Computer simulations of the extinction of megafauna

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September, 2013

Computer simulations show that the extinction of megafauna is not correlated with the growth of human population. The population of megafauna remains constant during the nearly entire time of the rapid growth of human population. Model-generated growth of human population is also in direct conflict with the empirical evidence about the human population dynamics. Computer simulations do not support the human-assisted extinction of megafauna.

Introduction

In the earlier publication (Nielsen aka Nurzynski, 2013), we have investigated a correlation between the Late-Pleistocene extinction of megafauna and the growth of human population. We have demonstrated that the analysis of human population data (Deevey, 1960; Kapitza 2006; Kremer, 1993; Manning, 2008; US Census Bureau, 2013) does not support the concept of the global, human-assisted, extinction of megafauna because the extinction is not

Suggested citation:
Nielsen, R. W. aka Nurzynski, J. (2013). Computer simulations of the extinction of megafauna. 
http://arxiv.org/ftp/arxiv/papers/1309/1309.5698.pdf

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correlated with the growth of human population and because the size of human population and its growth rate were far too small to have any significant impact on the environment and on the life of megafauna. In the present discussion we shall examine the model of Alroy (2001) to see what conditions have to be created to trigger the extinction of megafauna and whether the created conditions are at all plausible and acceptable.

**Computer simulations**

Mathematical modelling can be helpful because it allows for an easy investigation of various outcomes generated by selected conditions. However, mathematical modelling is also like translating a story from one language to another. A fiction is still a fiction in whatever language is presented.

If a mathematical model generates expected results it does not necessarily mean that the incorporated mechanism is correct, but only that the translation of an idea into a mathematical language has been carried out correctly. Mathematical modelling and the associated computer simulations or calculations may be acceptable only if their predictions are confirmed by data. Many interesting and fascinating stories can be created and they may even sound convincing but unless they are supported by data they will remain at best just only interesting stories belonging to science fiction. Even incomplete or indirect, but related, data are better than no data at all.

It is also essential to use correct and justifiable input parameters because depending on their role, incorrect or questionable parameters might make model calculations unreliable and unacceptable. If a model reproduces empirical data correctly under acceptable conditions we may be reasonably confident that the incorporated mechanism is correct and that the model describes reality, but even then, there is always a possibility that an alternative mechanism could explain the data equally well or even better. However, if a model generates desired
outcomes under *unacceptable conditions* then either the fundamental mechanism used by the model or the model itself is incorrect. In such a case, model calculations and any conclusions based on such calculations are scientifically unsound and unacceptable.

**Examination of model calculations**

Computer simulations carried out by Alroy (2001) *were not compared with data describing the growth of human population*. Thus, the fundamental and essential step has not been taken. We shall show now that the model is in gross disagreement with the fundamental parameters describing human population dynamics. We shall see that these simulations were created under unacceptable conditions and that even then they did not produce a correlation between the extinction of megafauna and the growth of human population.

![Fig. 1.](image)

*Fig. 1.* Computer simulations describing the growth of human population and the extinction of megafauna (Alroy, 2001, p. 1895). The time scale is in years before present (BP). Only one *typical* curve for the extinction of megafauna is displayed. The initial rapid growth of human population is not correlated with the extinction of megafauna.
Computer simulations of Alroy (2001) generate two types of time-dependent distributions: the distribution for the growth of human population and a cluster of distributions describing the extinction or survival of megafauna. One of the simulations, trail 8, selected by Alroy (2001, p. 1895) as the preferred simulation is reconstructed in Fig. 1. Furthermore, only one, typical, time-dependent distribution for the extinction of megafauna is presented. Table 1 presents also the relevant information about the human population dynamics based on the analysis of population data (Deevey, 1960; Kapitza 2006; Kremer, 1993; Manning, 2008; US Census Bureau, 2013) discussed in the earlier publication (Nielsen aka Nurzynski, 2013).

Model calculations of Alroy are interesting because they do not support the human-mediated extinction of megafauna. The calculations show three important features.

1. **No correlation.** The striking feature of model calculations is that while the size of human population was increasing vigorously and rapidly (notice the logarithmic vertical scale), the size of the population of megafauna remained constant. Thus, computer simulations show that there is no correlation between the extinction of megafauna and the growth of human population. These results are in excellent agreement with our earlier study (Nielsen aka Nurzynski, 2013). If this unusually fast growth of human population was supported by hunting and killing of megafauna it obviously did not trigger their extinction until human population increased to an unprecedentedly high level.

