Arctic Peatlands

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Abstract

Arctic peatlands are mire ecosystems distributed across the vast northern edges of the Eurasian and North American continents and the islands and coastal areas of the Arctic and far northern Atlantic and Pacific Oceans. Arctic peatlands are mostly represented by "frozen" mires with much of their organic deposits remaining frozen throughout the year, whose water regime and other characteristics are strongly dependent on permafrost.

Primary production in arctic peatlands is low, but the tendency for peat to accumulate is enhanced by the low decomposition rates. The peat layer in arctic

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peatlands is not thick, and only in rare cases does the peat exceed 4–6 m in depth. Three main permafrost processes are responsible for the variability of arctic frozen peatlands: thermokarst, frost heaving, and cracking. Arctic peatland diversity and distribution across the landscape depends on the climate conditions, permafrost presence, and hydrology-connected landscape dynamics, and adheres to a characteristic pattern which is beneficial to consider in inventory, mapping, or planning of wetland management.

The ecosystem diversity of arctic peatlands is presented by paludified shallow peatlands; "frozen" peatland types such as polygon mires, peat plateaus, and palsa mires; and "nonfrozen" peatland types like patterned string fens, raised bogs, riparian mires, coastal tundra, and some types of coastal marsh.

Arctic ecosystems are characterized by low species diversity, and typical species are highly specialized and intimately linked to their habitats. The short growing season limits annual production and the ecological niche capacity of these species.

Arctic peatlands are highly integrated ecosystems which are extremely fragile to both natural and human-induced perturbations.

With climate change, the arctic region will continue to warm more rapidly than the global mean. Peat, as a thermo-isolating material, plays a crucial role in minimizing permafrost thaw. However, climate change-induced peatland degradation introduces positive feedback with permafrost thaw. Accompanying rapid in situ peat decomposition is an increase in greenhouse gas (GHG) emissions, specifically methane from saturated peat water and that which was formerly bound in frozen permafrost.

Development in such areas often ignores the special hydrological and ecological characteristics that are central to the productivity of these areas. Increased development of the oil and gas industry and its supporting transport infrastructure significantly fragments the landscape and disrupts its hydrology. Even traditional land uses such as reindeer herding are being industrialized. The resulting changes in peatland status will in turn restrict use of the land by the indigenous people who have traditionally depended on peatlands for food including herded reindeer, game, and fish.

Thus, there is an urgent need to promote sustainable practices.

Keywords
Climate change · Palsa mires · Peat plateau · Permafrost · Polygon mires · Positive feedback · Shallow peatlands · Thermokarst · Thermo-isolation · resistance

Introduction

Arctic peatlands are mire ecosystems (i.e., peatlands where peat is currently being formed and accumulating – Joosten and Clarke 2002) distributed across the vast northern edges of the Eurasian and North American continents and the islands and coastal areas of the Arctic and far northern Atlantic and Pacific Oceans. The Arctic is a vast and diverse region, usually delimited at its southern boundary by the Arctic

Circle, but differing definitions include not only tundra but also the northernmost part of the boreal zone and the forest-tundra (CAFF 2002, 2013).

Arctic peatlands are mostly represented by “frozen” mires with much of their organic deposits remaining frozen throughout the year and in which the water regime and other characteristics are strongly dependent on permafrost (permanently frozen subsoil). However, in areas in which permafrost is sporadic or absent –valleys, deltas, and coastal areas (Zhang et al, 2008) – nonfrozen peatlands more typical of the boreal zone may be common. Frozen peatlands are also found far to the south of the Arctic, especially in continental Asia, associated with isolated and sporadic permafrost. Peatlands similar to arctic peatlands are also reported for the Southern Hemisphere, but their distribution is limited by available land area.

Compared with more temperate locations, primary production (by photosynthesis) in arctic peatlands is low (although the shortness of the summer is partially compensated by long daylight hours), but the tendency for peat to accumulate is enhanced by the low decomposition rates. The effectiveness of decomposer organisms is severely impeded under arctic conditions, being active only during the part of the year when the peat is not frozen. This is just a portion of the already short summer, because seasonal thawing is delayed by the heat input required to change ice into water. Once they become locked into the permafrost, plant remains are often still recognizable to species level for millennia.

