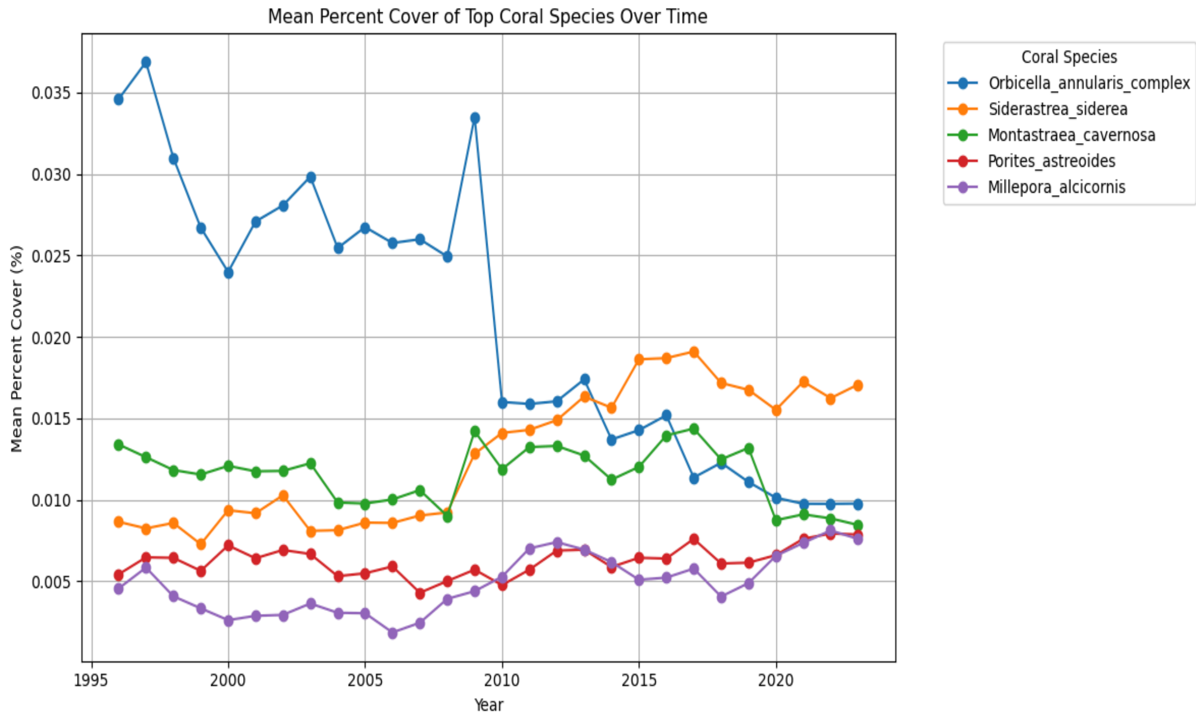
Exploratory Data Analysis

->Analyze the evolution of stony coral percentage cover across different stations during the study period

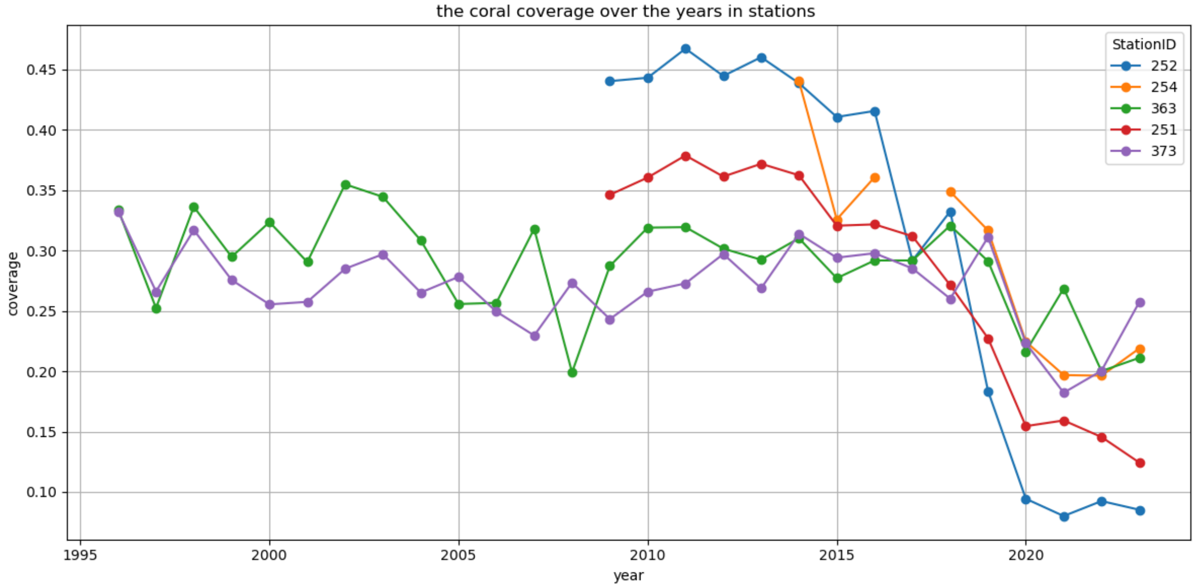
Used Csv is CREMP_Pcover_2023_StonyCoralSpecies.csv

Due to presence of many coral species ,i just used one the top coral species with high mean percent age

“Despite being one of the top five corals in terms of mean percent cover and overall net increase, Orbicella annularis complex experienced a consistent decline from 2010 to 2020. This suggests a more complex temporal pattern, where the species may have suffered losses due to environmental stressors during the decade, followed by a limited recovery in recent years.”
“Siderastrea siderea exhibited a consistent upward trend in percent cover from 2010 to 2020, indicating its resilience and potential competitive advantage in the face of environmental changes. Its growth trajectory contrasts with the decline of more sensitive species such as Orbicella annularis complex, suggesting a possibe shift in coral community structure.”

