Transworld Research Network
37/661 (2), Fort P.O.
Trivandrum-695 023
Kerala, India

Understanding the dynamics of emerging and re-emerging infectious diseases using mathematical models, 2011:000-000 ISBN: 978-81-7895-549-0 Editor: Steady Mushayabasa

7. A mathematical model of Bieber Fever: The most infectious disease of our time?

Valerie Tweedle[1] and Robert J. Smith?[2]

[1]Department of Biology, The University of Ottawa, 585 King Edward Ave, Ottawa ON K1N 6N5 Canada; [2]Department of Mathematics and Faculty of Medicine, The University of Ottawa 585 King Edward Ave, Ottawa ON K1N 6N5, Canada

Abstract. Recently, an outbreak of Bieber Fever has blossomed into a full pandemic, primarily among our youth. This disease is highly infectious between individuals and is also subject to external media pressure, further strengthening the infection. Symptoms include time-wasting, excessive purchasing of useless merchandise and uncontrollable crying and/or screaming. We develop a mathematical model to describe the spread of Bieber Fever, whereby individuals can be susceptible, Bieber-infected or bored of Bieber. We analyse the model in both the presence and the absence of media, and show that it has a basic reproductive ratio of 24, making it perhaps the most infectious disease of our time. In the absence of media, Bieber Fever can still propagate. However, when media effects are included, Bieber Fever can reach extraordinary heights. Even an outbreak of Bieber Fever that would otherwise burn out (driven by fans becoming bored within two weeks) can

Correspondence/Reprint request: Dr. Robert J. Smith?, Department of Mathematics and Faculty of Medicine The University of Ottawa 585 King Edward Ave, Ottawa ON K1N 6N5, Canada.
E-mail: rsmith43@uottawa.ca

still be sustained if media events are staggered. Negative media can rein in oversaturation, but continuous negative media (the Lindsay Lohan effect) is the only way to end Bieber Fever. It follows that tabloid journalism may be our last, best hope against this fast-moving and highly infectious disease. Otherwise, our nation's children may be in a great deal of trouble.

1. Introduction

Bieber Fever n.
an individual's exorbitant obsession with Justin Bieber

A novel infectious disease has recently arisen and has begun spreading through populations all over the world. It is particularly endemic in the developed world and is age-dependent, primarily (although not exclusively) affecting children. Unchecked, it may consume our youth. This disease is Bieber Fever.

Bieber Fever has similar properties to other infectious diseases, such as a rapid rate of transmission in large populations, eventual recovery and debilitating scarring (in the form of inappropriate tattoos of Justin Bieber's name/face). Symptoms include uncontrollable crying and/or screaming, excessive purchasing of memorabilia, making poor life choices (e.g. copycat hairstyles), and distraction from everyday life [1].

Similar strains to this disease have arisen in the past for boy bands such as New Kids on the Block and the Backstreet Boys, in addition to other solo artists such as Justin Timberlake. However, none of those cases reached the same magnitude and affected, at such a young age, as large a portion of the population as Bieber Fever. To understand the spread and severity of Bieber Fever, we first need to understand its origin.

Justin Bieber was born on March 1st, 1994, in London, Ontario, Canada, but was raised in Stratford, Ontario. He seemed to have an affinity for music early on; he taught himself to play the drums, guitar, and knew how to play the trumpet and keyboard [2]. He was signed to Def Jam Records in 2008 at the age of 13, after being discovered because of videos he posted on the online media share website YouTube. Scooter Braun, a talent agent, saw Justin Bieber's videos and worked to get him meetings with Usher and Justin Timberlake [2] and eventually a record deal.

Following that, his career exploded. Through YouTube, he already had a large local fan base which continued to expand with his increased exposure. Intense media exposure has been responsible for accelerating his career: his music video for the song "Baby" is one of the top videos on YouTube [3], he had an album at the number five position on the Billboards Top 200 for 2010 [4] and is now one of the most searched names on the internet [5].

To help illustrate the extent of media buzz surrounding him, Figure 1 shows the percentage of tweets related to Justin Bieber on the popular media share website Twitter over a 180 day period (from approximately September 12, 2010 to March 12, 2011) [6]. Consistently, 1% of all tweets are related to him and, on one occasion, the number of tweets increased to approximately 4%. These peaks are often related to major media events surrounding him. For example, the peak around the 11th of February 2011 where he reached 4% corresponds to the release of his movie, Justin Bieber: *Never Say Never*.

Figure 2 shows the trends of Google searches related to Justin Bieber throughout 2010. The y-axis shows the average amount of daily search traffic related to Justin Bieber, scaled to 1.0 [7]. Therefore, any peaks above 1.0 represent an increase in Justin Bieber searches. The labels in the figure represent some of the major news events related to him. Figure 3 illustrates the number of search results related to Justin Bieber since 2008 [8].

Justin Bieber has released a total of five albums, three of which contain original songs and two of which are remakes and remixes. A total of 20 singles from these CDs have been released, 10 of which have accompanying music videos. In 2010 alone, he was nominated for 28 music awards, of which he won 19 [9]. He also released a concert movie called *Justin Bieber: Never Say Never* on February 11, 2011. In the United States and Canada on its opening weekend, it made just under $30 million [10]. Collectively, it has made approximately $91 million in theatres worldwide, with approximately

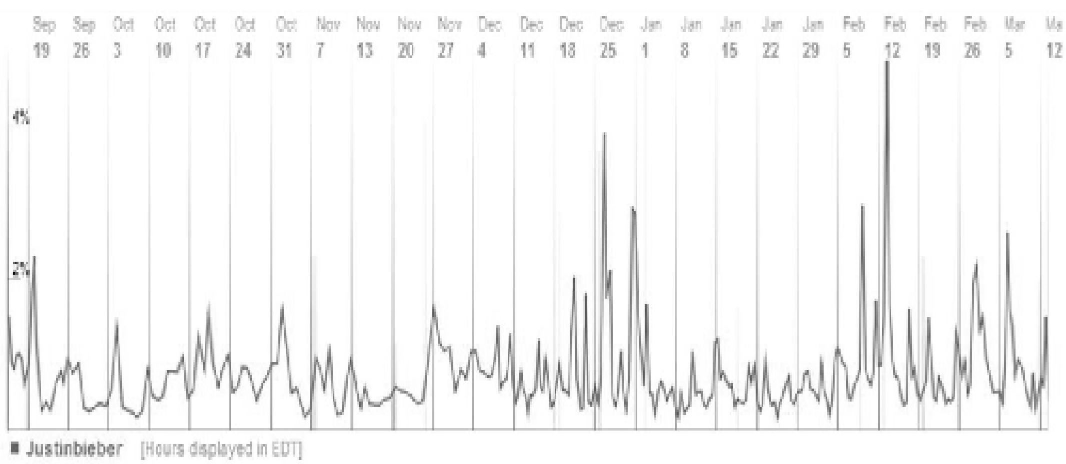

Figure 1. Percentage of Twitter tweets related to Justin Bieber over a period of 180 days (from September 2010 to March 2011). The figure was created using the Trendistic application, although in fairness we suspect the application was actually invented to track tweets about Justin Bieber and for no other purpose.