The peat layer in arctic peatlands is not thick, and only in rare cases does the peat exceed 4–6 m in depth (Vasilchuk et al. 1983; Peteet et al. 1998; Andreev et al. 2001; Pitkanen et al. 2002). Peatlands by definition require a minimum peat depth and it is difficult to distinguish arctic peatlands from the much more common shallow peatlands. Although together (hereafter referred to as peatlands) they represent the most widespread wetland types in the Arctic, it is only relatively recently that they have they been the focus of heightened scrutiny. Attention is now being directed toward arctic peatlands and their specific origin and practical requirements due to the pronounced effects of climate change in high latitudes, related thawing of permafrost, shifts in traditional land use, and industrial development.

Arctic Peatland Distribution and Diversity

Wetlands, as defined by the Ramsar Convention on Wetlands, are the dominating land cover type in the Arctic, covering more than 60% of the area (Minayeva and Sirin 2009). There are two main factors responsible for the vast distribution of wetlands in the Arctic: presence of large north flowing rivers within ancient wide valleys still experiencing natural flood regimes and the presence of permafrost in all watersheds and terraces providing a permanent source of water due to the freeze-thaw processes.

Arctic peatland diversity and distribution depends on the climate conditions and permafrost and hydrology-connected landscape dynamic. The distribution and diversity of wetlands across the arctic landscape adheres to a characteristic pattern (Fig. 1) that it is beneficial to consider in inventory, mapping, or planning of wetland

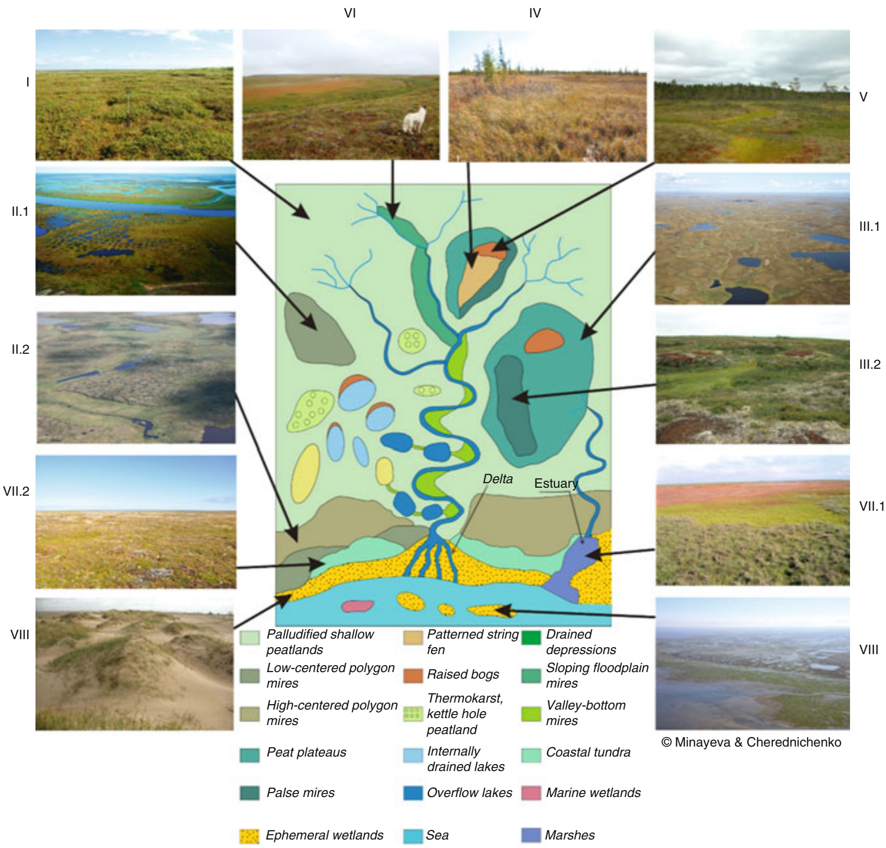

Fig. 1 Arctic wetland diversity and their relative position in the landscape: *I* Paludified shallow peatlands; *II* Polygon mires (with and without thermokarst ponds); *II.1* Low-centered polygon mires; *II.2* High-centered polygon mires; *III* Peat plateaus and Palsa mires (with and without thermokarst ponds); *III.1* Peat plateau mires; *III.2* Palsa mires; *IV* Patterned string fen; *V* Raised bogs; *VI* Riparian mires; *VII* Coastal wetlands; *VII.1* Saline marshes; *VII.2* Coastal tundra; *VIII* Ephemeral wetlands (Image credit: T. Minayeva and O. Cherednichenko © Rights remain with the authors)

management. The terrestrial wetlands of the Arctic are mostly peatlands (Tarnocai and Zoltai 1988) in which the long-term rate of organic matter production exceeds the rate at which it decomposes and include some freshwater (e.g., riparian mires and drained depressions) as well as brackish marshes. This coarse description of arctic wetland diversity is coincident with both the Ramsar classification of wetland types (Ramsar Convention Secretariat 2010) and the CAFF (2013) approach to ecosystem consideration (terrestrial, freshwater, marine).