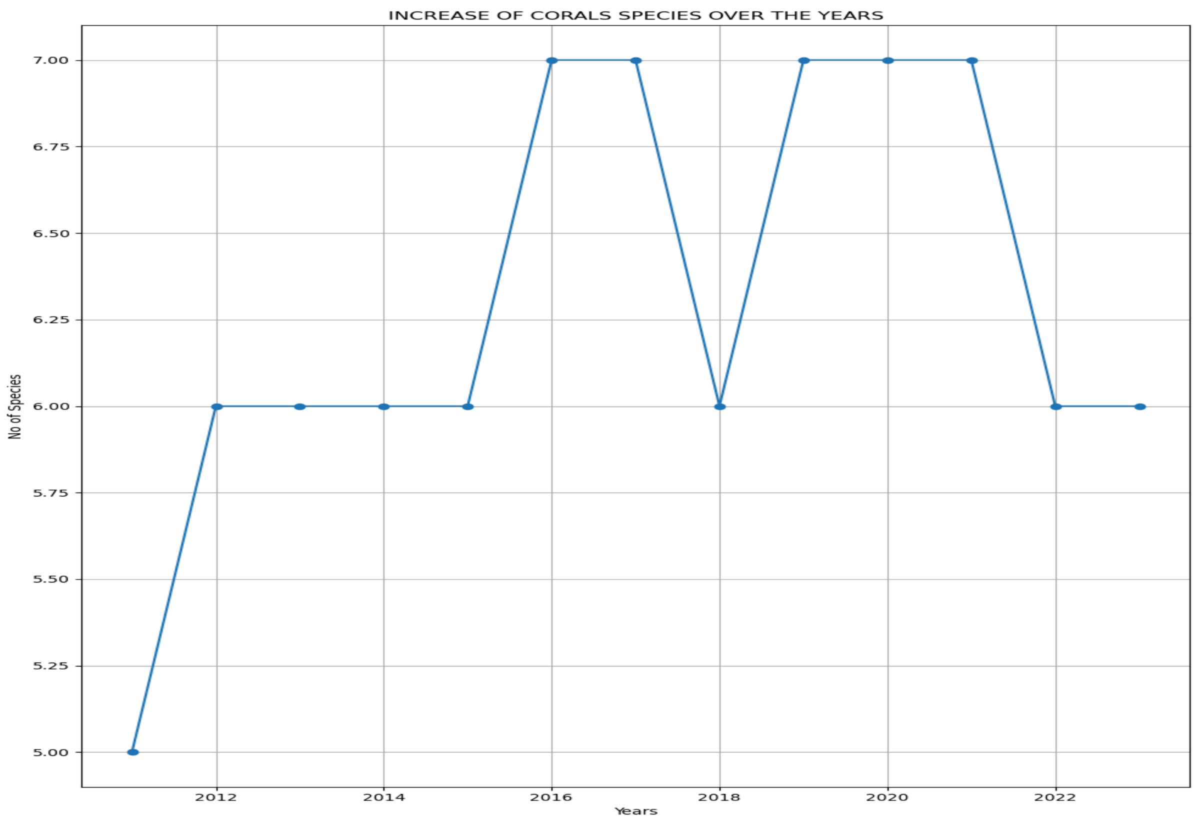


Change over the years by station



We see a dip it 2020 the factors might be inaccessibility of humans to ocean ,maybe the coverage decreased due to corals populating naturally rather than with the help of humans

- **Identify and interpret trends in species richness of stony corals over the years.**



We see a sudden increase from 2014-2016 and a dip in 2018 maybe a natural disaster like hurricane or tsunami and an increase in 2018-2022 and it dipped again due to natural disaster

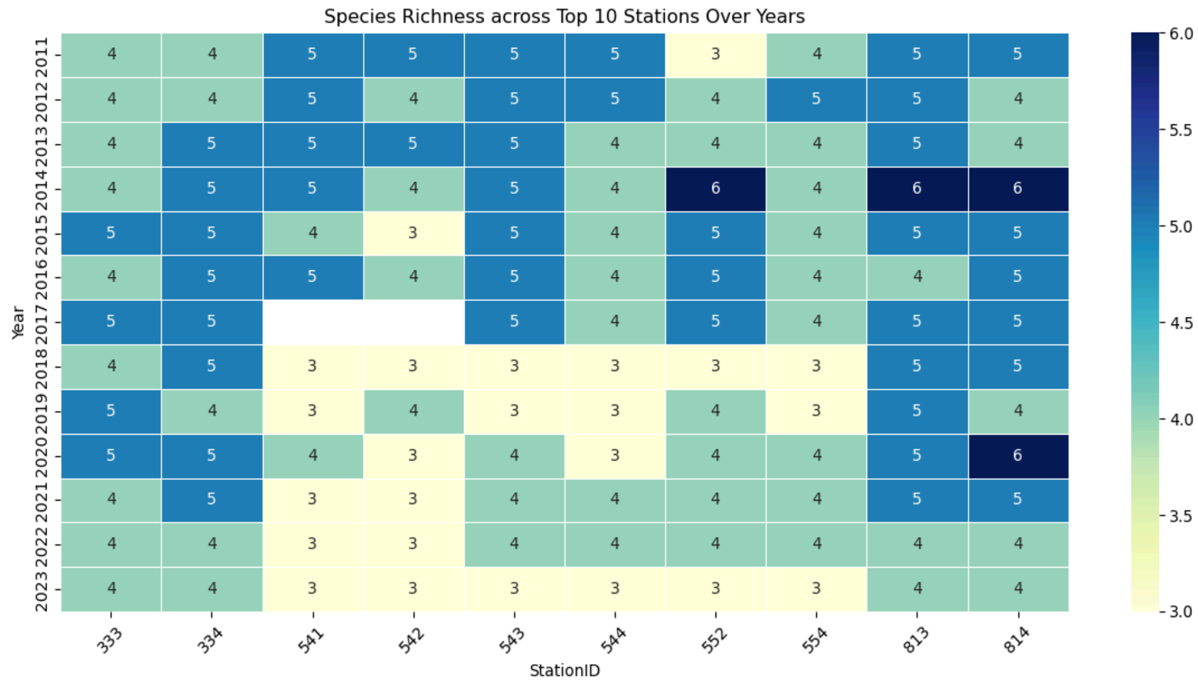
- Examine how the density of octocoral species varies across stations and over time.

>Between 2013-2016, species richness was relatively high across most stations.

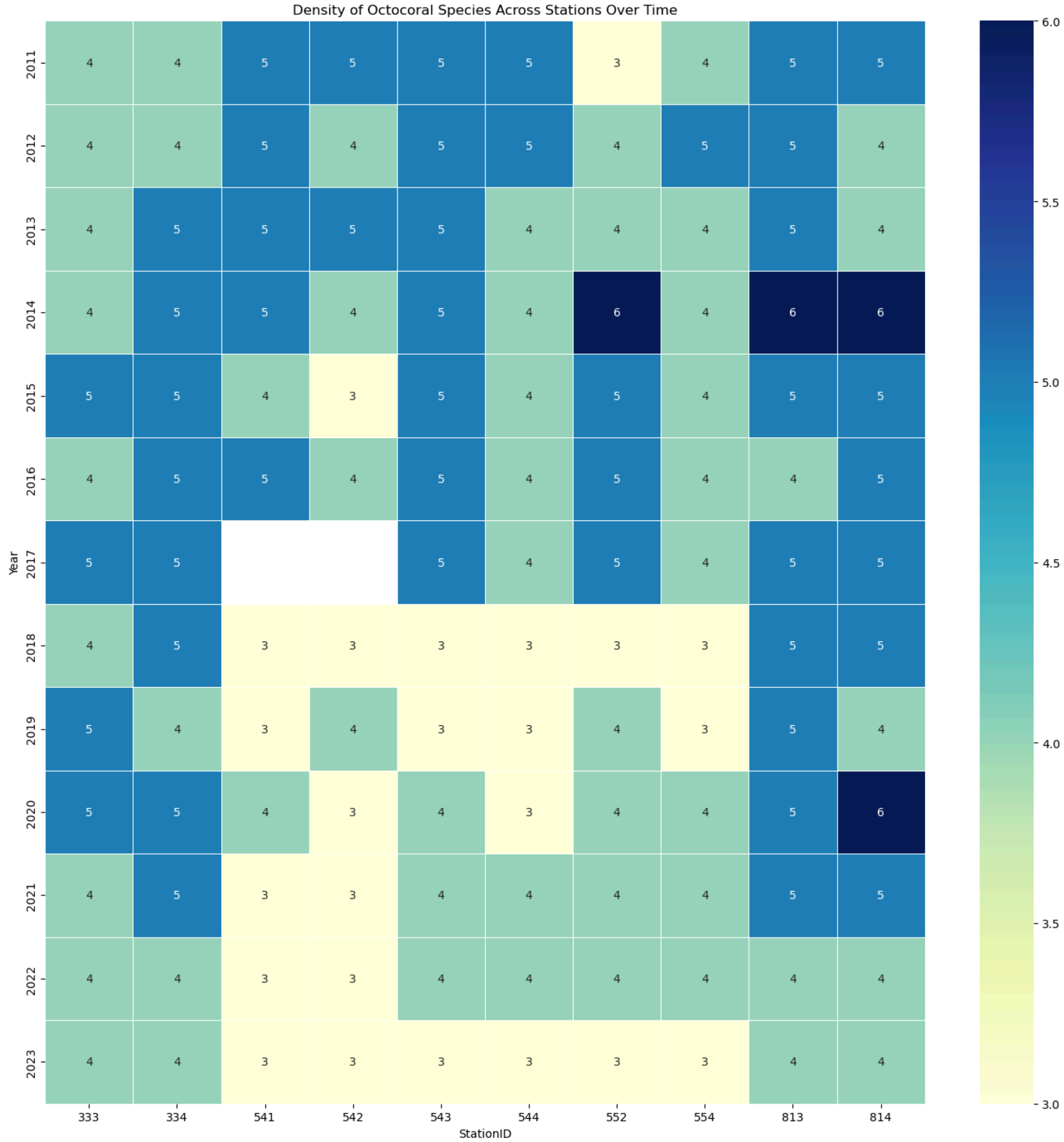
->A noticeable dip around 2018–2020, likely due to environmental stressors or sampling reduction.