Figure 2. Google trends related to Justin Bieber, showing the average amount of daily search traffic related to Justin Bieber throughout 2010. A: Justin Bieber by the numbers (Chicago Tribune, Apr 1 2010). B: Justin Bieber leaves New Zealand (stuff.co.nz, Apr 28, 2010). C: Justin Bieber to write memoir (News24, Aug 3 2010). D: Justin Bieber Wins Best New Artist VMA (MTV.com, Sep 13 2010). E: Justin Bieber a laser loser? (Detroit Free Press, Oct 18 2010). F: Justin Bieber sweeps American Music Awards (Reuters India, Nov 22 2010). One of these things is not like the others. But at least now we know why Detroit is giving away its press for free.

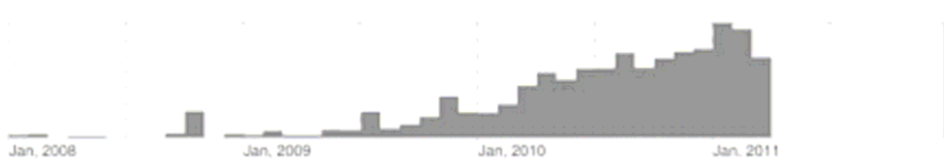

Figure 3. Total number of search results related to Justin Bieber between January 2008 and March 2011. If you're reading this with an unusual degree of intensity, then you probably contributed to this statistic.

$72 million of that being from domestic sales [11].

He has published two autobiographical books [12]; another 13 biographies have been published about him. In addition, he has made innumerable television, magazine and radio appearances, which have ensured that he stays in the public eye at all times. Through constant exposure, Bieber Fever has incubated and spread. Millions are already infected, with more at risk every day. Action is urgently needed.

2. The model

We will model Bieber Fever's spread using an SIR model with some variations. The compartments represent the susceptible (S), Bieber-infected (B) and removed (R) populations. In this model, the removed category represents individuals who are "immune" to infection, i.e. those who have lost interest in Justin Bieber; however, this compartment is not an end stage, as"immunity" can be lost. In addition, beyond the typical SIR model, we have also incorporated the effect of the media on transmission [13].

We assume there is a total amount of media (M), a certain proportion (ϵ) of which are positive (P) and the remainder negative (N). Thus

$$M = \epsilon P + (1 - \epsilon)N$$

Media events include the release of any new albums, singles, movies, dolls or interviews with media companies on either radio, television or in magazines/ newspapers. The proportion simply represents how often positive media events versus negative media events are broadcast to the public.

The flow of individuals is shown in Figure 4. Individuals enter the susceptible population by a given recruitment rate (π). They then become infected through one of two routes. They can either become infected by coming incontact with individuals infected with Bieber Fever (transmission rate, β). Alternatively, individuals can become infected through positive media exposure (ϵP).

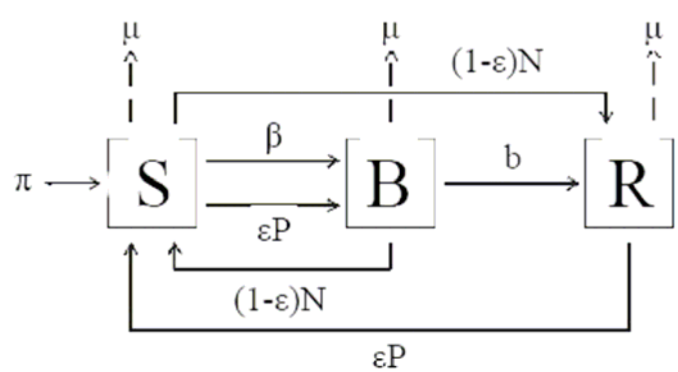

Figure 4. The mathematical model. Individuals can be Susceptible (S), Bieber-infected (B) or Recovered (R). New individuals are recruited at rate π and grow out of Bieber at rate μ. Susceptible individuals can become infected at rate β and become bored of Bieber at rate b. A proportion ϵ of the media coverage is positive. Positive media P turns susceptible individuals into Bieber fans, while it makes recovered individuals open to infection again. Negative media (N) reverses these effects. If this looks too scary for you, this simple exercise might help: where you see "S", imagine a curious young girl; where you see "B" , imagine that same young girl screaming at a concert; and where you see "R", imagine a sullen teenager who won't listen to a word you say, but still wants you to drive them to the mall.

Infected individuals can recover by losing interest in Justin Bieber (at a boredom rate, b). Individuals can also be removed at any point by maturing beyond the age of 17 years (maturation rate, μ). We restrict ourselves to considering only individuals in the 5-17 age range, since it encompasses the largest portion of his fan base.

Beyond the flow from susceptible to infected to recovered, media can also affect the flow of individuals between compartments. First, positive media can directly infect susceptible individuals. Positive media can also remove the immunity of a recovered individual, making them susceptible again to the charms of Justin Bieber at some future date. Conversely, negative media can decrease excitement about Justin Bieber in infected individuals, thus returning them to the susceptible population. Lastly, negative media can also push a susceptible individual into the recovered population by completely removing interest in Bieber.

The ordinary differential equations (ODEs) for this model are:

$$\begin{aligned} S' &= \pi - \beta SB - \epsilon PS + (1-\epsilon)NB - \mu S + \epsilon PR - (1-\epsilon)NS \\ B' &= \beta SB + \epsilon PS - (1-\epsilon)NB - bB - \mu R \\ R' &= bB + (1-\epsilon)NS - \epsilon PR - \mu R. \end{aligned} \tag{2.1}$$

An interesting property of our model is that there is no disease-free equilibrium. Thus, so long as there is positive media about Justin Bieber, Bieber Fever can break out without anyone initially having it.

We assume that Bieber Fever can only be transmitted through contact with infected individuals or through media exposure and that these interactions can be described by mass-action modelling. Similarly, we assumed that each individual experiences frequent and constant media exposure. We believe this is a valid assumption, since with the internet, television, radio, magazines/newspapers and society's dependence on portable media devices, individuals can be constantly exposed to media. Lastly, we assumed the proportion of media exposure and the number of media events remains constant over time.

