ACTION D.4: Second Monitoring of C4 action

SubAction D.4.1 Monitoring angiosperm growth

SubAction D.4.2 Monitoring biodiversity and the environmental quality status

Beneficiary responsible for implementation: HCMR

Athens,

Status: Final

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Contributors: Laura Bray, Vasilis Gerakaris, Nikolaos Providakis, Anastasios Triantafylidis, Nikolaos Katsiaras, Emmanuela Voutsinas, Ioanna Drakolopoulou, Giorgos Arvanitakis, Evgenia Apostolakis, Sofia Reizopoulou

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Second Monitoring report for Amvrakikos

• EXECUTIVE SUMMARY

This report presents the results obtained from the second year of monitoring within the project (2022), and is based on the monitoring protocols described in the first C4 monitoring report for the two sub-actions (D.4.1 Monitoring angiosperm growth, and D.4.2 Monitoring biodiversity and the environmental quality status). For the sub-action D.4.1, the following parameters were measured: survival of transplanted sods, rooting of the rhizomes, rate of expansion of each transplanted sod and the estimate of the coverage of the newly formed meadows. For sub-action D.4.2 (monitoring biodiversity and the environmental quality status), the yearly monitoring was undertaken in 5 stations (three from the main transplant areas A, B, D, one in the centre of the lagoon, and one in the donor site). Parameters regarding the water-column and the sediment were collected inline with the monitoring protocols outlined in the first monitoring report. In addition, the ecological status of each monitoring site was calculated based on the macroalgae and macrobenthos biological components (MaQI, BITS, M-AMBI) for sub-action D4.2. Approximately 4050 rhizomes were transplanted in May 2022 (16 stations), however by October 2022 the average sod survival rate of the second transplantation campaign was drastically low (0.82%) compared to the first year of monitoring (75%). In parallel with the transplantation sites both the donor lagoon and the recipient lagoon experienced drastic reductions in the above-ground biomass of Zostera noltei in October 2022 in comparison with six months earlier. The reasons for this decline are unclear, as it is expected that the angiosperms will be at the end of their annual growth cycle during the Autumn months. In response to this apparent decline, an increase in the monitoring frequency of the physico-chemical parameters of the lagoon is required, along with a further examination of the anthropogenic pressures in the region with the assistance of the GIS systems which are now up and running (Action A5). The second monitoring results indicate that the donor site. remains in a good ecological status in accordance with benthic ecological quality status indices, and that the transplant site is still categorised as being in a "moderate" condition (according to the M-AMBI and MAQI indexes), an change in the ecological status of the lagoons has not been yet noted in parrallel with the restoration actions.

• Action D.4: Monitoring of C4 action

Monitoring within the context of a restoration project is essential for assessing the efficacy and impact of angiosperm transplant actions. As is the aim of the restoration action, it is expected that following successful transplantation, a natural dispersion of the seeds produced by the transplanted sods will occur. The seeds that will take root increase the habitat extent of seagrass meadows and operate as source populations for natural seed dispersion and meadow recolonization. Monitoring is necessary for quantifying the results in terms of success/failure of sod transplants and verifying the possible need for corrective interventions (i.e., transplantation of new sods). Effective monitoring implies that accurate ecological baseline levels are established before the transplantation process (See A.2 Amvrakikos Ex-Ante Report), and that the monitoring sampling design is effective in quantifying ecological changes during, and after, the angiosperm transplant process. The frequency of sampling should be sufficient to detect and identify any changes that affect the consolidation process of the transplanted prairie. At the same time, the parameters to be measured must be able to identify not only the growth of the angiosperm but also the community it supports and the potential ecosystem services it provides due to the importance of these species as habitat-formers and biodiversity generators. The progress of the restoration actions (see below) will as measured yearly, and a range of metrics will be monitored to assess the growth of the transplanted angiosperm sods (Sub-action D4.1), and the overall biodiversity and ecological status of the lagoon where the angiosperm sods will be transplanted (Sub-action D4.2). Finally, it is essential to monitor the environmental factors that affect, and are influenced by the transplantation process, both in the water column and in the sediment, to allow for up-scaling of the methodology in regions of similar abiotic conditions. Here below is the transplantation progress of the second year (2022), and a presentation of the results from the second year of monitoring.

● Second-year transplantation progress

The second-year transplants of the species *Zostera noltei* in the Amvrakikos pilot site were successfully executed in May of 2022 (05-13/05/22). Sods were extracted from the donor site of Mazoma lagoon (Figure 1), transferred, and re-planted in the Logarou recipient sites (Figure 2). To address issues encountered in the field with the transplantation process (see first monitoring report), in March 2022 the tools were designed, constructed, and trialed for use in the specific conditions encountered in the Amvrakikos pilot site, with the aim of ensuring an effective and efficient transplantation schedule (Figure 3). With the aid of the new tool, a total of 18 stations were planted (in comparison with the two sites planted in 2021) (Table 1).

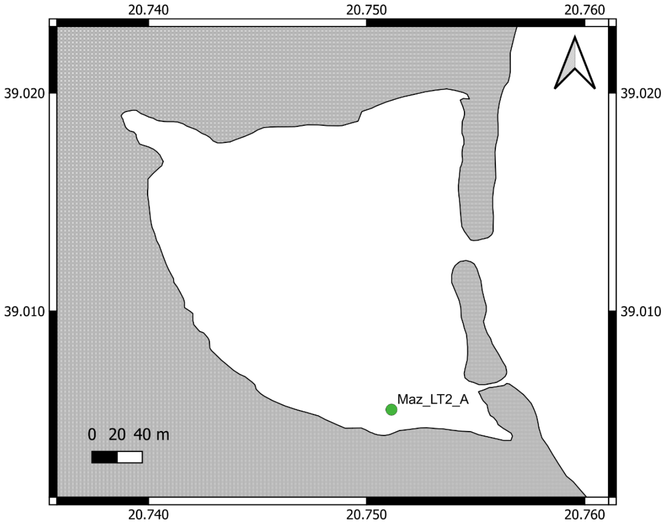


Figure 1. *Extraction site within Mazoma lagoon for the second year (May 2022).*

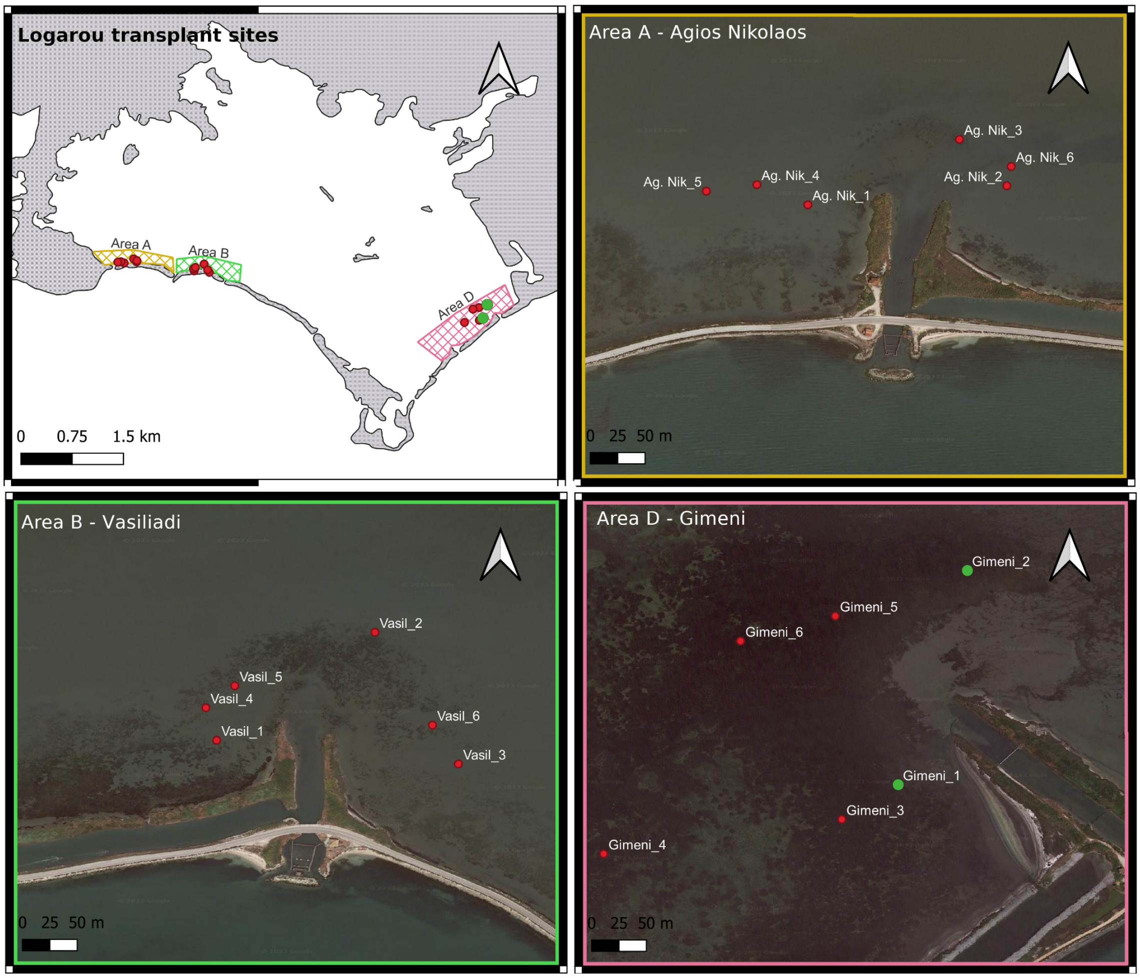


Figure 2. *Transplantation sites within the Logarou recipient site for the second year (2022). The two stations planted during the first year in Area D (Gimeni_1 and Gimeni_2) are shown in green.*

Figure 3. *Transplantation tool used for 2022 transplantations*

Table 1. *Transplant station information for the second-year transplantation actions (2022). *The total number of Z. noltei rhizomes (shoots) transplanted is calculated as approximately 25 rhizomes per sod*

