ANALYZING CIGARETTE BUTT POLLUTION IN THE CITY OF PACIFIC GROVE

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CAPSTONE PROJECT

Submitted in partial satisfaction of the requirements for the degree of

BACHELOR OF SCIENCE

in

MATHEMATICS OR STATISTICS

in the

COLLEGE OF SCIENCE

at

CALIFORNIA STATE UNIVERSITY,

MONTEREY BAY

Approved:

____

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Spring 2020

Acknowledgements

We would like to thank Dr. Steven Kim for guiding us through this project. We would also like to thank Mrs. Lila Seldin for giving us the opportunity to volunteer for the City of Pacific Grove, allowing us to use photos from previous cigarette butt collection, and informing us about the new ordinance.

Abstract

Tobacco cigarettes are addictive, toxic and non-biodegradable. A study conducted by Thomas E. Novotny indicates that at least 4.5 trillion cigarette butts are littered worldwide each year [11]. These littered remains feature tobacco cigarette filters made of cellulose acetate, a non-biodegradable plastic, that causes cigarettes to last longer and minimizes smoke particles making nicotine easier to absorb [8]. Unfortunately, cigarette butt pollution has been difficult to combat due to the many misconceptions associated around cigarettes. Because of these implications, various environmental groups, advocates and cities alike, have worked together to suggest and implement regulations that will decrease the impacts of cigarettes. In particular, a recent city ordinance passed in Pacific Grove that aims to regulate the use of tobacco cigarettes, led capstone members to investigate the ordinances' effectiveness by estimating the expected count of littered cigarette butts along with estimating the overall reduction in the expected count of littered cigarette butts in three sampled commercial areas. To conduct this analysis, capstone members volunteered weekly to collect littered cigarette butts and applied a Poisson regression model and Bayesian analysis to analyze the collected data. Additionally, this analysis was later extended to analyze cigarette butt pollution on a street within CSU Monterey Bay, a smoke-free public campus. Ultimately, it was concluded that the amount of littered cigarette butts in these sampled areas decreased due to the volunteer work done by capstone members, but littered cigarette butts will continue to pile up when the volunteer work is discontinued. Despite these results, the analysis of this study was impeded by the global COVID-19 pandemic. Most importantly, it should be noted that the results of this study are limited to the city of Pacific Grove. Meanwhile, to achieve a meticulous review of cigarette butt pollution it is ideal that potential researchers survey areas of regular social interaction, partition sample locations into equal segments, and examine such areas with regularity to prevent abnormalities. Nonetheless, this research signifies how cigarette butt pollution remains a global concern but with proper attention its impacts can be minimized to promote a healthier and cleaner environment for future generations.

Contents

Acknowledgements ii

Abstract iii

Introduction 1
- Background 1
- Literature Review 2
- Motivation 3
- Objectives 3

Methods 4
- Data Collection 4
- Statistical Method 4

Results 6
- Raw Data 6
- Quasipoisson Model 6

Discussion 10
- Limitations 11
- Suggestions for Future Studies 11

Conclusion 13

Bibliography 14

Appendix A: Graphs 15

Appendix B: Poisson Regression Model 18

Appendix C: Bayesian Analysis 19

Introduction

Background

Cigarette butt pollution has been a constant problem around the world, with the issue persisting primarily on our coastal regions and commercial areas. One study conducted by Thomas E. Novotny, indicates that at least 4.5 trillion cigarette butts find their way into the environment every year [11]. Meanwhile, the demand and consumption of tobacco cigarettes continues to prosper. This notion in particular is due to the addictive toxins and ingredients the tobacco industry puts into making their cigarettes. While it may be difficult for its users to stop such use, which may prevent damaging health effects, there exists another greater issue that comes with smoking cigarettes, cigarette butt pollution. Because of a tobacco cigarette's addictiveness, users are tempted to smoke a cigarette at any given moment and fail to recall that the remains need to be properly disposed of.

As a result of constant smoking, it becomes a user's second nature to just flick their finished cigarette into a nearby bush, sewer, or other discrete area instead of tossing the remains into a pre-designated cigarette receptacle. Nonetheless, these littered cigarette butts along with their toxins can travel and make their way into a nearby water supply, such as rivers, lakes, oceans, etc. Ultimately, these toxins can cause harm to the sensitive species living in such marine areas which can then spread and affect an entire ecosystem. Fortunately, to combat such an issue, environmental advocates have taken several measures to minimize the harmful effects of littered cigarettes on marine life and humans by placing non-smoking signs and designated cigarette butt receptacles, passing legislative actions along with having individuals volunteer to clean up tossed cigarette butts in populated areas.

Figure 1. A seagull with a cigarette butt.

Literature Review

Smoking tobacco cigarettes remains a common trend for adults. Unfortunately since its creation, smoking cigarettes has had a negative impact on the environment as well. Technically, it can be noted that a cigarette is a thin cylindrical roll of tobacco and filters wrapped in thin paper material [7]. Meanwhile, cigarette butts are the remains of these smoked cigarettes consisting of a combination of plastic filters. Consequently, the filters of these cigarettes are left behind which eventually results in cigarette butt pollution. Cigarette plastic filters were first introduced in the 1950's by the tobacco industry as a marketing tool to address rising concerns over hazardous health effects associated with smoking. Prior to this, tobacco companies had used a variety of different filter materials, such as cotton, charcoal, and food starch. However, it was soon found that with plastic cellulose acetate filters, cigarettes lasted longer and smokers became more addicted to smoking which in part was due to the notion that filters are designed to minimize smoke particles which makes nicotine easier to absorb [8]. So as a result, this caused a user's addiction to increase. More specifically, these filters are made of a non-biodegradable plastic, cellulose acetate, which is made by cutting, forming and polishing sheets of plastic. Eventually with this new alternative, tobacco industries began to feature cellulose acetate filters in their cigarette products and aimed to recruit smokers and promote the continued use of cigarettes [12]. As a result, this gave way for tobacco companies to promote these filters as a safer alternative. Since then, plastic cellulose acetate filters have remained as the primary choice for the creation of tobacco cigarettes amongst tobacco industries.

