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A Path Analysis to Understanding the Epidemiology of Murine Typhus in South Texas

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Abstract: This study aims to investigate statistically if there is a causality for the murine typhus endemic disease related to precipitation, temperature and the natural cycle of flea development in South Texas. Path analysis was used to determine the mediating and moderating variables that cause murine typhus disease. Three path diagram models were tested. Model 3 shows a clearer path on how the Rickettsia fleas were transmitted to the patients or subject, where rate of flea development is a mediating variable between sources of transmission and disease contraction, whereas precipitation moderates the source of transmission on its effect on rate of flea development with fleas in the environment and temperature average as covariates. The results of the path analysis support this hypothesis. Graphical research indicates that the number of murine typhus cases reaches a maximum during the month of May, when the temperature is between 65-80°F with about 70% humidity for flea development and the precipitation increases the probability that bacteria, fleas and hosts get into contact with humans. The results of this research suggest that the Laredo population should be made aware that the presence of rickettsia-infected *Xenopsyllia cheopis* and *Ctenocephalides felis*, the development of environmental conditions that increase the possibility of contact of wild and domestic animals with human beings can also increase the possibilities of the manifestation of the disease.

Keywords: Path Analysis, Murine Typhus, South Texas, Epidemiology

Introduction

In applied statistics, path analysis is used to describe the directed dependencies among a set of variables. Other terms used to refer to path analysis include causal modeling, analysis of covariance structures and latent variable models (Path Analysis Statistics, 2022). Rather than using the equations to present the picture of relationships, which are assumed, the path diagram represents them in a clearer way than the equations. Moreover, correlation results together with the literature provide a basis for preliminary models for path analysis. In 1918-21, sewall wright, the biological geneticist who developed path analysis, emphasized drawing the path diagram and decomposing the correlation and total determination in terms of model parameters. Sewall wright used path analysis to distinguish the three types of effects: Direct, indirect and total effects (Du *et al*., 2021; Ye *et al*., 2014). Path analysis has been used by previous researchers to identify factors influencing health skills and behaviors in adolescents (Ye *et al*., 2014) and some other related applications. As an extension of multiple linear regression, path analysis holds the assumptions such as linear relations among the variables, no interactions among the variables, continuity in endogenous variables and zero covariances among the disturbance terms (Streiner, 2005). Path analysis has also been used in studies of epidemiology (Salman and Meyer, 1987; Brown, 1969).

Murine typhus is an infectious disease caused by rickettsia typhi or rickettsia felis. The bacteria are obligated to intracellular microorganisms, these bacteria must enter the cell cytoplasm to multiply (Mobeen *et al*., 2023). It was common in the US in the 1940s, when rats and other animals carried fleas and lice infected with strains of rickettsia. Because fleas are holometabolous,

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their life cycle consists of four stages: Egg (embryo), larva, pupa and adult (imago). The flea egg incubation period usually ranges from two to twelve days. The flea species *Xenopsylla cheopis* passes through three molts during the larval stage; this typically ranges from nine to fifteen days. However, it can last up to two hundred days. During the larva stage the larva spins a silk cocoon, which remains until it is finished pupating. In the pupal stage, environmental factors can affect its developmental rate. For example, changes in temperature and humidity outside the cocoon can inhibit emerging for up to a full year. Flea eggs have a smooth surface, are ovoid and can be up to 0.05 mm in size. Eggs are commonly laid in a host's surrounding environment or nest or can be laid on the host. During this stage eggs are adapted to relatively high humidity and females can produce up to six eggs daily and as many as 300-400 eggs during a lifetime (Gage and Fleas, 2005). Eggs typically take two weeks to develop fully. During the larval stage fleas increase in size threefold (ranging from 0.5-3 mm). Larval development ranges from nine to fifteen days. However, it can last up to two hundred days in poor environmental conditions (Trivedi, 2003). Ambient temperature and environmental cues directly affect the length of time of this developmental stage. The range of this stage can be from two to nine weeks. The oriental rat flea thrives in temperatures between 65-80°F with about 70% humidity for egg laying. Conditions outside of these parameters inhibit egg laying and increase the overall life span of *Xenopsylla cheopis*. Eggs usually do not hatch on the hosts but rather on their nests because fleas are nidicolous parasites, meaning they live on hosts' nests. *Xenopsylla cheopis* breed year-round, as long as the temperature and humidity favor egg laying.