Station code	Transplant area	Transplant date	Latitude	Longitude	Total number of sods	Total number of Rhizomes (shoots) *
LOG_A_1	A	4/5/22	39.036500	20.877400	9	225
LOG_A_2	A	4/5/22	39.036700	20.879500	9	225
LOG_A_3	A	5/5/22	39.037190	20.879000	9	225
LOG_B_1	B	5/5/22	39.035180	20.889220	9	225
LOG_B_2	B	5/5/22	39.036320	20.890890	9	225
LOG_B_3	B	5/5/22	39.034930	20.891770	9	225
LOG_D_3	D	6/5/22	39.026824	20.937364	9	225
LOG_D_4	D	6/5/22	39.026460	20.934852	9	225
LOG_D_5	D	6/5/22	39.028969	20.937296	9	225
LOG_D_6	D	6/5/22	39.028706	20.936296	9	225
LOG_A_4	A	12/5/22	39.036712	20.876862	9	225
LOG_A_5	A	12/5/22	39.036644	20.876329	9	225
LOG_A_6	A	13/5/22	39.036904	20.879546	9	225

LOG_B_4	B	13/5/22	39.035523	20.889106	9	225
LOG_B_5	B	13/5/22	39.035755	20.889411	9	225
LOG_B_6	B	13/5/22	39.035340	20.891497	9	225
				Total	162	4050

However, as stated by the executive project (September 2021), two transplantation campaigns were foreseen for the second year (Spring and Autumn). During the Autumn visit to Amvrakikos in October 2022 (20-23/10/22), the donor site and the recipient site were resurveyed to monitor the survival and sod growth of the transplantation stations (Figure 5). From the first day in the field, it became clear that there had been a shift in the environmental conditions of the two surveyed lagoons. The above ground biomass of the donor site (Mazoma lagoon) was severely reduced, to the point whereby attempts to collect donor sods were unsuccessful. The extraction was also hampered by the presence of a Cyanobacteria bloom throughout the whole lagoon which reduced the visibility of the site to approximately 15 cm from the surface (Figure 4). This meant that ground truthing of sites could only be done with the sod extraction tool, as aerial and in-situ tools were ineffective. The three main areas of seagrass meadows known in the site were sampled (covering a surface of approximately 5 km2) and no suitable sites for extraction were identified, and thus sod transplantation during the Autumn sampling period did not take place.

Table 2*. Sod extraction for the second year of angiosperm monitoring (2022) from the donor site (Mazoma Lagoon). The total number of rhizomes (shoots) extracted is calculated as approximately 25 rhizomes per sod.*

Donor site	Year	Season	Total Number of sods extracted	Total Number of rhizomes (shoots) extracted*	Total Surface area of meadow extracted
Mazoma lagoon	2022	Spring	162	4050	2.835 m^2

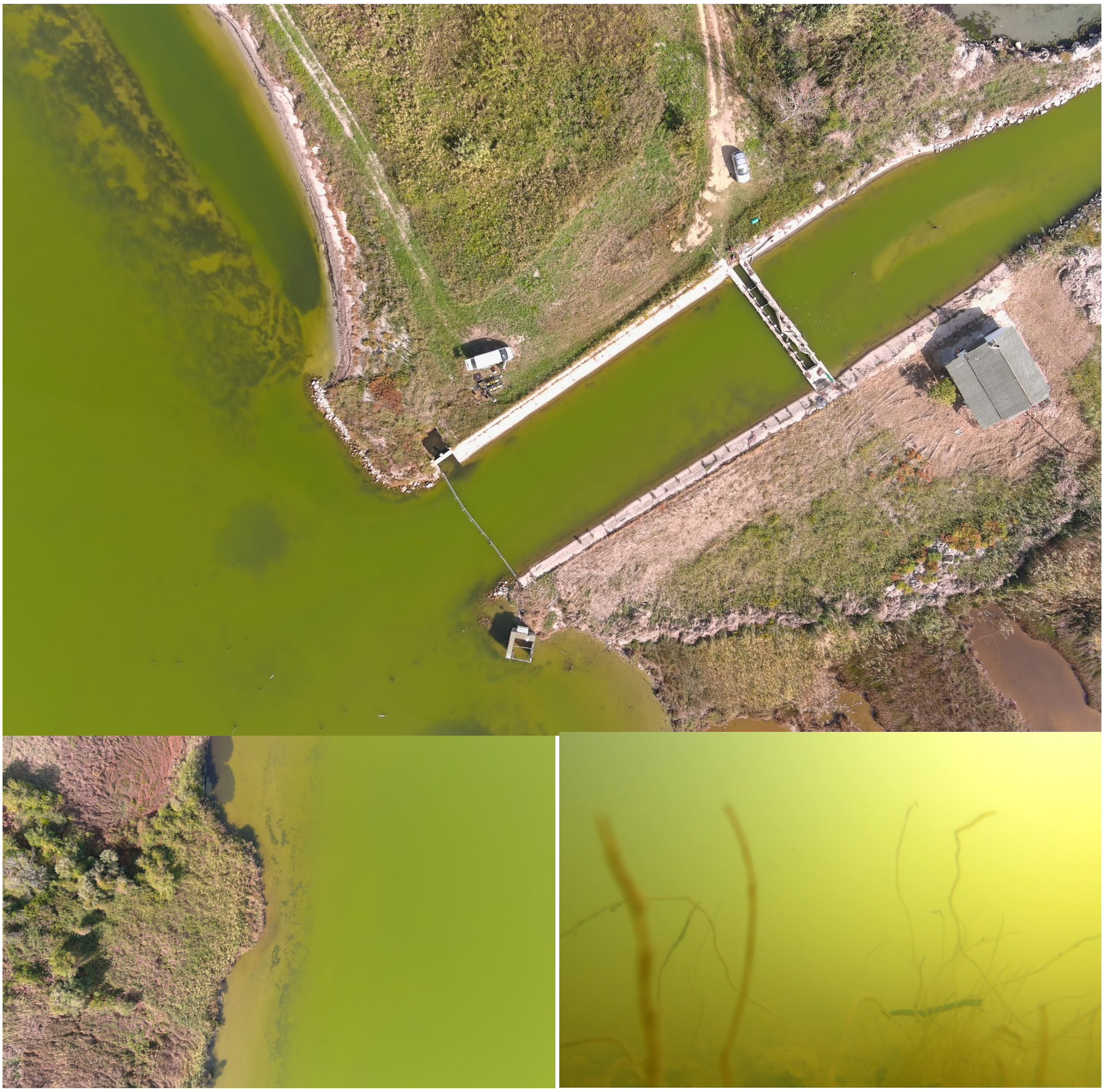


Figure 4. *Aerial survey of Mazoma lagoon during October 2022 with cyanobacterial bloom and average visibility of 15cm. After groundtruthing, darker areas identified as Chaetomorpha sp.*

Second year monitoring protocol implementation progress

D.4.1 Monitoring angiosperm growth

In this sub-action, the monitoring of angiosperm rooting and growth was carried out by evaluating the following parameters:

i) survival rate of transplanted sods,

ii) growth rate of each transplanted sod and

iii) coverage estimation of the newly formed meadows.

In-line with the monitoring protocols defined by the first monitoring report (June 2021) , the survival rate and growth of transplanted sods were assessed by measuring their number and diameter at each station. This was done by observers in-situ (Figure 5). The total sod coverage of each transplant area of 10 x 10 m was recorded in field sheets and estimated as per cent coverage (Figure 5).

As mentioned in the first monitoring report, meadow growth is expected to become effective after the first year of transplantation after the plants have adapted well to the new environment. In case of partial decay, the sods should be replaced with other new sods. If however, the failure concerns the entire station, the causes will be analysed and another area will be selected with chances of success may be greater, without additional costs for the project. As the overall survival rate of the two (2) stations planted during the first year (2021) had a 75% survival rate, only the sods that had not survived were replanted. The monitoring of all of the second-year transplantation stations took place in Autumn 2022, six months after the 18 stations were transplanted. The overall survival rate for the second monitoring campaign decreased drastically to 0.82%, with only 3 sods surviving from the 2021 stations and 1 sod from the 2022 stations.

Table 3. *D4.1 Results for the second year of monitoring (2022). THe mean sod growth is calculated based on the sods that survived. The surface area of the original sods was 225cm^2*

Transplant station	Transplantation period	Sod survival rate 2023	Mean sod Growth (cm^2)	Estimated total coverage per site (m^2)
LOG_D_1	Autumn 2021	7.4%	Increase (750 cm^2)	0.016 (0.02%)
LOG_D_2	Autumn 2021	3.7%	Increase (270 cm^2)	0.027 (0.03%)
LOG_A_1	Spring 2022	0%	NA	0
LOG_A_2	Spring 2022	0%	NA	0

LOG_A_3	Spring 2022	0%	NA	0
LOG_A_4	Spring 2022	0%	NA	0
LOG_A_5	Spring 2022	0%	NA	0
LOG_A_6	Spring 2022	0%	NA	0
LOG_B_1	Spring 2022	0%	NA	0
LOG_B_2	Spring 2022	0%	NA	0
LOG_B_3	Spring 2022	0%	NA	0
LOG_B_4	Spring 2022	0%	NA	0
LOG_B_5	Spring 2022	0%	NA	0
LOG_B_6	Spring 2022	0%	NA	0
LOG_D_3	Spring 2022	3.7%	Stable (225 cm^2)	0.02 (0.03 %)
LOG_D_4	Spring 2022	0%	NA	0
LOG_D_5	Spring 2022	0%	NA	0
LOG_D_6	Spring 2022	0%	NA	0
	Total	2.5%	1200	0.068

Figure 5. Monitoring for sod survival rate during Autumn monitoring campaign (October 2022)

The transplantation of seagrass sods from Mazoma to Logarou appeared to be unsuccessful in 2022. The causes for this failure are not immediately apparent yet and may be due to adverse environmental conditions, physical stress from sediment resuspension , herbivory and grazing pressure, or pathogens (Boudouresque et al., 2021). It is of importance to note however that aerial surveys and in-situ ground truthing of both the donor site and the recipient site indicated an extensive rescindment of above ground biomass throughout both of the two lagoons in October 2022 (Figure 6; Figure 7), this is despite the fact that Autumn is typically when *Zostera noltei* is at its most abundant, having come to the end of it's typical annual growth cycle (Sfriso et al., 2021). The widespread decrease in above ground biomass of *Z. noltei* in the Amvrakikos lagoons in Autumn may indicate a difference in growth cycles with other partner countries (e.g. the Venice lagoon; Sfriso et al.,2019; 2021). In addition, findings from the Venice lagoon suggest that in some areas the limited colonization of this species from transplantation was the consequence of the excessively high summer temperatures (<30 °C) of choked areas (Sfriso et al., 2021). To outrule the possibility of high summer temperatures being the cause of the above ground biomass of *Z. noltei,* temperature, conductivity, and light sensors will be installed on a permanent basis in the donor and transplant sites to increase the availability of physico-chemical measurements throughout the year.

