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WHAT DOES THE BELL-DISTRIBUTION HIDE? SPATIAL BEHAVIOR AND DEMOGRAPHIC DEVELOPMENT OF THE FUNNEL BEAKER CULTURE POPULATIONS IN BRONOCICE REGION, POLAND

ABSTRACT

Diachenko A., Kruk J. and Milisauskas S. 2016. What does the bell-distribution hide? Spatial behavior and demographic development of the Funnel Beaker culture populations in Bronocice region, Poland. *Sprawozdania Archeologiczne* 68, 25-38.

Spatial archaeology usually links population estimates to settlement functions. Normal (Gaussian) or binomial distributions of a variable reflecting population values are used for groups of sites identified as seasonal occupations, hamlets, villages, centers etc. However, using this approach the demographic development remains hidden in bell-curves. To solve this issue we propose a research procedure that considers spatio-demographic development of the population. Application of this procedure to Funnel Beaker sites in the Bronocice region led to the identification of at least 7 sub-phases in the 'classical' period Bronocice 3 (BR II) and 4 (BR III) and could be increased to 8-9 sub-phases.

Keywords: spatial behavior, demographic development, Neolithic, Bronocice, Funnel Beaker culture, bell-curve
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INTRODUCTION

To what extent does spatial hierarchy reflect economic development and socio-political organization in prehistoric societies? Following the models developed in analytical geography, spatial archaeology usually links population estimates to settlement functions. Normal (Gaussian) or binomial distributions of the variable reflecting population, usually settlement size, is used for sites identified as seasonal occupations, hamlets, villages, centers, etc. Using this approach the demographic development remains hidden in bell-curves. Population growth is better described by Pareto distribution than Gaussian distribution. Empirical studies have shown numerous cases when the population size in regional settlement hierarchy and at the supra-regional level follow power-laws (Allen 1997; Andriani and McKelvey 2009; Bak 1996; Batty 2007; Hamilton *et al.* 2007a; 2007b; 2009; Mandelbrot 1999; Mandelbrot and Hudson 2004; Woldenberg and Berry 1967; Zipf 1965). Different patterns of demographic development can be misinterpreted for specific types of socio-political organization. Considering this issue, our study focuses on demographic development and spatial behavior of the Funnel Beaker (FB) populations in Bronocice region, Poland.

DATA INPUT

The State University of New York at Buffalo and the Institute of the History of Material Culture, Polish Academy of Sciences, now the Institute of Archaeology and Ethnology, Polish Academy of Sciences, conducted a cooperative archaeological project at the Bronocice site, Świętokrzyskie province, between 1974 and 1978. The Director and Principal Polish investigator of this cooperative project was Witold Hensel and Sarunas Milisauskas was the Principal American investigator (Kruk and Milisauskas 1981; 1985; 1999; Kruk *et al.* 1996; Milisauskas *et al.* 2012; Milisauskas and Kruk 1984; 1989; 1993; 2008). The objectives of this archaeological project were twofold: 1) to investigate the prehistoric environments, chronologies, economies, settlement systems, and social organizations of the Middle Neolithic Funnel Beaker and Late Neolithic Funnel Beaker-Baden communities in the basin of the Nidzica River and 2) to demonstrate the origin of complex societies in that region.

The chronological and cultural sequence in the Bronocice region includes several archaeological cultures (Table 1). By 3900-3800 BC, the earliest Funnel Beaker material, phase 1 (BR I) had appeared at Bronocice. After a brief occupation by a small group of Lublin-Volhynian people (Phase 2) of 50-100 years Funnel Beaker people returned to Bronocice and reestablished a new settlement in the southeast section of the site. This Funnel Beaker occupation (classic phase) lasted 400 years and is divided into two Phases referred to as Phase 3 (BR II) (3700-3500 B.C.) and Phase 4 (BR III) (3500-3300 BC)

Table 1. Chronology, cultural sequence, settlement size and population estimates at Bronocice

Phase	Culture	Dates BC Calibrated	Settlement size	Population estimates
1 (BR I)	Funnel Beaker	3900-3800	2 ha	48
2 (L-V)	Lublin-Volhynian	3800-3700	2.4 ha	57
3 (BR II)	Funnel Beaker	3700-3500	8 ha	I92
4 (BR III)	Funnel Beaker	3500-3300	21 ha	504
5 (BR IV)	Funnel Beaker-Baden	3300-3100	26 ha	624
6 (BR V)	Funnel Beaker-Baden	3100-2900/2800	17 ha	408

based on ceramic typologies and radiocarbon dates. By 3300 BC phase 5 (BR IV) Funnel Beaker ceramics had taken on characteristics of Baden ceramic forms and surface treatments and so it is referred to as Funnel Beaker-Baden. This culture occupied the site from 3300 to 2900/2800 BC.