The California's Smoking Regulations are intended to protect children, elderly, and those with poor health from the exposure of secondhand smoke. Since the inhalation of tobacco smoke may lead to diseases or even death, the laws are passed in hopes that it would encourage active smokers to stop smoking. These laws are applied toward both traditional tobacco products and electronic smoking devices. As of 2016, it is prohibited to smoke where children under the age of 18 are present. This includes schools, playground, youth events, day care center, busses, and motor vehicles. It is also prohibited to smoke in multi-unit housings, public transportation, workplaces, and government buildings [5]. An example of a government building is California State University (CSU) campuses. It is prohibited to smoke on CSU campuses to ensure a smoke and tobacco free campus. The purpose of this is to promote a healthy and pleasant experience to all students, faculty, and visitors [1]. In addition, it is prohibited to smoke and dispose cigarette butts on state parks and beaches. This applies to anything that contains tobacco, weed, nicotine, plant alternatives, as well as e-cigarette and vapor cigarettes. Signs must be posted in order to prohibit smoking and a violation to this will result in a 25 dollar fine [4]. As of December 2019, California raised the minimum age to purchase and smoke tobacco products from the age 18 to 21 [6]. Furthermore, it is prohibited for anyone to sell or give single-use filters, electronic cigarettes, and vaporizer devices [3].

Unfortunately, the issue of cigarette butt pollution has not been easy to combat because of the many misconceptions that are associated with cigarettes. Primarily, many cigarette consumers are unaware of the fact that tobacco cigarettes are made of plastic and majority of them assume that the contents wrapped up in a cigarette are just tobacco, cotton-like material and the cylindrical wrapping paper [9]. So as a result, it is often suggested that these contents will be burned when smoked or disintegrated quickly once in the environment. Nonetheless, another common misunderstanding is that cigarette butts are biodegradable which suggests that cigarette butts are capable of being decomposed by bacteria or other living organisms [9]. Yet on the contrary, many users are unaware of the notion that it takes more than a decade for littered cigarette butts to completely break down. And even when these littered cigarette butts do finally manage to break down, these remaining cigarette butts will break down into tiny pieces of plastic, classified as microplastic. Lastly, it is also misinforming to suggest that cigarettes do not contain any other toxins beside tobacco. Contrary to belief, there are approximately 250 toxins found in tobacco cigarette products, where at least 70 of these toxins have been proven to cause cancer and the remaining 180 toxins are responsible for causing harm to the human body in other ways [10]. Overall, these false beliefs have been responsible for leading cigarette consumers to continue their tobacco use while also preventing users from properly controlling their pollution.

Motivation

As of December 2019, the City of Pacific Grove updated their smoking regulations due to an increase in the use of electronic smoking devices and an abundance of cigarette butt litter. Studies showed that second hand smoke is just as dangerous as those directly smoking as smoke inhalation can lead to respiratory failure, lung cancer, and other health hazards. Not to mention, it is especially dangerous for the elderly and for those with cardiovascular disease. That being said, California had enforced a law that bans smoking at a "place of employment." The purpose of this ordinance is to ban smoking in areas deemed necessary, but not yet included in Section 6404.5 of the Labor Code. Based on the updated ordinance, it is prohibited to smoke in Enclosed Areas, Multi-Unit residences, and Unenclosed Areas. Enclosed Areas includes, but is not limited to public buildings, elevators, public transportation, and public schools. Similarly, Unenclosed Areas includes any outdoor area open to the public such as outdoor dining, parks, sidewalks, streets, and public events. In addition, the City of Pacific Grove prohibits disposing smoking components on sidewalks, parking lots, street, or anywhere that may be considered litter or may contribute to pollution. That being said, conspicuous non-smoking signs should be posted in areas where smoking is prohibited with letters no smaller than one inch in height [2].

Objectives

Essentially, the groundwork of this project has been framed to estimate the expected count of littered cigarette butts in commercial areas of Pacific Grove. Coincidentally, this research has estimated the overall reduction in the expected count of littered cigarette butts. In addition, this research was extended to a street located within CSU Monterey Bay in which the expected count of littered cigarette butts was estimated. More implicitly, the intentions of this capstone project has been to deliver awareness to residents as to how damaging cigarette butt pollution can be to surrounding environments. Meanwhile, this project has also implicitly shown that cigarette butt pollution is still an ongoing issue that continues to harm the global environment.

Methods

Data Collection

The data collection consisted of the capstone group physically going to the designated areas in Pacific Grove on a weekly basis and collecting cigarette butts that were littered on the community's sidewalks. The targeted areas included Safeway and Lucky's as well as the intersection on Lighthouse Avenue and Forest Avenue. This group included the following variables in their model: count, week, segments, distance, non-smoking signs, average temperature, and rain. The week is a numeric variable ranging from 1 to 6 to indicate the week of data collection, segments is a categoric variable that was assigned by breaking down the covered location area by blocks, non-smoking signs is a numeric variable and was counted based on the number of signs in that segment, average temperature is a numeric variable (degrees in Fahrenheit) and was calculated weekly, and rain is a categoric variable and was scaled from (0-7) by how many days out of the week rain occurred. In the three targeted areas, a total of 3,206.16 feet were covered for 6 weeks (from February 1, 2020 to March 7, 2020).

The capstone group consisted of four members. Each member was provided a glove, safety vest, and bag. The members were split into two groups and each group was responsible for counting the cigarette butt as it was being picked up. At the end of each location, the two groups met up to share and record the results.

