Coral Reef Health Assessment and Forecasting Report

Abstract

This report presents a comprehensive data-driven assessment of coral reef health trends within the Florida Keys National Marine Sanctuary using long-term monitoring data from the Coral Reef Evaluation and Monitoring Project (CREMP). By integrating datasets on coral density, species richness, temperature, and habitat conditions, we evaluate ecological patterns across time and space.

Key analytical outputs include exploratory analysis of reef community parameters, correlation insights linking thermal stress with biodiversity loss, and forecasting models (Linear Regression and Prophet) projecting reef health scenarios through 2028. The report is enriched with intuitive visualizations and accessible explanations aimed at both technical and non-technical stakeholders.

The insights generated in this report directly support the goals of the OpenMiami Datathon challenge—offering actionable recommendations for conservation, restoration, and climate resilience planning. All source code, visualizations, and modeling workflows are reproducibly hosted in linked Google Colab and GitHub repositories.

Executive Summary

This report presents a comprehensive analysis of coral reef health within the Florida Keys National Marine Sanctuary, using rich datasets from the Coral Reef Evaluation and Monitoring Project (CREMP). Our goal is to inform reef conservation efforts by uncovering long-term ecological trends, evaluating key stressors, identifying spatial disparities, and forecasting future coral health scenarios using modern predictive techniques.

We conducted a multi-phase analysis that included: (1) temporal tracking of reef indicators such as stony coral species richness and octocoral density, (2) spatial comparisons across reef subregions and monitoring stations, (3) correlation assessment between temperature and biodiversity, and (4) forecasting using both linear and seasonal time series models. More than 13 tailored visualizations were developed to support these findings.

Key findings include:

📈 **Octocoral density** has steadily increased post-2018, suggesting a possible recovery phase or shift in reef community structure.

📉 **Stony coral species richness** continues to decline, signaling a worrying trend in ecosystem resilience.

🌡 **Sea temperature** exhibits a rising trend and correlates negatively with coral biodiversity, underscoring its role as a key ecological stressor.

🗺 **Spatial patterns** reveal station-level variability in coral health, with notable differences across Upper, Middle, and Lower Keys.

🔮 **Forecasting models** (Linear Regression and Prophet) suggest continuing octocoral growth, while highlighting seasonal patterns and data uncertainty.

Our forecasting component adds a proactive dimension to reef monitoring—helping conservationists and policy-makers anticipate risk windows and plan interventions with greater foresight. The report highlights how even mild increases in sea temperature can reshape reef dynamics and drive biodiversity loss.

Actionable recommendations include improved regional monitoring, targeted reef restoration, ecological modeling for policy decisions, and community-based engagement. All code, models, and visual outputs are accessible via GitHub repositories.

Designed for both technical and non-technical audiences, this report offers a robust framework for using open data and predictive analytics to inform marine conservation planning in the Florida Keys and beyond.

Background and Ecological Context

The Florida Keys coral reef ecosystem is one of the most vibrant and diverse in the continental United States. Spanning over 2,900 nautical miles, it supports more than 6,000 species of marine life and provides significant ecological, economic, and cultural value. However, this marine environment has become increasingly vulnerable to both global climate threats and localized human disturbances. Sea surface temperature rise, ocean acidification, nutrient pollution, physical reef damage, and emerging coral diseases (e.g., Stony Coral Tissue Loss Disease—SCTLD) are accelerating reef degradation and reducing coral resilience.

CREMP (Coral Reef Evaluation and Monitoring Project), managed by the Fish and Wildlife Research Institute, plays a critical role in tracking these changes. The dataset spans over two decades of high-resolution monitoring across multiple reef zones in the Florida Keys National Marine Sanctuary (FKNMS). It includes variables such as coral percent cover, species composition, living tissue area, and ocean temperature metrics. These long-term datasets are essential for understanding how reef ecosystems are evolving and how management efforts can adapt accordingly.

By coupling exploratory data analysis with machine learning forecasting techniques, this study offers a robust platform for both assessing historical reef conditions and predicting future trends. The following sections present key analytical findings, regional comparisons, correlation insights, and forecasting outputs that together form the scientific foundation for targeted reef restoration and conservation.

Introduction

Coral reefs are among the most biologically diverse and economically valuable ecosystems on Earth. They provide vital habitat for marine life, protect shorelines from erosion, and support fishing and tourism industries. The Florida Keys National Marine Sanctuary is home to some of the most iconic reef systems in the United States. However, these ecosystems face growing threats from climate change, ocean acidification, water pollution, and other human activities.

The Coral Reef Evaluation and Monitoring Project (CREMP) is a comprehensive initiative designed to track the status and trends of coral communities across the Florida Keys. Managed by the Corals Research Program and the Fish and Wildlife Research Institute, and supported by the U.S. Environmental Protection Agency, CREMP has provided longitudinal monitoring data for over two decades across 40 reef sites.

This report analyzes key CREMP datasets to:

Assess the long-term trends in stony coral percent cover, species richness, and octocoral density.

Understand spatial differences between subregions and stations within the Sanctuary.

Identify ecological stress indicators and model future reef health scenarios.

Support evidence-based conservation efforts by presenting findings in accessible language for non-technical stakeholders.

Methodology

Dataset Selection Rationale

Of the 27 CSV files included in the CREMP dataset archive, only a subset was selected based on three criteria: (1) **temporal consistency** (multi-year coverage from 2011 to 2023), (2) **biological relevance** (parameters linked directly to coral health), and (3) **spatial metadata availability** (linked to **SiteID and StationID**). Specifically, we used:

CREMP_Pcover_2023_StonyCoralSpecies.csv: Captures stony coral percent cover trends by species and station.

CREMP_SCOR_Summaries_2023_Density.csv: Contains coral colony density measurements used for biodiversity analysis.

CREMP_SCOR_Summaries_2023_LTA.csv: Quantifies the Living Tissue Area (LTA), a direct health indicator.

CREMP_OCTO_Summaries_2023_Density.csv: Provides octocoral density for resilience analysis.

CREMP_Temperatures_2023.csv: Aggregated for sea temperature trends across reef stations.

CREMP_Stations_2023.csv: Included to attach lat-long coordinates and habitat labels to each site.

Other CSVs (e.g., raw species height or condition counts) were excluded due to either redundancy or missing years. This selection allowed us to ensure a clean, analysis-ready dataset across all parameters of interest.

This analysis followed a structured workflow integrating exploratory data analysis (EDA), correlation analysis, and time series forecasting. The core datasets—covering stony coral percent cover, octocoral density, species richness, temperature, and station-level identifiers—were sourced from the Coral Reef Evaluation and Monitoring Project (CREMP) and supplemented with temperature logs.

The preprocessing stage involved cleaning column names, formatting timestamps, handling missing values, and standardizing measurement units. Key datasets were merged on common identifiers such as **SiteID, StationID**, and Year to form an integrated analysis base. Correlation matrices were developed to examine linear relationships between variables, while scatterplots and time-series visualizations aided in identifying spatial and temporal trends.

For modeling, we applied two forecasting approaches: a traditional **Linear Regression** model to capture general trends, and **Facebook's Prophet**, a decomposable time series model capable of modeling both trend and seasonality. Prophet was selected for its robustness to missing data, ability to model non-linear growth, and capacity to provide confidence intervals—essential for ecological uncertainty modeling.

