NEW ARCHAEOLOGICAL, PALEOENVIRONMENTAL, AND ^{14}C DATA FROM THE ŠVENTOJI NEOLITHIC SITES, NW LITHUANIA

Gytis Piličiauskas[1] • Jonas Mažeika[2] • Andrejus Gaidamavičius[2] • Giedrė Vaikutienė[3] • Albertas Bitinas[4] • Žana Skuratovič[2] • Miglė Stančikaitė[2]

ABSTRACT. Archaeological, geological, and paleoecological investigations supported by radiocarbon dating enabled us to present a reconstruction of chronologically based paleoenvironmental and human activity changes in the Šventoji region, NW Lithuania, during the period 4000–800 cal BC. In addition, we describe the main stages of the Late Glacial and Holocene periods in the area. The Baltic Ice Lake regression was succeeded by a terrestrial period until the Littorina Sea maximal transgression at 5700–5400 cal BC. A marine bay with brackish water was transformed into a freshwater lagoon before the oldest archaeological evidence of human presence, i.e. 4000/3700 cal BC. However, the presence of *Cerealia* type and *Plantago lanceolata* pollen dating back to about 4400–4300 cal BC suggests earlier farming activities in the area. Pollen analyses show the minor but continuous role of cereal cultivation after 3250 cal BC. Due to the predominance of the boggy landscape in the immediate vicinity of the Šventoji sites, agricultural fields were situated further away from the sites themselves. Exploitation of remote areas of the freshwater basin by diverse fishing gear was proven by the discovery of a new fishing site, Šventoji 41 (2900–2600 cal BC). This finding together with data of previous research suggest a complex and elaborate coastal economy involving seal hunting and year-round freshwater fishing during the 3rd millennium cal BC. A decline in human activity is seen in the pollen diagram after 1800 cal BC, which could be due to significant environmental changes, including overgrowth of the freshwater lagoon basin with vegetation.

INTRODUCTION

The Šventoji archaeological complex (Rimantienė 2005) together with several other Neolithic lake regions in the SE Baltic, i.e. Sārnate (Vankina 1970; Bērziņš 2008), Kretuonas (Girininkas 1990), Lubanas (Loze 1979), and Biržulis (Butrimas 1982), are famous due to their perfectly preserved Neolithic artifacts in wetland sites that frequently produce astonishing evidence of everyday and ritual life, offering very favorable perspectives for interdisciplinary paleoenvironmental studies. From a coastal perspective, the Šventoji sites can be recognized as a part of a circum-Baltic seal hunters' and fishermen's community that was managed using diverse and abundant coastal food resources during the 4th and 3rd millennia cal BC (e.g. Olson 2008). Despite numerous and diverse affinities shared by European wetland and coastal sites, there is at least several cultural attributes emphasizing the uniqueness of the Šventoji region. Two very fundamentally different cultural traditions were recorded in pottery making during the 4th millennium cal BC there, i.e. the Bay Coast/Globular Amphorae and Narva ceramics. The elaborate style of Bay Coast ceramics highlights early contacts with farming communities in central Europe and a remarkable level of innovation that emerged under conditions of plentiful food resources, large coastal communities, and well-developed social contacts.

The Šventoji archaeological complex was discovered during drainage construction in NW Lithuania in 1966 (Rimantienė 2005) (Figure 1). More than 40 archaeological sites were found. Some of them were extensively investigated, uncovering an area of ~14,000 m^2 by 2009. All the sites were situated on the banks and littoral parts of a former freshwater system. They were dated to the Middle to Late Neolithic (3700–1800 cal BC) with the exception of a single Bronze Age site, 41B. Many of them

[1]Lithuanian Institute of History, Kražių 5, 01108 Vilnius, Lithuania. Corresponding author.
Email: gytis.piliciauskas@gmail.com.
[2]Nature Research Centre, Institute of Geology and Geography, T. Ševčenkos 13, 03223 Vilnius, Lithuania.
[3]Department of Geology and Mineralogy, Vilnius University, Čiurlionio 21/27, 03101 Vilnius, Lithuania.
[4]Coastal Research and Planning Institute, Klaipėda University, H. Manto 84, 92294 Klaipėda, Lithuania.

Proceedings of the 6th International Radiocarbon and Archaeology Symposium, edited by E Boaretto and N R Rebollo Franco
RADIOCARBON, Vol 54, Nr 3–4, 2012, p 1017–1031

are wetland sites with well-preserved organic materials found in waterlogged lake sediments (gyttja). Great amounts of well-preserved pottery as well as wooden and bone fishing equipment were uncovered during excavations. The remains of intensive amber processing also became evident (Juodagalvis and Simpson 2000; Rimantienė 2005). Large-scale seal hunting and freshwater fishing were inferred, in contrast to very few signs of a farming economy in the Šventoji region during the Neolithic (Daugnora and Hufthammer 1999; Daugnora 2000; Stančikaitė et al. 2009).

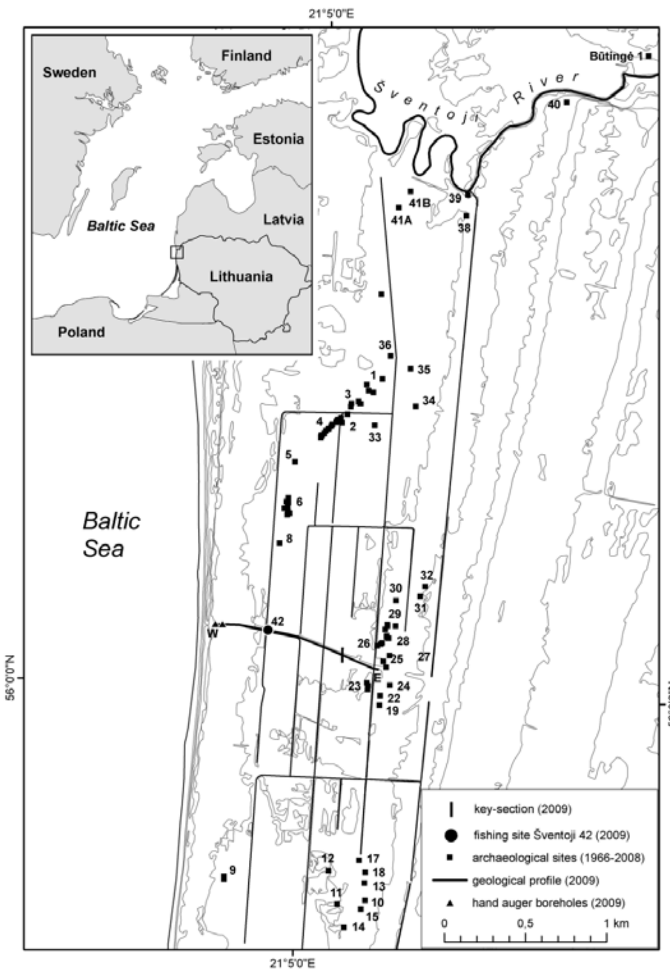

Figure 1 Map of the research area and the location of Šventoji sites. Contour lines mark elevation every 2 m.

One aim of the current paper is to renew the chronological framework and attempt to reconstruct water and land-use systems within the context of important changes in culture, vegetation, and landscape in Šventoji during the Neolithic. Results of new archaeological, sedimentological, pollen, diatom, and radiocarbon surveys are also presented here as valuable data for current and future investigations.