Phase 3 ceramics of the Funnel Beaker culture exhibit diverse forms and ornamentation. They have the typical attributes of the southeastern group of the Funnel Beaker culture (Milisauskas and Kruk 1984; Kruk and Milisauskas 1990; Kruk *et al.* 1996; Nowak 2009; Włodarczak 2006; 2013; Zastawny 2015).

Phase 4 ceramics show minor differences in shape and ornamentation when compared with phase 3 material, the most important being the appearance of early proto-Baden motifs that were incorporated into the Funnel Beaker ceramics (Burchard 1973; Zastawny 2008; Przybył 2009).

The location of all Neolithic sites in the Bronocice region was recorded by a systematic survey conducted in a 314 km^2 area centered on that site (Kruk 1969, Milisauskas and Kruk 1984). This survey has located 54 Funnel Beaker settlements ranging from 1 to 21 hectares.

Low-level hierarchy was noted of the FB settlements in Bronocice region (Milisauskas and Kruk 1984). Three groups of sites were identified: small, less than 2 ha; middle, 2.1-6 ha, and large, over 9 ha. The major center of this region, the site of Bronocice, increased in size from 8 ha during Bronocice 3 (BR II) to 21 ha during Bronocice phase 4 (BR III) (Kruk *et al.* 1996). The other large settlement Mozgawa, c. 30 ha in size, is located about 12 km from Bronocice (Florek and Wiśniewski 2008). Economy of the FB populations in southeastern Poland included subsistence agriculture and livestock herding (Kruk 1980; Kruk and Milisauskas 1999; Milisauskas *et al.* 2012). The FB sites are represented by settlements and seasonal occupations.

Our sample for analysis includes 54 sites (Milisauskas and Kruk 1984). The size of the largest settlement Bronocice 3 (BR II) and 4 (BR III) phases is counted twice. The data is given in Table 2. Size-frequency distribution of settlements in the range of 1.2-3.1 ha and 3.2-5.6 ha with a step of 0.5 ha is close to binomial (Fig. 1). It should be noted that the largest settlement, Bronocice, is not represented in Figure 1. Polish Archaeological Records

Table 2. Size of the 'classic' period sites of the Funnel Beaker culture in Bronocice region (after Milisauskas and Kruk 1984)

Site No	Size (ha)	Site No	Size (ha)	Site No	Size (ha)
1	2.0	19	2.2	37	2.3
2	3.0	20	1.2	38	9.0
3	5.1	21	1.7	39	5.0
4	3.0	22	2.9	40	1.5
5	1.4	23	4.3	41	1.3
6	2.3	24	5.6	42	1.8
7	3.7	25	3.6	43	4.5
8	2.2	26	2.3	44	2.2
9	2.9	27	4.4	45	2.8
10	1.3	28	4.1	46	4.0
11	1.6	29	4.3	47	3.1
12	1.6	30	9.0	48	1.2
13	3.0	31	1.4	49	2.0
14	3.6	32	5.0	50	1.8
15	8.0/21.0*	33	3.4	51	1.4
16	4.3	34	2.7	52	2.2
17	1.8	35	5.1	53	1.8
18	2.5	36	1.3	54	2.0

*Size of the settlement of Bronocice during Bronocice 3 (BR II), 8 ha, and Bronocice 4 (BR III) phase, 21 ha.

(Archeologiczne Zdjęcie Polski) includes much higher number of sites; however, size of the FB settlements at multi-layered occupations is not clearly identified yet. The sample of 54 sites is representative enough for the purposes of this research. The following section considers basic assumptions of this study and issues of simulations.

