CORDED WARE CULTURE FISHERMEN IN THE EASTERN BALTIC

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ABSTRACT

Between 2800 and 2400 cal BC pastoralists from central and southeastern Europe migrated into the eastern Baltic paving the way for the Corded Ware culture (CWC), and a new type of economy, animal husbandry. Traditionally the CWC people were viewed as highly mobile due to the lack of substantial dwellings and material culture at settlement sites, and were reliant on an economy based on animal husbandry as demonstrated by zooarchaeological and stable isotopic evidence. However, this paradigm is beginning to shift. Here, we present new AMS radiocarbon (14C) measurements, pollen and macrobotanical data from sediment samples and a portable fish screen, as well as technological, molecular and isotopic data obtained from ceramic vessels from three CWC sites in the eastern Baltic. Overall, our results indicate a de-Neolithisation process by some CWC groups, particularly in lacustrine and coastal ecotones, and a return to hunting, gathering and fishing.

INTRODUCTION

Traditionally the people of the Corded Ware culture (hereafter CWC) were considered mobile stock breeders who brought animal husbandry into the eastern Baltic, ca. 2800-2400 cal BC; a viewpoint substantiated by reconstructed settlement patterns and a lack of substantial structures at CWC sites, which despite being located in various environments have largely yielded little material culture. Indeed, the zooarchaeological evidence alongside the stable isotope data obtained from human bone collagen have generally been in agreement, which have demonstrated an economy orientated towards the consumption of terrestrial-derived protein (Lõugas et al. 2007; Piličiauskas et al. 2017a, 2017b; Piličiauskas 2018; Piličiauskas et al. 2018a). This paradigm, however, is beginning to shift, notably through the application of organic residue analysis of ceramic vessels whereby wild resources, including aquatic organisms, were processed (Heron et al. 2015; Piličiauskas et al. 2018b; Robson et al. 2019; Pääkkönen et al. 2019).

Although CWC groups occupied lakeshores previously inhabited by the pottery producing hunter-gatherer-fishers of the Subneolithic, they also resided in river valleys; the latter of which generally lack evidence of habitation during this period. In Lithuania alone, the majority (80%) of CWC settlement sites have yielded less than five vessels per site indicating a mobile economy (Piličiauskas 2018). Similarly, the lack of or scarcity of CWC dwelling structures and material culture in general has also been documented elsewhere (Edgren 1970; Loze 1992; Kriiska 2000; Nordqvist & Häkälä 2014; Nordqvist 2016). However, two wetland sites from the eastern Baltic do not conform to this general pattern. Daktariškė 5 in northwestern Lithuania and Abora 1 in eastern Latvia are characterised by extraordinary rich CWC pottery assemblages with a minimal number of 59 and 100 vessels respectively, inconsistent with small bands of CWC herders moving throughout the mixed woodlands of the region.

In order to elucidate the diet and economy of the CWC communities at the two sites, a multidisciplinary study was undertaken. We reconstructed the extent of Lake Biržulis where Daktariškė 5 is situated, analysed the pottery from both sites typologically, performed organic residue analyses on ceramic vessels from both sites (some data reported in Piličiauskas et al. 2018b; Robson et al. 2019), conducted macrobotanical and pollen analyses at Daktariškė 5 and acquired 10 AMS radiocarbon (14C) dates to create an age-depth model for the stratified lacustrine sediments there. Moreover, we present a rare and well-preserved isolated CWC artefact, a rollable fish screen, recovered from the wetland locality of Šventoji 58 in northwestern Lithuania. Building on previous research (e.g. Heron et al. 2015; Piličiauskas et al. 2018b; Robson et al. 2019) we provide further evidence for the exploitation and consumption of aquatic resources, notably fish, in the eastern Baltic.

BACKGROUND TO THE SITES

*DAKTARIŠKĖ 5, NORTHWESTERN LITHUANIA*

Daktariškė 5 is situated at the foot of an island amid a swamp of the former Lake Biržulis (Fig. 1). Here, artefacts dating from the Subneolithic to the Early Bronze Age (ca. 4450-1600 cal BC) were found within waterlogged lake gyttja (Piličiauskas 2018). Unfortunately, ploughing has destroyed the dwelling zone of the site, and only a refuse layer of the prehistoric settlement along the littoral zone of the former lake was excavated. Between 1987 and 1990, an area of 648 m² was investigated by Butrimas (1992). In 2016, a trench measuring 49 m2 was excavated by GP. Near the former shoreline the archaeological deposits were 0.15-0.2 m thick and unstratified while further into the lake, a stratified cultural layer up to 0.8 m was documented. Although wooden piles were encountered, they were between 2 and 6 cm in diameter and infrequent, thus are probably not associated with pile-dwellings or stationary fishing gear, i.e. weirs. Among the ca. 12,000 pottery sherds discovered during both excavation campaigns, Subneolithic shell-tempered pointed-based Narva, Comb-like, and Porous Wares predominated while Neolithic Globular Amphora, Corded and post-Corded wares were represented by smaller numbers of vessels, 32, 59, and 45 vessels respectively. The assemblage of 59 individual CWC vessels is presently the largest in Lithuania.

*ABORA 1, EASTERN LATVIA*

Abora 1 is situated on the northern shoreline of Lake Lubāns (Fig. 1), and near to the former outflow of the River Aiviekste. Between 1964-1965 and 1970-1971 as well as 2008, an area of 1,313.5 m² was excavated by Loze (1979; Loze & Eberhards 2015). Unlike Daktariškė 5, a dwelling zone, including numerous Subneolithic and Neolithic artefacts, postholes and fireplaces, was encountered within a 0.5 m thick sandy loam. Furthermore, 61 Subneolithic graves were uncovered within and below this cultural layer. In the lowermost area of the site, similar to Daktariškė 5, a waterlogged and stratified layer of peat and gyttja (up to 1.5 m thick) was excavated. Here, numerous well-preserved wooden and bone artefacts were recovered. The pottery assemblage was dominated by shell-tempered flat-based Porous Ware while Corded Ware vessels were infrequent (Loze 1979).

*ŠVENTOJI 58, NORTHWESTERN LITHUANIA*

Šventoji 58 is presently situated on the Baltic coast (Fig. 1). Around 60 archaeological sites dating to ca. 4000-500 cal BC have been discovered or investigated there since 1966 (Rimantienė 2005; Piličiauskas 2016). Although the majority of localities were situated on the banks or in the middle of the former lagoonal lake, some were situated on former riverbanks. The site of Šventoji 58 was recently discovered in 2015 during systematic test-pitting of the area. Whilst the majority of artefacts were recovered from a prehistoric river channel that had infilled with peat and sand, a rollable fish screen made of wooden twigs was found in the lake gyttja just outside (Juškaitis et al. 2016a).

METHODS

EVALUATION OF POTTERY

The pottery assemblages from Abora 1 and Daktariškė 5 were examined by the naked eye by GP to ascertain a number of attributes, including technology and style, as well as the clay temper. To estimate the minimum number of ceramic vessels in the assemblages, individually shaped and/or ornamented pottery sherds from the upper portions of vessels were counted.