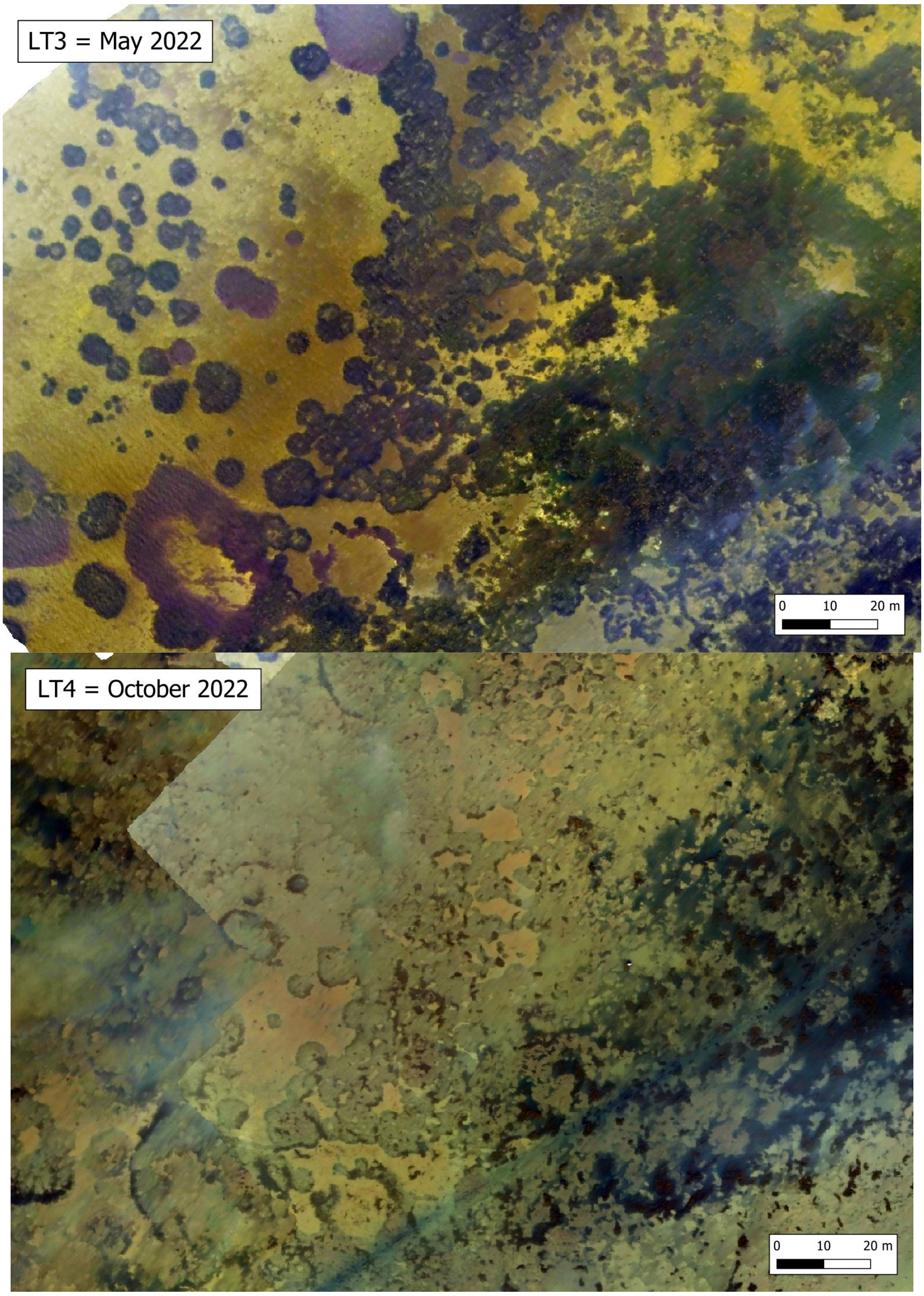


Figure 6. Example of the reduction of above ground biomass from the same location in Area D between May 2022 and October 2022. In the above image ground truthing identified a mixture of *Zostera noltei* and red macroalgae species (e.g. Polysiphonia sp.), for the bottom image the lighter brown colour is floating rafts of Valonia species, and the darker green is bottom dwelling Valonia and Chaetomorpha sp.

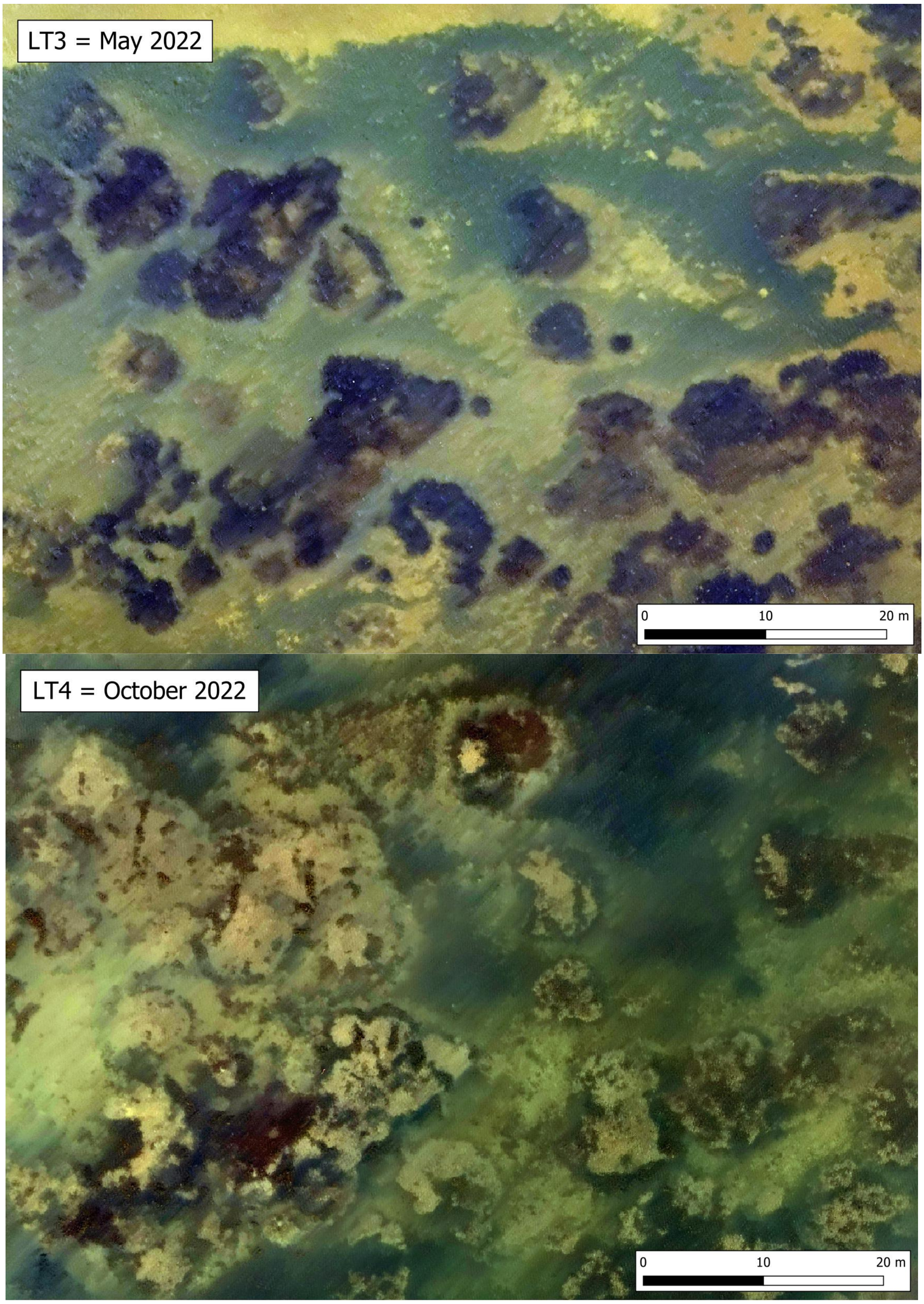


Figure 7. Example of the reduction of above ground biomass from the same location in Area D between May 2022 and October 2022. Ground truthing data indicated that for the above image the darker colour was *Zostera noltei*, whereas in the bottom image the darker colour was identified as Valonia sp., and the greener colour Chaetomorpha sp. Zostera was not identified in this frame for October 2022.

