RESEARCH NOTE

MAPPING CANINE RABIES OCCURRENCE IN PAMPANGA, PHILIPPINES, AND DETERMINING ITS ASSOCIATION WITH TEMPERATURE, RAINFALL, AND HUMIDITY

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ABSTRACT

This study determined the spatial distribution of canine rabies infection from 2014 to 2018 in Pampanga, Philippines by generating a heatmap using QGIS. The association temperature, rainfall, and humidity with canine rabies infection in the province were also determined. Data on canine rabies infections in Pampanga were obtained from the Regional Animal Disease Diagnostic Laboratory. The spatial distribution of canine rabies cases was plotted using QGIS. On the other hand, temperature, rainfall, and humidity data were obtained from the Philippine Atmospheric, Geophysical, and Astronomical Services Administration. Rabies cases in Pampanga were seen to increase from 2014 to 2018. Higher rabies cases were observed in February to June than in any other month. The spatial distribution of canine rabies infections in Pampanga is scattered throughout the province. No clustered patterns were observed. Of climatic parameters tested, only rainfall showed a significant negative relationship with the number of canine rabies cases in the province. This study suggests that rabies cases in Pampanga increased from 2014 to 2018. No clear pattern of rabies cases is shown in the generated heat map. Only rainfall showed a significant association with canine rabies cases in climatic factors.

Keywords: *rabies, QGIS, GIS, rainfall, temperature, humidity*

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INTRODUCTION

Rabies is a highly fatal viral disease caused by *Lyssavirus*. This disease is usually transmitted from the bite of rabid animals such as cats and dogs. However, other warm-blooded mammals such as raccoons, skunks, and foxes also carry the same virus, leading to the same infection when transmitted to humans through bites. Aside from the usual bite exposure, rabies may also be transmitted to humans by other means such as contamination of virus-laden saliva to scratches, open wounds and intact mucosa, aerosols, exposure to caves with infected bats, corneal transplantation, and also due to any laboratory exposure. Research studies have shown that yearly, human deaths due to rabies are approximately 59,000 in over 150 countries wherein most cases are mainly concentrated in Africa and Asia. In the Philippines, rabies is a significant threat to public health and is responsible for many deaths annually of which most of the cases are involve children 15 years old below. Even with best efforts to control rabies in the Philippines, many problems are still faced by the national government. These include lack of standardized diagnostic tests, inadequate

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enforcement of laws and policies by local government units (LGUs), insufficient funds for rabies vaccines, high cost of treatment, poor access and compliance to treatment, and dependence on traditional healers (Barroga *et al.*, 2018; Centers for Disease Control and Prevention, 2019; Rupprecht, Kuzmin, and Meslin, 2017; World Health Organization, 2020).

When clinical symptoms start to appear, rabies is almost fatal. Still, with on-time and accurate post-exposure prophylaxis (PEP) that includes wound washing, vaccine, and in some instances administration of rabies immunoglobulin (RIG), death is almost entirely preventable. However, access to PEP is limited in many countries and when available, is often costly. In nine of 23 (39%) countries, rabies vaccine was provided free of charge and is readily available to the public sector. In 10 of 23 (43%) countries, some, if not all, patients in the public sector were required to pay for the vaccine of which a single dose ranges from US$ 6.60 to US$ 20. The identified reason for the high price is the lack of funding to subsidize vaccine costs (Rysava *et al.*, 2019; Sreenivasan *et al.*, 2019). In the Philippines, the main program aimed to eliminate rabies by 2020 is overseen by the National Rabies Committee consisting of the Department of Agriculture - Bureau of Animal Industry (DA-BAI), Department of Health (DOH), Department of Interior and Local Government (DILG), Department of Education (DepEd), and Department of Natural Resources (DENR). The program organized a multi-sectoral rabies approach per LGU that focuses on dog immunization, anti-rabies human immunization, and creating rabies awareness (Department of Health, 2012, 2018; Leonardo *et al.*, 2020). Yet, even with the programs set by the national government, the target of rabies elimination by the year 2020 may unlikely be achieved. This may be due to the lack of implementation of LGUs on the recommended policies (Leonardo *et al.*, 2020). One possible way of controlling and preventing human rabies infections is by managing canine rabies infection which can be achieved by determining the incidence of animal infections in the locale. This may be accomplished by using geographic information systems (GIS).

