Summary Report

Exploring Geographic Variations in Shelter Dog Outcomes

Jennifer Gillespie

Pennsylvania State University – World Campus

GEO596B

Fall 2 - 2021

Contents

Abstract

Previous research has identified the existence of geographic variation in shelter animal outcomes; however, no clear explanation for this variation has yet to be identified. Pet ownership rates are known to vary by race, income, housing status, and geographic location. This study attempts to determine if similar socioeconomic and demographic variables may account for the regional differences in shelter outcomes. The author used shelter dog statistics from the Shelter Animals Count Database to attempt to find a correlation in shelter dog euthanasia rates and surrounding community characteristics at the county and state level. Data was investigated using linear regression and spatially weighted regression utilizing Environmental Systems Research Institute's (ESRI) ArcGIS desktop suite and the free and open-source software GeoDa. The results indicate that shelter dog outcomes may be influenced by household size, mean temperature, and stray rates. Limited evidence was found to support the idea that economic factors (such as state per capita income) impact euthanasia rates. Indeed, it is likely that actions at the shelter level (such as transfer programs) are more important than characteristics of the surrounding community.

Background

Every year approximately 6.5 million companion animals enter animal shelters, of these 1.5 million dogs and cats will be euthanized either for medical or behavioral reasons, or more commonly simply due to lack of resources (ASPCA, 2020). Over the past 50 years there have been enormous strides in reducing companion animal euthanasia in shelters. This has been documented by researchers (see below paragraphs) and animal humane societies. Best Friends Animal Society (Best Friends) estimates that the number of companion animals has declined from two million in 2015 to 347,000 in 2020. While this is good news, research on both owned and sheltered dogs and cats have revealed that there are regional and demographic differences in both pet ownership trends and animal sheltering trends (notably, euthanasia rates). The study of these trends can be informed using geographic information systems (GIS) technologies that can harness the power of location to reveal community level patterns.

Temporal investigation into state sheltering trends in Colorado have revealed a decline in the number of companion animals being euthanized yearly in shelters (Hawes et al., 2019). Research into trends at a national level have supported these findings (Rowan & Kartal, 2018; Woodruff & Smith, 2016). However, while overall euthanasia rates are declining, rates can vary dramatically by location. Sinski and Gange investigated shelter statistics from 2013 across Kentucky and found that live release rates varied widely by county. In fact, six counties had live release rates between 0 and 25 percent whereas one county had a live release rate near 100 percent (2016). Intrastate geographic variation was also identified by Rowan and Kartal in 2018. They analyzed state level trends across several states and found that coastal counties in California have lower euthanasia rates than inland counties.

Unsurprisingly, variations in shelter outcomes have also been identified between states and regions. Woodruff and Smith estimated the number of dogs in shelters and their outcomes and identified differences in outcomes between shelter funding source as well as geographic region (2016). Dogs were mostly likely to be euthanized in the southeast, but significantly lower rates were found in the midwest, northeast, and west. Differences in intakes were also regional with the fewest dogs entering shelters in the northeast and the most in the southwest. Rowan and Kartal found a similar trend during their effort to identify animal sheltering trends throughout the nation (2018). Dog euthanasia rates were lowest in the northeast and higher in the southeast. The authors suggested that differences may be due to local laws, spay/neuter programs, and pet ownership. Indeed, dog ownership rates are the lowest in the northeast (Rowan & Kartal, 2018; AVMA, 2018).

With an eye to determining why shelter outcomes are so variable, Hal Herzog found that of the states with the highest and lowest euthanasia rates, state income is negatively correlated with euthanasia rates i.e., as state income increases, euthanasia rates decrease (2018). Herzog looked at only 11 states in the nation, it is not known if this correlation exists when all states are considered or at different geographic scales. Furthermore, additional demographic factors have not been studied to determine if a correlation exists between euthanasia rates and other community characteristics.

While widescale studies have not taken place to determine characteristics of people who are adopting shelter animals, there is available information on characteristics of pet owners. There are two surveys which gather data on pet ownership. The American Veterinary Medical Association (AVMA) runs a survey every five years (most recently in 2019) and the American Pet Products Association (APPA) runs a survey every two years (most recently 2019-2020). These two surveys do not include animals in shelters but are useful for examining regional ownership trends and have been cited widely in the literature. The 2017-2018 edition of the AVMA survey found that pet ownership is divided along racial, economic, family, and geographic lines. Dog owners are more likely to be white, live in a house they own, be married with children, live in rural areas, and not live in the northeast (AVMA, 2018). Additionally, rate of dog ownership increases as income increases until reaching a household income of approximately $55,000 at which point dog ownership rates remain stable. Results of this survey are supported by earlier research finding these same factors were highly correlated with pet ownership (Saunders, 2017). Saunders determined that there are significant sociodemographic differences between people who live with companion animals and those who do not. In that study, the factors playing the largest role in differences in pet ownership were race, family composition, and housing.