Statistical Method

Poisson regression model was used to estimate the expected number of littered cigarette butts for each independent location. Instead of using the standard Poisson model, the Quasipoisson model was conducted to eliminate over-dispersion in the data. Downtown, Lucky, and Safeway were first considered in the model, but after seeing a significantly low p-value for each variable, the team decided to include the week variable in the model. To estimate the reduction in the expected count with respect to week (conditioning on each targeted area), the following model was used corresponding to Table 2:

$$\theta = e^{\beta_0 + \beta_1 L + \beta_2 S + \beta_3 week}$$

This model provided and allowed the group to make reasonable and important conclusions that were essential to the research question and provided answers to the community regarding the issue. Aside from using the Quasipoisson model to estimate the expected number of littered cigarette butts for each independent location, the Bayesian analysis was applied. The purpose of this analysis was to make statistical inferences. Before data collection occurred the team took a personal guess estimation of expecting 60 cigarette butts per 100 feet applying to all three locations and constructed a distribution (prior of theta) with this chosen value for each location. This guess was then compared and evaluated in accuracy to the actual collected cigarette butts, which resulted in another distribution (posterior of theta). This information became valuable in allowing a construction of prediction distributions (theta prediction) for each independent location.

Results

Raw Data

Data was collected in the time span of six consecutive weeks and recorded on a Google Spreadsheet.

TABLE 1. Example of Collected Data

Date	Location	Segment	Distance (ft.)	Count	Avg. Weather per Week (°F)
2/1/20	Downtown	D1	398.771	9	63.86
2/1/20	Lucky	L1	246.286	28	63.86
2/1/20	Safeway	S1	305.859	22	63.86
2/8/20	Downtown	D1	398.771	11	58.14
2/8/20	Lucky	L1	246.286	21	58.14
2/8/20	Safeway	S1	305.859	44	58.14

Table 1 shows the first two weeks of cigarette butt count in the first segment of each location. We also included the distance (ft) of each segment and the average temperature for the week. 1.

Quasipoisson Model

TABLE 2. Quasipoisson Model by Weeks 1 - 6

Coefficients:	Estimate	Std. Error	t value	$\Pr(>\|t\|)$
(Intercept)	2.2429	0.2941	7.627	$1.76e-10$
locationLucky	1.7236	0.2715	6.349	$2.83e-08$
locationSafeway	1.4165	0.3275	4.325	$5.65e-05$
week	-0.2990	0.0645	-4.636	$1.88e-05$

(Dispersion parameter for quasipoisson family taken to be 21.91634)

This analysis was essential to calculate the slope of each independent variable to construct the three individual graphs shown in Table 2.

Based on Table 2, the p-value for both week and location is significantly small. To predict the following week's expected cigarette butt count, we used the coefficient for the week variable. We found exp(-.299) = 0.741. That being said, we will find twenty-six percent of the 6th week cigarette butt count in the 7th week.

Assuming that the model will not be a linear function, we included week square in our model to determine if the model will be a quadratic function. Since the p-value for week square was 0.911, it was removed from the model because it was not statistically significant. Similarly, we added temperature to the model assuming that it would fit the data well. Since the p-value for temperature was 0.728, temperature is not a statistically significant predictor of cigarette butt count. Thus, we removed temperature from the model.

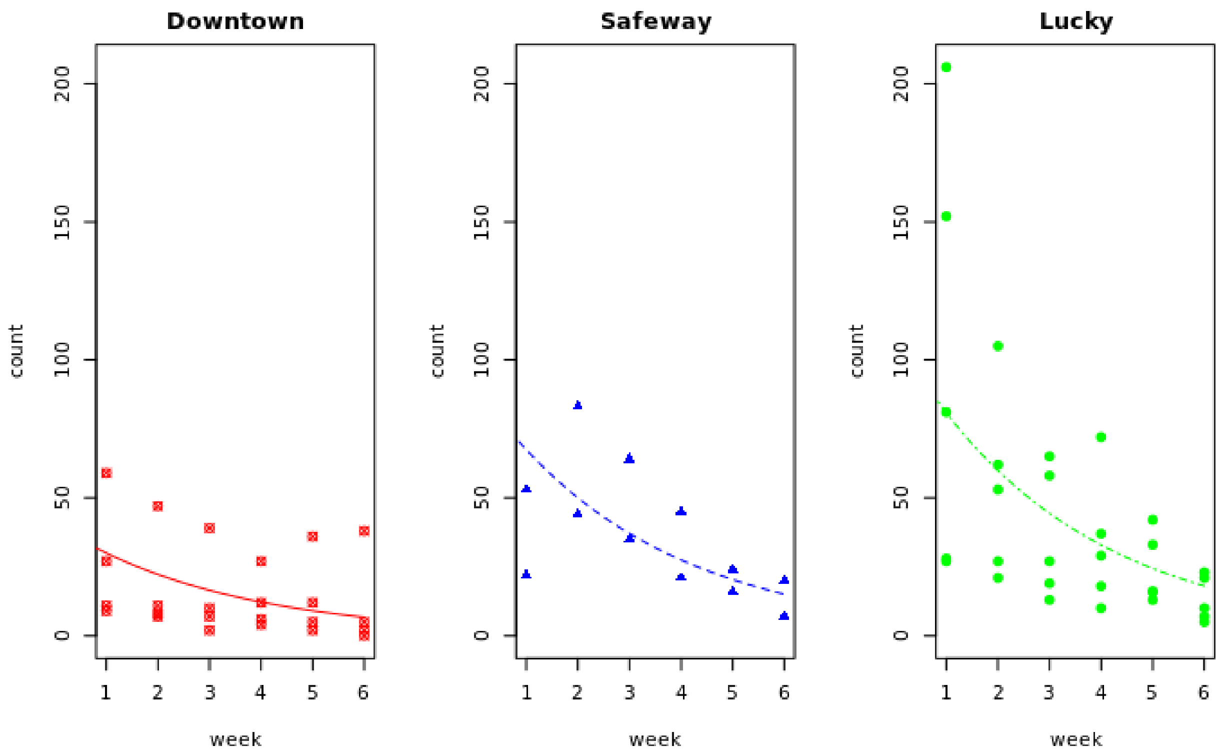

Figure 2. Current Graph of Regression per Location by week

Figure 2 shows the regression of each location in the span of six weeks. From the figure, we can observe in all three locations there is a negative correlation between count and week; as week increases, count decreases. Lucky has the highest initial count, so it has the steepest slope for the regression graph. We can account that there being more foot traffic and a lack of laws preventing smoking in the area. The Downtown area has a much lower initial count, which we can assume are because of the laws put in place to keep more the more touristic parts of Monterey clean and beautiful.

