Modeling the Romero Zombie Apocalypse

Tony Boyles
Georgia Institute of Technology
INTA 6004: Modeling, Forecasting, and Simulation
Dr. Peter Brecke
Fall 2010

Zombies have captured the minds of generations of horror enthusiasts, and very recently the attention of academia. However, no one has yet ventured quantitatively to answer the question of under what conditions, and given what responses by the living, is a zombie apocalypse survivable. This paper seeks to address this question within the Romerian zombie universe by constructing system dynamic models to simulate the conditions within *Night of the Living Dead* and some of its sequels.

Zombie Literature

The study of zombies is both a celebrated and neglected pursuit. While a highly popular monster in horror cannon, the analysis of zombies has only recently caught the attention of Political Scientists. In particular, Dan Drezner has opened the dialogue on zombies by attempting to construct a cohesive analysis of the zombie menace as responded to by the paradigms of International Relations. Drezner concludes that despite the camp to which a theorist adheres, any undead threat must be dealt with quickly and aggressively in order for humanity to have any hope of survival (Drezner 2010). This is a sensible conclusion. Zombie stories tend to end bleakly, though not necessarily devoid of hope. It is this hope upon which a model must be built to determine the conditions under which humanity will survive or perish under the threat of the zombie.

Such a contestable claim has not gone unchecked. Daniel Nexon responded to Drezner with an argumentative piece suggesting (in particular) that realism is not as simple as Drezner suggests, and that the product of the zombie apocalypse may be a world-wide American Empire (Nexon 2010). Little zombie cannon suggests that this is likely. Instead, zombie stories tend to focus on the fates of individuals, either at the start of the outbreak, in the midst of it, or in the wreckage of society left behind. While the emergence of the U.S. military as *deus ex machina* is

a common theme, whether the military could support a world-wide empire to keep the undead hordes at bay is not widely explored in the literature. Instead, works which take place following the zombie apocalypse tend to view government either as a crippled entity with little governing power, or an element of a society which has long since dissolved.

These conclusions are testable. Though we have no empirical data on zombies, a simple forecasting model can reveal the conditions under which humanity is doomed, and under which we have a chance. Some (most notably Idu and Oladele 2009) have borrowed the methods of epidemiology to analyze the zombie threat. However, no such study has been restricted to a single cannon, instead borrowing zombie characteristics from different stories. Thus no study to date can confirm or refute our worst fears about the specter of the zombie.

The closest thing to empirical data available to researchers is the imaginings of those artists who channel zombies to haunt the public. For this reason, the most appropriate mode of analysis is to restrict considerations of a model to issues presented within a single zombie universe. Many such universes have emerged, particularly in the last decade (Drezner 2010), giving us movies like *28 Days Later* and *Planet Terror*, video game franchises like *Left 4 Dead* and *Resident Evil*, and books like The Zombie Survival Guide (Brooks 2009) and Pride and Prejudice and Zombies (Austen and Smith, 2009). None of these, however, can compare in experience with the genre to the works of director George Romero.

In the years following his graduation at Carnegie Mellon University, George Romero became fascinated by the horror genre, and aspired to create films for it. He first did so in 1968, with the production of *Night of the Living Dead*. While zombies had existed in horror films long before Romero's influence, Romero set the stage for a zombie apocalypse, injecting zombies into the public consciousness. Because of his direction of that film (and its numerous successors),

Romero has been titled "the Grandfather of the Zombie." There have been six films in his cannon to date (not counting his executive production of two remakes), during which time his zombies have evolved from lumbering corpses to nimble, intelligent beasts. For this evolution, Romero's universe is a perfect launching point for a more rigorous forecast of the future following the zombie apocalypse. In order to generate meaningful predictive models, I mean to generate models that are explicitly loyal to the story Romero told, and revise them only such that the effects within the time period of the film are not meaningful, but the long-term effects will be telling.

Zombie Models - *Night of the Living Dead (1968)*

Night of the Living Dead provides an interesting basis on which to build. It has a straightforward plot in comparison to later zombie films, and is therefore simple to analyze empirically. This can be exemplified in a Plotweaver diagram, as seen in Figure 1.