An adult *Xenopsylla cheopis* can survive up to 100 days in temperatures of 45-50°F. The maximum life span for *Xenopsylla cheopis* is approximately one year under favorable conditions. A long-life span increases survival rates of *Xenopsylla cheopis* and is of particular concern for public health because it allows for a greater chance of transmitting pathogens (Brown, 1969). The ideal temperature for adult oriental rat fleas is 65-80°F. *Xenopsylla cheopis* doesn't like temperatures outside this range. These temperatures are close to the human body temperature and can explain why humans can become accidental hosts for *Xenopsylla cheopis*. Fleas are known for their jumping ability, which allows them to be a great nuisance because they can move easily between hosts and nests. The oriental rat flea is capable of jumping approximately 12 inches in height.

Increased flea-borne (murine) typhus activities have been reported in the southwest Texas region. Accordingly, the Texas department of state health services issued a typhus health alert on November 30, 2017, to all health-care providers to increase their clinical suspicion for patients presenting with fever-like symptoms. Researchers have been predicting that global warming and global climatic conditions are contributing factors to the cause of this epidemic. Precipitation increases the probability of wild animals, domestic animals and human beings coming into contact with one another. There is a possibility the weather phenomenon is impacting the number of murine typhus cases. The transmission vectors are fleas, *Xenopsyllia cheopis* and *Ctenocephalides felis* (Bitam *et al*., 2010; *Xenophilia cheopis*, 2018; Azad and Beard, 1998). The bacteria are symbiotic to fleas. The natural hosts are rodents, *Rattus* spp. The bacteria are transmitted via infected flea feces inhaled or rubbed into the skin and mucous membranes. Its main pathological effect is the invasion of endothelial cells, where it causes injury to the cell membrane, producing edema. There are no vaccines for murine typhus. Personal hygiene and reducing contact with rodents and other wild and domestic animals can be used to prevent the disease (Azad *et al*., 1997; Azad, 1990).

The use of DDT and the control of rats reduced the number of cases to fewer than 100 in the US in the mid-1950s (Blanton *et al*., 2016). Lately, the Texas department of state health services has reported an increase in the number of cases per year in several counties. The counties with a higher increase in the number of cases are Bexar, Cameron, Galveston, Harris, Hidalgo, Nueces, Tarrant and Webb Countys. The total number of cases per year in Texas increased from 157 in 2008-738 in 2018. The Texas department of State Health Services issued a Typhus Health Alert on November 30, 2017 (Burridge *et al*., 1977).

The objective of this study is to develop an application of path analysis for the study of the factors affecting the presentation of murine typhus in South Texas from 2017-2019 and find the best model to analyze flea development. From the statistical point of view, this study is valuable because it helps in the understanding of the application of path analysis in the study of biological processes. From the epidemiological point of view, this study is valuable because flea-borne diseases can reemerge in epidemic form because of changes in vector-host ecology and environmental and human behavioral changes. It is also basic to understanding and determining the factors that affect the manifestation of the disease to be able to prevent and control an epidemic presentation of the disease. A summary analysis of the relevant literature (Blanton *et al*., 2016; Mobeen *et al*., 2023; Azad *et al*., 1997; Bitam *et al*., 2010; Azad and Beard, 1998) is reflected in the predictive model shown in Fig. 1 regarding how each of the factors facilitate the contraction of the murine typhus disease. Fleas in the environment, sources of transmission, temperature and precipitation can affect flea development. If flea development comes with the presence of pets, it can cause disease.

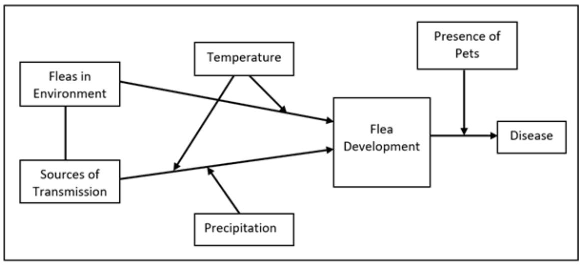

Fig. 1: Predictive model based on literature review

This research was approved by Texas A and M International University Institutional Review Board (TAMIU IRB).