SITE DESCRIPTION

From the geological-geomorphological point of view, the investigated area is represented by a undulating sandy and boggy plain that formed during different stages of the Baltic Sea development throughout the Late Glacial and Holocene, i.e. during the Baltic Ice Lake (~11,700–9600 cal BC) and the Littorina Sea (~6300–2100 cal BC) (Bitinas et al. 2005; Damušytė 2011). The slopes of the Baltic Ice Lake and the Littorina Sea terraces can be tracked eastward from the investigated area. There is a belt of eolian sediments between the plain and the Baltic Sea coast—the thickness of eolian sand not exceeding 8–10 m in the foredune and a few meters in the eolian cover eastward. The total thickness of Quaternary sediments reaches up to 70–80 m and is mainly represented by glacial, glaciofluvial, and glaciolacustrine sediments.

The current research area is located in the central part of the Šventoji archaeological complex extending from a coastal sandy ridge to the eastern edge of the drained Pajūris bog. The very elongated shape of the research area was influenced by an engineering project developed in 2009 for a sewer pipe. The 934-m open trench, together with 2 boreholes, made up a research line of 1.05 km (from 56°00′4.65″N, 21°05′26.31″E to 56°00′12.35″N, 21°04′27.89″E; Figure 1).

Prior to 2009, only a few stray wooden artifacts trapped in gyttja were discovered during deep archaeological test-pitting in swampy meadows stretching over the investigated area (Piličiauskienė and Piličiauskas 2009; Piličiauskas 2010). However, the cultural layer and archaeological structures have been not registered there. Large collections of wood, bone, and stone fishing tools as well as amber waste and ornaments were collected at the adjacent Šventoji 23 and 26 sites, which were investigated in 1966, 1970–1971, and 2002–2005. Some flint tools and animal bones were also gathered (Rimantienė 2005; Juodagalvis 2006).

METHODS

Geological Survey and Sampling

In 2009, a visual survey was carried out of the mechanically excavated sewage trench, and hand-augered boreholes were made during field research in the Šventoji archaeological complex. The trench was 934 m long, 1.5–8 m wide, and 3–6 m deep, lying almost perpendicular to the sea coast. Wall segments 0.5–10 m wide were cleaned for sedimentological recording every 10–20 m. Two boreholes up to 3 m deep were drilled with a hand auger to extend the surveyed area closer to the present-day sea coast. Sediment sampling was performed in 2 ways. Systematic sampling every 2 cm took place in the key section in order to take a full core of sediments for pollen and diatom analyses, determination of granulometric composition, estimation of loss-on-ignition (LOI), as well as for ^{14}C dating. However, a single sampling point was not enough for a paleogeographical reconstruction of the research area. Non-systematic sampling for ^{14}C dating was performed in various places and depths in the excavated trench. Samples were taken by trowel and sample thickness varied between 2 and 10 cm.

Loss-on-Ignition

The estimation of calcium carbonate ($CaCO_3$), organic, and terrigenous content was determined in the investigated core. To ascertain the loss-on-ignition (LOI), sediments were dried at 500 °C for 4 hr. The determination of $CaCO_3$ content followed Gedda (2001), and the amount of mineral matter was calculated by eliminating organic and carbonate content from the dry matter.

^{14}C Dating

The samples, including peat-like sediment, sandy sediment with organics, and wood from archaeological finds were crushed and treated by acid-alkali-acid (AAA) washing to remove contamination by carbonates and humic acids. For benzene production, the remaining bulk organic carbon was used. Benzene output for most of samples was 1–3 g. The technological lines for benzene synthesis and purification used in this study were produced at the Kiev Radiocarbon Laboratory. The specific activity of ^{14}C in benzene was measured by the liquid scintillation counting (LSC) method as described in Gupta and Polach (1985), Arslanov (1985), and Kovaliukh and Skripkin (1994) using the liquid scintillation analyzer Tri-Carb 3170TR/SL in the Radioisotope Research Laboratory, Nature Research Centre, Vilnius. The ^{14}C calibration program OxCal v 4.1 (Bronk Ramsey et al. 2010) and the calibration curve IntCal09 (Reimer et al. 2009) were used for the calibration of ^{14}C dates and geochronological assessment. All dates used here are calibrated to calendar years BC.

Paleobotanical Investigations

Pollen. Samples for pollen analysis were prepared using a standard chemical procedure (Erdtman 1936; Grichiuk 1940), including treating the sediments with a heavy liquid (CdI2+KI). *Lycopodium* tablets were added to enable pollen concentrations to be estimated (Stockmarr 1971). Identification of pollen taxa was based on Moore et al. (1991). All the spreadsheets and percentage diagrams were plotted using the programs TILIA and TILIA-graph (Grimm 1992).

Diatoms. The laboratory preparation of samples was performed following Battarbee (1986) and identification of the diatom species was based on Krammer and Lange-Bertalot (1986–1991). The succession of the most frequent and ecologically important taxa is presented as percentages of the total sum of identified taxa. According to their salinity requirements, diatom species were grouped into marine, brackish, and freshwater (freshwater halophilous, freshwater indifferent). Moreover, 3 habitat groups of diatoms were distinguished: planktonic, benthic, and epiphytic (Van Dam et al. 1994; Barinova et al. 2006).

Archaeological Investigations

Visual survey of the mechanically excavated trench was the main archaeological method during fieldwork for the 2009 season in Šventoji. More careful but smaller-scale excavations were conducted only where wooden poles had been detected. The position of the wooden poles and other artifacts was recorded by total station. Samples of wooden poles have been taken for ^{14}C dating and other analyses. The eastern European definition of the Neolithic period was accepted in the current study; thus, the appearance of ceramics rather than farming was considered a starting point of the period. The Neolithic periodization proposed by Antanaitis-Jacobs and Girininkas (2002) was adopted.

RESULTS

Chronology

Ten new ^{14}C dates were obtained by dating sediment samples and artifacts collected from the investigated area (Table 1). Samples have been chosen in order to date both the sedimentological processes and the newly discovered archaeological site. Sediment samples were dated to a timespan between 5710–5480 and 1690–1600 cal BC, which corresponds to the Littorina Sea and Post-Littorina Sea stages of the Baltic Sea development (Damušytė 2011). Two ^{14}C dates were obtained for wooden poles from the Šventoji 42 site. The range of 2925–2570 cal BC is evidence of site use during the first half of the Late Neolithic.

Table 1 New ^{14}C dating results of sediment samples and archaeological finds from the Šventoji area.

Lab code	Sediment unit or artifact nr	Coordinates	Altitude[a] (m)	^{14}C age (BP)	Calibrated age range (1 σ)
Vs-1972	7	56°00′07.84″N, 21°05′10.27″E	1.12 bsl	6670 ± 140	5710–5480 BC, 68.2%
Vs-1960	7	56°00′07.84″N, 21°05′10.27″E	0.98 bsl	6610 ± 140	5670–5460 BC, 63.1%; 5440–5420 BC, 1.5% 5410–5380 BC, 3.6%;
Vs-1966	6	56°00′12.43″N, 21°04′37.31″E	0.67 bsl	6400 ± 140	5490–5210 BC, 68.2%
Vs-1963	4	56°00′10.45″N, 21°04′57.56″E	1.18 bsl	6290 ± 170	5470–5400 BC, 9.5%; 5390–5050 BC, 58.7%
Vs-1984	4	56°00′07.15″N, 21°05′13.43″E	0.09 bsl	4480 ± 60	3340–3090 BC, 68.2%
Vs-1982	4	56°00′07.15″N, 21°05′13.43″E	0.09 bsl	4430 ± 85	3330–3210 BC, 20.8%; 3180–3160 BC, 2.2% 3120–2920 BC, 45.2%
Vs-1983	3	56°00′12.42″N, 21°04′34.48″E	0.83 asl	3340 ± 50	1690–1600 BC, 46.9%; 1580–1530 BC, 21.3%
Vs-1956	Wooden pole 3	56°00′11.47″N, 21°04′47.10″E	0.4 asl– 1.07 bsl	4280 ± 40	2925–2875 BC, 68.2%
Vs-1981	Wooden pole 14	56°00′11.51″N, 21°04′46.26″E	bottom part 1–1.6 bsl	4090 ± 50	2860–2810 BC, 14.0%; 2750–2720 BC, 5.2% 2700–2570 BC, 47.1%; 2520–2500 BC, 2.0%
Vs-1999	3	56°00′12.42″N, 21°04′34.48″E	1.21 asl	10 ± 50	AD 1690–1720, 12.8%; AD 1810–1840, 9.3% AD 1870–1920, 31.5%; AD 1950–1960, 14.7%

[a]asl = above sea level; bsl = below sea level.