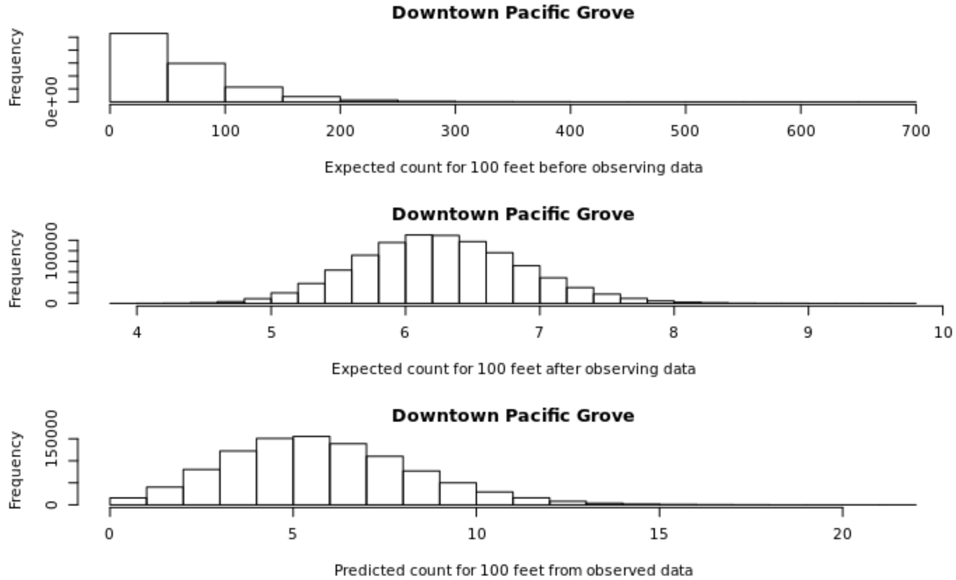

FIGURE 3. Downtown Prediction, Count Average per 100 ft. Histogram based on Week 1 data.

For Figure 3, we are given three Bayesian graphs of the Downtown area for the first week. Before we looked at the data, we expected to find 60 cigarette butts per 100 feet and the first graph represents this. The second graph shows the true expected count per 100 feet from the data. The first week had between 5 and 8 cigarette butts per 100 feet in the Downtown area. The third graphs shows the predicted count of cigarette butts to be found per 100 feet in the future. So, there is a predicted count of 1 to 11 cigarette butts per 100 feet.

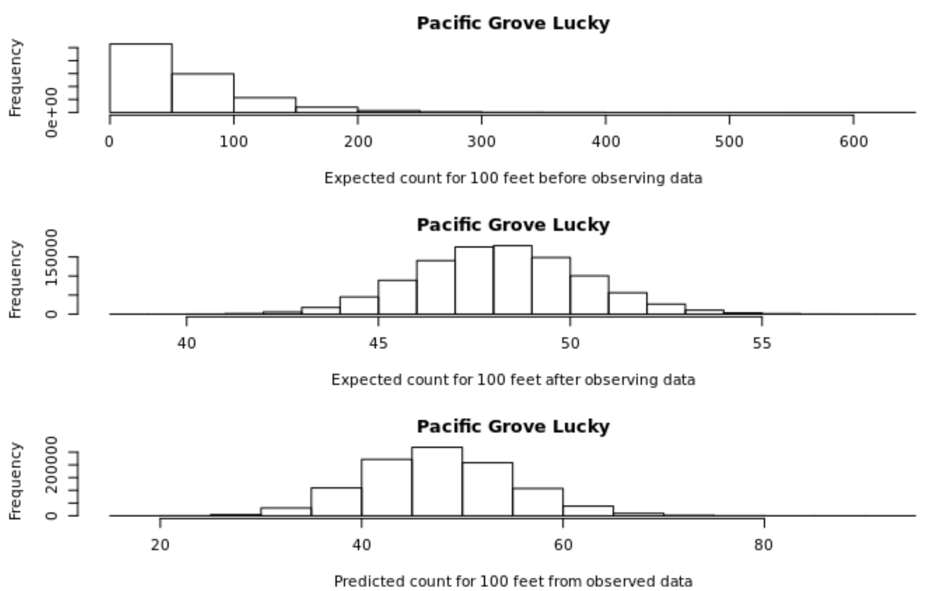

FIGURE 4. Lucky Prediction, Count Average per 100 ft. Histogram based on Week 1 data.

For Figure 4, we are given three Bayesian graphs of the Lucky area for the first week. Before we looked at the data, we expected to find 60 cigarette butts per 100 feet and the first graph represents this. The second graph shows the true expected count per 100 feet from the data. The first week had between 43 and 54 cigarette butts per 100 feet in the Lucky area. The third graphs shows the predicted count of cigarette butts to be found per 100 feet in the future. So, there is a predicted count of 30 to 65 cigarette butts per 100 feet.

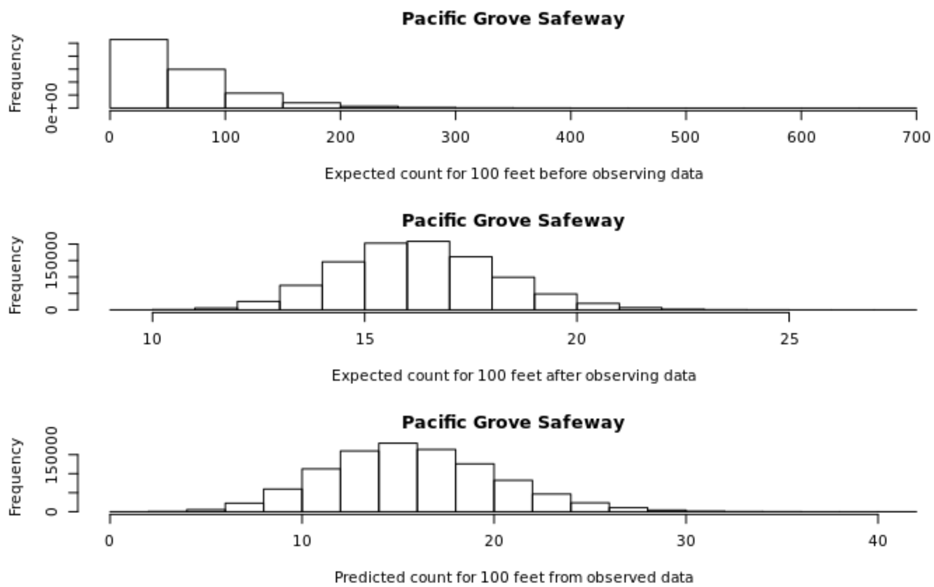

FIGURE 5. Safeway Prediction,Count Average per 100 ft. Histogram based on Week 1 data.