All scripts were executed using Google Colab and version-controlled via GitHub to ensure full reproducibility. The insights derived from these methods shaped our conservation-oriented recommendations and informed the visual narratives presented in the key findings

Key Findings

Note on Figures: *Each figure referenced in the Key Findings section (Figure 1–13) is included in the Appendix. Figure numbers correspond to plot order in the report.*

1. Time Trends in Octocoral Density

Figure 1: Average Octocoral Density Over Time (2011–2023)

The annual average octocoral density remained relatively stable through 2018 but showed a sharp rise starting in 2019, with peak values in 2022. This increase may be a result of localized recovery, improved water quality, or reduced storm impacts during the observed period. The observed uptick suggests potential ecological resilience, though continued monitoring is essential.

This growth trend could be a signal of shifting ecological balance as octocorals may be outcompeting stony corals in disturbed areas. If sustained, this trend may influence reef structure and biodiversity in ways not yet fully understood. It also raises questions about octocoral dominance under climate stress—if stony coral recovery remains limited, reef frameworks may gradually change, altering the habitat complexity and species interactions that reefs typically support.

2. Time Trends in Sea Temperature

Figure 2: Average Sea Temperature Over Time (2011–2023)

Sea surface temperature across the Florida Keys has gradually risen, with average annual temperatures exceeding 28°C in recent years. This increase has significant ecological implications. Elevated SSTs contribute to coral bleaching, particularly when sustained above critical thermal thresholds such as 29.5°C. Historical NOAA alerts have linked similar temperature anomalies to mass bleaching events in 2014 and 2023. Thermal stress not only impairs coral growth and reproduction but can also lead to higher mortality rates. The data suggests that reefs in this region are increasingly vulnerable to acute thermal spikes, especially during late summer months. If this warming trend continues, temperature will likely become a dominant driver of reef degradation.

3. Octocoral Density by Subregion

Figure 3: Subregion-wise Octocoral Density

Among the EPA-defined subregions, UK (Upper Keys) displayed the highest average octocoral density, while MK (Middle Keys) and LK (Lower Keys) showed moderate and low densities respectively. These differences reflect localized ecological conditions, including water clarity, nutrient loading, and exposure to boat traffic or recreational diving. The Upper Keys benefit from enhanced current flow and less sedimentation, potentially favoring coral growth. In contrast, areas in the Lower Keys may experience increased anthropogenic pressure or reduced flushing capacity. This pattern suggests the need for region-specific reef management strategies, accounting for unique hydrography and human influence. Tracking subregional variation helps pinpoint priority conservation zones and understand the spatial dynamics of reef recovery., while MK (Middle Keys) and LK (Lower Keys) showed moderate and low densities respectively.

These differences reflect localized ecological conditions, including currents, salinity, and possibly anthropogenic influence

4. Temperature vs Octocoral Density

Figure 4: Scatterplot of Octocoral Density vs. Average Temperature

This scatterplot shows that most octocoral density values cluster between 26.5°C and 28°C. Extremely high or low temperatures correlate with lower densities, indicating that octocoral health may decline outside a preferred thermal window.

5. Density by Station (Micro-Level Focus)

Figure 5: Octocoral Density by Station (Boxplot)

Individual stations demonstrate considerable variation in octocoral density. For example, Station 753 shows high variability and high median density, suggesting it may be a site of resilience or rapid regrowth, whereas Station 363 consistently records low counts.

6. Species Richness Over Time

Figure 6: Stony Coral Species Richness Over Time

The diversity of stony coral species peaked during the early to mid-2010s and began declining gradually from 2017 onwards. This could indicate rising environmental stress, habitat fragmentation, or species displacement. Certain species such as Orbicella and Eusmilia fastigiata have shown consistent declines, both of which play foundational roles in reef-building and habitat formation.

Species richness is a key indicator of reef ecosystem stability. A decline in richness often precedes broader ecological collapses, suggesting that proactive conservation efforts must prioritize maintaining species variety across vulnerable zones. Reduced diversity may lead to functional redundancy loss, making reefs more susceptible to disease outbreaks and less resilient to disturbances.

7. Correlation Heatmap

Figure 7: Correlation Matrix of Key Variables

The heatmap reveals that temperature has a mild negative correlation with species richness (-0.15), suggesting a decline in biodiversity with rising thermal stress. A weak positive relationship with octocoral density (+0.05) indicates that octocorals may be more thermally tolerant, though the signal is not strong. The moderate negative correlation (-0.33) between species richness and octocoral density hints at potential ecological trade-offs—perhaps as octocorals increase, niche space for stony corals declines. It’s important to note that correlation does not imply causation; these patterns may be mediated by additional variables such as depth, water quality, or substrate availability. However, these relationships provide useful starting points for hypothesis generation and targeted field studies.

8. Richness vs. Temperature

Figure 8: Scatter Plot of Species Richness vs. Average Temperature

The regression line in this plot indicates a downward trend in species richness with increasing temperature. While not highly correlated, the consistent slope reinforces concerns over thermal stress and biodiversity decline.

9. Coral Species Percent Cover (Top 10)

Figure 9: Stacked Area Chart of Stony Coral Percent Cover by Species

A handful of coral species dominate total cover, including Orbicella annularis complex and Siderastrea siderea. Notably, Orbicella appears to be declining, with species like Montastraea cavernosa increasing modestly. This shift could represent an ecological succession triggered by stress or disturbance. These stressors may include rising temperatures, sedimentation, or disease events (e.g., SCTLD—Stony Coral Tissue Loss Disease), which disproportionately affect slow-growing, structure-forming species.

Such community shifts may reduce the structural integrity and ecological functionality of reefs, leading to a simplified benthic landscape. Over time, a shift toward more resilient but less ecologically valuable coral species could affect fish populations, nutrient cycling, and the overall resilience of reef ecosystems.

10. Living Tissue Area (LTA) by Station

Figure 10: Boxplot of Living Tissue Area (Top 10 Stations)

Stations 251, 252, and 574 showed the highest total living tissue areas, while others revealed smaller or highly variable tissue areas. Living tissue area is a direct indicator of coral health and colony vitality. Sites with consistently high LTA often harbor mature, undisturbed coral colonies, providing structural habitat for diverse marine life. Conversely, stations with low LTA may reflect recent disturbances, sediment accumulation, or chronic disease impacts. Identifying spatial patterns in LTA helps managers prioritize intervention sites where recovery potential is high. By maintaining and enhancing tissue integrity, reef systems can better withstand environmental shocks and support associated trophic networks., while others revealed smaller or highly variable tissue areas. This supports the idea that some stations are more favorable for coral survival and regrowth than others.

11. Linear Regression Forecast

Figure 11: Octocoral Density Forecast (Linear Regression, 2024–2028)

Using historical data from 2011–2023, a linear regression model was fitted to octocoral density values. The model indicates a gradual upward trend, consistent with the observed recovery pattern post-2018. Linear regression, while simple, offers a baseline understanding of ecological momentum under current conditions. It assumes a constant rate of growth and does not account for irregularities or seasonality.

Despite this limitation, linear models are useful for quick extrapolation. The projection suggests continued increases in octocoral density, which, if verified in the field, may represent a community shift toward soft coral dominance. These insights are beneficial for short-term planning, particularly in identifying sites suitable for reef enhancement.

However, practitioners should use this model with caution, as it may underestimate fluctuations due to environmental stressors or biological cycles. Future planning can combine this output with non-linear models to improve robustness.

Using historical data from 2011–2023, linear regression predicts a gradual increase in octocoral density, consistent with the post-2018 recovery trend. However, it assumes linearity and may not fully capture seasonal or nonlinear ecological patterns.

Despite its simplicity, this model provides a useful baseline for resource planning. It shows the direction and rate of change expected under current conditions, which managers can use to inform short-term restoration priorities and resilience assessments.