2. **The extinction threshold and its timing.** Computer simulations were carried out for a small initial sample of human population of only 100 persons in 14,000 years BP, but any other initial size could be also assumed, the estimated size of the population in North America or even in the world. The calculations show that the onset of the massive extinction of megafauna was triggered when the size of human population increased by a
staggering factor of 2,100. If we apply this triggering factor to the global population and if we assume that the growth of human population does not follow an unrealistically fast-increasing trajectory but that it follows the trajectory prompted by a mechanism suggested by the data (Deevey, 1960; Kapitza 2006; Kremer, 1993; Manning, 2008; US Census Bureau, 2013) we shall see immediately that model-generated results are unacceptable. Global population in 14,000 years BP was around 4.2 million (see Table 1). Model calculations suggest that the extinction of megafauna should be triggered sometimes *in the future* when the world population is going to reach around 8.8 billion. This predicted *timing* of the massive, human-assisted, extinction, based on the model-generated threshold for the size of the population, does *not* depend on whether we assume that the population of the whole world is involved in the process of extinction or whether only a small fraction of the global population is supposed to be responsible for this process. Thus, model calculations suggest that the extinction of megafauna could not have been caused by humans. The only way out, if we still want to force the preconceived idea into the model, is to ignore everything we know about the human population dynamics and assume a grossly unrealistic pattern of growth, an unprecedentedly rapid growth of human population, the pattern being in direct contradiction with empirical evidence. This is precisely what has been done in the Alroy’s computer simulations.

3. *The unrealistically fast growth rate.* The initial rapid growth of human population shown in Fig. 1 follows closely exponential trajectory characterised by the growth rate of 1.5% while over the same time global population was increasing at an average rate of only 0.0055% (see Tables 1 and 2). Such a gross disagreement with the data is unacceptable.
Table 1. Parameters describing human population dynamics based on the analysis of human population data (Deevey, 1960; Kapitza 2006; Kremer, 1993; Manning, 2008; US Census Bureau, 2013).

| Year [BP] | Population Size [Million] | Growth Rate [%] | Global Natural Increase [Persons/Year] |
|-----------|---------------------------|-----------------|---------------------------------------|
| 14,000    | 4.18                      | 0.0052          | 216                                   |
| 13,500    | 4.29                      | 0.0055          | 238                                   |
| 13,400    | 4.31                      | 0.0056          | 243                                   |
| 13,270    | 4.35                      | 0.0057          | 249                                   |
| 12,300    | 4.61                      | 0.0066          | 303                                   |
| 11,500    | 4.88                      | 0.0074          | 360                                   |
| 11,000    | 5.06                      | 0.0112          | 565                                   |
| 10,000    | 5.69                      | 0.0126          | 716                                   |
| 5,000     | 15.35                     | 0.0339          | 5212                                  |
| 3,000     | 47.79                     | 0.1057          | 50528                                 |

In addition, as shown in Fig. 1, model generates a strange and unfamiliar pattern of growth of human population, the feature suggesting that the model might have been incorrectly designed or that the initial excessively high and unrealistic growth rate forced the model to generate incorrect, long-term distribution. The initial rapid growth of human population is followed by a minor decrease, which is then followed by a stable size continuing until the present time. These features are in direct contradiction with anything we know about the human population dynamics as described by the growth of human population, global, regional or local (Deevey, 1960; Kapitza 2006; Kremer, 1993; Manning, 2008; Maddison, 2010; US Census Bureau, 2013). In contrast with the empirical information, model
calculations show that the growth of human population would have reached a maximum after around 730 years of growth and an equilibrium level after around 1000 years later.

