POPULATION DEMOGRAPHICS OF *XESTOSPONGIA MUTA* IN THE FLORIDA KEYS FROM 2014 TO 2024

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Introduction

Giant barrel sponges, *Xestospongia muta*, are important contributors to Florida's Coral Reef (FCR) because they add biomass and increase reef complexity, provide habitat and food for other organisms, and filter out bacteria and excess nutrients from the water column. The Coral Reef Evaluation and Monitoring Project (CREMP) has assessed the health and condition of *X. muta* at 10 deep forereef sites since 2014. During this time, multiple disturbances have impacted FCR, including the thermal stress in 2014/2015, Hurricane Irma in 2017, Hurricane Ian in 2022, and the 2023 marine heatwave.

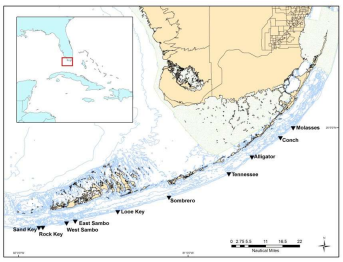
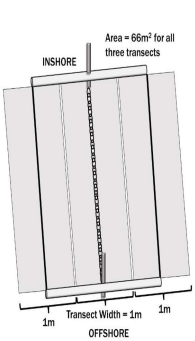
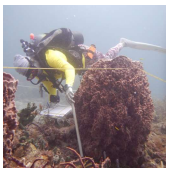


Figure 1. Location of the ten *X. muta* monitoring sites: Molasses, Conch, Alligator, Tennessee, Sombrero, Looe Key, East Sambo, West Sambo, Rock Key, and Sand Key

Methods

- Six 1m x 22m transects per site
- Total survey area per site: 132 m^2
- All sponges within survey area fate-tracked
- Measurements taken:
  - Maximum diameter of the base (DB)
  - Maximum diameter of the apex (DA)
  - Height (H)
- Sponge health assessment:
  - Recent mortality
  - Presence of Disease
  - Predation
  - Condition of tissue
- Data from 2017 excluded due to Hurricane Irma





Results

Abundance:

Longterm (2014 - 2024):

- Keys-wide trend: Increasing – highest total abundance in 2024 with 632 sponges
- Site-level trends: Alligator and West Sambo significantly increased; Tennessee significantly decreased
- Over half of sponges within size classes I and II; only 31% within size classes IV and V

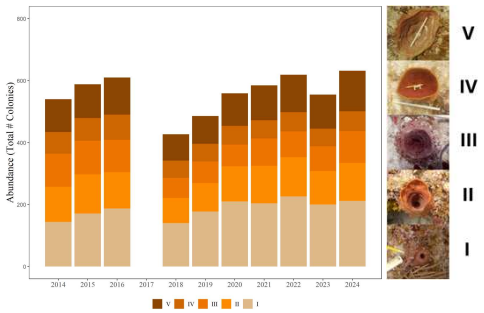


Figure 2. Total abundance of each size class of *X. muta* within all stations at all sites from 2014-2024. Sponges were sorted into size classes based on sponge volume as described in McMurray et al 2015: I (≤ 0.00014 m^3), II (>0.00014 m^3 and ≤0.00108 m^3), III (>0.00108 m^3 and ≤0.00567 m^3), IV (>0.00567 m^3 and ≤0.017384 m^3), and V (>0.017384 m^3).

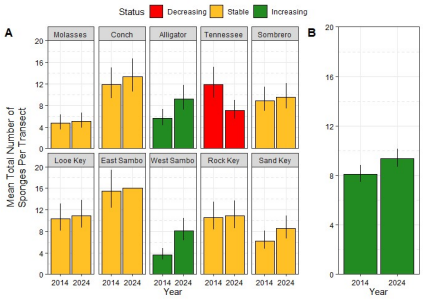


Figure 3. Long-term comparisons of sponge abundance (a) by site and (b) keys-wide. Means and corresponding p-values were estimated based on a Poisson regression model using all data from 2014-2024 (excluding 2017). Status indicates a significant increase or decrease based on FDR adjusted p-value ($p < 0.05$).

Post-Irma (2016 vs. 2018):

- Keys-wide: Decreased
- Site-level: Looe Key, Sombrero, and Tennessee significantly decreased
- 183 sponges lost; 25.7% belonging to size class I, 21.9% in class III, 19.7% in class II, 19.1% in class V, and 13.7% in class IV

Post-2023 Marine Heatwave (2022 vs. 2024):

- No significant change, Keys-wide or at site-level
- 64 sponges lost

Volume:

Longterm (2014-2024):

- Keys-wide trend: No significant change – highest total volume in 2024 with 11.45 m^3
- Site-level trends: East Sambo significantly increased; Tennessee significantly decreased
- Size class V contributes the most to biomass (85% averaged for 2014-2024), with size classes I and II collectively contributing less than 1%

