Blue carbon and nitrogen storage in seagrass meadows of Amvrakikos Gulf

Sevasti-Aliki Kounida
Supervisor: Ioannis Karakassis
Scientific Supervisor: Dr. Apostolaki Eugenia

Introduction

The need to reduce CO2 concentrations has increased the interest of scientists in learning about many coastal ecosystems that can sequester carbon. Such ecosystems are also seagrass (Serrano et al., 2016). Seagrass have the ability to capture and store organic carbon in their sediments on centennial and/or millennial scales (Fourqurean et al., 2012; Kelleway et al., 2017; Kauffman et al., 2020). Despite their small extent (~ 0.2% of the ocean; McKenzie et al., 2020), seagrass ecosystems can capture almost 10–18% of organic carbon (Corg) stored in the sediment of the ocean (Mcleod et al., 2011). The magnitude of stocks depends on seagrass traits (i.e., species, abundance, health) and on environmental factors (e.g., hydrodynamics) and biogeochemical conditions (e.g., origin and composition of organic matter). Corg stock in seagrass meadows ranges from 0.9-7.2 kg m-2 in large seagrass species to 0.5-4.6 kg m-2 in small species (Mazarrasa et al., 2018). If the seagrass are small fast-growing species (Zostera spp.) then autochthonous will be lower than allochthonous and that's from organic matter that comes from the water column (Serrano et al., 2016). Many coastal waters have been degraded by eutrophication and nutrient over-enrichment, especially of nitrogen and phosphorus, which has been implicated as a major factor in the global disappearance of seagrass (Green and Short, 2003). A typical case of eutrophication in Greece is the coastal ecosystem of Amvrakikos Gulf. One of the characteristics of Amvrakikos is that the current water circulation in the center of the Gulf is incredibly low in the summer, which contributes to the reduction of dissolved oxygen with depth, causing frequent anoxic events. Due to this, Amvrakikos has higher levels of eutrophication than other Gulfs found close to major cities (e.g. Thermaikos) and it has been identified the existence of toxic phytoplankton (Nikolaidis et al., 2005). The aim of this thesis was to assess the carbon and nitrogen stocks of seagrass ecosystems extending in Amvrakikos Gulf and determine the potential change of stocks with seagrass degradation.

Figure 1: Study Area: Amvrakikos Gulf

Materials & Methods

Three Stations were selected in the study area. Station 1 was located at Mazoma lagoon and characterized by a dense *Z. noltei* meadow. Station 2 was inside on Logarou lagoon and was defined by a sparse *Z. noltei* meadow and the last Station was inside the Gulf and was characterized by a dense *Cymodocea nodosa* meadow. For these Stations were taken into consideration the environmental variables of 2021 and 2022 (Spring and Autumn). At each Station, sediment -from each Station- was collected with cores and was sliced into 1 cm sections, except for two cores of *C.nodosa*, which were sliced into 5 cm intervals. Subsamples of each slice were used for the determination of grain size. Dry bulk density (DBD) was calculated as the dry weight of the soil subsamples multiplied by the compression correction factor of every corer and expressed as gram (dry weight) per cubic centimeter. Other subsamples of each sediment slice were milled to a fine powder and were used for the determination of : Organic carbon (Corg), Total nitrogen (TN) and the stable carbon & nitrogen isotopic composition (δ13C and δ15N). The cumulative product of element concentration, DBD, and decompressed sediment slice thickness was used to estimate stocks. In cases where the length of sediment was less (in 8 out 9 cores) or more than 1 m a linear regression of cumulative stock per slice against sediment depth was fitted a so they can be comparable. Analysis of Variance (ANOVA) and t-test was used to test possible significant differences in the Stocks of organic carbon, total nitrogen and inorganic carbon among Stations. Levene's test and the Shapiro-Wilk test were used to determine whether the residuals were normal and whether their variance was homogeneous. Principal component analysis (PCA) was used to identify patterns of variance between Stations. The ordination of Stations based on their vertical profiles was analyzed using permutational multivariate analysis of variance (PERMANOVA) to identify any potential significant differences. Stable isotope mixing models were run for each Station to estimate the contribution of potential sources to the sediment Corg pool in the three Stations.

