A4. Terrestrial Ecosystems/Biomes

A4.1 Vegetation of the Mackenzie River Basin

Barbara Nicholson[1], S. E. Bayley[1], S. Zoltai[2], D. H. Vitt[1], and D. Gignac[1]
[1] *U. of Alberta*
[2] *Northern Forestry Centre*

The drainage basin of the Mackenzie River stretches some 2400 kms from southwest of Edmonton to the arctic coastline and encompasses 3,600,000 sq. Km. A diverse flora exists within the drainage basin and the basin is dominated by the Boreal and Subarctic Ecoclimatic Provinces (Ecoregions Working Group 1989). The vegetation of the Mackenzie is primarily Boreal forest in the south and Subarctic woodlands in the north (Figure A4.1). On the western boundary of the basin the higher elevations of the mountains create a complex mosaic of vegetation types which are normally tree dominated. On the eastern side of the basin the subarctic woodlands and zone of continuous permafrost extends much further south than in the western portion of the drainage basin. The eastern portion of the basin is underlain by the Precambrian shield with minimal soil. This portion also has numerous lakes, which are far less common in the western and southern portions of the basin. Peatland areas of the Mackenzie River Basin have not been mapped in detail, although peatlands are numerous in both the Boreal and Subarctic Ecoclimatic Provinces (Figure A4.2). The Alberta peatlands have been classified and mapped in great detail (1: 1,000,000) and our data show that the peatlands of Alberta cover 13,774 x 10^3 hectares of which 12% are permafrost bogs, 16% are bogs, 32% are poor fens, and 40% are rich fens. The majority of Alberta peatlands occur in the Mackenzie River Basin. Here we summarize the terrestrial and wetland vegetation of the Mackenzie River Basin.

A4.1.1 Boreal Ecoclimatic Province

The Boreal forest predominates in the southern portion of the drainage basin. The Boreal forest is characterized by closed canopy forests of northern tree species. In this region of Canada the Boreal forest is subdivided into three regions; Subhumid Low Boreal, Subhumid Mid-boreal, and Subhumid High Boreal.

The most southerly region, the Subhumid Low Boreal, is dominated by deciduous forests of trembling aspen (*Populus tremuloides*), and balsam poplar (*Populus balsamifera*) (Ecoregions Working Group 1989). Dry sandy sites are dominated by open stands of jack pine (*Pinus banksiana*). Peatlands in this area are generally restricted to basin fens and bogs. Fens are often *Larix laricina* dominated with a variety of bryophytes. *Picea mariana* bogs contain an understory of *Ledum groenlandicum, Sphagnum fuscum, Sphagnum magellanicum,* and *Sphagnum angustifolium. Typha* marshes commonly surround shallow open-water bodies which can be fringed with *Salix* and *Calmagrostis canadensis.*

In the Mid-Boreal ecoclimatic region *Picea glauca, Picea mariana* and *Abies balsamea* become more predominant, particularly as secondary successional species (Ecoregions Working Group 1989). *Pinus banksiana* and *Picea mariana* still dominate in well drained upland soils. Wetlands become restricted to fens and bogs dominated by bryophytes, along with open stunted stands of *Larix laricina* and *Picea mariana.* Patterned fens are common along with permafrost peat plateaus and basin bogs (Zoltai et al. 1988).

Subhumid High Boreal forests are characterized by forests of *Abies balsamea, Picea glauca, Picea mariana, Populus tremuloides,* and *Betula papyrifera* (Ecoregions Working Group 1989). In the areas surrounding the Hay and Peace Rivers there are northward extensions of the mixedwood forest which are dominated by *Populus tremuloides* (Parkes 1973). The Subhumid High Boreal extends considerably northwards along the Mackenzie River Valley (Fig. A4.1). Here on the alluvial flats bordering the Mackenzie River *Picea glauca* and *Populus tremuloides* grow, along with *Betula papyrifera* occupying old leeves (Parkes 1973). At higher elevations above the floodplain, pines and aspen can be found growing on well-drained soils, while *Picea glauca, Picea mariana* and *Betula papyrifera* are found on average soils (Crampton 1973). Normal understory flora consists of *Pleurozium schreberi, Cladonia alpestris, Cornus canadensis, Maianthemum canadense, Epilobium angustifolium, Rosa acicularis, Cornus stolonifera, Rubus pubescens, Calamagrostis canadensis,* and *Ptilium crista-castrensis.* In this area peat plateaus and sloping shallow peatlands (veneer bogs) are more common than the fens (Zoltai et al. 1988).

