent. The other species, more important commercially, are not highly dependent on the estuary as a food base. They are, however, highly dependent on the estuary as a habitat; most of these species move through the "head of the tide region", especially during the spring and fall periods of high runoff. Young of salmon, smelt, alewife, and tomcod feed in the estuary before going to sea. Thus, although the quantitative consumption of food by commercially important fishes in the estuary is probably less important than in more southern marshes, inshore commercial fisheries in our area are no less dependent on the existence and integrity of the marsh-estuarine system.

Mollusc production may constitute a more important secondary production level in our system than in those to the south. For example, for Petpeswick Inlet, Nova Scotia, where eelgrass and intertidal marsh occupy 34% of the surface area, Burke and Mann (1974) estimated that mollusc production (chiefly soft shelled clam, edible mussel, periwinkles and Macoma) in the macrophyte beds amounted to 4.7% of the macrophyte production, a much higher transfer than estimated for the Louisiana system. They believed that molluscs are the chief primary consumers in Petpeswick Inlet.

Clam-digging in the lower intertidal sandy banks fronting salt marshes

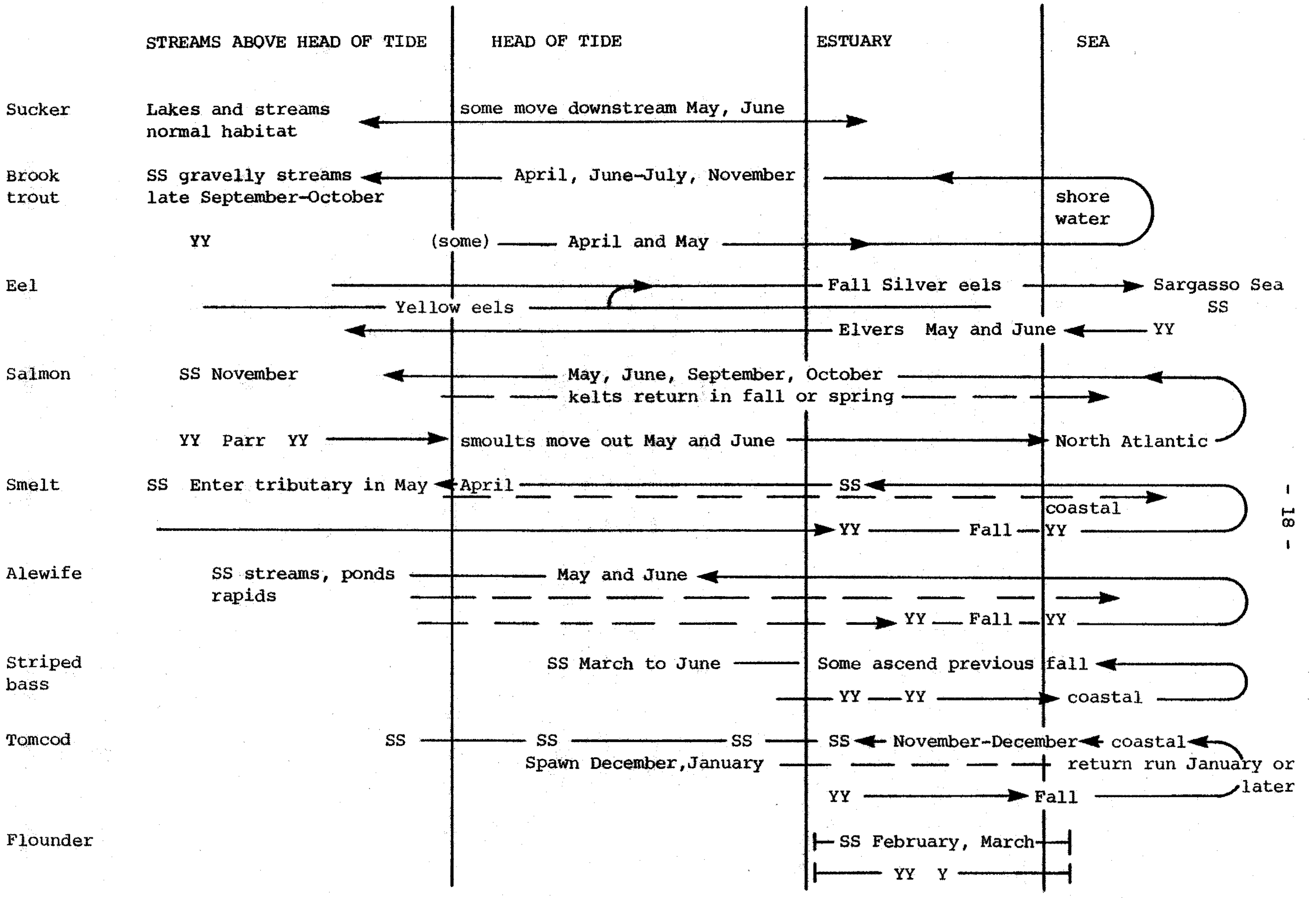


Figure 5. Spatial occurrence of edible fish species in New Brunswick estuary.

YY = young
SS = spawning

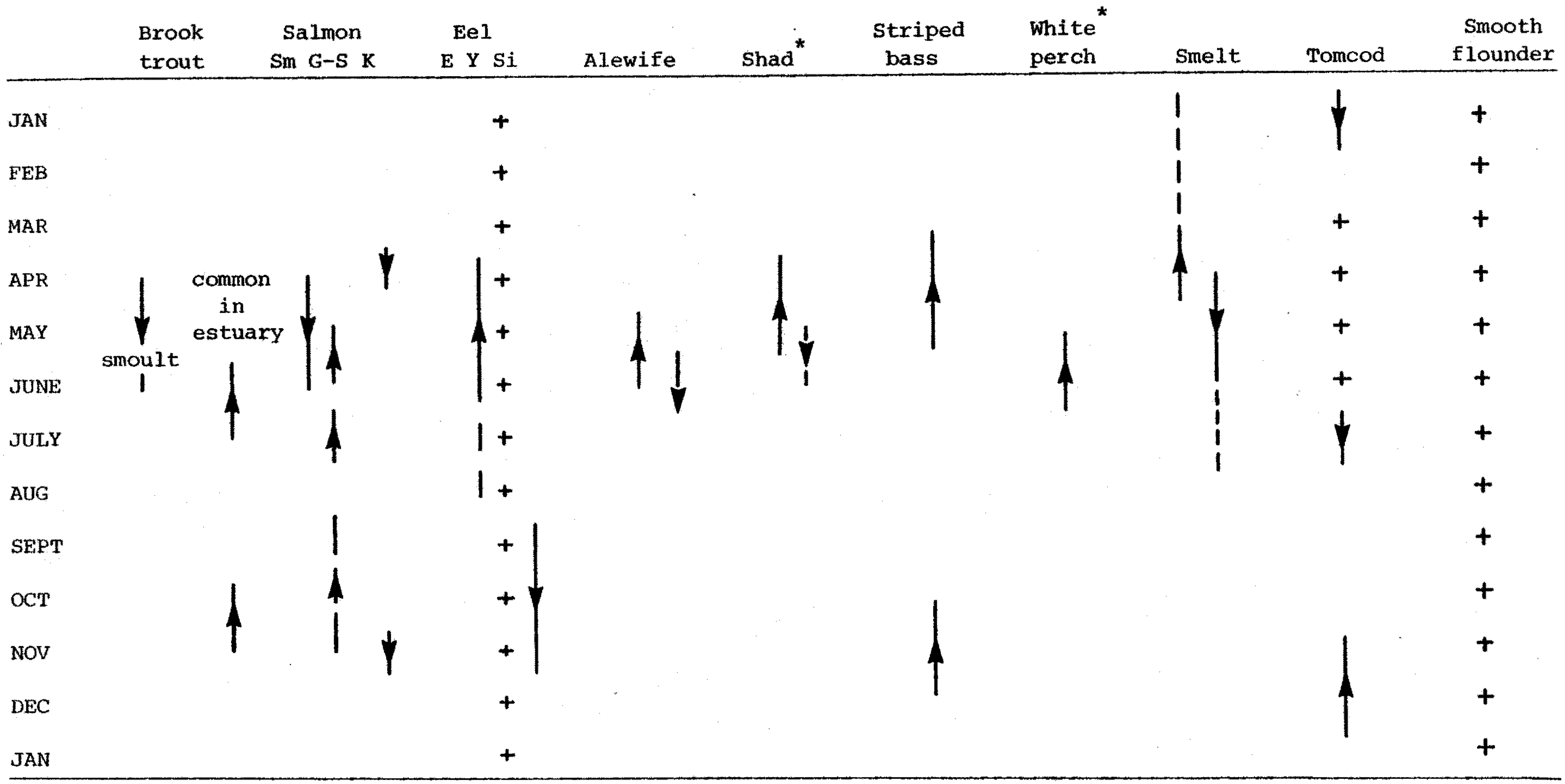


Figure 6. Seasonal occurrence of edible fish species in a New Brunswick estuary.

Sm = Smolt; G-S = Grilse & Salmon; K = Kelts; Y = Yellow eel; Si = Silver eel, E = Elver;.

*We have not caught species with asterisk.

Upstream and downstream migrations are indicated by directions of arrows.

is a popular recreational activity on the Eastern Shore. Where regulation of exploitation is required to maintain harvests, rotation harvest schemes may be both simple to institute and effective. For intensively exploited clam productions in Kouchibouguac Park, New Brunswick, Patriquin and Butler (1976) calculated that a 3-year rotation scheme (1/3 of the region exploited in any one year) would result in a 5-fold increase in catch per unit effort, and in doubling of total yields, as well as ensuring maintenance of a large breeding population.

The amount of marsh production "exported" from the immediate estuarine system to the open coastal region will depend on the dynamics of water exchange. In more open systems, it will be higher than in systems with restricted exchange. For Petpeswick Inlet, Bedford Institute scientists found no or very little net export of either phosphorus or carbon from the inlet to the ocean, but they did observe a large net export of nitrogen, principally in the form of dissolved organic nitrogen. This is not to say that no organic carbon leaves the inlet, but only that no more leaves than comes in. Export of dissolved organic nitrogen reflects high nitrogen fixation rates occuring within the inlet, mainly in the root region of the macrophytes (Zostera marina and Spartina alterniflora).

