Diatom-inferred palaeolimnological changes in a small lake in the context of the Holocene Baltic Sea transgressions: a case study of Lake Goluboye, Karelian Isthmus (NW Russia)

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Abstract. A sedimentary diatom record of Lake Goluboye, Karelian Isthmus (NW Russia) revealed two transgressive stages of the Baltic: the Ancylus Lake and the Litorina Sea, followed by two “small-lake” stages. During the Ancylus Lake transgression, a shallow bay of the Ancylus Lake existed in the Lake Goluboye basin, and species-rich benthic-dominated diatom assemblages formed in oligotrophic, low-mineralisation environments. The isolation from the Ancylus basin took place after ca. 9800 cal. yrs BP, when a small nutrient-rich lake formed in the basin. Two Litorina Sea transgressive phases were inferred from the diatom record of Lake Goluboye, both characterised with similar low-salinity environments. Such a weak signal of the marine transgression, compared with the other coastal sites in the Karelian Isthmus, might have resulted from the sheltered position of the lake. Our data also suppose that the maximum transgression level in the study area was lower than has previously been suggested. With the termination of the Litorina transgression shallow-water conditions with extensive macrophytes growth was established in the lake. Before ca. 4800 cal. yrs BP nutrient-rich small-lake conditions, similar to the post-Ancylus stage, became established.

1. Introduction
With the Scandinavian Ice Sheet retreat, a series of fresh and salt water palaeo-basins (Baltic Ice Lake, Yoldia Sea, Ancylus Lake, and Litorina Sea) successively occupied the Baltic Sea basin (BSB), starting from 17-15 ka cal yr BP [1], until it evolved to its present state by the second half of the Holocene. The major driving forces of this evolution were glacio-isostatic rebound and eustatic sea-level rise. The changing elevation of the threshold between the ocean and the BSB determined the water-level and salinity of the Baltic palaeo-basins. During the transgressive stages, vast areas of the coastal lowlands were inundated, which affected the morphology and sediment stratigraphy of the Baltic coastal areas. During the regressive phases numerous basins of small coastal lakes were isolated and they are now valuable archives for shore displacement studies.
The Karelian Isthmus in NW Russia is located between two large waterbodies, the Gulf of Finland of the Baltic Sea in the west and Lake Ladoga in the east (figure 1), and it was substantially influenced by their transgressive and regressive stages in the late and postglacial times [2]. These notable water-level fluctuations can presently be recognised in terraces and other coastal landforms, and exposed geological sequences [3-8]. The elevation of the Baltic palaeo-shorelines in the Karelian Isthmus increases from SE to NW due to uneven glacio-isostatic rebound that was faster in the NW.

However, there are certain limitations when using only geological and geomorphological evidence to reconstruct past relative water-level changes in the Baltic. Sometimes, only fragments of the palaeo-shorelines are preserved or are morphologically detectable, and they are scattered along the uplift gradient. Moreover, various post-sedimentary erosional and/or slope processes commonly transform the size and shape of ancient coastal landforms (terraces, beach ridges), which also complicates estimation of the relative water-level at the time of their formation. The outcrops (coastal exposures, riverbanks), in turn, may expose incomplete sediment sequences where the older deposits were reworked or destroyed during subsequent transgressive / regressive events.

In contrast to these archives, lake sediments normally contain uninterrupted records of various palaeoenvironmental changes [9, 10], representing an invaluable source of information for palaeo reconstructions. Palaeolimnological studies have been performed in the Karelian Isthmus since the 1960s [10]. The diatom analysis has been proven to be one of the most reliable tools in reconstructing environmental changes resulting from the transgressions and regressions of the Baltic palaeo-basins, since each of them has its indicative diatom species [11-13]. Once inundated by the waters of a large basin, a small lake preserves the signal of this event in its diatom record. These relic lakes that have been incorporated into large basins are widespread in the Karelian Isthmus [14]. Thus, palaeolimnological studies enabled the reconstruction of changes in the hydrological network in the Karelian Isthmus [14, 15], and combined with geomorphological and stratigraphic investigations they have significantly contributed to the studies of shoreline displacement associated with the postglacial evolution of the Baltic [8].

The aim of this study was to reveal palaeolimnological changes in a small lake in the Karelian Isthmus corresponding to the Holocene water-level changes in the BSB, and thus contribute to the relative sea-level and shoreline displacement studies in the eastern Baltic Sea coasts.