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gure A4.1. *Approximate boundaries of the ecoclimatic regions of the Mackenzie River Basin (Intergovernmental Seminar 1972 and Ecoclimatic Regions of Canada).*

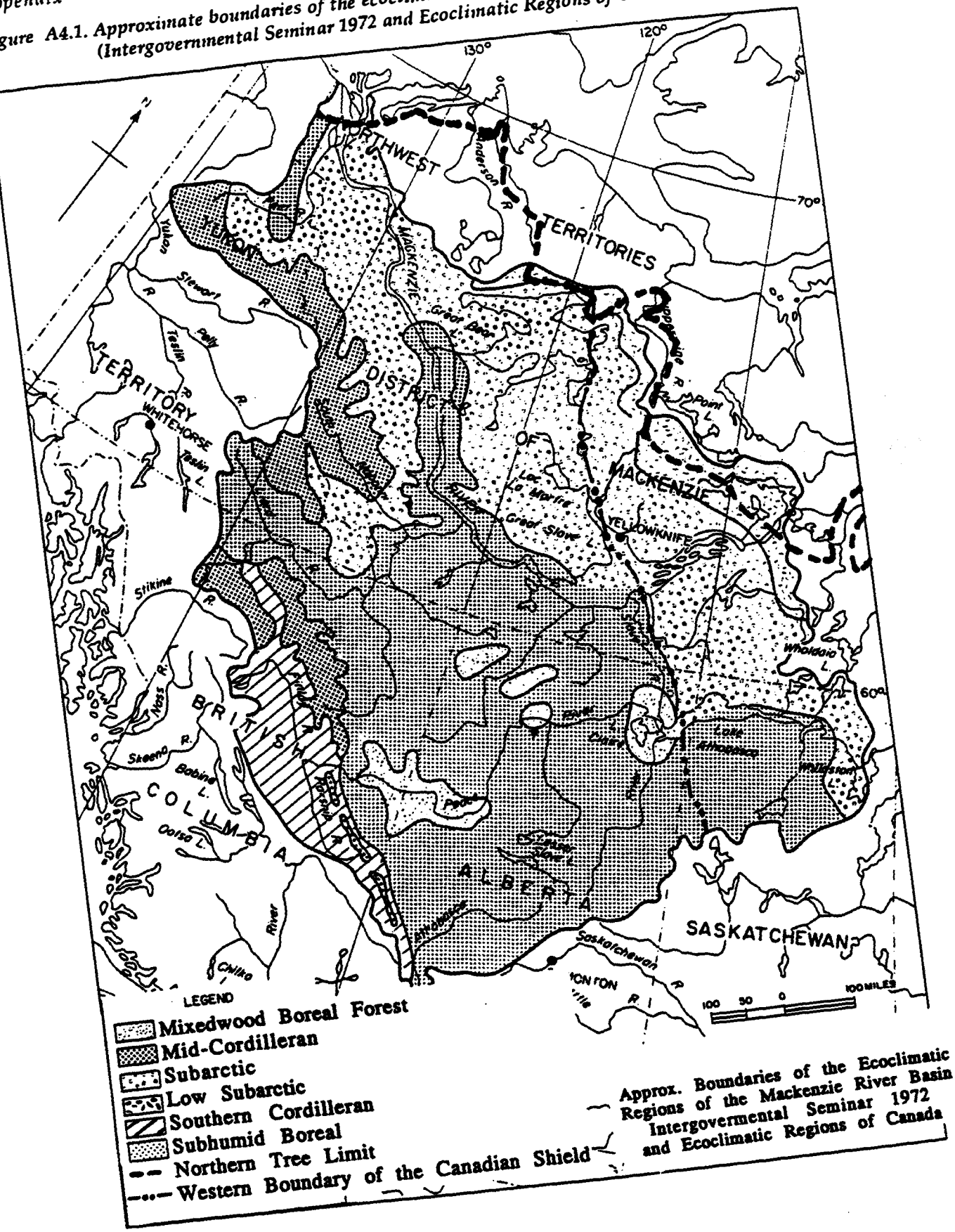
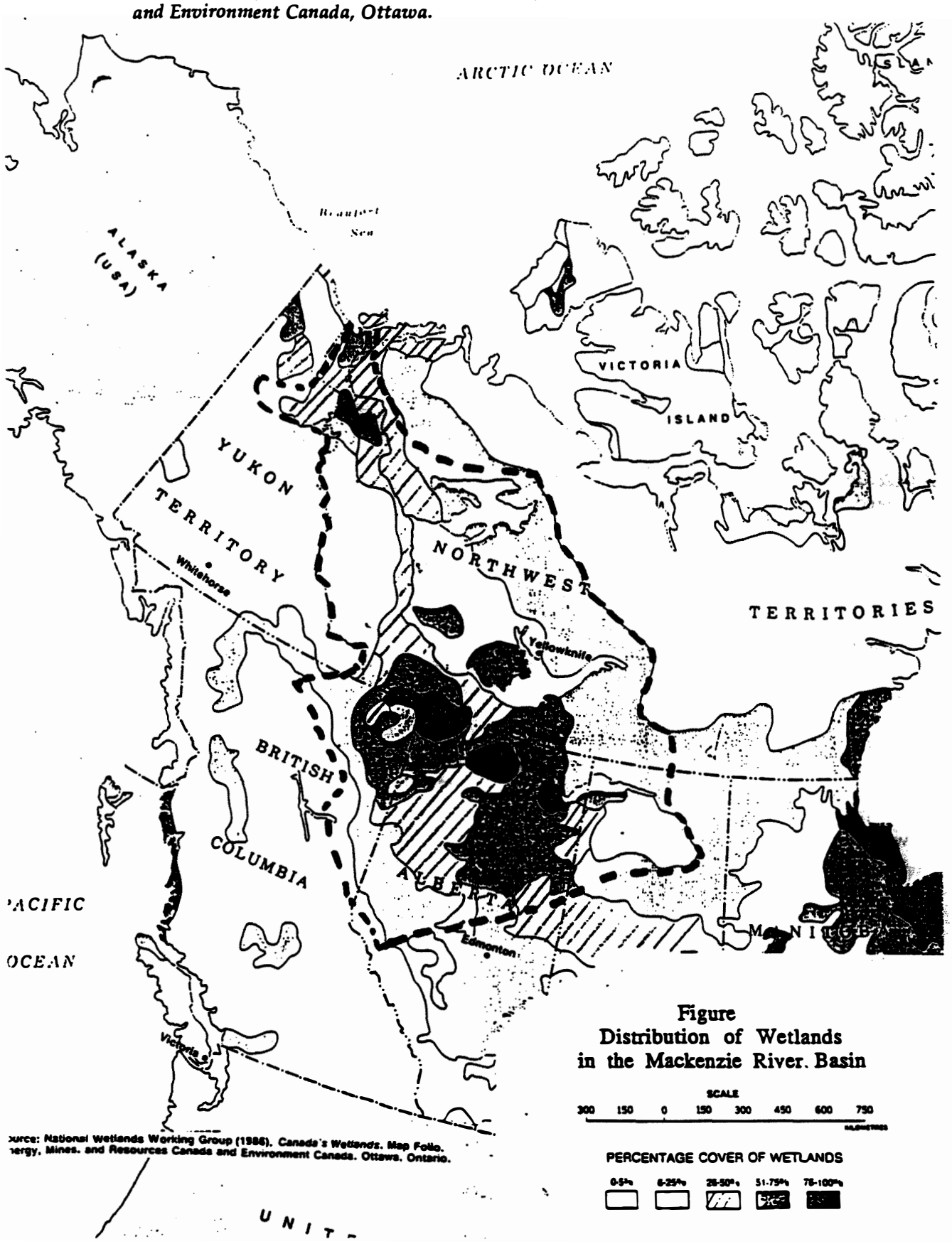


