Spatio-temporal Analysis of Animal Rabies Cases in Negros Occidental, Philippines from 2012 to 2018

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Rabies is a dangerous and deadly zoonotic disease that infects domestic and wild animals and is transmissible to humans. Animal rabies, particularly of canine and feline type, is considered to be a serious threat to public health. Thus, all prevention and control efforts to reduce the cases of human rabies are stemming from the identification of high-risk communities where presence of canine or feline rabies cases are prevalent. Having recorded the highest number of cases in recent years, this research utilized the spatio-temporal analysis of animal rabies cases in Negros Occidental, Western Visayas, Philippines. The hotspot analysis was based on Getis-Ord-Gi* statistic to estimate statistically significant hotspots of animal rabies cases in the province. Mean center and standard deviational ellipse were performed to identify the epicenter, dispersion, and yearly directional trends of animal rabies cases. The emerging hotspot analysis based on the Getis-Ord-Gi* and Mann-Kendall statistics was performed to identify statistically significant clusters with significant temporal trend. Spatial analysis identified the major cities such as Bacolod City and Bago City and their surrounding cities and municipalities to be of high risk to animal rabies cases from 2012 to 2018. The epicenter of cases is slowly shifting from the northern part in earlier years towards the central part of the province in recent years. Twenty-six (26) space-time clusters of animal rabies cases in Negros Occidental were found to have “intensifying”, “consecutive”, “oscillating”, and “sporadic” time trends. Two clusters classified as “new” hotspots were identified in the central part of the province. Results presented in this study could be of service for rabies cases surveillance, and in developing care and prevention programs for rabies control.

Keywords: animal rabies, spatio-temporal analysis, zoonosis, rhabodoviruses

1. Introduction

Rabies is an infectious and zoonotic disease caused by a virus belonging to the genus *Lyssavirus* and family *Rhabdoviridae*. It is a highly fatal disease throughout the world. The World Health Organization (WHO) estimated that 59,000 humans die annually in over 150 countries because of rabies, with 95% of the cases occurring in Africa and Asia (WHO, 2018).

In the Philippines, rabies remains a public health concern despite the efforts in addressing the problem. According to the recent report of WHO Western Pacific Region Office (WPRO), the Philippines is among the top 10 countries with the highest incidence of rabies worldwide with an estimate of 200 to 300 deaths annually (WPRO, 2019).

Dogs and cats are the most common reservoir of rabies virus in the majority of human rabies cases worldwide. The virus is transmitted to humans through bite by an infected animal or by direct exposure of virus-laden saliva on mucosal surfaces such as breaks in the skin, lips, mouth, and eyes (WHO, 2018). In a veterinary public health practice, there is always a direct linkage between the occurrence of rabid dogs and cats and incidence of human rabies, so as the reduction of canine and feline rabies is correlated with the reduction of rabies in humans (Burgos-Caceres, 2011). Therefore, majority of the mitigation efforts against rabies, if not all, is aimed at the important source of infection such as dogs and cats. Creation of local ordinances regarding dogs and cats control measures, vaccination of dogs and cats, and education on responsible pet ownership are some of the most cost-effective measures against rabies that has been done in the Philippines.

A distinct problem was seen in Negros Occidental in recent years. The province has been experiencing an uneasy situation on both human and animal rabies cases which posted the highest number of human rabies deaths from 2013 to 2018 among the six provinces in Western Visayas (Guadalquiver, 2019). Annual reports on human rabies deaths in the province is continuously increasing with notable outbreaks every year since 2010. In addition, Negros Occidental has ranked number one among the provinces in the country with the highest number of positive animal rabies cases in 2017 and 2018.

In January 2019, Negros Occidental has stepped up its efforts as means to reduce, if not eliminate, human and animal rabies with the implementation of 2019 Rabies Control Action Plan. With the established linkage between the density of rabid animals and incidence of human rabies, the action plan pushes to reduce primarily the number of animal rabies cases in the province.

Part of the goals of 2019 Rabies Action Plan is to intensify the data gathering particularly on the population of dogs and cats in every city and municipality of Negros Occidental. In line with this, the action plan has set to formulate a risk-based map of high-risk barangays based on the prevalence of animal rabies cases (Nicavera, 2019). Mapping out the distribution and trend of animal rabies cases could play a big role in the proper allocation of both human and material resources by prioritizing high-risk barangays. In this way, the Negros Occidental Provincial Health Office (PHO) could properly and effectively sort out cost-effective programs and activities to critical hotspot areas rather than the whole province which may save efforts and provincial funds.

