Optimizing Rabies Tag Distribution for Orleans Parish

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DSC 680 – Fadi Alsaleem

May 9, 2021

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ABSTRACT

Anyone who owns a pet is familiar with the routine of yearly rabies vaccinations. Rabies is a virus that affects mammals and is most often transmitted through an infected animal's bite. [10] When a pet receives a rabies vaccination, the owner is given a tag to put on the animal's collar. Rabies vaccination programs are managed differently by each municipality and offer more benefits than just mitigating the rabies occurrence in the community. They generate additional revenue for the agencies providing animal welfare services and can aid in the return of lost animals. The income from the Orleans Parish rabies tag program plugs a hole in the funding deficit from the city of New Orleans for animal control services provided by the Louisiana SPCA's Humane Law and Rescue team. In this project, the distribution of tags over time for Orleans Parish was explored for the entire program to determine if future quantities could be predicted. Individual clinics were also assessed for areas of improvement in distribution. The limited quantity of data for the program resulted in overfitting and poor model performance; however, the same process can be applied if more data is found from years prior to 2015. Efficiently managing this program can allow staff the time to work towards more vaccinations, increasing revenue from the program, and reuniting lost animals with their owners.

INTRODUCTION

Most cases of rabies reported to the CDC each year occur primarily in wild animals like bats, raccoons, skunks, and foxes; however, any mammal can be infected including domestic dogs, cats, and humans. [10] Between one and three cases of rabies are reported in humans annually in the United States; however, about 55,000 people get treated to prevent rabies infections after being bitten or scratched by an animal. [2] Many areas in the United States have laws that require domestic animals to be vaccinated against rabies, which has led to the drastic reduction in occurrence in domestic dogs and cats. Only 60-70 dogs and 250 cats are infected each year, mostly due to unvaccinated animals being bitten by wildlife. [4] A challenge facing the elimination of rabies is the effective organization and adaptation of vaccination

programs across regional levels.[5] Even though rabies vaccinations are mandatory for dogs across the United States, only half of dogs are properly vaccinated. [1]

The city of New Orleans and its suburbs are in Orleans Parish in Louisiana. Chapter 18 of the parish ordinances outline laws surrounding animals for the parish. Chapter 18-168 requires that "every dog or cat between three and four months old shall, at [the owner's] expense, have such dog or cat vaccinated by a Louisiana-licensed veterinarian with rabies vaccine." [3] The vaccine must be repeated in 12 months and then subsequently every 36 months. Section 18-169 requires the tag to be always affixed to the collar of the animal. [3] Even if the animal is receiving the vaccine every 3 years, the owner must purchase a new tag from their veterinarian each year. [3] Louisiana SPCA Humane Law and Rescue division is responsible for administering the rabies program for Orleans parish. They issue the tags to the veterinarians in the area and field calls placed to the number on the tags when an animal is found.

LITERATURE REVIEW

Broad studies have been performed for rabies program cost effectiveness, efficacy in reducing rabies, and the ability for lost animals to be found through their tag. A retrospective study on the economic costs and effectiveness of Mexico's national rabies program found that 13,000 human lives were saved while incurring a cost of $300 million USD over 25 years, which was acceptable when compared to the cost of care for those who would have been infected with rabies. [6] Another study was performed to determine the required number of stray dogs that would need to be vaccinated to reduce the spread of rabies. They found the required number of stray dog vaccinations is directly related to the total population of dogs in the area. [8] In Ohio, a study performed in 2007 on the ways lost animals were recovered found that 18% of animals were recovered through a call from the number on the rabies tag, and dogs that were wearing a license tag had a higher likelihood of recovery. [9]

DATA

The Louisiana SPCA's Humane Law and Rescue team performs vital services for Orleans Parish at a high-quality level with compassion. Based on the current funding allocated by the city of New Orleans, they respond to calls in the field 5 days a week, emergencies around the clock, and administer the rabies tag distribution for area clinics. [7] This program has been managed manually with Excel workbooks and has not been organized or mined properly to provide meaningful information.

The workbook used for logging the tags distributed to clinics contains a worksheet for each year tags were issued for rabies vaccinations between 2015 and 2020. Each row is an action related to the delivering and retrieving rabies tags from a veterinary clinic. Table 1 describes the columns contained in each one of these worksheets.

Variable	Description	Type
Beginning tag #	The beginning tag number for the range of tags given to the clinic.	string
Ending tag #	The ending tag number for the range of tags given to the clinic	string
Delivered	The date the tags were delivered/returned	date
Volume	The number of tags delivered or returned. A negative value indicates a return.	number
Returned	If the tags were returned, "Returned" is listed here.	string
Clinic Name	The clinic name.	string

Table 1 Data for each Year Rabies Tags were Issued

This workbook contains another worksheet with contact information for each of the clinics that received tags. The variables are outlined in Table 2. Two additional unnamed worksheets contained data but were not included in the analysis because of the uncertainty of the meaning.