Figure A4.2. Distribution of wetlands in the Mackenzie River Basin. Source: National Wetlands Working Group (1986), Canada's Wetlands. *Map Folio. Energy Mines and Resources Canada and Environment Canada, Ottawa.*



The presence of permafrost affects the vegetation cover in the Subhumid High Boreal region. Crampton (1973) arranged vegetation types of the upper and central Mackenzie Valley into land systems based on the presence or absence of near-surface permafrost. In this area, well drained upland soils with near-surface permafrost are dominated by *Picea glauca, Picea mariana,* and lichens. Seasonally waterlogged soils without near-surface permafrost contain *Picea mariana, Larix laricina, Betula papyrifera, Betula glandulosa, Populus balsamifera, Salix,* ericaceous shrubs, *Sphagnum fuscum, Sphagnum rubellum, Carex,* and *Eriophorum.* Seasonally waterlogged lands having near-surface permafrost have a 'marbloid' appearance due to a increase in the amount of lichens. Open stands of *Picea mariana* occur on these sites with ground covers of lichen, ericaceous shrubs, *Ledum, Empetrum,* shrubby cinquefoil, dwarf birch, and *Salix.*

Peat plateaus have sparse Picea mariana cover with Betula papyrifera and Pinus. Ledum grows profusely along with Vaccinum vitis-idaea, Potentilla fruticosa, and Rubus chamaemorus. Collapse scar fens contain Sphagnum squarrosum and Equisetum. Slopes in this region are lineated with a sub-parallel drainage pattern consisting of runnels located from 50-600 yards apart. Picea mariana grows in the runnels. Lower slopes are wet with Sphagnum, Carex, Betula, and Salix dominating the areas in between the runnels, whereas upper slopes are dry having lichen, Ledum, Betula, Empetrum, Vaccinum vitis-idaea, and shrubby cinquefoil between the runnels.

On the western fringes of the Subhumid High Boreal, such as the upper Liard region, lodgepole pine (*Pinus contorta*) can be found on the upper plateaus with *Picea glauca* and *Populus tremuloides,* while *Abies balsamea* occurs with *Picea glauca, Pinus contorta,* and *Populus tremuloides* nearer the treeline (Parkes 1973).

A4.1.2 Cordilleran Ecoclimatic Province

According to the Ecoclimatic classification scheme, the Cordilleran Ecoclimatic Province has been subdivided into Southern, Mid, and Northern regions as well as Boreal, Subalpine, and Alpine reflecting an altitudinal as well as an longitudinal gradient.

The Boreal Southern Cordilleran Ecoclimatic Region contains mixed forests of *Populus tremuloides, Populus balsamifera, Betula papyrifera, Pinus contorta, Picea glauca, Picea mariana* and *Abies balsamea* (Ecoregion Working Group 1989). On dry sites open stands of *Pinus contorta* and *Populus tremuloides* occur. Poorly drained depressions contain *Larix laricina* and *Picea mariana.*

The Subalpine Southern Cordilleran Ecoclimatic Region has closed canopies of *Pinus contorta, Picea engelmannii,* and *Abies lasiocarpa* (Ecoregions Working Group 1989). Typical understory species are *Vaccinium scoparium, Pyrola,* bryophytes, and *Rhododendron.* Alpine areas contain *Cassiope* and *Phyllodoce, Salix, Carex, Dryas,* and *Kobresia* (Ecoregions Working Group 1989).

