A Simulation on the Effect of a Major World War on the Population of the World

Chenyun Zhang
Governor's School for Science and Technology
Hampton, VA
chenyun.zhang@nhgs.tec.va.us

Julie Zhou
Governor's School for Science and Technology
Hampton, VA
julie.zhou@nhgs.tec.va.us

ABSTRACT

During the Cold War, many people around the world felt the immense threat of nuclear warfare. Even as tensions calmed, the development of nuclear arsenals did not. Growth in nuclear weapon testing, political instability, and the increase in terrorist activity make war and war casualties a global concern. The purpose of this project was to simulate, through NetLogo, changes in the world population under a variety of war scenarios. Data about the current population and growth rate for each country that came from the CIA World Factbook were put into a shapefile, which is a geographic information system file. Casualty data from World War I and World War II were also collected and integrated into the shapefile. The program applies the natural growth rate and, if a battle took place, the coefficients derived from Lanchester's Theory of Warfare to the population and updates the map with the population change. The Lanchester's Theory of Warfare uses historical battles and past causalities data. The user can specify the initial soldier amount for both sides of a battle and the factors for each, such as the weapon efficiency, which are used in Lanchester's Theory of Warfare. Furthermore, the user can choose between the World War I data and the World War II data. This process is repeated for each tick, which is the count of days that has passed in the simulation. While the population will inevitably decrease in the case of a war, the different coefficients of war have different impacts on the population.

ABOUT THE AUTHORS

Chenyun Zhang is a senior at the Governor's for Science & Technology in Hampton, Virginia. She is completing coursework in the Governor's School's Scientific Programming strand, which contains classes in scientific programming and inquiry physics. Along with those classes, she is taking multivariable calculus/ linear algebra, research application/ mentorship, and environmental science. At Grafton High School, Chenyun participates in the Girls' Varsity Tennis Team and in multiple honor societies.

Julie Zhou is a senior at the Governor's for Science & Technology in Hampton, Virginia. She is taking rigorous courses in scientific programming and inquiry physics, which are in the Scientific Programming strand. Furthermore, she is taking calculus, research application/ mentorship, and environmental science in the Governor's School. She participates in the York High School's Girls' Varsity Tennis Team, as well as other activities such as National Honor Society and the Green Club.

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INTRODUCTION

The concept of a new catastrophic world war (i.e. "World War III") has been an active area of speculation and interest for many people, and the speculation is for good reason. In recent years, North Korea announced their nuclear missile testing and willingness to use these weapons to counter foreign threats, resulting in heightening tensions with multiple countries, such as the United States (Gale and Lee 2016). Growth in nuclear missile testing is not the only problem that the world is facing; terrorist acts have also increased within the last century and have quickly developed into a global problem. Especially after the September 2001 attacks, people around the world have recognized the threat of terrorism on civilization (Vertigans 2010). Furthermore, improvements in weaponry have enabled weapons to affect a wider area and cause heavier damage to a population. These developments have led to the possibility of a modern world war taking place, which could lead to mass military and civilian casualties.

However, in the case of an outbreak of a major war, war simulations can help gauge the effects of a conflict. They can also test the outcome of different scenarios. In a recent study, two researchers incorporated the Lanchester's Theory of Warfare in their simulation of the American Civil War battle of Pickett's Charge in order to see whether or not the Confederate army could have won in three different situations (Armstrong and Sodergren 2015). Although there are many factors involved in warfare that are hard to trace, war simulations are still used to analyze past conflicts; this analysis can provide more foresight into future conflicts (Helmbold 1961). Simulations that use the Lanchester's theory aim to measure combat attrition, which takes in the casualties of one side and compares it to the size of its forces. Although the model has been proven effective (Perry 2011) Lanchester models do not measure troop engagements, mobility, and other complex characteristics of combat. This study implements the Lancaster Theory of Warfare in order to replicate battles of World War I and World War II and calculate casualties based on user-defined efficiencies and soldier amount. In order to observe changes in population of different countries during a war, this study incorporates past world war data and various parameters that the user can manipulate to produce varying war casualty results.

OBJECTIVES AND OVERVIEW

A simulation was created to predict the condition of the world population during and after the outbreak of a modern world war. Patterns in growth or decline in the different populations, and which countries would change the most dramatically, were observed in the results. These changes led to results that could be possible consequences of a major world war.