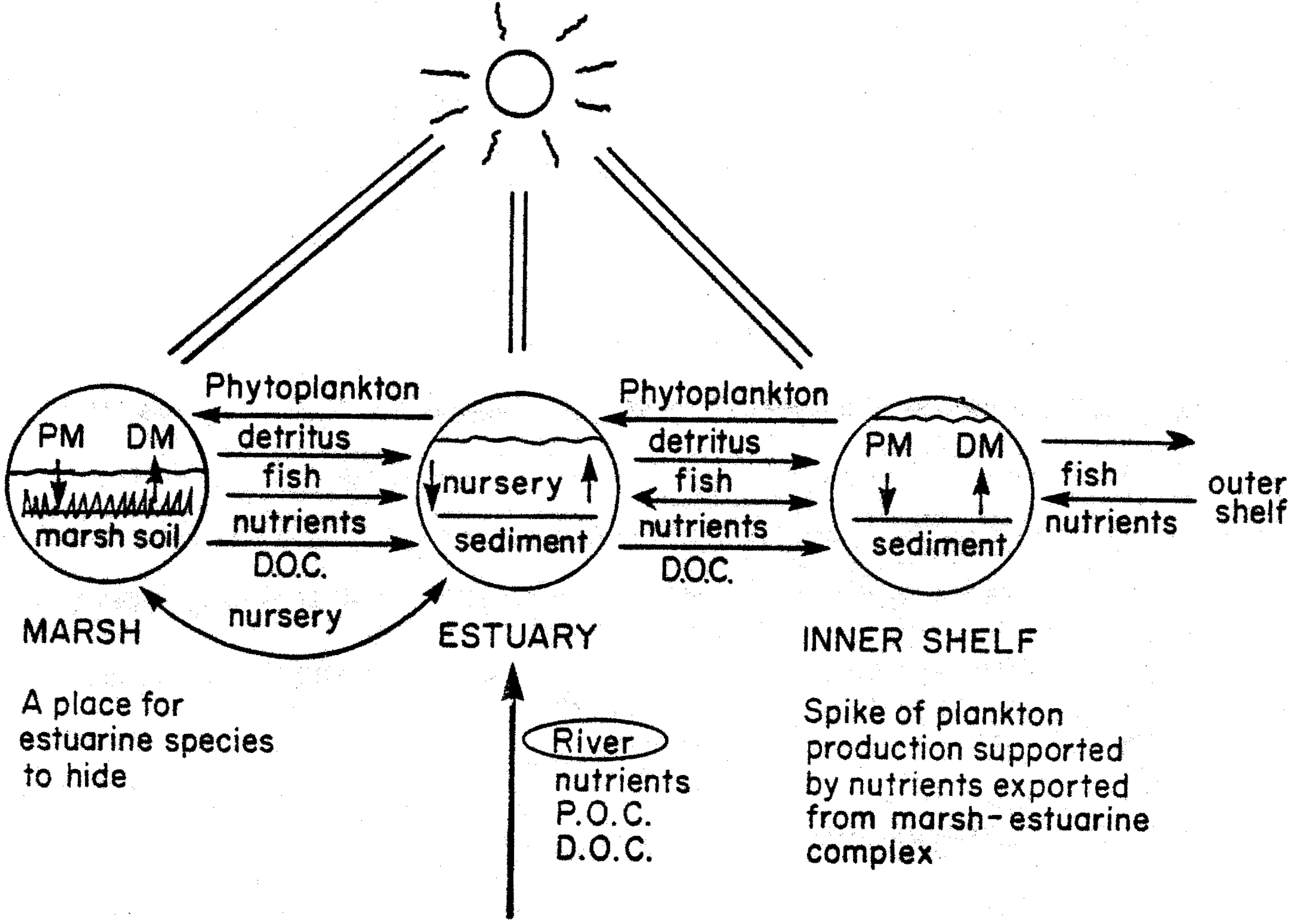
EELGRASS COMMUNITIES

Eelgrass (Zostera marina) frequently occurs in the lower intertidal and subtidal zones adjacent to salt marshes. This plant suffered a precipitous decline in abundance in the early 1930's, the reasons for which remain obscure. It is only since the late 50's, and the 60's that it has begun to re-establish itself in its former abundance. Observations by the author on the growth habit of this plant suggest that it is still increasing in abundance in inlets and bays along the Eastern Shore, and probably elsewhere. Recent recurring declines of eelgrass in the U.S. may be associated with runoff of herbicides from agricultural lands.

Eelgrass is highly productive and supports a rich fauna. Certain birds (e.g. brant) feed directly on eelgrass. However, extensive, uninterrupted stands of eelgrass in shallow water (blades extending to the surface) may be deleterious for certain desirable species (e.g. bass, salmon, clams) because of physical obstruction of movement, and because oxygen consumption at night in the eelgrass stands may be sufficient to lower oxygen concentration to critical levels. The most productive situation in shallow water seems to be one in which stands of eelgrass are interspersed with open sandy areas or with deeper channels. These open areas allow movement of fish, and feeding on invertebrates which migrate away from the eelgrass beds at night. Conservation of the integrity of channels through eelgrass beds is particularly important. A detailed study of the biology and hydrology of an eelgrass dominated lagoonal-estuarine system in New Brunswick, which is similar to many of those in Nova Scotia, was conducted for Parks Canada by Patriquin and Butler, 1976.

The idea that marsh detritus is the major food base within the marsh-estuarine complex has undergone some revision as a result of the discovery by Evelyn Haines at the University of Georgia that carbon isotope ratios for many invertebrates in this system are closer to that of marine phytoplankton than to that of salt marsh angiosperms; this and other work has led to an expanded concept of the marsh-estuarine food systems (Figure 7). Nutrients exported from the marsh-estuarine complex support a "spike" in plankton productivity ouside the mouth of the estuary; tidal exchange carries a portion

Figure 7. The marsh-estuary shelf complex.



A "spike" of production outside of the estuary acts as a "sponge" for nutrients coming out of the estuary and originating in the marsh. Plankton, in turn, is carried back into the estuary/marsh, providing high quality food for filter feeders. (After E. Haines) of this high quality food (versus detritus, which is low quality food) back into the estuary, where it is utilized by filter-feeding invertebrates such as oysters and clams. In other words, while there may not be a large net export of carbon from the complex, there is an exchange of low quality food for high quality food. This concept is an important one because it indicates that the marsh should not be considered in isolation, but as part of a larger marsh-estuarine-inner shelf complex. One implication of this is that if we restrict the exchange between the marsh-estuarine complex and the inner shelf, productivity of some of the more desirable or useful species within the estuarine complex may be lowered.

USE OF SALT MARSHES BY AQUATIC BIRDS

The importance of salt marshes as aquatic bird habitats has been emphasized by Reed and Moran (1971). For St. Lawrence estuary tidal marshes they report that "a large population of black ducks inhabits the Spartina marshes during the spring and summer where it finds almost all of its breeding needs. Breeding populations of common eiders, herring gulls, great black-backed gulls, great blue herons, black-crowned night herons and several species of shorebirds, as well as migrating populations of Canada geese, Atlantic brant and other aquatic birds rely on this habitat as a source of food." Pond holes are particularly important areas of black duck feeding. These various birds use all zones of the marsh, from the shore through high marsh and intertidal marsh to regions outside of the tidal marsh (where they may even be dependent on exported production of the marsh).

ECONOMIC USES OF SALT MARSHES (OTHER THAN PRODUCTION OF EDIBLE SPECIES)

There are few direct economic benefits or uses of undyked salt marshes. In the U.K., salt marsh grasses provide fodder for cows, donkeys, horses, pigs and sheep. The grasses are used as reserve foods, cut and stacked for winter. Use of these grasses seems to result in tainted milk, restricting the use for cows. Experiments were done in England during the war to determine the possible use of salt marsh grasses for making paper. The fibres are resistant to bleaching, preventing use for fine papers. Use for producing brown paper was not considered economical at the time.

On the other hand, the indirect economic benefits that accrue from salt marshes are probably greater now than in the past. *Spartina townsendii* has been used extensively for foreshore stabilization in Europe, and *Spartina alterniflora* is used for a stabilization of dredge spoils in the U.S. Seeding has been found to be very effective in the U.S., and can produce uniform coverage within one growing season.

I consider that the greatest economic benefit of salt marshes lies in their function as buffer zones in instances of oil pollution. Several studies have shown that pulse oil pollution results in little long-term damage to perennial salt marsh grasses, although annuals may be severely affected. Marsh soil is highly active microbiologically, and probably denatures oil more rapidly than does other sediment types. Further, the physical structure of the marsh grasses is effective in preventing oil spillages reaching the shore. Long-term oil pollution may, however, be deleterious. In a situation in the U.K. where cooling water carrying 10-20 ppm oil flowed over a marsh for a period of about 20 years, death of *Spartina* and associated species occurred over 35 hectares.

There has been much interest in the possible use of salt marshes in tertiary effluent treatment (tertiary treatment refers to the removal of N and P). Some studies have shown increases in grass production with few apparent deleterious effects in marshes treated with sewage sludge, and one worker considered that salt marshes had a value of $2500 per acre in relation to tertiary sewage treatment costs (1972 dollars). However, this is a somewhat controversial area, and many workers believe that salt marshes cannot tolerate recurrent inputs of effluents. As with respect to oil pollution, the importance of salt marshes lies in their function as buffer-degradation zones in instances of pulse pollution.

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Geology and Hydrology of Salt Marshes in Nova Scotia

J. Gordon Ogden, III
Department of Biology
Dalhousie University
Halifax, N. S.

INTRODUCTION

The salt marshes which border the Atlantic, Fundy, and Northumberland Strait coasts of Nova Scotia have individual histories related to different responses of the eastern, western and northern coasts of Nova Scotia to isostatic deformation and eustatic changes of sea level. The dynamics can be related to the post-glacial history of Nova Scotia. From an initial shoreline along the Fundy Coast, as much as 75 m above present sea level, about 14,000 years ago, and subsequent exposure of the land to depths 25 m below present sea level in the period 10,000 - 8,000 years ago, the subsequent history has been one of progressive submergence on all coasts.

Although the vegetational components of Nova Scotian salt marshes are generally similar throughout the area, zonation of the plants depends upon the interaction of crustal delevelling, sea level rise, and changes in fresh water hydrology adjacent to the marshlands.