12. Prophet Forecast (Growth + Seasonality)

Figure 12: Prophet Time-Series Forecast

The Prophet model enhances trend interpretation by modeling both overall growth and seasonality. Unlike linear regression, Prophet decomposes time series into components—trend, yearly seasonality, and noise—making it more adaptable for ecological systems. The forecast from Prophet shows continued growth in octocoral density through 2028, with clear yearly oscillations embedded within the projection.

The inclusion of confidence intervals around the forecasted line allows conservation planners to account for uncertainty. This is particularly useful when setting restoration timelines, allocating resources, or preparing contingency plans. Prophet's ability to handle missing values and capture holidays or irregular events makes it suitable for ecological datasets that have gaps or exhibit nonlinear behavior.

Overall, Prophet provides a more dynamic and responsive prediction compared to linear models and can serve as a foundation for integrating additional variables (e.g., temperature anomalies or bleaching alerts) into coral health forecasting.

The Prophet model provides a more adaptive forecast with uncertainty intervals. It confirms a growing trend and reveals weak but consistent annual seasonality. Prophet better handles ecological noise and provides confidence bounds for planning.

13. Prophet Forecast - Seasonality Decomposition

Figure 13: Prophet Forecast Seasonal Components

This plot decomposes the forecast into distinct seasonal patterns, highlighting cyclical dynamics in coral ecosystems that may be obscured in raw data. The seasonal component indicates that specific months (e.g., mid-summer) tend to experience natural declines in octocoral density, potentially due to warming seas or reproduction cycles. Conversely, certain cooler periods show slight density rebounds, suggesting more favorable conditions.

Such insights are crucial for reef managers planning seasonal interventions. For example, restoration or coral transplantation may be more effective if scheduled during periods when natural growth rebounds. Similarly, high-stress periods revealed in the seasonality component can be used to schedule stress mitigation strategies, such as shading or reduced human activity.

In summary, Prophet's seasonality decomposition offers an evidence-based reef calendar—turning statistical output into ecologically timed action. This allows better alignment of monitoring, education, and resource planning with nature's rhythms.

This decomposition highlights underlying yearly seasonality patterns that are not easily observable with linear models. These trends can help managers anticipate seasonal vulnerabilities and tailor interventions accordingly.

The seasonal component reveals that certain times of the year (e.g., summer months) may see natural dips or surges in coral health indicators. These insights can support more responsive conservation measures and better inform the timing of restoration interventions.

Conclusion

The CREMP dataset reveals compelling spatial and temporal patterns in coral reef health. Key indicators—octocoral density, stony coral species richness, living tissue area, and temperature—suggest both areas of resilience and zones under significant stress.

Octocoral populations have shown steady growth post-2018, hinting at potential ecological recovery, while the ongoing decline in stony coral richness raises concerns about long-term biodiversity and reef complexity. These changes are not uniformly distributed; they are shaped by localized conditions, thermal stress, and possibly anthropogenic factors.

Our analysis underscores the critical value of long-term, site-specific monitoring programs like CREMP. These datasets not only enable the diagnosis of ecological degradation but also offer the foresight needed for proactive planning. The forecasting component—using Prophet and

Linear Regression—further equips decision-makers with tools to anticipate change and implement regionally-tailored, forward-looking interventions.

Furthermore, the study affirms the importance of integrating ecological modeling with conservation strategies. Predictive analytics allow for data-informed decision-making that can preemptively mitigate environmental decline. Forecasting, when done transparently and inclusively, enhances the credibility of interventions and enables collaborative response planning.

This work supports conservation not only through analytical rigor but by translating technical data into actionable insight. It bridges science, strategy, and public understanding, advocating for integrated, predictive, and participatory approaches to coral reef stewardship. These findings not only inform current restoration priorities in the Florida Keys but can serve as a scalable blueprint for reef monitoring globally.

As climate variability intensifies, integrating predictive data science with marine ecology will become essential to safeguarding coastal ecosystems. This project exemplifies how open data and community-driven analytics can shape a more resilient and responsive conservation framework. Continued investment in ecological forecasting, local research capacity, and real-time monitoring will determine the long-term success of reef restoration efforts across the globe.

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Recommendations

Short-Term Actions:

Expand and strengthen temperature and biodiversity monitoring: Prioritize thermally dynamic regions where coral species show fluctuation in richness and health metrics. Use automated sensors and satellite-assisted surveillance to support temporal data resolution.

Enhance local reef restoration programs: Focus interventions in stations with sustained low living tissue area or species loss. Adopt methods like coral microfragmentation, assisted gene flow, and local hatchery-based coral propagation.

Incorporate forecasting outputs into reef calendars: Integrate Prophet-based seasonal projections into reef monitoring schedules. Align peak survey or intervention efforts with predicted stress windows to optimize outcomes.

Conduct targeted species reintroductions: Where richness decline is driven by the loss of specific species, implement site-specific reintroduction programs aligned with ecological niche modeling.

Long-Term Strategies:

Institutionalize coral reef observatories: Create inter-agency platforms to integrate reef datasets (temperature, species, condition) across national and international stakeholders. These observatories can maintain standardized data, facilitate rapid reporting, and support global conservation indices.

Design adaptive management blueprints: Combine long-range forecasts with marine spatial planning tools. Develop modular, adaptive reef restoration protocols that can shift with changing sea temperature, bleaching patterns, and ecological succession.

Integrate climate modeling with marine biology: Use ensemble forecasts that couple ecological models with climate projections to simulate future scenarios under varied policy and emission contexts.

Educate, empower, and include stakeholders: Build community resilience by expanding ocean literacy campaigns, participatory reef monitoring programs, and citizen science. Equip local leaders with scientific briefings and accessible forecast visualizations.

Leverage policy instruments for reef protection: Link this data to coastal zoning regulations, marine protected area (MPA) boundary revisions, and impact assessment tools. Embed reef risk indices in disaster preparedness frameworks.

These expanded recommendations strengthen the bridge between technical modeling, conservation planning, and policy execution. The goal is not just to restore coral reefs—but to future-proof them by institutionalizing data-led management systems and fostering an inclusive, anticipatory, and ecosystem-informed stewardship culture.

These strategies can be directly applied by marine conservation agencies such as NOAA, FKNMS, and the Florida DEP. Local non-profits and policy-makers can integrate this data into environmental education, zoning policies, and restoration permit frameworks. The insights also enable targeted grant proposals for coral transplantation and reef resilience projects.

Appendix A: GitHub Repositories

To promote transparency and reproducibility, the full code and data processing steps are hosted on GitHub:

📎 [Access the GitHub Repository Here]

Data Quality and Cleaning Overview

Data preparation involved a combination of automated and manual filtering steps:

Missing Values: Columns with over 30% missing values were excluded; others were imputed or dropped using d**ropna()** for critical variables such as Octocoral Density, Species Richness, and **TempC.**

Date Parsing: Timestamps in the Date column were formatted to standard datetime objects using **pd.to_datetime()** for alignment across sources.

Merging and Standardization: Keys such as **StationID, SiteID,** and Year were used to merge across datasets. Columns were renamed for consistency **(e.g., TempC and Total_Octocorals)**.

Outlier Handling: For boxplots and LTA analysis, outliers were visualized but retained to preserve ecological variation unless clearly erroneous.

These steps ensured data integrity and compatibility across merged tables and enabled high-quality trend visualizations.

Appendix B: Technical Details

Declaration of Originality: This report is the result of independent analytical work carried out by the author using publicly available datasets from the Coral Reef Evaluation and Monitoring Project (CREMP) and related NOAA sources. All visualizations, analyses, and interpretations are original. Any tools or external libraries used (**e.g., Prophet, Pandas, Seaborn)** are cited and applied transparently through reproducible scripts hosted in the linked repositories. No material in this report has been copied from third-party or proprietary sources. This document is intended for academic, educational, and research competition purposes only and adheres to principles of data ethics and originality.