The model has two different options: a World War I and a World War II model. While there has been a substantial change in technology and tactics since the time that these wars occurred, World War I and World War II are two of the wars that are considered as fought worldwide. A majority of the major war battles and the causalities in each battle were implemented into the model through a shapefile. A shapefile is a geospatial vector data for geographic information system, which allows the model to connect each country to specific data. The user is able to define what day the war will start on, what percentage of a country would become soldiers, the percentage that the weapon efficiency increased from the war that data was gathered from, and which country's population to track. After running the simulation, the map projection displays various color changes for the countries, which represent shifts in population.

RESEARCH

For the map projection of the model, a free country Geographic Information System (GIS) shapefile from the Natural Earth vector and raster map database was used to visualize the changes in the population of each country. The current population and the yearly growth rate for each country were taken from the Central Intelligence Agency (CIA) World Factbook and were joined into the country shapefile through the open-source QGIS software. The population growth rate uses the annual average percent change, which is the difference of the current population and past population all divided by the past population and the outcome of a surplus or deficit in births in comparison to deaths. The population growth rate also uses the annual average percent change to the net migration of the country, which is the difference between the immigrants and emigrants of a country. These data served as the starting attributes of each country in the model and provided the basis for how the countries would develop without war (Figure 1). Casualty data, which includes the people killed and wounded, from the battles in World War I and World War II were taken from online databases. These data were also added into the shapefile under columns that were titled by the date of the battle, such as F08231914; F08231914 stands for August 23, 1914. Rough sizes of the military of each country involved in World War I and World War II were added into the file for the replication of past battles and as comparison to the user-input war factors. If the country was not in World War I or World War II, the program defaulted the size of the military to 1,000 in order to avoid any cases of divide by zero.

name_long	Pop	Pop_grow
Australia	22751014	1.0700000...
Austria	8665550	0.5500000...
Azerbaijan	9780780	0.9600000...
Burundi	10742276	3.2700000...
Belgium	11323973	0.7600000...
Benin	10448647	2.7800000...
Burkina Faso	18931686	3.0300000...
Bangladesh	168957745	1.6000000...
Bulgaria	7186893	-0.580000...
Bahamas	324597	0.8400000...
Bosnia and...	3867055	-0.130000...
Belarus	9589689	-0.200000...
Belize	347369	1.8700000...
Bolivia	10800882	1.5600000...
Brazil	204259812	0.7700000...

Figure 1. QGIS Shapefile Attributes

NETLOGO

NetLogo is an agent-based programming software and relies on patches, which are the pixels that the model is made up of, and turtles, which are the agents that move on the grid; this model was created by patches rather than turtle because it was not interacting at the agent level. Within NetLogo, patches can have their own variables; the variables are used to characterize each patch. In the simulation, each patched was identified as a part of a country, which allowed it to contain the name of the country, the population of the country, and the population growth rate of each country. The data that are contained within the variables that the patch owns are extracted from the shapefile, which are implemented through GIS extension from NetLogo.

NetLogo has extension modules that provides features such as arrays, matrices, and GIS elements. The GIS extension within NetLogo can read in geo-specific data from shapefiles and projection files. It also has the ability to load vector dataset and raster dataset through shapefiles and ASCII grid files (GIS Extension). Thus, the program used the extension to load the projection file, which created a map, and the datasets within the shapefile. Due to the apply-coverage method, each column of the shapefile can be designated to a variable, which is owned by every patch.

Data Visualization

In order to project the populations of a country on the map, the patch-owned variables were used. When the population data of a patch falls within the range for a specific color, the patch will turn to the color that is described by the corresponding map key (see Figure 2). The population color key is represented by an upper bound population size/color pair and a lower bound population size/color pair (preceding key). The colors ascend from a lighter shade to a darker shade; however, if the two colors are on the same scale, such as violet + 1 and pink + 1, the pink color represents a larger population. The key does not follow a specific trend because some of the population cluster around a specific color. Furthermore, China and India skews the key to larger numbers. This causes the rest of the map to have the same color because the range that China and India skews is very large. To allow for flexibility, users can define different variables, such as the percentage of the population that will participate in the war that will impact the outcomes of the simulation.

