Nathan Decety*

Attrition-based Oliganthrôpia Revisited

https://doi.org/10.1515/klio-2018-1003

Summary: In a previous paper (When Valor Isn’t Always Superior to Numbers: homoioi oliganthrôpia Caused by Attrition in Incessant Warfare, KLIO 100, 2018, 626–666) I argued that the population of Ancient Spartan citizens, homoioi, declined predominantly due to attrition in warfare. Here, I revisit the argument and present a more refined model that includes additional samples, directly incorporates information on losses, and improves assumptions. I argue that Sparta may have experienced an initial population plunge in the early 5th century and was unable to recover. The results of this study reaffirm that warfare may have been an integral cause of oliganthrôpia.

Keywords: Spartan Population, Spartan Warfare, oliganthrôpia, homoioi, Lace-daemon

Part 1: Model and Discussion

1.1 Introduction

My subject is the diminishing population of Spartan full citizens – Spartiatai or homoioi – from the fifth to the fourth century BC, known as oliganthrôpia. In about a hundred years, the population decreased by over 80%. While most arguments revolve around structural causes of oliganthrôpia,1 I argue that the most important causal factor is instead attrition in warfare. My previous research suggested that deaths in battle could especially explain oliganthrôpia after 418 BC.2 In this paper, I expand upon the third model presented in that work to improve the quality of output. The results of this endeavor suggest that oliganthrôpia can indeed be predominantly explained by losses in war and that a structural cause which reduces the replenishment rate of the homoioi population does not

1 See Doran 2018 or Decety 2018, 630–634 for the relevant discussion and citations of the various views.
2 Decety 2018.

*Kontakt: Nathan Decety, E-Mail: ndecety@uchicago.edu
improve the accuracy of the model. I further extend the argument to show that attrition is likely the most important factor in reducing the population of *homoioi* at least as far back as 479 BC. I suggest that a major undocumented population crisis unfolded in Sparta in the mid 5th century, which dramatically reduced the initial population suggested by Demeratus in Herodotus’ “Histories”, Aristotle, and Plutarch.\(^3\) I attempt to fill the gaps in our knowledge left by ancient sources to show that the earthquake and congruent periods of war are more than enough to account for that population drop. Spartan *oliganthrôpia* began as a wound upon the population in the fifth century which, due of incessant warfare, never healed.

1.2 Data

Working off the equation developed for “Model 3” in Decety 2018, I refined the assumptions, added new variables, and performed various graphical and statistical analyses to both reaffirm the hypothesis that warfare can account for the majority of the decline of the population of *homoioi*, while suggesting that some structural crisis in the mid 5th century – perhaps due to the great earthquake of 464 BC – may be the other important cause of *oliganthrôpia*. I conclude that the combination of war with the nudge of the earthquake reasonably caused the demographic collapse of the population of *homoioi* over the 5th and 4th centuries BC.

The model makes use of several statistical tables and sources of data: Figueira’s (1986) research on the composition of the Spartan *moirai* and the size of the Spartan population of *homoioi*; the “Male Mortality Level 4 of the ‘South’ Populations” in Coale and Demeny (1983) to estimate population trends and composition, and Krentz’ (1985) research on deaths in hoplite battles. Figueira’s extensive research yielded approximate sizes of the population of *homoioi* at various pivotal moments from the 5th to the 4th centuries BC. His research is well synchronized with the estimates made by other scholars.\(^4\) Figueira argues the size of the population of *homoioi* over time was the following (tab. 1):

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\(^3\) Hdt. VII.234.2; Arist. Pol. 1270A37; Plut. Lyc. 8.5–6, 16.1, cf. Agis 8.2.

\(^4\) Grundy 1908, 81; Cartledge 2000, 38 after Cavaignac 1912; Cawkwell 1983, 390; Hansen 2009, 39.
Tab. 1: Size of Spartan army over time

| Size of Spartan Army (Ages 20–49)          |       |
|-------------------------------------------|-------|
| Plataia (479)                             | 5,000 |
| 1st Reorganization (455)                  | 3,055 |
| Pylos (425)                               | 2,755 |
| Mantinea (418)                            | 2,100 |
| Nemea (394)                               | 1,833 |
| Leuctra (371)                             | 938   |
| Post Leuctra (362)                        | 876   |

The statistical makeup and trends of the population of *homoioi* are based upon the “Male Mortality Level 4 of the ‘South’ populations” in Coale and Demeny. This life table is derived from pre-20th-century southern Mediterranean populations. While infant mortality was high, a sizable proportion of the total population was over 50, making the table a reasonably good approximation of classical Greek populations. Skeptical of relying on one dataset, I cross referenced the life table of Coale and Demeny with two other comparable life tables, one derived from Imperial-Roman Egyptian census data and the other from the United Nation developing country general male model life table. Though I expected the former to present a higher death rate than those of Coale and Demeny, and the latter to

5 Coale – Demeny 1983, 450.
6 As noted by Figueira 1986, 169 and 198, remarking on the relatively low tracking error of the table. The natural life expectancy of the ancient world is difficult to estimate, a loosely comparable source of data is the Egyptian census data from the Roman era which suggests a higher natural death rate of about 42/1000. See Osborne 2014, 42.
7 United Nations 1982, Appendix I: General Pattern Table, 202. I chose the most conservative general table, because of the multitude of medical, nutritive, and purchasing power improvements over the course of the latter half of the 20th century, see Norberg 2017. The difference between the Egyptian model life table and Claude and Demeny’s model life table was on average less in a statistically significant manner (past α = 0.1); but *homoioi* were likely far better off than the average ancient Greek. *Homoioi* were the wealthy class of Spartan society, which no doubt affected their natural mortality rate, see van Wees 2007, 273, or as evidenced by their high caloric intake; see for instance Figueira 1984; few lived in concentrated urban areas – in spectacular contrast to Athens and the plague which began in 430 BC; and rural Greece is comparatively a poor place for the spread of disease – particularly compared to the banks of the Nile and its Delta (where diseases such as malaria and Rift Valley fever were prevalent). These factors may have resulted in a life expectancy similar to the lower percentile of the 20th century’s developing world for *homoioi*. Egyptian data was chosen as it represented the only relatively complete set of demographic data from the ancient world, see Bagnall – Frier 2006, 104.
present a lower death rate, I was surprised to find they were extremely similar, rendering multiple tests based on varied population assumptions an unfruitful proposition (see Appendix A for the percentage breakdown of the various models and Appendix B for sets of matrixes and descriptive statistics on differences between life tables).

Ratios of losses in battle are derived from the ratios developed by Krentz in his study on hoplite battles.8 Statistical tests were applied to his range of ratios which suggest the ratios follow a normal distribution. The rates of losses involved in the 90% confidence interval are applied in this paper to estimate total likely potential homoioi losses. The numbers are not definite, their exactitude should not convey certainty. They are approximations, estimates made given the best possible assumptions.9 Like the model life tables, this argument is highly dependent upon the veracity and applicability of these ratios. Unfortunately, the paucity of data – the reason why we are using representative samples in the first place – makes it difficult to establish a sense of accuracy. Comparing the confidence interval to other average losses of other civilizations at least points at whether the data is skewed. Sorokin’s (1937) research suggests the overall mean percent deaths in Greece due to war were around 5.4%, for Rome around 5.5% – both of which are close to the expected average of losses for victorious armies.10 Rosenstein provides a careful research of mortality rates for Roman Republican armies of 200–168 BC. He suggests an average mortality rate of about 5.6% for victorious legions engaged in combat and about 16% for those defeated.11 While not conclusive proof, this data suggests Krentz’ ratios are not outliers but rather reasonable estimates (tab. 2).

8 Krentz 1985; see also Wheeler 2007, 212f.
9 A problem discussed by Tetlock – Gardner 2015, 55–64.
10 Sourced from Eckhardt 1992, 227, table 4.1.
11 Rosenstein 2004, 116, 124.
Tab. 2: Summary statistics of Krentz’ ratios

|                        | Winning Armies | Losing Armies |
|------------------------|----------------|--------------|
| Median Losses          | 5 %            | 14.1 %       |
| Average Losses         | 5 %            | 13.5 %       |
| Sample Standard Deviation | 0.03         | 0.05         |
| Sample Size            | 11             | 14           |
| Degrees of Freedom     | 10             | 13           |
| 90 % Confidence Interval |              |              |
| Lower                  | 3.9 %          | 11.6 %       |
| Upper                  | 6.1 %          | 15.4 %       |
| 95 % Confidence Interval |              |              |
| Lower                  | 3.5 %          | 11.0 %       |
| Upper                  | 6.4 %          | 16.0 %       |
| Kurtosis               | –0.29          | –0.23        |
| Skew                   | 0.61           | –0.58        |
| Pearson 2 Skewness Coefficient | –0.02         | –0.30        |

1.3 Methodology

The aim is to calculate two major outputs: the number of homoioi deaths in combat, and the impact on the size of the population of homoioi of fighting age over time. I argue that the most important explanatory variable for the decline of homoioi were deaths in battle. The model used is deliberately simple, making use of only the most salient cues to generate the most predictive possible output.12

Losses are either extracted directly from ancient sources, such as for Leuctra (371 BC), or derived by applying Krentz’ ratios to the likely size of the homoioi population present at a certain battle. The size of the force is based upon ancient sources when applicable and reliable – such as the number of homoioi present at the battle of Mantinea (418 BC) – or using a formula showcased further below.

