COASTAL
Collaborative Land-Sea Integration Platform

Environmental status of the Messinia case study area
Deliverable D33

Final Report

WP2 Knowledge Transition T2.1 - Data and Model Base
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PREFACE

Socio-economic and environmental data are important for understanding the current state of land-sea systems and making policy recommendations evidence-based. Furthermore, field data can be applied to derive regionalized functional relationships between key variables, to be used in supporting models. In particular for the SW Messinia Multi-Actor Lab a need existed for additional field sampling. This document presents in detail the environmental data collected in SW Messinia within the framework of COASTAL project, and the subsequent ecological assessment. New or additional field data are not necessary for all case studies of COASTAL. The case of SW Messinia, which constitutes the Greek rural-coastal interactions multi actor lab-MAL is rather unique, since it has never been studied under that perspective, and ecological assessment of inland streams, transitional waters, and the coastal zone were generally lacking.

The SW Messinia is an area where intense tourism meets monoculture of olives, and olive oil production is one of the highest in Greece both in quality and quantity, whereas other subsidiary economic activities are also present such as fisheries. The future economic development of the specific area, as well as other relatively small coastal areas in Europe with similar characteristics, depends heavily on the quality and sustainability of ecosystem services. It is evident that high-class tourism will not develop in a coastal zone suffering from environmental degradation. Hence, our effort here concentrates in the collection and subsequent analysis of the environmental data required to assess the current status of the area and its sub-regions, together with a long-term estimation of trends for sensitive environmental parameters.

The marine sector is of high environmental quality, it overlooks the Ionian Sea and exhibits continuous growth over the last decades in attracting tourists with high economic status willing to pay high prices at the luxurious hotels lying along the beach. At the same time, the cultivation of olives edible and for olive oil production has expanded rapidly since decades and pushed all other types of crops. Inevitably, fertilizers and pesticides, herbicides use has increased, as well as water consumption for irrigation. Moreover, the extraction of olive oil generates for a few weeks every year thousands of tons of organic, phenol-rich residues that through the stream network flush to the sea. The eminent questions arise: Is the environment healthy enough to continue offering its valuable ecosystem services? Is this combination of economic activities viable in the future? Can we predict how the rural-coast system will behave in next decades? Can we formulate solutions to preserve sustainability or avoid potential threats? The only way to find suitable answers to those questions can be only based on solid scientific analysis of field data which reveal the current condition of the ecosystem and may predict its future evolution.

In this framework we designed a matrix of field studies spanning from 2018 to 2021 to fill the gap of missing information. The work was conducted in all six streams draining the study area, the Gialova lagoon and the coastal zone that acts as the receiving water body of the above. In all cases we capitalized on the expertise of HCMR's scientists by using state-of-the-art techniques for sampling and analysis of environmental data. The assessment of ecological status was based on various indices each one carefully selected to serve the specific purpose. In that manner, results are efficiently and independently evaluated, whereas non-experts (e.g. stakeholders) are informed comprehensively.

Both inland and at sea, physical, chemical, and biological parameters were measured in water and sediments. The former, provide invaluable information on the current status of each parameter examined, whilst the latter give an overall assessment of past years, and future trends. All important and site-relevant pollution types were considered, including nutrient over-enrichment, eutrophication, inorganic and inorganic pollutants, and beach litter. The report follows the same structure for each parameter studied: Introduction, Materials and methods, Results and discussion, and Conclusions in order to facilitate reading and understanding. An overall assessment chapter follows combining all findings, and a data section concludes the report.

With respect to COASTAL's structure and work package interrelations, the present deliverable serves as a science basis to make the System Dynamics Modeling and road maps evidence-based. The deliverable evolved during the duration of the project with the progress of the field sampling. After the first two years of sampling initial results were used to feed the models, whereas in the following two years the results were re-evaluated, conclusions became more robust, and thus used to validate the existing and new models. Finally, all field data sampled in the COASTAL project will be made available through the COASTAL community on the Zenodo open data repository[1].

[1] https://zenodo.org/communities/773782-coastal/

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1. Geological & Environmental Setting of the study area

THEODORE D. KANELLOPOULOS

The study area is located in the south-western part of Peloponnese (Fig. 1.1) and belongs to the Gavrovo geotectonic zone. The northern coasts are composed of Holocene alluvial deposits, mainly clayey and marly sediments, and sand dunes, while the southern coasts consist of Plio–Pleistocene deposits of conglomerates, marls and fine-grained sandstones, and Eocene-Oligocene flysch, with clayey, marly and sandy beds. The basement of the catchment area consists of Upper Cretaceous to Eocene limestone (Varnavas et al., 1987; Avramidis et al., 2015).

Figure 1.1 Left: Greece (A) and location of the study area (B); right: SW Messinia.

A number of streams, namely Arapi Poros, Selas, Xerolagado, Vayioremma, Gianouzagas and Xerias, flow into the area (Fig. 1.2).

While the environmental status of the marine part of SW Messinia is not studied sufficiently, the reverse is true for the Gialova Lagoon (Fig. 1.2).

The Gialova Lagoon is located in the northern coast of Navarino Bay. It is a part of an active tectonic depression, which consists of the Navarino embayment and the Gianouzagas alluvial plain (Katrantsiotis et al., 2018), while it was isolated from the sea at ca 3300 cal. BP (Emmanouilidis et al., 2018). It is a shallow lagoon with maximum and mean depths of 1 m and 0.5 m, respectively, while its surface area is ca 2.5 km2 and its average volume 2 million m3. It is one of the most important ecological areas in Greece and it is listed in the Natura 2000 European Community Network as a Special Protected Area and Site of Community Importance. Various reclamation and canalization works in the area's streams since the 1950s, accompanied by the construction of artificial inlets and levees, resulted to significant reduction of the lagoon area and consequent initiation of several oxygen depletion and dystrophic events (Koutsoubas et al., 2000). Moreover, in October 1993, the lagoon ecosystem suffered from an oil spill from the Greek tanker "ILIAD" in the adjacent Navarino Bay, which however had a short-term reversible impact. On 1998, two canals were opened in the lagoon in order to bring fresh water from the Gianouzagas and Xerolagado streams, with uncertain consequences for the composition of the macrobenthic communities of the lagoon. The lagoon is characterized as hypereutrophic during summer and as eutrophic during spring in terms of phosphate, whereas ammonium concentrations display high values throughout the year (Papakonstantinou, 2015).

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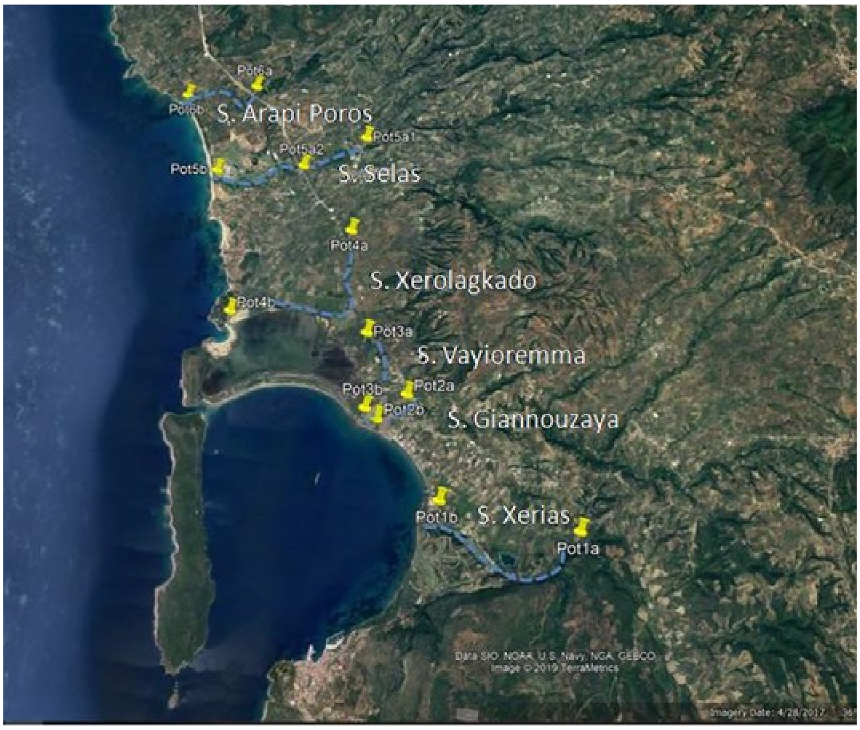

Figure 1.2 Place names and streams of the study area.

To the west, a belt of sand dunes separates the Gialova Lagoon from the adjacent semi-circular Voidokilia Bay and the Ionian Sea. All this area, from the coastal sand dunes of Voidokilia, to the north of the Costa Navarino resort, including the Sfaktiria Island, is also part of the wider Natura 2000 site (Maneas et al., 2019).

The pollution sources of the area include domestic sewage from the town of Pylos and small villages across the northern coasts, while industrial effluents are of minor importance. However, a major environmental concern is for the effluents of the oil mills. Messinia is one of the major olive oil centers of Greece, and the district of Pylia (the study area) has, according to Chatjipavlidis et al. (1996), the higher volume of olive oil mills wastewater of the other ones (Messini, Kalamata, Mani). This waste is claimed to be one of the most polluting effluents among those produced by the agrofood industries, owing to its contents (14-15%) of organic substances and phenols (Ranalli et al., 2003). The latter are characterized by high specific COD (chemical oxygen demand). The olive oil extraction process in the area starts around the end of October and is completed by the end of January or the middle of February. Fig. 1.3 shows the inland water sampling stations, Fig. 1.4 shows the sampling stations in the Gialova Lagoon, and Figs. 1.5 & 1.6 show the marine sampling stations

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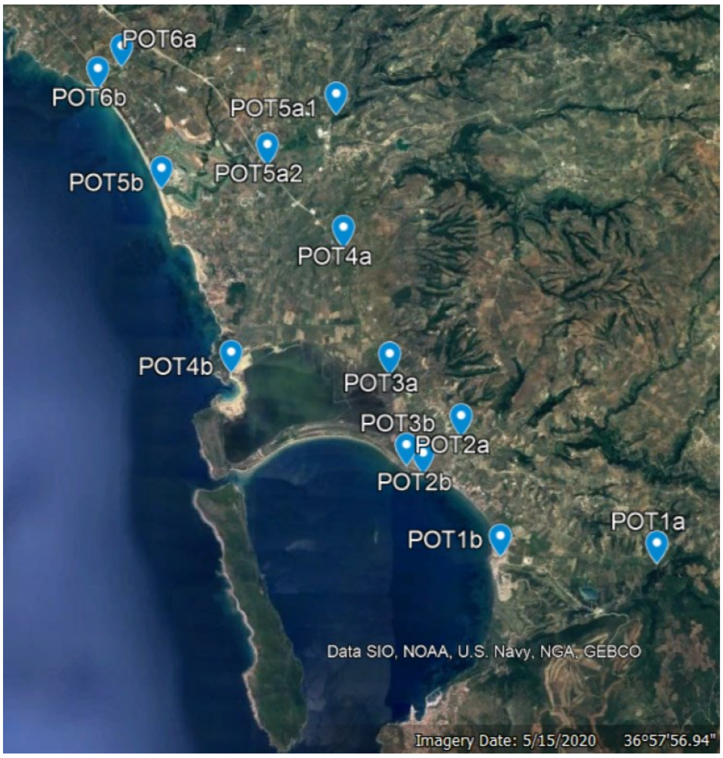

Figure 1.3 Inland water sampling stations,

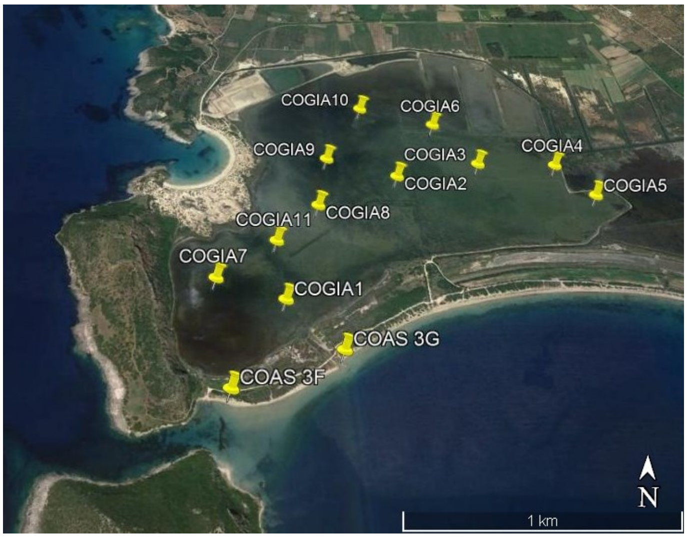

Figure 1.4 Sampling stations in the Gialova Lagoon.

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Figure 1.5 Transects of marine sampling stations (North).

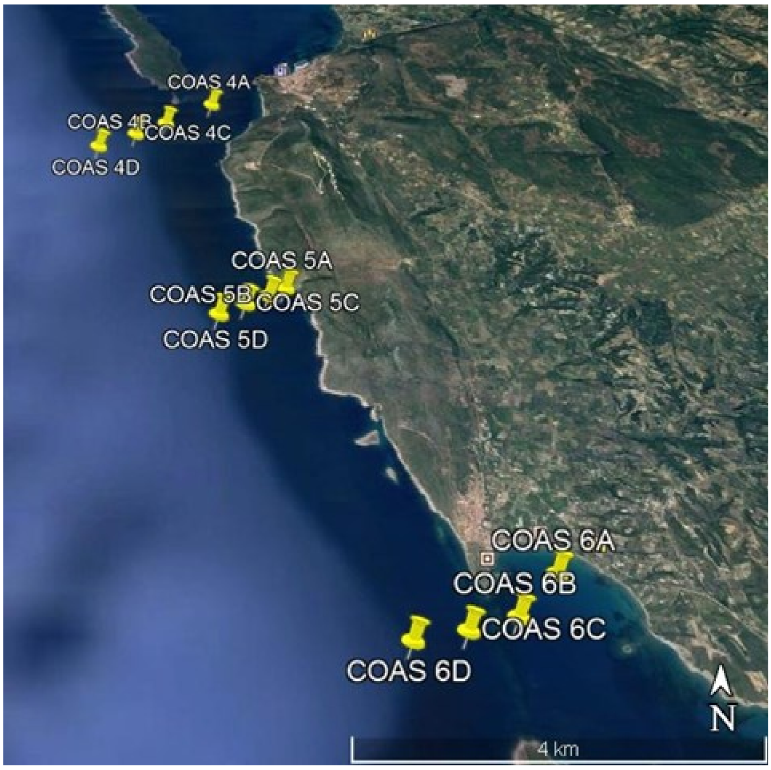

Figure 1.6 Transects of marine sampling stations (South).

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2. Water quality assessment in six streams at SW Messinia, based on benthic macroinvertebrates, diatoms and physicochemical parameters

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2.1. Introduction

In the framework of the COASTAL project the Institute of Marine Biological Resources and Inland Waters (IMBRIW) of HCMR studied and evaluated the water quality of six small rivers flowing into Navarino Bay (SW Messinia, Greece) to better understand the environmental status of the surrounding marine area. This kind of evaluation follows the European Water Framework Directive 2000/60/EU, which includes biotic and environmental characteristics, with emphasis on the Biological Quality Elements.

In the framework of COASTAL project, benthic macroinvertebrates and diatoms were used among these elements, combined with the principal physicochemical parameters during four sampling periods.

Figure 2.1 Inland water quality sites at the rivers of West Messinia (six outlets to the sea and six respective upstream sites).

2.2. Study area

The study area is located at West Messinia, where a network of 13 sampling sites was created (Fig. 2.1; Table 2.1).

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Table 2.1. The sampling sites of the study area.