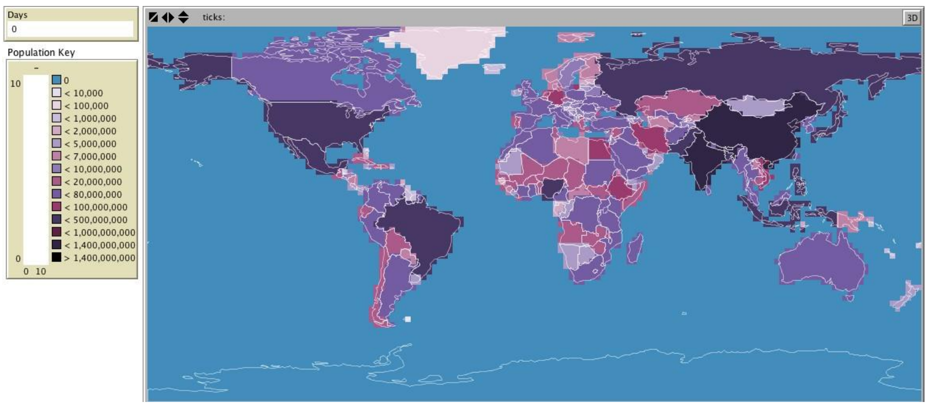

Figure 2. The map projection with the key

SIMULATION

Since there are many scenarios that may happen when a war breaks out, the simulation should be flexible enough to cover the different situations, such as when there are not many soldiers participating in the war. The users can define a war start date. The user can also choose which country to monitor. Through a drop-down menu, the user can select a country and the population of the country will be displayed below it, which allows the user to carefully track one specific country during the war. In order to monitor the population, the program checks to see if the name variable of the patch is equal to the name of the country that the user would like to monitor. If it is, the program assigns the variable that is displayed with the population data that the patch contains. The user can also choose whether the World War I data or the World War II data will be used. These two wars were chosen because the wars were the two large-scale wars that are closest to modern day. Information on the battles and the deaths, therefore, were readily available. After the user selects a war, the program will find the first battle of the war through its property respective property names: F08051914 for World War I, and F03171939 for World War II.

The program finds the name and assigns the variable, start index, as the column number that the property name was found. The deaths that occurred during each battle can also be adjusted by the user; the user can input numbers for the percentage of the citizens that are soldiers for each country and for the percentage that the weapon efficiency increased since the original battle. These two variables are key components of the Lanchester's Weapon Theory. The theory states that the rate of casualties for the two forces are the effectiveness of the two forces times the numerical strength of the two forces (Watkins n.d.). Thus, the percentage that numerical strength of the forces increased is the percentage of the citizens that are soldiers divided by the original number of soldiers, which is multiplied by the weapon efficiency divided by 100. This number is multiplied by the original death count and added the death count to create a new variable, new_death. Through the Lanchester's Weapon Theory, the users are able to manipulate the strength of each country. After these variables are set, the simulation ends the set-up stage.

Once the simulation starts, the simulation will run by ticks, which represents one day. In every tick, the program takes the growth rate of each country and multiply it by the current population. The resulting number will be rounded and added to the current population. If the war has started, the program will determine if the day of which the model is on is equal to the day that a battle happened during one of the major wars. The days of the battles are provided in a list of numbers. For example, if a battle happened on the first day of the war, the number zero will be the first number in the list. If the two numbers are equal, the model will obtain the data on the battle by finding the column in the shapefile. The program finds the battle in the shapefile by taking the start_index and adding the array count to it, which is initially zero. Once the death data are obtained, the program calculate the new_death variable and subtract it from the current population. If the resulting number is greater than the current population, the population will be set to zero because a country cannot have a negative population size. After the population is manipulated through the growth rate and the battle, the new population will be implemented. The day count will increase by one, and the population will be manipulated again.

RESULTS

In the simulation, the soldier percentage was set to 10%. This was chosen because during World War I, around 4% of people in America went to war and around 19% of people in United Kingdom went to war. In World War II, around 9% of Americans went to war, while the percentage in United Kingdom was very similar. Other countries, such as Germany, that were active in the war had between 0% to 20% percent of the population in the war. Thus, the soldier percent was set to 10%, while different efficiencies were tested.

During the initial stage of the simulation, which was when the day is equal to zero, North America, South America, Asia, and Europe mainly consisted of darker colors; Africa on the other hand, was consisted of some lighter colors (Figure 3).