Note that if $\Sigma = S + B + R$ is the total target population, then

$$\Sigma' = \pi - \mu\Sigma.$$

It follows that, in the long term, the entire population will approach

$$\bar{\Sigma} = \frac{\pi}{\mu}.$$

Thus, regardless of infection status, the population will equilibrate. If this doesn't strike fear into the heart of every parent, then they have no soul.

3. Parameter values

The values we assigned to each parameter are listed in Table 1. We modelled the spread of Bieber Fever in a small community of approximately 1000-2000 individuals. This might represent a large school, a small town, or simply a representative sample. We keep the numbers small in order to satisfy the assumption of mass-action dynamics: every infected individual has equal chance of infecting any susceptible individual.

The lifespan in the model is 12 years ($1/\mu$) since we are looking at an age range of 5-17 years. We consider two scenarios for the rate of boredom: slow ($b = 1/24$) and fast ($b = 2$). In the former case, it takes approximately two years to get bored of listening to his music and playing with his dolls. In the latter case, fans get bored after two weeks. (We believe the former case is far more likely and include the latter case only for comparison purposes.)

We used a recruitment rate of 10 individuals per month, so that the population at equilibrium is $\frac{\pi}{\mu} = 1440$ individuals. We assumed a greater proportion of media exposure would be positive since his record label would be more interested in keeping his image positive rather than negative, which is why we assigned ϵ to be 0.75. This means that positive stories are being broadcast to the public about three times as effectively as negative stories.

Considering the number of albums, singles, movies and books released in 2010 alone, we assumed positive media events were occurring fairly often and assigned P a value of twice a month. However, gossip magazines

Table 1. Parameter values. Two values of the boredom rate are included, in order to examine different scenarios: $b = 1/24$ for slow boredom and $b = 2$ for fast boredom. But let's be honest, we all know which one it really is, don't we?

Variable	Symbol	Sample/initial value	Units
Susceptible	S	1500	people
Bieber-infected	B	3	people
Recovered	R	0	people
Recruitment rate	π	10	people month^{-1}
Transmission rate	β	8.3×10^{-4}	people^{-1}month^{-1}
Maturation rate	μ	1/144	month^{-1}
Boredom rate	b	$\{1/24, 2\}$	month^{-1}
Positive media rate	P	2	month^{-1}
Negative media rate	N	1	month^{-1}
Positive media proportion	ϵ	0.75	-

thrive on slandering celebrity images so we also assigned a relatively high value to *N*, at once a month.

Note that although we consider both slow and fast rates of boredom, we expect that slow boredom is more likely. In this case, when $b = 1/24$, then $R_0 = 24$. It follows that Bieber Fever is extremely infectious, even more than measles [14], which is currently one of the most infectious diseases [15]. Bieber Fever may therefore be the most infectious disease of our time.

4. The absence of media

In the absence of media, the model is

$$\begin{aligned} S' &= \pi - \beta SB - \mu S \\ B' &= \beta SB - bB - \mu R \\ R' &= bB - \mu R. \end{aligned} \tag{4.2}$$

Let $r = \pi - \dfrac{\mu(b+\mu)}{\beta}$ Then this model has two equilibria,

$$\left(\frac{\pi}{\mu}, 0, 0\right) \text{ and } \left(\frac{r}{\beta}, \frac{br}{\mu(b+\mu)}, \frac{r}{b+\mu}\right),$$

which are the disease-free equilibrium (DFE) and endemic equilibrium (EE), respectively.

The EE only exists if

$$r = \pi - \frac{\mu(b+\mu)}{\beta} > 0$$

so we have

$$R_0 = \frac{\pi\beta}{\mu(b+\mu)}.$$

Model (4.2) has Jacobian matrix

$$J = \begin{bmatrix} -\beta B - \mu & \beta S & 0 \\ \beta B & \beta S - b - \mu & 0 \\ 0 & b & -\mu \end{bmatrix},$$

with characteristic equation

$$\lambda^2 + (\beta B + \mu + \beta S + b + \mu)\lambda + \beta bB + \beta\mu B - \beta\mu S + \mu b + \mu^2 = 0.$$

At the DFE, the constant term of the characteristic equation, *c*, satisfies

$$c = -\beta\pi + \mu(b + \mu).$$

Clearly, $c < 0$ when $R_0 > 1$. Since the coefficient of λ is always positive, it follows that the DFE is unstable if and only if $R_0 > 1$.

At the EE,

$$c = \beta\pi - \mu(b + \mu).$$

Clearly, $c > 0$ when $R_0 > 1$. It follows that the endemic equilibrium is stable whenever it exists.

Figure 5 illustrates the case when there is no media and a slow boredom rate ($b = 1/24$). In this case, $R_0 = 24$ and so Bieber Fever will spread. There is

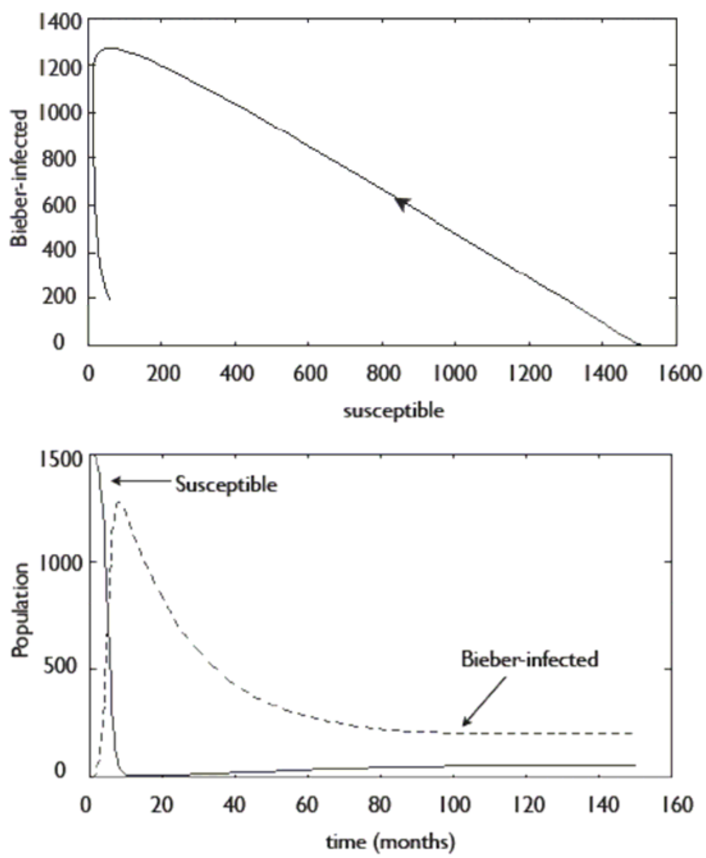

Figure 5. An outbreak in the absence of media attention. All parameter values are as in Table 1, with slow boredom rate ($b = 1/24$ and thus $R_0 = 24$). A. The phase plane, illustrating susceptible and infected individuals. B. The time series, illustrating the long-term effects. In this case, Bieber Fever has an initial outbreak and then remains endemic in the population, at low levels. This result will likely please the CD manufacturers and makers of Bieber keyrings, but likely has Rupert Murdoch quaking in his boots.

