ACTION A.2: Ex-Ante Monitoring

Sub-action A2.3 Ex-ante Monitoring in Amvrakikos Lagoons, Logarou Lagoon

Beneficiary responsible for implementation: HCMR
Responsibilities in case several beneficiaries are implicated:

Athens 19/11/2021

Status: Final

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Executive Summary

During April 2021, four lagoons of the Amvrakikos lagoon complex were surveyed and data collected were analysed with two main objectives in mind: 1) to establish the current baseline conditions of the lagoons, and 2) to identify similarities (or lack of) between potential seagrass donor sites and transplant recipient sites. Having a clear picture of the current ecological situation is crucial for gauging any future successes of the restoration actions, whilst ensuring the similarities in donor and recipient sites will hopefully increase the viability of seagrass transplantation success. Water column parameters measured in each lagoon included: Depth, visibility, temperature, salinity, conductivity, dissolved oxygen, pH, heavy metals, particulate organic matter, Chlorophyll alpha, nutrients, total nitrogen, total phosphate, and phytoplankton. Sediment parameters included granulometry and total organic carbon content. The main characteristics of benthic communities (i.e., macrobenthos and phytobenthos) were also examined to determine the similarities (and any obvious differences) between extraction and recipient sites.

The ex-ante *in-situ* survey revealed two well established seagrass meadows (*Zostera noltei*) in Mazoma lagoon, indicating its suitability as a donor site. For two of the lagoons (Rodia and Tsoukalio), no well-established seagrass meadows were present, and several stations registered relatively high levels of nutrients, and significantly lower salinity values, than both Mazoma and Logarou lagoons. Although the two lagoons appear ideal for future restoration actions, the absence of any large seagrass meadows and elevated nutrient levels in the water column implies that the outcomes of sod transplantation may not be successful without addressing the local - anthropogenic pressures to the ecosystem.

The physico-chemical parameters measured throughout the Logarou lagoon (e.g. depth, temperature, salinity, and pH) were similar to those observed in the Mazoma lagoon (identified as the potential donor site). Based on analyses of the macrobenthic community, two stations towards the centre of the lagoon were classified as being below the threshold for a “Good” ecological status, highlighting the need for ecological restoration activities in the lagoon. After consideration of the physico-chemical similarities between the potential donor site and Logarou lagoon, five priority habitat restoration areas were identified (Areas I- V) in the lagoon for future actions within the Action A4.4. Executive Project of sod extraction for Amvrakikos Lagoon.

Introduction

The Amvrakikos gulf is the largest and one of the most ecologically valuable wetland areas in Greece, and has thus been the focus of many ecological and socio-ecological studies in the past (See Reizopoulou and Nicolaidou 2004; Kormas, Nicolaidou, and Reizopoulou 2001; Nicolaidou and Karlou 1983; Christia and Papastergiadou 2006 amongst others). The Gulf, the nearby coastal region and some of the largest lagoons with the Amvrakikos Gulf have been included in the national monitoring network of the Water Framework Directive since 2008; however, the current extent and location of seagrass meadows within its lagoonal complex is relatively unknown as records are based on older, sporadic documentation of limited spatial extent.

The ex-ante baseline survey was aimed to address this knowledge gap, provide information regarding the current baseline conditions of the lagoons, and identify possible sites (donor and recipient) for seagrass restoration actions. Having a clear picture of the current ecological situation of benthic communities (i.e., macrobenthos and phytobenthos) before the start of any restoration actions under the framework of the LIFE-TRANSFER project is crucial for gauging any future successes of the restoration actions.

Methodology

Physico-chemical, biotic and sediment parameters were examined at a total of 20 stations across four lagoons (Table 1). Although not all parameters were measured at each station, in each lagoon, at least one site was measured for both benthic parameters (percentage of sediment fine fraction (<63μm), content of organic carbon, total carbon, total nitrogen in sediment, structure of macrozoobenthic community, seagrass presence and composition) and water column parameters (depth, transparency, temperature, salinity, pH, dissolved oxygen, Chl-a, phaeopigments, oxidized nitrogen, dissolved silicates, dissolved inorganic phosphorus, total ammonium, total nitrogen, total phosphorus, total suspended solids).

