the section, immediately after the degradation of the glacier, the lake was not restored, although the crustal rise must have taken place with considerable delay. This indicates that the presence of a glacial dam in the north could be an important factor for the formation of the lake. With its disappearance, the conditions for the formation of the lake basin also disappeared.

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APPLICATION OF FRESHWATER DIATOMS IN THE PALEOLIMOLOGY OF YAKUTIA

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As north Siberia is an area with high present-day warming rates (IPCC, 2013), reliable tools for environmental reconstructions to track lake-system adjustments to climate change on millennial to decadal time scales is of high importance. In addition, the use of environmental indicators that can assess past environments by analysing samples collected from remote sites where continuous monitoring is not feasible would help to decipher recent change. For that purpose, this study aims to set up a regional indicator-diatom set for selected environmental variables for Yakutia. In arctic and subarctic lake waters where low temperatures and ice cover limit other algae, diatoms often substantially contribute to or even dominate the lake primary production (Smol & Douglas, 2007).

Diatoms are sensitive to various environmental variables such as nutrient content and salinity (Anderson, 2000). Diatoms thus have a high potential for indicating change in most environments given that regional diatom–environment relationships are known. Such knowledge is mostly based on diatom assemblages obtained from lake surface-sediments as diatom remains, in contrast to most other algae, are preserved due to their resistant silica valves. While such sub-fossil data-sets already exist for other parts of the Arctic or Eurasia, the distribution of diatom assemblages and their relationship to environmental characteristics in lakes from Siberia in general and Yakutia in particular has not been extensively explored.

Typically, the environmental indication of complete diatom spectra are investigated using multivariate statistical methods, while the indicator value of individual taxa is less often examined (Lotter et al. 1998; Ter Braak & Van Dam, 1989; Wunsam et al., 1995). Gaining such information for Yakutia would be particularly useful to allow a more reliable qualitative and semi-quantitative interpretation of the remarkable number of available fossil diatom spectra (e.g. Pestryakova, 2000; Laing et al., 1999) previously published without the need for taxonomic harmonisation as would be necessary when applying multivariate transfer functions to fossil data.

In particular, this study aims (1) to examine the indicator value of individual species for specific environmental variables and (2) vegetation types (arctic tundra, forest tundra, northern taiga, mountain taiga, typical taiga), and (3) to evaluate the use of such information for both past environmental reconstruction and modern environmental assessments in Yakutia.

The study area comprises the Republic Sakha (Yakutia) situated in eastern Siberia, Russia. The investigated sites are scattered across a large area (56.35-72.83°N; 110.2-161.0°E) covering more than 3,000 km^2. Around 70% of the Yakutian territory is covered by mountains and upland areas. Lowland plains are widespread in the northern and central areas. Modern relief was formed during the Cenozoic. Yakutia is dissected by thousands of rivers (among them the Anabar, Olenek, Vilyuy, Lena, Aldan, Indigirka, and Kolyma) which mostly originate in the various mountainous regions and flow towards the Polar Sea. Yakutia experiences an extreme climate and belongs to three climatic zones: arctic (along the Arctic Ocean shore), subarctic (north of the Vilyuy and northeast of Aldan River), and temperate (the Lena-Vilyuy and Aldan region in Central Yakutia). The upland areas of the Central Siberian Plateau, the Aldan Mountains and the Verkhoyansk-Kolyma highland act as barriers to the warm airflows of western, south-western, and eastern origin (Matveev, 1989).

Arctic vegetation dominates about 26% of Yakutia, the other regions are covered by boreal vegetation (Isaev et al., 2010). The forest-tundra border lies along 72°N in the West of Yakutia and gradually descends to 69°N in the East.The arctic tundra is mainly composed of mosses, Carex, Dryas, Cassiope and dwarf Salix and in its southern part of shrubby Betula, Alnus and further Ericaceae. Trees in forest-tundra and the northern taiga are formed by Larix gmelinii in the eastern part (to the Lena River) and by Larix cajanderi in the west. The typical taiga of central Yakutia is mainly composed of Larix cajanderi (on sandy sites also of Pinus silvestris), and various shrub taxa (Vaccinium vitis-idaea, Arctostaphylos uva-ursi), Forest-steppe occur at few dry places in central Yakutia.

Yakutia has a large number of lakes, (there are ~700,000 lakes with a size >1 ha; most of them of permafrost (thermokarst) origin. Central Yakutian lakes are usually ice-covered from late October until mid May, whereas lakes in the northern part do not become ice-free until late June. Lake levels rise in spring due to snow melt, reach their maximum in July, and are at their lowest from November to April. Many central Yakutian lakes with closed lake basins are characterised by high ion concentrations due to strong evapotranspiration and evaporative ion concentration (Herzschuh et al., 2013).

