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# CHARACTER OF PALEOVEGETATION CHANGE IN LAKES PILCINES, PILVEĻU AND PADĒLIS

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## ABSTRACT

Paleovegetation studies of lake development using carpology method (analysis of seeds and fruits in sediments) can provide significant information about evolution of lakes and indirect data about change of water level, run-off changes and geochemical processes in catchment area of the lake.

In this study vegetation changes during the evolution of three lakes in Latvia – Pilcines, Pilveļu and Padēlis and its likely reasons was investigated. These lakes are small, presently shallow glacial origin lakes. The catchment territories of these lakes are mostly covered by forests and mires.

Full sediment profiles (4 m lakes Pilveļu and Padēlis and 3 m Lake Pilcines) were taken and each of them was cut into 10 cm slices (each sample approximately 50 $cm^3$). Until analysis they were stored at - 20°C. Samples for macrofossils analyzes were washed through sieve (0.25 mm) with a gentle spray of water. Treated sediments were investigated using a microscope. Loss on ignition (*LOI*) method was used to estimate moisture, organic matter and carbonate content of sediments.

In Lake Padēlis seven plant assemblages was determined using the macrofossil analyzing method and six plant assemblages were determined in lakes Pilcines and Pilveļu as well. Based on different patterns for each assemblage, it was found, that the character of vegetation change in each lake have different character due to diversity of sediment composition in the catchment area and human impact.

Key words: macrofossils, lake sediments*, Naja flexilis*, *Cladium mariscus, Trapa natans*

## INTRODUCTION

Studies of the long-term changes of ecosystems are of utmost importance to identify their reaction to human impacts and natural environmental variability (Veski et al., 2012). Communities react to ecological factor fluctuations developing tolerances and changes in their structures (Ammann et al., 2007). Knowing ecosystem reaction character it is possible to reconstruct paleoenvironmental conditions.

One of the ways to make the reconstructions is to investigate sediments of lakes. For sediment studies multiproxy approach can help to identify past environmental conditions. Palaeoecological records preserved in sedimentary deposits can provide unique insight into the nature of past ecosystems and the long-term plant population, plant community dynamics (shifts in vegetation, Holocene species migration). In addition it can be used to obtain data about water level changes, run-off and geochemical processes in the catchment area of the lake (Bjune, 2005;

Work et al., 2005; Veski et al., 2012).

Macrophytes are an important component of lake ecosystems and their processes, because they play a primary role in the formation and stabilization of lake sediments, such as sapropel. Sapropel sediments are capable to absorb and release nutrients from the lake water supporting internal loading and influence the trophic status of water bodies. They provide food and habitats for many other lake organisms (algae and animals) as well.

Plant macroremains are usually well preserved in anaerobic lake sediments. The macrofossil assemblages are usually determined by aquatic and shore plants and the vegetation in the catchment. The most common fossil plant remains are seeds, fruits, and leaves, but other characteristic parts may also be identified and used in reconstructions (Baker, 2007; Gaillard & Birks, 2007). The analysis of the macrofossils in lake sediments thus provides a valuable information on the lake ecosystem changes through the time. The main factors affecting the structure and composition of aquatic vegetation within a lake are: water depth, water chemistry and nutrient-status (alkalinity, base cations, nitrogen, and phosphorus) and temperature as well as run-off from the catchment area and depositional environment (Gaillard & Birks, 2007; Cañellas-Boltà, 2012).

The aim of this article is to study vegetation changes during the evolution of three lakes in Latvia – Pilcines, Pilveļu and Padēlis and the contribution of plant macrofossil analysis to paleovegetation studies.

