Geoscience Canada

Coastal Studies in James Bay, Ontario

I. P. Martini, R. I. G. Morrison, W. A. Glooschenko and R. Protz

Volume 7, Number 1, March 1980

URI: https://id.erudit.org/iderudit/geocan7_1art02

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Publisher(s)

The Geological Association of Canada

ISSN

0315-0941 (print)
1911-4850 (digital)

Explore this journal

Cite this article

Martini, I. P., Morrison, R. I. G., Glooschenko, W. A. & Protz, R. (1980). Coastal Studies in James Bay, Ontario. *Geoscience Canada*, *7*(1), 11–21.

Article abstract

Interdisciplinary studies have endeavoured to understand the geomorphology, sediments, soils, vegetation, and wildlife of the Ontario coast of James Bay, which is unique for its fast emergence (70 to 100 cm/century) related to post-glacial isosta-tic rebound. From a geomorphological-sedimentological point of view, the coast has many similarities to other mesotidal settings, although typical features due to ice-rafting and scouring of arctic and subarctic areas are recorded in thin (3 m) sedimentary sequences. Gleysolic soils form in its low-lying wetlands, and Regosolic soils evolve into Podzolic soils on sandy and gravelly beach ridges as they emerge and become forested.

The vegetation of the marshes is typical of subarctic areas. The most common colonizing plants of intertidal zones are Puccinellia phryganodes in salt marshes, and Hippurus vulgaris in brackish marshes. Associated with large rivers, inverted marshes occur with brackish zones near the shoreline, and saltier zones inland due to evaporation of waters brought in by storm surges. The fauna of this coast ranges from numerous mosquitoes and other insects, to invertebrates, to migratory birds. The shore has irreplaceable international importance because it contains the breeding and feeding grounds of the migratory avifauna of central and eastern America. Tens of thousands of shorebirds and waterfowl feed on specific parts of the ecosystem depending on their food requirements and their anatomical limitations imposed by depth of burrowing of infauna, depth of water in marsh pools, and height of vegetation indifferent marshes at different times of the year.

Whereas studies of this virgin, rapidly changing environment can help in understanding and perhaps managing the wildlife resource, and in predicting the response of the coastal zone to future human activities, such as regulation and diversion of rivers, all these processes leave their imprints in the sedimentary and soil sequences. In sedimentological terms the study of this coast will lead to a definition of a recognizable model of a cold, brackish, shallow, regressive, inland sea similar to those that have occupied this area during Pleistocene times, or other more ancient, emergent, glacial, arctic basins.

Coastal Studies in James Bay, Ontario

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Abstract
Interdisciplinary studies have endeavoured to understand the geomorphology, sediments, soils, vegetation, and wildlife of the Ontario coast of James Bay, which is unique for its fast emergence (70 to 100 cm/century) related to post-glacial isostatic rebound. From a geomorphological-sedimentological point of view, the coast has many similarities to other mesotidal settings, although typical features due to ice-rafting and scouring of arctic and subarctic areas are recorded in thin (3 m) sedimentary sequences. Gleysolic soils form in its low-lying wetlands, and Regosolic soils evolve into Podzolic soils on sandy and gravelly beach ridges as they emerge and become forested.

The vegetation of the marshes is typical of subarctic areas. The most common colonizing plants of intertidal zones are *Puccinellia phryganodes* in salt marshes, and *Hippurus vulgaris* in brackish marshes. Associated with large rivers, inverted marshes occur with brackish zones near the shoreline, and saltier zones inland due to evaporation of waters brought in by storm surges. The fauna of this coast ranges from numerous mosquitoes and other insects, to invertebrates, to migratory birds. The shore has irreplaceable international importance because it contains the breeding and feeding grounds of the migratory avifauna of central and eastern America. Tens of thousands of shorebirds and waterfowl feed on specific parts of the ecosystem depending on their food requirements and their anatomical limitations imposed by depth of burrowing of infauna, depth of water in marsh pools, and height of vegetation in different marshes at different times of the year.

Whereas studies of this virgin, rapidly changing environment can help in understanding and perhaps managing the wildlife resource, and in predicting the response of the coastal zone to future human activities, such as regulation and diversion of rivers, all these processes leave their imprints in the sedimentary and soil sequences. In sedimentological terms the study of this coast will lead to a definition of a recognizable model of a cold, brackish, shallow, regressive, inland sea similar to those that have occupied this area during Pleistocene times, or other more ancient, emergent, glacial, arctic basins.

Introduction
In order to foresee and plan for future changes in natural environments, as well as to recognize their occurrences in ancient deposits, we need to know the physico-chemical and biological features that characterize those environments, and the processes that mold them.

The emerging western coast of James Bay and Hudson Bay has been selected for a multidisciplinary study which includes four major components (Figs. 1, 2): 1) analysis of the origin and distribution of coastal sediments, 2) study of the formation of soils in the raised coastal areas, 3) study of vegetation that colonizes intertidal and supratidal zones, 4) evaluation of the use (breeding and feeding) that wildlife, particularly shorebirds, makes of various coastal settings (Glooschenko and Martini, 1978). This paper integrates general aspects of research being conducted along the Ontario coast of James Bay (Fig. 1).

Methods
The coast was subjected to a rapid survey, and representative transects (approximately one every 5 to 25 km) were studied in detail from the low tide mark to upper parts of marshes. The transects were surveyed, and sediments, soils, intertidal infauna, and vegetation were collected in a stratified fashion at intervals, ranging from 400 metres in wide homogeneous zones, to 10 metres for rapidly changing vegetated reaches.

Sediment samples were collected with Senckenberg boxes and from shallow pits (Bouma, 1969). Bulk samples for textural and chemical analysis were taken, and peels and in-situ samples were utilized for study of sedimentary structures, micromorphology and soil characterization. Laboratory analysis of sediments and soils included determinations of grain size (methodology after McKeague, 1976, and for selected samples methodology after Folk, 1974), shape, mineralogy of sand grains and pebbles, x-ray determination of clay mineralogy (Black, 1965); pH, electrical conductivity, NH_4-oxalate extractable Fe and Al, Na-pyrophosphate extractable Fe and Al, organic matter, and calcium carbonate equivalent (McKeague, 1976).

The vegetation was described utilizing one metre square quadrats and recording the percentage cover of different plant species according to the method of Braun-Blanquet (1932).

Intertidal zones were sampled for infauna by taking 3 cores per site, 15 cm deep and 11 cm in diameter, and washing and sieving through a 500 μm screen. Samples were preserved in 70 per cent ethanol and returned to the laboratory for sorting, identification, counting and measurement of both living organisms and residual shells.