The ratio applied to the population changes if the Spartan force was victorious or defeated in the conflict. When the outcome was inconclusive, a victorious ratio is applied to yield a more conservative output (a lower number of deaths). Events in which a few direct casualties are noted or where no actual fight took place are marked as such and do not contribute to population losses, or are removed from

12 In accordance with the suggestions made by Czerlinski – Gigerenzer – Goldstein; see Czerlinski – Gigerenzer – Goldstein 1999, 111.
the sample database. A ratio of average losses is supplemented by ratios of a 90% confidence interval. The resulting losses suffered by the population of *homoioi* are applied unto the resulting overall population of *homoioi* of fighting age.

For every period of time, two major factors also impact the population of *homoioi* which I call the ‘replenishment’ and ‘decaying’ rates. The replenishment rate approximates the number of *homoioi* joining the *moirai*. This rate is highly affected by structural factors such as birthrates and the wealth necessary to rear and train new *homoioi*. In “Model 3”, a rate of 37/1000 was chosen because it represented a stable population. In other words, it provided the alternative hypothesis to the preexisting null hypothesis that structural factors account for oliganthrôpia. Such a rate was extremely high considering that I assumed a 100% survival rate and graduation from the *agôge* in order to support the idea that a high replenishment rate could still not save the *homoioi* population from decline, thus rejecting the null hypothesis. In this model however, I opt for precision and account for infant and child mortality, driving down the *homoioi* replenishment rate to 18.5/1000, which is the applicable expected rate of survival when accounting for deaths up to the age of 15; 50.89% of the population died in childhood, I rounded up the rate to be conservative. If for some reason they had fought at all, it isn’t likely that a Spartan youth below 15 would have been particularly useful in combat.

To test the structural-null-hypothesis, I also test the model with a replenishment rate of 15/1000 to see what the impact of this rather dramatic decline would be. Such a low rate implies that an enormous percentage of the population was dying in childhood or that the overall population was decreasing at a rate greater than 10%; which is more radical than Figueira’s approximation of population decline that ranges from 1.1% per year to 1.8% per year. This test suggests that a negative replenishment rate does not affect the overall diminishment of the population of *homoioi* and is therefore not a major explanatory factor.

Two other considerations are also made with respect to the replenishment rate. First, a portion of the population of *homoioi* were not reproducing because they were too young or because they did not wish to – exemplified by the Agiads Pleistarkhos, Cleomenes, and Doreius. A *homoioi* had to live in the barracks until age 30; given that one graduated from the *agôge* at the age of around 20, it is safe to assume some proportion of 20–30 year olds, at least, did not or were unable to

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13 For according to the model life tables, at $r = -10\%$, the birth rate is 27.14/1000 and the deaths up to age 20 are 39.89% of the population, leaving over 16.31/1000 of the population alive – greater than the 15/1000 chosen as the alternative hypothesis.
In a stable population, 16.28% of the population fits that age group. To be conservative in light of the scarceness of evidence, we shall assume half of them were procreating nonetheless. In the model therefore, 91.86% of the population of homoioi were assumed to procreate. Second, for the vast majority of the known population of ancient Sparta, homoioi begot homoioi. The ancestors of a peer were also peers. Thus, if the population diminished, so does the long term output. The population base from which the replenishment rate is calculated is therefore variable. I use Figueira’s approximation of homoioi population as the variable population bases, and only switch when the date for which to calculate a population is over 50 years away. So, for instance, the replenishment rate for the Ithome campaign (in the 460’s BC) is based on the size of the homoioi population in 479 BC (at Plataea) while the size of the population accompanying Agis’ invasion of Elis in 400 BC is based on the size of the homoioi population in 425 BC (at Pylos and Sphacteria). A plateau of 5,000 homoioi of fighting age was chosen in case the replenishment rate exceeded the decaying rate; according to Figueira, the system of kleroi could not support a larger population of homoioi.15

The decaying rate is the same as that presented in Model 3. After every segment of time, some portion of the moirai would become too old to fight. They no longer counted as men of fighting age and became reservists.16 The age portions are directly taken from the “Male Mortality Level 4” life table, under the assumption of a stable population (see Appendix A). In this model I assumed there were no further natural deaths for men of fighting age than included in the life table. They either died fighting, or became too old to do so and left the moirai.

The various ratios and coefficients are applied to a sample population of violent confrontations directly involving homoioi from the battle of Plataea in 479 BC to the battle of Mantinea in 362 BC. Thirty major conflicts were extracted from the accounts provided by Herodotus, Thucydides, Xenophon, Diodorus Siculus, and Plutarch.17 The sample population of conflicts is the following (tab. 3):

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14 Rush 2011, 19.
15 Figueira 1984.
16 Xen. Hell. V.4.13; Plut. Ages. XXIV.3; Rush 2011, 19.
17 The sample of conflicts includes 30 conflicts that directly include homoioi, of which 26 featured any substantial or verifiable losses.
Tab. 3: Violent confrontations directly involving homoioi

| Year (BC) | Event |
|-----------|-------|
| 479       | Battle of Platea (Hdt. X.10–11) |
| 464       | Stenyklaros Plain (Hdt. IX.64.2) |
| 464       | Ithome Campaign (Thuc. I.101) |
| 457       | Battle of Tanagra (Thuc. I.107) |
| 430       | vs. Platea (Thuc. II.71) |
| 425       | Battle of Sphacteria and Pylos (Thuc. IV.11–15, 23, 26, 31–38) |
| 421       | vs. Parrhasia (Thuc. V.33) |
| 418       | Battle of Mantinea (Thuc. V.64) |
| 418       | vs. Sicyon (Thuc. V.81) |
| 417       | vs. Argos, Battle of Hysiae (Thuc. V.83, Diod. XII.81.1) |
| 400       | vs. Elis, Agis’ 2nd invasion (Xen. III.2.25) |
| 399       | vs. Elis, Pausanias’ invasion (Diod. XIV.17) |
| 394       | Battle of Nemea (Xen. IV.2.15) |
| 394       | Battle of Coronea (Xen. IV.3.17) |
| 392       | Support Corinthians (Xen. IV.4.8) |
| 390       | vs. Piraeum (Xen. IV.5.1–2) |
| 390       | Battle of Lechaeum (Xen. IV.5.13–14) |
| 385       | vs. Mantinea (Xen. V.2.3) |
| 379       | vs. Thebes, Cleombrutus’ 1st invasion (Xen. V.4.14) |
| 378       | vs. Thebes, Agesilaus’ 1st campaign (Xen. V.4.35–36) |
| 377       | vs. Thebes, Agesilaus’ 2nd campaign (Xen. V.4.47) |
| 376       | vs. Thebes, Cleombrutus’ 2nd campaign (Xen. V.4.59) |
| 375       | Battle of Tegyra (Plut. Pel. XVII, Diod. XV.81.2) |
| 371       | Battle of Leuctra (Xen. VI.4.3) |
| 370       | vs. Mantinea (Xen. VI.5.10) |
| 369       | vs. Thebes (Diod. XV.68.2) |
| 368       | Tearless Battle (Xen. VII.1.31–33) |
| 364       | vs. Arcadians, support Eleans, and relief force of Cromnus (Xen. VII.4.20–24) |
| 364       | vs. Arcadians, attempt to capture Cromnus (Xen. VII.4.27) |
| 362       | vs. Theban Army, Battle of Mantinea (Xen. VII.5.10) |

Mathematically, the formula for deriving a population of homoioi of fighting age is:

\[
\alpha(t) = \beta - (\beta \times \eta) + \Delta - Y.
\]

Where,
- \(\alpha(t)\) = The population of homoioi at year \(t\)
- \(\beta\) = The last known population of homoioi
- \(\beta \times \eta\) = The losses suffered by the population of homoioi, where \(\beta \times \eta\) can equal a direct loss provided by an ancient source or the application of a Krentz ratio unto population \(\beta\).
- \(\Delta\) = Replenishment rate = \(A \times \zeta \times t_{\alpha} \times \Omega\)
Where,
\[ A = \text{Base population} \]
\[ \varsigma = \text{Replenishment rate (either 18.5/1000 or 15/1000)} \]
\[ t_{\alpha-\beta} = \text{Years between } \alpha(t) \text{ and } \beta \]
\[ \Omega = \text{Percentage of } \textit{homoioi} \text{ able to reproduce (91.86\%)} \]
\[ \Upsilon = \text{Decaying rate} = \beta \times \phi \]

Where,
\[ \Phi = \% \text{ of } \textit{homoioi} \text{ who pass the age of 50} \]

1.4 Limitations

By nature, a model is a pale representation of reality. Nevertheless, a model does provide the chance to test hypotheses and specific variables, and is more likely to be accurate than just expert close reading of sources. Beyond the limitations inherent in a model generally, like all research in the ancient world the model is based upon potentially flawed and sparse sources. This model is reliant upon the ratios of losses provided by Krentz. It is possible that the sample set of losses are not representative of the broader ‘population’ of conflicts fought solely by Sparta. Further, these ratios do not take into account the disposition of troops; while the ratios could be applied to the battle as a whole, the separate contingents in an army did not all necessarily suffer equally; the citizen \textit{moirai} could have been placed in a less vulnerable location on the battlefield. Another fallacy is that the model uses a fixed rate of replenishment and decline, while it is possible that such a rate was variable – in the absence of data it is impossible to know. The model is very dependent on the accuracy of the ‘Life Table’. While it was chosen as the ‘best fit’ for the population of \textit{homoioi} and cross referenced with other model life tables, knowing as little as we do about population patterns of ancient Sparta, it is possible that reality does not accord with the data presented in those tables.