GIS are types of spatial data management systems associated with specific geographic features. They can easily be described as smart maps that simulate real-world events to the users. One key feature of GIS is that spatial data represented are related to specific descriptive data (Robinson, 2019; Van Kreveld, 2017). Such systems generate information regarding data associated with the location for collection, management, storage, processing, analysis, and visualization in a digital environment (Abbott and Argentati, 1995; Fradelos *et al.*, 2014). These information systems vastly impact public health and several studies have already been conducted that use this technique (Bui and Pham, 2016; Mahara *et al.*, 2016; Pakzad *et al.*, 2018; Ramezankhani, Hosseini, Sajjadi, Khoshabi, and Ramezankhani, 2017; Zambrano *et al.*, 2017). These researches are mainly conducted to predict and simulate diseases in a locale through various models. In addition, GIS plays a vital role in disease surveillance, management, and analysis. GIS provides tools for analyzing and visualizing epidemiological data which depicts a more straightforward interpretation of trends and correlation due to the images generated (Cromley, 2003). Hence, GIS development and its potential application in disease surveillance may be used to better monitor and manage diseases and health programs.

Conducting such GIS-based modeling studies for the prevalence of canine rabies infection would be important to public health since rabies infection remains a threat to human health in the region. Research on climate-sensitive health outcomes in developing countries with tropical climates is limited. Studies show that the developmental pattern of diseases can be affected by climatic variability. The relationship between climatic factors and diseases may reflect a critical implication for climate change adaptation strategies and public health decisions (Phung *et al.*, 2018). Different weather conditions are documented to significantly affect infectious diseases (Polgreen and Polgreen, 2018). Several studies have observed that there is a seasonal trend in rabies cases (Courtin, Carpenter, Paskin, and Chomel, 2000; Domingo and Mananggit, 2014). Hence, weather conditions can be used to provide additional insights into the planning and implementation of rabies control programs (Lachica *et al.*, 2020).

However, even if there are published data regarding human rabies infections, limited data on animals, specifically canine rabies infection, are available online. However, limited data on animal distribution and climatic factors with rabies infections in the Philippines is available. Hence, this study will determine the spatial distribution of canine rabies cases in Pampanga, Philippines and its association with climatic factors such as temperature, rainfall, and humidity. The distribution of canine rabies infection from 2014 to 2018 in the province of Pampanga will be determined by developing a heat map using QGIS. This would help monitor the trend of confirmed canine rabies cases that could support the development of programs and even policies to mitigate the possible transmission of the viral infection to humans. On the other hand, the association of climatic factors with the occurrence of rabies infections was conducted through the statistical treatment of the obtained data.

MATERIALS AND METHODS

Study Design

A retrospective research design was used in this study wherein data of confirmed canine rabies infections in Pampanga, Philippines (by municipality and including Angeles City) were obtained from the Regional Animal Disease Diagnostic Laboratory (RADDL). The RADDL, manned by licensed veterinarians, provides essential services vital to developing the livestock and poultry industry in Central Luzon. Its services include accurate diagnostic tests, such as confirmation of animal rabies, that serve as a basis for therapeutic, prophylactic, control, and eradication measures of disease outbreaks (Department of Agriculture, 2020). The RADDL reports of rabies infections were confirmed using Direct Microscopic Examination (DME), the screening test, Fluorescent Antibody Testing (FAT), the confirmatory or gold standard test. A sample is declared rabies positive if it shows greenish fluorescence in FAT (if the confirmatory lesion or reaction in any two tests). Samples with incomplete records were removed from the database.

On the other hand, climatic data such as temperature, rainfall, and relative humidity were requested from the Philippine Atmospheric, Geophysical, and Astronomical Services Administration (PAG-ASA). The data obtained were from the Clark Freeport Zone satellite of the agency and covered the entire province of Pampanga. All data collected cover the years 2014 to 2018.

Data Collection and Storage

Data provided by both the RADDL and PAG-ASA were encoded in a Microsoft Excel spreadsheet and stored in a password-protected cloud storage. Only the researchers involved in the study had access to the data. Information such as the name of the canine's owner was coded for anonymity. Other data not relevant to the study were disregarded so as to strongly adhere to the Data Privacy Act of 2012.