Geological Profile and Lithological Composition of Key Section

The geological profile was made by correlating lithological layers at the trench and 2 boreholes. Twelve layers were distinguished visually (Figure 2). The indicated lithological composition reveals multiple stages in the development of the sedimentation basin. Till occurring at the base of the

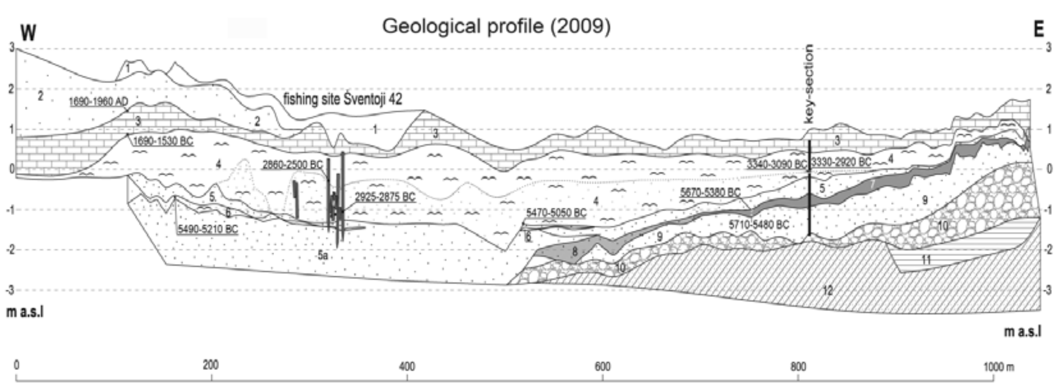

Figure 2 Geological profile: 1) technogenic layer; 2) eolian sand with varying grain sizes; 3) calcareous peat; 4) gyttja and sandy gyttja; 5) fine-grained sand; 5a) fine- and medium-grained sand with mollusk shells; 6) gyttja sand/silty sand with mollusk shells; 7) fine-grained sand with organic material; 8) fine- and medium-grained sand; 9) fine-grained sand; 10) sand with varying grain sizes, as well as gravel and pebbles; 11) silt; 12) till.

sequence (depth 277 cm) confirms a glacigenic sedimentation later changed by the glaciofluvial (depth 277–254 cm) environment. Fine-grained sand (254–194 cm) lying above this unit was formed within the sedimentary basin by predominant terrigenous sedimentation. A few interlayers of fine-grained sand with organic matter (up to 50.17%) in particular intervals were discovered at a depth of 194–170 cm. A sub-horizontally laminated fine-grained sand layer, having various colors, occurs at 170–117 cm deep. A thin layer (117–110 cm) of fine-grained silty sand enriched by organic matter (up to 15–31%) covers the sandy strata. The uppermost part of the key section is represented by sandy gyttja (110–68 cm) with organic matter content up to 46.67% and calcareous peat (68–42 cm) with organic matter content up to 81.69%.

Paleobotanical Data

Pollen. The pollen data have been described in terms of local pollen assemblage zones (LPAZ, Figure 3) based on visual and statistical evaluations of the spectra.

> Šv$_P$-1 (194–138 cm). LPAZ is marked by a high frequency of *Pinus* and *Betula*. *QM* species as well as *Picea* are also well represented. Scattered pollen grains of *Cerealia* and *Plantago lanceolata* are recorded in the upper part of the zone.
>
> Šv$_P$-2 (138–118 cm). The second LPAZ starts at 4100 cal BC dominated by *Pinus* and *Picea*. The number of *Cerealia* pollen increased along the zone.
>
> Šv$_P$-3 (110–58 cm). This zone is characterized by culmination of *QM*, i.e. *Quercus*, *Ulmus*, and *Tilia*. *Corylus* and *Alnus* culminated simultaneously, whereas the number of *Picea* decline. Regular occurrences of *Cerealia* suggest an anthropogenic impact.
>
> Šv$_P$-4 (58–42 cm). Re-expansion of *Pinus* and *Picea* is typical for this zone, while other AP decreased noticeably. The regular presence of cereal pollen in all samples of this zone is an indicator of the increasing human impact in the region since about 1700–1600 cal BC onward.

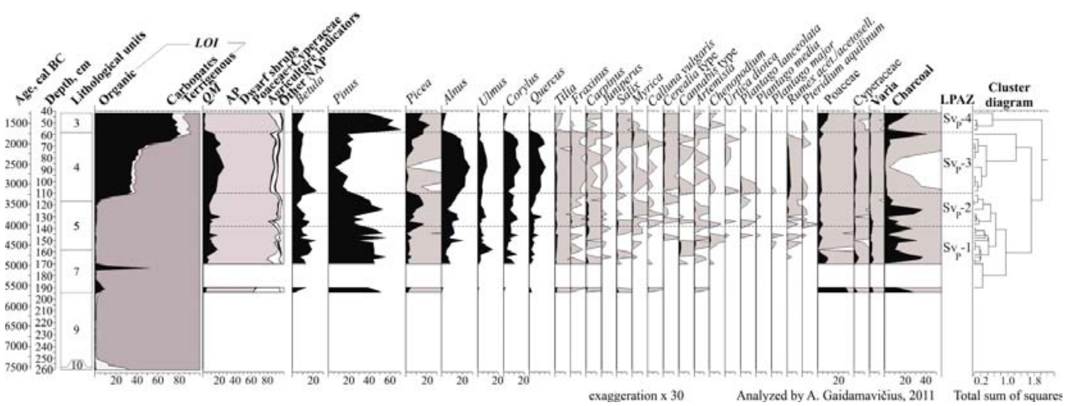

Figure 3 Pollen diagram with loss-on-ignition (LOI) data. Lithological units according to Figure 2.

Diatoms. Results of diatom analysis are presented in Figure 4. A great number of diatoms were identified at the 67–152 cm interval, whereas only single freshwater benthic and epiphytic representatives were found at 259–152 cm and 67–39 cm depth. Four local diatom assemblage zones (LDAZ) have been defined according to the diatom species composition, following statistical evaluation of the spectra.

Šv$_D$-1 (152–118 cm). Predominance of freshwater benthic and epiphytic (*Cocconeis neodiminuta*, *Amphora pediculus*, etc.) diatoms show that sedimentation took place in a shallow littoral zone of a mainly freshwater basin during the Littorina Sea stage. The presence (up to 40%) of brackish benthic species (*Catenula adhaerens*, *Biddulphia subaqua*) indicates stable connections between the freshwater lagoon and brackish sea.

Šv$_D$-2 (118–85 cm). Because of the Littorina Sea regression, the freshwater lagoon remained shallow (*Staurosira construens* and *C. placentula*), but almost without marine water inflow. A short-term rise of the water level (*Aulacoseira ambigua*) seen at the beginning of the zone may have been related to the increasing river run-off.

