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VARIABILITY IN 4TH MILLENNIUM BC LIVESTOCK MANAGEMENT PRACTICES IN THE BRONOCICE REGION, SOUTHEASTERN POLAND

ABSTRACT

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Livestock management systems are complex reflections of economic practices. During the mid-fourth millennium BC in southeastern Poland distinct economic activities were revealed using portable x-ray fluorescence (herein *pXRF*). Portable X-ray fluorescence was used to measure elemental levels of strontium in the teeth of cattle, sheep and pig. Strontium is fixed in dental enamel after a tooth has formed. By comparing strontium in teeth of different developmental ages it was possible to segregate individuals into local and non-local animals from three sites. The patterns observed reveal two levels of stock-herding in the Bronocice region. One pattern of low strontium diversity revealed the existence of unique localized management strategies for each species indicating they were managed separately. Another pattern of high strontium variability confirmed the importation of non-local animals on an increasing scale over time revealing another aspect of Bronocice's involvement in long distance trade.

Keywords: Neolithic, Funnel-Beaker, livestock management practices, Bronocice, X-ray fluorescence, strontium, southeastern Poland
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INTRODUCTION

Reconstructing livestock management practices is critical to understanding past economies based on agricultural production and stock-herding. The fourth millennium BC was a period of dynamic social change in the Bronocice region. Funnel Beaker settlements were rapidly consolidated into a two-tier social hierarchy with Bronocice at the center of the system (Kruk and Milisauskas 1999). This settlement expanded in size, population and economic complexity over a period of six hundred years. Bronocice derived its economic power from trade in livestock and various commodities including textiles and stone axes. During the Funnel Beaker occupation livestock management practices were intensified in large part due to increasing importation of animal.

This article focuses on management strategies involving cattle, sheep and pig through the examination of elemental strontium by *pXRF*. Portable X-ray fluorescence analysis of strontium levels in dental enamel was effective in distinguishing local from non-local animals. The period covered ranges from 3900 BC (Phase 1) to 3300 BC (Phase 4) at Bronocice (Table 1). These data are compared with those from the small nearby settlements of Zawarża, a single occupation site overlapping in date with Phase 3 at Bronocice, and Niedźwiedź, a multi-component site, of which the Funnel Beaker occupation overlaps with Phase 4 at Bronocice (Figure 1).

The results of the analysis revealed that cattle and sheep were managed in similar ways during all phases and sites. During the earliest phases at Bronocice and the two small sites cattle and sheep were composed mainly of locally raised animals, while during Phases 3 and 4 at Bronocice the majority of animals were non-local. Pigs on the other hand showed very different patterns during the earliest phases and at Zawarża. With the exception of Phase 2 at Bronocice and Phase 4 Niedźwiedź, pigs were generally composed of a majority of non-local animals. The apparent difference between pig and the other two species suggests that a different economic strategy was involved in their management. Two patterns were observed that revealed patterns of movement that can be explained as seasonal transhumance and importation of animals from outside the region.

METHODOLOGY

Portable X-ray fluorescence elemental analysis was used to measure strontium concentrations in the dental enamel from cattle pig, and sheep specimens recovered from all three sites. Strontium concentrations found in dental enamel of all mammal species varies by geographical location and since it is fixed for the life of an individual can be used as a spatial marker. During dental formation strontium is absorbed and replaces calcium in the apatite structure of teeth becoming fixed in the enamel and therefore a marker of geological place. By comparing strontium levels in dental samples it is possible to distinguish locally born from non-locally born individuals. The frequency compositions of local and

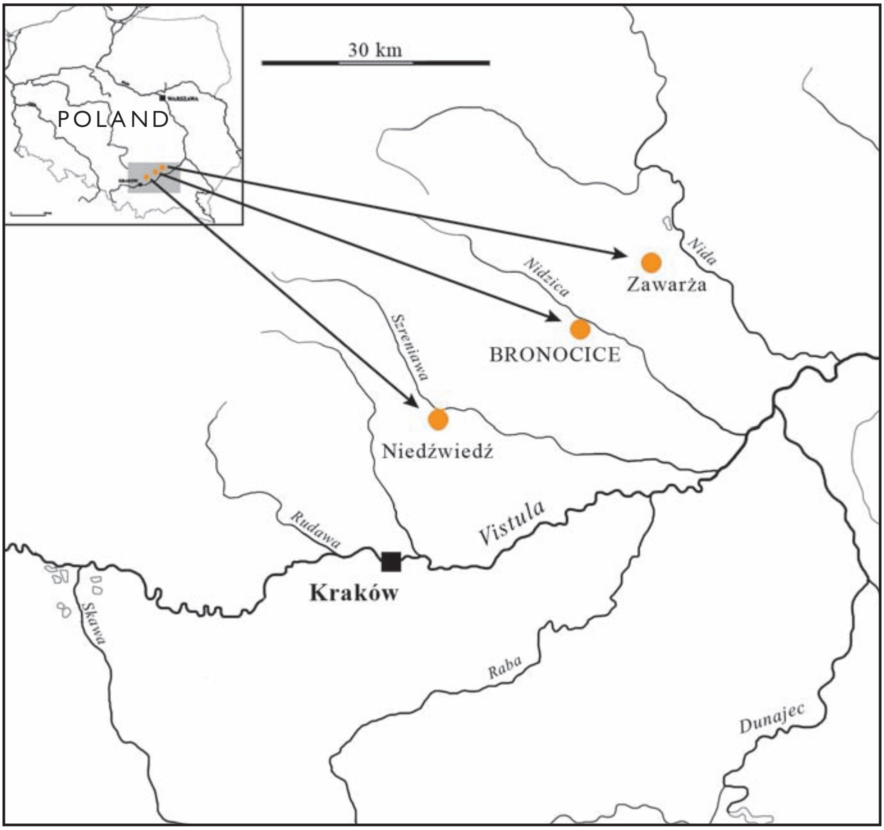

Fig. 1. Map of Poland showing location of the three sites. Methodology

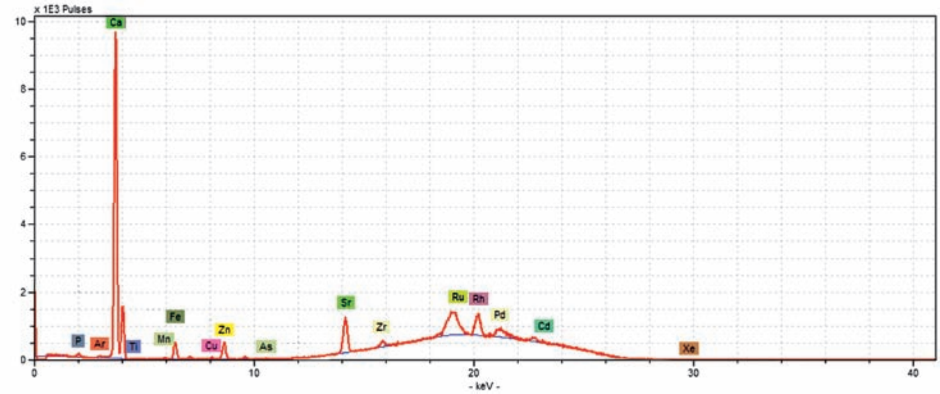

Fig. 2. Example of a full spectral reading. The Y axis indicates the peak intensity of elements while the X axis indicates which elements fluoresce at what voltage