Data Processing and Analysis

Once data were finalized, summary statistics were derived and spatial distribution was determined through QGIS. QGIS was used to create heatmaps from the aggregated Pampanga rabies positive canines from 2014 to 2018. For the heatmap generation, centroids of the polygons were determined using the built-in centroid tool found under the vector tab of QGIS. Since there are no exact locations provided for the positive cases, the generated centroids of the barangay polygons were used in plotting the cases in the heatmap as the location where the positive case was recorded. The 1500m for the radius of influence of each point was used in reflecting the positive cases. The association of yearly rabies occurrence with the yearly temperature, rainfall, and humidity in the province of Pampanga was determined using Spearman's correlation.

RESULTS AND DISCUSSION

From the data obtained from the RADDL, most animals tested from 2014 to 2018 are canine (n=423). Other animals were also tested in the laboratory, and some tested positive for rabies, such as felines (n=14) and porcine (n=1). The summary of the animals that tested for rabies from the RADDL database is summarized in Table 1 and Figure 1.

Based on Table 1, it can be observed that cases of canine rabies infection sharply increased from 2014 to 2018 even with the efforts of the national government in controlling and eliminating rabies in the Philippines. The increasing number of canine rabies infections may also lead to an increase in human rabies infections. Data from the National Rabies Prevention and Control Program (NRPCP) shows a 13.5% increase in positive human rabies cases from 243 cases in 2009 to 276 in 2018. Among the regions, Central Luzon has the highest number of cases from 2015 to 2018 and even shows an increase of 100% from 29 in 2015 to 58 in 2018 (Department of Health Philippines, 2019). The alarming cases may be attributed to the country lagging behind the 70% vaccination coverage target at any location to achieve herd immunity (Singh, 2018). Inadequate funding is also a reason for the failure of the country's early efforts to eliminate rabies (Department of Health Philippines, 2019).

From the data on canine rabies infection obtained, a line graph highlighting the distribution of canine rabies cases per month from 2014 to 2018 was generated (Figure 1). A previous

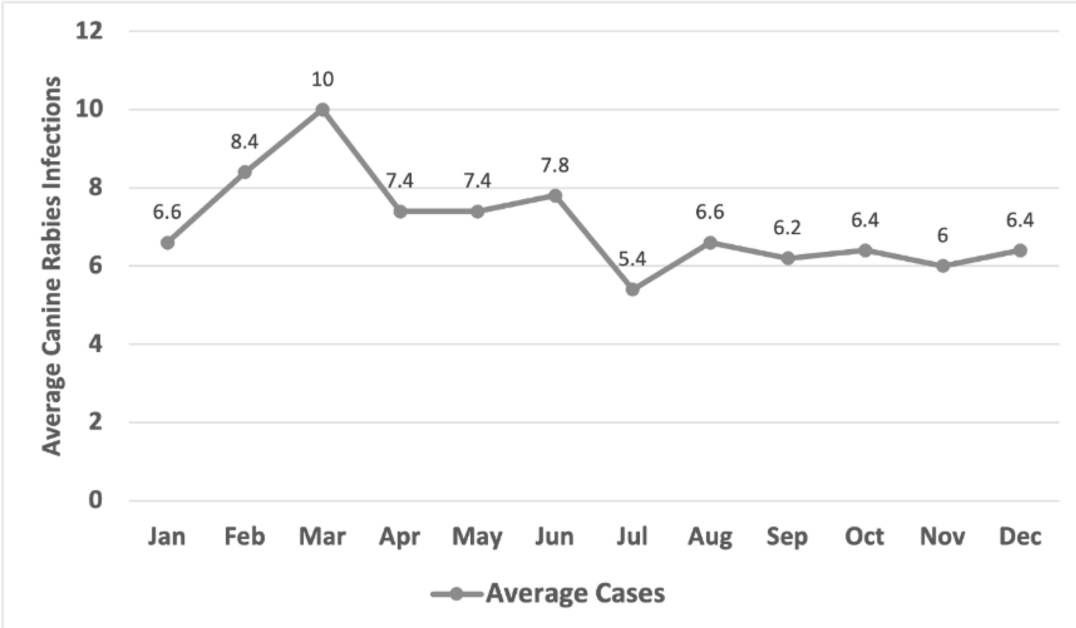

Figure 1. Monthly canine rabies infections (n=423) from 2014-2018.

Table 1. Frequency of Animal Rabies Infections in the RADDL from 2014 to 2018.