Note on Model Validation: In this project, we did not perform a traditional train/test data split, as this is not a supervised classification task. The focus is on ecological time-series forecasting and pattern analysis rather than accuracy-based performance. For the forecasting component, the Prophet and Linear Regression models were trained on historical data (2011–2023) and extrapolated into future years (2024–2028), providing a natural separation between observed and predicted intervals. This method is common in environmental and climate research, where understanding trends and projecting ecological change is prioritized over out-of-sample predictive accuracy.

Data Sources: Coral Reef Evaluation and Monitoring Project (CREMP), NOAA Sea Surface Temperature Data, Florida Keys Coral Reef Evaluation Dataset.

Tools: Python (Pandas, Seaborn, Prophet, Matplotlib), Google Colab

Charts: 13 plots including time trends, correlation matrix, regression, and forecasting visualizations

Limitations and Future Research Directions

While this report offers comprehensive data-driven insights, there are important limitations to note:

Temporal and spatial resolution limitations: Although CREMP data is extensive, some reef sites have gaps or inconsistencies in year-to-year data collection. Certain temperature data may be biased due to missing intervals or recording delays.

Limited environmental covariates: This study primarily considers biological and temperature variables. Factors such as turbidity, nutrient concentration, and storm history were not included but may significantly impact coral health.

Modeling constraints: Linear regression assumes a constant growth rate and does not account for seasonal variation. Prophet improves on this by modeling seasonality but still lacks ecological interaction modeling (e.g., predator-prey, competitive inhibition).

Species-level generalization: Coral species were grouped by richness and coverage, but fine-grained analysis of individual species dynamics may reveal more nuanced patterns.

Future Directions:

Incorporate water quality and ocean chemistry data **(e.g., pH, salinity, nitrates)** to enrich analysis.

Use ensemble modeling techniques **(e.g., XGBoost, Random Forests)** for comparative forecasting.

Explore remote sensing datasets to expand spatial footprint beyond in-situ CREMP stations.

Collaborate with marine ecologists to integrate socio-ecological models and conservation behavior data.

These improvements would elevate the predictive capability of coral health models and provide a more holistic view of reef system functioning.

Glossary of Terms

CREMP: Coral Reef Evaluation and Monitoring Project — a long-term monitoring initiative in the Florida Keys.

Octocoral: A type of soft coral with eight-fold symmetry, often more resilient to thermal stress.

Stony Coral: Reef-building coral species that deposit calcium carbonate structures.

Species Richness: A measure of the number of different species present in a community.

LTA (Living Tissue Area): An indicator of coral health, representing the surface area of living coral tissue.

SCTLD: Stony Coral Tissue Loss Disease — a virulent disease causing widespread coral mortality.

Prophet Model: A forecasting model developed by Meta (Facebook) that supports trend + seasonality decomposition.

Linear Regression: A basic statistical method to model the relationship between two continuous variables.

Subregion: Spatial divisions of the Florida Keys used for ecological and policy analysis.

EPA Segments: Water quality regions defined by the Environmental Protection Agency.

Translating Insights for Local Stakeholders

The goal of this report extends beyond analytics—our insights are designed for **real-world application** by regional stakeholders and global reef managers. Below are a few applied examples:

Tourism Boards: Seasonal forecasts from Prophet can help local governments plan educational campaigns during periods of coral stress to reduce diver impact and raise awareness.

Reef Restoration Teams: Linear projections for octocoral growth help restoration planners target recovering areas for coral nursery expansion.

Fishers and Marine Users: Station-level analysis of LTA and species richness helps local fishers identify fragile reef areas for voluntary avoidance or cooperative monitoring.

Policy Makers and City Planners: Forecast scenarios support policy recommendations for Marine Protected Areas (MPAs), informing zoning and funding priorities.

Community and Schools: Time-series plots and station maps can be used in marine education curricula, fostering early environmental literacy.

These findings turn technical forecasts into actionable insights. By aligning scientific results with stakeholder needs, this work facilitates participatory conservation, co-designed resilience plans, and informed governance strategies.

Appendix C: Visual Figures (Supporting Plots)