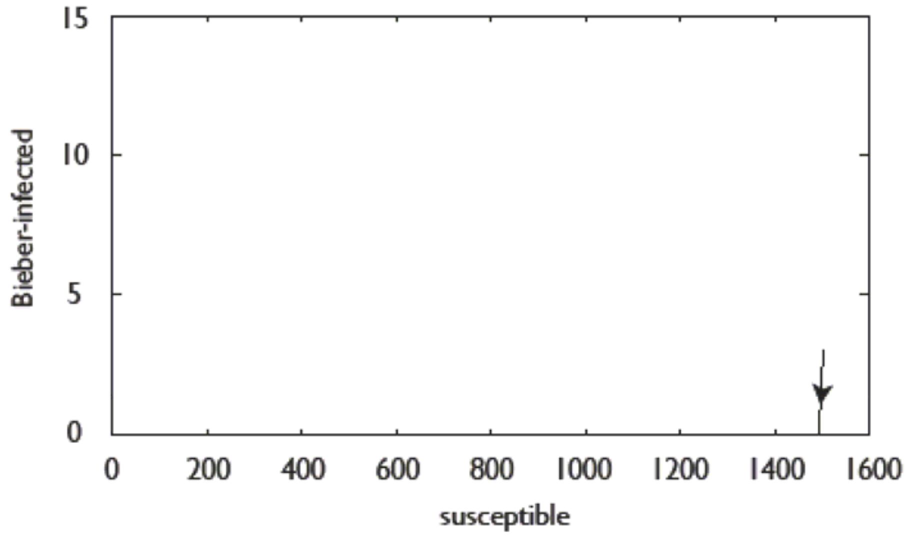

Figure 6. A lack of outbreak in the absence of media. Parameters were as in Table 1, with fast boredom rate (b = 2 and thus R_0 = 0.59). In this case, Bieber Fever never takes off and dies out on its own. If Justin Bieber was your uncle and his ageing garage band, that is.

an initial peak of infection, during which almost all susceptible individuals are infected. Eventually, however, Bieber Fever settles into an endemic state, with a moderate number of Bieber-infected individuals persisting in the long term.

Figure 6 illustrates the case when there is no media and a fast boredom (b = 2). In this case, R_0 = 0.59 and so Bieber Fever cannot persist. The disease-free equilibrium is stable and the infection clears naturally.

Well okay, not really. But we had you going for a moment there, didn't we?

5. Media-awareness threshold

Suppose that, initially, the media is unaware of the impact of Justin Bieber (as happened initially). We can approximate low-level mixing by a simplified system of impulsive differential equations. See [16, 17, 18, 19]. That is, we assume that new infected individuals arrive at fixed times, t_k, but that susceptible and infected individuals do not mix, in the absence of media. This model is

$$\begin{aligned} S' &= \pi - \mu S & t &\neq t_k \\ B' &= -bB - \mu R & t &\neq t_k \\ R' &= bB - \mu R & t &\neq t_k \\ \Delta B &= B^i & t &= t_k. \end{aligned}$$

Then the Bieber-infected class has solution

$$B(t) = B_k e^{-(b+\mu)t} \qquad t_k \le t < t_{k+1}.$$

Using the impulsive effect, we have the recurrence relation

$$B_{k+1}^- = (B_k^- + B^i)e^{-(b+\mu)(t_{k+1}-t_k)}.$$

where B_k^- is the value of B immediately before the *kth* impulse.

If the arrival times are constant, so that $t_{k+1} - t_k = \tau$, then the recurrence relation has solution

$$B_\infty^- = \frac{B^i e^{-(b+\mu)\tau}}{1 - e^{-(b+\mu)\tau}}.$$

Hence,

$$B_\infty^+ = \frac{B^i}{1 - e^{-(b+\mu)\tau}}.$$

These two values form the endpoints of an impulsive periodic orbit.

If the media become aware of Bieber Fever at some threshold B_{crit}, then, for $B > B_{crit}$, we can assume mixing occurs between susceptibles and infecteds, as well as media effects (both positive and negative). This threshold may be either large or small, depending on the degree of "newsworthiness" that the media assign to Bieber Fever; that is, it may only take relatively few isolated cases before the media put together a story based on "human interest" or it may take a large number of cases before the media report a general trend that is sweeping our nation's children.

However, media events do not occur continuously. Thus, we can use impulsive differential equations to model discrete media events. To do this, we assume that positive media will attempt to reach the entire population (since it will try to recruit either susceptible or recovered individuals, while also reinforcing devotion in the Bieber-infected), whereas negative media will be targeted only towards those currently infected with Bieber Fever. We assume that both positive and negative media events occur simultaneously; for example, coverage in monthly magazines, or responses to a given incident (such as Justin Bieber's infamous haircut).

Thus, the model in the upper region becomes

$$\begin{aligned} S' &= \pi - \beta SB - \mu S && t \neq t_k \\ B' &= \beta SB - bB - \mu R && t \neq t_k \\ R' &= bB - \mu R && t \neq t_k \\ B^+ &= \frac{\epsilon\pi}{\mu} - (1-\epsilon)B^- && t = t_k. \end{aligned}$$

If we consider the upper bound $S \leq \frac{\pi}{\mu}$ (ie, in the long term, everyone becomes infected with Bieber Fever), then we can overestimate the Bieber infected class via the one-dimensional impulsive differential equation

$$\begin{aligned} B' &= \frac{\beta\pi}{\mu}B - bB - \mu B && t \neq t_k \\ B^+ &= \frac{\epsilon\pi}{\mu} - (1-\epsilon)B^- && t = t_k. \end{aligned}$$

Since

$$B^+_{k+1} = B^-_k e^{m\tau},$$

where $m = \dfrac{\beta\pi}{\mu} - b - \mu$, the solution after the nth impulse is

$$B^+_n = \frac{\epsilon\pi}{\mu}\left(\frac{1-(-1)^n e^{nm\tau}(1-\epsilon)^n}{1+e^{m\tau}(1-\epsilon)}\right) + (-1)^n B(0)e^{nm\tau}(1-\epsilon)^n.$$

We shall consider the worst-case scenario (from the point of view of the infection), i.e. that Bieber Fever is unable to sustain itself in the absence of media. If $R_0 < 1$ in the absence of media, then $m < 0$. In this case,

$$B^+_\infty = \frac{\epsilon\pi}{\mu(1+e^{m\tau}(1-\epsilon))}.$$

If $\epsilon \approx 1$, then $B^+_\infty \approx \frac{\pi}{\mu}$, whereas if $\epsilon \approx 0$, then $B^+_\infty \approx 0$.