All relevant metadata, including habitat features, were recorded in field logs on site. Physico-chemical parameters of the water column were measured by an *in-situ* portable multi-parameter instrument (YSI 650/YSI 6-Series Sonde). Samples for phytoplankton biomass (Chl-*a*) and phaeopigments were filtered through Ø47mm filters, whilst samples for the determination of inorganic nutrients and dissolved organic nitrogen and phosphorus were kept deep-frozen (~ -20°C) until their analyses in the certified biogeochemical laboratories of HCMR (ELOT EN ISO/IEC 17025:2005). For sediment parameters, either two or three replicates were taken with an Ekman box corer (sampling surface of 0.025 m^2), depending on the station. Stations Logarou lagoon, identified early on as being a likely recipient site, were assigned a higher priority and three sediment replicates were taken at these sites (LOGA-01,

LOGA-02, LOGA-03, LOGA-04, LOGA-05, LOGA-06, LOGA-07). Sediments were sieved using a metal sieve with a 0.5 mm mesh. Small subsections of the excavated material (i.e. sediment) were collected and frozen in plastic containers at -18°C before being transported to the laboratory to be analysed for sediment granulometry, organic carbon and nitrogen content.

At all sites, indicative maps of the presence and extent of seagrass meadows in each lagoon were created based on ground-truthing data collection via a visual census.

Table 1. Parameters measured at stations. Stations measuring both sediment and water parameters are highlighted in bold

Lagoon	Station	Latitude	Longitude	Sediment parameters	Water column parameters
Mazoma lagoon	**MAZO-03**	**39.0138**	**20.7464**	**YES**	**YES**
Mazoma lagoon	MAZO-01	39.01768	20.74513	NO	YES
Mazoma lagoon	MAZO-02	39.01268	20.75231	NO	YES
Tsoukalio lagoon	**15TW**	**39.06753**	**20.81103**	**YES**	**YES**
Tsoukalio lagoon	TSOU-01	39.05972	20.81408	NO	YES
Tsoukalio lagoon	TSOU-02	39.04522	20.84426	NO	YES
Tsoukalio lagoon	TSOU-03	39.07777	20.80676	NO	YES
Rodia lagoon	**RODI-02**	**39.09173**	**20.81578**	**YES**	**YES**
Logarou lagoon	**LOGA-01**	**39.04167**	**20.89167**	**YES**	**YES**
Logarou lagoon	**LOGA-02**	**39.0625**	**20.90000**	**YES**	**YES**
Logarou lagoon	**LOGA-03**	**39.04583**	**20.90417**	**YES**	**YES**
Logarou lagoon	**LOGA-04**	**39.02917**	**20.92083**	**YES**	**YES**
Logarou lagoon	**LOGA-05**	**39.04167**	**20.92917**	**YES**	**YES**
Logarou lagoon	**LOGA-06**	**39.01667**	**20.92500**	**YES**	**YES**
Logarou lagoon	**LOGA-07**	**39.04166**	**20.91173**	**YES**	**YES**
Logarou lagoon	LOGA-08	39.02885	20.92878	NO	YES
Logarou lagoon	LOGA-10	39.03281	20.92878	NO	YES
Logarou lagoon	LOGA-11	39.03542	20.88895	NO	YES
Logarou lagoon	LOGA-12	39.04932	20.88292	NO	YES

Results

Mazoma lagoon

The in-situ survey identified two areas within the lagoon (one in the northern part of the lagoon, and one close to the sea openings and along the southern coasts) where seagrass meadows extend to more than 500 ha (Figure 1A, B). In general, the lagoon appears well oxygenated (All stations >100 % dissolved oxygen; Table 2), relatively shallow (<1.3 m depth in the centre, Table 2), and the sediment substrate has a high percentage of fine sediments (>70%; Table 3). During the ex-Ante sampling campaign period (Spring 2021) relatively low levels of nutrients (phosphates, nitrates and silicates) were observed in the water column in line with previous studies of Mazoma lagoon in the same season (Vasileiadou et al. 2016). At the time of sampling the salinity throughout the lagoon was around 22 psu, and the temperature of the water column ranged from 17.2 - 18.4 °C. The ecological status of the macrobenthic community was only measured at one station (MAZ-03; Figure 1) where incidentally seagrasses were not found, however despite this, the ecological status of the MAZO-03 station (based on the M-AMBI index) is classed as “Good” with a high percentage of fine fraction sediment (>70%; Table 3). Considering the relatively large extent of seagrass meadows and its good ecological status, Mazoma lagoon appears to be a suitable donor site for the transplantation of *Zostera noltei*.

