DIET IN EARLY LITHUANIAN PREHISTORY AND THE NEW STABLE ISOTOPE EVIDENCE

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Abstract

This article reviews current scientific evidence of food resources exploited in the Lithuanian Stone and Bronze Ages and presents the new direct, biochemical stable isotope evidence. Stable carbon and nitrogen isotope analyses were performed on 75 Stone and Bronze Age animal bone samples and 23 human bone samples. We discuss how the obtained values relate to diet and other evidence of diet, compare the obtained values with regional stable isotope data, and consider sociocultural implications.

Key words: stable isotopes, palaeodiet, Stone Age, Bronze Age, Lithuania, East Baltic, Corded Ware Culture

1. Introduction: The research question and the research material

The exploitation of food resources and its evolution in Lithuanian Stone and Bronze Age territory has been examined and/or discussed by means of archaeological (i.e., Rimantienė 1996; Girininkas 1994), zooarchaeological (Daugnora et al 2002; Duoba and Daugnora 1994; Daugnora and Girininkas 1995, 1996, 1998, 2004), and more recently chronological (Ramsey et al 2000), archaeobotanical (Stančikaitė 2000; Antanaitis et al 2000; Antanaitis-Jacobs et al 2001, 2004), palaeodental (Palubeckaitė and Jankauskas 2006), and combined bioarchaeological data (i.e., Zvelebil 1998; Antanaitis 2001). One Lithuanian stable isotope study of six Neolithic-Bronze Age humans and one millet sample has previously been published (Antanaitis and Ogrinc 2000). The 98 bone samples submitted for stable isotope analysis in this study include both human and animal bone from key Mesolithic, Neolithic, and a couple Bronze Age archaeological sites in Lithuanian territory (see Figure 1, Table 1).

Prehistoric faunal and floral data in archaeological contexts are in themselves significant in the determination of ancient inhabitants' diet. Palaeodental evidence such as tooth wear and changes in caries and calculus rates can suggest types of food consumed and changes in dietary patterns such as those that occurred during the transition to farming. Still, various factors such as the differential preservation of organic remains or the overrepresentation of seasonal hunting refuse in the material record can bias accurate interpretations interpretations and can be considered only as indirect evidence. Stable isotope analyses of human remains are especially valuable in dietary studies since they provide direct quantitative information on what the people ate specifically regarding the protein element of diet.

The particular ecology of sites can vary both geographically and chronologically. Locationally and temporally specific faunal stable isotope data illustrate the expected range of stable carbon and nitrogen isotope values in a particular place and time and are important for an accurate interpretation of the human data.

Human bone collagen is continuously resorbed and replenished, so that its isotopic composition reflects dietary averages over at least 10 to 20 years of an individual's life (Sealy 2001, Lee-Thorp 2008). Stable isotope data not only can suggest the importance of certain food sources in a population, but also intra-individual variation in diet (Eriksson 2003) and possible sociocultural or ideological implications (Antanaitis 2001, Eriksson 2003, Eriksson et al 2006, Fornander 2005/2006).

Stable isotopes are of great value as a tool in the interpretation of ancient diets. In this article, we focus mainly on the new stable isotope evidence related to diet on the direct quantitative information on what people in Lithuania in early prehistory ate. Just like other sources of paleodietary information, however, isotope measurements are subject to a number of significant uncertainties and potential biases (Milner et al 2004, but see Richards and Schulting 2006). Considering the potential biases to which every source of information is subjected, in the end, the best analytical strategy for scientifically establishing early prehistoric human diet includes a comparison of related cross-disciplinary data. We precede the presentation of our stable isotope study's results by a review of what other data suggest regarding human diet in early Lithuanian prehistory.

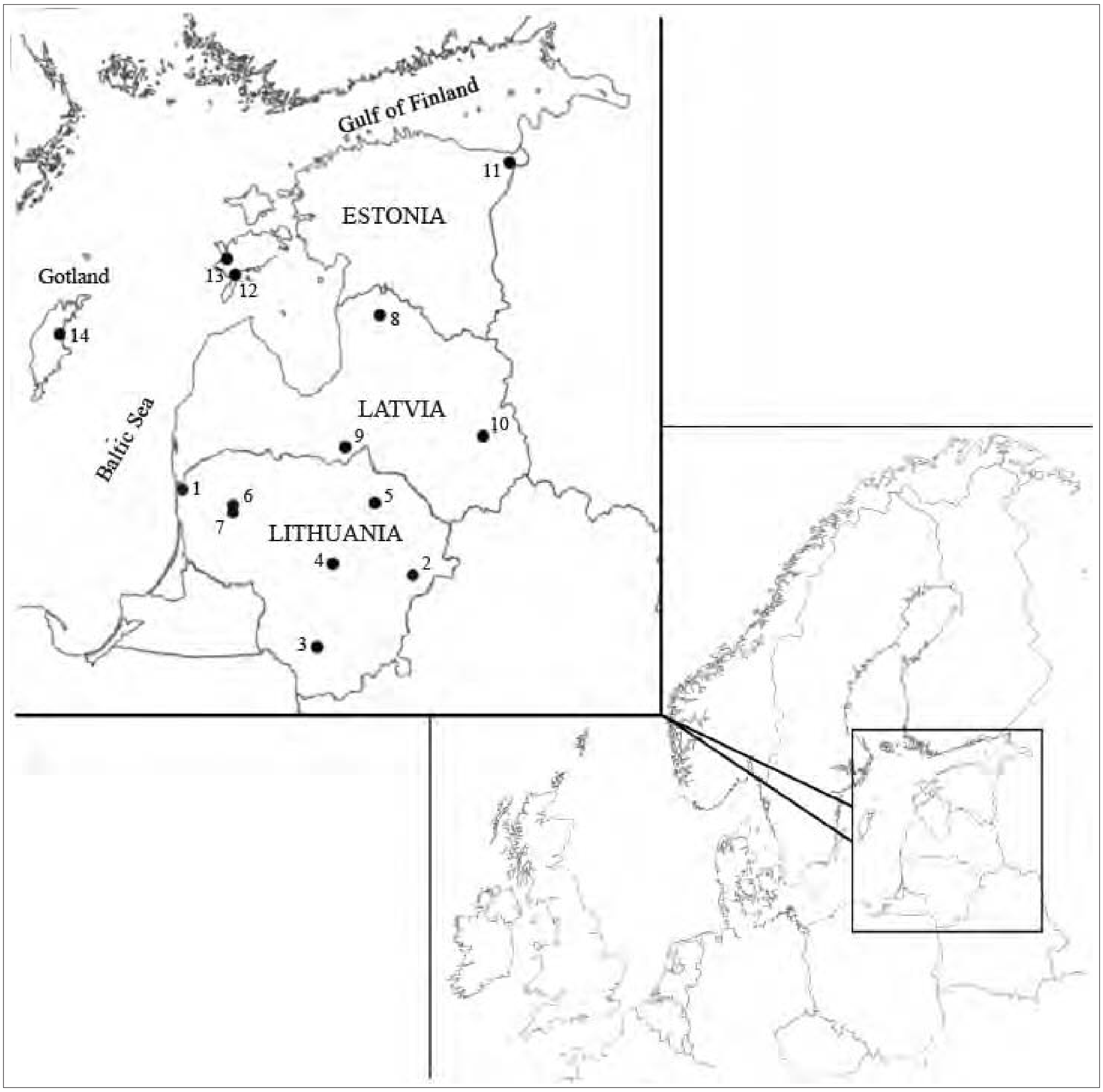

Figure 1. Location of Lithuanian and other East Baltic archaeological sites: 1. Šventoji, 2. Kretuonas/Žemaitiškė, 3. Turlojiškė/Kirsna, 4. Plinkaigalis, 5. Gyvakarai, 6. Donkalnis, 7. Spiginas; 8. Zvejnieki, 9. Selgas, 10. Sarkaņi, 11. Kudruküla, 12. Naakamäe, 13. Loona, 14. Västerbjers.

2. Other bioarchaeological evidence of diet in early Lithuanian prehistory

The Zooarchaeological evidence

Hunting and fishing tools in the East Baltic Stone Age included arrow points, spear points, bows, harpoons, fishhooks, nets, weirs, leisters, netfloats, boats, oars, dams, knives, scrapers, etc. (Daugnora and Girininkas 1995). During the entire Mesolithic, the animal that appeared to be most hunted in the entire East Baltic was the elk. Others hunted include red deer, aurochs, boar, marten, and beaver (Daugnora and Girininkas 2004, p.278). Seals were being hunted along the Baltic coast from the very beginning of the Mesolithic (Lõugas 1997, p.38; Storå 2000, 2001; Forsten and Alhonen 1975). The hunting of seals became especially widespread and reached its maximum in the Neolithic (Lepiksaar 1986, p.62). Faunal remains found within the Donkalnis graves include 183 animal tooth pendants, mostly of elk and red deer (93.44%), then aurochs (2.73%), boar (2.18%), bear (1.09%), and roe deer (0.53%) (Daugnora and Girininkas 1996, p.77).