Materials

The city of Laredo public health department located at 2600 cedar avenue, Laredo, Texas 78044-233 has various substations deployed throughout the Webb County. These substations are being reported any potential cases as they occur in various municipalities. They are being gathered by the health department and documented properly. TAMIU has been provided with these data for analysis and for dissemination to curb its impact in the aggregate forms. The authors were able to have access to this data for further analysis and reporting. The IBM® SPSS® software platform that offers advanced statistical analysis and a vast library of machine learning algorithms, provided the much-needed capabilities for statistical analysis that to be carried out.

Methods

Data

The data consist of 58 reported cases (confirmed and not confirmed) of murine typhus that have occurred in Laredo, Texas, from May 2017 to July 2019, including their epidemiological factors and weather data consisting of precipitation and temperature averages.

Graphical statistical methodologies were used to study the relationships among the murine typhus endemic disease within Laredo, Texas; the natural history of the disease; the natural history of the flea cycle; reported cases (confirmed and not confirmed); weather data; and demographic information for preliminary correlational analysis. To support this hypothesis, path analysis was performed and analyzed.

Variables

Independent Variable

Sources of Transmission (SourceTr). The sources of flea transmission are the sum of the coded scores from following variables using the code 0 = no/not present/not sure and 1 = yes/present/with indicators: History of flea bites, rodents in patient's environment, other wild animals in patient's environment, stray animals in environment, dog owner, cat owner, history of tick bites, having pets that had fleas or ticks removed by patient, traveling outside the country, environmental inspection done and recent outdoor exposure.

Covariate

Fleas in the Environment (FleaEnvi). The presence of *Xenopsyllia cheopis* and *Ctenocephalides felis* Rickettsia fleas in the environment was determined through an ocular inspection or actual visitation to the patient's residence and neighborhood by a representative of the city of Laredo.

Mediating Variable

Rate of flea Development (FleaDev). This is the sum of the coded scores from the following variables using the code 0 = no/not present/not sure and 1 = yes/present/with the following indicators: Rickettsia fleas in the environment, sources of transmission, temperature average and precipitation.

Temperature Average (TempAvg). This temperature is the average of the minimum and maximum temperatures in degrees Fahrenheit, which are tied to the patient's onset of the disease.

Moderating Variable

Presence of Pets (PetsPres). This is the number of pets, such as cats and dogs, present/interacting with the patients or subjects in their household. This is considered a moderating variable to the rate of flea development that may contribute to the contraction of the murine typhus disease for model 1.

Dependent Variable

Disease. This refers to the reported cases or status of cases (confirmed or not confirmed contraction) of the Rickettsia disease in Laredo and Webb County, Texas, tied to the date of the onset of the disease. Variable values are summarized in Table 1.

Table 1: Summary of variable values

	Value		
Variable	0	1	2
FleaEnvi	No flea	Can't be confirmed	Confirmed flea present
SourceTr	No/not present	Yes/present	NA
TempAvg	≥80 F or ≤ 65 F	(65, 80)	NA
Precipitation	No rain	Rain	NA
FleaDev	No present	showing in SourceTr, TempAvg, or precipitation	NA
Disease	Not confirmed case	Confirmed case	NA

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Statistical Tools

Pearson product-moment correlation or pearson r was used for continuous scale or interval data such as sources of transmission, temperature average, precipitation and rate of flea development. Spearman rho correlation was used for binary, categorical, or dichotomous data such as presence of fleas in the environment, presence of pets in the patient's household and contraction of typhus disease. Based on the correlation results, a preliminary path diagram model on how the variables relate to one another was conceptualized. To formulate the hypothesis, both the literature review and correlation results were considered. From there, three path diagram models were proposed. The hypothesis that the rate of flea development mediates the relation between the independent variable (sources of transmission) and the covariate (rickettsia flea in the environment) to the contraction of the typhus disease as the dependent variable with the interaction (moderating effect) of the presence of pets in the household was tested using logistic regression path analysis via the SPSS process macro v3.5 (Hayes and Aut, 2018). Other moderating variables included in the path diagram models include temperature average and precipitation to affect the rate of flea development (mediating variable). The process macro provides estimates of the path coefficients (β) and standard error (se) in the moderated mediation models with a bootstrapped 95% confidence interval. The process macro allows testing of direct and indirect effects of mediating and moderating variables with proposed causality between independent and dependent variables.

Results

Table 2 shows a summary of murine typhus cases, temperature average, precipitation and flea development from May 2017 to September 2019.

Figure 2 displays the distribution of murine typhus cases from May 2017 to September 2019.