Animal	2014	2015	2016	2017	2018	Total
Canine	42	87	76	94	124	**423**
Feline	1	1	0	7	5	**14**
Others	0	0	0	1 (Porcine)	0	**1**

study noted that animal rabies cases in Central Luzon are higher from January to May (Domingo and Mananggit, 2014). As observed in this study, higher canine rabies cases are observed during February to June than in other months. The months where higher canine rabies cases are recorded coincide with the dry season of the Philippines (December to May) which is similar to the findings of Domingo and Mananggit in 2014. One probable reason is that the dry season is also the mating season of animals, and when precipitation is low, animals usually disperse (Courtin *et al.*, 2000; Wera, Mourits, and Hogeveen, 2015).

A heatmap of the spatial distribution of the rabies cases per year from 2014 to 2018 was generated using QGIS (Figure 2). Based on the heatmap, canine rabies infections are scattered throughout the province. No clustered patterns are observed in each of the generated map. It can be noted that barangays Dolores, Maimpis, and Pulung Maragul have the highest intensity of positive cases.

The descriptive summary of weather parameters is shown in Table 2. The mean rainfall is 173.64 mm (sd=185.29 mm), the mean temperature is 27.91 °C (sd=1.32 °C), and as for humidity, the mean is 74.83% (sd=7.47%). On the other hand, Table 3 presents the correlation of the number of rabies cases and the following weather parameters. Of the three parameters considered, only rainfall was significantly correlated with the number of rabies cases (p=0.04). Rainfall negatively affects the number of rabies cases which means that higher rainfall is associated with fewer rabies cases. In comparison, a lower rainfall is associated with higher cases

Based on the correlation results, a significant negative relationship is observed between rainfall and canine rabies infections. This suggests that as the amount of rainfall increases, the cases of canine rabies decrease. As also depicted in Figure 1, high cases of canine rabies infections are observed during the rainy seasons in the country. Other studies conducted in the Philippines also show the same findings. A study