Cumulatively, the boar (Sus scrofa), elk (Alces alces), and beaver (Castor fiber) very often dominate the faunal assemblages of Lithuania, Latvia, and Estonia during the Neolithic and Early Bronze Age. Other top five most popular mammals represented in Lithuanian territory in general is the red deer (Cervus elaphus). Seals (Phocaidae) were very important in sea coastal sites; geographic location is clearly an important variable.

Table 1. Lithuanian Stone and Bronze Age chronology

ARCHAEOLOGICAL PERIOD	DEFINING FEATURE OF ARCHAEOLOGICAL PERIOD	C14 bp	ENVIRONMENTAL PERIOD, bp
Late Mesolithic	Post-glacial and pre-Neolithic hunter-gatherers of Atlantic period; Kunda, Nemunas, Janislawice cultures	c. 8 000 – 6550/6300	Early Atlantic (8000 – 6700) and beginning of Late Atlantic (6700 – 5000); formation of Littorina Sea
Early Neolithic	Appearance of (Narva and Nemunas Culture) ceramics (Late Mesolithic in Scandinavia)	6550/6300 – 5600/5400	Late Atlantic
Middle Neolithic	Appearance of Comb-and-Pit Pottery culture	5600/5400 – 4400/4300	Late Atlantic - Early Subboreal (5000 – 4000)
Late Neolithic	Appearance of Corded Ware culture	4400/4300 – 3500	Middle/ Late Subboreal (4000 – 2500)
Early Bronze Age	First metal objects	3500 – 3100	Late Subboreal
Late Bronze Age	New kinds of bronze objects, cremations or earliest barrows with stone constructions, appearance of hillforts	3100 – 2500	Late Subboreal; at end of Subboreal, Littorina Sea changes into (salty) Limnea Sea

References

Antanaitis 2001; Antanaitis-Jacobs and Girininkas 2002; Juodagalvis 2005; Kabailienė 1990, 1998; Mangerund et al 1974.

The aurochs (Bos primigenius) begins to rise in popularity from the Middle Neolithic onward. Bird bones are poorly preserved in general, and often also unidentified, although the existing record clearly shows that in some sites there were significant numbers of bird bone remains (Daugnora et al 2002). Waterfowl (Anseriformes), especially mallards (Anas platyrhynchos), dominate bird bone assemblages. On the whole, pike (Esox lucius) is by far the best represented species of fish on the majority of the sites (Makowiecki 2003). Perch (Perca fluviatilis), pikeperch (Lucioperca lucioperca, Stizostedion lucioperca), and cyprinids followed pike as most popular fish species in investigated sites as a whole. (Daugnora 2000, 2000a; Antanaitis 2001).

The presence of domesticated animals–cattle (Bos bovis), sheep/goat (Ovis avies/Capra hircus), pig (Suis suis) – is apparent in the Middle Neolithic in Lithuania and Latvia, but not, by known data, in the best published archaeological sites of Estonia, where they begin to occur in the Late Neolithic. The Lithuanian sites appear to show the earliest and highest proportions of domesticated animals 6.15% at the Middle Neolithic Kretuonas 1B site and up to 18% at the Kretuonas 1D site by MNI (minimum number of individuals), for example, but the percentages need to be treated with caution due to small sample sizes. The Early Bronze Age in the East Baltic is still poorly researched. The second half of the Bronze Age suggests a marked change in the subsistence economy; domesticated animals in Late Bronze Age hillforts in Lithuania, Latvia, and Estonia constitute the majority of zooarchaeological remains (Daugnora and Girininkas 1998, Antanaitis 2001).

The Human palaeodental evidence

Comparatively very few early prehistoric human burials have been discovered in Lithuanian territory. The largest known concentration of interred Stone Age humans in the East Baltic area is the burial ground of Zvejnieki, in neighboring Latvia. Three hundred seventeen human burials have thus far been discovered (Zagorskis 1987, 1994). The analysis of dental pathologies of a sample of 118 individuals (2586 permanent teeth) from Zvejnieki was performed in order to test the “classic” Neolithization model which accentuates changes in dental health during the transition to agriculture (Palubeckaite and Jankauskas 2006). High dental wear, intensive teeth use, and low antemortem tooth loss (AMTL) together with a low incidence of caries is usually attributed to individuals in which subsistence is based on hunting and gathering. Subsistence based on agriculture generally is associated with lower tooth wear, increased caries rates, and AMTL due to changes in food preparation and increased reliance on agricultural products (Alexandersen 1988, p.15; Larsen 1997, p. 67; Mays 1998, p.153).

Dental wear at Zvejnieki was severe during the entire Stone Age. A high degree of attrition is typical of hunter-gatherers or populations with mixed economy (Alexandersen 2003, p.15; Bennike 1985, p.149). However, abrasiveness of food alone cannot explain asymmetry in dental wear and greater attrition of anterior teeth compared to molars. The same severe asymmetrical dental wear was found in the Mesolithic population of Skateholm (Alexandersen 1988, p. 157). The wear could be from activities other than eating. Ethnographic studies of Inuit populations had revealed a similar attrition pattern from the intensive use of teeth as tools, such as to soften hides or tighten fish lines (Merbs 1983, p. 154). An intensive use of teeth as tools could also result in broken or fractured teeth and unusual wear facets (Larsen et al 1998, p.142). This feature also was found in Zvejnieki. The biting and chewing of hard food products like bones, nuts, and roots also could have been responsible for the severe anterior dental attrition and chipping of posterior teeth in this population.

One of the most unexpected results of the dental study was the high caries rate at Zvejnieki, since a diet based on animal protein, fish, and vegetables with a low sugar content is not cariogenous (Mays 1998, p.149). According to the incidence of decay, Zvejnieki individuals were close to Stone Age foragers from southern Europe and the Mediterranean who had high caries rates, probably due to an access of fruits rich in carbohydrates (Meiklejohn and Zvelebil 1991, p.132). The highest number of affected teeth was found in the Mesolithic, with a substantial decline in the Neolithic, and a slight increase in the Bronze Age. Corrected caries rates, however, eliminated significant differences between these periods, suggesting the absence of dramatic change in diet during the transition to the Neolithic. A considerable amount of occlusal caries in the Mesolithic may suggest the existence of some sticky cariogenous food (e.g., honey) that could adhere to dental fissures long enough to cause decay. Most cavities in the Neolithic were localized on the cervical region of teeth. This is expected, taking into account high dental attrition, which leads to a compensatory over eruption of teeth and root exposure. Occlusal caries decreased almost twofold in the Neolithic. Such a shift in caries location could be due to changes in food preparation or due to the general increase of teeth use.

Extensive dental calculus (calcified dental plaque) is correlated with a diet based on proteins (meat, fish, nuts) (Hillson 1986, p.322). Mesolithic individuals had 55% of their teeth affected, a significantly lower incidence than the Neolithic (95.1%) and Bronze Age (100%) individuals. The dental calculus of the Mesolithic individuals, however, was mild, while 25.5% of the Neolithic and 14.3% of the Bronze Age individuals had teeth with moderate and severe calculus. The appearance of calculus together with caries could confirm diversity in diet, with a representation of both animal protein and carbohydrates (Palubeckaitė and Jankauskas 2006).

The analysis of dental pathologies at Zvejnieki suggests that caries rates did not change dramatically over time, while calculus rates showed a tendency to increase. Available data suggest slight and gradual changes in diet and food preparation, with, perhaps, a similar ratio of animal protein and plant food.

The Palaeobotanical evidence

While the lack of cereal pollen does not necessarily indicate a lack of cereals (Behre 1981, p.226-227; Poska et al 1999, p.307), the first pollen of cereals appeared in the East Baltic during the Late Atlantic: a single oat (Avena) pollen grain, Cerealia pollen, and hemp/hops (Cannabis/Humulus) in Lithuania, barley (Hordeum) in Latvia, Cerealia and Avena in Estonia. The most noteworthy and prolific finds of plant food on Mesolithic and Neolithic archaeological sites in all the Baltic States are hazelnut (Corylus avellana) and water chestnut (Trapa natans). Nuts, shells, and husks of these plants are found around hearths sometimes in large quantities together with wooden mallets as well as wooden and stone hoes in archaeological sites by the Middle Neolithic (Vankina 1970, Rimantienė 1996). The large number of remains of these nuts in macro form is typical not only of the East Baltic, but is widely documented throughout Europe during the Atlantic and Subboreal climatic periods.