For Figure 5, we are given three Bayesian graphs of the Safeway area for the first week. Before we looked at the data, we expected to find 60 cigarette butts per 100 feet and the first graph represents this. The second graph shows the true expected count per 100 feet from the data. The first week had between 13 and 21 cigarette butts per 100 feet in the Safeway area. The third graphs shows the predicted count of cigarette butts to be found per 100 feet in the future. So, there is a predicted count of 8 to 26 cigarette butts per 100 feet.

Discussion

Over the course of six weeks, we estimated about 74% reduction in the expected count of the 7th week on average. In Figure 2, we can observe that all three locations have a decreasing slope, but the Downtown area has a gentler slope than the other two locations due to Downtown having a smaller initial count. In the other two areas, we could find very old butts hidden under foliage which makes it harder to locate. The commercial areas in Downtown, on the other hand, had very few areas with foliage and were kept clean. Also, the smoking regulations were more emphasised in the Downtown area than the other two areas because Downtown is where many tourist visits. Since Lucky is in a shopping mall, it had more foot traffic than Safeway. That being said, Lucky had more segment to collect cigarette butt. This explains why we see a steeper slope for Lucky in Figure 2. In addition, we noticed that the parking lots and the areas with mulch had a high cigarette butt count. It was more convenient to toss cigarette butt at the nearest location than to toss it in the nearest smoking receptacles. These shopping areas had smoking receptacles in front of the stores. Cigarette butts tossed in the ashtrays could potentially fly out because of the wind which can create unintentional litter. To reduce the amount of littered cigarette butts in Safeway and Lucky, we should put up non-smoking signs and replace the current smoking receptacles to the one provided in Downtown (see Figure 6).

FIGURE 6. Smoking receptacle in Downtown.

Limitations

Ultimately, it was expected that there would be several setbacks that may have caused difficulties in conducting an accurate analysis of littered cigarette butts in the Pacific Grove area. More notably, it was possible that when collecting littered cigarette butts in the designated areas, some cigarette butt remains were well hidden within surrounding foliage along with older cigarette butts that may have already broken down into smaller fragments, which made the remains difficult to account for and distinguish from regular plastic waste. So to address this challenge, capstone group members had walked through the designated areas multiple times to ensure that no remains were left behind including smaller and broken fragments of older cigarette butts. Nonetheless, this potential challenge was important to note because it affected the overarching objectives of the study. Meanwhile, this setback also could have caused skewed results which would have resulted in an inaccurate Poisson model that would predict faulty amounts of littered cigarette butts in the designated commercial areas of Pacific Grove due to such abnormalities and miscalculations.

Unfortunately, a national pandemic caused by the virus COVID-19, had a significant impact on the physical collection of littered cigarette butts in Pacific Grove. As a result of this infectious disease, a shelter-in-place county order was enforced throughout the community and required residents to remain indoors with the exceptions of traveling to work and purchasing essential goods. So because of this order, individuals who usually smoke in these designated areas of Pacific Grove may not have been able to continue their habit of smoking outdoors in these areas on account of the legal action that could be taken against them if caught disobeying the order. Additionally, this order prevented group members from volunteering to pick up littered cigarette butts which would have helped to reach a much more accurate analysis provided if more data could have been collected. Meanwhile, let it be noted that the commercial areas of Safeway and Lucky are considered to be essential during this crisis. So, those cigarette smokers who are employed in essential retail stores may opt to take a break and choose to go outside and take a smoke break nearby the store. Which may result in littered cigarette butts in the areas being studied. As a result, the expected counts estimated from the Poisson regression model may differ.

Suggestions for Future Studies

Although it is unlikely that the global concern of cigarette butt pollution will subside any time soon, it is possible that other advocates will take interest upon conducting their own analysis of littered cigarette butts. For more accurate studies, it would be ideal for potential researchers to survey areas that feature a regular volume of social interaction from various age groups. By doing so, this would imply that the data collected features a variation of tobacco cigarette consumers. Additionally, it would be beneficial for researchers to measure and partition designated areas into equal segments, which will provide researchers some insight as to which segments within the areas are responsible for providing any abnormalities of littered cigarette butts since many users have particular designated areas to smoke discreetly. Meanwhile, it would be crucial to examine such designated areas on a regular basis to prevent the miscalculation and compilation of cigarette butts. In addition to these suggestions, researchers may find it necessary to account for any form of smoking regulations and potential environmental factors. More specifically, non-smoking signs, cigarette receptacles and ashtrays may be responsible for a variation of collected littered cigarette butts amongst the designated areas chosen to study. Most importantly, it should be noted that the local weather serves as a central factor for smokers in determining whether or not to smoke tobacco cigarettes outside. Overall, these are some of the many critical factors that should be considered when conducting an improved study of cigarette butt pollution to provide contemporary findings that will fit modern regulations and social trends regarding cigarette consumption.

Conclusion

One of the factors for the declining rate in the locations can be contributed to people littering less because they saw others picking up after them. After workers at Lucky saw a group cleaning up cigarette butts on Saturdays, the employees were told to stop throwing their litter on the ground by their manager. On the 7th week we can expect to find 12 cigarette butts per 100 feet in Safeway, 14 cigarette butts per 100 feet in Lucky, and 5 cigarette butts per 100 feet in Downtown. We can expect to see a continuing decline in cigarette butt pollution in all areas if there were to be people picking up cigarette butts every week. These areas are seeing a better quality in cleanliness when it comes to litter, but there has to be an effort on the people's part as well.