->Station 814 remained relatively rich in species consistently from 2014–2021.

->Overall, richness seems to be stabilizing post-2020, though slightly lower than the 2013–2016 peak.



Station 813 consistently shows high species richness in later years (2014-2023). The dark blue cells and values of 6 indicate a potentially thriving ecosystem at this station.
Station 552 appears to have relatively lower species richness compared to others. The lighter colors and lower numerical values across several years suggest this might be a less diverse location.
There are fluctuations in species richness over time at individual stations. For example, Station 333 shows a mix of values across the years, indicating some variability in its biodiversity.
Some stations show a trend of decreasing species richness in recent years. Notice how some rows towards the bottom (later years) have lighter colors for certain stations compared to earlier years. This could be a point of concern warranting further investigation.
Station 541 experienced a notable dip in species richness in 2017 and 2018. The yellow cells with a value of 3 stand out, suggesting a potentially significant event impacted the biodiversity at this location during those years.
Station 544 shows a relatively stable but moderate species richness over the years. The consistent light blue/green hues suggest less dramatic fluctuations.

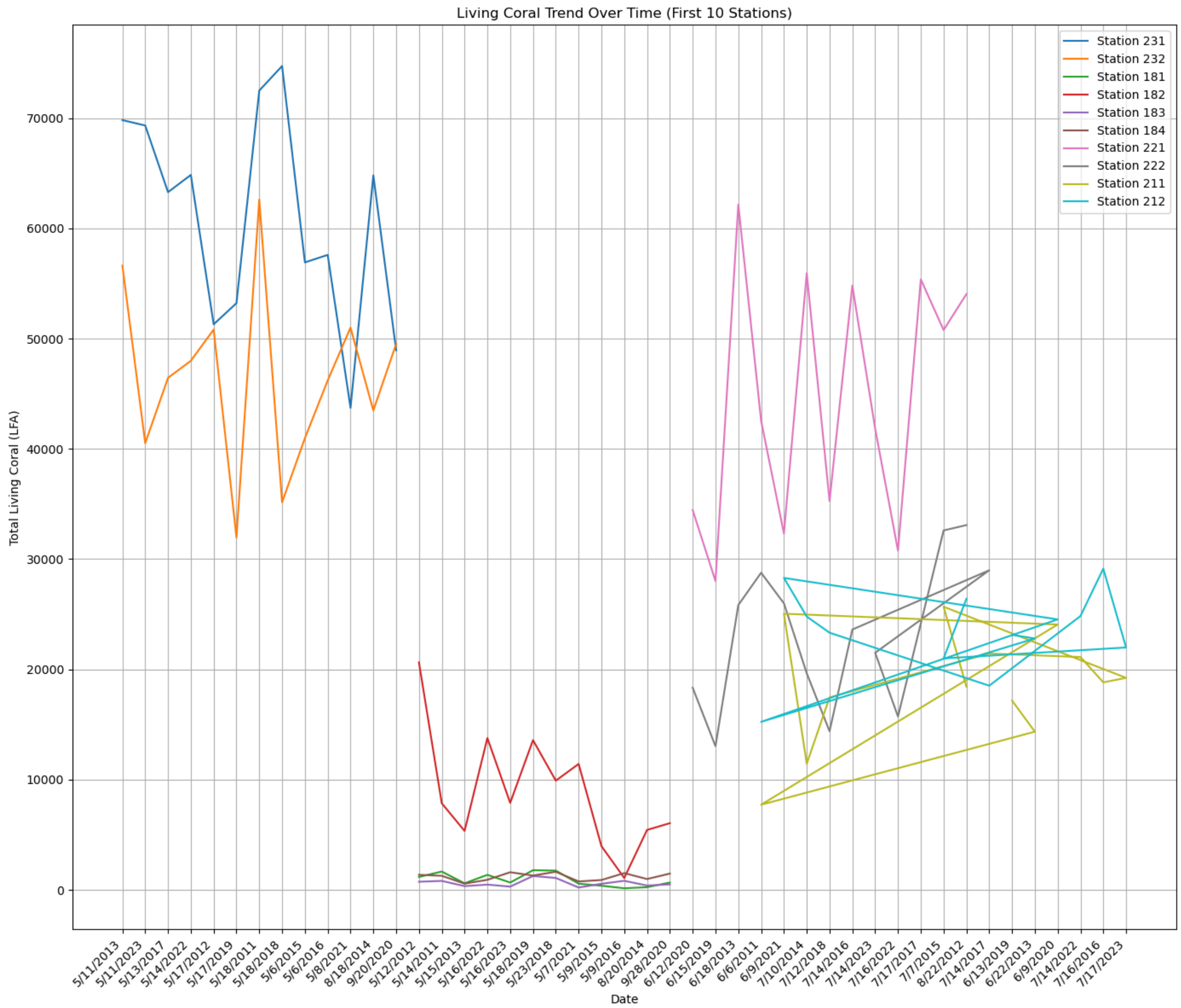


Overall Trends:

- **Fluctuating Densities:** The color variations across the heatmap indicate that the density of octocoral species isn't constant. We see periods and locations with higher densities (darker blues) and others with lower densities (lighter yellows and greens).
- **Spatial Variation:** There's a clear difference in octocoral density across the different stations (labeled along the x-axis). Some stations consistently show higher or lower densities compared to others throughout the study period.
- **Temporal Changes:** The density at specific stations also changes over the years (labeled along the y-axis). We can observe increases or decreases in density at particular locations as time progresses.

