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## Frequency of typhoon occurrence accounts for the Poisson distribution of human leptospirosis cases across the different geographic regions in the Philippines

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### ABSTRACT

**Objective:** To study the distribution of human leptospirosis cases across the different geographic regions in the Philippines in 2015-2017 and to determine the relationship between the frequency of typhoon occurrence and human leptospirosis cases. **Methods:** Information on the frequency of leptospirosis cases and typhoon occurrence across the different regions in the Philippines from 2015 to 2017 was retrieved from the databases of the Department of Health and the Philippine Atmospheric, Geophysical, and Astronomical Services Administration, respectively. Descriptive measures on the prevalent cases and occurrence of typhoons across the different regions were summarized. Linear regression analysis was employed to establish the functional relationship between leptospirosis cases and typhoon occurrence. The distribution of human leptospirosis cases was assessed using the Poisson distribution. **Results:** The frequency of typhoon occurrence accounted for the significant linear variation in the geographic distribution of human leptospirosis cases in the Philippines ( $P < 0.001$ ). Moreover, the human leptospirosis cases obeyed a Poisson distribution ( $\lambda = 6.89$ ,  $P < 0.001$ ). **Conclusions:** The Philippines has frequently experienced severe weather perturbations such as typhoons resulting in flooding and subsequently increasing the risk of transmitting bacterial infections including leptospirosis. Information obtained regarding the determinants and distribution of human leptospirosis will provide better understanding of the disease propagation for subsequent design of optimal disease prevention measures, appropriate resource allocation, effective control strategies, and necessary public health programs.

## 1. Introduction

The Philippines is a third world nation located in Southeast Asia with a land area of 298 170 km<sup>2</sup>[1] and houses over 96.6 million people[2]. Due to the archipelagic nature of this country, surrounding waterways and reservoirs serve as a significant source of livelihood, which residents rely on. However, in recent years, it has become evident that this dependency on available waterways only increased the rate of pollution due to improper waste management practices. The state of the country also cultivated a prime breeding ground

for several viral and bacterial diseases that plague the people of the local community subsequently posing certain health risks. As with several diseases, the living and sanitary conditions of the people largely determine their susceptibility and vulnerability to pathogens. The most notable of these is leptospirosis, which spreads

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through water contaminated with rat urine[3]. Concurrently, in a test conducted in Kanda, Sri Lanka, where leptospirosis is endemic, 73.9% of rats tested were found positive for this disease[4]. This in turn was translated to its prevalence within humans exposed to infested waters which greatly increased the likelihood of contracting the infection, amounting to a further cause for concern. In addition, contaminated water merging with other sources of water, such as rivers, hastens the spread of this disease, as water travels between neighboring communities.

Moreover, the Philippines is often subject to severe weather perturbations such as typhoons which result in flooding with subsequent significant damage in affected areas and increasing risk of possible contraction of leptospirosis. Flooding, as further heightened by the prevalent pollution in the city, increases the risk of transmitting bacterial infections. In terms of flooding as a factor of disease propagation, the spread of leptospirosis rises dramatically during the rainy season in the Philippines with most seropositivity identified in areas involved in agriculture[5]. Moreover, the lack of sanitation in communities exacerbates the propagation of the disease making the residents in the slum areas highly vulnerable to this infection[6]. During heavy rain, water becomes a medium for the spread of waste. Since fecal matter, urine, and other pollutants compromise the safety of waterways, contaminated water can also result from exposed drainage systems, which may be accessed beneath roads. Rat population throughout certain areas also increases the risk of water contamination, as their urine becomes a vector for the propagation of leptospirosis[3]. Due to the relatively unsanitary circumstances present in the environment within the regions of the Philippines, it has become evident that the health of several Filipinos had been severely affected. Several individuals in various age groups are exposed to different pathogens, including *Leptospira* spp., a health hazard which can subsequently affect a person's overall quality of life, rendering the safety and health of those afflicted with waterborne diseases a significant issue. Hence, the present study identified the distribution of human leptospirosis cases across the different geographic regions in the Philippines in 2015-2017. Specifically, a linear functional relationship between frequency of typhoon occurrence and reported human leptospirosis cases was established using the available information from the databases of the Philippine Atmospheric, Geophysical, and Astronomic Services Administration[7] and the Department of Health[8]. Information derived on the determinants and distribution of human leptospirosis cases across the different regions in the Philippines will provide better understanding of the disease propagation and identify high-risk populations of acquiring the infection eventually intended for the design of optimal disease prevention measures, appropriate resource allocation, effective control strategies, and necessary public health programs to reduce disease morbidity and mortality rates.