Sampling sites	Streams
Pot1a	S. Xerias
Pot1b	S. Xerias
Pot2a	S. Giannouzaya
Pot2b	S. Giannouzaya
Pot3a	S. Vayioremma
Pot3b	S. Vayioremma
Pot4a	S. Xerolagkado
Pot4b	S. Xerolagkado
Pot5a1	S. Selas
Pot5a2	S. Selas
Pot5b	S. Selas
Pot6a	S. Arapi Poros
Pot6b	S. Arapi Poros

According to Water Framework Directive, all these sites represent calcareous, low altitude and not steep-sloped streams.

Stream Xerias

Site Pot1a is located near stream springs. It is a slight slope site of temporary flow, which hosts a rich macroinvertebrate habitat. Olive trees are dominant in the area, and there is a limited disposal of rubbish and household appliances, upstream of the site.

In the area where site Pot1b is located, there are agricultural cultivations and small enterprises, as well as significant presence of reeds (Arundo donax). The bed material is generally fine-grained, there is no slope and the water flow is permanent throughout the year.

Stream Giannouzagas

Site Pot2a is a coarse grain, slight slope site. The main land uses are orchard, olive and horticultural cultivations. There was water during all sampling periods, with an impressively increased quantity during the summer period. The second site (Pot2b) of the same stream is located near the estuary. It is a fine-grained poor site regarding the presence of benthic macroinvertebrates, with an extended presence of reeds (Arundo donax).

Stream Vayioremma

Pot3a is a modified site of stream Vayioremma. It has been aligned, with gates communicating with other channels when needed. It is a soft substrate ecosystem of almost zero slope and rich vegetation covering of Typha sp. and Phragmites australis, as well as an extended presence of filamentous algae. In the wider area, there are a few monocultures, while a large part of the canal extends along the Gialova Lagoon. This type of ecosystem continues along Pot3b site which is located further downstream, a few meters before the sea. Both sites had water during both sampling periods.

Stream Xerolagkado

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Pot4a, is a temporary flow, fine-grained, slight slope site, with small discharge values when there is water. Olive cultivations are dominant in the area. Site Pot4b downstream, is a fine-grained, zero slope site, which is located on a modified part of the stream. Regarding vegetation type, Juncus sp. is dominant on its banks. The discharge is so little, that the water barely reaches the sea.

Stream Selas

There are three sites along this stream of permanent flow. Pot5a1, is a coarse grain, small slope site, which presents great discharge fluxes from November until spring. Olive cultivations are dominant in the area. Site Pot5a2 also has a coarse grain bed material and there is a great presence of Arundo donax species on its banks. Finally, Pot5b is a fine-grained (95% sand), minimum slope site. It is located near the sea and regarding benthic macroinvertebrates, it is characterized as poor.

Stream Arapi Poros

Pot6a is a dry site. Water is present only after intense rainfall. As in the case of the majority of the sites, olive cultivations are also dominant here. Since it is a site of an extremely difficult access, the only sample was collected further downstream. Site Pot6b is near the sea. It has zero slope and a fine-grained bed material. Vegetation presents the same pattern, with Arundo donax species growing on its banks and some monocultures and olive cultivations in the wider area.

2.3. Land uses and pressures

Spain, Italy and Greece are the three biggest olive-oil production countries globally, with an annual average of 2.8 million tons of olive oil, which accounts for the 75% of the world production.

Other countries with significant olive-oil production are also Portugal, Tunisia, Morocco, Algeria, Turkey as well as countries in the Middle East and Australia (Doula et al., 2012). In Greece, olive-oil production is characterized as the main agro-industrial activity with the highest olive-oil production taking place in Messinia Prefecture. Olive cultivation covers an area of 604 thousand hectares out of a total of 847 thousand hectares of arable land (Agricultural Census, 2009). There are 230 (101 biphasic and 129 three-phase) olive press plants in the Prefecture of Messinia that produce olive oil, five more which produce olive oil and pomace (Foteinopoulos & Darakas, 2018) and 70 packaging standardization plants (https://www.agro24.gr).

These two types of olive presses are also operating in Messinia: the three-phase type, which uses older and more conventional technology, and the two-phase, which is based on more recent and modern technologies. The first type produces large amounts of waste, while in the case of the second, the production of waste is extremely limited. The pomace produced from both types, is further processed in other olive oil and pomace processing plants. The corresponding production is 20,000 tons of olive oil, 100,000 tones pomace and 12,000 tons of two-phase waste and 30,000 tons of olive oil, 75,000 tons of pomace and 150,000 tons of three-phase waste (NCSR "Demokritos", 2016; Foteinopoulos & Darakas, 2018). This significant amount of liquid and solid waste is disposed in river ecosystems, rainwater drainage, soil and sea. Exhaust tanks are an additional source of pollution because they usually do not meet some operation standards resulting in the possibility of soil and groundwater contamination (Doula et al, 2009). They are also responsible for the creation of severe odour, since they don't function well in areas with high humidity, precipitation or rainfall during the summer months. Therefore, this method is more appropriate for distant areas, away from urban or tourist activities, as long as they meet all environmental standards (Lazaridou, 2014).

The olive-oil production wastes that are disposed on riverine ecosystems are dark in color with high organic load, increased polyphenols and solids, and a relatively high (acidic) pH. It is worth noting that the pollutant load generated by the processing of one tone of olives is equivalent to 50 to 100 inhabitants. Thus, they have serious impacts on aquatic ecosystems, they are toxic for aquatic organisms (Danellakis et al, 2011), and they are responsible for strong antimicrobial activity against certain microbial species (Niaounakis & Halvadakis, 2006). In general, olive oil production waste contains 80-96% water, 3.5-15% organic matter and 0.5-2%

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inorganic salts. Its organic part contains sugars, polyphenols, polyalcohols, pectins, lipids, nitrogenous compounds, organic acids, carotenoids and almost all water-soluble components of the olive oil, while the inorganic fraction contains chlorides, sulfates and phosphates, potassium, calcium, iron, magnesium, sodium, copper and other elements in lower concentrations and in various forms (Doula et al, 2012). In small quantities they can have soil-enhancing effects (Mekki et al, 2009), but in larger quantities, they undoubtedly cause serious alterations in the natural environment.

2.4. Materials & Methods

Samplings and measurements were collected in seven periods, including macro-invertebrate fauna, physicochemical parameters and diatoms. The first one took place in October 2018, the second one in December 2018, the third in April 2019, the fourth in August 2019, the fifth in November - December 2019, the sixth in December 2020 and the last one in December 2021. The last campaign was emerged as it was deemed necessary to further investigate the effects of the olive oil mills. It should be noted that some extra water samples were taken for chemical analysis. Specifically, the periods January 2018, April 2018, June 2018, May 2019 and June 2019.

Benthic Macroinvertebrates

Following all the WFD requirements, samples of benthic macroinvertebrates were collected from 13 sites (Table 2.1). The "AQEM" methodology (AQEM Consortium, 2002; Buffagni et al, 2001; Hering et al, 2003) was used in the framework of this Project. It is a methodology for the collection of benthic macroinvertebrates, specially designed for the monitoring programs under the WFD (2000/60/EU). The selection of sampling stations is the first thing included, taking into consideration a variety of criteria (Barbour & Yoder, 2000).

Besides the collection of benthic and water samples as well as the measurements of basic physicochemical parameters, some other features related to the morphology and composition of habitats, hydrology, riparian vegetation, flow types, artificial interventions, the presence of point or non-point point sources of pollution etc., were also recorded as they are essential for the identification of the ecological profile of the sampling station (AQEM Consortium, 2002; Barbour, & Yoder, 2000; Cairns, 1995; Barbour et al, 1999). All these parameters that fully describe the site and provide information on both the sampling procedure and the collected samples are recorded in a specific field protocol.

Benthic macroinvertebrate data, as well as data from the field protocol were recorded in the AQEMdip 2.6 database (www.eu-star.at). This database was created through the European Programs AQEM and STAR, which were undertaken by the Institute of Marine Biological Resources and Inland Waters of HCMR, and it consists a handy tool for the storage of biotic and abiotic data. Subsequently, the data was introduced into ASTERICS assessment software (http:// www.aqem.de/), for the calculation of biotic indicators and metrics.

Diatoms

Diatom sampling and sample preparation was based on European standards (European Committee for Standardization 2003, 2004). Samples were collected from stones (wherever possible) or plants from a lit area away from the river shore, and were preserved with 70% ethanol. In the lab, samples were treated with hot hydrogen peroxide to remove organic matter and obtain clean frustules, used for diatom species identification (Battarbee, 1986). Clean frustules were mounted with Naphrax©. 400 frustules per sample were identified to species level with a light microscope, at 1000X magnification. For the taxonomy, the work of Cantonati et al., (2017) was mainly used. Diatom ecological quality indices were calculated with the OMNIDIA software, version 5.3 (Lecointe et al., 1993; http://clci.club.fr/index.htm).

Chemical - Physicochemical Parameters

During field samplings water physicochemical parameters (pH, electrical conductivity, dissolved oxygen, temperature, salinity and turbidity) is measured in situ with a portable multi-parameter probe Horiba U-50

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Multiparameter Water Quality Checker. Prior to the measurement campaign the probe is calibrated according to the standards provided by the respective constructor.

For the physicochemical classification in five (5) quality categories based on nutrients and dissolved oxygen, the below systems are used. The Greek Classification System for the classification of the sites based on nutrients (Skoulikidis et al. 2006) and the Norwegian classification system for the classification of the sites based on oxygen (Cardoso et al., 2001), (Tables 2.2 & 2.3).

Table 2.2. Nutrients quality classes base on Skoulikidis et al. (2006)

		High	Good	Moderate	Poor	Bad
N-NO_3^-	mg/l	< 0.22	0.22-0.60	0.61 -1.3	1.31-1.80	> 1.80
N-NH_4^+	mg/l	< 0.024	0.024-0.060	0.061-0.20	0.21-0.50	>0.50
N-NO_2^-	μg/l	< 3	3–8	8.1–30	31-70	> 70
P-PO_4^{3-}	μg/l	<70	70-105	106-165	166-340	> 340
TP	μg/l	<125	125-165	166-220	221-405	> 405

Table 2.3. Dissolved oxygen quality classes based on Norway classification system (Cardoso et al., 2001)

	High	Good	Moderate	Poor	Bad
Dissolved oxygen (mg/l)	> 9	9–6.4	6.4-4	4-2	< 2

HYDROLOGICAL STATUS

Flow and wetted cross-section measurements were carried out using a flow probe (FP111 Global Water Flow Probe, Global Water, College Station, Texas, USA). The wetted cross-section was divided to subsections based on the width of each examined stream. The area and the flow of every subsection were measured and then the two measurements were multiplied in order to estimate the discharge of the corresponding subsection. To find the mean discharge of each examined stream site we used the summed up the discharges of each subsection.

2.5. Results & Discussion

CHEMICAL - PHYSICOCHEMICAL PARAMETERS

Conductivity and salinity were quite high (Fig. 2.2).especially in the downstream sites, which are located near the estuary and can be considered as transitional water bodies. PH values ranged from 7 to 8.8 for all sites and periods. Exceptions were the pH values of four sampling sites (POT3a, POT4b and POT5a1) in autumn of 2018, which were very low. DO values were high for the most upstream sampling sites (POT1a, POT2a, POT4a, POT5a1, POT6a) in all periods except those located near to olive mills and receiving their waste (POT3a, POT5a2). In addition, the downstream sampling sites (POT1b, POT2b, POT3b, POT4b, POT5b, POT6b) presented high DO values in all periods apart from autumn 2018 and winter 2020. The extremely high values of the turbidity in winter 2021 were due to rain that had proceeded.

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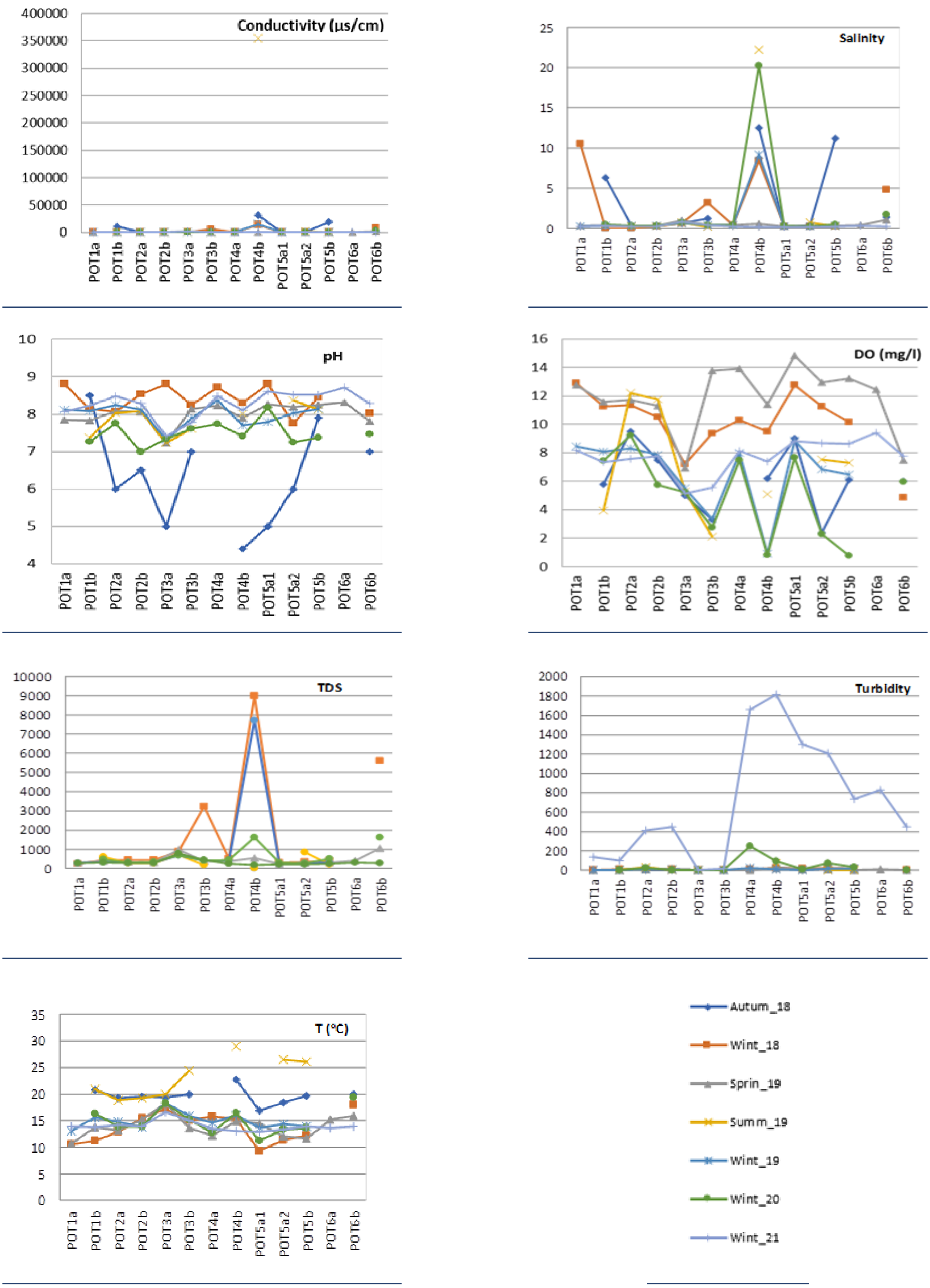

Figure 2.2. Physicochemical parameters per sampling site and per sampling period.

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Regarding the chemical - physicochemical quality, 12 field campaigns took place from 2018 to 2021 and the quality was ranged from HIGH to MODERATE (Table 2.4). All the periods, at the least 83% of the sites had not lower than GOOD chemical – physicochemical quality. For example, in January 2018, the majority (75%) of the river sites had GOOD chemical- physicochemical status. Only, the sites Pot1b and POT2b had HIGH and MODERATE quality, respectively. The same percentage of sites with GOOD quality, has occurred in October 2018. In March 2019, all the sites had GOOD quality. In addition, in all periods apart from four (January 2018, June 2018, October 2018 and December 2020) the 100% of the sampling sites had GOOD and HIGH quality.