Seasonal abundance of surface-active insects was investigated in vegetated areas of the marsh at North Point (NP) during the period 1976-1978 by placing pitfall traps at stations located in various distinct vegetational zones of the marsh (Fig. 1). Samples were collected on a weekly basis from late May to early September.

Positions of birds were recorded where they occurred on surveyed transects, along with notes on their behaviour and activities, such as feeding and resting. Further information on habitat use was gained through shorebirds censuses on as many adjacent parts of the marsh and flats as possible with similar vegetational or sedimentological zonation. Food resources used by birds were determined by direct observation and collection of specimens where appropriate. Aerial surveys were carried out to determine the distribution of shorebirds using a helicopter flying at an altitude of 120 feet above sea level.

Environmental Conditions
Physiography. The landscape of western James Bay is comprised of:
1) A coast that is characterized by a uniform, gentle offshore slope of approximately 0.5 m/km. It bounds a shallow brackish inland sea that is covered by ice for approximately six months of the year.
2) Wide bays, particularly in the southern part, which receive large amounts of fresh water from rivers such as the Albany, Moose and Harricanaw (HA) (Fig. 1).
3) Wide, low promontories that expose Paleozoic carbonate bedrock, tills, or accumulations of erratics or ice rafted boulders (Sanford *et al.*, 1968). Erosional (half-heart bays) and depositional (spits)

landforms develop on their southern downdrift sides (Martini and Protz, 1978).
4) Narrow promontories that extend several kilometres on the shallow shelf and may develop transverse ridges, some of which have seaward bifurcations (Martini *et al.*, 1980).
5) Sequences of beach ridges and spits that develop parallel to the main coast. They contain sandy fine gravels (Martini and Protz, 1978).
6) Wide sand flats.
7) An inland area where low coastal features have been obscured by growth of vegetation and development of wide wetlands. Features such as old promontory complexes, raised longitudinal beach ridges, and chevron ridges. The latter is a landform characterized by a combination of transverse and longitudinal ridges (King, 1972) and remains recognizable because it supports well-developed coniferous forests (Martini and Protz, 1978; Martini *et al.*, 1980).

Predominant Processes. The coastal environments and materials are acted upon by:
1) Glacial rebound of the land that began approximately 7000 years ago at about 3 m/century and still continues at a rate of approximately 70-100 cm/century (Barnett, 1966).
2) Marine semi-diurnal tides that generally have a low range (0.7-1.5 m), reaching a maximum of 3 m at some localities. The tidal waters carry much silt and clay in suspension (Martini *et al.*, 1979).
3) Large waves which are generated in the open bay during storms, can occasionally sweep tidal flats and rework sand and pebbles onto beach ridges. On the whole, this coast is considered a low energy shore, because of the rarity of large storms and the dampening effect the shallow offshore area has on open sea waves.
4) A slow (0.8 m/sec maximum recorded) marine current moves generally in a counterclockwise direction (Martini *et al.*, 1979). In straits and bays, local currents and gyres develop, which re-distribute and trap fine sediments.
5) Sea ice covers and protects the coast for approximately six months of the year. However, ice floes raft much material along tidal flats and push and scour sediments.
6) Wind may rework sediments of the upper parts of tidal flats and beach ridges locally and for short periods of time. Blowouts and foredunes occur on coasts of the tundra zone south of Cape Henrietta Maria (Fig. 1).
7) Cold climate (Dfe in the Köppen system) sustains intense freeze-thaw processes especially for susceptible bedded rocks such as limestones and dolostones. No permafrost and permafrost features are recognizable near the coast. Frozen ground is found during summer, only inland in northern parts of James Bay, where the ground bearing fresh water is insulated by a cover of bog vegetation and peat.
8) The physical and biochemical action of organisms in tidal flats and inland areas, combined with chemical weathering, modify the primary characteristics of upper parts of the deposits and a variety of soils develop.

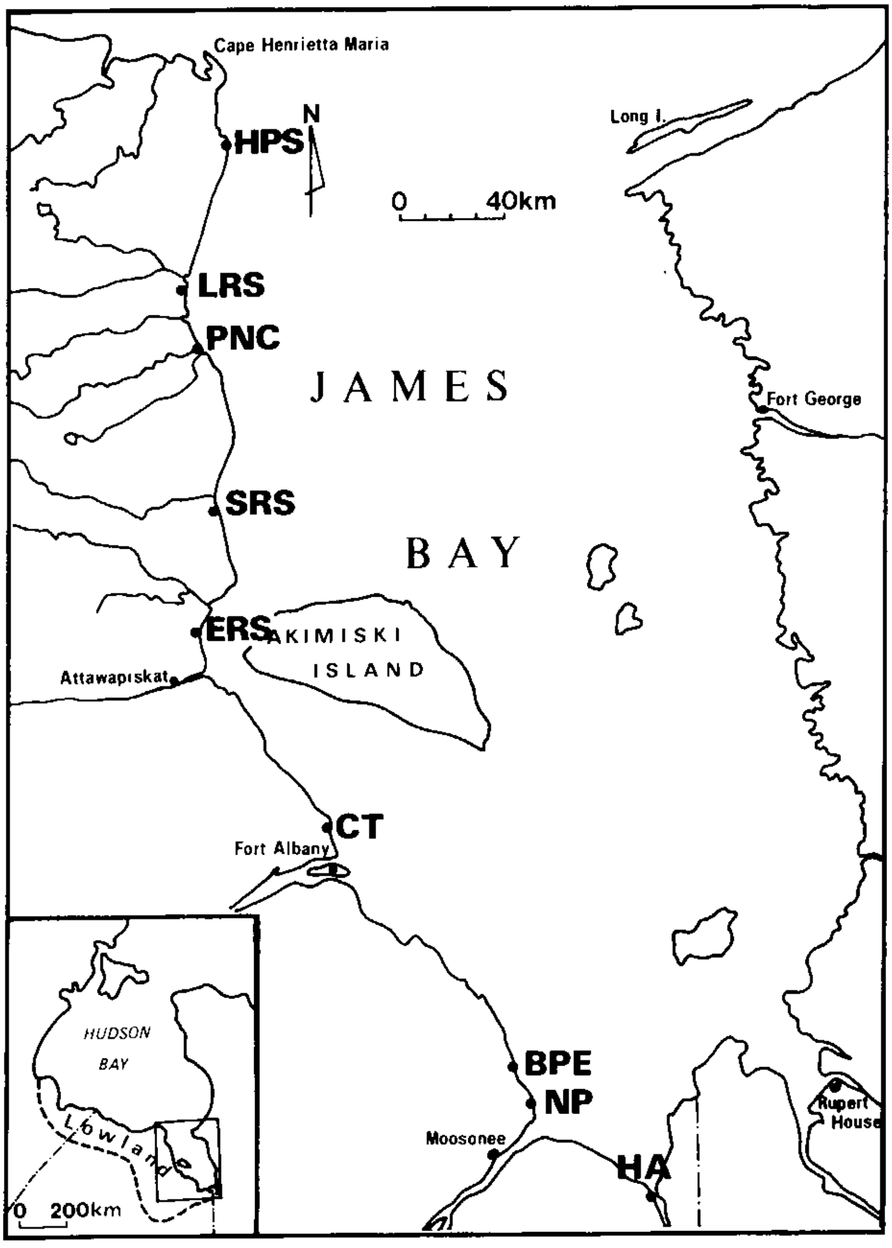


Figure 1
Location map. Symbols indicate coastal transects mentioned in the text, such as BPE stands for Big Piskwanish East.