Specific Observations:

- **High Density Hotspots:** Stations 813 and 814 appear to consistently exhibit higher octocoral densities, particularly in the later years (around 2014, 2020, and 2021). Station 553 also shows a notably high density in 2014.
- **Lower Density Areas:** Stations 541 and 554 generally seem to have lower octocoral densities compared to the other stations across most of the years.
- **Notable Shifts:**
    - Station 541 shows a very low density in 2017, which is quite distinct from the surrounding years.
    - Station 552 appears to have relatively low densities in the earlier years, with some increase in later years.
    - Station 544 shows a period of lower density around 2020.
- **Year-to-Year Variability:** For most stations, there's a noticeable amount of fluctuation in octocoral density from one year to the next, suggesting that environmental or ecological factors are likely influencing these populations.
- **Determine whether there are significant differences in the living tissue area of stony corals between monitoring sites.**

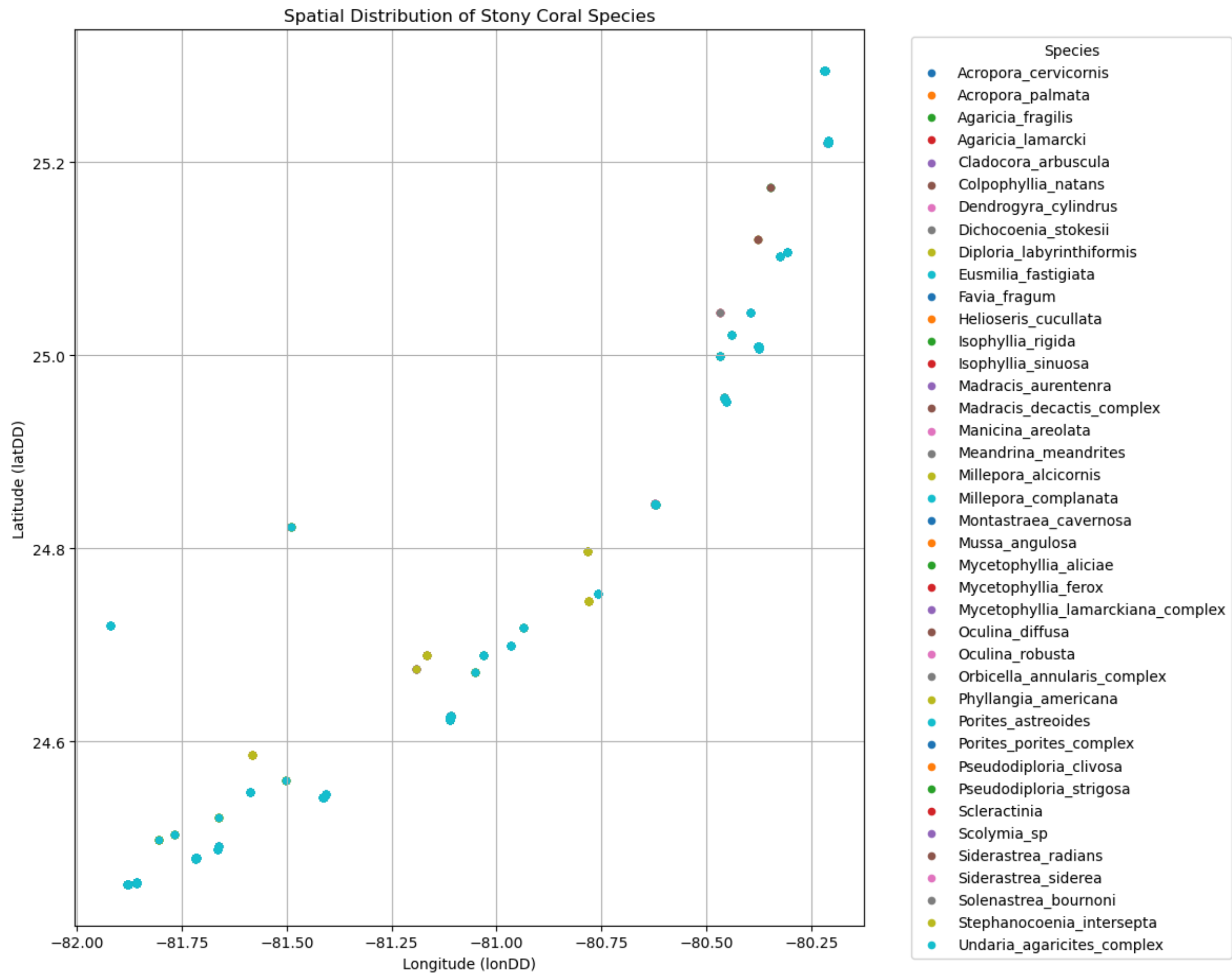


Varying Levels of LFA: There are substantial differences in the absolute levels of living coral area between the different monitoring stations. For instance, Station 231 and Station 232 generally exhibit much higher LFA values compared to stations like 181, 182, 183, and 184.

Different Temporal Trends: The way LFA changes over time is also unique for each station: Some stations (e.g., 231, 232) show considerable fluctuations, with periods of increase and decrease. Other stations (e.g., 181, 182, 183, 184) generally maintain lower LFA values with their own patterns of variation. Stations that appear later in the legend (e.g., 221, 222, 211, 212) have data starting at later time points. Potential Events: Some stations show sharp declines or increases in LFA at specific points in time, which might correspond to environmental events (e.g., storms, bleaching events, disease outbreaks) that could have differentially impacted the sites.

Data Gaps: As noted before, there are periods where data is missing for certain stations, making it harder to assess long-term trends for those specific locations.

- **Assess spatial patterns in the distribution of different coral species and how these patterns change over time.**

