Relationship between associated biodiversity and ecosystem functioning in *Cymodocea nodosa* seagrass in a costal lagoon system (Stagnone di Marsala, Western Sicily) – Preliminary results

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INTRODUCTION

Biodiversity loss, driven by human activities and climate change, poses a significant threat to ecosystem functioning and the essential services upon which humans depend. Ecosystem functions result from interactions between biotic and abiotic components, with biodiversity playing a crucial role in these processes. In marine environments, impacts range from biogeochemical cycles to overall ecosystem resilience, highlighting the need to prioritize ecosystems that support key biodiversity and vital processes. Seagrass meadows, such as *Cymodocea nodosa*, enhance ecosystem services by influencing productivity, carbon cycling, filtration, and food webs. Their structural attributes, linked to spatial variability, are key drivers of biodiversity by providing shelter and food. This underscores the importance of conserving and managing seagrass ecosystems to maintain their multifunctional benefits and the biodiversity they support.

Here we address the following questions: *How is biodiversity affected by changes in ecosystem functions? Can changes in biodiversity be linked to alterations in ecosystem processes? Furthermore, is it possible to assess biodiversity loss within a community by examining aspects such as abundance and richness along natural gradients of structural complexity?* By exploring these questions, we aim to enhance our understanding of the relationships between structural complexity, biodiversity, and ecosystem functionality in seagrass ecosystems.

METHODS AND RESULTS

AIM 1. To assess whether the abundance of the associated benthic community increases with rising structural complexity.
AIM 2. To investigate whether the biodiversity composition differs among the three levels of shoot density (low, medium, high).

***C. nodosa* shoot density was used as a proxy for habitat structural complexity.** A total of 24 samples (n = 8 for each shoot density level: Low, Medium, High) were collected from a meadow at **Stagnone di Marsala, Sicily**. Each sample encompassed a portion of the community, including the canopy and the sediment extending up to 8 cm deep. The biodiversity of benthic macrofauna within these samples was identified and quantified.

Sediments' properties and functional indicators measured were: granulometry, organic and inorganic matter content, dry bulk density, chlorophyll-a, concentrations of proteins, carbohydrates, and lipids.

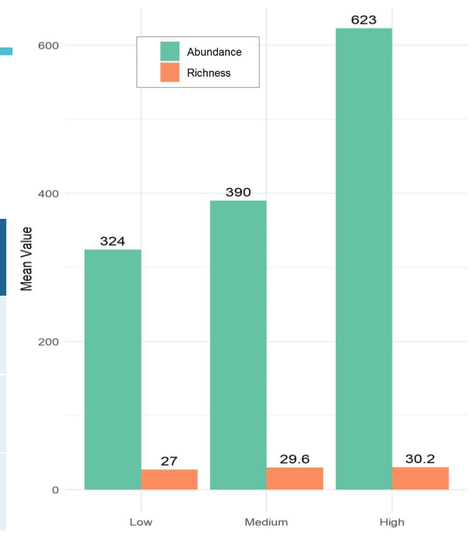
Non-metric multidimensional scaling (NMDS) was performed using the Bray-Curtis distance (*vegan* package) using the benthic macrofauna community composition (**Fig 1**). A PERMDISP analysis confirmed homogeneity of multivariate dispersions (ANOVA $p > 0.05$; **Fig 2).** PERMANOVA test showed a significant effect of level on community composition ($F_{2,27} = 2.3819$, $R^2 = 0.18491\%$, $p = 0.0013$), with a significant difference between Low- and High-density levels.

There was no significative differences between the biodiversity indices between each shoot density groups but there was difference in composition between levels Low and High (**Fig 2**). The indicator species from different taxonomical families were highlighted using the *multipatt* function from the *indicspecies* package. New ordination based on indicator species in **Figure 3**.

Significant differences among shoot density levels were highlighted when testing the communities based on indicator species among shoot density levels (PERMANOVA test $F = 7.14$, $p = 0.002$). To compare the ecosystem function values, we performed a redundancy analysis (RDA; **Figure 4**) on sedimentary function indicators with no problems of collinearity: sand (%), organic and inorganic matter content (OM and IC; %), chlorophyll-a (Chl_a; μg g^{-1}), biopolymeric carbon (BPC; mg C g^{-1}). RDA function indicators and indicator species, significantly ($F = 2.9723$, $p = 0.001$) explained the variation in environmental variables: RDA1 reflected a shift from sandy, low-productivity areas to more organic, high-productivity environments; RDA2 captured variations in organic matter content.