2. Materials and methods
Lake Goluboye (N 60° 40.477’, E 28° 52.931’) is a small lake (water surface area ~ 0.55 km²) located in the NW part of the Karelian Isthmus, approximately 4 km SE of the town of Vyborg (figure 1). The elevation of the water-level is 12 m a.s.l., and it drains towards the NE (figure 2). The surface of the surrounding swampy lowland lies at 12-15 m a.s.l., while the 15-m isobase contours the area with an opening towards the NE (figure 2). From the north, west and south, the lowland is surrounded by arc shaped gravelly ridges up to 25-30 m high, with large boulders on the top and on the slopes.

The coring was conducted in the western overgrown part of the lake, approximately 100 m from the coastline. A manually operated Russian-type peat corer, 1 m in length and 7 cm in diameter, was used. A preliminary lithological description was performed directly in the field, while a more detailed lithological investigation and subsampling were undertaken in the lab.

Radiocarbon dating of sediment samples was performed by accelerated mass-spectrometry (AMS) in the laboratory for radiocarbon dating and electronic microscopy at the Institute of Geography, Russian Academy of Sciences. The radiocarbon calibration program Calib Rev 7.1.0 [16] was used for the calibration of the dates.

Diatom analysis was performed for the 10.20–4.00 m interval, with 6 to 20 cm steps, depending on the lithology. The treatment of the samples for the diatom analysis followed the standard procedure, with the use of H_2O_2 to destroy organic matter [17]. Clay particles were removed by repeated decantation. At least 400 diatom valves were counted in each sample. Diatom identification followed Krammer and Lange-Bertalot [18]. Additionally, the floristic diversity “index” (FDI), a simple
measure of floristic diversity [19], was calculated as the ratio of the number of taxa identified in a sample to the number of valves counted in this sample.

**Figure 1.** Location map of the Karelian Isthmus and the study site. Symbols: star – Lake Goluboye, black squares – localities where two Litorina transgressive phases were recorded, white squares - localities where one Litorina transgressive phase was recorded; dashed arrow – location of the Heinjoki straight. Numbers for the localities mentioned in the text and their elevations above sea level in brackets: 1 – Häyry mire, 2 – Chyornaya Rechka, 3 – Lakhtinskoye mire, 4 – Suursuo mire, 5 – Lake Vysokinskoye, 6 – Privetinskoye mire, 7 – Lake Sestroretskiy Razliv, 8 – Ozyornoye-3 archaeological site.

**Figure 2.** Detailed scheme of the Lake Goluboye location. Shadowed areas are peat bogs.
Siliceous cysts of the chrysophytes (golden algae, Chrysophyceae) were counted alongside the diatoms. The “cysts to diatoms” ratio [20] was subsequently calculated. The diatom diagram was drawn using the palaeoecological software C2 Version 1.5 [21]. The diatom species were grouped according to their ecological preferences (salinity and habitats) based on Davydova [17] and Van Dam et al. [22].

3. Results
The lithological description and AMS radiocarbon dates are summarised in Table 1.

Table 1. Lithology and AMS dates for Lake Goluboye.

| Lithologic unit (LU) | Depth, m | Description                                      | C14 ages, (sample ID)/ depth, m            |
|----------------------|----------|-------------------------------------------------|-------------------------------------------|
| VIII                 | 3.10-0   | brown peat, various degree of decomposition, upper 2 m are water-saturated |                                            |
| VII                  | 4.00-3.10| dark-brown gyttja                               |                                            |
| VI                   | 4.23-4.00| brown peat / gyttja peat                        |                                            |
| V                    | 4.65-4.23| dark-brown gyttja                               |                                            |
| IV                   | 5.00-4.65| greenish                                        |                                            |
|                      | 8.00-5.00| olive-green                                     | 4260±25 (IGANAMS 6910) / 4.98-4.95        |
| III                  | 8.12-8.00| brownish-green gyttja, sharp lower boundary     |                                            |
| II                   | 8.60-8.12| grey                                           | 8800±30 (IGANAMS 6914) / 10.17-10.14       |
|                      | 9.00-8.60| bluish-grey                                     |                                            |
|                      | 10.18-9.00| greenish-grey                                   |                                            |
| I                    | 10.27-10.18| grey sandy clay, sharp upper boundary           |                                            |

In total, 266 diatom species (including intraspecific taxa, cf and sp) were identified in the diatom assemblages of Lake Goluboye. The relative abundance of the main taxa, the habitat and salinity groups, the floristic diversity index (FDI) values and the “cysts to diatoms” ratios are shown in figures 3 and 4. Five local diatom assemblage zones (LDAZ) were recognised based on the changes in the diatom assemblages and corresponding to the main stages of the lake's evolution.