Figure 1. An indicative map of *Zostera* meadows in relation to stations in Mazoma lagoon. Green polygons depict the extent of *Zostera* meadow, while sampling stations in blue colour indicate where only physico-chemical parameters of the water column were taken.

Table 2. Values of physico-chemical parameters measured in Mazoma lagoon.

Station code	Depth (m)	Transparency (m)	Temp (°C)	Conductivity (µS cm-1)	Salinity	Dissolved Oxygen (%)	Oxygen (mg l-1)	pH	Seagrass	Seagrass species
MAZO-03	1.3	1.3	17.2	35.74	22.61	111.7	9.4	8.61	No	-
MAZO-01	0.5	0.5	18.36	30.5	22	140	12	7.8	Yes	*Z. noltei*
MAZO-02	1	1	18.12	35.58	22.49	155	12.8	8.74	Yes	*Z. noltei*

Table 3. Values of sediment parameters measured in Mazoma lagoon.

	Fine Fraction <63µm (%)	Organic Carbon (%)	Total Carbon (%)	Total Nitrogen (%)	MAMBI
MAZO-03	70.41	3.4805	5.1665	0.546	Good

Table 4. Values of water column parameters measured in Mazoma lagoon.

	Chlorophyll (Chl a) (µg/l)	Phaeopigments (mg/l)	Oxidized nitrogen (NO3 + NO2) (µmol/l)	Dissolved Silicates (SiO4) (µmol/l)	Dissolved inorganic Phosphorus(PO4) (µmol/l)	Total Ammonium (NH4) (µmol/l)	Total Nitrogen (µmol/l)	Total Phosphorus (µmol/l)
MAZO-03	0.78	0.569	1.02	6.87	0.05	1.2	22.3	0.58

Rodia and Tsoukalio lagoons

The two interconnected lagoons Rodia and Tsoukalio showed little evidence of seagrass meadows. The lagoons are typically deeper than Mazoma lagoon (2.7m Rodia Lagoon; Table 5), and *Z. noltei* was found in only three small, sparse, patches surrounded by large areas of bare sediment throughout the two lagoons (Figure 2A, B). In addition, much lower salinities were observed in the two lagoons in comparison to Mazoma lagoon (10.36-14.12 psu) indicating a higher level of freshwater input (Table 3). A similar comparison of lower salinity values in Rodia and Tsoukalio lagoon in comparison to Mazoma and Logarou lagoons was also noted in 2011 (Vasileiadou et al. 2016). The level of nitrates and silicates observed in the water column were much higher than those found in Mazoma lagoon (Table 7), although still are in range of values recorded in previous studies over 20 years ago (Kormas, Nicolaidou, and Reizopoulou 2001). Phosphate levels of Tsoukalio lagoon also appear slightly elevated in regards to Mazoma lagoon (Table 7). Organic carbon and total nitrogen/carbon in the sediments also mirrored this pattern (Table 6). Chl- a levels of the water column are low, similar to those recorded in Mazoma lagoon and in-line with expected values for the sampling season.

Table 5. Values of physico-chemical parameters as measured in Rodia and Tsoukalio lagoons.

Station code	Depth (m)	Transparency (m)	Temp (°C)	Conductivity (µS cm-1)	Salinity	Oxygen (%)	Oxygen (mg l-1)	pH	Seagrass presence	Seagrass species
RODI-02 (Rodia)	2.7	2.5	16.11	17.53	10.36	100.4	9.28	8.24	No	-
TSOU-01 (Tsoukalio)	1.6	1.6	15.73	22.17	13.37	104.1	9.43	8.25	No	-
RODI-01 (Rodia)	0.8	0.8	15.79	22.42	13.56	100	9.09	8.22	Yes	*Z. noltei*
TSOU-02 (Tsoukalio)	0.8	0.8	16.12	23.25	14.12	100	9.04	8.2	Yes	*Z. noltei*
TSOU-03 (Tsoukalio)	1.2	1.2	16.68	17.52	10.37	100	9.16	8.16	Yes	*Z.noltei*