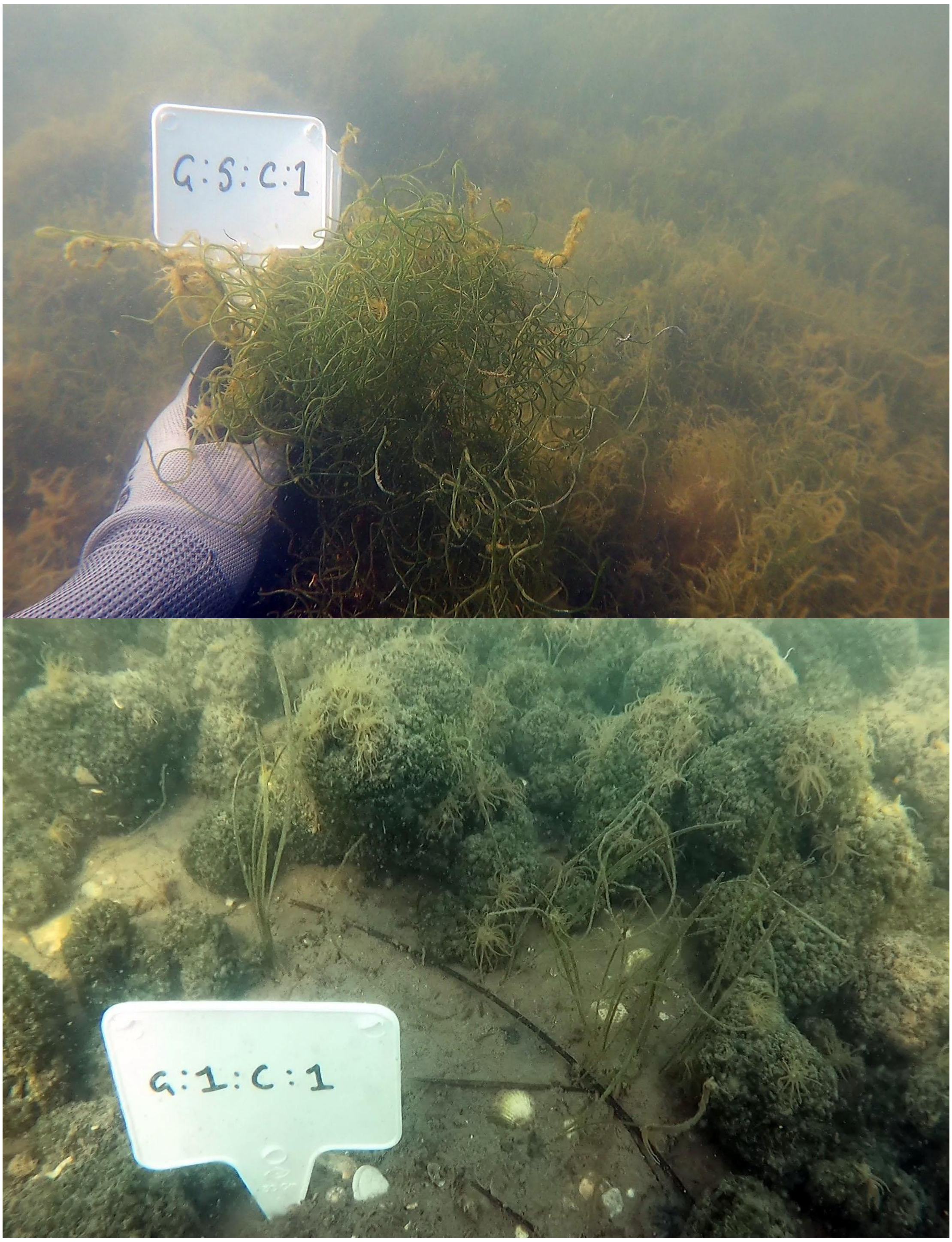


Figure 8. Top image shows an example of the large presence of macroalgae species and in particular *Chaetomorpha* and *Valonia* species. The bottom image shows a viable sod from one of the 2021 transplant stations (Table 3).

- D.4.2 Monitoring biodiversity and the environmental quality status

Presented below are the monitoring results from the second year of transplantation based on the monitoring protocol for physico-chemical parameters, biodiversity and ecological quality outlined in the first monitoring report. In total five stations are monitored for the biodiversity and environmental quality status (Executive project; First monitoring report), the locations of which are shown below in Figure 9. One is located in the donor site (Maz_Mon_1), three in the transplant areas (Log_Mon_A, Log_Mon_ B, Log_Mon_D), and one in the centre of the recipient lagoon (Log_Mon_0).

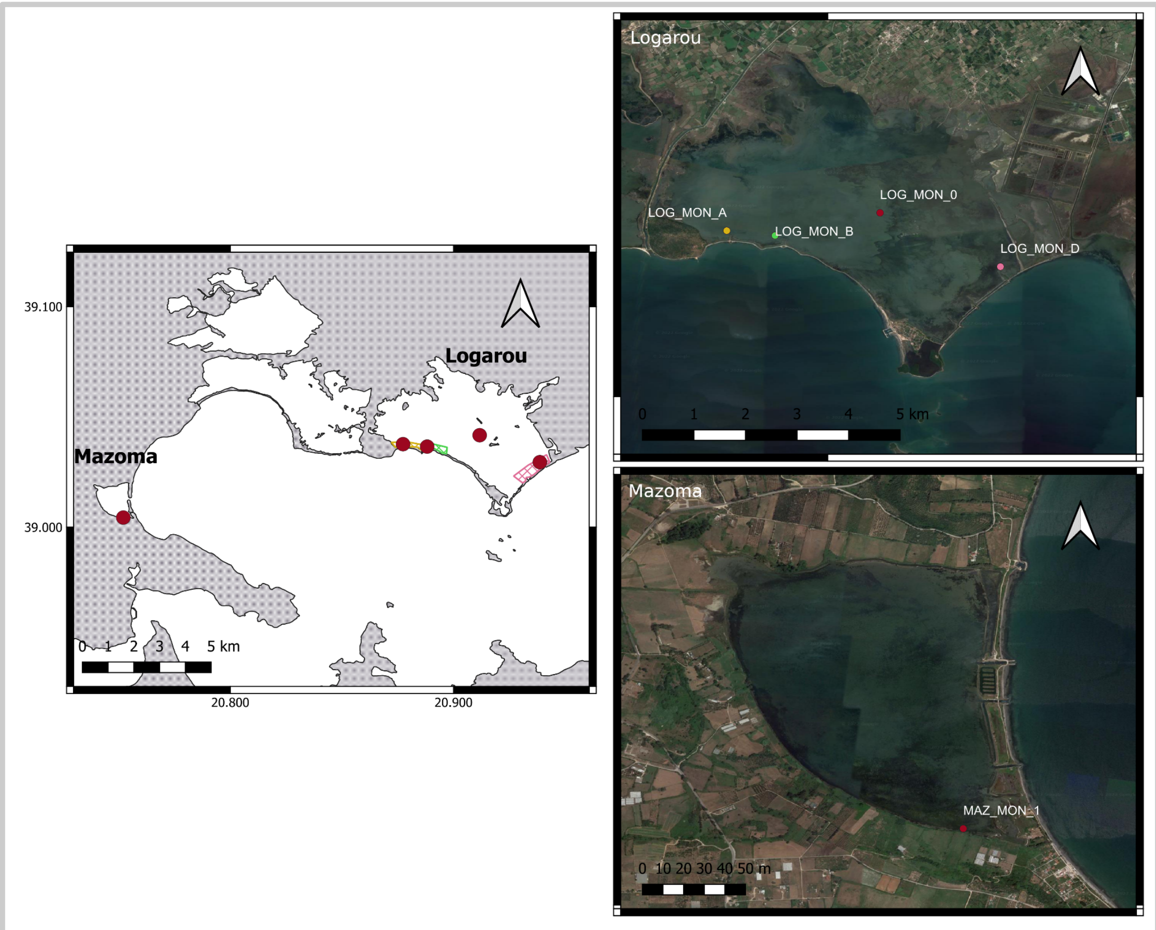


Figure 9. Location of monitoring sites for the biodiversity and environmental quality status.

Water column hydrological parameters

As was identified by the first monitoring report the physico-chemical parameters of the water column for the donor and the recipient site are very similar further reinstating it;s suitability as a donor site. There is a higher percentage of coarse sediment in Area D compared to the rest of the lagoon sites is likely associated with larger hydrodynamic flow in the site (Table 5).

Table 4. *Average Physico-chemical parameters of the water column at each monitoring station for 2022*

	Depth (m)	Visibility (m)	Temp (oC)	Conductivity (µS/cm)	Conductivity (TDS g/l)	Salinity (ppt)	Dissolved Oxygen (%)	Dissolved Oxygen (mg/L)	pH	Turbidity (FNU)
LOG_MON_A	0.5 ± 0.0	0.5 ± 0.0	20.8 ± 0.3	45.5 ± 0.0	41.8 ± 0.3	29.6 ± 0.1	117.8 ± 2.1	8.8 ± 0.3	8.2 ± 0.0	12.0 ± 1.2
LOG_MON_B	0.5 ± 0.1	0.5 ± 0.1	19.8 ± 0.2	45.4 ± 0.1	41.0 ± 0.0	29.5 ± 0.1	93.0 ± 3.6	7.1 ± 0.3	8.2 ± 0.1	19.0 ± 5.4
LOG_MON_D	0.6 ± 0.1	0.4 ± 0.1	20.2 ± 0.8	56.5 ± 9.6	40.5 ± 0.5	31.0 ± 1.4	86.8 ± 11.9	6.4 ± 0.9	8.2 ± 0.1	11.0 ± 3.8
MAZ_MON_1	0.3 ± 0.0	0.3 ± 0.0	21.3 ± 0.0	51.6 ± 0.0	33.9 ± 0.0	25.8 ± 0.0	96.2 ± 0.0	7.0 ± 0.0	8.4 ± 0.0	10.4 ± 0.0

Table 5. *Sediment parameters for monitoring sites*

Monitoring station	% of Sand	% of Silt	% of Clay	% of Fine material
MAZ_MON_1	7.01	5.28	87.71	92.99
LOG_MON_A	2.33	7.23	90.44	97.67
LOG_MON_B	7.18	5.95	86.86	92.81
LOG_MON_D	48.98	2.98	48.05	51.03
LOG_MON_0	27.43	4.31	68.26	72.57

Biodiversity metrics

In total, 1503 benthic macroinvertebrate individuals were identified from 73 taxa. The transplant areas were dominated by *Abra segmentum and Nephtys hombergii* which are typically found in finer muddy sediments, similar to those of the transplant areas. In-line with the first monitoring report, the Mazoma monitoring site was dominated the typically freshwater origin taxa of Chirinomidae, suggesting the lagoon has higher freshwater or brackish influences, and appears more isolated from the sea.

Table 6. Species that contribute to the top 90% of the total abundance of the donor and recipient lagoons (Areas A, B, D, and 0 of the recipient site are pooled).

Donor Site		Recipient sites (Pooled)	
Taxa which contribute to 90% of sample	**% of samples in which taxon contribute**	**Taxa which contribute to 90% of sample**	**% of samples in which taxon contribute**
Chironomidae	25.47	*Abra segmentum*	41.29
Sinelobinae	19.66	*Nephtys hombergii*	25.38
Abra segmentum	14.70	*Naineris laevigata*	5.88
Mytilaster minimus	9.91	*Cerastoderma glaucum*	3.38
Cerastoderma glaucum	7.35	Scolelepis	3.38
Lekanesphaera monodi	3.08	Oligochaeta	1.96
Monocorophium insidiosum	2.91	*Lekanesphaera monodi*	1.74
Gammarus aequicauda	2.22	*Armandia cirrhosa*	1.63
Tanaididae	2.05	*Idotea balthica*	1.53
Gammarus insensibilis	1.88	*Capitella capitata*	1.42
Gammarus sp.	1.71	*Microprotopus maculatus*	1.20
		Mytilaster minimus	1.09
		Nereiphylla rubiginosa	0.98

Table 7. List of macroalgae species found at donor and recipient sites.