In LDAZ-1 (10.20–9.9 m, LU-I and lower part of LU-II) benthic diatoms prevail (59–76%), including the species typical of the Ancylus Lake diatom assemblages, for example, Cocconeis discusculus, Opephora martyi, Navicula jentzschii, N. scutelloides, Ellerbeckia arenaria, Diploneis domblittensis, and D. maulleri (figure 3). Some of them reach 5% to more than 10% of the total diatom assemblages. Among the planktonic diatoms Aulacoseira islandica, a species typical of the freshwater stages of the Baltic (i.e., the Baltic Ice Lake and Ancylus Lake), dominates. The halophobous taxa reach their highest abundances (17–39%). The highest values of the “cysts to diatoms” ratio (> 30%) are recorded in LDAZ-1 (figure 4). The zone is also characterised by higher FDI values (0.12–0.14).

In LDAZ-2 (9.9–8.0 m, LU-II and LU-III) the “Ancylus species” disappear from the diatom assemblages, except for A. islandica that, however, does not exceed 6% of the total diatoms. Planktonic Aulacoseira ambiguа, A. granulata and A. subarctica, typical of a small nutrient-rich lake,
are dominants in this zone. Salinity-indifferent taxa prevail (up to 89%), while halophobous species contribute 7–24% of the total diatom assemblages (figure 4).

Apart from the overall predominance of planktonic taxa (to 89%) in LDAZ-2, a sudden increase in the benthic percentage (up to 56%) is recorded at around 8.96–8.93 m (figure 4). This interval is also characterised by increased abundances of some eutrophic planktonic taxa, such as *Cyclostephanos dubius*, also known as halophilous, and salinity-indifferent *Cyclotella radiosa*. Some other halophilous species, for example, *Cocconeis pediculus*, *Cyclotella meneghiniana*, *Epithemia sorex*, *Mastogloia smithii*, *Navicula cari*, and *N. tuscua* also appear in the diatom assemblages (figure 3). Total halophilous abundance reaches 19%, and the “cysts to diatoms” ratio and FDI values increase simultaneously, up to 16% and 0.14, respectively, in contrast with the rest of the zone where they remain rather low (2.8–4.8% and 0.06–0.08, respectively).

**Figure 3.** Relative abundances of the main diatom taxa in Lake Goluboye, lithological units (LU) – see table 1 for description, age, diatom zones and diatom-inferred stages of the lake evolution (AL – Ancylus Lake, sl- small lake, LT1, LT2 – Litorina Sea transgressive phases).

**Figure 4.** Relative abundances of the main ecological groups, lithological units (LU), age, diatom zones and diatom-inferred stages of the lake evolution.
In LDAZ-3 (8.0–6.30 m, lower LU-IV) planktonic *Aulacoseira* spp drastically decrease, and the diatom assemblages change to benthic-dominated, with epiphytic *Staurosirella pinnata* and *Staurosira venter* being the most abundant (figure 3). The proportion of epiphytes increases upwards from 40% to 73%, while the planktonic abundance decreases accordingly from ~42% to 11%. The abundance of bottom-living taxa also increases compared with LDAZ-2. Halophilous taxa (*C. dubius*, *C. meneghiniana*, *E. sorex*, *M. smithii*, *N. cari*, *N. cryptotenella*, *N. tuscula* etc.) reappear in the diatom assemblages making up to 18% in total. However, the relative abundances of the individual halophilous taxa rarely exceed 1–2%, except for *C. dubius*. Salinity-indifferent taxa still prevail in the diatom assemblages, and minor amounts of halophilous species are also observed. Increased “cysts to diatoms” ratios (7–20%) and FDI values (0.14–0.20) are characteristic for LDAZ-3 (figure 4).

In LDAZ-4 (6.30–4.55 m, upper LU-IV and lowest LU-V) halophilous species almost completely disappear from the record (figure 4). Epiphytic diatoms prevail in the diatom assemblages (63–93%), with high abundances of *Fragilariaeae* (*Staurosira construens*, *S. venter*, and *Staurosirella pinnata*). Bottom-living taxa gradually decrease, while the total planktonic abundance varies from 3% to 23%, with an increasing proportion of eutrophic *Aulacoseira ambiguа*. The “cysts to diatoms” ratio and FDI decrease upwards, from 5.2–7.8% in the base of the zone to 1% in its upper part, and from 0.12–0.15 to 0.04–0.05, respectively.