## MATERIALS AND METHODS

### *Study site*

Full sediment profiles from three lakes in Latvia

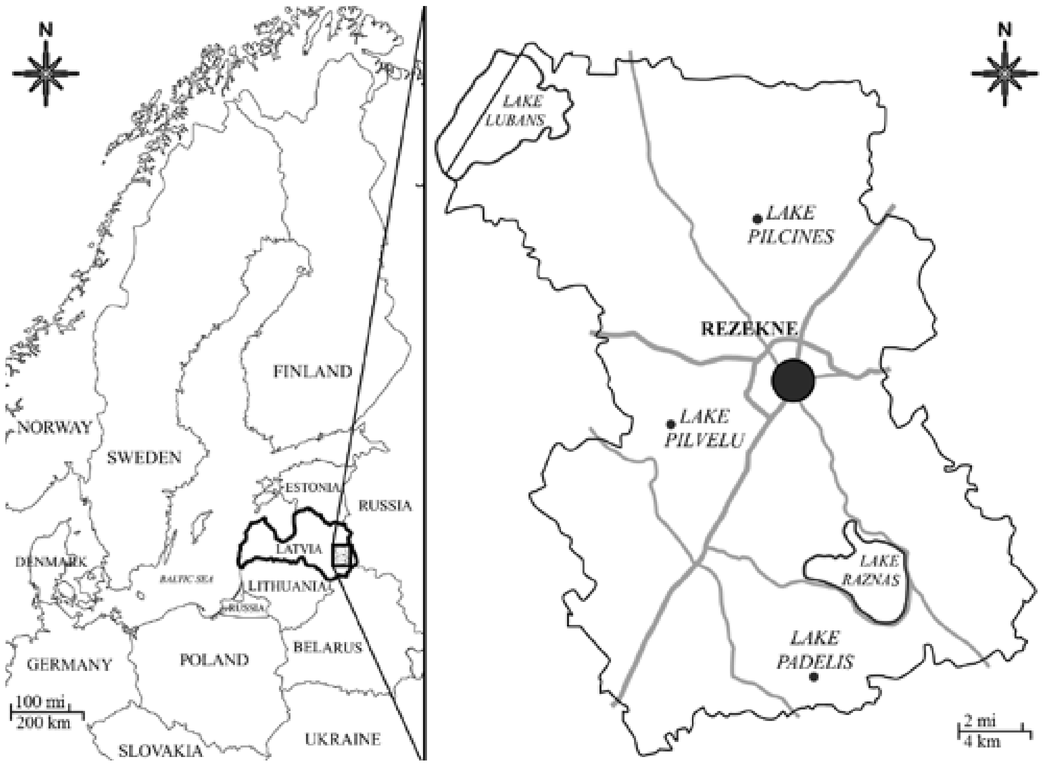


Figure 1. Map of the study area.

were used in this study. The lakes – Padēlis, Pilcines and Pilveļu – are located in Rēzekne district, Latgale region (Figure 1). Despite that lakes are near to each other, they are located in different natural areas. Lake Pilveļu is situated in the south-west part of Rāznavas hilly area (Markots, 1997). Lake Pilcines is situated in north-west part of Burzavas hilly area, but Lake Padēlis in south-east part of Maltas depression (Markots, 1994; Markots, 1995). All the lakes are inter-hilly water bodies and in origin belong to the glacial type. Sedimentation of Lake Pilcines and especially Lake Padēlis were affected by the admixture of fragments of bedrock sediments (dolomites, marlstone and carbonates) to the glacial deposits during deglaciation process (Markots, 1995).

The area is uninhabited and surrounding territory mostly is covered with forests and mires. 100 m wide belt with fen divide Lake Padēlis west coast from Lake Stiebrājs. In 20th century first part both lakes still was connected with channel (Topo 50k PSRS; Topo 75K). Both lakes are situated in the same inter-hilly zone in Malta's depression, showing that probably once they were one lake. The water surface area of each lake does not exceed 10 hectares, and the sediment fills the lakes' trench for more than 80% (Table 1).

Sampling points were selected considering the lakes' characteristics and preliminary data for sapropel layers in the given location. Full sediment profiles (4 m lakes Pilveļu and Padēlis and 3 m Lake Pilcines) were taken and each of them were cut into 10 cm slices (each sample approximately 50 cm$^3$). Until analysis they were stored at - 20°C

***Methods***

Loss on ignition (LOI) method was applied in order to estimate moisture, organic matter and carbonate matter content in the sediments (Dean, 1974; Heiri et al., 2001). At first, the moisture of sediments was determined after drying at 105°C. The content of organic and carbonate matter was analyzed by ashing samples sequentially at 550°C for 4 h and at 900°C for 2 h.

Samples for macrofossils analysis (approximately 50 cm3) were washed through sieves with a gentle spray of water. The residue was washed gently off the sieve into a container and kept cold until analyzed. Small quantities of the residue were suspended in a shallow dish (e.g., Petri dish) and examined systematically under a stereomicroscope at about 40 magnifications until the whole sample had been examined. Remains of interest were picked out and sorted, identified, using different books (Ellenberg, 2009; Ellenberg et al., 1992; Sloka, 1978; Velichkevich & Zastawniak, 2006; Velichkevich, & Zastawniak, 2008) counted, and tabulated (Birks, 1980). The graphic pictures were made using Tilia 1.17.6. program.

Samples of organic deposits from sediment's profiles were dated by means of $^{14}$C method. The samples were analyzed at the Institute of Geology (Tallinn University of Technology), Estonia. In total, 9 horizons were dated (Table 2). The dates were calibrated, and an age/depth model was built with Clam 2.1 out model (Nita & Szymczyk, 2010).