METHODOLOGY

Economy of the FB populations consisted of plant cultivation and livestock herding. Settlements were abandoned after a period of 30-50 years occupation and population moved to new places within micro-regions and within a region. The 'classic' period of the FB in southeastern Poland could be divided into 8-13 sub-phases. Necessary subdivision of Bronocice 3 (BR II) and 4 (BR III) phases was noted much earlier. Detailed relative chronology based on ceramics was not yet established. Only maximal population estimates were possible (Milisauskas and Kruk 1989; Kruk *et al.* 1996). Duration of the largest settlements was estimated to few centuries (e.g. Kruk *et al.* 1996; cf. Rzepecki 2014). Two types of mobility, referred to types 'bb' and 'bd' in Neustupný's (1984) scheme, allowed several models of spatial behavior of the FB populations (Kruk 1980; Nowak 1993; 2009; Pelisiak 2003; 2015). Considering the timespan of settlements, we formulated the basic assumptions of this study as follows.

1. Population grew naturally. The nearest groups of sites obtained in the ranking of population estimates or related values, reflect the increase in the number of people during 30-50 years. Population growth between the extremums of each group has to be considered as well. It should be noted that a similar assumption was used for the chronological division of the LBK sites (Stehli 1994).

2. If a certain group of the population size or related values *A* does not correspond to group *B* through the simulated increase of population, then several smaller sites were branched off from the settlement of a group *A*.

3. Considering assumptions 1 and 2, one can state that settlements of nearest groups obtained in the result of the ranking of population estimates or related values should be clustered near each other. For example, if the number of people at the settlement of a group *D* corresponds to natural growth of population at the settlement of a group *C*, while number of people at the settlement of group *E* corresponds to the natural growth of population at the settlement of group *D*. Therefore, settlements belonging to groups *C*, *D* and *E* should form specific settlement patterns. This is also the case of settlements belonging to groups *A* and *B* (see assumption 2).

Since the density of houses within the sites of different size is not known, the settlement size was chosen for a proxy of population values. However, one should note that this is the case of possible simplification of population value estimates, because the density of houses is assumed to be equal for all settlements and seasonal occupations, based on the linear relationship between settlements size and population estimates. Population density is estimated at 24 people per 1 ha (Kruk *et al.* 1996; Milisauskas and Kruk 1984). This value is taken for constant. Increase in settlement size and population is assumed to be equal. Another simplification concerns the simulation of population growth. Dealing with a relatively short time span, we assumed exponential increase in population that is expressed as follows.

(1) $$P_t = P_o e^{rt},$$

where P_t is the population after time span t, P_o is the initial population, e is the base of natural logarithm (≈2.7183) and r is the annual rate of population growth.

According to Hassan (1981, 140), the annual growth rate in prehistoric populations is limited to 0.52%. This value corresponds to doubling of a group size in 133 years.

SYSTEMATIZATION OF DATA AND SIMULATIONS

Now let's consider systematization of the original data and simulation of the demographic 'links' between the identified groups of sites. Obtained values were rounded to three digits after the decimal point. Ranking of settlement size is represented in Figure 2. The estimate of annual population growth between the medians of groups and the extremums of groups allowed for minor corrections to the results of site ranking and preliminary conclusions (Tables 3 and 4).

The average annual rate of population growth is estimated at 0.2-0.4%. The rate of population growth between the medians of 4.05 and 4.30 ha and the extremums 4.00, 4.10, 4.30 and 4.50 is too low. It would be reasonable to combine the settlements that reached the size of 4.00 to 4.50 ha into a single group. This removes the issue of the relatively high rate of population growth in areas between the medians 3.60 and 4.05 ha. Since the estimated growth in areas between the medians of 1.45 ha and 2.00 ha and the extremums of 1.20 and 1.80 ha exceeds the natural increase in the number of people in prehistoric groups, only the largest settlements in this range, (estimated to have a size of 1.8 ha) were the basis for formation of sites that reached 2 ha. Thus, the following groups of settlements reflect the demographic development in the Bronocice region: *a*, 1.80 ha; *b*, 2.00 ha; *c*, 2.20-2.30 ha; *d*, 2.50 ha; *e*, 2.70-3.10 ha; *f*, 3.40-3.70 ha; *g*, 4.00-4.50 ha; *h*, 5.00-5.10 ha; *i*, 5.60 ha; *j*, 8-9 ha; and *k*, 21 ha. Sites of 1.70 ha or less probably represent seasonal occupations.