In the Boreal Mid-Cordilleran Ecoclimate Region closed canopies of *Pinus contorta* predominate with an understory of *Alnus, Vaccinum, Rosa,* low growing herbs, and dwarf evergreen shrubs (Ecoregions Working Group 1989). Climax vegetation is considered to be *Picea glauca* X *engelmannii* with *Picea mariana* and feathermosses. Dry sites support *Pinus contorta, Vaccinium, Arctostaphylos,* and lichens. Poorly drained sites contain *Picea mariana, Picea glauca, Ledum, Equisetum,* and bryophytes.

Subalpine Northern Cordilleran Ecoclimatic Regions have a scattered cover of stunted *Picea glauca, Pinus contorta* and *Abies lasiocarpa.* Shrub birch, willow, mosses and lichens abound between the stunted trees. Lower elevations also contain *Empetrum, Vaccinum, Alnus,* and *Ledum groenlandicum.* Mid and low slopes are dominated by *Picea mariana, Ledum, Eriophorum, Carex,* bryophytes, and lichens. Drier sites may support *Populus tremuloides, Populus balsamifera, Pinus contorta, Arctostaphylos,* Gramineae, bryophytes and lichens.

A4.1.3 Subarctic Ecoclimatic Province

Just north of Yellowknife, the black spruce canopy thins out, forming the woodlands of the Low Subarctic Ecoclimatic Region. Understory vegetation is dominated by dwarf birch, *Ledum groenlandicum, Alnus crispa, Salix, Shepherdia canadensis* and *Hylocomium splendens. Betula papyrifera* can be abundant following fires.

Dry sites are dominated by open stands of *Picea glauca* and *Betula papyrifera* with *Arctostaphylos, Vaccinium vitis-idaea, Ledum groenlandicum, Cornus canadensis, Pyrola, Cladina arbuscula, Hylocomium splendens,* and *Pleurozium schreberi.* In warm protected areas, *Picea glauca,*

Betula papyrifera and *Populus tremuloides* can occur. Imperfectly and poorly drained soils have pure stands of *Picea mariana* or mixed forests of *Picea glauca, Picea mariana* and occasionally *Larix* and *Populus balsamifera* (Lavkulich et al. 1972). The moderate shrub cover consists of *Ledum groenlandicum, Rosa acicularis, Vaccinium uliginosum, Betula glandulosa,* and *Potentilla fruticosa.* Ground cover species are *Arctostaphylos, Petasites palmatus, Equisetum scirpoides, Pyrola, Vaccinium vitis-idaea, Cladina arbuscula, Cladina alpestris, Cladina rangiferina, Hylocomium splendens, Tomenthypnum nitens, Ptilium crista-castrensis, Aulacomnium palustre* and the occasional *Sphagnum* hummock.

Peat plateaus and fens are the common wetlands in the area (Zoltai et al. 1988). Peat plateaus have stunted open *Picea mariana* cover with *Betula glandulosa, Myrica gale, Ledum palustre, Ledum groenlandicum, Andromeda polifolia, Vaccinium vitis-idaea, Empetrum nigrum, Rubus chamaemorus, Arctostaphylos rubra, Smilacina trifoliata,* and *Drosera rotundifolia* (Lavkulich et al. 1972). *Sphagnum* mounds also contain *Cladina rangiferina, Cladina arbuscula, Cetraria cucullata, Polytrichum strictum,* and *Dicranum undulatum.* Fens are much rarer than bogs in this area. Vegetation in the fens is dominated by *Carex* and *Eriophorum* with scattered *Sphagnum* hummocks. Shrubs and herbs identifed in this area were; *Betula glandulosa, Myrica gale, Ledum palustre, Ledum groenlandicum, Chamaedaphne calyculata, Kalmia polifolia, Andromeda polifolia, Drosera rotundifolia,* and *Tofieldia* (Lavkulich et al. 1972).