Table 1. ANOVA of the diversity indices result between each level of shoot density paired: Plot (right) shows the increase in mean abundance and richness by level.

Benthos ANOVA	Richness	Abundance	Simpson	Shannon	Evenness
Low - Medium	F = 1.078, p = 0.317	F = 0.934, p = 0.35	F = 0.066, p = 0.8	F = 0.299, p = 0.593	F = 1.248, p = 0.283
Medium - High	F = 0.047, p = 0.831	F = 4.592, p = 0.0502	F = 0.001, p = 0.97	F = 0.261, p = 0.617	F = 0.001, p = 0.972
Low- High	F = 1.208, p = 0.29	**F = 10, p = 0.00692**	F = 0.117, p = 0.738	F = 0.002, p = 0.968	F = 2.084, p = 0.171



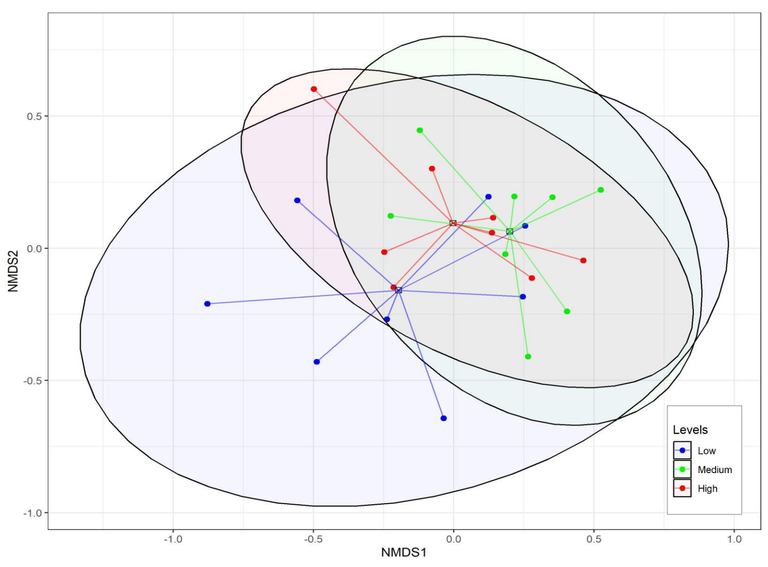


Figure 1 NMDS of benthic macrofauna species.

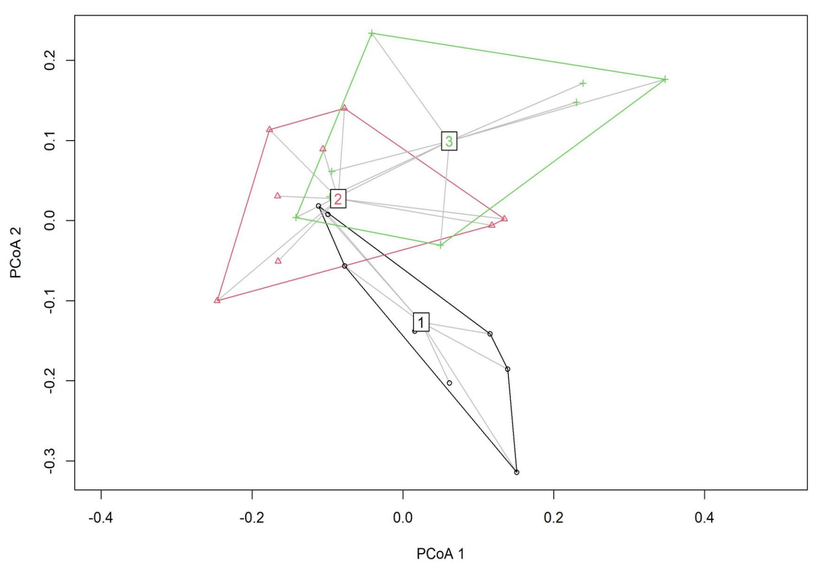


Figure 2 Dispersion plot (PERMDISP analysis).

