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POLICY BRIEF

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Analysis of the zooplankton size distribution in the tropical Atlantic

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MAIN HIGHLIGHTS

This research investigates the size structure of marine zooplankton in the tropical Atlantic and its correlation with various environmental factors and reveals that:

➔ Zooplankton size distribution and abundance vary with depth, with increased overall abundance found at the surface, and a higher proportion of larger organisms found at depth, which also change on a daily basis as they migrate within the water column.

➔The proportion of large organisms and the overall biomass decrease in warm waters.

➔ Higher abundance of zooplankton are found under low oxygen conditions, likely acting as refuge against higher trophic predators limited by such concentrations.

1. Background

Marine zooplankton play a fundamental role in driving the energetic transfer of marine production between the first and the third trophic level (Kiko et al., 2020; Lombard et al., 2019), and in controlling several biogeochemical processes, as they are known to partly regulate the transformation and export of organic carbon, nutrients, and phosphorus to the deep ocean as part of the biological pump (Ducklow et al., 2001).
They do so by feeding and repackaging phytoplankton production into heavy fecal pellets that sink relatively fast. Additionally, their oxygen consumption might contribute to the formation of Oxygen Minimum Zones (OMZs), like the one found in the Eastern Tropical North and South Atlantic (Maas et al., 2021), as they migrate up in the water column at night to feed on surface phytoplankton, and migrate down in the water column at day time to hide from visual predation. They then respire the organic carbon acquired at the surface during nighttime at mesopelagic depth during daytime. Their controls on major biogeochemical and ecological processes in the ocean depend on their abundance and biomass. However, biomass alone does not adequately describe the zooplankton community and is not enough to estimate the biogeochemical pathways in general since physiological contributions to biogeochemistry are size-dependent (Maas et al., 2021). Also, most trophic dynamics are generally related to organismal size, hence distinct communities may present the same biomass while having diverse fingerprints on marine biogeochemical cycles.
The size distribution of marine plankton can therefore reveal processes by which biogenic matter is transferred to high trophic levels like fishes, transformed, and removed, eventually driving important climatic and societal changes (Clements et al., 2022).

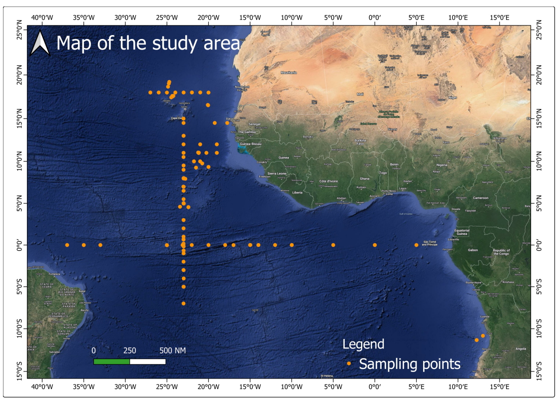
Despite the importance of the size distribution, the relevant scale to measure its spatial and temporal variability remains out of reach.

Therefore, measuring the pelagic size structure, along with important environmental variables, is essential to (1) improve understanding of the processes that control the abundance, distribution, and composition of zooplankton, (2) explore the relationships between zooplankton distribution and environmental factors like oxygen concentration, and (3) provide data necessary to constrain and improve current ecosystem and biogeochemical models, based on the response of community composition, trophic interactions, and biogeochemical fluxes under present and future environmental conditions (Heneghan et al., 2019; Lombard et al., 2019).

Plankton size is generally studied by calculating the Normalized Biovolume Size Spectrum (NBSS), representing the size structure of a given community (Soviadan et al., 2021). The NBSS slope is an important indicator of plankton dynamics, driven by biomass transfer efficiency between a continuum of sizes, whereas the intercept can reflect the total biomass of a community (Matsuno et al., 2012; Quinones et al., 2003; Sprules & Munawar, 1986). A higher intercept indicates a higher overall biomass. A steeper slope (more negative) indicates that the plankton predominantly consists of small organisms, with a lower proportion of large organisms and a lower ecological transfer efficiency.