		No. of total macroalgal taxa	**Species**	**Relative abundance (%)**
Recipient sites (Areas A, B and D)	LOG_MON_A	1	*Chylocladia verticillata*	92.3
		2	*Cladophora sp.*	0.1
	LOG_MON_B	1	*Chylocladia verticillata*	85.0
		2	*Cladophora sp.*	0.1
	LOG_MON_D	1	*Chaetomorpha aerea*	21.9
		2	*Valonia aegagropila*	15.6
		3	*Cladophora sp.*	0.1
		4	*Chylocladia verticillata*	0.0
Donor site	MAZ_MON_1	1	*Chaetomorpha aerea*	71.4

		2	*Chylocladia verticillata*	15.2
		3	*Polysiphonia elongata*	6.5
		4	*Cladophora sp.*	0.5
		5	*Lithophyllum pustulatum*	0.1
		6	*Ceramium sp.*	0.1

Ecological status

The ecological status of the transplant sites remained in a "Moderate" condition with the M-AMBI index (with reference condition calibrated for Greek restricted lagoons e.g. Logarou and Mazoma). In comparison, the BITS index overestimates the ecological quality in all stations, classifying the transplant and donor sites in "Good" ecological status, and the centre of the Logarou lagoon in a "High" ecological status. Both indices classified the Mazoma donor site in a "Good" ecological status. The assessment of ecological status as "Moderate" for the transplant sites and "Good" for the donor site was additionally confirmed by the MaQI index (Table 9).

Table 10 compares the ecological status identified by the M-AMBI index for Ex-ante report, the first monitoring report, and the present report, no changes in the ecological status have been noted in parallel to the restoration actions yet.

Table 8. *Multi-biotic Indices for the Ecological Quality Status of the monitoring stations*

Monitoring station	M-AMBI score	M-AMBI Status	BITS score	BITS status	MaQI	MaQI statu
LOG_MON_A	0.47	Moderate	1.59	Good	0.55	Moderate
LOG_MON_B	0.56	Moderate	1.76	Good	0.55	Moderate
LOG_MON_D	0.6	Moderate	1.71	Good	0.55	Moderate
LOG_MON_0	0.78	Good	1.77	High	-	-
MAZ_MON_1	0.69	Good	2.06	Good	0.65	Good

Table 9*. Macrophyte metrics and MaQI determination in the monitoring stations.*

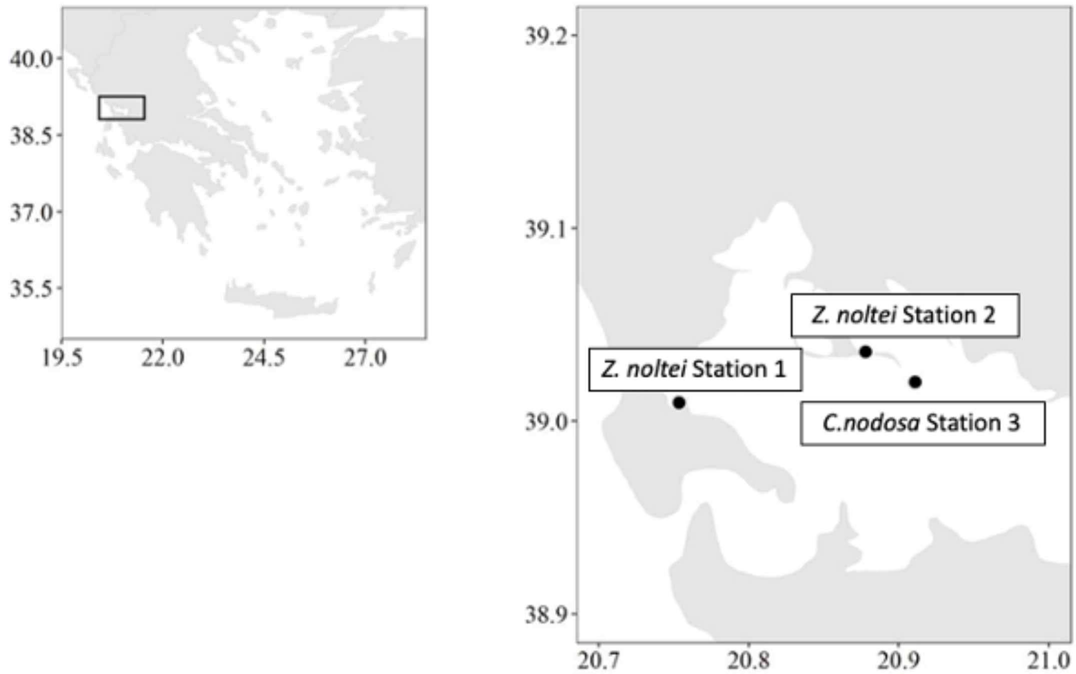
Stations	No. of total macroal	Sensitive taxa	Relative abundance (%)	Macroalgal cover (%)	Angiosperm cover %	MaQI

	gal taxa	No. of sensitive taxa (score 2)	Sensitive taxa %	Rhodo phyta %	Chloro phyta %	Max cover %	*C. nodosa*	*Z. noltei*	EQR	Ecological status
LOG_MON_A	2	1	50	99.9	0.1	50	0	40	0.55	Moderate
LOG_MON_B	2	1	50	99.9	0.1	50	0	40	0.55	Moderate
LOG_MON_D	4	2	50	0.1	99.9	75	0	30	0.55	Moderate
MAZ_MON_1	6	2	33.3	23.3	76.7	30	0	75	0.65	Good

Table 10. Evolution of the ecological status of the monitoring sites based on the M-AMBI index from the ex-ante report until the present monitoring report.

	Ecological status (M-AMBI)		
	Ex-ante (2021)	1st monitoring (2021)	2nd monitoring (2022)
MAZ_MON_1	Good	Good	Good
LOG_MON_0	Good	-	Good
LOG_MON_A	-	-	Moderate
LOG_MON_B	-	-	Moderate
LOG_MON_D	-	Moderate	Moderate

- Blue carbon
-



Map of the three Stations in Amvrakikos Gulf

Seagrass sediments of Amvrakikos Gulf were particularly fine, with high percentage of mud (mean ± SE across stations of 31 ± 2.3 %),very fine (31 % ± 0.9) and fine (23 % ± 1.3) sands, and very low percentage of medium (9 % ± 0.8) and coarse sands (5 % ± 0.7) and gravel (1 % ± 0.2). Overall, *Z. noltei* sediments were characterized by mud (40 % ± 2.4) and very fine sand (28 % ± 1.1), while those of *C. nodosa* ranged between very fine (36 % ± 1.2) and fine (39 % ± 2.2) sands. Between *Z. noltei* stations, station 2 at Logarou had the highest contribution of mud, which was 61 % ± 2.2, while station 1 was mainly composed of very fine sands (32% ± 1.7). The vertical distribution of each grain size fraction showed low variability at all stations (Figure 1).

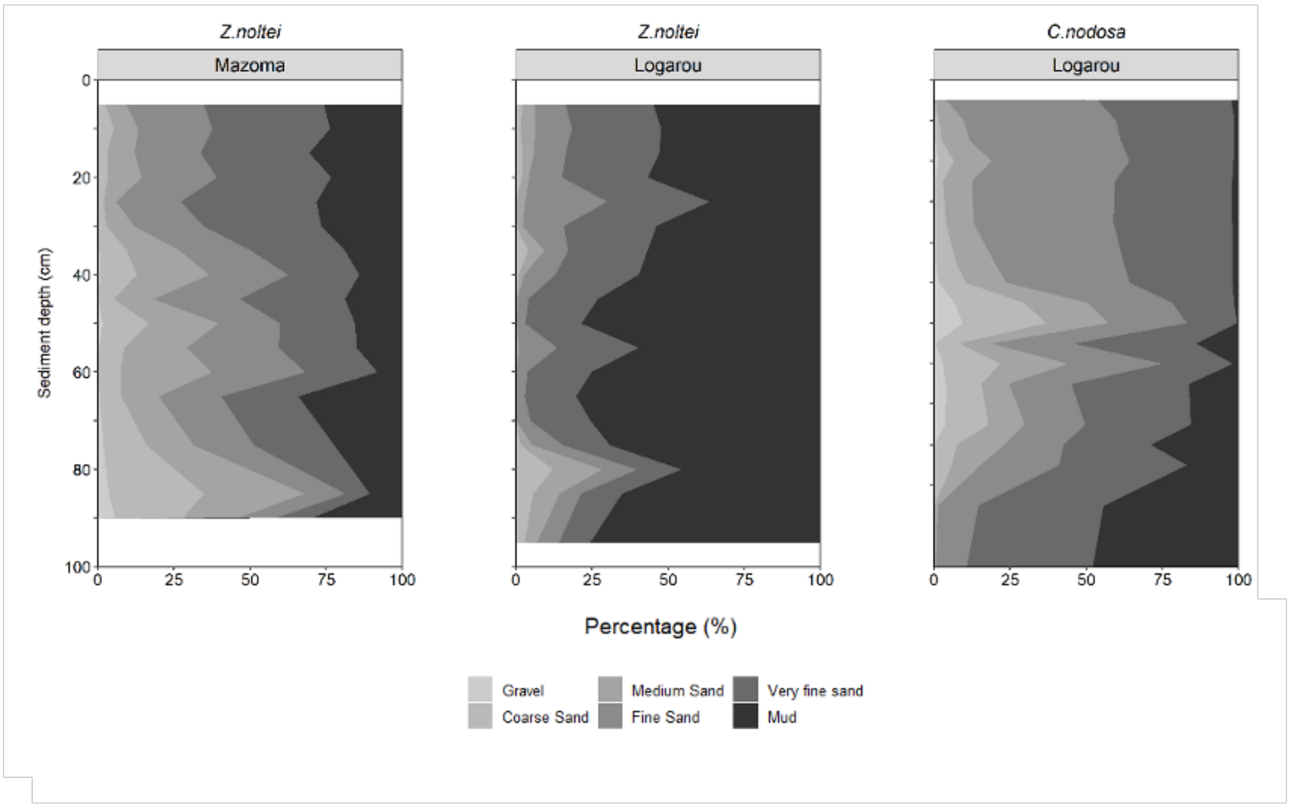


Figure 1: Percentage of Grain classes per Station

DBD decreased towards the sediment surface at *Z. noltei* stations, while it did not show variability at the *C. nodosa*station (Figure 2). Overall, DBD ranged between 0.59 ± 0.02 and 1.32 ± 0.03 g cm^{-3}, with a mean ± SE of 0.82 ± 0.02 g cm^{-3} across stations.