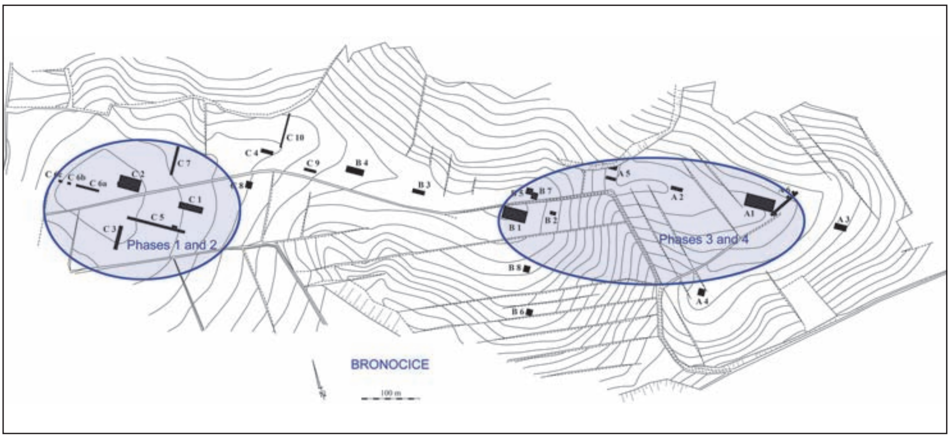

Fig. 3. Site plan of Bronocice

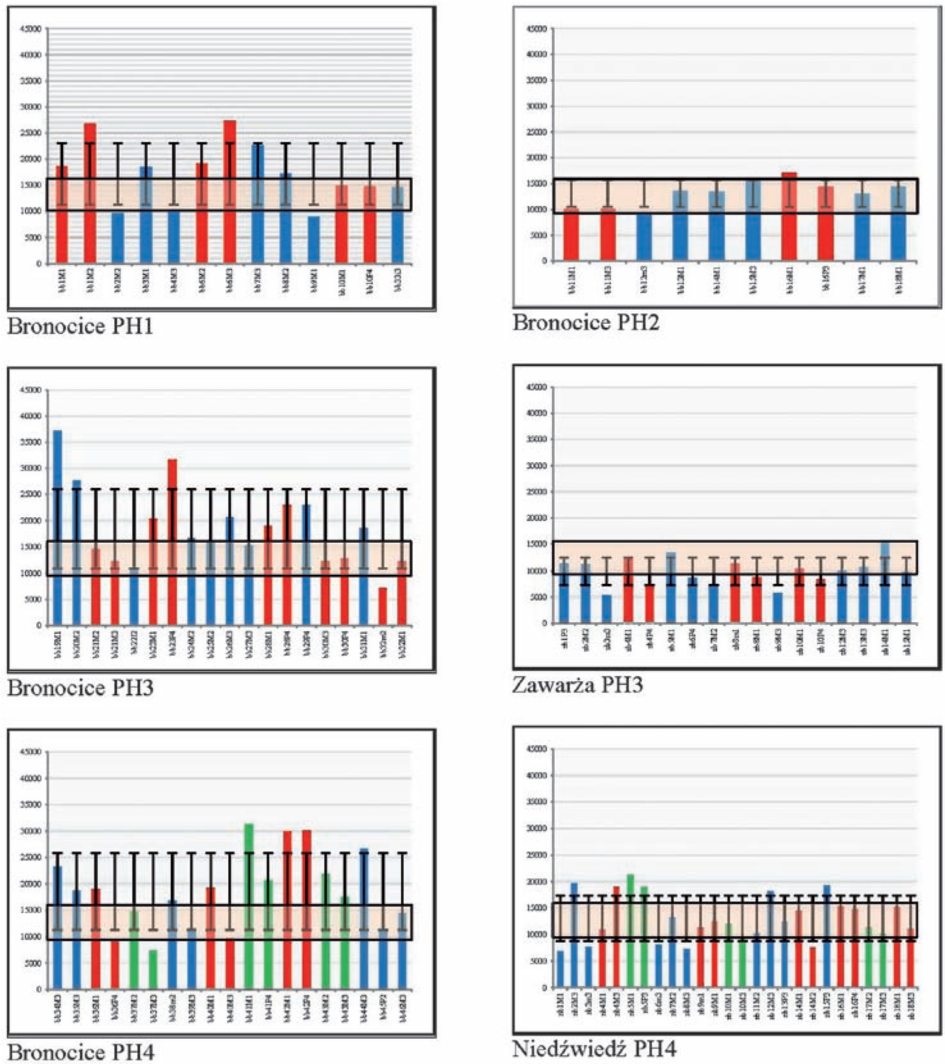

Fig. 4. Cattle peak frequencies. Each individual is indicated by number and by tooth. Blue indicates individuals represented by a single tooth, red and green indicate individuals represented by more than one tooth. Vertical bars indicate 1 standard deviation

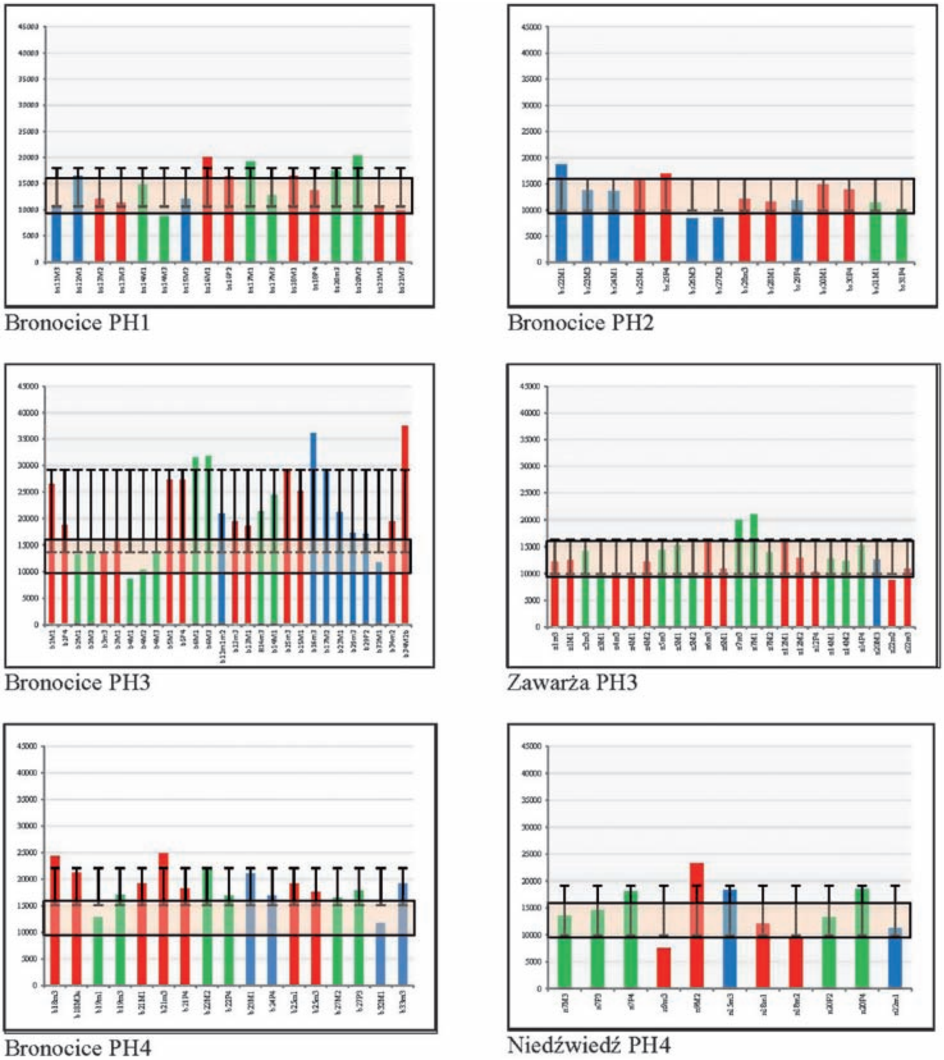

Fig. 5. Sheep peak frequencies. Each individual is indicated by number and by tooth. Blue indicates individuals represented by a single tooth, red and green indicate individuals represented by more than one tooth. Vertical bars indicate 1 standard deviation

