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Making absolute population estimates in the Intermediate Area using the area and density of ceramic sherd scatters: An application of regression analysis

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ABSTRACT

The demographic dynamics of human settlements are a fundamental part of understanding complex society development, and population estimates are a fundamental part of understanding those dynamics. Many types of demographic analyses can be carried out on the basis of relative population estimates, but a deeper understanding of demographic processes can be gained by converting those estimates into absolute numbers of people. Using regression analysis this paper develops a technique for making absolute population estimates based on the area and density of ceramic sherd scatters. This technique can be used to make absolute population estimates in many parts of the world, though here its application is illustrated using data from the Intermediate Area and Amazon region. Unlike previous approaches to demographic reconstruction this technique provides a basis for establishing population error ranges for different degrees of statistical confidence.

1. Introduction

Settlement demography has long been an important subject of complex society research (Alden, 1979; de Montmollin, 1987; Johnson, 1982; Sanders et al., 1979; Wilson, 1988; Wright and Johnson, 1975). Central to the study of settlement demography are population estimates that can be used to asses demographic scale, which can be expressed in either relative or absolute terms. These estimates provide insight into a wide range of demographic processes, including growth, interaction, migration, and more, which in turn shed light on fundamental aspects of economic, political, ritual, and/or social organization. Many archaeologists remain skeptical of population estimates but they are nonetheless required for any comprehensive understanding of complex society development. Over the years the methods for making population estimates have become more refined, and the assumptions on which they are based more reliable. Only by continued attempts to refine those methods and strengthen those assumptions can the precision and reliability of population estimates improve.

The first step to making population estimates is to establish a suitable demographic proxy that can be taken to reflect the relative size of human populations in different parts of the landscape and/or different periods of time. Just what sorts of evidence archaeologists use as this proxy can be highly variable (see Drennan et al., 2015:11–43; Hassan, 1981:63–82), depending on the part of the world in which one works and the sorts of evidence that remain. One common proxy that has developed a long history of use in archaeology is the area (ha) and density (sherds/m^2) of ceramic sherd scatters (see Sanders et al., 1979), the product of which results in a combined index that quantifies the total number of sherds discarded (Drennan and Peterson, 2011; Drennan et al., 2015). This index provides a proxy that reflects the relative size of human populations, while the area and density of ceramic sherd scatters reflect the area and density of occupation. That this proxy accounts for variation in both the area and density of human settlements is one of its greatest advantages, as is the number of world regions and scales of analysis for which it can be used. This is because the basic principles of human behavior on which use of this proxy is based (Section 2) are applicable to populations regardless of their size or geographic context.

Population proxies provide relative population estimates with which many useful types of demographic analyses can be (and have been) carried out (e.g. Bauer and Covey, 2002; de Montmollin, 1987; Wright and Johnson, 1975; see Drennan et al., 2015:51–92). Our understanding of the demographic and societal processes we seek to study, however, can be taken much further by converting these estimates into absolute numbers of people:

First, absolute population estimates frame our analyses in far more socially meaningful terms. That one settlement was approximately ten times larger than another, for instance, is useful information in and of itself, but the conclusions one draws about the economic, political, ritual, or social dynamics of those settlements may be very different if

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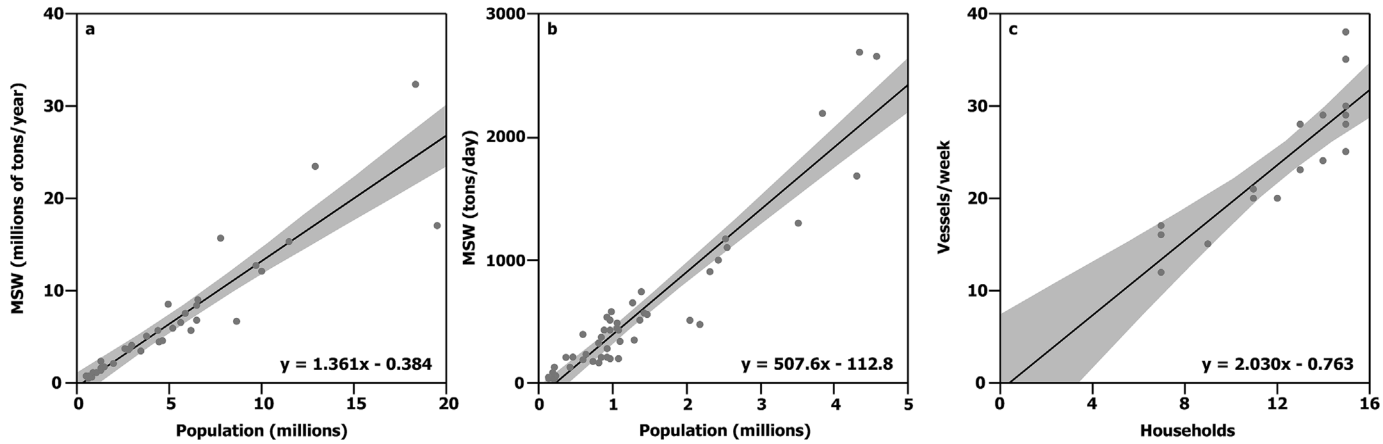

