**SBML Model Report**

# Model name: “Munz2009 - Zombie SIZRC”

May 6, 2016

## 1 General Overview

This is a document in SBML Level 2 Version 4 format. Table 1 provides an overview of the quantities of all components of this model.

Table 1: Number of components in this model, which are described in the following sections.

| Element | Quantity | Element | Quantity |
|---|---|---|---|
| compartment types | 0 | compartments | 1 |
| species types | 0 | species | 4 |
| events | 0 | constraints | 0 |
| reactions | 8 | function definitions | 0 |
| global parameters | 8 | unit definitions | 5 |
| rules | 1 | initial assignments | 1 |

### Model Notes

Munz2009 - Zombie SIZRC

This is the model with an latent infection and cure for zombies described in the article.

This model was originally created by libAntimony v1.4 (using libSBML 3.4.1).

This model is described in the article:When zombies attack!: Mathematical modelling of an outbreak of zombie infectionP. Munz, I. Hudea, J. Imad and R.J. Smith?Infectious Disease Modelling Research Progress 2009, chapter 4, pp 133-150. Editors: Jean Michel Tchuenche and C. Chiyaka; Nova Science Publishers, Inc., NY, USA.

Abstract:

Zombies are a popular figure in pop culture/entertainment and they are usually portrayed as being brought about through an outbreak or epidemic. Consequently, we model a zombie attack,

using biological assumptions based on popular zombie movies. We introduce a basic model for zombie infection, determine equilibria and their stability, and illustrate the outcome with numerical solutions. We then refine the model to introduce a latent period of zombification, whereby humans are infected, but not infectious, before becoming undead. We then modify the model to include the effects of possible quarantine or a cure. Finally, we examine the impact of regular, impulsive reductions in the number of zombies and derive conditions under which eradication can occur. We show that only quick, aggressive attacks can stave off the doomsday scenario: the collapse of society as zombies overtake us all.

This model is hosted on BioModels Database and identified by: MODEL1008060001 .

To cite BioModels Database, please use: BioModels Database: An enhanced, curated and annotated resource for published quantitative kinetic models .



## 2 Unit Definitions

This is an overview of eight unit definitions of which three are predefined by SBML and not mentioned in the model.

### 2.1 Unit `substance`

**Name** individuals(thousands)

**Definition** kitem

### 2.2 Unit `time`

**Name** days

**Definition** 86400 s

### 2.3 Unit `perday`

**Name** per day

**Definition** $(86400\ \mathrm{s})^{-1}$

### 2.4 Unit `perdayperind`

**Name** per day per thousand individuals

**Definition** $(86400\ \mathrm{s})^{-1} \cdot \mathrm{kitem}^{-1}$

### 2.5 Unit indperday

**Name** thousand individuals per day

**Definition** $(86400\ \mathrm{s})^{-1} \cdot \mathrm{kitem}$

### 2.6 Unit volume

**Notes** Litre is the predefined SBML unit for volume.

**Definition** l

### 2.7 Unit area

**Notes** Square metre is the predefined SBML unit for area since SBML Level 2 Version 1.

**Definition** $\mathrm{m}^2$

### 2.8 Unit length

**Notes** Metre is the predefined SBML unit for length since SBML Level 2 Version 1.

**Definition** m

## 3 Compartment

This model contains one compartment.

Table 2: Properties of all compartments.

| Id | Name | SBO | Spatial Dimensions | Size | Unit | Constant | Outside |
|---|---|---|---|---|---|---|---|
| env | environment | | 3 | 1 | litre | ☑ | |

### 3.1 Compartment env

This is a three dimensional compartment with a constant size of one litre.

**Name** environment

## 4 Species

This model contains four species. Section 9 provides further details and the derived rates of change of each species.

Table 3: Properties of each species.

| Id | Name | Compartment | Derived Unit | Constant | Boundary Condition |
|---|---|---|---|---|---|
| S | Susceptible | env | kitem | ⊟ | ⊟ |
| I | Infected | env | kitem | ⊟ | ⊟ |
| Z | Zombie | env | kitem | ⊟ | ⊟ |
| R | Removed | env | kitem | ⊟ | ⊟ |

# 5 Parameters

This model contains eight global parameters.