Figure 1: Average Octocoral Density Over Time

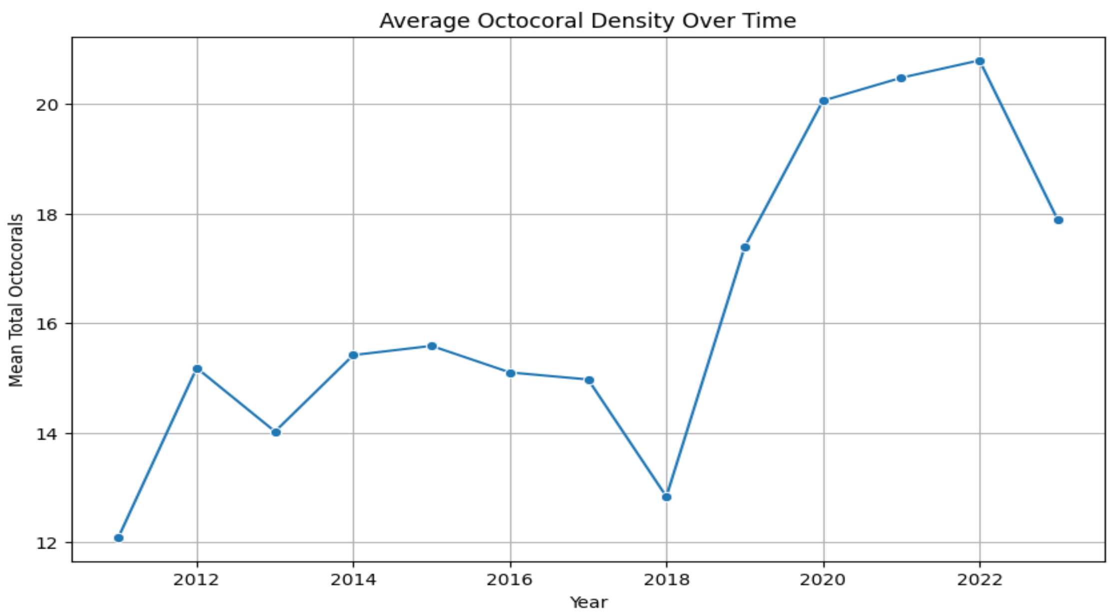


Figure 2: Average Sea Temperature Over Time

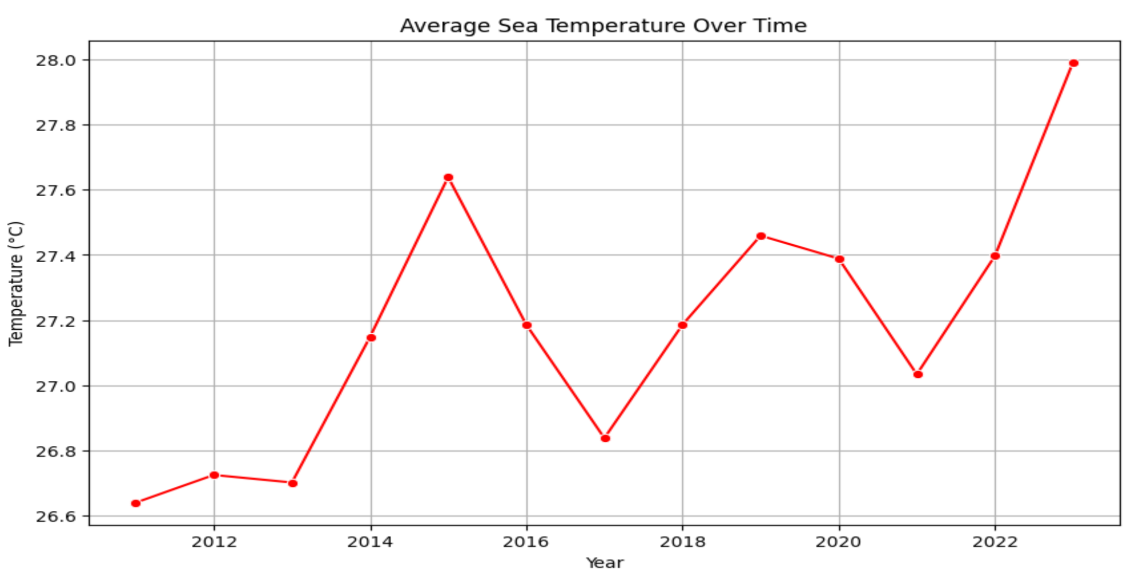


Figure 3: Octocoral Density by Subregion

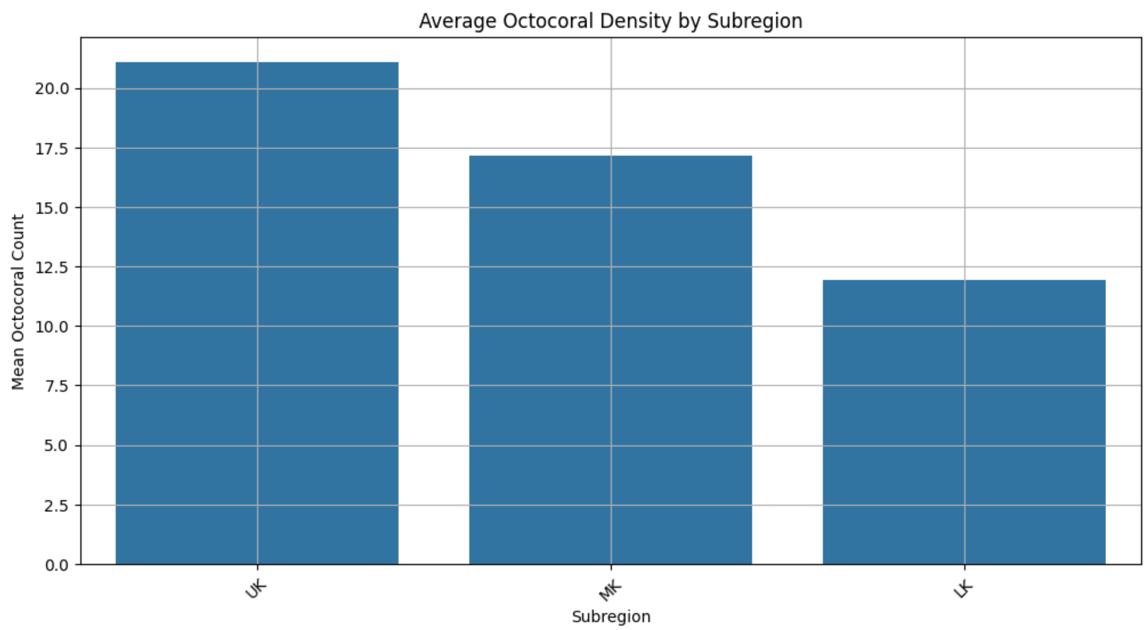


Figure 4: Temperature vs. Octocoral Density

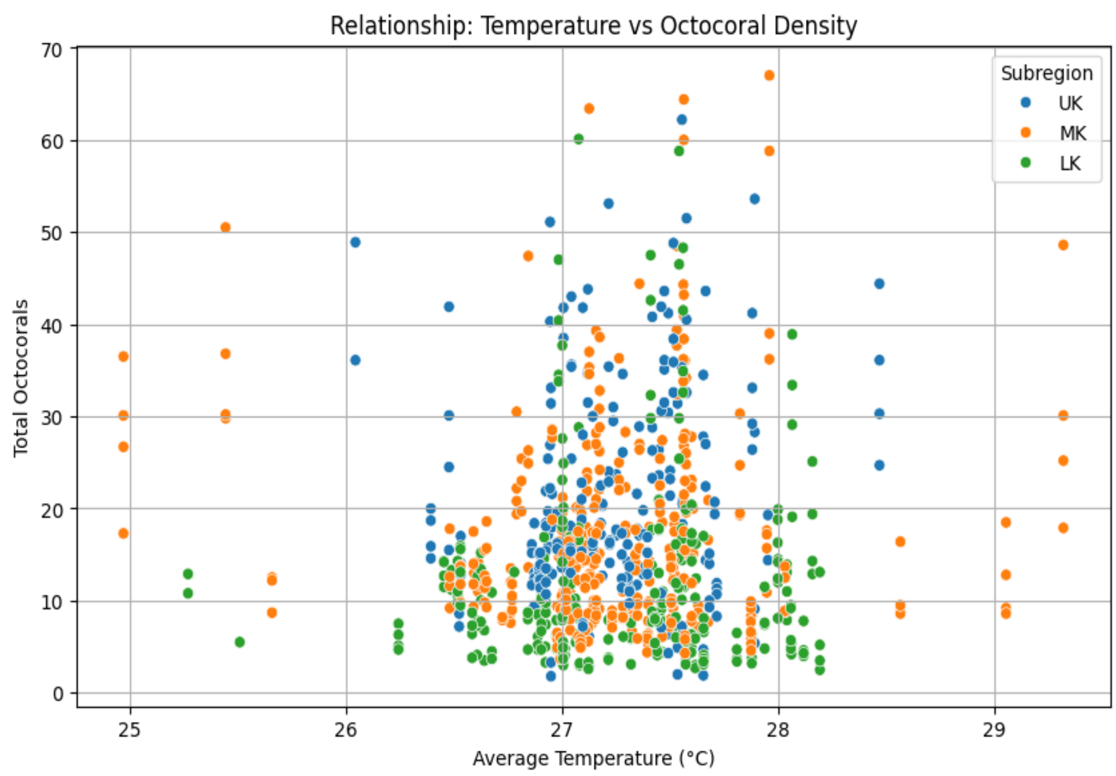


Figure 5: Octocoral Density by Station (Boxplot)