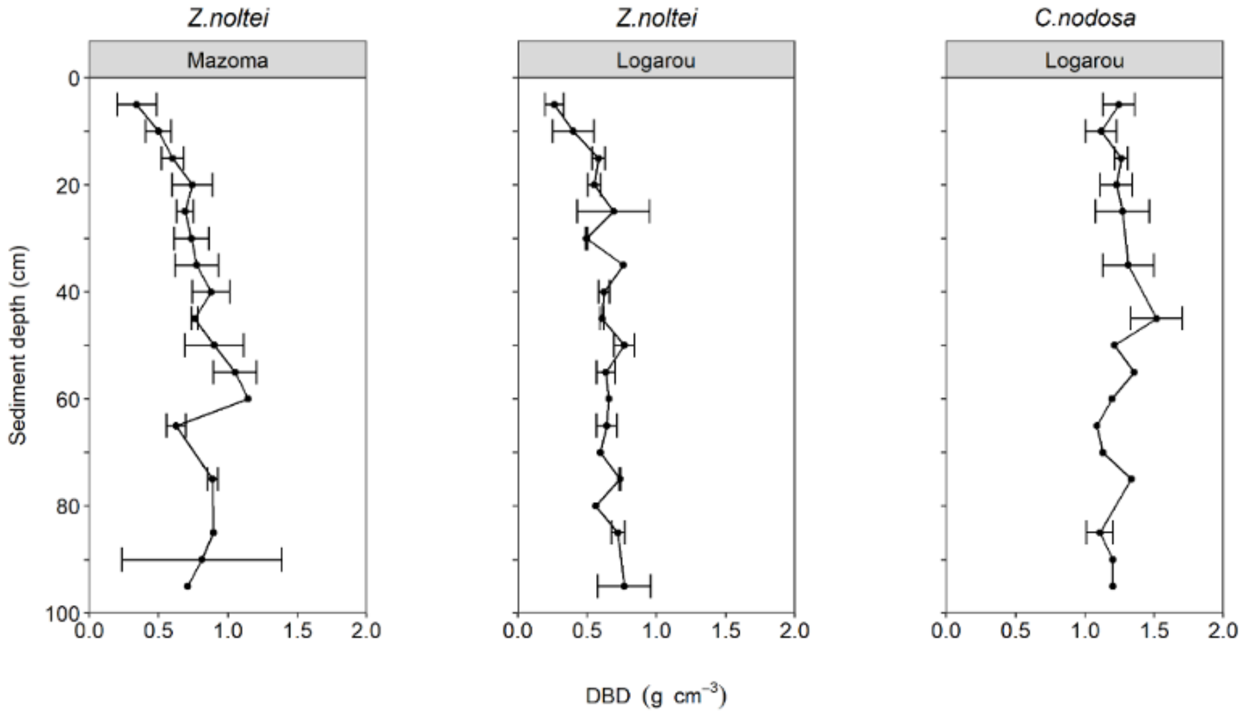


Figure 2. Vertical profile of DBD (g cm^{-3}) with Standard Errors

The vertical distribution of elemental concentrations and isotopic composition differed between stations, with *Z. noltei* cores showing a higher range and larger variability within the sediment profile.

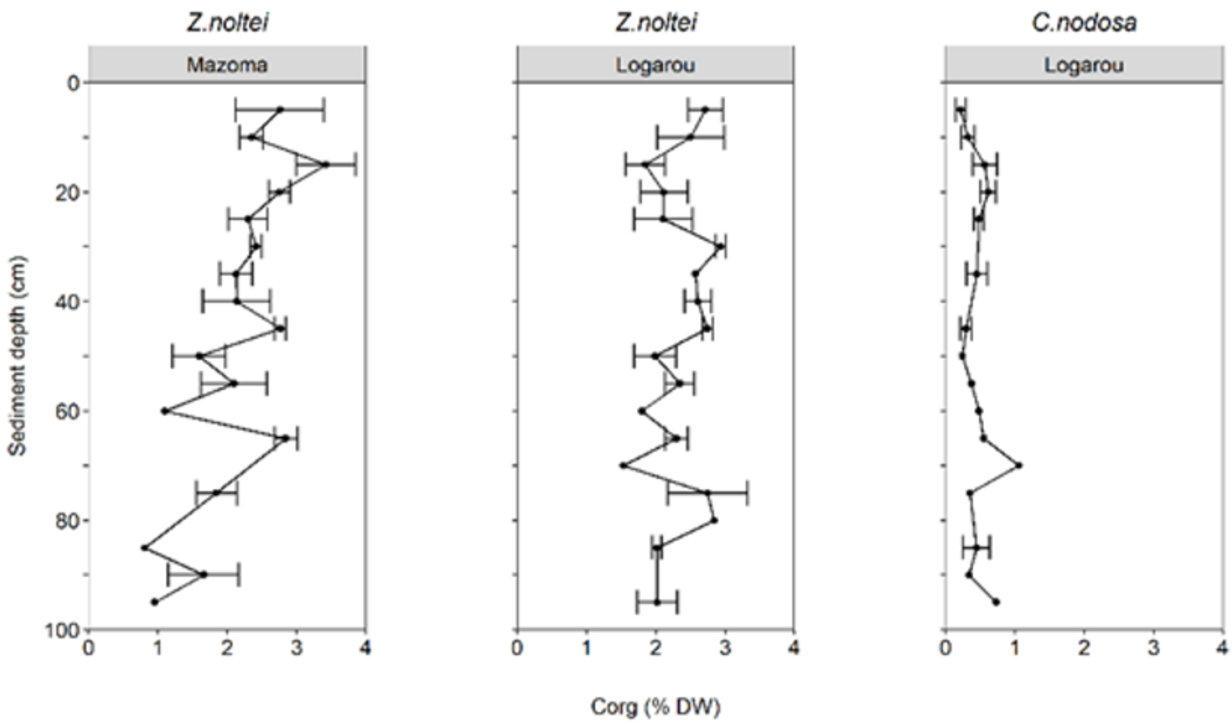


Figure 3. Vertical profile of Corg (%DW) with Standard Errors

At *Zostera noltei* stations Corg increased towards the surface sediment and in Station 1 Corg showed high variability from 100 cm to surface, while Corg seemed to decreased at the *C. nodosa* station (Figure 3). In total, Corg ranged between 0.50 ± 0.06 and 2.35 ± 0.21 % DW, with a mean ± SE of 1.73 ± 0.17 % DW across stations.

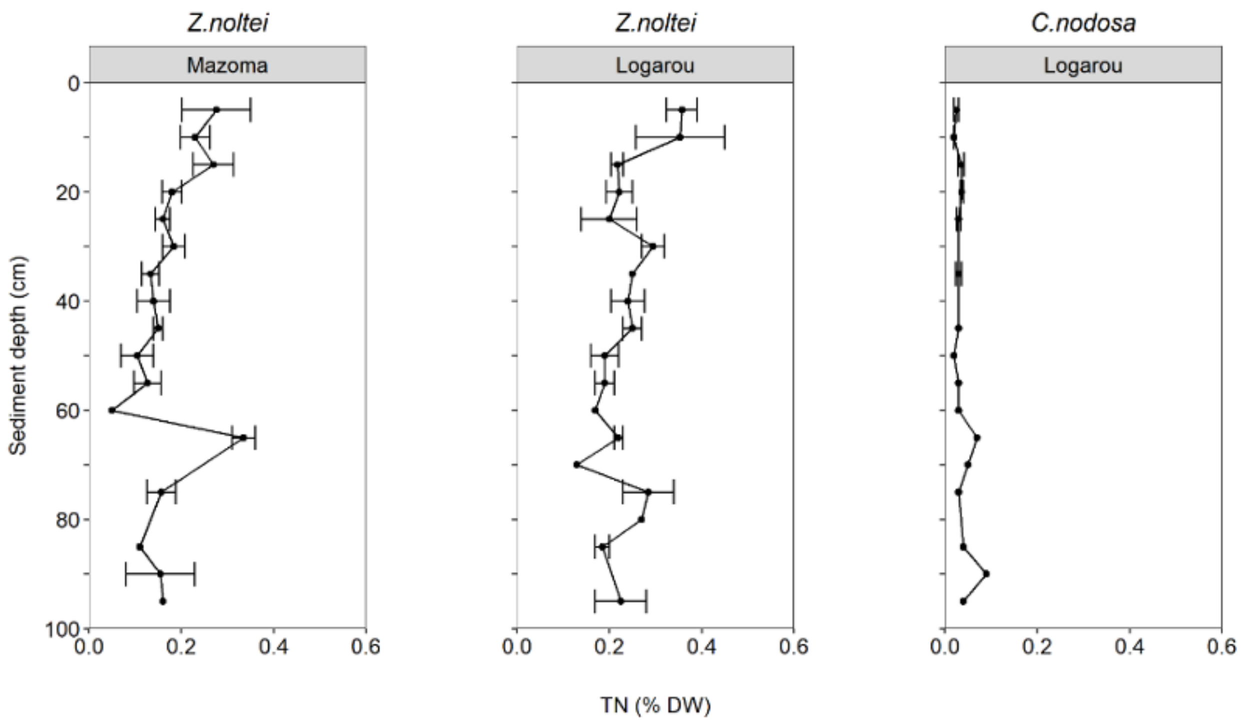


Figure 4. Vertical profile of TN (%DW) with Standard Errors

TN didn't show variability at *C. nodosa*. Nitrogen had a small increase and showed variability towards the sediment surface (Figure 5). The range of TN was between 0.038 ± 0.004 and 0.25 ± 0.03 % DW, with a mean ± SE of 0.16 ± 0.02 % DW across stations.