Bibliography

[1] Alvarez, A., 2017. Policy On Systemwide Smoke And Tobacco Free Environment; Executive Order (EO) 1108 :: Policystat. [online] The California State University. Available at: https://calstate.policystat.com/policy/6591951/latest/ [Accessed 13 March 2020].

[2] An Ordinance of the City of Pacific Grove. 2019. Amending Chapter 11.24 of the Pacific Grove Municipal Code Regarding Smoking Regulations. [online] Available at: ⟨https://www.cityofpacificgrove.org/sites/default/files/city-council/ordinances/year/19-019-smoking-ord.pdf⟩ [Accessed 9 April 2020].

[3] Californians Against Waste. 2015. SB 424 (Jackson)—Tobacco Waste Reduction And EPR. [online] Available at: https://www.cawrecycles.org/sb-424-jackson [Accessed 13 March 2020].

[4] Californians Against Waste. 2015. SB 8 (Glazer) / AB 1718 (Levine)—Smoking Ban For State Parks And Beaches. [online] Available at: https://www.cawrecycles.org/sb-8-glazer-/-ab-1718-levine [Accessed 13 March 2020].

[5] California Department of Public Health. 2016. California's Statewide Smoke-Free Air Laws. [online] Available at: https://www.cdph.ca.gov/Programs/CCDPHP/DCDIC/CTCB/CDPH%20Document%20Library/Policy/SecondhandSmoke/SHSLawBrochureFinal.pdf [Accessed 13 March 2020].

[6] California Department of Public Health. 2020. California Tobacco 21 Law. [online] Available at: https://www.cdph.ca.gov/Programs/CCDPHP/DCDIC/CTCB/Pages/Tobacco21.aspx?gclid=EAIaIQobChMIvYiQsPyX6AIVEhitBh3jMQWCEAAYASAAEgL99fDBwE [Accessed 13 March 2020].

[7] Cigarette. [online] Merriam-Webster Dictionary. Available at: https://www.merriam-webster.com/dictionary/cigarette [Accessed 9 April 2020].

[8] Curtis, S. Cigarette Butts are Plastic and Compound the Nicotine Health Risk from Smoking. 2018. [online] Plastic Pollution Coalition. Available at: https://www.plasticpollutioncoalition.org/blog/2018/8/6/cigarette-butts-are-plastic-and-compound-the-nicotine-health-risk-from-smoking [Accessed 9 April 2020].

[9] Hahn, J.D. 4.5 Trillion Cigarette Butts — the Biggest Man-Made Ocean Contaminant — Are Littered Each Year. 2019. [online] People. Available at: https://people.com/human-interest/cigarette-butts-oceans-trash/ [Accesssed 9 April 2020].

[10] Harmful Chemicals in Tobacco Products. [online] American Cancer Society. Available at: https://www.cancer.org/cancer/cancer-causes/tobacco-and-cancer/carcinogens-found-in-tobacco-products.html [Accessed 9 April 2020].

[11] Novotny, T.E., Zhao, F. Consumption and Production Waste: Another Externality of Tobacco Use. 1999. [online] Available at: https://tobaccocontrol.bmj.com/content/8/1/75 [Accessed 9 April 2020].

[12] Rainey, J. Plastic Straw Ban? Cigarette Butts are the Single Greatest Source of Ocean Trash. 2018. [online] NBC News. Available at: https://www.nbcnews.com/news/us-news/plastic-straw-ban-cigarette-butts-are-single-greatest-source-ocean-n903661 [Accessed 9 April 2020].

