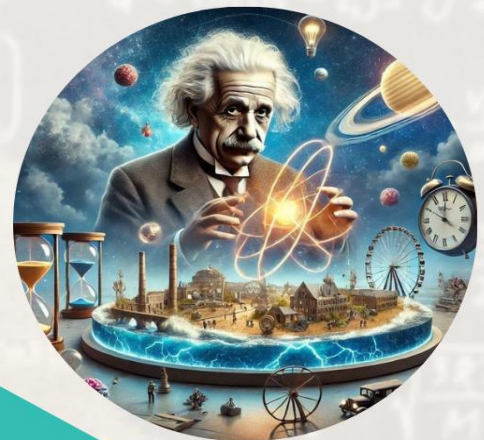


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## An Investigation into the Causes and Control of Murine Typhus in the Lone Star State

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**Abstract:** This research seeks to statistically examine the potential relationship between precipitation, temperature, and the natural flea development cycle in South Texas and the murine typhus endemic illness. Using path analysis, we were able to identify the mediators and moderators of murine typhus illness. We tried out three different types of route diagrams. Model 3 provides a more streamlined explanation of the Rickettsia flea transmission chain. In this model, the rate of flea development mediates the relationship between the sources of transmission and the disease contraction. Additionally, precipitation moderates the effect of the sources of transmission on the rate of flea development, with environmental fleas and average temperature serving as covariates. The route analysis confirmed this theory. May is peak season for murine typhus cases, according to graphical research. This is because the weather is warm (65–80°F), humid (about 70%), and rainy, all of which make it more likely that fleas, bacteria, and hosts will come into contact with humans. This research's findings highlight the need to inform the Laredo population about the presence of rickettsia-infected *Xenopsylla cheopis* and *Ctenocephalides felis*, as well as the need to address environmental factors that can lead to more frequent contact between humans and both wild and domestic animals.

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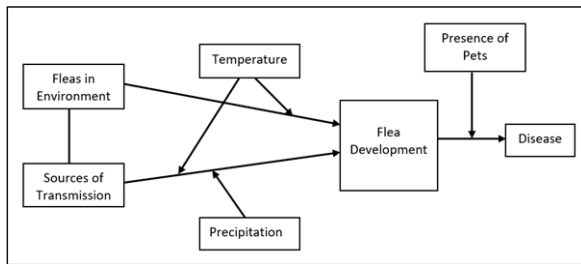
**Keywords:** Path Analysis, Murine Typhus, South Texas, Epidemiology

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### **Introduction**

To illustrate the directional dependencies among a group of variables, route analysis is used in the field of applied statistics. Causal modeling, study of covariance structures, and latent variable models are other names for path analysis (Path study Statistics, 2022). An improved alternative to equations is the route diagram, which more clearly depicts the presumed connections than the former. A foundation for initial path analysis models is laid forth by correlation data in conjunction with the literature. The developer of path analysis, a biological geneticist named Sewall Wright, put a premium on creating the route diagram and breaking down correlation and total determination into model parameters between 1918 and 1919. The three kinds of impacts were identified by Sewall Wright using route analysis: direct, indirect, and total (Du et al., 2021; In 2014, Ye et al. Among other relevant uses, path analysis has been used by prior researchers to determine what variables impact teenagers' health-related abilities and behaviors (Ye et al., 2014). Path analysis is an expansion of multiple linear regression that uses the following assumptions: that all variables are directly related to one another, that there are no interactions between them, that endogenous variables are continuous, and that disrupting terms do not have any correlations (Streiner, 2005). Studies in epidemiology have also made use of path analysis (Brown, 1969; Salman and Meyer, 1987). Infectious rickettsia typhi or rickettsia felis causes murine typhus. According to Mobeen et al. (2023), in order for bacteria to grow, they are obligatory intracellular microbes. Infected fleas and lice brought by rats and other animals in the 1940s were a major problem in the United States. Due to the fact that fleas are holometabolans, There are four phases to their life cycle: egg, larva, pupa, and adult. In most cases, the time it takes for flea eggs to hatch is between two and twelve days. *Xenopsylla cheopis*, a kind of flea, goes through three metamorphoses when it's a larva, which usually takes nine to fifteen days. It may, however, persist for as long as 200 days. The larva builds a silk cocoon while it is in the larval stage and keeps it until it finishes pupating. The pace of growth during the pupal stage may be influenced by external stimuli. For instance, it can take up to a year for an insect to emerge from its cocoon if the weather outside is too hot or too humid. Flea eggs are round, roundish, and smooth; their size may reach 0.05 mm. It is normal practice for hosts to lay their eggs in a nest or in the host's immediate vicinity. Females may lay as many as six eggs per day and 300–400 eggs in their lifetimes while their eggs adapt to relatively high humidity (Gage and Fleas, 2005). The normal development time for an egg is two weeks.

