# Time Series Analysis of Coral Health Indices in the Florida Reef Tract

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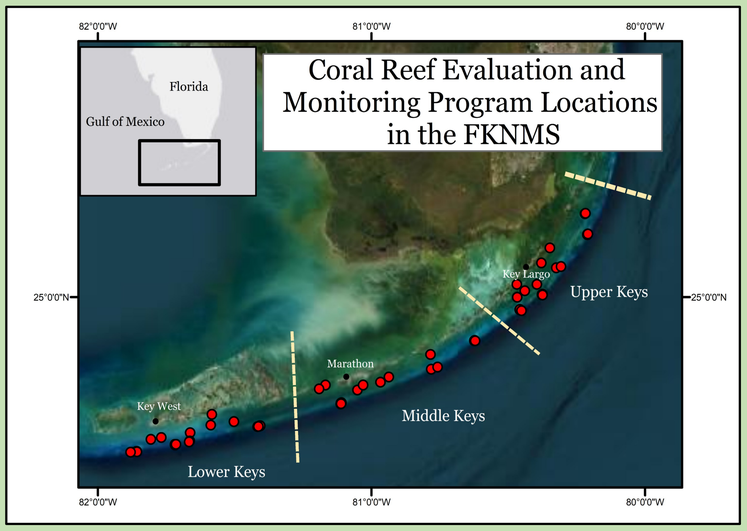
## Introduction:

Florida coral reefs have been declining over the last 30 years and action needs to be taken to save these vital ecosystems. We attempt to understand how biodiversity is changing by combining two long standing time-series databases along the Florida Keys National Marine Sanctuary (FKNMS) into three coral health indices. The goals of this research is to better understand their applicability and ability to evaluate changes among the Florida coral reefs. Additionally, we looked at "healthier" reefs to try and identify which of the input values explained more variation within the health indices.

## Study area:




## Data & Methods:

- FKNMS Coral Reef Evaluation and Monitoring Program (CREMP[1]) was evaluated over a twenty-year (1999-2018) time period to monitor changes to coral and fish biodiversity.
- Reef Visual Census Data[2] and National Marine Fisheries Service[3] are the source of fisheries data.
- Each Coral Reef (~30) was assessed separately and later compared to other reefs based on habitat, subregion, and MPA type.
- **Habitat** was found be to be the most significant environmental parameter to the input data (PERMANOVA analysis) and is furthered analyzed with the "healthiest" reefs.
- "Healthy" reefs were defined as scores one standard error higher than the mean of all the sites for each index, and a Canonical Analysis of Principal coordinates (CAP) was performed on the raw input variables of these reefs to see which of the variables explains the most variation.

## Health Indices:

### *Coral Health Index (CHI)[4]*

- % Stony Coral Cover, % Macroalgae Cover, Fish Biomass (g/m²)
- $\left[\left(\frac{xFishBiomassValue}{xFishBiomassMax}+\left(\frac{yMacroalgaeValue}{yMacroalgaeMax}-1\right)+\frac{zStonyCoralValue}{zStonyCoralMax}\right)/3\right]*100 = CHI\ Value\ per\ Year$
- These values were normalized to the maximum values of each parameter within each reef
- 0-20 (very degraded), 21-40 (degraded), 41-60(Fair), 61-80(healthy),81-100 (very healthy)

### *Reef Health Index (RHI)[5]*

- Values 1—5 were given to each coral reef per indicator per year based on these intervals and averaged for one value per year

| RHI Indicators | Very Good (5) | Good (4) | Fair (3) | Poor (2) | Critical (1) |
|---|---|---|---|---|---|
| Coral Cover % | ≥40 | 20–39.9 | 10–19.9 | 5–9.9 | <5 |
| Fleshy algae cover % | 0–0.9 | 1–5 | 5.1–12 | 12.1–25 | >25 |
| Herbivorous Fish biomass (g/m²) | ≥17 | 16–8 | 7.9–4 | 3.9–1.9 | <1.8 |
| Commercial Fish biomass (g/m²) | ≥48 | 47.9–23.5 | 23.4–13.2 | 13.1–6.2 | <6.1 |