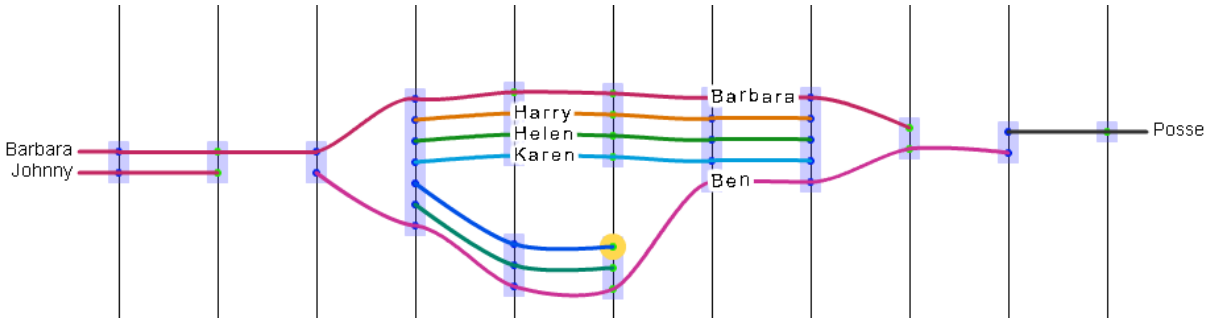

Figure 1: Plotweaver[1] Diagram of *Night of the Living Dead*(1968)

The film also presents a straightforward conception of the zombie as a slow reanimated corpse with little agility or (presumably) mental capacity remaining—only the desire to feast upon living human flesh. The human's motivation is much more complex (survive, protect loved

[1] Vertical distances represent rough groupings of characters. Horizontal distances are discrete steps in plot to the next point in the story in which the groups change (i.e. members break off, join up, or die).

ones, seek a stable and sustainable shelter), though this topic is not explored extensively in this first film[2].

In order to appropriately scale the events of the film up the size of a world-wide event, the model begins with simple global population model. By adjusting the model to the expected lifespan, fertility and mortality rates (according to a simple linear regression) in a given year, the model can project with reasonable accuracy the trajectory of the world population over a 40-year time span. The Stella diagram for this base model is given in figure 2.

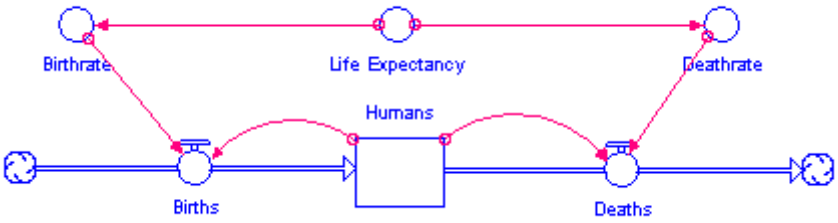

Figure 2: Stella Diagram of Global Population Model

This global population model give the zombie model a firm basis in reality, into which we may generalize the events of the film. This brings us to the formulation of the first zombie model, representing the global outcome of Night of the Living Dead. In addition to the stock of humans, we must introduce a stock to represent the zombie population. Because zombies (or "ghouls," as they're called in the film) are reanimated corpses, there must be a mechanism by which a human becomes a zombie. While more contemporary portrayals of zombies have employed viruses as the means of infection, Romero's zombies are dead humans. Thus, in addition to the natural process by which human may leave the population, death, there is a second flow leading from humans, here termed "undeath."

[2] Examples of the underpinning concept do appear: Jane follows Tom to the gas station, knowing that her life would be threatened by the undead horde; Harry and Helen refuse to harm their daughter, even after she is zombified, resulting in their own gruesome deaths; etc…

Because this model is intended to represent global infection, the appropriate stock of humans equals the global population at the time of the outbreak. According to the World Bank, the global population in 1968 (the year the movie was produced) was approximately 3.5 billion. Setting the stock of zombies is slightly more difficult. The stated source of the zombies in the movie is the recently deceased. A reasonable estimate of an outbreak (assuming it were practically spontaneous, as seems to be the case in the film), might therefore take the form of equation 1:

$$\left(\frac{G}{L}\right)_{L_Z} = O \tag{1}$$

where G is the global population at the time of outbreak, L is the mean human lifespan at the time of outbreak, L_Z is mean lifespan of a zombie, and O is the size of the outbreak. Dividing the human population by the mean human lifespan gives the number of people expected to have died in a given year. Multiplying that quantity by the lifespan of a zombie (measured in years) gives the number of sufficiently fresh corpses available to be reanimated at the initial outbreak.

