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# FEN AND RAISED BOG DEVELOPMENT IN THE AREAS OF FORMER LITTORINA SEA LAGOONS IN THE COASTAL LOWLAND OF LATVIA

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## SUMMARY

The studies of mire development in areas of former Littorina lagoons have been carried out in mires from the Coastal Lowland in Latvia. Lake sediments and peats from Sarnate, Bazi, Engure and Sleperi mires were studied by palynological, plant macroremains and peat botanical composition methods. Sediments were dated by the $^{14}C$ method and age-depth diagrams were created. This approach provides a better understanding of mire development processes in the ancient lagoon areas due to lake terrestrialisation after the Littorina Sea regression.

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KEYWORDS: peat, fen, bog, mire, Littorina Sea lagoon

## INTRODUCTION

The relief in the Coastal Lowland of Latvia has been formed under conditions of changing basins of the Baltic Sea stages, geological processes, climate and human impact. The study sites are located in the Coastal Lowland that stretches along the coast of the Baltic Sea and the Gulf of Riga (Fig. 1). The Coastal Lowland is an area that has been submerged by waters of different Baltic Sea stages which had a higher level than the present Baltic Sea e.g. the Baltic Ice Lake, the Ancylus Lake and the Littorina Sea (Veinbergs, 1979). The coastal area of Latvia is rich in Littorina lagoonal lakes, particularly the central and western coast of the Gulf of Riga, as well as the coast of the Kurzeme Peninsula. All areas of former Littorina lagoons are nowadays located approximately from 1 m to 5-6 m above sea level. During the transgression of the Littorina Sea ($Lit^a$) stage the Baltic Sea the lowest parts of the coastal area were covered by seawater and lagoons appeared. Fluctuations and the fall in the Littorina Sea level caused the formation of lagoonal lake basins in places where shallow depressions were formed in the coastal relief.

The lagoons were gradually cut off from sea by underwater bars, which later appear above the water and were covered by parallel dune ridges, separating the lagoons of Sarnate, Purciems and Engure from the open sea (Eberhards, Saltupe, 2000), and basin conditions changed from brackish to freshwater.

Lake terrestrialisation took place in almost all former lagoons. Nowadays only the largest former lagoons are still lakes, however the shallowest parts of them and the bays are gradually filling in and becoming overgrown with *Phragmites australis*, *Carex dioica*, C. ni*gra*, C. *panicea* and various *Salix* species (Pakalne, Kalnina, 2005). This is typical vegetation dominant in fens in the early stages of mire development.

Paleoecological studies indicate that ancient lagoons became coastal lakes as a result of the Littorina Sea ($Lit^b$) regression. Some of the lagoons, like Sarnate, Purciems, Priedaine and areas around Kanieris and Engure Lake, are completely filled in, and mires have developed in these areas. Around the lakes (Engure, Kanieris, Pape) and also some completely overgrown areas (Purciems, Priedaine) fens have formed, and raised bogs have developed in some mires, such as Sarnate and Sleperi. Mires have also formed in coastal areas close to the sea, where, after sea level lowering in open sandy areas a peculiar relief of dunes and depressions, called *kangari-vigas*, was formed, due to strong wind activity. In depressions between dunes inter-dune mires developed.

The aim of the study is to ascertain the characteristics of mire development in coastal areas with former lagoons.

Hypothesis of the study: the development of fens and raised bogs from the areas of former Littorina Sea lagoons varies, depending on their location and local conditions.