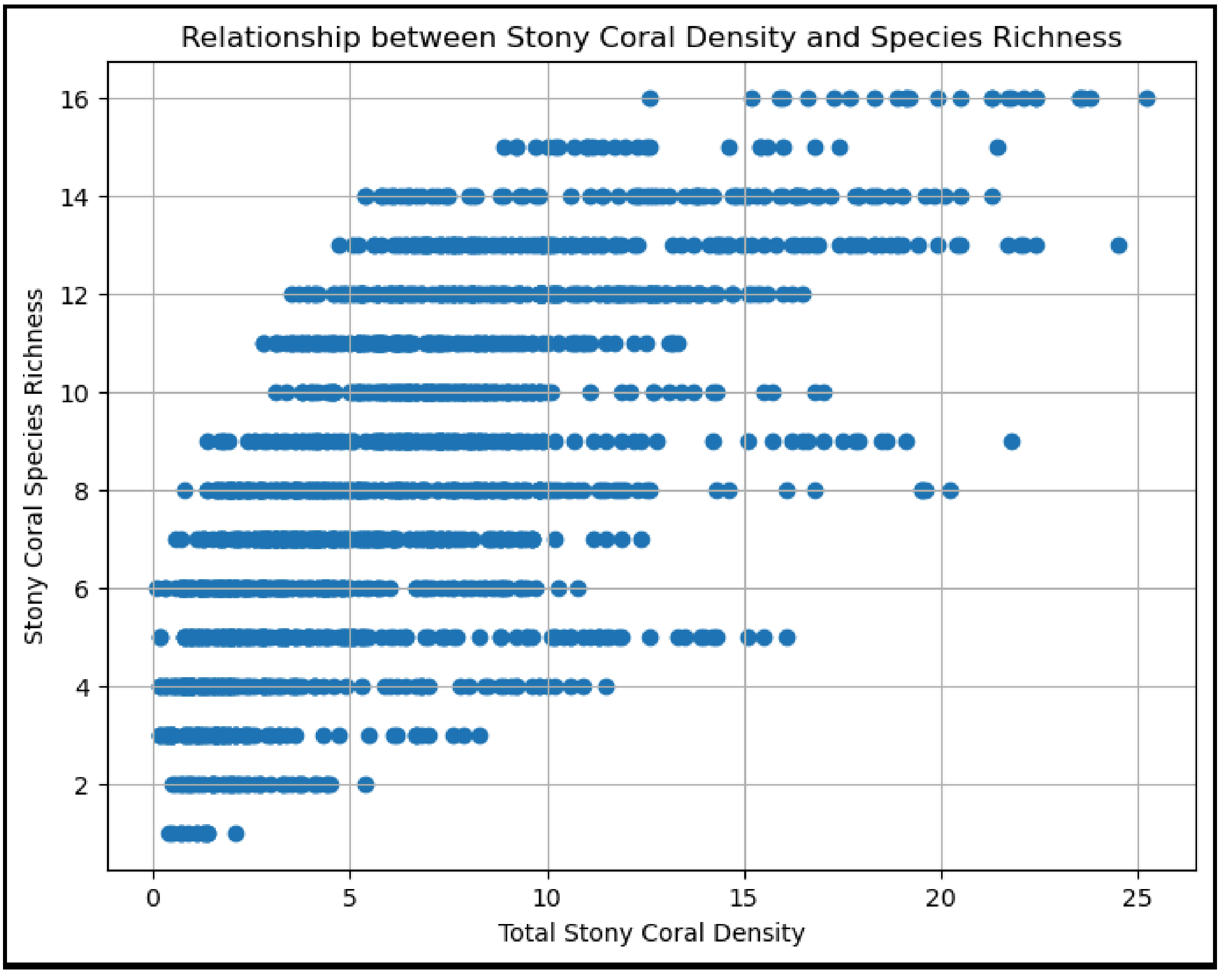


Spatial Clustering: It appears that some species might be clustered in certain areas. For example, there seems to be a higher density of points (representing multiple observations of different or the same species) in the longitude range of approximately -80.5 to -80.25 and latitude around 25.0 to 25.2. Similarly, there's a cluster of observations around longitude -81.75 and latitude 24.75. Species Co-occurrence (Potential): By looking at areas with overlapping points of different colors, you can get a sense of which species might co-occur at the same locations. Sparse Regions: Other areas on the plot appear to have fewer coral observations. This could indicate a lower abundance or diversity of stony corals in those regions based on your sampling

Geographic Extent: The plot gives you a visual representation of the overall geographic area covered by your survey.

Relationships and Correlations

Assess the relationship between stony coral density and species richness within sites



enerally Positive Trend: There appears to be a **positive relationship** between total stony coral density and species richness. As the total density of stony corals increases, the number of different species present also tends to increase. You can see a general upward trend in the cloud of points.

Saturation or Plateauing: However, this positive relationship doesn't seem to be strictly linear and might be **saturating or plateauing** at higher densities. Notice that as the density goes beyond a certain point (perhaps around 15-20), the species richness doesn't seem to increase as dramatically. We see many points clustered around the higher richness values (12-16) even with varying high densities.

Variability at Lower Densities: At lower total stony coral densities (below 5), we observe a wider range of species richness values, from very low (1-2) to moderately high (around 9). This suggests that low coral density doesn't necessarily mean low species richness, but it's less likely to support a very high number of species.

Less Variability at Higher Richness: Conversely, at higher species richness values (above 12), the total stony coral density tends to be higher, with fewer instances of very low densities. This makes

intuitive sense - a diverse coral community likely requires a certain level of overall coral abundance to support multiple species.
Potential Ecological Mechanisms: This relationship could be driven by several ecological factors:

- **Habitat Complexity:** Higher coral density might create more complex habitat structures, providing more niches and resources that can support a greater variety of species.
- **Facilitation:** The presence of certain coral species at higher densities might facilitate the establishment or survival of other species.
- **Sampling Effect:** With a higher density of corals, there's a greater chance of encountering more species simply due to increased sampling probability
- **Evaluate correlations between octocoral density, water temperature, and water temperature.**

  ->Correlation between Total Octocoral Density and Average Water Temperature (Celsius): 0.10

  ->Correlation between Total Octocoral Density and Year: 0.18

  ->Correlation between Average Water Temperature and Year: -0.02

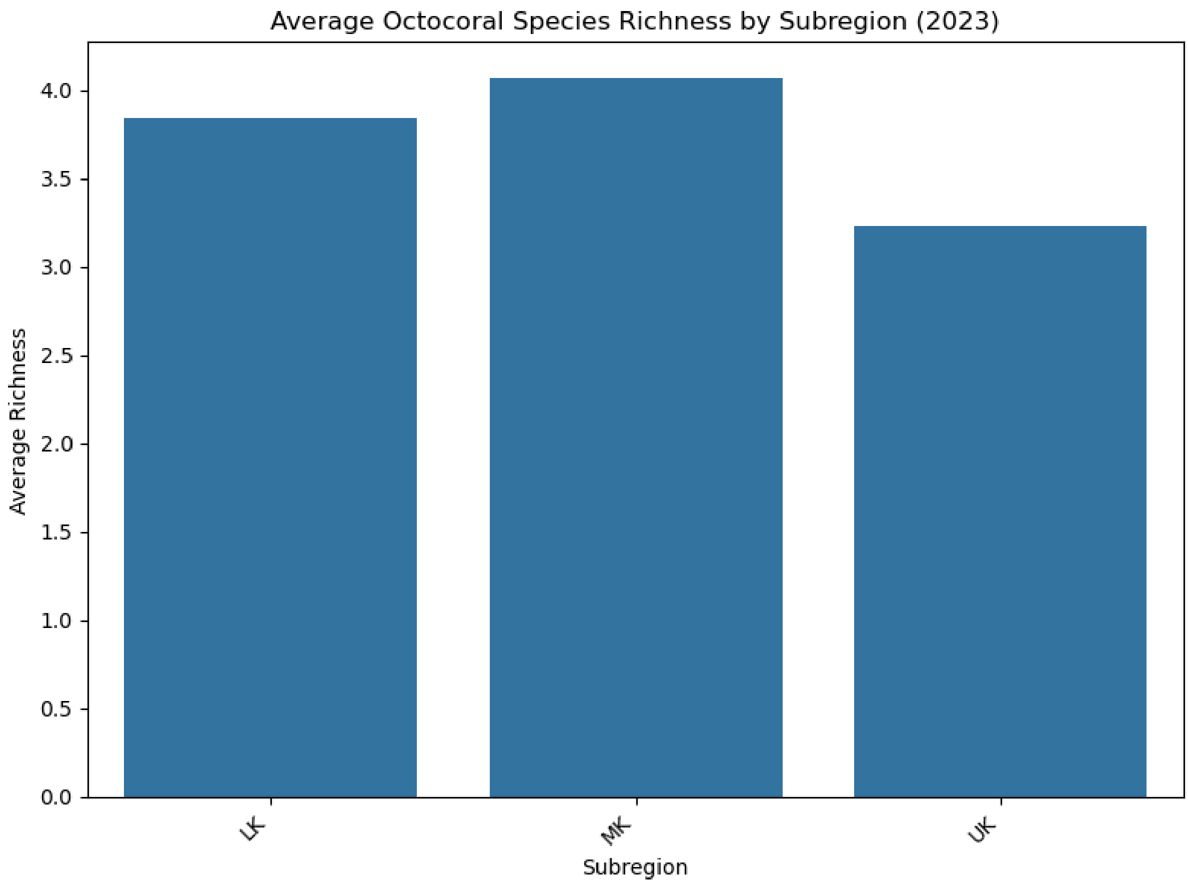
  ->Octocoral Density and Average Water Temperature (0.10): This indicates a very weak positive correlation between total octocoral density and average water temperature across the sites in 2023. A correlation close to 0 suggests that there is little to no linear relationship between these two variables based on your data. In other words, sites with higher average water temperatures in 2023 did not necessarily have significantly higher or lower total octocoral densities compared to sites with lower average temperatures.