West Lithuania's and East Latvia's Late Neolithic archaeological sites reveal a marked increase in hoes, grinding stones, and sickles (Butrimas 1996, Loze 1979, Rimantiene 1999). Pollen and seed analysis show cultivated plants were emmer wheat (Triticum dicoccon), barley, millet (Panicum), Italian millet (Setaria italica), and hemp (Rimantienė 1996). Palynological data suggest the intensification of cattle breeding and that agriculture became a common activity in the second half of the Early Subboreal or Late Neolithic (Stančikaitė 2000).

The least amount of information is available in regards to East Baltic Early Bronze Age farming. Late Bronze Age archaeological data show signs of intensive agriculture throughout the region, illustrated by the extent and intensity of cereal cultivation by palynological data, such finds as the stash of charred millet grains (Panicum miliaceum) at the Turloji kė site, radiocarbon dated to 2590+75 BP (Ua-16681) (Antanaitis and Ogrinc 2000, p.7), various grindstones, and even bronze sickles on archaeological sites in Lithuania by the end of the Late Bronze Age. Ardmarks found underneath fortified settlements, hundreds of stone shaft-hole axes (slashing tools) in fields, finds of cereal grains (including millet), seeds of perennial weeds, and cultivation tools, all suggest that slash and burn agriculture was dominant in Latvia by the beginning of the first mil. BC (Vasks et al 1999, p. 300-301, Graudonis 1989, p.73). The discovery of numerous fossil fields of so-called Celtic and Baltic types of the Late Bronze Age in Estonia suggest that farming was well established there by then (Lang 1992, 1994a, 1994b, 1994c, 1995).

3. The New Stable Isotope Evidence

Materials

Faunal samples in this study were taken from the most representative archaeological localities in Lithuania: the prominent Neolithic-Early Bronze Age ventoji site series in coastal Northwestern Lithuania (Rimantienė 1979, 1980, 1996; Juodagalvis and Simpson 2000), the Neolithic-Early Bronze Age inland, lacustrine site series of the well-known Kretuonas/ Žemaitiškė archaeological complex in Northeastern Lithuania (Girininkas 1990; Girininkas 1994; Daugnora and Girininkas 1996, 2004), and the Late Neolithic-Bronze Age Kirsna/ Turlojiškė archaeological complex near the Kirsna River in Southwestern Lithuania (Merkevičius 1998, 2000; Antanaitis et al 2000) (See Table 2).

The human bone collagen samples came from six different areas in Lithuania. The Donkalnis and Spiginas burial sites both occur in West Lithuania's Samogitian Highland, on separate islands in Biržulis Lake; 8 more-or-less intact and 6 derranged (from gravel pit digging) burials were found at Donkalnis, 4 burials – at Spiginas. The Donkalnis burial site was adjacent to a habitation site, as were the Kretuonas and Turlojiškė area burials. The Plinkaigalis individuals were buried in a cemetery in Central Lithuania's Kėdainiai district; most of the graves in the Plinkaigalis cemetery date from the 3rd to the 6th/7th C. AD, but this study's two individuals date to a different time, to the Late Neolithic's Boat Battle Axe Culture of the Corded Ware culture horizon (Butrimas et al 1985; Kazakevičius 1993, p. 160, 165). The Gyvakarai individual, from the Gyvakarai village in the Kupi kis district in northeastern Lithuania, also archaeologically is ascribed to the Late Neolithic Boat Battle Axe Culture (Tebel kis 2001, Tebel kis and Jankauskas 2006) (See Table 3).

Our study was limited in certain instances by the availability of materials. Unfortunately, little suitable Mesolithic bone other than human was available. As well, certain species of fauna are not represented equally throughout the Neolithic subperiods. The lack of chronologiclly or species-specific finds limits the data. Also not presented here are the data of 32 faunal samples and 5 human samples of the study, as the analyses did not yield valid results due to not enough collagen for measurement or a poor C:N ratio. These sorts of lacunae are, unfortunately, not atypical of the early prehistoric material record.

Methods

The chemical composition of an individual's bones contains information about what the individual ate (Lee-Thorp 2008, Sealy 2001). Since the stable isotope ratios of carbon (C) and nitrogen (N) occur in varying proportions in different foods and are passed on to the bones of the consumer, stable isotope ratios of bone collagen provide information about the consumer's diet. Stable isotope data of bone collagen are a direct biochemical means of ascertaining information about diet, specifically, the protein element of diet. Stable carbon isotope values, indicated as δ^{13}C, have been used in two ways in palaeodietary reconstruction. The first and most popular way they are used is to determine the amount of marine protein in diet, compared to terrestrial protein (Schwarz and Schoeninger 1991; Tauber 1981, 1986).

The carbon isotopic value for an individual living entirely on a marine or a terrestrial diet, or its end-value, is slightly variable. The expected isotopic end-value for bone collagen of people in inland Scandinavia and northern lattitudes in general consuming only terrestrial (C_3) protein has an average δ^{13}C value of -20 to -21‰ (Lidén and Nelson 1994, p.18; Lovell et al 1986). The marine end-value, however, is correlated with salinity. The marine end-value of oceans is -11 to -12‰ whereas the Baltic Sea's is -14 to -15‰ because it is not as saline (Lidén 1995, p.16-17).

The second way that stable carbon isotope values also are used in palaeodietary reconstruction is to determine the amount of C4 plant protein such as maize (Bender 1968, Bender et al 1981) or millet (Murray and Schoeninger 1988) in diet. Most European palaeodietary reconstruction studies disregard C_4 plants in Stone Age diet since C_4 plants do not naturally occur in Europe. Palaeobotanical data from Lithuania and Latvia, how-

Table 2. Archaeological site summary

Site	Site type	Location	Climatic Period	Archaeological Period	Archaeological Culture	Available C14 bp dates
Spiginas	Burials	On island in lake	Atlantic–Subboreal	Late Mesolithic – Late Neolithic	Maglemose/ Kunda, Narva? Corded Ware	7780-4080
Donkalnis	Burials	On island in lake	Atlantic	Late Mesolithic – Early Neolithic	Maglemose/ Kunda, Narva?	7405-5785
Šventoji	Series: habitation	Coastal, lagoon	Late Atlantic–Subboreal	Middle Neolithic – Early Bronze Age	Narva, Globular Amphorae, Baltic Haff	5110-3490
Kretuonas/ Žemaitiškė	Series: habitation, burials	Inland, lake	Late Atlantic–Subboreal	Early Neolithic – Early Bronze Age	Narva, Comb and Pit Pottery, Funnelbeaker	5580-3340
Turlojiškė/ Kirsna	Series: habitation, burials	Inland, river	Subboreal	Late Neolithic – Late Bronze Age	Corded Ware, Stroked Pottery?	Br 2895-2590
Plinkaigalis	Burials	Inland, river	Middle Subboreal	Late Neolithic	Corded Ware	4280-4030
Gyvakarai	Burial	Inland, river	Late Subboreal	Late Neolithic	Corded Ware	3730
Zvejnieki	Burial ground, habitation	Inland, lake	Atlantic–Subatlantic	Mostly Mesolithic and Neolithic	Maglemose, Kunda, Narva?, Comb and Pit Pottery, Corded Ware,	8240-2370
Selgas	Burial	Inland, river	Middle Subboreal	Late Neolithic	Corded Ware	4165
Sarkaņi	Burial	Inland, lake	Middle Subboreal	Late Neolithic	Corded Ware	4285
Västerbjers	Habitation, burials	Coastal, island	Middle Subboreal	Middle Neolithic	Comb and Pit Pottery0	Mostly 4300-4100
Kudruküla	Habitation, burials	Near coast, river	Subboreal	Middle - Late Neolithic	Comb and Pit Pottery, Late Comb and Pit	4840-4770
Naakamäe	Habitation, burials	Coastal, island	Subboreal	Late Neolithic	Comb and Pit Pottery, Late Comb and Pit	4125
Loona	Habitation, burials	Coastal, island	Subboreal	Late Neolithic	Late Comb and Pit + Bronze Age	4270-4050, 2620

Table 2 References.

Antanaitis 1999, Antanaitis et al 2000; Antanaitis-Jacobs et al 2001; Butrimas et al 1985, 1994; Daugnora and Girininkas 1996; Erikkson 2003, 2004, Eriksson et al 2003; Girininkas 1990, 1994, 2002; Grasis 1996; Jaanits et al 1982; Juodagalvis and Simpson 2000; Kazakevičius 1993; Kriiska 1996; Kunskas et al 1985; Lõugas 1997, Lõugas et al 1996; Lõugas V. 1970; Merkevičius 1998, 2000; Rimantienė 1992, 1996, 2005; Tebelškis 2001; Tebelškis and Jankauskas 2006; Zagorska 1997, 2000; Zagorskis 1987; Žilinskas 1931, Žilinskas and Jurgutis 1939.

ever, confirm the presence of millet by the end of the Stone Age.

