MODELING THE 2014 EBOLA OUTBREAK

Math 470, Project 3

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THE 2014 EBOLA OUTBREAK

Beginning in West Africa, the 2014 outbreak of Ebola was the worst outbreak of Ebola in its' history.

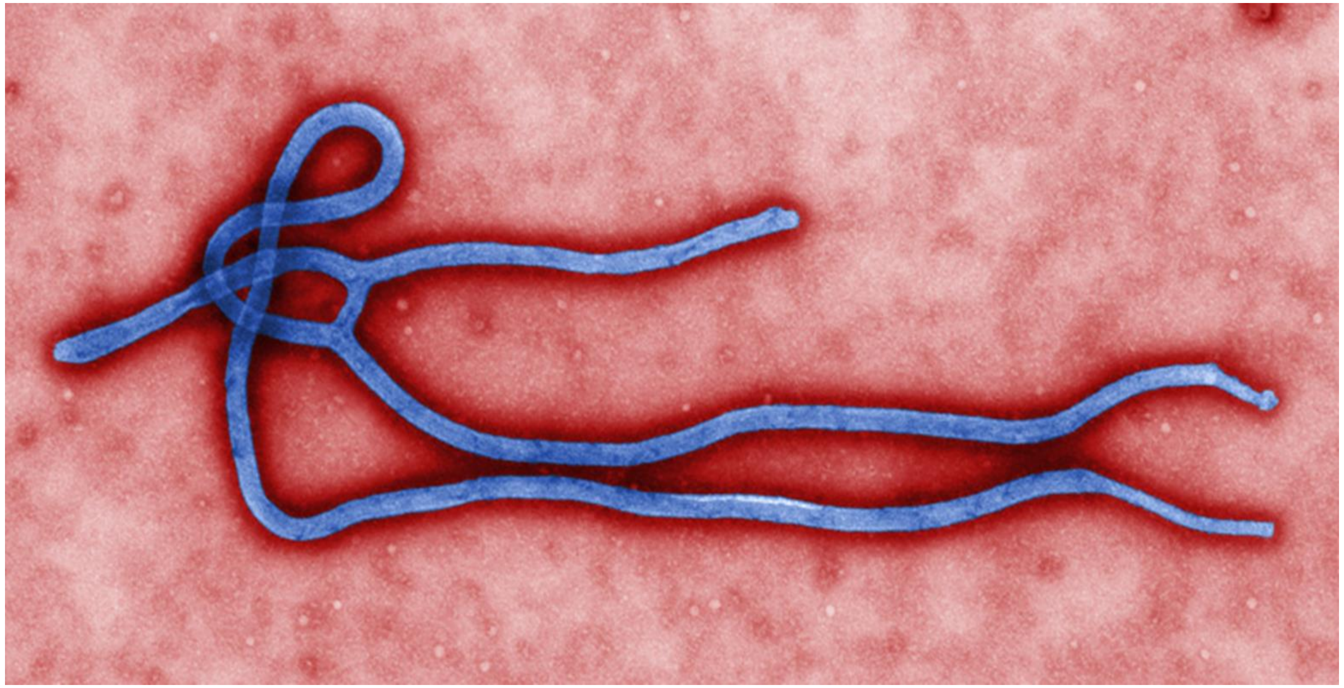
Approximately 28,000 people became infected, with around 11,000 deaths.

The outbreak lasted from March 2014 through to June 2016. Several countries were involved, with the worst hit being Guinea, Liberia, and Sierra Leone.

Our project will be modelling this outbreak, using the information gathered from various sources and incorporating the SIR model.