Šv$_D$-3 (85–73 cm). At the onset of the Post-Littorina Sea, the basin became a very shallow (*S. construens*, *Pseudostaurosita brevistriata*) freshwater lagoon with nearshore environmental conditions.

Šv$_D$-4 (73–39 cm). The onset of the Post-Littorina Sea was followed by insignificant transgression and marine water reached the area (*Campylodiscus echeneis, C. clypeus*). Nevertheless a freshwater regime with negligible inflow of brackish water predominated in the shallow lagoon.

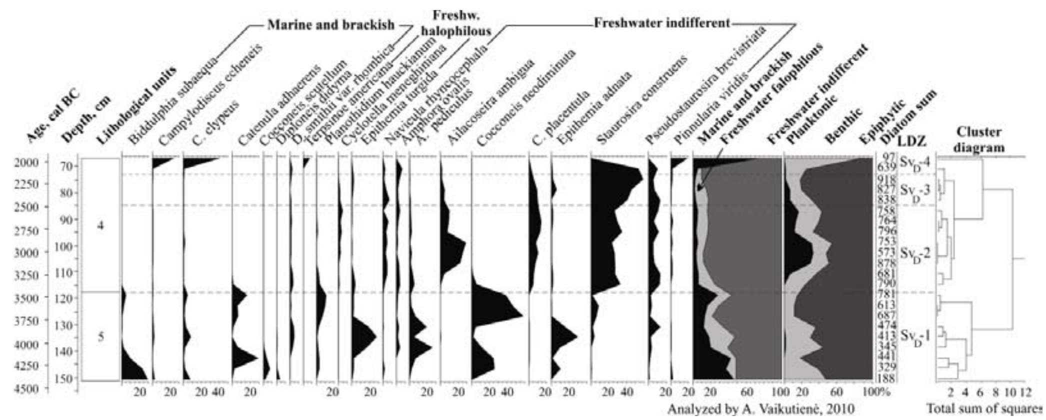

Figure 4 Diatom diagram. Lithological units according to Figure 2.

Archaeological Data

A new archaeological site located at 56°00′11.55″N and 21°04′47´″E was recorded during a geoarchaeological survey in 2009. Fifteen wooden poles were driven through gyttja into marine sand. The poles were distributed in a trench segment 15 m long and 1 m wide (Figure 2). Some of the poles lay in the horizon of sandy gyttja. They were 5–10 cm in diameter and up to 2 m long. The bottom parts were sharpened by removing several splinters up to 0.5 m long. Judging visually by their straight trunks without branches and bark remains, most of them were made of hazel trees. Some thinner stakes (2–4 cm in diameter) with notched and broken ends were also noticed. Several pine laths were discovered lying horizontally in sandy gyttja sediments (2–2.15 m depth). Components of fishing nets were also found, i.e. net sinker made of a seashore pebble and a pine-bark perforated float. No amber flakes, ceramics, flint, or other stone tools were uncovered.

DISCUSSION

Chronology of Šventoji Sites

Forty-nine ^{14}C dates directly associated with human activities are available from Šventoji sites (Figure 5). Wooden artifacts, animal and fish bones, and charred food crust from ceramics were dated at various laboratories. The 2 youngest ^{14}C dates from the Šventoji 1 site (Le-835: 3860 ± 50 BP and Le-865: 3880 ± 80 BP) gave offsets from the main chronological range of the other dates by 220–260 ^{14}C yr. Questionable dates were obtained from samples of wooden artifacts in the Leningrad (St. Petersburg, Russia) laboratory in 1970s. Timofeev (1992:11) argued for a systematic shift of 200–400 ^{14}C yr to younger age of Le dates compared to the Berlin (Bln), Groningen (GrN), and Tartu (Ta) laboratories during 1960–1980. That seems to be the case with dates Le-835 and Le-865 from the Šventoji 1 site. These dates should be omitted or used with a certain reserve when investigating the chronology of Šventoji sites.

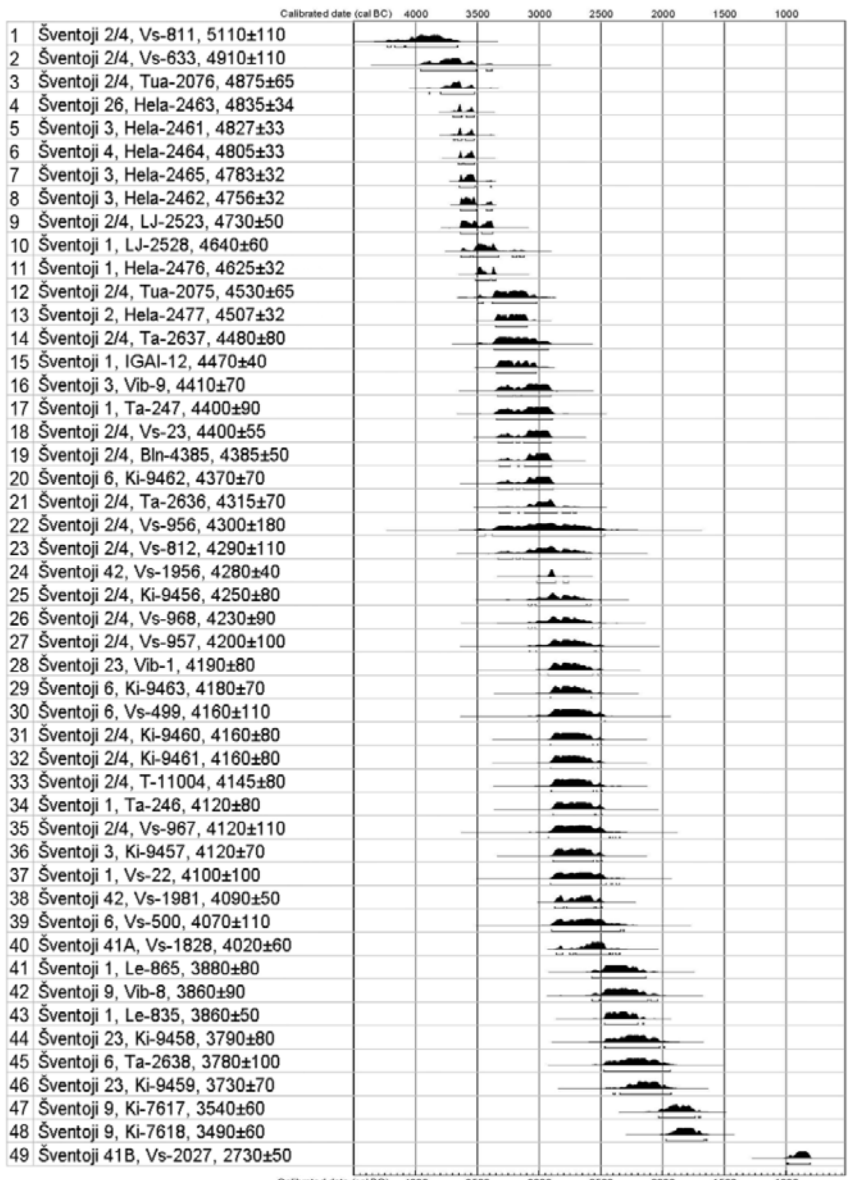

Figure 5 Overview of ^{14}C dates from Šventoji sites according to Juodagalvis and Simpson (2000), Rimantienė (2005), Piličiauskas et al. (2011), with additions by the authors of new dates: nr 24, 38, 40, and 49.