Fleas grow three times larger (from half an inch to three millimeters) when they're larvae. Nine to fifteen days is the typical duration for larval development. In unfavorable environments, nevertheless, its lifespan may reach 200 days (Trivedi, 2003). The duration of this stage of growth is directly influenced by environmental factors and ambient temperature. This period typically lasts between two and nine weeks. When producing eggs, oriental rat fleas prefer temperatures of 65 to 80 degrees Fahrenheit and relative humidity of around 70%. Outside of these ranges, *Xenopsylla cheopis* do not deposit eggs and live longer in general. Since fleas are nidicolous parasites, they often take up residence in hosts' nests, rather than the hosts themselves, where their eggs will eventually hatch. As long as the weather is suitable for laying eggs, *Xenopsylla cheopis* may reproduce at any time of year. *Xenopsylla cheopis* adults can endure temperatures between 45 and 50 degrees Fahrenheit for as long as 100 days. Under ideal circumstances, *Xenopsylla cheopis* may live for up to a year. A longer life span makes *Xenopsylla cheopis* more likely to survive, which is bad news for public health as it increases the likelihood of disease transmission (Brown, 1969). Fleas on adult oriental rats prefer temperatures between 65 and 80 degrees Fahrenheit. Extreme heat or cold is bad for *Xenopsylla cheopis*. *Xenopsylla cheopis* may inadvertently host people at these temperatures since they are so near to the average human body temperature. Fleas are a major pain because they may hop from host to host and nest to nest thanks to their remarkable leaping abilities. The vertical leap of an oriental rat flea may reach a height of around twelve inches. The southwest Texas area has seen an uptick in cases of murine typhus, which is spread by fleas. On November 30, 2017, the Texas Department of State Health Services issued a typhus health warning, urging all healthcare professionals to enhance their clinical the suspicion of individuals who have symptoms similar to a fever. Scientists have long hypothesized that changes in weather patterns throughout the world, brought about by human-caused global warming, are a driving force behind this pandemic. The likelihood of interactions between humans, domestic animals, and wild animals rises when it rains. The number of cases of murine typhus might be affected by the meteorological phenomena. According to Bitam et al. (2010), *Xenophilia cheopis* (2018), and Azad and Beard (1998), fleas, namely *Xenopsyllia cheopis* and *Ctenocephalides felis*, are the vectors that spread the disease. Fleas are symbiotic with these bacteria. Rodents (*Rattus* spp.) are the main host species. Infected flea feces may be breathed or rubbed into the skin and mucous membranes to spread the bacterium. When it invades endothelial cells, it damages their membrane and induces swelling, which is its primary pathogenic consequence. Murine typhus has no immunizations. Avoiding mice and other animals, both wild and domestic, and practicing good personal cleanliness are ways to avoid contracting the illness (Azad et al., 1997; Azad, 1990). In the mid- 1950s, the number of cases in the US dropped to 100 due to the use of DDT and the control of rats (Blanton et al., 2016). A number of counties in Texas have recently seen an uptick in the annual case count, according to the state health services department. As far as county counts go, Bexar, Cameron, Galveston, Harris, Hidalgo, Nueces, Tarrant, and Webb have all seen bigger increases. From 157 in 2008 to 738 in 2018, the annual case count in Texas rose significantly. On November 30, 2017, a Typhus Health Alert was issued by the Texas Department of State Health Services (Burridge et al., 1977). In order to determine the most effective model for studying flea growth, this research aims to create an application of path analysis to examine the variables impacting the presentation of murine typhus in South Texas from 2017 to 2019. Statistically speaking, this work is valuable as it clarifies how route analysis may be used to investigate biological processes. The work is important from an epidemiological perspective because shifts in the relationship between fleas and their hosts, as well as changes in the environment and human behavior, may cause flea-borne illnesses to resurface in epidemic form. In order to avoid and control an epidemic presentation of the illness, it is essential to study and determine the elements that govern its manifestation. The prediction model shown in Figure 1 mirrors a literature review on the subject (Blanton et al., 2016; Mobeen et al., 2023; Azad et al., 1997; Bitam et al., 2010; Azad and Beard, 1998) about the ways in which each element promotes the spread of murine typhus illness. Factors that influence flea growth include environmental fleas, vectors of transmission, temperature, and precipitation. Disease may spread if flea development occurs when pets are around.