## MATERIAL AND METHODS

### Site location

Four sites in the Coastal Lowland were chosen for study: central the coast of the Gulf of Riga (Sleperi Mire, 56º97'30'' N, 23º91'86'' E), the western coast of the gulf (Engure Lake, coastal fen 57º18'10'' N, 23º15'42'' E), the top of the Kurzeme peninsula (Bazi Mire, 57º69'40'' N, 22º48'17'' E) and the western coast of the peninsula (Sarnate Mire, 57º09'49'' N, 21º46'96'' E)

### Field Methods

After initial survey of sediment thickness at the study sites, coring and deposit sampling was done with a soft sediment sampler with a 0.5 m long and Ø0.07 m chamber. Sediments were documented and field estimations (colour, composition, structure, admixtures etc.) were done. The sediment samples (50 cm long monoliths) were put into a special cartridge and wrapped in polyethylene film to preserve natural moisture, brought to the laboratory and sliced into 5 cm intervals.

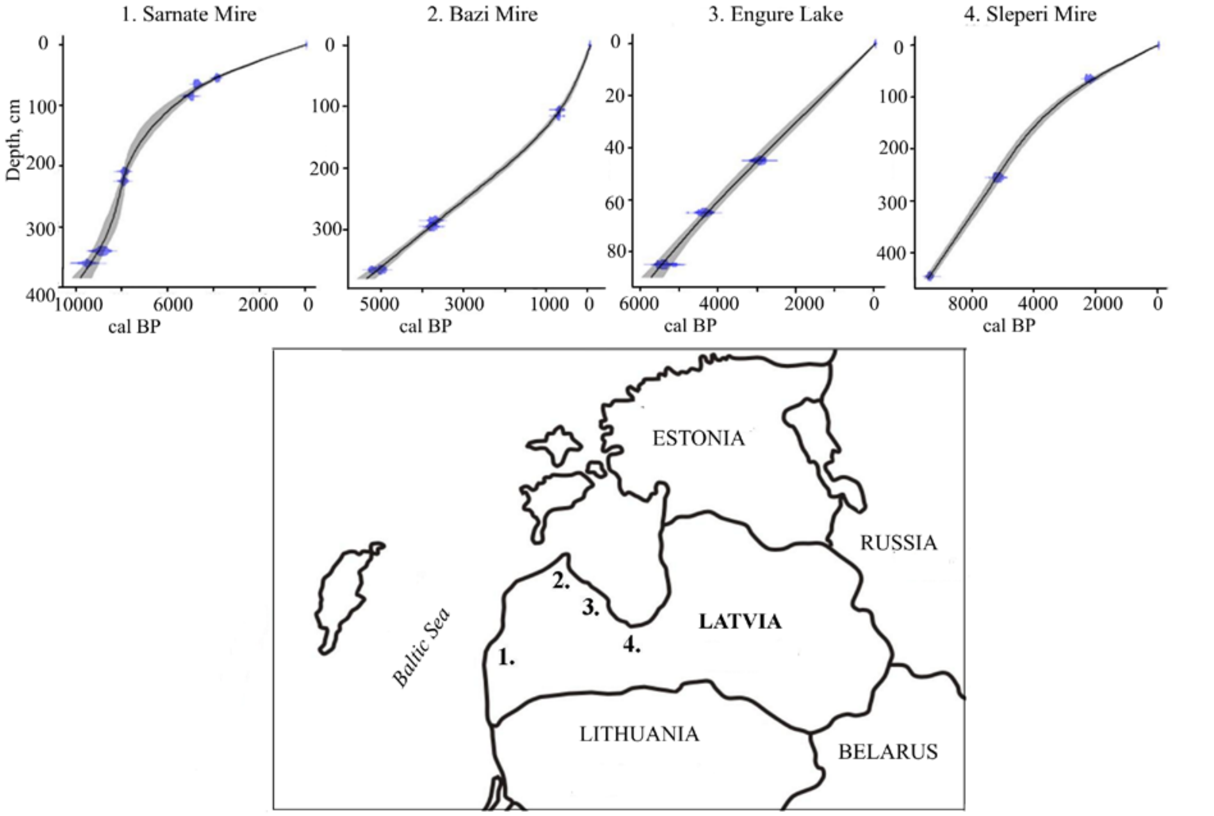


Fig. 1. Location of study sites (1. Sarnate Mire, 2. Bazi Mire, 3. Engure Lake, 4. Sleperi Mire) and age-depth model for each study site. $^{14}C$ dates and calibrated ages BP (median age with 2 σ error margins).

