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Spatial and social variables in the Bronze Age Phase 4 cemetery of Ban Non Wat, Northeast Thailand

Baylee A. Smith [a,b], Tilman M. Davies [a,*], Charles F.W. Higham [b]

[a] Department of Mathematics and Statistics, University of Otago, PO Box 56, Dunedin 9054, New Zealand
[b] Department of Anthropology and Archaeology, University of Otago, PO Box 56, Dunedin, 9054, New Zealand

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ABSTRACT

The twelve occupation and mortuary phases at the prehistoric site of Ban Non Wat in Northeast Thailand began with late hunter-gatherers in the early 2nd millennium BC and ended with the late Iron Age in about AD 500. There are five Bronze Age mortuary phases, dating to between 1050 and 430 BC. These began with burials of exceptional wealth, but by the fourth phase, graves were markedly poorer. The 162 burials of phase 4 appear visually to form distinct groups and in the initial publication of this site, no differences between the compositions of the mortuary offerings between the five putative groups were noted. In this paper, we first conduct exploratory statistical analyses to test for the validity of spatial patterning within the cemetery, and identify four groups of burials. This is followed by the application of multinomial logistic regression to test for significant differences between them. It is concluded that three artefact classes, ceramic vessels, bivalve shells and shell beads, distinguish between the identified groups. Each of these is evaluated to clarify the subtleties of possible social distinctions in a cemetery hitherto seen as uniform.

1. Introduction

Ban Non Wat is a key site in dating the transition into the Bronze Age in Southeast Asia, and tracing the course of social changes during this period over a span of six centuries (Higham and Kijngam, 2012). There was a sharp rise in the intensity of the rituals of death during Bronze Age (BA) 1–3, followed by an equally encompassing fall with BA 4 and 5. The rise has been attributed to the social leverage exercised by a dominant lineage which, over a span of 8–10 generations, gained preferred access to exotic symbols of status, including copper-base implements and ornaments of marine shell and marble. Elite death rituals involved elaborate feasting. Although the same basic mortuary ritual continued into the Bronze Age mortuary phase (BA) 4, the quantity and range of items placed with the dead fell away dramatically, reflecting the instability of the early rise in social distinctions. The BA4 cemetery comprises 162 burials of men, women, children and infants (Fig. 1). In reporting on these, Higham (2012) identified by visual inspection five nuclei of graves, disposed in rows and head to toe in columns. He tabulated all the mortuary offerings in each burial, and was unable to find any distinctions between each of his groups save for the presence of grey clay and spindle whorls in the most eastern nucleus. These, he suggested, might have been the latest since with the ensuing BA5, many burials were associated with these two artefacts that probably reflect the preparation of yarn for weaving cloth. At issue is the validity of identifying the lobes of a cemetery on the basis of visual inspection alone. This will be tested by the application of a series of statistical analyses.

2. Digitising the data

To perform the new spatial analysis of the BA4 cemetery, we required an objective method to pinpoint a single coordinate to represent the location of each grave. Based on a digital scan of the image in Fig. 1, we traced the convex polygons surrounding each burial, and generated the coordinates seen in Fig. 2 by calculating the geometric centroids of said polygons. These steps were performed using the Java-based image processing programme ImageJ (Rasband, 2014).

With respect to the data themselves, each burial has up to 72 attributes. These begin with the sex and age of the deceased, and proceed to the range of mortuary offerings. In the case of BA4, the offerings comprise up to 33 different forms of ceramic vessel, animal and fish bones that may have been part of feasting events, shell and marble jewellery, bivalve shells thought to have had ritual significance, and artisanal tools. One man, for example, was clearly a specialist in bronze casting, for he was interred with multiple clay moulds for casting bronze axes and bangles.

The final variable is the spatial group, labelled from A to E, into which Higham initially placed each grave. Identifying statistically validated spatial groups is essential, and so care must be taken in precisely how this is done. Validation of Higham's subjectively defined five groups is

* Corresponding author.
E-mail addresses: smiba540@student.otago.ac.nz (B.A. Smith), tdavies@maths.otago.ac.nz (T.M. Davies), charles.higham@otago.ac.nz (C.F.W. Higham).