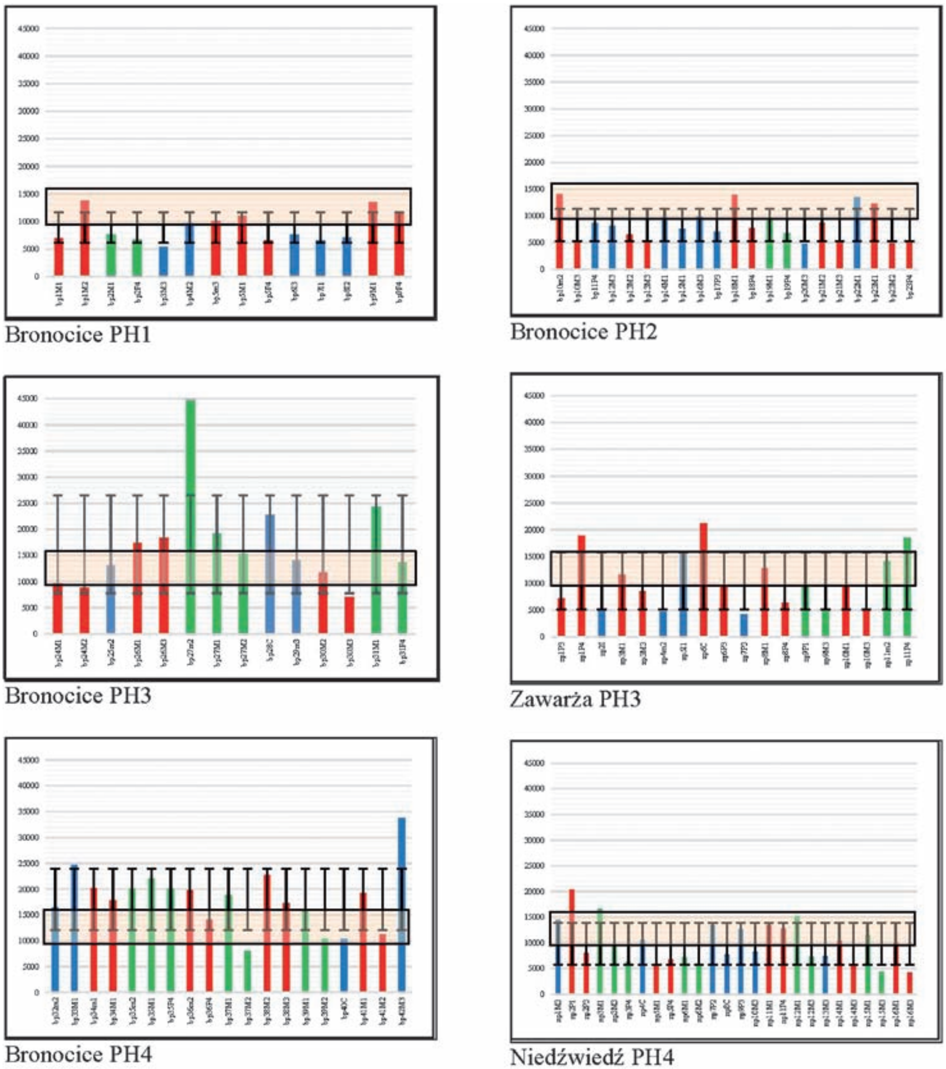

Fig. 6. Pig peak frequencies. Each individual is indicated by number and by tooth. Blue indicates individuals represented by a single tooth, red and green indicate individuals represented by more than one tooth. Vertical bars indicate 1 standard deviation

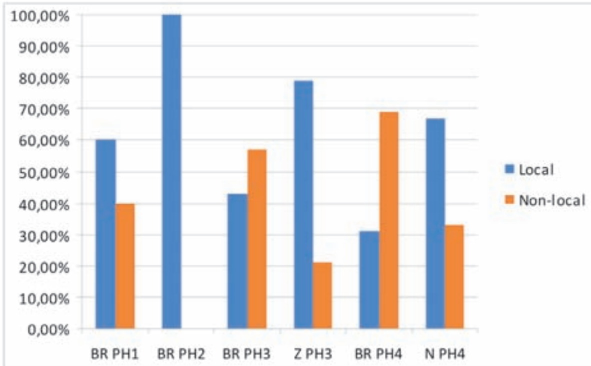

Fig. 7. Relative frequencies of local and non-local cattle by site and phase

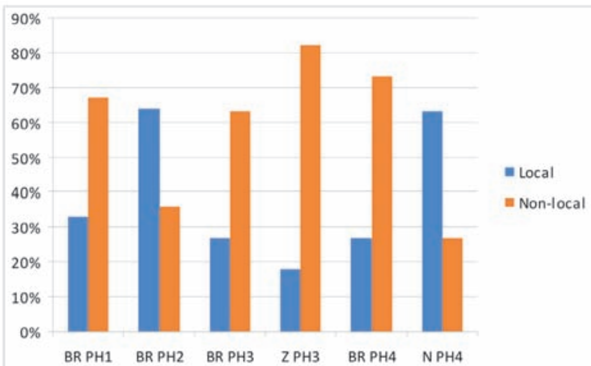

Fig. 8. Relative frequencies of local and non-local sheep by site and phase

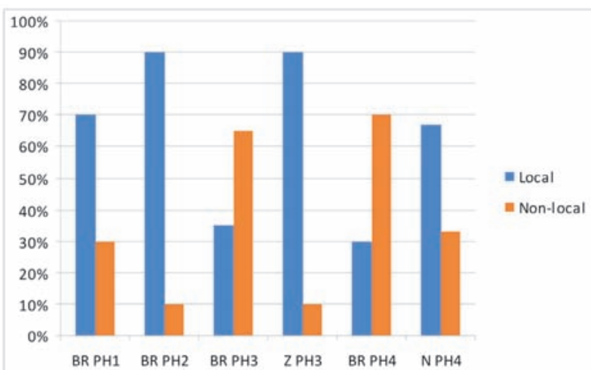

Fig. 9. Relative frequencies of local and non-local pig by site and phase

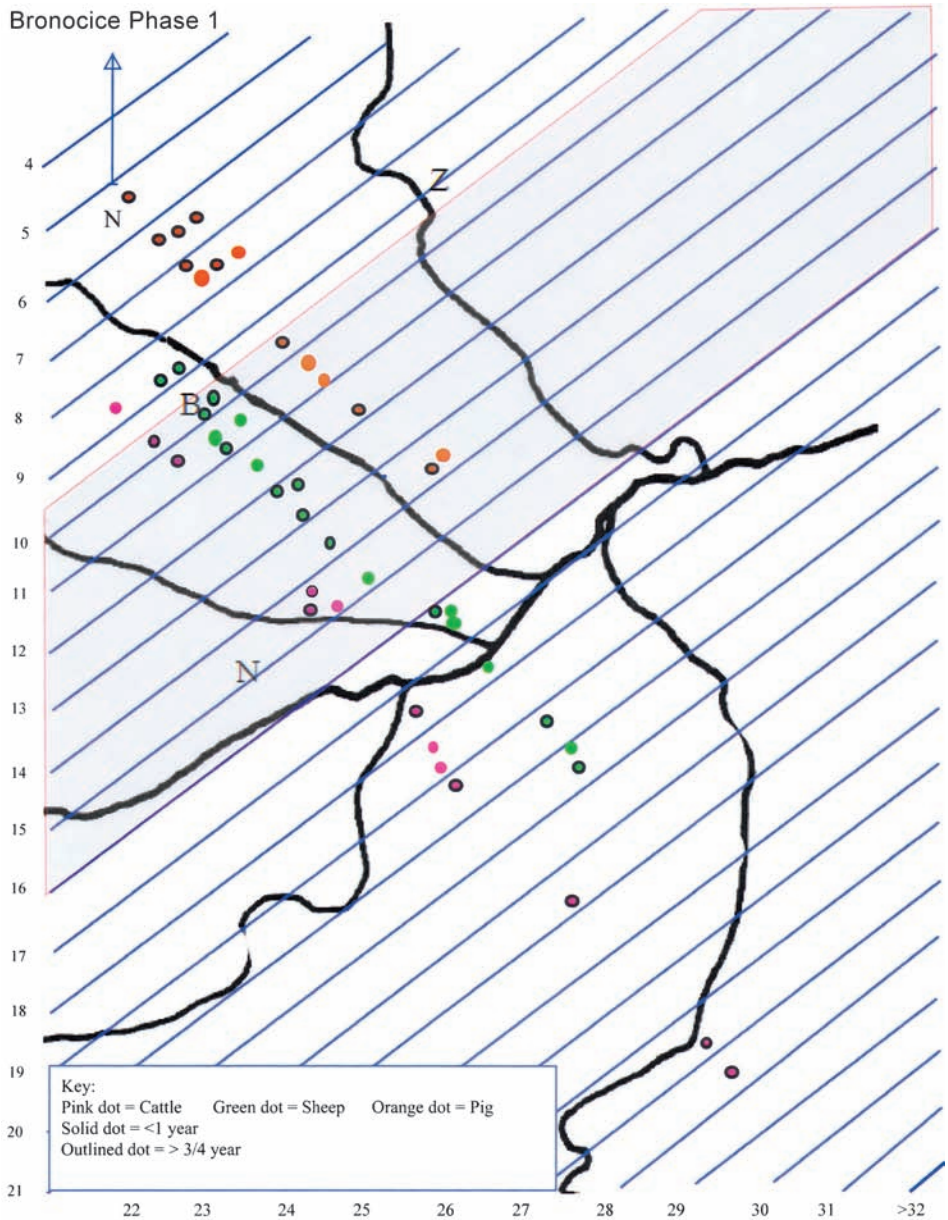

Fig. 10. Bronocice Phase 1 cattle, sheep and pig movements. Gray area is the local range