BACKGROUND

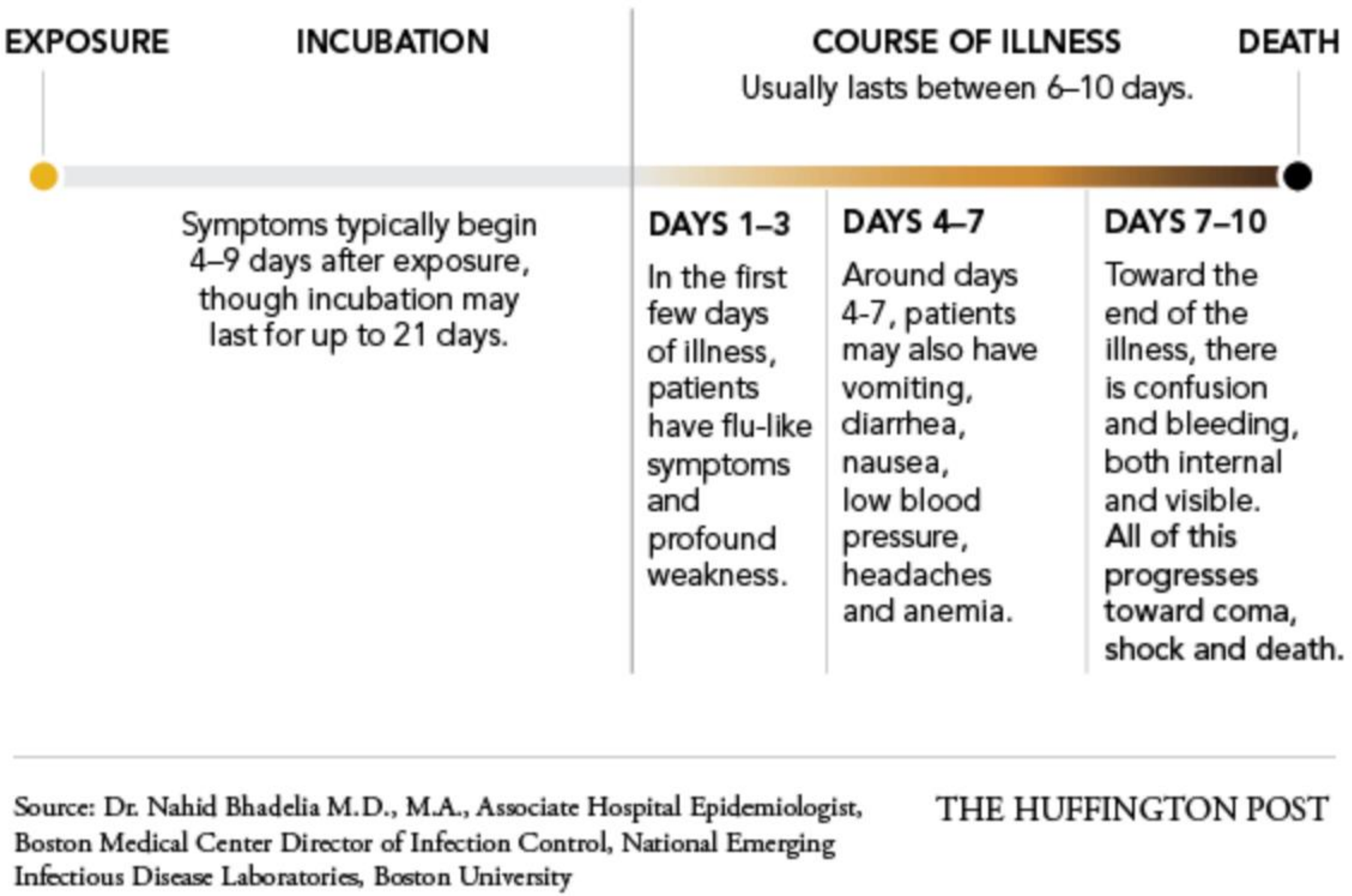
- The Ebola Virus Disease (EVD), formally known as Ebola Hemorrhagic Fever, is a severe and often fatal disease.
- The disease is initially transmitted from humans contact with certain carriers of the disease, such as chimpanzees, fruit bats, gorillas, and other animals found in the forest. From there, transmission is based upon direct contact through blood, open wounds, and other fluids.