Variable	Description	Type
Clinic Name	Name of the Clinic	string
Address 1	Street name and number	string
City	City of the clinic	string
State	State of the clinic	string
ZIP	Zip of the clinic	string
Phone Number	Phone number for the clinic	string
Fax Number	Fax number for the clinic	string
Contact	Primary contact for the clinic	string
Mailing Contact	Contact to whom mail should be addressed	string
Email Address	Email address for the contact	string
Comments	Notes about the clinic	string

Additional Contact info	Additional contact instructions	string

Table 2 Data for Veterinary Clinic Contacts

The data from each worksheet was loaded into the same dataset with sheet name as an additional variable to represent the tag year. Data was contained in random cells throughout the worksheet which caused unnamed columns to be loaded to the dataset. The shape of the data prior to data cleansing was 1541 observations and 17 variables, including the unnamed variables. Summary statistics were viewed on numerical and categorical variables. Interesting observations about the data derived from these statistics were:

- The most delivery and return actions took place for 2020 tags.

- The Louisiana SPCA Community Clinic has the most delivery and return actions for tags.

- The returned column has 6 unique values; it should only have one to indicate the action was a return.

- Beginning and ending tag numbers, action dates, and clinic name contained missing values observed by their count being less than the total number of records. Returned was also less, but it was expected to be that way.

- Some records were missing the volume which is necessary for the analysis. This was most likely due to spaces left in the Excel file for readability.

- The maximum volume for a single action was 9639 which was likely due to Excel summary field being imported as an observation.

METHODS

Data Preparation

Python was used through Jupyter Notebook to prepare the dataset for analysis using the pandas, numpy, and datetime libraries. The unnamed columns contained a high number of non-null values. The values that were present were random datatypes and inconsistent values. Because meaning could not be derived, they were removed from the dataset. Observations with null values for beginning and ending tag numbers, volume, or clinic were removed. Delivered was renamed to action date and converted to a date time value. Additional variables were created for the action year and month. Unknown action dates remained in the dataset for analysis since volumes and clinics were present. Beginning and ending tag numbers were removed because they were not relevant to the tag distribution analysis.

The values in the returned column were evaluated because one value was expected and six were present. Observations listed as destroyed and void with no associated clinics were removed, and similar values were combined. A new column was created for the action with the values of delivered, returned or void. If any values were still null, the volume was used to determine if it was a delivery or return. Any values with an action of returned with a positive volume, the volume was updated to negative because the user deliberately typed returned as the status.

Clinics with unidentifiable text entered, like question marks or random characters, were removed, and clinics with similar names were combined. A special clinic grouping was created for the Annual Rabies Vaccination Drive. This is a yearly event where vaccination clinics are set up around the parish on a single day to issue low-cost rabies vaccinations pets in the community. A list of clinics included in this group can be found in Appendix A. Another special group was created for the Louisiana SPCA, the organization that runs the rabies vaccination program, which was listed 14 different ways throughout the data. The list of clinics listed in these categories can also be found in Appendix A. Observations with non-clinic values entered in the clinic column were removed, like special notes.

The contact worksheet was merged with the original dataset. Any locations that could not be matched up automatically were manually reviewed and corrected for naming inconsistencies between the two worksheets. The final dataset used in analysis contained 1520 observations and 10 variables listed below in Table 3.

Column	Description	Datatype
volume	The number of tags delivered or returned	number
clinic	Clinic name	string
tag_year	Tag year	string
action	The action associated with the tags: Delivered, Returned, Void	string
action_date	The date of the action	string
action_year	The year of the action	string
action_month	The month of the action	string
address	Address of the clinic	string
city	City of the clinic	string
zip	Zip of the clinic	string

Table 3 Variables Included in Analysis

Exploratory Data Analysis

Exploratory Data Analysis was performed using R with the tidyverse library for data manipulation and ggplot2 with directlabels for visualization. Univariate analysis was performed with visualizations to understand the distribution of the numerical and categorical variables and identify outliers. The Louisiana SPCA and Annual Rabies Vaccination Drive clinics were considered anomalies because they skewed the total volume of tags delivered, tags returned, and actions performed. The Louisiana SPCA is the organization that manages the tag program so optimizing the distribution of these tags would not offer any benefit to overhead. The Annual Rabies Vaccination Drive is a single day event with an unusually large quantity of tags distributed on the same data. Both clinics were excluded from further analysis and modeling. Multivariate graph analysis was performed to view the relationships between the variables.