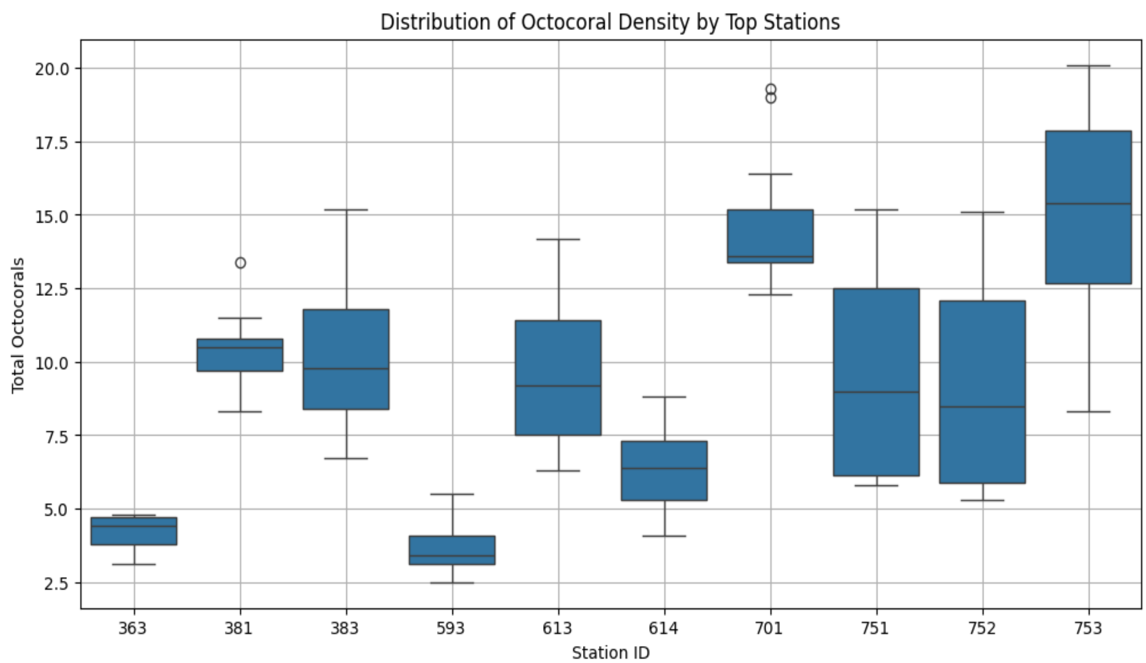


Figure 6: Species Richness Over Time

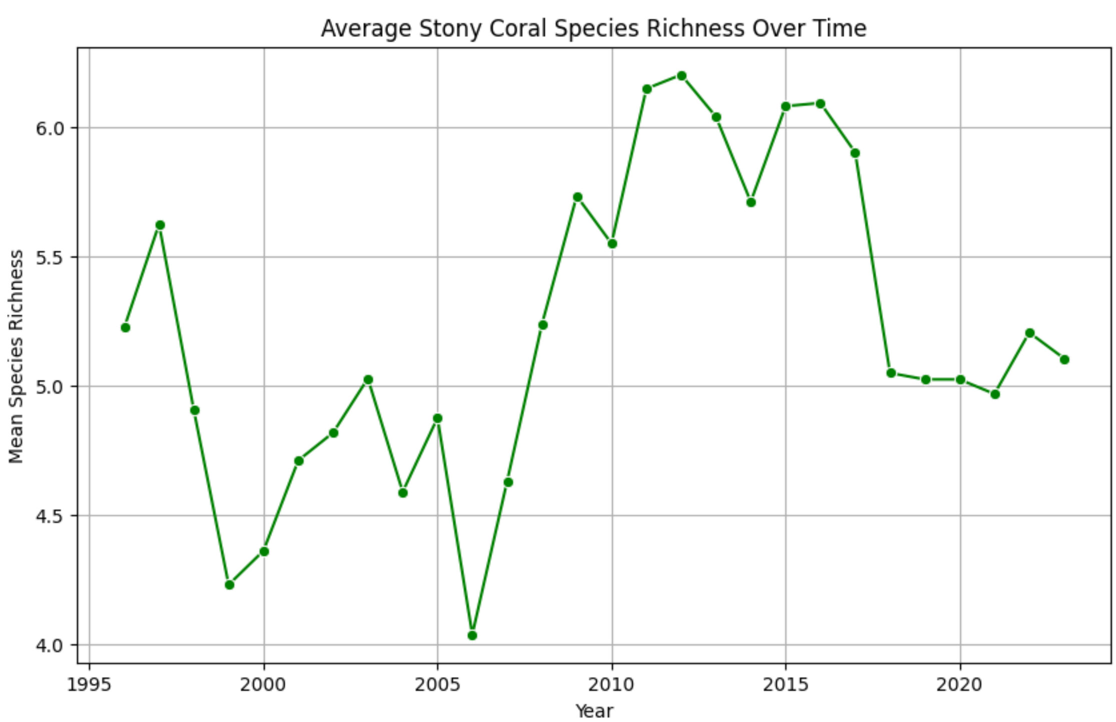


Figure 7: Correlation Heatmap

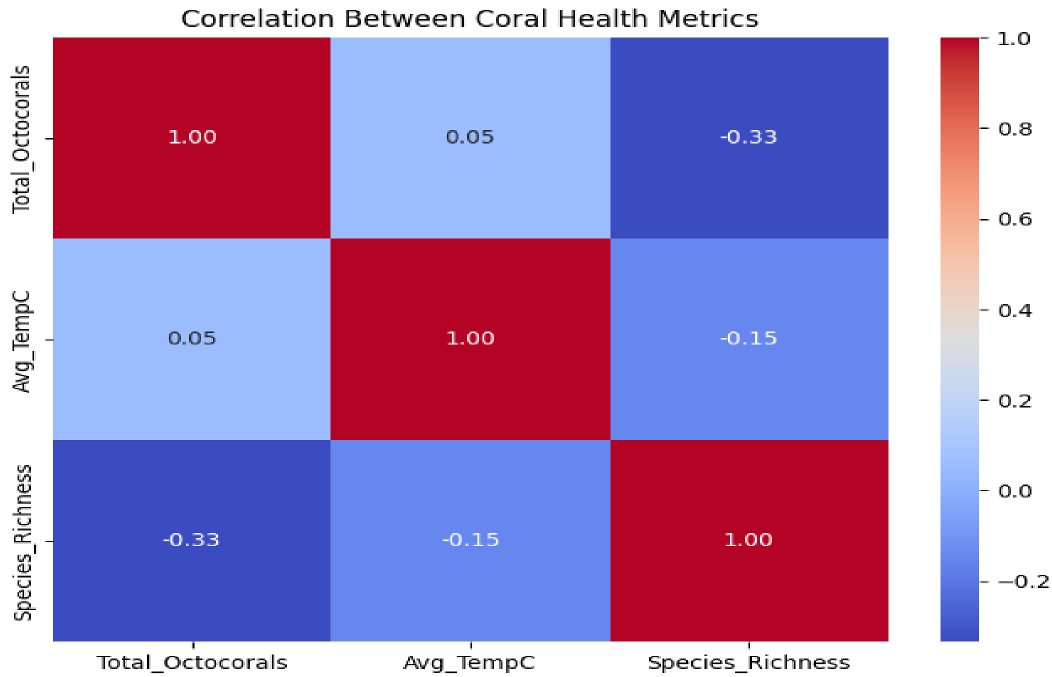


Figure 8: Species Richness vs. Average Temperature

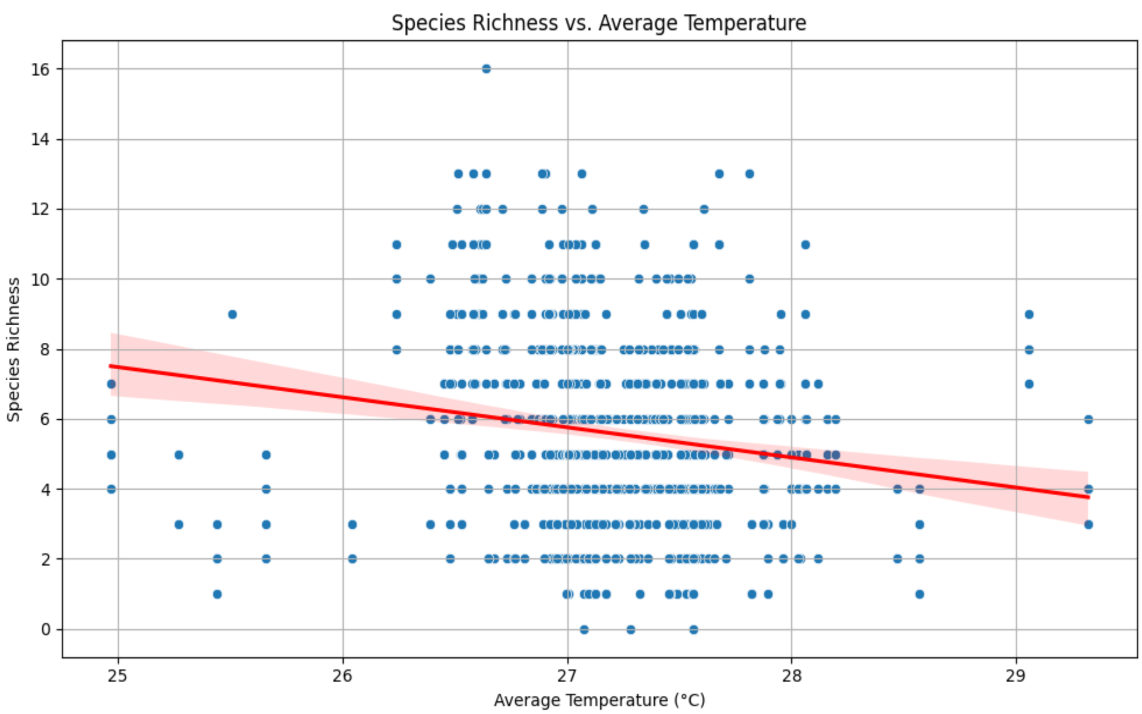


Figure 9: Coral Species Percent Cover (Top 10)