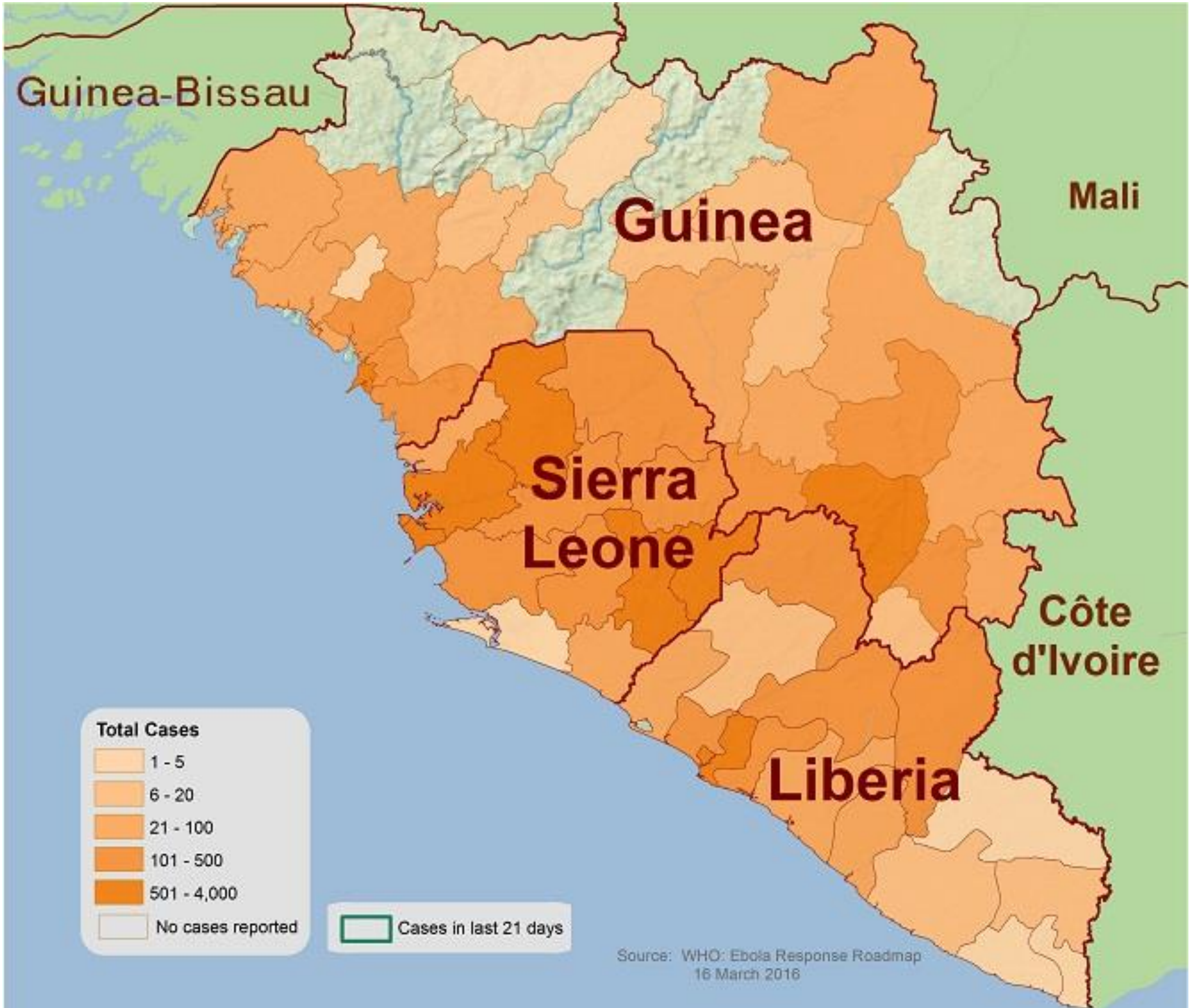


BACKGROUND

- The mortality rate is on average 50%, though in certain areas that mortality rate varies between 25% and 90%.
- Symptoms include sudden onset of fever, fatigue, muscle pain, headache and sore throat. This is followed by vomiting, diarrhea, rash, symptoms of impaired kidney and liver function, and in some cases, both internal and external bleeding.
- There is no vaccine, and no medicine. If you get this disease, the best thing for you is to hope that you survive. You will be provided with electrolytes and fluids, and recovery from this disease is dependent on good supportive care and your immune response.