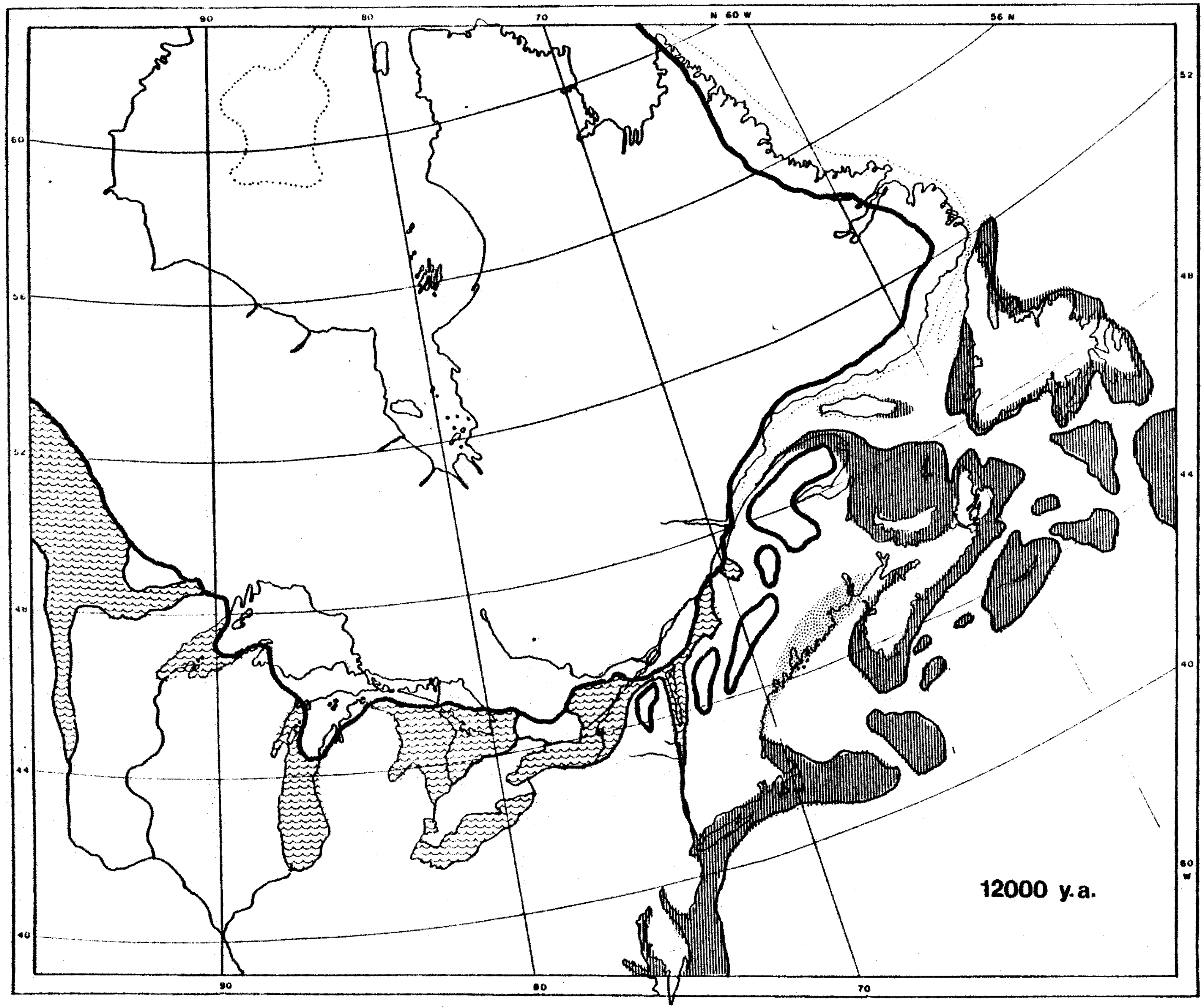
Where dyked lands (Acadian Soils) are maintained, paludification is inevitable, as these lands lack the sediment subsidy brought in by flooding tides which enable salt marshes to keep pace with rising sea levels (2-4 mm/yr).

GEOLOGICAL HISTORY

While there is still dispute as to whether the last advance of the Wisconsinan ice over Nova Scotia was part of the Labradoran ice, or coalescence of local ice cap massifs, the net effect was to cover all of Nova Scotia with glacier ice beyond all present coastlines. The weight of the main ice, as well as of more local ice masses, caused downwarping of the crust. However, this pressure was uneven, being greater near the ice margins. The effect in Nova Scotia was to produce crustal depression of as much as -75m (relative to present sea level) along portions of the Fundy coast of Nova Scotia. The Atlantic coast of Nova Scotia was also depressed, but by much less. Hence, when the ocean waters began to rise as the ice melted, substantial flooding of coastal areas of Maine, New Brunswick and the Fundy coast of Nova Scotia took place. Wave-cut benches near Digby at elevations of 60 m, and the marine deltas near Parrsboro, illustrate this period of marine transgression.

Figure 1 attempts to show the situation around Nova Scotia 12,000 years ago. Vertical lines indicate the area of the Scotian Shelf exposed as a result of lowered sea level. Differential warping produced inland flooding in Maine extending up to New Brunswick, but initial rebound in Nova Scotia was beginning to return levels toward present sea levels. On the Atlantic coast, because downwarping was not as extensive, sea levels were somewhere out on the Shelf. In other words, the history of transgression of the sea upon the land is longer on the Atlantic coast than on the Fundy coast by several thousand years. The situation is less clear on the Northumberland Strait coast, partially because delayed melting of ice in the Gulf of St. Lawrence and northern New Brunswick areas confused the

Figure 1. Nova Scotia 12,000 years ago.



interface between land, ice and sea water, and partly because the New Brunswick area was depressed more than the eastern Nova Scotia-Cape Breton area. In any event, over most of the Northumberland Strait area, exposure of the shallow shelf by lowered sea levels precluded extensive marine transgression.

By 10,000 years ago (Figure 2), crustal rebound in the Maritimes area was nearly complete, and all ice had left the region. There is disputed evidence of some residual ice caps on highland elevations, but for the most part, the bulk of the ice had retreated north of the St. Lawrence, and the Champlain Sea reflects the marine transgression caused by crustal depression in that area. Much of the Bay of Fundy was dry land and available for colonization by salt marshes and forest. The area could serve as a corridor for early man, who had reached Debert, near Truro, Nova Scotia, by 10,500 years ago.

By 8,000 years ago (Figure 3), crustal rebound was much slower than sea level rise (eustatic rise), and shoreline retreat was fairly uniform throughout the region. We must remember that due to the rebound of land to the north in the wake of retreating ice, there is a residual component of crustal rebound even today. In the Hudson Bay area, present rates of rebound are on the order of 90 cm/century, despite the final disappearance of all ice caps from the ice centers in Keewatin and Labrador by about 6,000 years ago.

Because of the shallow waters on the Shelf and in the southern Gulf of St. Lawrence, summer surface water temperatures in the coastal waters underwent considerable warming, according to a study of benthic and littoral invertebrates by Bousfield (1975) of the National Museum

Figure 2. Nova Scotia 10,000 years ago.

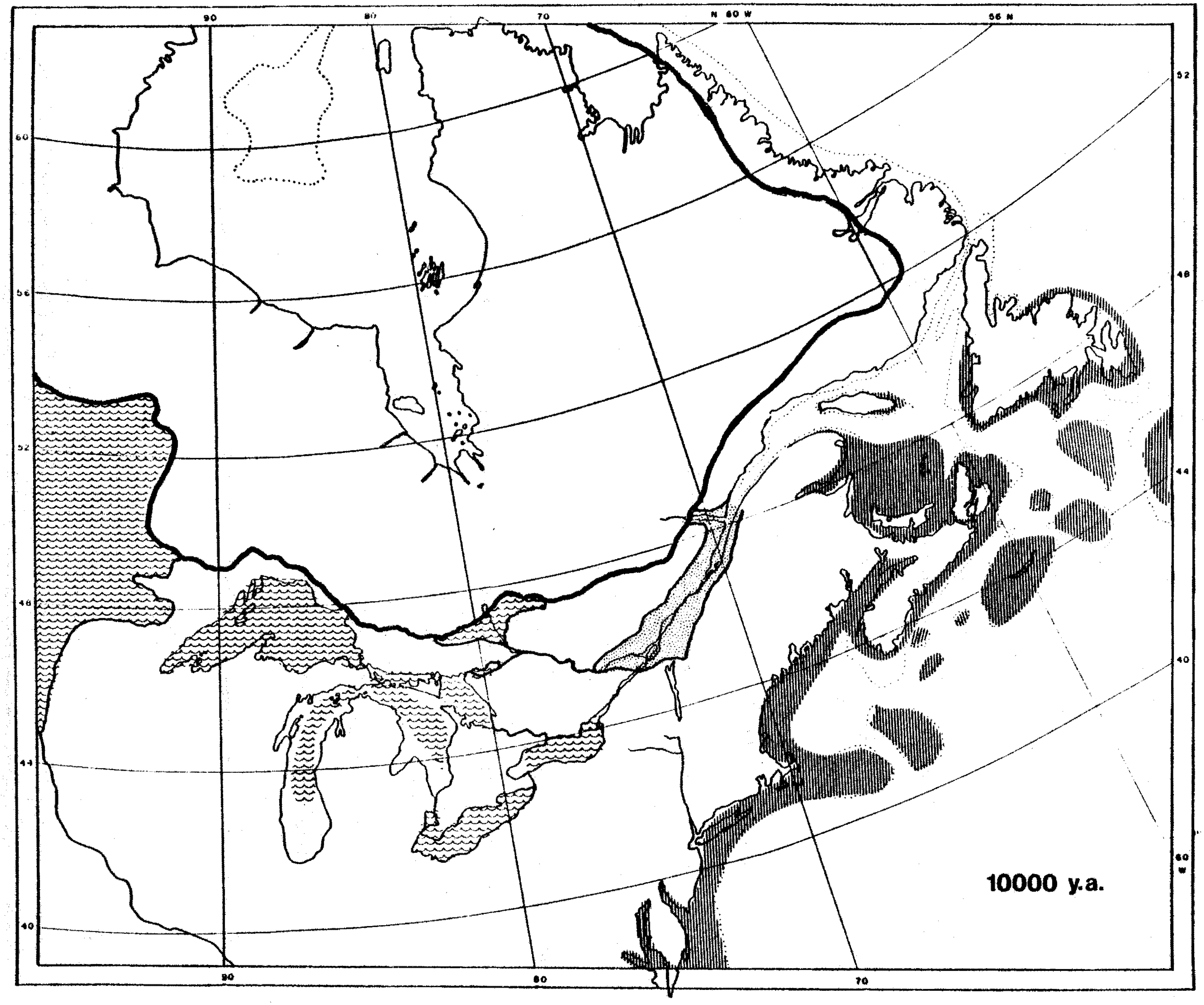
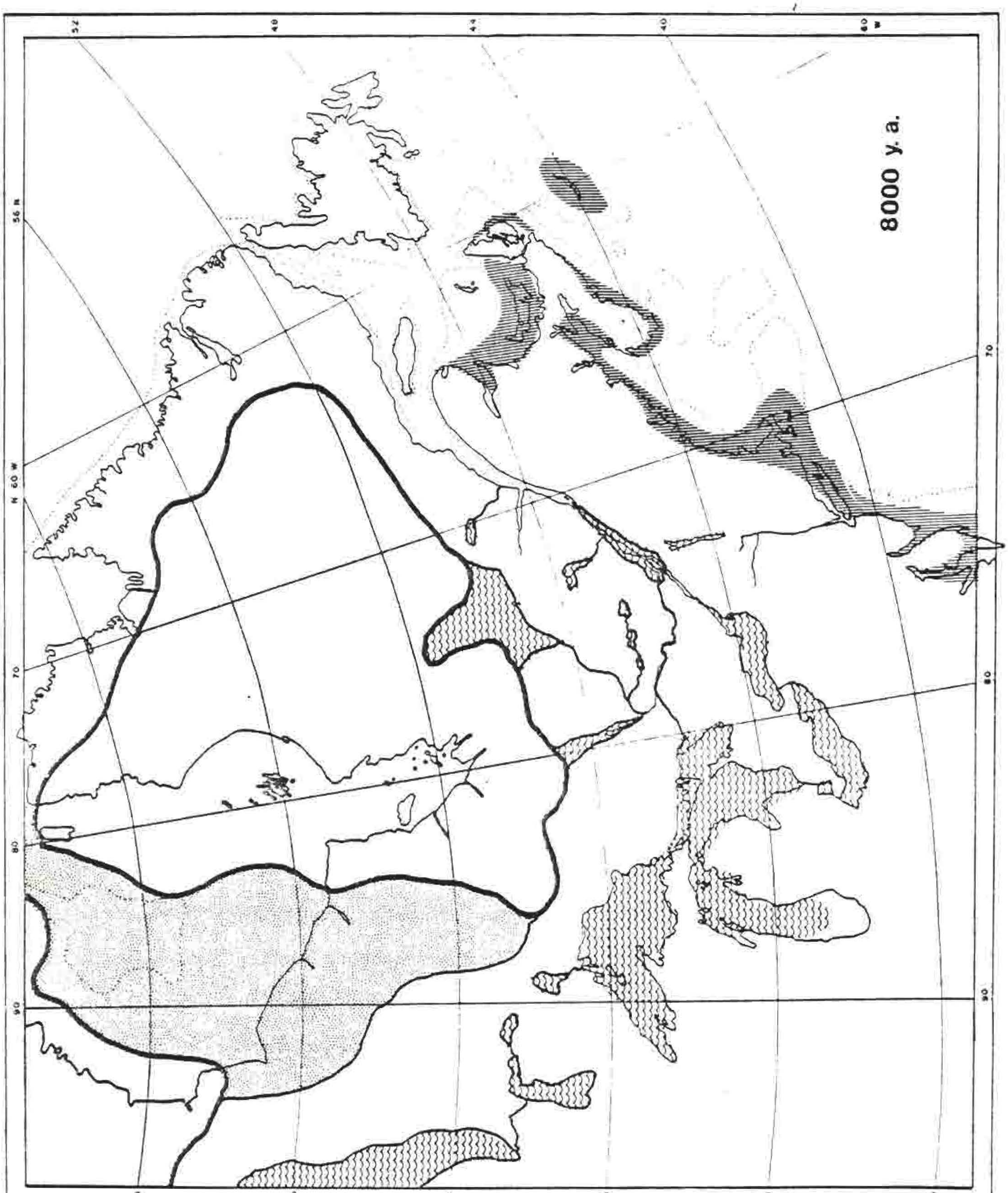