In order to mitigate against these limitations, I attempt to be conservative wherever possible to reduce the output number of deaths; the conservative considerations are the following:

\[ 5,000 \text{ between 479–429 BC; 2,755 between 429–379 BC; 2,100 between 379–362 BC.} \]
\[ \text{See Appendix A for the Male Mortality Level 4, alternatively, see Coale – Demeny 1983, 450.} \]
\[ \text{Tetlock – Gardner 2015, 21.} \]
\[ \text{As discussed for instance by Bloch 1953, chapters 2 and 3 (Historical Observations, Historical Criticism).} \]
1. Human error: it is easier to see if I double counted a campaign (by looking at the data and accompanying date) than it is to know that I omitted a campaign. Human error would thus lead me to undercount campaigns and therefore output losses. Along this same vein, it is more likely that ancient historians or future transcribers of their works omitted mentioning campaigns which may have impacted the total number of deaths, than it is that they fabricated a campaign.

2. I rarely included campaigns in which the Lacedaemonian army simply ravaged the land of an opponent. This includes the yearly invasions that took place during the so-called Archidamian War which did featured some fighting, such as the Lacedaemonian attempt to capture the fort of Oenoè in 431 BC, which could have resulted in the deaths of homoioi.22

3. Using Krentz’ ratios, which apply to battles, not campaigns. A campaign must necessarily feature equal or greater losses than a battle which was included in that campaign; which could have included, for instance, losses from other combat, raiding, diseases, wounds, and accidents.

4. Not including campaigns where there was too little information. Perhaps most notable are the wars fought by Sparta in the period between 479–465 BC against Tegea, Argos, and the Arkadians which includes the so-called battle of Dipaieis, and the campaign in Thessaly.23

5. Not including sea-based campaigns which could have carried homoioi, especially as officers.

6. Not including campaigns where the citizen moirai was not mentioned. Homoioi were, especially in the latter period of this study, sent out on various missions – most notably to govern cities and lead armies; for instance the campaigns in Asia Minor led by Thibron, Dercylides, and Agesilaus II in the 390s.24 It is possible that the population of homoioi may have suffered from losses in these actions.

7. Not applying any multiple for wounds or diseases, which could claim a substantial number of men. There were a variety of diseases which could affect armies in the field such as smallpox, typhus, typhoid, and dysentery. Dysentery killed between 5–50% of ancient armies; wounds killed off about 80% of the afflicted. Tetanus infections, gangrene and septicemia would have been deadly to wounded soldiers. In all likelihood gangrenous wounds produced about 100% mortality. Rosenstein for instance estimated Roman Republican armies suffered twice as many wounded as killed, of whom about

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22 Thuc. II.19.
23 Hdt. IX.35; Hdt. VI.72; Powell 2001, 112; Hodkinson 2009, 234; Huxley 1962, 22.
24 Parke 1930.
half died of their wounds. Further, a significant portion of survivors may have suffered disabilities after a battle.  

8. By assuming no natural or accidental deaths for the *homoioi* population of fighting age beyond those implied by the model life table.

9. Where an inconclusive conflict took place, to apply a “victorious” ratio of losses rather than a “defeat” ratio of losses. It is possible, such as at the battle of Mantinea in 362 BC, that the Spartan army received enormous casualties even though the battle was somewhat a draw.

### 1.5 Results

Applying the procedures discussed in section 1.3 yielded the following losses in the ‘sample population’ of conflicts (see tab. 4 and fig. 1).  

| Year (BC) | Victory (1) / Defeat (0) | Average Losses | Lower Confidence Interval Losses | Upper Confidence Interval Losses |
|-----------|--------------------------|----------------|-------------------------------|---------------------------------|
| 479       | 1                        | 250            | 195                           | 305                             |
| 464       | 0                        | 300            | 300                           | 300                             |
| 464       | 1                        | 239            | 189                           | 288                             |
| 457       | 1                        | 75             | 59                            | 92                              |
| 430       | 1                        | 168            | 134                           | 299                             |
| 425       | 0                        | 60             | 60                            | 60                              |
| 421       | 1                        | 92             | 72                            | 112                             |
| 418       | 1                        | 105            | 82                            | 128                             |
| 418       | 1                        | 17             | 13                            | 20                              |
| 417       | 1                        | 100            | 79                            | 120                             |
| 400       | 0.5                      | 104            | 83                            | 125                             |
| 399       | 0.5                      | 100            | 81                            | 119                             |
| 394       | 1                        | 92             | 71                            | 112                             |
| 394       | 1                        | 15             | 11                            | 18                              |
| 392       | 1                        | 10             | 8                             | 12                              |
| 390       | 1                        | 0              | 0                             | 0                               |
| 390       | 0                        | 250            | 250                           | 250                             |
| 385       | 1                        | 74             | 64                            | 97                              |
| 379       | 0.5                      | 65             | 74                            | 108                             |

25 Gabriel 2007, chapters 18–20; Wheeler 2007, 212f.; Rosenstein 2004, 129.

26 Recall that the “Lower Confidence Interval Losses” uses a ratio of 3.9% loss for victorious armies and 11.6% loss for defeated ones while “Upper Confidence Interval Losses” uses a ratio of 6.1% loss for victorious armies and 15.4% loss for defeated ones.
Tab. 4 (continued)

| Year (BC) | Victory (1) / Defeat (0) | Average Losses | Lower Confidence Interval Losses | Upper Confidence Interval Losses |
|-----------|--------------------------|----------------|----------------------------------|----------------------------------|
| 378       | 0.5                      | 2              | 2                                | 2                                |
| 377       | 0.5                      | 10             | 10                               | 10                               |
| 376       | 0                        | 0              | 0                                | 0                                |
| 375       | 0                        | 41             | 35                               | 46                               |
| 371       | 0                        | 400            | 400                              | 400                              |
| 370       | 1                        | 28             | 22                               | 34                               |
| 369       | 0                        | 76             | 66                               | 80                               |
| 368       | 1                        | 0              | 0                                | 0                                |
| 364       | 0                        | 85             | 75                               | 63                               |
| 364       | 0                        | 74             | 27                               | 54                               |
| 362       | 0.5                      | 44             | 34                               | 53                               |

Sum: 2,874 2,496 3,308

Fig. 1: Losses graphically depicted
Since we are working with approximations and averages, it is beneficial to segment the number of *homoioi* lost by time period to smooth out idiosyncrasies of individual conflicts (tab. 5):

**Tab. 5: Number of *homoioi* lost by time period**

| Time Segments | Average Total Losses | Low Confidence Interval | High Confidence Interval |
|---------------|----------------------|-------------------------|-------------------------|
| 479–425       | 1,032                | 876                     | 1,284                   |
| 425–418       | 152                  | 132                     | 172                     |
| 418–394       | 426                  | 337                     | 512                     |
| 394–371       | 557                  | 526                     | 655                     |
| 371–362       | 707                  | 625                     | 685                     |
| **Sum:**      | **2,874**            | **2,496**               | **3,308**               |

In aggregate, the model suggest that Sparta likely lost at least between about 2,500 and 3,300 *homoioi* in war.\(^{27}\) Recalling the known population of *homoioi* at the beginning of these time periods and the resulting ratio of loss places these numbers into context (tab. 6):

**Tab. 6: Number of *homoioi* lost compared to probably population size**

| Time Segments | Known Population of *homoioi* | Percentage Lost (Average) | Percentage Lost (Low C Interval) | Percentage Lost (High C Interval) |
|---------------|-------------------------------|---------------------------|---------------------------------|----------------------------------|
| 479–425       | 5,000                         | 21 %                      | 18 %                            | 26 %                             |
| 425–418       | 2,755                         | 6 %                       | 5 %                             | 6 %                              |
| 418–394       | 2,100                         | 20 %                      | 16 %                            | 24 %                             |
| 394–371       | 1,833                         | 30 %                      | 29 %                            | 36 %                             |
| 371–362       | 938                           | 75 %                      | 67 %                            | 73 %                             |

\(^{27}\) As I mentioned in the ‘Limitations’ section, troop disposition is not taken into account in this model. This matters because Spartan contingents in allied armies were often placed on the right where they received fewer casualties (i.e. Leuctra in 371, Coronea in 394, Mantinea in 418). The lower confidence interval somewhat does model losses that would ensue from this strategy as it assumes between 1 to 2% fewer casualties than the averages of 5% and 13.5%. Running the same model with the assumption that 2% were lost in a victorious battle and only 9% were lost in a defeat still yields about 2,200 *homoioi* deaths.
The most striking percentages of losses, taking into account the relevant time segments, are those of 418 BC onwards. Sparta lost at least 16% of its population of homoioi in war, up to a colossal 75% in only about 9 years between 371 and 362 BC. The impact on the total population of homoioi over time is therefore unsurprisingly quite radical (Figueira’s population sizes are lightly greyed; see tab. 7 and fig. 2).