Table 2.4. Chemical – physicochemical status per sampling site and per sampling period.

River Site	Jan-18	April 18	June 18	Oct-18	Dec-18	Mar-19	May-19	Jun-19	Aug-19	Dec-19	Dec-20	Dec-21
POT 1a					HIGH	GOOD				HIGH	GOOD	HIGH
POT 1b	HIGH	GOOD	GOOD	GOOD	HIGH	GOOD	HIGH	GOOD	GOOD	HIGH	GOOD	GOOD
POT 2a				GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD
POT 2b	MODERATE	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD
POT 3a	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD		GOOD	GOOD	GOOD	GOOD
POT 3b	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	MODERATE	GOOD
POT 4a	GOOD	GOOD			GOOD	GOOD	GOOD			HIGH	GOOD	GOOD
POT 4b	GOOD	HIGH	GOOD	HIGH	HIGH	GOOD	GOOD		HIGH	GOOD	HIGH	GOOD
POT 5a				MODERATE	GOOD	GOOD	GOOD	GOOD	GOOD	HIGH	MODERATE	GOOD
POT 5b	GOOD	GOOD	MODERATE	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	HIGH		GOOD
POT 6a						GOOD				**DRY**	GOOD	GOOD
POT 6b	GOOD	GOOD		GOOD	GOOD	GOOD	GOOD	GOOD		GOOD	HIGH	GOOD

Hydrological status

As expected, the highest flow rates recorded were in the winter, followed by those in the spring and summer (Fig. 2.3). Intermittent flow regimes were observed in POT1a, POT4a and POT6a sites. Also, particularly low flow regimes were measured in POT1b, POT3a and POT4b sites. On the contrary, Pot2a and Pot5a2 had continuously and satisfactory flow regimes.

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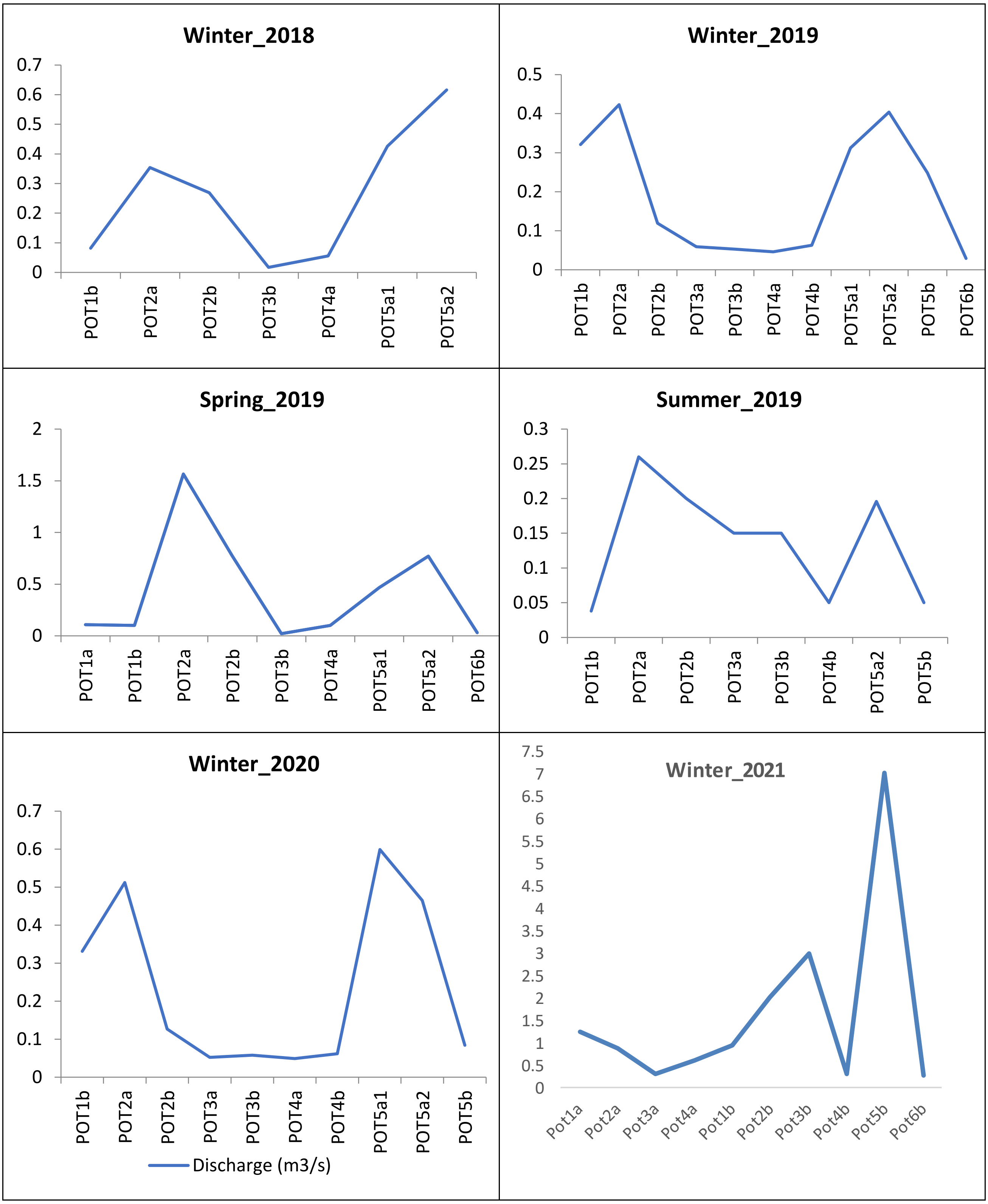

Figure 2.3. Discharge (m^3/s) per sampling site and per sampling period.

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STAR_ICMi

The composition of a macroinvertebrate community at any point in a river reflects the average water quality at that particular point. For this reason, macroinvertebrates are widely used in the assessment of river quality. For the classification of the biological quality, the polymetric index STAR_ICMi (Buffagni et al., 2007) was used, by combining the following 6 indices:

1- Gold (1- Total Abundancies of Gastropoda, Oligochaeta & Diptera)

EPT (Ephemeroptera, Plecoptera, Trichoptera)

ASPT

Shannon-Wiener diversity index (biodiversity index)

Number of families

Log10 (Sel_EPTD+1) - log10 (sum of Heptageniidae, Ephemeridae, Leptophlebiidae, Brachycentridae, Goeridae, Polycentropodidae, Limnephilidae, Odontoceridae, Nemouridae, Dolichopodidae, Stratyomidae, Dixidae, Empididae and Athericidae families + 1)

The STAR_ICMi index, fully meets the requirements of WFD 2000/60/EU, since each criterion of the directive is supported by 2 or 3 included metrics.

The STAR_ICMi index was estimated for the sampling river sites for the periods autumn 2018, winter 2018, spring 2019, summer 2019, winter 2019, winter 2020 and winter 2021 based on the benthic samples, and the results are presented below:

In autumn 2018, the biological quality of the river sites sampled was ranged from BAD to MODERATE (Table 2.5). Most sites (5) exhibited POOR quality and the sites Pot1b and Pot4b were ranked with BAD quality status. Pot1b site has habitats which are poor for the macroinvertebrate communities, has low flow regimes and is located in an area which there are anthropogenic pressures. Pot4b site has poor habitats, has almost flow and is a modified channel located downstream of the stream Xerolagkado, near the estuary where the levels of salinity and conductivity are high. In winter 2018, the biological quality of the stream sites sampled ranged from BAD to GOOD with the majority of the stream sites to be classified as POOR (Table 2.6). One site only, Pot5a1 from Stream Selas showed GOOD quality status due to the presence of good habitats within the site suitable for supporting macroinvertebrate communities and its location upstream of the river, where there are no significant agricultural land uses and urban activities. On the contrary, the site Pot5b belonging to the same stream was classified with BAD quality status, as it is located downstream, near the estuary and its habitats are poor for supporting macro-invertebrates.

Table 2.5. Classification of river sites according to STAR_ICMi for autumn 2018.

River sites	STAR_ICMi	
Pot1b	0.206	BAD
Pot2a	0.485	MODERATE
Pot2b	0.412	POOR
Pot3a	0.575	MODERATE
Pot3b	0.423	POOR
Pot4b	0.221	BAD
Pot5a1	0.479	MODERATE
Pot5a2	0.402	POOR
Pot5b	0.346	POOR

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Pot6b	0.324	POOR

Table 2.6. Classification of river sites according to STAR_ICMi for winter 2018.

River sites	STAR_ICMi	
Pot1b	0.387	POOR
Pot2a	0.461	POOR
Pot2b	0.302	POOR
Pot3a	0.492	MODERATE
Pot3b	0.352	POOR
Pot4a	0.489	MODERATE
Pot4b	0.316	POOR
Pot5a1	0.740	GOOD
Pot5a2	0.354	POOR
Pot5b	0.152	BAD

In spring 2019, although the values of STAR_ICMi ranged from POOR to GOOD quality, the majority of the river sites were ranked as MODERATE (Table 2.7). The site Pot5a1 from stream Selas continued to exhibit GOOD quality in spring. The only site that falls into the BAD quality status was the site Pot6b from stream Arapi Poros that is located near the estuary of the stream, where the saltwater is being mixed with the freshwater and the habitats within this site are poor for macro-invertebrate communities to thrive. Also, this site is enriched with water from a pumping station located 150 meters above.

In summer 2019, the benthic samples collected were fewer than the samples from the previous seasons, as many sites were dry due to the high temperatures in summer (Table 2.8). The STAR_ICMi index was ranged from BAD to GOOD quality. The sites Pot2a and Pot2b from stream Giannouzagas showed GOOD and BAD quality status, respectively. The site Pot2a is located upstream, the habitats within the site are good and therefore, suitable for supporting macro-invertebrate communities and had high flow regime, whereas the Pot2b is located near the estuary and the habitat is poor for these communities.

Table 2.7. Classification of river sites according to STAR_ICMi for spring 2019.

River sites	STAR_ICMi	
Pot1a	0.572	MODERATE
Pot1b	0.525	MODERATE
Pot2a	0.511	MODERATE
Pot2b	0.432	POOR
Pot3a	0.509	MODERATE
Pot3b	0.415	POOR
Pot4a	0.406	POOR
Pot5a1	0.810	GOOD
Pot5a2	0.619	MODERATE
Pot6b	0.208	BAD

Table 2.8. Classification of river sites according to STAR_ICMi for summer 2019.

River sites	STAR_ICMi	
Pot1b	0.569	MODERATE

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Pot2a	0.827	GOOD
Pot2b	0.230	BAD
Pot3a	0.423	POOR
Pot3b	0.301	POOR
Pot5b	0.538	MODERATE

In winter 2019, the values of STAR_ICMi ranged from BAD to GOOD biological quality, with the majority of the river sites were ranked as POOR and BAD (40 and 30% of the sites, respectively) (Table 2.9). The rest of the sites were in MODERATE (Pot1b and Pot4a) biological quality. Only one site (Pot5a1) had GOOD biological quality. In contrast to other periods, Pot2a site had BAD quality maybe due to the liquid olive waste.

In winter 2020, the benthic samples collected were fewer than the samples from the previous seasons, as many sites were dry due to the high temperatures in summertime (Table 2.10). The STAR_ICMi index was ranged from BAD to MODERATE biological quality. The 62.5% and 25% of the sites had BAD and POOR biological quality, respectively. Only one site (Pot3a) had MODERATE biological quality.

In winter 2021, 11 benthic samples were collected. It was the first winter we met water in so many river stations (Table 2.11). Although, the values of STAR_ICMi ranged from BAD to GOOD quality, the majority of the river sites were ranked as POOR (64%). From the others sites, the Pot5a1 and the Pot4b had GOOD and BAD biological quality, respectively.

Table 2.9. Classification of river sites according to STAR_ICMi for winter 2019.

River sites	STAR_ICMi	
Pot1b	0.537	MODERATE
Pot2a	0.104	BAD
Pot2b	0.333	POOR
Pot3a	0.457	POOR
Pot3b	0.133	BAD
Pot4a	0.563	MODERATE
Pot4b	0.271	POOR
Pot5a1	0.611	GOOD
Pot5a2	0.216	BAD
Pot5b	0.269	POOR

Table 2.10. Classification of river sites according to STAR_ICMi for winter 2020.

River sites	STAR_ICMi	
Pot1b	0.422	POOR
Pot2a	0.104	BAD
Pot3a	0.550	MODERATE
Pot3b	0.262	POOR

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Pot4a	0.192	BAD
Pot4b	0.104	BAD
Pot5a2	0.196	BAD
Pot5b	0.104	BAD

Table 2.11. Classification of river sites according to STAR_ICMi for winter 2021.

River	STAR_ICMi	
Pot1a	0.613	MODERATE
Pot2a	0.365	POOR
Pot3a	0.445	POOR
Pot4a	0.465	POOR
Pot1b	0.513	MODERATE
Pot2b	0.302	POOR
Pot3b	0.391	POOR
Pot4b	0.231	BAD
Pot5b	0.332	POOR
Pot5a1	0.718	GOOD
Pot6b	0.273	POOR

EPT Taxa

The number of EPT taxa (EPT= Ephemeroptera, Plecoptera, Trichoptera), is representative of the good quality of a river ecosystem (Allan, 1995; Mason, 1996). This is due to the fact that the majority of organisms belonging to these three large groups are sensitive to pressures and especially to organic pollution (Buffagni, 1997; Buffagni & Comin, 2000).

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Figure 2.4. EPT taxa in autumn, winter 2018, spring, summer, winter 2019, winter 2020, 2021.

Regarding EPT taxa, there are no significant differences between the seasons (Fig. 2.4). The result showed that site Pot5a1 (Selas Stream) recorded the highest EPT taxa with 7 taxa in spring 2019, followed by Pot5a2 (Selas Stream) with 5 taxa in spring 2019, and Pot1a (Xerias Stream) during winter 2021 and Pot5a1 (Selas Stream) in winter 2019 and 2021, with 4 taxa. The sites which present lowest prices of EPT Taxa are located downstream, showed high prices of conductivity and salinity (sea spray), and are most affected of pressures to organic pollution.