Table 2 results support Špitalská (2016) findings who identified the time range for tick. Peaks of adult fleas could be observed from April to May and from September to October with a strong dominance of spring activity. The major peaks of nymphs could be observed from May to July and from September to October, also with a strong dominance of spring activity (18).

Table 3 shows a binary correlation result between and among the factors included in the study.

Three models were developed and investigated that fit with (Hayes and Aut, 2018) using SPSS process: Models 1-3. These three models using moderation-mediation path analysis are analyzed and presented in Figs. 4-6.

Table 2: Summary of murine typhus cases, temperature average, precipitation and flea development from May 2017 to September 2019

Month	Cases	TempAvg	Precipit	Flea development
05-2017	6	74.92	4	15
06-2017	2	74.23	0	5
07-2017	1	76.40	4	9
08-2017	1	88.11	3	9
09-2017	1	85.47	0	8
10-2017	1	89.03	4	12
11-2017	1	87.49	1	10
12-2017	0			
01-2018	2	80.99	1	12
02-2018	4	71.12	5	13
03-2018	1	55.92	1	10
04-2018	4	62.82	4	10
05-2018	2	74.99	0	5
06-2018	4	84.56	4	14
07-2018	4	79.64	1	6
08-2018	4	88.05	1	2
09-2018	0			
10-2018	1	90.45	1	5
11-2018	3	82.35	5	14
12-2018	2	74.83	5	15
01-2019	4	73.14	2	11
02-2019	0			
03-2019	0			
04-2019	1	57.86	3	4
05-2019	2	72.43	1	9
06-2019	0			
07-2019	2	79.84	2	11

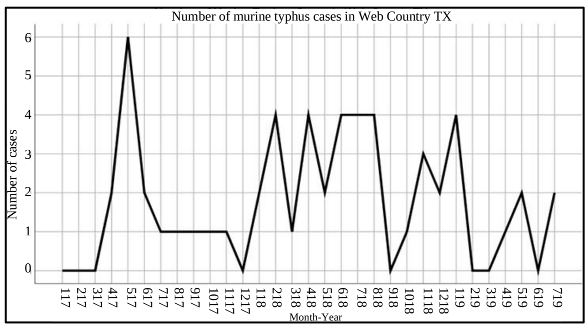

Fig. 2: Number of murine typhus cases in Webb County, TX

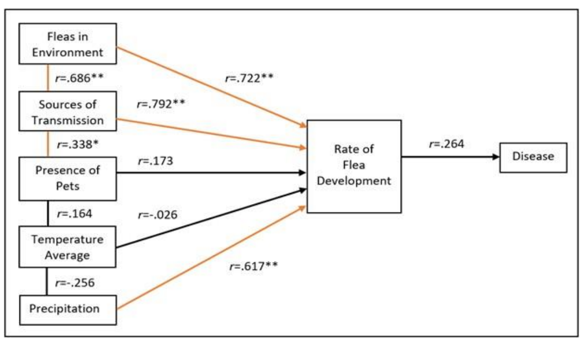

Fig. 3: Preliminary path model using correlation results

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Table 3: Correlation results

No.	Variable	1	2	3	4	5	6	7
1	FleaEnvi	1.000						
2	SourceTr	686**	1.000					
3	TempAvg	207	202	1.000				
4	Precipit	104	080	-256	1.000			
5	FleaDev	722**	792**	-026	617**	1.000		
6	PetsPres	086	338*	164	-086	173	1.000	
7	Disease	136	202	046	203	264	145	1.000