**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 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

disease; the natural history of the flea cycle; reported cases (confirmed and not confirmed); weather data; and

Variable

-----  
 0                      1                      2

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

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

*Statistical Tools*

For continuous scale or interval data like transmission sources, average temperature, precipitation, and flea development rate, the Pearson product-moment correlation or pearson *r* was used. Flea populations, pet ownership, and typhus cases are all examples of binary, category, or dichotomous data that were analyzed using Spearman rho correlation. A tentative model for the relationships between the variables was developed using the correlation values and a route diagram. The findings of the literature research and the correlation were both taken into account while formulating the hypothesis. Based on it, three types of route diagrams were suggested. The hypothesis that flea development rate mediates the relation between rickettsia flea in the environment and the contraction of typhus disease was tested using logistic regression path analysis in SPSS process macro v3.5. The independent variables were sources of transmission and the covariate was the presence of pets in the household. The interaction term was the presence of pets as a moderating effect (Hayes and Aut, 2018). The route diagram models also include other moderating elements, like as precipitation and average temperature, which influence the flea development rate. Within the moderated mediation models, the process macro offers estimations of the path coefficients ( $\beta$ ) and standard error (se) together with a bootstrapped 95% confidence interval. By using the process macro, we can examine the hypothesized causal relationship between the dependent and independent variables, as well as the direct and indirect impacts of mediating and moderating factors.

**Results**

From May 2017 through September 2019, the following data is shown in Table 2: murine typhus cases, average temperatures, precipitation, and flea development.

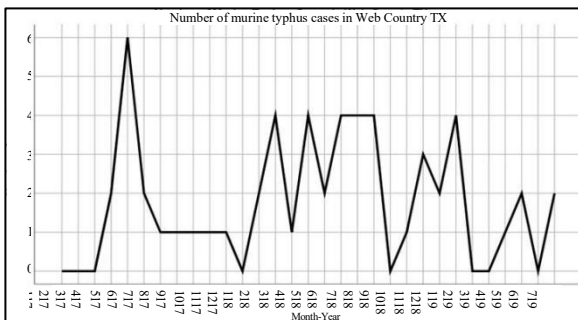
From May 2017 to September 2019, Figure 2 shows the spread of murine typhus cases.

The findings of Špitalská (2016), who determined the tick time range, are corroborated by Table 2 data. Adult flea activity peaked between April and May and September and October, with the former showing far stronger dominance. During the months of May to July and September to October, nymph activity increases, with spring activity being particularly prominent (18).