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NUMBER OF TAXA AND NUMBER OF SENSITIVE TAXA

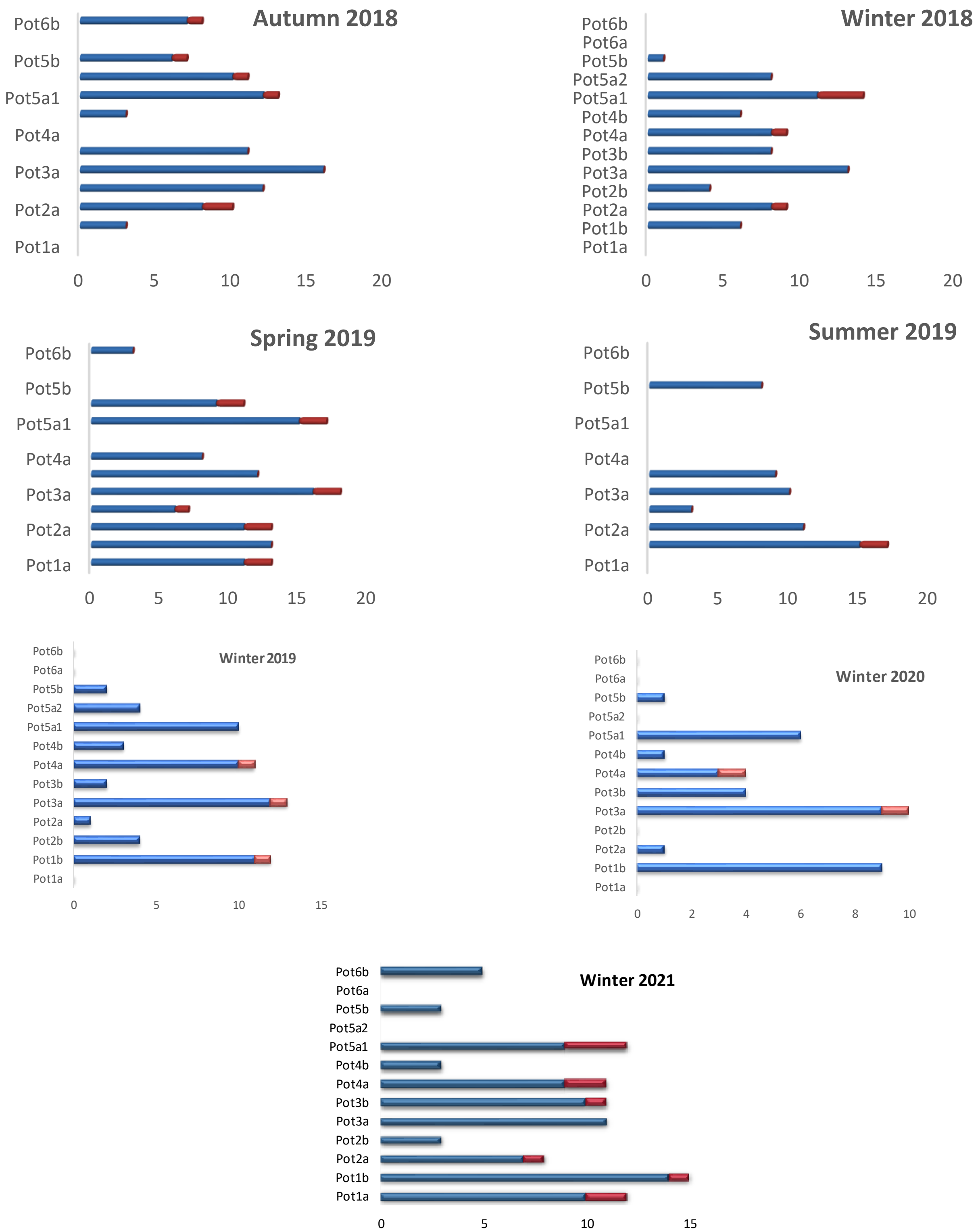

Figure 2.5. Number of taxa (blue color) and number of sensitive taxa (red color, according to Austrian list) per sampling site and per season.

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In autumn 2018, benthic fauna samplings were applied in 10 of the 13 sites (Fig. 2.5). The number of taxa ranged from 3 to 16. Four sites (Pot5a1, Pot5a2, Pot5b, Pot6b) had only one sensitive taxon and Pot1b site had two sensitive taxa. During the winter 2018 campaigns, samplings were carried out in 10 of the 13 sites. The number of taxa ranged from 1 to 13. The 30% of the sites had sensitive taxa. Specifically, Pot2a and Pot4a sites had only one sensitive taxon, while Pot5a1 site had 3 sensitive taxa. In spring 2019, benthic fauna samplings were applied in 10 of the 13 sites. The number of taxa was from 3 to 16. The 50% and 10% of the sites had 2 and 1 sensitive taxon, respectively. In summer 2019, samplings were carried out only in 6 of the 13 sites. The number of taxa ranged from 3 to 15. While, only Pot1b site had two sensitive taxa. In winter 2019, benthic fauna samplings were carried out in 10 of the 13 sites. The number of taxa ranged from 1 to 12 and the 30 % (i.e. 3 sites, Pot1b, Pot3a and Pot4a) of the sites had 1 sensitive taxon. During the winter 2020 campaigns, samplings were applied in 8 of the 13 sites. The number of taxa ranged from 1 to 9. Only two sites (Pot3a and Pot4a) had one sensitive taxon. In winter 2021, benthic fauna samplings were taken from 11 of the 13 sites. The number of taxa was ranged from 3 to 14. The 45% of the sites had 1 or 2 sensitive taxa. While, one site (Pot5a1) had 3 sensitive taxa.

Although annual and seasonal sampling periods were planned, some samplings were not conducted due to the following reasons. First, several sites of the examined streams were dry when visited. Second, some sampling sites were inaccessible. Overall, all the streams located in the examined region were found to be degraded. This result is supported by the Number of sensitive taxa and EPT (Ephemeroptera - Plecoptera - Trichoptera) taxa, as well as the number of taxa and the estimated Biotic index STAR_ICMi. The biological quality was differentiated seasonally, apart from the quality at the site Pot3b that remained stable. This seasonal quality differentiation is highly correlated with the habitat variation due to the water discharge and the stream type (permanent or not). The olive oil production waste also plays an important role to the quality differentiation that should not be neglected. It is a fact that the benthic fauna is strongly affected by the physicochemical parameters. Values of conductivity and pH were pretty high in the streams due to whitewash used for the waste process inside the olive oil mills' tanks (Fig. 2.6). Also, the high values of conductivity and salinity might be due to the fact that the most of the downstream sites are located near to estuaries. It is worth mentioning that there is a need to develop indices suitable for the latter habitats in order to assess the biological quality that adapt to their specific features.


Figure 2.6. The whitewash used for the waste process inside the olive oil mill's tanks is visible inside the stream.

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Diatoms

From the total of 91 samplings, 24 samples were not collected, 21 samples did not contain an adequate frustule abundance to be counted, 8 samples contained mainly species found in brackish waters and could not be used for calculating biological quality (Table 2.12).

Biological Quality Index-IPS

The Specific Pollution Sensitivity Index (IPS-Cemagref, 1982) was used for a broad assessment of biological quality, as it is able to detect different types of pollution (organic pollution, salinity, eutrophication) in rivers (Prygiel & Coste, 1993). It is widely used for ecological studies (Descy & Coste, 1991) and it has been proved to be the most efficient index in Mediterranean rivers (Gomà et al., 2004). IPS ranges from 1 to 20 with increasing ecological quality. The general limits of the index are shown in Table 2.13 and the results in Table 2.14.

Table 2.12. Summary of the analyzed diatom samples. NS-no sampling, ND-no diatoms present, BR-brackish assemblage, √-biological quality defined.

	Autumn 2018	Winter 2018	Spring 2019	Summer 2019	Winter 2019	Winter 2020	Winter 2021
Pot1a	NS	NS	√	NS	NS	NS	ND
Pot1b	ND	ND	√	√	BR	√	√
Pot2a	√	√	√	√	√	√	√
Pot2b	BR	√	√	√	ND	√	ND
Pot3a	√	√	√	√	√	√	√
Pot3b	√	√	√	√	√	ND	√
Pot4a	NS	ND	√	NS	√	ND	ND
Pot4b	BR	BR	NS	NS	BR	BR	ND
Pot5a1	√	ND	√	NS	ND	NS	√
Pot5a2	√	ND	√	NS	ND	ND	NS
Pot5b	ND	ND	NS	√	√	ND	ND
Pot6a	NS	NS	NS	NS	NS	NS	NS
Pot6b	BR	BR	ND	NS	√	NS	ND

Table 2.13. Classification of biological water quality based on the IPS index

IPS	Quality status
1-5	BAD
5-9	POOR
9-13	MODERATE
13-17	GOOD
17-20	HIGH

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Pot1a

This site was sampled only twice (in spring 2019 and winter 2021), however, only during spring 2019 there was an adequate number of frustules to determine a biological quality, which was found good (IPS=14.7). The dominance of Melosira variance indicates eutrophic conditions in the site (Taylor et al 2007).

Pot1b

This site presented a very low frustule abundance in autumn and winter samplings of 2018. It presented a good (IPS=14.5) and a high (IPS=17.1) biological quality in spring and summer samplings respectively. This increase follows the increase of the relative abundance of Achnanthidium minutissimum, a species found in clean fresh water conditions (Taylor et al 2007). In winter 2019 the assemblage presented a high number of species found in brackish environments and the biological quality could not be assessed. In winter 2020 the site presented a good biological quality (IPS=15.4). In winter 2021, the site presented good biological quality (IPS=14.4). The species Nitzschia denticula (found usually in oligo- to mesotrophic standing waters-Cantonati et al 2017) dominated the diatom assemblage.

Pot2a

This site presented a high biological quality in the winter 2018 sampling (IPS=18.3) and a good biological quality during all other seasonal samplings -autumn 2018, spring 2019 and summer 2019 (IPS=14.8, 13.5 and 15.2 respectively). The biological quality was also good in winter 2019 and winter 2020 samplings (IPS=15.4 and 15.7 respectively). However, in winter 2021 sampling, the biological quality deteriorates to moderate (IPS=12.6), due to the increased abundance of *Luticola mutica*, a species that can tolerate a moderate level of pollution (Taylor et al 2007).

Pot2b

This site had a brackish assemblage in the autumn 2018 sampling but presented good biological quality during the winter 2018 (IPS=16.9), the spring 2019 (IPS=14.4) and the summer 2019 (IPS=16.7) samplings, when *Achnanthidium* spp were dominant. In winter 2019, the site presented a very low frustule abundance. In winter 2020 it presented good biological quality (IPS=13.2) where the dominant species *Ulnaria ulna* indicates increased eutrophication levels (Taylor et al 2007). In winter 2021, the frustule abundance was very low and biological quality could not be calculated.

Pot3a

This site presented a good biological quality in autumn 2018 (IPS=14), a moderate quality in winter 2018 and spring 2019 (IPS=9.9 and 12.1 respectively) and a poor biological quality in summer 2019 (IPS=7.3). This was depicted in the shift of dominance of *Brachysira vitrea* and *Gomphonema* spp (mostly found in clean waters-autumn) to *Tabularia fasciculata* (favored by high conductivity-winter), *Gomphonema olivaceum* (spring) and *Nitzschia* spp (eutrophic waters with high conductivity-summer). In winter 2019, the biological quality was again good (IPS=13.2) with the dominance of *Achnanthidium rivulare,* whereas in winter 2020 biological quality was again decreased to poor (IPS=8.8), where the species *Lemnicola hungarica* and *Amphora pediculus* dominated the assemblage, showing increased pollution levels (Taylor et al 2007). In winter 2021, the biological quality was again good (IPS=15.6), where *Achnanthidium* spp and *Brachysira vitrea* (species present in clean waters- Taylor et al 2007) presented increased abundances.

Pot3b

This site presented a good biological quality during the four seasonal first year samplings (from autumn to summer IPS=16, 15.4, 16 and 13.8 respectively). There was a shift of dominant species from *Achnanthidium minutissimum* (autumn and spring) to *Cymbella affiniformis* (winter) and to *Nitzschia dissipata* (summer), the last one explaining the drop in the index value. In winter 2019, the site presented a moderate biological quality

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(IPS=10.5), with increased abundances of several *Nitzschia* spp, usually found in eutrophic waters with high conductivity (Taylor et al 2007). In winter 2020, the site presented very low frustule abundance. In winter 2021, the site presented high biological quality (IPS=18) due to the high dominance of *Brachysira vitrea*, a species mainly present in clean, oligo- to mesotrophic waters (Taylor et al 2007).

Pot4a

In the winter 2018 and 2020 samplings this site had a very low frustule abundance. It presented a good biological quality in the spring 2019 and winter 2019 samplings (IPS=15.8 and 16.5 respectively), where *Achnanthidium minutissimum,* a species found in clean fresh water conditions dominated. In spring 2019 *Nitzschia dissipata* was the co-dominant species whereas in winter 2019 *Amphora pediculus* co-dominated, both species indicating relatively elevated eutrophication levels (Taylor et al 2007). In winter 2021, the site presented very low frustule abundance and biological quality could not be calculated.

Pot4b

In the autumn and winter 2018 and in winter 2019 and 2020 samplings this site had brackish diatom assemblages and it was not sampled in spring and summer 2019. In winter 2021, the site presented very low frustule abundance.

Pot5a1

In the winter 2018 and 2019 samplings there was a very low frustule abundance, but in the autumn and spring samplings the site presented a good biological quality (IPS=15.7 and 13.7 respectively). The dominance of *Ulnaria* spp. in spring indicates a shift to more eutrophic conditions (Taylor et al 2007). In winter 2021, the site presented good biological quality (IPS=13.2), due to increased abundance of *Achnanthidium minutissimum*, a species usually found in clean, running waters (Taylor et al 2007).

Pot5a2

In all the winter samplings there was a very low frustule abundance, but in the autumn and spring samplings the site presented a good biological quality (IPS=14 and 15 respectively). The dominance of *Amphora pediculus* in autumn indicates higher eutrophication levels during this season (Taylor et al 2007). In winter 2021, the site was not sampled.

Pot5b

In the autumn and winter 2018 and in winter 2020 and 2021 samplings this site had a very low frustule abundance. It presented a good biological quality in the summer 2018 and winter 2019 samplings (IPS=14.7 and 14.6, respectively), due to the dominance of *Achnanthidium minutissimum,* a species found in clean fresh water conditions (Taylor et al 2007).

Pot6a

This site was not sampled for diatoms in any of the samplings.

Pot6b

In the autumn and winter 2018 samplings this site had brackish diatom assemblages, in spring 2019 a very low frustule abundance and it was not sampled in summer 2019 and in winter 2020. In winter 2019 the site presented low frustule abundance but the biological quality could be calculated and was found poor (IPS=8.4). In winter 2021, the site again presented a very low frustule abundance and the biological quality could not be calculated.

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Table 2.14. Biological quality based on diatoms. Blue corresponds to high, green to good, yellow to moderate, orange to poor and red (not present) to bad quality.

	Autumn 2018	Winter 2018	Spring 2019	Summer 2019	Winter 2019	Winter 2020	Winter 2021
Pot1a	NS	NS		NS	NS	NS	ND
Pot1b	ND	ND			BR		
Pot2a							
Pot2b	BR				ND		ND
Pot3a							
Pot3b						ND	
Pot4a	NS	ND		NS		ND	ND
Pot4b	BR	BR	NS	NS	BR	BR	ND
Pot5a1		ND		NS	ND	NS	
Pot5a2		ND		NS	ND	ND	NS
Pot5b	ND	ND	NS			ND	ND
Pot6a	NS	NS	NS	NS	NS	NS	NS
Pot6b	BR	BR	ND	NS		NS	ND

2.6. Conclusions

- The quality of benthic macro-invertebrates showed that there is degradation in the study area. On the other hand, diatoms indicate a good biological quality of most sites, coinciding with good and high physico-chemical quality, as diatoms are mostly affected by changes in nutrients. According to the Water Framework Directive 2000/60/EU, when the quality indices from the benthic fauna and diatoms of a site are not in agreement (POOR – GOOD), the worst estimated class is taking into account. This was the case in a few sampling sites in the present study, as mentioned before.
- The degradation reflected in the results, using the macroinvertebrates, does not correspond to reality. There could be explained as follows: (i) Existing biological indices are based primarily on the response of macroinvertebrates to pollution (not natural pressure). But in our case, we believe that the composition of the benthic fauna in our river sites is due to natural causes/ pressures received by the river, as many of our sites are located in temporary parts of the rivers. (ii) The most of the downstream sites are located near to estuaries and therefore have high conductivity and salinity values. Habitats with these characteristics host transient organisms which have not been included in biological indices, while they are considered inhospitable to those included.
- Sites located very close to the sea or salt marshes were usually dominated by species commonly found in brackish waters, as they were much affected by sea water. In most of these cases, the IPS index of biological quality could not be calculated, as these species do not take any scores.
- Many sites were deprived of the presence of diatoms, mostly during the winter samplings. This could be attributed to (i) increased water flow that washes the biofilm off or (ii) sudden high increase of water level due to precipitation. The latter could result in a sampled substrate that was not submerged for sufficient time for a biofilm to be developed.

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- It is worth mentioning that there is a need to modify or develop indices suitable for habitats: (i) in temporary rivers, taking in account the response of macroinvertebrates to drought, and (ii) near to estuaries of streams in order to assess the biological quality (using the benthic fauna) that adapt to their specific features (high values of conductivity and salinity and low flow regime).
- However, in order to capture the bigger picture of the overall biological quality of the study area, the sampling network should be revised and all the Biological Quality Elements should be estimated according to the Water Framework Directive 2000/60/EU.

