487

Biomathematics Innovation Group

Modeling Biological Phenomena

Controlling the Spread of Measles in an Unvaccinated School Population

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Abstract

The Orthodox Jewish population in Rockland County, NY does not vaccinate due to religious beliefs, which allows diseases to spread quickly through the population. A caveman model was created to represent a private Jewish school typical of those in Rockland County, where n.caves = 25 and cave.size = 20 to create a population of 500 unvaccinated students. A measles infection (R_0 = 15) was introduced and infected individuals were removed from the school during the eight-day infectious period at a varying number of days after infection, ranging from Day 0 to Day 8. The data was analyzed for normality using a Shapiro-Wilk test and an ANOVA was performed to determine whether the data was statistically significant. Two boxplot graphs were created, representing the number of infected individuals and the length of the epidemic as a function of the day infected students were removed from the school. Removing children from the school within the first three days after infection significantly decreased the number of individuals who became sick as well as the duration of the outbreak in the school.

Background

Measles is a virus which lives in the mucus of the throat and nose, and is spread through the air via cough or sneeze particles[1]. Measles symptoms can take up to two weeks to develop and include the typical rash of flat red spots accompanied by a fever, cough, runny nose, and red and watery eyes[1]. Though mostly eradicated in the United States, measles still spreads rapidly among unvaccinated populations due to its high reproduction number [2].

Figure 1. The measles rash[1].

This value, R_0 (pronounced "R naught"), represents the number of secondary cases that result from a single infection in a completely susceptible population. One such population is the Orthodox Jew community in Rockland County, NY[3], who do not receive vaccinations due to religious beliefs[4]. Members of this community become exposed to the virus when travelers return from Israel, where outbreaks are more common than in the US, and unknowingly spread the virus through contact with their families[4]. Before visible symptoms are present, the virus may be spread to other public places, such as private religious schools, which often do not have a vaccination rate high enough to allow for herd immunity.

Methods

A cavemen model was created using R to represent the spread of measles through an unvaccinated population. Parameters were set to create 25 "classrooms" with 20 people in each, for a total population of 500 individuals. The R_0 of measles is 12-18, and an intermediate value of R_0 = 15 was chosen for this model for simplicity. The length of the infectious period was set to 8 days, accounting for 4 days prior to and following the onset of the rash, when infected individuals are contagious.