In LDAZ-5 (4.55–4.05 m, LU-V and LU-VI) the total planktonic abundance increases from 40% to 71%, with the predominance of *A. ambiguа* (figure 3). The proportion of epiphytes decreases accordingly. Salinity-indifferent diatoms prevail in the record (up to 92%), and the total halophilous increases (6–17%). The “cysts to diatoms” ratios and FDI values remain rather low (figure 4).

4. Discussion

The presence of the Ancylus Lake species in the diatom record at the earliest stage (LDAZ-1) of the evolution of Lake Goluboye suggests that the diatom assemblages formed during the freshwater Ancylus transgression of the Baltic started ca. 10700 cal. yrs BP [1]. Such species as *Aulacoseira islandica*, *Diploneis domblittensis*, *Ellerbeckia arenaria*, and *Opephora martyi*, etc. are commonly listed as the most typical representatives of the “Ancylus” diatom flora [11-13, 15]. Taking the ecological preferences of *A. islandica* and the above-mentioned benthic taxa into account, cold-water and oligotrophic environments are inferred for this period (LDAZ-1). The predominance of benthic taxa suggests that the basin (probably, a bay of the Ancylus Lake) was not deep, while high abundances of halophilous species reflect the low mineralisation of its waters. Higher values of the “cysts to diatoms” ratio indicate more favourable environments for the growth of chrysophytes, compared with the later stages. Higher FDI values, in turn, reflect the diversity of the habitats, especially benthic ones, provided by the variety of substrata in the littoral zone of the large basin.

Sedimentary diatom evidences for the Ancylus transgression are presently found in small lakes and peat bog profiles in the inland and coastal areas of the Karelian Isthmus. In the central and northern parts of the Karelian Isthmus, along the so-called Heinjoki straight (figure 1) that connected the Ancylus basin and Lake Ladoga in the early Holocene, Ancylus sediments are observed at elevations of 9–23 m a.s.l. in small lake basins, peat bogs, and outcrops [14, 23]. Along the Baltic coast of the Karelian Isthmus, due to the uneven glacio-isostatic uplift the sites with Ancylus Lake diatom records are located at elevations of 0.5 m a.s.l. near St Petersburg [24, 25] to more than 20 m a.s.l. in the NW part of the Karelian Isthmus [23].

At the next stage (LDAZ-2), the “Ancylus” species disappear from the diatom assemblages and a there is a shift towards the predominance of “small-lake” taxa, which indicates a rapid transition to the isolated-lake conditions due to the Ancylus Lake regression (figure 3). The radiocarbon age of the base of LU-II suggests that the isolation of Lake Goluboye took place after ca. 8800 yrs BP (ca. 9800 cal. yrs BP; table 1). It is comparable with the other coastal sites in the Karelian Isthmus that became isolated from the Ancylus Lake between 10000 cal. yrs BP and 8500 cal. yrs BP, depending on their altitude and the local uplift rate [7]. The abundant planktonic *Aulacoseira* taxa (*Aulacoseira ambiguа*, *A. granulata* and *A. subarctica*) observed at this stage should not be attributed to the increased water...
depth but rather they indicate that there were nutrient-rich conditions which favoured the growth of these species. Such *Aulacoseira*-dominated diatom assemblages are typical for many present-day lakes in the Karelian Isthmus [26]. Diatoms might outcompete chrysophytes for the dissolved silica under such nutrient-rich conditions (cf [27]) as reflected by the decreased “cysts to diatoms” ratios. A drop in the FDI values following the isolation suggests a decrease in the benthic habitat diversity and, probably, availability, which is the case in many contemporary humic-rich brown-water lakes in the Karelian Isthmus where the low water transparency limits the depth of the photic zone. Interestingly, no clear signal of the Ancylus regression was observed in the sediment stratigraphy (table 1) demonstrating a rather gradual increase in the organic content in LU-II.

A prominent, although apparently short-lived episode of increased proportions of benthic and halophilous diatoms intervening the planktonic *Aulacoseira*-dominated small-lake stage most probably relates to the initial phase of the marine Litorina transgression at the BSB, dated ca. 8450 cal. yrs BP in the Karelian Isthmus [8]. No corresponding lithological change could be visually recognised, though (table 1).