According to the World Bank, the average human lifespan (world-wide) was approximately 59 in 1970 (the closest data they have to the year of production, 1968). Thus, the most reasonable approximation (within this framework) for the number of deaths world-wide in 1968 is around 60 million people. The lifespan of the zombie is another question entirely. In general, zombies encountered within the context of a story are incapacitated by gunshots or blows to the head long before they cease to function from exhaustion. For this piece of information, we can guess at an upper bound[3], approximately 3.5 million.

[3] Because the human population will be decimated, any quantity of time greater than the time it takes to achieve equilibrium will yield a model isomorphic (though not numerically equal) to one in which the zombie lifespan is equal to the amount of time needed to reach equilibrium. For this reason, the exact number is not necessary—only a number large enough that the model consistently achieves equilibrium, should one exist.

The model itself takes the form of a simultaneous system of differential equations. A Stella diagram representing this model is show in figure 3.

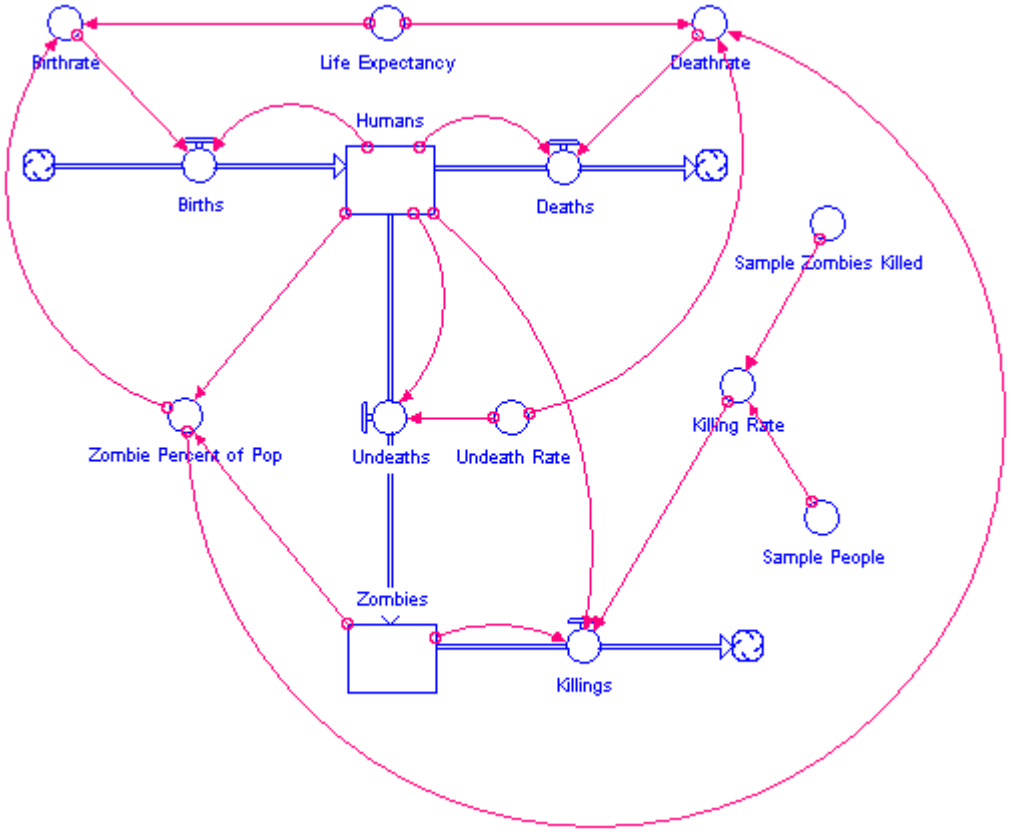

Figure 3: *Night of the Living Dead* Model

This model contains some particular properties of note. Namely, the killing rate is the rate at which living humans can kill zombies. It is based off a census of zombies killed and people appearing in the film. Also, the undeath rate is the probability that a randomly-selected person becomes a zombie posthumously.