AMS 14C DATING

AMS radiocarbon (14C) dating was undertaken at the Poznań Radiocarbon Laboratory (Poland) and the Mass Spectrometry Laboratory Centre for Physical Sciences and Technology, Vilnius (Lithuania). The standard acid-alkali-acid (AAA) pretreatment was used for the wood and charcoal samples, whilst the HCl pretreatment was used solely for the one carbonised residue sample as described elsewhere (see Brock et al. 2010). In this study all radiocarbon ages were calibrated using the OxCal 4.2 software and IntCal13 atmospheric curve (Bronk Ramsey 2009; Reimer et al. 2013). The same software was used for the age-depth modelling. Calibrated dates are presented at 95.4% probability in BC.

RECONSTRUCTION OF THE PALEOLANDSCAPE

We reconstructed the extent of Lake Biržulis during the CWC period using LiDAR data. We assumed that there were no dramatic changes in the dryland topography since 2500 cal BC, however, in the boggy areas between 1 and 2 m of gyttja and peat sediments have formed during the last 4500 years as evidenced by 14C dated boreholes and archaeological trenches (Stančikaitė et al. 2006; Piličiauskas 2018). Thus, an interpolated relief was flooded to the 152.5 meters a.s.l. mark to account for the lake water level at ca. 2500 cal BC, which corresponds with the locations of 11 CWC sites situated on higher ground.

POLLEN ANALYSIS

Sediment samples, ca. 5 cm3 in size, were taken every 2 cm from the column sample, excavated during the 2016 field season at Daktariškė 5, for pollen analysis and prepared using previously published methodologies (Erdtman 1936; Grichiuk 1940), which included treatment with a heavy liquid (CdI2+KI). The concentration of spore and pollen in the sediments was calculated using *Lycopodium clavatum* (Stockmarr 1971). More than 500 terrestrial pollen grains were counted from each sample. Pollen identification was based on Moore et al. (1991). Percentage calculations of identified taxa was based on the sum of arboreal (ΣAP) plus non-arboreal (ΣNAP) taxa. The pollen diagrams were subsequently created using TILIA (2 version), TILIA-GRAPH (2.0 5b version) (Grimm 1992) and CorelDRAW 7. The pollen diagrams were subdivided into local zones by using the stratigraphically constrained cluster analysis (CONISS) function (Grimm 1987).

MACROBOTANICAL ANALYSIS

Sixty five samples, ca. 2 cm thick (500 cm3 in volume), were taken from the same column sample at Daktariškė 5. Plant macrofossils were extracted by wet sieving over two screens with mesh sizes of 0.2 and 0.5 mm. The identification of macrofossils was based on Berggren (1969, 1981), Grigas (1986) and Cappers et al*.* (2006) in conjunction with a reference collection of known modern plants. The plant macrofossil diagrams were constructed using TILIA and TGView software (Grimm 2000, 2004). The identified taxa were grouped according to their habitats to eco-groups, for example trees and shrubs, water plants, wetland plants, xeromesophytes/ruderals and others. Using the sum-of-squares cluster analysis (Grimm 1987), the diagram was subdivided into local plant macrofossil zones (LMAZ).

To determine the species of wood used to construct the rollable fish screen recovered at Šventoji 58, thin sections were analysed using an aid of bright-field microscope, Optica B-193, at between 40 and 1000x magnifications, and through consultation of Schoch et al*.* (2004) and Wheeler (2011). Polarized light microscopy was used to identify the binding material from the rollable fish screen. Plant fibre analysis was undertaken at the University Museum of Bergen. A microscope, Leica DM750 P equipped with objectives HI PLAN POL (10x/0,25; 20x/0,40; 40x/0,65 and 100x), was used. Samples were first observed in transmitted white light in a longitudinal direction to confirm that they were of tree bast and not from fibrous leaves or coarse, untreated plant bast strips, which could have been used as a binding material (see Rast-Eicher 2005; Harris et al. 2017). Polarized light and a full wave compensator (λ= 530 nm) was used to undertake the modified Herzog test (Bergfjord & Holst 2010; Haugan & Holst 2013, 2014), and to investigate the calcium oxalate crystals that are very durable and common in tree bast and some types of plant bast (Schoch et al. 2004; Lukešová 2017). Samples were gently cleaned and prepared in distilled water using a stereomicroscope. Half of them were mounted in distilled water whilst the remainder were mounted in Meltmount nD=1,662 according to an established protocol (Lukešová 2017) to obtain results in different refractive indices. Samples were compared to modern bast specimens, including lime (*Tilia* L.), oak (*Quercus* L.), poplar (*Populus* L.), willow (*Salix* L.) and juniper (*Juniperus* L.), which have been identified as sources of tree bast throughout prehistory in Northern Europe (Myking et al. 2005; Hurcombe 2007; Hardy 2008; Jørgensen 2013; Harris et al. 2017). The reference material was extracted by retting in a water bath for 8 weeks at 20 °C. The water bath was changed weekly. After the retting process, the tree bast was peeled off mechanically by hand and prepared in the same way as the archaeological samples. Characteristic features, including birefringence, extinction, fibrillary orientation, fibre lumen, fibre cross markings, rays, frequency of calcium oxalate crystals and their shape, pleochroism as well as position in the sample were used for tree bast identification.

ELEMENTAL ANALYSIS-ISOTOPE RATIO MASS SPECTROMETRY (EA-IRMS)

Between 1.0 and 1.5 mg of the carbonised surface residues were directly removed from the vessel surfaces using a scalpel. The bulk carbon (δ13C) and nitrogen (δ15N) stable isotope ratios were measured at the Laboratory of Mass Spectrometry, Center for Physical Sciences and Technology, Vilnius, Lithuania using an Elemental Analyser Flash EA1112 linked to a Thermo V Advantage Mass Spectrometer. Accuracy was assessed by the repeated measurements of internationally recognised standards. Standard deviations were < 0.1‰ for both δ13C and δ15N. Some samples were analysed in duplicate, then averaged. The stable isotope ratios are reported as delta (δ) values, and expressed per mille (‰) relative to Vienna Pee Dee Belemnite (V-PDB) and air N2 (AIR) for δ13C and δ15N respectively. Analytical precision was better than 0.9% and 0.2% for δ13C and δ15N respectively.

ORGANIC RESIDUE ANALYSIS

Between 5.9 and 22.7 mg of the carbonised surface residues were removed from the interior surfaces of 10 CWC sherds from the site of Abora 1 using a scalpel. These were homogenised using a mortar and pestle for acidified methanol extraction (Craig et al. 2013; Papakosta et al. 2015) followed by Gas Chromatography-Mass Spectrometry (GC-MS) and Gas Chromatography-Combustion-Isotope Ratio Mass Spectrometry (GC-C-IRMS) (see Craig et al. 2012; Robson et al. 2019).