We collected surface sediments from 206 lakes scattered throughout Yakutia in summers between 2001 and 2009. The lakes were chosen in order to cover large gradients in geography, climate, vegetation, and lake chemistry. The investigated lakes are generally shallow (median: 2.9 m) and small (median: 0.74 km^2), with small catchments. Our selected sample set includes lakes from five vegetation zones: 40 lakes are located in the arctic tundra zone, 21 lakes in the forest-tundra zone, 25 lakes in the northern taiga zone, 16 lakes in mountain taiga, and 104 lakes are located in the typical taiga zone among them 15 in Pinus-Larix forests and 13 in Betula-Larix forests and 76 in Larix forests. Surface sediments were obtained from the deepest part of each lake using a sediment grab or a UWITEC® gravity corer (upper ~2 cm of sediment).

Limnological parameters (pH, electrical conductivity, lake area, maximum lake depth, and Secchi depth) were measured in the field. Water samples were collected from 0.5 m below the surface of each lake, immediately prior to retrieval of the sediment samples. Cation content of the water was analysed by inductively coupled plasma optical emission spectrometry (ICP-OES, Perkin-Elmer Optima 3000 XL), while the anion content was determined by ion chromatography (IC, Dionex DX-320). Alkalinity was measured using a Metrohm Basic Titrino 794. The ion balance was calculated for each sample in order to ensure the reliability of the analytical methods, resulting in deviations of less than ±5% for most samples. In this study only the information on Si concentration was finally included. Information on mean July air-temperature was taken from New et al. (2002) and interpolated for the geographical position of each lake.

Diatom analyses were conducted on about 1 g of sediment. The calcareous and organic components were removed by heating with HCl (10%) and H2O2 (30%). Cleaned diatom samples were mounted on microscope slides with Naphrax®. About 500 diatom valves per slide were counted along random transects. The samples were analysed using a Zeiss microscope equipped with a differential interference contrast at a magnification of 1000x.

Out of the 26 environmental variables we selected Electrical conductivity (EC), pH, silica concentration, water depth and mean July air temperature (TJuly) because of their known relevance for structuring diatom communities and their relatively weak inter-correlation as inferred from a PCA of environmental parameters.

EC of the lake waters ranges from 8 to 7743 µS/cm which equals an ion concentration of roughly 5 to 5000 mg/l (Table 1). Further reliable indicators, but only occurring rarely, are *Epithemia turgida* (424 µS/cm) and *Navicula oblonga* (414 µS/cm). Electrical conductivity optima of >500 µS/cm are inferred for 13 species among them all taxa that belong to the genera *Anomoeoneis*, *Cocconeis*, *Stephanodiscus*, and *Epithemia*, which may indicate the preference of these genera for high electrical conductivities. Reliable indicators of high conductivities are *Epithemia adnata* (586 µS/cm), *Cyclotel-*

la meneghiniana (866 µS/cm), *Anomoeoneis sphaerophora var. jakutica* (1489 µS/cm), and *Anomoeoneis sphaerophora var. polygramma* (1641 µS/cm).

Table 1

Ranges (minimum and maximum values) and median values (in brackets) of environmental variables for the studied lakes by vegetation type

	Arctic tundra (n = 40)	Forest tundra (n = 21)	Northern taiga (n = 25)	Typical taiga (n = 104)	Mountain taiga (n = 16)	All lakes (n = 206)
EC (µS/cm)	8-277 (47.3)	14-306 (45.1)	47-633 (176)	31-7744 (609)	19-550 (133)	8-7744 (218)
T_{July} (°C)	7.6-11.7 (10.8)	9.8-13.8 (11.8)	11.5-15.2 (13.4)	16.2-18.8 (17.9)	8.2-15.1 (12.6)	7.6-18.8 (15.0)
Si (mg/l)	0.1-4.7 (0.4)	0.1-3.2 (0.7)	0.4-10.4 (2.6)	0.0-26.0 (1.4)	0.0-37.2 (3.1)	0.0-37.2 (2.4)
pH	4.8-7.5 (6.9)	5.2-7.9 (7.0)	6.0-9.6 (7.6)	6.4-10.2 (8.4)	5.0-7.5 (6.6)	4.9-10.2 (7.7)
Depth (m)	0.3-12.4 (2.8)	1.5-6.3 (3.5)	1.5-10 (2.8)	0.9-72 (2.5)	1.7-80 (5.5)	0.3-80 (2.9)