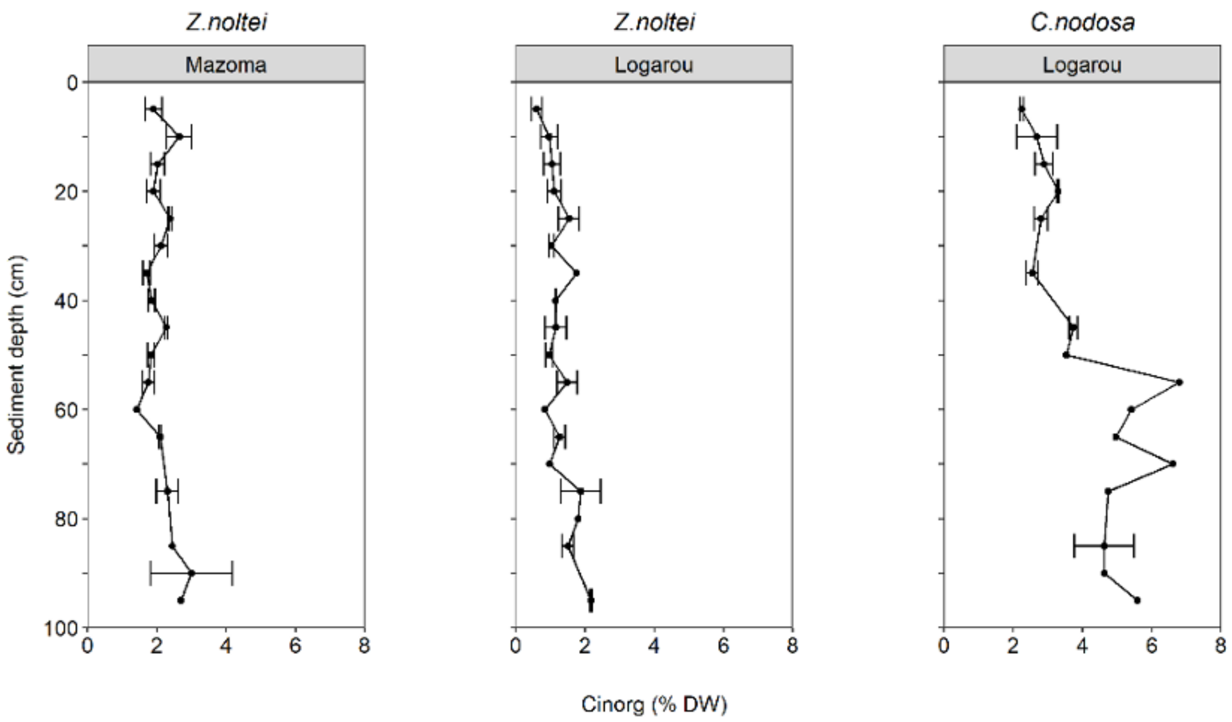


Figure 5. Vertical profile of Cinorg (%DW) with Standard Errors

Cinorg ranged between 1.22 ± 0.12 and 3.57 ± 0.42 % DW, with a mean ± SE of 2.30 ± 0.25 % DW across stations. From 100 cm to surface of the sediment Cinorg decreased at *Z. noltei* stations and *C.nodosa* Station and at the *C. nodosa* station (Figure 6) it showed high variability.

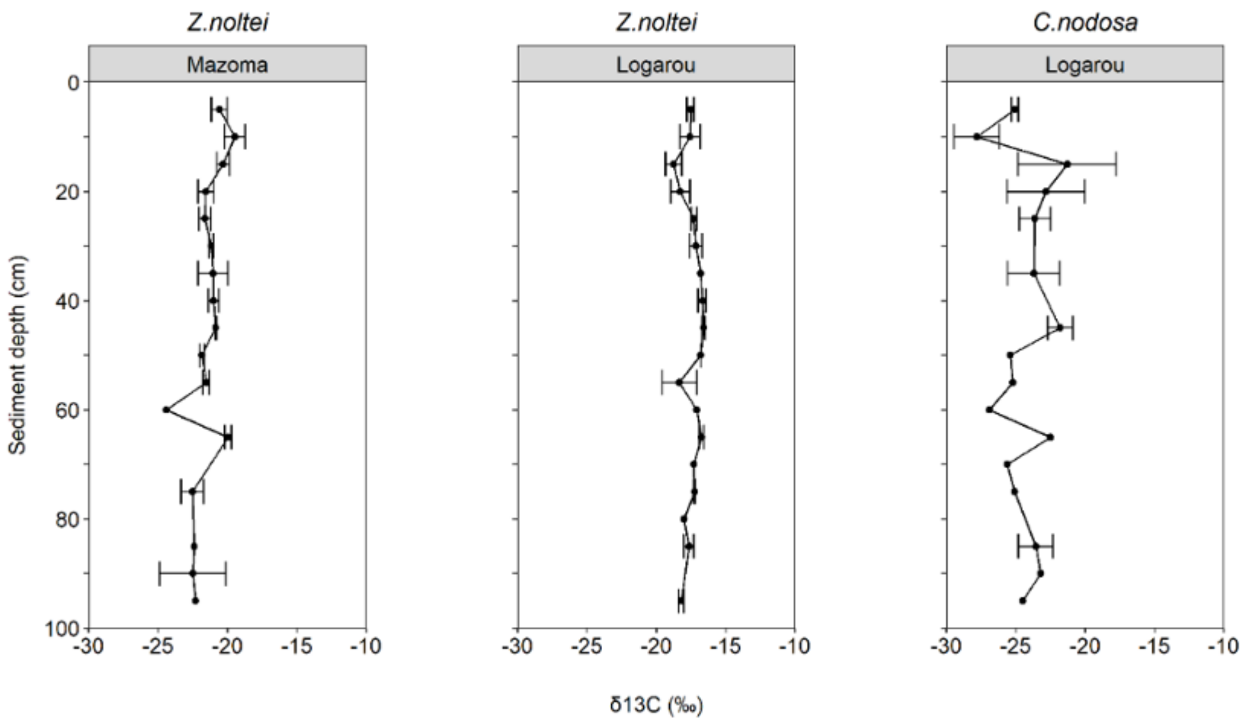


Figure 6. Vertical profile of $\delta^{13}C$ (‰) with Standard Errors

$\delta^{13}C$ ranged between -23.66 ± (-2.79) and -17.58 ± (-1.84) ‰, with a mean ± SE of -20.80 ± (-2.19) ‰ across stations. Until sediment surface $\delta^{13}C$ did not show variability at *Z. noltei* stations, while at the *C. nodosa* station (Figure 7) showed variability but the values from bottom to top didn't have difference.

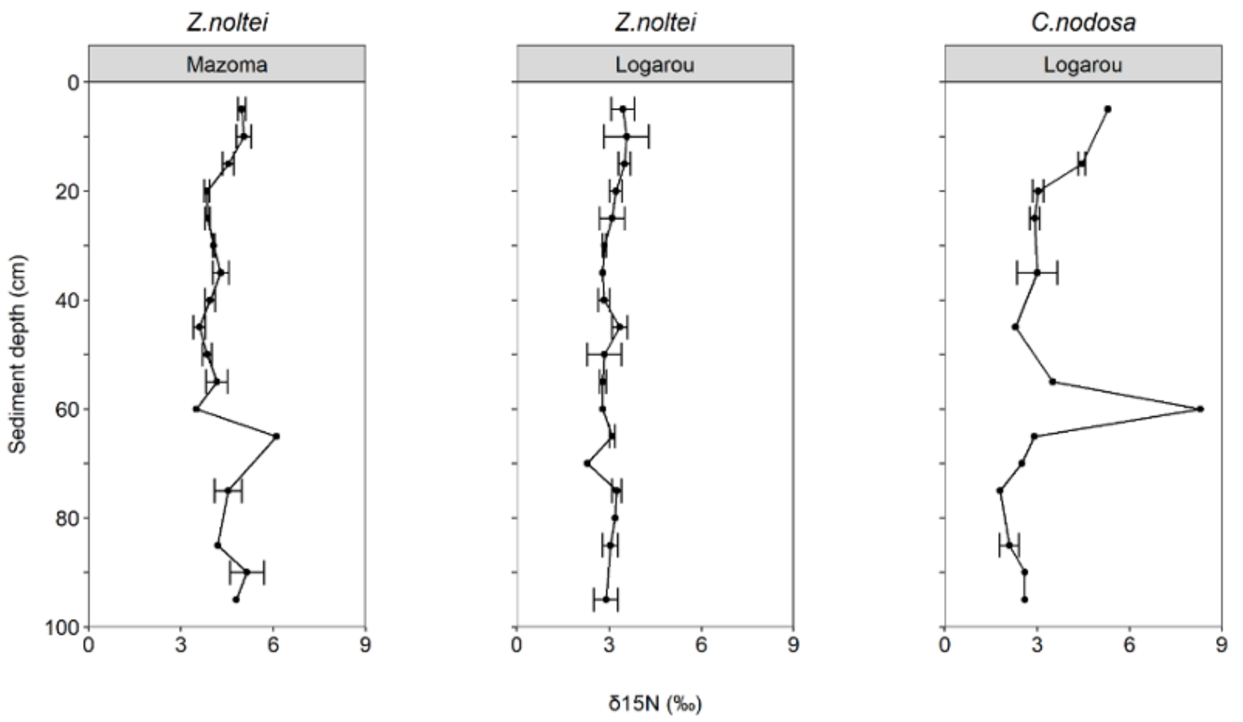


Figure 7. Vertical profile of $\delta^{15}N$ (‰) with Standard Errors

At *Zostera noltei* stations $\delta^{15}N$ didn't show variability towards the surface sediment, while $\delta^{15}N$ seemed increased at the *C. nodosa* station (Figure 8). $\delta^{15}N$ ranged between 3.14 ± 0.32 and 4.41 ± 0.40 ‰, with a mean ± SE of 3.58 ± 0.37 ‰ across stations.