Recent Environments with Emphasis on the Coast at Big Piskwanish East (BPE)

Sediments. The interaction between landscape and processes generates a variety of sedimentary deposits which singly are not unique to James Bay, but whose associations characterize regressive coastal sequences of cold, tidal, inland seas. The sedimentary deposits vary from bouldery and pebbly accumulations piled up as beach ridges near promontories to thick silty accumulations that develop in poorly drained tidal flats and marshes associated with large rivers. Between these two extremes, particularly in southern parts of James Bay, wide sand flats evolve in protected areas, typically in northern updrift sides of long, narrow promontories, and on those coasts whose orientation prevents breaking of storm waves directly onshore. Those tidal flats have thick sedimentary sequences (2-3 m) and they may develop sand undulations (sand ridges) in their intertidal zone to adjust the slope to the prevailing wave conditions (Martini and Protz, 1978). Most sandy flats have wide coastal marshes.

The tidal flat of Big Piskwanish East (BPE) is taken as a representative example (Figs. 1, 3). The sand flat shows a shoreward fining in particle size (Fig. 4). Vertical profiles have alternating sandy and silty accumulations with occasional poorly developed upward coarsening in grain size (Fig. 5, profile 1). In high tidal flats and marshes the trend is of a well developed fining upward in grain size (Fig. 5, profiles 3, 4). Very little coarse material is present in recent sediments, except for local, rare lenses of ice-rafted pebbles. Till forms the substratum of this coast.

The suite of sedimentary structures of the sand flat is characterized by alternating massive silts and sandy cosets of flood-dominated ripple cross-laminations, seldom showing reversal and herringbone characters (Fig. 6, profiles 1, 2). Low angle, shoreward inclined laminations are seldom present, and possibly they are associated with very shallow inter-tidal sand ridges. Plane beds are rare, and they are formed primarily by wind-driven sheet flows at ebb tide. The lowermost part of the sand flat is bioturbated by burrows of *Macoma balthica* and roots of *Zostera marina* (Fig. 6, profile 1). Burrowing decreases markedly in middle parts of the flat; and in the upper parts sediments are colonized by algae and marsh plants. In the marshes, the sedimentary structures vary from well developed thin silty algal laminations in open ponds and evaporation pans, to a typical alternation of organic rich lensing laminae and silty organic-poor thin beds related to storm deposits (Fig. 6, profile 4).

Soils. As coastal sediments are slowly uplifted above sea level, they are progressively modified through pedogenesis. Regosols characterize sand and gravel beaches, and Gleysols form in marshes (Canada Soil Survey Committee, 1978). Initially the soil colors are black (2.5Y 2/0) due to the reduced state of the materials under salt water conditions. In upper, fresher parts of the marshes the soils become better drained and incipient B horizons with grayish brown colors (2.5Y 5/2) are recognizable.

Major processes active in the coastal Gleysolic soils of James Bay are:
1) progressive oxidation of upper parts of the profile and mobilization of iron and aluminum oxides (Figs. 4, 5); 2) a gradual accumulation of organic matter and formation of an Of horizon (Figs. 5, 6);
3) a fairly rapid removal of sodium and chloride from the soil profile with an associated drop in electrical conductivity; and 4) obliteration of sedimentary structures through pedoturbation (Fig. 5). Most of these trends are well defined in the transect of big Piskwanish East. The soils deviate from the general trend for the electrical conductivity, and have local high values probably related to evaporation pans (Fig. 5, profile 4). Accumulations of extractable iron and aluminum in the solum correspond to the normal pedogenic processes. High Fe and Al values measured in profiles of the lower tidal flats are probably associated with concentrations of seaweeds in some fine grained layers (Fig. 1, profile 1). The nearly complete obliteration of primary sedimentary structures and formation of embryonic soil horizonations develop in uppermost parts of the marshes (Fig. 6).

