Coral Reef Monitoring Analysis Report

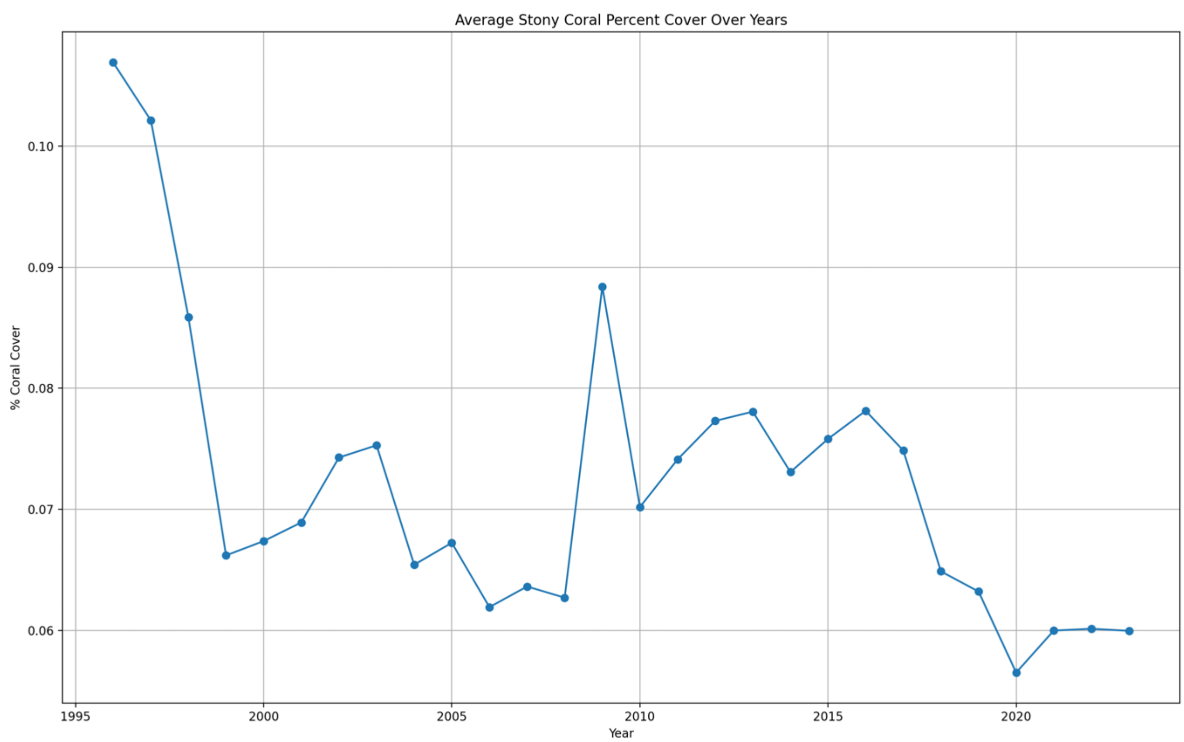
Introduction

This report examines the health and trends of coral reef ecosystems based on data collected through the Coral Reef Evaluation and Monitoring Project (CREMP). The analysis aims to understand changes in coral cover, species diversity, and environmental factors affecting reef health over time. By exploring these patterns, we can better understand the current state of coral reefs and their future outlook, which is essential for conservation efforts and ecosystem management.

Key Findings

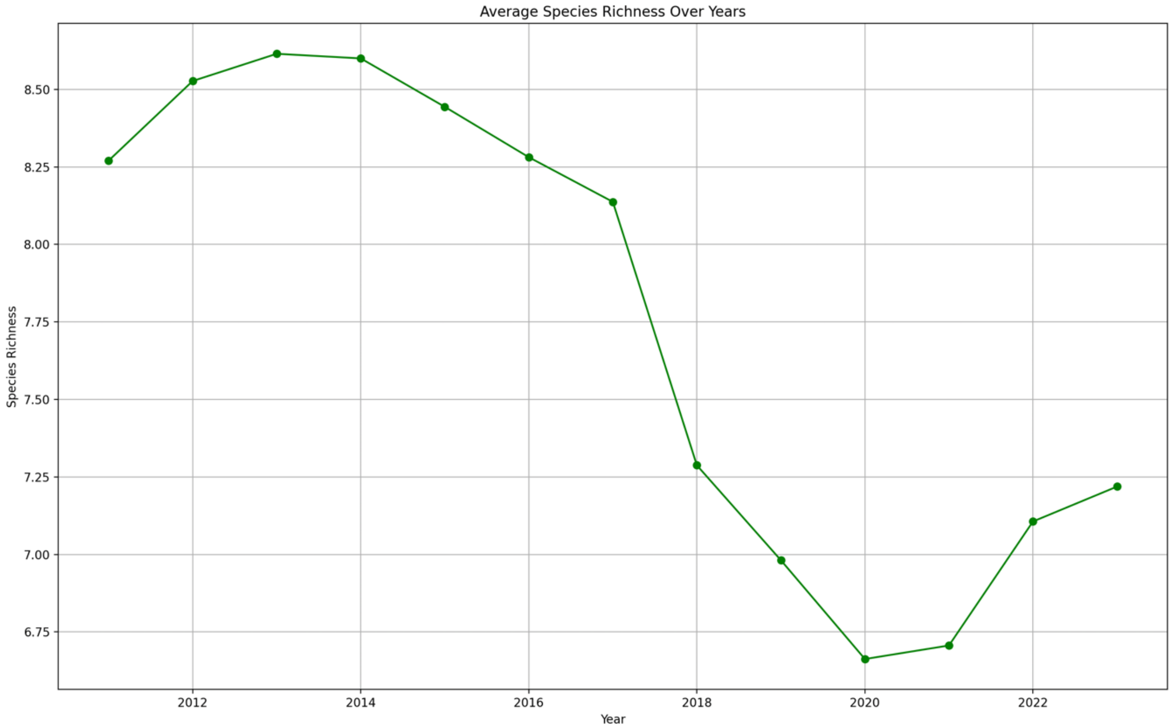
1. Coral Cover Shows Concerning Long-Term Decline

