Dispersal patterns of insects after a major disturbance event is applied to a disturbance gradient that conformed to the intermediate disturbance hypothesis in an urban ecosystem

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Abstract:

Insects have been losing their habitats with the rapid expansion of many urban cities such as Toronto. This study aims at understanding the dispersal patterns insects take once they are placed under a heavy amount of disturbance. The use of power line corridors allows us to have a disturbance gradient within an urban city that allows us to observe the normal distribution of insects across the gradient and compare it to how their distribution patterns change once a disturbance has been applied. It is important in understanding insect dispersal patterns, because only then can we accurately create conservation strategies, and plan urban development to minimize the amount of damage done to insect populations. In this study, sweep nets, pan traps, and point counts were used to sample five areas of a disturbance gradient along a power line corridor. The experiment was conducted over three weeks and it was found that the gradient studied followed a quadratic distribution pattern predicted by the intermediate disturbance hypothesis, although with the application of disturbance, the insects diapered into an exponential type pattern in which the greatest abundance of insects were found in the area of least disturbance. The findings of this study have important implications in understanding the effects of disturbance on insects in urban ecosystems and are a step in the direction of forming a unified theory of insect/disturbance dynamics.

Introduction:

It is important to be able to track the movement of insects in urban areas. Among their many roles, insects are pollinators of plants (Plischuk et al. 2013), help add nitrogen to soil (Lenoir 2001), and they of course play critical roles in their respective food webs (Labandeira 2013).

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Due to increasing land use and disturbance in cities such as Toronto, insects are losing their urban habitats (Connor et al. 2002), and it is necessary to track the dispersal patterns of the surviving members in order to not only determine the effects of disturbance on insects but to also understand how to properly conduct conservation efforts for their restoration; if need be (Frankie and Ehler 1978). Not only do insects play productive roles in their urban ecosystems, but they may also be vectors of disease (Yoo 2013), and it is therefore critical that we understand how disturbance affects the dispersal patterns of insects, because our activities may or may not entice more insects to colonize urban areas, and thus potentially cause harm to the human residents. There are currently controversial models such as the intermediate disturbance hypothesis (IDH) that predict the distribution of species over a disturbance gradient (Kershaw and Mallik 2013; Santos and Cheylan 2013), although there are no similar models (let alone concrete ones) that predict how the abundance distribution of insects will change once they have been subjected to large amounts of disturbance.

Power line corridors have been known to act as disturbance gradients due to their frequent landscaping and mowing of areas closer to human spaces than to areas further down the corridor (Hessing and Johnson 1982). As documented by Dwyer and Morris (2005), mobile organisms (e.g. insects) can disperse in a resource and disturbance dependent fashion wherein which they move towards an area of low disturbance from an area of relatively higher disturbance when there is a trigger of some sort.

Presently, there are not a large number of studies that have documented the dispersal patterns of insects after disturbance in urban environments. Applying the intermediate disturbance hypothesis, it has been shown that that species diversity will normally follow a general quadratic

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function in relation to disturbance (Riis et al. 2008). Considering this, the first null hypothesis can be proposed (H1n), in which the distribution of insect abundances over a disturbance gradient (provided by a power line corridor) will not follow a quadratic distribution relative to the amount of disturbance. Alternatively, it is also hypothesized (H1a) and predicted that that the distribution of insect abundances over a disturbance gradient will follow a quadratic distribution relative to the amount of disturbance. In this scenario, species abundance can be used in place of diversity when invoking the intermediate disturbance hypothesis, because Sattler et al. (2010) showed that there is little variation between species within environmental gradients in urban ecosystems, thus there will not be a wide range of different competitive K-selected and opportunistic r-selected species (i.e. species will compete in relatively the same way, and thus accounting for the different species of a gradient is redundant, because they are so similar).

If H1a holds, a more critical second hypothesis (H2a) can be proposed in which it is predicted that due to the documented similarities between insects in their native ranges and insects in urban habitats (Rubio et al. 2012; Choi et al. 2011), when a large amount of disturbance is uniformly applied to the power line corridor that is acting as the venue for a disturbance gradient, the insects in the area will change their normal quadratic distribution patterns and disperse in order to realign themselves towards the direction of higher resources and less disturbance, as they would normally do so in their natural environments (Frankie and Ehler 1978). In conjunction, a second null hypothesis (H2n) is proposed, stating that when a large amount of disturbance is uniformly applied to the power line corridor, the insects in the area will show no detectable change their native quadratic distributions.

