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Optimising human community sizes

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ABSTRACT

We examine community longevity as a function of group size in three historical, small scale agricultural samples. Community sizes of 50, 150 and 500 are disproportionately more common than other sizes; they also have greater longevity. These values mirror the natural layerings in hunter-gatherer societies and contemporary personal networks. In addition, a religious ideology seems to play an important role in allowing larger communities to maintain greater cohesion for longer than a strictly secular ideology does. The differences in optimal community size may reflect the demands of different ecologies, economies and social contexts, but, as yet, we have no explanation as to why these numbers seem to function socially so much more effectively than other values.

1. Introduction

Although humans are capable of living in structurally diverse societies, our communities, even in the digital world, have a distinctive layered structure with successive cumulative layer sizes of 15, 50, 150, 500 and 1500 (Fuchs, Sornette, & Thurner, 2014; Hamilton, Milne, Walker, Burger, & Brown, 2007; Zhou, Sornette, Hill, & Dunbar, 2005). While the smallest of these is not normally a stand-alone grouping, the others appear as natural community sizes in hunter-gatherer societies: Lehmann, Lee, and Dunbar (2014) give values of 42.8 ± 18.0SD (bands), 127.3 ± 43.8 (clans), 566.6 ± 166.2 (mega-bands) and 1727.9 ± 620.6 (tribes) for 20 contemporary hunter-gatherer societies (see also Hamilton et al., 2007; Zhou et al., 2005). These values reappear in both offline and online egocentric social networks (Hill & Dunbar, 2003; Sutcliffe, Dunbar, Binder, & Arrow, 2012; Dunbar, Arnaboldi, Conti, & Passarella, 2015; Arnaboldi, Passarella, Conti, & Dunbar, 2015; Dunbar, 2016; MacCarron, Kaski, & Dunbar, 2016), which are characterised by distinct layers that represent quite specific frequencies of interaction and levels of emotional closeness (Roberts, Dunbar, Pollet, & Kuppens, 2009), reflecting the levels of intimacy that individuals maintain with each other. Even more surprisingly, perhaps, Kordsmeyer, MacCarron, and Dunbar (2017) found that the sizes of residential campsites in contemporary Germany also adhere to these values.

This fractal structure suggests that there might be natural fission points that result in organisations having distinct sizes, with these representing optimal values that maximise some quantity such as coherence, and hence stability through time. Optimal community size will, of course, ultimately be determined by the functional demands of the socio-ecological environment (Dunbar, Korstjens, & Lehmann, 2009). However, the question arises as to whether there are natural "sweet spots" at which communities are likely to be more successful (i.e. survive longer without fissioning) because they map better onto natural grouping patterns and their underpinning psychology.

We test this possibility using historical datasets from three types of collectivist societies: 19th century American utopian communes, Hutterite colonies of South Dakota (USA), and Israeli kibbutzim (for details, see ESM). Although their economic and political circumstances vary widely, all involve small scale agricultural communities established to be self-sufficient within a communal ideology. Like all primate social groups, human communities are not fixed in size, but grow dynamically over time so long as births exceed deaths; once they reach a limiting size set by their local ecology, they then fission, resulting in a cyclic pattern of slow growth followed by sudden collapse (Dunbar et al., 2009; Dunbar, MacCarron, & Robertson, submitted). Our central question, then, is: do such communities have an optimal size, and how does size affect community survival and longevity? We use the mean layer values for hunter-gatherer societies (given above) as our benchmark for comparison.

2. Methods

We use two datasets on community sizes compiled by RS and colleagues. One collates data on C19th American utopian communities, based on Oved (1988), which has previously been used in a number of

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analyses (Sosis, 2000; Sosis & Bressler, 2003); the other collates data on the size and duration of Israeli kibbutzim, based on Ben-Rafael (1997) and Pavin (2007). Of the 83 communes in the US database, size at foundation and duration are known for 53 (21 religious foundations and 32 secular foundations). There are 240 kibbutzim in the Israeli database, with foundation date and current size known for each. Although date of foundation is known for both datasets, size at foundation is available only for the American utopian communes; only the current community size (as of a 2005 census date) is available for the Israeli kibbutzim.

We also use data on Hutterite community fission events covering the period 1880–1970 given by Olsen (1987). This dataset includes the community size at fission, and the sizes of the resulting daughter communities, for two colonies (*leuts*) of South Dakota Hutterites (the Schmiedenleut and the Lehrerleut) for all but a handful of fission events. The two *leuts* are named after their founding fathers, and have led separate existences since the 1870s. In all, data are available for 48 fissions in the Lehrerleut and 49 fissions in the Schmiedenleut (with no data on community sizes for an additional six fission events). When fission occurs, one daughter community remains on the community's farm and the other starts a new colony on new land. The Hutterites are a natural fertility population, and population growth rates are high (4.5% per annum in the Schmiedenleut and 4.1% the Lehrerleut), with the interval between successive fission events averaging 14.3 years (range 4–39 years). The dataset represents a total population of 12,470 individuals.

The data are available in the ESM.