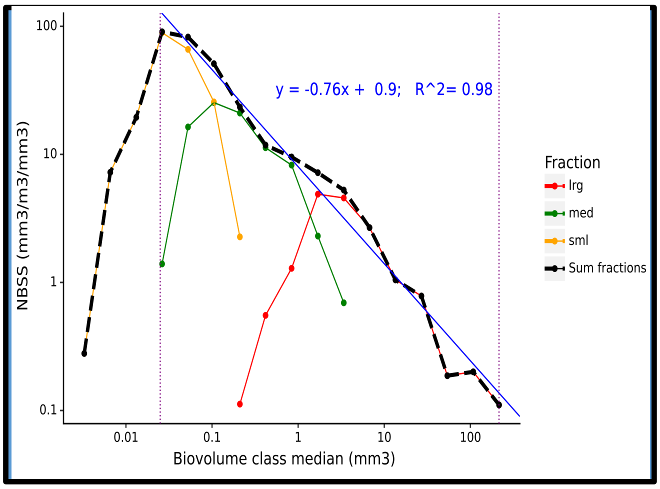
2. Approach and findings

The zooplankton size distribution has been historically difficult to measure, and thus continuous regional assessments of the pelagic size structure are still scarce in the tropical Atlantic, a region that should be strongly impacted by climate change as oxygen minimum zones are expanding as a response to altered circulation and biogeochemical processes driving deoxygenation (Stramma et al., 2008).



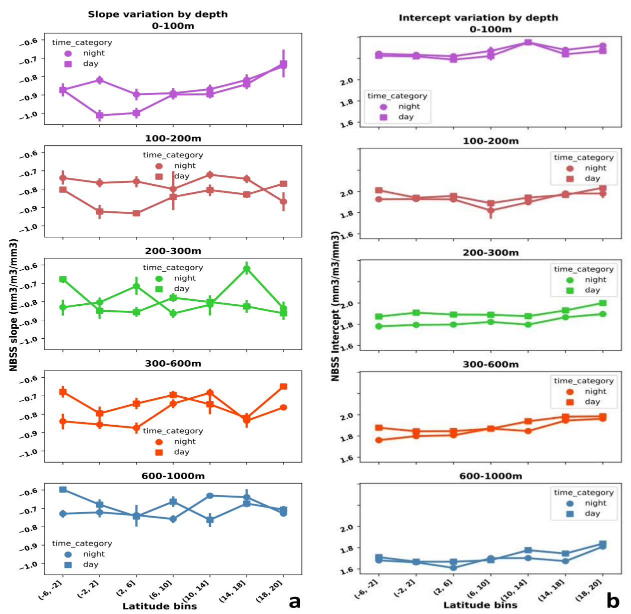
Picture 1: Multinet sampling stations

Between 2012-2019, zooplankton size distribution was characterized across 130 locations in the tropical Atlantic using Multinets deployed in 5 depth layers spanning 0 to 1000m. Net-collected samples were scanned in the laboratory using a flatbed scanner in order to count, size, and identify individual zooplankton in the size range 200-10,000 µm. Size observations were grouped within discrete size classes (Kiko et al. 2022) to calculate zooplankton NBSS from the sum (Σ) of all particles biovolume (mm3) divided by the volume imaged (m3) and the size range (mm3) within a size class as follows:



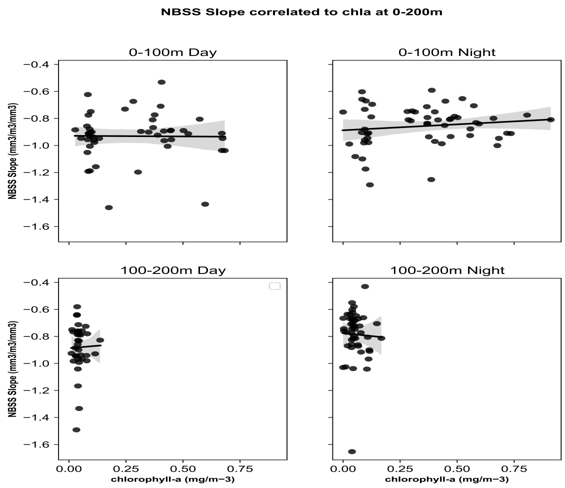
Picture 2: Normalized Biovolume Size Spectrum (NBSS)

In terms of vertical variability, our analysis demonstrates that zooplankton were overall more abundant, as represented by higher intercepts, and included smaller zooplankton, yielding steeper slopes, at the surface compared to the deeper layers.