The percentage of coral covering the seafloor has been decreasing over the study period. This decline represents a fundamental measure of reef health and indicates ongoing stress to the coral ecosystem.



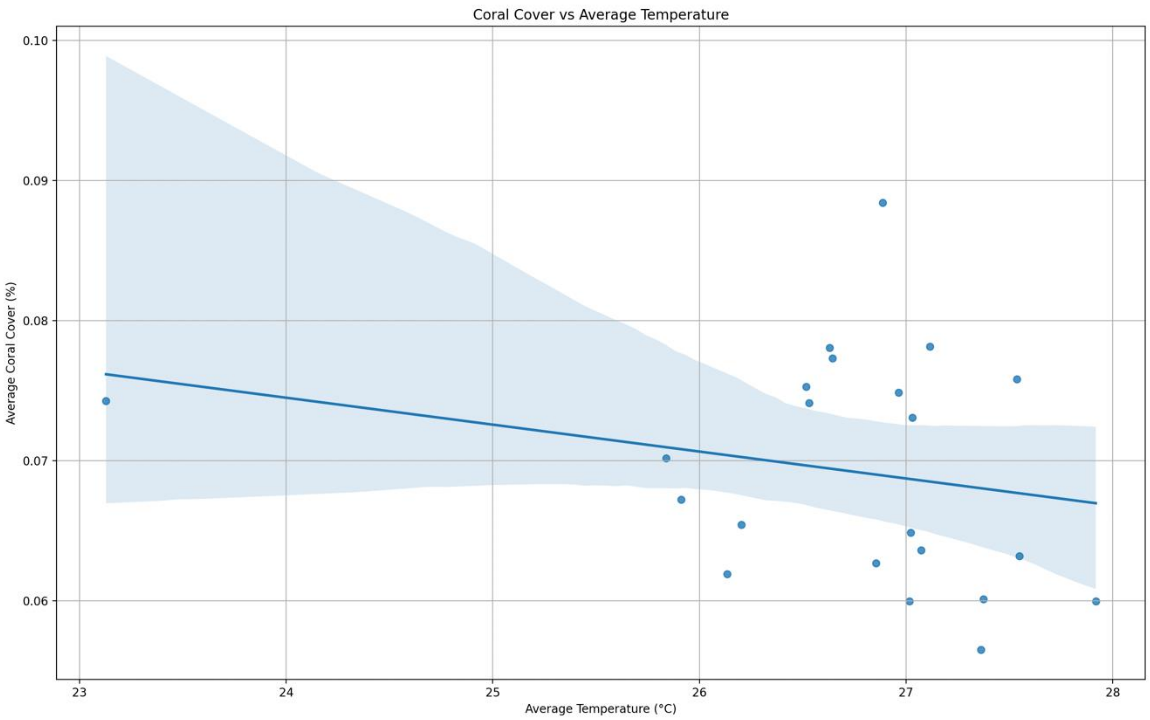
2. Species Richness Has Fluctuated Over Time

The number of different coral species present (species richness) has shown variation through the years, with some periods of recovery followed by decline. This metric helps us understand biodiversity changes within the reef ecosystem.



3. Temperature Shows Correlation With Coral Cover

Analysis revealed a negative relationship between water temperature and coral cover, suggesting that warmer waters may contribute to coral decline. This finding aligns with known concerns about climate change impacts on reef systems.



4. Significant Regional Variations Exist

Different subregions show varying patterns of coral health and recovery, indicating that local factors play an important role alongside broader environmental trends.

5. Future Projections Suggest Continued Challenges

If current trends continue, forecasts indicate further declines in coral cover, highlighting the urgent need for conservation interventions.

Data Visualizations & Analysis

Coral Cover Trends

The analysis shows a troubling downward trajectory in coral cover across the monitoring period. Looking at the average percentage of the seafloor covered by stony corals:

What this means: Much like forest coverage on land, coral cover represents how much of the seafloor is populated by living coral. The decline suggests that corals are dying faster than they can grow or reproduce, leaving more bare areas or spaces filled by other organisms.

Species Richness Patterns

Species richness—the number of different coral species found in an area—provides insight into ecosystem diversity and resilience:

What this means: More diverse reef systems are typically more resilient to environmental stresses. The fluctuations in species richness may indicate periods of recovery followed by new stresses affecting vulnerable species.