Modeling

Modeling was performed using Python 3 in a Jupyter Notebook using the pandas and numpy for data manipulation, pycaret time series regression for modeling, and plotly for visualizations. Multiple approaches were considered for predicting the ideal volume of tags to be issued in the future. The first model aimed to predict the tags issued based on the rabies tag year for the entire program and resulted in a dataset of 6 observations. The volume was summarized by each tag year and split into training and testing sets. The training set consisted of data from 2015-2018 and the test set was 2019 and 2020. To offer more data to the model, the dataset was summarized again by the quarter of the delivery or return. This increased the dataset to 25 observations. The training and test datasets had the same segmentation. The number of tags issued was derived from summing the deliveries and returns in the date range. Mean absolute error (MAE) was used to evaluate each model's performance.

ANALYSIS

Univariate and multivariate graph analysis was performed on each variable to identify trends and anomalies in the data, of which the most interesting are outlined below.
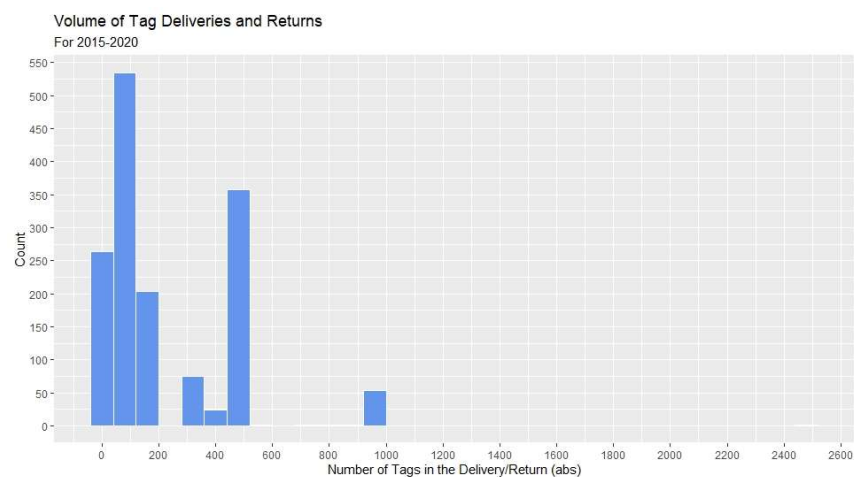
Volume

Figure 1 Volume of Tags Delivered and Returned in each Trip

Figure 1 shows a histogram of the volume of tags delivered or returned in each observation, called trips for the purpose of analysis. The most trips were to deliver or return approximately 100 tags. The absolute value was used to plot the volumes on the same y axis and to get a clear picture of the tags exchanging possession. The graph was positively skewed indicating an outlier, which was observed in the summary statistics at 2500 for the Louisiana SPCA.

Clinics

When plotting the number of trips for each clinic, the Louisiana SPCA and the Annual Rabies Vaccination Drive clinics were observed to have two to three times as many trips as the other clinics. As mentioned previously, the Louisiana SPCA is the agency managing the tag program. The Annual Rabies Vaccination Drive is a single day event where large numbers of tags are issued. Managing tags for these locations would not follow the same process as other clinics so they were excluded from further analysis. A full graph of clinics (excluding Louisiana SPCA and Vaccination Drive) and number of trips can be viewed in Appendix B.

