**Methods:**

**Variables**

The monthly number of rabies cases was used as the primary outcome variable. ARV, MDV, and two climatic variables- temperature and rainfall, and season (Pre-monsoon, Rainy, and Winter) are used as the covariates for the regression analysis.

**Statistical analysis**

We analyzed the monthly rabies incidence, ARV, MDV and meteorological data for the period of 2006-2024. In the first stage, descriptive analysis was conducted to determine the characteristics of rabies cases and deaths with mean, and standard deviation in each year and each month for the entire period. Then, we compared rabies cases, ARV, MDV, and weather parameters in before and after large scale rabies control initiative (2006-2013 and 2014-2024) using paired sample t-test. Then, we compared rabies cases, ARV, MDV, and weather parameters in three major season of Bangladesh (Pre-monsoon, Rainy, and Winter) using ANOVA test.

Next, we calculated the monthly growth factor (GF) of rabies cases by dividing the number of rabies cases reported in each month by the number of rabies cases reported in the previous month and repeating this process for each month from 2006 to 2024 1. The formula for the growth factor can be given by

where indicates the number of rabies cases in th month. To avoid the occurrence of zeros in some months, we added 1 to the total number of cases for each month. This allows us to obtain a real-valued measurement of the GF for the above equation. The distribution of GF was skewed; therefore, we used the first natural log transformation before the data was further examined. However, we have also performed a reverse transformation of the log (GF) values by exponentiating values to convert them to the original scale for ease of interpretation1.  We also conducted a Mann-Kendall (M-K) trend analysis to determine possible upward or downward trends 2. We also performed the Sen's slope test to assess variations in annual rabies cases3.

We, then used a time series count generalized linear model (GLM), more specifically, a time-series Poisson regression model to determine whether the climatic factors were associated with the rabies cases over time 4. The non-normality, heteroscedasticity, and non-linearity that characterize count data can be fitted easily using GLMs. The time-series observations may possess autocorrelation and they might be nonnegative integers, and thus GLM is useful in overcoming both issues [20, 21, 22]. Monthly rabies cases were utilized as the outcome variable in this model, along with data from the Bangladesh Meteorological Department (BMD) on temperature and rainfall. We used the statistical program RStudio, version 3.5.2.2 for the analyses 5.

**Results:**

**Table 1: Comparison of rabies cases, ARV, MDV, and weather parameters between the before large scale rabies control initiative (2006–2013) and after large scale rabies control initiative (2014–2024) in Bangladesh**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | 2006-2013 | 2014-2024 | Total | P-value |
| Monthly Mean Rabies Cases (±Standard deviation [SD]) | 10.82 ± 4.68 | 4.95 ± 2.69 | 7.45 ± 4.68 | <0.001 |
| Monthly Mean ARV used (±SD) | 9072.17 ± 5017.92 | 19751.78 ± 3715.87 | 17287.26 ± 6055.03 | <0.001 |
| Monthly Mean MDV used (±SD) | 2501.12 ± 3936.95 | 19764.41 ± 31997.78 | 16690.12 ± 29780.26 | <0.001 |
| Monthly Mean Total Rainfall (±SD) | 159.22 ± 175.62 | 162.98 ± 163.26 | 161.38 ± 168.27 | 0.870 |
| Monthly Mean Temperature (±SD) | 26.62 ± 3.82 | 30.28 ± 38.76 | 28.72 ± 29.46 | 0.289 |

Between 2006 and 2024, there were a total of 1,902 rabies cases, averaging 7.45 cases per month (standard deviation: 4.68). From 2006 to 2013, there were 1135 cases, with a monthly average of 10.82 cases (standard deviation: 4.68). In the period from 2014 to 2024, there were 767 cases, resulting in a monthly average of 4.95 cases (standard deviation: 2.69).

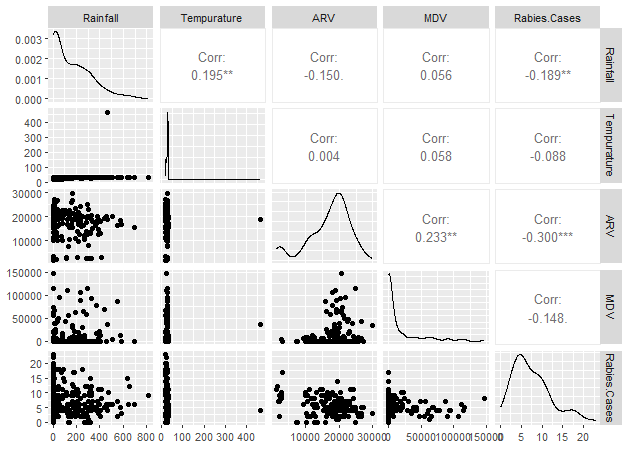
**Table 2: Comparison of rabies cases, ARV, MDV, and weather parameters between three major seasons in Bangladesh**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Pre-monsoon | Monsoon | Winter | Total | P-value |
| Monthly Mean Rabies Cases (±Standard deviation [SD]) | 6.25 ± 4.01 | 6.70 ± 3.88 | 9.34 ± 5.51 | 7.45 ± 4.68 | <0.001 |
| Monthly Mean ARV used (±SD) | 16728.54 ± 6007.1 | 16333.74 ± 5606.15 | 18898.19 ± 6407.58 | 17287.26 ± 6055.03 | 0.059 |
| Monthly Mean MDV used (±SD) | 25215.56 ± 33140.46 | 11771.7 ± 23753.09 | 16453.92 ± 32824.8 | 16690.12 ± 29780.26 | 0.100 |
| Monthly Mean Total Rainfall (±SD) | 145.98 ± 124.67 | 285.68 ± 159.62 | 15.33 ± 28.25 | 161.38 ± 168.27 | <0.001 |
| Monthly Mean Temperature (±SD) | 36.40 ± 57.8 | 29.43 ± 0.77 | 21.9 ± 2.32 | 28.72 ± 29.46 | 0.019 |