Three dates from the Radiocarbon Laboratory of the Lithuanian Institute of Botany (1971–1975) should also be questioned (Vib-1, Vib-8, and Vib-9). Date Vib-1: 4190 ± 80 BP is older by 400–460 ^{14}C yr than 2 other ^{14}C dates from the Šventoji 23 site. Date Vib-8: 3860 ± 80 BP is older by 270–320 ^{14}C yr than 2 other ^{14}C dates from the Šventoji 9 site. Date Vib-9: 4410 ± 70 BP is older by 290 ^{14}C yr than the main range of other ^{14}C dates coming from the Šventoji 3 site (excluding the oldest accelerator mass spectrometry [AMS] dates from ceramics). Today, we can speculate about possible methodological problems that the Radiocarbon Laboratory of the Lithuanian Institute of Botany may have faced in the beginning of its short existence. The use of these dates in chronological modeling would not be correct under the aforesaid circumstances.

Seven AMS ^{14}C dates were obtained from charred food crusts of 7 Neolithic sherds (Figure 5). Marine and especially freshwater reservoir effects of several hundred years are very likely here because of the Neolithic humans' strong dependence on freshwater food and seals in the Šventoji region (Piličiauskas et al. 2011).

Thirty-three ^{14}C dates from the Šventoji 1, 2, 3, and 4 sites (4000/3700–2500 cal BC) are worth combining under a single cluster because all these sites present a continuous (in a horizontal sense) refuse layer up to 2 m thick in the bed of a narrow paleochannel. The Šventoji 26 site with a single date 3660–3540 cal BC also falls within that period. Five ^{14}C dates from the Šventoji 6 site fall within a period ~3000–2200 cal BC that overlaps partly or completely with the age of the Šventoji 1, 2, 3, 4, 41A, 42, and 23 sites. A gap of only a few hundred years is evident between the sites Šventoji 23 (~2300–2100 cal BC) and 9 (~1900–1700 cal BC). The date of fishing site 41B (1260–910 cal BC) points to the Late Bronze Age and represents a single but clear indicator of human activity in the current region beyond the Stone Age.

Paleogeography

According to the results of complex investigations, a few stages with different paleogeographic conditions could be distinguished in Šventoji during the Late Glacial and Holocene. The first is linked with the Last Glacial, when the area was covered by the Scandinavian Ice Sheet. In northwestern Lithuania, the ice finally melted in approximately 12,500–11,300 cal BC (Stančikaitė et al. 2008; Rinterknecht et al. 2008). After deglaciation, the investigated area was covered by glacial (till, layer 12, Figure 2) and glaciolacustrine (silt, layer 11) sediments. During the Baltic Ice Lake (BIL) transgression (~11,700–9600 cal BC; Damušytė 2011), the uppermost part of glacigenous sediments was eroded—the relics of these sediments are represented by a layer of various-grained sand with gravel and pebbles (layer 10). During the BIL, the area of investigation was a near-shore zone of the lake where sandy sediments accumulated (layer 9). Broken remnants of freshwater epiphytic diatoms (*Epithemia* sp., *Fragilaria* sp.) imply that sedimentation occurred in a basin with intense water dynamics (swells, near-shore currents). The BIL regression was succeeded by a terrestrial period for a long time as the Yoldia Sea and Ancylus Lake did not reach the area (Kabailienė 1997; Damušytė 2011). The second stage of geological development is linked to the second (maximal) Littorina Sea transgression (5700–5400 cal BC; Damušytė 2011) when the investigated area was submerged again. During the initial stages of water transgression, the older sediments were partly eroded, forming sandy sediments with lenses of organic matter (layers 7 and 8). There was a connection between the sea and the lagoon for the first time. This confirms the relatively high amount of marine and brackish water diatoms in the sand and the admixture of mollusks such as *Macoma balthica*, *Cerastoderma glaucum*, *Mytulus edulis* (described by A Damušytė) (layers 5a, 6), which are characteristic species for a marine littoral environment. The marine bay was separated from the sea by a sandy bar, which later transformed into a spit. The semi-open lagoon became a well-isolated freshwater lagoon

(5400/5000–1600/1500 cal BC) where sandy gyttja accumulated (layer 4). The content of diatom species (Figure 4) confirms a freshwater sedimentation environment with rare intrusions of brackish water, probably during strong storms. The last stages of geological development are linked to the marine regression (~1600–1500 cal BC) when the water level dropped and the investigated area became a peat bog (layer 3). Later, some of the peat bog was partly covered (starting ~1700–1900 cal AD) by eolian sediments (layer 2). The uppermost parts of the eolian sediments, peat bog, and lagoonal sediments were partly destroyed by recent human activity in particular segments of the investigated area (layer 1).

Vegetation History and Signs of Human Impact

Early Neolithic (5500–4400 cal BC)

The pollen record representing the initial stages of the Early Neolithic suggests a prevalence of forest in the vegetation communities (Figure 3). The predominance of sandy soils in the habitats that emerged after the regression of the Littorina Sea, as well as the presence of vast wet plots, may have played a leading role in the formation of vegetation cover. Vegetation was dominated by pine (*Pinus*) in sandy areas, while birch (*Betula*) flourished on wet ground. Because broad-leaved species, i.e. lime (*Tilia*), elm (*Ulmus*), and oak (*Quercus*), require fertile soil, this taxa grew at a distance of 4–6 km eastwards from the investigated area. The number of herbs is generally low, suggesting the existence of small-scale open plots. Here, pioneer species, i.e. mugwort (*Artemisia*) and goosefoot (*Chenopodium*), and those prevailing in wet areas (Cyperaceae) may have thrived. Elevated hemp/hop (*Cannabis/Humulus*) pollen values as well as occurrence of the scattered pollen grains of cereals (*Cerealia*) at the end of the Early Neolithic, i.e. at ~4400–4300 cal BC, could be associated with the earliest tillage.

Middle Neolithic (4400–3100 cal BC)

Further development of the forest cover suggests the increasing importance of spruce (*Picea*) that gradually spread into habitats with clayey soils. Pine still thrived on the sandy plots stretching along the coast of the sea and lagoon, though the increasing number of hazel (*Corylus*), alder (*Alnus*), hornbeam (*Carpinus*), and broad-leaved species suggests the formation of a mosaic-like landscape with small-scale openings where herbs and grasses predominated. Furthermore, the presence of cereals (*Cerealia*) and increasing representation of ruderals (*Artemisia*, *R. acetosa/acetosella*) recorded in the pollen diagram and dating to ~4300 cal BC could be interpreted as traces of human interference or agricultural activity in area. Though the earliest apparent signals of crop cultivation are at ~4000 cal BC in Lithuania and Estonia (Lang 1999; Poska et al. 2004; Stančikaitė et al. 2006), some older indications were discovered in Latvia (4300 cal BC, Vasks et al. 1999) and coastal Poland (4350 cal BC, Ralska-Jasiewiczowa and Latałowa 1996), which are in good agreement with our new data from Šventoji.

Late Neolithic (3100–1800 cal BC)

The reduction of pine, birch, and spruce as well as the good representation of alder, hazel, oak, and elm could be interpreted as traces of remarkable changes in forest structure. Deciduous trees, especially those predominating on wet soil, flourished in the area. Simultaneously, the increasing number of non-arboreal pollen suggests the formation of open plots. Despite the small number of the discovered pollen grains, continuous representation of cereal pollen accompanied by weeds, such as ribwort plantain, nettle (*Urtica*), and dock (*Rumex*), could be evidence of small-scale tillage within the investigated area or in the nearest vicinities. Alternatively, cereal pollen may reflect cereals brought to and utilized by people during their stay at the Pajūris bog (Stančikaitė et al. 2009). Further, the continuous appearance of ruderals may be evidence of settlement, and this presumption has been supported by the appearance of numerous archaeological objects from the Late Neolithic (Rimantienė 1996). An increasing intensity of farming was recorded in numerous pollen sequences representing different parts of Lithuania (Stančikaitė et al. 2002, 2006) and the whole eastern Baltic (Ralska-Jasiewiczowa and Latałowa 1996; Veski 1998; Vasks et al. 1999; Niinements and Saarse 2006, 2009).