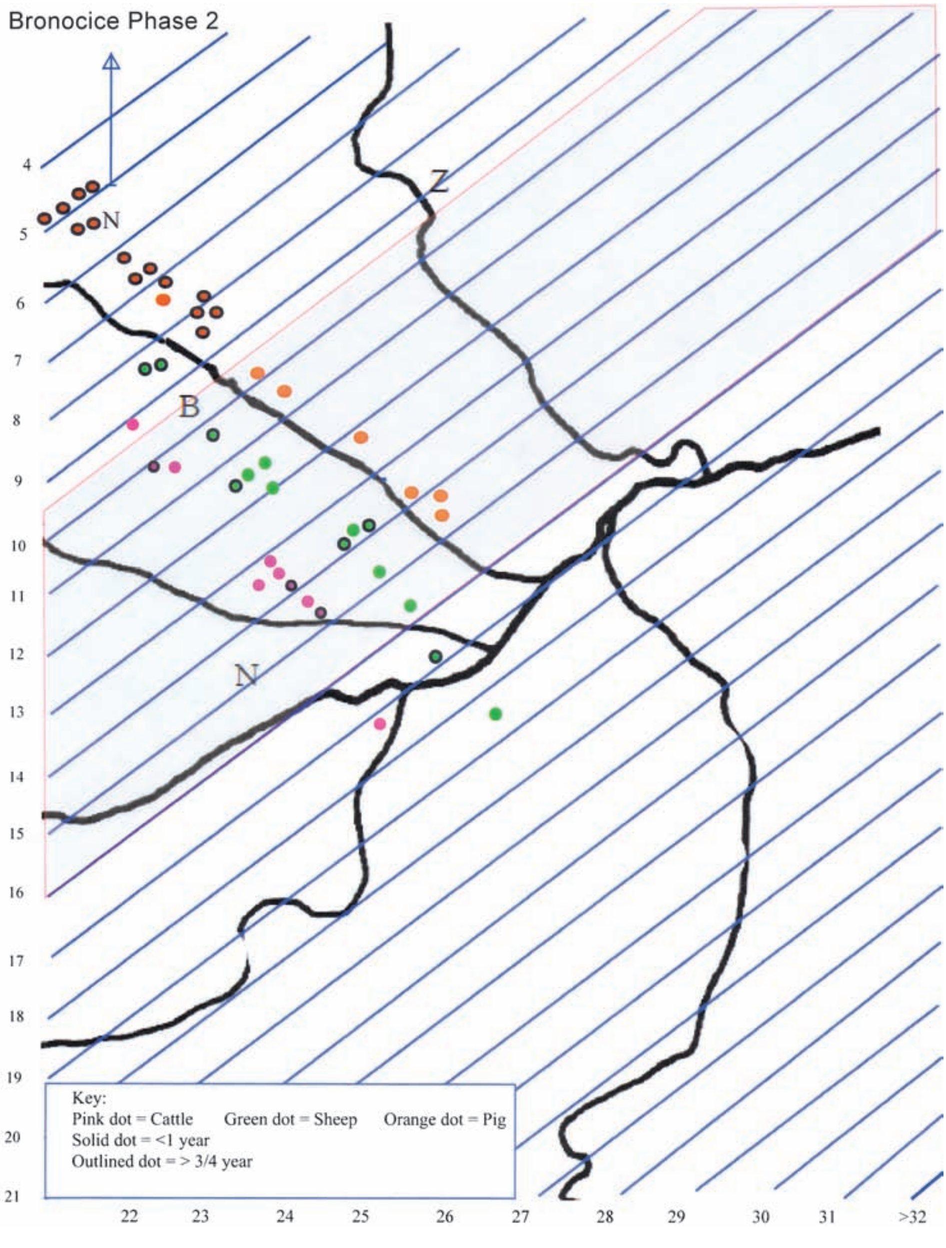

Fig. 11. Bronocice Phase 2 cattle, sheep and pig movements. Gray area is the local range

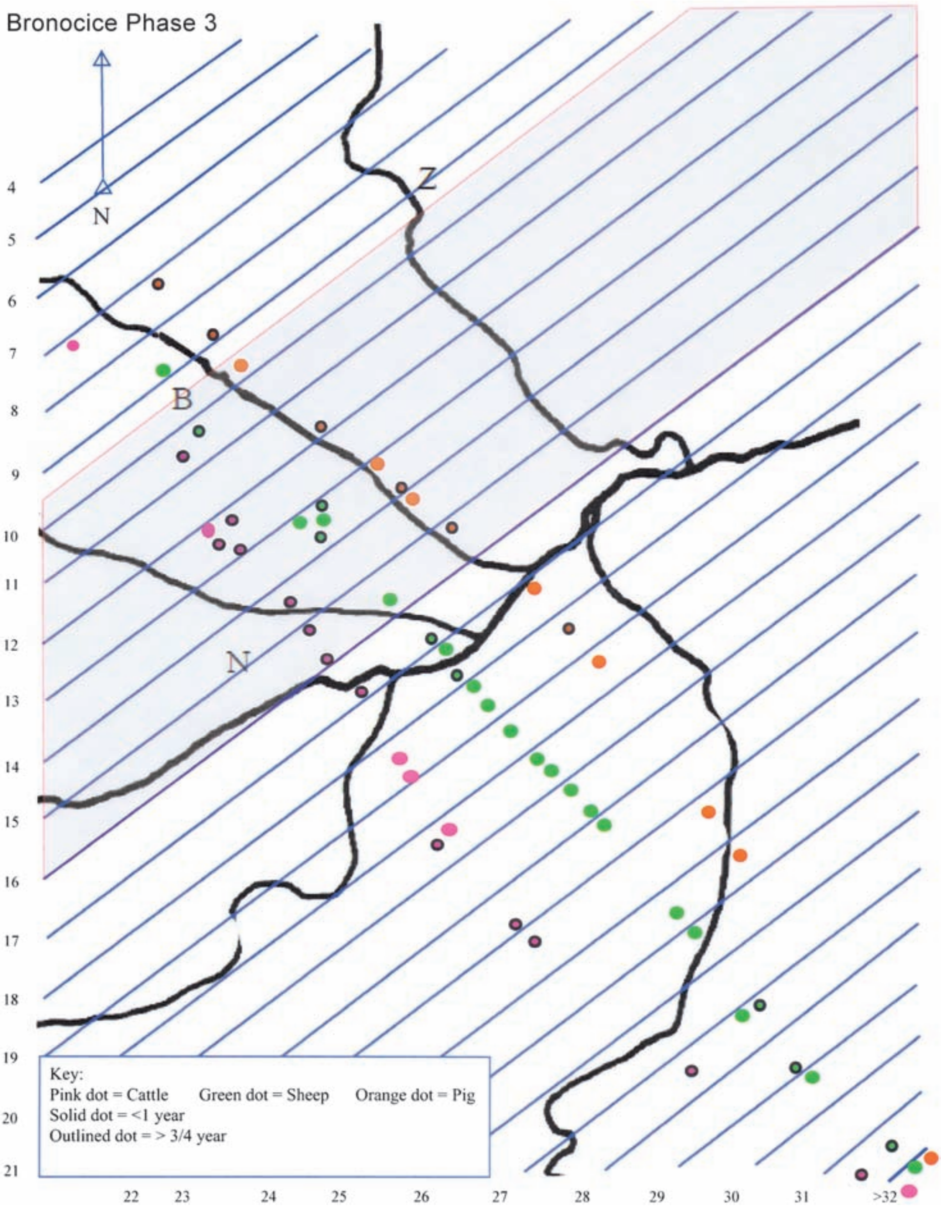

Fig. 12. Bronocice Phase 3 cattle, sheep and pig movements. Gray area is the local range