During the pre-monsoon season, there were 413 rabies cases, averaging 6.25 cases per month (standard deviation: 4.01). In the monsoon season, a total of 724 cases were reported, with a monthly average of 6.70 cases (standard deviation: 3.88). In winter, there were 765 cases, leading to a monthly average of 9.34 cases (standard deviation: 5.51).



**Figure 1: Number of season wise rabies cases, ARV and MDV recorded in Bangladesh (2006–2024).**



**Fig. 2: Correlation coefficients between various factors for confirmed rabies cases**

The correlation coefficients indicate a statistically significant negative association between rabies cases and ARV, with an r value of -0.300 (p-value < 0.005). Similarly, the correlation coefficients reveal a statistically significant negative association between rabies cases and rainfall, with an r value of -0.189 (p-value < 0.005).



**Figure 3: A) Number of yearly rabies cases, ARV, and MDV (B) Number of monthly rabies cases, ARV and MDV recorded in Bangladesh (2006–2024).**

The highest number of rabies cases was recorded in 2006 (n=167), while the lowest occurred in 2024 (n=28). December had the most cases during the period from 2006 to 2024, with a total of 189 cases, whereas May and July both saw the fewest cases, each with 98.



**Fig 4: (Top) Mean monthly growth factor for the period of 2006–2024. (Bottom) The monthly growth factor for the individual year 2006–2024. The horizontal dashed line indicates monthly growth factor 1 (the same number of rabies cases in 2 subsequent months).**

The overall mean GF for the number of rabies cases per month was 1.12 (SD = 0.70). However, in pre-monsoon (March-May), the average monthly GF was below 1 (0.99), while for the rest of the months, the monthly GF was above 1 (GF of Rainy season = 1.21 and winter season=1.12). Almost 60% (134/225) of months for the period 2006–2024 had mean monthly GF > 1 compared to other months of the same period. August had the highest GF with a mean value of 1.46 indicating that cases would be more than 1.46 times higher in the next month (September). The lowest GF was recorded in May with a mean of 0.82 indicating that cases in June would be lower compared to the number of cases recorded in May (Fig. 2).

**Table 3: The Mann-Kendell trend test of rabies cases in Bangladesh**

|  |  |  |  |
| --- | --- | --- | --- |
| **Test** | **Rabies Cases** | **ARV** | **MDV** |
| **Mann-Kendell trend analysis** |  |  |  |
| Tau | -0.84 | 0.615 | 0.52 |
| p-value | <0.001 | 0.004 | 0.024 |
| **Sen’s Slope (95% CI)** | -7.5 (-9.50 to -5.33) | 16245.83 (6756.11 to 22310.73) | 16342.62 (4386.33 to 25594.67) |



In the M–K trend analysis, we found a negative trend of rabies cases (p-value < 0.001 and tau = -0.84). In Sen’s slope test, the slope was -7.5 (95% CI: −9.50 to -5.33), indicating a significant downward trend.

**Table 4: The incidence risk ratio (IRR) of ARV, MDV, season on rabies cases in Bangladesh using time-series count Generalized Linear Model.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **2006-2013** | | **2014-2024** | | **Total** | |
|  | **Adjusted IRR**  **(95% CI)** | **P-value** | **Adjusted IRR**  **(95% CI)** | **P-value** | **Adjusted IRR**  **(95% CI)** | **P-value** |
| **ARV** | 0.99 (0.99 – 1.00) | 0.202 | 0.99 (0.99 – 1.00) | 0.550 | 0.99 (0.98 - 0.99) | <0.001 |
| **MDV** | 1.01 (0.99 – 1.01) | 0.663 | 0.99 (0.99 – 1.00) | 0.299 | 0.99 (0.99 – 1.00) | 0.318 |
| **Rainfall** | 0.99 (0.99 – 1.00) | 0.327 | 0.99 (0.99 – 1.00) | 0.513 | 0.99 (0.99 – 1.00) | 0.153 |
| **Temperature** | 0.95 (0.86 – 1.04) | 0.239 | 0.99 (0.99 – 1.00) | 0.946 | 0.99 (0.99 – 1.00) | 0.953 |
| **Season** |  |  |  |  |  |  |
| Rainy | 1.31 (0.85-2.08) | 0.229 | 1.08 (0.85-1.38) | 0.514 | 1.01 (0.92-1.40) | 0.242 |
| Winter | 1.09 (0.50-2.34) | 0.832 | 1.35 (1.06-1.72) | 0.015 | 1.34 (1.18-1.79) | <0.001 |
| Pre-monsoon | Reference |  | Reference |  | Reference |  |

Using the GLM, over the period of 2006-2024, we estimated the effect of each variable presented as the incidence risk ratio (IRR). The model indicates that rabies cases would rise by 1% in rainy season than the pre-monsoon season. In addition, the rise of rabies cases high (34%) in Winter season than the pre-monsoon season.

References:

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