Early and Middle Bronze Age (1800–1200 cal BC)

At the beginning of the Early Bronze Age, pine and spruce regenerated in the local vegetation. The recorded decline of mostly deciduous trees, i.e. alder, hazel, etc., might have been determined by environmental changes, such as a drop in the water level and subsequent development of the peat bog in the area. The decreasing non-arboreal pollen values and number of identified taxa indicate a gradual consolidation of the vegetation structure. Although pollen grains from the cereals are still seen in the spectra, weeds and ruderals nearly disappeared, suggesting a decline in human activity.

Paleoenvironmental Model and Settlement Pattern

A schematic reconstruction of site distribution and former freshwater bodies was created in accordance with the available archaeological and paleoenvironmental data (Figure 6). This reconstruction should be treated as only a very rough model for several reasons. A systematic and high-resolution archaeological survey was performed on many scattered, and in most cases small, plots. The surveyed area represents only 4.4% of the total area of the archaeological complex today. Only 10 sites from 43 known were dated by ^{14}C and only 8 sites from 43 known were investigated to a larger extent. Currently, we are unable to reconstruct and date changes of prehistoric water bodies at many parts of the archaeological complex. Theoretically, the lagoonal lake should be isolated from the Littorina Sea by a sandy strip. We can expect that many Neolithic sites have been located there, i.e. on dry land between the sea and the lagoon instead of the low and wet eastern coast. Archaeological data from the Curonian Spit, which isolates the Curonian Lagoon from the Baltic Sea, provides clear evidence of the importance of sandy belts in the land-use system of Neolithic seal hunters and fishermen (Rimantienė 1999). However, no geological evidence of a sandy spit from the Littorina Sea era has been found yet in the Šventoji region. Probably, a sandy spit was located west of the present-day coast but it was eroded by subsequent Baltic Sea waves and currents. Despite the aforementioned limitations, some insights are possible to infer even today.

The earliest archaeological signs of human presence are from the Būtingė 1 site situated on the right bank of the Šventoji River (Rimantienė 2005). It is a multiperiod, nonstratified sandy site located some distance eastward from the sea bank of the Littorina Sea maximal transgression (Figure 1). Some microlithic flint tools from the Būtingė 1 site (Rimantienė 2005: Abb. 383) could be dated typologically to the Late Mesolithic. Mesolithic layers without artifacts were identified, buried under the Littorina Sea, and later sediments in some places (e.g. Figure 2). At the Šventoji 41A site, a willow trunk was found *in situ* and dated to 6420–6260 cal BC (Vs-1829: 7480 ± 50 BP).

A shallow lagoon emerged on a terrace created by the Littorina Sea beyond 5700–5400 cal BC. A wide water basin in the south and narrow channels with standing water beside the Šventoji River emerged. However, we do not have any archaeological evidence of human presence during the Early Neolithic (i.e. 5500–4400 cal BC) in Šventoji. The Šventoji 2, 3, and 4 sites were occupied in 3700 cal BC or even a bit earlier. The lagoon had transformed into a freshwater basin before that time, according our new data described above. The earliest sites are located on a narrow channel 50–100 m wide. Likely, the channel has connections with both the Littorina Sea (through the lake and

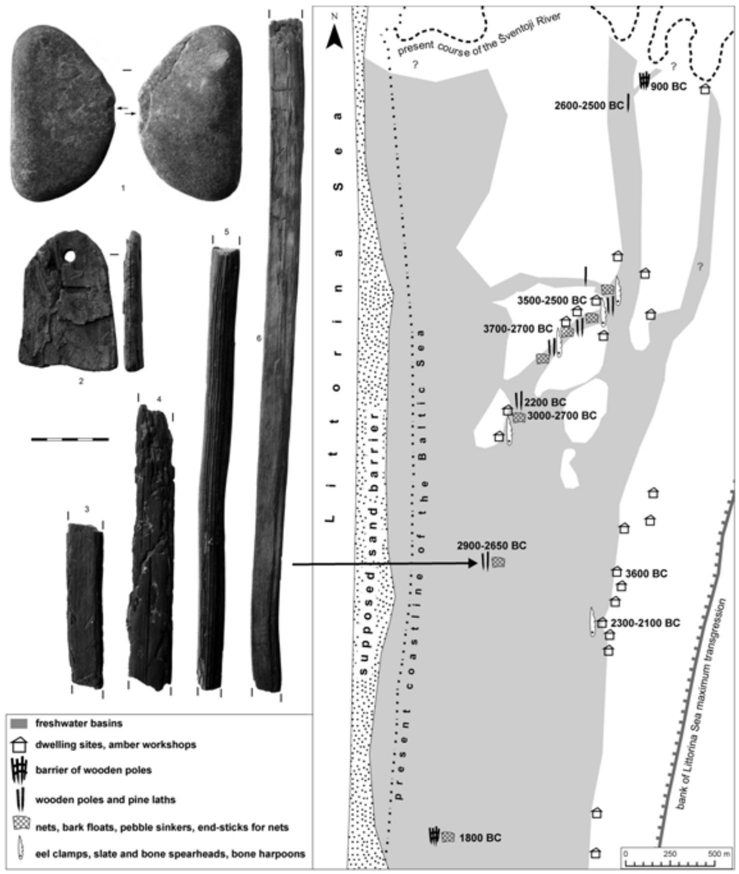

Figure 6 Artifacts from the fishing site Šventoji 42 and a reconstruction of freshwater bodies, as well as the distribution of prehistoric dwelling and fishing sites in Šventoji area in 3700–900 cal BC. Water level changes are not considered here.

other channels) and the Šventoji River, at least during periods of high water levels. It was an important route for freshwater and migratory fish species. Large amounts of various fishing gear together with ceramics and other refuse were found in the channel's sediments, i.e. gyttja. Fishermen tried to settle by the most productive fisheries, and a variety of rubbish including fish skeletons were dumped in the water, creating a gyttja layer containing large amounts of fish scales and bones including burned pieces (Brazaitis 2007; Piličiauskas 2010). The channel's banks were low (1–2 m asl), wet, and could be flooded in spring or during storms. The eastern bank of the lagoonal lake (>2 m asl) was used as an alternative dwelling area, e.g. site Šventoji 26. However, the wide and shallow littoral here was not suitable for fishing activities. The main fisheries on the channel were situated 1.5 km away from the dwelling site Šventoji 26.

A great cultural change is evident at 3300–3000 cal BC in coastal Lithuania. Pointed-bottom clay vessels, characterized by a clay mass tempered with mollusk shells (Narva type), were replaced by flat-bottom vessels having a clay mass tempered with mineral materials (Bay Coast/Globular Amphorae type). The change is explained by some kind of human migration and shift to a farming economy (Rimantienė 2005). However, very few domestic animal bones (excluding dogs) have been identified (Stančikaitė et al. 2009). Furthermore, no decline in fishing practices was observed.