## 2. Materials and methods

Information on the frequency of leptospirosis cases and typhoon occurrence across the different regions in the Philippines from 2015 to 2017 was retrieved from the databases of the Department of Health[8] and the Philippine Atmospheric, Geophysical, and Astronomical Services Administration[7], respectively.

In order to measure the susceptibility of a region to acquiring leptospirosis, the proportion of cases to regional population per year was computed. Descriptive measures on the prevalent cases and occurrence of typhoons across the different regions were summarized. Moreover, zoonosis is prevalently underreported due to barriers to healthcare experienced by its primary afflicted demographic, those below the poverty line. Thus, these estimates may be used to identify which regions are likely to contract leptospirosis in the four weeks following a typhoon. Only cases reported in the following four weeks of a typhoon were considered since leptospire have an incubation period of 5 to 14 d, with a range of 2–30 d[9]. Linear regression analysis was employed to establish the functional relationship between leptospirosis cases and typhoon occurrence. The distribution of human leptospirosis cases was assessed using the Poisson distribution[10]. Statistical analyses were performed using Microsoft Excel© and STATA© software at 5% level of significance. Spatial analysis on the distribution of cases was described using Quantum GIS 2.18 software (QGIS Development Team).

## 3. Results

Reported frequencies of leptospirosis cases in the Philippines from 2015 to 2017, retrieved from the databases of the Department of Health, were summarized (Table 1). For the year 2015, there was no available information regarding these human leptospirosis cases during the months of September and October. In 2016, there was a complete reporting of these cases. Only reported cases from January to September in 2017, in addition to the reported cases in the previous years, were included for analysis in this paper since data during the last quarter of 2017 were not available to the authors. Hence, the parameter estimates of the regression model and the Poisson distribution reported in this study are descriptions of the only information accessible to the authors.

**Table 1**

Distribution of human leptospirosis cases across the different regions in the Philippines, 2015-2017 (Frequencies of cases retrieved from the databases).

Region	Population[2]	Leptospirosis cases[8] (n, %)		
		2015	2016	2017
I	5 026 128	52(7.99)	315(17.78)	162(10.69)
II	3 451 410	26(3.99)	64(3.61)	74(4.88)
III	11 218 177	179(27.50)	308(17.38)	154(10.17)
IV-A	14 414 774	25(3.84)	136(7.67)	53(3.50)
IV-B	2 963 360	30(4.61)	33(1.86)	6(0.40)
V	5 796 989	32(4.92)	58(3.27)	56(3.70)
VI	4 477 247	72(11.06)	195(11.00)	198(13.07)
VII	6 041 903	20(3.07)	28(1.58)	71(4.69)
VIII	4 440 150	24(3.69)	13(0.73)	86(5.68)
IX	3 629 783	11(1.69)	19(1.07)	18(1.19)
X	4 689 302	26(3.99)	57(3.22)	64(4.22)
XI	4 893 318	33(5.07)	39(2.20)	125(8.25)
XII	4 545 276	5(0.77)	7(0.40)	6(0.40)
ARMM	3 781 387	2(0.31)	2(0.11)	4(0.26)
CAR	1 722 006	7(1.08)	39(2.20)	45(2.97)
CARAGA	2 596 709	12(1.84)	19(1.07)	40(2.64)
NCR	12 877 253	95(14.59)	440(24.83)	353(23.30)
Total	96 565 172	651(100.00)	1 772(100.00)	1 515(100.00)

In 2015, Region VI (Western Visayas) and Region III had 16 leptospirosis cases per 1 000 000 people, while Region I (Ilocos Region) had 10 cases per 1 000 000 people. Region I had 63 leptospirosis cases per 1 000 000 people in 2016, whereas Region VI had 44 cases per 1 000 000 people. In 2017, Region VI remained to have 44 cases per 1 000 000 people, while Region I had 32 cases per 1 000 000 people. However, the National Capital Region (NCR) consistently yielded the highest frequencies of leptospirosis cases notably in the incubation period following the onset of a typhoon, with a peak value of 34 leptospirosis cases per 1 000 000 people in 2016. With the high population density of the region, it rendered significant reduction in the proportion of leptospirosis cases within the region. The distribution of these human leptospirosis cases in the Philippines from 2015 to 2017 was presented in Figure 1.