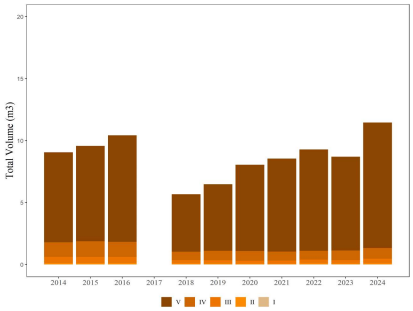


Figure 4. Total volume of *X. muta* colonies within all stations at all 10 sites from 2014 to 2024. Volume was calculated using the formula for the frustum of a cone: $V = (1/12)\pi h(DB^2 + DB*DA + DA^2)$, where V= sponge volume, h= sponge height, DB= base diameter, and DA= top diameter. See sponge size classes in Figure 5.

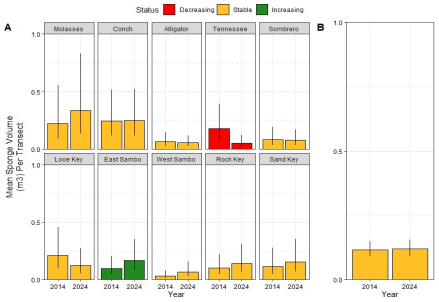


Figure 5. Long-term comparisons of sponge volume (a) by site and (b) keys-wide. Means and corresponding p-values were estimated based on a Tweedie regression model using all data from 2014-2024 (excluding 2017). Status indicates a significant increase or decrease based on FDR adjusted p-value ($p < 0.05$).

Post-Irma (2016 vs. 2018):

- Keys-wide: Decreased
- Site-level: Sombrero and Tennessee significantly decreased
- Total loss of 4.75 m^3; a 54% loss in total biomass

Post-2023 Marine Heatwave (2022 vs. 2024):

- No significant change, Keys-wide or at site-level
- Total loss of 0.58 m^3

Height:

Longterm (2014-2024):

- Keys-wide trend: Decreasing – highest mean height in 2014 with 21.5 (±0.75) cm
- Site-level trends: Alligator, Tennessee, Sombrero, Looe Key, and West Sambo decreased significantly

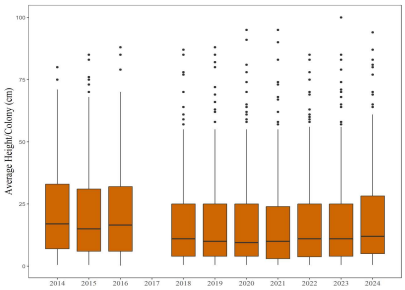


Figure 6. Mean height (cm) per *X. muta* colony from 2014 to 2024. Lower and upper box limits represent the 25th and 75th percentile, respectively. The black line inside the box is the median, the lines extending from the box represent the minimum and maximum values, and the black dots represent outliers in the dataset.

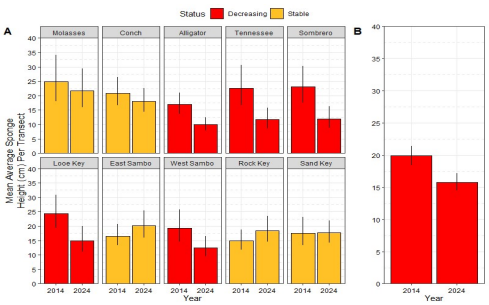


Figure 7. Long-term comparisons of mean sponge height (a) by site and (b) keys-wide. Means and corresponding p-values were estimated based on a Tweedie regression model using all data from 2014-2024 (excluding 2017). Status indicates a significant increase or decrease based on FDR adjusted p-value ($p < 0.05$).

Post-Irma (2016 vs. 2018):

- Keys-wide: Decreased
- Site-level: Sombrero and Tennessee significantly decreased
- Total mean loss of 4.36 cm per sponge

Post-2023 Marine Heatwave (2022 vs. 2024):

- No significant change, Keys-wide or at site-level
- Mean height increased by 0.6 (±0.15) cm

Conclusion

- Despite several major disturbances, overall *X. muta* population abundance increased Keys-wide between 2014-2024.
- Long-term abundance increased at two sites and decreased at one, mean volume increased at one site and decreased at one, and mean height decreased at five sites.
- Hurricane Irma significantly decreased the abundance, mean volume, and mean height of the *X. muta* population. Two metrics (abundance and mean volume) recovered by 2024, but more time will be required before mean height can recover to pre-Irma levels.
- Although the 2023 marine heatwave resulted in the mortality of some sponges, it did not translate into significant declines in abundance, mean volume, or mean height, indicating that *X. muta* are more tolerant of thermal stress than stony or soft corals.

- All work conducted under EPA Coral Reef Evaluation and Monitoring Program awards SF-02D04821 and X7-00D39315