Table 1.
The characteristic features of lakes.

| Lake | Coordinates | | Depth, m | | Area, ha | Fill of trench, % |
|---|---|---|---|---|---|---|
| | E | N | Max | Average | | |
| Padēlis | 6237403 | 707644 | 1.7 | 1.5 | 3.5 | 80 |
| Pilveļu | 6263437 | 692728 | 1.0 | 0.9 | 9.9 | 90 |
| Pilcines | 6284669 | 701748 | 1.7 | 1.5 | 7.0 | 80 |

Table 2.
Radiocarbon dates from the three lakes studied, sample depth, material dated, $^{14}C$ age BP and calibrated age BP.

| Lake | Depth, m | Material dated | Age ($^{14}C$ yr BP)) | Age (Cal yr BP) |
|---|---|---|---|---|
| Padēlis | 1.76 | sapropel | 6671±0,7 | 7088 |
| | 2.79 | sapropel | 7885±80 | 11405 |
| | 3.90 | sapropel | 10090±80 | 11608 |
| Pilveļu | 1.80 | sapropel | 4947±60 | 5278 |
| | 2.40 | sapropel | 5292±55 | 6520 |
| | 3.90 | sapropel | 8983±85 | 9980 |
| Pilcines | 1.50 | sapropel | 4136±55 | 4578 |
| | 2.00 | sapropel | 4925±55 | 5670 |
| | 2.90 | sapropel | 6253±65 | 7219 |

## RESULTS AND DISCUSSION

Littoral sediment composition is determined by the geological composition of the drainage area, morphological features of the shoreline and biological, physical as well as chemical processes in lakes (Schmieder et al., 2005). Catchment of Lake Padēlis bedrock is overlaid by carbonatic sand and gravel (Markots, 1995), which affected the tolerance of common species in respect to alkaline reaction. Catchment of Lake Pilcines bedrock is overlain

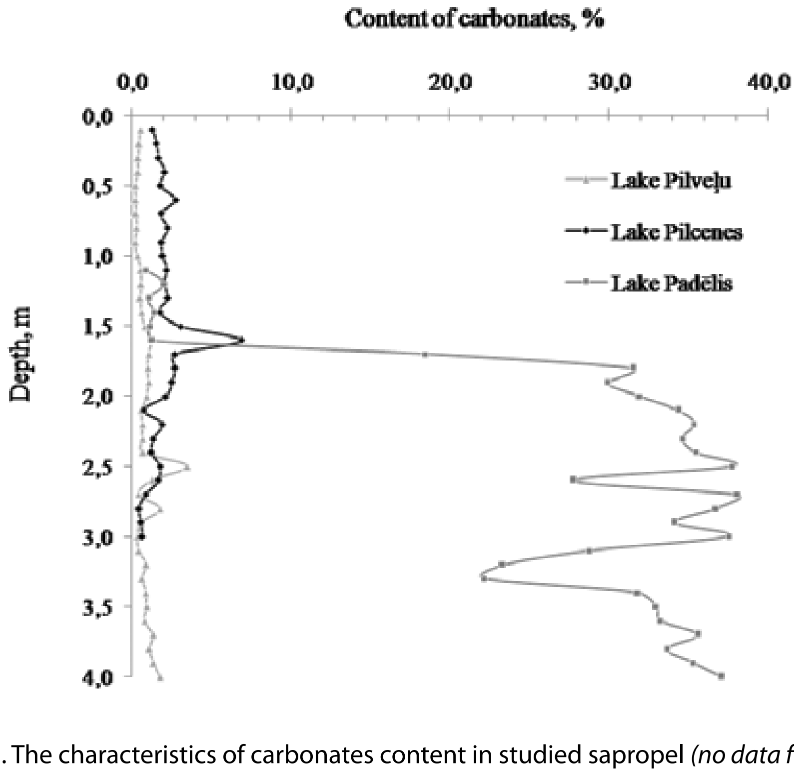


Figure 2. The characteristics of carbonates content in studied sapropel *(no data for first meter of Lake Padēlis sediments*).

by sand, silt and clay, with small amounts of carbonates (Markots, 1994) influencing presence of carbonates in the lake sediments (Fig. 2.). Catchment of Lake Pilveļu bedrock is overlaid by loam and sandy loam with low carbonate content (Markots, 1997).

***Lake Pilcines***

Near the sampling point spring flows into the lake, so coastal and land plants occurred regularly in whole sediment profile. The most extensive diversity of species and the biggest amount of remains was in the sediment's top layer, which is related to heavy lake overgrowing and eutrophication.

Generally, grounded on the main assemblages of macrofossils sediment core of the Lake Pilcines can be divided into six zones (Figure 3):

I – *Picea-Carex* (3 - 2.7 m), slightly occurred remains of bryozoa *Cristatella mucedo* (Cuvier, 1798) statoblasts and some *Orthotrichia* larval cases and *Carex* nuts. Fragments of *Picea* needles and pieces of wood and washed in leaves of tree-plants from coastland was found as well.

II – *Potamogeton praelongus-Menyanthes-Picea* (2.7 - 2.4 m) zone consisted of aquatic plant *Potamogeton praelongus* (Wulfen) and *Potamogeton natans* (L.), coastal water plant *Menyanthes,* telmatic plants *Cicuta virosa* (L.), *Carex* and fragments of *Equisetum* culm. Fragments of *Picea abies* ((L.) H. Karst) and *Pinus sylvestris* (L.) needles occurred abundantly. Total volume of detritic remains rapidly increased. In sediments quartz sand grains and rounded off pieces of wood were found in small amounts, as well as few charcoal. Plenty of larval cases of the hydroptilid *Orthotrichia* and bryozoa statoblasts occurred. This may be related to water level decrease, intensification of eutrophication and air temperature rise. Amount of washed in remains proves, that littoral was not overgrown and had not become bogged up yet – remains from coastland with high water easily could be washed into the lake.