On the contrary, some diversification and intensification of fishing activities could be proposed for the Šventoji region instead. Fishing sites including remote ones with stationary equipment were found at various localities of the former freshwater basin in 3000–2500 cal BC (Figure 6). Fishing equipment trapped in lake sediments (gyttja) is clear evidence that the newly discovered site Šventoji 42 had been used as a fishing site. Vertical poles could be used for a very wide range of human activities, such as to stabilize a dugout or hold stationary nets or other equipment. Fragments of pine laths indicate that at least some of the wooden poles were used in association with lath screens. Bērziņš (2008) presented ethnographic parallels and archaeological evidence from the coastal Latvian Neolithic site Sārnate for the use of moveable fishing structures consisting of screens made of laths up to 2.5 m long, bound together. Some new coastal segments started to be used for dwelling and fishing, e.g. the Šventoji 6 site (Rimantienė 1996), which was located at a transitional zone between a narrow channel and a wide lake. The refuse layer here contains wood and bone fishing equipment, ceramics, amber ornaments, and flint tools. Most of the ^{14}C dates from the Šventoji 6 site pointed to the period 3000–2200 cal BC. Archaeological materials dated to 3000–2200 cal BC were also found at the Šventoji 1, 2, 3, 4, 23, 41A, and 42 sites. Exploitation of various parts of the freshwater basin and the diversity of fishing gear used could be signs of an elaborate coastal economy involved in year-round freshwater fishing.

The youngest Neolithic sites, Šventoji 23 and 9, were dated to about 2400–2000 and 1950–1750 cal BC, respectively (Figure 5). A ^{14}C date of peat shows that the freshwater lake became overgrown with vegetation by 1600 cal BC, perhaps with the exception of some of the deepest parts of the lake. Until 2009, Early Metal period (1800–1 cal BC) sites were unknown in Šventoji. The discovery of the Šventoji 41B site considerably altered that view. The remains of a fishing barrier made of wooden poles were detected in sediments of a narrow channel (Figures 2 and 6). The channel was formed prior to 1260–910 cal BC (sediment sample date Vs-2028: 2870 ± 130 BP), while the fishing barrier was erected in 920–820 cal BC (wooden pole date Vs-2027: 2730 ± 50 BP).

A high dependence on marine and freshwater food resources is a characteristic feature of the coastal economy in the Šventoji region during 3700–1800 cal BC. Within the context of a large part of the Baltic Sea coastline, it seems quite a common picture (Kriiska et al. 2001; Makowiecki 2003; Olson 2008), with the exception of Denmark, where a significant shift to farming took place much earlier, i.e. ~4000 cal BC (Fischer 2007). In the Šventoji region, the human subsistence and settlement pattern underwent great changes in the Early Metal period instead of the Neolithic. Environmental changes were probably responsible for the changeover of the economy. Economical readjustment was recognized by prehistoric people as a practical way to solve the gradually increasing nutrition problems caused by the decay of the highly productive freshwater system. The Šventoji 41B fishing site demonstrates that in some places the still-available resources of freshwater food were still utilized, even during the metal ages. However, the lack of Bronze and Iron Age dwelling sites in the Šventoji region prevents us from drawing a detailed picture of the shift to an agricultural economy.

CONCLUSIONS

Paleoenvironmental research has enabled the dating and description of several successive stages of the Baltic Ice Age, Littorina Sea bay, and freshwater lagoon in the multidisciplinary research area of Šventoji, NW Lithuania. The Baltic Ice Lake regression was succeeded by a terrestrial period until the Littorina Sea maximal transgression at 5700–5400 cal BC. A marine bay with brackish water was transformed into a freshwater lagoon already before the date of the oldest archaeological evidence of human presence, i.e. 4000/3700 cal BC. The freshwater basin was overgrown with vegetation and became a peat bog around 1600–1500 cal BC at the research area.

A new fishing site (2920–2500 cal BC) was discovered in the middle of the former lagoonal lake during an archaeological survey in 2009. Exploitation of remote parts of the freshwater basin by very diverse fishing gear could be seen as a sign of a complex and elaborate coastal economy involving seal hunting and year-round freshwater fishing during the 3rd millennium cal BC.

The great cultural changes that occurred at ~3300–3000 cal BC in coastal Lithuania were not accompanied by radical economic changes according to the archaeological data. However, pollen data demonstrates a minor though continuous role of cereal cultivation after 3250 cal BC in coastal Lithuania. A decline in human activity is noticed in the pollen diagram after 1800 cal BC, which could be related to significant environmental changes, i.e. overgrowth of lagoonal lake.

ACKNOWLEDGMENTS

This study was funded by the Research Council of Lithuania (grant No. LEK-02/2010). The Lithuanian Academy of Science provided a grant for young researchers to Piličiauskas.

REFERENCES

Antanaitis-Jacobs I, Girininkas A. 2002. Periodization and chronology of the Neolithic in Lithuania. *Archaeologia Baltica* 5:9–40.

Arslanov KhA. 1985. *Radiocarbon: Geochemistry and Geochronology.* Leningrad. In Russian.

Barinova SS, Medvedeva LA, Anissimova V. 2006. *Diversity of Algal Indicators in Environmental Assessment*. Tel-Aviv: Pilies Studio. 498 p.

Battarbee RW. 1986. Diatom analysis. In: Berglund B, editor. *Handbook of Holocene Paleoecology and Paleohydrology.* Chichester: Wiley and Sons. p 527–70.

Bērziņš V. 2008. Sārnate: living by a coastal lake during the East Baltic Neolithic. *Acta Universitatis Oulensis* B86.

Bitinas A, Žaromskis R, Gulbinskas S, Damušytė A, Žilinskas G, Jarmalavičius D. 2005. The results of integrated investigations of the Lithuanian coast of the Baltic Sea: geology, geomorphology, dynamics and human impact. *Geological Quarterly* 49(4):355–62.

Brazaitis D. 2007. Šventosios 1-osios, 4-osios ir 36-osios radimviečių ir jų aplinkos tyrinėjimai. *Archeologiniai tyrėinjimai Lietuvoje 2006 metais*:35–42.

Bronk Ramsey C, Dee M, Lee S, Nakagawa T, Staff RA. 2010. Developments in the calibration and modelling of radiocarbon dates. *Radiocarbon* 52(3):953–61.

Butrimas A. 1982. *Akmens amžius Žemaičių aukštumoje. Daktariškės neolito gyvenvietė: katalogas*. Vilnius: LTSR istorijos ir etnografijos muziejus.

Damušytė A. 2011. *Lietuvos pajūrio geologinė raida poledynmečiu. Daktaro disertacijos santrauka*. Vilnius: Vilniaus universiteto leidykla.

Daugnora L. 2000. Fish and seal osteological data at Šventoji sites. *Lietuvos Archeologija* 19:85–101.

Daugnora L, Hufthammer A. 1999. Fishes in the Stone Age settlement area of Šventoji. A preliminary report from Bergen-Lithuanian joint excavation project. *Fourth Baltic-Nordic Workshop in Veterinary Anatomy of the Baltic and Nordic Countries*. Oslo, Norway, 4–6 June 1999. p 23–6.

Erdtman G. 1936. New methods in pollen analysis. *Svensk Botanisk Tidskrift* 30:154–64.

Fisher A. 2007. Coast-inland mobility and diet in the Danish Mesolithic and Neolithic: evidence from stable isotope values of human and dogs. *Journal of Archaeological Science* 34(12):2125–50.

Gedda B. 2001. Environmental and climatic aspects of the early to mid Holocene calcareous tufa and land mollusc fauna in southern Sweden. Lundqua thesis 45, 50 p.

Girininkas A. 1990. *Kretuonas: Middle and Late Neolithic*. Lietuvos Archeologija 7. Vilnius: Mokslas. In Russian.