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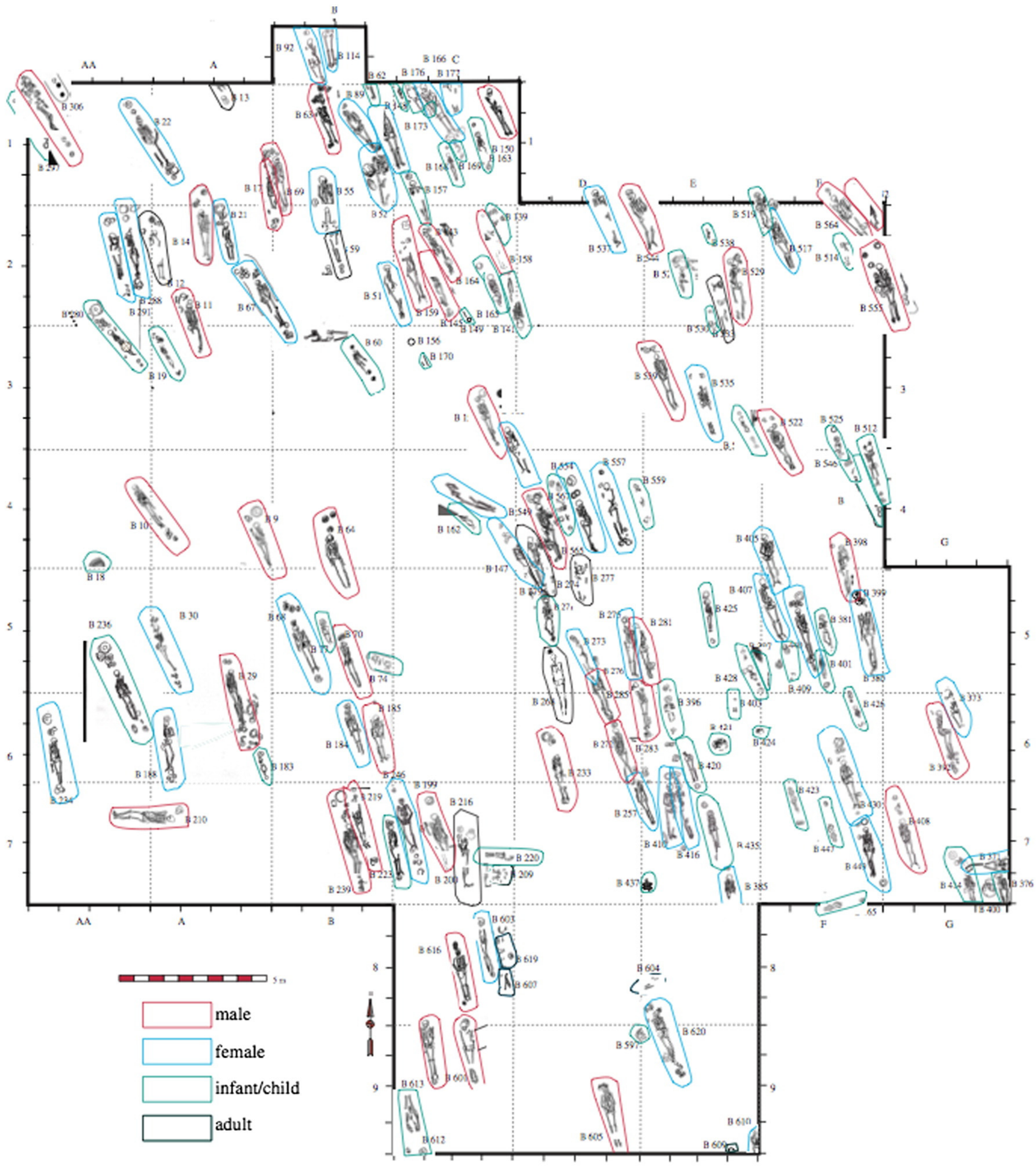

Fig. 1. Phase 4 Bronze Age burials.

difficult – as he himself stressed, his approach is “bound to be to a certain extent arbitrary and dependent on the eye of the beholder” (Higham and Kijngam, 2012:515).

3. Exploring spatial groups

It should be noted at the outset that any patterns identified in these burials are unlikely to have been caused by taphonomic processes such as patchy preservation as burials are clear, obvious and very well preserved. Rather than rely solely on Higham's subjectively identified groups, the analysis of the BA4 cemetery first entails identifying statistical evidence for uniformity, or lack thereof, in the spatial distribution of burials by comparing the observed with randomly generated uniform data. Exploratory tests for statistical evidence of clustering will then be examined before k-nearest neighbour and sphere-of-influence graphing to visually identify any clusters.

An important concept in spatial statistics is that of complete spatial randomness (CSR) (Diggle, 2003; Illian et al., 2008). If we have n points within some bounded region R, then CSR implies that the observed points are an independent sample from the 2-dimensional uniform distribution on R. In other words, the probability density function of an observed point pattern will be constant over the study region R.

If there are clusters in the phase four Bronze Age burials of Ban Non Wat (or if we find evidence to support this) then we may conclude the observations are not uniformly distributed in R, which in turn indicates that CSR does not hold.

3.1. Kernel density estimation

In order to assess uniformity of the density of the point pattern we turn to kernel smoothing. First, we calculate a two-dimensional kernel density estimate of the observed burial pattern (see Wand and Jones,

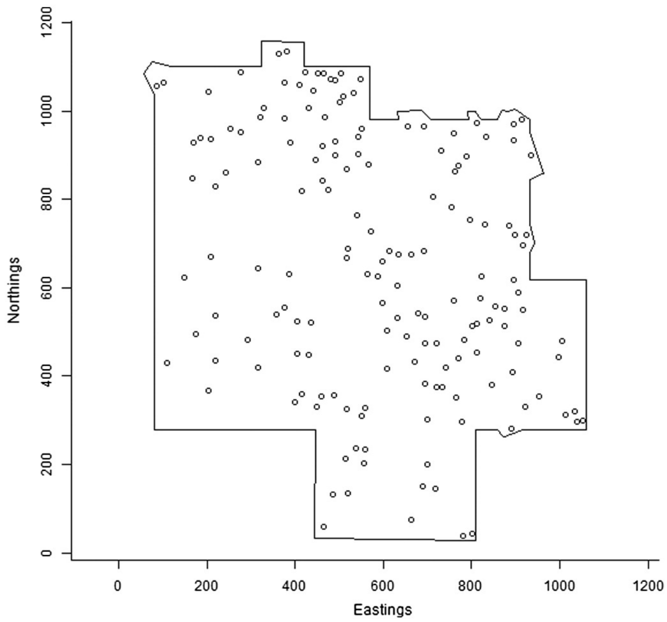

Fig. 2. Phase 4 Bronze Age burial point pattern.

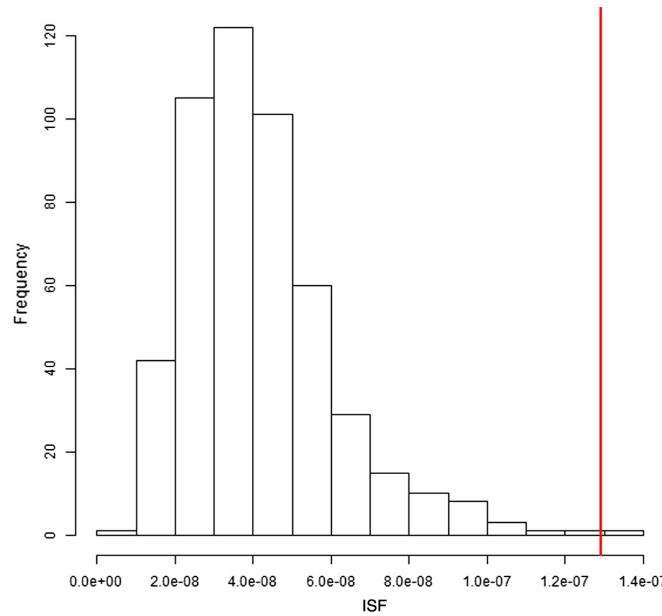

Fig. 3. Empirical sampling distribution for kernel-based ISE assuming CSR of n points in R. The test statistic t is given as a solid vertical line. (For interpretation of the references to colour in this figure, the reader is referred to the web version of this article.)