Thus, even if Bieber Fever would otherwise die out, sufficient positive media coverage suggests that everyone would be infected.

Figure 7 illustrates the media-awareness threshold. Initially, there is limited mixing that would lead to an impulsive periodic orbit at low levels. However, at the media awareness threshold (of 1.9 per 1000 individuals or

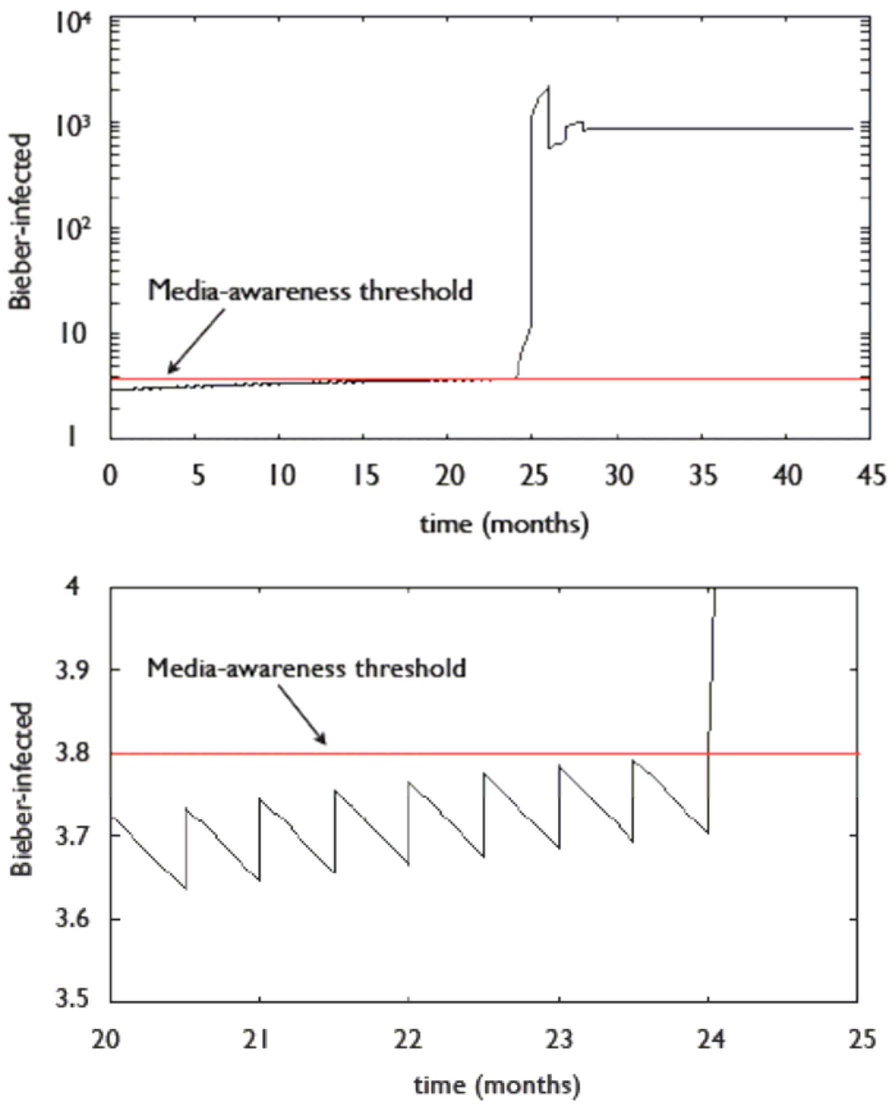

Figure 7. An initial outbreak of Bieber Fever with slow boredom rate (b = 1/24 and thus R_0 = 24). A. When the low-level mixing crosses the media-awareness threshold, the result is a large outbreak. Note the log scale on the y-axis. B. Closeup of the media-awareness threshold. In 1974, they went mad for Evel Knieval too, you know. (If you're under 30 and don't know who that is, google him, but please remember that it was a simpler time and we didn't have the internet back then.)

3.8 per 2000 in our example), there is a sudden explosion in interest, driven by significant mixing of the susceptible and Bieber-infected individuals, and a series of media pulses.

Figure 8 illustrates the effect of media pulses in more detail. In this case, there is initially an oversaturation of media, causing the first spike. A backlash of negative media then kicks in, dragging the number of