Another increase in the proportions of the total halophilous is observed in the following stage of the lake evolution (LDAZ-3) and apparently corresponds to the second phase of the Litorina transgression. These two intervals of relatively higher salinity demonstrate a close similarity in terms of the halophilous species composition and their total abundances, a decline in the *Aulacoseira* population, the predominance of benthic taxa, and increased “cysts to diatoms” ratios and FDI values. This leads us to the conclusion that the diatom assemblages of LDAZ-3 and the “higher salinity” episode of LDAZ-2 formed in principally similar environments. At the same time, the predominance of salinity-indifferent taxa and comparably low proportions of halophilous taxa (both individual species and total sum) suggests only a minor salinity increase in the Lake Goluboye basin in response to the Litorina sea-level rise. Moreover, the most abundant halophilous species, planktonic *Cyclostephanos dubius*, commonly thrive in shallow eutrophic waters [28], and thus its increase in the diatom assemblages could also indicate the higher trophic state of the basin. Epiphytic *Staurosirella pinnata* and *Staurosira venter* increasing at this stage are known to be tolerant to unstable environmental conditions, and therefore are often abundant in sedimentary diatom assemblages of coastal lakes prior to, during, or after the lake’s isolation from the sea [29]. Their indifference to the slightly increasing or fluctuating salinity might have supported the proliferation of these taxa under the influence of the Litorina transgression. The predominance of epiphytic and bottom-living taxa in the diatom assemblages of LDAZ-3 largely obscured the expected water-level rise in Lake Goluboye. These benthic-dominated diatom assemblages could result from the increased availability of the submerged substrate for colonisation, as the surrounding lowlands turned into wetlands when the transgression proceeded. It is likely supported by the transition to organic accumulation which started in LU-IV. The high FDI values also probably reflect changes in habitat availability and hydrochemical variables, in particular increased salts content, which favoured the formation of more diverse diatom assemblages.

The number of Litorina transgressive phases varies along the Baltic coast [30-33], and their duration and magnitude are still under discussion. In the Karelian Isthmus, E. Hyypää [5] recognised up to four Litorina transgressive phases based on palaeo-shoreline studies and reported one to three transgressive phases based on coastal peat bog stratigraphies [5]. In later studies, two periods of higher sea level were reported for a number of sites along the coast of the Gulf of Finland [6, 8, 34, 35, 36], such as the Häyry mire, the Chyornaya Rechka riverbank, and the Lakhhtinskoye mire, (figure 1, No.’s 1, 2, and 3). Two transgressive phases were reconstructed for the SE (Ingermanland) coast of the Gulf of Finland, and smaller scale oscillations were also suggested [2, 33]. Other coastal sites in the Karelian Isthmus, however, only record a single Litorina transgressive phase [8, 34, 37], such as the Suursuo mire, Lake Vysokinskoye, the Privetinskoye mire, and Lake Sestroretskiy Razliv, (figure 1, No.’s 4, 5, 6, and 7). Our record also suggests two phases of the Litorina transgression, the earlier apparently shorter in duration than the latter. However, in our record both phases are characterised by only a minor salinity increase, as suggested from the diatom assemblages, compared with the other aforementioned sites, where abundant and diverse halophilous and brackishwater taxa contribute to the
diatom assemblages [5, 8, 25, 34, 37]. The salinity of the Gulf of Finland during the Litorina transgression was higher than at present (8% versus 3%, [38]). Sedimentary diatom studies indicate that brackish water environments were established in the easternmost Gulf of Finland starting from 7800 cal. yrs BP [33]. The Lake Goluboye basin, however, is located in the northeastern part of the Gulf of Finland which gained a large amount of freshwater from Lake Ladoga via the Heinjoki strait (figure 1). Therefore, the Litorina waters inundating the coastal area near the mouth of the Heinjoki strait should have been subject to substantial freshening. However, the diatom record from the Häyry peat bog, located 5 km NE of Vyborg (figure 1, No 1), where brackishwater species contribute to 70% of the total diatom assemblages, did not prove this [34].

The rather weak signal of the Litorina high-standing observed in our diatom record compared with the other sites along the coast of the Karelian Isthmus could also suggest the insignificant or indirect influence of the transgression. One can speculate that the Litorina transgression level did not substantially exceed the lake’s threshold, i.e. it was slightly above 12 m a.s.l. If this is the case, our results apparently underestimate the Litorina level previously inferred for the NW part of the Karelian Isthmus.