HOW THE DISEASE WORKS





WEST AFRICA

Liberia : 4,391,000 people

Sierra Leone : 7,079,000 people

Guinea : 11,810,000 people

Total Infected : 28,603 people

Total Recovered : 17,302 people

Total Dead : 11,301 people

THE SIR MODEL

The SIR model (susceptible, infected, recovered) models the rate and spread of disease. It finds the number of people who can become infected with a contagious illness given a fixed total population over time.

Using differential equations, the rates of change for the Susceptible, Infected, and "Recovered" populations are modeled.

In our model, we are lumping together those who survived the virus and those who did not survive the virus together in the "recovered" population.

ASSUMPTIONS

- Independent variable is time "t" weeks
- A number of people get infected every week (person moves from susceptible group to infected group)
- A number of people will recover/perish every week (person moves from infected group to recovered group)
- No one is added to the susceptible groups
  - No births or immigration is included

SIR MODEL, TERMS AND DEFINITIONS

$s(t)$; the susceptible fraction of the population.

$i(t)$; the infected fraction of the population.

$r(t)$; the recovered fraction of the population.

b ; the fixed number of contacts per day of an infected person with any other person.

k ; the fixed fraction of the infected group that could recover, on any given day.

THE GENERALIZED SIR MODEL

$$\frac{ds}{dt} == -b*s(t)*i(t)$$

$$\frac{dr}{dt} == k*i(t)$$

$$\frac{di}{dt} == b*s(t)*i(t)-k*i(t)$$

$$\frac{ds}{dt}+\frac{di}{dt}+\frac{dr}{dt} == 0$$

$S(0) = 23,280000$

$I(0) = 86$

$R(0) = 0$

$s(0) = 1$

$i(0) = .00000369415807 6$

$r(0) = 0$

HOW WE DEVELOPED OUR MODEL

1) Gather initial values and data regarding the 2014 outbreak.

2) Using the data, created initial values and conditions for our equations.

3) Using Euler's Method, constructed recurrence equations from the differential equations in our initial findings.

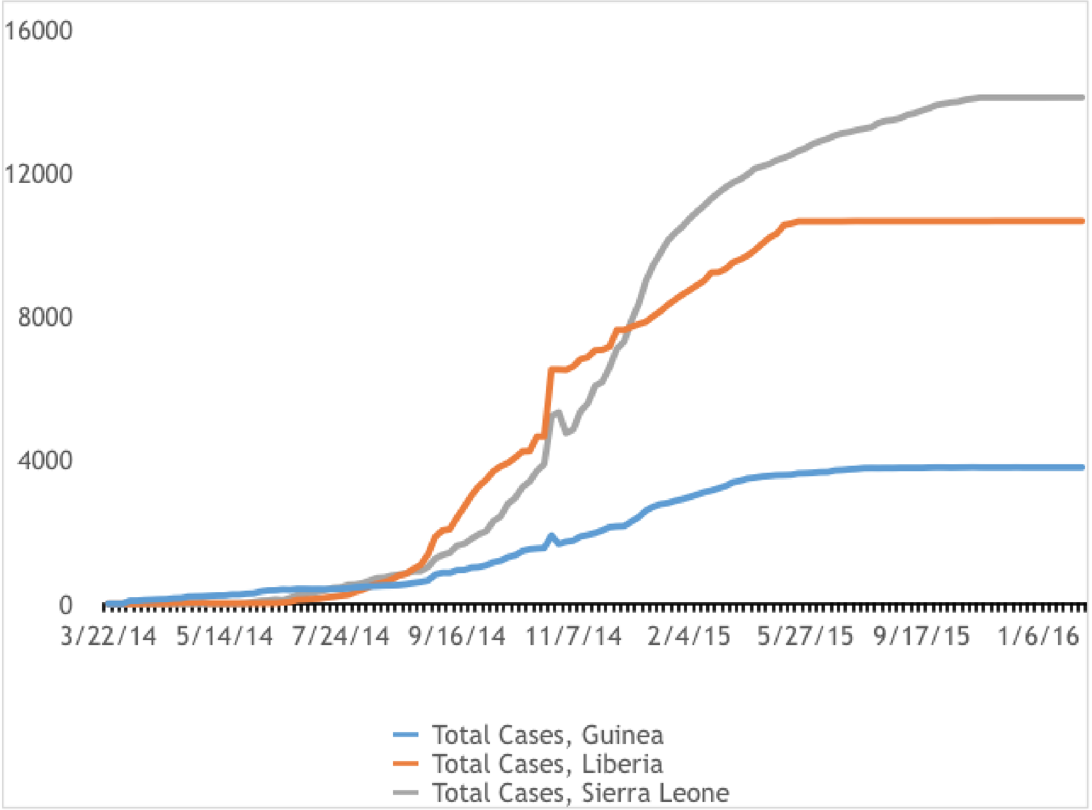
4) Used Excel to plot the values and constructed graphs of each value over time.