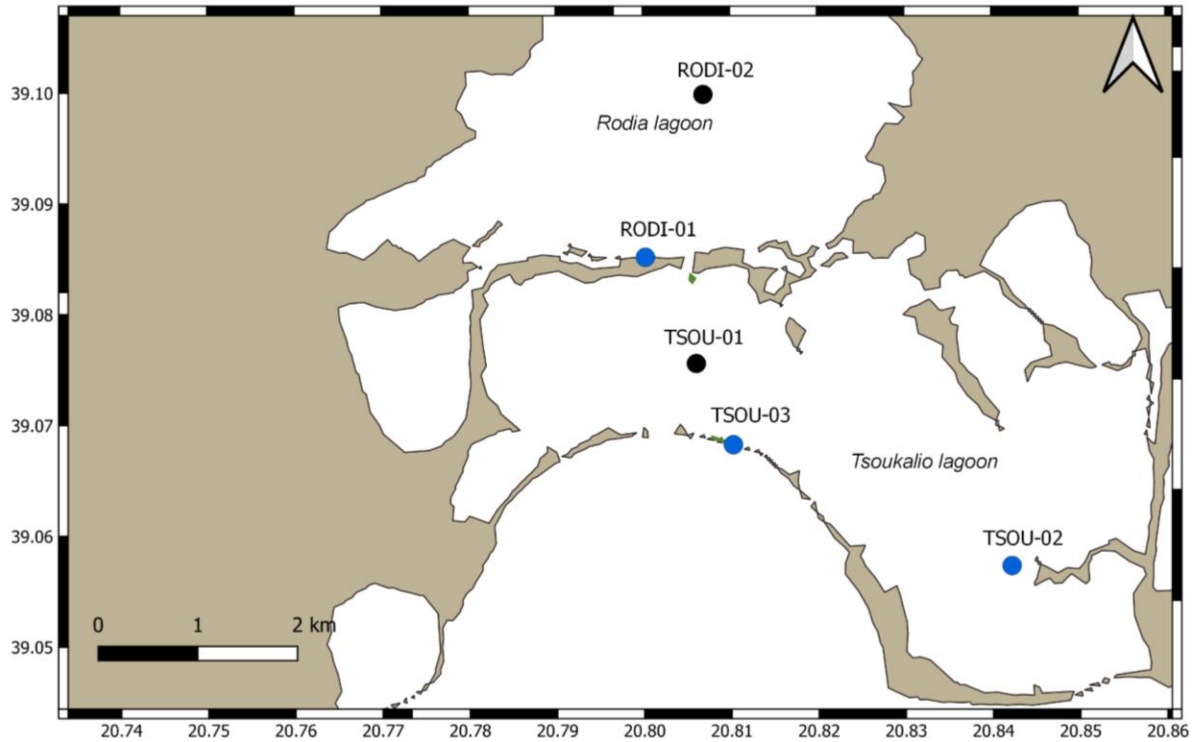

Figure 2. Presence of *Zostera* meadows in relation to stations in Rodia and Tsoukalio lagoons. *Zostera* meadow highlighted by green polygon, blue labels indicate stations where only physico-chemical parameters of the water column were taken (black all parameters).

Table 6. Sediment parameters of Rodia and Tsoukalio lagoons

	Fine Fraction <63µm (%)	Organic Carbon (%)	Total Carbon (%)	Total Nitrogen (%)	MAMBI
RODI-02 (Rodia)	63.36	8.98	10.915	1.088	Good
TSOU-01	91.77	4.838	8.581	0.933	Good

(Tsoukalio)					

Table 7. Water column parameters of Rodia and Tsoukalio lagoons

	Chlorophyll (Chl a) (µg/l)	Phaeopigments (mg/l)	Oxidized nitrogen (NO_3 + NO_2) (µmol/l)	Dissolved Silicates (SiO_4) (µmol/l)	Dissolved inorganic Phosphorus(PO_4) (µmol/l)	Total Ammonium (NH_4) (µmol/l)	Total Nitrogen (µmol/l)	Total Phosphorus (µmol/l)
RODI-02 (Rodia)	0.894	0.821	8.7	32.6	0.14	3.32	51.4	0.63
TSOU-01 (Tsoukalio)	0.633	0.616	7.99	44.8	<0.04	1.86	45.9	0.72