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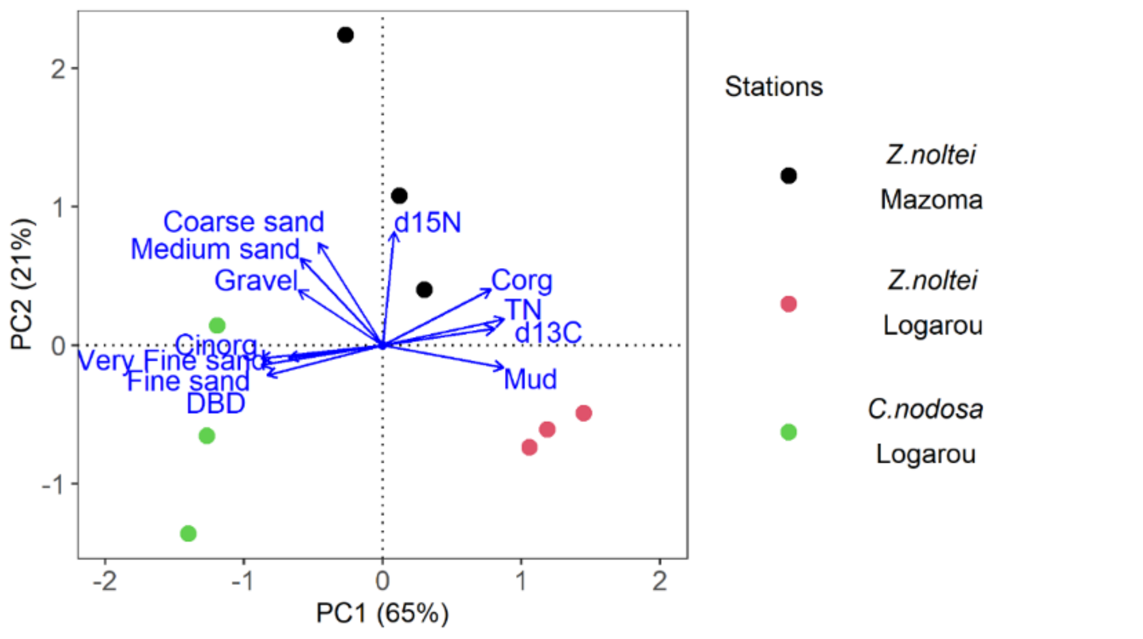

Figure 8. PCA biplot of the vertical profiles of geochemical variables (grain size fractions, DBD, Corg, TN, Cinorg, $\delta^{13}C$, $\delta^{15}N$) for all stations.

Two principal components (PC) explained 86 % of the total variability of the geochemical variables studied. The PC1 axis explained 65% of the total variability, while PC2 accounted for 24% of the total variability. PERMANOVA showed a strong clustering of stations based on their profiles.

Table 1. Results of the PERMANOVA test

	Df	SumOfSqs	R2	F	Pr(>F)
Station	2	77.648	0.80883	12.693	0.005549 **
Residual	6	18.352	0.19117		
Total	8	96.000	1.00000		

C_{org} stock at the top meter of soil ranged from 14.1 ± 2.5 kg m^{-2} to 15.8 ± 3.7 kg m^{-2} at *Z. noltei* stations (Figure 9). C_{org}stock was significantly lower at *C. nodosa* station 6.2 ± 1.3 kg m^{-2}. Values of TN Stocks of *Zostera noltei* stations are higher than these of *Cymodocea nodosa*. TN stocks at top meters ranged from 1.2 ± 0.4 kg m^{-2} to 1.4 ± 0.2 kg m^{-2} at *Z. noltei* stations (Figure 10) and at *C.nodosa* station TN stock had 0.4 ± 0.1 kg m^{-2}.

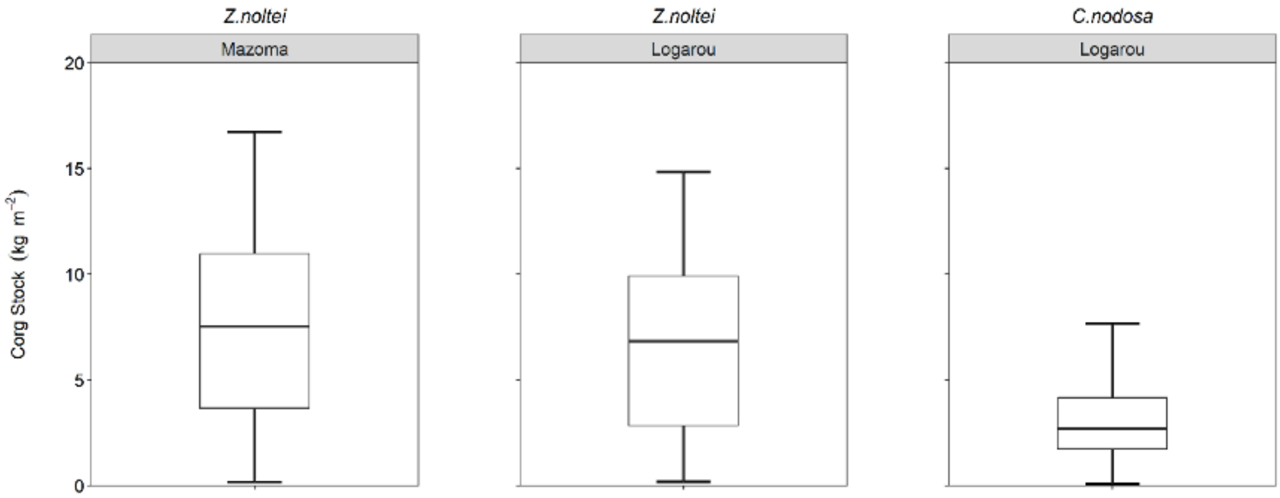

Figure 9. Averages of Corg Stocks 1m between Stations

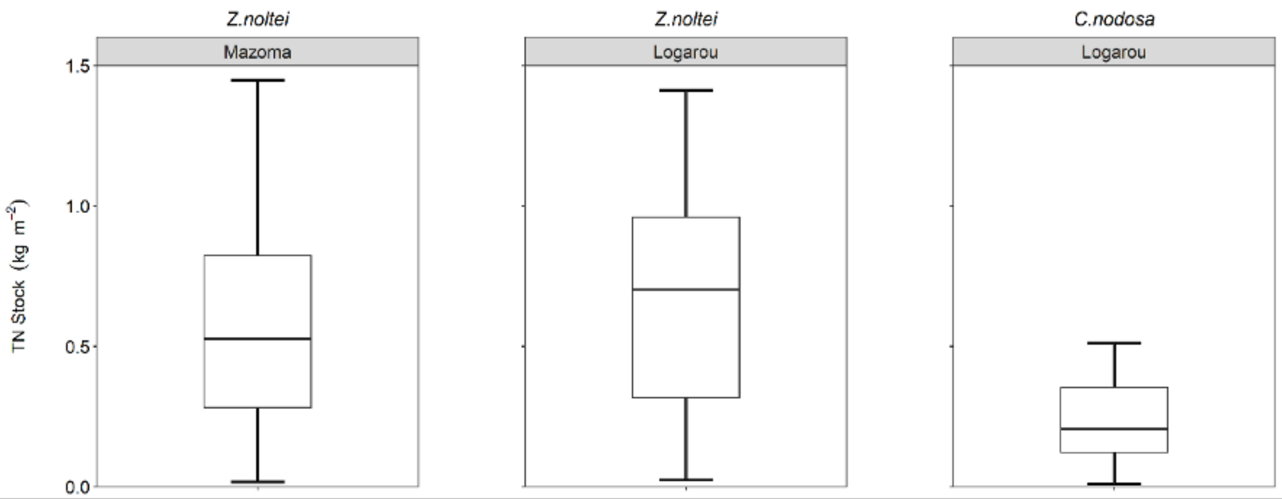

Figure 10. Averages of TN Stocks 1m between Stations

At the top meter of sediment C_{inorg} stock ranged from 8.0 ± 2.4 kg m^{-2} to 15.4 ± 2.8 kg m^{-2} at *Z. noltei* stations (Figure 11). Values of C_{inorg} stock was significantly higher at *C. nodosa* station such as 47.8 ± 5.3 kg m^{-2}.

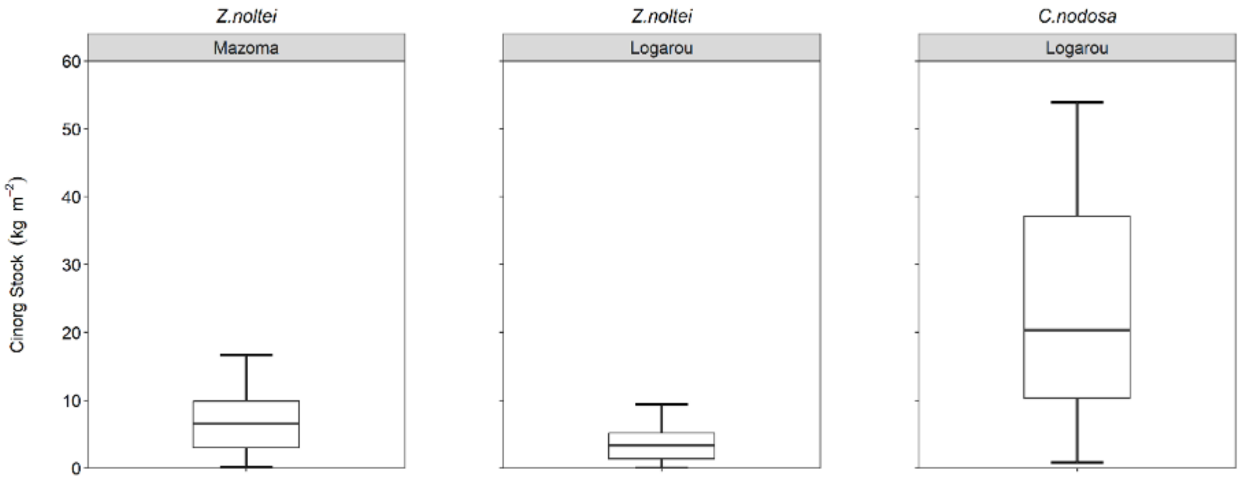

Figure 11. Averages of Cinorg Stocks 1m between Stations

Table 2. 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			

- ## References

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