Because the number of living people falls by a half in the roughly 24-hour period of the film, the living population should follow an exponentially decreasing curve. This curve can be seen by running the proposed model, as seen output by figure 4.

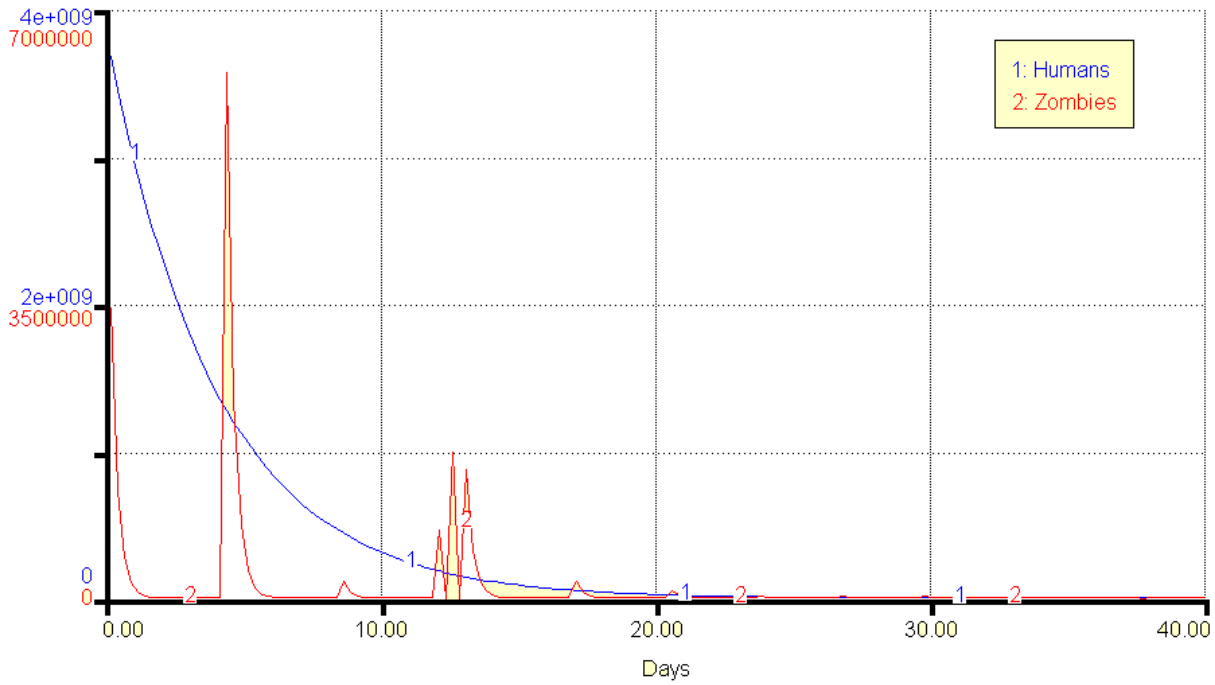

Figure 4: Projected Zombie and Human Populations

Of the eight named human characters, none survives to the end of the film. Two became zombies though presumably all could potentially have become zombies. Therefore a wide range of infection rates exists against which to test the growth rate of the zombie population. For this reason, we must test the model against the marginal bounds of the each of these values. Figure 4 shows the results given that the undeath rate is set to an initial estimate of .25. This represents the lower bound of potential undeaths. The upper bound is 1—that is, every human who dies necessarily becomes a zombie. Under this condition, we derive the result graphed in Figure 5.