Logarou lagoon

The main focus of the survey was to determine the suitability of Logarou lagoon as a recipient site for transplantation activities. To this end, seven stations were sampled for benthic macrofauna communities to provide a representative view of the lagoonal ecosystem; a further four stations were sampled for physico-chemical parameters and phytobenthos. Several patchy seagrass meadows were found throughout the lagoon and are typically found near openings to the Amvrakikos gulf (Figure 3A, B). *Zostera noltei* meadows, and mixed *Cymodocea nodosa /Zostera noltei* meadows were identified inside the lagoon. At several sites towards the centre and the northern part of the lagoon, macroalgae species (e.g. *Chaetomorpha* sp) were also present (Figure 3). Most physico-chemical values were similar to those recorded in Mazoma lagoon e.g. the salinity ranged from 19.63 - 22.95 (Table 4). Nutrient values were not particularly elevated, and the lagoon was generally well oxygenated (Table 8). The amount of suspended solids was much lower than previously recorded (a range of 25.2 - 110.4 was recorded in Logarou lagoon in 1994 (Kormas, Nicolaidou, and Reizopoulou 2001). Based on the application of the M-AMBI index (Borja *et al.*, 2004; Muxika *et al.*, 2007)) two stations towards the centre of the lagoon (LOGA-01 and LOGA-03) were identified as having a "Moderate" ecological status (Table 10). Following the approach of the European Water Framework Directive, this status indicates that mitigation measures should be taken by member states to restore the status of the water body to "Good" or "High".

Historically the seagrass meadows of Logarou are in decline, and the considerable loss of benthic vegetation in the lagoon has led to a decline of biodiversity and productivity of the ecosystem (Reizopoulou and Nicolaidou 2004; Zoulias, Kapiris, and Reizopoulou 2014). As the meadows identified during the baseline survey are relatively patchy yet cover a relatively wide surface area of the lagoon, it appears Logarou lagoon is a suitable candidate site for restoration activities; however, the results from the macrobenthic community analyses will provide a more detailed and holistic overview of the lagoon ecosystem.