Given the geographic variation in shelter dog outcomes, the lack of previous research, and documented demographic differences in dog owners, the objective of this study was to determine if there exist demographic factors which are correlated with shelter dog euthanasia rates. If such demographic differences exist, the data may be useful to shelter organizations and local governments who can use the information to support policy changes and programs which may help to reduce euthanasia rates in their area.

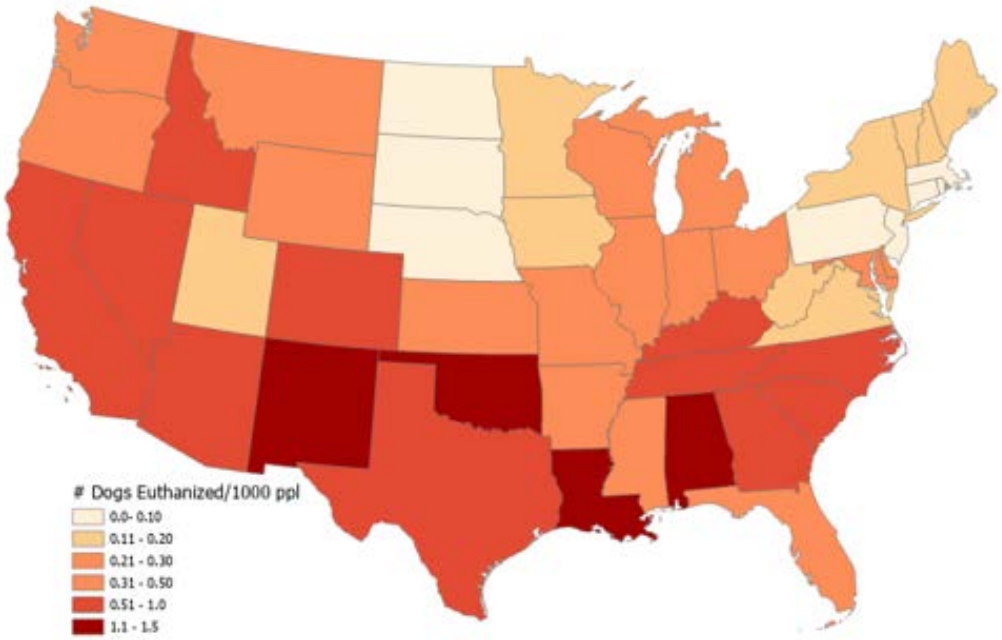

Figure 1. Map of the continental US showing geographic variation in state euthanasia rates. Data was obtained from the Shelter Animals Count Database for shelters and rescues reporting a full dataset for the year of 2019. Southern states generally have higher euthanasia rates than northern states.

Methodology

Geographic Scope

The analysis was conducted within the continental US at two geographic scales, local (county) and regional (state). Alaska and Hawaii were removed from the analysis as outliers (likely due to island effects).

Data Sources

Shelter statistics were obtained from the Shelter Animals Count (SAC) database. This database contains self-reported data from animal shelters and rescue organizations across the country. Full datasets (data which included all 12 months) from the year of 2019 were utilized. While data from 2020 was available a larger than average number of dogs were adopted out of shelters during this year, partially due to the COVID-19 epidemic which began in early 2020.

The SAC dataset was provided as an excel spreadsheet with columns for shelter information (name, ID, location, type), time (month and year), and animal intake and outtake divided into canine and feline data and subdivided by age. The excel file contained nearly 200,000 rows. The data was organized into a Microsoft Access database to extract and combine data as needed. The data was then aggregated by county, resulting in data from 1106 counties and from the contiguous 48 states and Washington D.C. From the SAC dataset two variables were calculated, euthanasia rate and stray rate. These were calculated by aggregating all dogs (stray or euthanized) at each geographic scale and then dividing by 1000 people within the same geographic space. Shelter Animals Count specifically disclaims all responsibility for any analysis, interpretations, conclusions and opinions contained herein.

Census data was obtained from the ESRI Living Atlas layer, popular demographics in the United States. The layer aggregates popular US Census Bureau data at multiple geographic scales including county and state and is available as a web layer through an ESRI subscription. Variables previously shown to be correlated with dog ownership rates (race, income, home ownership, and family composition and size) were obtained. Two additional geographic variables were used in the analysis; temperature and distance to major US cities (defined as cities with a population over 500,000).

Process

Potentially correlated variables were investigated through graphing of scatterplots. Scatterplots were created in GeoDa version 1.14.0. Scatterplots are useful for determining if correlations exist based on calculation of the r-squared value. Higher r-squared values indicate higher correlation, with an r-squared value of 1 indicating the variables are perfectly correlated. In addition to scatterplots, data was mapped using ESRI's ArcGIS Pro version 3.8. Mapping provided further insight into the data allowing the visualizations of trends and identification of outliers.