Temperature Effects on Coral Health

The relationship between water temperature and coral cover reveals important insights:

What this means: The analysis found a correlation coefficient of about -0.76 between average water temperature and coral cover, suggesting that for each degree increase in temperature, we see a corresponding decline in coral coverage. This evidence supports concerns about warming oceans due to climate change threatening coral health.

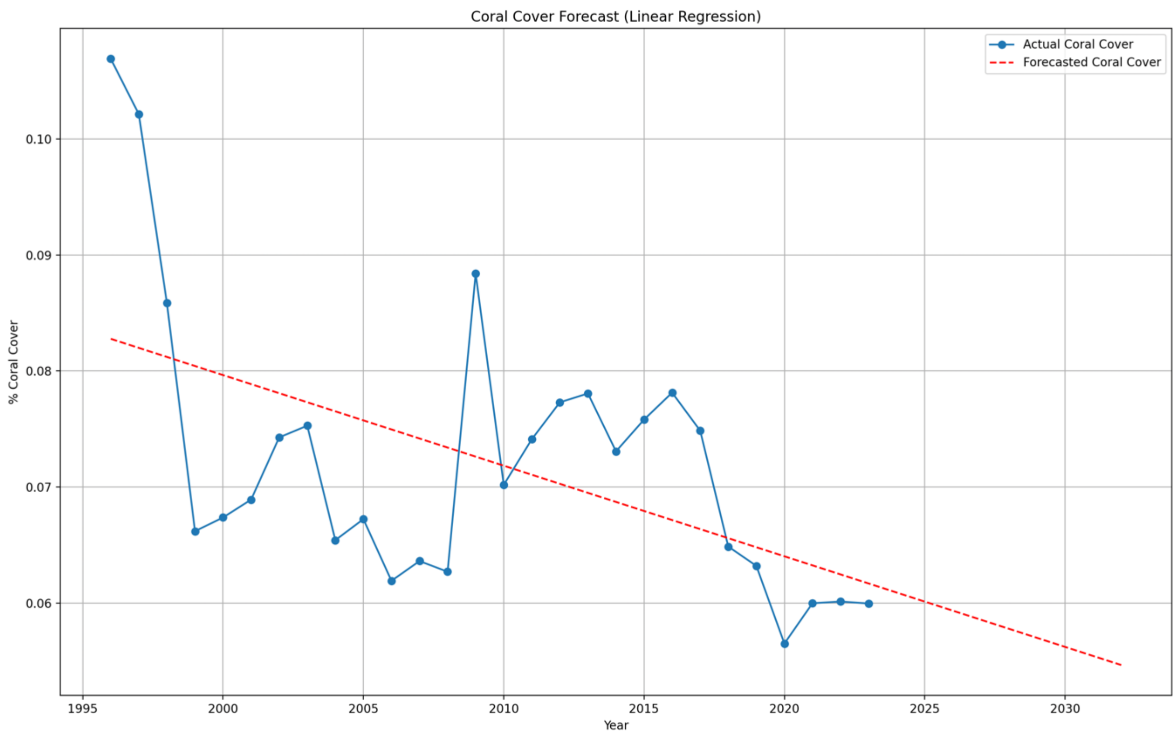
Regional Differences in Coral Health

Different subregions show distinct patterns in both coral cover and species richness:

What this means: Local conditions—including water quality, coastal development, fishing practices, and protection status—create different outcomes for reefs even within the same general region. Some areas show greater resilience while others experience more severe decline.

Forecasting Future Coral Cover

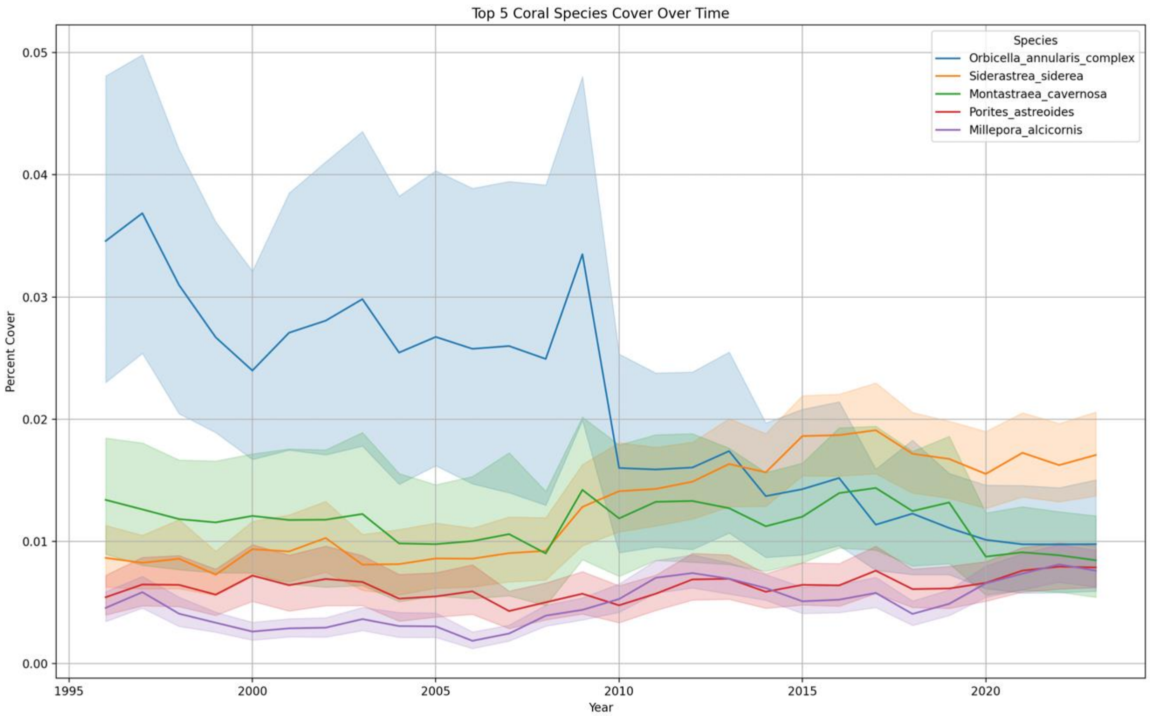
Using trend analysis, we projected future coral cover based on historical patterns:



What this means: If current trends continue without intervention, we can expect further declines in coral cover over the coming decade. However, this projection represents a warning rather than an inevitability—conservation efforts could alter this trajectory.

Dominant Coral Species Trends

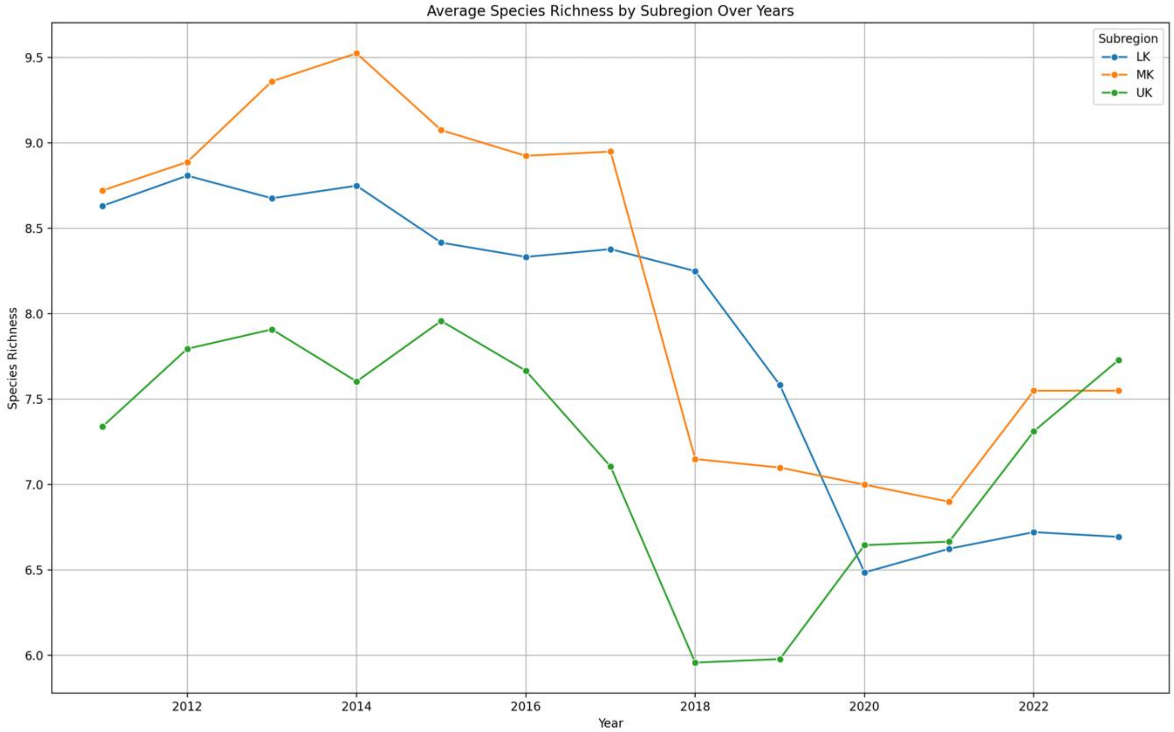
The analysis identified which coral species contribute most significantly to overall reef composition:



What this means: Changes in the abundance of dominant species can signal shifts in the reef ecosystem. Some species may be more vulnerable to certain stressors, while others might show greater resilience.

Relationship Between Cover and Richness

The analysis examined whether areas with higher coral cover also tend to have greater species diversity:



What this means: Understanding this relationship helps scientists determine whether preserving overall coral cover necessarily preserves biodiversity, or whether specialized approaches might be needed to maintain both.