Three main permafrost processes are responsible for the variability of arctic frozen peatlands: thermokarst, frost heaving, and cracking. Thermokarst includes all changes in topography originating from the processes of permafrost thawing, particularly negative forms of relief such as *inter alia* depressions, sinks, funnels, and gullies. Frost heaving results in different forms of positive relief such as palsas, mounds, and hummocks. Cracking is the key process forming the polygonal morphology of land surface widely present in the Arctic. All three processes can combine at different spatial levels to form specific types of arctic peatlands, e.g., mounds of palsa mires are formed by frost heaving in which peat heads are often cut by cracks and fen depressions are created by thermokarst.

Paludified Shallow Peatland (Tundra)

This is the most widespread terrestrial wetland type on the interfluves of the Eurasian Arctic, forming vast areas of shallow peatland overlying sandy or loamy soils. It occurs more sporadically in North America, where it is often replaced by peat plateaus (see Fig. 1). The peat layer can be partly degraded or decomposed; and the profile can contain alternating layers of peat and mineral material, which indicate that the peatland has periodically been re-covered by mineral soil. In the Russian Arctic, shallow peatlands make up more than half of the peat covered area (Vompersky et al. 2005).

The lighter sandy soils are associated with alluvial (riverine, lacustrine or oceanic) processes and are colonized by dwarf shrub-lichen vegetation. Patches with more snow host mainly fruticose lichens belonging to the genus *Cladonia*. Areas with less snow have species of *Cetraria* and *Alectoria*.

The heavier loamy soils are associated with diluvium (sediment deposited by flood water). They help to retain water in shallow peat layers, leading to increased dominance of both green mosses (in the southern tundra zone) and *Sphagnum* (in northern areas and uplands), cottongrass, sedges, and dwarf shrubs.

The shallow peat tundra on coastal or highland plateaus can have features resembling polygon structures, and here the cracks between polygons can host green mosses, dwarf birch, and willow. Degraded areas that retain some peat or an organic soil layer are covered by crustose lichens (*Gymnomitrion concinnatum* as well as members of the genera *Ochrolechia* and *Pertusaria*). The main colonizers of degraded tundra with sandy soil are psammophyte species, for example, in Nenetsky Okrug, the lichen *Sphaerophorus globosus*, the mosses *Racomitrium lanuginosum* and *Polytrichum piliferum*, and the vascular plants *Armeria maritima*, *Juncus trifidus*, *Festuca ovina*, *Diapensia lapponica*, and *Loiseleuria procumbens*.

Polygon Mires (With or Without Thermokarst Ponds)

Polygon landscapes arise as a consequence of thermal contraction and expansion processes in the frozen active layer and near-surface permafrost (Mackay 2000). Tension cracks propagate from the surface through the frozen active layer into the underlying permafrost in winter. Before they close in summer, snowmelt water migrates into the open cracks and freezes. As the cycle repeats annually, the original vertical ice veins are augmented and ice wedges develop. Their spacing, thickness, and depth will vary with the nature of the host materials. Initially, the growing ice wedges force host sediments upward to form polygon shoulders and create low-center polygons. When they occur in peat – a soft, unstable, and very wet substance – the effects are accentuated, forming deep ice-filled cracks which soon become secure water sources for maintenance of the mire, and in some cases for peat formation. There are two main types of polygon mire, namely, low-centered (concave) and high-centered (mounded) (Tarnocai and Zoltai 1988). Successful functioning of the mire system depends upon a complex construction of different types of peat, permafrost, and mineral soil (Fig. 2). This mire type is an integrated dynamic system driven by structural (vegetation, soil) and permafrost processes, so that even partial physical disturbance or destruction can unpredictably shift the equilibrium of the whole system. Peat thickness depends on the landscape position. The peat layer is usually 1–2 m and sometimes 3–5 m thick on watersheds, on old terraces, and in deep erosion gulleys. In valleys and on small terraces it may be only 0.2–0.5 m thick.