III – *Picea-Betula* (2.7 - 2.4 m) – zone presented few fragments of *P. abies* and *Pinus* needles, and remains of bryozoas and *Orthotrichia*. Total amount of remain was paltry and consisted of plants' detritus and zooplankton's chitin. This may be related to water level increasing.

IV – *Trapa natans-Potamogeton-Nuphar lutea* (2.2 - 1.5 m) – zone consisted of aquatic plant *Potamogeton acutifolius* (L.) and *P. natans*, *Trapa natans* (L.), *Nuphar lutea* (L. (Sm.)). Total amount of detritus was small. Water level of lake still remained high. Slowly increased remains' amount of bryozoas, which may be related to growing up aquatic plant quantity in lake, because bryozoas live attached to aquatic plants stems. Presently bryozoa *Cristatella mucedo* as well as *T. natans* are rare in Latvia (Sloka, 1978; Žvagiņa et al., 2005). The water chestnut (*T. natans*) grows in slowly flowing or stillwater bodies, in well warmed areas protected from wind (Dementeva & Petushkova, 2009).

V – *Trapa natans-Potamogeton-Nuphar-Scirpus lacustris* (1.5 - 0.4 m) – still in the lake remains of *T. natans* were distributed (till 0.9 - 1 m depth) as well as *P. natans, N. lutea*, *Typha*. Generally, *Typha* occurrence is indicative of increased amount of nitrogen in the lake ecosystem. Telmatic plants *Lycopus europaeus* (L.), *Carex,* C. *virosa* occurred regularly. From 0.8 m appeared remains of ruderal plant *Raphanus raphanistrum* (L.). Lake level decreased and amount of aquatic plant increased because of the overgrowth. Littoral plant belt with *Typha, Scirpus lacustris* (L.)*, Alisma plantago aquatic* (L.)*, Equisetum* become wider. Leaves of hypnum moss together with remains of marsh plant *Andromeda polifolia* (L.) occurred regularly, indicating mire formation. Abundant remains of bryozoas and *Trichoptera* were found. This zone was the first one with Daphnia occurrence.

*T. natans* grows in calcium-poor backwater till the depth of 1 – 2.5 m. In the climatic optimum of Holocene it was present in large quantities in Lake Lubāna (Loze & Jakubovska, 1984; Ceriņa et al., 2007). Nowadays *T. natans* is present in 3 lakes (Žvagiņa et al., 2005).

VI – *Potamogeton-Nuphar-Nymphaea-Carex-Chenopodium-Linum usitatissimum* (0.4 - 0 m) – in this zone various species of pond-weed (*Potamogeton gramineus* (L.), *P. natans, Potamogeton perfoliatus* (L.)) are most common. Plants with big floating leaves *N. luteu, Nymphaea alba* (L.) occurred. Remains and species number of telmatic plants (*Carex, Taraxacum officinale* (F.H.Wigg), *Persicaria minor* (Huds), *Comarum palustre* (L.) etc.) were increased. Plenty of ruderal plants as *Chenopodium album* (L.), *Raphanus raphanistrum* (L.), *Spergula arvensis* (L.) and seeds of cultivated plant flax *(L. usitatissimum)* started to occur. These seeds indicated intensive agriculture activity near the lake.

In Latvia general *L. usitatissimum* seeds have been found in Kivtu settlement (Early Iron Age, 2th – 4th century), in Āraišu lake castle (Middle Iron Age, 5th – 9th century), but *R. raphanistrum* have been found only in Ķenteskalns before (Late Iron Age, 12th – 13th century) (Rasiņš & Tauriņa, 1983). In Estonia fruits of *R. raphanistrum* have been found in sediments from 16 – 17th century, but seeds of *L. usitatissimum* in sediments starting from 13th century (Sillasoo & Hiie, 2007).

### *Lake Padēlis*

Sampling point was located in lakes southeastern coast. In this side of the lake swell could be observed because of dominant northwestern winds. This factor could determinate that more organic matter from coast was washed in, especially during the floods.

Generally, based on the main assemblages of macrofossils sediment core of the Lake Padēlis can be divided into seven zones (Figure 4):

I – *Najas marina-Characeae-Carex* (4 - 3.4 m) – seeds of *N. marina* L. and Characeae oogonias regularly appeared regularly in small amounts. To the top remain amount of aquatic plants and water animals increased gradually. In to the carbonatic sediments plant detritus occurred in little amounts as fragments of hypnum leaves and aquatic plant epidermis. Remains of zooplankton were the most common. This indicates that lake was shallow and littoral belt was relatively near.