## Laboratory Methods

Collected peat samples were analysed by peat botanical composition and degree of decomposition, pollen content and plant macro remains, and dated by $^{14}C$ method.
Peat botanical composition reflects the presence and amount of the majority of plants growing in mire during accumulation of the peat layer and indicates plant feeding conditions. The analysis of peat botanical composition was performed according to the methods of Tjuremnov (1976) and Katz et al. (1977), using a Carl-Zeiss binocular microscope at a magnification of 100x and 400x.
Pollen analysis is principally is based on a standard method described by Berglund and Ralska-Jasiewiczowa (1986) and Bennett and Willis (2003). Pollen data help to estimate the time of peat formation, climate changes and vegetation development in the region as well as to interpret peat properties (botanical composition, moisture etc.).
Plant macro remains reflects vegetation composition during the development of fen. Plant macrofossil analysis was done according to Warner (1990).
Three to six sediment samples from studied sites were radiocarbon-dated using conventional techniques at the Institute of Geology, Tallinn University of Technology, Estonia.

## RESULTS

The lowermost peat layer in the studied section No. IX of Sarnate Mire has been found in the bottom of the mire depression, where a *Hypnum* peat layer has been formed on sandy sediments earlier than 9720–9340 BP. Later the peat was covered by calcareous clay, which accumulated in a basin, evidently during the maximum of the first Littorina Sea transgression (Lit[a]). Higher up in the section the clay becomes more calcareous and rich in plant remains, mainly sedges and wood. During the Littorina Sea regression phase the lagoon was cut off from the sea and a peaty gyttja layer formed in a shallow lake. The water level in the basin gradually decreased and the lagoonal lake gradually became filled in and covered by wood-grass fen peat. In the early stages of mire development *Carex* species dominated, e.g. *Carex elata,* C. *lasiocarpa,* C. *teretiuscula, C.aproximate* and *Hypnum*. Trees are mainly represented by *Betula pubescens* and *Salix* species, which usually dominate in fens. Peat in the whole section is well decomposed and the degree of decomposition varies from 35 to 45% and to 50% in the top interval of section.

Later, during the Subboreal, the peat composition shows a decrease in the amount of coniferous trees and remains of different grasses, and wood-grass peat was formed. The shallow lagoonal lakes during the Subboreal were separated by low, paludified flatlands. Since the second part of Subboreal the lakes have gradually terrestrialised and filled in with fen peat and later also raised bog vegetation. Raised bog vegetation occurs at that time in the northern part of the mire.

Data from the central part of Sarnate Mire (section No. 11) show *Sphagnum* peat deposition during the Subatlantic (the last 3000-2800 years). During the Subatlantic period, as the climate became cool and wet, raised bog vegetation developed and *Sphagnum* peat formed in almost the entire area of Sarnate Mire, except for areas where surface and groundwater was available for plants. When raised bog development started, many of the currently rare plant species, like *Myrica gale, Cladium* mariscus, *Trapa natans*, *Salix myrtiloides* and *Hammarbya paludosa,* were common (Pakalne, Kalnina, 2005).

A similar course of changes in the sedimentary environment have been observed in other former lagoonal areas (Kalnina et al., 2009; Saarse et al., 2009).