Polygon mires are not rich in biodiversity and host no more than 30 species of vascular plants, 30 species of mosses, and 45 species of lichens, but they represent a unique ecosystem type. Low-centered polygons have sedge-cotton grass-moss vegetation typical of peatland hollows, their shoulders offer better-drained conditions and often support shrubs like dwarf birch (*Betula nana*) and Labrador tea (*Ledum palustre* ssp. *decumbens*), and the ice in the trenches is covered by *Sphagnum* peat and *Sphagnum* carpets. The tops of high-centered polygons are usually covered by cloudberry, dwarf shrubs, and some mosses which remain sparse because they do not compete successfully with the dwarf shrubs, especially *Empetrum nigrum*. In the High Arctic and on coastal terraces, the caps of high-centered polygons are covered by lichens with sparse dwarf shrubs.

Polygon mires occur in the High Arctic. In North America they are found on the arctic coastal plains of Alaska and in the Canadian Mackenzie Delta. In Eurasia, there are relic mounded polygons along the shore of the White Sea, both types occur regularly on the shore terraces along the Barents Sea coastline, and farther east they are found on the terraces of large inland rivers. They are abundant in eastern Yamal and on the Gydansky Peninsula; and they cover immense parts of the Yenisey lowlands in Taymyr, the Yana-Indigirka and Kolyma lowlands, and the Lena delta. Relic polygon mires have also been described in Northern Sakhalin and even the Amur River delta.

Peat Plateau and Palsa Mires

The palsa mires make up the second group of peatlands whose genesis and maintenance is related to permafrost (Pyavchenko 1955; Novikov et al. 2009). The mounds are not created by peat formation but by heaving of the underlying mineral ground; the hummocks consist of fen peat (formed from mesotrophic plant communities), but their present vegetation is oligotrophic; the underlying mound of mineral material contains ice lenses; and the upper limit of permafrost is close to the ground surface in palsa mounds and deeper or absent in the intervening depressions (Fig. 3). Numerous authors have suggested mechanisms for palsa formation on the basis of their own analyses of this general structure (Tyuremnov 1976; Seppälä 1986; Tarnocai and Zoltai 1988; Kujala et al. 2008; Vasilchuk et al. 2008).