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3. Hydrological features of coastal waters

DIMITRIS VELAORAS

3.1. Introduction

The area of interest lies on the Greek coast at southeastern Ionian Sea. The Ionian Sea circulation in this area at the first 200 m follows the coastline, mostly with a southerly direction (Malanotte-Rizzoli et al., 1997). Temperature in the surface layer varies according to season, while salinity appears greater than 38.7 ppt.

3.2. Materials & Methods

The area was surveyed twice. At the end of the autumn period (December 2018), and during the end of the winter period (March-April 2019). The results of the 28 sampling stations are summarized below.

Temperature and salinity was measured throughout the water column (from surface to bottom) with the use of a SBE19plus CTD unit equipped with pressure, temperature and conductivity sensors. Salinity and density were calculated from sensor data by using international formulas (PSS-78 & IES-80).

3.3. Results & Discussion

FIRST SAMPLING PERIOD

The first sampling period took place on December 18th 2018. The profiles of the properties for all stations are show in Figure 3.1. The bottom depths vary from less than 25 m (1 m of depth ~ 1 dbar of pressure) up to a maximum of 88 m.

The water column in all stations is fairly well homogenized due to the convection of the winter period. Station COAS 3E is an exception. In this station, surface density up to 10 m is lower (~38.8 ppt) due to the lower salinity of this layer. The latter might be attributed to the existence of slightly less saline surface water in Navarino bay, as this station is situated at the mouth of the bay. In all stations salinity is ⩽39 ppt, temperature ranges between ~19-19.3 °C and density ~1028 kg/m^3, with the exception of COAS 3E where density appears slightly lower at the first 10 m.

SECOND SAMPLING PERIOD

The second sampling period took place on March 22-23th 2019. The profiles of these properties for all stations are shown in Figure 3.2. The bottom depths vary from less than 20 m up to a maximum of 105 m.

Compared with the first sampling period, the temperature throughout the water column is significantly lower. This is an indication of a strong convective episode between December and March that has reduced temperature to almost 15.5 °C at the deeper layers. However, a seasonal thermocline has started to develop at the first 10 – 15 m as at this layer the temperature has increased to 16 – 17 °C due to the warming caused by the beginning of the spring season. Salinity appears ⩾ 39 ppt in all stations, with the exception of first 10-15 m in station transects COAS 1, 2 and 3. This is possibly due to the influence of the slightly less saline Navarino bay outflow. However, the salinity reduction in these stations is small (salinity ⩽38.9 ppt). Density appears in all stations around 1029 kg/m^3, with the exception of the first 10-15 m in station transects COAS 1, 2 and 3 due to the lower salinity of this layer.

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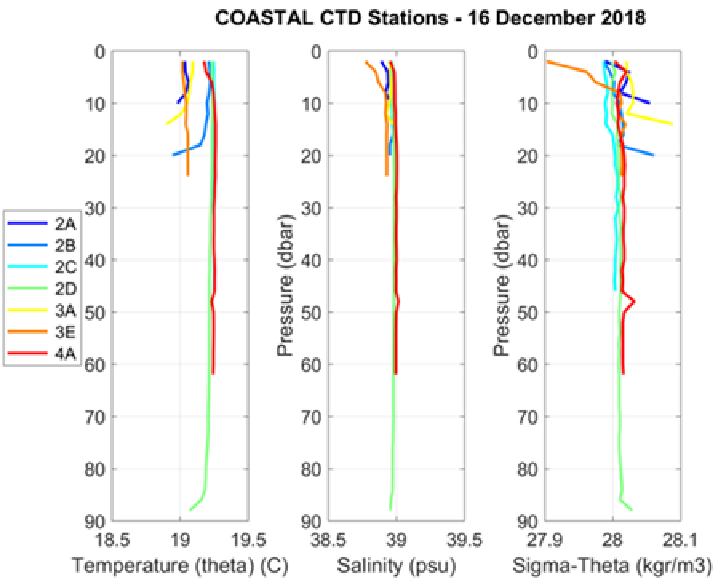

Figure 3.1 Temperature, Salinity and Sigma-Theta vertical distributions during December 2018.

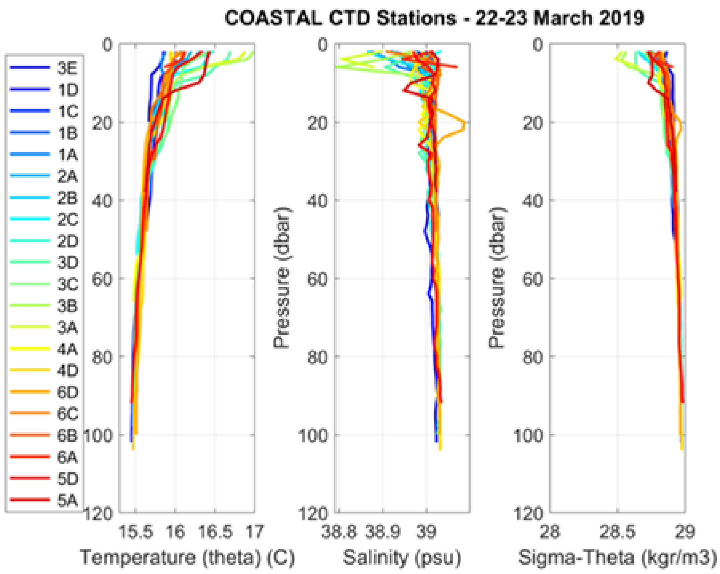

Figure 3.2 Temperature, Salinity and Sigma-Theta vertical distributions during March 2019.

3.4. Conclusions

A convective episode between December and March has reduced the water temperature and mixed the whole column. Small surface salinity variations (lower salinity) were observed close to the Navarino Bay exit.

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4. Nutrients and Chlorophyll-a in coastal and lagoon waters

ALEXANDRA PAVLIDOU, ELENI ROUSSELAKI, GEORGIA ASSIMAKOPOULOU, PANAGIOTA ZACHIOTI, VASSILEIA FIORAKI, ANGELIKI KONSTANTINOPOULOU

4.1. Introduction

In this chapter we present the Nutrient and Chl-a concentrations of all the coastal marine and lagoon waters in Ionian Sea and Gialova Lagoon. An eutrophication index has been applied for the assessment of the trophic status of the studied areas.

4.2. Materials & Methods

Samples from the coastal zone were taken during December 2018 and March 2019. The full grid of 21 stations was covered during March 2019. In the Gialova Lagoon, samples were taken from 5 stations during October & December 2018, and March 2019. The samples for the determination of inorganic nutrients and dissolved organic nitrogen and phosphorus were kept deep frozen (~ -20 °C) until their analysis in the certified according to ELOT EN ISO/IEC 17025:2005 biogeochemical laboratories of HCMR. A Seal III autoanalyzer and a VIS/UV spectrophotometers were used for the analysis according to standard methods (Mullin & Riley, 1955, for silicate; Strickland & Parsons, 1977, for nitrate-nitrite; Murphy & Riley, 1962, for phosphate; Koroleff, 1970, for ammonium). According to the accreditation protocols of the methods used for nutrients analyses, the Limits of Quantification (LOQ) are: 0.025 µmol/L for nitrite, 0.153 µmol/L for nitrite+nitrate, 0.274 µmol/L for silicate, 0.010 µmol/L for phosphate and 0.102 µmol/L for ammonium. DON and DOP analysis was performed after a wet-oxidation with persulfate in low alkaline conditions and measured using a SEAL III autoanalyzer (Pujo-Pay & Raimbault, 1994; Raimbault et al., 1999). Values were corrected for the reagent blank. Samples (2l) for phytoplankton biomass (chlorophyll a) were filtered on board through Ø47mm. The filters were kept deep frozen in dark (at –15oC) and analyzed at the laboratory on a TURNER 00-AU-10 fluorometer according to Holm-Hansen et al., (1965).

4.3. Results & Discussion

GIALOVA LAGOON

Nutrient and Chl-a values follow seasonal variability with higher nutrient values during winter and, in some cases, during spring period. The highest Chl-a values were recorded during spring bloom, as expected. Ammonium and phosphate values during December 2018 were high (Fig. 4.1). According to Eutrophication Index (E.I.; Primpas et al., 2010), the lagoon was at BAD trophic status (Table 4.1).

Table 4.1 Trophic status of Gialova lagoon during October, December 2018 and March 2019.

DATE	STATION	E.I.	STATUS
Oct-18	Gial-1	0.87	**POOR**
Oct-18	Gial-2	1.88	**BAD**
Oct-18	Gial-3	1.44	**POOR**
Oct-18	Gial-4	1.89	**BAD**
Oct-18	Gial-6	1.79	**BAD**
Dec-18	Gial-1	5.10	**BAD**
Dec-18	Gial-2	5.96	**BAD**

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Dec-18	Gial-3	6.01	**BAD**
Dec-18	Gial-4	7.86	**BAD**
Dec-18	Gial-6	7.14	**BAD**
Mar-19	Gial-1	8.29	**BAD**
Mar-19	Gial-2	7.76	**BAD**
Mar-19	Gial-3	7.04	**BAD**
Mar-19	Gial-4	8.12	**BAD**

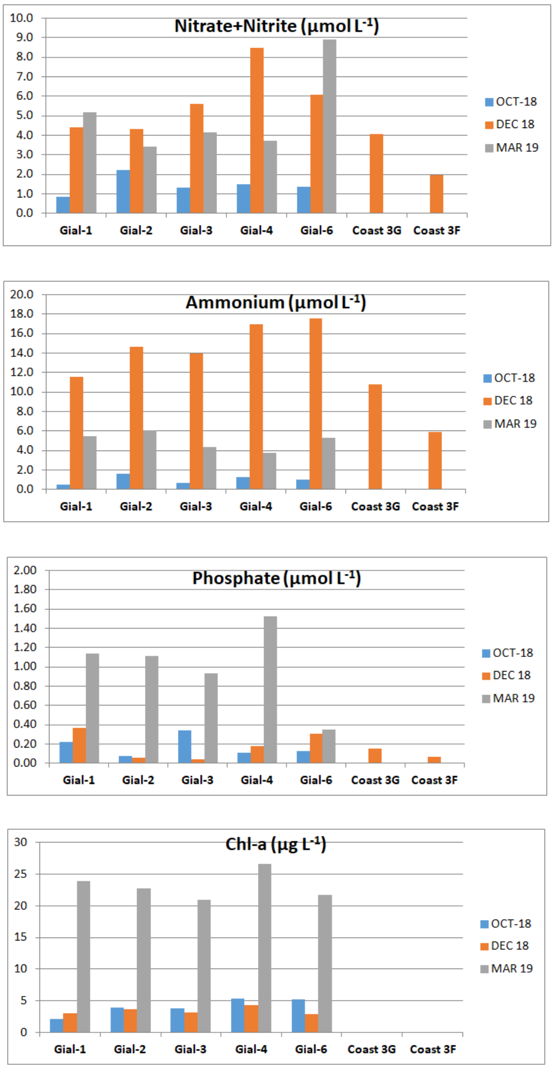

Figure 4.1 Nutrients and Chl-a in Gialova Lagoon during October, December 2018 and March 2019.

Coastal Zone

Similarly to the lagoon, nutrient and Chl-a values follow seasonal variability with the highest Chl-a and nitrate values during spring. Ammonium and phosphate values were higher during December 2018 at the stations located closer to the coastline, indicating that they are probably affected by discharges and activities from the

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land (Fig. 4.2). Moreover, higher value of Dissolved Organic Nitrogen was measured at Station COAS A2, near the coast, during December. According to Eutrophication Index (E.I.; Primpas et al., 2010) the study area was at GOOD status at both sampling periods

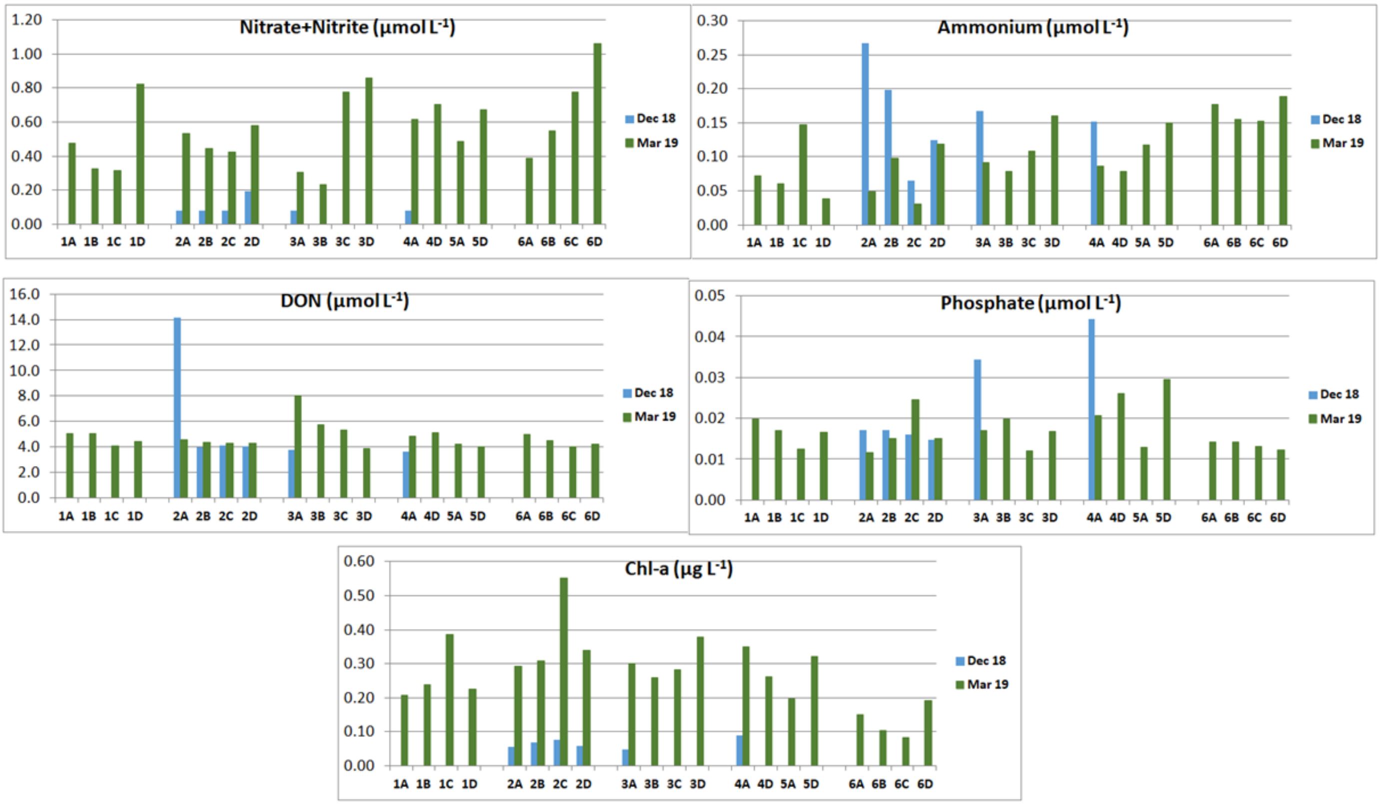

Figure 4.2 Nutrients and Chl-a in the marine stations during December 2018 and March 2019.

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5. Mesozooplankton biomass in SW Messinia

SOULTANA ZERVOUDAKI, THEODORE ZOULIAS

5.1. Introduction

Plankton plays a pivotal role in oceanic carbon flux as the primary biological mechanism for the sequestration of carbon out of the atmosphere into surface waters, while the evaluation of its quantitative composition is essential for the study of marine ecosystems.

This report presents the results of mesozooplankton biomass from samples taken in December 2018 (16/12/2018) and in March 2019 (22-23/3/2019).