Stable nitrogen values, indicated as $\delta^{15}N$, are also used in two ways when reconstructing diet: 1) in determining how much plant food was consumed in diets and 2) in determining the trophic level of an organism in an ecosystem. Whether terrestrial or marine, nitrogen values are enriched up a food chain by 2-4‰ (Schoeninger and DeNiro 1984). Organisms belonging to the lowest level in a food chain are photosynthesizing plants and will have a $\delta^{15}N$ value of approximately 3‰ (air is used as the standard and is 0‰), organisms feeding entirely on plants will have a $\delta^{15}N$ value of approximately 6‰ or 3‰ higher than the previous level, and so on. Marine and freshwater food chains are longer than terrestrial, so the end value of marine food chains are higher than the corresponding terrestrial value; the top predator in a marine environment such as a seal may have a $\delta^{15}N$ value of 18‰, a Greenland Eskimo who eats the seal may have a $\delta^{15}N$ value of 20‰, while a top predator in a terrestrial environment like a bobcat will have an end value of approximately 10‰ (Lidén 1995, p.18; Schoeninger et al 1983; Schoeninger and Deniro 1984).

Methodology

Collagen was extracted from the bone samples following a modified Longin method (Richards and Hedges 1999) with the addition of an ultrafiltration step (Brown et al 1988). Sample preparation and isotope

Table 3. Burial summaries of study's human samples

Burial	C14 bp (Lab No.)	Archaeological culture	Gender	Age	Grave goods, Pathologies, Other
Spiginas 1	5020+200 (GIN-5569)	Kunda? Narva?	M	35-45	Traces of ocre, 2 rhomboid projectile points
Spiginas 2	4080+120 (GIN-5570)	Corded Ware	M	50-55	No grave goods, no pathologies, crouched burial
Spiginas 3	7780+65 (OxA-5925)	Kunda	F	?	No grave goods, unique body build; oldest known burial in Lithuania
Spiginas 4	7470+60 (GIN-5571)	Kunda	F	30-35	Lots of ocre, projectile point, 7 pendants of elk/red deer and boar teeth; Cervical and lumbar vertebra show osteochondrosis
Donkalnis 1	Mesolithic? Neolithic?		F	20-25	Patches of ocre; Harris lines (stress indicators) on distal ends of both radii and on first metatarsals
Donkalnis 2	7405+45 (CAMS-85221)	Kunda	M	20-25	Ocre, 57 animal tooth pendants; Harris line on right radius' distal end
Donkalnis 3	5785+40 (CAMS-85220)	Narva??	F	25-30	Ocre, 4 Harris lines on right tibia and on each radius; completely healed blunt injury to skull vault
Donkalnis 4	6995+65 (OxA-5924)	Kunda	M	50-55	Intensive ocre, 83 animal tooth pendants; scalping trauma (?), osteoarthritis of shoulder joints, possible posttraumatic arthritis of left wrist joint
Donkalnis 5	Mesolithic? Neolithic?	Kunda? Narva?	2 small children	~7 and younger	Ocre, lancet projectile point; scattered animal tooth pendants; bones of both youth scattered throughout the pit
Donkalnis 6	Mesolithic? Neolithic?	Kunda? Narva?	F	35-40	No grave goods; Healed parry fracture of left ulna; gave birth 4 or 5 times
Donkalnis 7	Mesolithic? Neolithic?	Kunda? Narva?	M	Over 45	Bear mandible and bear tooth pendant, triangular heart-shaped arrow point; Healed right clavicle fracture, distal end of right tibia shows signs of "squatting facet"
Donkalnis, derranged	Mesolithic?		?	?	[deranged as result of gravel pit excavation]
Kretuonas 1B, gr. 1	5350+130 (OxA-5935)	Narva?	F	20-25	~1/2 cm dark soil underneath upper body, broken bone dagger under right arm
Kretuonas 1B, gr. 3	5580+65 (OxA-5926)	Narva?	M	50-55	2 horse teeth
Plinkaigalis 241	4030+55 (OxA-5928)	Corded Ware	F	50-55	Buried with bent legs; Very worn teeth
Plinkaigalis 242	4280+75 (OxA-5936)	Corded Ware	F	Over 40	2 flint blades, 1 retouched flint knife, much charcoal in pit; Bent legs
Gyvakarai	3745+70 (Ki-9470) 3710+80 (Ki-9471)	Corded Ware	M	35-45	Boat-shaped polished stone axe, flint hafted axe, flint blade-knife, hammer-headed bone (antler?) pin
Turlojiškė 1 (1996), gr. 3 [Area 3, Plot 2]	3570+130 (Vs-1097)	Stroked Pottery??	M	25-30	2 wooden artefacts, copper pendant!, whetstone; skull trauma as probable cause of death; bog "sacrifice"?
Turlojiškė	2835+55 (OxA-5927)	Late Bronze Age	M	25-30	Previously regarded as Neolithic Nemunas Culture representative; brachychranic, protolaponoid elements
Turlojiškė 4 (1998) [Area 2, Plot 10]	Same cultural layer as millet dated 2590+75 (Ua-16681)	Late Bronze Age	M	20-25	Heavily patinated flint arrowpoint; skull trauma is probable cause of death; bog "sacrifice"?
Kirsna	2895+55 (OxA-5931)	Late Bronze Age	M	25-30	Individual's skull discovered in peatbog in association with bone artefacts, bone axes, daggers, harpoons, flint knives

References:

Antanaitis 1999; Butrimas et al 1985, 1992; Girininkas et al 1985; Kazakevičius 1993; Kunskas et al 1985; Merkevičius 1998, 2000; Tebelškis 2001, Tebelškis and Jankauskas 2006.

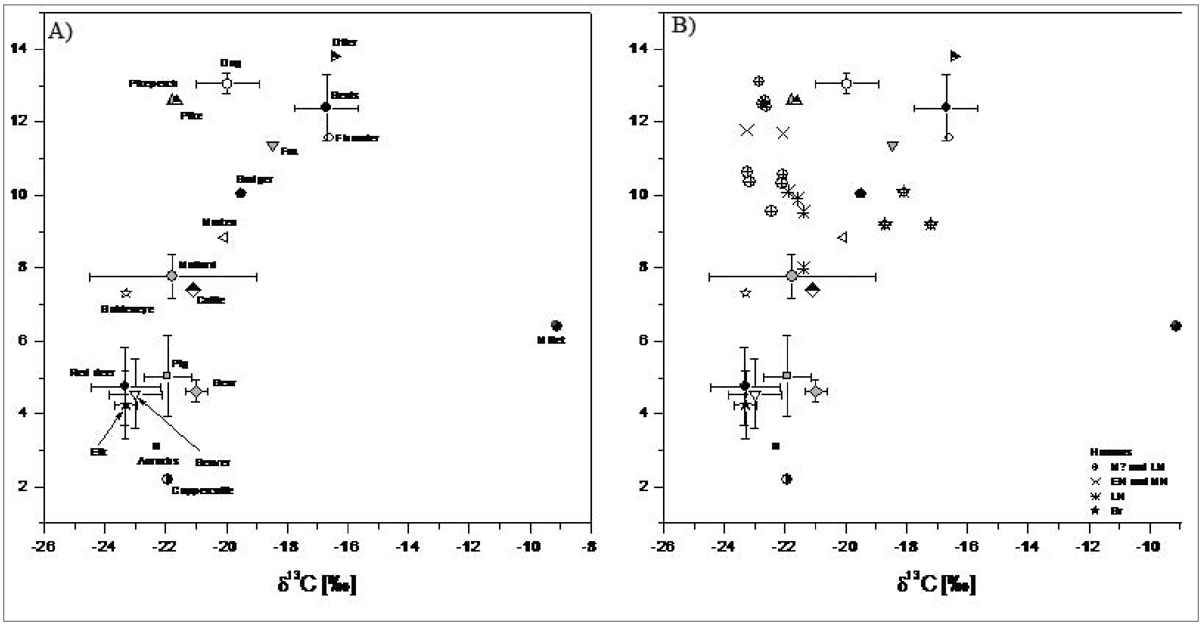

Figure 2. δ^{13}C and δ15N bone collagen values of A) averages and standard deviations for animals and millet and of B) averages and standard deviations for animals, millet, and all data for humans.

measurements were made at the Department of Human Evolution, Max Planck Institute for Evolutionary Anthropology, Leipzig, Germany. Results presented here had collagen carbon to nitrogen ratios between 2.9 and 3.6 (DeNiro 1985).

Results

The results of the Lithuanian Stone-Bronze Age stable isotope analyses are presented in Table 4 and Figure 2. Of 75 faunal samples, 43 yielded valid stable isotope data; of 23 human samples, 18 yielded valid data. The stable carbon values of two Kretuonas 1B human samples (Ramsey et al 2000) and stable carbon and nitrogen data of one millet sample obtained elsewhere (Antanaitis and Ogrinc 2000) are included in this study.

