A FUNCTIONAL ESTIMATOR OF POPULATION FROM FLOOR AREA
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ABSTRACT
This paper presents an alternative to Naroll's formula for estimating population size from settlement area. It uses an allometric model modified for hunter-gatherer camps. In this model, the parameters are derived theoretically to describe mean area per person and the geometric properties of population distribution. The proposed model is then tested on 16 !Kung Bushmen settlements.

Museum of Anthropology
The University of Michigan
July, 1973

Archaeologists have long sought a method for estimating the sizes of populations that were in residence in prehistoric sites. Recent attempts to relate population size to living area have followed 2 basic courses. One of these is directed toward establishing a constant divisor which, when applied to area calculations, yields an approximate population size; the other attempts to define functional rates of change between these 2 variables and makes use of a special form of the allometric principle.

The law of allometric growth has been widely used in the biological and social sciences. This law states that "the rate of relative growth of an organ is a constant fraction of the relative growth of the total organism" (Nordbeck 1971:54). The allometric principle holds in growth relationships of several forms (Bertalanffy 1968:64), but only the logistic form will be considered in this paper.

Naroll (1962) applies this principle to 18 societies using floor area and settlement population as an allometric pair, and suggests that the population of a settlement is a constant fraction of its floor area. More precisely, he concludes that archaeologists can roughly estimate the population of a prehistoric settlement as 1/10 of the floor area in square meters of dwellings. Although this method might prove useful in certain situations (LeBlanc 1971), it is inappropriate for hunting and gathering societies for the following reasons:

(1) Area under the roofs of dwellings is not a meaningful measurement for groups who carry out most household tasks outside their small dwellings.

(2) Floor areas of dwellings are difficult to estimate from archaeological remains, particularly those of the paleolithic. Total settlement area would provide a more accurate and practical measure of living space.

(3) Naroll allows for no flexibility in the parameters of his model to make allowances for different settlement types and their corresponding density distributions. He proposes a constant to describe the area per person in situations as diverse as villages of 75 and cities of 200,000 people.

(4) Naroll does not recognize the possibility of cultural variation in interpersonal living space.

(5) Exactly how Naroll derives this constant of 10 m² per person is unclear. Using the model, area = a × Population^b. On his data set, he obtains an a-value of 21.7 and a b-value of .84195. Because the exponent (b-value) is not equal to 1, population cannot be a constant fraction of floor area. Rather, the rate of relative growth of floor area will be a constant fraction, .84, of that of population. And since .84 < 1 there will be increasingly less area per person as population size gets larger. Naroll then ignores his own empirical findings, and for reasons which he does not specify and by a method which he does not explain, rounds off the parameters of his model to a = 10 and b = 1. Thus, he chooses only the special case of the log/log allometric model that could make population a constant fraction of area.

Because of these reasons, Naroll's data fit his predictions poorly. Out of the 18 societies...
considered, only 8 have between 5 m² and 15 m² of living space per person. The remaining 10 have less than 5 m² or more than 15 m².

Nordbeck (1971:55) gives an alternative formulation of the law of allometric growth:

Instead of assuming the measurement of a growing individual at different times, it is assumed that a series of individuals all have the same shape (form) but are of different size. In this case, the law of allometric growth states that it is possible to estimate values of one variable y by means of measured values of another variable x.

He goes on to argue that all Swedish urban areas have the same basic form of population density. He then proposes the same model used by Næroll, \( \text{Area} = a \times \text{Population}^b \), to estimate population from total settlement area. However, in this case the b parameter is derived theoretically and describes the ratio of the dimensions of area measured to those of the shape of the population density build-up.

A profile through an urban area will always be of the same type as the diagram in Fig. 1. This diagram reminds one very much of a corresponding profile through a volcano. The population density is low in rural districts and increases very rapidly in the outlying suburban areas. The downtown (center) has a lower residual population density than the apartment house dwelling area.

It seems legitimate to claim that all urban areas have the same form and shape. Thus, it follows that the allometric formula is valid for urban areas. In the same way that a volcano is a volume of dimension 3, so we may consider population as a Tatort (urban area) as a volume with the same dimensionality. The area A of a Tatort has the dimension 2. It follows then that the b-value in the allometric growth formula \( A = a \times \text{Population}^b \) ought to be 2/3 [Nordbeck 1971:56-57].