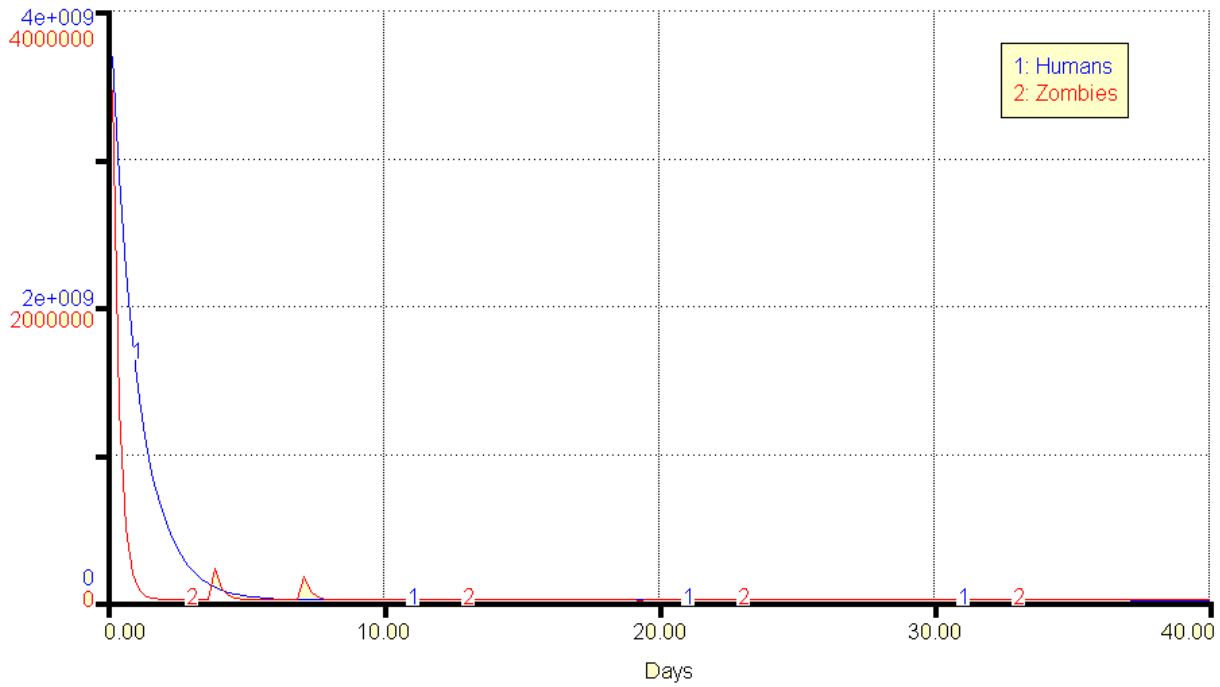

Figure 5: Projected Human and Zombie Populations (undeath rate = 1)

This result is a little curious, given the difference in magnitude between the spikes in zombie populations during the two runs of the model. Presumably, with more humans becoming zombies, more zombies would exist at any given time. However, an emergent property of survivor dynamics is that as fewer humans survive, those humans are more capable of defending themselves. Therefore, those survivors will kill off zombie at a faster rate (exponential), even as zombies appear at a faster rate (quadratic).

At this point, the empirical information available in Night of the Living Dead is exhausted, and we must seek additional information in order to continue inquiry. For this, we must move forward in the canon.

Dawn of the Dead

In Dawn of the Dead, Romero started with a world in which zombies have coexisted with humans for an apparently brief period of time. No one is surprised to see zombies, and the war seems to be raging. The story follows four humans who steal a traffic helicopter in search of a

place free and safe from the undead menace. These people are *survivors*, individual who survive beyond the collapse of the global population by burrowing in to indefinitely sustainable conditions. We thus have our first necessary revision to the model—that there exists a class of people who will not be eliminated in the stochastic decimation of the rest of the population.

Because the story plays out over several months, and one of the primary characters is pregnant, it becomes clear that births are a non-trivial consideration. If we adjust the birthrate to adhere to observed fertility dynamics during natural disasters (Lin 2010), the model gains a feedback process. While the zombies and survivors population dynamics offer little other information which is of relevance to the model, we can garner some critical information from the discourse of a scientist featured on television broadcasts seen periodically throughout the film. He reveals that all corpses with intact brains become zombies. Thus, we know our revision to the model can eliminate "death" as a possible flow from the human population. This gives a diagram as seen in Figure 6.