5) Adjusted our parameter values (b,k) to best fit the data presented.

- k value was chosen based on the average amount of time it takes to recover/perish from Ebola (8 days… so on any given week one person on average has a 7/8 chance of recovering)
- b value was adjusted until our model accurately represented the actual data set on spread of Ebola

PRE-MODEL DATA COLLECTION

WHO report date	Total Cases, Guinea	Total Deaths, Guinea	Total Cases, Liberia	Total Deaths, Liberia	Total Cases, Sierra Leone	Total Deaths, Sierra Leone
3/22/14	0	0	0	0	0	0
3/23/14	0	0	0	0	0	0
3/24/14	0	0	0	0	0	0
3/25/14	86	59	0	0	0	0
3/26/14	86	60	0	0	0	0
3/27/14	103	66	8	6	6	5
3/31/14	112	70	8	6	0	0
4/1/14	122	80	8	2	0	0
4/2/14	127	83	8	5	0	0
4/7/14	151	95	18	7	0	0
4/10/14	157	101	22	14	0	0
4/17/14	197	122	27	13	0	0
4/21/14	203	129	27	13	0	0
4/23/14	208	136	34	11	0	0
4/30/14	221	146	13	11	0	0
5/5/14	231	155	13	11	0	0
5/14/14	233	157	12	11	0	0
5/23/14	258	174	12	9	0	0
5/27/14	258	174	12	9	1	4
5/28/14	281	186	12	9	16	5
6/2/14	291	193	13	9	50	6
6/5/14	344	215	13	9	81	7
6/10/14	372	236	15	10	89	7
6/11/14	376	241	15	10	117	19
6/18/14	398	264	33	24	97	49
6/24/14	390	270	51	34	158	34
7/2/14	413	303	107	65	239	99
7/7/14	412	305	115	75	252	101
7/8/14	408	307	131	84	305	127
7/14/14	409	309	142	88	337	142
7/16/14	406	304	172	105	386	192
7/21/14	410	310	196	116	442	206
7/24/14	415	314	224	127	454	219
7/28/14	427	319	249	129	525	224
7/31/14	460	339	329	156	533	233
8/3/14	472	346	391	227	574	252
8/4/14	485	358	486	255	646	273
8/8/14	495	367	554	294	717	298
8/12/14	506	373	599	323	730	315
8/13/14	510	377	670	355	783	334
8/15/14	519	380	786	348	810	348
8/19/14	543	394	834	466	848	365



https://www.cdc.gov/vhf/ebola/outbreaks/2014-west-africa/cumulative-cases-graphs.html