The exploratory regression tool in ArcGIS Pro was used to further refine and identify variables with potential correlations within a multi-variate regression model. The tool "evaluates all possible combinations of the input candidate explanatory variables, looking for OLS [ordinary least square] models that best explain the dependent variable within the context of user-specified criteria" (ESRI, n.d.). The dependent variable used in all regression models was euthanasia rate.

The use of OLS regression models for geographic data is often problematic given the inherent nature of spatial data. Therefore, GeoDa was utilized for the ability to run spatially lagged regression models which take into account the spatial properties of the data.

Results

For the year of 2019, 2506 shelters within the continental US reported a full dataset. These shelters and rescues represent 1109 counties. Some geographic regions have sparse data, especially in the northern and central portions of the country. Upon review of the counties with at least one shelter reporting a full dataset from 2019, these counties do appear to account for the densest areas of human habitation. Compare Figure 2 showing the reporting counties, with Figure 3, a map of human population density for the continental US.

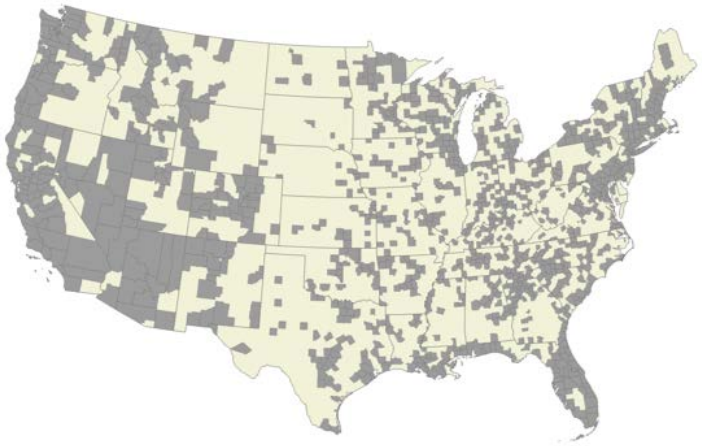

Figure 2. Counties with at least one shelter reporting a full dataset for the year of 2019.

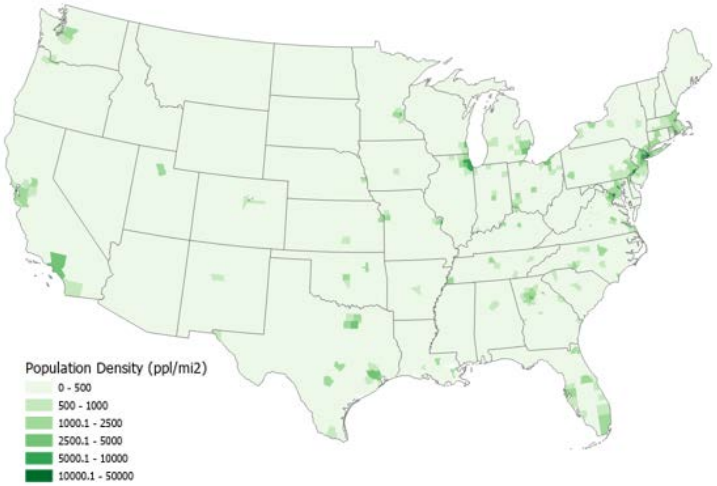

Figure 3. Human population density with the densest areas shown in dark green.

Scatterplots

No statistically significant correlations (p-value <0.05) were identified between euthanasia rates and the demographic variables owner occupancy rate, unemployment rate, population density, population growth, household size, or race at either the state or county level.

At the state and county levels, statistically significant correlations were present between euthanasia rate and household income. A statistically significant correlation was present between euthanasia rates and median age at the state level only (Table 1). Statistically significant correlations were also found between stray rates and euthanasia rates. At the state level the r-squared value is 0.50 and at the county level r-squared equals 0.58. See Figure 4 for the scatterplots.

Variable	R-squared	P-value
Household Income (State)	0.146	0.005
Household Income (County)	0.004	0.046
Median Age (State)	0.084	0.039

Table 1. Results of independent variables with statistically significant correlations with euthanasia rate at the county and state levels.