Figure 3. Nova Scotia 8,000 years ago.

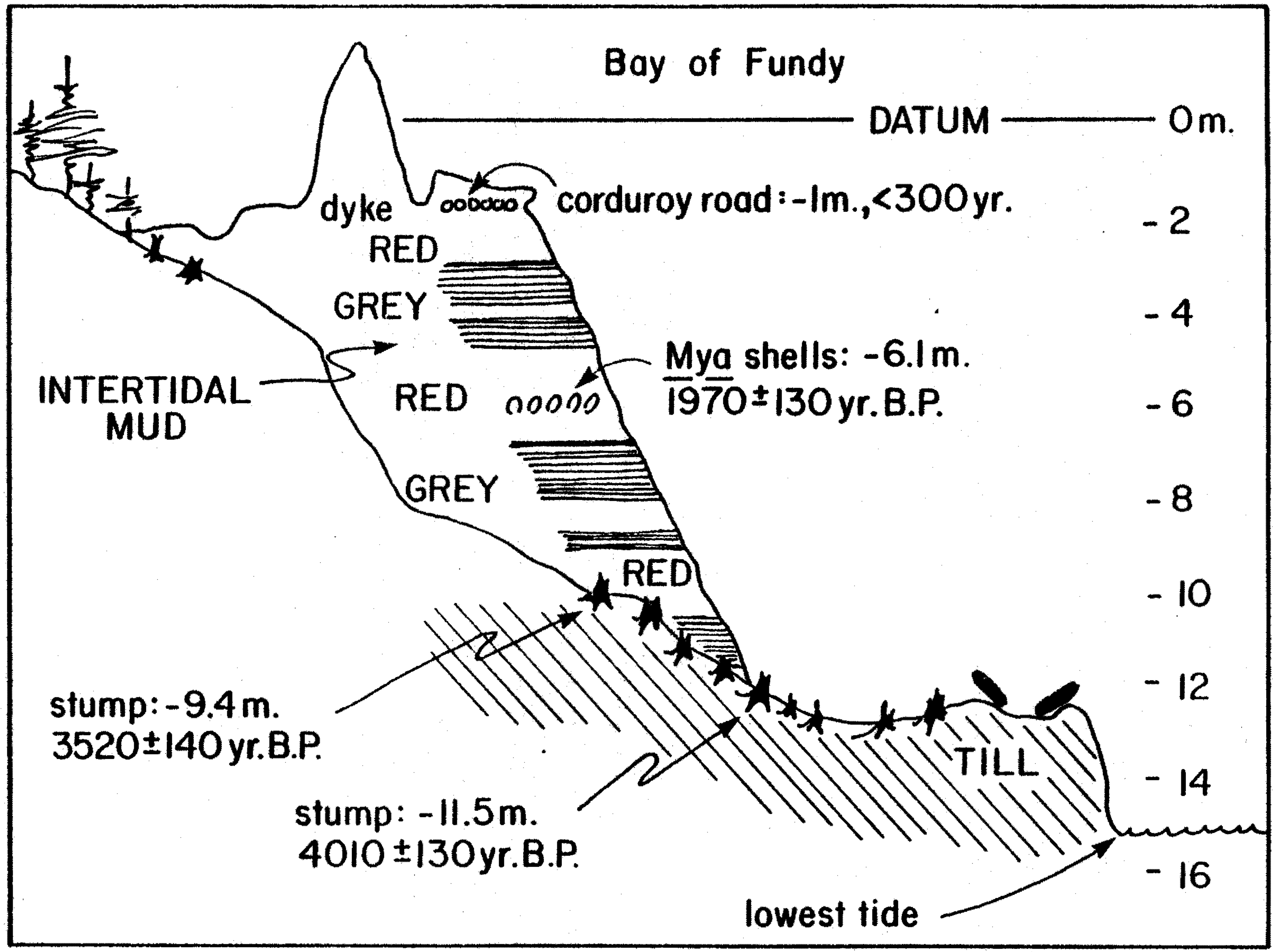


of Canada. By 6,000 years ago, surface water temperature of 15°C were common from Cape Cod around the east coast of Nova Scotia and continuous with the southern portions of the Gulf of St. Lawrence. Thus, invertebrates with motile larval stages could achieve a continuous distribution from southern Massachusetts to northern Nova Scotia. Similarly, thermally restricted fish would have common access to the waters of the southern Gulf of St. Lawrence from Cape Cod northward. Populations of striped bass (Roccus saxatilis) were probably continuous at this time. Rising sea levels (and reduced crustal rebound) resulted in gradually deepening waters over the sill at the mouth of the Bay of Fundy (Georges Bank and Browns Bank) and gradual increase in tidal amplitude in this area. Similarly, as waters deepened over the Scotian Shelf, the cold Labrador current interrupted the warm surface water temperature characteristics of the Shelf, effectively isolating the present "bathtub" along the Northumberland Strait shores. By 4,000 years ago (according to Bousfield, 1975), summer surface water temperatures of less than 12°C were characteristic off the east coast of Nova Scotia.

Figure 4 is adapted from Grant (1975) and shows the succession of intertidal mud accumulations at Fort Beausejour, New Brunswick. As sea levels rose, and tidal flooding amplitude increased with increasing depth over the sill at the mouth of the Bay of Fundy, marsh accretion was able to keep pace by shoreward retreat, and by deposition of silt as tides flooded the marshes. Cores driven through marsh sediments record alternate layers of Spartina alterniflora peat and S. patens peat as the marshes retreated landward.

An important point to be recognized in land use management decisions

Figure 4. Succession of intertidal mud accumulations, Fort Beausejour, New Brunswick.



is that in the face of rising sea levels, the only way that marshes can keep pace is by seasonal flooding and deposition of silt from the high tides that cover the marshes. Natural levees created by deposition in the *S. alterniflora* (tall) zone are partially leveled each year and distributed over the marshes by ice scour, which also removes enormous quantities of dead organic particulate material with ice melt each spring.

Lacking an annual sediment subsidy, as sea levels continue to rise, it is inevitable that maintenance of dykes will become more expensive, and that ultimate paludification is inevitable with eventual failure of the dykes.