4. Data Interpretation

Stable isotope ecology: the faunal and floral data

The faunal remains represent marine, terrestrial, and freshwater environments with both herbivores and carnivores for all three ecological systems. As seen in Figure 2A, isotopic analyses of the animals are relatively well clustered by species and trophic level.

Carbon isotope values from the six herbivores (red deer, elk, beaver, aucrochs, bear, and capercaille) range from -24,1 to -20.7‰. They are typical of animals feeding on C3 plants. The δ^{13}C values of the omnivore (Sus Scrofa – pig) also fall within this range. Among the carnivores (dog, fox, badger, and marten), the δ^{13}C values are higher, ranging between -20.7 and -18.5‰. The pike and pikeperch, highly carnivorous fish, have the average δ^{13}C value of -21.8 ± 0.1‰. As expected, the δ^{13}C values of marine animals are higher, ranging between -18.7 and -15.5‰.

The herbivores' δ^{15}N values in bone collagen are the lowest, ranging from 2.2 to 5.5‰ with an average δ^{15}N of 4.6 ± 0.8‰. δ^{15}N values ranged in carnivores from 8.8 to 13.3‰ and averaged δ^{15}N = 11.3 ± 1.9‰. The δ^{15}N of the pig ranged from 3.8 to 6.5‰ and lies within the range of the herbivores. On average, the increase from herbivores to carnivores is +3.0‰ for the δ^{13}C values and +6.7‰ for the δ^{15}N. These differences are not what we could expect within a single food web, but indicate that some animals also consumed freshwater or marine food. The highest deviation in δ^{15}N values was observed in marine animals from 10.6 to 13.9‰, indicating the different feeding behavior of the species.

The Lithuanian territory's average δ^{13}C value for elk of 22.8 + 0.7‰ and corresponding δ^{15}N average value of 4.4 + 1.9‰ illustrate well the diet of herbivores. The δ^{13}C value of 6 bone samples of elk in Zvejnieki cemetery range from 22.0 to 22.8 with a corresponding δ^{15}N value range of 3.1 to 6.4 (Eriksson 2006, p. 190). An Early Subboreal Middle Neolithic elk value from the Estonian Kudruküla site had a δ^{13}C value of -22.6‰ (Lougas et al 1996, p. 405). It was found that Subboreal or Late Neolitic animals at Žemaitiškė have on average lower δ^{13}C values compared to other animals, suggesting a more forested environment. This interpretation coincides with palaeobotanical data at the adja-

Table 4. Lithuanian Stone And Bronze Age Stable Isotope Data

Lab Code	Site / Grave no.	Envir. chrono	Archy chrono	Species	Common name	d13C	d15N	C:N
J176A	Donkalnis 1	A?	M?	*Homo sapiens*	human	-23.2	10.6	3.2
J235G	Donkalnis 5	A?	M?	*Homo sapiens*	human	-22.1	10.6	3.4
J235F	Donkalnis 6	A? S?	M? N?	*Homo sapiens*	human	-22.1	10.3	3.2
J237B	Donkalnis 7	S?	N?	*Homo sapiens*	human	-22.4	9.6	3.3
J245D	Donkalnis, derranged	A?	M?	*Homo sapiens*	human	-23.2	10.4	3.3
102	Spiginas 3	EA	LM	*Homo sapiens*	human	-22.9	13.1	3.6
98	Spiginas 4	EA	LM	*Homo sapiens*	human	-22.7	12.6	3.5
J236A	Donkalnis 2	EA	LM	*Homo sapiens*	human	-22.6	12.4	3.3
103	Donkalnis 4	EA	LM	*Homo sapiens*	human	-22.8	12.5	3.6
J236B	Donkalnis 3	LA	EN	*Homo sapiens*	human	-22.1	11.7	3.3
J709B	Spiginas 1	LA/ES	MN	*Homo sapiens*	human	-23.3	11.8	3.6
J990A	Spiginas 2	MS	LN	*Homo sapiens*	human	-21.4	9.5	3.3
6927	Plinkaigalis 242	MS	LN	*Homo sapiens*	human	-21.6	9.9	3.3
101	Plinkaigalis 241	MS	LN	*Homo sapiens*	human	-21.4	8.0	3.3
69924	Gyvakarai	LS	LN	*Homo sapiens*	human	-21.9	10.1	3.3
6925	Turlojiškė 1 (1996), gr. 2	LS	EBr	*Homo sapiens*	human	-18.7	9.2	3.3
6928	Kirsna	LS	LBr	*Homo sapiens*	human	-18.1	10.1	3.2
6926	Turlojiškė 4 (1998)	LS	LBr	*Homo sapiens*	human	-17.2	9.2	3.3
43	Šventoji 2B	ES	MN	Alces alces	elk	-23.6	4.9	3.3
57	Šventoji 1B	S	MN or LN	*Alces alces*	elk	-23.1	3.6	3.4
36	Žemaitiškė 1	S	LN	*Cervus elaphus*	red deer	-24.1	4.0	3.5
6919	Turlojiškė	S	Br	*Cervus elaphus*	red deer	-22.5	5.5	3.4
86	Žemaitiškė 3B	LA	EN	**Ursus arctos**	brown bear	-20.7	5.0	3.3
48	Šventoji 3	ES	MLN	*Ursus arctos*	brown bear	-21.4	4.5	3.3
53	ventoji 6	S	LN	**Ursus arctos**	brown bear	-20.9	4.4	3.3
96	Kretuonas 1B	LA	MN	*Sus suis* or *Sus scrofa*	pig or boar	-23.6	6.4	3.5
58	Šventoji 1B	S	MN or LN	*Sus scrofa* (or *Sus suis*?)	boar (or pig?)	-21.8	4.1	3.4
45	Šventoji 3	ES	MLN	*Sus scrofa* or *Sus suis*	boar or pig	-21.3	3.8	3.3
46	Šventoji 3	ES	MLN	**Sus scrofa**	oar	-21.7	5.5	3.4
52	Šventoji 6	S	LN	*Sus scrofa*	boar	-21.6	5.3	3.4
38	Žemaitiškė 1	S	LN	*Sus scrofa*	boar	-23.3	6.5	3.5
89	Kretuonas 1D	S	LN	*Bos primigenius*	aurochs	-22.3	3.1	3.3
73	Šventoji 4B	LA or S	MN	*Anas platyrchynchos*	mallard	-24.8	7.2	3.3
75	Šventoji 23	S	LN	*Anas platyrchynchos*	mallard	-21.1	7.8	3.5
6918	Turlojiškė	S	LN	*Anas platyrchynchos*	mallard	-19.4	8.4	3.4
68	Žemaitiškė 2	S	LN	*Bucephala clangula*	common goldeneye	-23.3	7.3	3.4
74	Šventoji 23	S	LN	*Tetrao urugalus*	capercaille	-21.9	2.2	3.6
41	Šventoji 2B	ES	MN	*Esox lucius*	pike	-21.6	12.6	3.3
78	Šventoji 4	ES	MN	*Lucioperca lucioperca*	pikeperch	-21.8	12.6	3.5
81	Šventoji 4	ES	MN	*Pleuronectes platessa*	flounder	-16.6	11.6	3.3
49	Šventoji 3	ES	MLN	*Castor fiber*	beaver	-22.1	5.4	3.4
31	Žemaitiškė 2	S	LN	*Castor fiber*	beaver	-23.9	4.8	3.3
32	Žemaitiškė 2	S	LN	*Castor fiber*	beaver	-23.0	3.5	3.5
55	Šventoji 23	S	LN	*Lutra lutra*	otter	-16.5	13.8	3.4
40	Šventoji 2B	ES	MN	**Phocidae**	Seals	-17.7	10.6	3.4
44	Šventoji 2B	ES	MN	*Phocidae*	seals	-16.3	12.2	3.4
60	Šventoji 2B	S	MN	**Phoca vitulina**	harbour seal	-16.1	12.0	3.4
70	Šventoji 1	S	MN or LN	*Phoca vitulina*	harbour seal	-15.5	13.1	3.3
63	Šventoji 4	LA or S	MN or LN	*Pusa hispida*	ringed seal	-18.7	13.9	3.4
65	Šventoji 4	LA or S	MN or LN	**Pusa hispida**	ringed seal	-15.8	12.4	3.3
64	Šventoji 1	S	MN or LN	*Pusa hispida*	ringed seal	-16.5	11.1	3.4
71	ventoji 6	S	LN	*Phoca hispida*	ringed seal	-17.1	12.6	3.4

Lab Code	Site / Grave no.	Envir. chrono	Archy chrono	Species	Common name	d13C	d15N	C:N
61	Šventoji 6	S	LN	*Phoca grenlandica*	harp seal	-16.6	13.3	3.4
69	Šventoji 23	S	LN	*Halychoerus grypus*	grey seal	-16.5	12.7	3.5
51	Šventoji 6	S	LN	*Canis familiaris*	dog	-20.7	13.3	3.4
54	Šventoji 23	S	LN	*Canis familiaris*	dog	-19.2	12.8	3.6
47	Šventoji 3	ES	MLN	*Vulpes vulpes*	fox	-18.5	11.4	3.4
29	Žemaitiškė 2	S	LN	*Martes martes*	marten	-20.1	8.8	3.5
30	Žemaitiškė 2	S	LN	*Meles meles*	badger	-19.5	10.1	3.6
6917	Turlojiškė	LS	LBrA	*Bos taurus*	cattle	-21.1	7.4	3.2

Abbreviations

PB = Preboreal (c.10-9 000 BP)
A= Atlantic (c. 8000-5000 BP)
EA= Early Atlantic (8000-6700)
LA = Late Atlantic (6700-5000)
S = Subboreal (5000-2500)

ES = Early Subboreal (5000-4000)
LS = Late Subboreal (4000-2500)
E=Early
M=Middle
L=Late

M=Mesolithic
N=Neolithic
Br=Bronze

cent Žemaitiškė 2 site, which indicate that in the Late Neolithic the lake was drying up and trees were spreading (Antanaitis-Jacobs et al 2002).