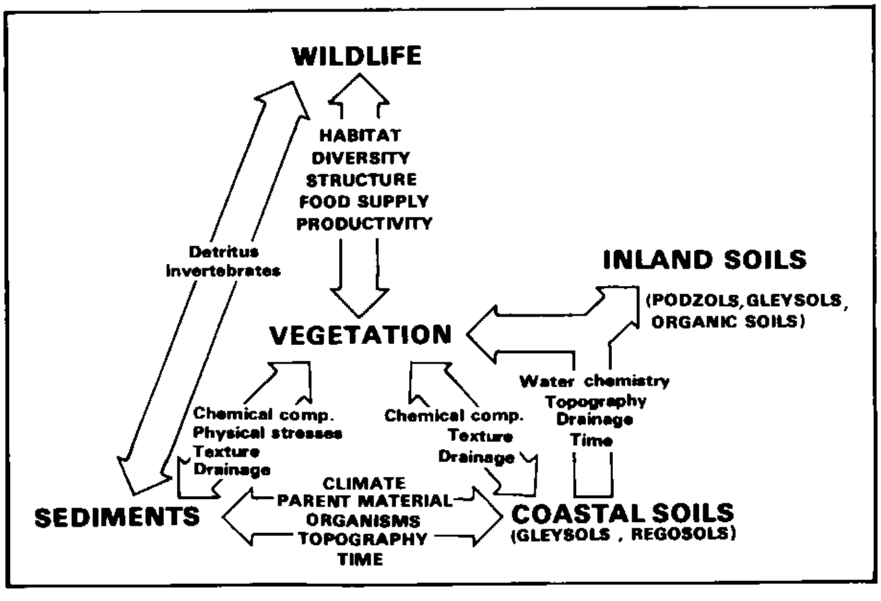


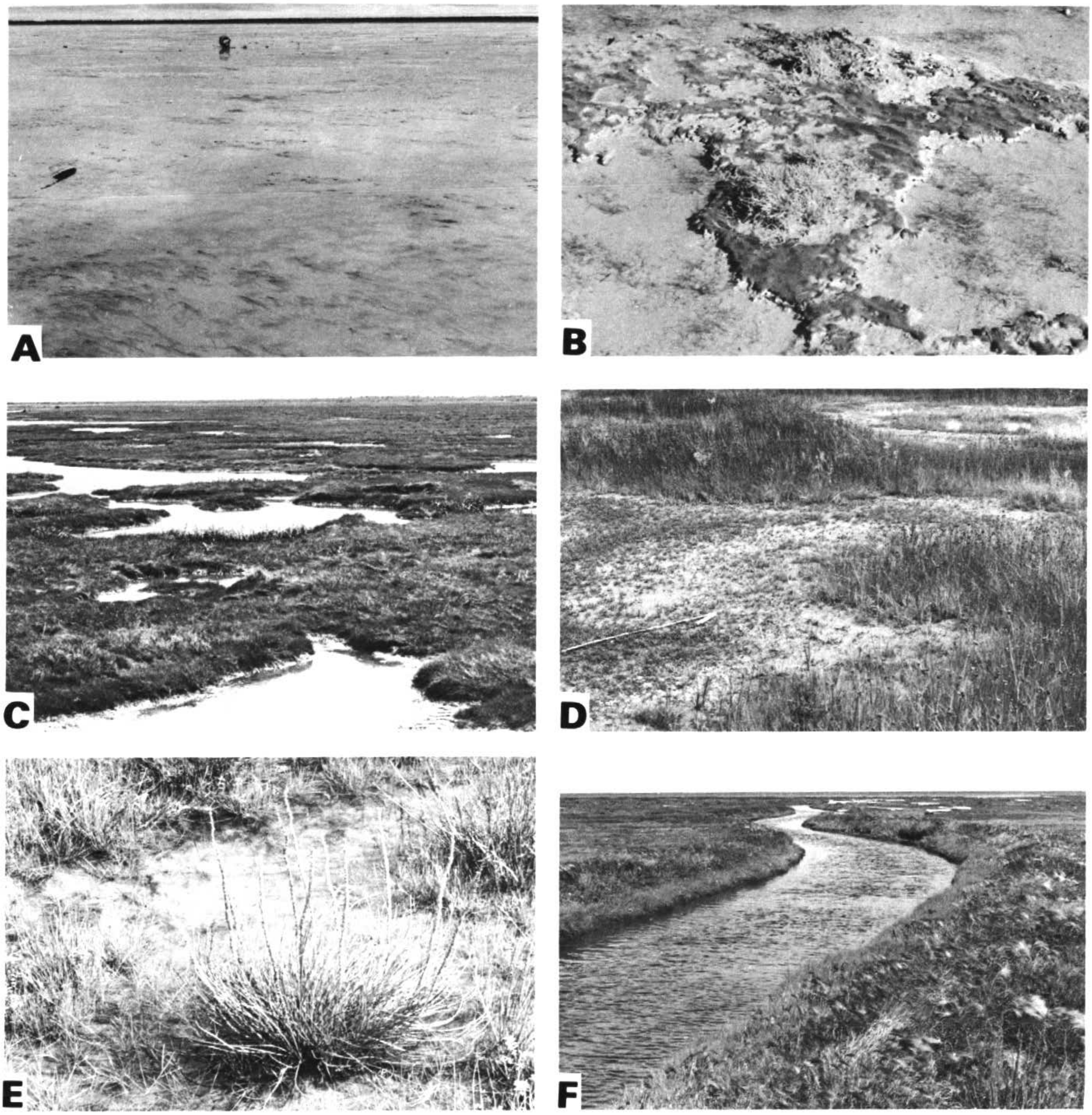
Figure 2
Components of the James Bay multidisciplinary study.

Vegetation. The salt marsh vegetation of the James Bay coast is similar to that of northern temperate, subarctic, and arctic salt marshes of Alaska, the Canadian Arctic, Greenland, the northern British Isles, Scandinavia and Russia. Few vegetation similarities are found with the Atlantic and British Columbia marshes of Canada (Chapman, 1960). This is most likely due to the climate of the region; in James Bay certain species reach the northern part of their geographic range, while other arctic species reach their southern limits.

An important control of vegetation in these salt marshes is the salinity regime. The nearshore water salinities of James Bay are brackish, owing to fluvial waters which stay near the shore as a result of the circulation patterns in the bay. However, soil salinities in the marsh can be elevated by evaporation, leading to the presence of true salt marsh vegetation. A phenomenon that occurs locally is that of "inverted" marshes. Near some river mouths, such as the Attawapiskat and Harricanaw Rivers (Fig. 1), the first plants that grow are typical freshwater species. At slightly higher elevations, "brackish" species occur followed by true salt marsh plants. This implies a salinity maximum inland related to brackish waters carried on elevated areas by storm surges. Such waters trapped by poor drainage evaporate in situ, leading to higher soil salinities, while soils closer to the shore are subjected to freshening by daily tidal inundations. This phenomenon is unusual and found in very few areas of the world including South America and upper parts of San Francisco Bay (West, 1977).

The vegetation of the salt marsh at Big Piskwanish East (BPE) is characterized by four major plant communites: 1) The Salt Marsh, 2) a narrow Saline Meadow Marsh, 3) a Brackish Meadow Marsh, and 4) a Willow Thicket Freshwater Fen/Marsh which marks the start of a freshwater wetland ecosystem (Fig. 3, 7).

1) The Salt Marsh consists of four zones. The first of these is the colonization zone. Here, vegetation is sparse, in part due to disruption by ice scouring and ice rafting during spring breakup (Glooschenko and



Figue 3
Views on most important features of the coast at Big Piskwanish East (BPE). A. Lower part of Sand Flat (note crouching man for scale); B. High Tidal Flat-Lower Marsh: sediments trapped by algal mat and colonized by a clump of Puccinellia phryganodes; *C. Lower Marsh with mats of* Puccinellia phryganodes; *D. Upper Marsh with pan vegetated by* Salicornia europea; *E.* Triglochin maritima; *F. Freshwater, spring-fed creek that crosses and drains marsh. Note concentrations of* Hordeum jubatum *on banks.*

