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An Early Warning System Based on Temperature for West Nile Neuroinvasive Disease in Northern Italy

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INTRODUCTION

In recent years, Northern Italy has experienced a rise in cases of West Nile Neuroinvasive Disease (WNND), the most severe manifestation of West Nile Virus (WNV) infection. Temperature, along with other meteorological factors, plays a crucial role in WNV transmission by influencing mosquito density and virus prevalence [1].

AIM

This study aims to investigate whether meteorological data—such as temperature and precipitation—can be used in an early warning system to predict the likelihood of WNND outbreaks in Northern Italy.

METHODS

We developed a spatial-temporal Bayesian hierarchical model using monthly confirmed WNND cases from 2014 to 2021 across 36 provinces in Northern Italy. The model assessed the relationship between WNND incidence, average temperature, and cumulative precipitation recorded in the three months preceding case reports. Spatial random effects were included using a Besag-York-Mollié model, while temporal random effects were modeled with an autoregressive structure, assuming a negative binomial distribution for observed cases. Using 2022 data, we evaluated the model's out-of-sample predictive ability with a 2-month lead time. An expanding window approach was adopted, progressively incorporating observed monthly meteorological inputs and WNND cases. To estimate the probability of WNND occurrence during the 2022 season, 1,000 samples were drawn from the posterior predictive distribution for each province and target month. The probability of WNND occurrence was calculated as the proportion of these samples in which the predicted number of cases was greater than or equal to 1. Model fitting was performed using the R-INLA software [2].

RESULTS

Between 2014 and 2022, 793 WNND cases were reported, with notable increases in 2018 and 2022. Among the meteorological variables, temperature recorded 1–2 months prior to case occurrence was strongly associated with WNND incidence, showing a clear linear exposure–response relationship, while no clear association was observed with cumulative precipitation. Thus, we specifically selected the model including temperature observed 2 months in advance as a predictor, aiming to forecast WNND occurrence using only observed meteorological inputs. The predictive ability of the selected model was evaluated using the Area Under the Curve (AUC); the temperature-based model achieved an AUC of 0.81, indicating good predictive accuracy.

CONCLUSIONS

Our results demonstrate that temperature recorded in the preceding months can be used to predict the occurrence of WNND cases with a 2-month lead time on a monthly basis. This modeling framework could be applied to predict WNND onset in other settings, in order to support decision-making processes for outbreak mitigation and prevention.

REFERENCES

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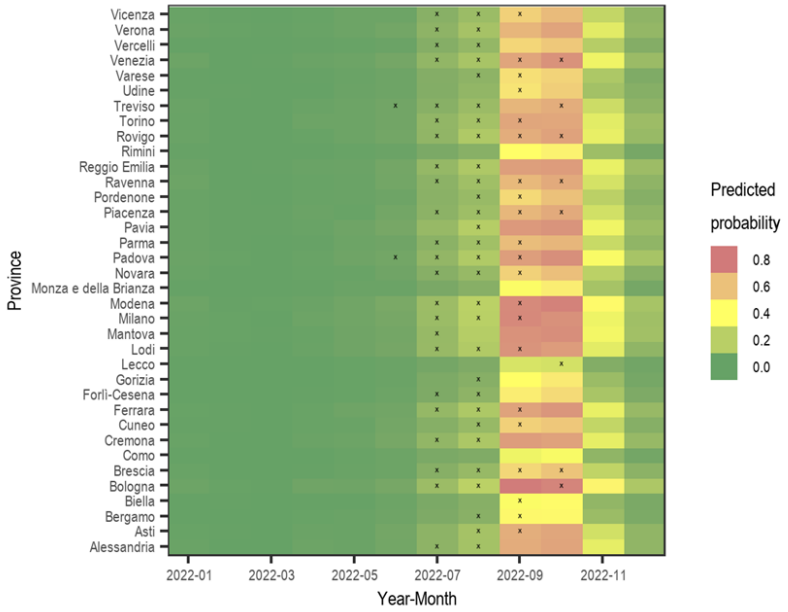
Figure 1. Probability of observing at least one WNND case for each province and month of 2022



Probability of observing at least one WNND case for each province and month of 2022. Months in which WNND cases occurred are marked with an "x".

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