The main objective of this research is to examine the spatial and temporal patterns of animal rabies cases in Negros Occidental from 2012 to 2018. The main objective hopes to coincide with one of the strategies of the 2019 Rabies Control Action Plan which is to formulate a risk-based pattern of disease based on the prevalence of animal rabies cases. Studying the spatial and temporal patterns of animal rabies cases could provide an insight of the natural dynamics of the disease. This study could be extremely useful for public health professionals, policy makers, and health systems to accurately optimize and formulate integrated control and prevention strategies for both human and animal rabies in the province. This is a pioneering document which could serve as a reference for the 2019 Rabies Action Plan to attain its goal.

2. Method

2.1. Study setting

The province of Negros Occidental is the target area for this study including its cities, municipalities, and barangays (see Figure 1). It is one of the provinces of Western Visayas region, with a total land area of 792,607 hectares or approximately 40% of the land area of the region. A total of 540,385.62 hectares or 68% of the province's land area are considered as alienable and disposable lands while 32% is classified as forestland (DENR, 2019). Negros Occidental has 19 municipalities, 13 cities, and 662 barangays.

2.2. Data collection procedure

Data on the cases of animal rabies cases in Negros Occidental is obtained from the Provincial Veterinary Office (PVO) located in Bacolod City. The data is at the case level, each of which includes information regarding the date of infection and place of incidence. The place of incidence is detailed down to the barangay level.

2.3. Data processing and analysis

Each case of animal rabies was georeferenced to the centroid of barangay according to the indicated location of incidence. The point locations of incidence were plotted using the QGIS version 3.6 (QGIS, 2019). The cumulative incidence was aggregated and mapped at a municipal level to obtain an initial intuition of areas where the animal rabies cases were most concentrated.

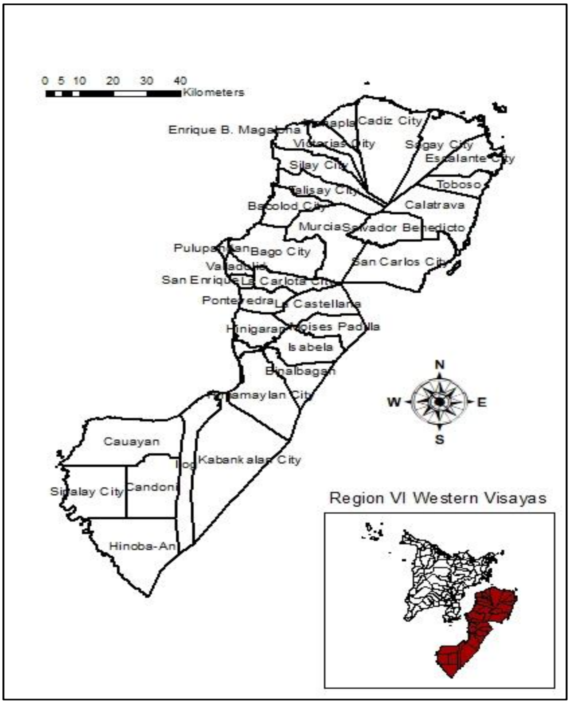

Figure 1. Map of Negros Occidental

2.4. Analysis of spatial and temporal patterns of animal rabies cases

The Getis-Ord-Gi* Hotspot Analysis was used to estimate the statistically significant clusters of high values or hotspots of animal rabies cases for the years 2012 to 2018. The Getis-Ord-Gi* statistic for each feature was obtained using the following formula by Getis and Ord (1992):

$$G_i^* = \frac{\sum_{j=1}^{n} w_{i,j} x_j - \bar{X} \sum_{j=1}^{n} w_{i,j}}{s\sqrt{\frac{\left[n\sum_{j=1}^{n} w_{i,j}^2 - \left(\sum_{j=1}^{n} w_{i,j}\right)^2\right]}{n-1}}} \tag{1}$$

where x_j is the attribute value for feature j, $w_{i,j}$, is the spatial weight between feature i and j, n is equal to the total number of features; while:

$$\bar{X} = \frac{\sum_{j=1}^{n} x_j}{n} \tag{2}$$

$$S = \sqrt{\frac{\sum_{j=1}^{n} x_j^2}{n} - \left(\bar{X}\right)^2} \tag{3}$$

The G_i^* statistic for each feature is a z-score. The larger the z-score, the more intense the clustering of high values or can be considered to be a hotspot. The smaller the z-score, the more intense is the clustering of low values or can be classified as cold spot.