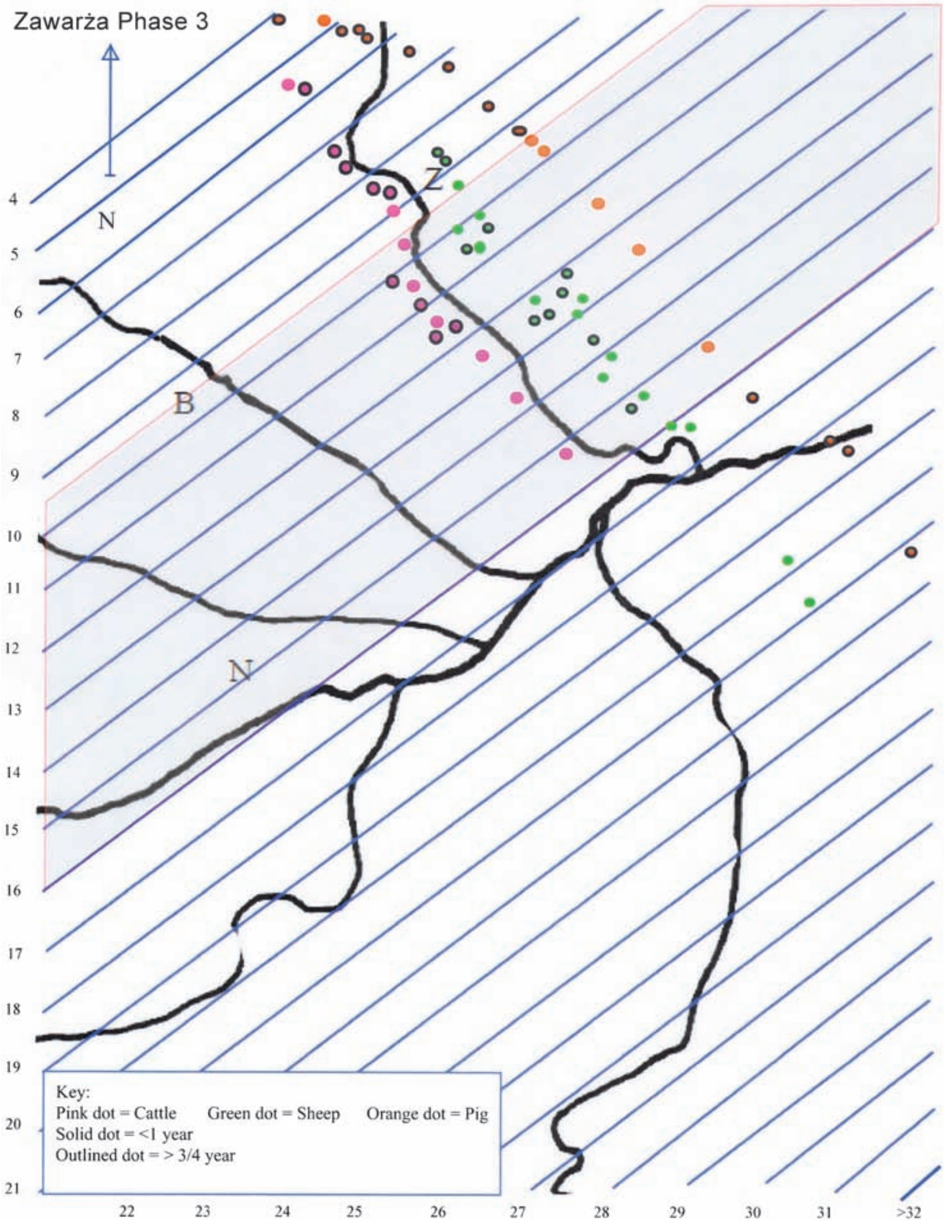

Fig. 13. Zawarża Phase 3 cattle, sheep and pig movements. Gray area is the local range

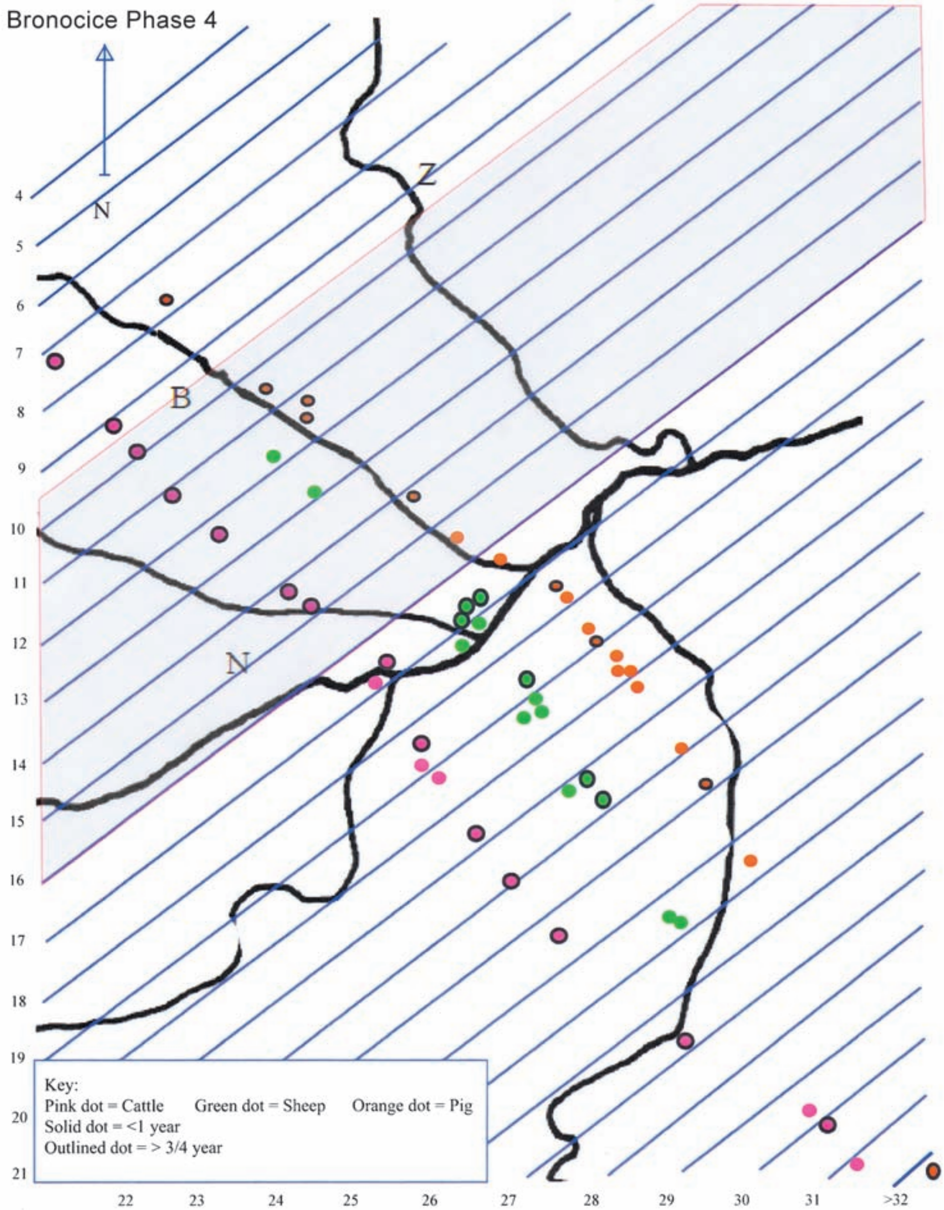

Fig. 14. Bronocice Phase 4 cattle, sheep and pig movements. Gray area is the local range