In the High Subarctic Ecoclimatic Region the well drained sites support stunted and very open stands of *Picea mariana,* with occasional *Larix laricina.* The ground is covered with nearly continuous lichen carpet, composed of *Cladina mitis, C. alpestris, C . rangiferina, Cetraria nivalis,* and *C. cucullata.* Low shrubs of *Betula glandulosa* and *Ledum palustre* are also frequent. Dry sites will support open stands of *Picea glauca, Vaccinium vitis-idaea, Arctostaphylos,* dwarf birch, moss and lichens. Tundra patches occur with increasing frequency as the tree line is approached, supporting *Alnus crispa, Salix Richardsonii* and *Betula glandulosa* shrubs, herbs and mosses. *Picea glauca* is often the treeline species, growing with *Salix* and *Betula* shrubs. *Populus balsamifera, Picea glauca* and *Betula papyrifera* grow in river valleys or on south facing slopes.

Characteristic wetlands for this area are polygonal peat plateau bogs and basin fens (Zoltai et al. 1988). The vegetation of polygonal peat plateau bogs is dominated by lichens (*Cladina mitis, Cladina rangiferina, Cetraria cucullata, Cetraria nivalis,* and *Alectoria ochroleuca*). In the wet trenches, *Betula glandulosa, Ledum palustre, Rubus chamaemorus, Sphagnum fuscum,* and individuals of *Picea mariana* can be found. Subarctic fens are dominated in the wetter areas by *Carex, Scirpus hudsonianus, Scheuchzeria palustris, Rhychospora alba, Carex limosa and Eriophorum vaginatum,* with *Drepanocladus, Scorpidium, Campylium, Tomenthypnum nitens,* and *Pohlia.* Shrubs and trees are usually absent or restricted to channel margins where drainage is slightly better (Zoltai et al. 1988). Floodplain marshes usually contain *Equisetum fluviatile,* with some *Salix alaxensis* and the moss *Leptobryum pyriforme.* In riverine swamps *Salix alaxensis* grows to 3-4 m with a complete ground cover of *Equisetum arvense.* Also found in these areas are *Hedysarum alpinum, Aster sibiricus, Campylium stellatum,* and *Leptobryum pyriforme* (Zoltai et al. 1988). Thermokarst lakes often contain *Carex aquatilis, Juncus, Lemna trisulca, Equisetum fluvatile, Menyanthes trifoliata, Hippuris vulgaris, Potamogeton richardsonii, P. foliosus, Myriophyllum,* and *Nuphar polysepalum.*

A4.1.4 Arctic Ecoclimatic Province

In the Low Arctic Ecoclimatic Region, which is only a small portion of the Mackenzie River Valley, tundra vegetation consists of dwarf birch, *Salix, Ledum palustre, Dryas,* and *Vaccinium* occurs (Ecoclimatic Working Group 1989). Corns (1972) identified 6 major community types for the eastern Mackenzie Delta Region and the Arctic Islands. The most extensive community he identifies is a Dwarf Shrub-Heath community comprised of *Betula nana, Salix glauca, Salix pulchra, Ledum palustre, Vaccinum vitis-idaea, Empetrum nigrum,* and *Lupinus arcticus.* Within this community he identifies two additional subgroups based on the increasing occurrence of *Salix.*

In the second vegetation community, Dwarf Shrub-Heath vegetation merges with *Eriophorum, vaginatum, Carex bigelowii, Andromeda polifolia, Chamaedaphne calyculata, Rubus chamaemorus,* and *Tofieldia pusilla* to form a Herb-Dwarf Shrub-Heath community. Subgroups of this community are a sedge-cottongrass-heath community, raised center polygons, lichen heaths, and gravel deposits. The raised polygons are characterized by raised centers covered by *Ledum palustre, Betula*

glandulosa, Salix, Arctostaphylos rubra, Empetrum nigrum, Vaccinium vitis-idaea, Rubus chamaemorus, Poa, Cetraria cucullata, C. nivalis and *Alectoria*. Ice wedge depressions contain *Ledum palustre, Vaccinium uliginosum, Chamaedaphne calyculata, Carex bigelowii, Andromeda polifolia, Arctophila fulva, Carex aquatilis,* and *Eriophorum angustifolium*. Extremely wet sites may also contain *Caltha palustris, Hippuris vulgaris,* and *Ranunculus*. Gravel deposits occupy only 3 % of the low arctic landscape but have high diversity. Common species are *Betula nana, Saxifraga tricuspidata,* and *Arctostaphylos rubra*. Rare species are *Populus tremuloides* and *Cnidium cnidiifolium*.