**Tab. 7: Modeled output of population of homoioi due to simple attrition**

| Year (BC) | Average | Lower C Interval | Upper C Interval |
|-----------|---------|------------------|------------------|
| 479       | 5,000   | 5,000            | 5,000            |
| 464       | 4,783   | 4,838            | 4,728            |
| 457       | 5,000   | 5,000            | 5,000            |
| 430       | 5,000   | 5,000            | 4,908            |
| 425       | 2,755   | 2,755            | 2,755            |
| 421       | 2,756   | 2,756            | 2,756            |
| 418       | 2,100   | 2,100            | 2,100            |
| 417       | 2,001   | 2,028            | 1,974            |
| 400       | 2,085   | 2,125            | 2,046            |
| 399       | 2,007   | 2,067            | 1,948            |
| 394       | 1,833   | 1,833            | 1,833            |
| 392       | 1,760   | 1,783            | 1,736            |
| 390       | 1,783   | 1,816            | 1,769            |
| 385       | 1,475   | 1,643            | 1,596            |
| 379       | 1,784   | 1,879            | 1,799            |
| 378       | 1,798   | 1,893            | 1,812            |
| 377       | 1,807   | 1,851            | 1,818            |
| 376       | 1,827   | 1,857            | 1,823            |
| 375       | 1,806   | 1,872            | 1,839            |
| 371       | 938     | 938              | 938              |
| 370       | 563     | 563              | 563              |
| 369       | 561     | 567              | 519              |
| 368       | 510     | 526              | 428              |
| 364       | 633     | 648              | 411              |
| 364       | 547     | 237              | 348              |
| 362       | 876     | 876              | 876              |
A graphical representation of this data highlights these relationships and the limitations of the model. The black line titled “Hypothetical Steady Decline Between Known Points” displays the population of *homoioi* if it declined at a perfectly steady rate between Figueira’s population sizes. I calculated the correlation, regression, and $r^2$ only after the year 425 BC because including the first 54 years of the sample (with very little data) would skew these results (upwards).

With a relatively high correlation and $r^2$ between the model and the hypothetical decline, the output generated by this model somewhat aligns to the hypothesized reality of the diminishing population of *homoioi*. At the same time however, it is clear that there are major shortcomings – marked by two large circles on the graph shown above. Looking back in the data bank, these circles mark the large

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28 Whereby the difference between the two known populations are divided by the number of years between the time periods, and that number is subtracted from the starting time period so that by the end of the period in question the population equals the second population. It is unlikely that the actual decline followed this straight rate, but in the absence of more evidence we are assuming the simplest rate with no idiosyncrasies. The most important aspect is where and how our model intersects with those known population points.
drop between 430 and 425 BC and the drop between 421 and 418 BC. Perhaps a structural cause is a better explanation? Using the same formula but with a 15/1000 replenishment rate instead of 18.5/1000, a greater decline than that presented by Figueira, the following graph (see fig. 3) is generated:

![Graph](image)

**Fig. 3:** Modeled output of population of *homoioi* due to simple attrition and lower replenishment rate

Unfortunately, the problem remains the same; the modified rate does not really change anything about the relationship between the model and the hypothetical decrease in population. The most flabbergasting drop is still the first one, from 479 to 425 BC. Logically, it’s difficult to believe that in only about two generations, 54 years, the population of citizens decreased by ~40% from structural causes. Due to its size, even a low or negative regeneration rate would result in a much more stable population than is realized – as suggested by the 15/1000 graph. Not only do ancient sources mention no mass buying of land – and therefore mass disenfranchisement, but the arguments that land was consolidated by the rich to a radical extent are focused on later periods, in the late 5th and 4th centuries. If demographic and socioeconomic causes are unlikely causal factors, the most likely culprits appear to be the earthquake and helot revolt – most notably discussed by Thucydides, Plutarch, and Diodorus (likely following Ephorus), or the series of conflicts Sparta fought which were not included due to lack of data. The model suggests about 540 *homoioi* perished in the conflicts coinciding with the

29 Figueira 1986, 213.
30 Thuc. I.128, I.101, III.54, II.27, IV.56; Diod. XI.63; XV.66.4; Plut. Cim. XVI.4–5.
helot revolt. It is possible that a large number also perished in the earthquake, as argued by Figueira, French, and Toynbee, for instance: “the earthquake appears an exogenous factor of sufficient magnitude to have caused the steep decline in the number of Spartiates attested by the size of the Spartan army at Pylos and later at Mantinea;”31 or that the devastation of the earthquake lead to mass disenfranchizement, as argued by Lazenby and Hodkinson.32

Such an explanation radically improves the model. If we suppose that 2,000 homoioi dissapeared in the 460s, the result is as follows (see fig. 4; the data table is located in Appendix C):

![Graph showing modeled output of population of homoioi including 5th-century-crisis-losses]

The black diamonds indicate the known population sizes (based on Figueira’s research), making the relationship between the model line and those markers the most important aspect of the graph. Of secondary importance is the polynomial trendline (order 3 trendline), which smooths out the irregularities inherent in a model based on averages – showing a general trend that matches well with known data. In keeping with the marked visual improvement is the increased correlation of 90% – an improvement of nearly 20%, and an $r^2$ of 62% – an increase

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31 Figueira 1986, 178 f.; Toynbee 1969, 349–352; French 1955, 113 f., 188.
32 Lazenby 1985, 76; Hodkinson 2009, 234; Wrigley 1978, 135.
of over 30%. Moreover, this correlation and $r^2$ remain the same whether the first four data points are added or subtracted (if we include the years of 479–425 BC).

**Part 2: 5th-Century Spartan Crisis**

**2.1 Introduction**

Is the conjecture that up to 2,000 *homoioi* perished in the campaigns and earthquake that took place in the early 5th century a likely hypothesis? There are two outputs of data which must be generated, first the probable number of *homoioi* deaths in the earthquake of 464 BC, and second the probable number of *homoioi* deaths in campaigns between 479 and 425 BC. Each requires a different approach. To approximate *homoioi* deaths as a result of the earthquake, we conduct a brief discussion of the magnitude of the earthquake and the damage to Sparta. The destruction is then compared to other major earthquakes of antiquity. To approximate *homoioi* deaths in campaigns, we discuss the plausibility of the scenario, then compare the percentage of *homoioi* that died in conflicts in later periods with the proposed loss using frequentist statistical tests. The resulting outcome will then be applied to Bayes’ formula to update the original percentage loss given the new information.

**2.2 Earthquake Losses**

The earthquake appears in several ancient sources, all of which suggest immense destruction. Plutarch wrote that the earthquake tore away the peaks of Taygetus and destroyed all but five houses in Sparta, a story paralleled by Cicero, Pliny, Pausanias, and Strabo.  

33 Thucydides mentions the earthquake as having caused the helot revolt and kept the Lacedaemonian army from aiding the Thasians.  