Sleperi Mire was the eastern part of the former Priedaine lagoon. Pollen and macroremain data from the Priedaine site indicate sediment formation mainly during shallow lagoon or lake conditions. A fine sand layer on the bottom has been covered by peaty gyttja with wood remains. Peat has been formed quite recently and only the upper 10 cm consists of *Sphagnum*-grass peat. The formation of deposits has been completely different in character in the eastern part of the former lagoon. In area where the present Sleperi Mire developed sandy gyttja has accumulated on a sand layer. At the depth interval 4.45 m gyttja has been covered by well decomposed (35%) fen-type wood-reed peat. Higher up in the section, at the level of 2.6 m, the environment has changed, the peat layer becoming so thick that plants do not reach mineralisated waters. Very well decomposed (50%) raised bog pine-cotton-grass peat accumulated before (5151–5206 years cal BP). It has been covered by well decomposed (40-45%) cotton-grass peat. The upper 2 m of deposit sequence at Sleperi Mire consists of *Sphagnum fuscum* and cotton-grass-*Sphagnum* peat, the decomposition of which decreases higher up, from 30 to 10%.

Engure Lake is the largest basin in the western coastal area of the Gulf of Riga, which has developed due to processes caused by the activities of the Baltic Sea stage basins. The area of the plain surrounding the lake is covered throughout by sand and gravel deposits (Eberhards and Saltupe, 2000). Engure Lake is connected to the Gulf of Riga through the canal that was excavated in 1842, which caused the lake water level to fall by 1.5 m and causing the terrestrialisation of former lake areas. Reed beds consisting of *Phragmites australis*, *Typha* *angustifolia, Scirpus lacustris* and rich submerged vegetation dominate in the shallow parts of lake. *Cladium mariscus* and *Myrica gale* occurs on lake shores and in the lower depressions rich fen vegetation characterized by high species diversity and including tall-sedge has developed. Analysed in this study is data from the lake southern coastal area, where the oldest peat accumulation has been found, and, where fen grass peat layer about 0.5 m thick has formed, while in areas around the lake peat layers do not exceed 15-20 cm. The age-depth model for this area of Engure Lake indicates uniform deposit accumulation (Fig.1).

Bazi Mire has formed in the most unusual zone of the Littorina Sea Plain, represented by series of alternating long narrow walls (beach barriers with a cover of aeolian deposits) and narrow depressions between ridges (usually occupied by mires and lakes). Comparatively high groundwater level in the depressions between dune ridges and calcareous bedrock resulted in the formation this specific mire type: inter-dune mires which are located between the coastal formations of the Littorina Sea. Fens have formed in the wet depressions between ridges. In some cases, when depressions have been filled in up to the top of the ridges, the mire has continued to grow and has also covered the ridges, and converged with other interdune mires, creating a continuous raised bog cover. At Bazi Mire the complex of dunes and inter-dune mires between them were formed during the Post-Littorina Baltic Sea development stage of the last 5251-5342 years cal BP. Peat formation become more intense and gradually changed from fen and transition peat to raised bog, where *Sphagnum* and *Eriophorum vaginatum -Sphagnum* dominate. The very upper *Sphagnum* peat layer of 1 m thickness has been formed during last 742 years or approximately 1.3 mm per year. This layer is mainly represented by poorly decomposed (5%) *Sphagnum* peat.

Pollen and macroremain data from the Priedaine site section indicate sediment formation mainly during conditions of shallow lagoon or lake. The fine sand layer on the bottom has been covered by peaty gyttja with wood remains. An admixture of sand grains is noticeable in the gyttja, the amount decreasing upwards. The composition of gyttja (amount of sand and plant remains, species of macroremains) frequently changes, which also indicates environmental changes. Pollen data reflect changes in regional and local vegetation composition from the Atlantic until the present day.

Comparison of data from all studied sites, which became shallow lagoonal lakes approximately at the same time, shows that terrestrialisation processes started at different times. The age-depth models for the studied sites reveal differences in mire development and peat formation intensity (Fig. 1). Models reflect the most intensive peat accumulation during the last thousand years in Sleperi and Bazi mires, where raised bog type peat accumulations have take place.

## CONCLUSION

The general conclusion of the study is that the variety of vegetation and peat botanical composition of fens mainly depends on local conditions and influences, and less on the variety and changes in regional climate.

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