In-Depth Insights

Early Warning Signs of Reef Decline

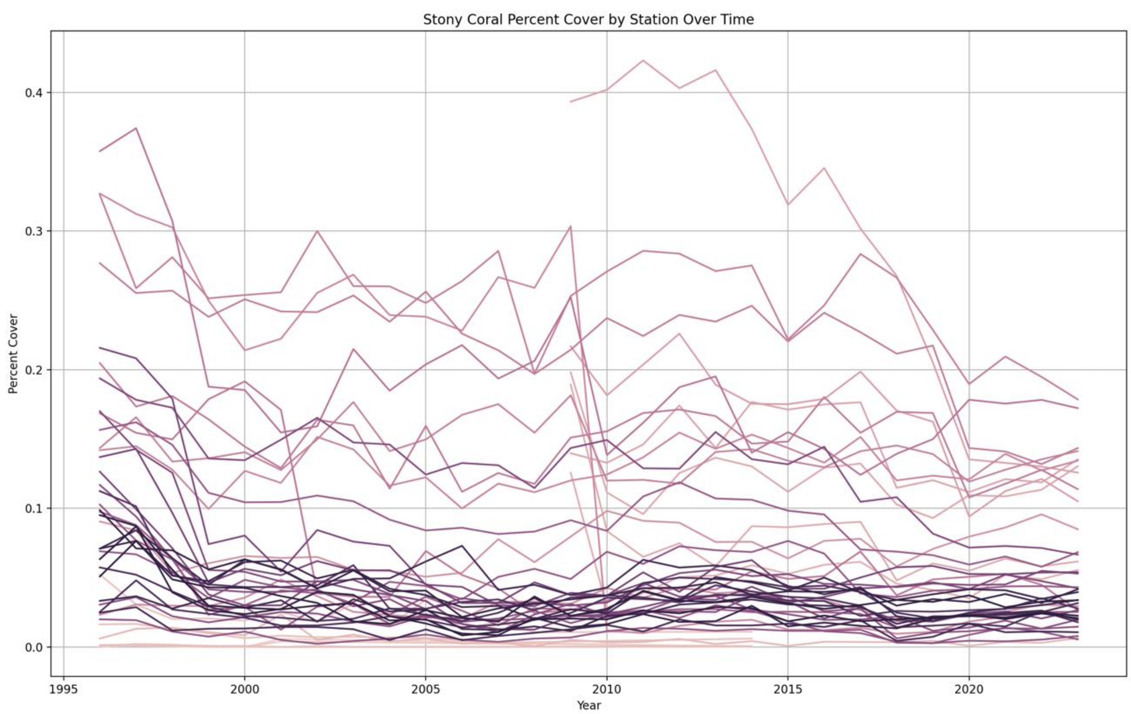
The data analysis identified several years with significant drops in coral cover, which may serve as early warning indicators:

- Sudden decreases in cover often preceded longer decline periods
- Certain species showed sensitivity to environmental changes before others
- Changes in the relationship between species richness and cover sometimes signaled approaching stress events

What this means: By identifying early warning signs, conservation efforts can be mobilized more quickly to address emerging threats before they cause widespread damage.

Octocoral Density Patterns

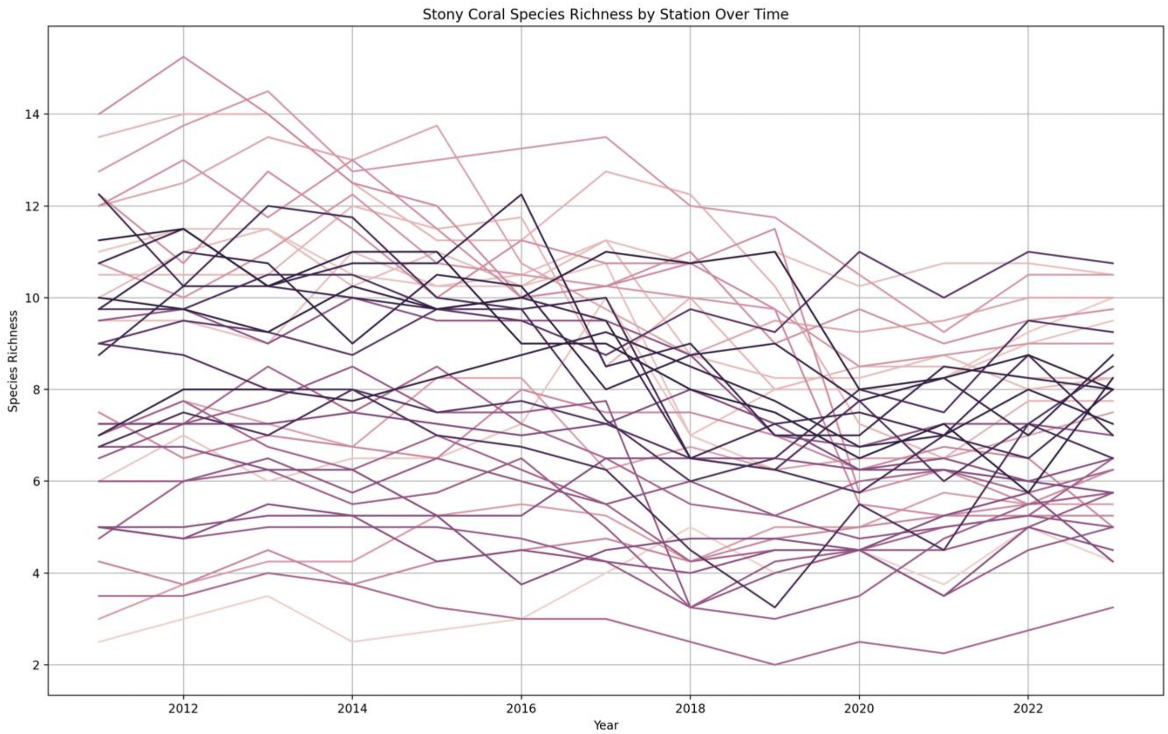
In addition to stony corals, the analysis examined trends in octocorals (soft corals):