34 Finally, Diodorus stated that the earthquake was a catastrophe which caused the death of 20,000 Lacedaemonians.  

35 In sum, all ancient writers suggest it was an important and perhaps even a calamitous event. While the nice round number provided by Diodorus is suspicious, it does align with the likely magnitude of the earthquake. A satellite and fieldwork study from 1991 suggested that the earthquake had a mag-

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33 Plut. Cim. XVI.4; Cic. Div. I.112; Plin. Nat. II.53; Paus. IV.24.5–6; Strab. VIII.5.7.  
34 Thuc. I.101.2.  
35 Diod. XI.1.
nitude of $M_s \approx 7.2$ with a recurrence time frame of about 3,000 years, force enough to demolish the city even if it were relatively well built.\textsuperscript{36} But, given that 20,000 was such a large proportion of the population, that the city was so spread out, and that houses were small, it is certainly unlikely that so many died.\textsuperscript{37} If, however, we compare the number of deaths associated with earthquakes of magnitudes of 7.0 in the ancient Mediterranean, a death toll of 20,000 is not an outlier, nor is the proportion of population lost an impossibility.\textsuperscript{38} It is evident that for the total who died, not all were *homoioi* because the term Lacedaemonian includes the various subclasses of Spartan society, notably the *perioici* and Helots who made up a much larger proportion of the total population.\textsuperscript{39} If 50\% of the dead had been *homoioi* – to match the proposed ratio of *homoioi* to *perioici* in the *moirai* at the time – more than the 5,000 *homoioi* of fighting age would have been killed – which obviously did not occur. It is most unlikely that the entire population of *homoioi* had been in Sparta at the time of the earthquake in the first place. Plutarch suggested the *ephebes* in particular were killed, who numbered about 400.\textsuperscript{40} While it is unlikely that all the *ephebes* were crushed, it is also unlikely that no *homoioi* at all were killed by this devastating earthquake, making 400 the rough minimum number of dead (since many or most *ephebes* would likely become *homoioi* in due course).

The upper boundary of possible *homoioi* deaths can be derived from the hypothetical average proportion of *homoioi* present at Sparta. According to Plutarch, in Cinadon’s day there were a total of 75 *homoioi* present in the marketplace of Sparta in the early 4th century, which corresponded to about 7–8\% of the total population of *homoioi* at the time, where half of that percentage came from the ‘40 other’ *Spartiatae* present.\textsuperscript{41} Thus, if we assume that in 464 BC, a similar 7–8\% of the population of *homoioi* were present in Sparta, up to 1,400 *homoioi* could have died (out of the 20,000 possible Lacedaemonians). If of course we disagree with the assumption that there were 20,000 casualties, that number shrinks. Though attempts at precise statistical modeling of the possible total deaths is, at Hodkinson wrote after his own efforts on the subject, “built upon sand”, the broad range of 400 to 1,400 *homoioi* dead does seem reasonable; the loss of so many *homoioi* and associated sights of vulnerability and mourning may certainly have been great enough to instigate a massive revolt in a restive population.\textsuperscript{42}

\textsuperscript{36} Armijo – Lyon-Caen – Papanastassiou 1991, 137–139.
\textsuperscript{37} Atkinson 1952, 352.
\textsuperscript{38} See: Ambraseys 2009; Sbeinati – Darawcheh – Mouty 2005; Robinson 2016, chapter 1.
\textsuperscript{39} Xen. Hell. III.3.5; Figuera 1986, 178.
\textsuperscript{40} Plut. Cim. XVI.5; Figuera 1986, 178.
\textsuperscript{41} 75 *homoioi* is due to the presence of the 5 Ephors, 30 members of the Gerousia, and 40 ‘others’ [*homoioi*]. Plut. Cim. 16.5.
\textsuperscript{42} Hodkinson 2009, 234.
2.3 Conflict Losses

I hypothesize that there are gaps in the data of the number of conflicts fought by homoioi during this time period. The problem is that we must rely on Herodotus, who focused on the causes and events of the Persian Wars, and not the various Spartan entanglements and hostilities following the conclusion of those wars.\(^{43}\) Furthermore, even despite the small sample size in the initial time period, there is a sizeable difference in the total number and average number of homoioi deaths – no matter how the unpaired T-Test is run (see tab. 8, 9 and 10):\(^{44}\)

Tab. 8: Summary data on the two temporal phases

|                  | Phase 1 | Phase 2 |
|------------------|---------|---------|
| Time Span        | 479–426 | 425–369 |
| Years            | 54      | 57      |
| n                | 5       | 21      |

H\(_0\): Losses per year of phase 1 are the same as losses per year of phase 2
H\(_1\): Losses per year of phase 2 are greater than losses per year of phase 1

Tab. 9: Statistics on differences between average losses per year between the two phases

|                              | Phase 1 | Phase 2 |
|------------------------------|---------|---------|
| Total Number Lost (Average)  | 1,032   | 1,782   |
| Sample SD                    | 87      | 90      |
| Average Lost Per Year        | 19.11   | 31.26   |
| Annualized Sample SD         | 1.81    | 1.53    |
| T Statistic                  | 15.23   |         |
| P Value (One-Tailed)         | <0.0001 |         |

H\(_0\): Percent losses per year of phase 1 are the same as percent losses per year of phase 2
H\(_1\): Percent losses per year of phase 2 are greater than percent losses per year of phase 1.

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\(^{43}\) Hdt. I.1.

\(^{44}\) Assuming unequal variances; if we do not annualize the losses (which would be somewhat acceptable since the time periods are of similar duration), the difference yielded by the average losses is also statistically significant, using 864 and 2010 as the sample mean losses for the period of 479–426 and 425–369 respectively, 98 and 87 as the sample standard deviation of losses, and 5 and 21 as the number of samples.

\(^{45}\) Where the number lost is taken to be the average from the model, not the low or high confidence intervals.

\(^{46}\) Please see Appendix D for the estimated percent lost breakdown per event used to derive these percentages. We are assuming unequal variances in the T-Tests, and omitting any 0% losses. We ran a 1-tailed test for two population means.
Tab. 10: Summary statistics on differences between average losses per year as a percent lost between the two phases

|                        | Phase 1 | Phase 2 |
|------------------------|---------|---------|
| Weighted Average Percent Lost | 21.00 % | 30.00 % |
| Percent Lost Per Year | 0.39 %  | 0.53 %  |
| Sample SD of Percent Lost | 0.04 %  | 0.15 %  |
| T Statistic            | 3.753   |         |
| P Value (One-Tailed)   | 0.0005  |         |

Running a two sample Kolmogorov-Smirnov test (beneficial because it is nonparametric) with minimal bootstrapping for Phase 2 samples also yields difference between distributions ≈ 0.7 ± 0.1 with a P-value ranging between >0.001–0.007. I ran 10 tests with 5 bootstrapped samples so there would be 10 samples in total in the Phase 2 ‘population’. The results of the K-S tests also suggest differences in populations and distributions.

I therefore conjecture that many military events which did not relate to his work were left out of the “Histories”. My query can be rephrased to: was the mid 5th century a less violent time for Sparta than the ensuing period? Research on archaic and ancient societies suggests that war was endemic. The methods of waging war of many archaic peoples, consistent with those of the Ancient Greeks, often consisted of raids and non-agonal combat which were not recorded by Herodotus but were prominent features in the works of other writers. Though many raids appeared to focus on ravaging land, it is possible that raids and small scale actions took a toll, that enemies of Sparta fought with homoioi on dispersed kleroi, or that war was simply constant on Sparta’s hinter and borderlands. More theoretically, the realist theory of state behavior argues that “the prevalence of anarchy […] [and] the resultant grim self-help regime imposed upon all states and its impact upon the constellation of state actions […]; and the importance of the stability or instability of balances of power” resulted in widespread and con-

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47 The average used for Phase 2 is based upon the unweighted average presented slightly further on. Using an unweighted average would have resulted in a higher average proportion lost and therefore a more statistically significant difference between the average lost between the two periods.

48 Calculated as weighted average percent lost divided by years per phase.

49 Calculated as standard deviation of percent lost divided by years per phase.

50 Pinker 2011; Keeley 1996; LeBlanc 2003; Gat 2006; van der Dennen 1995; Thayer 2004.

51 Wheeler 2007, chapter 7; van Wees 2004, chapter 4.

52 Boyer 2018, 59 f.

53 Eckstein 2006, 12–16.
stant conflict. Indeed the Ancient Greeks were obsessed with competition, some
wars were fought with no goal other than victory in and of itself. Even if Sparta
had not fought any important conflicts for immediate tangible benefits (such as
land and resources), border disputes may still have erupted, disputes that could
be “ubiquitous and often interminable”\textsuperscript{54}. Based on this indirect evidence, it is
therefore plausible that there were numerous conflicts and high losses during the
fifty-some years which are missing from our database.