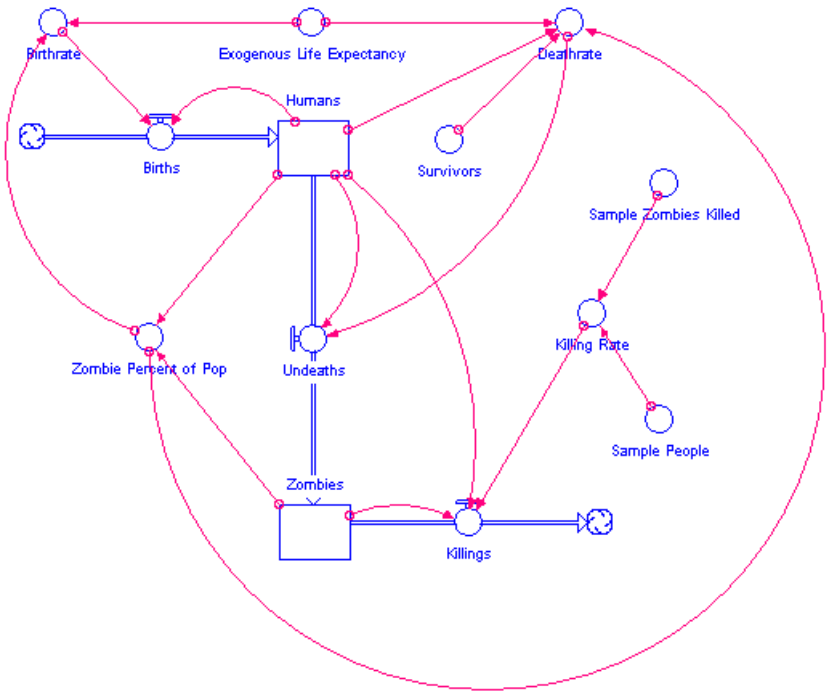

Figure 6: Dawn of the Dead Model

The output of this model is identical to that seen in Figure 5, because the conditions are exactly the same, save that the lower bound of humans is equal to the number of survivors. Once again, having established a rigorous model, we have exhausted the empirical information available in the context of the film, and must therefore seek new data in another film.

Day of the Dead

In Day of the Dead, Romero began to explore the psychology of the zombie, with the sympathetic zombie, Bub. While a fascinating pursuit, I claim it is the apparatus which allows him to do this that makes a more meaningful point in the model. He reveals that the military and armed civil forces are effectively intact. This means that their numbers should not have been diminished as dramatically as the rest of the human population. With this in mind, the model is exactly the same, but the run parameter on the variable "survivors" must change. Instead of the conservative estimate of 10,000, the appropriate number should match the world population of military and paramilitary forces, approximately 90 million. Under this condition, a run of the model yields this result.