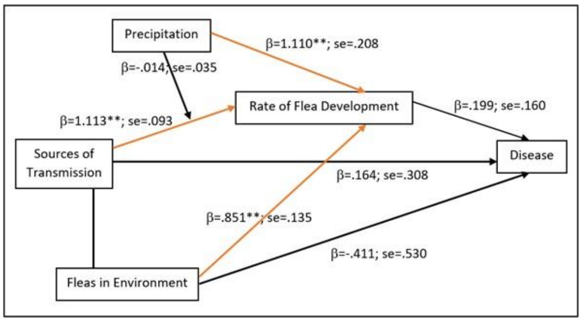

Fig. 4: Path analysis following SPSS macro model 1

Discussion

The results found in Fig. 2 and Table 1 indicate that there is not a one-to-one relationship among weather variables and presentation of murine typhus cases. For example, the presence of precipitation by itself does not necessarily affect the presentation of cases; Fig. 2 shows the murine typhus cases observed in May 2017 and September 2019. Changes in temperature do not relate directly to the number of cases, as can be observed in Fig. 3 when comparing May and September 2017. However, analyzing the three variables together, a pattern was found. In Table 2, there is a highly positive significant correlation between fleas in the environment and sources of transmission ($r = .686$; $p<.01$) Looking at the relationship of rate of flea development and fleas in the environment, correlation results show a positive significance ($r = .722$; $p<.01$) Correlation results also reveal a positive significant relationship between rate of flea development and sources of transmission ($r = .792$; $p<.01$) and that of precipitation ($r = .617$; $p<.01$). Moreover, data suggest that source of transmission is significantly correlated with the presence of household pets ($r =.338$; $p<.01$). The correlation results lead to the development of the preliminary path model provided in Fig. 3.

Model 1

As shown in Fig. 4, part 1 of model 1 (rate of flea development is a mediating variable between sources of transmission and disease contraction, whereas precipitation is a moderating source of transmission on its effect on rate of flea development with fleas in the environment as covariate), this is significant, $p<.0000$. The amount of precipitation or humidity (level) significantly affects the rate of flea development ($\beta = 1.110$ **; se = .208). Sources of transmission significantly affect the rate of flea development ($\beta = 1.113$ **; se = .093). Fleas in the environment significantly affect the rate of flea development ($\beta = .851$ **; se = .135). The moderating interaction or effect of precipitation with sources of transmission on the rate of flea development is not significant ($\beta = -.014$; se = .035).

Part 2 of model 1: The model is not significant, $p<.2149$. The sources of transmission have no significant direct effect on disease contraction ($\beta = .164$; se = .308). The flea in the environment has no significant direct effect on the contraction of the disease ($\beta = -.411$; se = .530) Also, the rate of flea development has no significant mediation effect between sources and transmission and disease contraction ($\beta = .199$; se = .160). The non-significance (in addition to the p value) of moderated mediation path analysis is confirmed also by the presence of zero (0) between BootLLCI and BootULCI. The index of moderated mediation by precipitation is -.003 (BootSE = .017).

In the Model 1 path diagram, the results show that fleas in the environment and sources of transmission significantly affect the rate of flea development. However, having fleas in the environment alone does not necessarily increase the rate of flea development. Conversely, the presence of fleas in the environment coupled with sources of transmission and moderated by precipitation (humidity) in the area facilitate the rate of flea development. Increased flea development in the area may expedite the contraction of the murine typhus disease. This is corroborated by the findings of Kreppel *et al*. (2016) that humidity affected the development time of death of synopsyllus fonquerniei. Synopsyllus fonquerniei dominates flea communities on rats caught outdoors while *Xenopsylla cheopis* is found mostly on rats caught in houses (Kreppel *et al*., 2016). This result confirms the literature that precipitation aids the rate flea development. On the contrary, there is no indicator of how the fleas were transmitted to the patients or subjects. Hence, this path model cannot completely provide a clear picture of how fleas in the environment could lead to contraction of the disease. In addition, Kreppel *et al*. (2016) provided a link to how the disease could be transmitted to humans by infected rats caught in houses. Model 3 path diagram may provide a better model of the disease contraction (Kreppel *et al*., 2016).

Model 2

As revealed in Fig. 5, part 1 of model 2, where rate of flea development is a mediating variable between sources of transmission and disease contraction, whereas precipitation and temperature average are moderating sources of transmission on their effects on rate of flea development with fleas in the environment as covariate, the model is significant, $p<.0000$.

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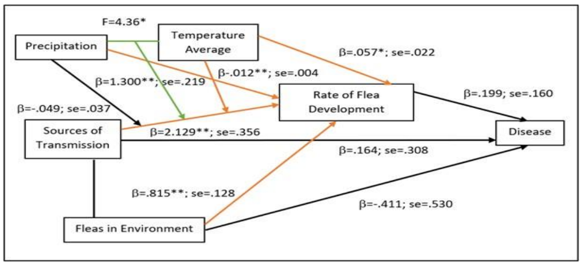
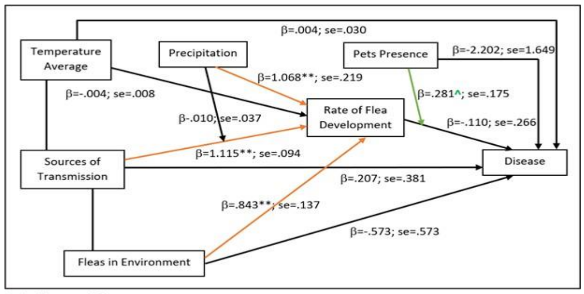