RESULTS AND DISCUSSION

CORDED WARE POTTERY AT DAKTARIŠKĖ 5 AND ABORA 1

In total, a minimum number of 59 and 100 vessels were identified at Daktariškė 5 and Abora 1 respectively, which currently represent the two largest CWC pottery assemblages in the eastern Baltic. At both sites grog temper predominated (86% and 30% respectively), however, sand (12%) and crushed rock (21%) temper were also a common feature particularly at Abora I (Fig. 2). Moreover, at Abora I a large number of vessels (37%) had been solely constructed out of silty clays without any observable temper, which may represent a deliberate act by the potters at the site. It was, however, not always possible to identify the grog temper in the ceramic vessels, which may indicate that it had been fired at a higher temperature (e.g. Lindahl 1990, 2002). Indeed, grog temper was widely used by CWC potters elsewhere, including Sweden, northwestern Russia, Poland and the Netherlands (Volkova 1996; Kurzawa 2001; Larsson 2009; Beckerman 2015; Piličiauskas 2018; Rauba-Bukowska 2018), whilst crushed rock temper was a core tradition of Globular Amphora and post-CWC wares.

Comparison between the sites of Daktariškė 5 and Abora 1 also yielded further differences in terms of the types of vessels recovered. The assemblage from Daktariškė 5 was dominated by short-wave moulded pots (Piličiauskas 2018, fig. 24, 32-36), whilst beakers predominated in the assemblage from Abora 1 (Fig. 2). Moreover, there were also differences in terms of ornamentation. Indeed, the CWC beakers at Abora 1 were largely decorated by the incised herringbone pattern, whilst the method of pinching and/or utilising fingernails was common at Daktariškė 5 (Figs. 3 and 4).

Overall then, it would appear that the CWC vessels at Daktariškė 5 were constructed using a similar method to that observed at other CWC sites in the eastern Baltic, whilst a more localised pottery making tradition is evident at Abora 1.

CWC CHRONOLOGY AT ABORA 1

During the investigations at Abora 1, CWC vessels were recovered from the same horizon as Porous ware (hereafter PW), which suggested to Loze (1979) that they were contemporaneous. Based on the initial radiocarbon (14C) measurements of wood and charcoal samples from the cultural layer, deposition of these vessels took place between ca. 2464-2215 and 2289-2054 cal BC (Le-671: 3870 ± 70 BP and Ta-394: 3770 ± 60 BP). Further determinations on presumbed older samples extended the CWC horizon to ca. 2940-2470 cal BC (Loze & Eberhards 2015). Unfortunately these analysed samples were not found in association with either wares and should be interpreted with caution.

To overcome this uncertainty, we selected carbonised organic residues (hereafter foodcrusts) adhering to the interiors of CWC vessels for AMS radiocarbon (14C) dating. Prior to AMS radiocarbon (14C) dating, the samples were analysed by EA-IRMS to ascertain their δ13C and δ15N values, which are considered rough proxies for distinguishing between aquatic and terrestrial-derived foodstuffs (Heron & Craig 2015). In general, marine residues are typically elevated in 13C compared with freshwater- or terrestrial-derived residues, whilst aquatic residues are elevated in 15N (> 6‰) compared with terrestrial-derived residues (Craig et al. 2007). Since the majority of the sampled foodcrusts (17/18) yielded relatively high δ15N values (between 7.4 and 12.4‰) they are most likely aquatic in origin, and inevitably affected by a currently unknown freshwater reservoir effect (hereafter FRE). Previously we have demonstrated that localised FRE’s cause offsets between radiocarbon ages obtained on terrestrial mammal remains compared with foodcrusts or aquatic organisms within the region (Piličiauskas & Heron 2015; Piličiauskas 2018). Moreover, given the variable FREs in both time and space as well as between and within species (Keaveney & Reimer 2012), coupled with often complex mixtures of different foodstuffs within foodcrusts, it is virtually impossible to apply a FRE correction to radiocarbon ages without paired dates (i.e. a foodcrust sample alongside a synchronous terrestrial sample) or analysis of modern aquatic organisms. Thus, we sampled the foodcrust with the lowest δ15N value (4.2‰), which is most likely terrestrial in origin. The result (FTMC-17-36: 4011 ± 41; ca. 2833-2461 cal BC) largely met our expectations and was consistent with the majority of dates obtained on wood and charcoal from the CWC horizon at Abora 1 (Loze & Eberhards 2015), an established CWC chronology for Lithuania as well as dates obtained on CWC human remains (largely unaffected by a FRE) throughout the region (Piličiauskas et al. 2018a, fig. 7). In addition to the CWC foodcrust sample, we dated a small piece of charcoal embedded within the clay mass of a PW flat-based vessel (FTMC-39-4: 4272 ± 42; ca. 3014-2706 cal BC). To our surprise, the result was statistically significantly older than that of the CWC foodcrust (T = 19.8, T’(5%) = 3.8, ν = 1; Ward & Wilson 1978) demonstrating that the CWC and PW materials at Abora 1 are asynchronous despite being commingled.

CWC CHRONOLOGY AT DAKTARIŠKĖ 5

Additionally we dated seven hazelnut (*Corylus* *avellana*) shell samples from Daktariškė 5 (Table 1). One was burnt whilst it was impossible to determine whether the remainder were anthropogenic or natural. Indeed, these dates were necessary to build a chronological model for the sediment column sample taken from the site (Fig. 2). Two measurements (Poz-89318: 4050 ± 35 BP and Poz-89317: 4105 ± 35 BP) demonstrated a slight inversion. The date of the lower sample (Poz-89318: 4050 ± 35 BP) was younger than the one obtained from the upper sample (Poz-89317: 4105 ± 35 BP). To discern whether the upper sample had been reworked from older deposits we sampled a further hazelnut shell that was found ca. 30 cm away at the same depth (Fig. 5). Indeed, this sample (FTMC-17-2) yielded a younger age (4000 ± 50 BP), which was incorporated into our age-depth modelling.

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| **No** | **Site** | **Sample** | **Lab. code** | **Radiocarbon age (BP) ± error** | **Calibrated age (BC)** |
| 1 | Daktariškė 5 | Hazelnut shell | Poz-89316 | 3320 ± 30 | 1683-1521 |
| 2 | Daktariškė 5 | Burnt hazelnut shell | FTMC-17-2 | 4000 ± 50 | 2835-2346 |
| 3 | Daktariškė 5 | Hazelnut shell | Poz-89318 | 4050 ± 35 | 2839-2473 |
| 4 | Daktariškė 5 | Hazelnut shell | Poz-89317  | 4105 ± 35 | 2866-2503 |
| 5 | Daktariškė 5 | Hazelnut shell | Poz-89319 | 4490 ± 40 | 3351-3029 |
| 6 | Daktariškė 5 | Hazelnut shell | Poz-89302 | 4780 ± 35 | 3646-3384 |
| 7 | Daktariškė 5 | Hazelnut shell | Poz-85279 | 5580 ± 35 | 4486-4348 |
| 8 | Abora 1 | Charred organic residue adhering to CWC beaker (VI76:5211(1692)) | FTMC-17-36 | 4011 ± 41 | 2833-2461 |
| 9 | Abora 1 | Embedded charcoal from the clay mass of a Porous Ware flat-based vessel (VI76-5302) | FTMC-39-4 | 4272 ± 42 | 3014-2706 |
| 10 | Šventoji 58 | Hazel twig from fish screen | Poz-77557 | 4000 ± 35 | 2619-2462 |

Table 1. AMS radiocarbon (14C) dates obtained in this study.