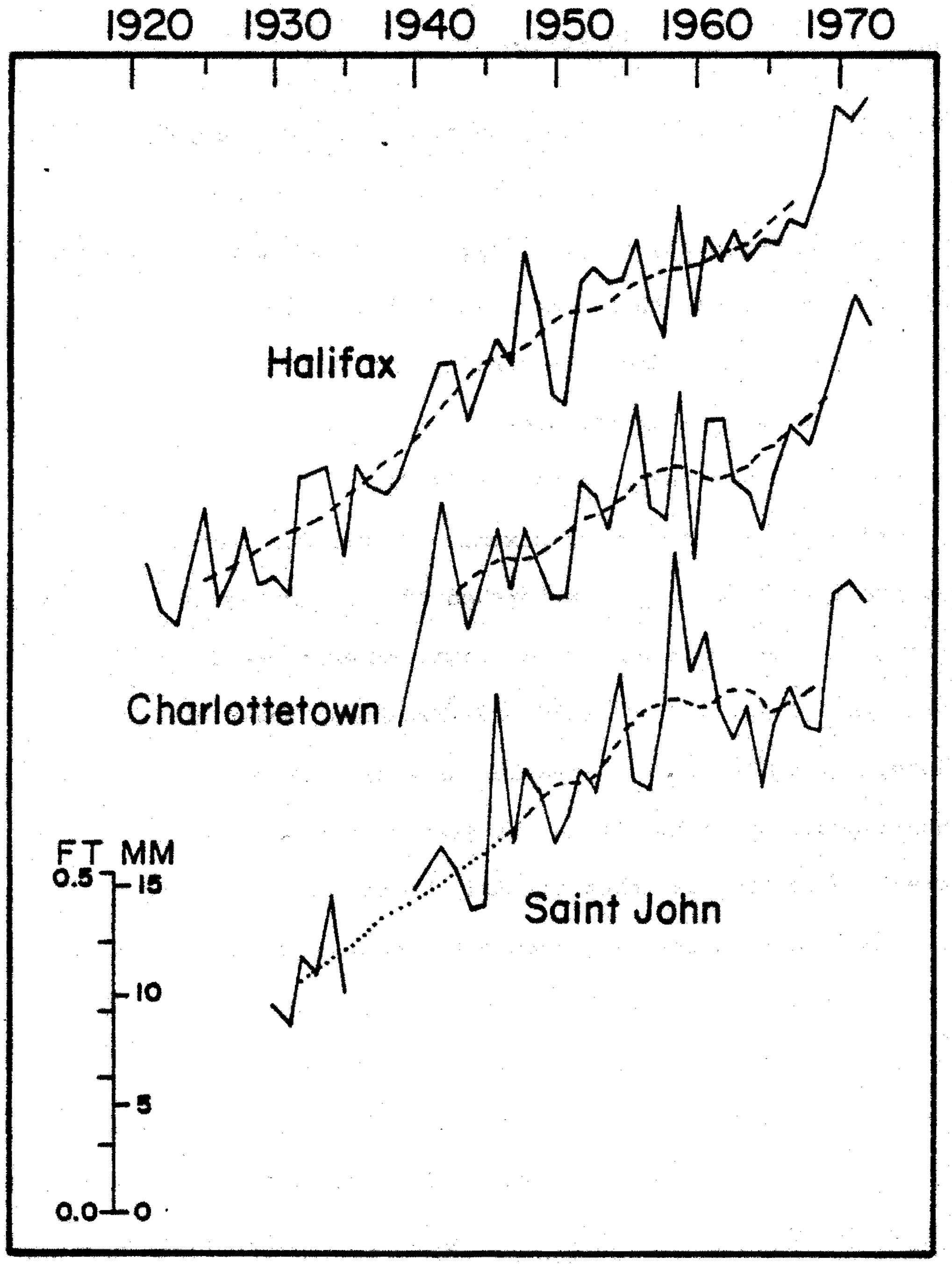
MODERN SEA LEVEL TRENDS AND THE FATE OF MARSHLANDS

Figure 5 shows tidal records from *ca.* 1920 for tide gauge stations at Halifax, Charlottetown and Saint John, New Brunswick. The consistent and parallel trends of rising sea level document the concern that coastal wetlands require an annual subsidy of at least 2.5 mm of sediment to maintain equilibrium against sea levels. In the Amherst region, preliminary measurements indicate annual deposition of 5-10 mm of sediment, which reflects the continuing increase in amplitude of Fundy tides in this portion of the Bay of Fundy.

It is important to recognize that dewatering and compaction of dyked lands (*ca.* 18,000 acreas in the Tantramar Marsh area alone) further exacerbates the problem of maintenance of coastal lowlands.

With different tidal amplitude regimes, and differential consequences of the interplay between isostatic delevelling processes and eustatic rise of sea level, the coastal wetlands of Nova Scotia are uniquely

Figure 5. Tidal records (from ca. 1920) for tide gauge stations at Halifax, Charlottetown and Saint John, New Brunswick.



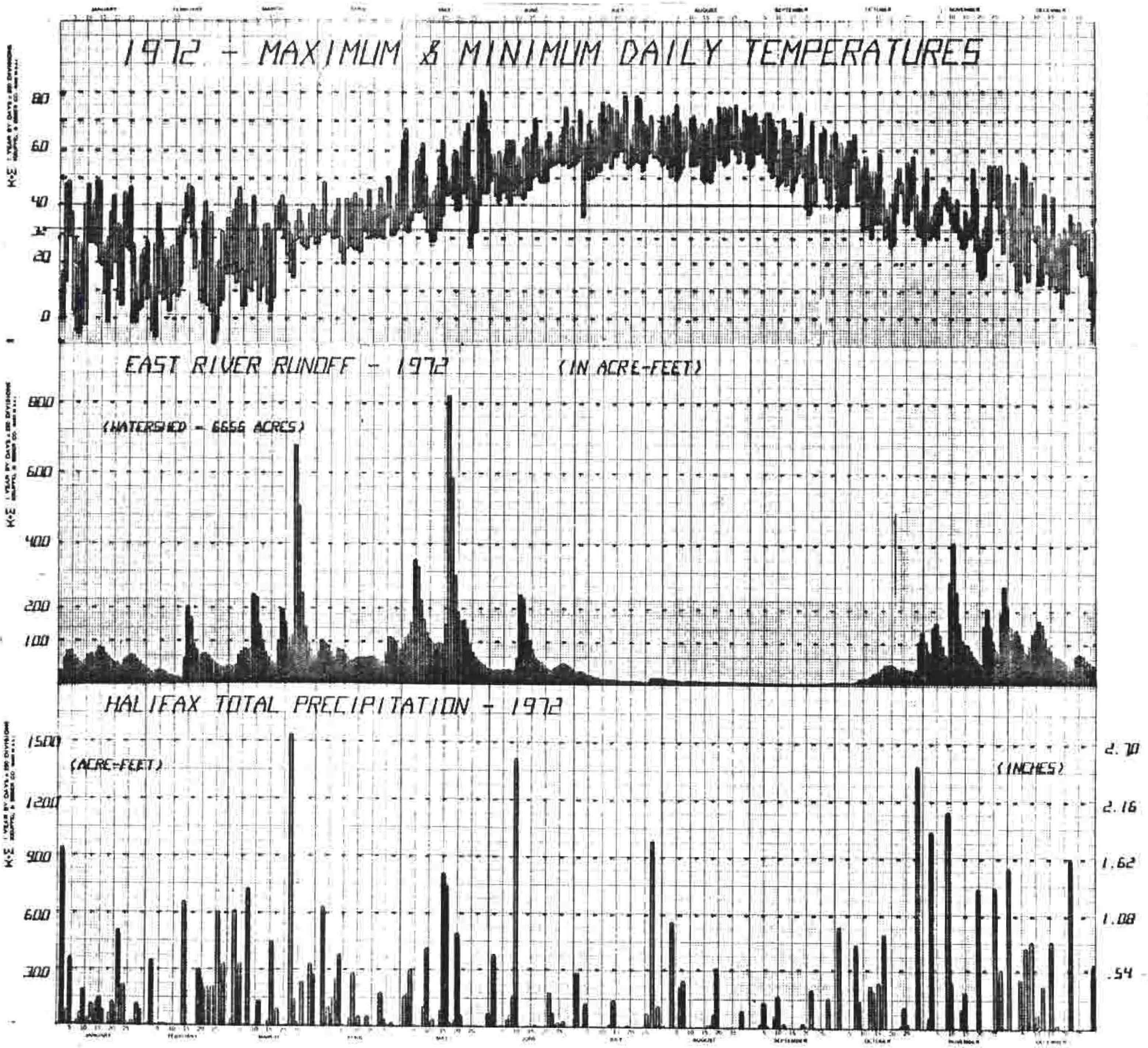
distinct, not only from other areas of North America, but also from each other. It is probable that there are more divisions, or greater distinctions, than the three (Fundy, Atlantic and Northumberland Strait) described above.

HYDROLOGY

We readily recognize that a salt marsh is subjected to wide variations in salinity. Periodic flooding by salt water raises salinity, sometimes to values exceeding normal seawater (during high evaporation stress in summertime). At other times, as during break-up of ice in the spring, salinity values may drop drastically, to 5% or less. It may be helpful to review a general hydrologic year in Nova Scotia, and then consider how the cycle may affect coastal wetlands.

Figure 6 shows a review of maximum and minimum temperatures, runoff, and precipitation for the watershed of the East River, St. Margaret's Bay, Nova Scotia. Daily maximum and minimum temperatures are plotted, together with the freezing point ($0^{o}C = 32^{o}F$) and a "lower biological activity level" of $40^{o}F$ ($4.5^{o}C$). Weather data are daily records from the Halifax (Shearwater) station. It can be seen that temperatures below freezing predominate from December to early March, and that temperatures below biologically active levels predominate from November through April. Daily runoff is shown in the middle graph, and is presented in acre-feet of water, based on data from the Water Survey of Canada. Precipitation input values are calculated in acre-feet (left side) and in inches (right side) of the bottom graph, based on Atmospheric Environment Service records from Shearwater. This station is used because the records provide greater detail. Correlations between Class 2 stations throughout the area covered

Figure 6. Maximum and minimum temperatures, runoff and precipitation, East River, St. Margaret's Bay, Nova Scotia.



by the watershed show values of greater than 0.8.

The "water year" begins in October, when plant activity is reduced by lower temperatures. At this time, groundwater supplies which have been depleted by increased transpiration during the growing season begin to be recharged. By November, groundwater supplies are sufficiently replenished to provide an approximate balance between input and output. Storage of water continues through February, as snow accumulation and ground frost alternate above-ground storage and infiltration. Early in March, as temperatures begin to rise above the freezing point, input/output precipitation-runoff relations again come into balance, until warming conditions prompt vegetational activity and transpiration begins to deplete groundwater supplies.

It is obvious that during the summer months, late June, July and August, very little input precipitation reaches the river, and low flow conditions prevail.

These relationships, characteristic of inland or upland environments have considerable effects upon coastal lowlands. _Spartina alterniflora_ has a vernalization requirement, meaning that its seeds will not germinate without a prolonged cold period. Moreover, germination and seedling establishment are enhanced by lower salinity waters. It should be no surprise, therefore, that the period shortly after ice break-up, a time of minimal salinities, favors germination and seedling establishment. Maximum salinities occur in August and September, by which time maximal primary production has taken place, and the marsh is ready to shut down for the winter.