Table 3. Rates of population growth between the medians of groups

Groups (extremums in ha)	Median (ha)	$\frac{P_t}{P_0}$	Annual growth rate r with $t = 30$	Annual growth rate r with $t = 50$	Annual growth rate r with $t = 30$-50 (%)
1.20-1.80	1.45	-	-	-	-
2.00	2.00	1.38	0.011	0.006	0.6-1.1
2.20-2.30	2.20	1.10	0.003	0.002	0.2-0.3
2.50	2.50	1.14	0.004	0.003	0.3-0.4
2.70-3.10	2.95	1.18	0.006	0.003	0.3-0.6
3.40-3.70	3.60	1.22	0.007	0.004	0.4-0.7
4.00-4.10	4.05	1.13	0.004	0.002	0.2-0.4
4.30-4.50	4.30	1.06	-	-	-
5.00-5.10	5.05	1.17	0.005	0.003	0.3-0.5
5.60	5.60	1.11	0.004	0.002	0.2-0.4
8.00-9.00	9.00	1.61	0.016	0.010	1.0-1.6
21.00	21.00	2.33	0.028	0.017	1.7-2.8

Table 4. Rates of population growth between the extremums of groups

Extremums (ha)	$\frac{P_t}{P_0}$	Annual growth rate r with $t = 30$	Annual growth rate r with $t = 50$	Annual growth rate r with $t = 30\text{-}50$ (%)
1.20 to 1.80	1.50	0.014	0.008	0.8-1.4
1.80 to 2.00	1.11	0.004	0.002	0.2-0.4
2.00 to 2.20	1.10	0.004	0.002	0.2-0.4
2.20 to 2.30	1.05	-	0.001	-
2.30 to 2.50	1.09	0.003	0.002	0.2-0.3
2.50 to 2.70	1.08	0.003	0.002	0.2-0.3
2.70 to 3.10	1.15	0.005	0.003	0.3-0.5
3.10 to 3.40	1.10	0.004	0.002	0.2-0.4
3.40 to 3.70	1.09	0.003	0.002	0.2-0.3
3.70 to 4.00	1.08	0.003	0.002	0.2-0.3
4.00 to 4.10	1.03	-	0.001	0.1
4.10 to 4.30	1.05	-	0.001	-
4.30 to 4.50	1.05	-	0.001	-
4.50 to 5.00	1.11	0.004	0.002	0.2-0.4
5.00 to 5.10	1.02	-	-	-
5.10 to 5.60	1.10	0.004	0.002	0.2-0.4
5.60 to 9.00	1.61	0.016	0.010	1.0-1.6
9.00 to 21.00	2.33	0.028	0.017	1.7-2.8

It is not possible to obtain settlement sizes in the Bronocice region, based on annual population growth rate of 0.2-0.4% for the settlements belonging to groups *i*, *j* and *k* (the correspondent values are, respectively, 6.2-6.3 ha; 10.0-10.2 ha; and 23.3-23.7 ha). These sites represent a state of 'critical' demographics. Their populations split into several smaller groups as time passed. Since the group *i* is represented by a single settlement, this list should be extended by the sites belonging to group *h*. This assumption explains the growth rate between medians of 4.30 and 5.05 ha, somewhat exceeding the average values. The sum of sizes of settlements that branched off from the sites belonging to group *h* should be equal to 5.5-5.8 ha. Group *g* reflects the stabilization point in population growth. The demographic development could have resulted in specific patterns of sites accompanied by the movement of 'excessive' populations to other settlements.

Now let us simulate the changes in number of sites of two step transition continued over a sub-phase. Assume that each of the identified settlement groups included one site. Settlements that belong to groups *a-g* were shifted to the next group according to their size. For example, a population that lived in a group *a* settlement built the group *b* settlement; while the population that lived in a group *b* settlement built a group *c* settlement.

Settlements that belonged to groups *h-k* became a base for the formation of a number of sites of the preceding groups by size. Two settlements of group *g* branched off from one settlement belonging to group *j*, while two settlements of group *j* and one settlement of group *i* branched off from the settlement belonging to group *k*. The expected number of settlements in the initial stage and those formed as the result of two-step transition is the same as the number of sites in the micro-region.

The total number of sites obtained with simulations and the number in our sample are quite similar for settlements that belong to the groups *g-k* (Fig. 3). A significant difference between the model and the empirical data for groups *a*, *c* and *e* is caused by simulation of the two-step transition instead of multi-steps transition. The unknown real number of settlements in the initial stage and 'noises' is caused by different possible scenarios of the spatio-demographic development, including the population growth that is not reflected by shifting of the settlement from one group to another (see Table 3). Clasterization of sites expected by the model is confirmed by their distribution in space, for example, see the location of settlements 4, 6, 7 and 9; 13 and 14; 37, 34 and 33; 44, 45 and 47; 17, 19, 18 and 22. Our conclusion regarding the decrease of the 'large' and 'medium' settlements is accompanied by the formation of 'small' settlements. This is confirmed by the specific patterning of sites as expected by the assumptions of this study (see the location of sites 15, 16, 35, 38 and 39; 15, 23, 24, 29, 30 and 32 – Fig. 4).