In total, 40 14C measurements are available for the site of Daktariškė 5 (Piličiauskas 2018), which show that the site was in use from ca. 4450-1650 cal BC (Fig. 6). Moreover, the age-depth model demonstrates CWC occupation between ca. 2775-2425 cal BC (Fig. 6), which is in good agreement with the directly dated foodcrusts from the site (ca. 2894-2492 cal BC) as well as the general CWC chronology proposed for Lithuania as a whole (ca. 2800-2400 cal BC) (Piličiauskas 2018).

ENVIRONMENTAL DATA FROM ABORA 1 AND LAKE LUBĀNS

Abora 1 is one of many Subneolithic-Early Bronze Age sites that have been recorded in the Lake Lubāns area. Today the lake covers an area between 2,500 and 10,000 ha depending on the water level, which is largely dictated by humanly built dams (Loze 1988). Although it is the largest lake in Latvia, it is shallow with an average depth of only 1.6 m. However, throughout prehistory the water coverage was much greater and included many hectares of terrestrial flora surrounding the lake (Eberhards 1989). Despite the numerous pollen and macrobotanical investigations undertaken in the Lake Lubāns area (e.g. Loze & Yakubovskaya 1984; Levkovskaya 1987; Loze 1988; Kalnina et al. 2004), evidence to support forest clearance during the CWC period remains unsubstantiated. Moreover, although single finds of *Cerealia*-type pollen grains have been identified (Levkovskaya 1987), these probably belong to wild congeners (see Lahtinen & Rowley-Conwy 2013 for a thorough discussion) due to the overwhelming dominance of identified macroremains from aquatic and bog plants (Loze & Yakubovskaya 1984). Their presence, however, also may be related to recent bioturbation since the CWC horizon is within 1 m of the topsoil and thus prone to contamination.

ENVIRONMENTAL DATA FROM DAKTARIŠKĖ 5 AND LAKE BIRŽULIS

The site of Daktariškė 5 is located on a hillock in the former Lake Biržulis basin, which has almost been totally reclaimed by vegetation since prehistory. Due to extensive melioration during the 20th century the lake has shrunk in size from ca. 754 to 120 ha (Kunskas & Butrimas 1985). However, in the 3rd millennium cal BC, the lake covered an area of ca. 3,300 ha (Fig. 7). In the deepest deposits at Daktariškė 5 artefacts were recovered within the former lake sediments, i.e. gyttja and coarse detritus gyttja (or peaty gyttja), which were covered by peaty ploughed topsoil and peat with thicknesses of 0.3 and 0.4 m respectively. Artefacts were, however, absent in the peat that accumulated after ca. 1680-1520 cal BC providing a *terminus post quem* for deposition. This cultural layer was 0.8 m thick. Here, it was possible to identify 12 lithological units due to the varying densities of plant macroremains within the gyttja (Fig. 5), which may have been caused by water level oscillations. The lowermost layer of peaty or detritus gyttja was underlain by calcareous clay lacking material culture. A clay layer formed at the beginning of the Holocene when the water level was much higher.

Although sediments from Lake Biržulis have previously been extensively studied by palynologists (e.g. Kunskas & Butrimas 1985; Guobytė & Stančikaitė 1996; Stančikaitė et al. 2004, 2006), none were directly taken from the site of Daktariškė 5. Moreover, those previously sampled were 14C dated using either lake sediments or plant macrofossils of undetermined species meaning that the FRE was not taken into consideration. Consequently the resultant pollen diagrams are unreliable for determining possible environmental changes during the CWC period. In order to rectify this, we took a sediment column from the deepest part of the 2016 excavation trench at Daktariškė 5. Indeed, hazelnut shells were directly AMS radiocarbon (14C) dated, whilst the CWC horizon was defined by material culture, i.e. ceramic typology (Fig. 5). In total, 65 sediment samples (lake and bog sediment) were taken every 2 cm for pollen and macrobotanical analyses to provide a detailed record of the local vegetation and evolution of the lake from the Subneolithic through Bronze Age (Figs. 8 and 9). Of relevance to this study, the CWC horizon (at a depth of between 100 and 106 cm) was marked by a short term increase (Fig. 8) in alder (*Alnus* sp.) and a decrease in oak (*Quercus* sp.) and elm (*Ulmus* sp.); however, it is presently unknown whether this in humanely or environmentally induced. That being said, a rise in the lake water table was also documented as evidenced by an increase in the number of aquatic and shoreline plants (Fig. 9). In addition, a small increase in charcoal was present in the lake sediments concurrent with the CWC period, which may be related with an increase in forest clearance on the island. Interestingly, this activity was less marked than that of the Subneolithic period, which was recorded at a depth of between 150 and 135 cm (Fig. 8). Lastly, cereals or other plants indicative of crop cultivation were entirely absent.

BULK CARBON AND NITROGEN STABLE ISOTOPE ANALYSIS OF CARBONISED RESIDUES

Bulk carbon (δ13C) and nitrogen (δ15N) stable isotope data were obtained from foodcrusts adhering to 29 CWC vessels from Daktariškė 5 (data reported in Piličiauskas et al. 2018b). These data are plotted in Fig. 10. The 29 samples had δ13C values ranging from -29.2 to -25.4‰ (mean δ13C value of -26.9 ± 0.9‰) demonstrating that the residues were either freshwater and/or terrestrial in origin. However, the samples yielded a broad range of δ15N values (2.0 to 10.4‰; mean δ15N value of 5.4 ± 1.9‰), and of these, 12 (41.4‰) had δ15N values > 6.0‰ indicating that aquatic resources are likely to have been processed in these vessels (Piličiauskas et al. 2018b), whilst mixtures of aquatic and terrestrial resources are envisaged for the remaining 17 (58.6%). Indeed, these interpretations were elucidated by organic residue analysis (see Robson et al. 2019).

For comparison, 18 foodcrusts adhering to CWC vessels from Abora 1 were sampled. To this we also sampled a CWC sherd from the coastal site of Celmi in western Latvia (Table 2). These data are plotted in Fig. 10 and summarised in Table 2. The Celmi foodcrust had δ13C and δ15N values of -27.0 and 6.4‰, which were very similar to the data obtained from CWC vessels in Lithuania (mean δ13C value of -26.7 ± 0.9‰; mean δ15N value of 5.6 ± 2.2‰; n = 58) (Piličiauskas et al. 2018b). However, to our surprise the Abora 1 foodcrusts had a broad range of δ13C (-31.3 to -24.5‰; mean δ13C value of -27.7 ± 2.0‰) and δ15N values (4.2 to 12.4‰; mean δ15N value of 9.6 ± 2.0‰), which were notably different to Daktariškė 5 as well as data obtained from other CWC inland localities. Although elevated in 13C (Fig. 10), the Abora 1 vessels had similar δ15N values to the Subneolithic vessels from throughout the region (mean δ15N value of 9.6 ± 2.1‰; n = 53), indicating that these residues are probably aquatic in nature. There was, however, one outlier, a beaker (Fig. 3:7; VI76:5211(1692)) with a δ15N value of 4.2‰. Since this foodcrust is probably terrestrial in origin it was AMS radiocarbon (14C) dated (see above). Indeed, the obtained radiocarbon age (FTMC-17-36; 4011 ± 41 BP) was consistent with an established CWC chronology (Piličiauskas et al. 2018a) demonstrating that it was not affected by a FRE.