Results and Analysis

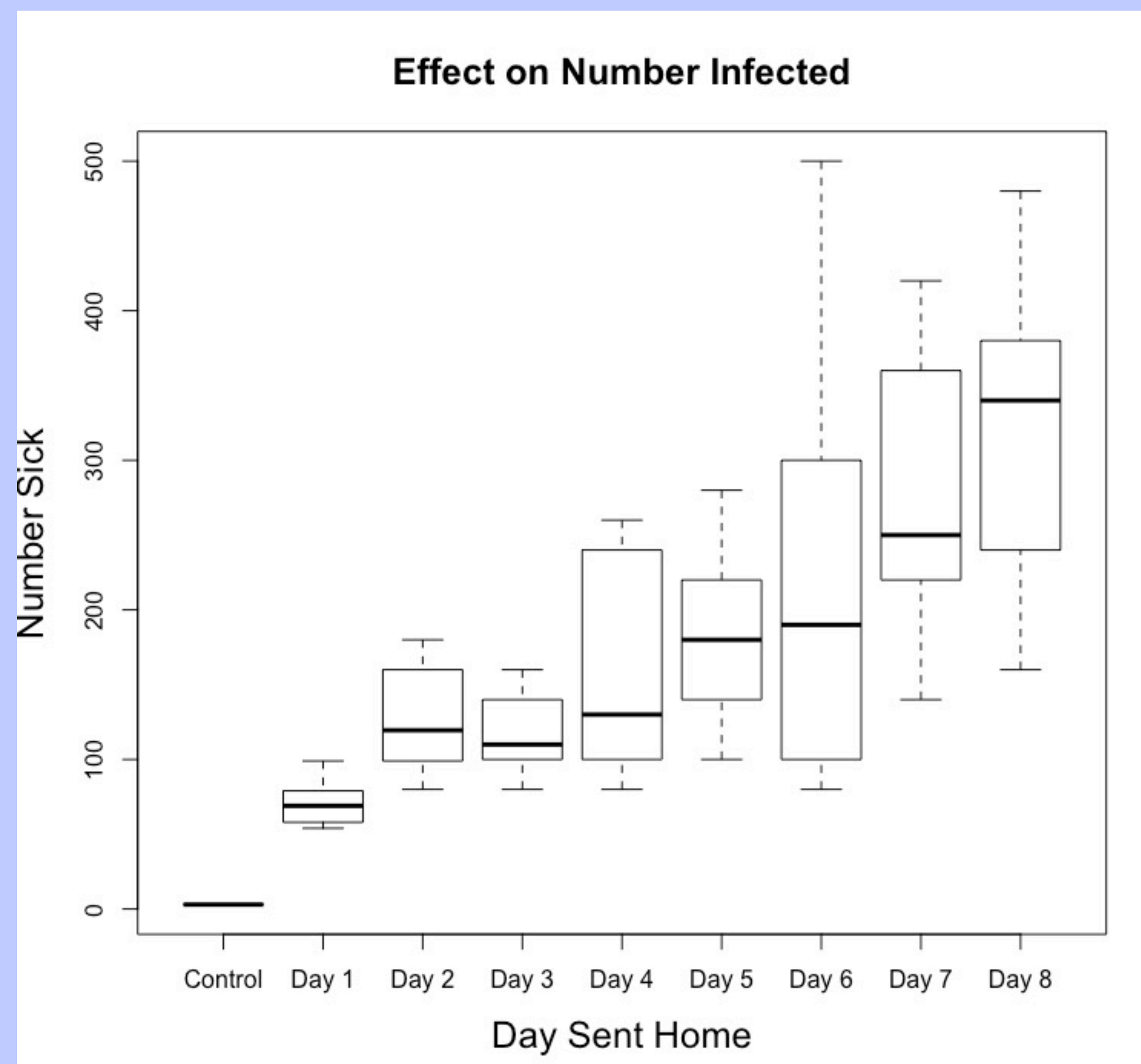

Figure 2. Boxplot of the number of infected individuals infected during the epidemic as a function of day of removal after infection.

