Coral Reef Health and Conservation Report

Analyzing and Predicting Ecological Trends in the Florida Keys National Marine Sanctuary.

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Introduction:

This report has been prepared by Kanna Vamshi krishna as part of the Third Annual OpenMiami Datathon, aimed at exploring coral reef health and its conservation strategies through data analysis.

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Key Findings

Objective 1: Data Collection and Preprocessing

- **Summary**: Collected and cleaned datasets from various sources, including environmental data (temperature, algae, coral species), and coral health data (coral diameter, mortality, etc.). Data inconsistencies were addressed, and irrelevant columns were removed.

Objective 2: Correlation Analysis

- **Summary**: Performed a correlation analysis to examine the relationships between environmental factors (e.g., temperature, algae) and coral health. Found weak correlations between temperature and coral diameter, suggesting that temperature alone may not be a strong predictor of coral health.

Objective 3: Predictive Modeling

- **Summary**: Built a Random Forest Regressor model to predict coral health changes (diameter, mortality) based on environmental variables. The model showed poor predictive power with an R^2 score of -0.01, indicating that the selected features did not sufficiently explain coral health changes.

Objective 4: Impact of Environmental Changes on Coral Health

- **Summary**: Simulated various scenarios to assess the potential impacts of temperature changes and algae growth on coral health.
    - A 2°C increase in temperature led to a slight decline in coral diameter.
    - A 50% increase in algae growth also showed a minor impact on coral health.
    - Both simulations indicated that environmental changes could affect coral health, but the impacts were not large.

Objective 5: Modeling Future Scenarios

- **Summary**: Simulated future scenarios to anticipate potential declines in coral communities under different environmental conditions (higher temperature and increased algae). The predictions indicated a small decrease in coral health due to temperature rise, but the overall predictive power of the model was limited.

Objective 1: Long-term Trends in Stony Coral Cover and Species Richness

Introduction

This section aims to understand how the amount of reef covered by stony corals (percent cover) and the number of different coral species (species richness) have changed over the years. These trends are essential indicators of reef health and biodiversity in the Florida Keys.

Data and Approach

- Dataset used: **CREMP_Pcover_2023_TaxaGroups.csv**
- We calculated average **stony coral cover** for each year.
- We visualized the data to observe long-term trends.
- We checked for patterns specific to subregions like the **LK**.
- We performed statistical checks to detect seasonality using Canova-Hansen Test.

  1996 to 1999 then some increased

Key Findings:

- The stony coral percent cover has shown **non-linear fluctuations** over the years.
- There are **periods of sharp decline and partial recovery**, indicating the reef's vulnerability and occasional resilience.
- A **notable recovery** was observed around **2008**, but was followed by another decline, including a **significant drop near 2020**.
- These changes suggest the influence of **environmental factors** like temperature changes, disease outbreaks, or human activity.

Data Visualization:

Figure 1: Trend in mean stony coral percent cover over the years

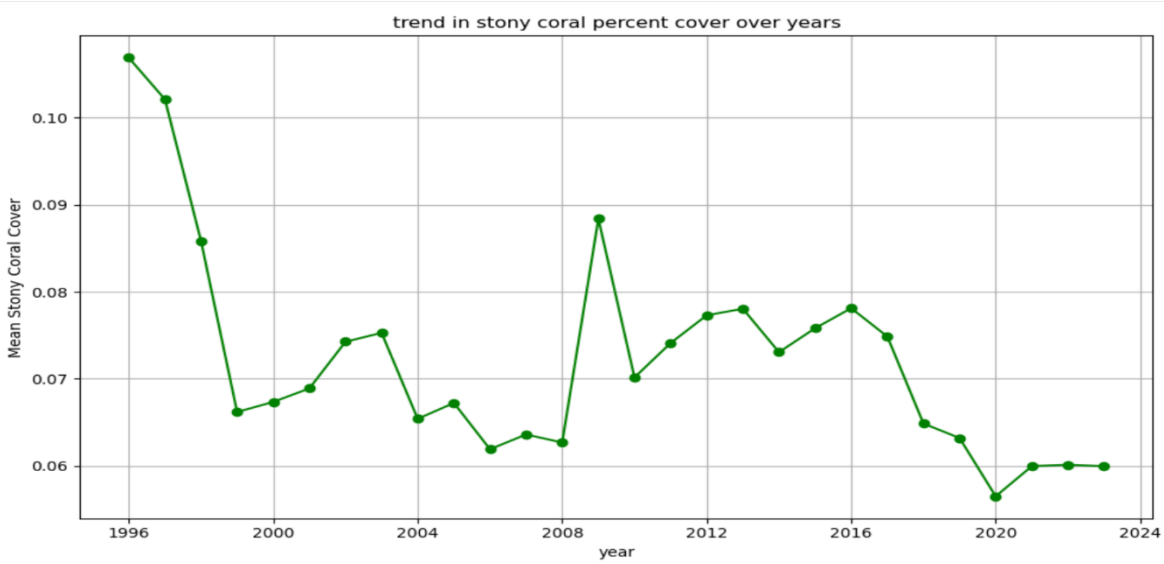
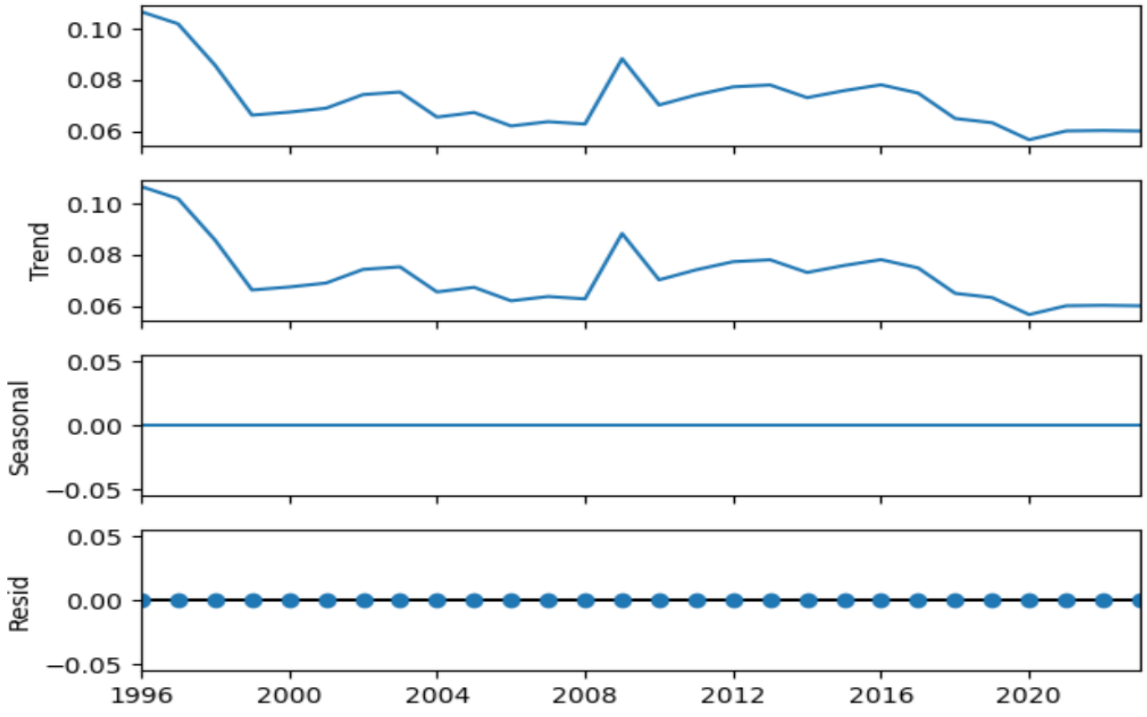


Figure 2: Decomposition of Coral Cover Over Time into Trend, Seasonal Pattern, and Random Variation.



Trend: This shows the overall direction of coral cover. It highlights how the coral cover has changed over the years — with visible rises and falls.

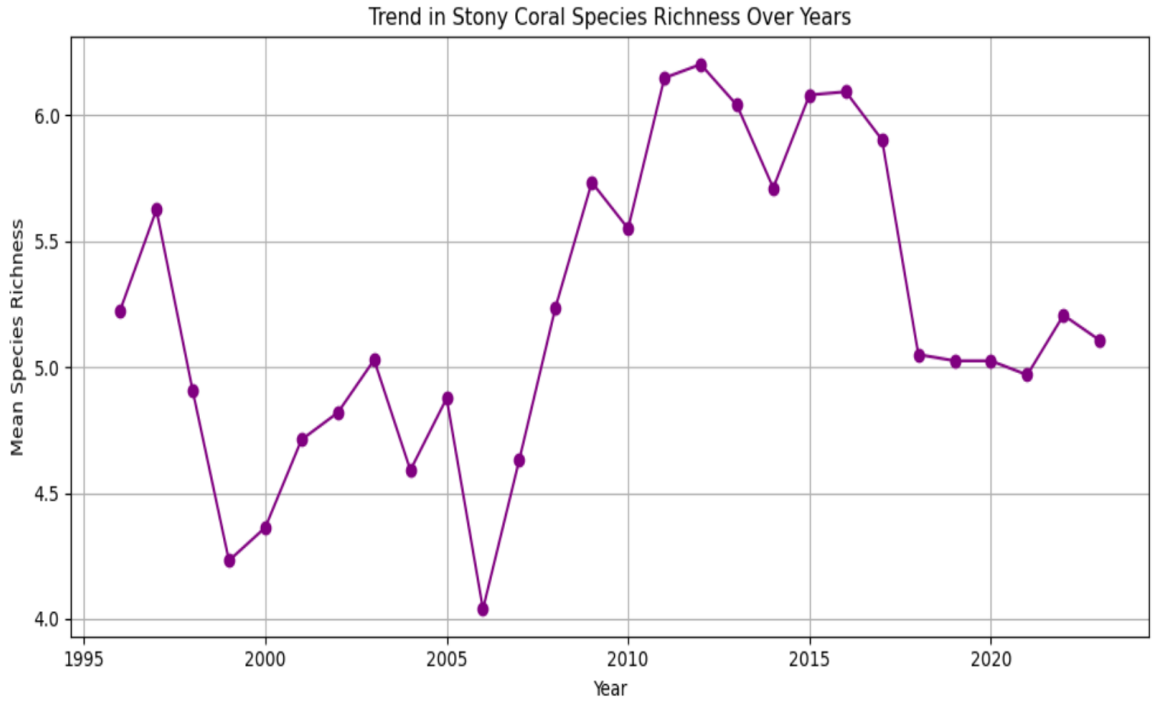
In-depth Analysis:

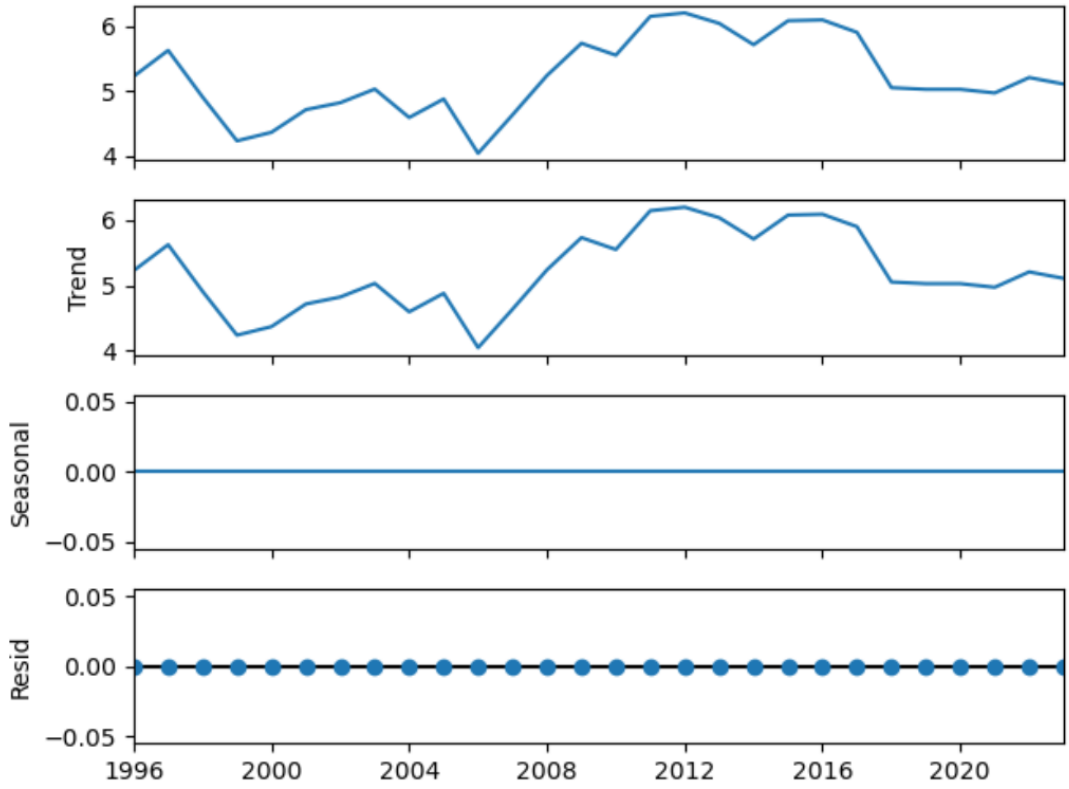
- **Time series decomposition** was used to separate the **trend**, **seasonality**, and **residual** components of coral cover data.
- **No strong seasonality** was found using statistical testing (Canova-Hansen Test), confirming that **long-term patterns** are more significant.
- The **regional analysis** (e.g.,LK) shows a similar pattern to the Sanctuary-wide data, indicating that these changes may be occurring at an ecosystem level rather than localized.