Because of the large number of clinics, the top and bottom ten clinics were isolated to view trends in the number issued by tag year. Figure 2 shows the change in tags issued for each tag year for the top ten clinics. Metairie Small Animal Hospital issues the most tags overall with consistent growth over each tag year. The Low Cost Animal Medical Center opened in 2017 and also has a steadily growing volume. The Southern Animal Foundation issued the most tags in 2015, but their volume has been steadily decreasing.
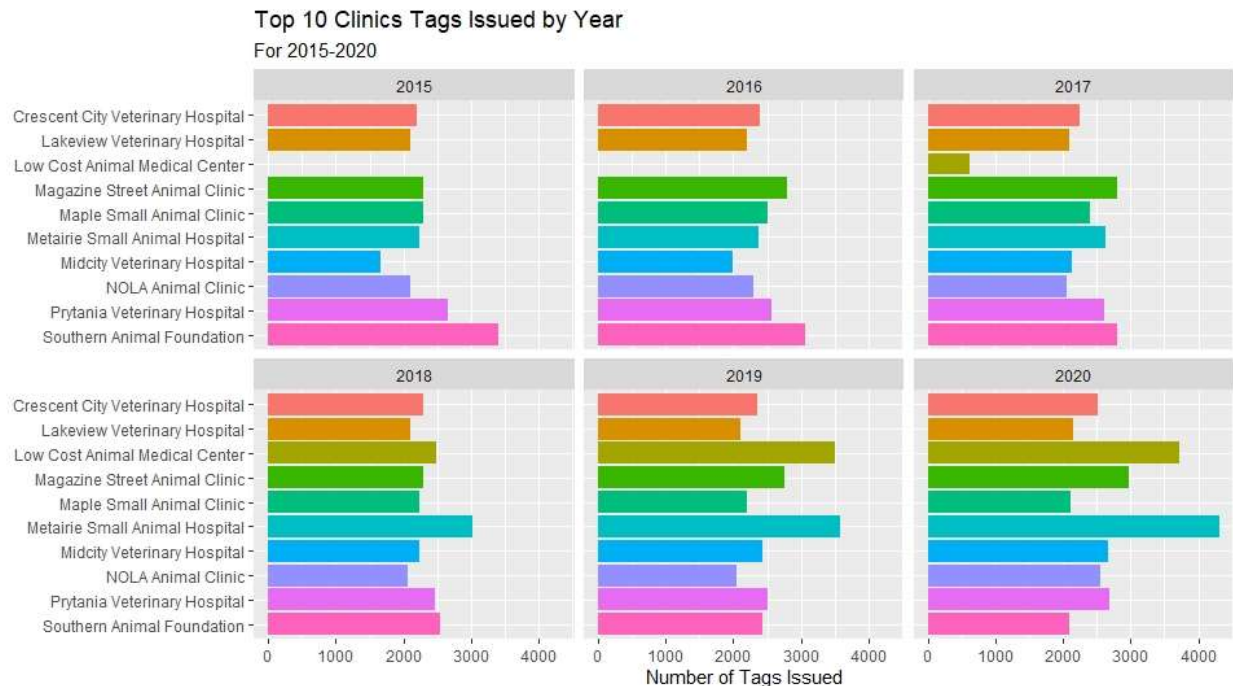
Figure 2 Top 10 Clinics - Change in Volume by Tag Year

The original set of clinics ranked at the bottom by number of tags issued did not participate in the program consistently each year. The bottom ten was reselected to include clinics that participated each year and graphed side by side, see Figure 3.   Most of these clinics were located outside of Orleans Parish, which explains why they were ranked at the bottom. The change in tags issued each year was sporadic except for Chalmette Pet Wellness which had a steady increase since 2015. The Animal Care Center saw a jump in 2020 while the home/mobile veterinary clinics saw a decrease. The in-home veterinary services' decline could be due to the shut down of businesses during the coronavirus pandemic.
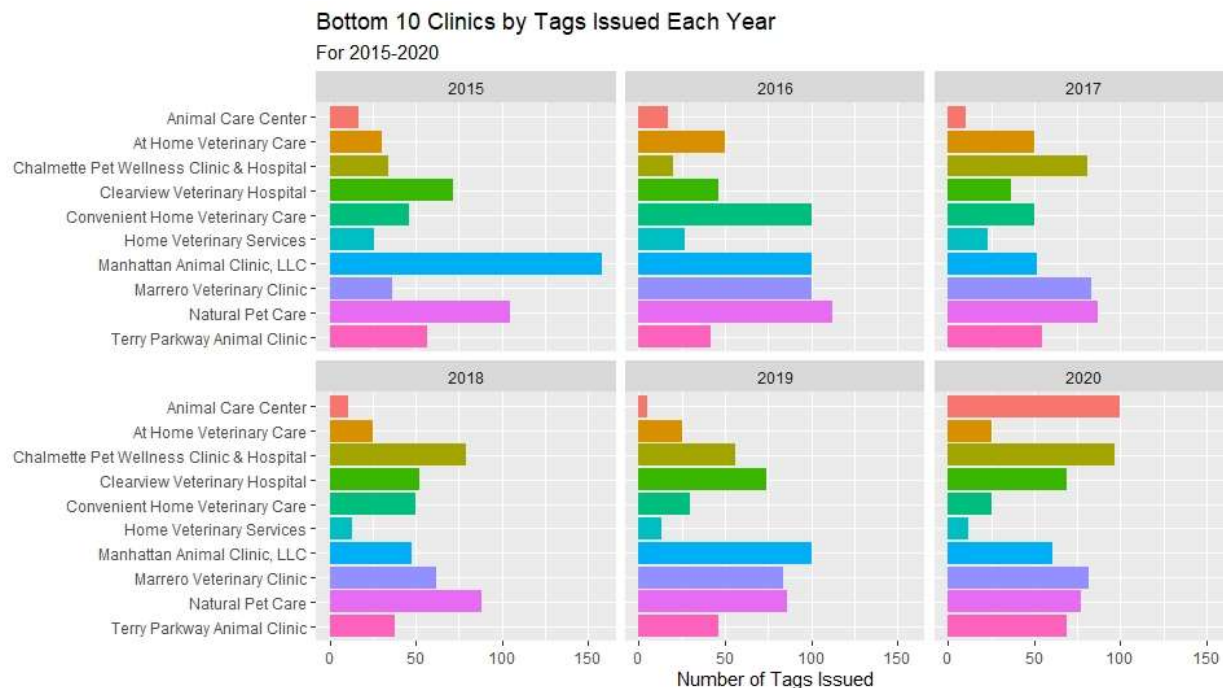
Figure 3 Bottom 10 Clinics - Change in Volume by Tag Year