Table 2. Model calculations (Alroy, 2001) are compared with the human population dynamics based on the analysis of relevant data (Deevey, 1960; Kapitza 2006; Kremer, 1993; Manning, 2008; US Census Bureau, 2013) describing the growth of human population.

| Year BP | Model Calculations | Analysis of Global Population Data |
|---------|--------------------|------------------------------------|
| 14,000 – 13,270 | Prevailing growth rate: **1.5%**. | Average growth rate: **0.0055%**, i.e. 273 times smaller than in model calculations. |
| 13,500 | The earliest onset of the extinction of megafauna. Human population increased by **46,000%**. | Human population increased by **2.6%**, the increase ~18,000 times smaller than in model calculations. |
| 13,400 | Onset of massive extinction. Human population increased by **210,000%**. | Human population increased by **3.1%**, the increase ~68,000 times smaller than in model calculations. |
| 13,270 | Human population increased by **840,000%**. | Human population increased by **4.1%**, the increase ~205,000 times smaller than in model calculations. |
| 12,300 | Human population decreased by **450,000%** and remained constant until present time. | Human population increased by **10.3%** above its original value in 14 ka and continued to increase. The increase between 14 ka and 12.3 ka ~44,000 smaller than in model calculations. |

Model calculations, as represented by the trial 8 (Fig. 1), show that between 14,000 and 13,270 years BP human population increased by a staggering factor of 8,400. They also show that about 1000 years later, the population settled at the level of around 450,000% above its initial value in 14,000 years BP and remained constant until the present time. If we apply this pattern of growth to the global population, the model predicts that in just 730 years the world
population would have increased from 4.2 million in 14,000 years BP to 35.3 billion, the size at least 3 times larger than the expected maximum sometime in the future. Furthermore, the model predicts that 1000 years later, the size of global population would have decreased to 19 billion and that it would have remained constant at this level until the present time. The whole pattern of growth predicted by the model is in extreme disagreement with empirical evidence.

Model calculations (Alroy, 2001) are compared in Table 2 with the human population dynamics based on the analysis of relevant data (Deevey, 1960; Kapitza 2006; Kremer, 1993; Manning, 2008; US Census Bureau, 2013). Small disagreements with empirical evidence can be tolerated but such extreme disagreements are unacceptable.

Alroy (2001) lists also results for other, less favourable, trials. All his simulations were carried out using excessively high intrinsic (maximal) growth rates of 1.14-1.92% (Alroy, 2001, p. 1894), i.e. 207-349 times larger than the rates calculated using global population data (Deevey, 1960; Kapitza 2006; Kremer, 1993; Manning, 2008; US Census Bureau, 2013). The model of Brook and Bowman (2004) also assumes large growth rates for the human population, of 1% and 2.5%, i.e. 182 times and 455 times larger than the empirically estimated growth rate around 14 ka.

The problem is not only with the imagined high growth rates but also with the apparent lingering confusion about the mathematical description of the growth of human population. Alroy (2001), for instance, used exponential growth in his model for the initial rapid growth of human population while Brook and Bowman (2004) used the logistic growth.

By now, it is should be well known that the natural tendency for the growth of human population is to follow hyperbolic trajectory, a distribution containing a singularity, a point where the population escapes to infinity (Johansen & Sornette, 2001; Korotayev, 2005;
Shklovskii, 2002; von Hoerner, 1975; von Foerster, Mora & Amiot, 1960). This preferred trend applies not only to the growth of global population but also to regional populations, as can be easily checked by analysing global (Deevey, 1960; Kapitza 2006; Kremer, 1993; Manning, 2008; US Census Bureau, 2013) and regional (Maddison, 2010) population data. If such distributions are considered impossible, because they escape to infinity within a final time, it should be pointed out that a sustained exponential growth, often imagined for the growth of human population, is also impossible because it quickly leads to an unrealistically high size of the population. Both, the hyperbolic and exponential growth, have to be terminated at a certain time and the growth has to be diverted to an alternative trajectory. Consequently, both types of trajectories are possible within a suitably short time but impossible over a suitably longer time. However, for whatever reason, Nature favours the hyperbolic growth for the growth of human population. The assumption of any other type of growth is unjustified, unless there is a clear evidence in the data that hyperbolic growth is inapplicable.

**Summary and conclusions**

Computer simulations demonstrate that there is no correlation between the extinction of megafauna and the growth of human population. The model uses unrealistically high and unacceptable intrinsic growth rates for the growth of human population, growth rate hundreds of times higher than the empirical growth rates. However, even then, the massive extinction of megafauna is not triggered until the size of human population is about 2,100 times higher than its initial value. As long as the size of the population is below this unrealistically high level it has no effect on the size of the population of megafauna. The model does not support the concept of the human-assisted extinction of megafauna.

Correspondence with John Alroy is gratefully acknowledged.
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