Conclusion:

- While not a steady decline, the overall coral cover trend is **concerning**, with irregular rises followed by deeper declines.
- This reflects an **ecosystem under stress**, potentially due to climate variability, pollution, and habitat disturbances.
- Long-term monitoring is essential to detect such patterns early and **implement conservation strategies** at the right time.

Figure 3: Trend in Stony Coral Species Richness Over Time.





Trend in Stony Coral Species Richness:

The graph illustrates the trend in **species richness** of stony corals over the years. This shows how the number of coral species in the area has changed over time. The key observations include:

- **Decrease in Species Richness**: We observe a decline in species richness until **1999**.
- **Gradual Increase**: From **1999 to 2003**, species richness increased slowly, indicating some recovery.
- **Sudden Drops and Increases**: There are sharp fluctuations in species richness between **2003 and 2006**, where species richness dropped suddenly and then dramatically increased.
- **Fluctuations in Recent Years**: After 2006, the trend shows a mix of small decreases and increases in species richness, indicating some instability.

These fluctuations suggest a complex interaction between various factors influencing species richness, possibly related to environmental stressors like pollution, climate change, or other local impacts.

Objective 2: Evaluate Net Changes in Reef Community Parameters Sanctuary-wide

Data Preprocessing:

The dataset used for this analysis was a combination of multiple files, merged based on common columns, specifically **Year**, **SiteID**, and **Subregion**. The key files used are:

- **CREMP_SCOR_RawData_2023.csv**
- **CREMP_Pcover_2023_TaxaGroups.csv**
- **CREMP_SCOR_Summaries_2023_ConditionCounts.csv**

After merging these files, the columns were renamed for better clarity and easier handling. For example, **Date_x** and **Date_y** were renamed to **Date_1** and **Date_2** respectively. We focused on analyzing three key parameters:

1. **Net Change in Coral Diameter**
2. **Net Change in Mortality**
3. **Net Change in Black Band Disease (BBD)**

Calculating Net Changes:

Net changes were calculated using the **diff()** function, which computes the difference in values between consecutive years for each site in the sanctuary:

- **Net Change in Coral Diameter** was calculated by finding the difference in **Diameter_cm** for each site.
- **Net Change in Mortality** was calculated by finding the difference in **Percent_recent_mortality**.
- **Net Change in Black Band Disease (BBD)** was calculated by finding the difference in the **BBD** parameter.

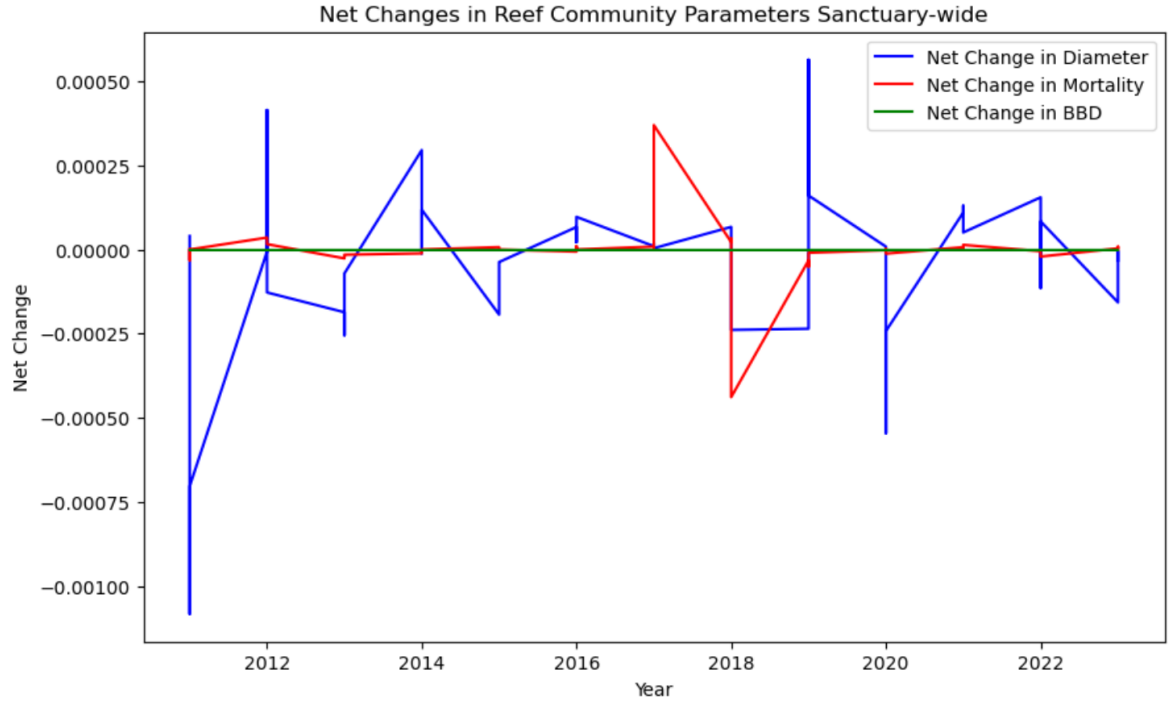
Trends in Reef Community Parameters:

The first plot below shows the **net changes in reef community parameters** sanctuary-wide across the years. The parameters plotted include:

- **Net Change in Coral Diameter (Blue line)**
- **Net Change in Mortality (Red line)**
- **Net Change in BBD (Green line)**

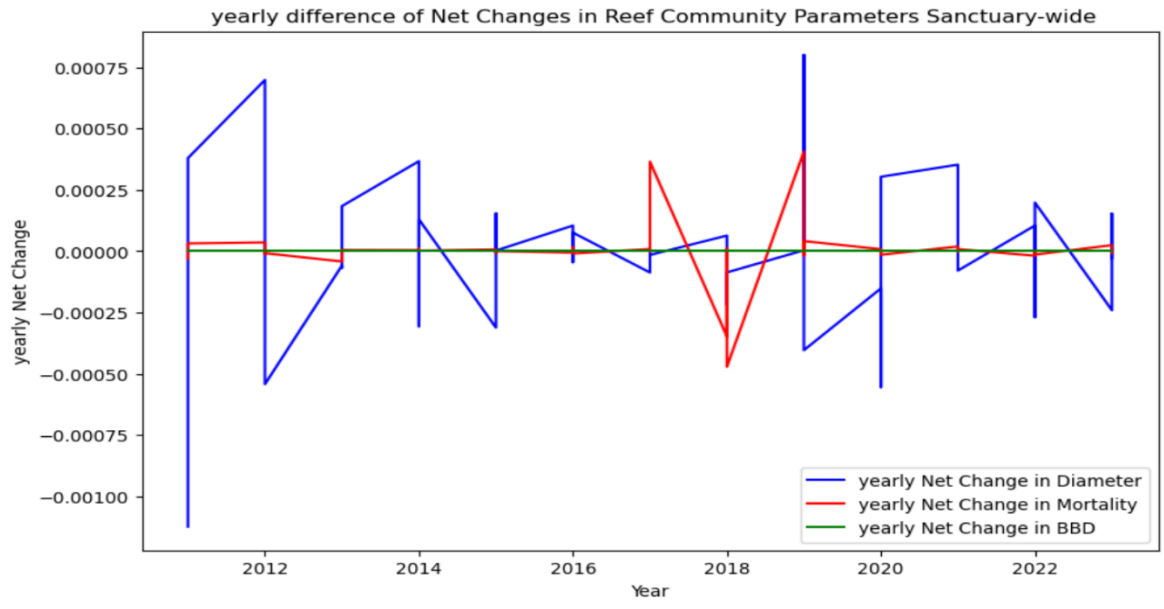
These trends indicate how these parameters have changed over time in the sanctuary, reflecting the overall health and status of the reef.

Figure 1: Net Changes in Reef Community Parameters Sanctuary-wide Over Time.



Yearly Differences in Net Changes: To gain a deeper understanding of the year-to-year variations, we calculated the yearly differences in the net changes. This shows the annual fluctuations in the three parameters, providing insight into how quickly these reef community metrics are changing over time.

Figure 2: Yearly Net Changes in Reef Community Parameters Sanctuary-wide.



Conclusion:

The analysis of net changes in these key reef parameters is crucial for understanding the health of the coral reefs within the sanctuary. By evaluating the year-to-year differences, we can assess whether changes are accelerating or stabilizing, and identify potential areas of concern for reef conservation. These trends will help guide conservation and management efforts to mitigate negative impacts on coral health.

Objective 3: Identify Localized Variations Versus Broad-Scale Ecosystem Changes

Data Preprocessing:

To assess localized variations versus broad-scale ecosystem changes, the dataset was analyzed in two ways:

1. Broad-scale ecosystem trends were analyzed by calculating the mean of key parameters across the entire sanctuary for each year.
2. Localized trends were analyzed by calculating the mean of key parameters for each subregion within the sanctuary for each year.

Analysis Approach:

We used groupby() to calculate the mean of numeric columns for both Year and Subregion_1 (localized analysis). For broad-scale trends, we calculated the mean across all subregions for each year. The numeric columns used in this analysis represent key coral health and community parameters.