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The purpose of this experiment is to understand the not only the normal distribution pattern of insects in an urban disturbance gradient, but more importantly, it is to also understand the dispersal pattern of said insects once disturbance has been applied to their habitat. The intermediate disturbance hypothesis is controversial, so it is important that research is conducted that either supports it or refutes it; only then can we synthesize a more accepted model of diversity distribution over a disturbance gradient. It is not the main goal of this study to provide evidence for or against the IDH, but it is to use the IDH as a framework upon which to build a better understanding of how surviving insects disperse after dramatic disturbance events. The disturbance applied in this study is meant to simulate the habitat loss that many insects are facing under pressure of expanding and developing cities. Understanding the actual insect dispersal patterns is the first step in being able to understand the effects of our constant expansion, and to create novel hypotheses on how declining and migrating insect populations will affect the general urban ecosystem, as well as the human populations that are responsible for their habitat loss.

Materials and Methods:

The Finch Hydro power line corridor was divided into 5 regions based on levels of disturbance. There was region denoted as disturbed (43.764067,-79.502257) which had constant disturbance from regular mowing and human activity. Conversely, there was another region was classified as undisturbed (43.762678,-79.507284) which experienced no significant external human activity. Between the disturbed and undisturbed areas, three regions were denoted as intermediate 1 (43.764024,-79.503205), intermediate 2 (43.763305,-79.504790), and intermediate 3

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(43.763018,-79.506505) in order of decreasing disturbance (Figure 1). Within each of these five regions, the location of sampling was randomly determined by geographically dividing each region and using a random number generator to dictate which subsection of the five sites shall be used as the sampling area.

Three weeks of insect sampling were conducted. Sampling during the first week (Week 0) was used to establish a baseline for the whole study region; during this week no external disturbances were applied to the region that would not have normally occurred. During the next week (Week 1), the entire study site, save the undisturbed region, was mowed over to induce a heavy amount of disturbance (to simulate the loss of insect habitat) and the site was again sampled after said disturbance was applied. The study region was then allowed to recover for one week, and then the final round of sampling was conducted (Week 2).

To sample the five regions, two sweep nets were used to sample each area by simultaneously sweeping 5m apart from each other for 30m towards the power line corridor. Three pan traps (coloured green, white and blue) containing water and Ultra Concentrated Original Scent Blue Dawn Dish Detergent were also placed in each of the sampling areas 2m apart from each other once the sweep net sampling was completed; insects were allowed to be collected in the pan traps for approximately one hour. As a third method of sampling, point counts of insects were taken whilst conducting both the sweep net sampling and the setting up of the pan traps.

As the dependent variable, the insect abundances for each of the five sampling sites were plotted separately for each of the three weeks of data collection against their distance from the nearby intersection of Sentinel Rd & Murray Ross Pkwy (43.764881,-79.501389) which was assumed to be an area of high disturbance, and thus further you move away from this area (in the direction of the power line corridor), the less disturbance there is (Figure 1). Microsoft excel was used to plot the data as a scatter plot, and regression analyses were conducted using SPSS (Figure 2). The overall mean abundance of insects across the five sampling sites was calculated for each of the three weeks, and to test if these means were significantly different from each other, a one-way ANOVA was performed with SPSS. Finally, in order to determine the effectiveness of the applied disturbance, the ratio of the mean abundance of insects of Week 1 to Week 0, and Week 2 to Week 0 were plotted as bar graphs with Microsoft Excel; standard errors were included as error bars (Figure 3).