The minimum number of point input features for Getis-Ord-Gi* Hotspot Analysis to be confidently reliable is 30 (Getis and Ord, 1992). This study utilized 126 animal rabies cases which concludes that the point input features are adequate enough to attain reliable results.

The Global Moran's I was used in a series of increasing distances to determine the neighborhood distance at which the highest spatial clustering could be found. The Moran's I statistic for spatial autocorrelation is given by (Getis and Ord, 1992):

$$I = \frac{n}{S_0} \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} w_{i,j} z_i z_j}{\sum_{i=1}^{n} z_i^2} \tag{4}$$

where z_i is the deviation of an attribute for feature i from its mean (x_i-$\bar{X}$), $w_{i,j}$ is the spatial weight between feature i and j, n is equal to the number of features. S_0 is the aggregate of all the spatial weights, given by:

$$S_0 = \sum_{i=1}^{n} \sum_{j=1}^{n} w_{i,j} \tag{5}$$

The z_I-score for the statistic is then computed as:

$$Z_I = \frac{I - E[I]}{\sqrt{V[I]}} \tag{6}$$

where

$$E[I] = \frac{-1}{n-1} \tag{7}$$

$$V[I] = E[I^2] - (E[I])^2 \tag{8}$$

The Mean Center together with the Standard Distance were performed to locate the epicenter of animal rabies cases from 2012 to 2018. The mean center is the average x and y coordinates of all the point locations of animal rabies cases in the province. It is given by:

$$\bar{X} = \frac{\sum_{i=1}^{n} x_i}{n}, \bar{Y} = \frac{\sum_{i=1}^{n} y_i}{n} \tag{9}$$

where x_i and y_i are the coordinates for cases i, and n is equal to the total number of cases.

The comparison of central tendency, dispersion, and directional trend of animal rabies cases for each year were done using the Standard Deviational Ellipse. The standard deviational ellipse is given by:

$$C=\begin{pmatrix} var(x) & cov(x,y) \\ cov(y,x) & var(y) \end{pmatrix}=\frac{1}{n}\begin{pmatrix} \sum_{i=1}^{n}\tilde{x}_i^2 & \sum_{i=1}^{n}\tilde{x}_i\tilde{y}_i \\ \sum_{i=1}^{n}\tilde{x}_i\tilde{y}_i & \sum_{i=1}^{n}\tilde{y}_i^2 \end{pmatrix} \tag{10}$$

where

$$var(x)=\frac{1}{n}\sum_{i=1}^{n}\left(x_i-\bar{x}\right)^2=\frac{1}{n}\sum_{i=1}^{n}\tilde{x}_i^2 \tag{11}$$

$$cov(x,y)=\frac{1}{n}\sum_{i=1}^{n}\left(x_i-\bar{x}\right)\left(y_i-\bar{y}\right)=\frac{1}{n}\sum_{i=1}^{n}\tilde{x}_i\tilde{y}_i \tag{12}$$

$$var(y)=\frac{1}{n}\sum_{i=1}^{n}\left(y_i-\bar{y}\right)^2=\frac{1}{n}\sum_{i=1}^{n}\tilde{y}_i^2 \tag{13}$$

wherein x and y are the coordinates for the cases i, $\{\bar{x}, \bar{y}\}$ represents the mean center of the cases and n is the total number of cases. The standard deviations for the x and y axes are then derived by factoring the sample covariate matrix into a standard form which results in the matrix being represented by its eigenvalues and eigenvectors:

$$\sigma_{1,2}=\left(\frac{\left(\sum_{i=1}^{n}\tilde{x}_i^2+\sum_{i=1}^{n}\tilde{y}_i^2\right)\pm\sqrt{\left(\sum_{i=1}^{n}\tilde{x}_i^2-\sum_{i=1}^{n}\tilde{y}_i^2\right)^2+4\left(\sum_{i=1}^{n}\tilde{x}_i\tilde{y}_i\right)^2}}{2n}\right)^{1/2} \tag{14}$$

The researchers used the standard deviational ellipse of 1 which covers approximately 63% of the cases derived from the Rayleigh distribution.