TIDAL HYDROLOGY AND MARSH PRODUCTION

Studies by Morantz (1976) in the John Lusby wildlife area of the Amherst, Nova Scotian marshes, have clearly shown that the Amherst area marshes have lower primary productivity than Northumberland Strait and Atlantic coast marshes. Interestingly, in the area of impoundments for wildfowl concentration where marsh hydrologic regimes have been disturbed by dykes, it appears that delay of tidal runoff following flooding tides is all that is required to bring Fundy marsh production up to levels equivalent to other Nova Scotian marshlands.

Differences in tidal hydrology are reflected in the biota of tidal marsh channels. Because of the substantial salinity and sediment changes in Fundy marshes, the drainage channel banks are virtually sterile, with no attached seaweeds or even benthic invertebrates. In contrast, the Wallace Bay marshes on the Northumberland Strait show vertical channel walls (as opposed to the broad V-shaped mud channels of the Amherst marshes), solidly lined with dense populations of blue mussel and oysters. Flat channel floors are carpeted with eel grass (Zostera marina), a characteristic of the Petpeswick marshes on the Atlantic Coast (Hatcher and Mann, 1975).

CONCLUSIONS

Crustal deformation due to ice loading from the last advance of glaciers across Nova Scotia continues to influence coastal environments. Similarly, eustatic rise of sea level due to ice melt of the glaciers is producing variable amounts of sea level rise in the Nova Scotian area. The unique characteristics of tidal amplitude in the Bay of Fundy are also influencing the hydrology of tidal marshes on the Fundy, Northumberland

and Atlantic coasts of Nova Scotia.

Geological history probably affects the invertebrate and perhaps vertebrate faunas of the three areas due to changing water temperatures and water depths since deglaciation. Vegetational similarities are modified by differential responses to tidal inundation, which at least affects primary net production due to differences in submergence times for low and high marsh segments.

It is clear that isolation of dyked lands for agricultural purposes denies the marshland soils their annual increment of sediment. This fact, coupled with rising sea levels, poses serious problems for the maintenance of productive marshland.

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AGRICULTURAL USAGE OF DYKED SALT MARSHES

THE AGRICULTURAL FUTURE OF DYKED LAND IN NOVA SCOTIA

J. D. Hilchey
Supervisor of Land Use Programs
N. S. Department of Agriculture and Marketing
Truro, Nova Scotia

INTRODUCTION

If all the land in Nova Scotia presently protected by dykes was being intensively used for agricultural production, one might not be concerned about either the present or the future use of this coastal resource. But it is obvious to anyone driving through Nova Scotia today that land in some areas is in a state of non-use, or actual abandonment. Other areas are dyked, and include by far the most fertile soil we have in the Maritimes, in terms of elements needed for crop production. We have to ask ourselves, why these differences? The reasons are complex and are not necessarily the same for each region. In order to more fully understand the problem, a brief review of the historic use of these soils is necessary.

HISTORICAL USE OF DYKED LANDS

The original dyking, done over 300 years ago by early French settlers, was for the purpose of growing food and fibre for themselves and their livestock. Thus, a ready market existed for most of the forage, flax, vegetables and grain produced. As the population of the settlements on the perimeter of the salt marshes increased, more land was reclaimed from the sea.

The relative value of dykeland over upland soils was recognized then, and still is, by those farmers who have been able to use dykelands to their full advantage. Many more have been frustrated in their attempts to do so. More about that later.

The turning point in marshland use coincides with the replacement of the horse by the tractor and truck. Tractors do not eat hay; therefore, a substantial proportion of the cash market for hay disappeared with the rapid conversion to motorized power on farms and highways. This was a double-barrelled blow to marshland use which came at a time when traditional manual labour for rebuilding and maintaining dykes and drains was being directed into the non-agricultural activities of war-time Canada.

It is significant, however, that those dyked areas used primarily to provide forage for cattle continued to be maintained and exploited. The areas developed primarily for hay production in the domestic market deteriorated rather quickly. Many of the marsh owners were not livestock farmers. In fact, some were not even residents of the province. In such a situation, it is easy to grasp the consequences of a lost cash market for hay. Owners without a livestock enterprise to consume the forage lost interest. The remaining owners still interested in the marsh could not cope with the maintenance of ditches and dykes for an entire marsh body, when so much of it was held by disinterested and absentee owners. In many situations, the clearing of ditches through adjoining properties would have been an act of trespass.

In summary, the total effect can be recorded as a chain reaction:

(1) Loss of the hay market caused a comparable loss of interest of non-farming dykeland owners, who consequently no longer kept up their share of the marsh body.

(2) Loss of the manpower to carry out maintenance work on dykes and ditches made imperative the use of large earth-moving equipment. Costs for this work were beyond the means of the remaining livestock farmers with a strong interest in the land.

(3) The replacement of the horse by the tractor, and the binder by the combine made the existing fields too small for economic use. Attempts by farmers to enlarge the fields by purchase of adjoining lands were, for the most part, exercises in futility.

ADMINISTRATIVE CONSTRAINTS TO MORE INTENSIVE USE

At this stage we have to ask ourselves why the adjustments in ownership did not take place. Why would disinterested landowners wish to retain a block of marshland useless to them? Most important, why was there no leadership by governments to remove this land from the state of limbo created by absentee ownership and non-use?

Even these questions are open to simplistic answers which do not tell the entire story.

1. Municipal taxes on unused marshland are low or absent. A continuing substantial tax lever against the land could be a powerful tool toward more intensive use. This tool is not being used. Municipalities can be further faulted for their unseemly haste in divesting themselves of properties acquired through tax sales. Had there been a sincere interest in developing a strong tax base, municipal governments, with provincial support, would have long since entered the land consolidation field, to provide adequate blocks of land for rent or purchase by prospective farmers.
2. Provincial governments also can be faulted for their apparent indifference to the longstanding problem of land ownership of marsh bodies. Fragmented and absentee ownership makes intensive use of any part of the marsh by an individual farmer nearly impossible. This statement does not apply to organized marsh bodies, but it does apply to the lands most in need of rehabilitation and those most grossly under-used.

Land ownership in Nova Scotia is a sacred cow. Provincial governments, no matter what their political persuasion, are extremely reluctant to expropriate land in the public interest. Expropriation immediately raises the hackles of just about every landowner in the province. So there is an understandable reluctance to act on the lease or the expropriation, consolidation and resale of marsh bodies now in a state of disuse. There is another reason — the chicken and egg syndrome. Why expropriate a marsh body, put in main drains and roads (i.e., put it into a condition where a farmer can take over) when there are no longer any farmers in the area? The question asked by governments here, and rightly so, is: If we spend public money on this marsh, will it pay off? Will farmers, not now in the area, develop and use these wetlands? I am not worried about this part of the problem. My faith in the value of the dykelands is too strong for that. However, not everyone is aware of the productive capability of dykelands under proper management.

RELATIVE NUTRIENT STATUS OF MARSHLANDS AND UPLANDS

Rising costs of energy in Canada and elsewhere are quickly reflected in the cost of just about everything we buy. Food costs are no exception. In Eastern Canada and the U.S.A., some of the most costly inputs to food production are the fertilizer components — nitrogen, phosphorus, potash, calcium and magnesium. The last two are usually added primarily as dolomitic limestone, a neutralizer of soil acidity, but the elements calcium and magnesium are usually in short supply in leached or podzolized upland soils.

People who should know better, often make the statement, "Nova Scotia is a natural grass country". Nothing could be further from the truth. The upland soils of Nova Scotia in their unimproved state are acid and infertile. The crops naturally suited to such soils are trees, blueberries, bracken and, in poorly drained sites, a few acid-loving crops such as cranberries.

The calculated values of these fertilizer elements based on 1977 prices were:

	Cost per lb
Potassium	12.4¢
Phosphorus	56.7¢
Calcium	1.25¢
Magnesium	2.08¢

Available elements in the top 30 inches of dykeland and upland soils based on the chemical analyses of 27 dykeland and 33 upland six-inch layers were as follows:

	Dykelands-lb/acre	Upland-lb/acre
Potassium	2175	340
Phosphorus	545	200
Calcium	7400	2240
Magnesium	4930	1205

Hence, the value of available elements, potassium, phosphorus, calcium and magnesium in the top 30" of cropped dykelands and uplands in the Nova Scotia sites were calculated as shown on the next page:

	Dykelands	Uplands
Potassium	$269.00	$ 42.00
Phosphorus	309.00	113.00
Calcium	92.00	28.00
Magnesium	102.00	25.00
TOTAL	$772.00	$208.00

NOTE 1 - Many upland soils show little root penetration beyond the 18/20 inch depth because of high bulk density. Thus elements below this depth are considered to be not accessible without recourse to radical soil amelioration treatments such as deep tillage or deep plowing.

NOTE 2 - Dykeland soils contain up to 60 percent of silt. This acts as a storehouse for many of the mineral nutrients needed for plant growth. As nutrients are depleted from the exchange complex by plant uptake or leaching, replenishment of exchange positions occurs through transfer from the silt fraction to the colloid fraction. Very little research has been done on this characteristic of the dykeland soils.

STEPS TO DYKELAND IMPROVEMENT

Dykelands have a potential for high, sustained production of a wide range of crops. However, the constraints standing in the way of maximum utilization of marshlands must be removed in a step-by-step process involving the Federal Government, the Provincial Government, the marsh-governing bodies and the landowner or lessee. The suggested steps are:

1. Dyking or reclamation of the marshes from salt water flooding and the construction of aboiteaux. This step is already underway and maintenance of these structures is continuing.
2. Consolidation into land units large enough to be economic entities for progressive, mechanized farm enterprises. This involves land purchase, or expropriation, or both, by the province.

3. Main drains and roads. A properly engineered and implemented main drainage system for each marsh body would involve both Federal and Provincial Government cost-sharing, probably on a 72-25 basis.

4. Return of the land to existing active farmers, through sale or lease, contingent upon the formation of an incorporated body of marsh owners. Such bodies should have powers to expropriate lands held by absentee owners, or held by owners who fail to pay marshland maintenance assessments.

5. Encouragement of physical works, which would enhance crop productivity of individual fields.

   NOTE: Maintenance assessments and land taxes should be high enough to encourage intensive use and to provide adequate funds for maintenance.