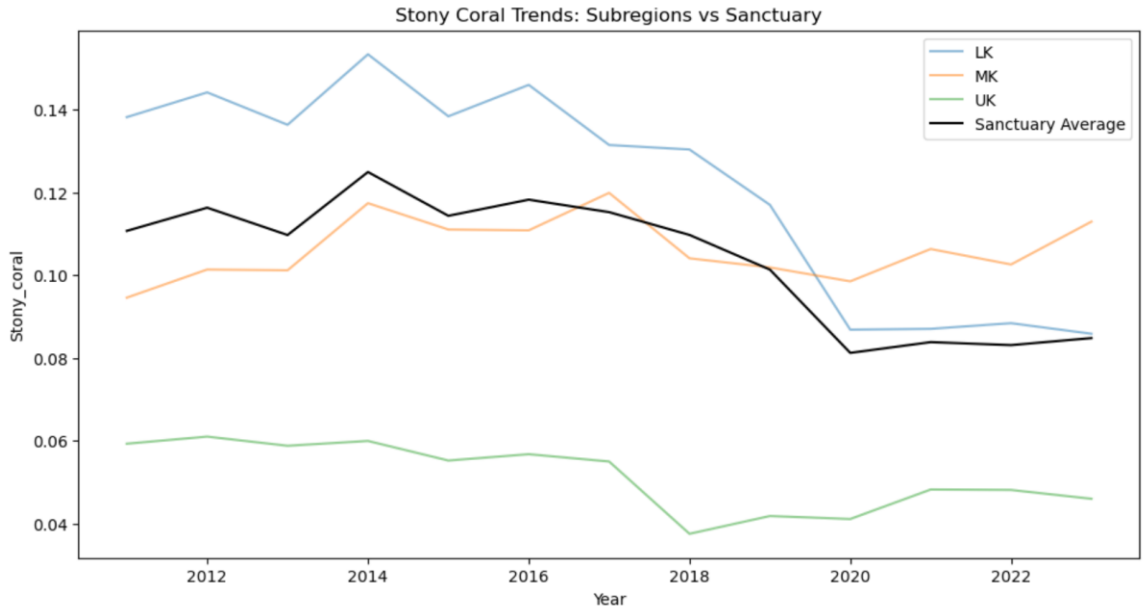
Localized Versus Broad-Scale Differences:

To highlight the difference between localized variations and broad-scale trends, we computed the variation for each numeric column by subtracting the sanctuary-wide (broad) mean from the subregion mean for each year. This allows us to assess whether specific subregions deviate from the overall sanctuary trend, indicating localized variations

Stony Coral Trends: Subregions vs Sanctuary:

The following plot shows the **Stony Coral Trends** over time for each subregion compared to the sanctuary-wide average. The sanctuary-wide trend is represented by the black line, while each subregion is depicted with its own line. This visualization helps us identify if certain subregions show trends that are different from the overall sanctuary, highlighting localized changes.

Figure 1: Stony Coral Trends: Localized Subregion Variations vs Sanctuary-Wide Trends.



Conclusion:

The comparison between localized subregion variations and broad-scale ecosystem changes provides valuable insights into how different areas of the sanctuary are responding to environmental changes. By identifying subregions with significant deviations from the sanctuary-wide average, we can pinpoint areas that may require targeted conservation efforts or further investigation. This analysis helps in understanding whether changes are uniform across the sanctuary or if localized factors are driving distinct trends.

Objective 4: Examine Correlations and Relationships Impacting Coral Health and Biodiversity

