HOW DO THE ENVIRONMENTAL FACTORS INFLUENCING CORAL BLEACHING SEVERITY VARY ACROSS THE THREE GREAT BARRIER REEF ZONES AROUND A MASS BLEACHING EVENT?

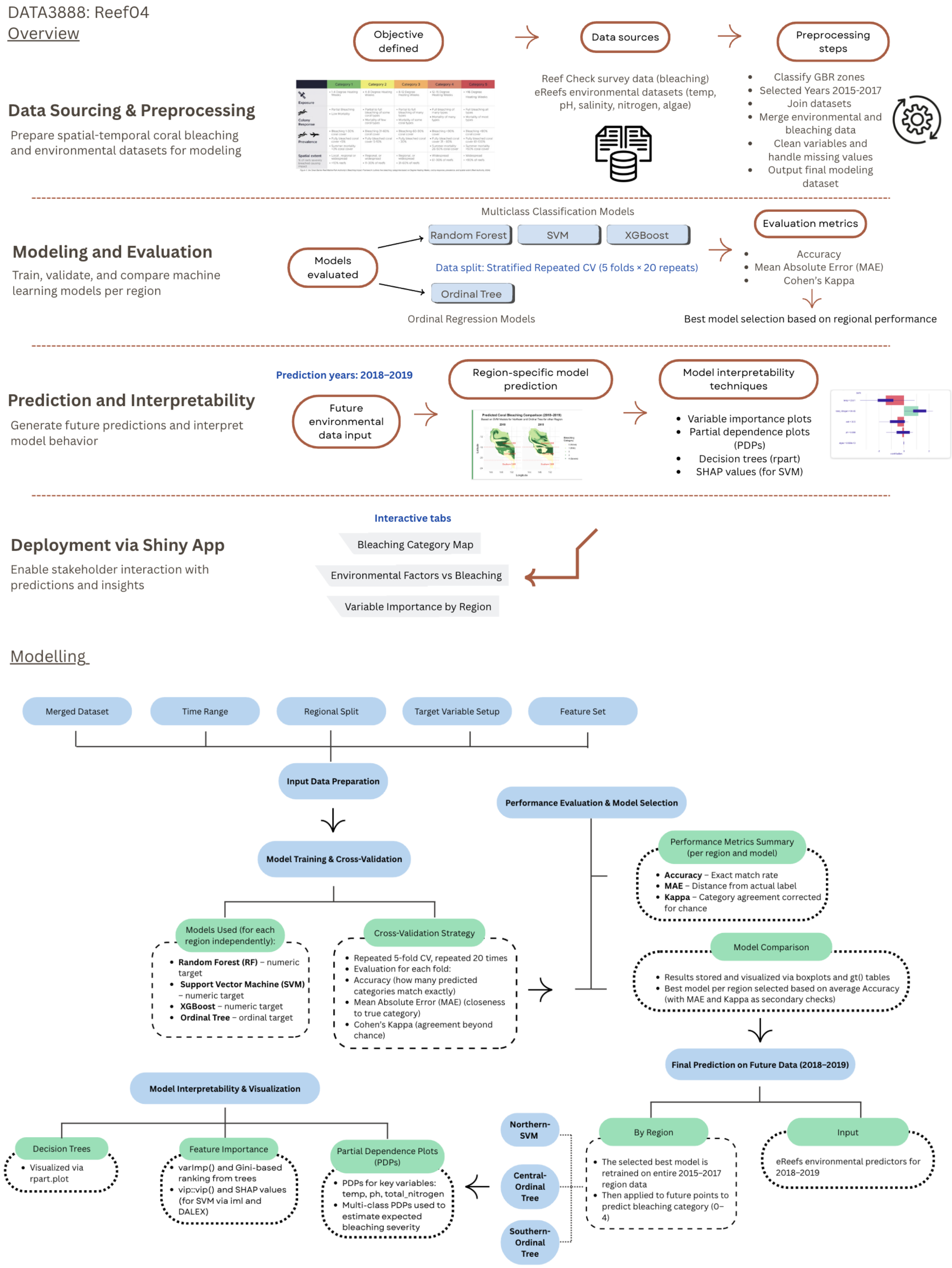

Figure 1. Project Schematic

Results - Part A

To determine the most appropriate model for forecasting coral bleaching severity across several Great Barrier Reef regions, we evaluated four machine learning algorithms—Random Forest, Support Vector Machine, XGBoost, and Ordinal Tree. The response variable was framed both ordinally and numerically, depending on the model type, and each model was evaluated using repeated 5-fold cross-validation (repeated 20 times). Three complementing criteria were used to assess performance: Cohen's Kappa, Mean Absolute Error, and Accuracy (classification correctness).