Emerging Hotspot Analysis was performed to identify statistically significant clusters with significant temporal trend of animal rabies cases. The analysis is based on the Mann-Kendall test to statistically assess if there is a monotonic upward or downward trend of rabies cases over time (Mann 1945, Kendall

1975, Gilbert 1987). The Mann-Kendall test is based on the assumption that the observations obtained over time are independently and identically distributed when no trend is present, not serially correlated over time. The Mann-Kendall test was performed as follows (Gilbert, 1987):

1. Listing the data in order in which they were collected over time, $x_1, x_2, \ldots, x_n$, which denote the measurements obtained at period 1, 2, … , n, respectively;
2. Determination of the sign of all $\frac{n(n-1)}{2}$ possible differences $x_j - x_k$, where $j > k$;
3. Defining $sgn(x_j - x_k)$ be an indicator function, where:

$$sgn\left(x_j - x_k\right) = \begin{cases} 1, x_j > x_k \\ 0, x_j = x_k \\ -1, x_j < x_k \end{cases} \tag{15}$$

4. Computation of the S statistic by:

$$S = \sum_{k-1}^{n-1} \sum_{j-k+1}^{n} sgn\left(x_j - x_k\right) \tag{16}$$

5. Computation of the variance of S statistic by:

$$VAR(S) = \frac{1}{18}\left[n(n-1)(2n+5) - \sum_{p-1}^{g} t_p(t_p - 1)(2t_p + 5) \right] \tag{17}$$

   where g is the number of tied groups and t_p is the number of observations in the pth group;

6. Computation of the Mann-Kendall statistic, Z_{MK}, as follows:

$$Z_{MK} = \begin{cases} \frac{S-1}{\sqrt{VAR(S)}}, & S > 0 \\ 0, & S = 0 \\ \frac{S+1}{\sqrt{VAR(S)}}, & S < 0 \end{cases} \tag{18}$$

   A positive value of Z_{MK} indicates an increasing trend while a negative value indicates that the data tend to decrease with time.

7. Testing of hypothesis where null hypothesis H_0 is the absence of monotonic trend. The H_0 is rejected if $|Z_{MK}| \geq Z_{1-\alpha/2}$ in a two-tailed alternative hypothesis H_a which pursues to examine the presence of either upward or downward

monotonic trend, where $Z_{1-\alpha}$ is the $100(1-\alpha)^{th}$ percentile of the standard normal distribution and α is Type I error rate. For a one-sided H_a, H_0 is rejected if $Z_{MK} \geq Z_{1-\alpha}$ when H_a examines the presence of upward monotonic trend, and if $Z_{MK} \leq -Z_{1-\alpha}$ when H_a examines the presence of downward monotonic trend, at Type I error rate.

The researchers used a temporal size of 2 months which is the average incubation period for animal rabies (Plotkin, 2000) and the neighborhood distance with the highest autocorrelation. The researchers used the categories suggested by the Environmental Systems Research Institute (ESRI, 2016) to describe the temporal pattern of each study location (Table 1). The spatio-temporal analysis was performed using Spatial Statistics, Spatial Analyst, and Space Time Pattern Mining Toolsets of ESRI ArcGIS version 10.5 (ESRI, 2011).

Table 1. Temporal Pattern Categories (ESRI, 2016)

Pattern	Description
No pattern detected	Does not fall into any of the hotspot or cold spot patterns
New hotspot	Statistically significant hotspot for the final time step and has never been a statistically significant hotspot before
Consecutive hotspot	Location with single uninterrupted run of statistically significant hotspot in the final time step intervals; the location has never been a statistically significant hotspot prior to the final hotspot run and less than 90% of all time intervals are statistically significant hotspots
Intensifying hotspot	Location that has been statistically significant hotspot for 90% of the time step intervals; the intensity of clustering of high counts in each time step is increasing overall and that increase is statistically significant
Sporadic hotspot	Location that is on-again and off-again hotspot; less than 90% of the time step intervals have been statistically significant hotspots and none have been statistically significant cold spots
Oscillating hotspot	Statistically significant hotspot for the final time step interval that has a history of being a statistically significant cold spot during prior time step

3. Results

3.1. Nature of animal rabies in Negros Occidental

A total number of 126 cases of animal rabies were reported in the province of Negros Occidental from 2012 to 2018, majority of which are of canine type comprising 98.4% of the total cases (Table 2). Bacolod City ranks first with the highest number of cases from 2012 to 2018, followed by Himamaylan City, Bago

City, and Cauayan (Figure 2). The highest number of animal rabies cases was recorded in 2018 with 26.2% of the total cases (Table 3). In terms of monthly incidence, animal rabies is at the maximum during the month of March followed by the number of cases during the months of February, April and June (Table 4).