1995), $\hat{f}(x)$; $x \in R$. Then, we calculate the integrated squared error (ISE) between $\hat{f}$ and F, a constant equal to the uniform density across R, at all x. Call this value t; mathematically speaking, $t = \int_R (\hat{f}(x) - F)^2, \; dx$. In a nutshell, t therefore provides us with a number that reflects the overall departure of $\hat{f}$ from a perfectly uniform density.

On its own, t itself is not especially useful, and depends on the scale of the data. However, this value is subsequently compared to the ISE calculated for the kernel-estimated densities of 499 artificially simulated point patterns of the same size and generated in the same region R as the observed data. Call these artificial ISEs t^*. Collectively, these values give us an empirical distribution of the ISE, for kernel density estimates for samples of size n falling in R, *under the assumption of CSR*. This distribution is plotted as a histogram in Fig. 3 and the value of t calculated from $\hat{f}$ based on the observed data set is superimposed as a red vertical line.

The ISE for the true point pattern is extreme when compared to the distribution of t^*. An empirical p-value of 0.002 is obtained with respect to t, which is significant at a conventional 99% threshold. Thus, we have numerical evidence through this approach that supports the fact that the data are not uniformly distributed.

3.2. The K-test

In finding that the point pattern of BA4 burials are unlikely to be uniformly distributed in R, it is useful to review whether this could be due to point aggregation or repulsion, the former where points cluster more, or repulsion, where they are more isolated than might be anticipated under the assumption of uniformity. One famous approach to examining this involves the evaluation of Ripley's K-function (Ripley, 1977).

The K-function is a widely used function that characterises the point pattern in terms of the number of points within a disc of radius R centred at a randomly selected point x_i. Once this has been computed for the data set at hand, yielding $\widehat{K}(r)$ (for a range of values of R), it is compared to the theoretical value calculated under the assumption of complete spatial randomness given by $K(r) = \pi r^2$.

These two curves are plotted in Fig. 4 along with the corresponding 95% empirical tolerance envelope for $K(r)$; a region in which we are 95% confident the estimated K value of a point pattern from a uniform point process will fall. The black solid line represents the estimated value $\widehat{K}(r)$ for the observed point pattern, the red broken line represents the theoretical value of K for a point pattern with the property of CSR, and the grey band represents the empirical 95% tolerance envelope for this value.

As our estimated values of the K-function for the observed data are consistently outside of the tolerance envelope, particularly for mid- to high-radii, we have further evidence to suggest that our data are not from a uniform distribution. In addition, as they are consistently *above* the envelope, this indicates that $\widehat{K}(r)$ is significantly greater than $K(r) = \pi r^2$ meaning that the typical point has more near neighbours than we would expect under the condition of uniformity. Thus, we have statistical evidence that the phase four Bronze Age burials of Ban Non Wat exhibit aggregation.

3.3. Graphical cluster detection

Having performed and concluded statistical evidence of non-uniformity and point aggregation via simulation with respect to kernel

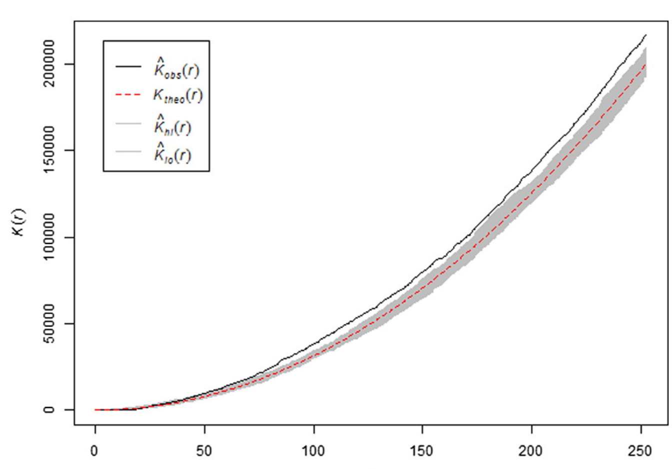

Fig. 4. Estimated K-function for the observed data, $\widehat{\boldsymbol{K}}$, with 95% empirical tolerance envelope for the theoretical K. (For interpretation of the references to colour in this figure, the reader is referred to the web version of this article.)

density estimation and the *K*-function, it is now necessary to identify possible spatial groups within the excavated area. There exist a number of techniques geared toward the identification of arbitrary clusters of points in space, generally classified within the realm of *percolation theory* (for a general overview of technical details, see e.g. Stauffer and Aharony, 1992). One well-known algorithm is *DBSCAN* (Ester et al., 1996), which works by progressively searching through the present observations and forming separate clusters based on distances to neighbouring observations. For a good description and an example of its use in archaeology, see Argote-Espino et al. (2012). While very flexible, the performance and final result of the algorithm is contingent upon specification of certain parameters, which can be difficult if the spatial scale of any potential clustering is not well understood. Furthermore, the success of cluster identification can be questionable for point patterns that are relatively diffuse over the study region. For these reasons, in this work we elect to use relatively simple graphical tools as an initial exploration of the data, with the secondary aim that any conclusions drawn will help inform a more rigorous statistical investigation thereof in future work.