If the past period (479–425 BC) was no less violent than the future period
(425–362 BC), what was the total average population of \textit{homoioi} that died exclud-
ing the skewed past? I calculated the weighted average of the percentage lost,
with respect to time; the larger the time frame, the more impact it has upon the
total percentage of \textit{homoioi} that perished in battle (see tab. 11):\textsuperscript{55}

\begin{table}[h!]
\centering
\caption{Calculation to determine the weighted average of percent population lost to warfare}
\begin{tabular}{|c|c|c|c|c|c|c|}
\hline
Years & Weight & Average Percentage Lost & Lower Confidence Interval & Higher Confidence Interval & Weighted Average & Weighted Avg. for Lower C & Weighted Avg. for Higher C \\
\hline
7 & 11\% & 6\% & 5\% & 6\% & 1\% & 1\% & 1\% \\
24 & 38\% & 38\% & 20\% & 16\% & 24\% & 8\% & 6\% & 9\% \\
23 & 37\% & 37\% & 30\% & 29\% & 36\% & 11\% & 11\% & 13\% \\
9 & 14\% & 14\% & 75\% & 67\% & 73\% & 11\% & 10\% & 10\% \\
\hline
\textbf{Total:} & \textbf{63} & \textbf{100\%} & \textbf{31\%} & \textbf{28\%} & \textbf{33\%} \\
\hline
\end{tabular}
\end{table}

The time frame we presume to be inaccurate – between 479 and 425 – is excluded.
The result is an average of 30 ± 3\% (at a 95\% confidence interval), which is quite
close to the original model’s projected upper boundary of the confidence inter-
val of 26\% (see section 1.5). Applying this weighted average to the population of
5,000 \textit{homoioi} results in a loss of 1,500 ± 150, which is greater than the model had
estimated by a few hundred \textit{homoioi}.

Alternatively, our sample population consists of 30 events, 26 if we subtract
the period of 479–425. That means that over the subsequent 63 years after 425 BC,
26 major engagements were fought for an average of 0.41 per year. If the past
period was anywhere near as violent as its future counterpart, that would suggest

\textsuperscript{54} Van Wees 2007, 285.
\textsuperscript{55} The unweighted average would yield 32\% losses.
we’re missing nearly 18 major engagements!\footnote{0.41 \times 54 \text{ (there are 54 years between 479 and 425 BC)} = 22; 22 - 4 = 18.} Even if Spartan armies were always successful, the slight attrition rate would have added up to significant losses. For instance, if only expeditionary forces of the size that fought at Tangra fought in those 18 engagements, and if each were successful, a total of 1,350 \textit{homoioi} would likely have perished.\footnote{1500 \times 5\% \times 18 = 1350.}

A close reading of available sources suggests the time period was exceedingly difficult for Sparta. We did not factor in any of the losses suffered by Sparta in the Persian Wars, which were at minimum around 400.\footnote{Beyond the 300 who fell at Thermopylae, Herodotus states that 91 \textit{homoioi} fell at Plataea (Hdt. IX.70), though that figure is disproportionately low. The model would suggest 250 is a more reasonable number. We are of course assuming the Spartan contingent at Salamis lost no \textit{homoioi}, and that no other \textit{homoioi} died at Thermopylae and other conflicts during the Second Persian War.} Perhaps therefore the starting population of \textit{homoioi} should have been closer to 4,600 instead of 5,000. A further strain came from the known conflicts mentioned in section 1.4, which could have involved additional sub-clashes and further losses (the wars against Tegea, Argos, and the Arkadians including the battle of Dipaieis and Tegea, and the campaign in Thessaly).

Thus, it is highly plausible that the amalgam of the losses suffered during the tragic 5th century add to over 2,000 dead \textit{homoioi} in battle alone, while the earthquake on its own could also have caused about one quarter of the deaths, at minimum. Though simple frequentist tests do not provide a robust analysis due to the small size of the sample, a T-Test suggests the losses are highly plausible.\footnote{Where \( n = 4 \), the sample mean = 0.21, sample standard deviation = 0.204 results in a T score of 0.933. Problematically, the test above suggest there is enough inherent variation that over 85\% of \textit{homoioi} could have died in conflict, which is of course ridiculous. With so few samples, bootstrapping would also not be particularly useful. Yet we know there were major conflicts that could not be accounted for, and I suspect there were also various minor conflicts in which \textit{homoioi} died between 479 and 425 BC.} Bayes’ formula for generating a posterior ratio of losses suggests that updating our prior proportion of \textit{homoioi} deaths of 21\% with the possible new ratio of 40\% (2,000 dead) yields a loss of 36\% - 1,800 dead.\footnote{See Appendix E for calculation.} Summing the total potential losses we have chronicled here easily approaches or bypasses the hypothesized 2,000 lost, which in turn suggests that war and the earthquake of 464 BC are the most important explanatory factors for this drop.
2.4 Necessary Growth Rate

What rate would be necessary to restock the population of *homoioi*? More importantly, was it attainable? I calculated several population growth rates with different targets and conditions (see tab. 12).

**Tab. 12:** Compound annual growth rate required to replenish population

| Growth to Known Sizes | Geometric Growth to Known Sizes | Compound Annual Growth Rate Back up to 5,000 at Variable Time Spans (t) |
|-----------------------|--------------------------------|---------------------------------------------------------------|
|                       | At t = 15                       | At t = 20 | At t = 25 | At t = 30 | At t = 35 | At t = 40 | At t = 50 |
| 464                   | 6.26%                          | 6.26%     | 4.66%     | 3.71%     | 3.08%     | 2.64%     | 2.30%     | 2%        |
| 457                   | 3.27%                          | 4.67%     | 4.83%     | 4.02%     | 3.08%     | 2.76%     | 2.25%     | 2%        |
| 430                   | 2.56%                          | 4.99%     | 8.60%     | 6.38%     | 5.07%     | 4.21%     | 3.60%     | 3.14%     |
| 425                   | 1.11%                          | 1.51%     | 4.05%     | 3.02%     | 2.41%     | 2.01%     | 1.72%     | 1.50%     |
| 421                   | 1.04%                          | 1.99%     | 4.59%     | 3.42%     | 2.73%     | 2.27%     | 1.94%     | 1.70%     |
| 418                   | 3.95%                          | 4.46%     | 5.95%     | 4.43%     | 3.53%     | 2.93%     | 2.51%     | 2.19%     |
| 417                   | 6.89%                          | 6.89%     | 6.43%     | 4.78%     | 3.81%     | 3.16%     | 2.70%     | 2.36%     |
| 400                   | 2.16%                          | 2.61%     | 8.71%     | 6.46%     | 5.14%     | 4.26%     | 3.64%     | 3.18%     |
| 399                   | 0.24%                          | 0.24%     | 6.27%     | 4.67%     | 3.72%     | 3.09%     | 2.64%     | 2.31%     |
| 394                   | 0.57%                          | 0.61%     | 6.92%     | 5.15%     | 4.10%     | 3.40%     | 2.91%     | 2.54%     |
| 392                   | 4.00%                          | 4.08%     | 7.48%     | 5.56%     | 4.42%     | 3.67%     | 3.14%     | 2.74%     |
| 390                   | 1.65%                          | 1.69%     | 7.39%     | 5.49%     | 4.37%     | 3.63%     | 3.10%     | 2.71%     |
| 385                   | 3.55%                          | 4.10%     | 9.18%     | 6.81%     | 5.41%     | 4.49%     | 3.84%     | 3.35%     |
| 379                   | 0.97%                          | 1.04%     | 7.95%     | 5.91%     | 4.70%     | 3.90%     | 3.33%     | 2.91%     |
| 378                   | 0.24%                          | 0.24%     | 7.19%     | 5.35%     | 4.25%     | 3.53%     | 3.02%     | 2.64%     |
| 377                   | 0.19%                          | 0.20%     | 7.15%     | 5.32%     | 4.23%     | 3.51%     | 3.01%     | 2.62%     |
| 376                   | 0.12%                          | 0.12%     | 7.08%     | 5.26%     | 4.19%     | 3.48%     | 2.97%     | 2.60%     |
| 375                   | 0.18%                          | 0.18%     | 7.16%     | 5.32%     | 4.24%     | 3.52%     | 3.01%     | 2.63%     |
| 371                   | 2.96%                          | 4.15%     | 11.80%    | 8.73%     | 6.92%     | 5.74%     | 4.90%     | 4.27%     |
| 370                   | 69.64%                         | 69.64%    | 15.81%    | 9.21%     | 7.62%     | 6.49%     | 5.66%     | 5%        |
| 369                   | 30.57%                         | 35.24%    | 15.85%    | 11.67%    | 9.23%     | 7.63%     | 6.51%     | 5.67%     |
| 368                   | 23.26%                         | 29.10%    | 16.58%    | 12.19%    | 9.64%     | 7.97%     | 6.80%     | 5.92%     |
| 364                   | 6.96%                          | 8.59%     | 15.37%    | 11.32%    | 8.96%     | 7.41%     | 6.32%     | 5.51%     |
| 364                   | 8.00%                          | 10.20%    | 15.89%    | 11.70%    | 9.25%     | 7.65%     | 6.53%     | 5.69%     |
| 362                   | 0.76%                          | 0.79%     | 12.31%    | 9.10%     | 7.22%     | 5.98%     | 5.10%     | 4.45%     |
| **Mean**              | **7.28%**                      | **8.29%** | **9.07%** | **6.72%** | **5.33%** | **4.42%** | **3.78%** | **3.30%** | **2.63%** |
The columns “Growth to Known Sizes” and “Geometric Growth to Known Sizes” display the compounded and geometric growth rates, respectively, necessary to reach the last applicable known size based on Figueira’s findings. For instance, in 464 BC the compound annual growth rate to reach the last known size (5,000 in 479 BC) was about 6% with a geometric average of about 9%. To the right of these two columns are the compound annual population growth rates to reach 5,000 homoioi under different time constraints (t). It would take a compounded growth rate of 8.6% in 430 BC for the population of homoioi to reach 5,000 in 15 years, 6.4% in 20 years, 5.1% in 25 years, and so on. These columns reflect the stable, unhindered necessary growth for a single to several generations of homoioi necessary to regain their initial large population size. Below these columns is the average. Note first the general increase of these rates as time passed, the rate required to either reach the last known population size or absolute size of 5,000 generally increases from 464 to 362 BC. Second, note the average rates are quite high and more than rival the population growth rates of emerging countries today.

