Predicting Coral Reef Bleaching Using Time Series Models

Sreya Mynampati Akshita Jawahar

Abstract

Coral bleaching is a critical threat to marine biodiversity, driven largely by climate-induced increases in sea surface temperature (SST). This study explores time series models to predict SST and assess the likelihood of bleaching events based on forecasted temperatures. Three models—ARIMA, ETS, and VAR—were analyzed to identify which model best forecasts SST and, consequently, coral bleaching risk. The ETS model showed the highest accuracy, providing a promising approach for early warning systems in coral reef conservation.

1 Introduction

Coral reefs are essential ecosystems, supporting biodiversity and offering ecosystem services to human populations. However, they are increasingly vulnerable to climate change, particularly rising SST, which can cause coral bleaching. This research focuses on using time series models to predict SST changes and identify potential bleaching events based on forecasted SST values.

1.1 Objectives

This study aims to:

- Predict SST using time series models.
- Identify the best model among ARIMA, ETS, and VAR for predicting SST.
- Determine potential bleaching events by comparing forecasted SST against a threshold.

2 Literature Review

Coral bleaching occurs when high SST disrupts coral symbiosis, leading to a loss of color and, often, coral mortality. SST, solar radiation, and salinity are significant environmental factors influencing bleaching events. Prior studies have used time series analysis for SST prediction, with ARIMA and ETS commonly applied in climate modeling. This paper builds on these studies by comparing model efficacy specifically for bleaching prediction.

3 Data and Methodology

3.1 Dataset

The dataset includes daily records of environmental variables from various reef locations, such as:

- **SST (Sea Surface Temperature)**: Key indicator for coral bleaching.
- **Solar Radiation**: Sunlight reaching the water surface.
- **Wind Speed, Cloud Cover, Wave Height**: Secondary factors affecting SST and water mixing.
- **Bleaching Indicator**: Binary variable showing bleaching events (1 if bleaching observed, 0 otherwise).

3.2 Data Preprocessing

- Converted the Date column to standard format for chronological analysis.
- Visualized SST trends by location and explored correlations between SST, solar radiation, and bleaching events.

4 Methodology

4.1 Time Series Models

- **ARIMA**: Suitable for univariate time series forecasting.
- **ETS**: Exponential Smoothing State Space model, which handles seasonality and trend without requiring stationary data.
- **VAR**: Multivariate model capturing relationships between SST and solar radiation.

4.2 SST Threshold for Bleaching

The SST threshold for potential bleaching was set at 29.5°C. Forecasted SST values above this threshold were flagged as high-risk periods for coral bleaching.

4.3 Model Evaluation

The models were evaluated using Root Mean Square Error (RMSE) and Akaike Information Criterion (AIC). The model with the lowest RMSE was considered the most accurate.

5 Results

5.1 Model Performance

- **ARIMA**: Moderate RMSE and AIC values.
- **ETS**: Lowest RMSE, indicating highest accuracy in SST prediction.
- **VAR**: Higher RMSE than ETS, capturing relationships between variables but less accurate overall.

5.2 Best Model Selection

The ETS model provided the most accurate SST forecasts, making it the preferred model for predicting potential bleaching events based on SST forecasts.

6 Discussion

The ETS model's superior performance demonstrates its utility in predicting SST accurately for coral bleaching risk assessment. Although the VAR model offered insights into relationships among variables, its SST prediction accuracy was lower. These findings highlight the value of direct SST modeling for near-term coral health monitoring.

6.1 Key Factors in Bleaching Events

In addition to SST, solar radiation was identified as a factor correlating with bleaching, although secondary to SST. Future studies may consider expanding multivariate models to include additional environmental factors and location-specific thresholds for improved accuracy.

7 Conclusion

- **SST and Coral Bleaching**: SST remains the primary predictor for bleaching events.
- **Best Model**: The ETS model provided the most reliable SST forecasts, offering a feasible approach for early warning systems.
- **Implications for Conservation**: Timely SST predictions enable targeted conservation actions during high-risk periods.
- **Future Research**: Incorporating more variables and larger datasets could enhance multivariate models, improving predictive capabilities and supporting broader conservation efforts.

8 References

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