Two visual cluster detection tools will be employed to help: *K*-nearest neighbour and sphere-of-influence graphing. The former simply involves drawing a line segment between each point and its *K* nearest neighbours. We found that a *K* value of 3 to 5 was most appropriate, in line with recommendations by others (e.g. Illian et al., 2008). These three versions of the *K*-nearest neighbour graph are visible in Fig. 5.

The sphere-of-influence method is slightly less prone to subjectivity by obviating the need to choose *K*. This approach involves creating a disc around each point with a radius equal to the distance between that point and its nearest neighbour (Illian et al., 2008). Line segments are then drawn between any two points with intersecting discs, thus highlighting clusters and gaps in the point pattern. The sphere-of-influence graph for our data is given in Fig. 6.

Groups are identified when the line segments create a clear, isolated cluster. As may be seen in Figs. 5 and 6, both techniques isolate a group in the north-eastern corner linked only by a tenuous line, if any, to a second group lying to the south. This group is a mirror image of that suggested by Higham as his group E. A second group lies in the north-western corner of the site, again only tenuously linked to the remaining observations, and matches Higham's group A. The third, located in the south-eastern part of the site, is a combination of Higham's groups C and D and the six most eastern burials in Higham's group B. These might well in fact represent a group that extended beyond the original excavation area. The final group is located in the south-eastern sector and matches Higham's group B, save for the six graves assigned to the group to the east.

Based on this investigation, and in contrast to Higham's original groupings, we conclude the presence of four spatial groups as defined above, and designated them W–Z in Fig. 7.

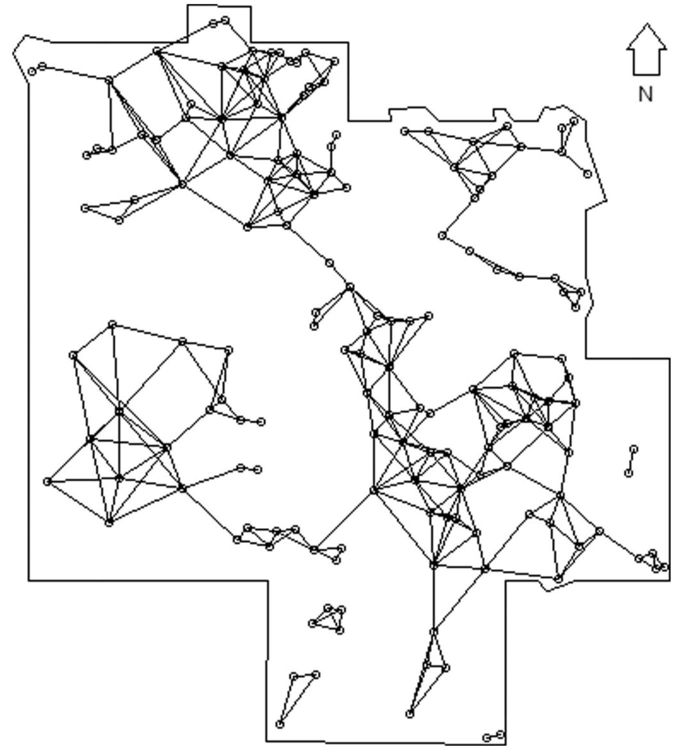

Fig. 6. Sphere-of-influence graph for the BA4 burials.

4. Modelling the data

We have visually identified four significant groups of BA4 burials at Ban Non Wat. This is the necessary prerequisite to exploring how these might differ in terms of mortuary treatment. It is emphasised that no differences were noted in the previous descriptions of this particular phase.

4.1. Logistic regression

To begin, we employ multinomial logistic regression to isolate any possibly significant variations between groups. Group W is taken to be the baseline response category in all subsequent models. The potential predictors consisted of the sex of the interred individual in each grave (where available) as well as the counts of the many different kinds of burial goods. In the case of the number of shell disc beads, it was not considered appropriate to treat this variable as a count due to the large range of values observed (0–470) coupled with its heavily skewed

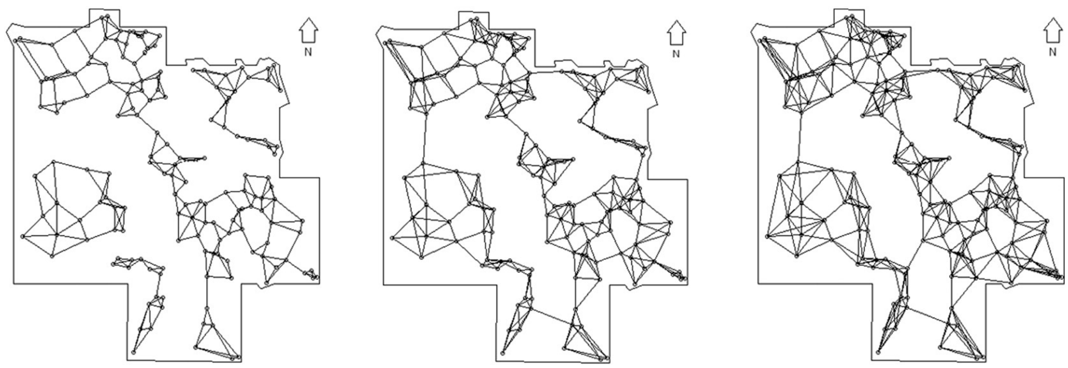

Fig. 5. *K*-nearest neighbour graphs of the BA4 burials, with *K* set to 3, 4 and 5, respectively from left to right.