Herb communities are found in flat, poorly drained areas. These are commonly low center polygons, thermokarst lakes, and wet facing banks of the Mackenzie River. Low center polygons usually contain *Carex rariflora, Rubus chamaemorus, Tofieldia pusilla, Eriophorum, Salix, Drepanocladus uncinatus, D. revolvens,* and *Calliergon giganteum*. Shoulders of the polygons are better drained and support *Betula glandulosa, Empetrum nigrum, Ledum palustre, Poa alpina, Carex, Cetraria cucullata,* and *Sphagnum*. The shores of thermokarst lakes often have *Eriophorum angustifolium, E. Scheuchzeri, Lemna trisulca, Caltha palustris, Carex aquatilis, C. saxatilis, Arctophila fulva , Ranunculus aquatilis, Potentilla palustris.* and *Drepanocladus revolvens*. Peaty mats surrounding the pools consists of *Tomenthynum nitens, Aulacomnium palustre, Hypnum bambergeri, Philonotis fontana, Campylium arcticum, Carex saxatilis, Eriophorum scheuchzeri, Juncus biglumis, Pedicularis arctica,* and *Saxifraga hirculus*. Only a few vascular species are found along the banks of the Mackenzie River. Major species include; *Artemesia frigida, Calamagrostis purpurascens, Pulsatilla patens,* and *Artemisia tilesii*.

A tall shrub vegetation community type is restricted to river channels, stream channels and lake shores. It is comprised of *Salix lanata, Salix alaxensis, Alnus crispa, Carex aquatilis, Calamagrostis candensis, Equisetum arvense, Eriophorum angustifolium, Arctagrostis latifolia, Hedysarum alpinum,* and *Parnassia palustris*. Less flooded areas also contain *Vaccinium uliginosum, Pyrola grandiflora* and *Pyrola secunda*.

On gentle slopes and places where snow accumulates a medium shrub community can be found. In these moist habitats *Betula nana, Alnus crispa, Ledum palustre, Vaccinium uliginosum, Cassiope tetragona, Andromeda polifolia, Eriophorum, Carex, Pinguicula villosa,* and *Sphagnum* can be found.

The most widespread wetlands in the Low Arctic are the low center polygon fens and bogs, along with peat mound bogs and horizontal fens with peat cushions (Tarnocai and Zoltai 1988). Marshes are common along the coast and deltas, and thermokarst lakes are a common feature in the tundra landscape. Peat mounds are the arctic variety of palsas. These are small peat-covered mounds that rise up to 1 meter above the surrounding fen. The better drained surfaces support *Sphagnum fuscum, Rubus chamaemorus, Ledum palustre, Andromeda polifolia, Vaccinium uliginosum, Vaccinium vitis-idaea, Betula glandulosum, Dicranum elongatum, Polytrichum strictum,* and *Ichmadophila ericetorum* (Tarnocai and Zoltai 1988). Fens in this region do not contain any vascular herbaceous species nor lichens. Occasionally scattered individuals of *Salix arctica* can be found. Dominant species are *Carex aquatilis, Carex chordorrhiza, Carex membranacea, Eriophorum angustifolium, Eriophorum vaginatum, Drepanocladus aduncus, Drepanocladus fluitans,* and *Scorpidium scorpioides* (Tarnocai and Zoltai 1988).