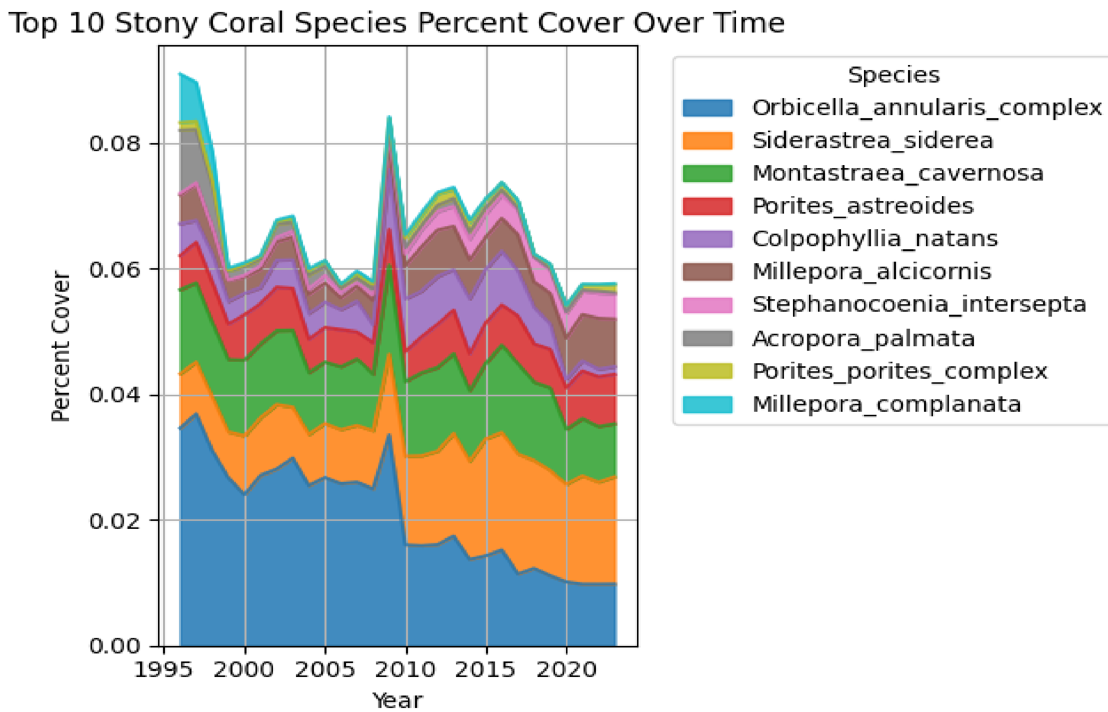


Figure 10: Living Tissue Area by Station (Boxplot)