Appendix A: Graphs

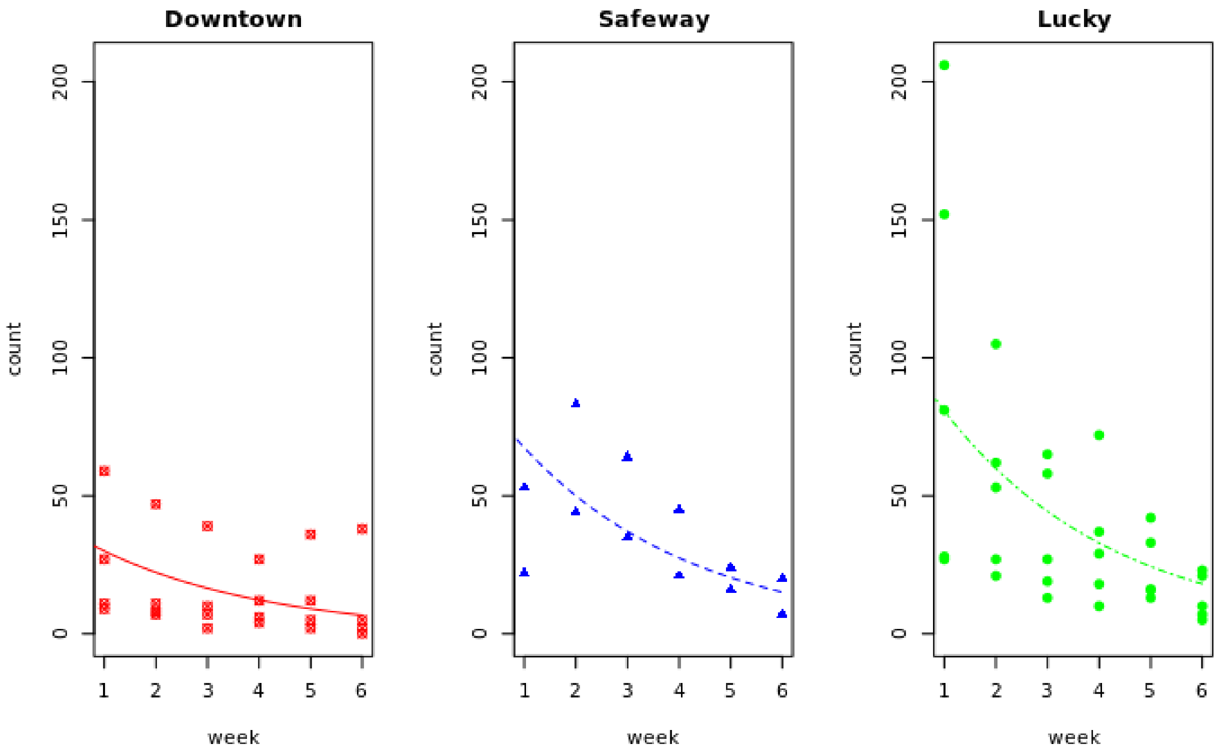

FIGURE 7. Current Graph of Regression per Location by week

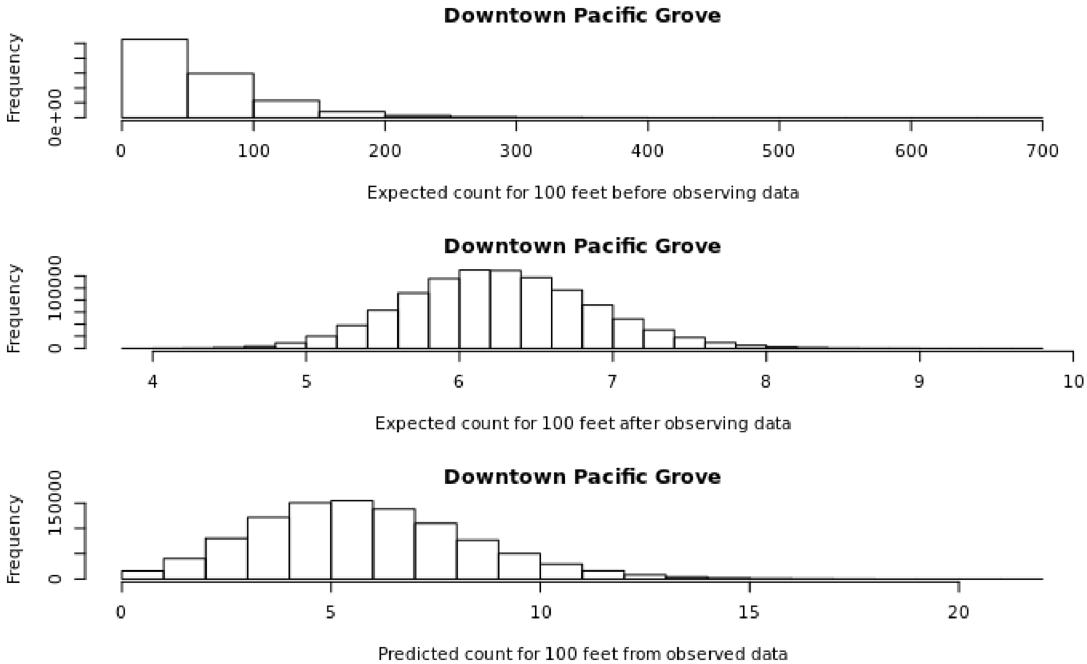

Figure 8. Downtown Prediction, Count Average per 100 ft. Histogram

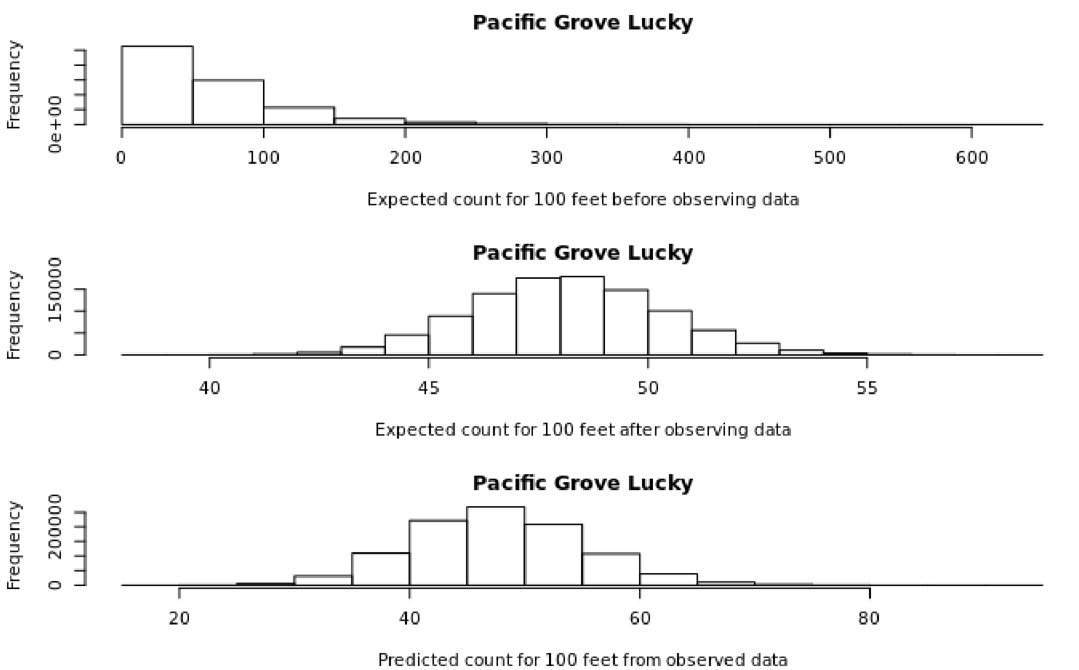

Figure 9. Lucky Prediction, Count Average per 100 ft. Histogram

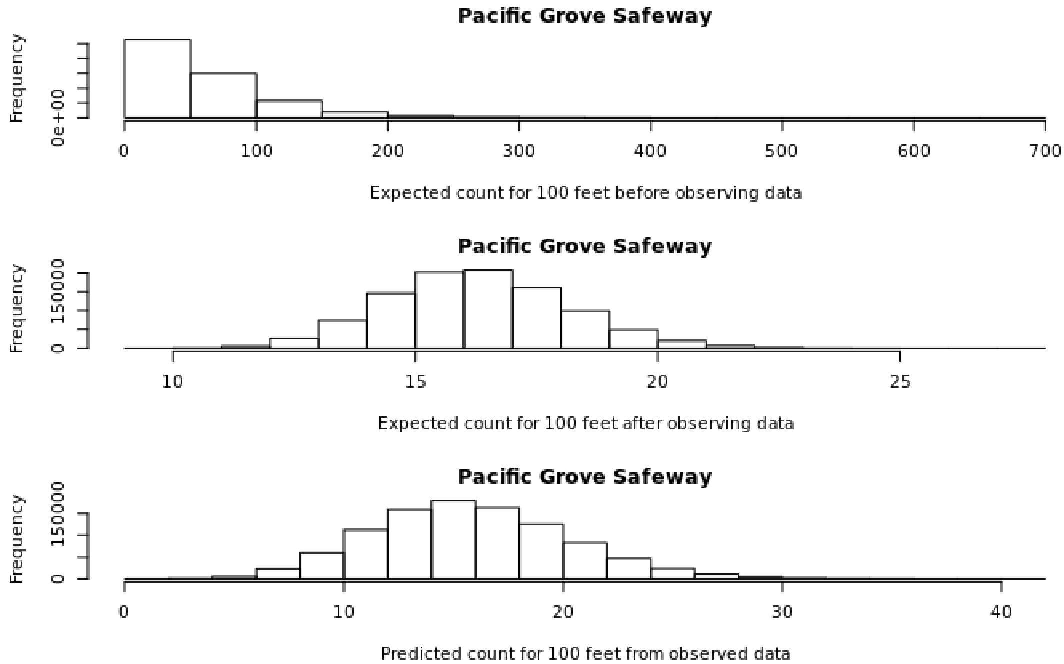

FIGURE 10. Safeway Prediction,Count Average per 100 ft. Histogram

Appendix B: Poisson Regression Model

```
week = rep( 1:9, each=11 )
location = data[,2]
segment = data[,3]
feet = data[,4] / 100
count = data[,5]
week.sq = week^2
temp = data[,6]

# Poisson regression model with week and location as the explanatory variable
and count as the response variable
lm.week = glm(count week + location, family=quasipoisson, offset=log(feet))
summary(lm.week)

# added temperature to the model
lm.temp = glm(count week + location + temp, family=quasipoisson, offset=log(feet))
summary(lm.temp)

# added week^2 to the model
lm.week.sq = glm(count week + location + week.sq, family=quasipoisson, offset=log(feet))
summary(lm.week.sq)
```

Appendix C: Bayesian Analysis

 # Downtown
par(mfrow=c(3,1))
a = 1.44
b = 0.024

theta.prior = rgamma(1000000, a, b) hist(theta.prior,main="Downtown", xlab = "Expected count for 100 feet before observing data", ylab = "", cex.lab=1.5, cex.axis=1.2, cex.main=2, cex.sub=1.5)

n = 1712.897
s = 106
a.star = a + s
b.star = b + (n/100)

theta.post = rgamma(1000000, a.star, b.star) hist(theta.post,main="", xlab = "Expected count for 100 feet after observing data", ylab = "", cex.lab=1.5, cex.axis=1.2, cex.main=2, cex.sub=1.5)

count.pred = rpois(1000000, theta.post)
hist(count.pred, main="", xlab = "Predicted count for 100 feet from observed data", ylab = "", cex.lab=1.5, cex.axis=1.2, cex.main=2, cex.sub=1.5)

 # Lucky
par(mfrow=c(3,1))

a = 1.44
b = 0.024