Following dyking, drainage (main ditches) and land consolidation, hopefully we will now have qualified farmers knocking each other over to get a piece of the action. However, there may be some isolated areas where farmers no longer live. Such areas would have to be consolidated and prepared for use on the assumption that new farmers not now in the area would take them up. For example, one farmer in Nova Scotia is interested in purchasing and developing a thousand acres of a single marsh body. This interest illustrates the high regard knowledgeable farmers have for dyked marshlands.

Hopefully, over the long-term, the farmer will use a combination of water control techniques aimed at producing a soil with good drainage and high trafficability throughout the cropping season. Ideally, the off-season water table should be sufficiently far removed from the surface to allow for the successful production of all planted grains and perennial legumes. In this way, crop production could be expanded beyond traditional hay crops.

CONCLUSIONS

There are more than 40,000 acres of dyked marshlands in Nova Scotia. It is conceded that a significant acreage of these marshes (perhaps as much as 10,000 acres) should be set aside for the use of waterfowl. There are times and situations where natural production is preferable to constructing the works necessary for agricultural use of land. The upper reaches of Amherst marsh and the low wet marshes of Yarmouth and Digby, all difficult to protect and drain, are clear examples of lands that should be utilized for waterfowl, wild rice production, or other uses which can capitalize on characteristics detrimental to their use for mechanized agriculture.

But it is also clear that other areas, now a neglected part of the agricultural land base, could, when developed to their potential, play a key role in agricultural food production in this province. After all, 30,000 acres, producing a ton and a half per acre of wheat, would more than double our present total grain production, with a very small increase over present fertilizer use.

RECREATIONAL AND WATERFOWL USAGE

SALT MARSH RECREATIONAL VALUES
AND MANAGEMENT CONSIDERATIONS

Fred Payne
Nova Scotia Dept. of Lands & Forests
Kentville, Nova Scotia

To the landowner who is unaware of its physical worth, a salt marsh is a vast wasteland. Direct recreational opportunity is extremely limited, when compared to alternative uses to which salt marshes might be put. The waterfowl hunter is probably the principal direct user of salt marshes. Of the 13,000 or so duck hunters in Nova Scotia, 70 percent trudge through salt marshes in pursuit of their recreational experience. Thirty-five percent pursue most, or all, of their duck hunting along salt marshes. Other than this significant group, there are but a few dedicated ornithologists and bird watchers, who actually slog the salt marshes to get to the pannes where a wider variety of birds can be seen. There are a few trappers who derive some income from the furbearing animals which frequent the upper reaches of our narrow estuaries. The harsh salt environment of our relatively exposed marshes does not attract the large numbers of furbearing animals that inhabit the vast brackish estuaries farther south.

Direct recreational use of lands dyked for agriculture certainly exceeds that of our salt marshes. Campgrounds, athletic fields, skating rinks, horseback riding trails, snowmobile and snowshoeing trails are found. Bird watchers, trappers, fishermen, mushroom pickers and pheasant, Hungarian partridge, duck, goose and fox hunters all use these dyke lands directly. On our two provincial wetland development areas behind dykes, recreational user opportunities are significant, and we can certainly build a strong case both for direct increased recreational benefits, and for direct economic return from these relatively closed wetland systems. If one were imaginative, more recreational use and greater commercial values could be developed behind dykes.

The indirect recreational values of salt marshes are significant. The organic detritus from Spartina alterniflora marsh is colonized by bacteria and algae, and used over and over in the marine system so as to support a number of recreational and commercial pursuits. The digging of softshell clams, bay clams and quahogs is a traditional coastal recreation, the economic value of which, were it known, might well exceed the commercial value of these species. Oysters, scallops, blue mussels and periwinkles are also gathered as a vacation or weekend recreational pursuit. It has been documented that the salt marsh food chain extends to almost all of the sport and commercial fin fishes. Salt marshes provide sanctuary for some sport fish during the larval stage. Striped bass, pollock, mackerel, tuna, haddock, cod, flounder and halibut are recreational sport fish attractions. Atlantic salmon and sea-run brook and brown trout also spend part of their life cycle in estuarine waters, feeding, in part, on the salt marsh-based food chain. Salt marshes both directly and indirectly provide food not only for waterfowl, but also for large numbers of shorebirds and for a variety of other birds. The coastal pursuits of shell collecting or beachcombing for biological specimens are enriched by the life forms that salt marshes contribute to the marine system.

To many people, the marshes are aesthetically pleasing, providing an undisturbed natural scene for viewers and photographers.

The salt marsh system to the biologist or ecologist is a beautiful life support system; something, which even when superficially understood, approaches the spiritual. Something which, if completely understood biologically, and then placed in realistic economic terms, would be viable, non-depreciating capital, worthy of the most careful and detailed management considerations.

But, although these values are real, we cannot quantify them in today's economic terms. We know how the food chain works, but we cannot say how many tons or pounds of shellfish are produced from an acre of salt marsh, or what part of a tuna comes from a marsh. We know marshes are extremely important, but we cannot play the traditional numbers game. In 1974, the Department of Lands and Forests and Environment Canada, Fisheries Service, surveyed resident and non-resident householders to whom a Nova Scotia freshwater fishing license had been sold (about 20 percent of Nova Scotians fish freshwater). In that year, 136,648 person-days recreation were provided through shellfish digging; 203,865 days were spent on inshore saltwater fin fish sport fishing by those families with licenses. An additional 67,000 recreation days were enjoyed by people chartering boats. More than 4 million dollars was spent by this sample of licensed freshwater fishermen and charter boat fishermen on these recreational activities. This estimate of expenditure does not consider the intangible values, or the value of harvest, or the other Nova Scotian and tourist households where freshwater fishing licenses were not sold. A great deal more must have been expended for this recreation, but how much and what proportion of this activity can be traced to the production of a salt marsh? — We do not know.

Leaving things as they are is certainly not the traditional or current concept of progress and growth. Many people consider "progress" in terms of the new jobs created, the capital invested and the profits which accrue directly from investments and employment. Natural capital, entropy and life support systems are foreign terms which are not understood, much less weighed. Quality of life is not a socio-scientific term but is rationalized to mean a higher standard of living.

By far, the most significant recreational and other commercial values of salt marshes accrue indirectly to society, and indirect benefits of existing systems are largely ignored or minimized in the present cost-benefit accounting process.

Agencies like recreation, tourism, fisheries, environment, development, municipal affairs, parks, wildlife or almost any other agency should be vitally interested in the salt marsh life support system, but as far as I am aware, Parks Canada, the Canadian Wildlife Service and the Department of Lands and Forests are the only public agencies who have attempted to purchase salt marsh in Nova Scotia.

The Department of Lands and Forests, the Canadian Wildlife Service and Ducks Unlimited became interested in the potential for increasing waterfowl production (as demonstrated by management in other areas), recreational use and detrital export from salt marsh through alteration. These agencies recognized the importance of marshes to the marine system, as well as to migratory birds, and agreed on an ecosystem approach to management, as opposed to a monoculture approach. They also agreed to provide funds to evaluate the basic effects of such management on the marine system. As responsible bodies, these agencies wanted to know if they could manage a salt marsh system so as to optimize its value to the people of Nova Scotia without detrimental tradeoffs. Where else has such a responsible approach to development been taken? Where else in Nova Scotia have the developing agencies provided funds, without outside pressure, to evaluate the basic aspects of development. One could go a long way to find an example.

We have learned a great deal from what amounts to a very small area of salt marsh, and we hope to learn a lot more in the future. We have started to build a case with numbers and to set an example for future salt marsh management in this Province. How successful we will be is not certain, but at least we will have some numbers upon which to base future decisions.

Wildlife biologists and ecologists are understandably negative toward certain developments and intensive management, since it has been short-term technological successes which have endangered species and crippled or irreversibly destroyed naturally productive habitats. Still, we must be careful in today's society not to lose credibility by always being negative. If we are responsible, we will try to change society toward a better end. We have a largely-neglected obligation to society to make positive recommendations for management, and to suggest biologically sound, if not ideal, alternatives to development proposals.

As our waterfowl management committee proposed, we take an ecosystem approach to salt marsh management. In this approach, we do not view salt marshes in terms of recreational uses, wildlife uses or aquaculture uses. Rather, we view them first as ecosystems that may be manipulated for the benefit of people, but always within their ability to self-correct. We must weigh the tradeoffs and put more emphasis on the neglected indirect benefits.

Certainly biologists and ecologists can take a positive approach toward management when life support systems are given first consideration. Certainly with the knowledge that management efforts bring, an understandable economic case can be made for ecosystem management. Certainly, if we take the initiative and a positive approach toward salt marsh management, we can go further, learn more and do a better job than if we just sit back and criticize everything anyone else proposes. Although sitting is a comfortable and safe position, it does little to improve anyone's approach to resource management.

The question extends beyond salt marshes into all aspects of renewable resource management. That is, can we manage an ecosystem — any ecosystem — on a long-term sustained yield basis within its abilities to self-correct, or must man eventually return to a tribal hunting and gathering existence, once all natural capital has been exhausted or disassociated?

We have an opportunity with the undervalued, unappreciated, relatively simple marsh ecosystems, to demonstrate how ecosystem management can benefit man both directly and indirectly. We can demonstrate how man can manipulate natural systems and increase productivity with long-term objectives. We can accept the challenge now with a positive approach, or we can continue debating the merits of various approaches, while salt marshes are taken over by other interests.

WATERFOWL USE OF NOVA SCOTIAN SALT MARSHES

Keith McAloney
Ducks Unlimited
Amherst, Nova Scotia

INTRODUCTION

Ducks Unlimited is a private conservation organization working to maintain and improve waterfowl populations through a program of habitat improvement and rehabilitation. Since 1965, in co-operation with Federal and Provincial governments and private landowners, we have developed 33 wetland projects in Nova Scotia, totalling approximately 9,800 acres. Two of those projects (total 110 acres) were constructed on salt marshes owned by the Canadian Wildlife Service in a joint effort to create some breeding and brood rearing habitat in areas used mainly for migration.

Those impoundments have been the subject of co-operatively funded studies on waterfowl usage, primary production and nutrient export. While the increase in waterfowl has been significant, the detrimental effect of decreased nutrient export has been the cause of some concern. Thus it is unlikely that additional impoundments will be constructed in the *Spartina alterniflora* zone of Nova Scotian salt marshes.

This paper is to define waterfowl usage of free or impounded salt marshes, and will discuss such usage in relation to the waterfowl's annual cycle, beginning with spring migration.