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| **No.** | **Identifier** | **Site** | **δ13C (**‰) | **δ15N (**‰) | **%C** | **%N** | **C:N** | **Fig.** |
| 1 | VI 76: 5063(109)**±** | Abora 1 | -30.5 | 12.4 | 48.6 | 8.1 | 7.0 | 3:2 |
| 2 | VI 76: 5317(4881) | Abora 1 | -25.1 | 12.0 | 47.3 | 5.6 | 9.8 | 3:8 |
| 3 | VI 76: 5210(158)**±** | Abora 1 | -30.4 | 10.9 | 44.3 | 7.1 | 7.3 | 3:1 |
| 4 | VI 76: 5212 | Abora 1 | -27.7 | 10.8 | 46.3 | 6.7 | 8.0 | 3:3 |
| 5 | VI 76: 5064(70)**±** | Abora 1 | -28.5 | 10.8 | 42.7 | 6.4 | 7.8 | 3:11 |
| 6 | VI 76: 5316**±** | Abora 1 | -31.3 | 10.7 | 42.4 | 6.6 | 7.5 | 3:10 |
| 7 | VI 76: 5210(146)**±** | Abora 1 | -28.2 | 10.7 | 44.0 | 6.6 | 7.8 | 3:5 |
| 8 | VI 76: 5214(2078) | Abora 1 | -27.7 | 10.6 | 45.0 | 5.8 | 9.1 | 4:3 |
| 9 | VI 76: 5068**±** | Abora 1 | -28.1 | 10.0 | 37.7 | 5.0 | 8.8 | 4:4 |
| 10 | VI 76: 5210 | Abora 1 | -24.5 | 9.9 | 45.7 | 6.2 | 8.6 | 3:4 |
| 11 | VI 76: 5317(5137)**±** | Abora 1 | -27.6 | 9.7 | 46.6 | 7.3 | 7.4 | 4:5 |
| 12 | VI 76: 5100(139)**±** | Abora 1 | -24.9 | 9.2 | 50.6 | 6.5 | 9.1 | 3:9 |
| 13 | VI 76: 5215(1607) | Abora 1 | -30.2 | 9.1 | 36.4 | 3.5 | 12.1 | 4:8 |
| 14 | VI 76: 5213**±** | Abora 1 | -27.3 | 8.7 | 45.1 | 7.4 | 7.1 | 3:6 |
| 15 | VI 76: 5215(824)**±** | Abora 1 | -24.6 | 7.6 | 46.6 | 6.9 | 7.9 | 4:7 |
| 16 | VI 76: 5214(3087) | Abora 1 | -27.0 | 7.6 | 31.6 | 4.0 | 9.3 | 4:9 |
| 17 | VI 76: 5215(1857) | Abora 1 | -27.6 | 7.4 | 44.0 | 4.0 | 12.7 | 4:2 |
| 18 | VI 76: 5211(1692)\* | Abora 1 | -26.9 | 4.2 | 37.1 | 3.8 | 11.5 | 3:7 |
| 19 | A13317:604 | Celmi | -27.0 | 6.4 | 30.7 | 2.6 | 14.0 | - |

Table 2. Bulk carbon and nitrogen stable isotope data obtained on foodcrusts from the sites of Abora 1 and Celmi. \*, analysed by AMS radiocarbon (14C) dating, **±**, analysed by organic residue analysis.

ORGANIC RESIDUE ANALYSIS

*POTTERY USE AT DAKTARIŠKĖ 5*

Recently, 10 CWC vessels were sampled for organic residue analysis from the site of Daktariškė 5 (see Robson et al. 2019). The vessels yielded lipid concentrations between 143.9 and 57,265.3 μg g-1 that were above the minimum amount required for interpretation (i.e. > 5μg g-1 for ceramic powder and > 100 μg g-1 for carbonised organic residues) (Evershed 2008; Craig et al. 2013).

In the acidified methanol extracts, a range of saturated fatty acids (C13:0-C28:0) dominated by C16:0 and C18:0 were identified by GC-MS. These data indicate that animal products are likely to have been processed in the vessels (Regert 2011). To identify aquatic-derived lipids (Cramp and Evershed 2014), the samples were analysed by GC-MS using a DB-23 (50%-cyanopropyl)-methylpolysiloxane column (60 m x 0.25 mm x 0.25 μm; J&W Scientific, Folsom, CA, USA) in single-ion monitoring (SIM) mode. Interestingly, 9/10 samples yielded *ω*-(*o*-alkylphenyl) alkanoic acids (APAAs) with C18 and C20 carbon atoms alongside at least one isoprenoid fatty acid, i.e. 4,8,12-trimethyltridecanoic acid (TMTD), pristanic or phytanic acid, which met the established criteria for the processing of aquatic organisms in archaeological pottery (Hansel et al. 2004; Evershed et al. 2008). To corroborate further, the ratio of the two naturally occurring phytanic acid diastereomers (*SSR*%) was also measured, which can largely discriminate between aquatic and ruminant foodstuffs (Lucquin et al. 2016). Excepting two samples with *SSR*% values falling within the range of ruminant milk (DK323, 15.1%) and aquatic resources (DK525, 29.4%) respectively (Lucquin et al. 2016; Robson et al. 2019), the samples could not be securely assigned to either source given the broad range of values obtained (40.4-63.8%). These data indicate that mixtures of aquatic resources with ruminant carcass, cheese and/or milk fats had been processed in the vessels (Robson et al. 2019).

Whilst the main feature of the lipid profiles was the presence of aquatic biomarkers, molecular evidence for the processing of plant and insect products was also frequent. In total, 8/10 vessels from Daktariškė 5 yielded long-chain alkanes, traces of odd-chain fatty acids (including C29), terpenes (including α-Amyrin, β-Amyrin, betulin and lupeol) and acyl lipids (including monoacylglycerols, triacylglycerols and diacylglycerols) (Robson et al. 2019).