Their higher δ^{15}C and δ^{15}N values suggest that the carnivores (fox, badger, and marten) also ate meat of herbivores living in open environments. It is interesting to note that fox have higher δ^{13}C and δ^{15}N values compared to red fox and arctic fox from the interglacial Upper Pleistocene period of Scladine Cave (Belgium) (Bocherens et al 1999). This would suggest a more carnivorous behavior as well as consumption of some marine animals. Also, the bears in our study have δ^{15}N values lower than Pleistocene brown bear populations (Bocherens et al 1995, 1997) indicating that the diet of bears in this study included more plants than during the colder climatic phases.

The highest δ^{15}N values among carnivores were observed in dog with the average δ^{15}N of 13.1 ± 0.3‰. The high isotopic value is most probably related to freshwater food consumption. The data are from the Late Neolithic and Subboreal lagoon archaeological sites of the ventoji series. The Zvejnieki cemetery's dog stable isotope data showed no patterns with human data, but rather three separate clusters of different diets. One represented a freshwater diet, the second marine, the third scavenger (Eriksson 2006, p. 197).

The boars' average δ^{13}C value of 21.9 + 0.8‰ and average δ^{15}N value 5.0 + 1.1 ‰ in Lithuanian territory also illustrate the diet of terrestrial ecosystem herbivores. The pooled δ^{13}C values of nine boar bones from the lakeside Zvejnieki burial ground averaged -23.3 + 1.0‰ while their corresponding δ^{15}N values averaged 6.4 + 2.0‰ (Eriksson et al 2003, p. 12). The δ^{15}N values of this latter boar are slightly higher than those of wild animals. Some of these wild pigs might have been slightly omnivorous, perhaps eating some food scraps of humans, or grazing on different plants. It is possible that the boar were tame scavengers, ingesting some human food refuse or cultivated plants. Nine boar samples from the mid-Subboreal pre-agricultural site of Västerbjers on the Gotland island coastal site had a δ^{13}C average value of -21.1 + 0.7‰ and δ^{15}N value of 5.5 + 1.3‰, interpreted as mainly feeding on plant material, perhaps supplemented by insects and worms (Eriksson 2004, p.142), are comparable with our data.

The three mallards and goldeneye have similar δ^{13}C and δ^{15}N values with an average of -22.2 ± 2.4 and 7.7 ± 0.5‰, respectively, which indicate omnivore feeding patterns based mainly on plants. The δ^{13}C value of the single mallard at Zvejnieki in Latvia was -17.6‰ and δ^{15}N was 6.0‰ (Eriksson 2006, p. 208).

The Lithuanian pike sample has a δ^{13}C value of 21.6‰ and δ^{15}N value of 12.6‰. The average δ^{13}C values of three pike from the inland lacustrine cemetery Zvejnieki were found to be -23.6 + 0.5‰ with a corresponding δ^{15}N average value of 12.5 + 0.7‰ (Eriksson et al 2003, p. 12). The δ^{13}C average value of five pike at Västerbjers was -12.0 + 1.5‰ while their δ^{15}N averaged 11.0 + 0.6‰ (Eriksson 2004, p.145). The difference in stable carbon isotope values of pike at the site compared to Lithuanian Žemaitiškė and Latvian Zvejnieki pike values could be due to the former's marine and latter's freshwater effect. The average of modern pike δ^{13}C values from Lake Baikal in Siberia and the Danube, Iron Gates region is -22.0‰ and their average δ^{15}N value is 12.0‰ (Richards et al 2001, p.15; Katzenberg and Weber 1999), similar to the data observed in our study. The highest δ^{15}N value of 12.6‰ was observed in another carnivorous fish, pikeperch. Unfortunately only one sample of each fish yielded valid results. In previous studies from the modern Lake Burtneiki and Canadian freshwater lake it was found that the trophic level within one species is correlated between size and δ^{15}N values and therefore high δ^{15}N variations could be expected in the same species as a result of changing diet with age (Olsson et al 2000; Hobson and Welch 1995).

This study's Šventoji sites' seal δ^{13}C values ranged from 18.7‰ to 15.5‰, while δ^{15}N values ranged between 10.6 and 13.9‰. The six pooled δ^{13}C values of seals from the Latvian Zvejnieki cemetery ranged from -18.2 to -15.4‰ and their δ^{15}N values ranged from 12.1 to 14.5‰ (Eriksson 2006:190). At the contemporary earlier Subboreal Estonian archaeological sites of Kudruküla, Naakamäe, and Loona, δ^{13}C values were from -17.1 to -14.9‰ (no δ^{15}N values) (Lõugas et al 1996). At the Swedish Gotland island Västerbjers site, the stable isotope ranges for seals were δ^{13}C -17.2 to -15.5‰ and δ^{15}N from 11.1 to 16.1‰ (Eriksson 2004, p.145).

Seals exhibit considerable isotope variability due not only to marine vs. freshwater habitats, but also and especially to their complex feeding strategy (seasonality, age, breeding are all factors, for example, as are some individuals feeding on more fresh and brackish water fish species in the Baltic, and other, more salt water species in the Atlantic), their migratory patterns, and their prey. Grey seals eat more fish than anything else, while harp and ringed seals also eat crustaceans (Eriksson 2004, p.145; Lawson et al 1995, Nilssen et al 1995, Tormosov and Rezvov 1978).

A single otter bone from Neolithic coastal lagoon site Šventoji 23 yielded a δ^{13}C value of -16.5‰ and a δ^{15}N value of 13.8‰. This carnivore would have fed on marine fish and shows a 2.2‰ enrichment in δ^{15}N over the marine fish such as flounder which is consistent with its higher trophic level. At lacustrine Zvejnieki, δ^{13}C values of -24.0‰ and -23.5‰ and δ^{15}N values of 12.4‰ and 13.0‰, respectively, were obtained from otter tooth pendants from Late Mesolithic child and adult grave no. 190 (Eriksson et al 2003, Eriksson 2006, p. 190).

The Late Bronze Age cattle in our study has a δ^{13}C value of -21.1 ‰ and δ^{15}N value of 7.4‰. Other Late Subboreal cattle dated to 3160+55 BP (Ua-19400) and 3095+65 BP (Ua-19407) at Västerbjers had δ^{13}C values of -21.4‰ and -20.8‰, respectively, and δ^{15}N values of 4.1‰ and 5.1‰, respectively (Eriksson 2004, p.141,143). The δ^{13}C values of cattle at the Neolithic of the Iron Gates region of the Danube valley were between -21.8 and -20.3‰ and their δ^{15}N value range was 4.5-7.7‰ (Bonsall et al 1997). The average δ^{13}C and δ^{15}N values of -20.7 ± 0.7‰ and 6.0 ± 0.4‰, respectively, were found in cattle in Neolithic Slovenia (Ogrinc and Budja 2005). Cattle δ^{13}C values from the Anglo-Saxon period at Berinsfield were between -21.8 and -21.4‰ and δ^{15}N values were between 5.3 and 6.3‰ (Privat et al 2002). Our cattle's δ^{15}N values were a little higher, suggesting different feeding patterns, perhaps ingestion of some cultivated plants (millet?) or human food refuse.