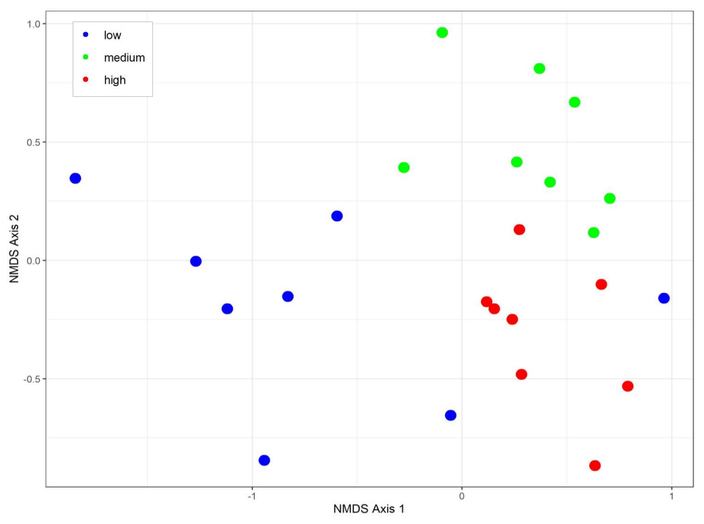


Figure 3 NMDS ordination plot to observe differences between the extracted indicator species from each level of shoot density (groups).

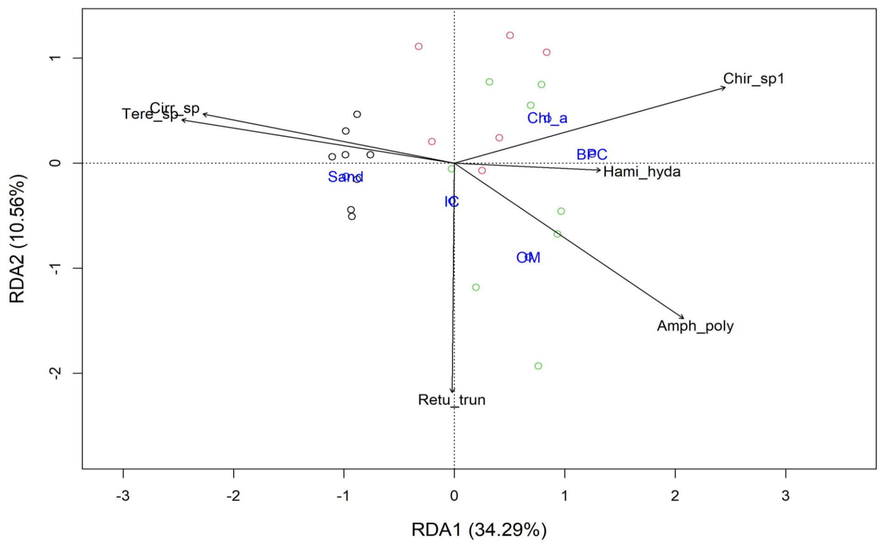


Figure 4 RDA function indicators and indicator species, indicating that the abundances of the indicator species significantly explain the variation in environmental variables.

PRELIMINARY FINDINGS

AIM 1: There is insufficient evidence to conclude that the structural complexity of the seagrass meadow enhances species biodiversity in terms of species richness. However, a significant difference in abundance was observed.
AIM 2: These findings suggest that species composition may be more critical than species richness alone. Overall, the results highlight the potential of using indicator species/taxa to emphasize the importance of species-environment interactions within ecosystems, particularly focusing on community composition rather than solely on species richness. **Nonetheless, these results are preliminary and only considered taxonomic biodiversity; further trait-based and functional analyses are necessary to deepen these insights.**

Summary: The abundances of indicator species explained the 51.2% of the variance in functional indicators (RDA-PERMANOVA $p = 0.001$), showing a strong relationship between species composition and the measured indicators of function.
Environmental gradients influencing species distributions were associated with sand content, chlorophyll-a and biopolymeric carbon. Species from the polychetes family Ampharetidae, the mollusk gastropod *Haminoea hydatis* and Chironomidae larvae were more prevalent in areas with higher primary productivity. Species from the polychetes family Terebellidae and Cirratulidae were associated with sandy substrates and low biopolymeric carbon. The mollusk gastropod *Retusa truncatula* was linked to organic-rich sediments.