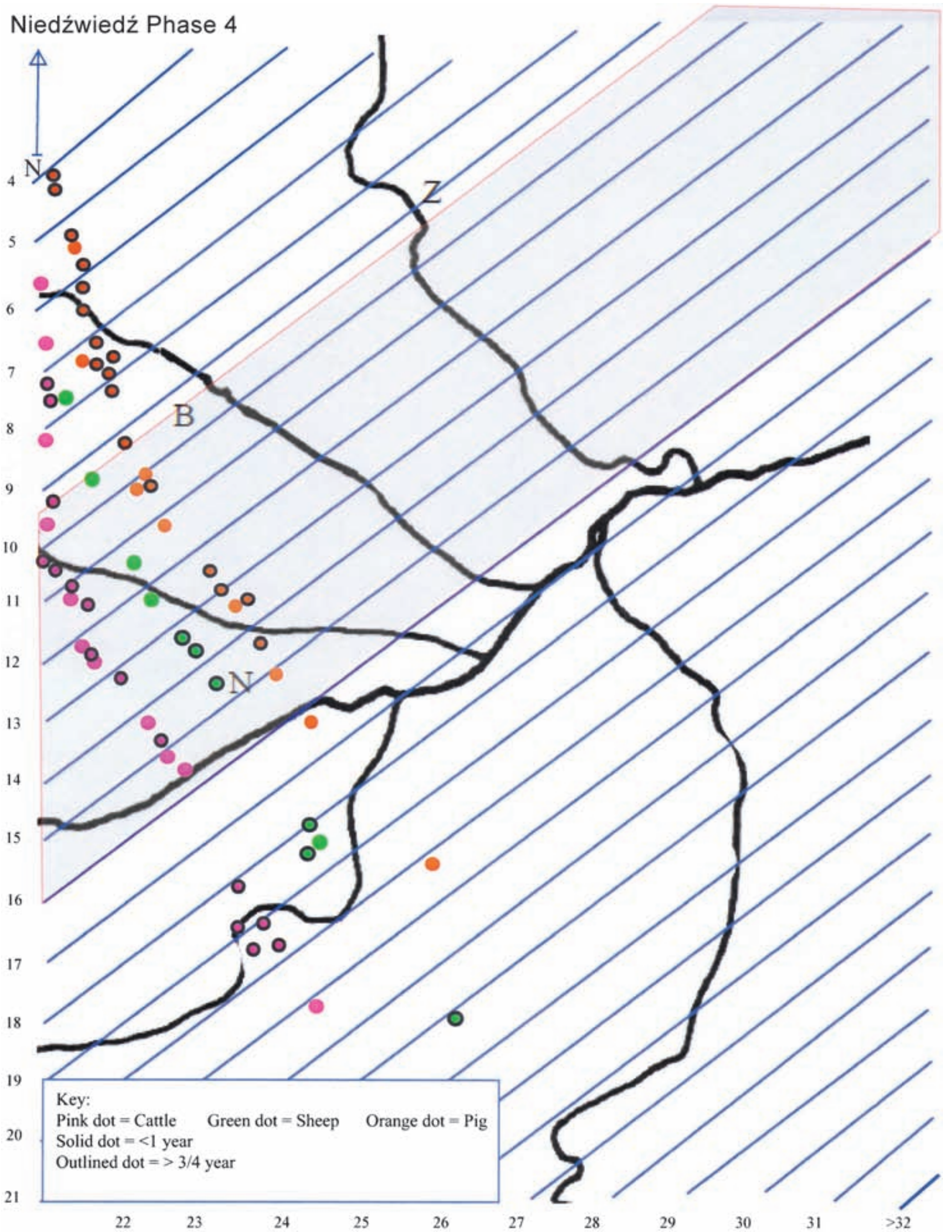

Fig. 15. Niedźwiedź Phase 4 cattle, sheep and pig movements. Gray area is the local range

non-local revealed complex patterns existed in animal husbandry practices and indicated that different economic strategies were used in managing cattle, sheep and pig.

Strontium and other elemental concentrations are found in mammalian teeth and bone. Strontium concentrations in animals vary by species dependent on their feeding habits and their trophic position in the food chain. Herbivores such as sheep are specialized feeders that absorb strontium by grazing on grasses and other vegetation. Carnivores, on the other hand, are one level removed in the food chain, absorbing strontium by eating other animals such as herbivores. The level of strontium which is absorbed by plants and then by herbivores is affected by the composition and age of geological substrates and varies geographically (Balasse and Ambrose 2002; Bentley 2006).

There are several methods available for measuring strontium levels in teeth and bone that range from highly destructive, partially destructive, and non-destructive techniques. The method chosen for this was portable x-ray fluorescence. Absorption in teeth happens over a brief period of time, lasting only as long as a tooth is being formed. The timing of tooth formation in mammals is species specific. Unlike humans, cattle, sheep and pig are born with a full set of deciduous teeth which are replaced with permanent teeth over a period of 3¾ years (Schmidt 1972). Variability in dental eruption rates do exist between breeding populations, but generally dental formation and eruption is highly patterned. The age at which an animal is slaughtered may be determined by examining its row teeth which may include different combinations of milk and permanent teeth, as well as teeth in various stages of eruption. Therefore the best information about where an animal was born and died resides in a set of teeth that includes a combination of deciduous and permanent teeth. Animals that were raised in a single location will show little to no variation in strontium levels regardless of when their teeth were formed and erupted. Conversely, animals that have been moved across the landscape will have distinct variations in strontium levels if their teeth formed in different locations. This forms the underlying premise for using *pXRF* to distinguish locally born and raised animals from outsiders at Bronocice, Zawarża and Niedźwiedź.

The use of *pXRF* in analyzing teeth, bone, antler, and shell among other materials is increasingly common, especially because of is non-destructive nature (Buddhachat *et al.* 2016, Gilberston 2015, and Granite 2012). Portable xray fluorescence devices have been used extensively for testing materials ranging from organic to inorganize materials and their results rarely challenged in terms of readability errors. In fact, *pXRF* devices are typically used in the US by law enforcement for forensic identification of murder victims of unknown origins (Bush *et al.* 2007). Instead, errors are generally considered to result from environmental contamination and sample preparation. Another important issue involves comparing absolute values between devices made by different manufacturers. As a method of relative measurement, the devices yield slightly different values on the same samples due to the coatings used on the inside of the tubes which are proprietary in nature and as such cross-device comparisons cannot be done reliably.

The likeliest source of contamination is depositional context, primarily ground-water.

For that reason, only specimens found in deposits of a meter deep or more were selected. Where possible, multiple individuals from the same deposits were selected. The sample population for this study was drawn from as many depositional contexts as possible at each site. Sample selection was also designed to test a range of individuals slaughtered at different ages.

Preference was given to individuals with a minimum of two or more teeth. In these cases the earliest and the latest erupted teeth were tested. Archaeological data, however, do not always present the ideal situation and so many individuals in the study were represented by a single tooth.

Prior to *pXRF* analysis dental specimens were extracted from maxillas and mandibles. The dental specimens were cleaned by dry brushing. Tracer III handheld *pXRF* device made by Bruker Elemental Inc. was used to analyze the dental samples selected for the study. The handheld device came with a stand and a platform that was fitted onto the reading window. This facilitated placement of the specimen and maintained a stable platform during testing. A protective cover was placed over the sample before each test. A filter was used to optimize the readings for strontium. Bruker Elemental provided a set of filters recommended for use with certain materials, such as teeth. Using a filter the *pXRF* device was restricted to an X-ray depth of 2 mm which in most cases was sufficient to read the entire enamel of a tooth. Da Silva *et al.* used a depth setting of 1.8 mm to analyze human incisor teeth (Da Silva *et al.* 2008). However, sheep enamel tends to be thicker than human incisors. A study conducted by Kubota (Kubota *et al.* 1974) determined that no strontium variations were observed between prepared ground dental samples and whole teeth. Other studies have shown that *pXRF* can be used on whole teeth (Boas and Hampel 1978).

The *pXRF* device works on the principle of photon excitation. It sends a photon beam that pulls an electron in the K shell orbit of an elemental atom forcing an electron from either the L or M shells to replace it. In the process energy emitted in the form of wavelengths characteristic of that element forms a peak fluorescence which is detected and recorded by the device. Initial timed trials were run at increasing intervals of 15 seconds beginning with 30 seconds and ending at 120 seconds. Each tooth was read three times and the results averaged. One Standard Deviation was calculated per phase population and site.