Tag Year

The tag year is the issue year for the rabies vaccination. This can differ from the year the tags were delivered and returned. The initial tag deliveries can be made the year prior to the issue year and returns can be made the year after the issue year. The number of delivery/return trips were plotted for each tag year as seen in Figure 4. The number of delivery/return trips was the highest in 2020 at approximately 275 although it did not contain the largest volume of tags issued. The most rabies tags were issued in for the 2019 tag year.

Trips Each Tag Year From 2015-2020
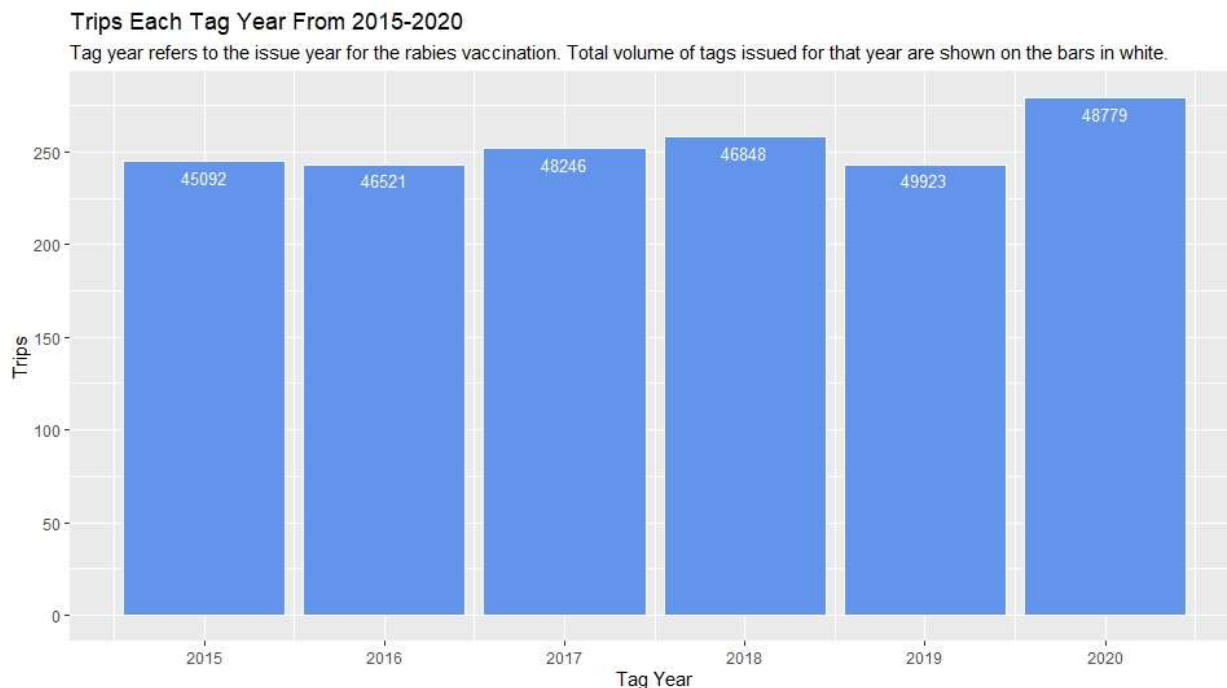Tag year refers to the issue year for the rabies vaccination. Total volume of tags issued for that year are shown on the bars in white.