5.2. Materials & Methods

Samples were collected in all the marine stations by vertical hauls of a WP-2 plankton net (Hydrobios, 0.5 m mouth diameter 200 μm), from the surface to the depth of each station. The volume (m^3) of filtered water for each tow was estimated taking into account the area of the net mouth and the difference in winch readings. The thickness of the sampled layer and the depth limits were computed taking into account the wire angle. After each haul the net was carefully rinsed. The contents of the cod ends were fixed immediately after collection, preserved in a 4% buffered-formaldehyde seawater solution and they are divided in two subsamples by Folsom splitter in the laboratory. For biomass estimation, the dry weight (mg m-3) of the preserved by formalin samples was measured according to Omori & Ikeda (1984).

5.3. Results & Discussion

The distribution and fluctuations of mesozooplankton biomass (mg dry weight per m^3) among the stations are shown in Table 5.1 and Figure 5.1. Overall, biomass values were higher in March 2019 (7.51 mg m^{-3}) compared to December 2018 (4.68 mg m^{-3}), while at very shallow stations (COAS 1A, 2A, 3A, 6A) significantly different biomass values were found compared to the other stations of each transect.

In December 2018, the highest value was found at station COAS 3A (9.41mg m^{-3}), while the lowest value was recorded in the COAS 2D station (0.69 mg m^{-3}). In March 2019, maximum values were recorded at the shallow stations COAS 6A, 2A and 3A (16.09, 13.32, and 12.44 mg m^{-3}, respectively), while the biomass values in the remaining stations of all transects varied between 5-8 mg m^{-3}. The significant increased zooplankton biomass values in March period can be explained by an analogous significant increase in Chl-a concentrations (Chapter 5) between the two study periods (0.070 and 0.278 μg l^{-1}, respectively). Many studies have shown the importance of the nutrients relationship between phytoplankton and zooplankton in coastal ecosystems. The growth of phytoplankton in the spring provides more food to the zooplankton and thus increases it through increased nutrition and reproduction rates (Kiørboe & Nielsen, 1994).

Table 5.1 Mesozooplankton biomass values (mg/m^3) in December 2018 and March 2019

Station	Layer (m)	Biomass (mgr m^{-3})
December 2018		
COAS 2A	0-11	8,20
2B	0-20	4,27
2C	0-45	2,69
2D	0-95	0,69

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3A	0-12	9,41
3E	0-20	4,79
4A	0-65	2,73
March 2019		
1A	0-7	9,87
1B	0-27	7,26
1C	0-47	5,33
1D	0-115	9.63
2A	0-8	13,32
2B	0-20	5,82
2C	0-53	6,26
2D	0-102	5,47
3A	0-7	12,44
3B	0-17	6,13
3C	0-52	8,16
3D	0-102	4,59
3E	0-19	6,82
4A	0-64	6,41
4D	0-102	8,08
5A	0-35	5,34
5D	0-85	5,14
6A	0-5	16,09
6B	0-27	5,23
6C	0-47	5,23
6D	0-100	5,17

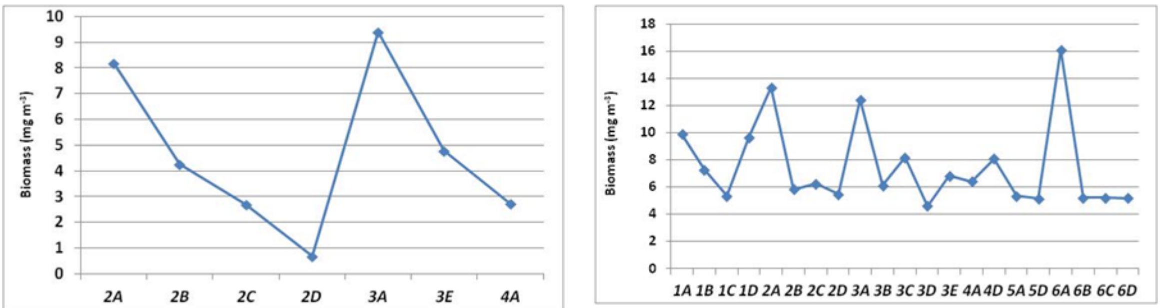

Figure 5.1 Mesozooplankton biomass values fluctuation in December 2018 (A) and March 2019 (B)

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6. Organic carbon and nitrogen in marine and lagoon sediments

AFRODITE ANDRONI, ELLIE ELEFTHERIADI

6.1. Introduction

Sediments act as both receptors and sources of bioavailable trace elements and play important role in biogeochemical cycles. Mobility of trace elements in marine sediments may be significantly affected by changes in physicochemical parameters in water, such as dissolved oxygen, pH, temperature, salinity and concentrations of organic substances.

The organic matter of the sediments consists of a plenty of organic compounds, some of which are trace elements, which results in the binding of their sediment and then their input into the food chain since this material is food for many benthic organisms.

Carbon is one of the key elements in organisms and non-living compounds on Earth. In marine sediments carbon occurs as organic matter intimately linked to the metabolic processes of plants and animals and as in inorganic carbonates (e.g. calcite, aragonite) contained within biogenic and abiogenic carbonate minerals.

The quantitative spatial and temporal distribution of organic carbon in marine sediments is important for paleoceanographic reconstructions of primary production and carbon burial.

In the present study we show the results of the organic carbon and nitrogen concentrations of all the marine and lagoon sampling stations.

6.2. Materials & Methods

During December 2018 and March 2019 surface sediments were collected from Stations COAS 1, COAS 2, COAS 4, COAS 5 and COAS 6 with transect sections A–B–C–D and COAS3 with transect sections A-B-C-D-E in the marine area SW of Peloponnese and from stations COGIA1-12 in Gialova Lagoon, using a grab sampler on board F/R “PHILIA” of the Hellenic Centre for Marine Research. The collected samples were stored in plastic containers and stored in -18 °C before they were transported to the laboratory, dried in 60-65 °C for at least 24 hours and powdered to a fine powder for 10 minutes in a twin swinging motorized mill with agate mortar and balls.

Flash EA (1112 Series) CHN-analyzer by Thermo Scientific was used for the determination of carbon and nitrogen following the procedures described by Verardo et al. (1990), Cutter and Radford-Knoery (1991), and Nieuwenhuize et al. (1994). Successful determination of organic carbon relies upon the separation of organic from inorganic carbon. For the separation of organic from inorganic carbon the sediment samples were separated in two parts; in the first one the removal of inorganic forms was achieved by acidification (HCl 2N), in the other one the quantity of total carbon and nitrogen was determined. A small amount of the sample (10-15 mg) was weighted in silver weighing pans for organic carbon determination and tin pans were used for total carbon and nitrogen determination. The sediments which were weighed in tin pans were closed, compacted and formed into a ball in order to be transferred into CHN-analyzer auto sampler. The sediments that were weighed in silver pans were acidified carefully. After the acidification, the samples were dried at 60°C overnight and then were closed and compacted before the analysis.

6.3. Results & Discussion

Figure 6.1 shows the percentage concentration of organic carbon and nitrogen in the marine sediments. Percentages of organic carbon (OC) in the marine study area ranged from 0.06 to 1.09% and nitrogen (N) from 0 to 0.10%. The sediments coming from the offshore stations COAS1D, COAS2D and COAS3D have higher percentages of OC.

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This corresponds to the higher percentage of silt and clay as shown in the following Table 7.1, and characterizes sediments of biogenic origin. Of biogenic origin are characterized sediments which derived from dead body scrap, such as shells, bones, teeth etc., that begin to sink after the death or from the biological activity of organisms and indicates high percentage of organic matter.

Sediments at the stations near the shore show lower POC and N percentages, due to the higher percentage of sand and are characterized as of terrestrial origin. Sediments of terrestrial or lithogenic origin come from the erosion of rocks in land, which are transported by rivers, wind or gravity from land to sea. The transported sediment can be deposited in coves, bays, lagoons, near the coast or even on the open sea by sea currents.

As shown in Figure 6.1, the concentrations of organic carbon and nitrogen increase offshore. Exceptions to this trend are Station COAS 3E (north strait between Sfaktiria Island and Navarino Bay) and the transect section COAS 4 (south strait between Sfaktiria Island and Navarino Bay). The sediments at Stations COAS 3E and COAS 4B have the same low percentages of OC and N and the same grain size percentages, as they seem to originate from river discharges.

Figure 6.2 shows the percentage concentration of organic carbon and nitrogen at the Gialova Lagoon Stations COGIA1-11. Organic carbon values range from 1.81 to 3.72% and N from 0.21 to 0.43%, and show that the sediments in the Lagoon are a mix of biogenic and terrestrial origin. Organic C contents are higher in Stations COGIA 4, 5 and 11, ranging between 3.24 to 3.72%. Elevated values are also observed at Stations COGIA 1, 2, 3, 7, 8, 9 and 10 (2.30-3.02%), while Station COGIA 6 had lower CO content (1.81%) and high sand value. The high contents of OC in the greatest part of the study area result largely from anthropogenic sources. Gialova is a shallow lagoon with depths between 0.5-1 m, where various canalization works have been done which resulted to significant reduction of the lagoon area and consequent initiation of several oxygen depletion and dystrophic events (Koutsoubas et al., 2000).

6.4. Conclusions

Percentages of organic carbon in the marine area ranged from 0.06 to 1.09% and nitrogen from 0 to 0.10%. Offshore stations (COAS 1D, 2D and 3D) showed higher percentages of OC due to the biogenic nature of the sediments. The stations with lower OC and N values indicate terrestrial sediment origin. The percentage concentrations of organic carbon and nitrogen increase at offshore stations. Station COAS 3E and transect COAS4 follow different pattern because of their location at the straits of Sfaktiria Island. Sediments close to the shore are of terrestrial origin and therefore the percentage of organic substances is low.

The percentage concentration of organic carbon and nitrogen at Gialova Lagoon is between 3.24 and 3.72%. Station COGIA 6 is poor to organic substances, in contrast to most stations, which coincide with the presence of terrestrial sediments (sand) that do not favor the accumulation of organic C. The relatively high OC and N content that appears in the rest of the stations is related to the presence of finer (silt and clay) sediments, and possible anthropogenic influence from the watersheds of the area.

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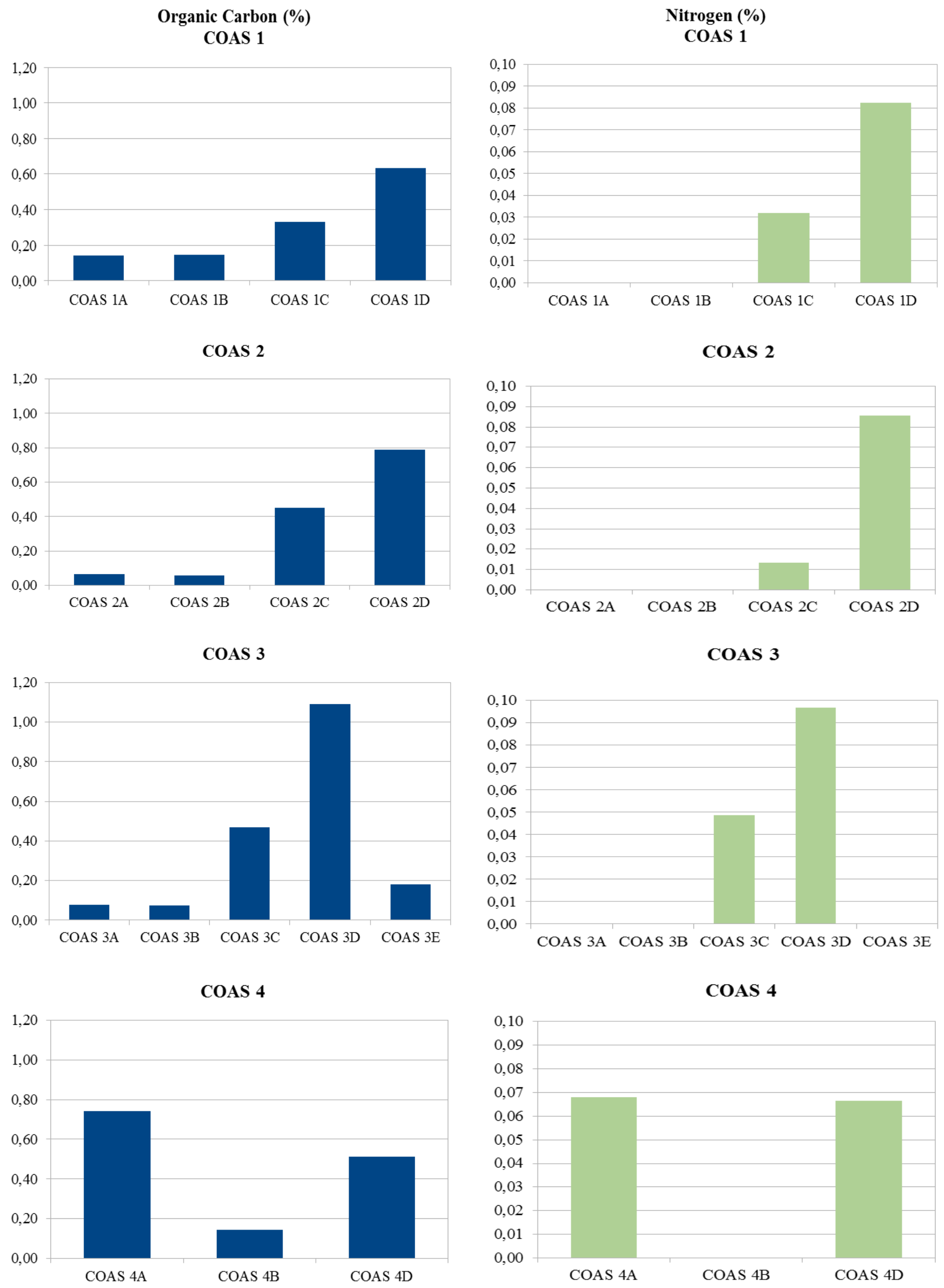

Figure 6.1 Organic carbon and nitrogen values (%) in the marine sediments.

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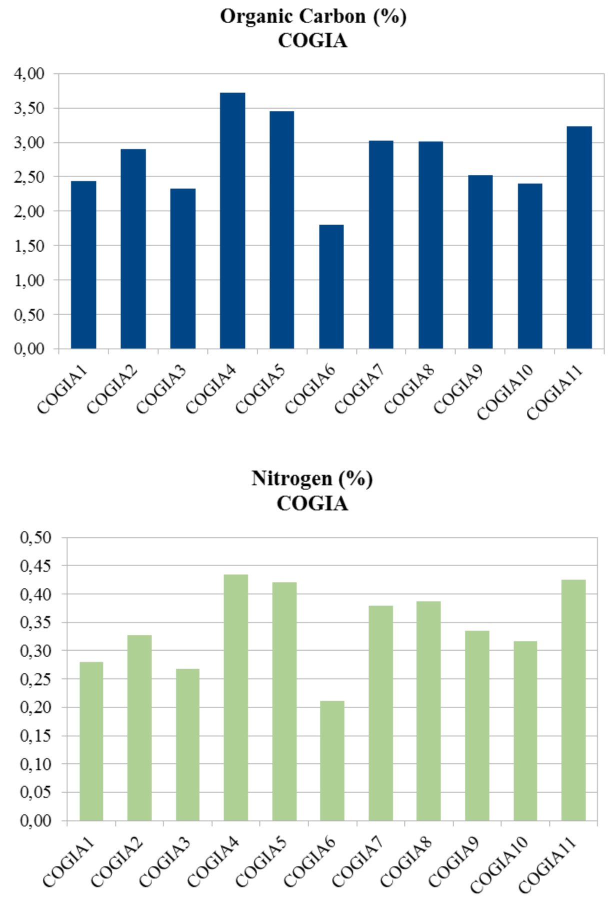

Figure 6.2 Organic carbon and nitrogen values (%) in the lagoon sediments.