The variables that were included in the research were found to have a binary association, as shown in Table 3. Using the SPSS procedure, three models were created and studied to see which one was most compatible with (Hayes and Aut, 2018): Different models. The three models that were examined and shown in Figures 4-6 are those that used moderation-mediation route analysis.

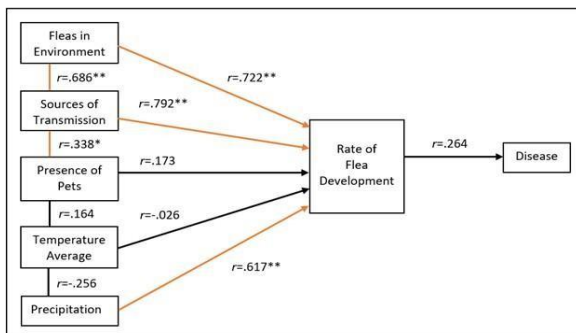
**Table 2:** Summary of murine typhus cases, temperature average, precipitation and flea development from May 2017 to September 2019

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



Number of cases

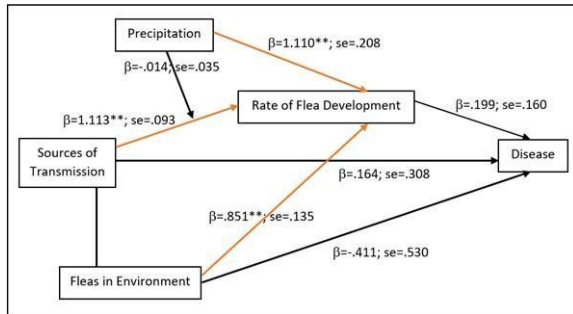
**Fig. 2:** Number of murine typhus cases in Webb County, TX



**Fig. 3:** Preliminary path model using correlation results

**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

There is no direct correlation between climatic factors and the occurrence of murine typhus cases, according to the data in Table 1 and Figure 2. Figure 2 displays the murine typhus cases recorded in May 2017 and September 2019, illustrating that the mere presence of precipitation does not always impact the presentation of cases. Figure 3 shows that when comparing May and September 2017, there is no clear relationship between temperature changes and the number of incidents. Nevertheless, a pattern emerged when combining the three factors. Fleas in the environment and vectors of transmission are significantly correlated in Table 2 ( $r = .686$ ;  $p < .01$ ). When we examine the connection between flea growth rate and environmental fleas, we find a positive and statistically significant correlation ( $r = .722$ ;  $p < .01$ ). There is a positive and statistically significant association between the rate of flea development and both the sources of transmission ( $r = .792$ ;  $p < .01$ ) and precipitation ( $r = .617$ ;  $p < .01$ ), according to the correlation findings. In addition, there is a strong correlation between the existence of family pets and the source of transmission ( $r = .338$ ;  $p < .01$ ), according to the data. The preliminary route model shown in Figure 3 was developed based on the correlation data.

### 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 ( $\beta = -.014$ ;  $se = .035$ ).

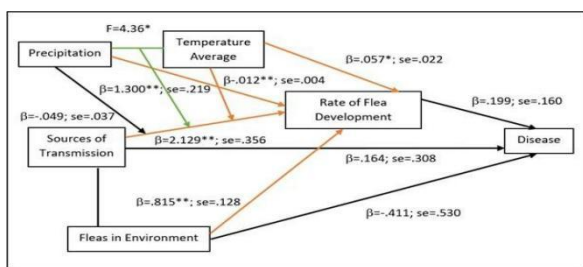
Part 2 of model 1: The model is not significant,  $p < .2149$ . The sources of transmission have no significant direct effect on disease contraction ( $\beta = .164$ ;  $se = .308$ ). The flea in the environment has no significant direct effect on the contraction of the disease ( $\beta = -.411$ ;  $se = .530$ ). 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,  $p < .0000$ .