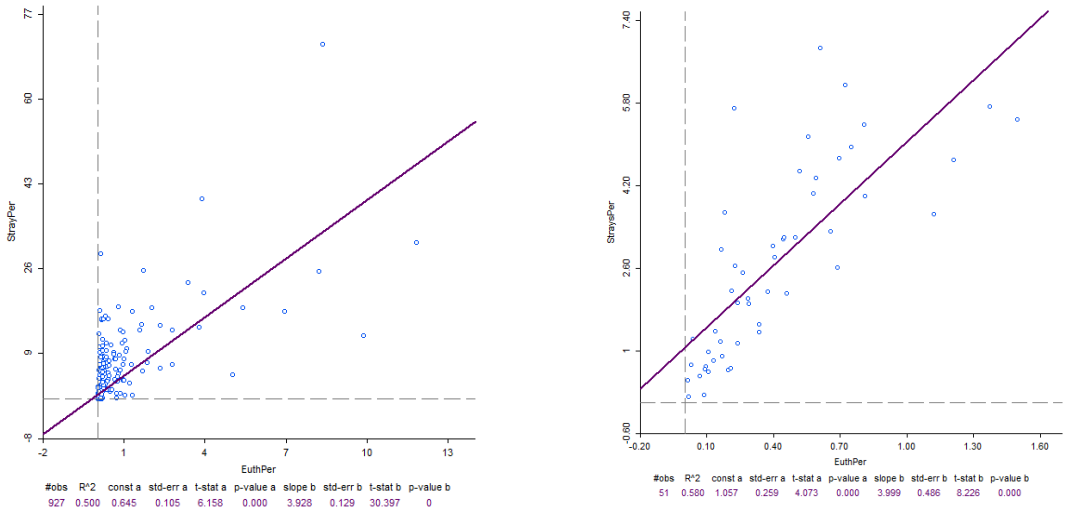

Figure 4. Stray Rate vs Euthanasia Rate at the county level (left) and state level (right). A statistically significant correlation is present at both the county and state level.

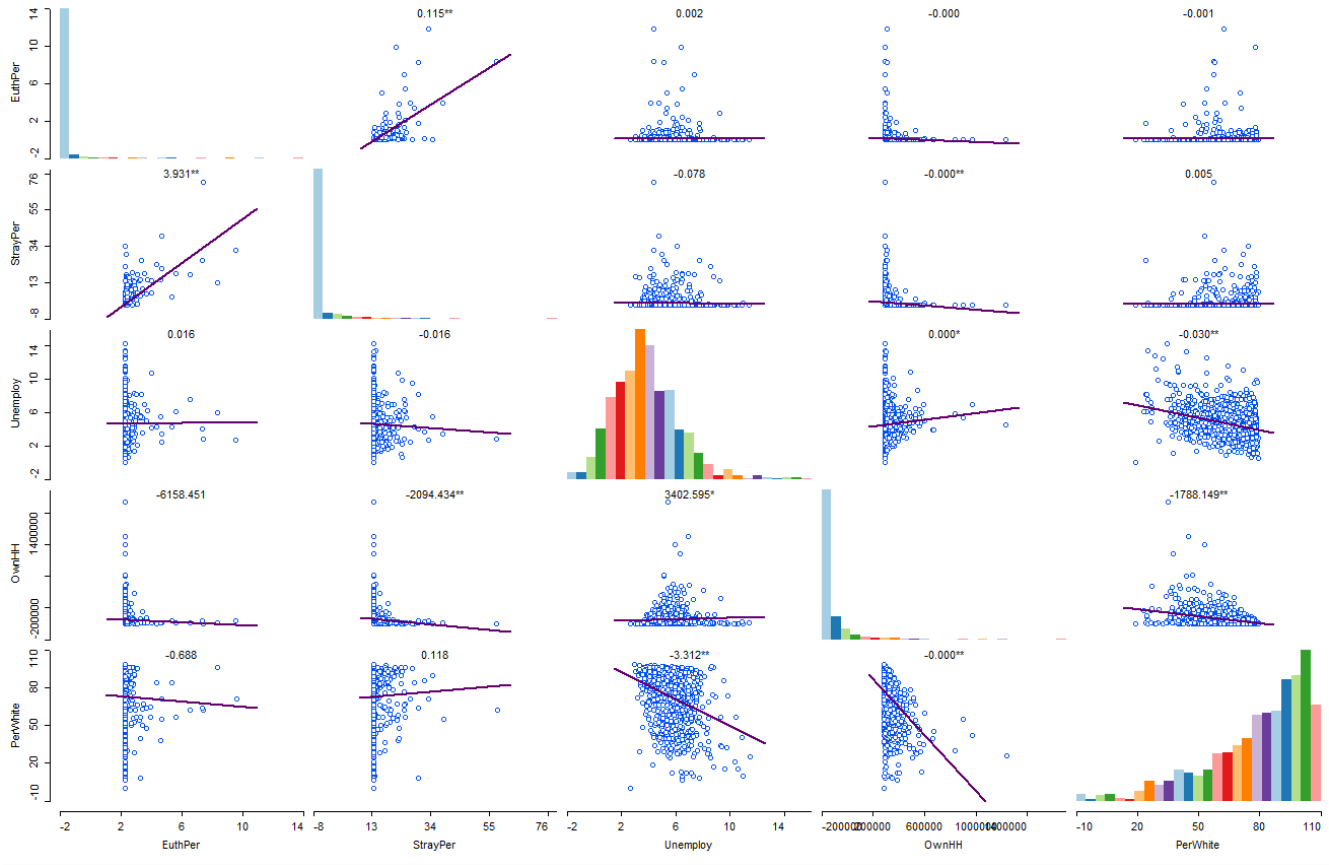

Figure 5. Scatterplots of euthanasia rates (EuthPer), stray rates (StrayPer), unemployment rate (Unemploy), owner occupancy rate (OwnHH) and percent while (PerWhite).