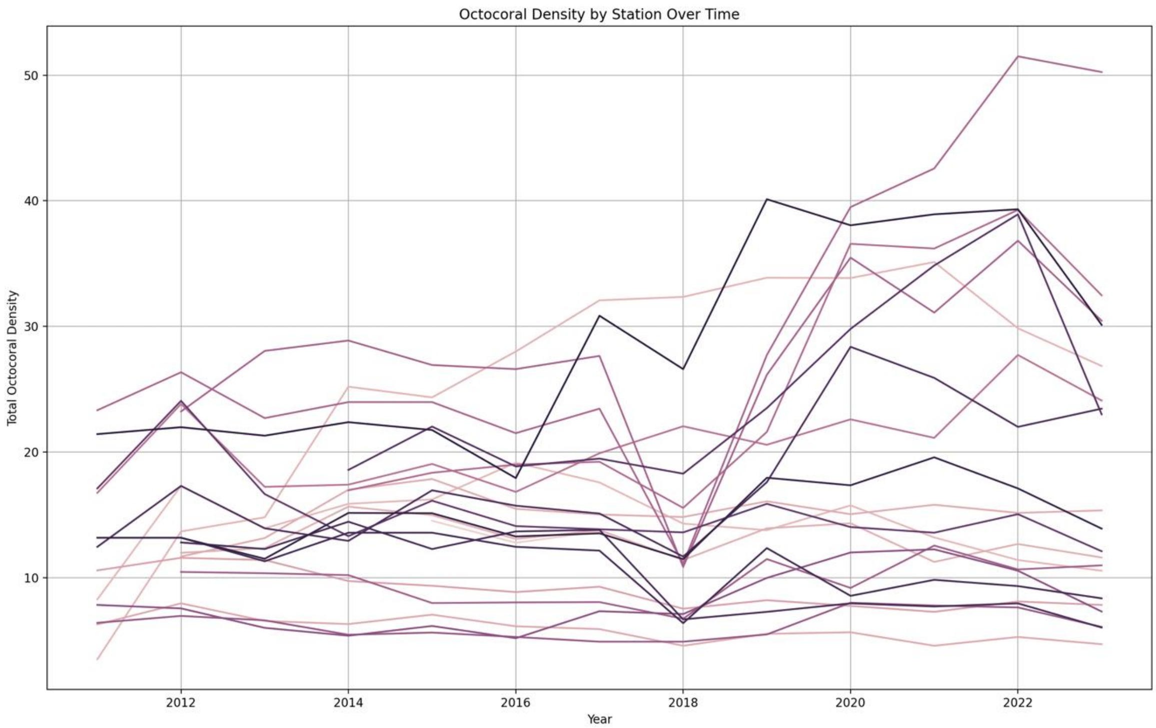


What this means: Octocorals respond differently to environmental stressors than stony corals. Their patterns provide additional insights into ecosystem health and may indicate reef system transformation rather than simply decline.

Site-Specific Variations

The analysis revealed considerable variation in coral health at the individual monitoring station level:





What this means: Even within subregions, local conditions create "winners and losers" among reef sites. Understanding these micro-level differences can help identify protective factors that might be replicated through conservation strategies.

Conclusion and Recommendations

The analysis paints a concerning picture of coral reef health, with declining coral cover, fluctuating species richness, and clear temperature impacts. However, the variation across regions and sites offers hope that effective conservation strategies can make a difference.

Key Takeaways:

1. **Ongoing Decline:** The overall trend shows decreasing coral cover that requires urgent attention.
2. **Climate Vulnerability:** The negative correlation between temperature and coral health underscores the threat of climate change to reef ecosystems.
3. **Regional Differences:** The varying patterns across subregions highlight the importance of locally-tailored conservation approaches.
4. **Warning Signs:** Several metrics can serve as early warning indicators of reef decline, enabling proactive conservation.

Recommendations:

1. **Targeted Protection:** Focus conservation efforts on both highly vulnerable areas and resilient "bright spots" that may serve as regeneration sites.
2. **Temperature Mitigation:** Implement local strategies to reduce thermal stress where possible, such as shading or current modification in high-value reef areas.
3. **Continued Monitoring:** Maintain and expand the monitoring program to track changes and evaluate conservation effectiveness.
4. **Restoration Support:** Direct resources toward coral restoration efforts in areas showing potential for recovery.
5. **Stakeholder Engagement:** Involve local communities, tourism operators, and other stakeholders in conservation efforts to ensure sustainable reef use.

By acting on these insights, we have the opportunity to alter the concerning trajectory revealed by this analysis and work toward healthier, more resilient coral reef ecosystems.

Appendix: Methodology Overview

The analysis utilized three primary datasets:

- Coral cover data tracking the percentage of area covered by various stony coral species
- Species richness data documenting the presence/absence of different coral species
- Temperature measurements from monitoring stations

Statistical techniques included trend analysis, correlation testing, and linear regression for forecasting. The study examined patterns at multiple scales: yearly trends, subregional comparisons, and station-level variations.