Figure 4 Graph of Trips per Tag Year including Volume

Action Date

An action is considered whether the trip was to return or deliver tags and the action date refers to that trip. Delivered tags refers to the Louisiana SPCA physically delivering or mailing rabies tags to a clinic. Returned tags refers to the clinic returning unused tags to the Louisiana SPCA, either physically or by mail. The action date is the day that tags were delivered to the clinic or returned to the Louisiana SPCA. The volume was plotted by action month and grouped by tag years. Figure 5 shows that most tags are distributed in the beginning of the current tag year. Tags are returned most frequently at the beginning of the following year.
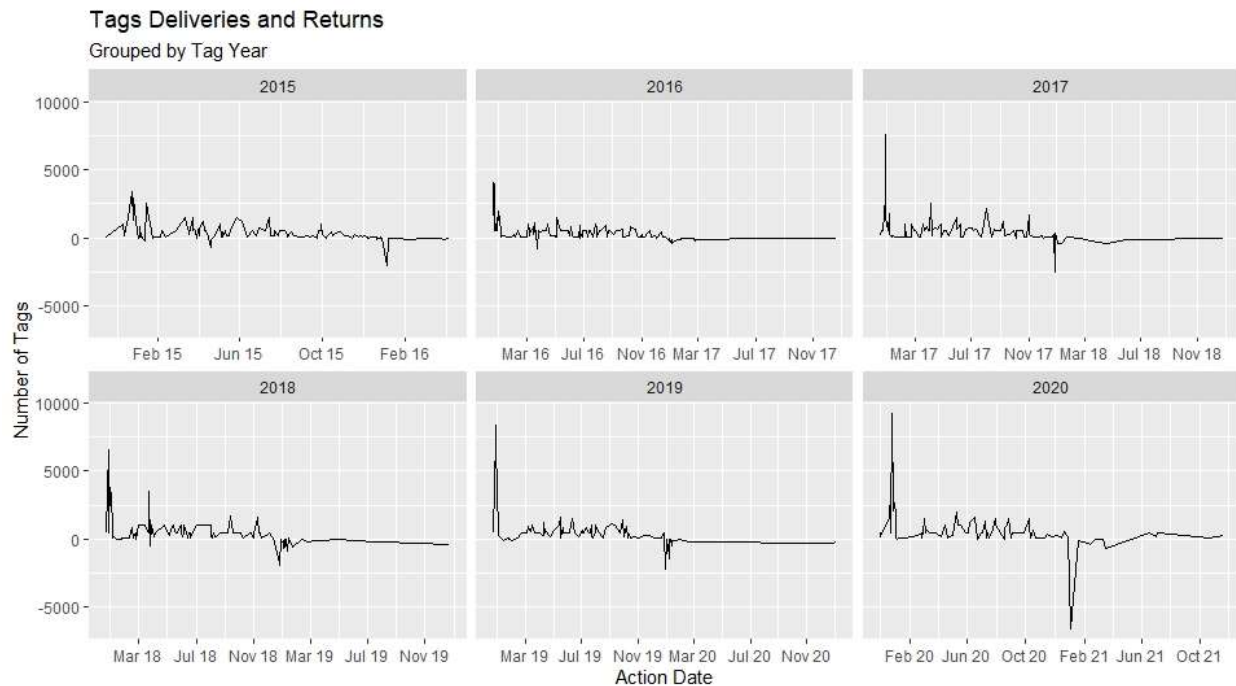
Figure 5 Time Series Graph for Delivery and Return Dates

RESULTS

Predicting Tags for the Entire Program based on Tag Year

Lasso Least Angle Regression was the best performing model for predicting the volume of tags

for the entire program by tag year with an MAE of 912.2453 for the training dataset, meaning that the

predicted volume could vary by 912 tags in either a positive or negative direction. When applying the

model to the test dataset, the MAE increased to 2670.4988, a 192% decrease in performance. When

viewing the plot of the actual versus predicted data, the predicted line is flat, indicating that enough data

was not available to predict the values based on the tag year, as showing in Figure 6.