We provided a more comprehensive view of model behavior across areas and metrics by visualizing the results using boxplots and comparative tables to supplement the numerical summary. By highlighting patterns like relative stability and outlier sensitivity, these visual aids improved interpretability. By combining these evaluation techniques, we were able to compare models in an organized and transparent manner and choose the best model for each region based on a fair assessment of accuracy, error rates, and consistency.

📊 Model Comparison – Central Region

	🎯 Accuracy		📐 MAE		✅ Kappa	
Model	Accuracy	Accuracy_SD	MAE	MAE_SD	Kappa	Kappa_SD
Random Forest	0.3493	0.0323	0.8486	0.0512	0.1965	0.0371
SVM	0.4184	0.0333	0.8104	0.0545	0.2488	0.0393
XGBoost	0.3505	0.0329	0.8478	0.0514	0.1986	0.0375
Ordinal Tree	0.4752	0.0293	0.8362	0.0636	0.3002	0.0370
CLM	NA	NA	NA	NA	NA	NA

Figure 2. Model Evaluation Results – Central GBR

Central GBR (Figure 2)

All evaluation metrics showed that the Ordinal Tree performed better in the Central GBR. It had the strongest agreement beyond chance (Kappa = 0.3002), relatively low MAE (0.8362), and the highest accuracy (0.4752). It also showed strong generalizability with little variability among folds when compared to other models. It was particularly appropriate for this area due to its ability to preserve interpretability while maintaining the ordered pattern of the bleaching categories. Given these strengths, the Ordinal Tree was selected as the final model for Central GBR prediction.

Model Comparison – Northern Region						
	Accuracy		MAE		Kappa	
Model	Accuracy	Accuracy_SD	MAE	MAE_SD	Kappa	Kappa_SD
Random Forest	0.4436	0.0149	0.7058	0.0224	0.2943	0.0187
SVM	0.4683	0.0145	0.7174	0.0244	0.3235	0.0183
XGBoost	0.4456	0.0149	0.7070	0.0229	0.2975	0.0188
Ordinal Tree	0.4787	0.0142	0.8833	0.0394	0.3341	0.0182
CLM	NA	NA	NA	NA	NA	NA

Figure 3. Model Evaluation Results – Northern GBR

Northern GBR (Figure 3)

We chose the SVM model for Northern GBR due to its stronger overall performance, even though the Ordinal Tree model had the highest accuracy (0.4787). With a greater Kappa (0.3235) and a lower MAE (0.7174), SVM provided a better balance across metrics, indicating more accurate predictions. Additionally, it was more consistent between folds, which increased its resilience to data volatility. We chose SVM as the final model because, given the complexity of the local environment, we valued stability and generalizability over peak accuracy.

Model Comparison – Southern Region						
	Accuracy		MAE		Kappa	
Model	Accuracy	Accuracy_SD	MAE	MAE_SD	Kappa	Kappa_SD
Random Forest	0.9349	0.0481	0.0651	0.0481	NaN	NA
SVM	0.9386	0.0450	0.0614	0.0450	NaN	NA
XGBoost	0.9349	0.0481	0.0651	0.0481	NaN	NA
Ordinal Tree	0.9386	0.0450	0.0614	0.0450	NaN	NA
CLM	NA	NA	NA	NA	NA	NA

Figure 4. Model Evaluation Results – Southern GBR

Southern GBR (Figure 4)

Despite being applied to the Southern GBR region, the Ordinal Tree model's performance was limited. There were very few instances of mild to severe bleaching in the training data, which was unbalanced. Consequently, the model showed no discriminatory power as it consistently predicted only Category 0 and 1 for all observations. We went ahead and made predictions for completeness, but we excluded Southern GBR from the variable importance analysis since the model was unable to identify significant patterns, which limited its applicability in identifying important environmental drivers in this area.

All things considered, a thorough, region-specific evaluation process was used to choose the final models. We made sure that model selection was data-driven and in line with the project's predictive objectives by integrating a variety of indicators and visual tools to assess performance.

Results - Part B

To enhance interpretability and usability, we used an interactive Shiny app application to implement our predictive models. Stakeholders can use the app to examine important environmental factors and coral bleaching patterns over time and space in the Northern, Central, and Southern Great Barrier Reef (GBR) zones.

Through intuitive features, stakeholders can explore the research question: How environmental factors influencing coral bleaching severity vary across GBR zones around a mass bleaching event? Users can examine expected bleaching intensity for 2018 and 2019 in the Bleaching Category Map tab, based on environmental data from 2015 to 2017. Bleaching intensity is visually communicated across the GBR by a continuous color gradient from yellow (no bleaching) to deep red (extreme bleaching). Users can examine local patterns and verify forecasts at specific locations by navigating the map or focusing on particular regions.