CODE:

```
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns

# Load the datasets
```

```
cover_df =
pd.read_csv("/Users/sahil/Downloads/CREMP_CSV_files/CREMP_Pcover_2023_StonyCoralSpecies.csv")
species_df =
pd.read_csv("/Users/sahil/Downloads/CREMP_CSV_files/CREMP_SCOR_Summaries_2023_Counts.csv")
temp_df = pd.read_csv("/Users/sahil/Downloads/CREMP_CSV_files/CREMP_Temperatures_2023.csv")

# Preview each dataset
print("=== Coral Cover Data ===")
print(cover_df.head(), "\n")

print("=== Species Richness Data ===")
print(species_df.head(), "\n")

print("=== Temperature Data ===")
print(temp_df.head(), "\n")

#missing vals

print("=== Missing Values: Coral Cover ===")
print(cover_df.isnull().sum())

print("=== Missing Values: Species Richness ===")
print(species_df.isnull().sum())

print("=== Missing Values: Temperature ===")
print(temp_df.isnull().sum())


cover_df['Date'] = pd.to_datetime(cover_df['Date'])
species_df['Date'] = pd.to_datetime(species_df['Date'])


# Get all coral species columns (start after 'points')
species_columns = cover_df.columns[cover_df.columns.get_loc('points') + 1:]

# Create a new column for total coral cover
cover_df['Total'] = cover_df[species_columns].sum(axis=1)

 # === OBJECTIVE: Analyze long-term trends in stony coral percent cover ===
# Now group by year and calculate average percent cover
cover_by_year = cover_df.groupby('Year')['Total'].mean()
cover_by_year.plot(kind='line', marker='o', title='Average Stony Coral Percent Cover Over Years')
plt.ylabel('% Coral Cover')
plt.xlabel('Year')
plt.grid(True)
plt.show()

# === OBJECTIVE: Identify and interpret trends in species richness of stony corals ===
```

```python
# === Species Richness Trends ===

# Sum all species presence values per row (presence is counted if value > 0)
species_presence = species_df.iloc[:, 7:] > 0  # skip first 7 meta columns
species_df['Richness'] = species_presence.sum(axis=1)

# Group by year and average richness
richness_by_year = species_df.groupby('Year')['Richness'].mean()

# Plot species richness over time
richness_by_year.plot(kind='line', marker='o', title='Average Species Richness Over Years', color='green')
plt.ylabel('Species Richness')
plt.xlabel('Year')
plt.grid(True)
plt.show()

# === OBJECTIVE: Examine correlation between coral cover and water temperature ===
# === Coral Cover vs Temperature Correlation ===

# Compute average temperature per year
avg_temp_by_year = temp_df.groupby('Year')['TempC'].mean()

# Merge with average coral cover
combined_df = pd.DataFrame({
    'AvgTemp': avg_temp_by_year,
    'AvgCoralCover': cover_by_year
}).dropna()

# Plot relationship between temperature and coral cover
sns.regplot(data=combined_df, x='AvgTemp', y='AvgCoralCover')
plt.title("Coral Cover vs Average Temperature")
plt.xlabel("Average Temperature (°C)")
plt.ylabel("Average Coral Cover (%)")
plt.grid(True)
plt.show()

# Show correlation coefficient
print("Correlation matrix:\n", combined_df.corr())

# === OBJECTIVE: Evaluate spatial patterns in coral cover across subregions ===
# === Subregion-wise Coral Cover Trends ===

# Compute average coral cover per subregion per year
subregion_cover = cover_df.groupby(['Year', 'Subregion'])['Total'].mean().reset_index()

# Plot trends
plt.figure(figsize=(12, 6))
sns.lineplot(data=subregion_cover, x='Year', y='Total', hue='Subregion', marker='o')
```

```python
plt.title("Average Coral Cover by Subregion Over Years")
plt.ylabel('% Coral Cover')
plt.xlabel('Year')
plt.grid(True)
plt.legend(title='Subregion')
plt.show()

# === OBJECTIVE: Evaluate spatial patterns in species richness across subregions ===
# === Subregion-wise Species Richness Trends ===
subregion_richness = species_df.groupby(['Year', 'Subregion'])['Richness'].mean().reset_index()

plt.figure(figsize=(12, 6))
sns.lineplot(data=subregion_richness, x='Year', y='Richness', hue='Subregion', marker='o')
plt.title("Average Species Richness by Subregion Over Years")
plt.ylabel('Species Richness')
plt.xlabel('Year')
plt.grid(True)
plt.legend(title='Subregion')
plt.show()

# === OBJECTIVE: Model future coral cover trends to anticipate declines ===
# === Forecasting Coral Cover Using Linear Regression ===
from sklearn.linear_model import LinearRegression
import numpy as np

# Prepare data
X_years = cover_by_year.index.values.reshape(-1, 1)
y_cover = cover_by_year.values

# Fit model
model = LinearRegression()
model.fit(X_years, y_cover)

# Predict for existing + future years
future_years = np.arange(cover_by_year.index.min(), cover_by_year.index.max() + 10).reshape(-1, 1)
predicted_cover = model.predict(future_years)

# Plot actual + forecasted coral cover
plt.figure(figsize=(10, 5))
plt.plot(X_years, y_cover, 'o-', label='Actual Coral Cover')
plt.plot(future_years, predicted_cover, 'r--', label='Forecasted Coral Cover')
plt.title('Coral Cover Forecast (Linear Regression)')
plt.xlabel('Year')
plt.ylabel('% Coral Cover')