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7. Sediment grain size and elemental geochemistry in the coastal area of SW Messinia and the Gialova Lagoon

Theodore D. Kanellopoulos, Ellie Eleftheriadi, Aristomenis P. Karageorgis, Georgia Kambouri, Alkiviadis Papageorgiou, Ioanna Stavrakaki

7.1. Introduction

In the present study we show the results of the grain size and the elemental geochemistry analyses of all the marine and lagoon sampling stations. Through the application of statistical analysis and the calculation of enrichment factors, we investigate the origin of the seabed, we compare the geochemical data of the study area with other adjacent marine areas, and we assess the possible anthropogenic influence in the studied sediments.

7.2. Materials & Methods

Surface sediments were collected using a grab sampler on board F/R "PHILIA" of the Hellenic Centre for Marine Research during December 2018 and March 2019. The collected samples were stored in plastic containers and stored in the refrigerator before been transported to the laboratory.

The grain size of the untreated sediment samples was determined separating the coarse fraction (> 63 µm, sand and gravel) from the finer one (< 63 µm, mud) by wet sieving treatment. The fine silt and clay fractions were analyzed in a Micromeritics Sedigraph 5100 X-ray grain-size analyzer.

Bulk (not sieved and unwashed) samples were oven dried, ground to a fine powder in a twin swinging motorized mill with agate mortar and balls. Major elements' oxides (SiO_2, Al_2O_3, TiO_2, Fe_2O_3, K_2O, Na_2O, CaO, MgO, P_2O_5, SO_3, MnO) were determined in fused beads. Fused bead preparation involved the complete fusion of 0.6 g of sample, with 5.4 g of flux (50:50 lithium metaborate, lithium tetraborate) and 0.5 g of lithium nitrate, the latter one being used as an oxidizer. Minor elements (V, Cr, Mn, Co, Ni, Cu, Zn, As, Rb, Mo, Pb) were determined in powder pellets prepared according to the following procedure: 5 g of powdered sample were mixed with 0.5 g of wax and subsequently pressed in a 31-mm aluminum cup. Both fused beads and the powder pellets were analyzed for their chemical composition in a Philips PW-2400 wavelength X-ray fluorescence (XRF) analyzer, equipped with Rh-tube.

Analytical accuracy was checked by parallel analysis of certified sediment standards (MESS-2, PACS-2, MAG-1) and was found to be satisfactory for all elements analyzed (for details see Karageorgis et al., 2005). Analytical precision was checked in sample replicates and was always better than 0.5%.

Al and Ti were also used as reference elements in the calculation of the Enrichment Factor (EF) values for heavy metals in the sediments (Ackermann, 1980; Luoma, 1990; Grousset et al., 1995). EF values were calculated according to the equation: EF = ([El]/[Al or Ti])sed : ([El]/[Al or Ti])rs, where [El]sed is the content of the chemical element in question in the sediments; [Al or Ti]sed is the content of Al or Ti in the sediments; [El]rs and [Al or Ti]rs are the concentrations of the element in question and of Al or Ti in the COAS 5A sample (reference sediment).

7.3. Results & Discussion

Table 7.1 shows the results of grain size percentages and Figure 7.1 presents the ternary grain size diagrams for the marine area and the Gialova Lagoon sediments.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 773782.

Marine area			
Stations	Sand	Silt	Clay
COAS 1A	98	0	2
COAS 1B	100	0	0
COAS 1C	65	4	31
COAS 1D	4	19	77
COAS 2A	96	0	4
COAS 2B	96	0	4
COAS 2C	56	5	39
COAS 2D	6	24	70
COAS 3A	98	0	2
COAS 3B	96	0	4
COAS 3C	32	12	57
COAS 3D	9	19	71
COAS 3E	97	0	3
COAS 4A	26	14	60
COAS 4B	98	0	2
COAS 4D	11	18	72
COAS 5A	94	0	6
COAS 5D	20	16	63
COAS 6A	89	1	11
COAS 6B	100	0	0
COAS 6C	79	2	19

Gialova Lagoon			
Stations	Sand	Silt	Clay
COGIA1	38	6	56
COGIA2	23	56	22
COGIA3	29	50	21
COGIA4	9	11	80
COGIA5	25	15	60
COGIA6	59	2	39
COGIA7	28	10	62
COGIA8	16	15	69
COGIA9	14	15	71
COGIA10	20	12	68
COGIA11	9	13	78

The marine sediments are sands, clayey sands, sandy clays and clays. The marine sediments show high sand values in most coastal stations (except in Transect COAS 4). The sandy character implies: a) for the northern transects (COAS 1, 2 & 3), the influence of the small rivers and streams that discharge in the area, and b) for the southern transects (COAS 5 & 6), the influence of the rocky coasts. The sediments with the clayey character are the offshore ones. It is remarkable that the silt fraction is absent in the marine sediments.

The sediments of the Gialova Lagoon are less sandy than the marine ones. Most sediments are sandy clays, while silty sands dominate in the center of the lagoon.

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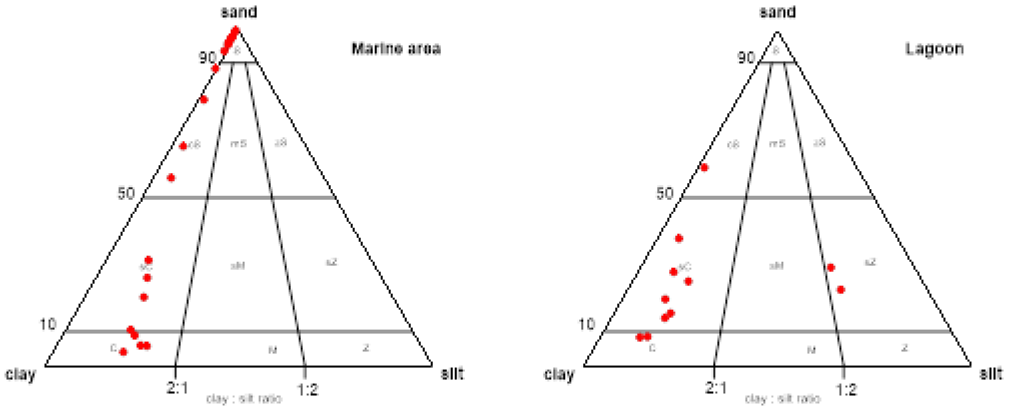

Figure 7.1 Ternary grain size diagrams (Folk, 1974) of the marine area and the lagoon sediment samples.

Tables 7.2, 3, 4 and 5 present the major elements oxides and the minor elements contents of the sediments of the marine area and the Gialova Lagoon.

Table 7.2 Major elements oxides percentages (%) of the marine sediments

Marine Area								
Stations	**Al**	**Si**	**K**	**Ca**	**Ti**	**Fe**	**Mg**	**S**
COAS 1A	4,64	72,1	0,57	9,0	0,540	2,01	0,58	0,026
COAS 1B	1,11	41,1	0,22	27,7	0,092	1,36	1,77	0,061
COAS 1C	3,84	67,8	0,87	10,7	0,314	1,68	0,66	0,066
COAS 1D	9,94	50,7	1,69	11,8	0,614	5,17	0,88	0,120
COAS 2A	2,13	71,4	0,72	6,6	0,454	1,13	0,03	-
COAS 2B	1,84	76,2	0,82	6,6	0,20	0,78	-	0,078
COAS 2C	3,39	58,2	1,01	11,2	0,23	1,56	0,30	0,113
COAS 2D	8,18	46,9	1,63	11,0	0,487	3,76	0,32	0,241
COAS 3A	1,33	72,8	0,70	9,0	0,208	0,70	0,05	0,052
COAS 3B	1,34	74,2	0,68	8,5	0,277	0,77	-	-
COAS 3C	3,95	51,3	1,07	11,2	0,30	1,74	0,5	0,187
COAS 3D	5,89	39,2	1,46	11,7	0,44	3,20	0,75	0,224
COAS 3E	-	12,9	0,24	41,8	0,025	0,35	1,76	0,395
COAS 4A	5,96	41,6	1,30	19,1	0,375	2,92	0,63	0,350
COAS 4B	0,79	75,1	0,47	11,3	0,058	0,70	0,94	0,012
COAS 4D	7,55	50,0	1,33	15,4	0,501	3,71	1,09	0,120
COAS 5A	1,5	6,0	0,26	43,3	0,108	0,94	3,41	0,410

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COAS 5D	5,81	48,9	1,09	17,9	0,416	3,02	1,33	0,141
COAS 6A	2,78	78,7	0,71	7,1	0,557	1,32	0,33	0,028
COAS 6B	0,26	3,3	0,17	45,5	0,028	0,68	3,4	0,321
COAS 6C	2,41	18,3	0,61	36,2	0,197	1,72	2,58	0,239
COAS 6D	8,44	50,2	1,48	14,1	0,549	4,26	1,16	0,132

Table 7.3 Major elements oxides percentages (%) of the Gialova Lagoon sediments

Gialova Lagoon								
Stations	Al	Si	K	Ca	Ti	Fe	Mg	S
COGIA 1	7,5	30,4	1,40	19,2	0,326	3,74	2,62	2,97
COGIA 2	8,9	24,3	1,33	20,3	0,318	3,83	3,15	3,10
COGIA 3	7,7	24,9	1,52	23,6	0,372	4,36	2,55	3,628
COGIA 4	11,1	30,7	1,89	9,5	0,436	5,20	3,82	3,711
COGIA 5	6,3	22,3	1,27	22,2	0,273	3,30	2,70	3,143
COGIA 6	4,4	16,1	0,81	32,5	0,172	2,13	1,83	1,956
COGIA 7	9,4	24,3	1,37	19,2	0,325	3,84	3,19	2,87
COGIA 8	7,9	23,6	1,33	21,6	0,284	3,64	2,75	2,60
COGIA 10	10,2	25,7	1,3	19,9	0,317	3,79	2,84	3,473
COGIA 11	10,0	28,4	1,68	13,6	0,391	4,51	3,67	3,308

Table 7.4 Minor elements contents (ppm) of the marine sediments

Marine Area										
Stations	As	Co	Cr	Cu	Mn	Ni	Pb	Sr	V	Zn
COAS 1A	7	4	3486	7	393	18	3	190	64	15
COAS 1B	35	4	123	6	670	10	1	848	44	5
COAS 1C	7	6	386	11	351	36	6	259	63	18
COAS 1D	17	13	265	31	723	119	18	265	199	60
COAS 2A	5	4	922	-	332	15	3	111	4	15
COAS 2B	7	1	291	1	229	13	4	115	15	9
COAS 2C	5	5	47	7	314	31	6	231	-	17
COAS 2D	14	12	178	26	580	92	15	257	81	56
COAS 3A	10	3	43	0	262	13	4	174	3	8
COAS 3B	9	3	364	2	271	13	3	147	5	8
COAS 3C	6	6	149	11	357	41	8	255	32	23
COAS 3D	9	12	19	15	400	77	16	290	-	48
COAS 3E	7	1	13	-	233	5	-	1369	-	1
COAS 4A	11	7	131	18	381	61	14	498	62	37
COAS 4B	12	2	43	32	259	12	5	303	27	18
COAS 4D	15	11	255	16	869	85	15	463	150	49

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COAS 5A	4	3	45	6	139	13	0	1516	29	8
COAS 5D	12	7	209	13	451	62	12	580	101	35
COAS 6A	3	6	1776	2	504	28	5	161	58	14
COAS 6B	20	3	29	2	604	7	3	1504	29	3
COAS 6C	11	6	106	9	312	41	6	1614	68	23
COAS 6D	17	11	245	22	542	99	17	386	149	49

Table 7.5 Minor elements contents (ppm) of the Gialova Lagoon sediments

Gialova Lagoon Stations	As	Co	Cr	Cu	Mn	Ni
COGIA1	10	8	146	21	804	84
COGIA2	9	9	138	21	1076	92
COGIA3	16	13	145	26	1060	115
COGIA4	9	15	154	40	861	131
COGIA5	7	10	115	25	926	83
COGIA6	8	5	99	15	846	55
COGIA7	8	11	130	19	867	93
COGIA8	9	13	130	30	1120	102
COGIA9	9	11	133	22	993	94
COGIA10	11	12	147	27	821	104

Tables 7.6 and 7.7 present summary statistics for the major and minor elements of the marine and the lagoon sediments

Table 7.6 Maximum and mean values of major elements oxides percentages (%) in the marine and lagoon sediments

	Al	Si	K	Ca	Ti	Fe	Mg	S
Marine area								
max	9,94	78,7	1,69	45,5	0,614	5,17	3,41	0,410
mean	3,96	50,3	0,868	17,6	0,316	1,98	1,12	0,166
Gialova Lagoon								
max	11,1	30,7	1,89	32,5	0,436	5,20	3,82	3,71
mean	8,34	25,1	1,39	20,1	0,321	3,83	2,91	3,08

Table 7.7 Maximum and mean values of minor elements contents (ppm) in the marine and lagoon sediments

	As	Co	Cr	Cu	Mn	Ni	Pb	Sr	V	Zn
Marine area										
max	35,3	12,6	3486	32,3	869	119	17,5	1614	199	59,9
mean	11,00	5,84	415	11,8	417	40,4	7,74	524	62,11	23,5

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Gialova Lagoon										
max	15,60	15,30	154	40,10	1120	131	30,5	1209	96,4	50,7
mean	9,47	10,8	134	24,9	950	96	25,1	600	74,0	39,0

It is evident that the values of the aluminum related major elements, such as K and Fe, and, in consequence, the finer minerals, are higher in the lagoon sediments, while Si, and coarse-grained quartz of fluvial origin, is higher in the marine sediments. Besides, Co, Cu, Mn, Ni, Pb and Zn, present enhanced values in the lagoon sediments, implying the aforementioned finer lagoon sediments and a possible anthropogenic influence.

Factor analysis in the marine sediments showed that the elements/variables are represented by three principal components that explain ~91% (~65, 17 and 9 %, respectively) of the variance in the original data set. The first component exhibited positive loadings for Al, Fe, Ti, K, Na, P, S, V, Cr, Mn, Co, Ni, Cu, Zn, Pb, silt and clay, and organic carbon. This component describes the aluminosilicate/detrital fraction of the sediments. The second component concerns Ca and Mg, and represents calcium carbonate of the shells of marine organisms. The third component showed high loading for Cr, and is related to the flysch of the area's parent rocks.

Factor analysis in the lagoon sediments revealed three principal components that explain ~ 88% (~43, 33, 12 %, respectively) of the variance. The first component showed high loadings for Si, Al, Fe, Ti, K, Mg, S, V, Cr, Co, Ni, Cu, Zn and As. The second component concerns Mg, P, Pb, clay and organic carbon. These two components represent the aluminosilicate/detrital fraction of the sediments. The third component involves Mn and silt, and is possibly associated with manganese mobility and diagenetic processes. Also, Ca shows high negative loading in the first component, implying the calcium carbonate of the lagoon organisms' skeletons.

In order to estimate the possible human contamination in the surface sediments of the study area, the Enrichment Factors (EFs) of the minor elements were calculated. Sample COAS 5A was used as a reference, as it is away from any anthropogenic influence. Moreover, its trace element values are between the lowest in the given data set. However, the EF calculation was proved to be non-applicable for the marine samples, due to their high sand and quartz content.

According to the EFs, the elements affected by anthropogenic influence (EF>2) in the Gialova Lagoon sediments are Mn and Ni, with EF values of 3.8 and 3, respectively. Taking into account that these EF values are low, and that these elements are associated with the detrital fraction and the within-sediment diagenetic processes, we conclude that there is not any human imprint in the lagoon sediments.

Table 7.8 presents, for comparison reasons, the maximum values of major elements oxides percentages and elements contents of the SW Messinia and the Gialova Lagoon, along with the ones of three adjacent marine areas, namely Messiniakos and Lakonikos Gulfs and Monemvasia Bay. The latter have been studied from HCMR in the past.

The marine area of the study area presents the maximum Si values compared with the other areas of Table 7.8. The enhanced Si values are related with the quartz grains, which are transferred to the sea through the small rivers and streams of the area. This is also the case for Cr, which shows very high values in the marine part of the study area, and comes from the flysch assemblages of the basin. The other minor elements present similar values with the ones of the adjacent areas, and significantly lower than the ones in polluted marine areas of Greece. The elemental values of the Gialova Lagoon are comparable with the ones of the adjacent marine areas.