Table 4: Properties of each parameter.

| Id | Name | SBO | Value | Unit | Constant |
|---|---|---|---|---|---|
| N | starting Population | | 500.000 | kitem | ☑ |
| p | | | 0.000 | $(86400\ \mathrm{s})^{-1} \cdot \mathrm{kitem}$ | ⊟ |
| delta | | | $10^{-4}$ | $(86400\ \mathrm{s})^{-1}$ | ☑ |
| beta | | | 0.010 | $(86400\ \mathrm{s})^{-1} \cdot \mathrm{kitem}^{-1}$ | ☑ |
| rho | | | 0.050 | $(86400\ \mathrm{s})^{-1}$ | ☑ |
| zeta | | | $10^{-4}$ | $(86400\ \mathrm{s})^{-1}$ | ☑ |
| alpha | | | 0.005 | $(86400\ \mathrm{s})^{-1} \cdot \mathrm{kitem}^{-1}$ | ☑ |
| c | | | 0.500 | $(86400\ \mathrm{s})^{-1}$ | ☑ |

# 6 Initialassignment

This is an overview of one initialassignment.

## 6.1 Initialassignment S

**Derived unit** kitem

**Math** N

# 7 Rule

This is an overview of one rule.

## 7.1 Rule p

Rule p is an assignment rule for parameter p:

$$\mathrm{p} = \mathrm{S} \cdot \mathrm{delta} \tag{1}$$

**Derived unit** $\mathrm{kitem} \cdot (86400\ \mathrm{s})^{-1}$

## 8 Reactions

This model contains eight reactions. All reactions are listed in the following table and are subsequently described in detail. If a reaction is affected by a modifier, the identifier of this species is written above the reaction arrow.

Table 5: Overview of all reactions

| № | Id | Name | Reaction Equation | SBO |
|---|---|---|---|---|
| 1 | birth | | $\emptyset \longrightarrow S$ | |
| 2 | death_healthy | | $S \longrightarrow R$ | |
| 3 | infection | | $S \xrightarrow{Z} I$ | |
| 4 | natural_death_infected | | $I \longrightarrow R$ | |
| 5 | zombification_infected | | $I \longrightarrow Z$ | |
| 6 | cure | | $Z \longrightarrow S$ | |
| 7 | resurrection | | $R \longrightarrow Z$ | |
| 8 | destruction | | $Z \xrightarrow{S} R$ | |

## 8.1 Reaction `birth`

This is an irreversible reaction of no reactant forming one product.

### Reaction equation

$$\emptyset \longrightarrow \mathrm{S} \tag{2}$$

### Product

Table 6: Properties of each product.

| Id | Name | SBO |
|---|---|---|
| S | Susceptible | |

### Kinetic Law

**Derived unit** $(86400\ \mathrm{s})^{-1} \cdot \mathrm{kitem}$

$$v_1 = \mathrm{p} \tag{3}$$

## 8.2 Reaction `death_healthy`

This is an irreversible reaction of one reactant forming one product.

### Reaction equation

$$\mathrm{S} \longrightarrow \mathrm{R} \tag{4}$$

### Reactant

Table 7: Properties of each reactant.

| Id | Name | SBO |
|---|---|---|
| S | Susceptible | |

### Product

Table 8: Properties of each product.

| Id | Name | SBO |
|---|---|---|
| R | Removed | |

### Kinetic Law

**Derived unit** $(86400\ \mathrm{s})^{-1} \cdot \mathrm{kitem}$

$$v_2 = \mathrm{delta} \cdot \mathrm{S} \tag{5}$$

## 8.3 Reaction `infection`

This is an irreversible reaction of one reactant forming one product influenced by one modifier.

### Reaction equation

$$\mathrm{S} \xrightarrow{\mathrm{Z}} \mathrm{I} \tag{6}$$

### Reactant

Table 9: Properties of each reactant.

| Id | Name | SBO |
|---|---|---|
| `S` | Susceptible | |

### Modifier

Table 10: Properties of each modifier.

| Id | Name | SBO |
|---|---|---|
| `Z` | Zombie | |

### Product

Table 11: Properties of each product.

| Id | Name | SBO |
|---|---|---|
| `I` | Infected | |

### Kinetic Law

**Derived unit** $(86400\ \mathrm{s})^{-1} \cdot \mathrm{kitem}$

$$v_3 = \mathrm{beta} \cdot \mathrm{S} \cdot \mathrm{Z} \tag{7}$$

## 8.4 Reaction `natural_death_infected`

This is an irreversible reaction of one reactant forming one product.

### Reaction equation

$$\mathrm{I} \longrightarrow \mathrm{R} \tag{8}$$

### Reactant

Table 12: Properties of each reactant.

| Id | Name | SBO |
|---|---|---|
| I | Infected | |

### Product

Table 13: Properties of each product.

| Id | Name | SBO |
|---|---|---|
| R | Removed | |

### Kinetic Law

**Derived unit** $(86400\ \mathrm{s})^{-1} \cdot \mathrm{kitem}$

$$v_4 = \mathrm{delta} \cdot \mathrm{I} \tag{9}$$

## 8.5 Reaction `zombification_infected`

This is an irreversible reaction of one reactant forming one product.