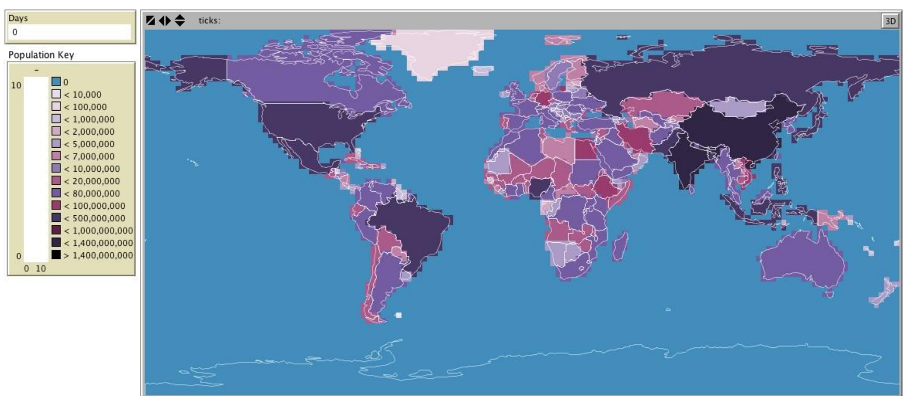

Figure 3. Initial Phase

When the weapon efficiency was set to 50%, and the selected option was World War I, there was not a drastic visual change in the colors of the map when it was stopped at around 1521 days, which was when the war ended (Figure 4). Sweden and some African countries, such as the Democratic Republic of Congo, were a few that got noticeably darker at the end of the simulation. However, there were still some countries, such as Libya, that got lighter in color, which shows that the population in that country decreased. However, the change in the major countries, such as Russia, America, and China, was not displayed through the colors, since the change did not exceed the limit for the color to change.

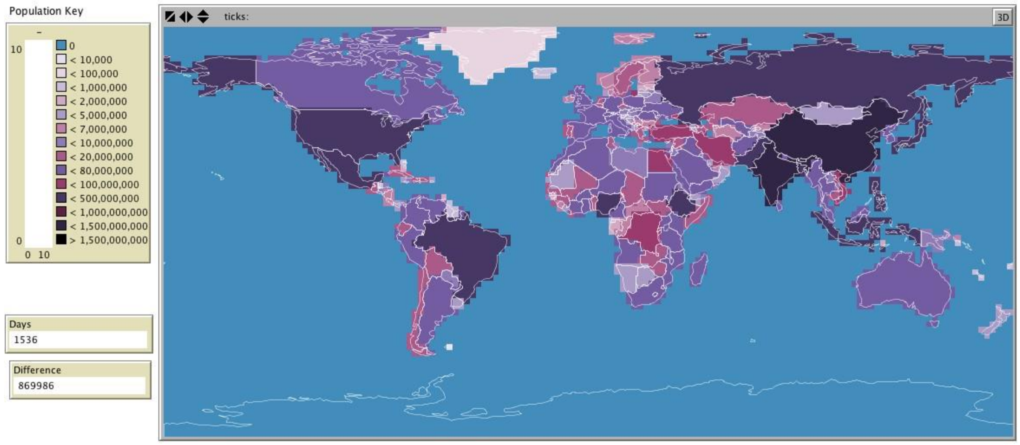

Figure 4. End of simulation with the weapon efficiency of 50% and with World War I data

In the World War II setting, most of the visual change occurred in the Northern African and Western European regions when it was stopped at around 2320 days (Figure 5). The Northern African countries, such as Mali, turned darker, which showed that their population increased. The Western European regions, except for Germany also became darker.