Predicted vs. Actual Volume of Tags Issued by Tag Year
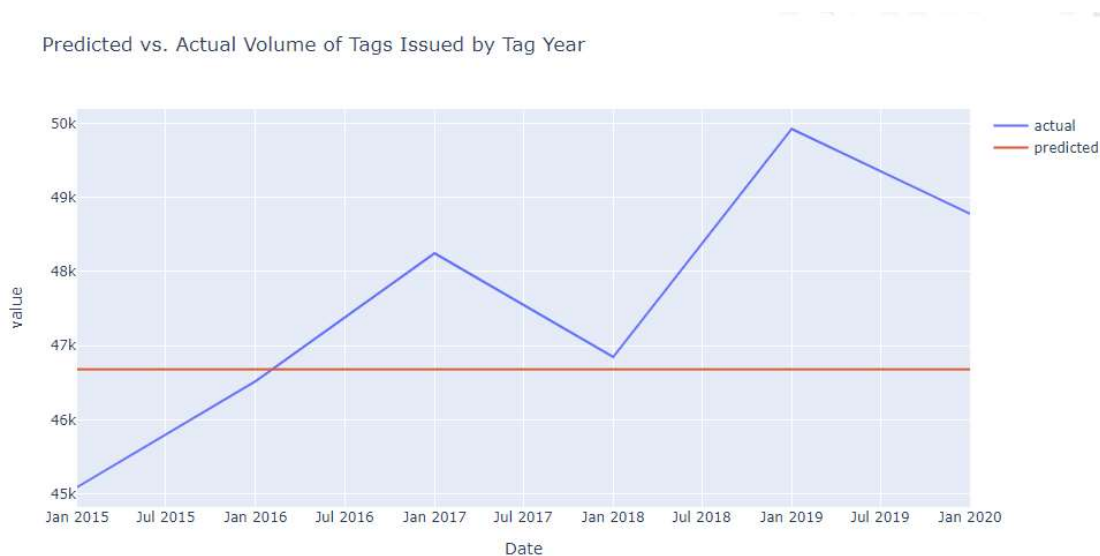
Figure 6 Model Performance for Entire Program Issued Tags

Predicting Tags for the Entire Program based on Action Quarter

The data was first plotted with the rolling average of tags issued each quarter, see Figure 7. The rolling average has very little movement up or down which offers an explanation as to why the original model's prediction was linear.
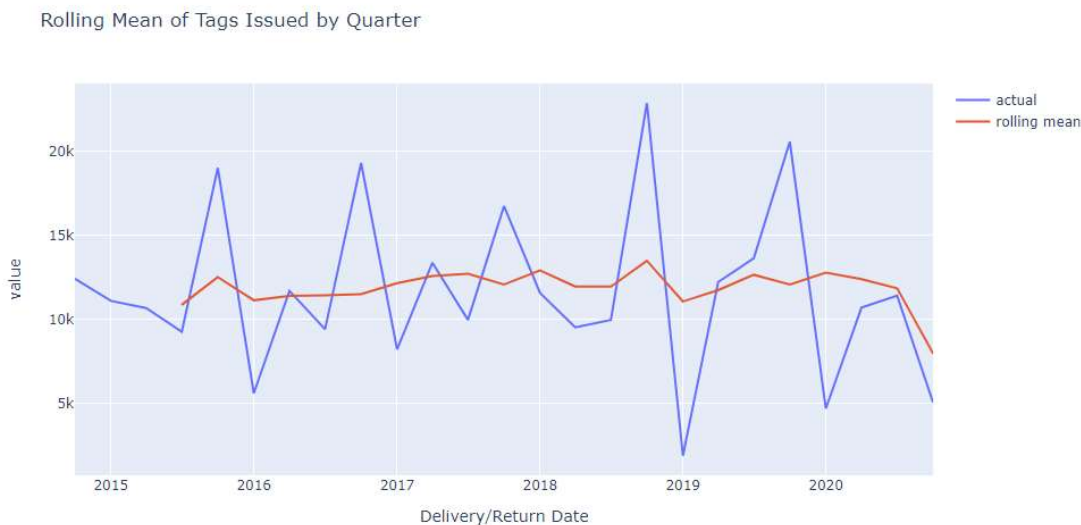
Rolling Mean of Tags Issued by Quarter

Figure 7 Rolling mean of Tag Deliveries and Returns

The Gradient Boosting Regressor algorithm was the best performing model for predicting the net volume of tags delivered and returned each quarter with an MAE of 2121.9030 for the training dataset, meaning that the predicted volume could vary by 2121 tags in either a positive or negative direction. When applying the model to the test dataset, the MAE increased to 5158.0455, a 150% decrease in performance. This is only slightly better than the first model performed for the program but still considered poor performance.