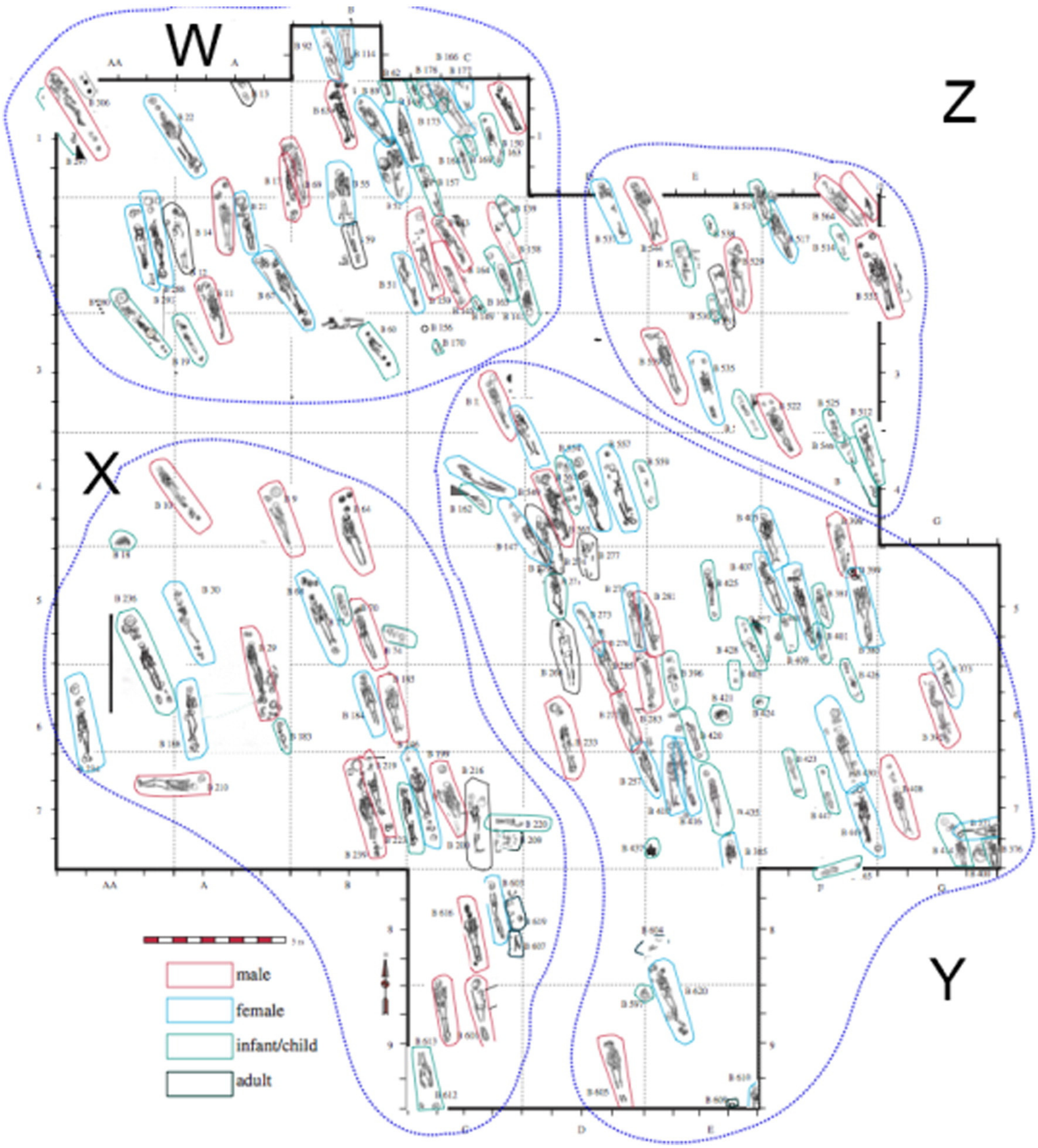

Fig. 7. Burial groups as identified by graphical cluster detection.

nature (i.e. a large number of zero-counts). Instead, this variable was treated as categorical with two levels, presence and absence, which is additionally appropriate considering the fact that these shells often make up a single ornament.

The procedure for finding an appropriate model followed a staged, bottom-up approach, to afford us the most insight into the impact of the predictor(s) on the response variable of spatial group. This strategy involved initially fitting each of the individual covariates separately to ascertain which are significant predictors on their own. The next stage of the bottom-up approach involves combining these significant covariates into unique two-way models, then three-way models and so on in order to explore which covariates maintain or lose their significance when other variables are accounted for.

For the single predictor stage (output not shown), we found that there are intriguing differences between the identified groups on the basis of three categories of mortuary offering that have not been identified in previous analyses of this Bronze Age cemetery-the number of pottery vessels, bivalve shells, and the presence of shell disc beads. Burials in the western part, Groups W and X, are more likely to have more pottery vessels. Burials in Group X, have fewer bivalve shells; while group W is set apart on the rarity of shell disc beads.

These three variables were then combined in three unique additive two-way models, reported in Tables 1–3.

When 'number of pots' and 'number of bivalve shells' are both covariates in the same model for the groups that we have identified, they are still significant to much the same extent as when they were fit

Table 1
Odds-ratios and corresponding 95% confidence intervals (CI) of the two-way model containing the covariates 'number of pots' and 'number of bivalve shell.

Group	Number of pots		Number of bivalve shells	
	Estimate	95% CI	Estimate	95% CI
X	0.97	(0.85, 1.10)	0.21	(0.05, 0.94)
Y	0.88	(0.78, 0.99)	0.78	(0.40, 1.52)
Z	0.81	(0.67, 0.98)	0.71	(0.27, 1.85)

Table 2
Odds-ratios and corresponding 95% confidence intervals (CI) of the two-way model containing the covariates 'number of pots' and 'presence of shell disc beads.'

Group	Number of pots		Presence of shell disc beads	
	Estimate	95% CI	Estimate	95% CI
X	1.02	(0.90, 1.17)	0.15	(0.04, 0.50)
Y	0.95	(0.84, 1.08)	0.13	(0.04, 0.37)
Z	0.88	(0.73, 1.07)	0.12	(0.03, 0.46)

Table 4
Odds-ratios and corresponding 95% confidence intervals (CI) of the three-way model.