In a previous study (Antanaitis and Ogrinc 2000), the Late Bronze Age Turlojiškė's common or broomcorn millet (Panicum miliaceum L.) was found to have a δ^{13}C value of -9.1‰ and δ^{15}N value of 6.4‰. The mean δ^{13}C value of Bender's 1968 study of both Panicum and Setaria millet was -14.3‰ (Murray and Schoeninger 1988). Isotopic composition depends on several physical and/or biochemical properties and geoclimatic conditions, and the isotopic composition of a plant from different regions could have different stable isotopic signatures. Climate can cause ~3‰ variation in the δ^{13}C of a single species of plant (Cormie and Schwarz 1996, Smith et al 1976, Winter et al 1982). Our millet grains were charred. Carbonization was found not to alter carbon isotopic values, but rather to stabilize plant remains, protecting them from isotopic alteration after burial (Araus et al 2001, Tieszen and Fagre 1993).

The Human data

Within the whole data set there are no clear differences in diets related to sex or age.

As seen in Figure 2B, there does appear to be a chronological trend in human diet, noticeable especially when comparing Late Mesolithic, Late Neolithic, and Bronze Age individuals.

One set of data cluster at Donkalnis's grave nos. 1, "deranged", 5, 6, and 7. These burials have not been radiocarbon dated. Originally these burials were presumed "Late Neolithic Baltic Haff Culture" (Kunskas et al 1985), then possibly Mesolithic (Ramsey et al 2000), currently Mesolithic or Neolithic (Česnys and Butrimas, in press). The average δ13C values of -22.6 ± 0.6‰ and δ^{15}N of 10.3 ± 0.4‰ suggest relatively uniform diets between males and females with animal proteins coming from freshwater fish and other animal protein. It is interesting to note that the stable isotope signature of the child(ren) (Donkalnis 5) is similar to the adults, suggesting similar feeding habits. The δ^{15}N values are lower than those from the Danube Iron Gates sites studied by Bonsall et al 1997. The values are more indicative of diets in which the majority of proteins come from terrestrial-based resources with an addition of a significant amount of river fish.

A similar situation is suggested by the average δ^{13}C value of -22.7 ± 0.1‰ of the clustered individuals we know by radiocarbon dates to belong to the Late Mesolithic (Spiginas graves 3 and 4; Donkalnis graves 2 and 4), but the elevated average δ^{15}N value of 12.6 ± 0.3‰ indicates a higher input from freshwater fish. The majority of Ukrainian data from the Dnieper Rapids region that correspond chronologically with Lithuanian Late Mesolithic individuals show δ^{13}C values between -22‰ and -24‰, values indicative of the addition of aquatic resources, most likely river fish, to the diets of the individuals (Lillie and Richards 2000, p. 967).

The Late Atlantic Early Neolithic (Donkalnis 3) and Middle Neolithic (Spiginas 1) data suggest that freshwater fish was still the main source of protein in the human diet. However, only one human sample represents the entire Early Neolithic and one human sample the entire Middle Neolithic here! Stable carbon values obtained elsewhere for Middle Neolithic Kretuonas 1B individuals (graves 1 and 3) in Lithuanian territory were -24.4‰ and -23.1‰ (Ramsey et al 2000). A Late Atlantic Middle Neolithic individual's δ^{13}C value from a burial at the site of Tamula in Estonian territory was -23.9‰ (Lougas et al 1996, p. 405). At Latvia's Zvejnieki burial ground, with the exception of one δ^{13}C outlier of -18.8‰, 26 analysed human samples had carbon isotope values ranging between -24.1 and -21.3‰, indicating freshwater/ terrestrial protein input, while the high stable nitrogen values suggested a substantial contribution of protein likely from freshwater sources. In Zvejnieki, one group of human values clustered tightly with otters' values: approximately -23.2 to -23.9‰ δ^{13}C and approximately 12 to 13‰ δ^{15}N values, suggesting that these individuals had a diet similar to otters who eat mostly fish, but also crustaceans, amphibians, small mammals, and birds (Eriksson et al 2003, p.12). Middle Neolithic Early Subboreal human stable carbon values at the Estonian Kudruküla I and II were -21‰ and -20,4‰ (Lõugas et al 1996, p. 405). In general, concerning Stone Age human values at Zvejnieki, Eriksson et al point out (2003, p. 14) a pattern of higher variability in diet beginning from the Middle Neolithic.

All Lithuanian Late Neolithic Battle Axe and Corded Ware culture sample data (Gyvakarai, Plinkaigalis 242, Spiginas 2, and Plinkaigalis 241) have very similar isotopic signatures with δ^{13}C values ranging between -21.9 and -21,4‰, and δ^{15}N values ranging between 7.99 and 10.1‰. The δ^{15}N values are still high, suggesting a diet of mainly animal protein, either meat or milk. It is unlikely that freshwater fish were consumed in any significant quantities. These stable isotope data correspond well with human values obtained from Late Neolithic Corded Ware Culture individuals at three sites in Latvian territory Zvejnieki, Selgas, and Sarkaņi. The Corded Ware Culture individuals from Latvian territory had an average δ^{13}C value of -21.7‰ and a δ^{15}N value of 10.1‰, with standard deviations of 0.3‰ in both cases (Eriksson et al 2003, p.17). The low standard deviations indicate a completely uniform diet for the Corded Ware Culture group of individuals (Eriksson et al 2003, p.17: Lovell et al 1986) and this very likely is in the sense that they were practicing animal husbandry.

The coastal Neolithic Pitted Ware Culture of the Baltic region, which corresponds to the Middle Neolithic Comb-and-Pit Pottery Culture in Lithuania, was partly coeval with the Late Neolithic Battle Axe Culture. Current stable isotope research has suggested that the archaeological Pitted Ware Culture was represented by a distinct group of people, with a distinct diet. The stable isotope signatures suggest a massive intake of marine high trophic foods, most likely from seals. These people likely were seal hunters with a common cultural identity (Eriksson 2004, Erikkson et al 2006, Lidén and Eriksson 2007).

During the Bronze Age (Turlojiškė 1 of 1996 (Early Bronze Age); Turlojiškė 4 of 1998 and Kirsna (both Late Bronze Age)), similar δ^{15}N values were observed as with the Lithuanian Late Neolithic individuals, but with even higher δ^{13}C values, averaging -18.4 ± 0.9‰. Higher δ^{13}C values could indicate marine protein in the diet, but the δ^{15}N values are too low. The data rather suggest a diet based on domestic animals and the C4 plant millet. This possibility is further supported by stable isotope data determined in the cattle (Table 4) found at the same period and environment.

5. Discussion, conclusions, future research

Individuals such as Donkalnis 2, Donkalnis 4, and Spiginas 1 whose grave goods of various animal tooth pendants would suggest that game constituted an important part of their dietary input turn out to be individuals who, by stable isotope evidence, actually had a significant amount of fish in their diets. Whereas zooarchaeological data might suggest big game hunting as a prominent subsistence base, stable isotope data suggest that people in Lithuanian territory in the Mesolithic and earlier Neolithic had a diet that largely consisted of freshwater fish. This pattern corresponds in general with Mesolithic and earlier Neolithic human stable isotope data in Latvian territory, at the Zvejnieki cemetery (Eriksson et al 2003, p.14). Also, stable isotope data of later Mesolithic humans of the Dnieper Rapids region suggest a slightly higher input from freshwater fish when compared to the Epipalaeolithic period (Lillie and Jacobs 2006, p.883).

Available Late Neolithic zooarchaeological material generally is associated with archaeological cultures other than the Corded Ware Culture (especially with the Narva Culture). Stable isotope data suggest that "Late Neolithic" Corded Ware Culture bearers in the East Baltic actually were the first "Neolithic" inhabitants inasmuch as the term refers to food production. Stable isotope data from individuals who archaeologically belong to the Corded Ware Culture horizon have very uniform values that suggest little or no consumption of fish and a diet mostly of animal protein, very possibly of animals such as cattle. These Late Neolithic human stable isotope data correspond with extensive palynological data which suggest that farming was making a noticeable impact on the environment in the Late Neolithic (Stančikaitė 2000).

Available human palaeodental data from Zvejnieki suggest slight and gradual changes through early prehistory in diet with, perhaps, a similar ratio of animal protein and plant food. Both palynological and dental data suggest the importance of cultivated plants in diet. The combination of nitrogen stable isotope data with the carbon stable isotope data suggest that by the Bronze Age, at least in the southwestern (Turlojiškė) region of Lithuania, both domestic animals such as cattle and the C_4 plant millet were important food sources. While the archaeological materials both of cattle bone and of charred millet grains that date to the Late Bronze Age have previously been discovered in southwestern Lithuania (Antanaitis et al 2000; Antanaitis and Ogrinc 2000; Antanaitis-Jacobs et al 2001, 2002), this study suggests that an individual from the Early Bronze Age may have had a similar diet of cattle and millet.

From where did the millet come to Lithuanian territory? The Dnieper-Donets river basins in Ukraine currently are being investigated by archaeobotanical, genetic, and isotopic means as one possible gateway for the spread of millet into Eastern Europe (see "The East-West Millet Project" http://www.arch.cam.ac.uk/millet/).