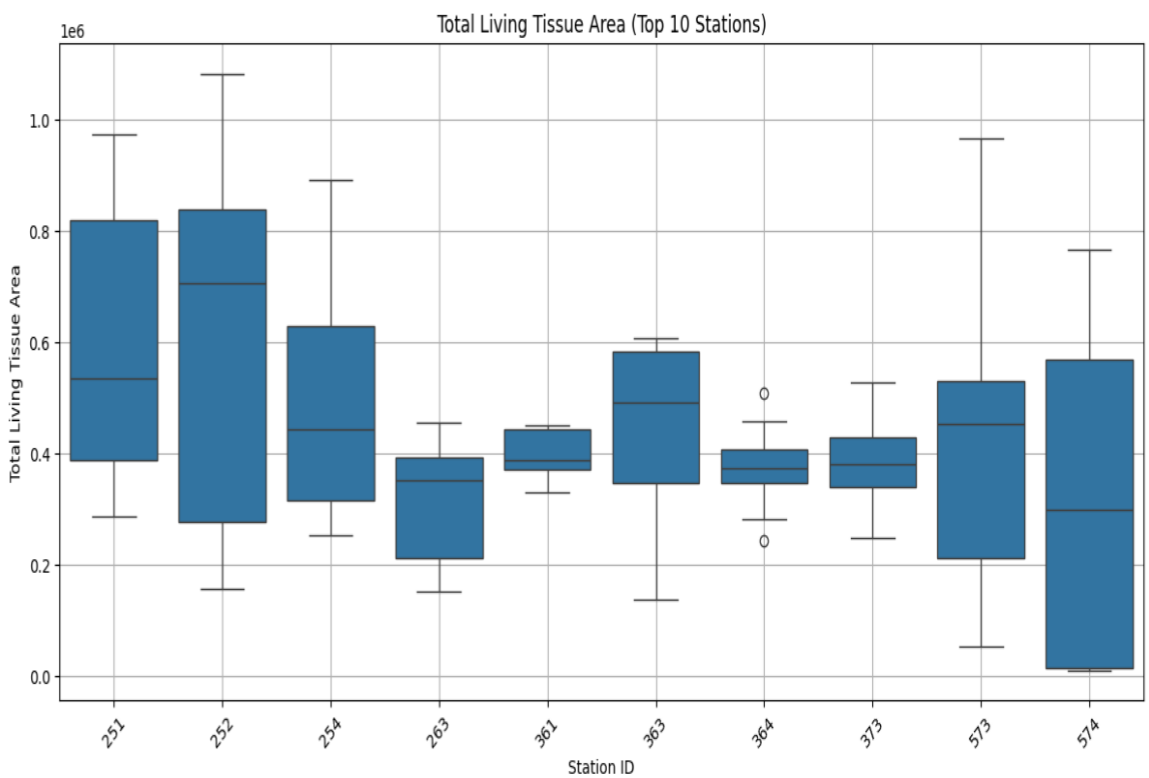


Figure 11: Linear Regression Forecast of Octocoral Density

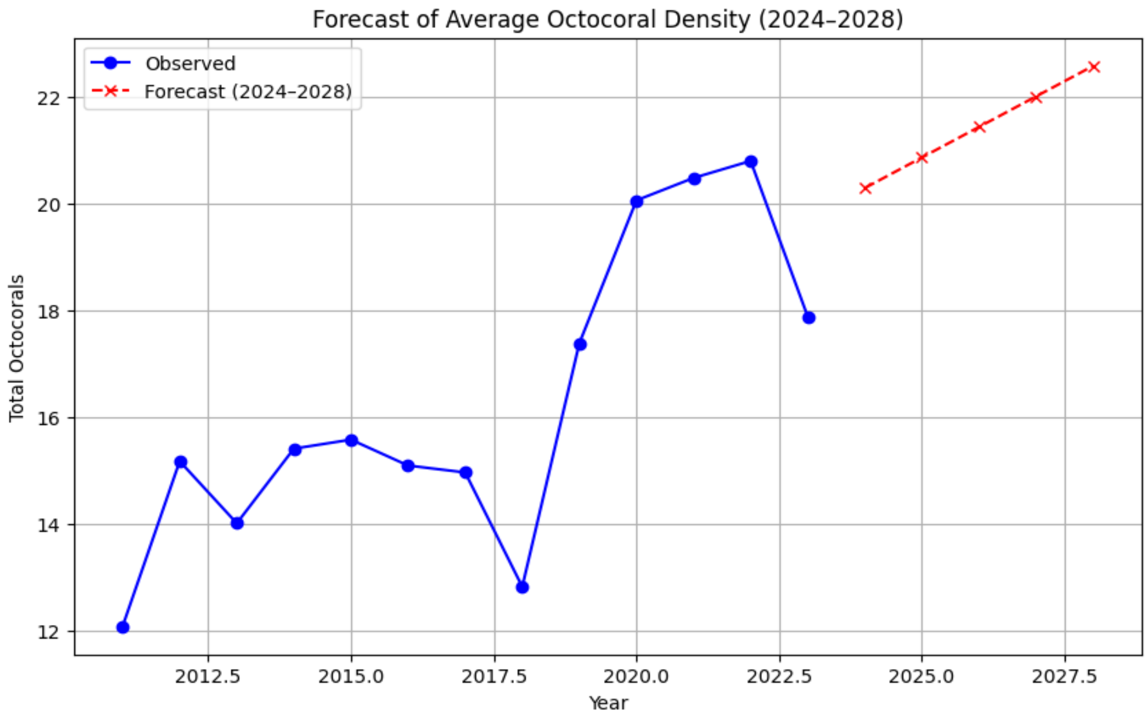


Figure 12: Prophet Forecast - Overall Trend

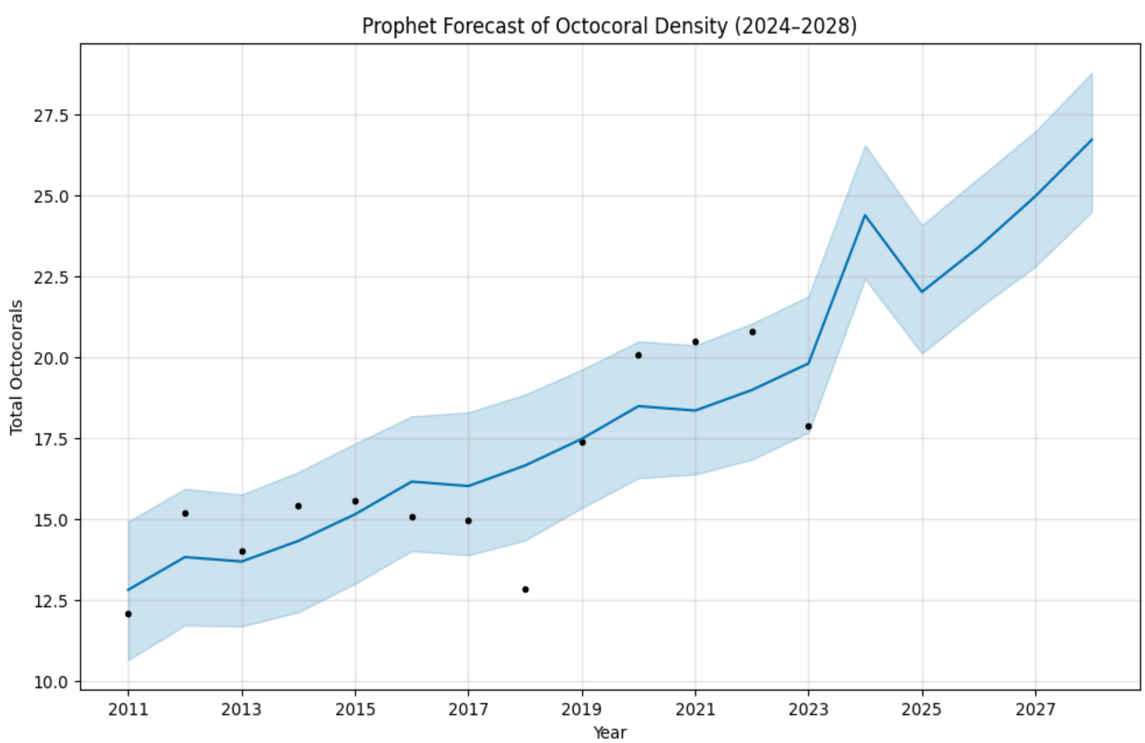
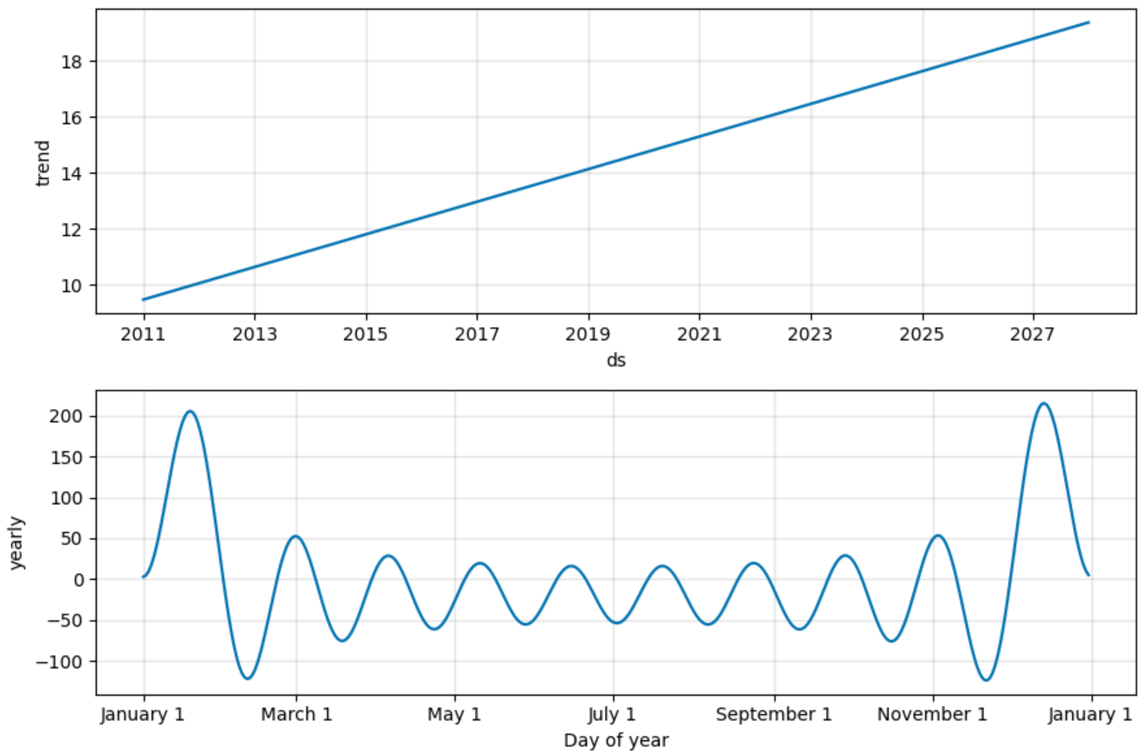


Figure 13: Prophet Forecast - Seasonality Decomposition



trend
ds
2011
2013
2015
2017
2019
2021
2023
2025
2027
10
12
14
16
18
yearly
Day of year
January 1
March 1
May 1
July 1
September 1
November 1
January 1
200
150
100
50
0
−50
−100