Could Nordbeck's formulation of the law of allometric growth and his theoretical derivation of b-values be modified for other types of settlements, it would have considerable advantages over Næroll's model. Unlike the latter, it utilizes total settlement area rather than floor area as a predictor of population. In addition, if b-values were varied according to settlement type, the allometric pair—area and population—would be related differently for each set of habitation sites which are distinctly dissimilar in form. This distinction is desirable. One would not expect the ratio of area per person to be the same for short-term hunter's campsites, in which relationships are largely kin-based and in which essentially no physical barriers separate individuals, as that for cities, in which relationships are more frequently associative and in which substantial physical barriers exist. Finally, in Nordbeck's model, the a-value (the intercept of the regression line) is a free parameter with empirically derived values that can be used to compare average densities of population between different societies while settlement form is held constant.

Before application of Nordbeck's model to hunting and gathering societies can be made, 2 assumptions are necessary: (1) that all hunter-gatherer camps have the same form (shape) of population distribution; and (2) that Nordbeck's theoretical derivation of the b-value can be applicable to this form.

In order to argue that hunter-gatherer camps have the same form, the definition of a camp will be limited to habitation sites; temporary gathering or butchering stations are excluded. According to many ethnographic reports (Turnbull 1965; Williams 1968; Woodburn 1968), such camps are composed of an aggregation of discrete household units arranged according to kin ties and current personal relations. As Yellen (n.d.) has observed among the !Kung Bushmen, each household is a spatially and functionally integral unit; a hut/hearth area contains the remains of all activities carried out in a household context which constitutes about 90% of all camp activities. Yellen goes on to point out that because most camp activities are household-centered, debris resulting from them is not spatially segregated, but rather lumped in the hut/hearth midden. The huts are arranged in a roughly circular layout with the center left empty for communal activities such as children's play, dancing, and so forth.

Consequently, hunter-gatherer camps should have the following regularities:

1. All hut/hearth units within a camp should be approximate replicates of one another in both form and content.

2. Because the camps are loose aggregates of the above similar hut/hearth units, they should have the same basic form with certain variations caused by topography, current personal relationships, location of shade, and so on.

Data from the !Kung Bushmen are examined to see if such patterns do in fact exist.

The data used here are taken from Yellen's ethnoarchaeological study of the !Kung Bushmen. These data include maps of 16 temporary
Fig. 1. Four two- and three-hut Bushmen camps (a-d) rotated to the same orientation and superimposed (e). Heavy lines delineate huts and lighter lines show extent of charcoal, bone, vegetable, and other debris around the hearth. Shaded areas represent hearths. In a-d, arrows indicate north in actual orientations.
Bushman camps varying in size, location, length of habitation, and number of occupations. Interview data regarding ownership of huts, length of stay, number of inhabitants, and animals eaten at each camp were also recorded. Fig. 1 shows 8 hut/hearth units from a single camp which are rotated to have identical orientations. As is clear from this figure, all 8 of these households are virtual duplicates of one another in both form and content. There is always an empty space where the hut was located, a hearth 1-1.5 m from the hut, and a thick deposit around the hearth composed of ash, floral and faunal remains, and other miscellaneous items.

Subsequently, 3 small camps (Fig. 2) and 2 large ones (Fig. 3) are superimposed upon each other and rotated until they are in a position where the features of one are directly over the similar features of the other. Other camps could have been added to these figures without significantly changing the results, but were left
Fig. 3. Diagram of population density: a. hunter-gatherer campsites, b. village, c. urban area. Plan view on the left and profile on the right. Arrows represent a. linear, b. areal, and c. cubic dimensions of population distribution.

out to avoid confusion. The huts, hearths, and debris of the camps shown in Figs. 2 and 3 overlap to such a degree that each camp seems but a replicate of the other, with only slight differences due to variability in topography, location of shade, and so on. Only in the case
Fig. 6. The relationship between settlement area (x-axis) and population (y-axis) of Bushmen camps. Area = \( a \times \text{Population}^b \) plotted on double logarithmic paper.

\[ a = 6.245, b = 0.750 \]
of reoccupation of an abandoned site does the integrity of hut/hearth units and the regular form of the camp layout break down.

Thus, it seems reasonable to assume that all single occupation camps have a regular shape—one which is roughly circular, with the population distributed fairly regularly around the perimeter as shown in Fig. 3a. It follows, then, that the populations of hunter-gatherer camps are distributed along a line (Fig. 3a), the perimeter of the circle, as opposed to the populations of cities which are distributed in a cubic dimension as cited by Nordbeck (Fig. 3c). Villages with more or less completely and evenly filled areas, but little vertical dimension, have an areal distribution. Correspondingly, the denominator of the b-value representing settlement dimensionality of population distribution would be 1 for camps, 2 for villages, and 3 for urban areas. The numerator in all cases is 2, the constant dimension of area. Thus, the b-value for camps would be 2/1.