Group	Number of Pots		Number of Bivalve Shells		Presence of Shell Disc Beads	
	Estimate	95% CI	Estimate	95% CI	Estimate	95% CI
X	1.04	(0.91, 1.20)	0.22	(0.05,1.00)	0.15	(0.04, 0.54)
Y	0.95	(0.84, 1.08)	0.83	(0.41, 1.70)	0.13	(0.04, 0.38)
Z	0.88	(0.72, 1.08)	0.77	(0.28, 2.07)	0.12	(0.031, 0.47)

individually. The exponentials of the coefficients, providing the estimated odds-ratios of changing from the reference category of the response to each of the non-reference categories, have changed very little from the simpler models.

In Table 2, we can clearly see that 'number of pots' has lost all significance once the presence of shell disc beads is also taken into account in the model. The factor 'presence of shell disc beads' on the other hand has retained its high significance at all three levels of the outcome variable.

When 'presence of shell disc beads' and 'number of bivalve shells' are combined in the same model, 'number of bivalve shells' is no longer significant at any level. 'Presence of shell disc beads', however, is still highly significant at all levels of the outcome variable. The significance of bivalve shells in group Y of the cemetery has diminished when 'presence of shell disc beads' is also taken into account but has had little effect on the significance of the presence or absence of shell disc beads.

Finally, the three-way model for these data was fitted. From Table 4 we can see that the only variable that retains noticeable significance is the factor 'presence of shell disc beads'. The odds-ratios imply a substantially reduced chance of falling in any of the non-reference levels of the response 'shell disc beads are present.'

We conclude that there are three important variables in determining the odds of a burial belonging to any one of the four identified groups: Number of ceramic pots, number of bivalve shells and presence or absence of shell disc beads. Of these, the most influential is the presence of the shell disc beads. Indeed, when combined with the other two in two-way and three-way models, the significance of pots and bivalve shells diminishes. Overall, the results strongly suggest Groups X, Y, and Z differ from W in terms of a substantially reduced likelihood of individuals being interred with shell disc beads.

4.2. Density ratios

To visually explore the spatial variation in burials as determined by the nature of the finds, we turn to kernel estimation of the so-called 'relative risk function' (Bithell, 1991; Kelsall and Diggle, 1995; Hazelton and Davies, 2009). This tool, originally defined for epidemiological studies to determine fluctuations in disease risk over a geographical region, has since seen popular use in many other disciplines, including archaeology (see e.g. Bevan, 2012; Bevan et al., 2013). Kernel relative risk involves the calculation of the ratio of two probability density functions, given as $\hat{s}(x) = \hat{f}/\hat{g}; x \in R$, for two-dimensional kernel estimates $\hat{f}$ and $\hat{g}$.

We will examine these density ratio estimates for the three predictor variables highlighted in the logistic regression modelling. With respect to each of these variables in turn, we split the observations into two categories. For shell disc beads, the data are already identifiable as such—one for burials with shell disc beads present, the other for absent. The remaining variables, number of pots and number bivalve shells, are re-cast to match this dichotomy-the observations are split into categories of those with a zero count (say, $c_i = 0$ for burial i), and those with a non-zero count ($c_i > 0$). We produce an estimate $\hat{s}$ with the 'numerator' density estimate $\hat{f}$ used for the presence category and the 'denominator' estimate $\hat{g}$ used for the absence category, for each of the three variables. In addition, for the bivalve shells and pots variables, $\hat{f}$ is multiplicatively weighted by the c_i (lending more weight to observations in the presence category with more items). Further technical details on this estimator and our implementation thereof, including issues such as bandwidth (smoothing parameter) selection, can be obtained from the authors upon request. All computations were performed in the R environment (R Core Team, 2015), using the packages 'spatstat' (Baddeley and Turner, 2005) and 'sparr' (Davies et al., 2011).

The result of a density ratio estimate is a surface $\hat{s}$ over the study region R which shows peaks in areas where $\hat{f} > \hat{g}$, troughs where $\hat{f} < \hat{g}$, and flatness at $\hat{s} = 1$ where $\hat{f} = \hat{g}$. Statistical significance of any peaks/troughs can be determined by 'tolerance contours' (Hazelton and Davies, 2009). These distinguish statistically significant fluctuations from random noise in $\hat{s}$.

The three estimated surfaces for our data are plotted as heat map-style plots in Fig. 8. In doing so it is customary to work on the log-scale for visual symmetry around zero, which does not affect spatial interpretations.

It is important to remember that the density-ratio approach is completely independent of the specification of the spatial groups W–Z (Fig. 6) as required for the logistic regression models. As such, the estimated surfaces here provide an opportunity for a kind of 'cross-validation' in terms of the methodology employed, based on the results obtained earlier. In the case of shell disc beads, the density ratio confirms their rarity in what can be identified group W, but it also reveals a progressive increase in their provenance as one proceeds in a south-easterly direction across the cemetery. Bivalve shells show a different pattern, their rarity concentrating in the area that is represented by group X, with matching increases in the other three groups. For pottery vessels, the density ratio surface reveals a relative scarcity in an area corresponding to group Z and a rise in the areas of both groups W and Y. In the case of Y, the values for pots increase as one proceeds to the west. It is concluded that density ratios, conform to the results of multinomial logistic regression, particularly for shell disc beads and bivalve shells.

Table 3
Odds-ratios and corresponding 95% confidence intervals (CI) of the two-way model containing the covariates 'number of bivalve shells' and 'presence of shell disc beads'.