Results:

The baseline Week 0 sampling showed that the greatest insect abundance was in the second intermediate zone and the abundance reduced when you move away from this zone towards either increasing or decreasing disturbance; the total abundance across the five sampling sites was 323 insects. Once the mowing disturbance treatment was applied during Week 1, it was found that the total abundance reduced to 135 insects, although, just as during the baseline week 0, the greatest insect abundance was in the second intermediate zone and the abundance reduced when you moved away from this zone towards either increasing disturbance (i.e. the intersection of Sentinel Rd & Murray Ross Pkwy) or decreasing disturbance (i.e. the undisturbed region). Regarding Week 2, after the one week recovery period, the total abundance had increased since Week 1 to the level of 198 insects, although the distribution pattern of insects had changed; the

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abundance of insects increased as the amount of disturbance decreased (Figure 2). Regression analysis showed that the distributions of data collected during Week 0 and Week 1 followed a quadratic function, whilst the data collected during Week 2 followed an exponential model (Table 1).

It was found that the overall mean abundance for the five sample areas during Week 0 was 27 insects, 39.6 insects during Week 1 and 64.6 insects during Week 2; a one-way ANOVA test on these means yielded a p-value of 0.002. Also, the ratio of the mean abundance of insects of Week 1 to Week 0 was shown to be lower than that of the ratio between Week 2 to Week 0 (Figure 3).

Discussion:

Expanding urban areas are destroying the habitats of insects (Connor et al. 2002). Such activity may be detrimental for the overall ecosystem (Plischuk et al. 2013; Lenoir 2001; Labandeira 2013), thus it is important that we understand the dispersal patterns that insects conduct once they have been subjected to disturbance. Without understanding how insects react to disturbance, we cannot create meaningful conservational strategies (Frankie and Ehler 1978), and urban planners will be unaware of the best method to minimize the damage to insect populations during urban development.

The sampling efforts during both Week 0 and Week 1 provided evidence for the first alternate hypothesis (H1a). The distribution of insect abundance across the power line during the baseline Week 0 was, as predicted, a quadratic function in relation to the amount of disturbance. Also,

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once the mowing disturbance was applied during Week 1, the general distribution pattern of insects did not differ from Week 0; they both followed quadratic functions, had statistically significant regression curves, and high coefficients of determination (Table 1). These are significant findings, because they give evidence for the somewhat controversial intermediate disturbance hypothesis (Kershaw and Mallik 2013; Santos and Cheylan 2013), and it is important to give evidence supporting or refuting such controversial models in the journey to create a more universal and concise theory.

The mean abundance of insects decreased during Week 1 compared to Week 0, and after the one week recovery period, the mean abundance statistically increased, although it was not able to recover to its natural Week 0 levels (Figure 3). Coupling this with the fact that the individual mean insect abundances for each week were found to be statistically different via an one-way analysis of variance test (p=0.002), the disturbance applied can be considered to have significantly reduced the abundance of insects, and thus provided the proper conditions in which to test the second hypotheses (H2a and H2n).

The sampling during Week 2 provided evidence to support H2a. After the one week recovery period from the disturbance applied during Week 1, in Week 2 it was observed that the surviving insects dispersed to realign their distribution pattern from one following a quadratic model (as seen in Week 0 and Week 1) to that of an exponential function, where the abundance of insects increases as disturbance decreases (Figure 2). Also, the regression analysis for Week 2 yielded a statistically significant p-value and high coefficient of determination (Table 1). There was clearly a migration of insects from the original disturbance gradient to the undisturbed region. In fact, in

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Week 2, the migration to the undisturbed zone was so great, that the insect abundance was higher in said region than during the baseline of Week 0 (Figure 2). These results are quite significant, because they provide novel insight into the dispersal patterns of insects in urban environments once a major disturbance has had an in effect. Such knowledge is key when designing conservation studies and policies (Penone et al. 2013), and when attempting to control for the spread of diseases that use insects as vectors (Dufourd and Dumont 2013).

A probable source of error regards the insect abundance levels measured at the undisturbed region during Week 0 and Week 1. Since the mowing disturbance was not applied to said region during Week 1, it should ideally have the same insect abundance levels as it did during Week 0, although the site had a reduced abundance in Week 1 relative to Week 0 (Figure 2). A possible explanation for this is that whilst the undisturbed regions were not directly mowed, the application of the disturbance may have still affected the area via the noise generated by the tractors. Parris and Schneider (2012) have shown that the probability of detecting certain species of birds declines with increasing traffic noise and volume. It is possible that their results may be extrapolated to the findings of this paper, wherein which the insects of the undisturbed region actually had disturbance unintentionally applied to them via the noise of the tractors mowing the rest of the area, and thus, a number of insects in the so-called undisturbed region had dispersed in search of an area of less disturbance. More specific research is needed in the field of urban insect dispersals, and perhaps this may be a future study to conduct in order to either support or discredit the results of this study.