Fig. 5: Path analysis following SPSS macro model 2

Precipitation significantly affects the rate of flea development (β = 1.300 **; se = .2186). The moderating interaction or effect of precipitation with sources of transmission on rate of flea development is not significant (β = -.049; se = .037). Temperature significantly affects the rate of flea development (β = .057 *; se = .022). The moderating interaction or effect of temperature average with sources of transmission on rate of flea development is significant (β = -.012 **; se = .004) The unconditional combined interaction or effect of precipitation and temperature average with sources of transmission on rate of flea development is significant (F = 4.36 *; p = .018) Sources of transmission significantly affect the rate of flea development (β = 2.129 **; se = .356). Fleas in the environment significantly affect the rate of flea development (β = .815 **; se = .128).

Part 2 of model 2: The model is not significant, p<.2149 Sources of transmission have no significant direct effect on disease contraction (β = .164; se = .308). Fleas in the environment has no significant direct effect on the path analysis model (β = -.411; se = .530). Rate of flea development has no significant mediation effect between sources and transmission and disease contraction (β = .199; se = .160). The non-significance (in addition to the p value) of moderated mediation path analysis is confirmed also by the presence of zero (0) between BootLLCI and BootULCI. The index of moderated mediation by precipitation is -.010 (BootSE = .020), whereas the index of moderated mediation by temperature average is -.002 (BootSE = .003).

In model 2, path diagram results show that presence of fleas in the environment coupled with sources of transmission and moderated (interacted) by average temperature ranging from 65-80°F in the area affects the rate of flea development. With multivariate and survival analysis, affirms that temperature had a significant effect on the development times of flea larva and pupae (Kreppel *et al*., 2016). Brumin *et al*. (2011) found that under normal 25°C (77°F) rearing temperature, genes associated with response to stress such as cytoskeleton genes are induced in the Rickettsia-containing population. Thus, the presence of Rickettsia in *B. tabaci* under normal conditions induces the expression of genes required for thermotolerance that under high temperatures indirectly lead to this tolerance (Brumin *et al*., 2011). However, the results cannot verify how the fleas were transmitted to humans.



^ significant at 0.10

Fig. 6: Path analysis following SPSS macro model 3

Model 3

As presented in Fig. 6, part 1 of model 3 (rate of flea development is a mediating variable between sources of transmission and disease contraction, whereas precipitation moderates the source of transmission on its effect on rate of flea development with fleas in the environment and temperature average as covariates; presence of pets in the subject's household also moderates the rate of flea development and disease contraction), the model is significant, p<.0000.

Precipitation significantly affects the rate of flea development (β = 1.300 **; se = .2186). The moderating interaction or effect of precipitation with sources of transmission on the rate of flea development is not significant (β = -.049; se = .037). Temperature does not significantly affect the rate of flea development (β = .057 *; se = .022). Sources of transmission significantly affect the rate of flea development (β = -.012 **; se = .004). Fleas in the environment significantly affect the rate of flea development (β = .843 **; se = .137).

Part 2 of model 3: The model is not significant, p<.2437. Sources of transmission have no significant direct effect on disease contraction (β = .207; se = .381) Fleas in the environment have no significant direct effect on the path analysis model (β = -.573; se = .573). Temperature average has no significant direct effect on the path analysis model (β = .004; se = .030). Rate of flea development has no significant mediation effect between sources of transmission and disease contraction (β = .110; se = .266). The presence of pets in the patient's household has no significant effect on disease contraction (β = -2.202; se = 1.649). The moderating interaction or effect of pets presence with rate of flea development on disease contraction is slightly significant (β = .281; se = .175 p = 0.10). The conditional moderating effect of presence of 2 pets (not with 1 pet alone) with rate of flea development on disease contraction is almost significant (β = .4531; se = .2354) at p = 0.054. The non-significance (in addition to the p value) of moderated mediation path analysis is confirmed also by the presence of zero (0) between BootLLCI and BootULCI. The index of moderated mediation by precipitation is -.003 (BootSE = .200). The indices of conditional moderated mediation by pets' presence in the patient's household is -.002 (BootSE =.022) for 1 pet and -.004 (Boot SE = .216) for 2 pets.

