**Methods:**

**Data Source:**

**Rabies Data Source**

We included various climate data parameters on a daily scale, such as rainfall (mm) and temperatures (°C), for the period from 2006 to 2024. This data covers eight divisional areas: Dhaka (Lat 23.46, Lon 90.23), Chattogram (Lat 22.16, Lon 91.49), Rajshahi (Lat 24.22, Lon 88.42), Rangpur (Lat 25.44, Lon 89.14), Sylhet (Lat 24.54, Lon 91.53), Barisal (Lat 22.45, Lon 90.20), Khulna (Lat 22.47, Lon 89.32), and Mymensingh (Lat 24.43, Lon 90.26). This data was sourced from the NASA Prediction of Worldwide Energy Resources website (https://power.larc.nasa.gov/data-access-viewer/).

**Variables**

The monthly number of rabies cases was used as the primary outcome variable. ARV, MDV, and two climatic variables- temperature, 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 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 before and after large-scale rabies control initiatives (2006-2013 and 2014-2024) using a paired sample t-test. Then, we used the ANOVA test to compare rabies cases, ARV, MDV, and weather parameters in three major seasons of Bangladesh (Pre-monsoon, Rainy, and Winter). For a more detailed analysis, we employed pairwise comparisons with Tukey's post-hoc test to clarify the relationships between each pair of seasons. 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. 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 | Mean | P-value |
| Annual Mean Rabies Cases (±Standard deviation [SD]) | 129.88 ± 39.23 | 58.00 ± 24.59 | 88.26 ± 47.58 | <0.001 |
| Annual Mean  ARV Used (±SD) | 108866 ± 70860.56 | 237021.4 ± 25166.03 | 207447.1 ± 66860.23 | 0.083 |
| Annual Mean MDV Used (±SD) | 21676.33 ± 21730.58 | 237172.9 ± 183600.1 | 187442.9 ± 185178.3 | 0.004 |
| Annual Mean Rainfall (±SD) | 1787.35 ± 329.08 | 2622.34 ± 762.82 | 2270.76 ± 738.1 | 0.006 |
| Annual Mean Temperature (±SD) | 25.39 ± 0.23 | 25.54 ± 0.46 | 25.48 ± 0.38 | 0.374 |

Between 2006 and 2024, there were a total of 1,902 rabies cases, with annual mean cases of 88.26 (standard deviation (SD): 47.58). From 2006 to 2013, there were 1135 cases, with an annual mean of 129.88 cases (SD: 39.23). In the period from 2014 to 2024, there were 767 cases, resulting in an annual mean of 58.00 cases (SD: 24.59). The annual mean cases for the two periods are statistically significant (P < 0.001).

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

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Pre-monsoon (MM-MM) | Monsoon  (MM-MM) | Winter  (MM-MM) | Total | P-value |
| Seasonal Monthly Mean Rabies Cases (±Standard deviation [SD]) | 6.25 ± 4.01 | 6.70 ± 3.88 | 9.34 ± 5.51 | 7.48 ± 1.74 | <0.001 |
| Seasonal Monthly Mean ARV used (±SD) | 9468.23  ± 8997.03 | 9061.28 ± 8466.25 | 13648.69 ± 10106.91 | 17287.26 ± 1972.5 | 0.059 |
| Seasonal Monthly Mean MDV used (±SD) | 8702.23  ± 19515.64 | 3824.14  ± 10224.12 | 2205.75  ± 6997.05 | 15620.24  ± 8946.46 | 0.108 |
| Seaoanl Monthly Mean Total Rainfall (±SD) | 190.69 ± 164.72 | 325.83 ± 161.53 | 22.26 ± 30.47 | 190.30 ± 160.7 | <0.001 |
| Seasonal Monthly Mean Temperature (±SD) | 28.41 ± 1.8 | 28.01 ± 1.01 | 19.95 ± 2.18 | 25.42 ± 4.32 | <0.001 |

Between 2006 and 2024, there were a total of 1,902 rabies cases, with monthly mean cases of 7.5 (SD: 4.68). During the pre-monsoon season, there were 413 rabies cases, averaging 6.25 monthly mean cases (SD: 4.01). In the monsoon season, a total of 724 cases were reported, with a monthly mean of 6.70 cases (SD: 3.88). In winter, there were 765 cases, leading to a monthly mean of 9.34 cases (SD: 5.51). The monthly mean cases for the three seasons are statistically significant (P < 0.001).

|  |
| --- |
|  |
| Figure: Pairwise comparison of rabies cases by season |

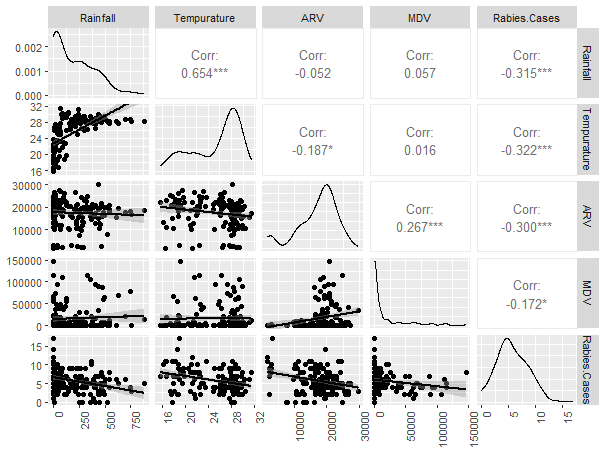
Note: \*\*\* = <0.001, \*\* = <0.01, \* = <0.05, ns = not significant

From the pairwise comparison, we observe that the difference between the monsoon and pre-monsoon periods is not statistically significant (P = 0.495). In contrast, the difference between the monsoon and winter periods is significant (P = 0.006). Additionally, the difference between the pre-monsoon and winter periods is also significant (P < 0.001).