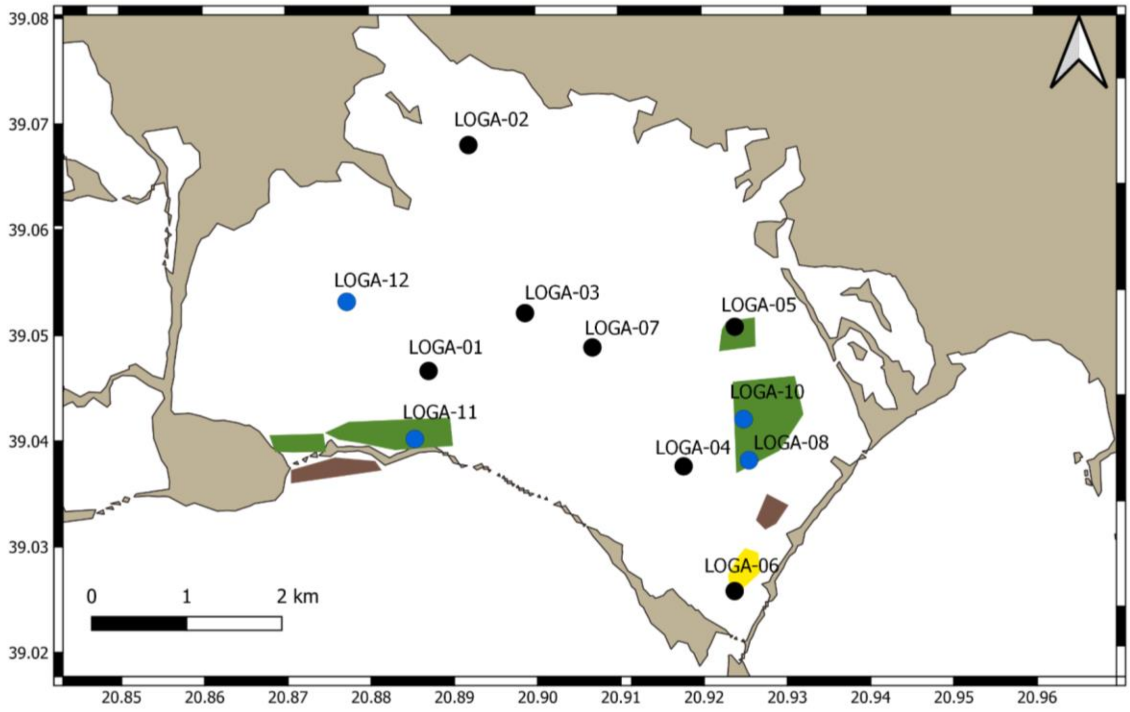

Figure 3. An indicative map of seagrass meadows in relation to stations in the Logarou lagoon. *Zostera* meadows highlighted by green polygons, *Cymodocea* meadows by yellow polygon and mixed meadows by brown. Blue colour indicates stations where only physico-chemical parameters of the water column were taken.

Table 8. Values of physico-chemical parameters and presence of seagrass species in Logarou lagoon.

Station Code	Depth (m)	Transparency (m)	Temp (°C)	Conductivity (μS cm-1)	Salinity	Oxygen (%)	Oxygen (mg_l)	pH	TSS	Seagrass presence	Seagrass species
LOGA-07	0.7	0.7	16.89	32.42	20.29	111.8	9.58	8.45	5.22	Yes	*Z. noltei*
LOGA-01	0.9	0.9	16.76	34.03	21.43	101.9	8.6	8.39	1.09	No	
LOGA-02	0.7	0.7	16.51	33.34	20.94	114.5	9.85	8.69	3.92	No	
LOGA-03	0.8	0.8	16.58	33.43	21	101.5	8.72	8.39	2.3	No	
LOGA-04	0.6	0.6	16.2	32.4	20.26	101.8	8.7	8.42	1.4	No	
LOGA-05	0.5	0.5	17.09	36.24	22.95	111.1	9.36	8.64	1.16	Yes	*Z. noltei*
LOGA-06	0.6	0.6	16.07	32.03	20.03	96.3	8.39	8.52	1.85	Yes	*C. nodosa*
LOGA-08	0.5	0.5	17.13	32.62	20.43	101	8.58	8.72	-	Yes	*Z. noltei*
LOGA-10	0.6	0.6	16.68	31.44	19.63	101.6	8.69	9.00	-	Yes	*Z. noltei*
LOGA-11	0.6	0.6	16.75	34.14	21.5	106.2	9.04	8.58	-	Yes	*Z. noltei*
LOGA-12	1	1	16.2	35.1	22.15	108.1	9.22	8.53	-	No	-