The results allow for the reconstruction of the settlement dynamics in the Bronocice region (Fig. 4). Several clusters of sites require special attention. Settlements 43 and 46 probably branched off from the settlement of 9 ha located to the north of site 43 (Kruk *et al*. 1996, 29, 31, table 3, fig. 7). Sites 24, 30 and 38 were formed as a result of segmentation of the population of Bronocice phase 4 (BR III), labeled as site 15 in Figure 4. With time, settlement 38 became the base for the formation of settlements 35 and 39. Settlement 16 later branched off from settlement 39. It is important to note that the location of site 16, (4.3 ha) near the site of Bronocice suggests a chronological gap between the two, and was probably necessary for forest regrowth and soil fertility. This is also the case for settlement 37 suggesting a chronological difference with settlement 38.

Settlement 28 was probably branched off from the settlement 24, while other sites of this cluster are located outside the 10 km radius from Bronocice. Settlement 30 became the base for the formation of settlements 29 and 32. The stabilization point in population growth is represented by settlement 23, which was developed from settlement 29. Settlement 27 was developed from 23.

The approximately equal distance between Bronocice and sites 24, 30, and 38, and the distance between Bronocice and site 3, suggests that site 3 (8 ha) was branched off from the settlement of Bronocice phase 3 (BR II) (Milisauskas and Kruk 1984). Other sites of this cluster are probably located to the east from micro-region. Assuming the forest regrowth around Bronocice during the gap in occupation, the duration of this gap can be estimated to be 70-80 years or 2-3 sub-phases. Site 3 belongs to the earliest of these sub-phases.

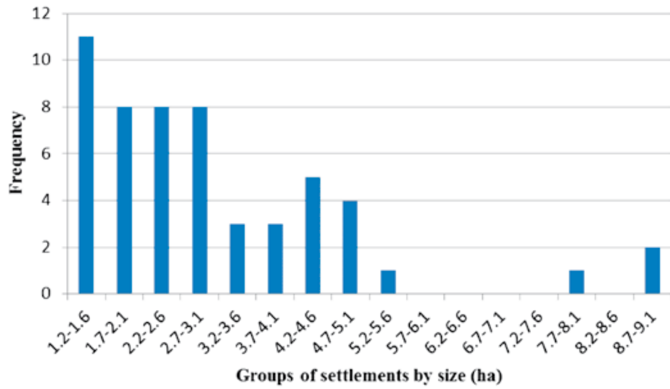

Figure 1. Size-frequency distribution of the FB sites in the range from 1.2 to 9 ha in Bronocice micro-region

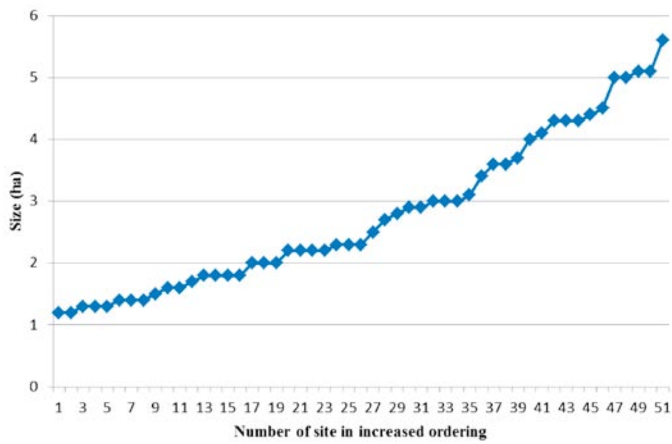

Figure 2. Systematization of the FB sites in the range from 1.2 to 5.6 ha in Bronocice micro-region