### *Coral Reef Resilience Indicator (CRRI)[6]*

- Stony coral cover %, Fleshy algae cover %, coral diversity (Simpson diversity), coral richness, bleaching resistant corals[6], herbivore biomass, herbivore diversity (Simpson diversity), herbivore richness
- These parameters were normalized to the maximum value of each parameters of all the reefs within the FKNMS for every year of data to give final resilience scores
  - 0–0.25 (Low), 0.251–0.50(Low-Med), 0.51–0.75(Med-High), 0.751–1.00 (High)

## Results:

| CHI Values > +1SE | | | |
|---|---|---|---|
| **Habitat** | # of Coral Reefs | Values > 1SE | % Healthy Reefs |
| Offshore Deep | 161 | 67 | 41.6% |
| Offshore Shallow | 181 | 94 | 51.9% |
| Patch | 12 | 9 | **75.0%** |
| | | | |
| **Subregion** | | | |
| Lower Keys | 163 | 81 | 49.7% |
| Middle Keys | 74 | 28 | 37.8% |
| Upper Keys | 117 | 61 | 52.1% |
| | | | |
| **MPA Type** | | | |
| Protected | 258 | 126 | 48.8% |
| Unprotected | 96 | 44 | 45.8% |

The number and percentage of coral reefs with values greater than 1SE separated by habitat, subregion, MPA type, for the CHI values.



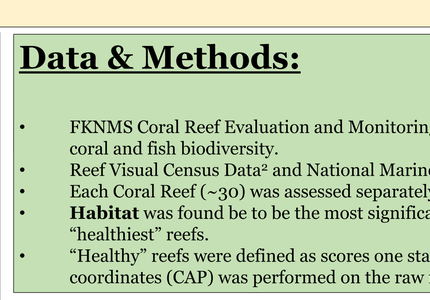

Mean CHI health trend for all Florida Coral Reef Tract sites from 1999 to 2018 with standard error bars representing variability among sites.




Healthy CHI reef CAP based on habitat type. Green diamonds = Offshore Deep (OD), red triangles = Offshore Shallow (OS), and blue squares = Patch reefs (P). The raw input values are MA = Macroalgae Cover, CC = Stony Coral Cover, and FB = Fish Biomass.

| RHI Values > +1SE | | | |
|---|---|---|---|
| **Habitat** | # of Coral Reefs | Values > 1SE | % Healthy Reefs |
| Offshore Deep | 171 | 61 | 35.7% |
| Offshore Shallow | 188 | 112 | 59.6% |
| Patch | 33 | 21 | **63.6%** |
| | | | |
| **Subregion** | | | |
| Lower Keys | 172 | 92 | 53.3% |
| Middle Keys | 90 | 33 | 36.7% |
| Upper Keys | 130 | 69 | 53.1% |
| | | | |
| **MPA Type** | | | |
| Protected | 262 | 133 | 50.8% |
| Unprotected | 130 | 61 | 46.9% |

The number and percentage of coral reefs with values greater than 1SE separated by habitat, subregion, MPA type, for the RHI values.



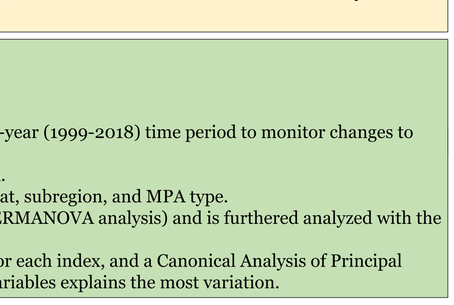

Mean RHI health trend for all Florida Coral Reef Tract sites from 1999 to 2018 with standard error bars representing variability among sites.