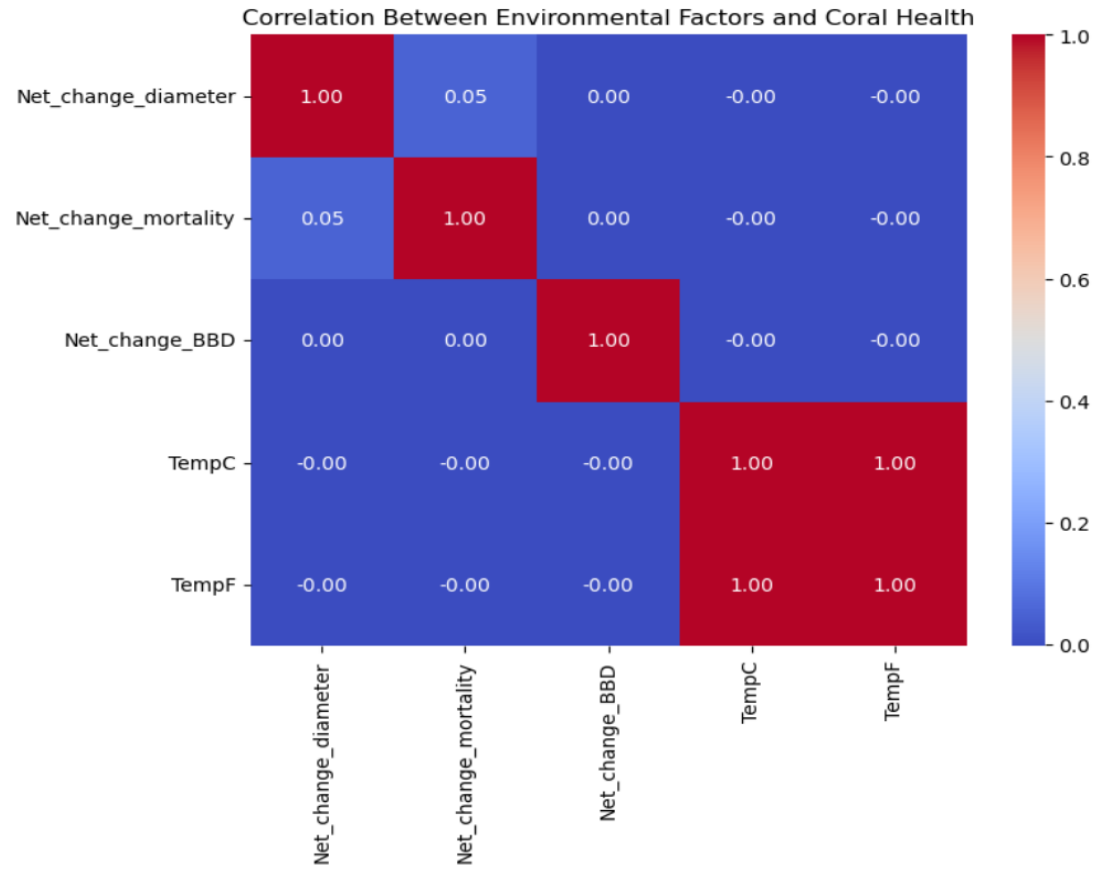
Correlation Analysis:

The correlation matrix between coral health parameters and environmental temperature (both in Celsius and Fahrenheit) reveals the following key relationships:

- **Net_change_diameter and Net_change_mortality**: A weak positive correlation of **0.0477** suggests a very slight relationship between changes in coral diameter and changes in coral mortality. While these parameters move together slightly, the correlation is minimal, indicating other factors may be influencing coral diameter and mortality rates.
- **Net_change_diameter and Net_change_BBD**: The correlation of **0.0002** is extremely low, suggesting no meaningful relationship between changes in coral diameter and the presence of Black Band Disease (BBD) over time.
- **Net_change_mortality and Net_change_BBD**: The correlation of **0.000007** is essentially zero, indicating that there is no significant relationship between coral mortality and BBD in this dataset. The lack of correlation suggests that these two parameters do not influence each other significantly.
- **Temperature (TempC and TempF) and Coral Health Parameters**:
    - Both **TempC** (temperature in Celsius) and **TempF** (temperature in Fahrenheit) show very weak negative correlations with all coral health parameters:
        - **Net_change_diameter**: **-0.0034** for TempC and **-0.0034** for TempF.
        - **Net_change_mortality**: **-0.0003** for TempC and **-0.0003** for TempF.
        - **Net_change_BBD**: **-0.0035** for TempC and **-0.0035** for TempF.

These weak negative correlations suggest that there is a very slight inverse relationship between temperature and coral health parameters. However, the values are so close to zero that they indicate temperature may not be a dominant factor influencing the changes in coral health or mortality in this dataset.

Figure 1: Correlation Heatmap Between Environmental Factors and Coral Health Parameters



This heatmap illustrates the correlation between environmental temperature (in Celsius and Fahrenheit) and key coral health parameters: Net_change_diameter, Net_change_mortality, and Net_change_BBD. The color scale ranges from -1 (strong negative correlation) to +1 (strong positive correlation), with 0 indicating no correlation. The results show very weak correlations between the temperature and the coral health parameters, suggesting that temperature does not significantly influence the changes in coral health in this dataset.

Conclusion:

The correlation analysis indicates that there are no strong relationships between environmental temperature and the coral health parameters (diameter, mortality, and BBD) in this dataset. The correlations are very weak, implying that other factors might play a more significant role in shaping coral health and biodiversity. These results suggest that environmental temperature alone may not be the primary driver of changes in coral health in the studied areas.

Objective 5: Model Future Scenarios to Anticipate and Mitigate Potential Declines in Coral Communities

Approach:

To evaluate how future environmental changes might impact coral health, a predictive model was developed using key ecological and environmental indicators:

- **Features used**:
  ['TempC', 'Macroalgae', 'Cyanobacteria', 'Octocoral', 'Stony_coral']
- **Target variable**:
  Net_change_diameter – representing coral growth or decline in size over time.