*N. marina* vertical distribution varies with the light penetration of the water. For example, in the sources of the Yarkon River (Israel) it appears no deeper than 1.5 m, even during the optimal growth season (Agami et al., 1984). This circumstance may confirm that lake in this period was shallow.

II – *Najas marina* (3.4 - 3.2 m) – seeds of *N. marina* were dominant. Characeae oogonias occurred in small amounts. *N. marina* is submerged aquatic plant, which is present in mesotrophic lakes with alkaline water reaction (Ellenberg et al., 1992). *N. marina* optimum depth for growing is 0.5 m – 2 m, but for Characeae – 6 m (Gaillard & Birks, 2007). Water level may be higher than before, because remains of coastal plants did not occur in this zone. Detritus consisted from zooplankton and aquatic plant fragments of epidermis.

III – Characeae-*Najas marina* (3.2 - 2.3 m) – Characeae was dominant species in this zone. Remains of *Najas marina* (L.) occurred in smaller amounts than in deeper layers. Leftovers of *Nymphaea alba* (L.), *Menyanthes trifoliata* (L.), *Cladium mariscus* (L.), *Carex* showed that process of overgrowing became more intensive. Saw sedge (*C. mariscus)* is a caulofitic rhizomous perennial (Komosa et al., 2006) and grows on nutrient-poor, shallow waterbodies, therefore it established that water reaction was alkaline and lake was shallow in this period (Salmiņa, 2003). Between 1.5 m and

1.6 m oogonias surface was covered with thin layer of carbonate calcium carbonate. It may indicate that water level slightly decreased and water temperature increased.

IV – *Najas marina*-Characeae-*Najas flexilis-Menyanthes trifoliata* (2.3 - 1.6 m) – *N. marina* was dominant in the first part, but in the second part amount of Characeae remains increased. Amount of coastal plant leftovers was found less that indicates water level, probably, rose. Fragments of plant epidermis were still the most common in detritus, but hypnum stems with leaves occurred from depth 1.1 m.

V – *Najas flexilis- Najas marina-Nymphaea alba-Menyanthes trifoliata-Cladium mariscus-Carex* (1.6 - 1.1 m) – Amount of *Najas flexilis ((*Willd.) Rostk. and Schmidt), *N. alba* and *M. trifoliata* seeds and leftovers of mire's and coastal plants rapidly increased. Plenty of pondweed species occurred. Border of bottom layer was sharp, indicating rapid sedimentation conditions changes. Probably this layer represented time, when Lake Padēlis split from current Lake Stiebrājs because of overgrowing.

VI – *Carex- Myosoton aquaticum- Thelypteris palustris* (1 - 0.3 m) – some seeds of aquatic plants and marsh plants (*Thelypteris palustris* (Schott) were still common in layer from 1 - 0.8 m, but in higher layers there were only seeds of *Betula* and fragments of *Pinus* needles. Sedge roots, plenty remains of hypnum moss and reeds were found in detritus. In the bottom layer of zone remains of reeds were predominant, but in upper layer - remains of hypnum moss. This may be caused by continuing water level decreasing because of overgrowing.

VII – Characeae-*Najas-Nymphaea alba* (0.3 - 0 m) – A large number *Characeae* oogonias occurred. Submerged plants *N. marina, N. flexilis*, *Potamogeton pusillus* (L.) and floating-leaved plant *N. alba* seeds were found. In layer from 0.3 m to 0.2 m reed peat accumulated, but from 0.2 m to the bottom there were less plant vegetative remains and significant amount of aquatic plants epidermis detritus.

Generally, in sediments of Lake Padēlis were found several rare and protected species *Najas marina, N. flexilis* and *C. mariscus* in nowadays. At present moment there are no *C. mariscus* in Latgales highland, but some specimens, which can be found in the eastern Latvia are considered to be relicts from climatic optimum period of Holocene (Salmiņa, 2003).

***Lake Pilveļu***

Sampling point was located 50 m from north-west coast. Coastal and land plants were in relatively small amounts because of comparatively far sampling point location.

Generally, based on the main assemblages of macrofossils sediment core of the Lake Pilveļu can be divided into six zones (Figure 5):

I – *Carex* (4 - 3.9 m) – seldom *Carex* nuts and *Characeae* oogonias occurred. Washed in *Betula alba* (Ehrh.) nuts were found. Chitin fragments of zooplankton and several hypnum moss leaves and culms occurred. Hence, it was suggested that in this period lake's vegetation was poor.

II – *Najas marina-Najas flexilis-Typha_Carex* (3.9 - 3.2 m) – *N. marina, N. flexilis* and *Typha*, *Carex* and *Characeae* oogonias regularly occurred. Plenty of bryozoans *Cristatella mucedo* (Cuvier, 1798) were found. Detritus consisted of washed in tree-plant leaves and fragments of twigs, aquatic plant remains were in little number.