Moreover, information about the frequencies of typhoons that hit the different regions in the Philippines from 2015 to 2017 and the number of human leptospirosis cases associated with these typhoons were summarized (Table 2). In the present study, only cases reported in the following four weeks of a typhoon were considered since leptospires have an incubation period of 5 to 14 d, with a range of 2–30 d[9]. In 2015, the region with the greatest number of cases was Region III, with 150 cases. On the other hand, Regions XII, ARMM, and CARAGA had no reported cases. Region II had the highest frequency of typhoons, a total of nine, relatively comparable to Region III. However, Region II only had 15 cases of leptospirosis, 4.7% of the total leptospirosis cases in 2015, despite of the given

number of typhoons that hit the area. Moreover, NCR was hit by four typhoons in 2015, and this was associated with 18 cases. In regions that had experienced a similar typhoon frequency, varying leptospirosis case frequencies were recorded. For example, both Region X and Region XII, with numerically comparable populations, were hit by same number of typhoons in 2015, but Region X had six leptospirosis cases, while Region XII had none.

In 2016, Region I had the greatest number of reported leptospirosis cases (a total of 150 cases) and had the highest frequency of typhoons (Table 2). Similarly, Region II had the same typhoon frequency with only 20 cases. On the other hand, Region I had a significant increase in the number of cases (from 32 cases in 2015 to 150 cases in 2016) as there was an increase in typhoon occurrence. Regions IX, XI, XII, and ARMM reported no leptospirosis cases in 2016. These regions, except Region XI, were not hit by any typhoon. Region III had relatively similar number of cases and typhoon frequencies in the years 2015 and 2016. On the other hand, there was a significant increase in the number of leptospirosis cases in NCR despite of relatively the same number of typhoons. In 2017, NCR had the highest number of cases while Region XII and ARMM had none (Table 2). Region IV-B had only three leptospirosis cases even if it was hit by the greatest number of typhoons. Interestingly, Regions I and III had a significant drop in the number of leptospirosis cases from 2016 to 2017.

Results of the linear regression analysis between the occurrence of typhoon and the frequency of leptospirosis cases across the