To distinguish the use of the vessels further, the 10 samples were analysed by GC-C-IRMS. δ13C values were obtained from the two main fatty acid methyl esters, methyl palmitate (C16:0) and methyl stearate (C18:0). These data are plotted alongside ellipses (at 95% confidence) established from data obtained from modern authentic reference animals in the region (Dudd 1999; Pääkkönen et al. accepted; Oras unpublished; Oras et al. unpublished). Four vessels fell within the range established for non-ruminant resources, i.e. freshwater fish (Figs. 11A and 11B) corroborating the molecular and bulk stable isotope data. A further four vessels, however, fell within the range established for wild and/or domestic ruminants, which could include aurochs (*Bos primigenius*), cattle (*Bos taurus*), elk (*Alces alces*), red deer (*Cervus elaphus*), roe deer (*Capreolus capreolus*) and sheep/goat (Ovis/Capra) (Figs. 11A and 11B). Moreover, two beakers (Dk240 and Dk466) had Δ13C values < -3.3‰, demonstrating the presence of dairy fats as defined by Copley et al. (2003) (Figs. 11A and 11B). Since these six vessels also yielded aquatic biomarkers, some mixing of vessel contents had taken place (i.e. freshwater fish with either ruminant carcass and/or dairy fats). For comparison, data obtained from five Subneolithic sherds from Daktariškė 5 are plotted (Courel et al. in preparation). Similarly, 4/5 vessels plotted within the range established for freshwater fish, and of these 3/5 met the established criteria for the processing of aquatic resources in pottery, whilst 1/5 indicated that a mixture of freshwater fish and ruminant carcass fats had been processed (Courel et al. in preparation). On the whole, these data demonstrate a degree of continuity in pottery use across the Subneolithic-Neolithic transition at Daktariškė 5 despite the introduction of domesticated animals.

*POTTERY USE AT ABORA 1*

In this study 10 foodcrusts adhering to CWC vessels were sampled for organic residue analysis to corroborate or contradict the bulk stable isotope data, which indicated that resources of an aquatic origin may have been processed in the ceramics. The 10 samples yielded sufficient quantities of lipids required for interpretation (i.e. > 100 μg g-1 (Evershed 2008; Craig et al. 2013)) further demonstrating that anaerobic conditions are conducive for lipid preservation. In comparison with Daktariškė 5, the lipid concentrations had a narrower range (133.2 to 1639.8 μg g-1).

A range of saturated fatty acids (C9:0 to C30:0) dominated by C16:0 and C18:0 were identified by GC-MS in the acidified methanol extracts. In addition, the cholesterol derivative, cholesta-3 5-diene, was present in 7/10 samples. These data demonstrate that animal products had been processed in the vessels (Regert 2011). The samples were similarly analysed by GC-MS using a DB-23 column operating in SIM mode (see above). On the whole, these data corroborated the bulk stable isotope data with all 10 samples from Abora 1 meeting the established criteria for the processing of aquatic resources in pottery (Table 3). Moreover, 4/10 samples had *SRR*% values that could be securely assigned to an aquatic source with values ranging from 78.5-82.4%. Since the remaining (6/10) samples had *SRR*% values ranging from 50.8-72.1% they could not be assigned to a single source demonstrating that mixtures of aquatic resources with terrestrial resources (i.e. ruminant milk, cheese and milk) had been processed in these vessels.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Sample no.** | **Vessel type** | **Lab no.** | **Lipid conc. (ug/g)** | **Aquatic biomarkers** | ***SRR*%** | **δ13C16 (‰)** | **δ13C18 (‰)** | **Δ13C (‰)** | **Interpretation** |
| VI 76: 5215(824) | Pot | ABO-1 | 1600.0 | APAA C16-22; TMTD; pri; phy | 72.1 | -28.5 | -30.2 | -1.6 | Aquatic (full suite; bulk; SRR?) + ruminant (Δ13C) |
| VI 76: 5213 | Beaker | ABO-2 | 1208.7 | APAA C16-22; TMTD; pri; phy | 62.3 | -30.2 | -33.3 | -3.1 | Aquatic (full suite; bulk) + ruminant (SRR; Δ13C) |
| VI 76: 5100(139) | Beaker | ABO-3 | 308.2 | APAA C16-22; TMTD; pri; phy | 64.3 | No data | Aquatic (full suite; bulk; SRR?) |
| VI 76: 5317(5137) | Beaker | ABO-4 | 189.0 | APAA C16-20; TMTD; pri; phy | 82.4 | No data | Aquatic (full suite; bulk; SRR) |
| VI76:5210 | Beaker | ABO-5 | 133.2 | APAA C16-20; TMTD; pri; phy | 70.4 | -28.9 | -30.9 | -2.0 | Aquatic (full suite; bulk; SRR?) + ruminant (Δ13C) |
| VI 76: 5068 | Pot | ABO-6 | 326.4 | APAA C16-20; TMTD; pri; phy | 78.5 | -32.6 | -32.2 | 0.4 | Aquatic (full suite; bulk; SRR, Δ13C) |
| VI 76: 5210(146) | Beaker | ABO-7 | 1639.8 | APAA C16-20; TMTD; pri; phy | 50.8 | -29.9 | -32.3 | -2.4 | Aquatic (full suite; bulk) + ruminant (SRR; Δ13C) |
| VI 76: 5316 | Beaker | ABO-8 | 1214.7 | APAA C16-22; TMTD; pri; phy | 79.0 | -33.2 | -32.3 | 0.9 | Aquatic (full suite; bulk; SRR; Δ13C) |
| VI 76: 5064(70) | Beaker | ABO-9 | 369.1 | APAA C16-20; TMTD; pri; phy | 69.8 | -31.8 | -31.6 | 0.2 | Aquatic (full suite; bulk; SRR?; Δ13C) |
| VI 76: 5063(109) | Beaker | ABO-10 | 333.0 | APAA C16-20; TMTD; pri; phy | 81.1 | -33.3 | -32.5 | 0.8 | Aquatic (full suite; bulk; SRR; Δ13C) |

Table 3: Summary of the molecular and isotopic data, including lipid concentrations, aquatic biomarkers, *SRR*%, δ13C values of the C16:0 and C18:0 *n*-alkanoic acids and interpretations, obtained for the 10 CWC sherds (all foodcrusts) sampled from the site of Abora 1. Blank cell, no data, APAA, *ω*-(*o*-alkylphenyl)alkanoic acids, TMTD, 4,8,12-trimethyltridecanoic acid, pri, pristanic acid, phy, phytanic acid, *SR*R%, Area *SSR*/Area *SSR*+Area RRR\*100, Δ13C, δ13C18:0-δ13C16:0.

Whilst compounds associated with the processing of plant and insect products were frequent in the CWC vessels from Daktariškė 5 (see above), comparable evidence at Abora 1 was scant. Small quantities of *n*-alkanes (including heptacosane and hexacosane) were identified in 4/10 samples, however, since these alkanes are ubiquitously encountered in soils, their presence is probably the result of contamination. Likewise, the ketone hentriacontane was only present in 2/10 samples, whilst a degradation product of phytosterol, stigmasta-3 5-diene, was identified in 1/10 samples. Lastly, dehydroabietate was identified in 2/10 samples. Interestingly, this diterpene is a marker of pine resin (Jerković et al. 2011; Mitkidou et al. 2007; Regert 2004), and was one of a number of terpenes frequently encountered in Early-Middle Neolithic pottery from the site of Zamostje 2 in the Russian Federation (Bondetti et al. 2019).

Indeed, the processing of freshwater fish or mixtures of freshwater fish with ruminant carcass fats was also demonstrated by the δ13C values of the C16:0 and C18:0 *n*-alkanoic acids, which plotted within the ellipses established from modern authentic reference animals (Figs. 11A and 11B). Interestingly, not a single vessel yielded a Δ13C value < -3.3‰, which is generally accepted as the cut-off for the presence of dairy fats in archaeological pottery (Copley et al. 2003). Short chain fatty acids (C4-C12), characteristic of dairy products, were present in trace amounts in many of the vessels. However, given the restricted range (C9-C12), these data are not conclusive. That said, we have previously demonstrated that CWC groups in coastal and hinterland regions used pottery for the processing and/or storing of dairy products (Heron et al. 2015; Piličiauskas et al. 2018a; Robson et al. 2019).