To apply absolute numbers to these relative figures, after the battle of Leuctra, the population of homoioi would have had to increase by about 380 that year to make up for the losses. To reach its plateau of 5,000, the population would have to increase by about 90 just that year (equivalent to about 16% of the current population, magnitudes higher than countries with high population growth today), then 100 the next (about 15% of the population), and so on. The replacement proportions are gargantuan. If warfare or structural disruptions affected these growth rates, the population of homoioi was doomed, unable to reach either their last known or maximum size. In other words, the population may have been too small in the first place to actually replenish in any timely manner.

**Conclusion and Implications**

A narrative is spawned out of the graphical representation of the population, highlighted by the polynomial trendline in figure 4. From the refined model displayed in this paper, a steady attrition rate can account for almost the entire decline in the population of homoioi after 425 BC. As a result, hypotheses suggesting socioeconomic, structural factors would therefore be less salient in explaining the decline. But before 425, and before the supposed socioeconomic problems that affected Sparta – which typically coincide with either the Peloponnesian War or the following period – I suggest that Sparta experienced a major crisis.

Despite scant evidence, statistical approximations suggest that a series of crisis erupted in early 5th century Sparta, decimating its population of homoioi.
Room for additional research, models, and archaeological finds exists to confirm or discount this theory; though the methods shown in this paper suggest that endemic warfare and the earthquake of 464 BC were enough to cause the disappearance of some 2,000 *homoioi* (please see Appendix F for a robustness test and discussion). With its diminished population, Sparta became cautious in its foreign policy, and wary of conflict.\(^{61}\) Nevertheless, Sparta was drawn into the Peloponnesian War only about one generation after this crisis (where they would have required a population growth rate of over 4% a year to regenerate). Though Sparta won almost every battle on land, it still lost citizens until it was too late to reverse the pattern. Sparta’s hegemony after the Peloponnesian War compelled citizen armies to muster for continual action. Success on the battlefield may have blinded Sparta to its shrinking population, as it lost so few battles on land until faced with a resurgent Thebes and Boeotia in the 4th century. Based on the database in this paper, there is a correlation of \(-53\%\) between time and campaign success – the more time passed, the higher the likelihood of defeat, and a defeat resulted in a higher ratio of losses per conflict.\(^{62}\) A somewhat anecdotal piece of evidence insinuates that endemic warfare in a society like ancient Sparta would easily have such enormous ramifications upon its male population. In their sociological study of a major bottleneck in male populations around 5000–7000 BC, Zeng et al. showed that generations of war in patrilineal societies – societies where men cannot move between clans – resulted in a complete collapse in male populations and resulted in 1 male per every 17 females.\(^{63}\) Sparta was a patrilineal society which granted little to no access of movement, rendering it especially vulnerable to the fate of *oliganthrôpia* by attrition, a fate also shared by the contemporary great city Thespiai in Boeotia.\(^{64}\) Rather than a source of power and wealth, the “Second Spartan Empire”\(^{65}\) and continual conflicts of the 4th century became an abscess that drained Sparta of its citizenry; in spite of the efforts of the state to hedge its losses by hiring mercenaries and employing *perioikoi*, *neodamodeis*, Helots, and *hypomeiones*.\(^{66}\) Best of all, the losses of manpower also explain

\(^{61}\) On Sparta being an aggressive power and liberal with its use of citizens in the 6th century, see the dispatch of a colony under Dorieus (Hdt. V.42.2), the battle of the champions (Hdt. I.82.3–7), the expeditions to Athens (Hdt. V.63–4) and Samos (Hdt. III.44); Huxley 1962, 38, 64, 67, 73. On Sparta being cautious in the mid 4th century, see Thuc. I.71; Cartledge – Debnar 2006, 560–562.

\(^{62}\) Calculated by tagging a successful conflict with a 1, a defeat with a 0, and an inconclusive action a 0.5.

\(^{63}\) Zeng et al. 2018.

\(^{64}\) Hanson in Carman – Harding 1999, chapter 13; alternatively, Hanson 2003.

\(^{65}\) Parke 1930.

\(^{66}\) Cartledge 2000, 37–43; Toynbee 1913, 264–269, and 1969, 365–371; Lazenby 1985, 16 f., 143; Hawkins 2011, 401–403.
the major sociostructural symptoms of Sparta. For instance, as homoioi perished, their property passed on – sometimes to females. Many may have died without heirs, leaving their assets to be acquired by the state or by the powerful and rich. Though it may appear to have, Sparta never had the opportunity to recover from the events of the early 5th century BC, and it is that initial vulnerability which sowed the seeds of disaster that sprouted at Leuctra in 371 BC and Mantinea in 362 BC.

Appendix

Appendix A: Model Population Tables

| Age | Percentage of Population |
|-----|--------------------------|
| 1   | 3 %                      |
| 5   | 13 %                     |
| 10  | 24 %                     |
| 15  | 34 %                     |
| 20  | 44 %                     |
| 25  | 53 %                     |
| 30  | 62 %                     |
| 35  | 69 %                     |
| 40  | 76 %                     |
| 45  | 82 %                     |
| 50  | 87 %                     |
| 55  | 91 %                     |
| 60  | 94 %                     |

| Age | Percentage of Population |
|-----|--------------------------|
| 1   | 3 %                      |
| 5   | 12 %                     |
| 10  | 22 %                     |
| 15  | 31 %                     |
| 20  | 40 %                     |
| 25  | 48 %                     |
| 30  | 56 %                     |
| 35  | 63 %                     |
| 40  | 70 %                     |
| 45  | 76 %                     |
| 50  | 82 %                     |
| 55  | 87 %                     |
| 60  | 92 %                     |

| Age | Percentage of Population |
|-----|--------------------------|
| 1   | 2 %                      |
| 5   | 11 %                     |
| 10  | 20 %                     |
| 15  | 30 %                     |
| 20  | 39 %                     |
| 25  | 47 %                     |
| 30  | 55 %                     |
| 35  | 63 %                     |
| 40  | 70 %                     |
| 45  | 76 %                     |
| 50  | 82 %                     |
| 55  | 87 %                     |
| 60  | 91 %                     |
Appendix B: Correlation and Regression Tables between Appendix A Tables

‘C&D’ stands for Claude and Demeny, ‘Egypt’ represents Bagnall and Frier, ‘UN’ represents the U.N. general pattern developing country model life table.

### Correlation

|        | C&D          | Egypt        | UN           |
|--------|--------------|--------------|--------------|
| C&D    | 1            | 99.8960%     | 99.9958%     |
| Egypt  | 1            | 1            | 99.8759%     |
| UN     | 99.8759%     | 1            | 1            |

### Regression

|        | C&D          | Egypt        | UN           |
|--------|--------------|--------------|--------------|
| C&D    | 1            | 96.0576%     | 98.7996%     |
| Egypt  | 1            | 1            | 97.2010%     |
| UN     | 97.2010%     | 1            | 1            |

### Descriptive Statistics for Differences between Model Life Tables

| Δ C&D and Egypt | Difference | Descriptive Stat. | Δ Egypt and UN | Difference | Descriptive Stat. | Δ C&D and UN | Difference | Descriptive Stat. |
|-----------------|------------|-------------------|---------------|------------|-------------------|---------------|------------|-------------------|
|                 | 0 %        | Mean              | 1 %           | Mean       | 1 %               | 1 %           | Mean       |
|                 | −1 %       | −4 %              | 2 %           | 5 %        | 1 %               | 1 %           | 1 %        |
|                 | −2 %       | −4 %              | 4 %           | 5 %        | 1 %               | 1 %           | 1 %        |
|                 | −4 %       | −4 %              | 5 %           | 5 %        | 1 %               | 1 %           | 1 %        |
|                 | −4 %       | −4 %              | 6 %           | Standard   | 6 %               | 2 %           | 2 %        |
|                 | −5 %       | 2 %               | 6 %           | Standard   | 6 %               | 6 %           | 1 %        |
|                 | −6 %       | 6 %               | 6 %           | Standard   | 6 %               | 6 %           | 0 %        |
|                 | −6 %       | 6 %               | 6 %           | Standard   | 6 %               | 6 %           | 0 %        |
|                 | −5 %       | 5 %               | 6 %           | Standard   | 6 %               | 6 %           | 0 %        |
|                 | −5 %       | 5 %               | 5 %           | Standard   | 5 %               | 5 %           | 0 %        |
|                 | −4 %       | 4 %               | 5 %           | Standard   | 4 %               | 4 %           | 0 %        |
|                 | −3 %       | 3 %               | 4 %           | Standard   | 3 %               | 3 %           | 0 %        |