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Another potential source of error in this experiment is the lack of monitoring that took place in the study site between the sampling times. While it was assumed that the site would experience equal amounts of “regular disturbance” (e.g. people walking over the site, litter thrown into the area, etc.) during the times in-between sampling, this many not be the case. It is impossible to determine with our given data if, for example, the study area experienced a large amount of irregular disturbance before the Week 2 sampling took place, and thus the collected species abundances are not indicative of the site under normal conditions for that week.

In conclusion, this study was able to find support for the two predicted hypotheses H1a and H2a. Support for the IDH was found, thus helping remove some of the controversy behind it. More importantly, this study has been able to use the IDH as a framework in order to describe the locomotive dispersal patterns insects conduct once they are under heavy disturbance which replicates of the habitat loss disturbance they experience in ever expanding urban cities. A novel application of the results of this study is that since it has been shown that disturbed urban insects orient themselves in the direction of relatively lower disturbance, urban planners can create “insect hotspots” in which they build an area for insects to recolonize that is nearby to any area that they plan to disturb for development sake; this would minimize the ecological repercussions of any human induced disturbance events that are deemed to be necessary for the city. Regardless, more research is necessary in order to solidify this model. Experiments similar to the ones conducted in this study should be applied to other parts of many different cities; the more evidence there is for the model, the stronger it becomes. Conversely, evidence against the findings of this study will also be productive in seeking out a more universally applicable model of insects’ dispersal patterns after disturbance.

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Figures and Tables:

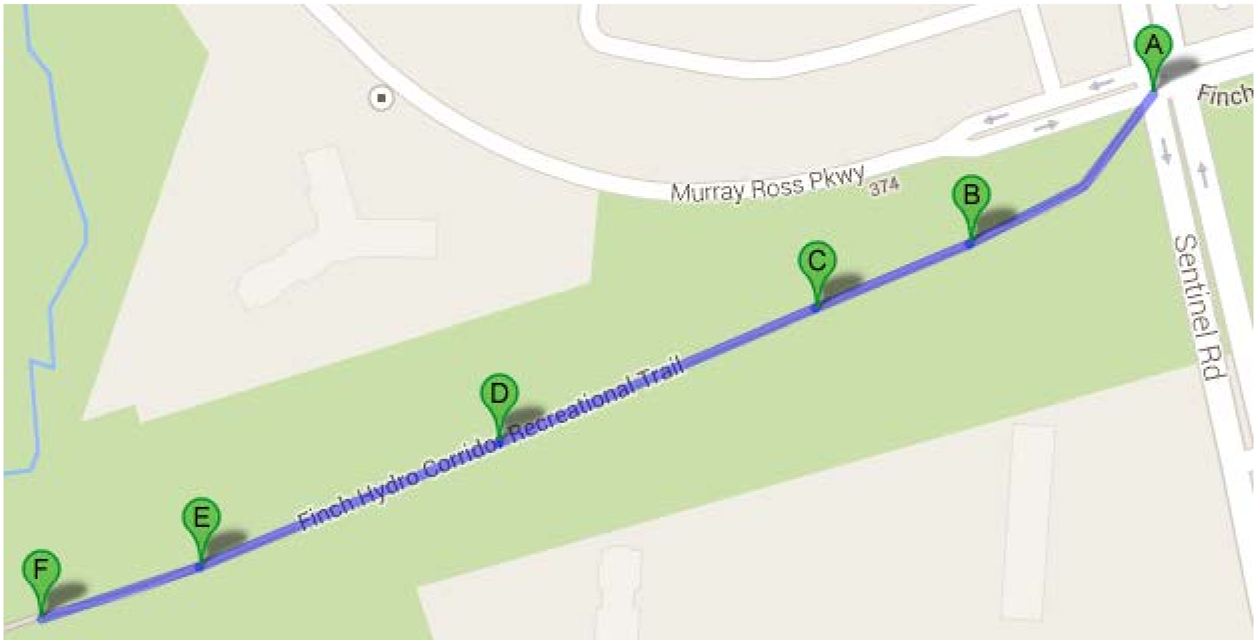

Figure 1: Point A denotes the intersection of Sentinel Rd & Murray Ross Pkwy, Point B is the area denoted as "disturbed," Point C is denoted as "intermediate 1," Point D is denoted as "intermediate 2," Point E is denoted as "intermediate 3," and finally Point F is denoted as the region called "undisturbed." The levels of human activity induced disturbance are assumed to decrease from Point A to Point F.

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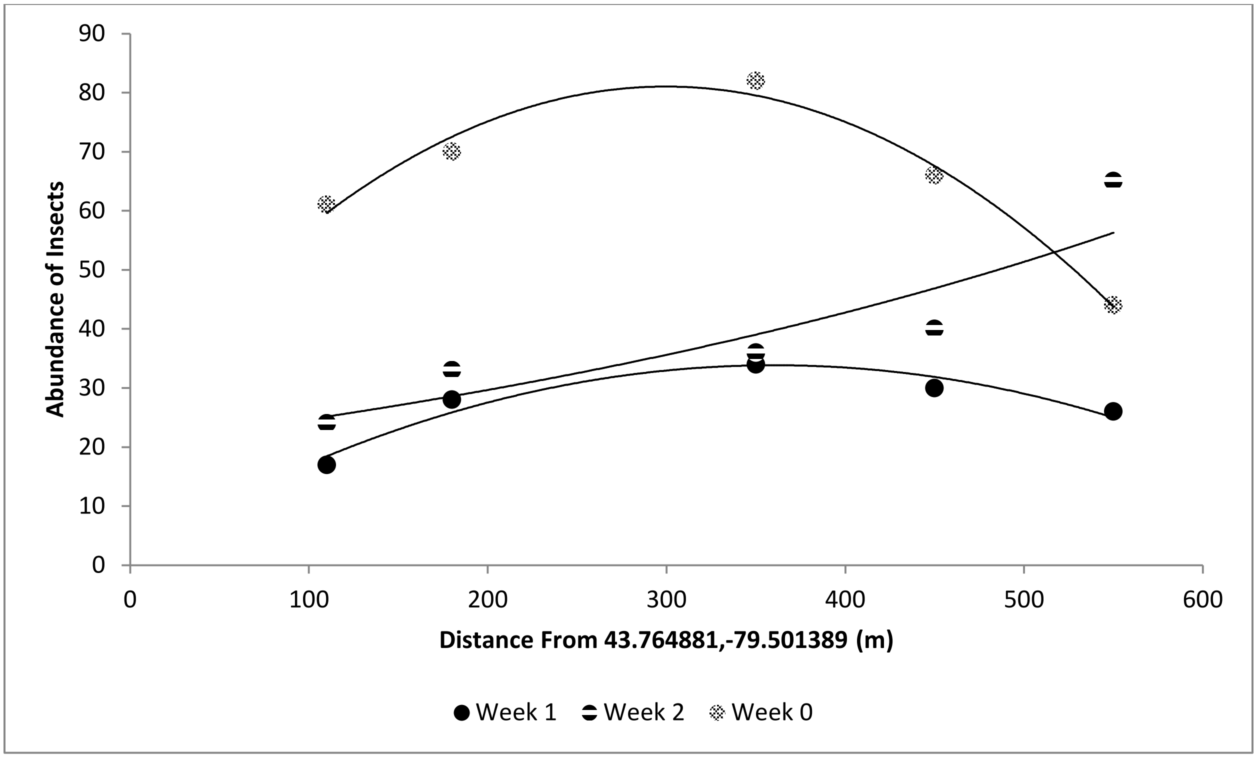

Figure 2: Insect abundance measured in each site plotted against the distance from the intersection of Sentinel Rd & Murray Ross Pkwy. Insects closer to the intersection are assumed to be under greater disturbance than insects further away from said intersection. A line of best fit has been modeled for the data collected during Week 0 and Week 1 using a quadratic regression analysis, and the data collected during Week 2 has a line of best fit modeled with an exponential regression analysis.