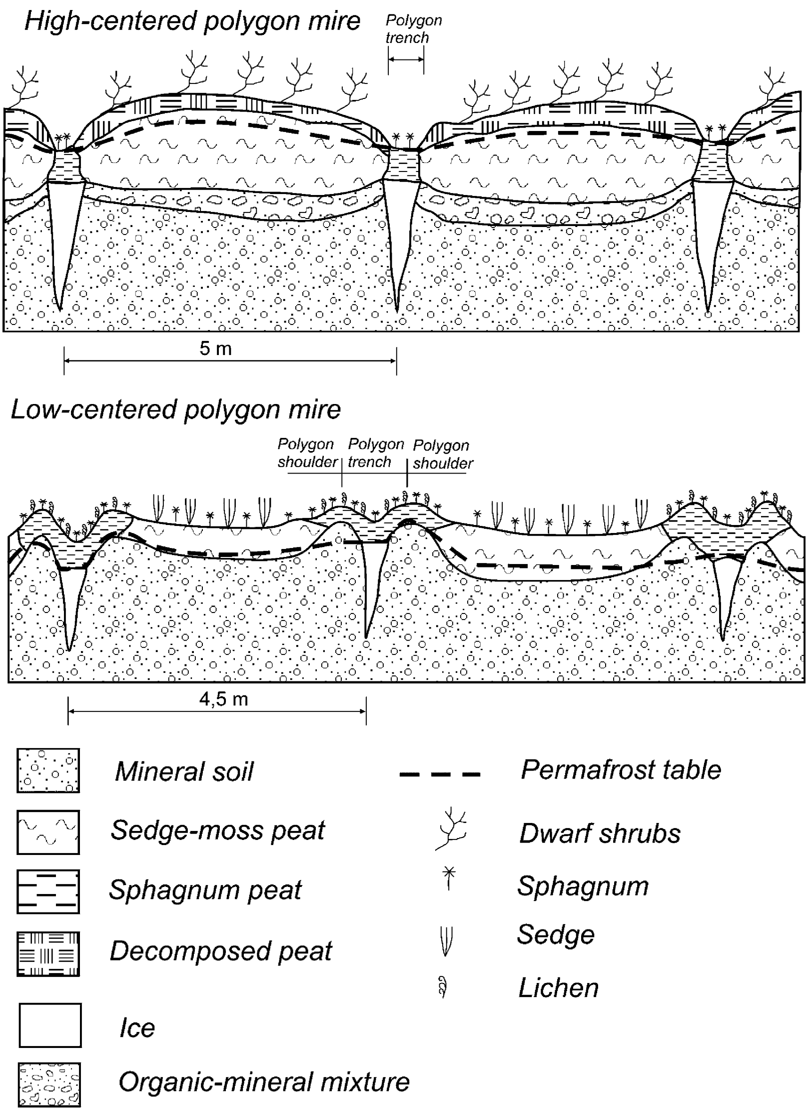

Fig. 2 Cross-sections of high-centered polygon and low-centered polygon mire (Adapted by T. Minayeva and O. Cherednichenko after Tarnocai and Zoltai 1988; © 1988, Minister of Supply and Services Canada, with permission of Environment and Climate Change Canada)

Palsa mires differ from polygon mires in that the permafrost-related processes in palsas operate below the surface rather than from the surface, and peat plays a more active role in creating the palsa structure. In polygon mires, the role of peat becomes pertinent when the basic structure is already in place – peat begins to form on the edges of preexisting ice wedge troughs and gradually modifies the hydrological and temperature regimes thereafter. In palsa mires, the peat is originally formed in

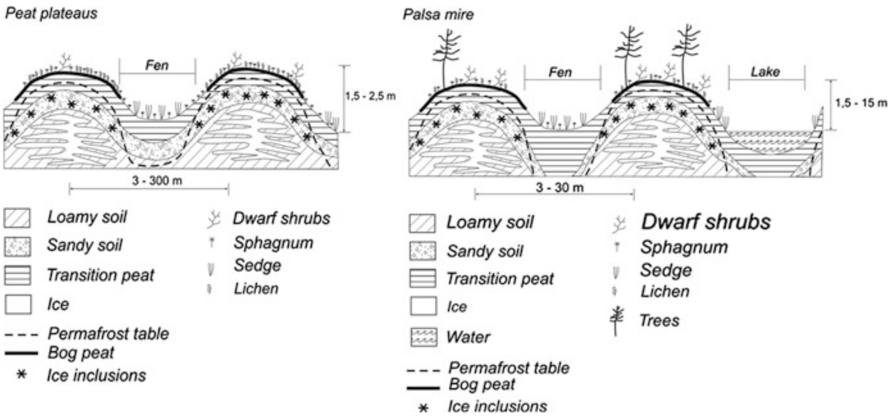

Fig. 3 Structural characteristics of peat plateau and palsa mires. Although both have the same basic structure, the indicated scale of the peat plateau/palsa is more typical for Russia. In North America, plateaus can cover tens of km^2 and the fens are only a minor part of the landscape. In this case the horizontal scale would be >300 m while the vertical would be 2.5 m (Adapted by T. Minayeva and O. Cherednichenko after Konstantinova 1963 cited in Tyuremnov 1976)

flooded sedge-moss plains (i.e., on flat areas). When a mire is present, the drier layer of peat at the surface protects ice from thawing and enhances freezing processes in the wetter mineral soil beneath. During the warm part of the year, the mineral soil becomes saturated with water, which subsequently freezes. The peat provides insulation which reduces heat gain in summer. In locations where the surface relief was originally uneven (e.g., in a hummock), ice lenses accumulate over many years, stacked on top of one another in the mineral core to progressively create the palsa mound. Thus, the mound-hollow relief of palsa mires is created by a frost-heaving process. Fine-textured mineral sediments are more susceptible to frost heaving than coarse ones, and the structure of the mineral soil beneath the peat is the main factor in determining how pronounced this relief becomes. True palsa mires with large convex mounds, separated by vast hollows and occasional ponds, are characteristic for regions with fine-textured mineral soils. “Peat plateaus” form where access to water is limited, either due to low permeability of the mineral sediments or because continuous permafrost permits water to migrate into the ice lenses only around the perimeters of the features. In either case the plateaus cannot attain heights of more than ~2.5 m because water can be drawn into ice lenses to grow superposed palsa-like features. When “palsas” on peat plateaus are sufficiently extended (up to 300 m in diameter), polygon structures can appear in their central parts, forming polygonal peat plateaus.