**Figure 1: Number of season-wise rabies cases, ARV and MDV recorded in Bangladesh (2006–2024). 1st Y Axis: Annual mean vaccine for the pre-MDV and post MDV period.**

**2nd Y axis: Annual mean rabies cases**



**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). Include a fitted line (between Rabies cases and other variables: Only in the bottom row. Include R2 value)

Rabies case & Rainfall = Adjusted R-squared: 0.09781

Rabies case & Average Temp = Adjusted R-squared: 0.08114

Rabies case & ARV = Adjusted R-squared: 0.4295

Rabies case & MDV = Adjusted R-squared: 0.07168

MDV & Rainfall = Adjusted R-squared: 0.001342

MDV & Average Temp = Adjusted R-squared: -0.004543

MDV & ARV = Adjusted R-squared: 0.1324

ARV & Rainfall = Adjusted R-squared: -0.0008286

ARV & Average Temp = Adjusted R-squared: 0.004027

Temp & Rainfall = Adjusted R-squared: 0.412



**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.



**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, and season on rabies cases in Bangladesh using a time-series count Generalized Linear Model.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **2006-2013** | | **2014-2024** | | **Total period** | |
|  | **IRR**  **(95% CI)** | **P-value** | **IRR**  **(95% CI)** | **P-value** | **IRR**  **(95% CI)** | **P-value** |
| **MDV** | 0.99 (0.98 – 0.99) | <0.001 | 0.99 (0.99 – 1.00) | 0.273 | 0.99 (0.99 – 1.00) | <0.001 |
| **Rainfall** | 0.99 (0.99 – 1.00) | 0.203 | 0.99 (0.99 – 1.00) | 0.178 | 0.99 (0.99 – 1.00) | <0.001 |
| **Temperature** | 0.98 (0.95 – 1.02) | 0.402 | 1.01 (0.96 – 1.05) | 0.915 | 0.99 (0.96 – 1.02) | 0.599 |
| **Season** |  |  |  |  |  |  |
| Rainy | 0.89 (0.73-1.08) | 0.233 | 0.89 (0.70-1.13) | 0.339 | 0.86 (0.74-0.99) | 0.049 |
| Winter | 1.12 (0.81-1.53) | 0.501 | 1.15 (0.75-1.77) | 0.525 | 0.99 (0.77-1.28) | 0.953 |
| Pre-monsoon | Reference |  | Reference |  | Reference |  |
|  |  |  |  |  |  |  |
| **Model Performance** |  |  |  |  |  |  |
| AIC | 552.92 | | 585.95 | | 1295.63 | |
| BIC | 568.30 | | 602.67 | | 1315.88 | |
| RMSE | 3.94 | | 2.59 | | 4.14 | |
| R2 | 49.50 | | 14.70 | | 47.80 | |

**Table 4** presents the incidence risk ratio (IRR) of various factors—including mass dog vaccination (MDV), rainfall, temperature, and seasonal variations—on rabies cases in Bangladesh, analyzed through a time-series count generalized linear model across three periods: 2006–2013, 2014–2024, and the total study period. For MDV, a significant protective effect was observed during 2006–2013 (IRR = 0.99, 95% CI: 0.98–0.99, p < 0.001) and the total study period (IRR = 0.99, 95% CI: 0.99–1.00, p < 0.001), while its impact during 2014–2024 was not statistically significant (p = 0.273). Rainfall exhibited a statistically significant association with rabies cases over the total study period (IRR = 0.99, 95% CI: 0.99–1.00, p < 0.001), but its effect was not significant in the two individual sub-periods. Temperature did not demonstrate a statistically significant relationship with rabies cases in any period.

Seasonal variations showed some influence on rabies incidence. During the total study period, the rainy season was associated with a significantly lower risk of rabies cases (IRR = 0.86, 95% CI: 0.74–0.99, p = 0.049), whereas no significant associations were found for the rainy season in the individual sub-periods. Winter season effects were also not statistically significant in any period, with IRR values close to 1. The pre-monsoon season served as the reference category for seasonal comparisons.

The model's performance metrics highlight differences in predictive accuracy across periods. The Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) values were lowest for the 2006–2013 model (AIC = 552.92, BIC = 568.30), indicating better model fit compared to the other periods. The root mean square error (RMSE) was lowest for the 2014–2024 period (2.59), suggesting better precision during this time, while the R² value was highest for 2006–2013 (49.50%), indicating greater explanatory power during this period compared to the 2014–2024 period (14.70%) and the total study period (47.80%). These results underscore the varying impact of vaccination, climatic factors, and seasonality on rabies dynamics across different timeframes in Bangladesh.

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