Exploratory Regression

Exploratory regression uses the OLS model to determine what combination of independent variables pass a series of statistical checks. No passing models were identified at the state level or the county level due to statistically significant Jaque-Bera tests. Failing this test indicates that the model may be misspecified (missing explanatory variables) or the data may be heteroscedastic (e.g. residuals vary widely based on spatial location). While no passing models were identified using OLS, exploratory regression provides a summary of variable significance which indicates which variables may have the highest likelihood to impact the dependent variable (Table 2). Based on exploratory regression results at both the county and state levels; percent stray rate, mean temperature, median age, and median household income have the highest significance.

Variable	% Significant	% Negative	% Positive
Percent stray rate	100.00	0.00	100.00
Net transfer rate*	63.67	63.67	36.33
Mean temp	42.97	0.00	100.00
Median age	28.52	96.48	3.52
Median household income	26.17	83.20	16.80
Percent owner occupancy	13.28	71.88	28.12
Distance to major city	10.94	36.33	63.67
Household size	7.42	87.89	12.11
Percent ethnically white	6.85	82.19	17.81
Population growth rate	1.37	25.11	74.89

Table 2. Exploratory Regression – Summary of Variable Significance (County Level)

Spatially Lagged Regression

Based on the observed statistically significant variables from the output of exploratory regression results, spatially lagged regressions were run in GeoDa using five independent variables: stray rate, household size, median age, mean temperature, and median household income. This required the development of spatial weights matrices to define neighbors at both the state and county levels. A spatial weights matrix at the state level was developed using Rook defined adjacency. For the county level spatial weights, a distance between neighbors had to be utilized because some counties existed with no contiguous neighbor.

At the county level the r-squared value was 0.496 and all variables, with the exception of household median income, had significant p-values. Table 3 provides the coefficients and p-values. However, the graph of the residuals (Figure 6) indicated that the data is heteroscedastic (cone shaped), and the results of the regression model are unreliable.

Variable	Coefficient	P-value
Stray Rate	0.118	0.00000
Household Size	-0.151	0.00993
Median Age	-0.010	0.00314
Mean Temp	0.005	0.00101
Median Household Income	0.000006	0.05992

Table 3. County Results of Spatially Lagged Regression

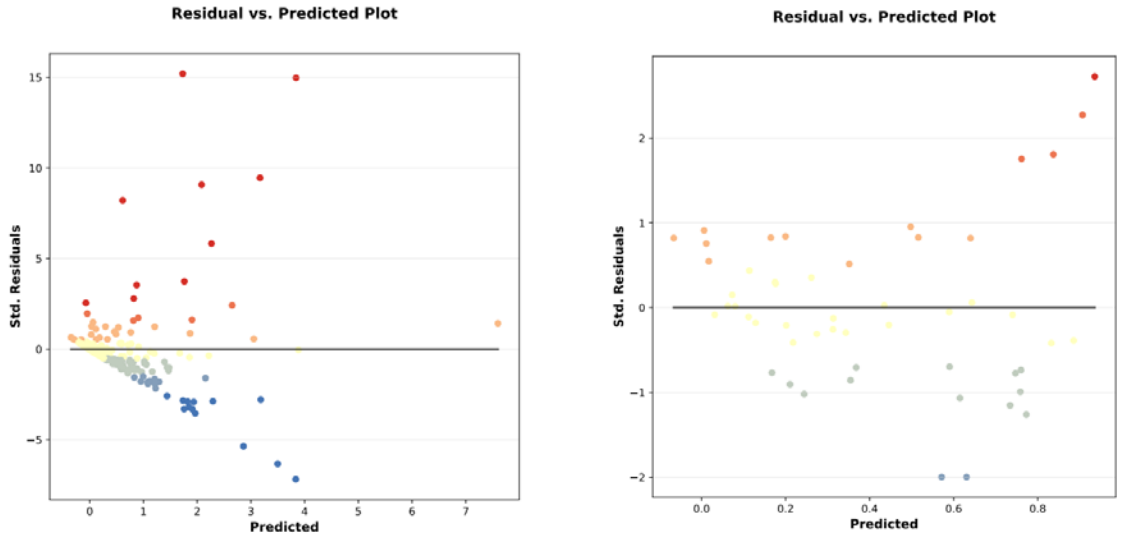

Figure 6. On left, residuals graph of county spatially lagged regression results (note the cone shape of the residuals indicating heteroscedacity) vs the residuals graph of state spatially lagged regression results on the right (note the well distributed resdiuals).