The allometric model with the above parameter values is then applied to the 16 Bushman camps previously described. Log of camp area was regressed on log of camp population. Measurements for area of camp include all of the space within a continuous border that encircles huts and major concentrations of bone, charcoal, vegetable remains, and other debris. This area always encompasses at least 90% of the total remains as well as all empty spaces between major concentrations of material. The figures for the number of inhabitants of each camp come from Yellen’s observations and interview data.

The results of the regression of area on population indicate that the proposed model fits the data quite precisely. The b-value, or slope of the regression line, was 1.96, which is remarkably close to the predicted value of 2.0. (See Fig. 4.) The correlation coefficient of .91 is also high. The corresponding a-value is close to zero, −0.23±0.68. These results give a starting point of about 5.9 m²/person for camps with a population of 10, and as predicted by the allometric formula, the area/person increases to 10.2 m²/person for camps of 25. Thus, any constant figure for area per person such as that proposed by Naroll would provide very inaccurate population estimates for camp sizes on either end of the spectrum.

Although the law of allometric growth with theoretically derived b-values seems to hold very well for a set of 16 Bushman camps, and is a well-tested model for urban situations (Nordbeck 1971; Tobler 1969), it requires considerably more testing on data from hunting-gathering camps. One critical question is whether or not the a-value will be similar for all band societies. That is, the allometric relationship could hold for the b-values (the slope of the regression line), although the intercept of this line could vary from society to society. Another unanswered question is whether this relationship continues to hold for Bushman camps with more than 25 individuals. Data will be gathered to answer this question in the near future.

However, if, after sufficient testing, Nordbeck’s model, Area = a × Population^b, does hold, it will have important implications for archaeology. Population can then be estimated from total settlement area by a model that relates settlement strategy to spacing behavior without the use of an unrealistic constant.

Acknowledgments. I would like to thank John Yellen for generously making his field data available for this paper.

Bortalanstey, Ludwig von
LeBlanc, Stephen
1971 An addition to Naroll’s suggested floor area and settlement population relationship. American Antiquity 36:210-211.
Naroll, Raoul
Nordbeck, Stig
Tebler, Waldo
Tumblin, Colin
Williams, Bobby Joe
Woodburn, James
Several conversion formats are available: Steiger and Suess (1966), Ralph and Michael (1969), Michael and Ralph (1972), Ralph, Michael, and Han (1973), and Damon, Long, and Wallick (1972) have published tables; Wendland and Donley (1971) an equation; and Suess (1967), Suess (1970) and Olson (1970) graphs. An estimation of the statistical uncertainty of the age conversion is necessary for precise utilization of the radiocarbon information (Long and Rippeteau 1974), and only the table of Damon, Long, and Wallick (1972) provides this.

The purpose of this paper is to provide a more accessible conversion table for single dates utilizing data up to the summer of 1973, omitting geophysical mechanism explanations. Graphs and conversion tables which attempt to model short-term variations in the radiocarbon time scale are fundamentally ambiguous for determining the corrected ages of single samples, particularly in periods of time where the radiocarbon concentration of the atmosphere is varying rapidly. Therefore, no attempt was made to model short-term variations. However, the statistical error listed in our table includes the errors due to these short-term fluctuations.

DENDROCHRONOLOGY OF BRISTLECON PINE

Bristlecone pine (Pinus longaeva, D. K. Bailey, sp. nov.) from the White Mountains of California has been the primary source of wood, especially in the B.C. period, for the calibration of the radiocarbon time scale. Radial growth-ring sequences in core samples extracted with a Swedish increment borer have provided most of the chronologic data, even when the emphasis shifted from the living trees to standing or fallen snags or large, eroded remnants of trees. Now, with the search for wood in the range of 7000 yr old or older, we collect, after an affirmative evaluation in the field, entire pieces having the appearance of age and without specific known origin in relation to any tree, living or dead. Such remnants provide more surface area for detailed study of the very narrow and often locally absent rings that are critical in chronology building, and they constitute the principal source of tree-ring material for radiocarbon analyses.

Dendrochronologic dating of the specimens