Could Donkalnis 5 and 6, perhaps 7, actually be chronologically closer to the Late Neolithic, eating just a bit more freshwater fish than their later Late Neolithic inhabitant counterparts? Or were they earlier Mesolithic individuals who, like those at Ukraine's Epipalaeolithic Vasilyevka III cemetery, relied less on freshwater fish and more on terrestrial food resources (Lillie et al 2003; Lillie and Jacobs 2006)? Radiocarbon dating of these individuals would help to solve this question. Precise chronology has been an issue in Lithuanian Stone Age prehistory (Antanaitis 1999; Ramsey et al 2000; Česnys and Butrimas, in press). Recent zooarchaeological work in Latvia of the Zvejnieki cemetery material, specifically of bird bones associated with human burials indicates chronological misassociations; the bird bones chronologically, in fact, cannot be interpreted as grave goods (Mannermaa et al 2007). Estonian zooarchaeological and radiocarbon data suggest that the beginning of the Corded Ware Culture in the East Baltic was between 3000 and 2700 cal BC (Lougas et al 2007), 200 years earlier than previously supposed for Lithuania (Antanaitis and Girininkas 2002, p.11) and 300 years earlier than had been supposed for Latvia (Antanaitis 2001).

A uniform diet apparently was shared, however, by the Corded Ware Culture bearers in Lithuanian territory, as in Latvian territory (Eriksson et al 2003), something that is suggestive of a common cultural identity. Such has been the proposed scenario of the partly coeval Pitted Ware Culture bearers of the Baltic region (Eriksson et al 2006, Lidén and Eriksson 2007). Could subsistence have been a base for the development of separate sociocultural groups in the Late Neolithic, say those of Pitted Ware Culture seal hunters and Corded Ware Culture animal herders?

Corded Ware / Boat Axe Culture bearers often are associated with Indo-Europeans (Gimbutas 1997; Mallory 1989, p. 108). Also they are associated with a very specific phenotype: extreme hypermorphy, pronounced dolichocrany, a high, broad, and strongly profiled face, and a robust body build. This phenotype is characteristic of the Spiginas 2, Gyvakarai, as well as Plinkaigalis 241 and 242 individuals (Česnys 1985), i.e., all the Late Neolithic and Corded Ware Culture bearers in this study. The phenotype is similar to that found in Estonia (Mark 1956), Prussia (for summary, see Česnys 1991a, 1991b, 1991c), and the later Fatyanovo Culture bearers from the Central Russian plain. Such a type has no precedent in this area and its origins are still obscure (Jankauskas and Antanaitis 2000). That all the known Corded Ware Culture burials in Lithuanian territory are singular, contain adult individuals, are associated with a particular set of grave goods, and are characterised by a very specific phenotype would appear to support the hypothesis of immigration. Isotopic analysis of Linearbandkeramik people in Central Europe (5200-5000 BC) prove that quite a number of individuals even 2000 years earlier could migrate to different locations during their life (Price et al 2001). Unfortunately, no valid ancient DNA data have yet been obtained from Late Neolithic Corded Ware Culture bearers to support or negate the possibility of immigrants. Over 50 Corded Ware Culture burial sites are known in the East Baltic (see Žukauskaitė 2004, Fig.1). Precise radiocarbon, stable isotope, bioanthropological, and DNA data of these specific Corded Ware Culture bearers could answer such questions.

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MITYBA LIETUVOS ANKSTYVOJOJE PRIEŠISTORĖJE IR NAUJI STABILIŲJŲ IZOTOPŲ DUOMENYS

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Santrauka

Straipsnyje apžvelgiami turimi archeologiniai, zooarcheologiniai, paleobotaniniai, odontologiniai duomenys apie Lietuvos akmens ir bronzos amžiais naudotus maisto išteklius ir pristatomi bei detaliai analizuojami nauji stabiliųjų izotopų tyrimų rezultatai, teikiantys tiesioginę informaciją apie mitybą. Stabiliųjų anglies ir azoto izotopų tyrimams panaudoti 75 gyvulių ir 23 žmonių kaulų mėginiai, datuojami akmens ir bronzos amžiais. Straipsnyje aptariama, kaip izotopų vertės koreliuoja su mityba bei kitais mitybos rodikliais, gauti duomenys lyginami su kitų autorių tyrimų rezultatais iš Baltijos regiono, aptariamas socialinis ir kultūrinis kontekstas. 1 pav. pristatomas tiriamasis regionas, 1 lentelėje – chronologija, 2 lentelėje trumpai aprašomi straipsnyje paminėti archeologiniai paminklai, 3 lentelėje – pateikiama informacija apie žmonių kaulų mėginius.

Tiksliai bioarcheologinių duomenų interpretacijai įtakos gali turėti įvairiausi veiksniai. Tuo atžvilgiu žmonių palaikų stabiliųjų izotopų tyrimai mitybos atžvilgiu yra ypač vertingi, nes jie suteikia *tiesioginę* kiekybinę informaciją, ką žmonės valgė, ypač apie baltymų dalį dietoje.

Lietuvos akmens ir bronzos amžių stabiliųjų izotopų tyrimų rezultatai pateikti 4 lentelėje ir 2 pav. Kaip matyti 2 B pav., žmonių mityboje būta tam tikros chronologinės tendencijos, kas tampa ypač akivaizdu lyginant vėlyvojo mezolito, vėlyvojo neolito ir bronzos amžių žmonių tyrimų duomenis.

Donkalnio kapų Nr. 1, 5, 6, 7 ir suardytų kapų medžiagos sudaro vieną grupę. Šie kapai radiokarbono metodu nebuvo datuoti. Stabiliųjų izotopų duomenys liudija santykinai vienodą vyrų ir moterų dietą, kurioje gyvuliniai baltymai buvo gaunami iš gėlavandenių žuvų ir kitų gyvulinės kilmės produktų. Individai, kurie pagal radiokarbono datas priskiriami vėlyvajam mezolitui (Spigino kapai Nr. 3 ir 4; Donkalnio kapai Nr. 2 ir 4), taip pat sudaro vieną grupę, o jų aukštesnės δ^{15}N vertės (12,6±0,3‰) liudija didesnę gėlavandenių žuvų dalį mityboje.

Vėlyvojo Atlančio, ankstyvojo ir vidurinio neolito duomenys (Donkalnio kapas Nr. 3, Spigino kapas Nr. 1) yra negausūs, tačiau leidžia manyti, kad gėlavandenės žuvys tebebuvo pagrindinis baltymų šaltinis. To paties laikotarpio duomenys iš kaimyninio Zvejniekų kapinyno yra panašūs: anglies izotopo vertės rodo gėlavandenės ar sausumos kilmės baltymų, o aukštos stabiliojo azoto izotopo vertės – didelę dalį baltymų dietoje, greičiausiai gėlavandenės kilmės.

Visuose Lietuvos vėlyvojo neolito laivinių kovos kirvių ir virvelinės keramikos kultūros žmonių mėginiuose (Gyvakarai, Plinkaigalio kapai Nr. 241 ir 242, Spigino kapas Nr. 2) nustatytos labai panašios izotopų koncentracijos: $\delta^{13}C$ vertės svyruoja tarp -21,9 ir -21,4‰, o $\delta^{15}N$ vertės – tarp 7,99 ir 10,1‰. $\delta^{15}N$ reikšmės vis dar aukštos, o tai liudija dietą, susidedančią daugiausia iš gyvulinės kilmės baltymų – mėsos arba pieno. Dar daugiau – maži standartiniai nuokrypiai rodo visiškai vienodą virvelinės keramikos kultūros žmonių mitybą, o tai leidžia manyti, kad jie vertėsi gyvulininkyste. Stabiliųjų izotopų duomenys liudija ir tokią pačią Latvijos virvelininkų dietą, o tai leistų numanyti ir buvus bendrą kultūrinę tapatybę. Panašus scenarijus buvo pasiūlytas ir Baltijos regiono šukinės keramikos atstovams, kurių stabiliųjų izotopų duomenys liudija maitinimąsi ruonių mėsa. Gal gyvenimo būdas ir mityba buvo atskirų sociokultūrinių grupių vėlyvajame neolite – šukinės keramikos ruonių medžiotojų ir virvelinės keramikos gyvulių augintojų – atsiradimo pagrindas? Į tokius klausimus atsakyti padėtų tikslūs virvelininkų radiokarbono, stabiliųjų izotopų, bioantropologiniai ir DNR duomenys.

Aukštesnės bronzos amžiaus individų $\delta^{13}C$ vertės galėtų liudyti jūros kilmės baltymus jų mityboje, tačiau $\delta^{15}N$ vertės yra per žemos. Tiek ankstyvojo, tiek ir vėlyvojo bronzos amžiaus duomenys liudytų dietą, kurios pagrindą sudarė prijaukinti gyvuliai ir C_4 augalas soros.