Overall, the analyses by GC-MS (n = 10) and GC-C-IRMS (n = 8) corroborated the bulk stable isotope data and confirmed that resources aquatic in origin had been processed in the CWC vessels. Indeed, the presence of the Eurasian beaver (*Castor fiber*), European perch (*Perca fluviatilis*), and northern pike (*Esox lucius*) in the zooarchaeological assemblage recovered from Abora 1 further supports these data (Loze 1979).

*POTTERY USE DURING THE CWC*

Although our analyses demonstrate that 19/20 CWC vessels from the sites of Abora 1 and Daktariškė 5 had been used to process aquatic organisms, the mixing of different foodstuffs was also commonly practiced (Fig. 11). At Daktariškė 5, 8/10 vessels indicated that plant or insect products had been processed, whilst 8/10 vessels had *SSR*% values indicating a mixture of aquatic resources with either ruminant carcass, cheese and/or dairy fats. Moreover, these data were corroborated by the δ13C values indicating that 6/10 vessels from the site had been used to process ruminant carcass and dairy fats (Robson et al. 2019). Likewise, mixing was evident at Abora 1. Plant processing may have taken place in 5/10 vessels, whilst 6/10 vessels had *SSR*% values indicating that ruminant carcass, cheese and/or milk fats had been processed, which were similarly corroborated by the δ13C values with 4/8 vessels falling within the ranges established for freshwater fish and/or ruminant carcass fats. Overall, these data are largely in agreement with previous studies whereby vessels from both coastal and inland sites had been sampled (Cramp et al. 2014; Heron et al. 2015; Piličiauskas et al. 2018b; Robson et al. 2019; Pääkkönen et al. 2019) indicating that a mixture of resources encompassing both domestic and wild resources and their products had been processed during the CWC. However, the data do disagree somewhat with ceramic use during the preceding Subneolithic Narva culture that was primarily directed towards the processing of aquatic resources (Oras et al. 2017; Papakosta et al. 2019). Interestingly though, mixtures of different resources were identified in Subneolithic ceramics from the region (Heron et al. 2015; Robson et al. 2019) and importantly from the site of Daktariškė 5 itself (Courel et al. in preparation), which demonstrates that a continuation in the use of pottery across the Subneolithic to Neolithic transition took place at a local rather than regional scale.

A CWC FISH SCREEN FROM THE SITE OF ŠVENTOJI 58

In 2015, an incomplete fish screen was discovered in the waterlogged gyttja deposits at Šventoji 58 in northwest Lithuania (Fig. 12). The screen was composed of rods measuring 1.8 m in length that were 1 x 1 cm in diameter, which had been bound together by a twisted knot with thread made from plant material. The rods were uniform in size and their shape, straight and without branches, demonstrates that they were obtained through coppicing. Unfortunately the binding was fragmentary and not well-preserved, however, it would appear that the rods were tightly plaited every 15 to 20 cm using plant thread. Vertical half hitch knots ('right over left') were tied around the rods (Fig. 13). When rolled up, the screen was probably transported by dugout canoe.

In this study we identified the rods and binding material used in its construction. Thin sections (transverse, tangential and radial) of two rods were analysed under a stereomicroscope. In the radial sections scalariform perforation plates with around 8 bars were visible. In the transversal sections pores were identified grouped in radial multiples and clusters with a slight dendritic pattern. Based on these anatomical features both rods were identified as common hazel (*Corylus avellana*) (Schoch et al. 2004; Wheeler 2011). Moreover, on many of the other rods the bark was retained that was visually similar to that of hazel. Thus, it is assumed that the screen had been constructed entirely out of hazel as has been demonstrated elsewhere throughout Northern European prehistory (e.g. Fischer 2007; McQuade and O’Donnell 2007; Klooß 2014). On the other hand, identification of the binding material was more complicated since it had largely degraded. Firstly, analysis of the fibrous leaves was excluded due to the presence of rays and absence of stomata. The use of plant bast, for instance hemp, flax or nettle, was excluded due to the thickness of the fibrous structure, presence of rays, remains of cambium and associated tissue with calcium oxalates that were of a size and shape typical of tree bast. The binding material was birefringent and extinction was observed in a South-North and East-West direction. Interference colours were week. It was difficult to separate the single fibres since the material was very brittle. However, those that could be isolated had an Orange I colour (according to Michel-Lévy interference colour chart) both in a South-North and East-West direction when a full wave compensator was inserted. This indicated that the crystalline structure was disturbed. However, adding a drop of 3% NaOH according to the procedure described by Lukešová (2017) made it possible to find several fibre examples confirming the fibrillary orientation was Z. The fibre lumen was difficult to detect, most probably due to the decayed structure, but cross markings were common. The repetitive nature of the fine ladder-shaped rays was clear and indicated the inner part of phloem of a lime (*Tilia* sp.) tree. Calcium oxalate in the shape of an oblong prism were common, however no rows of crystals in plant cells were detected. Based on comparison with reference samples, the binding material from the rollable fish screen was most likely made of lime tree bast.

Fish screens made of pine laths bound together with various plant materials are well known in the eastern Baltic as well as northwest Russia both archaeologically and ethnographically (Bērziņš 2008; Koivisto & Nurminen 2015; Lozovski & Lozovskaya 2016). They were used for stationary fishing in shallow calm waters and had probably been attached to wooden poles, which were driven into the bottom of lakes or rivers. Fish weirs of various forms may have been constructed using rollable screens or more stable lath screen panel sections, which could then be used in combination with or without traps or baskets. Rollable fish screens made of pine laths are largely an eastern Baltic Subneolithic phenomenon since fish weirs in the western Baltic dating to the Mesolithic and Neolithic periods were generally constructed using hazel rods and wicker screens (Karsten & Knarrstrom 2003; Klooß 2014). In Finland, the pine laths of Subneolithic fish screens were bound by birch bark (Koivisto 2012), whilst in northwestern Russia, common reed (*Phragmites australis*) was used (Lozovski & Lozovskaya 2016). On the other hand, at Sārnate and Šventoji in western Latvia and Lithuania respectively, lime bast was mostly used for the construction of Subneolithic fishing gear (Rimantienė 2005; Bērziņš 2008).