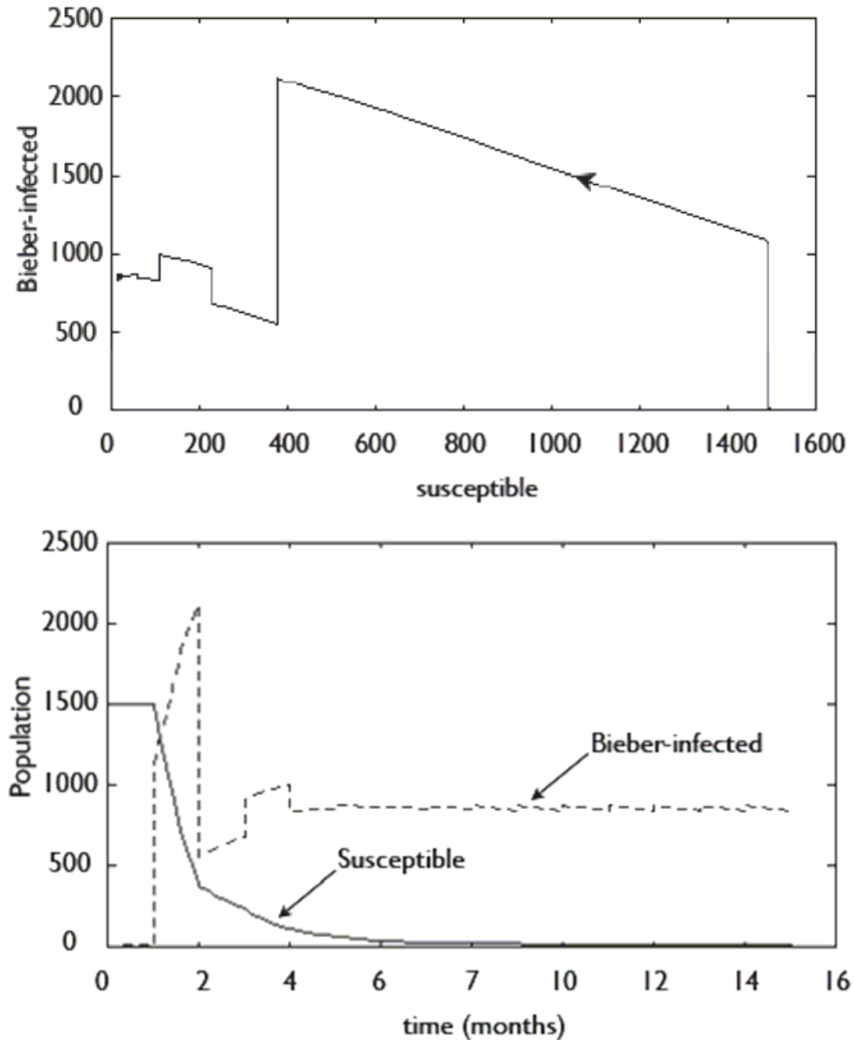

Figure 8. Media pulses for slow boredom rate (b = 1/24 and thus R_0 = 24). A. When media oversaturation occurs, negative media has a drag effect. The system oscillates due to competing effects of positive and negative media. B. The time series showing the system approaching a stable equilibrium, with no susceptible individuals. You belong to us. You will be like us.

Bieber-infected individuals down. Positive media then responds and the system oscillates towards an equilibrium. Since the boredom rate is slow, infection takes over with a depletion of susceptibles and a majority of individuals becoming Bieber-infected in the long term.

Figure 9 illustrates the effect of media pulses on Bieber Fever with fast boredom. In this case, a disease which would otherwise die out will be sustained by the media. The number of Bieber-infected individuals does not approach equilibrium, but instead approaches an impulsive periodic orbit, oscillating between 200 and 1000 individuals every month, as Bieber fans are

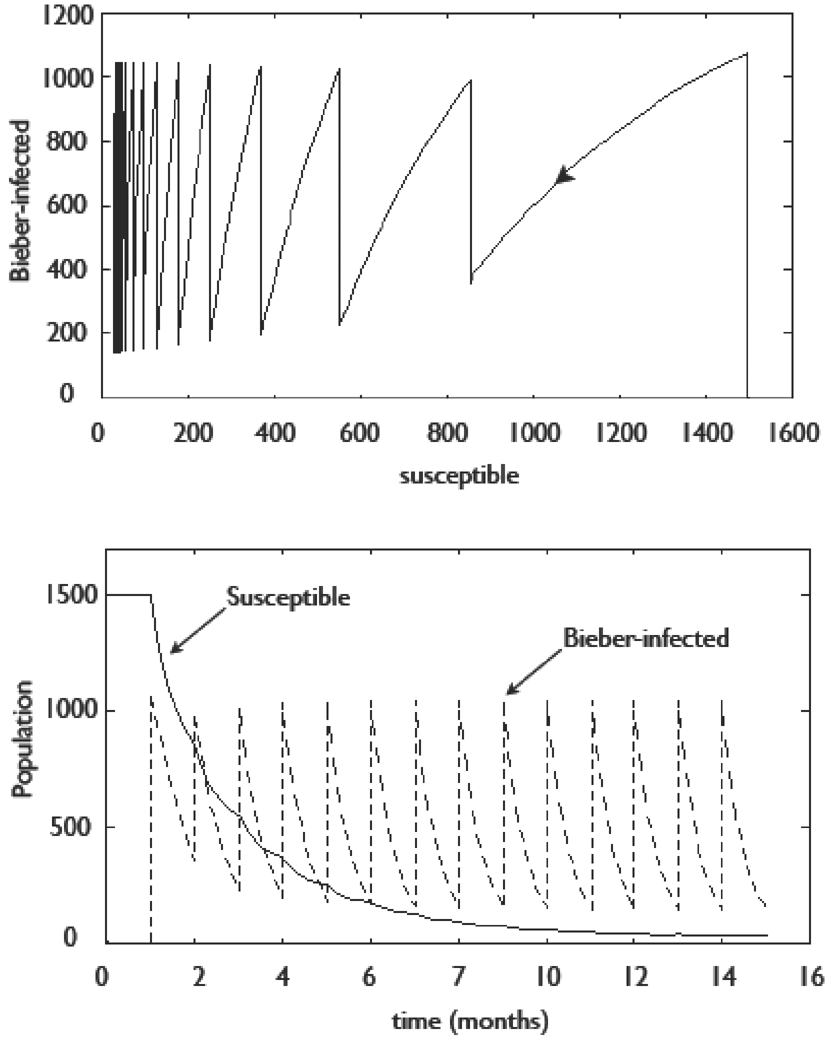

Figure 9. Media pulses for fast boredom (b = 2 and thus R0 = 0.59). A. The phase plane, showing that susceptible individuals are phased out, but that Bieber-infected individuals do not approach an equilibrium, but instead continue to oscillate in impulsive periodic orbit. B. The time series. When the disease would otherwise die out, media pulses can sustain Bieber Fever. This is what keeps PR departments in gainful employment. So now you know who to blame.

alternately bored by the most recent development and then excited by the next one.

Is it just us, or does this seem disturbingly plausible?

6. Continuous positive media

Suppose media occurs continuously, which approximates media saturation. Then $\epsilon = 1$ and the model becomes

$$\begin{aligned} S' &= \pi - \beta SB - PS - \mu S + PR \\ B' &= \beta SB + PS - bB - \mu R \\ R' &= bB - PR - \mu R. \end{aligned} \tag{6.3}$$

Note that if $P > 0$, then this model has no DFE. Thus, an outbreak of Bieber Fever will always occur in the absence of negative media. Equilibria of model (6.3) satisfy

$$\begin{aligned} \bar{R} &= \frac{b}{P+\mu}\bar{B} \\ \bar{S} &= \frac{(b+\mu)\bar{B}}{\beta\bar{B}+P} \end{aligned}$$

and

$$g(\bar{B}) = \frac{Pb\beta}{P+\mu}\bar{B}^2 + \left[\pi\beta - (\beta+P+\mu)(b+\mu) + \frac{P^2 b}{P+\mu}\right]\bar{B} + P\pi = 0.$$

As P becomes large, we have

$$\begin{aligned} \lim_{P\to\infty}\frac{g(\bar{B})}{P} &= -\mu\bar{B} + \pi = 0 \\ \bar{B} &= \frac{\pi}{\mu}. \end{aligned}$$

Thus, as continuous media coverage saturates the airwaves, the only equilibrium will have the entire population infected.