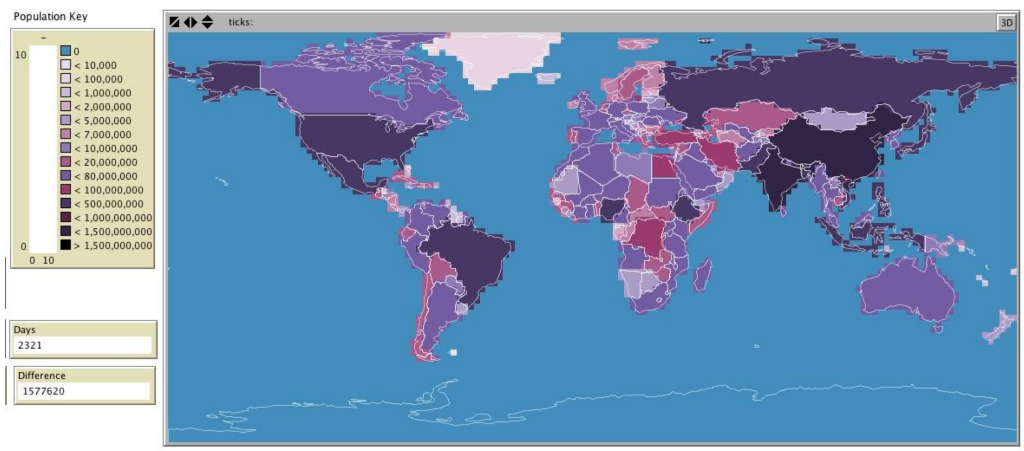

Figure 5. End of simulation with the weapon efficiency of 50% and with World War II data

When the efficiency rate was set to 100% with the World War I dataset, the colors of the map did not dramatically change from the ones with the weapon efficiency of 50%. Due to the fact that the changes in color represent a dramatic change in the population, this stable color trend also occurred within the World War II dataset. Even though the color did not change dramatically, the population of each country were still impacted through the change of weapon efficiency (Figure 6). The changes between the different options do not seem like much but for Japan, the population went down 868,880 from the original 126, 919, 659 in the World War I option and 1,584,757 in the World War 2 option. Germany had losses of 9,446,042 in World War I scenario and 1,001,349 in the World War II scenario.

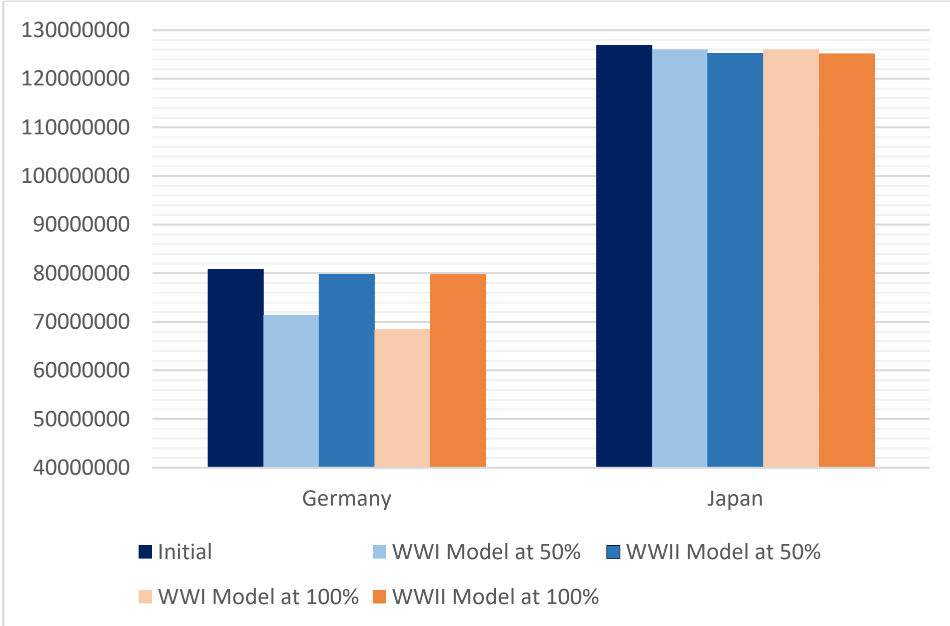

Figure 6. Populations of Japan and Germany with the World War I and World War II options

DISCUSSION

This model is a user-friendly, basic simulation that shows the consequences of war on population through different weapon efficiencies and soldier count. It could serve as an aid for the military and first responders to assess if an area is capable of surviving a battle. The possible consequences shown can also help determine what still needs to be done to further prepare the area in case of a major world war. History teachers could also use this model to help students get a better understanding of the effects of war. In most cases, the number of casualties seem very minute compared to the current population of the world, which skews the perception that students may have on the impact of the two major wars during that time period. However, since the model is based on past world war data, it is unable to display the effects of countries that were not included in those battles. Because not all of the battles of World War II were included and not all the factors of war were taken into account, the model does not provide a simulation of warfare. This may also be the cause of why there was a greater decrease in population in the World War I option, even though World War II is known for being one of the deadliest conflicts in history.