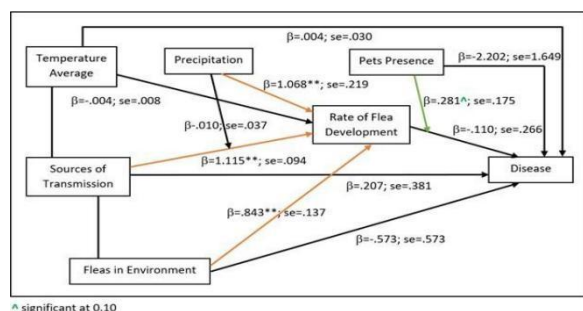


**Fig. 5:** Path analysis following SPSS macro model 2

Precipitation significantly affects the rate of flea development ( $\beta = 1.300^{**}$ ;  $se = .2186$ ). The moderating interaction or effect of precipitation with sources of transmission on rate of flea development is not significant ( $\beta = -.049$ ;  $se = .037$ ). Temperature significantly affects the rate of flea development ( $\beta = .057^{*}$ ;  $se = .022$ ). The moderating interaction or effect of temperature average with sources of transmission on rate of flea development is significant ( $\beta = -.012^{**}$ ;  $se = .004$ ). 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 ( $\beta = 2.129^{**}$ ;  $se = .356$ ). Fleas in the environment significantly affect the rate of flea development ( $\beta = .815^{**}$ ;  $se = .128$ ).

Part 2 of model 2: The model is not significant,  $p < .2149$ . Sources of transmission have no significant direct effect on disease contraction ( $\beta = .164$ ;  $se = .308$ ). Fleas in the environment has no significant direct effect on the path analysis model ( $\beta = -.411$ ;  $se = .530$ ). 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  $-.010$  (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.



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

Part 2 of model 3: The model is not significant,  $p < .2437$ . Sources of transmission have no significant direct effect on disease contraction ( $\beta = .207$ ;  $se = .381$ ) Fleas in the environment have no significant direct effect on the path analysis model ( $\beta = -.573$ ;  $se = .573$ ). Temperature average has no significant direct effect on the path analysis model ( $\beta = .004$ ;  $se = .030$ ). Rate of flea development has no significant mediation effect between sources of transmission and disease contraction ( $\beta = .110$ ;  $se = .266$ ). The presence of pets in the patient's household has no significant effect on disease contraction ( $\beta = -2.202$ ;  $se = 1.649$ ). The moderating interaction or effect of pets presence with rate of flea development on disease contraction is slightly significant ( $\beta = .281$ ;  $se = .175$   $p = 0.10$ ). 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 ( $\beta = .4531$ ;  $se = .2354$ ) 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 route models have shown potential factors that indicate the facilitation of murine typhus disease transmission. There is a clearer demonstration of Rickettsia flea transmission in Model 3. Models 2 and 3 demonstrate that flea development rate and disease transmission have been enhanced due to changes in precipitation and weather patterns. Another major factor in the spread of illness is the presence of pets. To prevent the transmission of murine typhus illness, it is advised that individuals wash their dogs before being near them or avoid contact with them during rainy seasons. The general public is also encouraged to do a comprehensive house cleaning and look for any potential hiding places for fleas. In order to prevent the possible spread of murine typhus and the number of hospitalizations caused by the illness, the department of health and human services may distribute flyers and set standards for proper home cleaning during rainy seasons.

To make these conclusions, we first examined data acquired from 2017 to 2019. A bigger sample size and analysis of data over several years are required to derive wider findings. According to this hypothesis, weather

The results of the route analysis provide credence to the theory that elements such as wetness and flea activity have a role in the increase in disease cases.

### **Acknowledgment**

This research relies on meteorological data supplied by TAMIU, Laredo, Texas, and epidemiological statistics given by the city of Laredo health department. The writers are grateful for everyone's help with this study and want to continue working together in the future months. At the 68th annual conference of diseases in nature transmissible to Man, which took place in Houston, Texas, May 23-25, 2018, the preliminary work of this research was presented on page 78 of the proceedings as a poster.

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