At the state level the r-squared value is 0.69, however only stray rate and household size had significant p-values. Table 4 shows the results. Residuals at the state level are well distributed (Moran's I = -0.022) indicating no heteroscedacity at the state level.

Variable	Coefficient	P-value
Stray Rate	0.119	0.00000
Household Size	-0.659	0.02430
Median Age	-0.0308	0.00966
Mean Temp	0.007	0.05199
Median Household Income	0.000002	0.05888

Table 4. State Results of Spatially Lagged Regression

Discussion

Results of regression analysis between demographic variables and shelter dog euthanasia rates revealed there is limited correlation between demographics and euthanasia rates. Weak correlations were identified for median household income, household size, and median age. A correlation between median household income and euthanasia rates is visible in scatterplots, however this correlation is not present within OLS or spatially lagged regression models. While Herzog identified a strong correlation (r-squared = 0.42) between income and euthanasia rates using a simple univariable regression model, a less strong correlation (r-squared = 0.146) was identified during this study. Herzog studied only the states with the highest and lowest euthanasia rates indicating that states at either end of the euthanasia spectrum are more likely to be influenced by income than states with moderate levels of euthanasia. The difference in results is also likely due a difference in data sets. This study focused on data from the SAC dataset from 2019 which has limited data while Herzog may have used older data or from a different source.

Weak correlations to euthanasia rates were also identified for median age and household size. This finding makes sense as families with children are more likely to be dog owners. Areas with a lower median age or larger households

(households with more children) have more potential adopters. However, these findings were weak and not present during all types of analysis. It is possible a lack of data at the county level has obscured the correlation.

Stray rates were found to be correlated with euthanasia rates at both the state and county levels. In fact, the percentage of stray dogs is the strongest indicator investigated for euthanasia rates. It is unclear if this correlation is also a matter of causation, however in the case of stray rates it makes sense that areas with more stray dogs are likely to have higher rates of euthanasia as there are not enough potential adopters for all dogs brought into shelters.

The interesting finding here is that economic demographics were poor indicators of euthanasia rates, indicating that there are other factors which are driving the national variation in euthanasia. One possibility for what may be occurring is that individual shelters vary in their programs to help dogs who enter their facilities. Evidence for this exists in the high correlation between net transfer rate and euthanasia rate. Net transfer rates tend to be negative in the northern half of the US (dogs are transferred into shelters) and positive in the southern half of the US (dogs are transferred out of shelters). This phenomenon is visible in Figure 7. The map indicates there is a general movement of dogs from red states (those with the highest euthanasia rates also have the highest transfer out rates) to green states (those with low euthanasia rates).

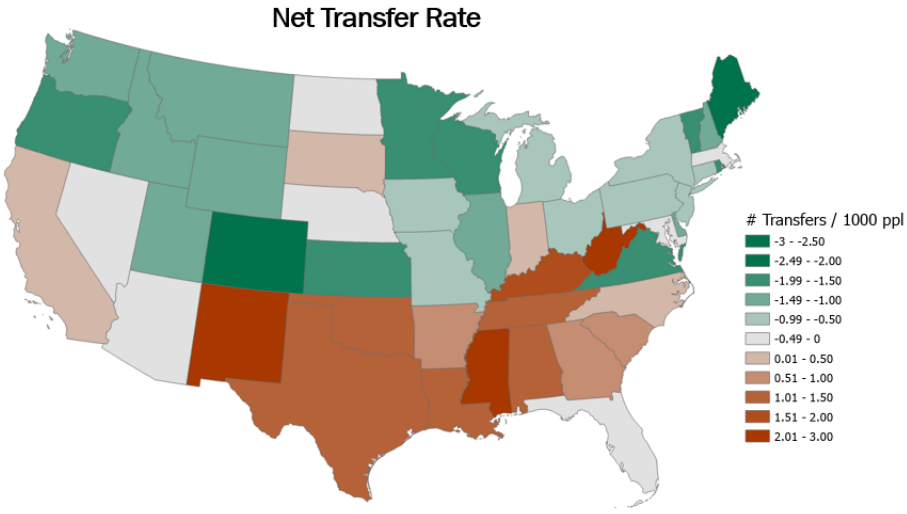

Figure 7. Net transfer rate between states. The transfer rate was defined as the number of dogs transferred out of shelters minus the number of dogs transferred into shelters divided by 1000 people to control of differences in human populations. States with negative net transfer rate (green) have higher transfers in than out.