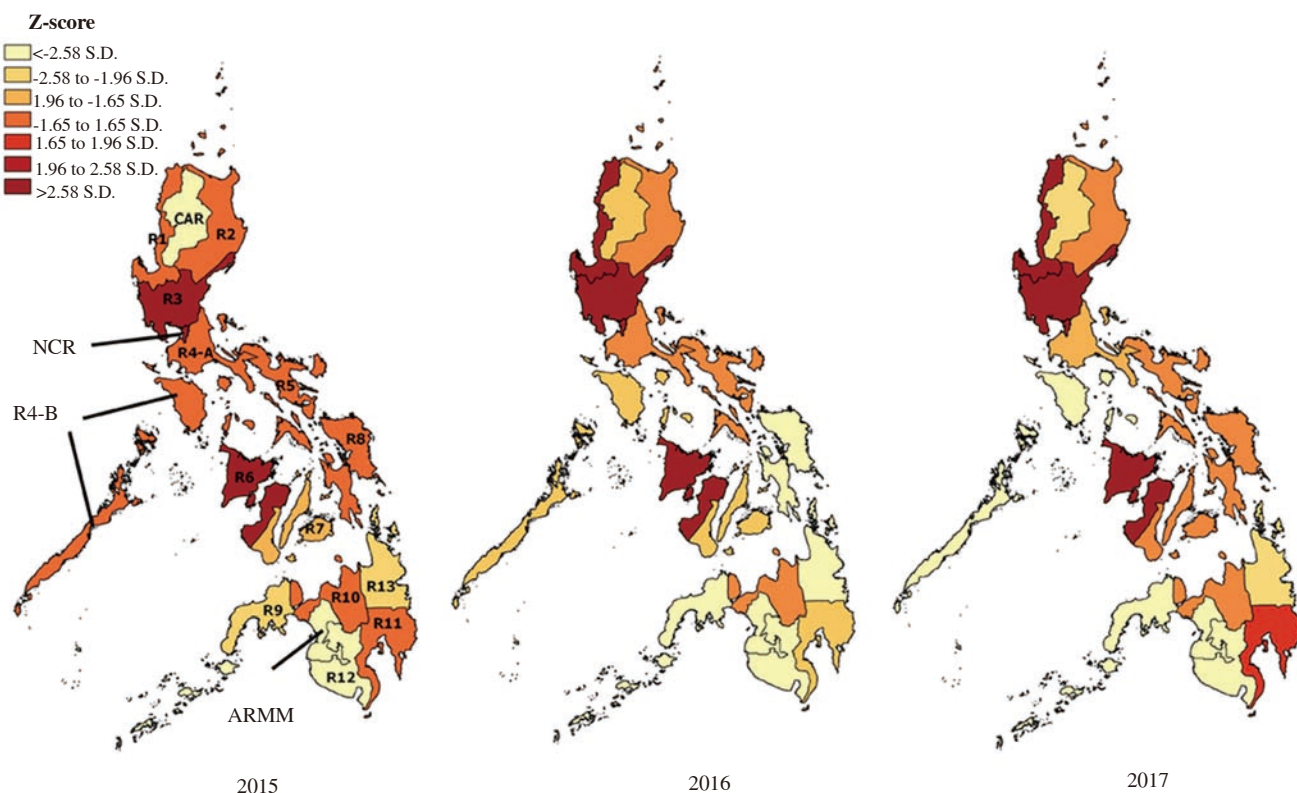


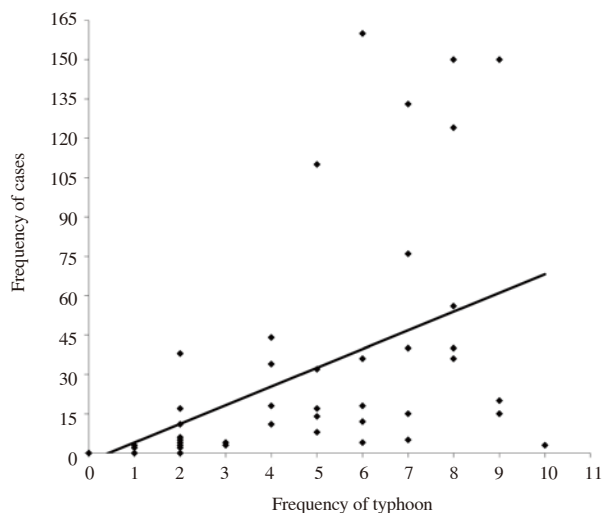
Figure 1. Hotspot analysis of human leptospirosis cases in the Philippines, 2015-2017.

different regions in the Philippines revealed a moderate correlation ( $r=0.4818$ ) (Figure 2). Despite of the moderate correlation obtained, the regression model was identified to be statistically significant ( $P=0.0003$ ). The linear regression equation,  $y=7.13x-3.13$ , is adequate in quantifying the contribution of frequency of typhoon occurrences ( $x$ ) to the frequency of human leptospirosis cases ( $y$ ) in a particular region. Moreover, human leptospirosis cases were determined to have a Poisson distribution ( $\lambda=6.89$ ,  $R^2=0.9604$ ,  $P<0.0001$ ) using the method suggested by Hoaglin[10]. Regarding the typhoon occurrence across the different regions in the Philippines from 2015-2017, with a total of 1 509 reported human leptospirosis cases (Figure 3), the highest likelihood of 15.12% that a region will be hit by 6 typhoons, followed by 7 typhoons with 14.89% probability was identified.

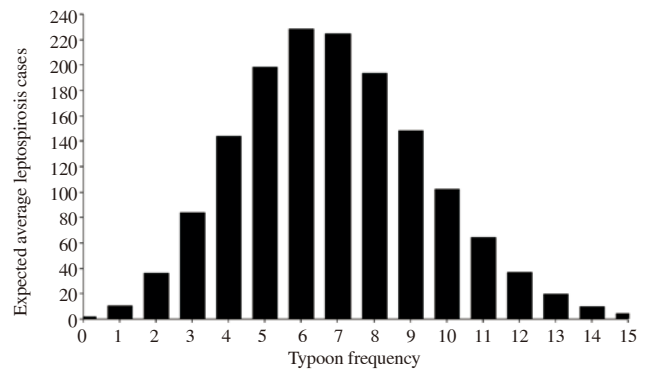
**Table 2**

Frequency of leptospirosis cases during typhoon episodes and frequency of typhoon occurrence across the different geographic regions in the Philippines, 2015-2017 (typhoon-related cases recorded following a typhoon).

Region	Leptospirosis cases			Typhoon occurrences		
	2015	2016	2017	2015	2016	2017
I	32	150	76	5	9	7
II	15	20	15	9	9	9
III	150	133	56	8	7	8
IV -A	12	36	15	6	6	7
IV -B	34	8	3	4	5	10
V	14	40	15	5	8	9
VI	17	44	124	5	4	8
VII	4	4	40	3	2	7
VIII	5	11	36	2	4	8
IX	2	0	2	1	0	2
X	6	11	38	2	2	2
XI	3	0	17	1	1	2
XII	0	0	0	2	0	1
CARAGA	0	3	3	2	2	3
CAR	5	4	18	7	6	6
ARMM	0	0	0	1	0	2
NCR	18	110	160	4	5	6



**Figure 2.** Regression analysis of leptospirosis cases and typhoon occurrence (slope=7.13, intercept= -3.13,  $r=0.4818$ ,  $P=0.0003$ ).