Whatever their sizes and shapes, the mounds of northern peat plateau and palsa mires are usually dominated by dwarf shrubs and lichens, whereas in the southern tundra their vegetation consists of *Sphagnum* and green mosses (mainly *Dicranum elongatum*, *Polytrichum juniperinum*, and *Sphagnum fuscum*). Treed palsas have also been described. Where the peat has become degraded it might be covered by scale lichens (*Icmadophila ericetorum*, *Ochrolechia frigida*, *Omphalina hudsoniana*) and form an effective springboard for invasions of new species from the south. The hollows have sedge-*Sphagnum* vegetation and often contain thermokarst ponds.

The degradation of palsas is described in numerous publications and is highly significant in the present context. As a palsa mound grows, the vegetation cover of its top gradually degenerates; this is a natural physical process. Following breakdown of the vegetation cover, the peat layer starts to degrade so that its thermal insulation function is gradually lost and the permafrost begins to thaw. In some cases, all of the supporting ice disappears leaving a roundish patch of bare peat in the tundra or a pond. The full cycle of palsa formation and degradation can be completed within a few decades.

Patterned String Fen (Aapa Mire) and Raised Bogs

These two wetland types occur in the arctic, subarctic, and boreal zones and are not directly connected with permafrost, although permafrost can play a role in certain stages of their formation. At first glance the patterns of hummock-hollow complexes in raised bogs look similar to those in patterned string fens. However, there are important differences between them in terms of structure and thickness of the peat layer, which lead to differences in hydrology and vegetation patterns. In patterned string fen, the dominant peat type is fen peat, with bog peat being found only on the hummocks (Botch and Masing 1979) (Fig. 4).

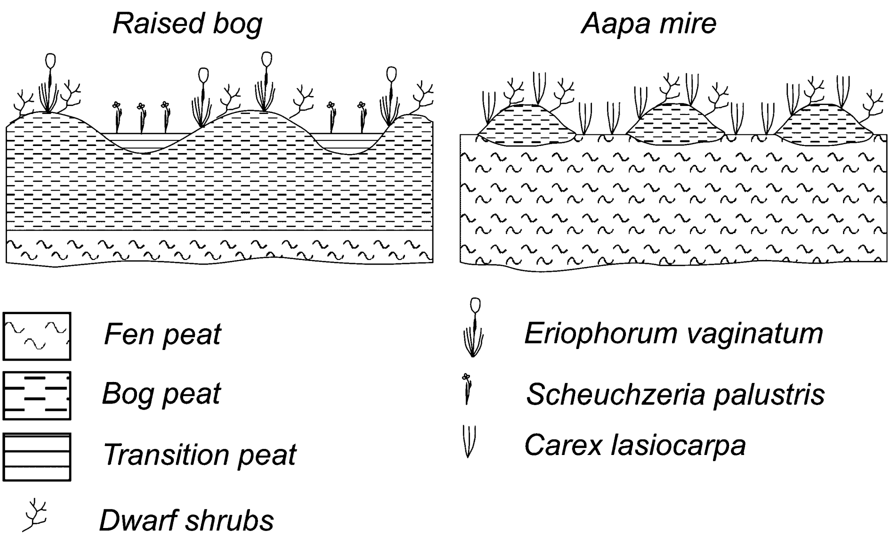

Fig. 4 Comparison of the structures of raised bog and aapa mire microtopes (Image credit: T. Minayeva and O. Cherednichenko © Rights remain with the authors; after Kats 1971 based on the description provided by Botch and Masing (1979))

Patterned string fen, or aapa mire, is widespread in the Eurasian Arctic and Subarctic, and it occurs in North America where it is known as ribbed or stringed fen. The main distinguishing feature of an aapa mire massif is its concave or inclined form, which means that it receives both direct rainfall and water with a higher mineral content as inflow from the surrounding land (Laitinen et al. 2007). The peat layer of aapa mire is shallow (0.8–1.5 m), so that deep-rooted plants can also access mineral-enriched water in the soil beneath. The typical landscape position of aapa mire is on gently sloping ground with permanent surface flow, which is a key factor in the formation of hummock-hollow complexes. The hummocks and hollows are usually well defined, and both host mesotrophic species. The patterns they form at landscape level depend on morphology. Aapa mires are nonfrozen peatlands, but seasonal ice in hummocks can persist throughout the summer under certain conditions. The strings or hummocks are largely composed of *Sphagnum* peat. The difference in peat characteristics between hummocks and hollows is more pronounced in northern ribbed fens than in southerly examples (Zoltai et al. 1988).