Healthy RHI reefs CAP analysis using the raw input data grouped by habitat type. Green diamonds = Offshore Deep (OD), red triangles = Offshore Shallow (OS), and blue squares = Patch reefs (P). The input values are MA = Macroalgae Cover, CC = Stony Coral Cover, HB = Herbivorous Fish Biomass, and CB = Commercial Fish Biomass.

| CRRI Values > +1SE | | | |
|---|---|---|---|
| **Habitat** | # of Coral Reefs | Values > 1SE | % Healthy Reefs |
| Offshore Deep | 171 | 79 | 46.1% |
| Offshore Shallow | 189 | 66 | 34.9% |
| Patch | 55 | 46 | **83.6%** |
| | | | |
| **Subregion** | | | |
| Lower Keys | 182 | 96 | 52.7% |
| Middle Keys | 96 | 33 | 34.4% |
| Upper Keys | 137 | 62 | 45.3% |
| | | | |
| **MPA Type** | | | |
| Protected | 262 | 87 | 33.2% |
| Unprotected | 153 | 104 | 68.0% |

The number and percentage of coral reefs with values greater than 1SE separated by habitat, subregion, MPA type, for the CRRI values.




Mean CRRI health trend for all Florida Coral Reef Tract sites from 1999 to 2018 with standard error bars representing variability among sites.




Healthy CRRI reefs CAP analysis using raw input data by habitat type. The habitats are green diamonds = Offshore Deep (OD), red triangles = Offshore Shallow (OS), and blue squares = Patch reefs (P). The categorical variables are macroalgae cover (MA), coral cover (CC), herbivore biomass (HB), herbivore richness (HR), Simpson diversity index of herbivorous fish (HD), coral richness (CR), Simpson diversity index of stony coral species (CD), and bleaching-resistant species (BR).

## Conclusions:

- CHI and RHI both indicate negative trends throughout the study area while the CRRI remained relatively constant
- Patch reef habitats had the highest values of "healthy" reefs and environment explained the most variation among all the health indices
- The CAP's indicated coral cover values were highest on patch reefs, and this explained the most variation. Macroalgae accounted for less variation but had higher values in offshore deep and offshore shallow areas
- The fish biomass tended to be higher in offshore sites, but there was more diversity in patch reefs
- Indicates further support for "Mission: Iconic Reefs" funded by NOAA and sets a good baseline to track restoration progress

## Next Steps:

- Petition to have more RVC sampling sites near patch reef environments to better understand the higher fish biodiversity coupled with the higher stony coral cover
- Add the RHI data into the newly updated AGRRA summary dashboard to be compared with the Mesoamerican coral reefs

## References:

1 Roberson, Kimberly Kay Woody, Shay Viehman, and Randy Clark. "Development of Benthic and Fish Monitoring Protocols for the Atlantic/Caribbean Biological Team: National Coral Reef Monitoring Program." (2014).
2 Smith, S. G., Ault, J. S., Bohnsack, J. A., Harper, D. E., Luo, J., & Mcclellan, D. B. (2011). Multispecies survey design for assessing reef-fish stocks, spatially explicit management performance , and ecosystem condition. Fisheries Research, 109(1), 25–41.
3 National Marine Fisheries Service (2018) Fisheries of the United States, 2017. U.S. Department of Commerce, NOAA Current Fishery Statistics No. 2017 Available at: https://www.fisheries.noaa.gov/feature-story/ fisheries-united-states-2017
4 Kaufman L, Sandin S, Sala E, Obura D., Rohwer F. Coral Health Index (CHI): measuring coral community health. Science and Knowledge Division, Conservation International, Arlington, VA, USA. 2011
5 Díaz-Pérez, Leopoldo, et al. "Coral reef health indices versus the biological, ecological and functional diversity of fish and coral assemblages in the Caribbean Sea." *PloS one* 11.8 (2016): e0161812.
6 Maynard J, Byrne J, Kerrigan K, Tracey D, Bohnsack K, Pagan F, Walczak J, and Williams GJ. 2017. Coral reef resilience to climate change in the Florida Reef Tract. Florida Department of Environmental Protection. Miami, FL. Pp. 1-30.
Reef Picture – https://www.sciencenewsforstudents.org/sites/default/files/scald-image/860_CI_Meds_from_Deep_0.png

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