The data on community size are typically highly skewed, with long tails to the right. For this reason we use geometric means, which are more appropriate when data are skewed. Our main statistical analysis involves two steps for each dataset. First, we use k-means cluster analysis to determine the optimal number of clusters that best describe the data. We run the cluster analysis for successive values of $k = 2 \ldots n$ and search for the value of k that maximizes the goodness of fit (indexed by the analysis of variance F-statistic) or at which F reaches an asymptote. This gives us the optimal number of clusters that best describe the data and the mean size of each cluster. Second, we ask whether the mean values so identified approximate the observed values for hunter-gatherer social groupings (as identified by Lehmann et al., 2014) and the adjacent sympathy group layer of personal social networks (Hill & Dunbar, 2003). For these purposes, we calculate the difference between each of these 'theoretical' values and the observed value as a standardized normal deviate, computed in the usual way as $z = (N_{obs} - N_{HG(i)}) / SD_{HG(i)}$, where N_{obs} is the observed mean group size, $N_{HG(i)}$ the mean size of the level *i* grouping in hunter-gatherers (where *i* identifies band, clan, etc.), and $SD_{HG(i)}$ the standard deviation for that grouping. We compare each cluster mean with the values for each of the four hunter-gatherer grouping layers in turn in order to identify the layer to which the observed value corresponds most closely. For these purposes, we seek the p-value closest to $p = 1.0$ (i.e. z closest to 0), subject to the proviso that $p > 0.05$ (i.e. the observed value is not significantly different from the theoretical value). We confirm the result with a model selection procedure, using BIC as our criterion.

In certain cases, we undertake regression analyses. We use a detrended analysis, a procedure commonly used in demography and conservation biology (for examples, see Cowlishaw & Dunbar, 2000) to standardise group size when populations are at different stages of their natural lifecycle. A detrended analysis plots the residual of group size regressed on time against another variable of interest. The second procedure is quantile regression, which is used in conservation biology and other areas to derive a regression equation for upper or lower bounds (i.e. where data are subject to an upper or lower limit). To do this, the X-axis is partitioned into, typically, 10 equal divisions; the highest (or lowest) Y-axis value is then identified in each division, and a regression set through these values (Blackburn, Lawton, & Perry, 1992).

3. Results

3.1. C19th US communes

Fig. 1a shows the size at foundation for 53 C19th American utopian communes. We plot the data on a log-scale because they have a strong skew with a long right tail. Excluding the extreme righthand datapoint (the rather unusual Zion City community, size = 5000, 31 standard deviations from the sample mean), the geometric mean size at foundation is 52.4 ± 87.1SD. This most closely approximates the hunter-gatherer band layer (Table 1). A *k*-means cluster analysis of the raw values yields an optimal division into three clusters (fewer or more clusters yield significantly lower fits) with cluster means at 49 (41 communities) and 268 (9 communities), with two communities centred at 700 ($F_{2,49} = 197.49$, $p \ll 0.0001$). These values equate best with, respectively, the band and mega-band layers of hunter-gatherer society (Table 1). There are no significant differences between religious and secular communities.

Plotting community survival against size at foundation (Fig. 1b) allows two important conclusions to be drawn. First, religious communities survived significantly longer than secular ones (on average, 35.6 ±

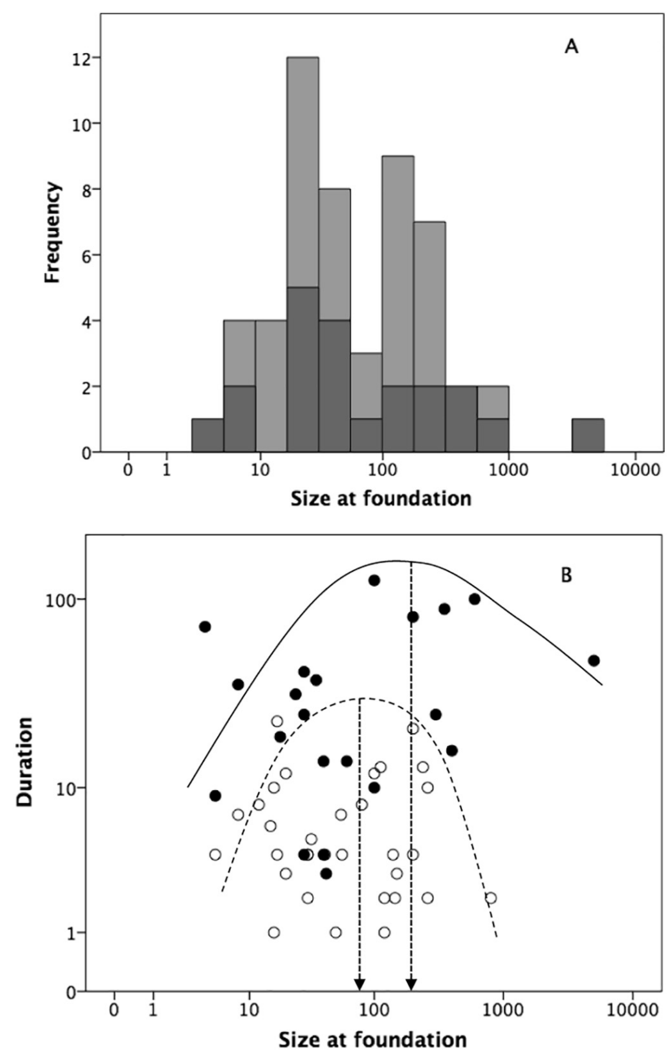

Fig. 1. (a) Size at foundation of 53 C19th US utopian communes. All but one (Zion City at 5000 members) were <1000 in size. Dark: religious communes; light: secular communes. (b) Commune duration plotted against size at foundation for religious (solid symbols, solid line) and secular (open symbols, dashed line) communes. Regression lines are quantile regressions on the upper bounds, and the vertical lines indicate foundation sizes that maximise longevity.