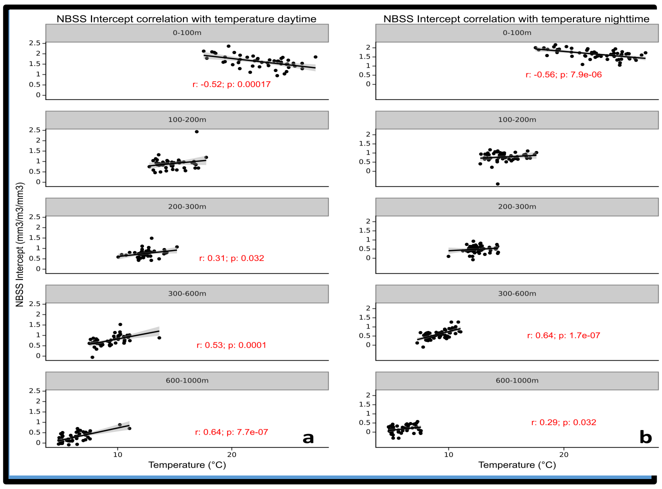


Picture 3: Latitudinal and vertical variation of NBSS

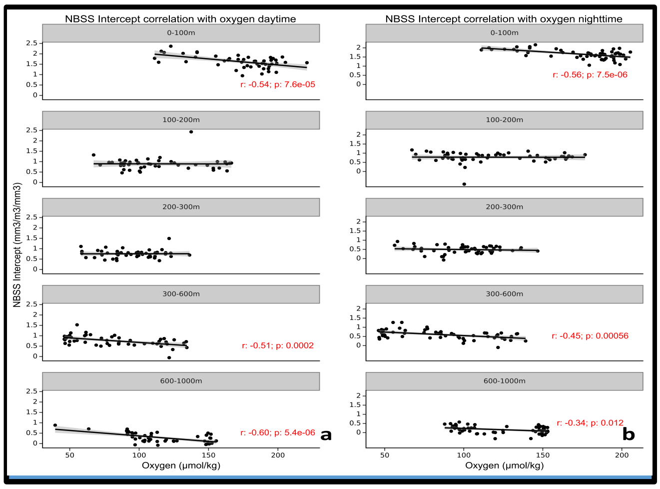
We used a correlation analysis to explore the relationship between NBSS parameters (slope and intercept) and environmental variables measured at the same locations (chlorophyll-a, temperature, salinity, and oxygen). Despite its use as a proxy for zooplankton food source, no correlation was found between NBSS parameters and chlorophyll-a. Conversely, temperature showed negative correlations at the surface and positives at deeper layer for both parameters. This indicates that high zooplankton abundances were found in cold, productive surface waters impacted by upwelling. Surprisingly, negative correlations were observed between the oxygen and both slope and intercept at all depth layers. This result is unexpected as low oxygen concentrations are known to inhibit the activity of zooplankton and thus areas with low oxygenation were thought to host less zooplankton.



Picture 4: NBSS parameters and Chlorophyll-a



Picture 5: NBSS parameters and Temperature



Picture 6: NBSS paramters and Oxygen

3. Conclusions and Policy Recommendations

In conclusion, this study provides valuable insights into the distribution, composition, and size structure of zooplankton populations in the tropical Atlantic such as:

- High abundances are found in highly productive areas (upwelling zones).
- Presence of large organisms at deeper layers.
- Decreased overall abundance with depth.
- No correlation with chlorophyll-a data.
- Decrease in the proportion of large organisms and overall biomass in warm waters.
- High abundance in areas of low oxygen level, likely related to the inhibition of zooplankton predators at 300-600m depth under low oxygen level, as it is known to limit their metabolism, while still providing increased nutrient and food availability to zooplankton.

Based on these findings several recommendations can be made:

1. Continue long-term monitoring efforts to capture temporal and spatial variations, especially in the context of OMZs expansion.
2. Focus on depth-specific investigations to better understand the mechanisms driving zooplankton community composition and size structure across different depth layers.
3. Explore diel patterns and the role of diel vertical migration (DVM) in shaping zooplankton composition and size distribution.
4. Further investigation is needed to understand the responses and adaptations of different zooplankton groups, and their predators, to these hypoxic conditions.
5. Use long-term satellite data to study the relationship between chlorophyll-a concentration and zooplankton abundance.

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Disclaimer: This policy brief is intended to provide a concise summary and analysis of the key findings and recommendations derived from the master thesis developped by the author in collaboration with thier supervisors. It has been prepared by the author based on his research and expertise in the subject matter.

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