A4.1.5 Possible Impacts of Climatic Warming

Climatic warming is expected to have severe effects upon the ecosystems of the northern boreal forest, including increases in intensity and frequency of fire, increased forest growth on good sites and reduction in soil moisture and runoff to lakes and rivers. The joint Canada/U.S. program called BOREAS (Boreal Ecosystem-Atmosphere Study) is addressing global change and biosphere-atmosphere interactions in the boreal forest biome. While some of the study sites are outside the Mackenzie River Basin, this program will aid our understanding of the boreal forest ecosystem within the Mackenzie River Basin. Wetland ecosystems which we are studying as part of the MBIS are possibly the best "indicator" ecosystems because they are extremely sensitive to climate change. Wetland species respond to the alteration of water tables by even a few centimetres. The most sensitive ecosystems include northern permafrost wetlands, wetlands in the discontinuous permafrost and wetlands at the boundary of the prairie and boreal forest.

A4.2 Wetland vegetation and the carbon cycle

The wetland vegetation in the ecoclimatic zones is described in detail above. Wetlands can be separated into several types (marsh, swamp, fen, and bog) based on hydrology, temperature and vegetation. Bogs and fens, characterized by accumulations of peat, are restricted to an area north of the prairie grassland zone and generally mark the boundary between boreal forest and the aspen parkland in the southern part of the Mackenzie River Basin. Any northward expansion of the grasslands into the boreal forest, as a result of increased temperatures, will be marked first by changes in these peatland ecosystems. Changes in wetland vegetation wil be evident long before actual grassland expansion or forest change becomes detectable. Subtle changes in the presence, absence, or abundance of wetland plant species that are sensitive to fluctuations in the water table and in the water chemistry (resulting from changes in the water table), offer an early warning indicator of large scale climate related changes. We are documenting these biotic responses as part of the MBIS.

Simplistic extrapolations of higher temperature into northern regions will not result in an accurate prediction of the ecosystems that would be developed. Changes in water levels, chemical changes and fires will alter the species response and will institute major shifts in ecosystems.

Our studies of the historical record of boreal wetlands (peat deposits) has dispelled the belief that wetlands originated at the end of the glaciation, nearly 10,000 years ago. We have shown that wetlands of the northern prairies disappeared during the hypsithermal, 6,000 years ago, when temperatures averaged only one degree C warmer than in the 20th century. We have also shown that our present wetlands originated after that period throughout much of the prairies. At the same time, most prairie lakes were probably dry. For example, the bottom of the present Lake Manitoba, one of the largest lakes in western Canada, is known to have been a grassland 6,000 years ago. The climatic changes predicted now are much larger than those that occurred 6,000 years ago. Obviously, this would have serious consequences for wetlands as well as other biological communities. The detailed models of wetlands we have developed as part of the MBIS are based on both contemporary and historical reconstructions (from lake and wetland sediments) of how biological communities respond to heat and to drought, and will permit us to avoid simplistic extrapolations of temperature.

Peatlands are common in the northern boreal region of the Mackenzie Basin (40% of the area in northern Alberta) and play an important role in the carbon cycle in these areas. Northern peatlands are major reservoirs of carbon in the northern hemisphere. In Canada, the average peat depth is over 2.2 metres with apporximately 50% of the peat made up of carbon. Peatlands are also one of the most important natural emitters of methane to the atmosphere. As temperatures increase and wter levels drop, decomposing peatlands may add to the concentrations of carbon dioxide and methane in the atmosphere. The large amounts of carbon stored in peat deposits are a result of slow decomposition rates caused by anaerobic conditions produced by high water levels. Permafrost formation also contributes to the build up of peat deposits. Lowering water levels and melting of the permafrost as a result of global warming would increase decomposition of the peat and would release carbon dioxide into the atmosphere. It is difficult to make accurate predictions about the amount of carbon dioxide and methane that would be contributed by the northern boreal peatlands to the atmosphere as a result of global climate warming.

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Mackenzie Basin Impact Study

Interim Report #1

Stewart J. Cohen, Editor
Canadian Climate Centre
Downsview, Ontario

Environment Canada Environnement Canada