Grichiuk VP. 1940. Processing of deposits poor in the organic material for pollen analysis. In: Grichiuk VP, editor. *Problems of the Physical Geography.* Moscow: Nauka. p 40–68. In Russian.

Grimm EC. 1992. Tilia and Tilia-graph: pollen spreadsheet and graphic programs. *Programs and Abstracts, 8th International Palynological Congress*. Aix-en-Provence, France, September 6–12. p 56.

Gupta SH, Polach HA. 1985. *Radiocarbon Practices at ANU, Handbook*. Canberra: Australian National University.

Juodagalvis V. 2006. Šventosios archeologinis kompleksas. *Archeologiniai tyrinėjimai Lietuvoje 2005 metais*: 9–12.

Juodagalvis V, Simpson DN. 2000. Šventoji revisited - the joint Lithuanian-Norwegian project. *Lietuvos Archeologija* 19:139–51.

Kabailienė M. 1997. Shore line displacement, palaeoecological conditions and human impact on the south-eastern coast of the Baltic Sea. In: Grigelis A, editor. *The Fifth Marine Geological Conference, Abstracts*. Vilnius. p 114–22.

Kovaliukh NN, Skripkin VV. 1994. An universal technology for oxidation of carbon-containing materials for radiocarbon dating. In: *Abstracts and Papers of Conference on Geochronology and Dendrochronology of Old Town's and Radiocarbon Dating of Archaeological Findings*. Vilnius, Lithuania, 31 October–4 November. Vilnius: Vilnius University Press. p 37–42.

Krammer K, Lange-Bertalot H. 1986–1991. *Süßwasserflora von Mitteleuropa. 2 (Teil 1–4). Bacillariophyceae*. Stuttgart/Jena: VEB Gustav Fischer Verlag.

Kriiska A. 2001. Stone Age settlement and economic processes in the Estonian coastal area and islands (PhD dissertation). Helsinki: Helsinki University.

Lang V. 1999. The introduction and early history of farming in Estonia, as revealed by archaeological material. *PACT* 57:325–38.

Loze I. 1979. *Late Neolithic and Early Bronze Age of Lubanas Plain*. Rīga: Zinatne. In Russian.

Makowiecki D. 2003. *Historia ryb i rybołówstwa w holocenie na Niżu Polskim w świetle badań archeoichtiologicznych*. Poznań: Instytut Archeologii i Etnologii Polskiej Akademii Nauk.

Moore PD, Webb JA, Collinson ME. 1991. *Pollen Analysis*. Oxford: Blackwell.

Niinements E, Saarse L. 2006. Holocene forest dynamics and human impact in southeastern Estonia. *Vegetation History and Archaeobotany* 16:1–13.

Niinements E, Saarse L. 2009. Holocene vegetation and land-use dynamics of south-eastern Estonia. *Quaternary International* 207(1–2):104–16.

Olson N. 2008. Neolithic fisheries. Osteoarchaeology of fish remains in the Baltic Sea region [PhD dissertation]. Theses and papers in Osteoarchaeology No. 5. Stockholm University: Edita Västra Aros.

Piličiauskas G. 2010. Šventosios akmens amžiaus gyvenvietė. *Archeologiniai tyrinėjimai Lietuvoje 2009 metais*:17–21.

Piličiauskas G, Lavento M, Oinonen M, Grižas G. 2011. New ^{14}C dates of Neolithic and Early Metal period ceramics in Lithuania. *Radiocarbon* 53(4):629–43.

Piličiauskienė G, Piličiauskas G. 2009. Žvalgomieji tyrimai Šventojoje. *Archeologiniai tyrinėjimai Lietuvoje 2008 metais*:23–8.

Poska A, Saarse L, Veski S. 2004. Reflections of pre- and early-agrarian human impact in the pollen diagrams of Estonia. *Palaeogeography, Palaeoclimatology, Palaeoecology* 209(1–4):37–50.

Ralska-Jasiewiczowa M, Latałowa M. 1996. Poland. In: Berglund BE, Birks HJB, Ralska-Jasiewiczowa M, Wright HE, editors. *Palaeoecological Events during the Last 15000 Years: Regional Syntheses of Palaeoecological Studies of Lakes and Mires in Europe*. Chichester: John Wiley and Sons. p 403–72.

Reimer PJ, Baillie MGL, Bard E, Bayliss A, Beck JW, Blackwell PG, Bronk Ramsey C, Buck CE, Burr GS, Edwards RL, Friedrich M, Grootes PM, Guilderson TP, Hajdas I, Heaton TJ, Hogg AG, Hughen KA, Kaiser KF, Kromer B, McCormac FG, Manning SW, Reimer RW, Richards DA, Southon JR, Talamo S, Turney CSM, van der Plicht J, Weyhenmeyer CE. 2009. IntCal09 and Marine09 radiocarbon age calibration curves, 0–50,000 years cal BP. *Radiocarbon* 51(4): 1111–50.

Rimantienė R. 1996. Šventosios 6-oji radimvietė. *Lietuvos Archeologija* 14:83–173.

Rimantienė R. 1999. *Die Kurische Nehrung aus dem Blickwinkel des Archäologen*. Vilnius: Dailės akademijos leidykla.

Rimantienė R. 2005. *Die Steinzeitfischer an der Ostseelagune in Litauen*. Vilnius: Litauisches Nationalmuseum.

Rinterknecht VR, Bitinas A, Clark PU, Raisbeck GR, Yiou F, Brook EJ. 2008. Timing of the last deglaciation in Lithuania. *Boreas* 37(3):426–33.

Stančikaitė M, Kabailienė M, Ostrauskas T, Guobytė R. 2002. Environment and man in the vicinity of Lakes Duba and Pelesa, SE Lithuania, during the Late Glacial and Holocene. *Geological Quarterly* 46:391–409.

Stančikaitė M, Baltrūnas V, Šinkūnas P, Kisielienė D, Ostrauskas T. 2006. Human response to the Holocene environmental changes in the Biržulis Lake region, NW Lithuania. *Quaternary International* 150(1):113–29.

Stančikaitė M, Šinkūnas P, Šeirienė V, Kiselienė D. 2008. Patterns and chronology of the Lateglacial environmental development at Pamerkiai and Kašučiai, Lithuania. *Quaternary Science Reviews* 27(1–2):127–47.

Stančikaitė M, Daugnora L, Hjelle K, Hufthammer AK. 2009. The environment of the Neolithic archaeological sites in Šventoji, Western Lithuania. *Quaternary International* 207(1–2):117–29

Stockmarr J. 1971. Tablets with spores used in absolute pollen analysis. *Pollen et Spores* 13:615–21.

Timofeev VI. 1992. Some problems of the chronology of the Eastern Baltic region. In: Lang V, Selirand J, editors. *Cultural Heritage of the Finno-Ugrians and Slavs*. Papers presented at the Soviet-Finnish Archaeological Symposium 10–16 May 1990, Tallinn. Tallinn: Varrak. p 9–23.

Van Dam H, Mertens A, Sinkeldam J. 1994. A coded checklist and ecological indicator values of freshwater diatoms from the Netherlands. *Journal of Aquatic Ecology* 28:117–33.

Vankina L. 1970. *Bog Site Sarnate*. Riga: Zinatne. In Russian.

Vasks A, Kalnina L, Ritums R. 1999. The introduction and pre-Christian history of farming in Latvia. *PACT* 57:291–304.

Veski S. 1998. Vegetation history, human impact and palaeogeography of western Estonia. Pollen analytical studies of lake and bog sediments. *Striae* 38:1–119.