Environmental drivers and bleaching outcomes can be directly compared using the Environmental Factors vs. Bleaching tab. Users can select a variable (e.g., pH, temperature, or algae) and examine the relationship between its distribution and bleaching intensity. Stakeholders can visually identify potential correlations by hovering over each site to uncover specific bleaching categories and associated environmental values.

Bar charts of the most significant bleaching predictors in the Central and Northern GBR are displayed on the Variable Importance by Region tab to aid understanding. Following prediction, the final models chosen were used to calculate these important scores. Due to the restrictions outlined in Results – Part A, we did not include the Southern GBR in this analysis as the model's interpretability was diminished by the limited variation in bleaching levels.

The Bleaching Category Map indicates bleaching severity occurring over the three sections of the reef (Figure 5). Predictor years (2015-2017) indicate what has previously happened demonstrating severe bleaching in the north and semi-moderate to severe bleaching in the central. Prediction years (2018-2019) indicate that mild bleaching would begin in the southern section, moderate bleaching in the central, whilst severe bleaching continues in the north (Figure 5).

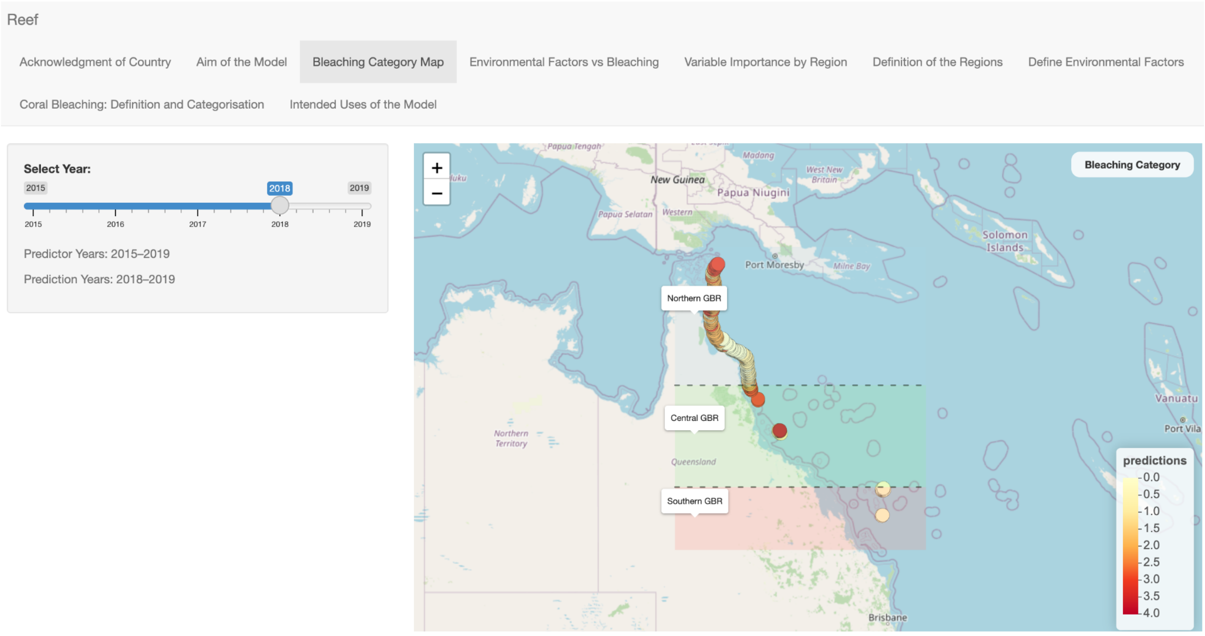

Figure 5. Bleaching Category Map available in shiny app demonstrating the bleaching severity predicted for 2018 across all three sections of the GBR

The Environmental Factors vs Bleaching map allows for the same analysis to be conducted, however highlights the environmental driving factors. The prediction map indicates that the north is the most volatile section of the reef with the largest changes in all environmental factors seen here. The central and south do see some changes however, not to the same extent. Additionally, for better comprehension, barcharts indicate the most influential drivers of bleaching for each region. Central bleaching is driven by temperature, pH and nitrogen concentrate. Inferring that coral is under stress due to above average sea temperatures and acidic waters as indicated in the map. Northern bleaching is driven by salinity and nitrogen concentration, a possible consequence of agricultural runoff changing nutrient availability in the water and thus, stressing corals.

All things considered, the app provides an interesting and user-friendly interface for analyzing model predictions, contrasting environmental variables, and gaining a deeper comprehension of the regional dynamics of coral bleaching intensity over time.