Studies of the shorelines performed in the early 20th century suggested that near Vyborg the Litorina Sea reached at least 20 m a.s.l. [5]. Recent investigations showed that the transgression maximum here was above 15 m a.s.l. [8], which is in good agreement with the studies of the peat bogs near the Gulf of Vyborg (figure 1, No.’s 1 and 4) where the Litorina sediments with halophilous and brackishwater diatoms were observed at ~15.5–17.5 m a.s.l. [34]. However, geochemical and biostratigraphic evidences from the buried archaeological site Ozyornoe-3, located ~16.5 m a.s.l. approximately 12 km NE of Vyborg (figure 1, No. 8), do not fully support this estimation. The cultural layer dated ca. 8400 cal. yrs BP, i.e., the onset of the Litorina transgression, is overlain by sands containing freshwater diatoms [39]. This led to the conclusion about the indirect influence of the Litorina transgression. As the transgression proceeded, the outflow from small lakes draining to the Baltic basin was dammed, which resulted in the lakes level rise and inundation of the surrounding areas [39]. These results suggest that the Litorina maximum did not reach 16 m a.s.l. in the NW part of the Karelian Isthmus.

The subtle “marine” signal in the Lake Goluboye diatom record could be also explained by its sheltered position, as the surrounding hills and ridges (figure 2) should have prevented a direct connection with the Baltic. A combination of two factors, a lower transgression level and the lake’s sheltered position, might affect the formation of the diatom assemblages. However, more coastal sites in the area need to be studied before reaching a final conclusion.

The termination of the Litorina transgression ca. 5200 cal yrs BP [8] caused a transition to the small-lake environments in Lake Goluboye (LDAZ-4). Shallow-water conditions were established, and the extensive growth of macrophytes favoured the increase in epiphytes. The most abundant epiphytic diatoms, Staurosira construnes, S. venter, and Staurosirella pinnata, commonly thrive in coastal lakes during and after isolation from the sea [29], and thus can be considered indicative for the termination of the transgression. The “cysts to diatoms” ratio, which is known to increase with isolation from the sea [40, 41], in Lake Goluboye demonstrates an opposite trend declining in parallel with the halophilous diatoms. One could speculate that the shifting of the “cysts to diatoms” ratio does not reflect decreasing salinity, but rather changes in some other environmental parameters (e.g., nutrients or habitat availability). The epiphyte-dominated diatom assemblages formed after the isolation subsequently turned into the plankton-dominated ones (LDAZ-5) before ca. 4300 cal. yrs BP (ca. 4800 cal. yrs BP; table 1). Similarly to the previous isolated-lake (post-Ancylus) stage, planktonic Aulacoseira ambiguа dominates in the diatom assemblages indicating a rather nutrient-rich environment.

5. Conclusions
The sedimentary diatom record of Lake Goluboye, Karelian Isthmus, NW Russia, enabled the reconstruction of the evolution of the lake in the Holocene.
Two transgressive stages of the Baltic, the Ancylus Lake, and the Litorina Sea, were recognised in the diatom record.

In the Early Holocene, the Lake Goluboye basin was inundated by the Ancylus Lake waters. Species-rich benthic-dominated diatom assemblages with abundant Ancylus taxa formed in a relatively shallow bay of the Ancylus Lake, in oligotrophic, low-mineralisation environments.

The subsequent small-lake stage followed the isolation from the Ancylus basin after ca. 9800 cal. yrs BP. The diatom assemblages suggest rather nutrient-rich conditions.

The expected water-level rise in the Lake Goluboye basin in response to the Litorina transgression was obscured by the predominance of benthic taxa which resulted from the increased availability of benthic habitats as the surrounding lowlands turned into wetlands.

The diatom record reveals two Litorina transgressive phases in the Lake Goluboye basin marked with the increased abundances of halophilous species. However, the predominance of salinity-indifferent taxa and a lack of brackish water diatoms suggest only a minor salinity increase, compared with the other coastal sites in the Karelian Isthmus.

The rather weak signal of the Litorina transgression in Lake Goluboye might result from its sheltered position that prevented its direct connection to the sea. One can also assume that the maximum transgression level in the study area was slightly above 12 m a.s.l. In this case, our results underestimate the Litorina Sea level previously inferred for the NW part of the Karelian Isthmus.

With the termination of the Litorina transgression shallow-water conditions were established in the lake. The transitional environments and the extensive growth of macrophytes favoured the epiphyte-dominated diatom assemblages. Before ca. 4800 cal. yrs BP nutrient-rich, small-lake conditions, similar to the post-Ancylus isolated-lake stage, were established in Lake Goluboye.

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