Problems Encountered

Multiple issues were encountered during the course of this study which must be understood as part of the interpretation of the results. These problems are generally related to the lack of animal sheltering statistics. The SAC dataset is self-reported and therefore shelter animal data is sparse. Many counites had no data and others were represented by only one shelter. Relying on only one shelter to represent an entire geographic area is likely to introduce bias into the results. Additionally, due to the nature of self-reported data, it is likely to artificially decrease euthanasia rates. Shelters with the most resources, and those with the best ability to keep track of all entering and exiting animals to the level of detail required for submission in to SAC database are also those which are likely to have the lowest euthanasia rates in their region. To visualize potential deflation of euthanasia rates, the data was compared to the Best Friends dashboard numbers. Data driving the dashboard are not publicly available, which means that euthanasia rates could not be obtained, however the save rate for each state is published online (Best Friends Animal Society, 2021a). Figure 8 (top map) shows the save rate calculated by Best Friends and Figure 8 (bottom map) shows the save rate (calculated using the published formula by Best Friends) from the SAC (Best Friends, 2021b).

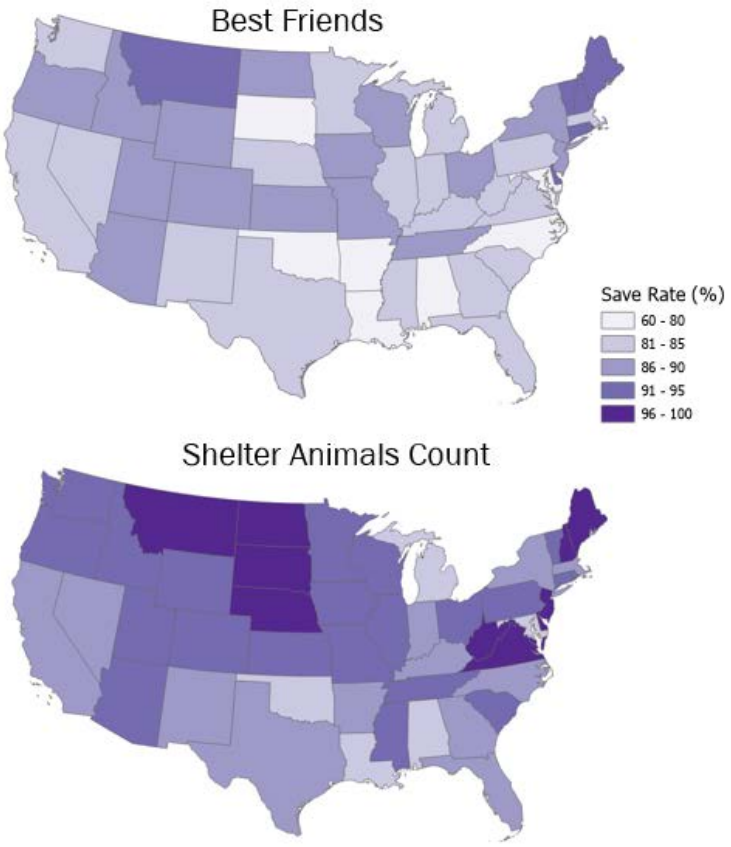

Figure 8. Comparison of the save rate between data from the Best Friend's Animal Society lifesaving dashboard and the save rate as calculated based on the Shelter Animals Count dataset.

There is a stark increase in the save rates from the SAC data, especially in states with the fewest reporting shelters (North Dakota, South Dakota, and Texas). This comparison indicates that reporting shelters are more likely to have lower euthanasia rates and are therefore potential vectors for introducing bias to the SAC dataset. It is possible that with a better representation of shelter data more correlations between euthanasia rates and demographics would emerge. However, given that there is no national reporting requirement for shelter animal data, researchers will have to wait for a larger increase in self-reporting shelters to fully investigate this issue.

Opportunities for Further Research

This study has raised more questions than it has answered as to what role demographics play in affecting euthanasia rates. More research is needed to determine what accounts for the spatial variation in shelter animal euthanasia rates. Possible avenues for further inquiry are as follows:

- Use different geographic scales (i.e. zip codes) or focus on one geographic region
- Investigate role of transfer programs
- Investigate the role of human attitudes towards animals on the impact of shelter outcomes
- Compare animal shelter statistics with human health outcomes
- Investigate multiple years including COVID data
- Explore correlation between cat data (or both cat and dog data) to community characteristics

References

American Veterinary Medical Association (AVMA). (2018). *Pet Ownership and Demographics Sourcebook: 2017-2018 Edition*. American Veterinary Medical Association: Schaumburg, IL, USA.