**Figure 3.** Expected frequencies of human leptospirosis cases using the Poisson distribution ( $\lambda=6.89$ ,  $R^2=0.9604$ ,  $P<0.0001$ ,  $n=1509$ ).

#### 4. Discussion

The susceptibility of a particular geographic region in acquiring leptospirosis can be computed as the proportion of cases in a given regional population. In the Philippines, Region I (Ilocos Region) and Region VI (Western Visayas) consistently had the highest proportions of leptospirosis cases. This may be attributed to both regions having topographies with large expanses of coastlines and multiple bodies of water, such as rivers and lakes[11] despite of experiencing varying typhoon cases. Moreover, the NCR consistently yielded the highest frequencies of leptospirosis cases notably in the incubation period following the onset of a typhoon, this is due to slums prevalently being erected within flood plains around Metro Manila which increase the susceptibility of residents to this waterborne disease[6]. However, with the high population density of the region, it rendered significant reduction in the proportion of leptospirosis cases within the region. Another notable situation is seen in the Cordillera Administrative Region with relatively low frequency of cases but with frequent typhoon occurrence experienced by the region yearly. The topography of the region is composed of mountain ranges which lessen the chances of water from pooling and becoming a vector for *Leptospira* spp. In fact, Cordillera Administrative Region is one of the regions with the highest proportion in an antithetical manner to that of NCR due to the relatively low population of the region. Regions with the lowest prevalence of leptospirosis over the past years were Region XIII (SOCCSKSARGEN) and the ARMM. The topography of ARMM is known for its hilly geography, although there are lowland areas like plains[12]. This predominantly highland geography could be a reason for the diminished cases of leptospirosis. Similarly, Region XIII has highland territories interspersed with lowlands[13], with agriculture as its major industry[14]. It is likely that both regions are less susceptible to leptospirosis due to fewer typhoon occurrences, an average of one typhoon per year. Over the years, these computed percentages appeared to be relatively small, and with the absence of global estimates for leptospirosis morbidity and mortality rates, classified leptospirosis a neglected disease[15,16].

The present study determined the functional relationship between

the occurrence of typhoon and the frequency of leptospirosis cases across the different regions in the Philippines in 2015–2017. Despite of the moderate correlation obtained, the regression model was identified to be statistically significant and adequate in quantifying the contribution of frequency of typhoon occurrence to the frequency of human leptospirosis cases in a particular region. The obtained model can possibly generate an underestimate or an overestimate of the observed reported leptospirosis cases in some geographic regions. The moderate strength of correlation was exemplified by a case in 2015, wherein Region III had eight typhoons with 150 cases (predicted 54 cases) suggesting an underestimate. The excess cases were possibly due to other factors, such as the lowland topography of Region III [11]. On the other hand, Region II experienced nine typhoons in 2016 with 20 leptospirosis cases (predicted 61), an overestimate, possibly due to Region II having several mountain ranges and areas of forestland [11].

For prediction purposes, the present study was able to identify the statistical distribution of the human leptospirosis cases as influenced by the frequency of typhoon occurrence. These human leptospirosis cases were determined to have a Poisson distribution. Over the years 2015–2017, a total of 1 509 human leptospirosis cases were reported. On the average, any geographic region in the Philippines is most likely to be hit, on the average, by 6–7 typhoons per year. This suggests further that the likelihood decreases when less than 6 or more than 8 typhoons are expected to hit a particular geographic area. Given that the frequency of typhoon occurrence accounts for the Poisson distribution of human leptospirosis cases in the Philippines, an average of 228 additional cases are expected to be reported in a given region if it is hit by 6 typhoons.

## 5. Conclusion

In this study, the human leptospirosis cases in the Philippines were determined to have a Poisson distribution and there is some functional relationship between the frequency of typhoon occurrence and these human leptospirosis cases. The resulting moderate correlation, possibly due to the variations in the topography, living and sanitary conditions of the different regions in the country, warrants further investigation by incorporating additional information involving the human host's behaviour, practices, and even animal-environment contact patterns. A better understanding of leptospirosis including its determinants and distribution will provide additional information regarding disease propagation and identify high-risk populations of acquiring the infection for the design of optimal disease prevention measures, appropriate resource allocation, effective control strategies, and necessary public health programs.

## Conflict of interest statement

The authors declare that there is no conflict of interest.

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