III – *Najas flexilis-Characeae-Potamogeton pussillus* (3.2 - 2.4 m) – Lot of Characeae oogonias, *P. pusillus* and especially *N. flexilis* were found. This kind of coexistence of *N. flexilis* and *P. pusillus* was established in sediments of climatic optimum period of Holocene and Subboreale chronozone in Poland (Galka et al., 2012). In some layers bryozoa statoblasts occurred in significant amounts. *C. mucedo* indicated relatively high water temperature, small wave action, medium or high levels of calcium, medium level of magnesium, slightly acidic water and medium water color (Økland & Økland, 2000). Seeds of coastal plants were not found, probably indicating small water level rising by the side of II zone.

IV – *Betula* (2.4 - 1.8 m) – almost no aquatic and telmatic plants were detected. Small fragments of zooplankton chitin and Daphnia remain were found. Some bryozoa *C. mucedo* statoblasts occurred. Hypnum moss leaves were found more than in III zone. Washed in *Betula* nuts were dominant. Lack of aquatic plants may indicate water level rising, but remains of hypnum moss about surrounding territories intensive bogging-up.

V – *Betula-Picea*-Characeae (1.8 - 0.9 m) – Characeae oogonias and seeds of *P. pusillus*, *Typha* sp occurred in small amounts. Remains of Daphnia rapidly increased. *Daphnia* spp. are considered to be particularly useful for answering questions regarding the effects of climatic warming on both plankton communities and whole ecosystems, as they represent a major link in the energy flow between primary producers and secondary consumers in food webs (Wojtal-Frankiewicz, 2012). Washed in spruce needles and seeds were indicating that spruce was growing over in surrounding territories. Increasing number of aquatic plants remains may present water level decreasing but growth of hypnum moss leaves especially from 1.3 m till 1.1 mb– about mirror-like surface reducing.

VI – *Potamogetons natans-Nymphaea alba*-Characeae (0.9 - 0 m) – dominant species were *P. natans, N. alba*, Characeae. Dapnia and bryozoa occurred in small amounts. *P. natans* and N. *alba* indicate, that in this period floating-leaved plants were more common. Increasing number of macrophytes species and total amount of aquatic plants remains were suggested that water level was slightly raising and water was enriched with nutrients. This may be caused by dam systems formation. From 0.2 m to 0 m sphagnum moss leaves were found indicating about transition mire development in the coast.

*N. flexilis, N. marina* and Characeae distribution in sediments (4 - 2.4 m) represented that in this time lake's water reaction was alkaline or near neutral (Feldmann & Noges, 2007). Further bogging-up process caused water acidification. This circumstance determinate *N. flexilis* extinction. Eutrophication and acidification of lakes are the main threats to *N. flexilis*. Acidification appears to reduce the ability of *N. flexilis* to produce seeds (potentially fatal for an annual). On the other hand, eutrophication leads to conditions where *N. flexilis*, an obligate carbon dioxide utiliser, cannot photosynthesise due to the predominance of bicarbonate rather than dissolved carbon dioxide in lake water (Wingfield et al., 2006).

## CONCLUSIONS

Studying lakes by paleolimnological methods gives valuable information of ecological changes. Based on different requirements for each assemblage, it was clarified, that the character of vegetation change in each lake have different pattern due to diversity of sediment composition in the catchment area and human impact. Nowadays in Latvia rare calciphyte species as *N. flexilis*, *N. marina* and *C. mariscus* were found throughout sediment profile of Lake Padēlis, except in zone, which precipitated before 4000 - 1000 cal. $^{14}$C year, because of water level decreasing. In Lake Pilveļu *N. flexilis* occurrence rapidly decreased before 6500 Cal $^{14}$C year, because of mire development caused water acidification. Weeds and ruderal plants intensive appearance were from 1000 cal. $^{14}$C year in Lake Pilcines. There seeds could be easily washed in from nearby cultivated fields. In Lake Pilveļu and Lake Padēlis sampling site were separated from cultivated areas with wide zone of mires and forests. In sediments of all lakes were established