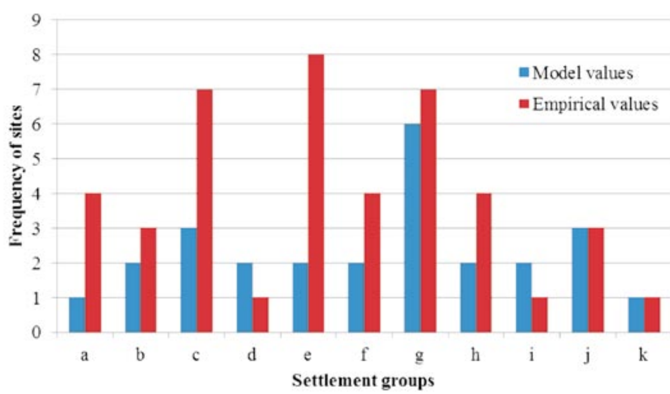

Figure 3. Frequency of Sites by Settlement Group

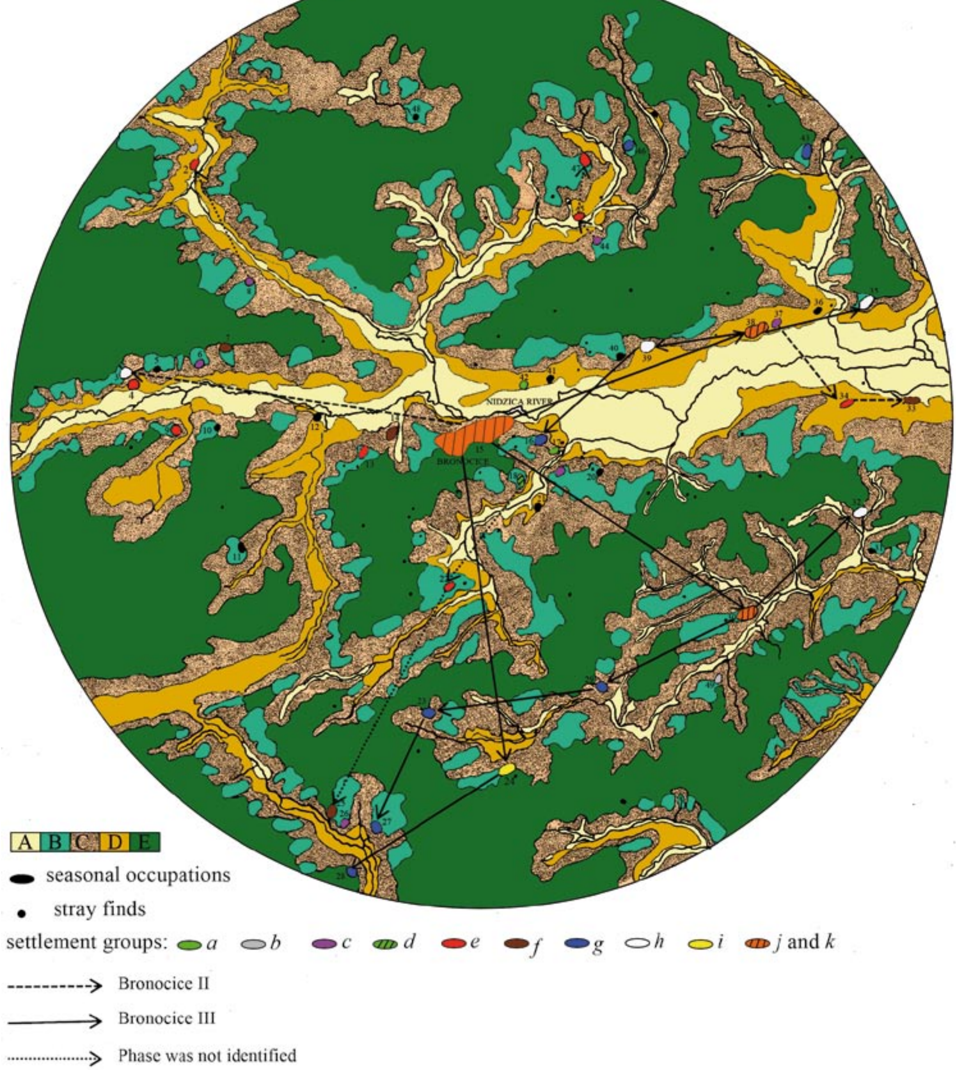

Figure 4. Spatial behavior of the FB populations in Bronocice micro-region (after Milisauskas and Kruk 1984 with modifications);
Settlement size: a – 1.80 ha; b – 2.00 ha; c – 2.20-2.30 ha; d – 2.50 ha; e – 2.70-3.10 ha; f – 3.40-3.70 ha; g – 4.00-4.50 ha; h – 5.00-5.10 ha; I – 5.60 ha; j – 8-9 ha; k – 21 ha; Ecological zones: A – alluvial zone; B – valley edge zone; C – slopes of the uplands zone; D – edges of the uplands zone; E – uplands zone

This assumption is confirmed by the location of the cluster of sites 37, 34 and 33 in relation to sites 38 and 35. Settlements 37 and 34 can be dated to Bronocice phase 3 (BR II).