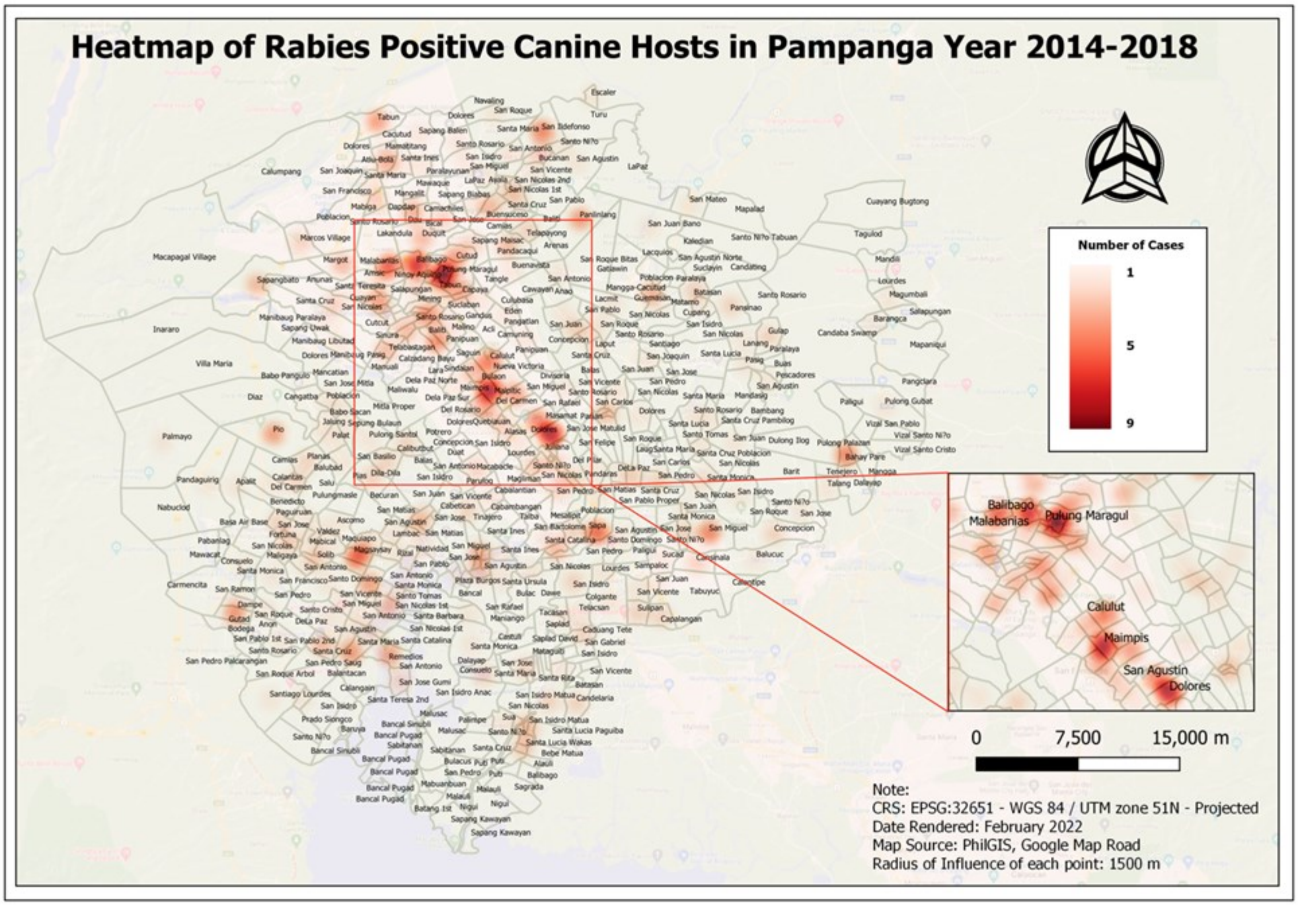

Figure 2. Spatial distribution of canine rabies positive cases (n=423) in Pampanga, Philippines from 2014 to 2018.

Table 2. Descriptive summary of weather parameters from 2014 to 2018 in the province of Pampanga.

PARAMETER	Mean	SD
Rainfall (mm)	173.64	185.29
Temperature (°C)	27.91	1.32
Humidity (%)	74.83	7.47

Table 3. Spearman's correlation of number of rabies cases with weather parameters.

PARAMETER	Spearman correlation coefficient	*p*-value
Rainfall	-0.270	0.04*
Temperature	0.092	0.49
Humidity	-0.256	0.05

* significant at *p*-value < 0.05

conducted in Davao City suggests that dog impounding, precipitation, and the presence of responsibly owned dogs are significantly associated with decreasing number of reported rabies cases (Lachica *et al.*, 2019). In addition, Abcede *et al.* in 2017 mentioned that during the rainfall season, dogs tend to be more comfortable, roam less, and can be found in predictable locations thus, reducing the transmission of the virus (Abcede, Agnas, and Aliño, 2017). Inversely, animals and humans are freer to roam around during dry seasons. Pregnant dogs start giving birth at the beginning of the year which results in a larger number of young dogs in the first quarter (Domingo and Mananggit, 2014).

Domingo and Mananggit (2014) also mentioned that the temporal distribution of canine rabies might be a strategic period for implementing control programs (Domingo and Mananggit, 2014). In this case, interventions such as vaccination and impounding may be carried out during the rainy seasons with low rabies cases due to less dog movements. Vaccinations at this point will build up immunity before the coming months of high rabies cases. Aside from vaccination, dog impounding may also be implemented to further control rabies cases in the province.

Overall, the findings show that canine rabies cases in Pampanga increased from 2014 to 2018, especially from February to March. In addition, the study has depcicted that there is an association between canine rabies cases and the amount of rainfall. This may indicate that rabies cases in the province are weather-sensitive. These results may be utilized in the implementation of rabies control strategies and interventions in the province based on the time and weather patterns observed, such as the intensification of rabies vaccination during dry seasons. However, given the limitations of the study namely: (1) data collected are only secondary data; (2) canine rabies data were provided by the RADDL and may not accurately represent the actual cases in the entire province since these are only testing those that were taken to the laboratory; (3) relative frequencies cannot be calculated since there are no existing records of animal population data in the locale; and (4) the heatmaps generated only made use of estimated locations since no exact address was provided, care should be taken when interpreting these results.

STATEMENT ON COMPETING INTEREST

The authors have no competing interests to declare.

AUTHOR'S CONTRIBUTION

RET, NT, MLL, and RBJ conceptualized, designed, and implemented the study. RET, NT, MM, MLL, PJM, and RB were all involved in the acquisition of the needed data. All authors participated in the analysis and interpretation of the data and writing of the initial draft of the paper. All authors also edited the paper and approved its version for submission to the journal. RBJ supervised the research team in the implementation of the study. The study received funding from the Commission on Higher Education K-12 Program under the DARETO (Discovery- Applied Research and Extension Trans/Interdisciplinary Opportunities) program.

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