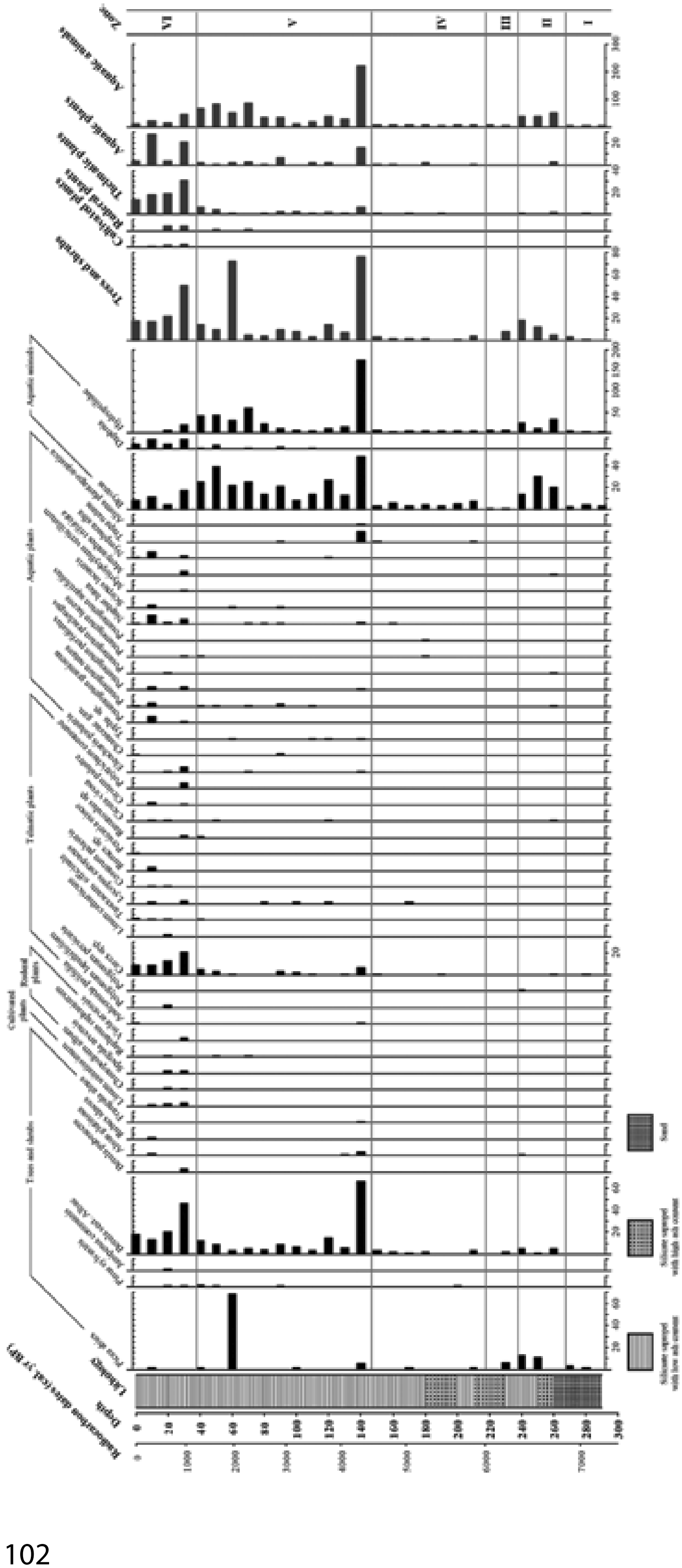

Figure 3. Macrofossil distribution in sediment profile of the Lake Pilcines.