The range of mean July air temperatures (TJuly) covered by this data-set spans from 7.6 to 18.8°C. For 35 taxa TJuly is selected as the major or second major split variable in the BRT analysis, but for only 8 taxa did it cause >50% of the splits. In total, 54 taxa have a low TJuly optimum (<13°C) with taxa from the genera *Achnanthes*, *Aulacoseira*, and *Cymbella* being most common. The 50 taxa with intermediate TJuly optima (13–15°C) belong to a large variety of genera. According to our definition no taxa have been selected as reliable indicators for intermediate temperatures, because of their large tolerances (median: 3.25°C). In total, 53 taxa have a high TJuly optimum (>15°C): among them all species of the genera Amphora and Anomoeoneis and most taxa of the genera Fragilaria (12 taxa). Furthermore, the more common and abundant taxa such as Fragilaria construens, Staurosira venter, Cocconeis placentula, Epithemia adnata, Fragilaria ulna, Navicula radiosa, and Stephanodiscus hantzschii belong to this group but either they have a large tolerance or temperature was not selected as the major split variable in BRT. Rhopalodia gibba (16.1°C), Amphora veneta (18.1°C), and Cyclostephanos dubius (18.2°C) are identified as reliable indicator species for high TJuly.

Silicate concentration in the Yakutian lakes ranges from 0 to 37.2 mg/l (median: 2.4 mg/l). Highest concentrations were observed in oxbow lakes on river floodplains, while lakes with zero silicate content are located in the Viluyi region of central Yakutia. Silicate concentration is the major split variable for only 17 taxa. Pseudostaurosira parasitica var. subconstricta (optimum: 0.5 mg/l), Sellaphora bacillum (0.5 mg/l), Cymbopleura cuspidata (0.8 mg/l), Eunotia sudetica (1.1 mg/l), Aulacoseira lirata (5.4 mg/l), and Stephanodiscus minutulus (12.5 mg/l) represent reliable silicate indicators.

pH ranges from 4.9 to 10.2. Only 10.7% of the lakes are acidic (pH <6.6) most of them are located in the tundra, forest tundra, and the mountains, while lakes in northern and typical taiga cover a wider pH range. Highest pH values were found in alas lakes of the Lena-Amga interfluve. In comparison to electrical conductivity, pH is less frequently selected as the major splitting variable in BRT (SOM 1). No taxon had an optimum below pH 6.5. Only Achnanthidium affine (pH optimum 7.0), Diploneis ovalis (7.1), Eunotia triodon (6.5), and Fragilaria construens (8.0) are identified as reliable pH indicators.

The water depth varies from 0.3 to 80 m (median: 2.9 m). Most of the central Yakutian lakes are shallow thermokarst lakes, while the deep lakes sampled are only found in the mountains. Within the data-set only three species are reliable indicators of water depth: Cyclotella radiosa (optimum 2.9 m), the epiphytic Cocconeis pediculus (2.0 m), and Navicula peregrina (2.4 m). Furthermore, Cavinula cocconeiformis can be accepted as a reliable indicator (88% of splits in BRT) even though it has a high tolerance relative to other taxa (0.35 (log+1) m), because of its large optimum of 6.2 m and the low number of lakes sampled within this depth range.

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DATABASES OF THE NORTHERN LAKES AS A BASIS FOR ECOLOGICAL AIMS

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Data about abiotic and biotic factors are necessary condition to conduct modern investigations in ecology and in paleogeography (and other areas). All our knowledge about modern features of ecosystems' functioning is basis for understanding of past ecosystems conditions. Furthermore the value of the system information about environmental components increases for the farthest poorly known regions such as Arctic or the North of Siberia.

One of the most interesting and sensitive component of the environment is lakes. They accumulate the most useful and informative material about natural conditions of their surroundings in bottom sediments (as remains of diatoms, cladocerans, chironomids etc.). During our every year work we have been gathering the information about the investigated lakes and systemize it into our databases. According with this activity during a few past years we invented useful databases. Among them are "Database of the Central Yakutian lakes", "Diatoms, morphometric and hydrochemical characteristics of the lakes located in basins of major rivers of Northern part of Yakutia", "Morphometric and hydrochemical parameters of thermokarst ponds located in the river basins of Northern Yakutia", and "Diatom spectra of the Anabar River basin". All the information which contains in the databases reflects the modern conditions of the water ecosystems because we use the results of the upper sediment observations (for biota), water chemistry analyzes and lake morphological measurements. On the