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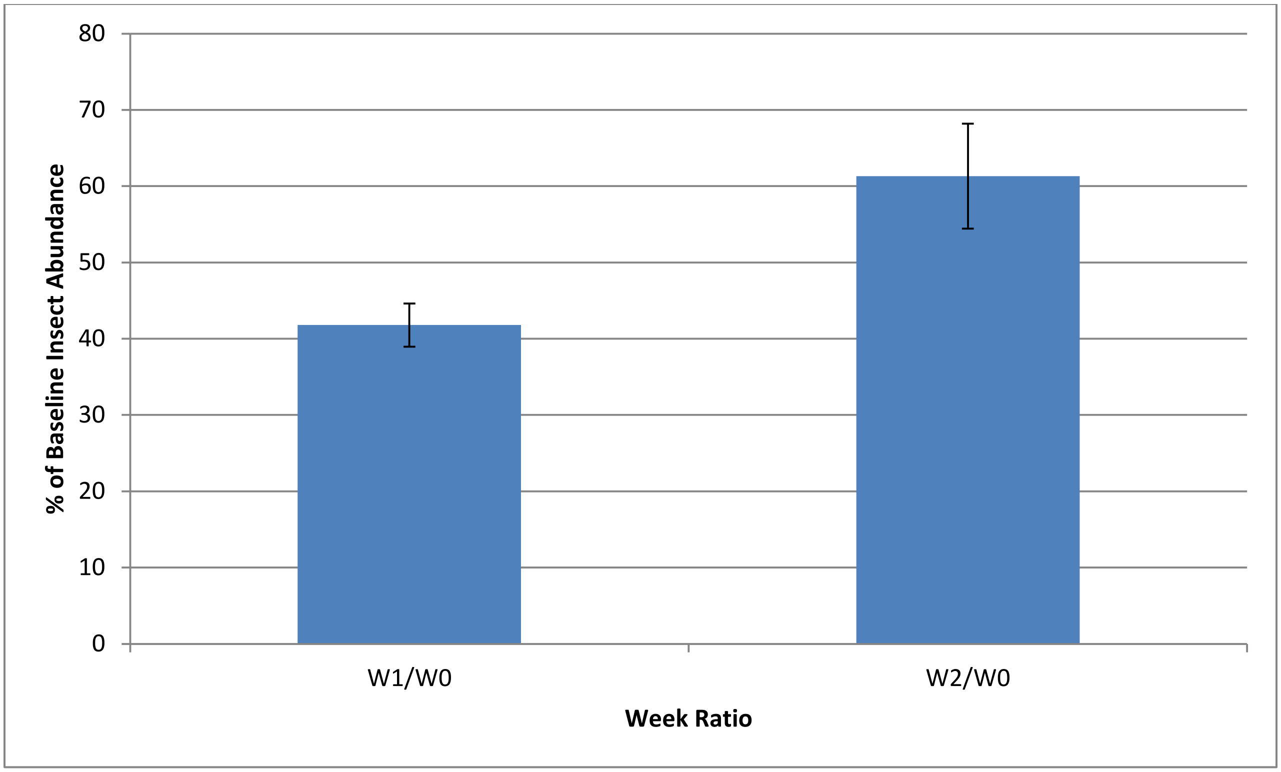

Figure 3: The ratio of the mean insect abundance of Week 1 to Week 0, and Week 2 to Week 0 is graphed with the errors bars denoting ± 1 standard error.

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Table 1: The results of the regression analysis for the data collected during each of the three weeks. Week 0 and Week 1 follow a quadratic model of insect abundance distribution and Week 2 follows an exponential model. All models are statistically significant (i.e. $p<0.05$) and have relatively high coefficients of determination.

Week	**Regression Equation**	**R^2**	**p-Value**
0	Y = -0.0006x2 + 0.3565x + 27.632	0.9781	0.016
1	$Y = -.0002x^2 + 0.1773x + 1.9266$	0.9299	0.041
2	$Y = 20.578e^{0.0018x}$	0.8566	0.024

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