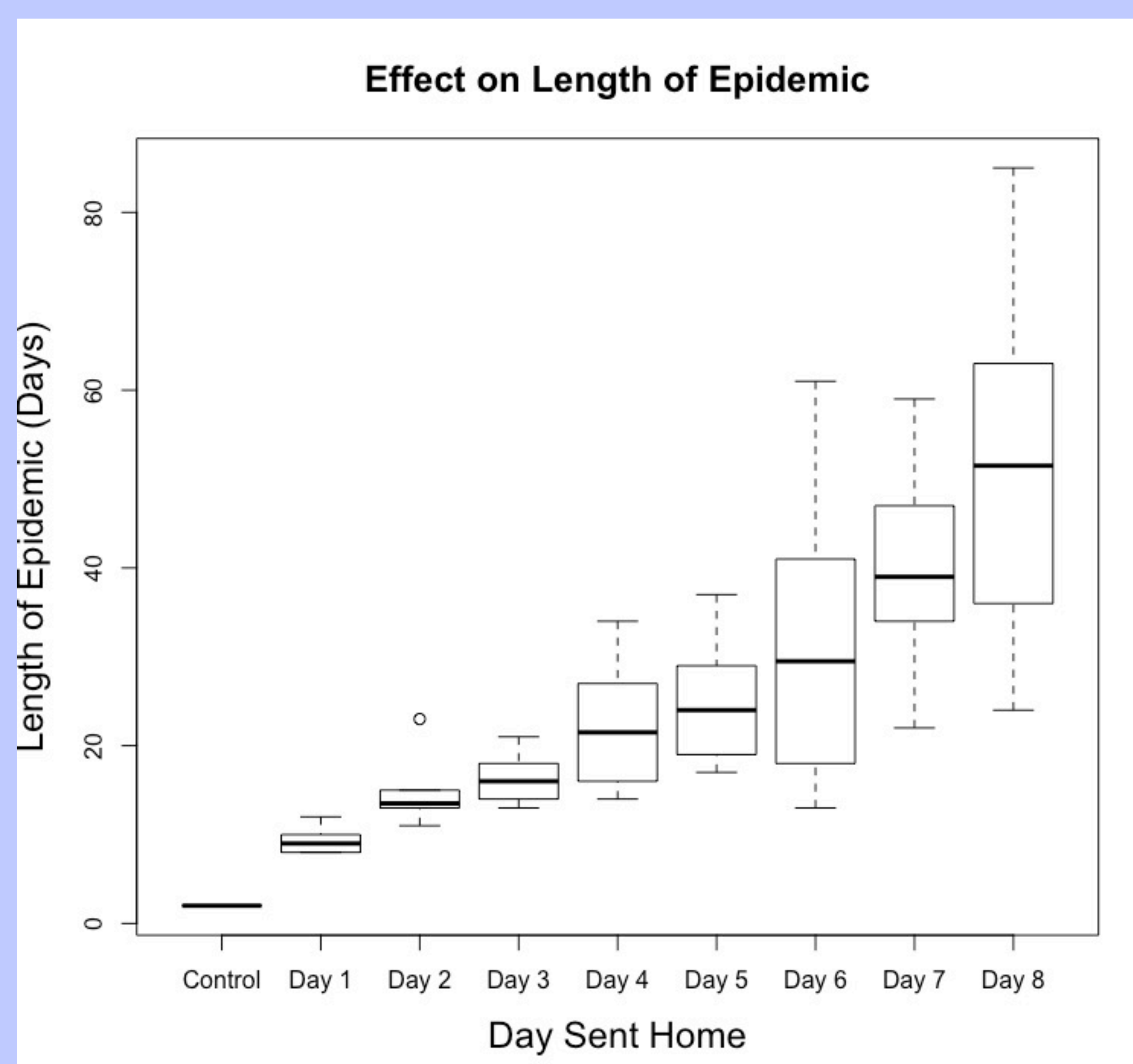

Figure 3. Boxplot of the duration of the epidemic in days as a function of day of removal after infection.

	Degrees of Freedom	Sum of Squares	Mean Square Error	F value	Pr(>F)
Day Sent Home	8	789829	98729	19.58	4.48e-16
Residuals	81	408506	5043		

Figure 3. Table of ANOVA results for the effect of day sent home on the number of individuals infected.

	Degrees of Freedom	Sum of Squares	Mean Square Error	F value	Pr(>F)
Day Sent Home	8	20100	2512.5	25.7	2.00e-16
Residuals	81	7918	97.7		

Figure 4. Table of ANOVA results for the effect of day sent home on the length of the epidemic.

Conclusion

A larger number of individuals became sick as infected students were sent home later in the infectious period, and the epidemic lasted longer as well. The Shapiro-Wilk test revealed that the data for number of sick individuals and length of epidemic were normally distributed [$p > 0.05$ for all values]. An ANOVA for the effect of day sent home on the number of infected individuals revealed a significant main effect of the day sent home [$F = 19.58$, $P < 0.001$]. The day sent home accounts for 65.91% of the observed variability in number of infected individuals. The ANOVA performed on the length of the epidemic as a function of the day sent home revealed a significant main effect of the day sent home on the length of the epidemic as well [$F = 25.7$, $P < 0.001$]. For this set of data, the day sent home accounted for 71.74% of the variability in the length of the epidemic. These effects demonstrate a highly significant effect of the day infected individuals are sent home on the severity of the epidemic. The importance of limiting the contact of infected or exposed individuals is demonstrated by the control values for number of individuals sick (N.sick = 3) and length of the epidemic (N.days = 2). As the measles virus is highly contagious, early detection of initial symptoms and removal of the individuals from public spaces is critical in limiting its spread.

References

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