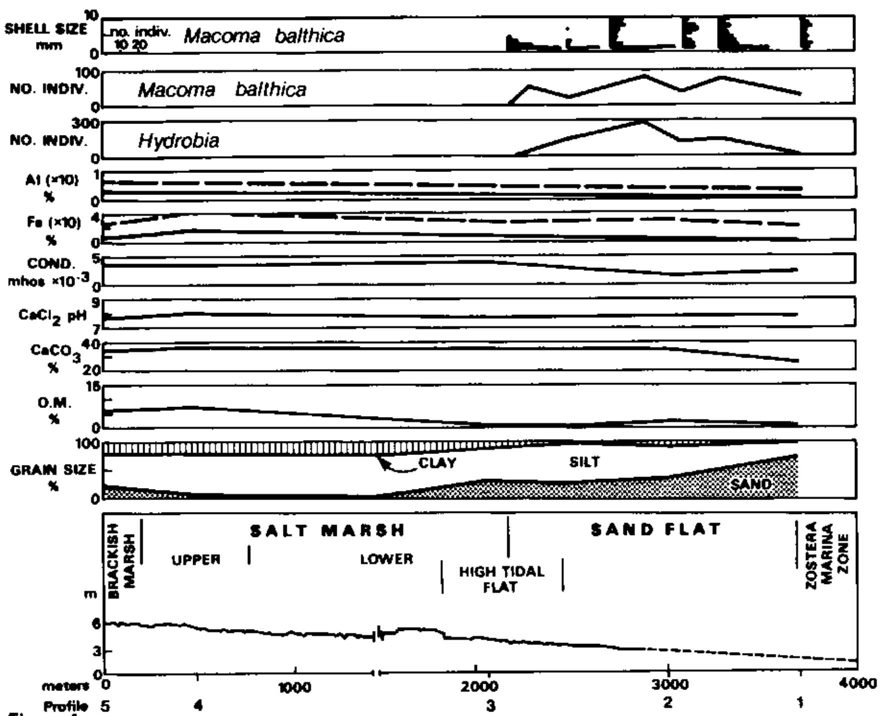


Figure 4
Lateral variations in environmental parameters measured on surface samples of BPE transect. Dashed lines indicate iron and aluminum values obtained from NH_4- oxalate extract, solid lines indicate values from Na- pyrophosphate extract. Mollusk frequencies of occurrences are for three cores per site. Dashed line on coastal profile indicates a paced zone.

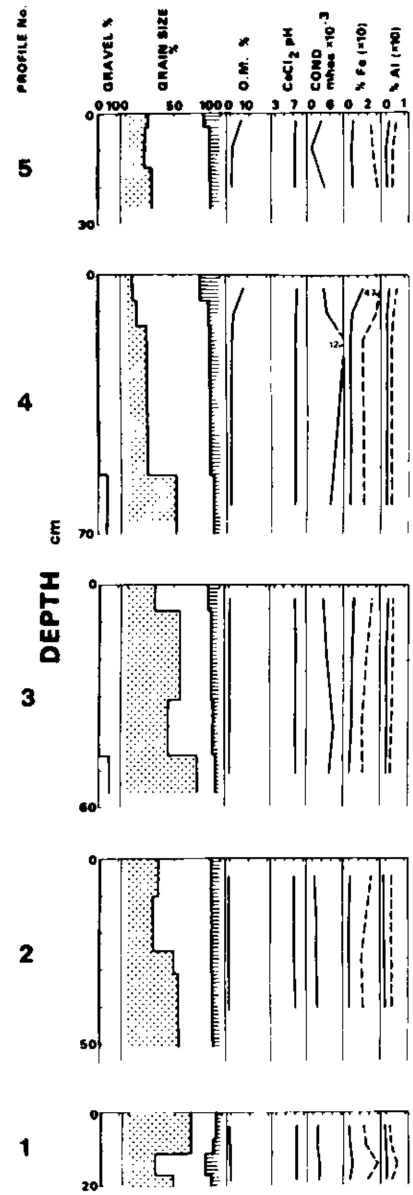


Figure 5
Vertical variations of measured variables in selected profiles of the BPE transect. For location of profiles and symbols see Figure 4.

Martini, 1978). Blue-green algal mats, diatoms, and clumps of small succulent forbs and the grass *Puccinellia phryganodes* characterize the colonization zone (Fig. 3B). This grass is the dominant colonization plant of subarctic and arctic salt marshes on a circupolar basis, locally forming extensive turfs. Its rhizomes serve as a major food source for geese.

The second zone of the Salt Marsh is the *Puccinellia phryganodes*/Forb zone (Figs. 3C, 7). It occurs on a slightly more elevated area landward of the ice-foot zone, where plants can root in more stable sedimentary conditions and grows intensively forming a turf-like carpet. Other plants are found which also occur throughout other parts of the salt marsh, including the forb *Poetentilla egedii*, the grass *Puccinellia lucida* and the sedge *Carex subspathacea*, a plant which forms more extensive turfs in the lower salt marsh zones of more northerly James Bay localities (Figs. 7, 8). This zone gives way to a broad area, the Lower Salt Marsh/Pan Zone. The vegetational composition here is basically similar to the previous zone; however, the area is somewhat lower in elevation, allowing tidal waters to collect in depressions where, through evaporation, soil salinities become elevated to the point where only the extremely salt-tolerant plant *Salicornia europaea* can grow (Fig. 3D). Such soil salinities may be 2 to 6 times higher than those in surrounding areas of slightly higher elevation where better drainage occurs. Another feature found in parts of this zone are shallow brackish ponds where the sedge *Scirpus maritimus* is associated with the grass *Puccinellia lucida*.

Landward of this zone is the Upper Salt Marsh Zone. Here, tidal inundation is less frequent and soil salinities are approximately one-half or one-third of those in lower portions of the marsh. Several species of plants disappear, while new species such as *Senecio congestus* occur. *Senecio* is a large yellow-flowered forb and is a good indicator of the upper limits of the salt marsh. The small forb, *Ranunculus cymbalaria* is located where shallow standing water is normally found, and *Hordeum jubatum*, a grass, begins (Fig. 3F).

2) The next inland zone still receives tidal inputs, but is better drained and is therefore called Saline Meadow Marsh. The two dominant species are the rush *Juncus balticus*, and the leguminous forb *Lathyrus palustris*. Several other small forbs occur, but are never found in abundance (Fig. 7).