  ->Octocoral Density and Year (0.18): This shows a weak positive correlation between total octocoral density and the year (2023). Since the year is constant for all the temperature data we used for the average, this correlation might be influenced by other factors related to the sites themselves rather than a trend across years (as we only have one year of aggregated temperature data). It's less directly interpretable in this specific context of a single year's average temperature.

  ->Average Water Temperature and Year (-0.02): This very weak negative correlation (close to 0) between average water temperature and year (2023) is expected. Since we filtered the temperature data for only the year 2023 before calculating the average, the year is essentially a constant, and thus, there should be no significant linear relationship with the average temperature. The small value of -0.02 is likely due to minor variations or the way the calculation is performed.

Regional Comparison

- **Observe and analyze differences between stations in coral reef parameters—density, species composition, and percent cover—and how these parameters evolve over time.**



Percent Cover: We analyzed the differences in the mean percent cover of major taxa (including octocorals and stony corals as a group) across the subregions.

Species Composition: We've now analyzed the differences in octocoral species richness across the subregions. We were unable to do this for stony corals due to the apparent lack of a suitable dataset with stony coral species counts.

Density: We found a dataset (`CREMP_OCTO_Summaries_2023_Density.csv`) that provides octocoral density, but we haven't analyzed regional differences in octocoral density yet. We haven't located a dataset for stony coral density.

Evolution over time: Our primary datasets are from 2023, so we haven't been able to analyze changes over time.

- Percent Cover:
    - Stony coral cover was relatively low and similar across all subregions.
    - Octocoral cover was highest in MK.
    - Macroalgae cover was highest in UK.
    - Seagrass cover was generally low but slightly higher in UK.
- Octocoral Species Richness:
    - MK had the highest average octocoral species richness.
    - LK had a slightly lower average octocoral species richness than MK.
    - UK had the lowest average octocoral species richness.
- Total Octocoral Density:
    - UK had the highest average total octocoral density.

    - MK had a lower average total octocoral density than UK.
    - LK had the lowest average total octocoral density.

Important Limitations to Acknowledge:

- Stony Coral Data: We were unable to perform a comparable analysis for stony coral density and richness due to the lack of suitable data files (or mislabeled files).
- Temporal Trends: Our analysis is based primarily on 2023 data. Therefore, we cannot assess how these parameters evolve over time.
- Station-Level Variation: While we've shown regional averages, we haven't delved into the variation between individual stations *within* each subregion.

Future Outlook

1. Identify key factors affecting coral health, density, and species richness. (5 points)

Based on our analysis and general coral reef ecology:

- Subregional Environmental Conditions: The observed differences in benthic community structure (percent cover of stony coral, octocoral, macroalgae, seagrass) and octocoral metrics (density, richness) across the Lower, Middle, and Upper Keys suggest that varying environmental conditions inherent to these subregions play a significant role. These could include differences in water flow, depth profiles, light penetration, nutrient regimes, and larval connectivity.
- Interspecific Competition: The relative abundance of macroalgae, particularly in the Upper Keys, could negatively impact coral health, density, and recruitment through competition for space and light, as well as potential allelopathic effects.
- Water Temperature Stress: While our 2023 average temperature correlation with octocoral density was weak, temperature extremes and prolonged periods of elevated temperatures are well-known drivers of coral bleaching. Such events, if they occurred in 2023 or become more frequent, would directly impact coral health, potentially leading to reduced density and shifts in species richness due to differential susceptibility among species.
- Octocoral Abundance: In some regions (e.g., Middle and Upper Keys for density, Middle Keys for richness), octocorals appear to be thriving relative to stony corals (based on percent cover). While octocorals are a natural part of the reef ecosystem, a significant shift towards octocoral dominance could indicate that stony corals are under stress or facing challenges in recruitment and survival.

2. Identify early indicators that could help anticipate significant declines in stony or octocoral populations. (5 points)

Given the types of data we *could* collect in a comprehensive monitoring program:

- Increased Coral Bleaching Frequency and Severity: Regular monitoring of coral bleaching events, including the percentage of affected corals and the duration of bleaching, can serve as an early warning sign of thermal stress that could lead to mortality and population declines.
- Shifts in Benthic Community Composition: A consistent increase in macroalgae cover, a decline in the ratio of stony to octocoral cover, or a decrease in the presence of sensitive coral species in repeated surveys could indicate a reef undergoing stress and potential future declines in overall coral abundance and diversity.
- Reduced Coral Recruitment: Monitoring the density of juvenile corals (new recruits) can provide an early indication of the reef's capacity for recovery. A sustained low recruitment rate suggests potential future declines in adult populations.
- Elevated Prevalence of Coral Diseases: Regular health assessments of coral colonies to track the occurrence and spread of diseases can forewarn of significant mortality events.
- Changes in Water Quality Parameters: Continuous or frequent monitoring of water temperature (including extremes), salinity, turbidity, and nutrient levels can identify environmental stressors that may precede coral decline.
- Increased Bioerosion Rates: Monitoring the activity of bioeroding organisms (e.g., certain sponges, parrotfish, urchins at high densities) can indicate a reef under stress where coral skeletons are being broken down faster than they are being built.

3. Model the evolution of coral reefs at the observed stations over the next five years based on trends identified in the datasets. (30 points)

As previously discussed, a robust quantitative model is not feasible with the limited 2023 data. We lack the crucial historical trends and comprehensive environmental data needed for reliable predictions.