However, in practice, the media is limited. Figure 10 represents continuous media using the values in Table 1. Compared to the case of media pulses (see Figure 8), a similar number of individuals ultimately become infected in the slow boredom case, but the peak of the infection is significantly lower than when media events are staggered. In the fast boredom case, although there is an outbreak of Bieber Fever, ultimately the infection clears and there are no long-term infected individuals. This contrasts with the case of media pulses (as in Figure 9), where staggered media events are able to sustain Bieber Fever, even when the boredom rate is high.

Did you catch that, corporate media and its various subdivisions? Unless you space it out a bit, you'll destroy the very thing you love. We're talking to you, 24 hour news cycle.

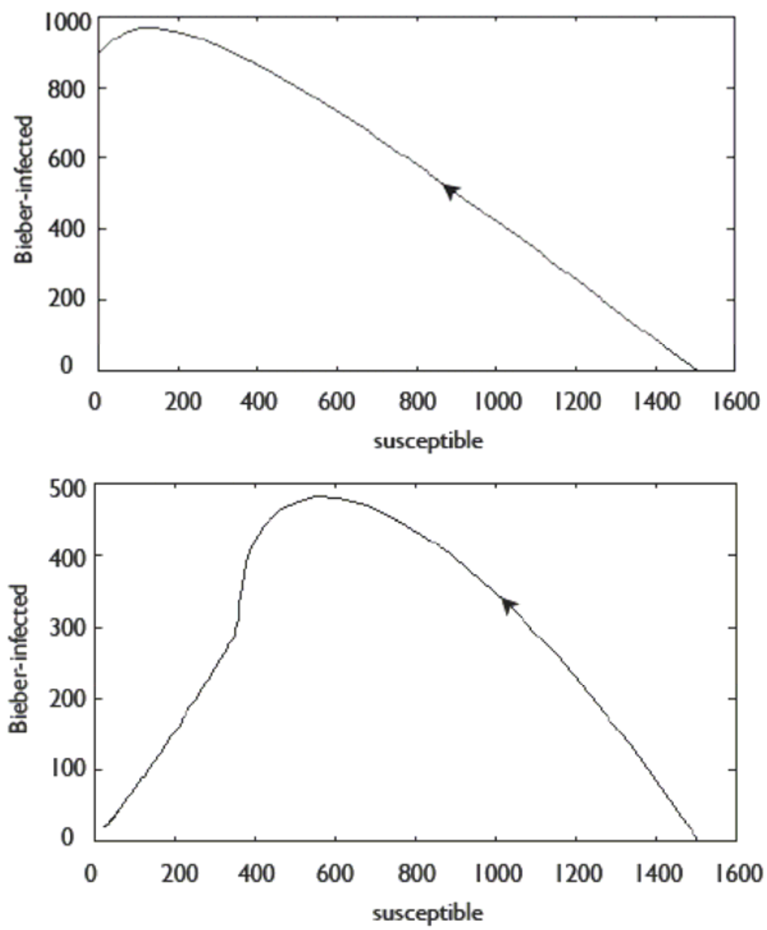

Figure 10. The effects of continuous media. A. Slow boredom (b = 1/24 and thus R_0 = 24). In this case, there is a moderate peak and susceptible individuals are depleted. B. Fast boredom (b = 2 and thus R_0 = 0.59). In this case, there is a small outbreak, but it is unsustainable in the long term. And this is why PR departments always take such long lunches.

7. Continuous negative media

Media coverage for celebrities can abruptly turn negative (see, for example, Britney Spears or Lindsay Lohan). Thus, we examined the hypothetical case of an onslaught of negative media attention. In this case, $\epsilon = 0$ and model (2.1) becomes

$$
\begin{aligned}
S' &= \pi - \beta SB + NB - \mu S - (1-\epsilon)NS \\
B' &= \beta SB - NB - bB - \mu R \\
R' &= bB + NS - \mu R.
\end{aligned}
$$

In this case, the DFE is

$$(\tilde{S}, \tilde{B}, \tilde{R}) = \left(\frac{\pi}{\mu + N}, 0, \frac{\pi N}{\mu(\mu + N)}\right)$$

and

$$R_{0,\text{neg}} = \frac{\pi\beta}{(\mu + N)(b + \mu + N)}.$$

If N is large, then $R_{0,\text{neg}}$ will be small and hence the DFE will become stable. In this case, Bieber Fever will die out. Specifically,

$$\lim_{N\to\infty}(\tilde{S}, \tilde{B}, \tilde{R}) = \left(0, 0, \frac{\pi}{\mu}\right).$$

Thus, if the Lindsay Lohan effect occurs and there is an onslaught of negative media attention, eventually everyone will become bored of Bieber.

Figure 11 illustrates the effect that continuous negative media can have on Justin Bieber's career. Positive media can lead to an initial outbreak and

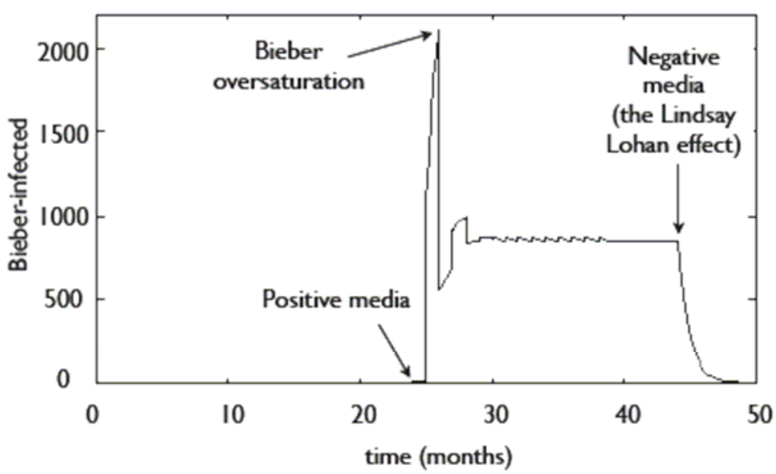

Figure 11. The effects of initial positive media, followed by subsequent negative media for the case of slow boredom (b = 1/24 and thus R_0 = 24). A positive media threshold at month 25 leads to an outbreak of Bieber-worshipping children, who might be spending their parents' income on dolls, lip gloss and kitschy pencil cases, but at least aren't roaming the streets. Subsequently, the effects of competing media rein in oversaturation as everyone comes to their senses, somewhat, and requests for Bieber tattoos decline markedly, triggering a minor recession, but – on the bright side – significantly reducing needle-borne infections. At month 44, media turns continuously negative (the Lindsay Lohan effect, although we desperately hope that there isn't a similar underwear-free incident), resulting in the eventual eradication of Bieber Fever. Thank goodness.

negative media pulses can reduce the effects of oversaturation, but continuous negative media can have an intense and rapid effect on the number of Bieber-infected individuals. Thus, continuous negative media can effectively end Bieber Fever.