Table 2. Animal Rabies Cases, by Animal Type, 2012 to 2018

Type	Frequency (%)
Dog	124 (98.4)
Cat	2 (1.6)
Others	0 (0.0)

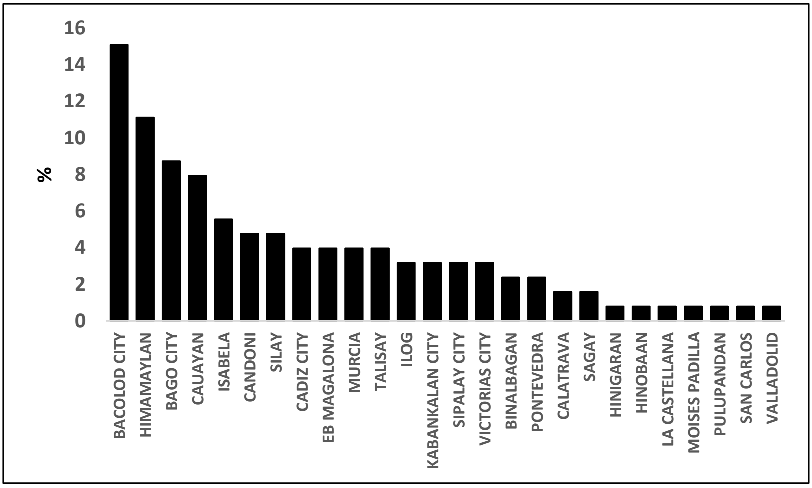

Figure 2. Animal Rabies Cases per Municipality, 2012 to 2018

Table 3. Distribution of all Animal Rabies Cases in Negros Occidental from 2012 to 2018

Year	Frequency (%)
2012	6 (4.8)
2013	10 (7.9)
2014	22 (17.4)
2015	13 (10.3)
2016	20 (15.9)
2017	22 (17.5)
2018	33 (26.2)

Table 4. Distribution of all Animal Rabies Cases in Negros Occidental per Month, 2012 to 2018

Months	Frequency (%)	Months	Frequency (%)
January	10 (7.9)	July	8 (6.3)
February	13 (10.3)	August	11 (8.7)
March	16 (12.7)	September	7 (5.6)
April	13 (10.3)	October	12 (9.5)
May	8 (6.3)	November	12 (9.5)
June	13 (10.3)	December	3 (2.4)

3.2. Spatial and temporal patterns of animal rabies cases

Through mapping out all the 126 animal rabies cases in Negros Occidental from 2012 to 2018, the accumulation was found within the neighboring major cities such as Bacolod City, Bago City, Talisay City and Silay City (Figure 3). Least number of clustering of animal rabies cases were found in the north-eastern and south-eastern part of the province.

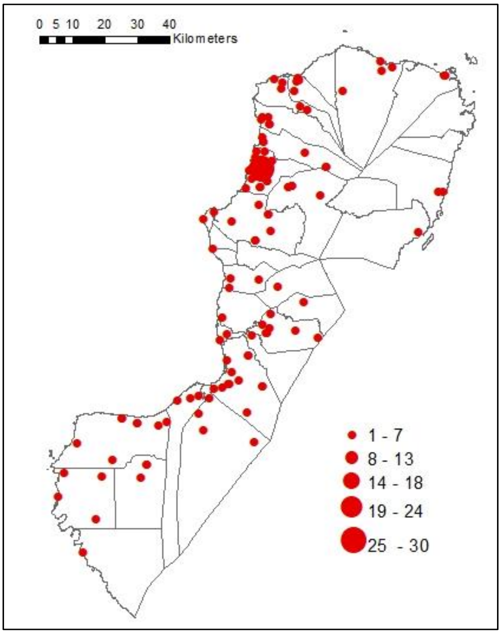

Figure 3. Distribution Map of Animal Rabies Cases, Negros Occidental, 2012 to 2018

The Global Moran's I or spatial autocorrelation test was performed as an initial step towards the investigation of spatial patterns of animal rabies cases. The test was used to determine the neighborhood distance with the highest spatial clustering. Table 5 shows the results of spatial autocorrelation test.

As shown in Table 5, the Moran's I statistics of animal rabies cases obtained different results across neighborhood distances ranging from 20 to 46 kilometers. It was found that the cases were clustered at a neighborhood distance of 46 kilometers which exhibited a positive and more statistically significant Moran's I in contrast with other neighborhood distances. Utilizing this as a reference for the neighborhood distance for autocorrelation, the researchers used the neighborhood distance of 46 kilometers for the succeeding analysis.