Model 3 path diagram reveals that presence of pets in the households of the subjects could explain how the fleas were transferred to the patients. The patients will likely contract the disease if they have at least 2 pets. The pets may have interacted with wild animals or rodents when their area has precipitation. Those wild animals or rodents might have the Rickettsia fleas while taking shelter together with the patient's or subject's pets. The pets may likely acquire the Rickettsia fleas from the wild animals or rodents and eventually bring them home. These pets may transfer the Rickettsia fleas to the subjects or patients. This confirms the study of about the involvement of domestic animals (e.g., dogs and cats) or wild animals coexisting in urban areas (e.g., opossums) maintains *R. felis* infection in nature. *C. felis* fleas serve as the main reservoir and likely have a central role in transmission of human illness (Pérez-Osorio *et al*., 2008). Also, the study by Gruhn *et al*. (2019) increased the knowledge about the species of ticks that occur in the region and provides important data about rickettsia found in them. It reported three Rickettsia species, one of them belonging to the spotted fever group, found in urban and rural areas with large movement of people and domestic animals (Gruhn *et al*., 2019). Therefore, model 3 also suggests that if the subjects do not have pets in their household, then the likelihood of contracting murine typhus disease is minimal. Furthermore, having pets alone in their household without the mediation of rate of flea development and moderating effects of precipitation and temperature in the area would not lead to contraction of the murine typhus disease.

Conclusion

The three path models have shown potential factors that predict the facilitation of the contraction of murine typhus disease. Model 3 shows a clearer path on how the Rickettsia fleas were transmitted to the patients or subjects. Precipitation and weather patterns have contributed to the facilitation of the rate of flea development and ultimately the contraction of the disease, as indicated in models 2 and 3. The present of pets also plays an important role in disease development. The public, during rainy seasons, is advised to not interact with their pets or to bathe their pets first before interacting with them to prevent contraction of murine typhus disease. Also, the public is encouraged to clean households and look for potential areas where fleas could linger in the household. The department of health and human services may produce handouts and determine guidelines on how to clean the household during rainy seasons to lessen the potential contraction of the murine typhus disease so the public will be more aware of fleas' detection, thereby lessening hospitalization and cases of murine typhus in the area.

The conclusions drawn are stemming from the preliminary data gathered for the year 2017 up to 2019. Analysis of multi-year data and use of an increased sample size are needed to generalize the patterns and conclusions made therein. The hypothesis that weather conditions such as precipitation and flea activities influence the increased cases of the disease is supported by the results of the path analysis.

Acknowledgment

Epidemiological information and weather data for this study were provided by the city of laredo health department and the Center for Earth and Environmental Studies (CEES) of TAMIU, Laredo, Texas, respectively. The authors wish to express appreciation for the collaboration on this research project and look forward to working with everyone in the upcoming months. The preliminary work of this study has been presented at the proceedings of the 68th annual conference of diseases in nature transmissible to Man, May 23-25, 2018, Houston, Texas, page 78 (a poster presentation).

Funding Information

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Author's Contributions

Hongwei Wang: Worked on the abstract section, cowrote with orlando patricio the results and discussion sections and worked as the corresponding author in the submission process.

Orlando M. Patricio: Determined the statistical measure used for the study; collaborated with coauthors regarding data coding and analysis; recoded and analyzed data for the study; conceptualized the path models; tested their significance; interpreted data; wrote portions of the methodology, discussion and conclusion sections; and helped in editing the article.

Fernando G. Quintana: Proposed the research; requested data from the City of Laredo health department, Epidemiology division and the TAMIU center of Earth and Environmental Studies, CEES; presented the work in a poster presentation related to the article; wrote a preliminary paper and participated in the development of the final manuscript.

Rohitha Goonatilake: Has reviewed the article many times and provided suggestions to improve the article. He assisted with grammar, sentence structure and the overall flow of the article and assisted with the poster presentation related to the article.

Amelia Solis and Raonaq I. Mia: Collected the data from the city of laredo health department and performed individual investigations on the murine typhus cases.

Ethics

This article is original and contains unpublished material. The corresponding author confirms that all of the other authors have read and approved the manuscript and no ethical issues involved.

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