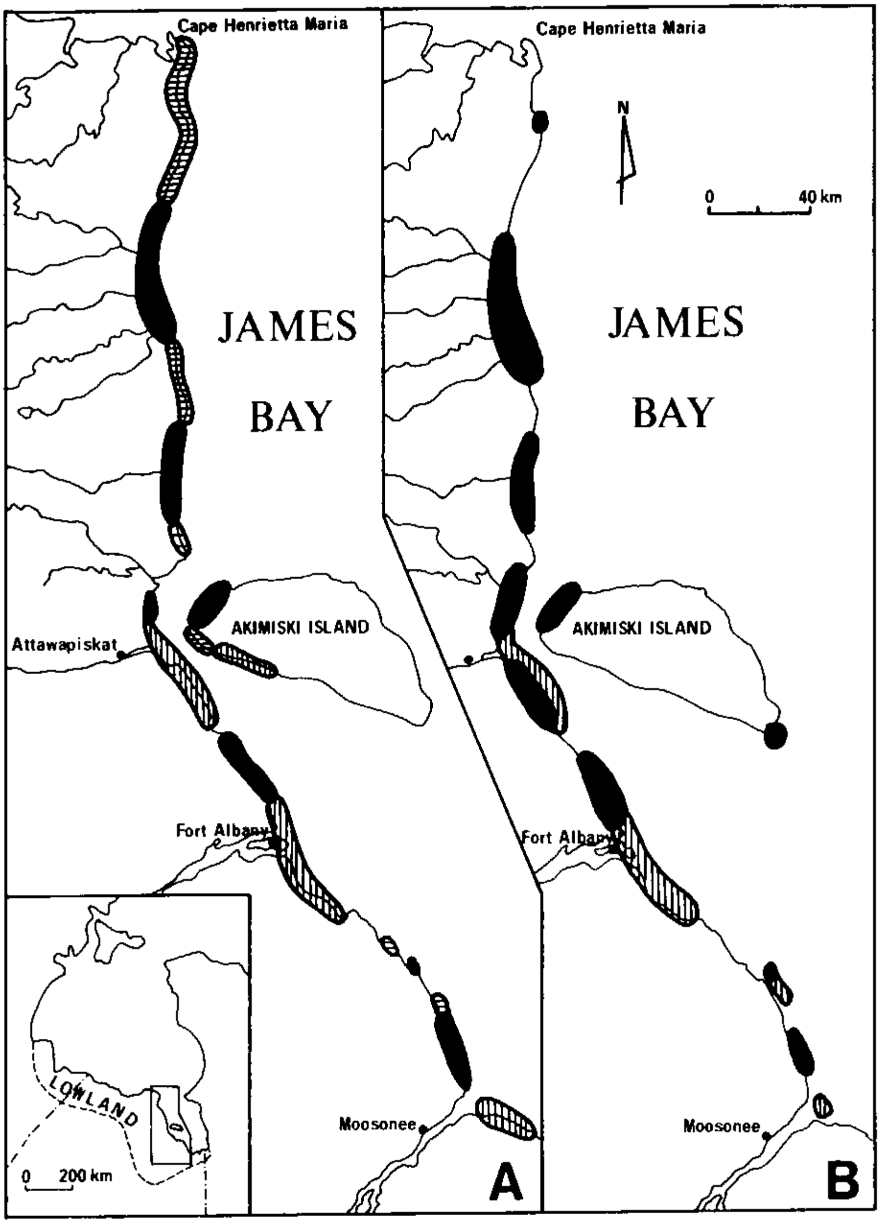


Figure 8
Distribution of marsh and coastal types and fall concentrations of shorebirds and waterfowl on the west coast of James Bay. A. Distribution of marsh types: ▬ *wide coastal marsh with* Puccinellia phryganodes; ▥ *coastal marshes characterized by soft, fine sediments with high water content and plants such as* Hippurus, Eleocharis, Carex; ▤ *High energy coastlines with beach ridges and little marsh development. B. Distribution of critical areas for birds (based on Canada Wildlife Service, 1976);* ▥ *waterfowl;* ▬ *shorebirds and waterfowl.*

piper (*Calidris fuscicollis*), Least Sandpiper (*Calidris minutilla*), Dunlin (*Calidris alpina*), Sanderling (*Calidris alba*), Pectoral Sandpiper (*Calidris melanotos*), Whimbrel (*Numenius phaeopus*), Marbled Godwit (*Limosa fedoa*) and the Common Snipe (*Gallinago gallinago*).

Most species of shorebirds in James Bay favour well-defined zones of the marsh or flats for feeding and roosting, and resource partioning on the basis of habitat or food type or size is apparent throughout the shorebird community (Fig. 9). For instance, *Macoma balthica* is a major food resource for several species utilizing the lower intertidal zone, particularly the Hudsonian Godwit and Red Knot, which prey on medium to large size specimens. Smaller size classes of *Macoma balthica* may be taken by Dunlin, Semipalmated Sandpipers and other small Sandpipers when they use this zone. The gastropod *Hydrobia minuta* is also taken regulary by the small Sandpipers and appears to be favoured by the White-rumped Sandpiper, especially when feeding in rocky intertidal zones. Amphipods are also utilized by various species feeding in rocky areas, such as the Dunlin at North Point (NP) and Hudsonian Godwit on northwest Akimiski Island (Figs. 1, 8). Most Semipalmated Sandpipers feed on the short grass (*Puccinellia phryganodes*) salt marsh, where they prey on dipteran larvae), and 3) at a local level: distribution of Semipalmated Sandpipers across varmated Sandpipers, Lesser Yellowlegs and Ruddy Turnstones, also feed on the swarms of small adult flies inhabiting the short-grass marsh. In central marsh zones, Pectoral Sandpipers and Lesser Yellowlegs are common, the latter feeding on invertebrates of ponds and sometimes on sticklebacks and small fish trapped in pools after tidal inundation.

Shorebirds respond sensitively to the distribution of their food resources at several levels: 1) over a wide geographical area: shorebird numbers observed on aerial surveys are related to food resources as determined at representative transects, 2) over intermediate stretches of coastline (10 to 15 km): distribution of Semipalmated Sandpipers using short-grass saltmarsh habitat is correlated with distribution of food resources (dipteran larvae), and 3), at a local level: distribution of Semipalmated Sandpipers across various zones of the marsh on habitat transects are correlated with distribution of food resources (dipteran larvae). Studies of seasonal abundance of invertebrates indicates that migration of some species is timed to correlate with peak numbers of prey species.

The significance of the food resources to shorebirds in James Bay lies in their use as materials which the birds convert to fat stores, essential as a fuel supply to enable long, non-stop flights over inhospitable "ecological barriers" such as boreal forest to the next migration stopover area. Many shorebirds make a direct flight to the Atlantic seaboard from James Bay, the Hudsonian Godwit probably to South America. While in James Bay, the birds feed intensively, distributing themselves across marsh and intertidal areas at low tide, and gathering to rest together, often in large numbers (a few hundred to several thousand) when feeding areas are unavailable at high tide. The availability of suitable resting areas and the type of vegetation of marshes influence shorebird distribution. Areas in central or inner parts of the marsh used extensively in the spring by short-legged species become unsuitable for use later in the autumn through growth of vegetation, though changing relative abundance of food resources also affects the pattern of habitat use.

Waterfowl. Geese and ducks make heavy use of the James Bay coastal marshes. Canada Geese (*Branta canadensis*) breed in large numbers, though at low densities, in inland marshy areas and are numerous on the coast on migration. Lesser Snow Geese (*Chen caerulescens*) are very abundant on migration and there is an extensive colony of some 50-60,000 pairs west of Cape Henrietta Maria (Figs. 1, 9). This colony is thought to have developed over the past 20-30 years. Brants (*Branta bernicla*) concentrate in areas of the coast where eel grass (*Zostera marina*) is abundant in the low intertidal zone.