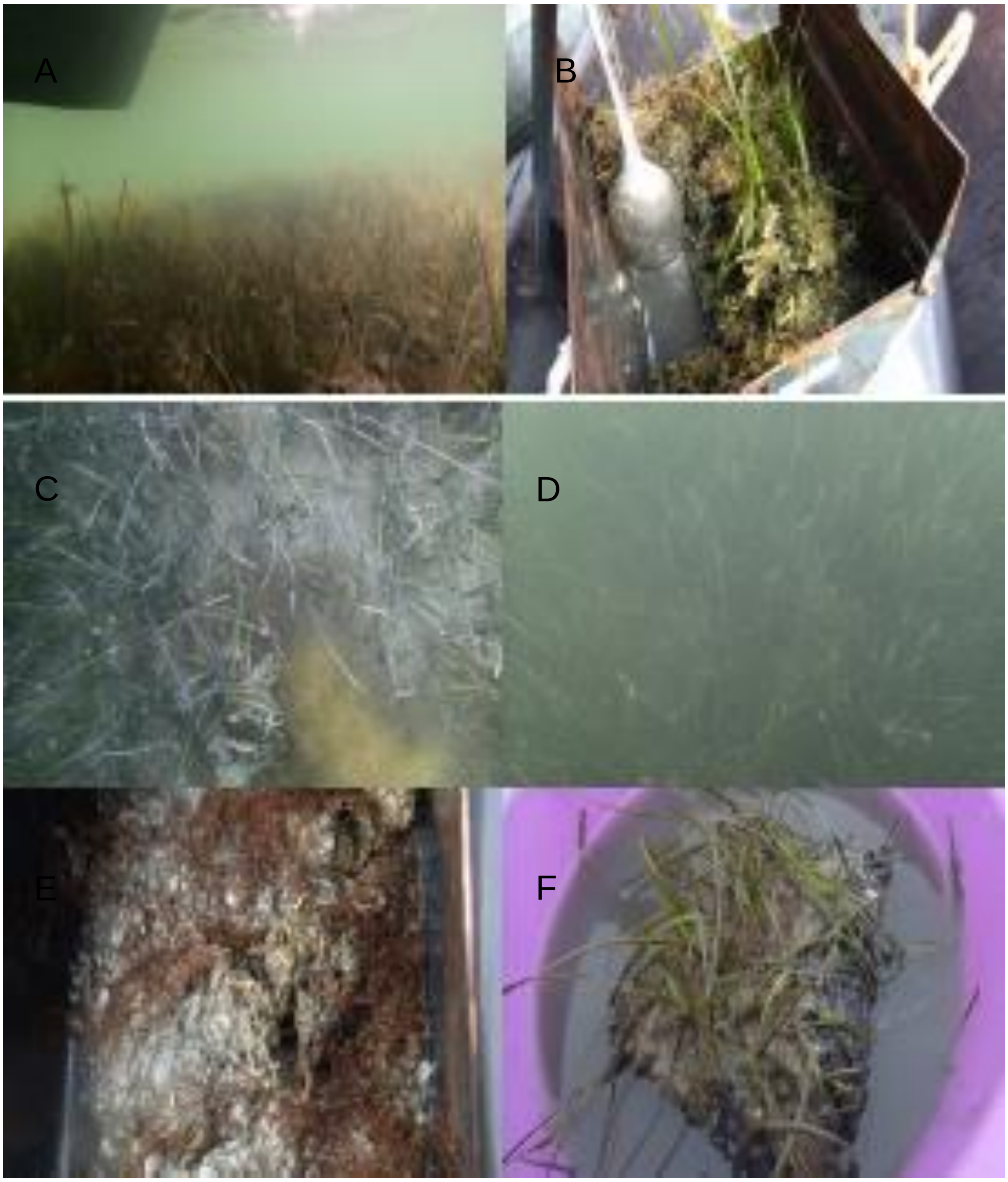

Figure 3. Images from Logarou stations A) Station LOGA-06, B) Station LOGA-05, C) Station LOGA-08, D) Station LOGA-10, E) Station LOGA-03, F) Station LOGA-11.

Table 9. Water column parameters of Logarou lagoon

	Chlorophyll (Chl a) (μg/l)	Phaeopigments (mg/l)	Oxidized nitrogen (NO3 + NO2) (μmol/l)	Dissolved Silicates (SiO4) (μmol/l)	Dissolved inorganic Phosphorus (PO4) (μmol/l)	Total Ammonium (NH4) (μmol/l)	Total Nitrogen (μmol/l)	Total Phosphorus (μmol/l)	Total suspended solids (TSS)
LOGA-01	0.29	0.128	0.74	5.32	<0.04	9.75	39.70	0.50	1.09
LOGA-02	0.57	0.222	1.37	7.96	0.08	3.01	38.60	0.72	3.92
LOGA-03	0.66	0.115	1.30	9.51	0.08	8.92	41.40	0.62	2.3
LOGA-04	0.80	0.312	0.32	3.81	0.05	0.80	33.80	0.63	1.4
LOGA-06	0.55	0.261	0.64	2.96	0.05	1.39	35.20	0.54	1.85
LOGA-05	0.51	0.059	1.00	3.22	<0.04	0.89	17.40	0.41	1.16
LOGA-07	0.327	0.288	3.92	9.04	0.05	12.03	47.6	0.64	5.22

Table 10. Sediment parameters of Loarou lagoon

	Fine fraction <63μm (%)	Organic carbon (%)	Total carbon (%)	Total nitrogen (%)	M-AMBI
LOGA-01	98.94	3.49	3.89	0.59	Moderate
LOGA-02	93.99	4.19	4.90	0.65	Good
LOGA-03	42.55	1.39	7.81	0.23	Moderate
LOGA-04	24.65	1.55	8.41	0.25	Good
LOGA-05	61.27	3.13	3.13	3.13	Good
LOGA-06	86.2	2.98	5.98	0.43	Good