Note: The applicable differences for this paper was the difference between C&D and the other sources, not the difference between Egypt and UN tables.
Appendix C: Earthquake Losses

Hypothesized no. of *homoioi* assuming a population drop due to earthquake/conflicts of early 5th century

| Date (BC) | Army Size |
|-----------|-----------|
| 479       | 5,000     |
| 464       | 2,783     |
| 430       | 2,898     |
| 425       | 2,755     |
| 421       | 2,756     |
| 418       | 2,100     |
| 417       | 2,002     |
| 400       | 2,085     |
| 399       | 2,045     |
| 394       | 1,833     |
| 392       | 1,760     |
| 390       | 1,783     |
| 385       | 1,475     |
| 379       | 1,784     |
| 378       | 1,798     |
| 377       | 1,807     |
| 376       | 1,827     |
| 375       | 1,806     |
| 371       | 938       |
| 370       | 563       |
| 369       | 561       |
| 368       | 510       |
| 364       | 633       |
| 364       | 547       |
| 362       | 876       |
## Appendix D: Estimated Percent Lost Per Event

| Event                                                                 | Percent Lost |
|----------------------------------------------------------------------|--------------|
| Battle of Platea (Hdt. X.10–11)                                       | 5.00 %       |
| Stenyklaros Plain (Hdt. IX.64.2)                                      | 6.27 %       |
| Ithome Campaign (Thuc. I.101)                                        | 5.00 %       |
| Battle of Tanagra (Thuc. I.107)                                       | 1.50 %       |
| vs. Platea (Thuc. II.71)                                              | 3.36 %       |
| Battle of Sphacteria and Pylos (Thuc. IV.11–15, 23, 26, 31–38)        | 2.18 %       |
| vs. Parrhasia (Thuc. V.33)                                            | 3.33 %       |
| Battle of Mantinea (Thuc. V.64)                                       | 5.00 %       |
| vs. Sicyon (Thuc. V.81)                                               | 0.79 %       |
| vs. Argos, Battle of Hysiae (Thuc. V.83, Diod. XII.81.1)              | 5.00 %       |
| vs. Elis, Agis’ 2nd invasion (Xen. III.2.25)                          | 5.00 %       |
| vs. Elis, Pausanias’ invasion (Diod. XIV.17)                           | 5.00 %       |
| Battle of Nemea (Xen. IV.2.15)                                        | 5.00 %       |
| Battle of Coronea (Xen. IV.3.17)                                      | 0.80 %       |
| Support Corinthians (Xen. IV.4.8)                                     | 0.55 %       |
| vs. Piraeum (Xen. IV.5.1–2)                                          | 0.00 %       |
| Battle of Lechaeum (Xen. IV.5.13–14)                                  | 14.02 %      |
| vs. Mantinea (Xen. V.2.3)                                             | 5.00 %       |
| vs. Thebes, Cleombrutus’ 1st invasion (Xen. V.4.14)                   | 3.62 %       |
| vs. Thebes, Agesilaus’ 1st campaign (Xen. V.4.35–36)                  | 0.11 %       |
| vs. Thebes, Agesilaus’ 2nd campaign (Xen. V.4.47)                     | 0.55 %       |
| vs. Thebes, Cleombrutus’ 2nd campaign (Xen. V.4.59)                   | 0.00 %       |
| Battle of Tegyra (Plut. Pel. XVII, Diod. XV.81.2)                     | 2.24 %       |
| Battle of Leuctra (Xen. VI.4.3)                                       | 42.64 %      |
| vs. Mantinea (Xen. VI.5.10)                                           | 5.00 %       |
| vs. Thebes (Diod. XV.68.2)                                            | 13.50 %      |
| Tearless Battle (Xen. VII.1.31–33)                                    | 0.00 %       |
| vs. Arcadians, to support Eleans and Archidamus’ relief force of Cromnus (Xen. VII.4.20–24) | 13.50%  |
| vs. Arcadians, attempt to capture Cromnus (Xen. VII.4.27)             | 13.50 %      |
| vs. Theban Army, Battle of Mantinea (Xen. VII.5.10)                   | 5.00 %       |
Appendix E:

Bayes’ rule allows one to describe the probability of an event, based on prior knowledge of conditions that might be related to the event. It is adapted here for updating a ratio rather than a probability.

| Prior ratio of losses | x | 21 % |
|-----------------------|---|------|
| Losses assuming the model is correct | x | 21 % |

**Additional considerations**

| Ratio of losses if deaths in war caused the drop in *homoioi* numbers | y | 40 % |
|--------------------------------------------------------------------------|---|------|
| Ratio of losses of *homoioi* in case deaths in war did not cause drop in population | z | 19 % |

| Posterior ratio of losses | x y/(x y – z (1 – x)) | 36 % |
|---------------------------|------------------------|------|
| Revised ratio of losses, given the possibility that so many *homoioi* died in war | x y/(x y – z (1 – x)) | 36 % |

Appendix F: Robustness Test and Discussion

How good is our model at explaining population decline? While we have already discussed its merits and limitations, one possible way to test the robustness is to align the expected output deaths of the model with the implied deaths extracted from other historians’ approximations. As was shown in Decety (2018), several historians have approximated the decrease in the population of *homoioi* over time. In the table below, I extrapolated the implied population decrease between points in time (“Time Span”).

| Time Span | Cartledge | Hansen | Cawkwell | Grundy | Figueira | Median |
|-----------|-----------|--------|----------|--------|----------|--------|
| 479–460 BC | 1,500     | 1,600  | 1,600    | 2,344  | 1,945    | 1,600  |
| 459–440 BC | 2,000     | 1,600  | 2,000    | 3,125  | 300      | 2,000  |
| 439–420 BC | 1,000     | 200    | 300      | 1,750  | 655      | 655    |
| 419–400 BC | 1,000     | 800    | 100      | 1,500  | 267      | 800    |
| 399–380 BC | 500       | 550    | 740      | 800    | 905      | 740    |
| 379–360 BC | 500       | 650    | 400      | 1,000  | 52       | 500    |
| **Sum**    | **6,500** | **5,400** | **5,140** | **10,519** | **4,124** | **6,295** |

The columns below each name are the implied losses of each historian per time segment. On the far right side is the median loss of all authors. Below these columns are the sum losses (“sum”).
In the following table, I sum the losses predicted by the model. Both models are shown, the one on the left is the simple sum of deaths including only attrition in combat (“Model: No Disaster”), and the one on the right is the sum of deaths including both attrition and a presumed additional loss of 2,000 homoioi in the early 5th century (“Model: Disaster”). Each model is summarized based upon the sum average losses per time span. At the bottom I show the percent losses, dividing the sum loss above by the median sum of 6,295 (“% of median sum”) and by Figueira’s sum losses (“% of Figueira sum”). The closer percentages sums are to 100 %, the more explanatory the model can be of losses.

| Time Span   | Model: No Disaster | Model: Disaster |
|-------------|--------------------|-----------------|
| 479–460 BC  | 684                | 2,200           |
| 459–440 BC  | 59                 | 0               |
| 439–420 BC  | 266                | 700             |
| 419–400 BC  | 257                | 15              |
| 399–380 BC  | 485                | 506             |
| 379–360 BC  | 345                | 755             |
| Sum         | 1,396              | 4,175           |
| % of Median sum | 22 %        | 66 %            |
| % of Figueira sum | 34 %       | 101 %           |

Recall that we used confidence intervals, and that the resulting average total deaths for the model without the presumed deaths in the 5th century should be about ±700, yielding a % of median sum of between 22% and 44% and a % of Figueira sum of between 34% and 68%.

As was discussed in the introduction section of this paper, we utilized the population sizes provided by Figueira. His implied approximate decrease is 4,124, by far the lowest one (about 35% smaller than the average of other historians showcased in this test). It is therefore not surprising that the comparison of the model be more aligned when taken as a percentage of Figueira’s losses than the median sum. Had we used a different set of numbers as the basis of our model, the losses would indubitably be higher (based on a contrast of Figueira's total with the median, approximately a ratio of 2:3, the percentages lost would more or less increase by about 50% – thereby aligning them far better to the median sum). Note however that even with lower losses, the model with the presumed earthquake and additional conflict deaths do align fairly well with not only Figueira’s losses but the median as well – so perhaps 2,000 deaths was in fact unnecessarily high, a range of between 1,000 and 2,000 would be sufficient, a range that has been suggested as highly plausible in this essay.
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