week	s(t)	i(t)	r(t)
0	1	0.0000036941581	0
1	1	0.0000036941581	0.000000000000
2	0.999999	0.000003723710886	0.000000923540
3	0.999997	0.000003768393356	0.000002319931
4	0.999995	0.000003828682068	0.000004204128
5	0.999993	0.000003905243818	0.000006597054
6	0.99999	0.000003998947651	0.000009525987
7	0.999986	0.000004110880965	0.000013025066
8	0.999982	0.000004242370108	0.000017135947
9	0.999977	0.000004395005983	0.000021908613
10	0.999971	0.000004570675335	0.000027402371
11	0.999965	0.000004771598548	0.000033687050
12	0.999957	0.000005000374973	0.000040844447
13	0.999949	0.000005260037016	0.000048970057
14	0.999939	0.000005554114489	0.000058175121
15	0.999929	0.000005886711027	0.000068589086
16	0.999917	0.000006262594734	0.000080362508
17	0.999903	0.000006687305668	0.000093670522
18	0.999887	0.000007167283290	0.000108716960
19	0.99987	0.000007710017604	0.000125739258
20	0.99985	0.000008324228464	0.000145014302
21	0.999827	0.000009020078378	0.000166865401
22	0.999802	0.000009809425154	0.000191670617
23	0.999773	0.000010706121927	0.000219872714
24	0.99974	0.000011726373481	0.000251991080
25	0.999702	0.000012889159363	0.000288635997
26	0.999658	0.000014216736030	0.000330525765

$$s(t) = s(t-1) - b * s(t-1) * i(t-1) * t$$

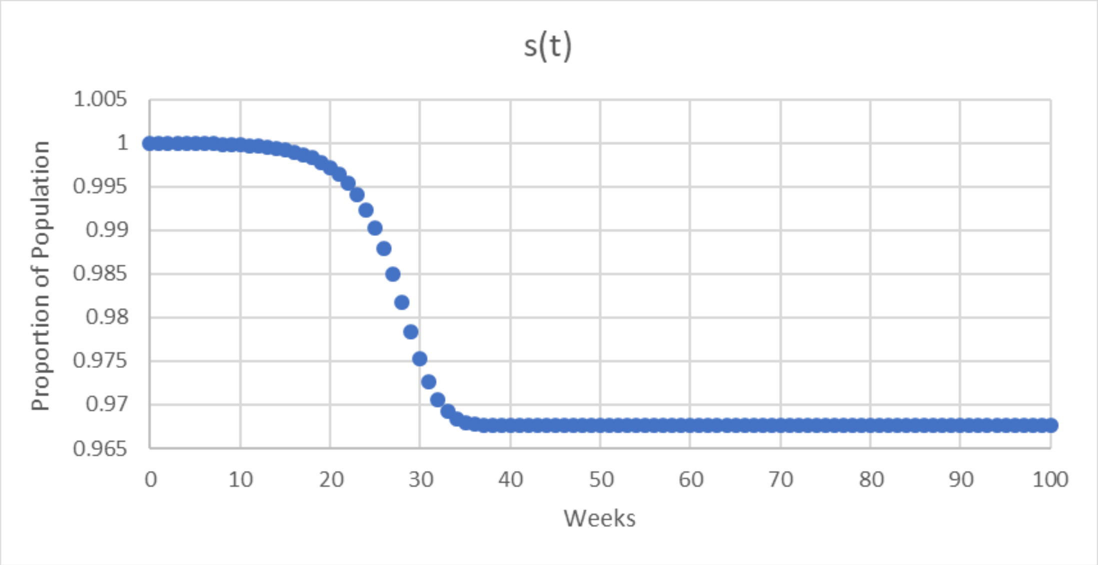
$$i(t) = i(t-1) + [b * s(t-1) * i(t-1) - k * i(t-1)] * t$$