Table 5. Spatial Autocorrelation by Distance

Distance (km)	Moran's Index	z-score	p-value
20	0.020	1.279	0.201
23	0.022	1.499	0.133
26	0.019	1.514	0.130
29	0.014	1.441	0.150
32	0.013	1.461	0.144
35	0.011	1.458	0.145
38	0.001	1.473	0.141
41	0.011	1.651	0.099
43	0.011	1.818	0.069
46	0.010	1.914	0.055

The Hotspot Analysis revealed significant clusters of animal rabies cases in Negros Occidental (Figure 4A). It was found that 19 cities and municipalities were classified to be statistically significant hotspots of animal rabies cases located on the major cities of Negros Occidental and their surrounding municipalities.

The central tendency of the ellipse of animal rabies cases for 2012 to 2018 was located in the northern part of the municipality of Pontevedra, about 30 kilometers further from the epicenter of the hotspot (Figure 4B).

Ellipses of standard deviation show the directional trend of animal rabies cases from 2012 to 2018 (Figure 5). The ellipses showed that in 2012 to 2013, the spatial trends of animal rabies were lying on the axis of northwest-southwest. In 2014 and 2015, the ellipses shifted on the northern part covering mostly the major cities of Negros Occidental such as Bacolod City and Bago City. The ellipses, however, showed different spatial trends between these periods. The spatial trend of animal rabies cases in 2014 was lying on the axis of southwest-northeast thus including the cities of Cadiz, Sagay, and some parts of Escalante, Taboso, and Calatrava. In contrast, spatial trend of animal rabies was lying on the axis southeast-northwest in 2015 concentrating on the major cities of the province. The standard deviational ellipse of animal rabies cases in 2016 to 2018 shifted on the mid-western part of the province. The central tendencies during those periods are located more on the central part of the province than in previous years.

Thus, outbreak distribution of animal rabies cases was mainly observed in the northwestern part from 2012 to 2015, and has slowly shifted to the central part of the province in subsequent years.

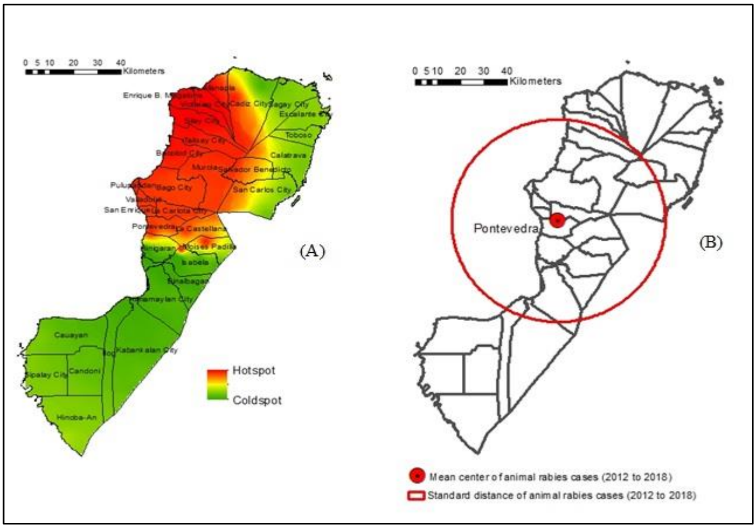

Figure 4. (A) Animal rabies cases hotspots derived from Getis-Ord-Gi* Hotspot Analysis; (B) Mean center and standard distance (size 1 standard deviation) of animal rabies cases, Negros Occidental, 2012 to 2018

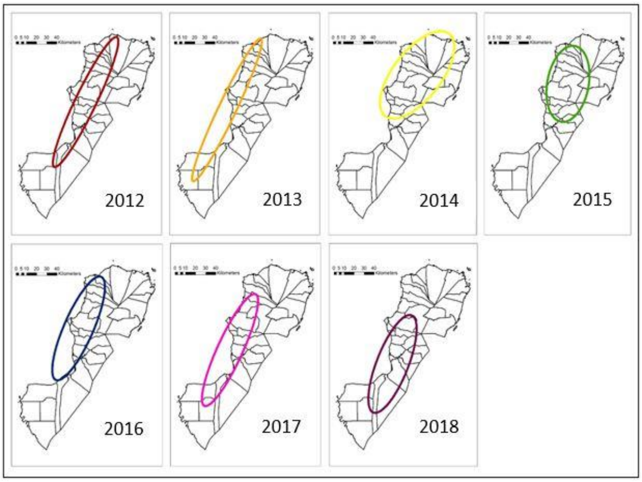

Figure 5. Directional Distribution (size 1 standard deviation) of Animal Rabies Cases from 2012 to 2018, Negros Occidental

