QUANTIFYING UNCERTAINTY IN DEMOGRAPHIC TEMPORAL FREQUENCY ANALYSIS (DTFA) [1]

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The goal of archaeological demography is to recover information about past human populations through archaeological research. Demographic temporal frequency analysis (dTFA) constitutes one of archaeological demography's primary modes of analysis. This mode of analysis comprises two related operations: (1) describe the changing abundance of cultural materials created over time in a given study region (temporal frequency distributions, or tfds); and (2) treat these tfds as proxy records for changing regional population size over time. dTFA has been applied in archaeology since at least the mid-1960s, though its early applications were largely ad hoc and its foundational principles and standards of practice remained largely implicit. Two decades later, John Rick's 1987 paper in the journal American Antiquity, "Dates as Data," provided a much-needed inaugural statement for dTFA's programmatic literature. Rick's paper systematically identified the program's definitive operations, foundational premises, and a theory of the tfd data generating process (DGP). This theory divided the tfd DGP into a sequence of sub-processes: creation of cultural material; preservation of cultural material over time following its creation; and archaeological investigation pursuing what cultural material has been preserved. Rick also recognized the potential for confounding entailed by this DGP with respect to demographic inference and previewed explicit attempts to mitigate such confounding in the context of his own preceramic Peruvian case study. Since Rick's paper, publications applying dTFA have continued to gain momentum, addressing regional and continental colonization and settlement processes, population responses to natural and cultural dynamics and events, and so on. A critical literature addressing dTFA's potential confounders and limitations has also developed alongside such applications, both among the program's proponents and its skeptics. Ongoing efforts to improve dTFA's best-practice protocols have include the development of methods to minimize both the systematic and random components of creation, preservation, and investigation error. Some gains have been made in our ability to understand and mitigate both systematic and random error, but further work is needed on both fronts.

Random error in the tfd DGP introduces artificial clusters and gaps into the temporal distributions of the datasets we use to construct tfds that are not representative of booms and busts in past population abundance. The papers constituting this dissertation scrutinize and evaluate current and emergent methods for containing such error. Collectively, they emphasize the complementary needs to be explicit about which unknown quantity is the target of particular operations in dTFA and to select the statistical tools most appropriate for those targets. Such targets include (a) the temporal distributions strictly of archaeological samples, which are obscured by chronometric uncertainty; (b) the distributional forms of the generative processes underlying datasets; (c) temporal changes in past population abundance and associated changes in population growth rates over time; and (d) measures of the relationships between changing population abundance and other time-varying variables. One type of tfd—the summed probability distribution (spd)—is shown to perform well as an estimator of the uncertain temporal distributions of archaeological samples. Likewise, for analyses attempting to measure the influence of various time-varying variables on population growth dynamics, the spd supports more accurate though less precise inferences than alternative kinds of tfd. However, when the research goal is to better understand the distributional form of the generative process underlying the data, neither the spd nor a second kind of tfd—a kernel density estimate (kde)—is well-suited. While both kinds of tfd can be modified to improve their performance in this respect, a third kind of tfd is recommended—the finite mixture model (fmm)—which improves upon several of the statistical limitations characterizing spds and kdes.
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