Figure 2: Cores used on Stations (Corer of *Z.noltei* on the left and of *C.nodosa* on the right)

Figure 3: Procedure of slicing the sediment of each core

Results

- ✓ Seagrass sediments of Amvrakikos Gulf were particularly fine, with a high percentage of mud across stations, very fine and fine sands, and a very low percentage of medium and coarse sands and gravel (1 % ± 0.2).
- ✓ DBD decreased towards the sediment surface at *Z. noltei* stations, while it did not show variability at the *C. nodosa* station.
- ✓ At *Zostera noltei* stations Corg increased towards the surface sediment, while Corg seemed to decrease at the *C. nodosa* station. TN didn't show variability at *C. nodosa*. Nitrogen at *Z.noltei* stations had a small increase and showed variability towards the sediment surface
- ✓ From 100 cm to surface of the sediment Cinorg decreased at *Z. noltei* stations and *C.nodosa* Station and at the *C. nodosa* station it showed high variability and a decrease.
- ✓ Until sediment surface δ13C did not show variability at *Z. noltei* stations, while at the *C. nodosa* station showed variability but the values from bottom to top didn't have a difference. At *Zostera noltei* stations δ15N didn't show variability towards the surface sediment, while δ15N seemed to increase at the *C. nodosa* station
- ✓ Corg stock was significantly lower at *C. nodosa* station while the values of TN Stocks of *Zostera noltei* stations were higher than these of *Cymodocea nodosa* and last the values of Cinorg stock were significantly higher at *C. nodosa* station

Table 1: One-way ANOVA results of Corg, TN, and Cinorg stocks between Stations.

	Df	Mean Square	F-value	P -value	Tukey's post-hoc
Corg Stock					
Station	2	77.64	10.67	0.0106 *	Station 3 ≠ Station 1,2 Station 1= Station 2
Residuals	6	7.28			
TN Stock					
Station	2	0.4762	56.46	0.000128 ***	Station 1 ≠ Station 2 ≠ Station 3
Residuals	6	0.0084			
Cinorg Stock					
Station	2	0.7661	11.1	0.00964 **	Station 3 ≠ Station 1,2 Station 1= Station 2
Residuals	6	0.0690			

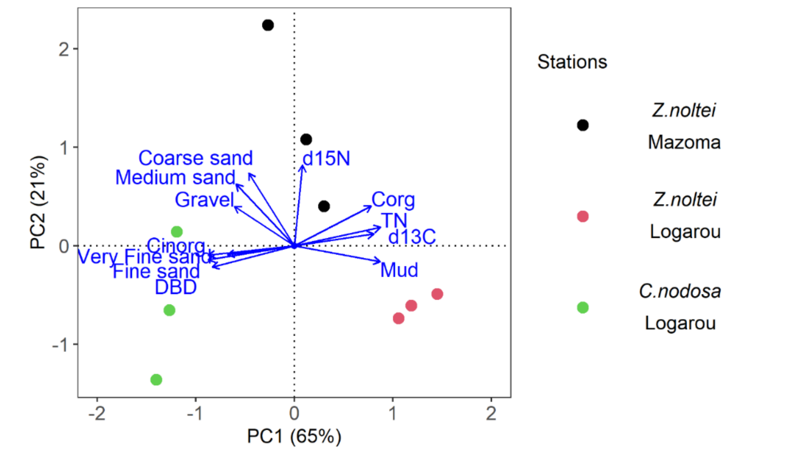

Figure 3: PCA biplot of the vertical profiles of geochemical variables (grain size fractions, DBD, Corg, TN, Cinorg, $\delta^{13}C$, $\delta^{15}N$) for all stations

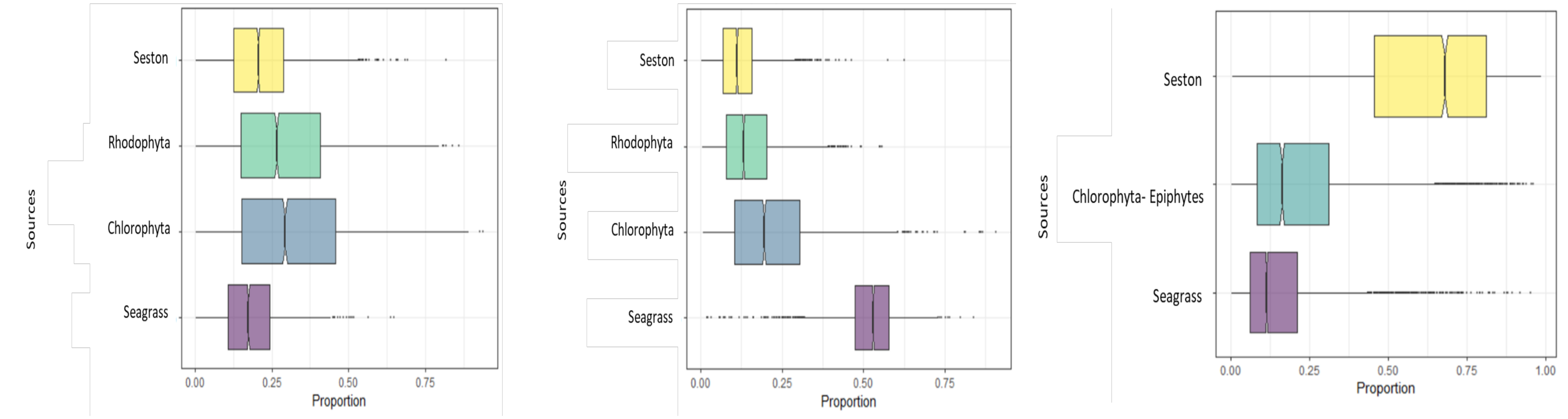

Figure 4: Proportion of each end-member to the Corg pool of the sediment at Station 1,2,3