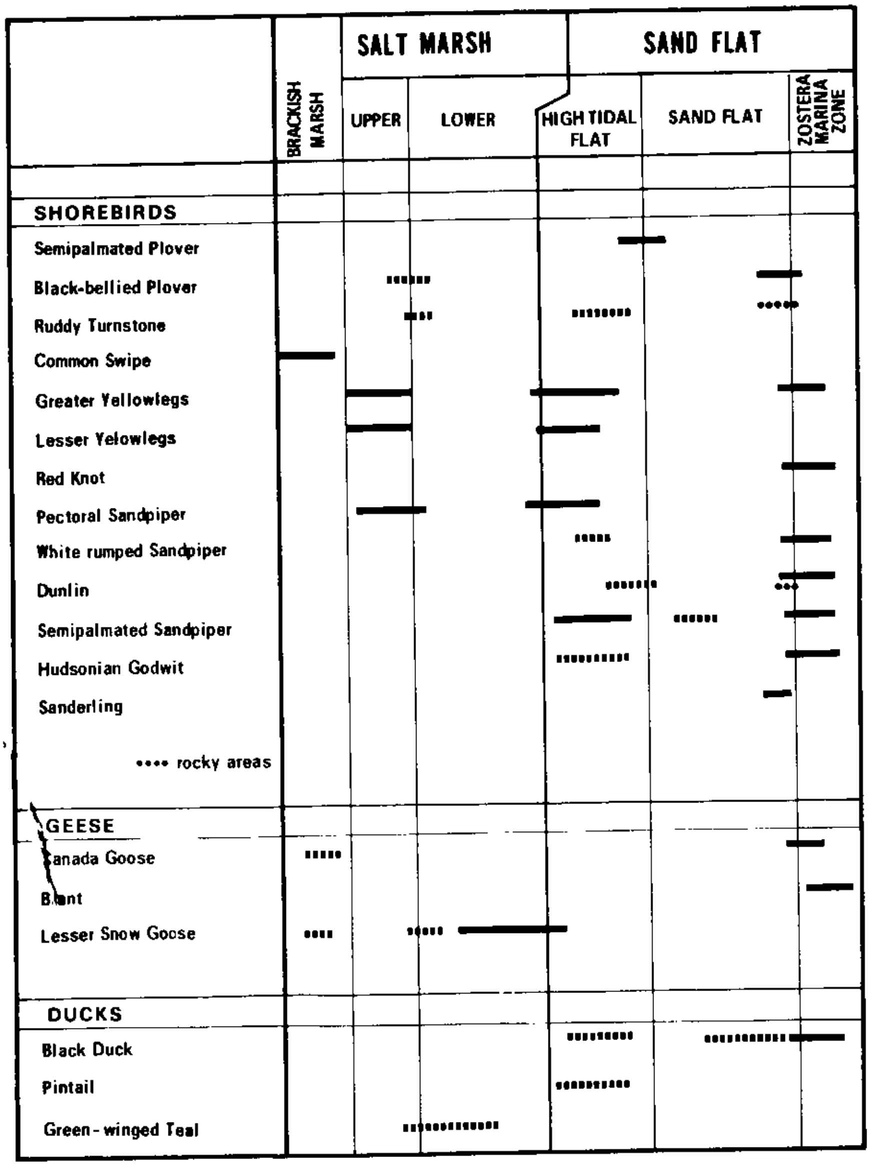


Figure 9
Zones of principal habitat use for selected species of birds, on open coastal marshes and tidal flats such as those of BPE.

Many species of ducks breed in inland areas and occur in large numbers on the coast on migration. Prominent species include Pintail (*Anas acuta*), Black Ducks (*Anas rubripes*), Green-winged Teal (*Anas carolinensis*), Mallard (*Anas platyrhynchos*), Widgeon (*Mareca americana*), and Scaup (*Aythya* sp.). Large rafts of Scoters (mostly Black Scoters *Melanitta vigra)* in flocks of several hundred to several thousand totalling up to about 40,000 birds, are found in the northern part of James Bay from around the Swan River (SRS) to Hook Point (HPS) (Figs. 1, 9). Mergansers (*Mergus* sp.) and loons (*Gavia* sp.) utilize coastal waters for feeding and inland lakes and ponds for breeding.

Geese and ducks prefer those areas in James Bay characterized by wide coastal marshes with an emergent zone of *Puccinellia phryganodes* and a variety of vegetational associations leading to fresh water inland fens (Fig. 9). Fall foods of Lesser Snow Geese in James Bay includes 40 species, of which 9 made up 90 per cent of the food items identified (Prevett *et al.*, 1979). *Triglochin palustris* is the most preferred and consistently selected plant (Fig. 3E). Other important foods are comprised of sedges (Cyperaceae), arrow grasses (Juncaginaceae), horsetails (Equisetaceae) and grasses (Graminae) (Prevett *et al.*, 1979).

The impact of the birds on vegetation and sediments is considerable. Geese feeding on plant shoots in the spring may leave areas of marsh uprooted and churned, and marshes in the Cape Henrietta Maria area are closely cropped to the ground after use by flocks of flightless, moulting geese and their young in the autumn. Feeding behaviour and movements of waterfowl in and out of marsh ponds influence the development of pools, the path and shape of drainage creeks, associated vegetational structure, and thickness and character of marsh sediments.

Summary and Conclusion

- The Ontario coast of James Bay is unique in several repects. It is a rapidly emerging coast of a shallow, inland, cold, mesotidal brackish sea covered for approximately six months of the year by sea ice. It is underlain by either Paleozoic calcareous bedrock, or till, or calcareous clay of the early post-glacial Tyrrell sea.
- Despite these unique conditions, many features observed there are common to other prograding coasts. Wave eroded benches occur on wide promontories where bedrock and till are exposed.

Sand and silt sedimentation occurs in bays and other protected areas. The sedimentary sequences show well-defined fining landward trends in grain size, and well developed fining upward variation in size in high tidal flats and marshes. Common sedimentary structures consist of ripple marks, alternating occasionally with plane laminations in tidal flat deposits; cross-beds separated by erosional reactivation surfaces in beach ridges; and lensing marsh laminations characterized by an alternation of organic-rich and organic-poor, storm-generated silt layers.
Sedimentary features more typical of James Bay relate to development of widely distributed, thin silty, sandy sequences bounded by discontinuous sandy and gravelly (usually fine pebbles), lensing layers of beach ridges. Although ice rafting and scouring are extensive on recent environments, few remnants as lenses of poorly sorted material, or cut and fills are preserved in the sedimentary record.