Group	Number of bivalve shells		Presence of shell disc beads	
	Estimate	95% CI	Estimate	95% CI
X	0.24	(0.05, 1.05)	0.173	(0.05, 0.57)
Y	0.82	(0.41, 1.65)	0.111	(0.04, 032)
Z	0.72	(0.27, 1.94)	0.089	(0.02, 0.33)

5. Discussion

Over seven seasons, an area was opened in the centre of Ban Non Wat, a large moated settlement on the Khorat Plateau of Northeast Thailand. The excavations have been fully published, making the data available for further analyses (Higham and Kijngam, 2009, 2011, 2012; Higham, 2012). As White has noted, Ban Non Wat is a great site, stressing that "how the new data can best be conceptualized socially, economically and politically, and then integrated with the larger set of regional data for this period, will likely engage regional archaeologists for at least the coming decade" (White, 2013:911).

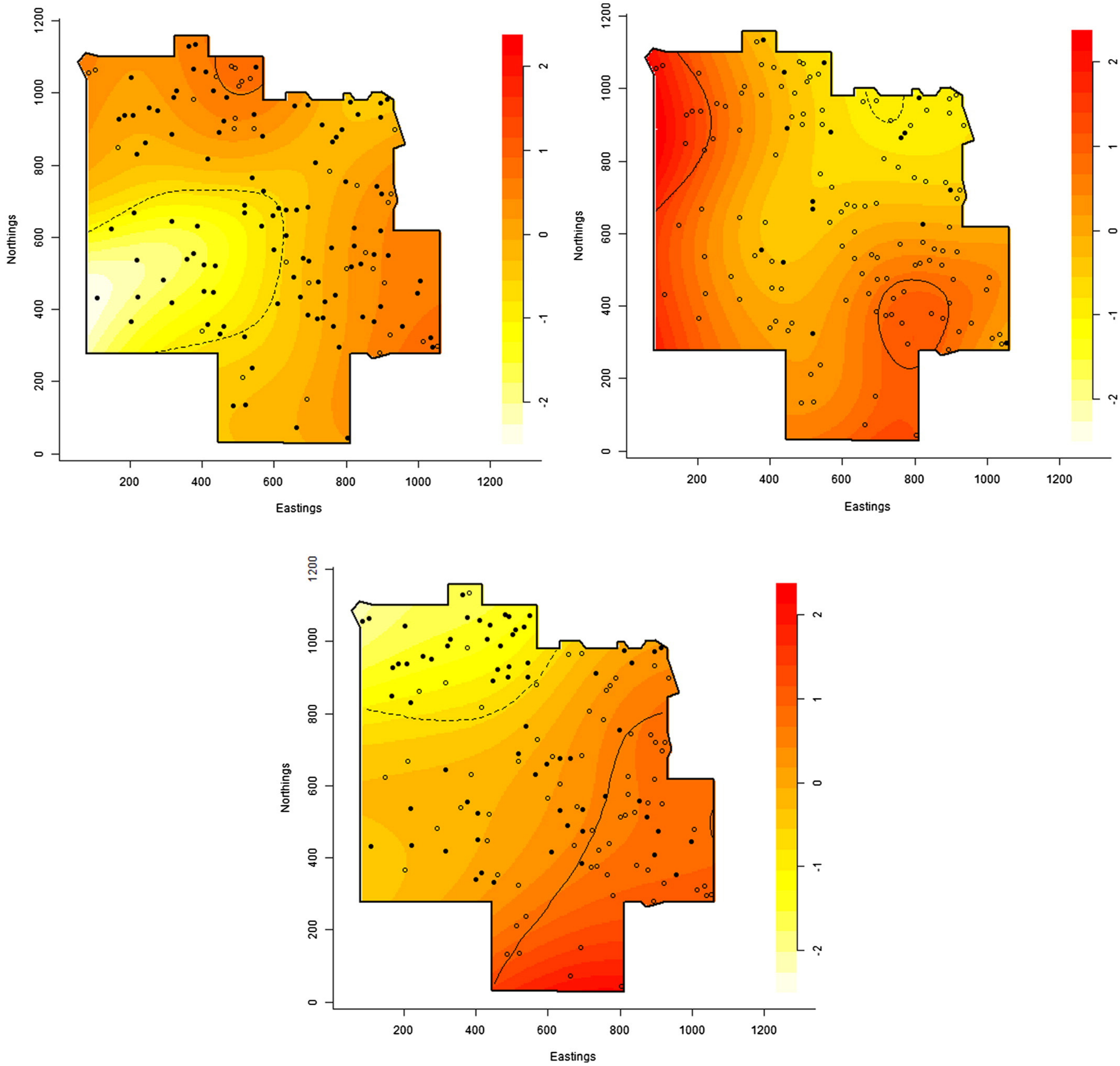

Fig. 8. Log-density ratios for presence/absence of bivalve shells (top left); shell disc beads (top right); and ceramic pots (bottom). Each surface includes tolerance contours delineating statistically significant peaks (solid line) and troughs (dashed line) at the 5% level. Filled dots indicate absence and empty dots indicate presence.

The transition into the Bronze Age took place in the late 11th century BC, and witnessed a significant rise in the rituals of death. While in BA1 graves the forms of the ceramic vessels showed little change from their immediate Neolithic predecessors, their quality was greatly improved and there were many more of them. Graves were more deeply excavated, exotic shell ornaments increased markedly, and the majority of the dead were accompanied by socketed copper base axes. During BA2, there was an unparalleled rise in the rituals that attended interment. There were now many more pot forms, and vessels were on occasion painted with complex designs of human faces and dancers. Copper base axes, chisels, awls, anklets and bells were placed with the dead, who were interred wearing tens of thousands of shell beads, as well as multiple marine shell and marble bangles. This degree of mortuary wealth continued into BA3A, but from BA3B, the mortuary rituals remained but the quantum of mortuary offerings fell as sharply and as rapidly as it had earlier risen.