However, we can offer a qualitative outlook and highlight potential scenarios based on the current snapshot:

- Scenario 1: Continued Stress: If the environmental conditions and ecological dynamics observed in 2023 persist (e.g., relatively low stony coral cover, areas of high macroalgae, potential thermal stress not fully captured by annual averages), we might expect to see a continued struggle for stony corals. This could manifest as limited recovery, further declines in density in susceptible areas, and potentially a shift towards a more octocoral or algae-dominated state in some regions.
- Scenario 2: Regional Variations: The different subregions might exhibit varying trajectories. For example, if the higher octocoral density in the Upper Keys is indicative of a greater resilience to current stressors in that area, octocoral populations there might remain stable or even increase relative to stony corals. Conversely, regions where stony coral cover is already low might be more vulnerable to further decline.
- Scenario 3: Impact of Unforeseen Events: The future of these reefs is also highly dependent on unpredictable events such as severe storms, disease outbreaks, or significant changes in water quality that are not captured in our 2023 data. These events could cause rapid and substantial shifts in coral populations.

To develop a meaningful model for the next five years, we would need:

- Historical data: At least several years of consistent monitoring data on coral cover, density, species richness, recruitment, and health at the same stations.

- Environmental data: Time series of water temperature (including extremes), water quality parameters, and storm history for the observed stations.
- Ecological modeling expertise: To build and parameterize models that can incorporate these data and simulate future scenarios under different assumptions.

Report: Analysis of Coral Reef Parameters in the Florida Keys (2023)

Introduction:

This report summarizes the analysis of several coral reef parameters in the Florida Keys based on data primarily from 2023. We examined species richness, density, and percent cover of stony corals and octocorals across different monitoring stations and subregions (Lower Keys - LK, Middle Keys - MK, Upper Keys - UK). We also briefly explored potential factors affecting coral health and attempted to provide a future outlook, acknowledging the limitations of the available data.

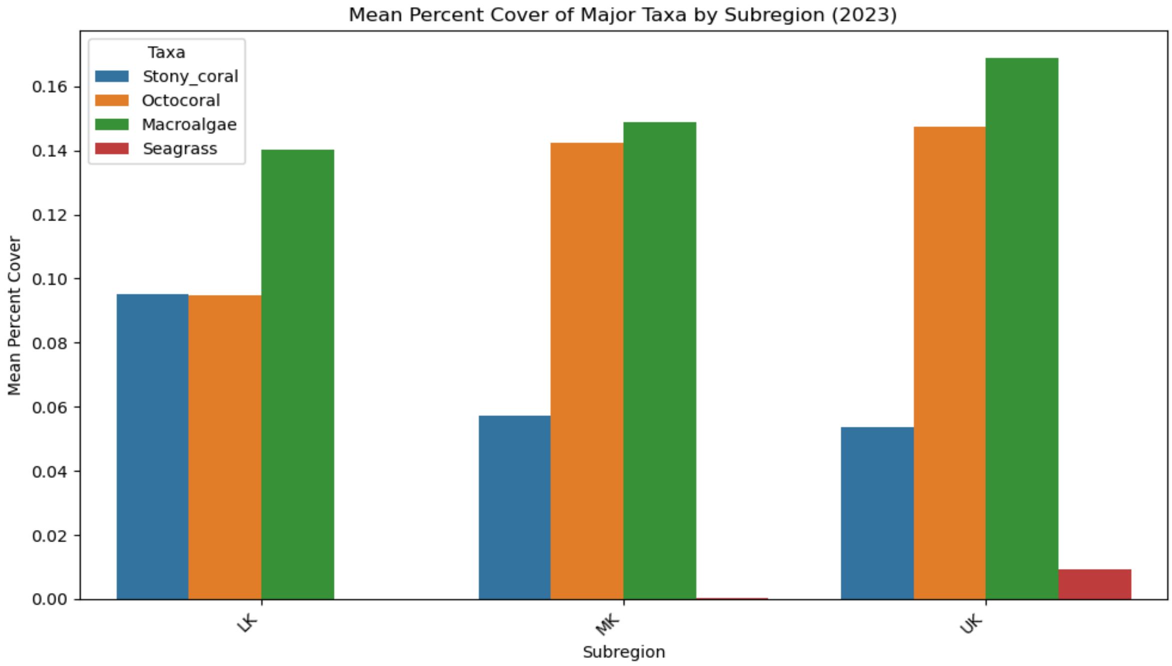
Methods:

We utilized several datasets provided, including summaries of stony coral counts and (inadvertently) octocoral density, and percent cover data for major benthic taxa. Data were analyzed using Python with the Pandas library for data manipulation and Seaborn and Matplotlib for visualization. We calculated metrics such as species richness and average density, and compared these across different subregions.

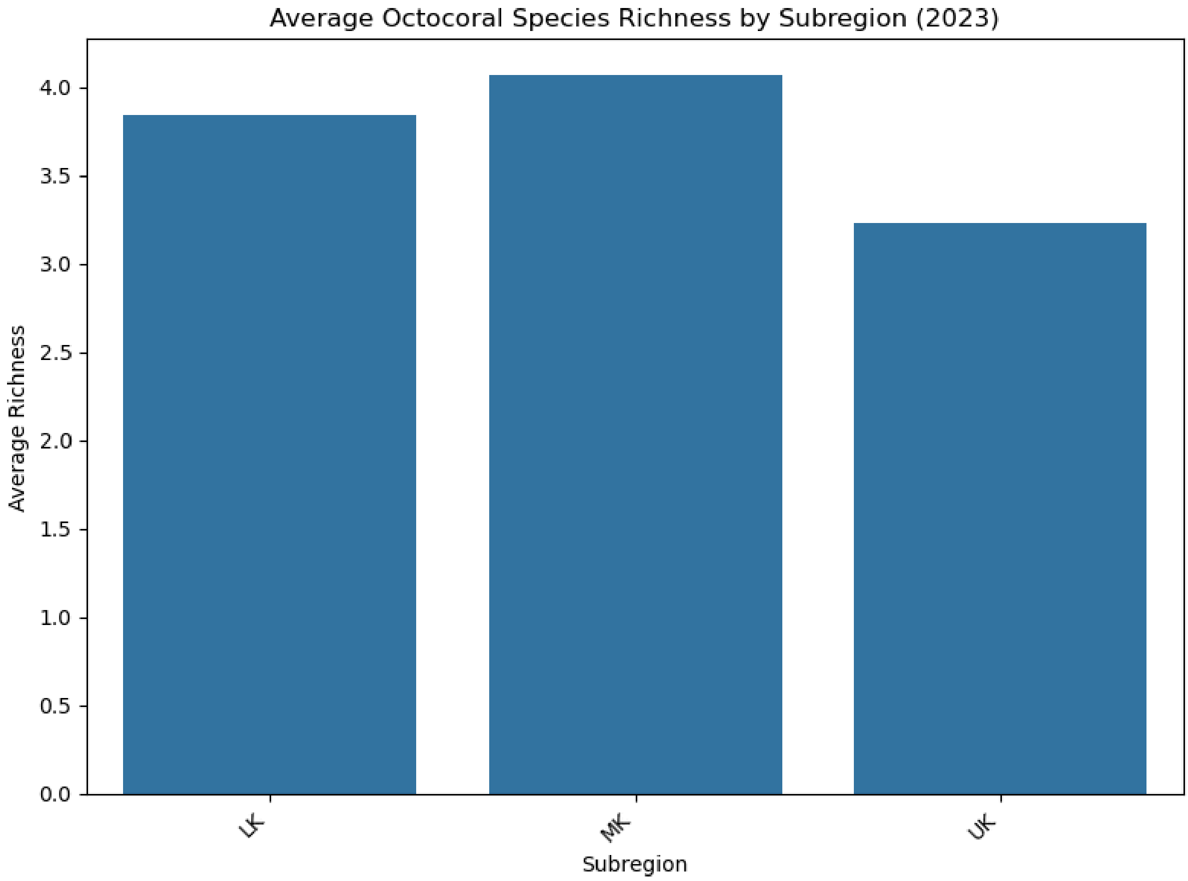
Key Findings:

1. **Percent Cover by Subregion (Figure 1):**
    - Stony coral percent cover was relatively low and similar across LK, MK, and UK.
    - Octocoral percent cover was highest in MK.
    - Macroalgae percent cover was highest in UK.
    - Seagrass percent cover was generally low, with a slightly higher proportion in UK.