LOGA-07	69.04	2.32	6.54	0.42	High

Conclusions

Based on the results from the ex-ante monitoring campaign, two main conclusions were drawn. The first being that Mazoma lagoon appears a suitable donor site for the sod transplantation methodology and secondly that it was possible to identify five primary areas were identified as the focus for habitat restoration activities in Logarou (Figure 4), based on the results of the physico-chemical analyses of the water column and sediment samples. The areas (I-V) are primarily located in regions with a good level of seawater exchange and relatively low levels of nutrients in an attempt to encourage the successful transplantation of seagrass sods. The first sod transplantations (from Mazoma lagoon to Logarou lagoon) was planned for October 2021 in one of the selected areas, and will continue incrementally in all areas throughout the duration of the LIFE TRANSFER program.

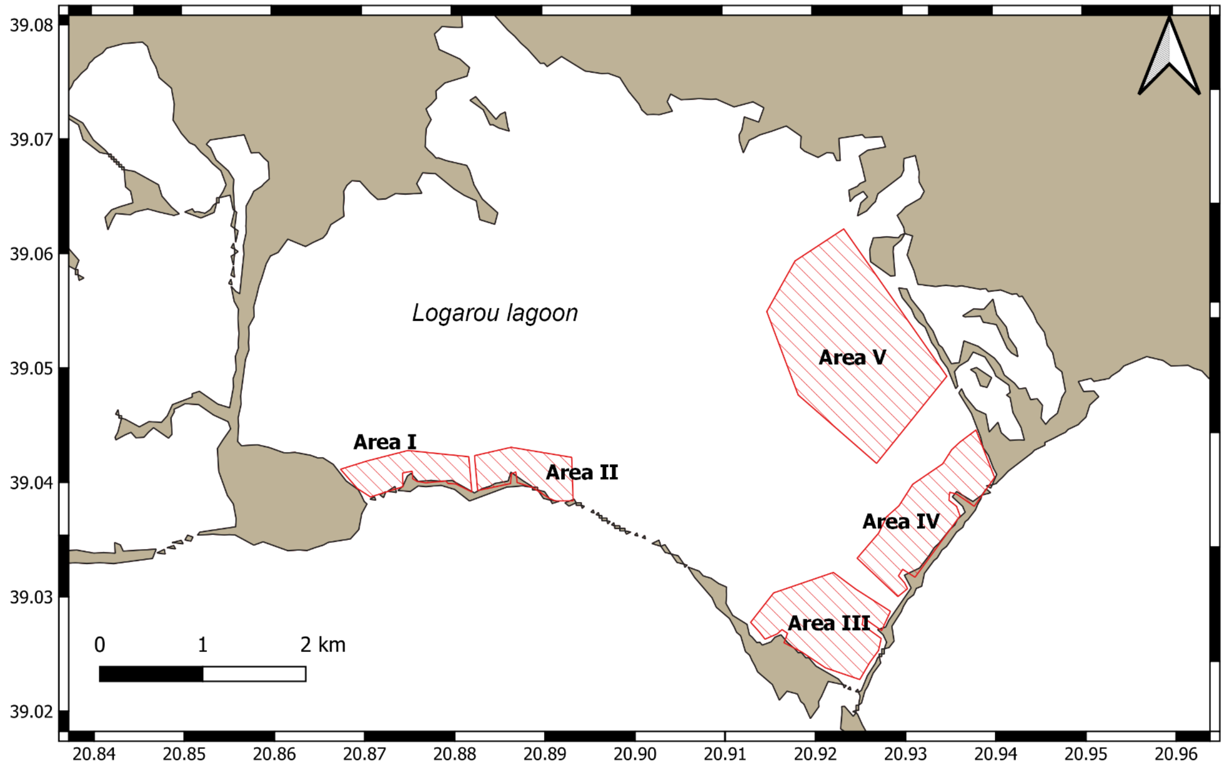

Figure 4. Map of transplant focus areas for future restoration actions

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