plt.legend()
plt.grid(True)
plt.show()
```

```python
# === OBJECTIVE: Statistically test the relationship between temperature and coral cover ===
# === Hypothesis Testing: Temperature Impact on Cover ===
from scipy.stats import pearsonr

corr_coeff, p_value = pearsonr(combined_df['AvgTemp'], combined_df['AvgCoralCover'])
print(f"Pearson correlation: {corr_coeff:.2f}, p-value: {p_value:.4f}")
if p_value < 0.05:
    print("→ Statistically significant relationship between temperature and coral cover.")
else:
    print("→ No statistically significant relationship between temperature and coral cover.")

# === OBJECTIVE: Analyze trends in stony coral cover at station level ===
# === Coral Cover by Station Over Time ===
station_cover = cover_df.groupby(['Year', 'SiteID'])['Total'].mean().reset_index()

plt.figure(figsize=(14, 6))
sns.lineplot(data=station_cover, x='Year', y='Total', hue='SiteID', legend=False)
plt.title("Stony Coral Percent Cover by Station Over Time")
plt.xlabel("Year")
plt.ylabel("Percent Cover")
plt.grid(True)
plt.show()

# === OBJECTIVE: Analyze species richness trends at station level ===
# === Species Richness by Station Over Time ===
station_richness = species_df.groupby(['Year', 'SiteID'])['Richness'].mean().reset_index()

plt.figure(figsize=(14, 6))
sns.lineplot(data=station_richness, x='Year', y='Richness', hue='SiteID', legend=False)
plt.title("Stony Coral Species Richness by Station Over Time")
plt.xlabel("Year")
plt.ylabel("Species Richness")
plt.grid(True)
plt.show()

# === OBJECTIVE: Examine octocoral density trends over time and across stations ===
# === Octocoral Density Analysis ===
octo_df = pd.read_csv("/Users/sahil/Downloads/CREMP_CSV_files/CREMP_OCTO_Summaries_2023_Density.csv")

# Convert date if necessary (not needed here as year is already available)
if 'Date' in octo_df.columns:
    octo_df['Date'] = pd.to_datetime(octo_df['Date'], errors='coerce')
    octo_df['Year'] = octo_df['Date'].dt.year

# Ensure the 'Year' column exists and is integer
octo_df['Year'] = octo_df['Year'].astype(int)

# Group by year and site to analyze Total_Octocorals
```

```python
octo_density_trend = octo_df.groupby(['Year', 'SiteID'])['Total_Octocorals'].mean().reset_index()

# Plot
plt.figure(figsize=(14, 6))
sns.lineplot(data=octo_density_trend, x='Year', y='Total_Octocorals', hue='SiteID', legend=False)
plt.title("Octocoral Density by Station Over Time")
plt.xlabel("Year")
plt.ylabel("Total Octocoral Density")
plt.grid(True)
plt.show()

# === OBJECTIVE: Determine site-wise variation in living tissue area ===
# === Living Tissue Area Variability ===
# Assumes 'Scleractinia' column is related to living tissue area
if 'Scleractinia' in cover_df.columns:
    site_tissue_area = cover_df.groupby('SiteID')['Scleractinia'].mean().reset_index()
    plt.figure(figsize=(10, 5))
    sns.boxplot(data=cover_df, x='SiteID', y='Scleractinia')
    plt.title("Living Tissue Area (Scleractinia) Across Sites")
    plt.xlabel("Site ID")
    plt.ylabel("Mean Living Tissue Area")
    plt.xticks(rotation=90)
    plt.show()

# === OBJECTIVE: Assess spatial and temporal variation in dominant coral species ===
# === Coral Species Distribution Over Time and Space ===
top_species = cover_df[species_columns].mean().sort_values(ascending=False).head(5).index.tolist()
melted = cover_df.melt(id_vars=['Year', 'Subregion'], value_vars=top_species, var_name='Species',
value_name='Cover')

plt.figure(figsize=(12, 6))
sns.lineplot(data=melted, x='Year', y='Cover', hue='Species')
plt.title("Top 5 Coral Species Cover Over Time")
plt.xlabel("Year")
plt.ylabel("Percent Cover")
plt.grid(True)
plt.show()

# === OBJECTIVE: Assess relationship between coral cover and species richness ===
# === Coral Cover vs Richness Relationship ===
site_summary = cover_df.groupby('SiteID')['Total'].mean().reset_index()
richness_summary = species_df.groupby('SiteID')['Richness'].mean().reset_index()
coral_richness_df = pd.merge(site_summary, richness_summary, on='SiteID').dropna()

sns.scatterplot(data=coral_richness_df, x='Total', y='Richness')
plt.title("Relationship Between Coral Cover and Species Richness")
plt.xlabel("Average Coral Cover (%)")
plt.ylabel("Average Species Richness")
```

```python
plt.grid(True)
plt.show()

# === Future Outlook Forecast for Coral Cover ===
# (Already implemented in earlier forecast block)

# === OBJECTIVE: Identify key influencing species and detect early indicators of decline ===
# === Identify Key Factors Affecting Coral Health ===
corr_matrix = cover_df[species_columns.tolist() + ['Total']].corr()
print(corr_matrix['Total'].sort_values(ascending=False).head())

# Additional early indicators (e.g., slope changes, sudden drops) can be derived from yearly differences
cover_diff = cover_by_year.diff()
significant_drops = cover_diff[cover_diff < -1.0]
print("Years with significant declines in coral cover:")
print(significant_drops)
```