Since the colors in the model did not dramatically change with a 50% weapon efficiency and a 100% weapon efficiency, it shows that the population of the world will not completely change. While the colors did not change, there is still a significant impact to the population. Furthermore, since nuclear weaponry were integrated with common weaponry, such as guns, a larger impact can be expected when nuclear weaponry is specifically simulated.

FUTURE WORK

In order to develop a more accurate simulation of war, more battles of each world war would need to be added into the model. The current strengths of the militaries of each country would also need to be taken into account, as well as data on migration during war and economic status. Typically, there would be a higher rate of emigrants from a war-torn country, so the migration rate in the model would need to be manipulated to fit a war situation.

Furthermore, the patch issue with the incorrect data must be fixed. Since the patches within NetLogo would cover more than one countries, the data within the patch would be skewed. While the data within most of the patches were fixed by hardcoding the data in, there were still some patches remaining that contained incorrect data. However, this did not significantly impact the map due to the fact that the correct data will quickly override the incorrect data. While the map was not significantly impacted, the ability to graph the data was significantly impacted. Since there were incorrect data points, the graph will suddenly dip when there were no battles. Thus, it provides a false sense that many people died when, in reality, no one did. This can either be fixed by using a different strategy, such as by finding the center of the country, which usually indicates that there are no other countries within the patch, or using another map that fits the shape of the patch.

For the interface, users could specify which countries to go to war with each other. By implementing war theories to determine how they will fight each other, the simulation could then run a battle and display the consequences of it on the user-selected countries. This allows for more possibilities to be shown, which creates a more realistic simulation of what a major world war may be like.

Although it was part of the original plan of this study, due to time constraints, the economic portion was not included. By including the gross domestic product (GDP) per capita, the GDP growth rate of each country, and the trends of war economies, the effects of war on the economy of the world could be simulated. This allows for the factor of how financial needs will impact the outcome of the war. During a war, it is possible that a country's economy is fall apart, which causes their military to become weaker through the lack of weaponry and necessities. This can lead to a larger count of death, which can also end the war earlier.

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REFERENCES

Armstrong, Michael J., and Steven E. Sodergren. 2015. Refighting Pickett's Charge: Mathematical Modeling of the Civil War Battlefield. *Social Science Quarterly* 96(4): 1153-1168. http://onlinelibrary.wiley.com/doi/10.1111/ssqu.12178/full (accessed October 8, 2016).

Gale, Alastair, and Carol E. Lee. 2016. "US Agreed to North Korea Peace Talks Before Latest Nuclear Test." *Wall Street Journal*, February 21, 2016. http://www.wsj.com/articles/u-s-agreed-to-north-korea-peace-talks-1456076019 (accessed June 5, 2016).

GIS Extension. "NetLogo User Manual version 5.3.1." Center for Connected Learning and Computer-Based Modeling, Northwestern University, Evanston, IL. http://ccl.northwestern.edu/netlogo/docs/gis.html (accessed June 28, 2016).

Helmbold, Robert L. 1961. *Historical Data and Lanchester's Theory of Combat. Part 1*. No. Corg-sp-128. Technical Operations Inc Fort Belvoir VA Operations Research Group. http://oai.dtic.mil/oai/oai?verb=getRecord&metadataPrefix=html&identifier=AD048095 (accessed October 16, 2016).

NetLogo Code. http://pasted.co/cce259dd

Perry, Nigel. 2011. *Applications of Historical Analyses in Combat Modelling*. No. Dsto-Tr-2643. Defence Science and Technology Organization (Australia) Joint Operation Division. http://oai.dtic.mil/oai/oai?verb=getRecord&metadataPrefix=html&identifier=ADA557493 (accessed October 16, 2016).

Vertigans, Stephen. 2010. British Muslims and the UK government's 'war on terror' within: evidence of a clash of civilizations or emergent de-civilizing processes?. *The British Journal of Sociology* 61(1): 26-44. http://onlinelibrary.wiley.com/doi/10.1111/j.1468-4446.2009.01300.x/abstract (accessed October 8, 2016).

Watkins, Thayer. n.d. "Lanchester's Theory of Warfare." San Jose State University Economics Department. http://www.sjsu.edu/faculty/watkins/war.htm (accessed September 20, 2016).