Emerging Hotspot Analysis (Figure 6) revealed 5 types of animal rabies hotspots in Negros Occidental. The first type is the “intensifying” hotspot defined as a place that has been statistically hotspot for 90% of the time. This is an area with cases in almost every year in the whole time frame and should be given the utmost importance. A total of 3 intensifying hotspots were identified spanning 44 barangays in Bacolod City and 3 barangays in Bago City. “Consecutive” hotspot is the second type identified defined as a place with a single uninterrupted run of statistically significant hotspot in the final time step less than 90% of the time and never have been a statistically significant hotspot prior. A total of 8 clusters covering 33 barangays in Silay City, Talisay City, Murcia, Binalbagan, Hinigaran, and Himamaylan City were identified as consecutive hotspots. Eleven clusters of “sporadic” hotspots were located in Bacolod City, Talisay City, Silay City, Murcia and Himamaylan across 39 barangays. These are places that are on-again off-again hotspots and less than 90% of the time are statistically significant hotspots. “Oscillating” hotspots, a statistically significant hotspot for the final time interval less than 90% of the time with a history of being a statistically significant cold spot, were found in 3 barangays in Himamaylan City. In addition, analysis revealed 2 clusters of “new” hotspots, a location that is statistically significant hotspot in the last time step and have never been statistically significant hotspot earlier, placed in the central part of the region specifically in Hinigaran and Isabela spanning 11 barangays. The appearance of “new” hotspots coincides with the directional trend (Figure 5) showing that animal rabies cases are slowly shifting towards the central part of the province in recent years.

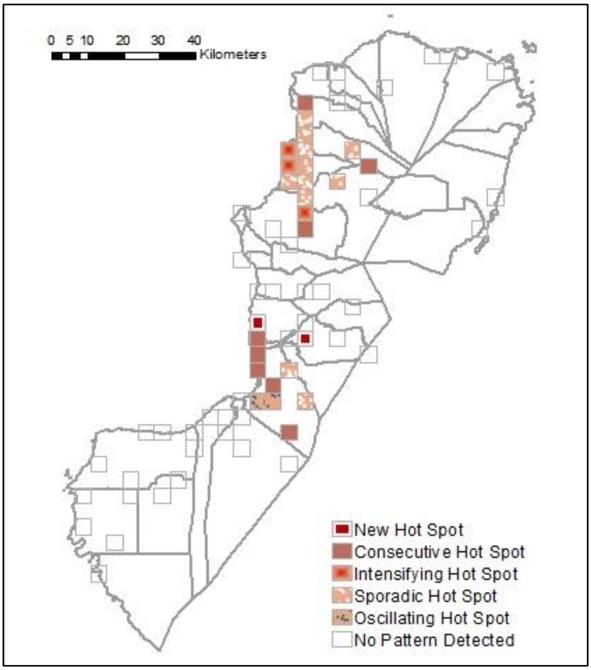

Figure 6. Emerging Hotspot Analysis of animal rabies cases, Negros Occidental, 2012 to 2018

Table 6. List of Barangays with Intensifying, Consecutive, Oscillating, Sporadic, and New Hotspot Trend, Negros Occidental

Hotspot Trend	Municipalities	Barangays		
Intensifying	Bacolod City	Aliijis Banago	Barangays 1 to 40 Singcang-Airport	Taculing
	Bago City	Abuanan, Damsite, Dulao		
Consecutive	Silay City	Balaring Barangay 1 Barangay 2	Barangay 6 (Poblacion) Cabatangan	Lantad Rizal
	Murcia	Alegria, Buenavista, Canlandog		
	Bago City	Atipuluan, Bacong-Montilla, Ma-ao Bario		
	Hinigaran	Cambugsa		
	Binalbagan	Canmoros Enclaro Marina Paglaum	Progreso San Juan San Pedro San Teodoro	Santo Rosario San Vicente
	Himamaylan City	Aguisan Barangay 4 Buenavista Carabalan	Mambagaton Nabali-an San Antonio	Sara-et Talaban
Oscillating	Himamaylan City	Caradio-an, To-oy, San Antonio		
Sporadic	Silay City	Barangay 2 Barangay 3 Rizal	Barangay 4 Barangay 5	Guinhalaran
	Talisay City	Bubog Zone 1 to 15 Efigenio Lizares	Matab-ang Katilingban	San Fernando Cabatangan
	Bacolod City	Bata Mandalagan Estefania Villamonte Vista Alegre	Tangub Pahanocoy Sum-ag Cabug	Handumanan Mansilingan Felisa
	Murcia	Cansilayan Dulao Damsite Allegria	Santa Cruz Blumentritt Zone 1 Zone 5	Salvacion Abo-Abo Buenavista
	Binalbagan	Bi-ao		
	Himamaylan City	Cabadiangan, Carabalan		
New	Hinigaran	Barangay 1 to 4 Tagda	Nanunga Pilar	Narauis
	Isabela	Rumirang Barangay 1 to 9	Bulad Maytubig	Himaya Gargato