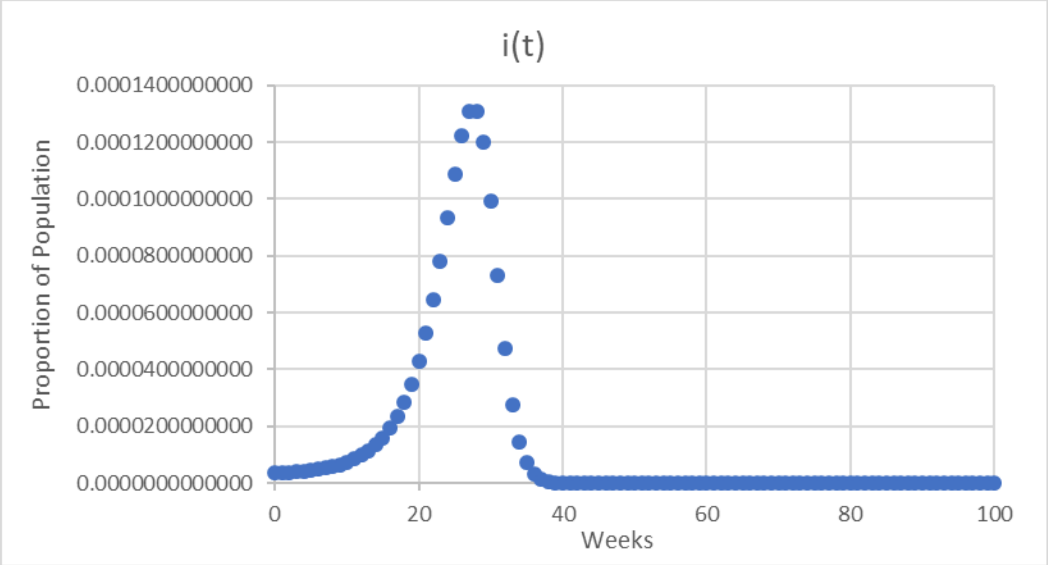
$$r(t) = r(t-1) + k * i(t-1) * t$$

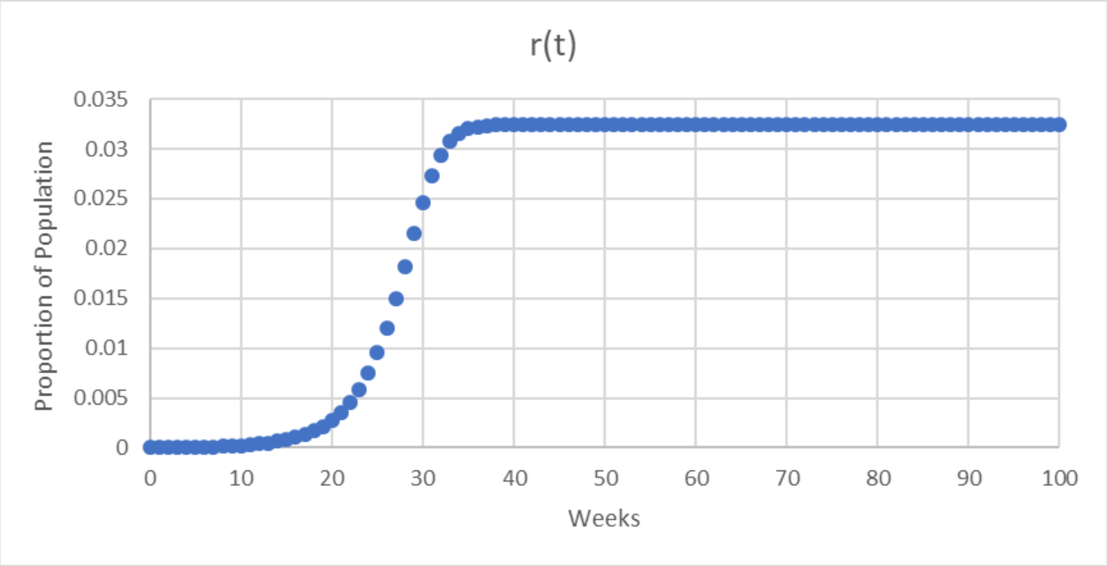
$$b = .8884$$

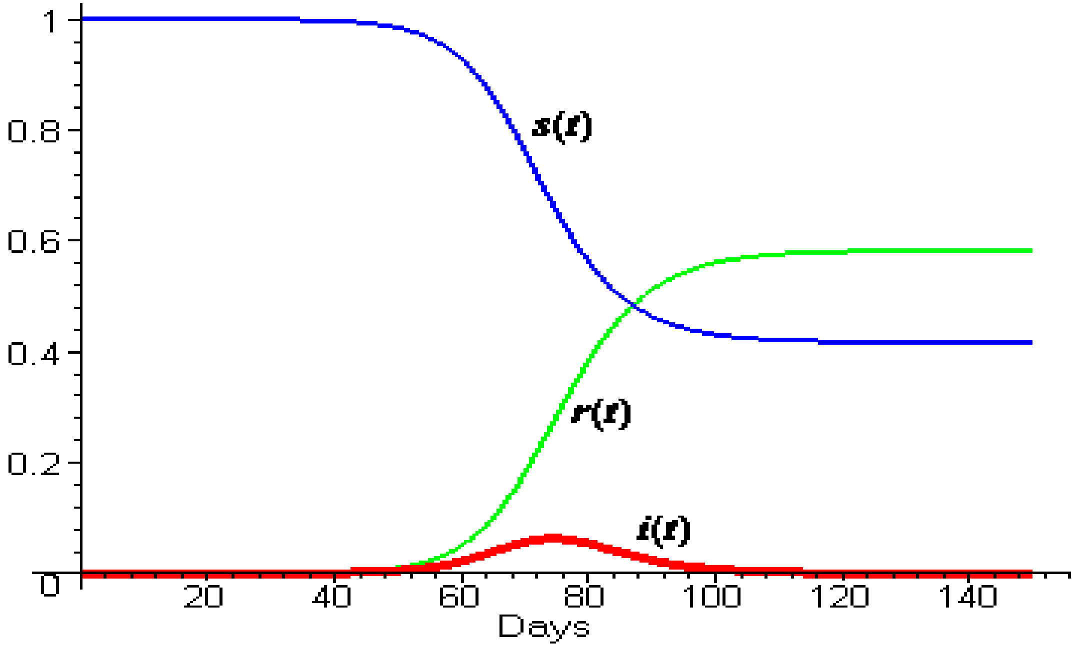
$$k = .875$$

S(t)	I(t)	R(t)
23280000	86.000000	0
23279988.906	86.000000	0.000000000000
23279966.7180106	86.687989	21.500000000000
23279933.1698066	87.728197	54.007996034896
23279887.9021868	89.131719	97.872094703708
23279830.4125051	90.914076	153.579418793908
23279760.0455228	93.095501	221.764975861156
23279675.9811516	95.701309	303.223539508015
23279577.2187755	98.762376	398.924848367861
23279462.5577392	102.315739	510.032521498757
23279330.5734826	106.405322	637.927195615517
23279179.5886727	111.082814	784.234513097704


s(t)
Proportion of Population
1.005
1
0.995
0.99
0.985
0.98
0.975
0.97
0.965
0
10
20
30
40
50
60
70
80
90
100
Weeks


i(t)
Proportion of Population
0.0001400000000
0.0001200000000
0.0001000000000
0.0000800000000
0.0000600000000
0.0000400000000
0.0000200000000
0.0000000000000
0
20
40
60
80
100
Weeks


r(t)
Proportion of Population
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
0
10
20
30
40
50
60
70
80
90
100
Weeks


1
0.8
0.6
0.4
0.2
0
s(t)
r(t)
i(t)
20
40
60
80
100
120
140
Days

HOW THEY MANAGED EBOLA & LIMITATIONS

Contrary to our model, Ebola only managed to infect 0.122% of the population in West Africa. Our model predicted 0.143%. What changed?

- High mortality rates made it difficult to model spread of Ebola

- Because there is no vaccine, avoidance of high probable transmission areas such as funerals and facilities where patients are being treated.

- Quarantining infected patients once they are infected.

- Avoidance of bats or nonhuman primates, and fluids / meats from these animals.

- Practice careful hygiene.

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