### Reaction equation

$$\mathrm{I} \longrightarrow \mathrm{Z} \tag{10}$$

### Reactant

Table 14: Properties of each reactant.

| Id | Name | SBO |
|---|---|---|
| I | Infected | |

### Product

Table 15: Properties of each product.

| Id | Name | SBO |
|---|---|---|
| Z | Zombie | |

### Kinetic Law

**Derived unit** $(86400\ \mathrm{s})^{-1} \cdot \mathrm{kitem}$

$$v_5 = \mathrm{rho} \cdot \mathrm{I} \tag{11}$$

## 8.6 Reaction `cure`

This is an irreversible reaction of one reactant forming one product.

### Reaction equation

$$\mathrm{Z} \longrightarrow \mathrm{S} \tag{12}$$

### Reactant

Table 16: Properties of each reactant.

| Id | Name | SBO |
|---|---|---|
| Z | Zombie | |

### Product

Table 17: Properties of each product.

| Id | Name | SBO |
|---|---|---|
| S | Susceptible | |

### Kinetic Law

**Derived unit** $(86400\ \mathrm{s})^{-1} \cdot \mathrm{kitem}$

$$v_6 = \mathrm{c} \cdot \mathrm{Z} \tag{13}$$

## 8.7 Reaction `resurrection`

This is an irreversible reaction of one reactant forming one product.

### Reaction equation

$$\mathrm{R} \longrightarrow \mathrm{Z} \tag{14}$$

### Reactant

Table 18: Properties of each reactant.

| Id | Name | SBO |
|---|---|---|
| R | Removed | |

### Product

Table 19: Properties of each product.

| Id | Name | SBO |
|---|---|---|
| Z | Zombie | |

### Kinetic Law

**Derived unit** $(86400\ \mathrm{s})^{-1} \cdot \mathrm{kitem}$

$$v_7 = \mathrm{zeta} \cdot \mathrm{R} \tag{15}$$

## 8.8 Reaction `destruction`

This is an irreversible reaction of one reactant forming one product influenced by one modifier.

### Reaction equation

$$\mathrm{Z} \xrightarrow{\mathrm{S}} \mathrm{R} \tag{16}$$

### Reactant

Table 20: Properties of each reactant.

| Id | Name | SBO |
|---|---|---|
| Z | Zombie | |

### Modifier

Table 21: Properties of each modifier.

| Id | Name | SBO |
|---|---|---|
| S | Susceptible | |

### Product

Table 22: Properties of each product.

| Id | Name | SBO |
|---|---|---|
| R | Removed | |

### Kinetic Law

**Derived unit** $(86400\ \mathrm{s})^{-1} \cdot \mathrm{kitem}$

$$v_8 = \mathrm{alpha} \cdot \mathrm{S} \cdot \mathrm{Z} \tag{17}$$

## 9 Derived Rate Equations

When interpreted as an ordinary differential equation framework, this model implies the following set of equations for the rates of change of each species.

### 9.1 Species S

**Name** Susceptible

**Initial assignment** S

This species takes part in five reactions (as a reactant in death_healthy, infection and as a product in birth, cure and as a modifier in destruction).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{S} = v_1 + v_6 - v_2 - v_3 \tag{18}$$

### 9.2 Species I

**Name** Infected

**Initial concentration** $0\ \mathrm{kitem} \cdot \mathrm{l}^{-1}$

This species takes part in three reactions (as a reactant in natural_death_infected, zombification_infected and as a product in infection).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{I} = v_3 - v_4 - v_5 \tag{19}$$

## 9.3 Species Z

**Name** Zombie

**Initial concentration** $1\ \mathrm{kitem} \cdot \mathrm{l}^{-1}$

This species takes part in five reactions (as a reactant in cure, destruction and as a product in zombification_infected, resurrection and as a modifier in infection).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{Z} = v_5 + v_7 - v_6 - v_8 \tag{20}$$

## 9.4 Species R

**Name** Removed

**Initial concentration** $0\ \mathrm{kitem} \cdot \mathrm{l}^{-1}$

This species takes part in four reactions (as a reactant in resurrection and as a product in death_healthy, natural_death_infected, destruction).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{R} = v_2 + v_4 + v_8 - v_7 \tag{21}$$

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