When plotting the actual and predicted values for each quarter, it appears that the actual line is not plotted from 2015 through 2019, see Figure 3. However, if we view the predicted and actual values side-by-side, the predicted values are almost 100% accurate, indicating overfitting of the model to the training data.
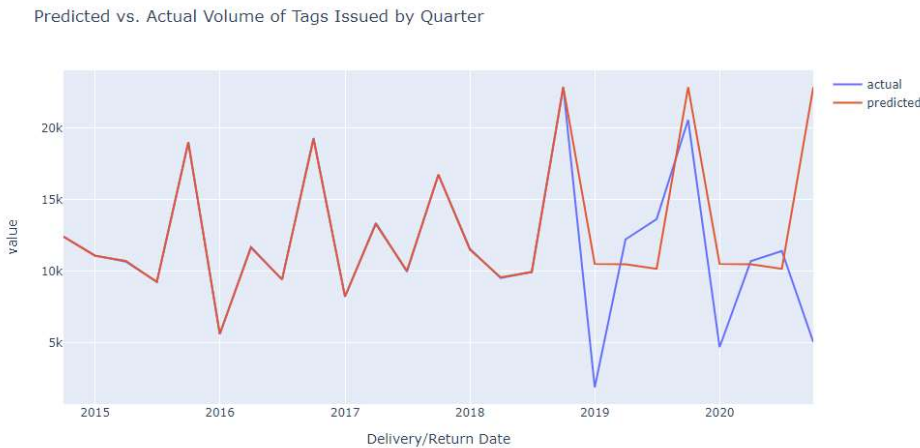

	Date	volume	Label	perc_acc
0	2014-10-01	12425	12428.491282	100.028099
1	2015-01-01	11108	11086.445447	99.805955
2	2015-04-01	10680	10724.899163	100.420404
3	2015-07-01	9267	9251.411190	99.831781
4	2015-10-01	19031	19012.078026	99.900573
5	2016-01-01	5600	5617.674311	100.315613
6	2016-04-01	11704	11646.898467	99.512120
7	2016-07-01	9416	9432.855393	100.179008
8	2016-10-01	19319	19256.701519	99.677527
9	2017-01-01	8213	8251.359591	100.467059
10	2017-04-01	13380	13309.190610	99.470782
11	2017-07-01	9975	10030.124722	100.552629
12	2017-10-01	16753	16762.621509	100.057432
13	2018-01-01	11578	11513.652254	99.444224
14	2018-04-01	9535	9575.108588	100.420646
15	2018-07-01	9964	9946.354091	99.822903
16	2018-10-01	22893	22884.274499	99.961886
17	2019-01-01	1878	10515.448479	559.928034
18	2019-04-01	12231	10496.059268	85.815218
19	2019-07-01	13648	10171.981693	74.530933
20	2019-10-01	20592	22884.274499	111.131869
21	2020-01-01	4689	10515.448479	224.257805
22	2020-04-01	10700	10496.059268	98.094012
23	2020-07-01	11425	10171.981693	89.032663
24	2020-10-01	5044	22884.274499	453.692992

Figure 8 Model Performance for Tag Delivery/Return Volume and Table of Predicted vs Actual Values

Despite the poor performance, the model for predicting the volume by quarter was used to forecast future tag volumes through 2023. The model was able to predict a rise in tags delivered in the first quarter of each year as well as a decline in the last part of each year.

Predicting the Tags Delivered Each Quarter through 2023

CONCLUSION

The objective of this project was to review the information in the log of tags delivered for the Louisiana SPCA to identify trends and determine if the rabies vaccination program could be improved by predicting the volume of tags needed in the future. The right variables are present in this data to predict future tag volumes; however, the poor performance of both models indicates that not enough data is present for reliable results. To improve upon these results, data should continue to be collected for the tags delivered and returned from clinics participating in the program. The Louisiana SPCA has administered the rabies tag program since before 2015; if that data can be found, it can be prepared using the same process and the model can be retrained using the additional data. Further modeling can also be performed for each clinic to determine how many should be issued at the start of each year.

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APPENDIX A: CLINIC ANOMALIES

The following clinics were combined into one clinic referred to as Annual Rabies Vaccination Drive:

- E0 (Louisiana SPCA)
- E0 NOPD Dwyer
- E1 (Magazine St)
- E1 (Magazine St.)
- E12 (Franklin Ave)
- E12 (Franklin Ave.)
- E16 (MLK)
- E17 (Woodland)
- E24 (Poland Ave)
- E24 (Poland Ave.)
- E25 (S. Carrollton)
- E27 (Elysian Fields)
- E35 (N. Carrollton)
- E36 (Read Blvd)
- E36 (Read Blvd.)

The following clinics were combined into one clinic referred to as Louisiana SPCA:

- LA-SPCA (Special Issue)
- Louisiana SPCA (Adoptions)
- Louisiana SPCA (Client Care)
- Louisiana SPCA (TBI)
- Louisiana SPCA (TBI) (client care?)
- Louisiana SPCA (Wellness TBI)
- Louisiana SPCA Adoptions
- Louisiana SPCA Client Care
- Louisiana SPCA Wellness TBI
- Wellness TBI
- Community Clinic
- Community Clinic (Out of Parish)
- Community Clinic (Special Issue)
- Louisiana SPCA

APPENDIX B: CHART OF DELIVERY AND RETURN TRIPS PER CLINIC