Presently it is hard to reconstruct the relationship between settlements 4, 6, 7 and 9, and date the cluster of sites 8 and 2; 44, 45 and 47, 17, 19, 18, 22 and 25 to any particular phase. Sites 17, 19 and 18 could belong to Bronocice phase 3 (BR II), while site 25 belongs to Bronocice phase 4 (BR III). This assumption is indirectly confirmed by the location of settlements 25 and 26 in relation to each other.

These results lead to a greater understanding of the spatial behavior and demographic development of the Late Neolithic populations in southeastern Poland and chronology of the FB sites.

CONCLUSION AND DISCUSSION

Spatial behavior of the FB populations of Bronocice 3 (BR II) and 4 (BR III) phases generally corresponded to linear-stream settlement patterns that exist in several forms in different parts of the world (e.g. Reynolds 2009). Population movement was caused by deforestation and reduction of soil fertility. The average annual growth rate of populations is estimated to 0.2-0.4 %.

Our simulations confirmed specific distribution of settlement sizes and location of sites. We identified at least 7 sub-phases in the 'classical' period of the FB in the Bronocice micro-region. This number could be increased to 8 or 9 sub-phases if regrowth of forest around Bronocice is taken into account. This corresponds to the number of 8-13 possible sub-phases that derived from the shortest possible range in absolute dating. Available ethnographic evidence regarding the productivity of agriculture suggests the duration of 30-50 years for a sub-phase (Nikolova 2002; Krasnov 1971). Considering the example of the Trypillia mega-sites in Ukraine, it is possible the largest settlements may exceed the duration of the sub-phase (Chapman and Gaydarska 2015, fig. 4; Diachenko 2012; Videiko 2013). Bronocice 3 (BR II) phase included at least 3 sub-phases represented by the cluster of settlements (15, 3); (37, 34, 33); and (17, 19, 18). Bronocice 4 (BR III) phase can be divided into at least 5 sub-phases that are represented by the following clusters of sites: (15, 38, 35); (39, 16); (15, 30, 32); (29, 23, 27); and (15, 24, 28). The largest settlement of this region, Bronocice was probably occupied two times with a chronological gap of at least 70-80 years between Bronocice 3 (BR II) and 4(BR III).

According to well-known spatial models, linear-stream settlement patterns usually correspond to the optimization of settlement systems described by the Christaller's (1966) *K*-value of K=2. This *K*-value was also found for Trypillia settlement systems in the Southern Buh and Dnipro interfluve in Ukraine, peripheral areas in the Near East, and settlement systems in Iowa and Northern Dakota in the USA (Berry 1967; Diachenko 2012; Johnson 1972). They are characterized by densely dispersed populations, relatively weak developed transportation and low number of administrative centers (Smith 1974). The similarity of this type of spatial organization and dendritic type of settlement systems suggests that production and exchange were concentrated in centers where the elites lived (Minc 2006). This is in agreement with current studies of fiber and textile production in Bronocice after 3700 BC that probably stimulated long-distance exchange (Milisauskas *et al.* 2012; Pipes *et al.* 2015).

Does the self-organized spatio-demographic development in the Bronocice micro-region, hidden in bell-curves, mean that the group size and location of settlements was simply misunderstood for the formation of low-level hierarchical societies? Recent studies in paleodemography presented archaeological and ethnographical evidence that cannot be explained from the perspective of simple relationships between group size, environment, subsistence strategies, or socio-political organization (Diachenko and Zubrow 2015; Fletcher 2006; Hamilton *et al.* 2007a; 2007b; 2009). Different forms of economy and social organization can overlap the deep non-linear trends in demographic development (Duffy 2015; Feinman 2011; 2013). The formation of low-level social hierarchy in Bronocice micro-region does not contradict the results of our simulations. Further studies in correlation of group size, socio-political organization, and economic development of ancient societies is needed.

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