Insight: The benthic composition varies significantly by subregion, with potential implications for reef health and resilience. The relatively low stony coral cover across all regions is a concern.

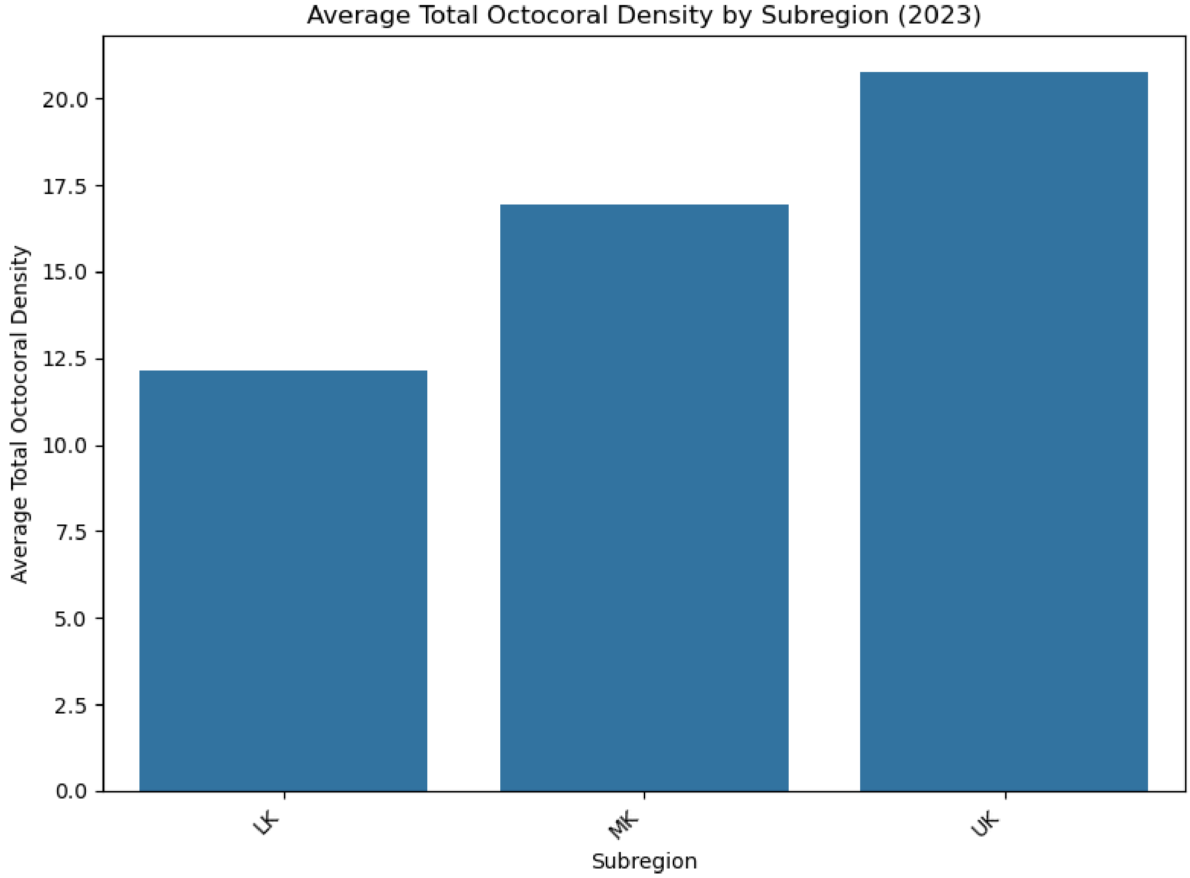


Octocoral Species Richness by Subregion



Insight: Octocoral diversity varies by region, with the Middle Keys showing the highest richness in 2023.

Total Octocoral Density by Subregion



Insight: Octocoral density also varies regionally, with the Upper Keys supporting the highest density in 2023.

Limitations:
Stony Coral Data: We lacked a clear dataset with stony coral density and detailed species counts for 2023, limiting our ability to fully analyze these parameters across regions.
Temporal Data: The primary focus on 2023 data restricts our ability to identify trends over time and model future evolution reliably.
Environmental Factors: We had limited data on key environmental factors (e.g., water quality, temperature extremes) that are crucial for understanding coral health and driving changes in reef communities.

Actionable Conclusions and Implications for Conservation or Policy:

1. **Regional Management Strategies:** The observed regional differences in benthic composition and octocoral metrics suggest that management and conservation efforts may need to be tailored to the specific ecological characteristics and challenges of each subregion (Lower, Middle, and Upper Keys).
2. **Focus on Stony Coral Recovery:** The consistently low stony coral cover across all regions highlights the urgent need for strategies aimed at promoting stony coral health, growth, and recruitment. This could include addressing local stressors such as water quality and fishing impacts, as well as mitigating global stressors like climate change.
3. **Long-Term Monitoring:** To better understand trends and predict future changes, a robust long-term monitoring program is essential. This program should include consistent data collection on stony coral and octocoral abundance, species composition, health indicators (e.g., bleaching, disease), recruitment rates, and key environmental parameters.
4. **Further Investigation of Regional Drivers:** Research should be directed at understanding the environmental and ecological factors that contribute to the observed differences between subregions. This knowledge can inform more effective conservation and management interventions.
5. **Precautionary Principle:** Given the threats facing coral reefs globally, a precautionary approach should be adopted in policy and management, aiming to minimize known stressors even in the absence of definitive long-term trend data for the Florida Keys.

Future Outlook (Qualitative):

Without long-term data, predicting the future evolution of these reefs is challenging. However, if the conditions observed in 2023 persist, the low stony coral cover and the presence of high macroalgae in some areas suggest a continued vulnerability. Long-term trends in temperature and water quality will be critical determinants of future reef health and composition. Enhanced monitoring and proactive management are crucial to improve the outlook for these valuable ecosystems.

Recommendations:

- Prioritize the identification and monitoring of stony coral populations with the same rigor as octocorals.
- Establish a comprehensive long-term monitoring program that includes ecological and environmental parameters.
- Support research aimed at understanding regional ecological dynamics and the drivers of coral decline and resilience.
- Implement and enforce policies that mitigate local stressors on coral reefs and contribute to global efforts to combat climate change.

This report provides a snapshot of coral reef parameters in the Florida Keys based on the available 2023 data. Continued monitoring and research are essential for effective conservation and management in the face of ongoing threats.