Raised bogs occur mostly in the boreal belt, where they can be recognized as separate mire landscapes. In the arctic and subarctic zones, raised bogs occur only as elements within peatlands and wetlands of other types which occupy lake depressions, relic water channels, etc., mostly in areas with thawed permafrost. Raised bogs have typical vegetation patterns made up of hummocks with ericaceous and non-ericaceous dwarf shrubs, sedges, cottongrass and *Sphagnum* mosses, and mesotrophic hollows with *Sphagnum* and small sedge carpets.

Thermokarst Kettle Hole Peatlands

Thermokarst kettle hole peatlands or alases are typical arctic wetland ecosystems. A kettle hole is a distinctive steep-sided depression formed by the thawing of permafrost, which may contain a thermokarst lake or an ecosystem in lake succession such as a floating mat or true peatland. The vegetation depends on the stage of development and can include sedges, hypnaceous mosses, or *Juncus*.

Drained Depressions (Syn. Khasyry)

Thermokarst processes very often lead to the drainage and drying-out of lakes and ponds. The resulting "former lakes" have the local name "khasyry" (which means "dry lake") in Nenents. These ecosystems are unique for the Eurasian Arctic insofar as peatland development and peat formation is relatively recent. Permafrost is not a factor in their genesis and function and for this reason they lack patterning. Their vegetation is species diverse, consisting of tall sedges (*Carex aquatilis*, *C. rariflora*, *C. rotundata*) and *Sphagnum* communities (*Sphagnum lindbergii*, *S. girgensohnii*, *S. squarrosum*, *S. fimbriatum*, *S. angustifolium*, *S. warnstorfii*) with forbs which can include some extremely rare species; for example, the Red Data Book species *Ranunculus pallasii* in the case of Nenetsky. In wetter places, *Sphagnum* mosses are replaced by green mosses like *Warnstorfia exannulata*, *Limprichtia revolvens*, *Calliergon stramineum*, *Sanionia uncinata*, *Mnium* spp., *Meesia triquetra*, and *Paludella squarrosa* and, more typically at mesotrophic sites, vascular plants like *Calamagrostis neglecta*, *Comarum palustre*, and *Epilobium palustre*. Occasional hummocks are present, and these host oligotrophic species (ericoid shrubs and *Sphagnum* mosses). In valleys of the southern tundra and the forest-tundra, khasyry are often colonized by pine or larch trees which grow very rapidly.

Riparian Mires

Deltas play a significant role in the ecology of the Arctic, as buffers for the impact of changing river flow. Deltas can contain all wetland types; from ephemeral dunes and sandy spits near beaches, to valley-bottom mires with sedges and *Hypnum* moss in oxbows and along low riverbanks with or without gravel embankments. Sloping floodplain fens which are dependent on the fluvial regime are also regarded as riparian mires.

Sloping floodplain fens, and especially valley-bottom fens, have homogeneous vegetation structure and highly organic soils including peat deposits. Their vegetation consists of willows, tall sedges, and mosses. These are the most productive of all arctic ecosystems and so have very high restoration potential.

Coastal Wetlands

Some coastal marshes, especially brackish and freshwater marshes, may contain a peat layer in their latest stages of development. Sedimentation of silt and accumulation of organic matter (vegetation remains) lead to a gradual rise of the marsh surface above sea level and, consequently, to changes in the periodicity and duration of seawater influence. A typical chronosequence in Eurasia would be, as the surface rises, pioneering associations of *Puccinellia phryganodes* and *Carex subspathacea* on unstable sand and silt giving way to medium-level marsh communities of *Carex subspathacea* with dicotyledonous grasses (*Potentilla egedii*, *Plantago schrenkii*, *Arctanthemum hultenii*) and associations dominated by *Calamagrostis deschampsioides* and *Carex glareosa*. In the final stage of succession, more elevated features – where seawater effects are limited to wave splash and occasional inundation by surges – are colonized by stable upper marsh communities dominated by *Festuca richardsonii* and *Salix reptans*, with *Rhodiola rosea*, *Parnassia palustris*, and other halophyte and salt-tolerant tundra species including mosses. When the moss cover develops, the marsh surface begins to rise again due to peat accumulation. Similar sequences occur in North America, often when different species of the same genera occupy the same niches as the Eurasian species.