ANNUAL CYCLE OF SALT MARSH USE

1. *Spring migration*: From the period of March 8 until May 15, our

salt marshes serve as feeding and resting areas during the spring migration of such waterfowl as Canada geese, black ducks, blue-winged teal, green-winged teal and pintail. For Canada geese and some black ducks, the marshes serve as waiting areas until their more northerly breeding grounds thaw out. Most of the other species are awaiting ice-out of inland fresh marshes at the same latitude as the salt marshes upon which they stage.

(a) *Numbers of waterfowl*: The 1,600 acre John Lusby salt marsh near Amherst has recorded the following numbers of waterfowl during spring migrations:

Canada geese - 2,500 to 6,000
Black ducks - 600
Green-winged teal - 235
Pintail - 100
Blue-winged teal - 20 to 7,000

As these counts are for peak numbers, with no consideration given to movement through the area, the maximum number of waterfowl using the area during migration could be much larger.

(b) *Food*: Canada geese were found to be eating mainly the leaves of *Puccinellia maritima* on the salt marsh, in addition to clover and timothy in adjacent upland fields (Van Zoost, 1970).

Black ducks, which arrive shortly after the geese, feed mainly on the snails *Hydrobia minuta* and *Littorina saxatilis*, with seeds of *Spartina alterniflora* and *Atriplex sp*. making up a lesser part of their diet. The late-arriving dabblers, such as teal and widgeon, use *Atriplex* seeds and invertebrates of the shallow saline ponds in their diet.

(c) Problems: The relative isolation of large salt marshes greatly reduces human disturbance and serious predation by other animals. The major problem is a prolonged or renewed winter with late ice-out. Such was the case in 1972, when deep snow covered the upland fields and the salt marshes were not cleared of snow and ice until April 15, some three weeks after the geese had returned. Under these conditions, a few geese died. But the most detrimental factor may have been the overall poor physical condition of many others, which may have prevented or greatly reduced the degree of reproduction that year. The black ducks feeding mainly on snails in tidal creeks appeared to show no ill effects of the late ice-out.

2. Breeding and brood rearing: Due to the tidal nature of the salt marshes and resulting water level variations, no waterfowl can actually nest on our salt marshes. For example, approximately 35 days elapse from the start of egg laying to successful hatching of a black duck nest, during which the marsh would be flooded for at least one four-day period. However, the saline ponds and tidal creeks do provide pairing areas for many species of waterfowl. The paired birds resulting from such courtship activity move inland to nest. Black ducks do use our salt marshes as brood rearing habitats. They nest on adjacent upland and move their young to the salt marshes at ages varying from one day to six weeks.

(a) Numbers: Brood use of free salt marshes is low in comparison to fertile fresh marsh, but the vast expanse of the salt areas in Yarmouth County make it an important production zone. MacInnis (1974) found 0.22 and 0.16 broods of black ducks per four hectares of salt marsh in his two-year study.

(b) Food: Young black ducks up to six weeks of age remain largely in the saline pools of the *Spartina patens* zone, feeding on invertebrates and *Ruppia* (Reed, 1970). They later move further into the tidal zone, where they feed on marine snails and seeds of *S. alterniflora* and *Atriplex*.

(c) Problems: One of the problems associated with the use of salt marshes as brood rearing areas is the mortality of ducklings during movement from the upland nesting site to the salt marshes. This problem is accentuated where major highways and railways pass between the upland site and the marsh. In addition, losses due to exhaustion and predation are related to the distance travelled from the nest to the rearing marsh.

Another problem, which is normally uncommon in Nova Scotia, is drought. Usually rainfall keeps the saline ponds full during the period between monthly high tides. However, the extreme conditions of the summer of 1975 created some serious problems in our salt marshes. As the small saline ponds dried up, the ducklings were concentrated on the few remaining pools, which led to increased predation by fox and raccoon. In at least one case, all water on a marsh disappeared and half-grown black ducks were found dead from what appeared to be starvation and dehydration.

3. Post breeding moult: All waterfowl go through an annual moult wherein they replace wing feathers and are, for a time, without the power of flight. Salt marshes are sometimes used for moulting areas. Sixty black ducks and 100 green-winged teal have been observed on the John Lusby marsh, while Fred Payne has reported flocks in excess of 300 black ducks, both males and females, in the Minas Basin. The attractiveness of salt marshes and shallow bays for moulting ducks is their isolation and visibility, which reduces predation.

4. Staging and migration: The next period of waterfowl usage of salt marshes is from August through November. Staging refers to the buildup of locally-produced ducks prior to their southward migration. Broods of black ducks, green-wings, blue-wings and pintails raised on inland fresh marshes fly to our coasts and merge into flocks prior to migration. Here they feed on the abundant invertebrate life of the intertidal zone, developing fat muscle tissue prior to migration.

Beginning in September and extending through November, northern produced geese, blacks and green-winged teal migrate through Nova Scotia, using our salt marshes as feeding and resting areas. The geese feed mainly on eelgrass on exposed flats, but frequently fly inland to feed on agricultural grain, peas and corn. Blacks, which are more carnivorous than most ducks, feed on snails and some S. alterniflora, while the teal and other dabblers feed on the seeds of Atriplex and Ruppia. Once again, the relative isolation and inaccessibility of the salt marsh stands the waterfowl in good stead by protecting them from heavy hunting activity.

5. Over-wintering populations: It is not entirely true that waterfowl fly north for the summer and south for the winter. Some of our black ducks have lateral migrations, meaning that they spend the summers inland and the winters on our coasts. The main species which winter in Nova Scotian salt marshes are Canada geese, black ducks, goldeneye and scaup. The numbers of Canada geese and black ducks vary with the severity of the winter. Numbers approaching 10,000 and 20,000 have been noted in mild, open winters. In harsh winters, the numbers are lower as more birds continue on down the Atlantic coast.

(a) Food: Canada geese rely heavily on eelgrass, while black ducks eat snails of the genus Littorina (Martel, 1969).

(b) Problems: The major problem of over-wintering waterfowl in Nova Scotia is the severity of some winters. As previously stated, this usually only forces the birds further south, but a sudden, severe, cold snap which forces the birds to huddle and not feed can sometimes be prolonged to the point where food becomes unattainable, and the birds can no longer migrate. Such was the case in the early 1960's, when an estimated 10,000 black ducks died due to a prolonged freeze-up of their wintering marshes in New Jersey.

SUMMARY

While of limited importance to actual production, salt marshes are closely associated with almost every other phase of our waterfowl's annual cycle. Without adequate protein obtained from marine invertebrates in the spring, a female black duck could not produce a large clutch of eggs. Just as important is winter habitat, which carries the birds over to start a new reproductive cycle. The U.S. Bureau of Sport Fisheries and Wildlife now has a program to buy any available salt marsh important to wintering waterfowl, to protect it against alternative land uses. I am sure that our Federal and Provincial governments also realize the value of our salt marshes to waterfowl and marine fisheries and will move to acquire or protect by legislation these valuable wetlands.

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GENERAL CONCLUSIONS AND RECOMMENDATIONS

GENERAL CONCLUSIONS AND RECOMMENDATIONS

From the management point of view, the most important conclusions emerging from the meetings were the following:

1. There are three major marsh types in Nova Scotia.

Fundy Marshes are restricted to approximately the upper one-third of the intertidal zone. The predominant angiosperms are *Spartina alterniflora*, *S. patens*, *Puccinnellia maritima*, *Juncus gerardii* and *Distichlis spicata*. The substrate consists almost entirely of fine silt with relatively little organic matter. Because of their relatively high location, most of the dead vegetation is not exported, or is exported either to deep waters during strong spring tides or landward on ice rafts, rather than being utilized by marine organisms locally. Most of the dykelands have been reclaimed from this type of marsh. The majority of participants in the seminars felt that such reclamation probably had involved relatively little interference in marine food chains because of the high marsh nature of the reclaimed lands, and because of the general low density of marine invertebrates in these marshes.

The Atlantic Marshes are limited in lateral extent, are characterized by low marsh vegetation, and appear to be just keeping pace with sea-level rise, which is maximal on the Atlantic coast. Soils are peaty-mineral types with a large sand component. Sessile invertebrates, such as the edible clam and the common mussel, are common. These marshes are important components of marine food chains in regions such as Petpeswick Inlet. Because of their limited extent and generally fragile nature, intensive activities of any sort should be avoided in the marshes of the Atlantic coast.

Northumberland Strait Marshes are more similar to the marshes of the eastern seaboard of the U.S., than are the Fundy or Atlantic marshes, and experience the highest water temperatures. Sessile invertebrates, such as oysters and the common mussel, inhabit the marsh channels in large numbers. Ribbed mussels and ear shells occur on the marsh surface. Spartina alterniflora and Spartina patens are the dominant salt grass species. Soils include a large peat component. Angiosperms, mummichogs and killifish (small fish species) are abundant in the channels and salt pannes, and various larger estuarine species move into the marsh on high tides to feed on them. Carnivorous birds also utilize this small fish production. Of the three marsh types, the Northumberland marshes are the most productive in the marine zone — a function which should be protected. It might be enhanced through aquaculture.

2. Mr. Hilchey reported that all marsh land that could be profitably used in agriculture is already dyked; thus no more pristine marsh land will be lost through further dyking. Of the 43,000 acres of dyked agricultural land, about 10,000 acres in the lowest lying regions might better be used for waterfowl management, flooded for wild rice production or left to revert to a pristine state. The other 33,000 acres, all in the Fundy-Minas Basin region, constitute, potentially at least, the most valuable farmland in Nova Scotia because of its high natural fertility. Good drainage is essential for agricultural use of the dyked lands. Concern was expressed that Fundy power projects might interfere with this drainage.

3. At present there is not an adequate data base for formulating an effective, comprehensive salt marsh management policy. The marshes in the province have not yet been listed or categorized. There is, however, evidence that some of these marshes play important roles in estuarine food

chains. Legislation protecting the undyked marshes is urgently required. Research and description of salt marshes should emphasize spatial variation (i.e., how one marsh differs from another), rather than concentrating on process studies at a single site.

The immediate priorities are:

(a) to classify and make inventory of all natural and dyked salt marsh land in Nova Scotia;

(b) to assess the "importance value" and "best usage" of this land based on indicator parameters such as:

1. water temperature and salinity,
2. flooding frequency and turbidity of flooding water,
3. soil type,
4. angiosperm zonation,
5. standing dead biomass in fall and spring,
6. occurrence of pannes and pools,
7. species lists.

If a comprehensive classification scheme is adopted, the information can be collected in a short time with minimal expense. With this data base, the importance of salt marshes can be assessed, and policy statements with respect to land management can be formulated. As the evidence stands at present, no alternative seems to outweigh the value of the non-dyked marshes being left in their pristine state.