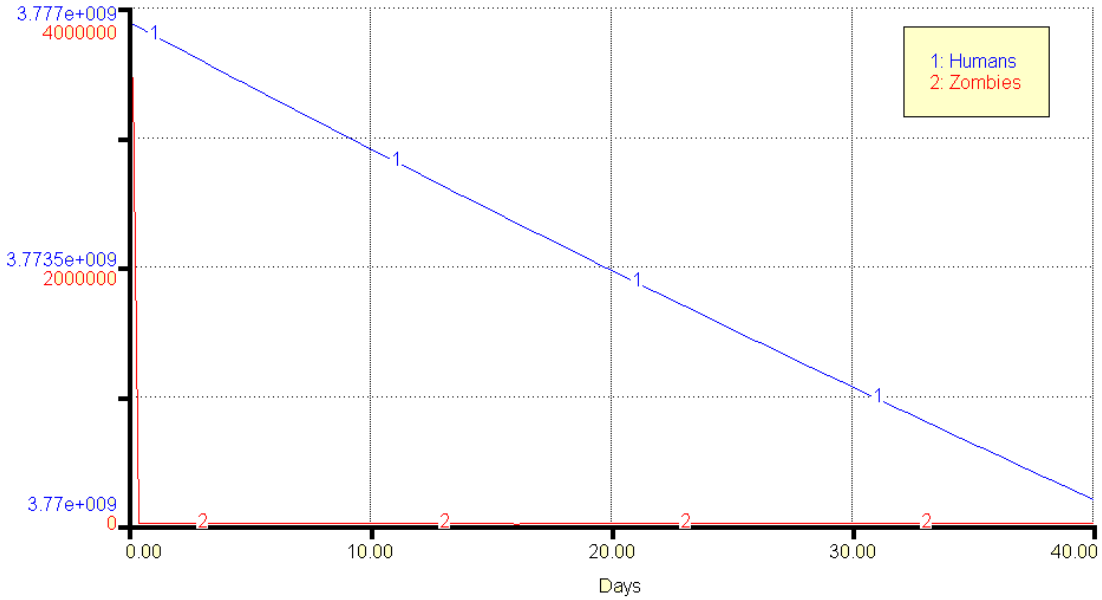

Figure 7: *Day of the Dead* Model

This is, again, a surprising outcome. It suggests that the zombie population should be brought under control within hours of the initial outbreak, simply because the defense forces worldwide are equipped to deal with it. Survivors kill zombies at a dramatically higher rate. If there are more survivors, they kill off more zombies at that faster rate—faster than zombies can kill people to become zombies. Thus the zombie population drops from the initial outbreak number to zero in a matter of hours. Once eliminated, zombie populations periodically appear in the hundreds, but solely as a byproduct of people experiencing natural deaths.

This suggests that Romero's cannon is pure fantasy, not just because zombies don't exist, but because a zombie epidemic overtaking the world *couldn't* occur. The rules of the world Romero constructs lead to outcomes which cannot be supported by population dynamics. Humanity, it seems, has nothing to fear from Romero's zombies.

Future Adaptations

Without much more complex adaptations considering the surrounding landscape (urban, rural, desert, forest, mountain, etc.) any conclusions must not be considered definitive. This model is predicated upon the assumption that all military and paramilitary forces will have the same force penetration capabilities in all terrains, and that they are homogenously distributed throughout the global population. These factors, however, exceed the bounds of system dynamic modeling. I propose that the next step in zombie-related research is not a more advanced system model with better international demographic data, but an agent-based model which accounts for these factors.

An additional point concerning future models: without functions defining the intelligence and dexterity of the zombies (as explored in the later Romero cannon), it is impossible to project

global outcomes without making large assumptions about rates of infection, etc. While these models make such assumptions, perhaps it is possible to model other worlds in which the population dynamics are better understood, and different outcomes are indeed a possible. We need not fear Romero's zombies, but that does not mean we are safe from the zombies of more contemporary works.

References

Brooks, Max. *The zombie survival guide: recorded attacks*. New York: Three Rivers Press, 2009.

Drezner, Daniel. "Night of the Living Wonks." Foreign Policy. http://www.foreignpolicy.com/articles/2010/06/21/night_of_the_living_wonks (accessed November 7, 2010).

Lakeland, D. (2010). Improved zombie dynamics. Models of Reality blog, 1 March. http://models.street-artists.org/?p=554

Messer, B. (2010). Agent-based computational model of humanity's prospects for post zombie outbreak survival. The Tortise's Lens blog, 10 March. http://thetortoiseslens.blogspot.com/2010/03/agent-based-computational-model-of.html

Munz, P., Hudea, I., Imad, J., and Smith, R. J. (2009). When zombies attack!: Mathematical modelling of an outbreak of zombie infection. In Infectious Disease Modelling Research Progress, ed. J. M. Tchuenche and C. Chiyaka, 133{150. Hauppage, New York: Nova Science Publishers.

Nexon, Daniel. "America's Triumph Over the Zombie Horde." Foreign Policy. http://www.foreignpolicy.com/articles/2010/08/16/americas_triumph_over_the_zombie_horde (accessed November 7, 2010).

Night of the Living Dead. Online Streaming. Directed by George Romero. 1968; Pittsburg, PA.

Smith, Seth, and Jane Austen. *Pride and prejudice and zombies: the classic regency romance--now with ultraviolent zombie mayhem*. Philadelphia: Quirk Books; 2009.