American Society for the Prevention of Cruelty to Animals (ASPCA). (2020). *Pet Statistics.* Accessed October 24, 2020 at https://www.aspca.org/animal-homelessness/shelter-intake-and-surrender/pet-statistics

Best Friends Animal Society (Best Friends). (2021a). *Pet Life Saving Dashboard Application*. Accessed online July 12, 2021 at https://bestfriends.org/2025-goal

Best Friends. (2021b). *Methodology*. Accessed online July 20, 2021 at https://bestfriends.org/methodology

Dolan, E. D., Scotto, J., Slater, M., & Weiss, E. (2015). Risk factors for dog relinquishment to a Los Angeles municipal animal shelter. *Animals*, *5*(4), 1311–1328. https://doi.org/10.3390/ani5040413

Dyer, J. L., & Milot, L. (2019). Social vulnerability assessment of dog intake location data as a planning tool for community health program development: A case study in Athens-Clarke County, GA, 2014-2016. *PLoS ONE*, *14*(12), 1–20. https://doi.org/10.1371/journal.pone.0225282

Environmental Systems Research Institute (ESRI). (no date). Exploratory Regression (Spatial Statistics). Accessed online on November 1 at https://pro.arcgis.com/en/pro-app/latest/tool-reference/spatial-statistics/exploratory-regression.htm.

ESRI hosted feature layer. Popular Demographics in the United States. Aggregated data from the U.S. Census Bureau. Available as part of the ESRI Living Atlas.

Hawes, S. M., Camacho, B. A., Tedeschi, P., & Morris, K. N. (2019). Temporal trends in intake and outcome data for animal shelter and rescue facilities in Colorado from 2000 through 2015. *Journal of the American Veterinary Medical Association*, *254*(3), 363–372. https://doi.org/10.2460/javma.254.3.363

Herzog, Hal. (2018). *The Puzzling Geography of Animal Shelter Dog Euthanasia.* Accessed October 20, 2020 from https://www.psychologytoday.com/us/blog/animals-and-us/201805/the-puzzling-geography-animal-shelter-dog-euthanasia.

New, J. C., Salman, M. D., King, M., Scarlett, J. M., Kass, P. H., & Hutchison, J. M. (2000). Characteristics of Shelter-Relinquished Animals and Their Owners Compared With Animals and Their Owners in U.S. Pet-Owning Households. *Journal of Applied Animal Welfare Science*, *3*(3), 179–201. https://doi.org/10.1207/s15327604jaws0303_1

Patronek, G. J. (2010)A. Mapping and measuring disparities in welfare for cats across neighborhoods in a large US city. *American Journal of Veterinary Research*, *71*(2), 161–168. https://doi.org/10.2460/ajvr.71.2.161

Patronek, G. J. (2010)B. Use of geospatial neighborhood control locations for epidemiological analysis of community-level pet adoption patterns. *American Journal of Veterinary Research*, *71*(11), 1321–1330. https://doi.org/10.2460/ajvr.71.11.1321

Patronek, G. J., & Crowe, A. (2018). Factors associated with high live release for dogs at a large, open-admission, municipal shelter. *Animals*, *8*(4), 1–16. https://doi.org/10.3390/ani8040045

Rowan, A., & Kartal, T. (2018). Dog population & dog sheltering trends in the United States of America. *Animals*, *8*(5), 1–20. https://doi.org/10.3390/ani8050068

Salman, M. D. (1998). Human and Animal Factors Related to Relinquishment of Dogs and Cats in 12 Selected Animal Shelters in the United States. *Journal of Applied Animal Welfare Science*, *1*(3), 207–223.

Saunders, J., Parast, L., Babey, S. H., & Miles, J. V. (2017). Exploring the differences between pet and non-pet owners: Implications for human-animal interaction research and policy. *PLoS ONE*, *12*(6), 1–15. https://doi.org/10.1371/journal.pone.0179494

Sinski, J. B., & Gagné, P. (2016). Give me shelter: the state of animal sheltering in Kentucky's county shelter system. *Contemporary Justice Review: Issues in Criminal, Social, and Restorative Justice*, *19*(2), 250–266. https://doi.org/10.1080/10282580.2016.1169706

Shelter Animals Count (SAC). (2019). *Animal Sheltering Statistics 2019*. Available for download at https://www.shelteranimalscount.org/data-reports

SAC Dataset. Obtained July 8, 2020. Provided by the Shelter Animals Count Database. Shelter Animals Count specifically disclaims all responsibility for any analysis, interpretations, conclusions and opinions contained in the information presented.

Weiss, E., Slater, M., Garrison, L., Drain, N., Dolan, E., Scarlett, J. M., & Zawistowsk, S. L. (2014). Large dog relinquishment to two municipal facilities in New York city and Washington, D.C.: Identifying targets for intervention. *Animals*, *4*(3), 409–433. https://doi.org/10.3390/ani4030409

Woodruff, K., & Smith, D. R. (2020). An Estimate of the Number of Dogs in US Shelters in 2015 and the Factors Affecting Their Fate. *Journal of Applied Animal Welfare Science*, *23*(3), 302–314. https://doi.org/10.1080/10888705.2019.1663735