The BA4 cemetery contained 162 graves which were divided into five groups in Higham's original analysis (Higham, 2012). In this paper, we have returned to this phase in order to evaluate the validity of these groups with the aid of statistical methods and identify if there are any significant differences between them that might reflect chronological or social distinctions. Having generated a point pattern derived from the centroid of each grave, we first examined whether or not it was consistent with a uniform distribution. The ISE between the estimated point density and a perfectly uniform density was calculated and compared with the same measure for randomly generated uniform point patterns, and was found to be highly significantly different (p-value $= 0.002$). By additionally evaluating the K-function, these results demonstrate evidence against the assumption of CSR for burial pattern. Thereafter, both *K*-nearest neighbour and the sphere-of-influence graphs were used to assist us in identifying four spatial concentrations of graves, which differed only slightly from the five that were suggested by Higham's visual inspection.

Multinomial logistic regression was then deployed to seek characteristic differences between these four groups. The presence of shell disc beads and the number of pottery vessels and bivalve shells were found to be significant. These findings were confirmed by the results of spatial density ratios for each variable, particularly for shell disc beads and bivalve shells.

5.1. Archaeological conclusions

In his initial analysis of the Phase Four Bronze Age cemetery at Ban Non Wat, Higham (2012) did not identify any differences between his five putative groups in terms of their mortuary offerings. In contrast we have identified four burial nuclei, potentially distinguished from each other by the number of pottery vessels, the number of bivalve shells and the presence or absence in a burial of shell disc beads. Each of these artefacts has the potential to illuminate underlying social factors.

Animal bones were commonly found in burials in association with carefully placed ceramic vessels and are believed to reflect mortuary feasting, which remains a common practice in South East Asia to this day (Hayden, 2009). Thus, pottery vessel frequencies are most likely to reflect the social persona of that individual, as a reflection of the degree of mortuary feasting that accompanied the interment. Bivalve shells were placed with the dead, in specific positions relative to the corpse, over much of South East Asia over a period of at least 2000 years. They have been interpreted as symbols of fertility and rebirth (Higham and Kijngam, 2012). Shell disc beads take much energy to manufacture. No isotopic studies have been applied to these beads as yet, but they may well have been of exotic marine origin. They are certainly seen as symbols of wealth and status, since a large number of such beads is usually associated with other exotic ornaments (Higham and Kijngam, 2012).

There are two main ways in which group differences may be interpreted. The four groups identified could represent distinct but contemporary individuals related by blood and/or marriage, where differences in mortuary goods between groups reflect differences in status, wealth or values with respect to the mortuary ritual. Alternatively, they could also represent a horizontal stratigraphic sequence which exhibits change over time. We do not have enough radiocarbon determinations to test the latter, though it is noted that this phase of the Bronze Age at Ban Non Wat has a span of little more than a century, which makes significant chronological differences unlikely (Higham and Higham, 2009).

There is an overall low incidence of ceramic vessels in the eastern part of the site (bottom image of Fig. 6). This part also contains several burials associated with grey clay. Clay was very common as a mortuary offering during BA5, and is thought to have been used as a dye or mordant in manufacturing fabric due to its close association in graves with spindle whorls. Moreover, one burial that fell in group Z (ID no. 517) contains a form 48 ceramic vessel that is typically associated with BA5. The position of this burial and the fact that it contains seven BA4 pot forms suggest it is late in the BA4 sequence. Therefore, the most plausible interpretation of the identified pattern in the distribution of ceramic vessels within this cemetery is that their overall decrease reflects a slight decline in the ritual value of pots over time, with the eastern burials being the latest in the BA4 cemetery. The variation we see within each group could be due to the effect of individual persona on the degree of mortuary feasting.

The concentration of bivalve shells in the area of spatial group W (see top left image of Fig. 6) is most likely to indicate that the individuals were particularly concerned with religious issues, for the placement and form of the bivalve shells are thought to symbolize fertility and rebirth (Higham and Kijngam, 2012). In contrast, group W also exhibits the lowest concentration of shell disc beads (Fig. 6, top right). A high concentration of beads is most parsimoniously interpreted as reflecting a group with greater access to symbols of wealth. Thus this area of the cemetery also appears relatively poor.

With a statistical exploration of the spatial and social variability of burials, it is possible to explore more deeply the social and chronological aspects of mortuary rituals. The excavation of Ban Non Wat represents a ground-breaking stage in regional prehistory due to the area examined, that has allowed a more in-depth exploration of social organisation that at any other site in Southeast Asia. Our statistical analyses have demonstrated the utility of the methods presented here for archaeological contexts but also provided new insights into the social organisation that initial analyses did not. These have enhanced and enriched our understanding of social change within the Bronze Age sequence.

Our methods can be adjusted to explore further this particular phase at Ban Non Wat and adapted to explore other phases and sites. Within Southeast Asia, it could be applied to the mortuary remains from Non Nok Tha and Nong Nor (Bayard and Solheim, 2010; Higham and Thosorat, 1998). Our understanding of the extensive areas opened in many prehistoric Chinese cemeteries would benefit from our approach. With respect to the density ratios, the effects of using spatially adaptive (rather than fixed/constant) kernel smoothing (Davies and Hazelton, 2010) could be explored. In addition, subsets of the data could be examined in greater detail. In particular, the males, females and infants could be studied separately in order to explore whether there were differences in how each group treated the different sexes and what social factors this may highlight, and whether differences existed in the way infants in each group were interred. An analysis of differences in treatment by gender for Bronze Age 4 has failed to identify any significant distinctions (Higham and Manly, 2012).

The next logical step would be to apply these methods to the other stages at Ban Non Wat to see if we see similar patterns with these same artefacts proving significant, or whether we see different patterns. Such results would enhance the overall understanding of social change at this site over time. Finally, it would be of immense interest to see what these methods could reveal about nearby sites in South East Asia to explore similarities and differences in their social development in order to provide a holistic picture of social organisation in this area of South East Asia after the advent of bronze technology.

This study has provided new insights on a complex data set and presented an exploratory approach that may be applied to future analyses that deal with similar data. Identifying relatively subtle distinctions that are not immediately obvious is seen as a major step in the methodology of social distinctions reflected in prehistoric ritual behaviour.

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