theta.prior = rgamma(1000000, a, b) hist(theta.prior,main="Lucky", xlab = "Expected count for 100 feet before observing data", ylab = "", cex.lab=1.5, cex.axis=1.2, cex.main=2, cex.sub=1.5)

n = 1026.114
s = 494
a.star = a + s
b.star = b + (n/100)

theta.post = rgamma(1000000, a.star, b.star) hist(theta.post,main="", xlab = "Expected count for 100 feet after observing data", ylab = "", cex.lab=1.5, cex.axis=1.2, cex.main=2, cex.sub=1.5) count.pred = rpois(1000000, theta.post) hist(count.pred, main="", xlab = "Predicted count for 100 feet from observed data", ylab = "", cex.lab=1.5, cex.axis=1.2, cex.main=2, cex.sub=1.5)

# **Safeway**
par(mfrow=c(3,1))

a = 1.44
b = 0.024

theta.prior = rgamma(1000000, a, b) hist(theta.prior,main="Safeway", xlab = "Expected count for 100 feet before observing data", ylab = "", cex.lab=1.5, cex.axis=1.2, cex.main=2, cex.sub=1.5)

n = 467.149
s = 75
a.star = a + s
b.star = b + (n/100)

theta.post = rgamma(1000000, a.star, b.star) hist(theta.post,main="", xlab = "Expected count for 100 feet after observing data", ylab = "", cex.lab=1.5, cex.axis=1.2, cex.main=2, cex.sub=1.5)

count.pred = rpois(1000000, theta.post) hist(count.pred, main="", xlab = "Predicted count for 100 feet from observed data", ylab = "", cex.lab=1.5, cex.axis=1.2, cex.main=2, cex.sub=1.5)

# **CSUMB**
par(mfrow=c(3,1))

a = 1.44
b = 0.024

theta.prior = rgamma(1000000, a, b) hist(theta.prior,main="CSUMB", xlab = "Expected count for 100 feet before observing data", ylab = "", cex.lab=1.5, cex.axis=1.2, cex.main=1.7, cex.sub=1.3)

n = 900
s = 424
a.star = a + s
b.star = b + (n/100)

theta.post = rgamma(1000000, a.star, b.star) hist(theta.post,main="", xlab = "Expected count for 100 feet after observing data", ylab = "", cex.lab=1.5, cex.axis=1.2, cex.main=1.7, cex.sub=1.3)

count.pred = rpois(1000000, theta.post) hist(count.pred, main="", xlab = "Predicted count for 100 feet from observed data", ylab = "", cex.lab=1.5, cex.axis=1.2, cex.main=1.7, cex.sub=1.3)