Fig. 1. Scatterplots illustrating the relationship between population size and the amount of garbage discarded in three modern-day contexts: a) the United States, excluding 13 states for which no MSW estimate was available ($r = 0.921, p < 0.0005$); b) cities in India with populations over 100,000, excluding Delhi and Greater Mumbai ($r = 0.945, p < 0.0005$); and c) Wanka communities of highland Peru ($r = 0.877, p < 0.0005$). The 90% confidence interval of the best fit-line is shown in light gray. Data from van Haaren et al., 2010, Hoornweg and Bhada-Tata 2012, and Hildebrand and Hagstrum 1999, respectively (MSW = Municipal Solid Waste).

their populations were 1000 and 100 (respectively), versus 10,000 and 1000.

Second, absolute population estimates are required to evaluate models of complex society development that invoke demographic pressure as a force of social change. Notable examples of such models are those based on resource stress (Carneiro, 1970; Santley, 1980) and scalar stress (Johnson, 1982; Kosse, 2001), both of which require comparing the size of a given population to some sort of expected demographic threshold, which is inherently expressed in absolute terms (see Bandy, 2004; Feinman, 2011; Haller, 2008; Kowalewski, 1980; Nicholas, 1989; cf. Billman, 1997).

Third, absolute population estimates can provide insight into aspects of organization that are not explicitly demographic in nature, and that may otherwise not be apparent if absolute estimates are not made. In central Panama, for instance, ceramic sherd densities revealed that settlements in the Río Tonosí valley were generally more dispersed than in the Río Parita valley; but only by making absolute population estimates was it possible to argue that such dispersal may have resulted from a system of agriculture in which families lived directly on or adjacent to the plots of land that they farmed (Berrey, 2014, 2015). Lacking evidence for either residential architecture or the perimetric features that define field boundaries in some parts of the world (Lemonnier and Vannière, 2013; see Stone, 1994), this argument was based (in part) on the amount of land estimated to have existed between households (75–100 m, on average), as inferred from estimates of residential densities (5–10 people/ha; see Drennan, 1988). Absolute population estimates, then, not only provided insight into the nature of settlement and interaction in the Río Tonosí valley, but revealed what is argued to have been a different system of agriculture than in the Río Parita valley, where settlements were more nucleated and swidden agriculture is thought to have been practiced (Haller, 2008).

Finally, absolute population estimates broaden the comparative scope of demographic analysis by providing a common basis on which to compare prehistoric populations in different parts of the world. Even if the same population proxy is used for all of the regions being compared, the estimates they produce may not necessarily be comparable. Estimates based on an area-density index, for instance, may not be comparable because of the different rates at which people used ceramics in different world regions. Such differences could have resulted from the different technologies people had at their disposal (such as the presence of metals in Europe or Asia), or from differences in daily cultural practice and in the range of activities for which ceramics were used. By taking these sorts of regional specifics into account and converting population proxies into absolute numbers of people (ideally using locally derived information from the regional context in quesiton), one is provided with a more comparable basis on which to compare prehistoric populations in different parts of the world. It also allows one to compare the size of prehistoric populations to those of the historic or modern era (e.g. Berrey, 2015; Kowalewski, 2003), a practice that has become increasingly common in the era of archaeology as a social science.

This paper presents a technique for making absolute population estimates using the area and density of ceramic sherd scatters. Specifically, it uses the best-fit line of a linear regression to assign residential densities to areas of occupation on the basis of their sherd densities. Unlike previous approaches to demographic reconstruction this method provides a basis for establishing population error ranges for different degrees of statistical confidence. Here this method is illustrated using data from the Intermediate Area and Amazon region, though it can be adapted for demographic reconstruction in other parts of the world. The data requirements that are needed to do so are discussed at the beginning of Section 3.1.

2. Demography and discard behavior

Using the area and density of ceramic sherd scatters not only as a basis for making population estimates, but one that accounts for variation in both the area and density of human occupation, is based on two general principles of discard behavior. The first is that larger groups of people produce larger amounts of garbage, and thus dispose of that garbage across larger areas and/or at greater densities than do smaller groups. This is a basic principle of human behavior that can be documented across a wide and diverse range of societies (Fig. 1). Despite the very different contexts and range of demographic scales that are represented in Fig. 1, these plots all illustrate strong and highly significant linear relationships between the size of populations and the amount of garbage they discard. This means that for any of these contexts the amount of garbage discarded by a population would provide a reasonably reliable basis on which to estimate its size relative to others within that same context. These relative estimates could then be converted into absolute numbers of people using the linear equation from each regression, though this would require repositioning the independent and dependent variables.

In behavioral terms it is the size of a population that determines the amount of garbage discarded. In regression analysis, then, population takes the place of the independent (x) variable and the amount of garbage discarded the dependent (y) variable (the latter is dependent on the former), as illustrated in Fig. 1. For the purpose of making