The *pXRF* test results were run on a spectral analyzer (SP1 *pXRF* software). Readings were done using the Soils Mode setting and converted to text files. A program called ARTAX, developed by Bruker Elemental Inc., was used to convert spectral images to qualitative data. A typical spectral reading includes a wide range of elements as illustrated in Figure 2. The peak intensity readings of strontium were converted into semi-quantified data by the software program ARTAX using the element Rhodium as an elemental constant to normalize all values. The program calculates elemental ratios using all readings from a group, which in the case consisted of all sheep readings. This method of conversion

Table 1. Chronological sequence of the cultural component, settlement size and population estimate at Bronocice

Phase	Cutlure	Dates cal. BCE	Settlement Size (Ha)	Estimated Population
1	Funnel Beaker	3900-3800	2	48
2	Lublin-Volhynian	3800-3700	2.4	58
3	Funnel Beaker	3700-3500	8	192
4	Funnel Beaker	3500-3300	21	504
5	Funnel Beaker-Baden	3300-3100	26	624
6	Funnel Beaker-Baden	3100-2900/2800	17	408
7	Corded Ware	2600-2500	-	-

Table 2. MNI by species, phase and size

Species	Bronocice	Bronocice	Bronocice	Zawarża	Bronocice	Niedźwiedź	Total
	Phase 1	Phase 2	Phase 3	Phase 3	Phase 4	Phase 4	
	MNI	MNI	MNI	MNI	MNI	MNI	MNI
Cattle	10	8	14	14	13	18	77
Pig	9	14	8	11	11	16	69
Sheep	10	10	17	10	10	6	63
TOTAL MNI	29	32	39	35	34	40	209

assumes all of the samples all have similar density and structure. Although like spectral imaging this is a relative comparative method it facilitates data presentation by allowing graphing of values in Excel.

The total number of individuals was 209: 77 cattle, 69 pigs, 63 sheep (Table 2).

Environmental factors can potentially affect the concentration of elemental strontium in teeth. In humid areas, elemental concentrations can be affected by changing land use (Herpin *et al.* 2002). Teeth are sensitive to diagenic processes once buried (El-Kammar *et al.* 1989). Elemental concentrations may be impacted by heat, soil chemistry, and moisture (Hedges 2002; Lambert *et al.* 1985; Pate *et al.* 1989; Tuross *et al.* 1989). While heat can be a factor in some places it was not considered to be a significant problem since this region has a temperate climate.

The region of Bronocice is a complex system of rivers, terraces and uplands that are composed of five different ecological zones. The underlying substrate in this region consists of Cretaceous, Jurassic and Tertiary rocks, a limestone layer overlaid by thick strata of loess deposits. Bronocice, Zawarża and Niedźwiedź were located in uplands areas and had similar soil types. They are within 50 kilometers of each other. Therefor it was assumed that small differences in strontium levels represented local geographical distances while larger strontium levels represented greater geographical distances.

Soil chemistry was discounted as a problem because all of the samples were retrieved from closed contexts at depths of one meter or more. Drouet *et al.* (2007) conducted a controlled study on forest soil formations in central Belgium, which is similar geologically to southeastern Poland, consisting of limestone substrate overlaid with a thick layer of loess soils. They examined how strontium and calcium were affected by soil leaching and mineralization, the vertical distributions of these elements, and their concentrations in soils. They found that biologically available strontium was primarily concentrated in the upper humic layers and that soil water interaction, considered to be the primary means of strontium displacement, was negligible with increasing depth.

Groundwater contamination was discounted as well. Only dental specimens were selected for *pXRF* analysis. Teeth are dense, less permeable, and known to be chemically resistant to diagenic influences (Pollard 2009). Drouet *et al.* (2007) found that the influence of groundwater in strontium accumulation in bone is not instantaneous but instead requires long-term exposure.

A final concern was the potential effect of developmental age on the rate of strontium absorption in an individual's teeth. The underlying assumption is that the absorption rate is constant at any age and that variability is tied to local geological substrate and linked to mobility patterns. Interpreting strontium levels would be more difficult if the absorption rate was also affected by the developmental age of teeth. If developmental age were a factor there should be a consistent pattern in the difference or similarities of specific teeth across individuals, such as deciduous m1, permanent M3. This was investigated by looking at individuals represented by a combination of deciduous and permanent teeth. An individual remaining in the same location throughout the period of years during which teeth are formed should have close or similar levels of strontium in deciduous and permanent teeth if the absorption rate remains constant. Strontium levels were found to be the same in teeth of different developmental ages for some individuals and not for others. Therefore, strontium absorption rates appear to remain constant in an individual's developmental life. Variability observed in strontium levels therefore is more likely to be tied to movement across different geological zones.

The Bronocice Phase 1 strontium levels of sheep were used as a reference point to establish the local range and for comparison with all later phases and sites. No living sample was obtained from the area. The use of the Phase 1 sheep levels as a basis of comparison gives a relative point from which to evaluate all other readings. Like other contemporary Funnel Beaker settlements in the region, the Phase 1 Funnel Beaker occupation at Bronocice was small, probably seasonal, and focused mainly on cattle rearing (Figure 3, Table 3) (Diachenko *et al.* 2016; Milisauskas *et al.* 2012; Pipes *et al.* 2009). The majority of dental specimens fell within the strontium peak intensity range of strontium Range = 9,500 to

16,000. This range was set as the standard for comparing all of the data from Bronocice. The standard deviations for both phases were nearly identical with this range.

Dental eruption patterns were used to classify individuals by age while strontium levels were used to classify individuals as either local or non-local in origin. When the strontium level of the earliest erupting tooth fell within the established local range the animal was classified as local and when the level was above or below the local range the animal was classified as non-local. Most local born individuals remained in the same area throughout their lives. However, a few were moved outside the region and later returned. Within the non-local group some animals were adults when they arrived at a site, others were very young, and still others were *in utero*. In the latter two cases, these individuals have later erupting teeth that had local strontium levels.

CULTURE HISTORY

Faunal analyses conducted on assemblages from Funnel Beaker sites across central Europe have demonstrated a fairly consistent pattern of animal husbandry practices with occasional variability generally depending on environmental setting (Bökönyi 1972; 1974; Ebersbach 1999; Glass 1991; Marciniak 2005; Midgley 1992). Many of these studies have interpreted faunal broadly only rarely considered the significance of intra-site or inter-site variability (Bartosiewicz 2005; Gumiński 2005; Hachem and Auxiette 1995).

Other studies focus on the logistics of feeding animals supported through the analysis of dung samples and cereal and weed profiles (Akeret and Rentzel 2001; Bogaard 2004; 2005; Delhon *et al.* 2008; Mainland and Halstead 2005) and seasonal shifts related to pasturage (Bentley and Knipper 2005).While all of these studies contribute to understanding of cultural behavior during this period, they are essentially limited to explanations on the regional scale or very specifically the site level, but and shed little light on the interactions between local communities or among households (Burchard and Eker 1964; Gregg 1988; Hatting 1978; Higham 1968; 1969a; 1969b; Kowalczyk 1962; Kulczycka-Leciejewiczowa 2002; Lasota-Moskalewska 1982; Lasota-Moskalewska *et al.* 2008; Makowicz-Poliszot 2002).

During the fourth millennium in the Bronocice region the settlement pattern shifted from an extensive dispersed population living in small hamlets during Phase 1 to an increasingly intensive occupation at Bronocice surrounded by 2 or 3 tiers of smaller villages in its vicinity (Milisauskas and Kruk 1984). Data from one non-Funnel-Beaker occupation at Bronocice is included here. This was an important though short lived occupation by a group of Lublin-Volhynian people. Zawarża was smaller than Niedźwiedź and had a very different internal arrangement of structures in comparison. Zawarża may have been occupied one or two generation whereas Niedźwiedź was occupied over an extended period of time and by different cultures (Burchard 1977). Funnel Beaker culture was extensive over much of central and northern Europe. Stockherding was focused mainly on cattle.