So one day in the future, after all the scandals and the bad haircuts, we'll all wake up with a Bieber hangover and wonder what on earth we were collectively thinking. That, and the tattoo-removal business won't just be limited to the aftereffects of inadvisable honeymoons.

8. Discussion

Bieber Fever represents a clear and growing challenge to our nation's children. While the disease may be beneficial in some ways – forming fan communities, bringing children together across differences in their love of Bieber – it may also contribute to intense obsession and time-wasting among youth.

Justin Bieber is clearly a child of the media. While he is undoubtedly talented, whom the media chooses to idolise – and whom they later choose to tear down – is only tangentially related to ability. In the absence of media, Bieber Fever will spread if the boredom rate is sufficiently low, although the extreme highs will eventually pass. However, even if $R_0 < 1$ (ie, even if the disease would die off on its own), Bieber Fever can still be sustained via a series of staggered media events. Sufficient media saturation can infect almost everyone.

Our results show that, in any population of young people exposed to Justin Bieber, there will be an outbreak of Bieber Fever, even if no one is initially infected. This makes the disease very dangerous and any population extremely susceptible. The only methods to help control the spread of infection are to publish more negative media stories about him than positive, such as involving him in a sex scandal or exploit his bad haircut choices and increasing the number of times those negative stories appear in the media. These measures may seem extreme, but they will need to be weighed against the possibility of our youth driving the general public mad with their obsession with Justin Bieber.

If we are to protect our children from this fast-moving disease, we must act immediately. Only sustained media attacks, delivered continuously, can turn the tide on what might well be the most infectious disease of our time. Tabloid journalism may be our last, best hope against total apocalyptic infection.

Eradicating Bieber Fever presents significant challenges, involving both local and media-driven events. It might be unlikely to happen in practice, but never say never.

Acknowledgements

We thank Rachelle Miron, Elissa Schwartz, Anthony Wilson and Shoshana Magnet for technical discussions, classrooms of enthusiastic nine year olds and Justin Bieber CDs (although not necessarily in that order). RJS? is supported by an NSERC Discovery Grant, an Early Researcher Award and funding from MITACS. But, before you ask, none it was actually spent on this research. Although, if you're posting about that in an internet forum, we suspect you didn't quite read this far, thus illustrating several stereotypes at once. For citation purposes, note that the question mark in "Smith?" is part of his name. Yes, really.

References

1. Bieber Fever. Urban Dictionary. http://www.urbandictionary.com/ define.php?term=Bieber%20Fever&defid=4925152 (Accessed 9 February 2011).
2. Justin Bieber is Officially King of YouTube. The Wall Street Journal (staff blog).15 July 2010. http://blogs.wsj.com/speakeasy/2010/07/15/ justin-bieber-is-officially-king-of-youtube/ (Accessed 9 February 2011).
3. Best of 2010: Top Billboard 200. Billboard.com (chart archive). http://www.billboard.com/#/charts-year-end/the-billboard-200? year=2010 (Accessed 9 February 2011).
4. V. H.-C. Chan. 2010 Year in Review: Top 10 Searches News http://yearinreview.yahoo.com/2010/us_top_10_searches#Top%2010 %20Searches (Accessed 9 February 2011).
5. Trendistic. Justin Bieber. http://trendistic.com/justinbieber/ 180-days (Accessed March 12, 2011).
6. Google Trends Help. Working with Google Trends: how is the data scaled. http://www.google.ca/intl/en/trends/about.html#7 (Accessed March 12, 2011).
7. GoogleTrends.JustinBieber.http://www.google.ca/trends?q=Justin+Bieber&ctab=0 &geo=all&date=ytd&sort=0 (Accessed March 12, 2011).
8. Google Results. Justin Bieber. http://www.google.ca/search?q=justin+ bieber&hl=en&tbo=1&prmd=ivns&sa=X&ei=1MWpTb_7F8fKgQfi9_TzBQ& ved=0CDoQpQI&tbm=&tbs=tl:1,tlul:2008,tluh:2011 (Accessed April 4, 2011).
9. Justin Bieber. Wikipedia. http://en.wikipedia.org/wiki/Justin_Bieber (Accessed April 4, 2011).
10. Weekend Box Office Results: February 11-13, 2011. Box Office Mojo. http://www.boxofficemojo.com/weekend/chart/?yr=2011&wknd=06&p=.htm (Accessed March 12, 2011).
11. Justin Bieber: Never Say Never. Box Office Mojo. http://www.boxofficemojo.com/movies/?id=bieber3d.htm (Accessed March 12, 2011).
12. Bieber, J. (2010). Justin Bieber: First Step 2 Forever - My Story, Harper Collins Publ. Canada.

13. Tchuenche, M., Dube, N., Bhunu, C., Smith?, R.J., Bauch, C.T. (2011).The impact of media coverage on the transmission dynamics of human influenza, BMC Public Health 11(Suppl 1):S5.
14. Griffin, D.E., Moss, W.J. (2006). Can We Eradicate Measles? Microbe 1:9, 409-413.
15. Todar K, Lectures in Microbiology: Measleshttp://textbookofbacteriology.net/themicrobialworld/Measles.html
16. Lakshmikantham, V., Bainov, D.D., Simeonov, P.S. (1989). Theory of Impulsive Differential Equations. World Scientific, Singapore.
17. Bainov, D.D., Simeonov, P.S. (1989). Systems with Impulsive Effect. Ellis Horwood Ltd, Chichester.
18. Bainov, D.D., Simeonov, P.S. (1993). Impulsive differential equations: periodic solutions and applications. Longman Scientific and Technical, Burnt Mill.
19. Bainov, D.D., Simeonov, P.S. (1995). Impulsive Differential Equations: Asymptotic Properties of the Solutions. World Scientific, Singapore.