Coastal Eurasian tundra (high-level marsh) resembles regular tundra, but is influenced by salt water. It is initially dominated by halophytes but eventually common tundra species like *Carex subspathacea*, *Calamagrostis deschampsioides*, *Carex glareosa*, *Festuca richardsonii*, *Salix reptans*, *Empetrum hermaphroditum*, *Rhodiola rosea*, *Parnassia palustris*, and *Comarum palustre*, and mosses belonging to the genera *Bryum* and *Drepanocladus* predominate. These Eurasian species have North American equivalents that fill the same niches. In some places, marshes are seriously affected by waterfowl populations.

Threats and Future Challenges

Arctic peatlands are highly integrated ecosystems which are extremely fragile to both natural and human-induced perturbations. Although their status has not yet been described comprehensively in the scientific literature, certain trends are clearly evident. These are dominated by direct and indirect effects of climate change arising from global warming, which has multiple and sometimes subtle implications for arctic peatlands (Minayeva and Sirin 2010).

In recent years the southern limit of permafrost moved significantly northward (AMAP 2011). Long-term temperature monitoring in the European part of the Russian Arctic (Nenets) shows a permanent temperature increase in permafrost upper layers. Loss of permafrost in Quebec has been attributed to the insulating effect of increased snowfall since the late 1950s rather than to temperature, which did not rise until the late 1990s, and has been accompanied by new peat accumulation on thawed areas (paludification) and in thermokarst ponds (terrestrialization) (Payette et al. 2004). Thus, small changes in weather conditions can cause abrupt changes in the direction of peatland system development. The distinctive polygonal patterns and palsa mounds of permafrost peatlands can exist only where the ground is permanently frozen. The thicker snow cover of the progressively milder arctic winters (with increased precipitation) already threatens the persistence of these remarkable peatland systems (Zuidhoff 2002; Hofgaard 2003; Kershaw 2003; Fronzek et al. 2006). Moreover, it is anticipated that trees and other boreal species will colonize arctic peatlands as the northern treeline migrates to higher latitudes in response to rising summer temperatures (CAFF 2013). This will not only affect biodiversity but also reduce albedo (surface reflectivity), further enhancing warming of the atmosphere.

In locations such as the High Arctic, where low temperatures currently limit primary production and thus peat growth, nonfrozen peatlands are likely to expand in topographically suitable locations with rising temperature. Peatlands in floodplains and lake basins are particularly susceptible to the increasingly dynamic river flow regimes that are expected as the intensity of rainfall and droughts continues to increase. The biota of surface water bodies are in turn vulnerable to changes in the load of dissolved and/or particulate organic matter (DOC, POC) in drainage water from any peatlands within their catchments that are degrading due to any cause.

The arctic region will continue to warm more rapidly than the global mean (IPCC 2014) with climate change, and this alone is expected to transform arctic peatlands through loss of permafrost. Peat as a thermo-isolating material plays a crucial role in minimizing permafrost thaw. However, climate change-induced peatland degradation introduces positive feedback with permafrost thaw. Accompanying rapid *in situ* peat decomposition is an increase in greenhouse gases (GHG) emissions, specifically methane from saturated peat water and that which was formerly bound in frozen permafrost.

The vast undisturbed peatlands of the arctic and subarctic zones are among the last remaining wilderness and natural resource areas of the world. Development in such areas often ignores the special hydrological and ecological characteristics that are central to the productivity of these areas. Although the Ramsar Convention, Convention on Biological Diversity, and UNFCCC have acknowledged that special action to conserve peatlands is urgently required, peatlands are still underrepresented in conservation strategies and seldom recognized as specific targets for management. For example, there is an urgent need for arctic peatland restoration technologies which, in order to be effective, must be designed specifically for permafrost systems.

Traditional and sustainable uses of arctic peatlands, such as grazing, hunting, and berry-picking have been carried forward into recent times. New advances in technologies have provided the means to overcome challenges presented by the harsh arctic environment, leading to increased development of the oil and gas industry and its supporting transport infrastructure which significantly fragments the landscape and disrupts its hydrology. Even traditional land uses such as reindeer herding are being industrialized, and the increased human presence means that wild mammals and birds are increasingly threatened by recreational hunting. There is thus an urgent need to promote sustainable practices.

Arctic ecosystems are characterized by low species diversity, and typical species are highly specialized and intimately linked to their habitats. The short growing season limits annual production and the ecological niche capacity of these species, so that communities have low resistance to disturbance and extremely limited potential for natural recovery. Thus impacts of increased industrial development will in turn reduce arctic peatland ecosystem diversity and thus their biodiversity value. The resulting changes in peatland status will in turn restrict use of the land by the indigenous people who have traditionally depended on peatlands for food including herded reindeer, game, and fish.

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