Discussion

- ✓ First assessment of BC and TN stocks of *Zostera noltei* and *Cymodocea nodosa* in Amvrakikos Gulf.
- ✓ The concentrations of Corg and TN stocks from previous studies in *Z. noltei* from Ria di Formosa in Portugal (Martins et al. 2022) and in *C. nodosa* measured in Greece and Spain (Apostolaki et al. 2019) are lower than our values.
- ✓ In meadows with a lot of anthropogenic pressure, allochthonous enriched Corg soil stocks are more possible to be found (Mazarrasa et al., 2017)

Αναφορές

1. Apostolaki E.T., Vizzini S., Santinelli V., Kaberi H., Andolina C., Papathanassiou E. (2019). Exotic Halophila Stipulacea is an Introduced Carbon Sink for the Eastern Mediterranean Sea. Scientific Reports 9, 9643
2. Fourqurean JW, Duarte CM, Kennedy H., Marba N., Holmer M., Mateo, M. A., Apostolaki E.T., Kendrick G.A., Krause-Jensen D., McGlathery K.J., Serrano O. (2012). Seagrass ecosystems as a globally significant carbon stock. Nature Geoscience 5, 505–509
3. Green E.P. and Short F.T. (2003). World Atlas of Seagrasses University of California Press, Berkeley
4. Kauffman J.B., Adame M.F., Arifanti V.B., Schile-Beers L.M., Bernardino A.F., Bhomia R.K., Donato D.C., Feller I.C., Ferreira T.O., Jesus Garcia M.d.C., MacKenzie R.A., Megonigal J.P., Murdiyarso D., Simpson L., Hernández Trejo H. (2020). Total ecosystem carbon stocks of mangroves across broad global environmental and physical gradients Ecological Monographs, 90
5. Kelleway J.J., Saintilan N., Macreadie P.I., Baldock J.A., Heijnis H. , Zawadzki A. , Gadd P. , Jacobsen G. , Ralph P.J. (2017). Geochemical analyses reveal the importance of environmental history for blue carbon sequestration. Journal of Geophysical Research Biogeosciences 122, 1789–1805
6. Martins M., de los Santos C.B., Masqué P., Carrasco A.R., Veiga-Pires C., Santos R. (2022). Carbon and nitrogen stocks and burial rates in intertidal vegetated habitats of a mesotidal coastal lagoon. Ecosystems 25, 372–386
7. Mazarrasa I., Marbà N., Garcia-Orellana J., Masqué P., Arias-Ortiz A., Duarte C.M. (2017). Dynamics of carbon sources supporting burial in seagrass sediments under increasing anthropogenic pressure. Plant Physiology 62, 1451–1465
8. Mazarrasa, I., Samper-Villarreal, J., Serrano, O., Lavery, P. S., Lovelock, C. E., Marbà, N., Cortés J. (2018). Habitat characteristics provide insights of carbon storage in seagrass meadows. Marine Pollution Bulletin, 134, 106–11
9. McKenzie L.J., Nordlund L.M., Jones B.L., Cullen-Unsworth L.C., Roelfsema C., Unsworth R.K.F. (2020). The global distribution of seagrass meadows Environmental Research Letters, 15
10. Mcleod E., Chmura G.L., Bouillon S., Salm R., Björk M., Duarte C.M., Lovelock C.E., Schlesinger W.H., Silliman B.R. (2011). A blueprint for blue carbon: toward an improved understanding of the role of vegetated coastal habitats in sequestering CO2. Frontiers in Ecology and the Environment 9, 552-560
11. Nikolaidis G., Koukaras K., Aligizaki K., Heracleous A., Kalopesa E., Moschandreou K., Tsolaki E., Mantoudis A. (2005). Harmful microalgal episodes in Greek coastal waters 9
12. Serrano O., Lavery P.S., López-Merino L., Ballesteros E., Mateo M.Á. (2016). Location and associated associated carbon storage of erosional escarpments of seagrass posidonia mats. Frontiers Marine Science 3, 4

DEPARTMENT OF BIOLOGY
UNIVERSITY OF CRETE

HELLENIC CENTRE FOR
MARINE RESEARCH