Table 3. Relative frequencies of cattle, sheep and pig from Bronocice (BR), Zawarża (Z) and Niedźwiedź (N)

Species	BR Phase 1		BR Phase 2		BR Phase 3		Z Phase 3		BR Phase 4		N Phase 4	
	NISP	Rel%	NISP	Rel%	NISP	Rel%	NISP	Rel%	NISP	Rel%	NISP	Rel%
Cattle	236	0.63	175	0.51	1064	0.59	1193	0.67	419	0.69	777	0.62
Sheep	94	0.25	123	0.36	424	0.23	406	0.22	87	0.14	194	0.16
Pig	46	0.12	43	0.13	320	0.18	194	0.11	105	0.17	278	0.22
Total NISP	376	1	341	1	1808	1	1793	1	611	1	1249	1

However, there are indications that in the Alpine region there may have been specialized pig rearing. Pigs were generally the second most abundant species in most faunal deposits (Pipes *et al.* 2009). In the Bronocice region a few settlements had unusually high frequencies sheep, especially during Phases 3 and 4 (Table 3). Later, when Baden influence had reached its peak, cattle became the major focus of animal husbandry practices and pigs gained in importance whereas sheep were diminished. The dramatic increasing sheep production had been discussed elsewhere (Pipes *et al.* 2014). The reasons for the surge appear to be related to textile production at Bronocice and fiber production at Zawarża.

RESULTS OF THE ANALYSIS

A total of 209 individuals were sampled in this study (Table 2). The samples were drawn from available mandibles and maxillae at each site so that there is some variability between them. The peak distributions for each individual by species, site and phase are presented in Figures 4 to 6. They are color coded to reflect individuals represented by more than one tooth (alternating red and green) and others by a single tooth (blue). Individuals represented by more than one tooth appear in order of the earlier erupted tooth followed by the later erupted tooth. The local range is highlighted in each graph allowing the reader to see when a tooth fell above or below the local range.

There were a number of generalized patterns. 1) Individuals from the earlier two phases at Bronocice and from Phase 3 at Zawarża were more often local than non-local. This indicates that Zawarża continued to operate according to an older Funnel Beaker tradition of livestock management. 2) None of the herds were ever composed completely of local or non-local animals, indicating that livestock trade was a constant. 3) The percentage of imported livestock increased dramatically at Bronocice during Phase 3 and continued into Phase 4 revealing a different economic model based in trade and importation of livestock was in operation at Bronocice by 3700 BC. 4) Some animals were born in Bronocice and taken out of the region for a period of time. This suggests they were traded out and then returned for slaughter later.

Table 4. Local and Non-local cattle MNI by phase and site

Origin	Bronocice		Bronocice		Bronocice		Zawarża		Bronocice		Niedźwiedź	
	Phase 1		Phase 2		Phase 3		Phase 3		Phase 4		Phase 4	
	MNI	Rel%	MNI	Rel%	MNI	Rel%	MNI	Rel%	MNI	Rel%	MNI	Rel%
Local	16	.55	26	.81	15	.38	22	.63	10	.29	26	.65
Non-local	13	.45	6	.19	24	.62	13	.37	24	.71	14	.35
TOTAL MNI	29	1.00	32	1.00	39	1.00	35	1.00	34	1.00	40	1.00

Based on their strontium peaks and whether early erupted teeth fell within or outside the local range, individuals from each species, site and phase were classified as local or non-local (Table 4, Figures 7-9). Overall, there was a majority of local animals for Phases 1 and 2 at Bronocice and at Zawarża and Niedźwiedź. Conversely, there was a majority of non-local animals for Phases 3 and 4 at Bronocice. However, when the data are examined by species it is clear that cattle and sheep ratios are quite different from those of pig.

During Phase 1 there were about the same frequencies of cattle and sheep local to non-local animals. However, sheep had a higher frequency of local animals while the reverse was true of non-local pigs. During Phase 2 there were only local cattle; a great majority of sheep were local as were a high frequency of pigs. The reason for the high frequencies of local of individuals may have been the result of social isolation or of social tensions between the Lublin-Volhynian group and local Funnel Beaker groups. By Phase 3 there were higher frequencies of non-local animals of each species. In comparison, at Zawarża which also dates to Phase 3, cattle and sheep consisted predominantly of local animals. Pigs on the other hand were represented by a much higher frequency of non-local individuals. During Phase 4 at Bronocice all three species were represented by very high frequencies of non-local animals. In comparison, at Niedźwiedź which also dates to Phase 4, all three species were represented by higher frequencies of local animals.

These data suggest that different livestock management strategies were in operation at different times and at all three sites. At the central settlement of Bronocice, which began its great expansion in Phase 3, the predominance non-local animals signals the start of a major trade in livestock, a trend which continued over an extended period of time. At Zawarża and Niedźwiedź, both much smaller and less socially complex settlements, the predominance of local livestock suggests they were engaged in localized trade and stock-herding. The occasional introduction of non-local animals may have been a way of maintaining the genetic health of the herds, rebalancing sex ratios, or replacing diseased or otherwise unfit animals such as unfertile females or males. The only exception to this is the high rate of non-local pigs at Zawarża for which no explanation is known at this time.

However, Glass (1991) noted that some Alpine sites in Germany yielded faunal assemblages with high frequencies of pig which are thought to have resulted from specialized pig rearing. Perhaps Zawarża was involved in another trading spehces.

In an attempt to graphically illustrate movement patterns a standardized peak value grid was overlaid on the Bronocice region with increasing strontium values to the southeast (Figures 10 to 15). The grid is an arbitrary overlay of the region around the site. The visual representation of livestock movement patterns is useful in understanding herding patterns by phase and site. There were different movement patterns seen when plotting out distances. These differences may reflect seasonal transhumance and animal importation. Variability was common within the local range and was often patterned according by species. By examining the strontium peaks of specific teeth within a species patterns were observed. For instance, juvenile local pigs were often moved out of the local area and returned later when they were older, a pattern which all three species exhibited. However, cattle and pigs tended to have lower strontium peaks for later erupting teeth, whereas sheep tended to have higher strontium peaks. This clearly suggests distinct herding patterns existed for each of the species. Small variability in peak values of earlier and later erupting teeth may be understood as herding strategies within a local area. Small differences in values suggest that herds were rotated on a seasonal basis. Another pattern was a large decrease in peak values above the local range and a large increase in peak values below the local range in latest erupted tooth. This pattern suggests the movement of animals in towards Bronocice. Last another pattern worth noting is that the peak values of non-local sheep, cattle and pig from Phases 1 and 2 at Bronocice are not as great as the extreme values seen during Phases 3 and 4 which suggests that these animals were not coming from as great a distance. Animals obtained during the latter two phases at Bronocice came from much greater distances.

CONCLUSIONS

X-ray fluorescence proved to be an effective tool in identifying herding patterns by measuring strontium concentrations in the dental enamel of cattle, pig and sheep. By comparing strontium in teeth of different developmental ages it was possible to segregate individuals into local and non-local animals from the three sites. The distinctive patterns observed make it clear that faunal remains are the result of complex socioeconomic activities and that it is necessary to consider the possibility that herding practices at Funnel Beaker sites may involve not only local but also non-local agents.

The patterns observed at Bronocice, Zawarża and Niedźwiedź revealed the existence of a minimum of two levels of stock-herding. The first pattern consisted of individuals with low strontium diversity in earlier and later erupted teeth which pointed to unique localized management strategies existing for each species and that they were herded separately. Archaeological survey of Funnel Beaker sites in the upper Vistula River basin has documented several seasonal camps thought to be associated with stockherders (Makowicz--Poliszot 2007).

The second pattern was of individuals exhibiting high strontium variability between early and later erupting teeth. This type of pattern is evidence of the importation of non-local animals which were moved across great distances. Additionally, the ratio of local to non-local individuals within all species changed over time. At Bronocice the majority of cattle, pig and sheep were of non-local origins by Phase 4 whereas at the satellite settlements the reverse was true. The increasing importance of livestock importation to Bronocice indicates the settlement was invested economically in livestock as a trade commodity. There was an outward redistribution of imported livestock to surrounding settlements. The low frequency of local animals during Phases 3 and 4 at Bronocice suggests that the focus of livestock management strategies at Bronocice was no longer primarily on local stockherding. The evidence for the increasing importance of livestock trade at the site adds another layer to what is already known about Bronocice's involvement in long distance trade.

Over time the direction of animal importation, regardless of species, appears to have coalesced into a single source for all livestock. This is interesting because by the end of Phase 6 agricultural settlements disappeared in the region. By the mid-3rd millennium this region of Poland was populated by Corded Ware people. Perhaps the increasing intensification in livestock management and trade set the stage for a major shift in subsistence practices to a pastoral way of life.

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