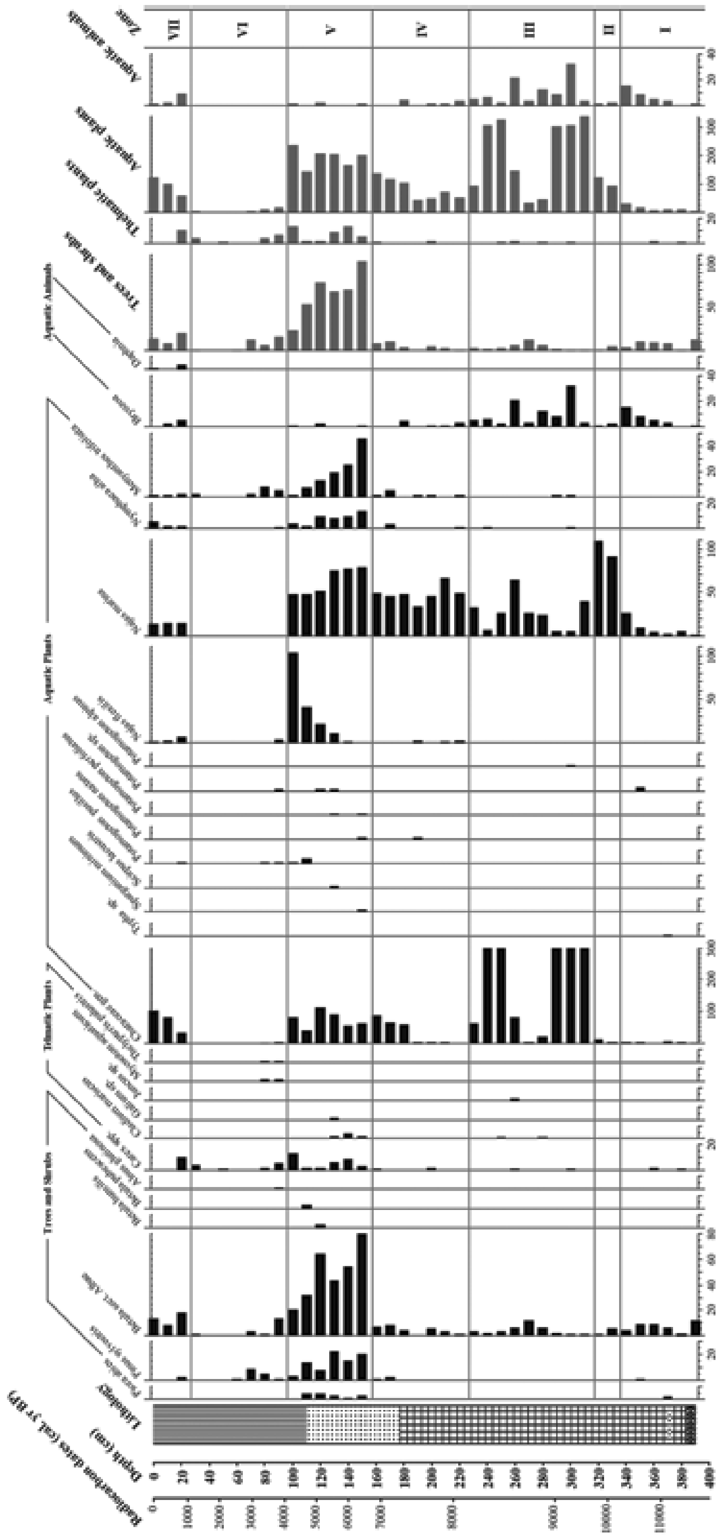


Figure 4. Macrofossil distribution in sediment profile of the Lake Padēlis.

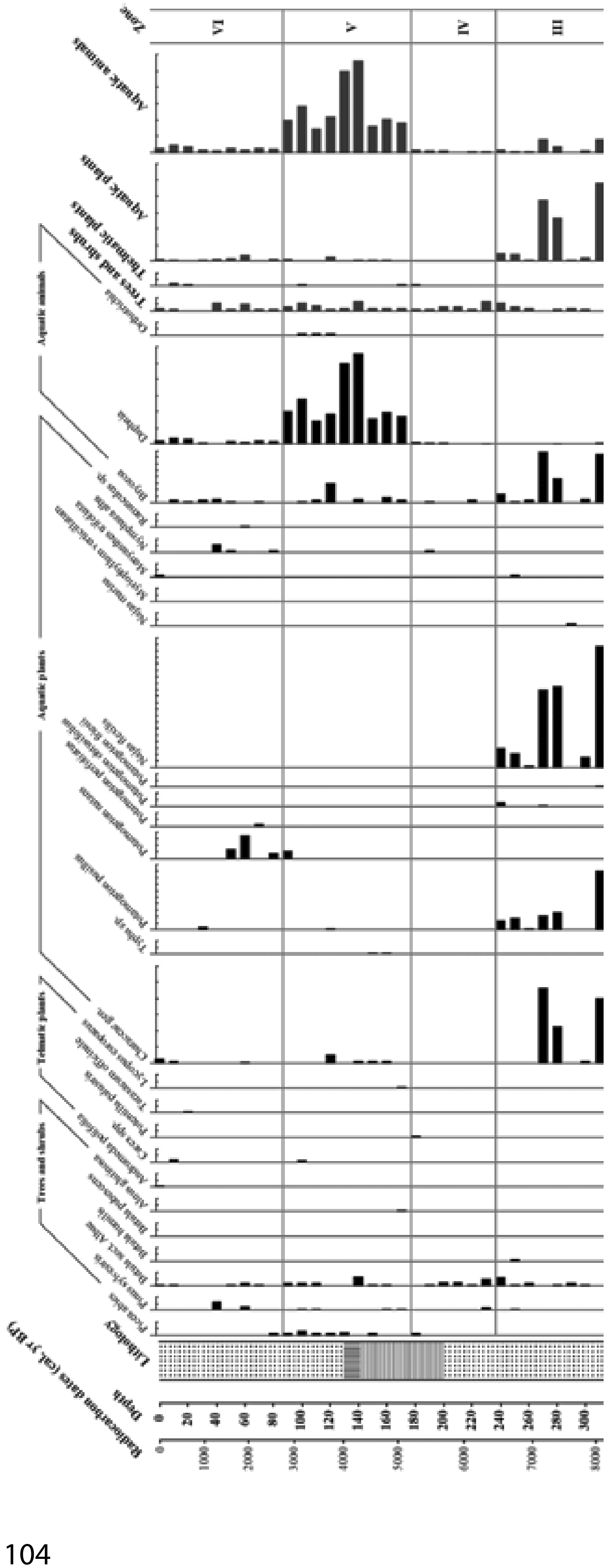

Figure 5. Macrofossil distribution in sediment profile of the lake Pilveļu.

aquatic plant remain and diversity increasing from ~ 1200. cal. $^{14}C$ year in Lake Pilcines and Lake Padēļa, and from ~ 2700 cal. $^{14}C$ year in Lake Pilveļu. It was connected with water level rising and additional flow of nutrients because of human impact.

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