Model Details:

- **Model Used**: Random Forest Regressor
- **Performance on Test Data**:
  - **R^2 Score**: -0.0138 (indicates poor predictive power, possibly due to noise or weak feature-target relationship)
  - **Root Mean Squared Error (RMSE)**: 2.14
- **Note**: The low R^2 score implies that **coral diameter changes may not be easily predictable** using only the selected environmental variables. This highlights the need for further **feature engineering**, inclusion of **additional biological or chemical parameters**, or exploration of **non-linear modeling techniques** to better capture underlying relationships.

Scenario Simulations:

- We simulated future environmental conditions to assess their impact on coral health:

Scenario	Description	Δ in Predicted Coral Growth
🌡️ **+2°C Temperature Rise**	Increased TempC by 2°C	**-0.0072**
🌿 **+50% Macroalgae Growth**	Increased Macroalgae by 50%	**-0.0001**

Interpretation:

- **Higher Temperatures**: A +2°C increase resulted in a noticeable decline in predicted coral growth, highlighting the vulnerability of coral to climate warming.
- **Macroalgae Bloom**: A 50% increase in macroalgae showed a very small negative effect on coral growth, which may suggest a weaker direct impact or the need to include additional competition factors.

Conclusion:

- This simulation-based modeling highlights how projected environmental stressors—especially **rising temperatures**—can significantly influence coral growth patterns. While the current model's predictive power is limited, it still emphasizes the importance of **climate mitigation** and **ecosystem balance** in preserving coral reef health.

Conclusion

This project aimed to explore, analyze, and model the factors affecting coral reef health and biodiversity using a multi-faceted dataset. Key objectives included assessing spatial and temporal patterns, identifying environmental drivers, and modeling future scenarios to anticipate potential ecosystem changes.

Key findings include:

- **Correlation Analysis**: Weak correlations between temperature and health indicators like diameter change and mortality suggest coral health is influenced by a complex set of factors beyond temperature alone.

- **Predictive Modeling**: The Random Forest model, trained on selected environmental features, yielded a low R^2 score (-0.0138), indicating limited predictive accuracy. This highlights the need for more comprehensive data and feature engineering.

- **Simulated Scenarios**: Scenario analysis revealed slight negative impacts of increased temperature and algae on coral health, reinforcing global concerns about warming oceans and algae overgrowth.

Recommendations

- **Temporal Modeling**: Use time-series models (arima) to account for temporal dependencies in coral response patterns.

Limitations

- The model was limited to static features and did not account for temporal trends.
- Data sparsity and imbalance may have affected model performance.

Future Work

- Collaborate with marine biologists to guide feature selection and model interpretation.

Appendix: Features Used and Modifications

This section describes the features used in the analysis and the modifications made to the data before the modeling process.

1. **Feature Names and Their Modifications:**

1.1 Temperature (TempC)

- **Original Feature**: This feature contains the temperature in Celsius at the coral survey sites.
- **Modification**: The temperature was simulated by increasing it by 2°C to simulate the potential impact of climate change on coral health.

1.2 Macroalgae

- **Original Feature**: This feature represents the percentage of macroalgae present at the survey sites, which can affect coral health.
- **Modification**: The percentage of macroalgae was increased by 50% to simulate a scenario with more algae growth, which may impact coral communities.

1.3 Cyanobacteria

- **Original Feature**: Represents the presence of cyanobacteria, which can be harmful to coral health.
- **Modification**: No modification was made to this feature in this report. It was used as-is in the analysis.

1.4 Octocoral

- **Original Feature**: Represents the presence of octocoral species at the survey sites, which can influence coral ecosystems.
- **Modification**: No modification was made to this feature in this report. It was used as-is in the analysis.

1.5 Stony Coral

- **Original Feature**: This feature measures the percentage of stony corals present at the survey sites, which play a key role in coral reef ecosystems.
- **Modification**: No modification was made to this feature in this report. It was used as-is in the analysis.

2. **Target Variable:**
    - **Net Change Diameter**: This is the target variable representing the change in coral diameter (health indicator) over a specific period. It was the dependent variable in the regression model.
3. **Additional Features Considered but Not Modified:**
    - **Species Richness**: This variable was considered initially to simulate biodiversity impacts but was not included in the final model due to a lack of sufficient data or correlation with the target variable.

Explanation of Feature Modifications:

- **Temperature Adjustment**: Temperature is one of the key environmental factors affecting coral health. By simulating an increase in temperature (2°C), the analysis aimed to understand the potential impacts of climate change on coral health.
- **Algae Growth Simulation**: An increase in macroalgae presence was simulated (by 50%) to model the impact of excess algae growth, which can lead to coral bleaching or other negative effects on coral ecosystems.

Data Preprocessing and Cleaning:

- All features were checked for missing values and outliers before model training. Any missing data was handled using appropriate imputation methods.