4. Discussion

This study examined the spatial and temporal patterns of animal rabies cases in Negros Occidental from 2012 to 2018. The emerging hotspot analysis which is based from the Getis-Ord-Gi* statistic and Mann-Kendall statistic, and the standard deviation ellipse were utilized to attain the goals of the study.

The data suggests that most of the animal rabies cases occurred between February to May, when the country experiences dry season. This coincides with the study of Courtin et. al. (2000) indicating dry season as a risk factor for the incidence of animal rabies. The same trend was also reported in Central Luzon in a study conducted by Domingo and Mananggit (2014). One plausible explanation is that the reproductive season of dogs coincides to the season of the place, in which the female dog becomes overprotective of the puppies and tends to attack any animal or human that may get near them (Domingo and Mananggit, 2014).

The monthly estimates of animal rabies cases could serve as a basis to forecast the months where rabies transmission usually occur. The evidence of estimation from the descriptive analyses can be incorporated in the decision-making process of healthcare managers as to when the interventions may be appropriately conducted. This anticipation is essential for both control and prevention of animal rabies which allow the entire population to take timely action. With an effective response prior the dry season, the incidence of animal rabies cases as well as its impact to healthcare and economic systems could be lowered.

Through mapping out all the cases from 2012 to 2018, the accumulation was found within the neighboring cities of the province such as Bacolod, Bago, Silay and Talisay. These cities have a combined total population of 962,000 which is almost one-third of the total population of Negros Occidental (PSA, 2019). We can therefore undertake that the density of animal rabies cases could be possibly dependent on population density of residents. This is supported by a similar study by Hunt et. al. (2018) on the spatio-temporal analysis of rabies in Tennessee in which highly populated areas were noted to have the highest densities of rabies.

The mean center location of all cases from 2012 to 2018 was found in the municipality of Pontevedra. Being the balance point of all the cases, the mean center location could serve as the strategic place where an intervention facility could be effectively located to accommodate all cases across the province. This information enables the PHO of Negros Occidental to allocate human and material resources more effectively in Pontevedra to better engage in all communities in prevention and control activities on animal rabies.

The directional trend of animal rabies cases from 2012 to 2018 was determined by utilizing the standard directional ellipse. It was found that the epicenter of cases is slowly shifting from the northwestern part during the earlier years towards the central part of the province in subsequent years. With the directional trend now on hand, the PHO has already the capacity to keep track of the animal rabies cases in the province, monitor and evaluate the effectiveness of animal rabies prevention and control programs of previously affected municipalities. This also enables health services to implement early interventions towards the central part of the province.

Emerging Hotspot Analysis revealed 26 space-time clusters of animal rabies cases in Negros Occidental found to have "intensifying", "consecutive", "oscillating", and "sporadic" time trends. In addition, 2 clusters were classified as "new" hotspots located in the central part of the province. As the emerging hotspot analysis hopes to provide spatial and temporal patterns of animal rabies cases, the healthcare managers can utilize the generated patterns for preparations of interventions and control strategies in the province. A risk-based map formulated in this study could play a big role in the proper allocation of both human and material resources by prioritizing high-risk barangays. In this way, the PHO could properly and effectively sort out the programs and activities to critical hotspot areas rather than the whole province which may save efforts and provincial funds.

The determination of spatial and temporal patterns of animal rabies cases could be of huge impact to the attainment of the goals of 2019 Rabies Control Action Plan in Negros Occidental. The findings can be useful for making decisions on the efficient allocation of control efforts. Future mitigation strategies such as programs and policies on animal rabies, and vaccination facilities would greatly benefit from the detection of spatial and temporal patterns.

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