Zombie Attack! An Introduction to Quantitative Modeling

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Outbreak!

It has happened, Zombies have appeared. They are beginning to take over large urban centers. In just a matter of weeks, several cities have been completely disabled. You are a disease researcher with the Centers for Disease Control & Prevention (CDC). Despite the CDC's Zombie Preparedness campaign, an effective strategy for dealing with the rapidly developing Zombie outbreak has still not been established. It is your responsibility to figure out how fast the number of Zombies will increase and whether or not human survival is possible. To do this, you develop a mathematical model to examine rates of spread and establish whether or not you can take action to slow or prevent the spread of Zombies.

The World Health Organization (WHO) believes the outbreak may be the result of a new parasitic fungal strain that has adapted to infect the brains of human hosts, similar to the fungus that attacks the brains of ants in the Brazilian rainforest (see below).

Zombie Ants

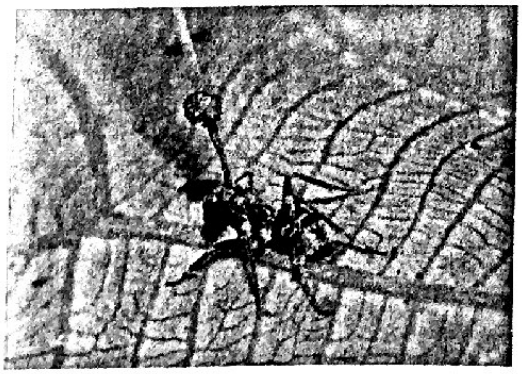
[The following is excerpted from the Wikipedia article "*Ophiocordyceps unilateralis*" accessed August 30, 2012 at http://en.wikipedia.org/wiki/Zombie_ants, CC BY-SA 3.0]

Ophiocordyceps unilateralis is a parasitoidal fungus that infects ants such as *Camponotus leonardi*, and alters their behavior in order to ensure the widespread distribution of its spores.

The species can be identified at the end of its lifecycle by its reproductive structure, consisting of a wiry yet pliant darkly pigmented stroma stalk extending from the back of the deceased ant's head.

The fungus's spores enter the body of the insect ... where they begin to consume the non-vital soft tissues. Yeast stages of the fungus spread in the ant's body and presumably produce compounds that affect the ant's brain and change its behaviour by unknown mechanisms ... .

The fungus then kills the ant ... . When the fungus is ready to reproduce, its fruiting bodies grow from the ant's head and rupture, releasing the spores. This process takes 4 to 10 days.



The changes in the behavior of the infected ants are very specific, giving rise to the term zombie ants, and tuned for the benefit of the fungus. ... According to David Hughes, "You can find whole graveyards with 20 or 30 ants in a square metre. Each time, they are on leaves that are a particular height off the ground and they have bitten into the main vein [of a leaf] before dying."

O. unilateralis has been known to destroy entire ant colonies. In response, ants have evolved the ability to sense that a member of the colony is infected; healthy ants will carry the dying one far away from the colony in order to avoid fungal spore exposure.

Disease researchers around the world have proposed several strategies for dealing with this outbreak. A few of the main strategies are outlined below:

- Assuming the parasitic-fungal-infection hypothesis is correct, release a broad-spectrum anti-fungal medication into the water supply, thereby decreasing the rate of new fungal infections occurring in humans.
- Develop a vaccine for the infection, so the currently healthy humans are no longer susceptible to the infection. It will take some time to develop an effective vaccine.
- Launch a wide-scale military attack with the goal of killing as many Zombies as possible. This may involve the complete decimation of populations in highly infected regions.
- Some combination of the above strategies.

Given the current rapid spread of the outbreak, you don't have the time needed to conduct the appropriate series of experiments required to determine the best approach, so a mathematical model seems to be the ideal way to evaluate the effectiveness of the different strategies outlined above. To develop the model, you need to be familiar with some basic Zombie natural history.

Zombie Natural History

- Zombies eat the living flesh of humans.
- They have minimal brain function but are able to hear and smell to locate food sources.
- They don't die unless killed by removing the head or destroying the brain.
- Humans can be "infected" by close contact with an infected Zombie (i.e., a bite or scratch). Once a human is infected, it can subsequently go through the process of zombification, passing from undead human into full-blown Zombie.

Your Challenge

1. Develop a model of the human-zombie interaction.
2. Analyze the model predictions to determine the best course of action for human survival.
3. Critically evaluate the model.