Often misidentified as fish trap panels by archaeologists (e.g. Rimantienė 2005, Abb. 112), rollable fish screens were widely used during the Subneolithic-Neolithic transition, ca. 3000 cal BC in the Šventoji landscape (Piličiauskas 2012, Figs. 2-4). However, there is one significant difference between those previous discoveries and the one from Šventoji 58, material. In the former, pine laths were used, whilst the latter was constructed out of hazel rods. According to the stratigraphy of the Šventoji 4 site as well as AMS radiocarbon (14C) dates from other fishing stations at Šventoji (e.g. Šventoji 42), rollable screens made out of pine laths were used by Porous Ware and Globular Amphora Ware fishers between ca. 3200 and 2700 cal BC (Piličiauskas 2016). However, the radiocarbon age of the Šventoji 58 fish screen was younger, ca. 2619-2462 cal BC (Table 1) indicating that it was constructed by CWC fishers (Piličiauskas 2016). It would appear that CWC fishers preferred different raw materials for the construction of fishing gear than the preceding local hunter-gatherer-fishers. For example, pine laths were not present at the Early Bronze Age sites of Daktariškė 5 (upper horizon), Šventoji 9 and Šventoji 55 (Rimantienė 2005; Juškaitis et al. 2016b; Piličiauskas 2018). Whilst, it may be inferred that the CWC marked the end of the pine lath making tradition in western Lithuania, in eastern Lithuania it was used through the Neolithic to the Bronze Age as demonstrated at the site of Kretuonas 1C (Girininkas 2004).

VARIABILITY OF THE CWC ECONOMY IN THE EASTERN BALTIC

During prehistory the three sites investigated in this study, Abora 1, Daktariškė 5 and Šventoji 58, were located near shallow water bodies within lacustrine or lagoonal environments, which would have been rich in aquatic fauna and flora. Given their abundance it is perhaps not entirely surprising that aquatic resources continued to be exploited by the CWC people in the eastern Baltic. Whilst the organic residue analysis of CWC ceramics (Heron et al. 2015; Piličiauskas et al. 2018b; Robson et al. 2019) and zooarchaeological evidence (Piličiauskas 2018) corroborate the data presented here, the stable isotope analysis of human bone collagen largely contradict. Indeed, these data generally demonstrate that the CWC peoples of the eastern Baltic mainly consumed terrestrial-derived protein, whilst a contribution of aquatic-derived protein, including freshwater fish, was evident for some individuals during certain times of their lives (Antanaitis-Jacobs et al. 2009; Piličiauskas et al. 2017a, b). Regardless, our data reinforce the notion that certain CWC groups were mainly fishers as opposed to farmers.

Our reconstruction of the Lake Bižulis water level and palaeolandscape demonstrates that 9/11 known CWC sites in the area were situated on islands at ca. 2500 cal BC (Fig. 7), which may have been selected for the mass capture and/or processing of fish as has been suggested elsewhere (Koivisto 2017). However, islets may also have been chosen for rearing livestock, which is corroborated by the presence of dairy fats in two CWC beakers at the site of Daktariškė 5 (Robson et al. 2019). Indeed, the selective rearing of livestock on islands has additional benefits, such as preventing escape as well as protection from predation and theft. Interestingly, this practice persisted in Lithuania until the middle of the 20th century; goats and sheep were transported to and from islets by boat whilst cattle often followed unaccompanied. Today, some islands in lakes and rivers are named the ‘island of cows’. In Finland, similar practices involving sheep are known since the beginning of the 16th century (see Tourunen 2008 and references cited therein). Around 100 islands of various sizes existed in Lake Biržulis during the CWC period (Fig. 7) amounting to ca. 470 ha of suitable pasture of rearing livestock. Howerer, it is difficult to substantiate whether this practice took place at Daktariškė 5 since the pollen and macrobotanical data do not demonstrate significant forest clearance or use of islands for pasture (i.e. an increase of *Calluna vulgaris*, Cyperaceae, *Juniperus communis*, *Melampyrum* sp., *Plantago lanceolata*, Poaceae, Ranunculaceae, and *Rumex* sp.).

Although CWC peoples migrated into the eastern Baltic as mobile stock breeders as evidenced by specific settlement patterns with many small sites scattered throughout various ecotones (Piličiauskas 2018), some groups, shortly after their arrival, incorporated fishing into their subsistence economies to varying degrees. This change was probably dictated by the local environment, for instance the densely forested woodlands of the region. Abora 1 and Daktariškė 5 should therefore be regarded as localities illustrating a process of de-Neolithisation. At Abora 1, the resident CWC group altered not only their subsistence economy, from stock breeding to fishing, but also their lifeway becoming more sedentary; as evidenced by the exceptionally large ceramic assemblage, a localised pottery making tradition and pottery use principally directed towards the processing of wild resources. At Daktariškė 5, fishing also became a significant part of the local CWC economy although stock breeding and the consumption/production/storage of dairy products persisted, perhaps symbolically (see Piličiauskas et al. 2018a) as demonstrated by the presence of dairy fats in two beakers (Robson et al. 2019). Here, pottery production was more inline with other sites in the eastern Baltic implying a degree of mobility as well as contact/communication with neighbouring CWC communities. On the Baltic coast, aquatic resources continued to be exploited as evidenced by the rollable fish screen at Šventoji as well as the remains of fish and presence of aquatic biomarkers in CWC vessels at the site of Alksnynė 3 (Piličiauskas 2018; Robson et al. 2019) and elsewhere (Heron et al. 2015; Pääkkönen et al. 2019). Animal husbandry was, however, practiced by other CWC groups and is perhaps clearer at sites located in the hinterland as demonstrated by the generally lower δ15N values of foodcrusts and greater occurrence of dairy and ruminant fats within ceramic vessels (Piličiauskas et al. 2018b; Robson et al. 2019). Whilst the role of local hunter-gatherers in the re-Neolithisation process is poorly understood, further investigations into CWC fishery sites are warranted.

CONCLUSIONS

* Overall, our results further demonstrate that the CWC people of Europe did not have a uniform way of life.
* Whilst previously viewed as a highly mobile population, certain groups, particularly in the eastern Baltic appear to exhibit a more sedentary way of life as evidenced by the unusually large pottery assemblages recovered from the sites of Abora 1 and Daktariškė 5.
* Moreover, these specific groups who resided in lacustrine environments were reliant on a mixed economy which incorporated both domestic livestock and the procurement of wild resources.
* The molecular and isotopic data obtained from the organic residue analysis of pottery shows that whilst a range of ruminant products, including milk, had been processed in the CWC vessels at the sites of Abora 1 and Daktariškė 5, they had been preferentially used for the processing of aquatic resources, notably freshwater fish.
* The pollen and macrobotanical analyses undertaken on sediment samples from the site of Daktariškė 5 did not yield any evidence indicative of crop cultivation or extensive forest clearance for stock breeding during the CWC period.
* The analyses of a portable fish trap from Šventoji 58 demonstrates that CWC groups in lagoonal environments were proficient in the collection, construction and use of hazel for the exploitation of aquatic resources, which is markedly different to the preceding local Subneolithic hunter-gatherer-fishers.
* To conclude, these data indicate that some CWC groups, particularly in lacustrine and coastal ecotones, partook in a process of de-Neolithisation and a return to hunting, gathering and fishing. Moreover, despite a change in the subsistence economy, there was no apparent change in pottery production. Indeed, these groups continued producing pottery akin to other assemblages from CWC sites in the eastern Baltic without incorporating other hunter-gatherer-fisher elements, thus demonstrating that the primary agent for the de-Neolithisation process was not assimilation with local hunter-gatherers-fishers.

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