- Infauna particularly *Macoma*, modifies the deposits slightly. Plants however, have a strong effect, firstly by trapping the fines on upper parts of the shore; secondly by bioturbating the marsh deposits and favouring local concentration of chemical components such as calcium carbonate and iron oxides; and thirdly by covering the mineral profile inland by a progressively thicker protective cover of organic matter.
- The avifauna, being highly migratory, is not in itself unique to the area. However, James Bay because of its geographical location and extensive amount and range of available coastal marsh and intertidal habitat, forms a coastline of major international importance for a number of species of waterfowl and shorebirds.
- Intense probing by shorebirds for infauna in tidal flats, and tramping and digging for rhizomes by geese in marshes, affect and modify sensibly the structures of recent sediments. However, definite criteria to recognize these effects in ancient deposits have not been yet established.
- At the present time, the coast of James Bay has been little affected by man. Possible future developments along the coast, especially those involving alteration of river discharges, pose potentially great problems of conservation, and prediction of possible changes which may occur is important in assessing the impact of any such scheme on coastal environments and wildlife. When environmental changes are accelerated by human activities, the danger exists that floral and faunal populations cannot adjust rapidly, and they may be placed under stress. For example, changes in amount and regulation of input of fresh waters may affect ice distribution and break-up in the bay, thus its climate, salinity of marshes, growing season of plants and invertebrates, and ultimately the populations of wildlife depending on those resources. The impact would depend much on the nature and amount of change in fresh water and sediment load entering the bay. Some changes, such as silting up, might extend habitats favourable to wildlife, but for birds this would depend on the type of marsh and intertidal fauna that resulted. For instance, if new marshes were of the type currently highly influenced by large freshwater input from major rivers leading to similar vegetational development and associated low densities of invertebrate food resources, then a negative effect on waterfowl and shorebirds would be anticipated. If, however, new sediment deposition and vegetational development led to the formation of new wide coastal marshes such as those described for Big Piskwanish East (BPE), new and valuable habitats for waterfowl and shorebirds could result.

The introduction of chemical pollutants or coal dust, as might result from the indiscriminate exploitation of lignite deposits in the Moose River Basin, may destroy useful habitats and threaten migratory bird populations on a large scale. Further integration of information from biological and geological studies on coastal processes and environments occurring in James Bay should lead to a much clearer understanding of factors affecting the present distribution of coastal sediments, associated marsh types, invertebrates and wildlife, and thus allow prediction of new conditions likely to emerge from changes to the existing regime.

Acknowledgements
Research projects in remote northern areas require collaboration from many individuals and organizations to succeed. This research was conducted under the auspices of the HBL Project of Environment Canada. The managers and the reseachers involved with such a project are thanked for their help. We like to single out B. Switzer, F. Brazeau, Y. Dejarsdins, and D. Grinham. Financial support was provided by Environment Canada, the National Science and Engineering Research of Canada (Grants A7371, A3547) and the Ontario Ministry of Agriculture and Food (Program 39). Ocean and Aquatic Sciences, Central Region, provided helicopter support.

References

Barnett, D. M., 1966, A re-examination and re-interpretation of tide gage data from Churchill, Manitoba: Canadian Jour. Earth Sci., v. 3, p. 77-78.
Black, C. A., ed., 1965, Methods of Soil Analysis: Amer. Soc. Agronomy, Madison, p. 671-698
Bouma, A. H., 1969, Methods for the Study of Sedimentary Structures: J. Wiley and Sons Inc., N.Y., 458 p.
Braun-Blanquet, J., 1932, Plant Sociology: McGraw-Hill, New York, 439 p.
Canada Soil Survey Committee, 1978, The Canadian System of Soil Classification. Canada Dept. of Agriculture, Publ. 1646, Ottawa, 164 p.
Canadian Wildlife Service, 1976, Critical and Important Areas for Migratory Birds in Southern Ontario and James Bay Maps and Descriptions: Ottawa, Canadian Wildlife Service Unpublished Report, 123 p.
Chapman, V. J., 1960, Salt Marshes and Salt Deserts of the Word: Interscience Publ. New York, 392 p.
Folk, R. L., 1974, Petrology of Sedimentary Rocks: Hemphill Co., Austin, 182p.
Glooschenko, W. A., and I. P. Martini, 1978, Hudson Bay Lowlands Baseline Study in Proceedings Coastal Zone '78 ASCE, San Francisco, p. 663-679
Kakonge, S. A. K., R. I. G. Morrison, and B. A. Campbell, 1979, An Annotated List of Salt Marsh Invertebrates from North Point, Ontario. Preliminary Unpublished Report. Ottawa, Canadian Wildlife Service, 200 p.
King, C. A. M., 1972, Beaches and Coasts. E. Arnold, London, 570 p.
McKeague, J. A., 1976, Manual on soil sampling and methods of analysis. Soil Research Institute, Ottawa, 212 p.
Martini, I. P., D. W. Cowell, and G. M. Wickware, 1980, Geomorphology of Southern James Bay: a Low Energy, Emergent Coast in S. B. McCann ed., Coastlines of Canada: Geol. Survey Canada, in press.
Martini, I. P., and R. Protz, 1978, Coastal Geomorphology, Sedimentology and Pedology of Southern James Bay, Ontario, Canada. Dept. of Land Resources Science, Tech. Memo 78-1, University of Guelph, 316 p.

Martini, I. P., R. Protz, D. Grinham, W. A. King, and K. E. Clarke, 1979, Studies of Coastal Sediments, Soils, and Biota, James Bay, Ontario, Canada. Dept. of Land Resource Science, Tech. Memo. 79-1, University of Guelph, 290 p.

Morrison, R. I. G., and B. A. Harrington, 1979, Critical Shorebird Resources in James Bay and Eastern North America: Proc. 44th Int. Wildlife and Natural Resources Conference, Toronto, March 1979: Washington, D.C., Wildlife Management Institute.

Prevett, J. P., I. F. Marshall, and V. G. Thomas, 1979, Fall foods of lesser snow geese in the James Bay region: Jour. Wildlife Manag., v. 43, p. 736-742.

Sanford, B. V., A. W. Norris, and H. H. Bostok, 1968, Geology of the Hudson Bay Lowlands (Operation Winisk): Geol. Survey Canada Paper 67-60, 118 p.

West, A. S., 1951, The Canadian Arctic and Sub-arctic mosquito problems: N. J. Mosquito Extermination Assoc. Proc., p. 105-110.

West, A. S., 1977, Tidal salt-marsh and Mangal Formations of Middle and South America: in V. J. Chapman, ed., Wet Coastal Ecosystems: Elsevier Scientific Publ. Co., N.Y., p. 194-213.

MS received December 3, 1979; revised December 10, 1979