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Table 7.8 Maximum major elements oxides percentages (%) and minor elements contents (ppm) of the study area and adjacent areas sediments

Element	SW Messinia	Gialova Lagoon	Messiniakos Gulf	Lakonikos Gulf	Monemvasia Bay
Si	78,7	30,7	25,4	35,4	32,5
Al	9,94	11,1	7,15	9,14	5,08
Ti	0,614	0,4	0,439	0,468	0,649
Fe	5,17	5,2	4,2	5,01	4,3
K	1,69	1,9	1,88	2,48	1,08
Ca	45,47	32,5	16,51	6,9	26,9
Mg	3,41	3,8	2,06	1,68	1,35
Mn	869	1120	4260	1975	315
Cr	3489	154	242	126	463
Cu	32,3	40,1	59	36,5	22
Zn	59,9	50,7	91,6	101	48
Pb	17,5	30,5	23,6	50,4	63
Ni	119	131	141	79,1	42
Ba	259	142	399	415	137
Sr	1614	1209	784	275	2271
V	199	96,4	143	142	114

7.4. Conclusions

The coastal sediments are mainly sands, with increasing clay percentages seawards, while the silt fraction is absent. The sandy seabed is the result of the rivers and streams discharges in the north and the rocky coasts erosion in the south, respectively. Silicon/quartz grains predominate in the coastal sediments, while the aluminosilicate/detrital fraction plays a minor role. Calcium carbonate from the marine shells and Cr from the flysch of the drainage basin were also recorded in the geochemical analyses. The Si and Cr values of the marine part of the study area are higher than the ones in adjacent marine areas, while there is not any anthropogenic influence in the coastal zone.

The sediments of the Gialova Lagoon are finer than the marine ones, mainly consisting of sandy clays and silty sands. Aluminum, K and Fe, along with a number of minor elements, i.e. Co, Cu, Mn, Ni, Pb and Zn, represent the detrital fraction of the lagoon sediments, while there is evidence of Mn diagenesis. Also, moderate Enrichment Factor values of Mn and Ni are not considered to be human related. Finally, the lagoon sediments present similar elemental values with other neighboring marine areas.

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8. Organic contaminants in marine and lagoon seawater and sediments

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8.1. Introduction

In this study we present the results of the analysis of various organic contaminants in seawater and sediment samples collected from marine and lagoon sampling stations. More specifically, we have studied: a) Polycyclic aromatic hydrocarbons (PAH), known to be produced from various anthropogenic activities (Latimer & Zheng, 2003), b) Organochlorine compounds (PCBs and DDTs), also coming from anthropogenic activities, c) various pesticides and insecticides related to the agricultural activities of the area, and d) phenols, known to be constituents of olive oil wastes.

8.2. Materials & Methods

8.2.1. Water samples

For PAH, organochlorine and pesticide analysis, seawater samples (2.5 L) were collected by Niskin bottles from the surface layer and close to the bottom of each station. For phenol analysis 500 mL were collected from each station and immediately acidified to pH<4. All the samples were analyzed in the H.C.M.R. organic chemistry laboratory which is accredited according to ISO/IEC 17025 for the analysis of polycyclic aromatic hydrocarbons (PAH) in seawater and sediments.

For PAH analysis, after the addition of internal standards (naphthalene-d8, acenapthylene -d10, phenanthrene-d10, pyrene-d10, chrysene-d12, perylene-d12, benzo(g,h,i) perylene-d12), the samples were extracted with 50 mL of n-hexane. The n-hexane extracts were dried over sodium sulphate and reduced first to 2ml in a rotary evaporator and then to a final volume of 50μL with the aid of a stream of pure nitrogen. Polycyclic aromatic hydrocarbons (PAH) were determined by gas chromatography - mass spectrometry (Agilent 7890GC-5975C MS) running in in SIM mode. The quantitation was based on the internal standards added before the extraction. In total 24 PAH were determined including parent compounds with 2-6 aromatic rings along with the alkyl substituted homologues of naphthalene and phenanthrene.

For organochlorine analysis, the samples were extracted with dichloromethane and the extracts were dried over sodium sulphate and reduced first to 2 ml in a rotary evaporator and then to a final volume of 50μL with the aid of a stream of pure nitrogen. The solvent was changed to isooctane and the determination was performed by gas chromatography - ECD (Agilent 7890GC)

For pesticide analysis, the samples were extracted with dichloromethane and the extracts were dried over sodium sulphate and reduced first to 2ml in a rotary evaporator and then to a final volume of 50μL with the aid of a stream of pure nitrogen. The solvent was changed to isooctane and the determination was performed by gas chromatography – mass spectrometry (Agilent 7890GC-5975C MS)

Phenols were determined by the 4-antipyrine photometric method after distillation of the samples in a Perkin-Elmer 835 spectrophotemeter

8.2.2. Sediment samples

Surface sediments were collected using a grab sampler, wrapped in aluminum foil and stored at -20°C prior to analysis. All the samples were analyzed in the HCMR organic chemistry laboratory, which is accredited according ISO/IEC 17025 for the analysis of polycyclic aromatic hydrocarbons.

For PAH analysis, in the laboratory, the sediment samples were freeze-dried, sieved through a 0.25-mm sieve and spiked with internal standards (naphthalene-d8, acenapthylene-d10, phenanthrene-d10, pyrene-d10,

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chrysene-d12, perylene-d12, benzo(g,h,i)perylene-d12, n-C24D50). Isolation of hydrocarbons was performed by 16 h Soxhlet extraction using a 2:1 dichloromethane– methanol mixture. The extract was saponified with methanolic KOH, and the non-saponified material was extracted with n-hexane, then cleaned up and fractionated by silica column chromatography. Two fractions were obtained, the first containing aliphatic hydrocarbons and the second the polyaromatic compounds. PAH analysis was performed by gas chromatography mass spectrometry (Agilent 7890GC-5975C MS). For the calculations, the molecular ion extracted chromatograms for each compound were used and the quantitation was based on the internal standards added before the extraction. A total of 32 PAH were determined including their alkylated homologues.

Phenols were determined by the 4-antipyrine photometric method after distillation of the wet sediment samples the samples in a Perkin-Elmer 835 spectrophotemeter.

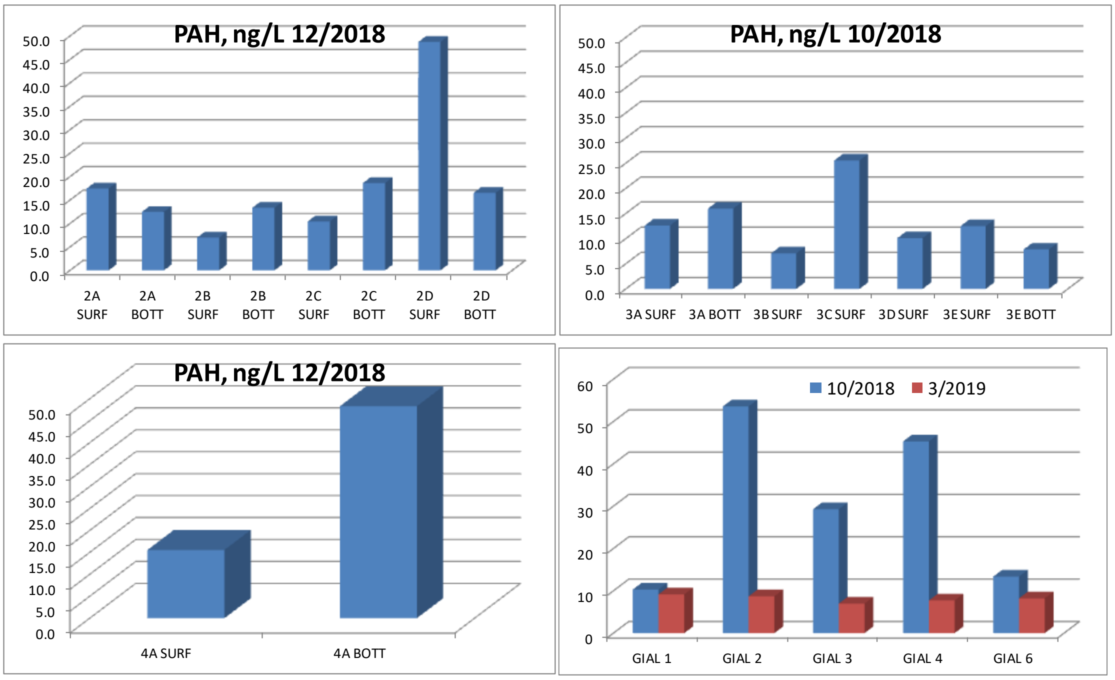
8.3. Results & Discussion

8.3.1. Seawater

Polycyclic aromatic hydrocarbons

Total Polycyclic aromatic hydrocarbon concentrations (The sum of the concentrations of all the compounds determined) in the various stations are given in Figure 8.1.

Their concentrations ranged from 7.0 ng/L to 53.6 ng/L (mean value: 20.6 ng/L) in lagoon waters and from 6.0 ng/L to 48.7 ng/L (mean value: 16.1 ng/L) in marine waters. These values are considered as low and indicate the absence of pollution (Hatzianestis & Sklivagou, 2002; Parinos & Gogou, 2016). No significant differences between the stations were observed. Naphthalene and its methyl derivatives were the dominant compounds in all the samples, followed by phenanthrene and its methyl derivatives, dibenzothiophene and low molecular weight PAHs (acenapthylene, acenapthene, fluorene). Concentrations of PAH with 4 or more aromatic rings (0.20 ng/L to 0.66 ng/L, mean value 0.40 ng/L), characteristic of pyrolytic origin, were in most case undetectable. No values exceeded the EQS thresholds set by European and National legislation (MSFD).



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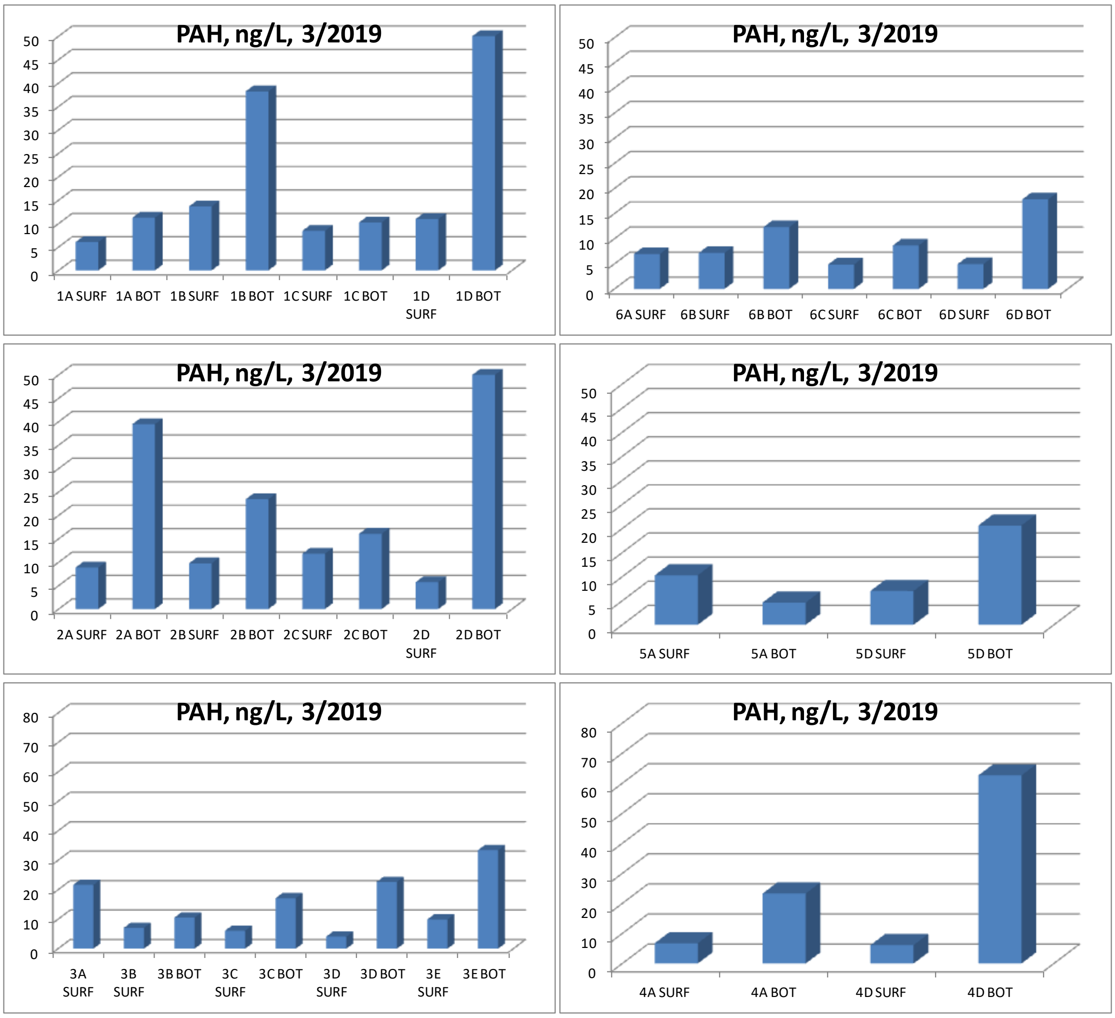

Figure 8.1 Total PAH concentrations (ng/L) in marine and lagoon waters.

ORGANOCHLORINE COMPOUNDS

Polychlorinated biphenyls and DDTs concentrations are shown in Figure 8.2.

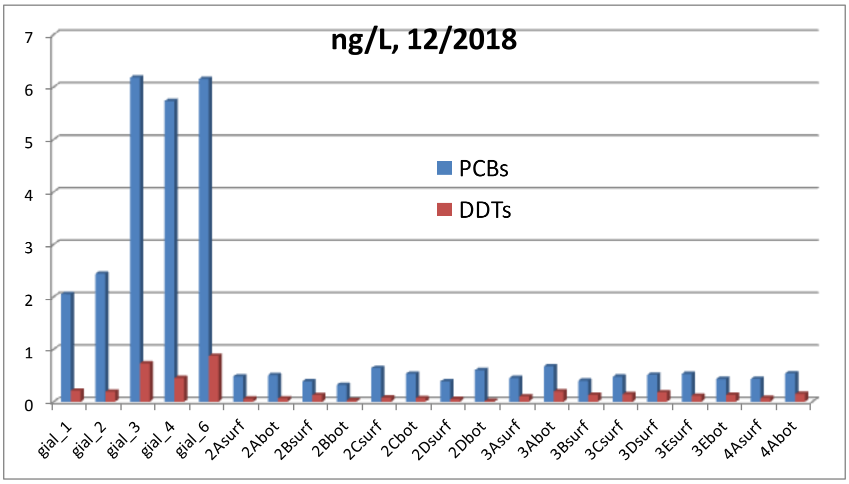

Figure 8.2 PCBs and DDTs concentrations (ng/L) in marine and lagoon waters.

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Total PCBs (the sum of 11 congeners) concentrations ranged from 2.1 ng/L to 6.2 ng/L (mean value: 4.6 ng/L) in lagoon waters and from 0.4 ng/L to 0.7 ng/L (mean value: 0.5 ng/L) in marine waters. Although all these values are considered as very low, it was clear that lagoon waters were more contaminated from PCBs than the marine waters.

Total DDTs (the of sum p,p'-DDT, p,p'-DDE, p,p'-DDD) concentrations ranged from 0.2 ng/L to 0.9 ng/L (mean value: 0.5 ng/L) in lagoon waters and from 0.01 ng/L to 0.19 ng/L (mean value: 0.10 ng/L) in marine waters. All these values are considered as very low.

Pesticides

Only lindane was detected in very low concentrations (0.5 – 3.2 ng/L in lagoon and < 0.03 ng/L in marine waters) (Figure 8.3)

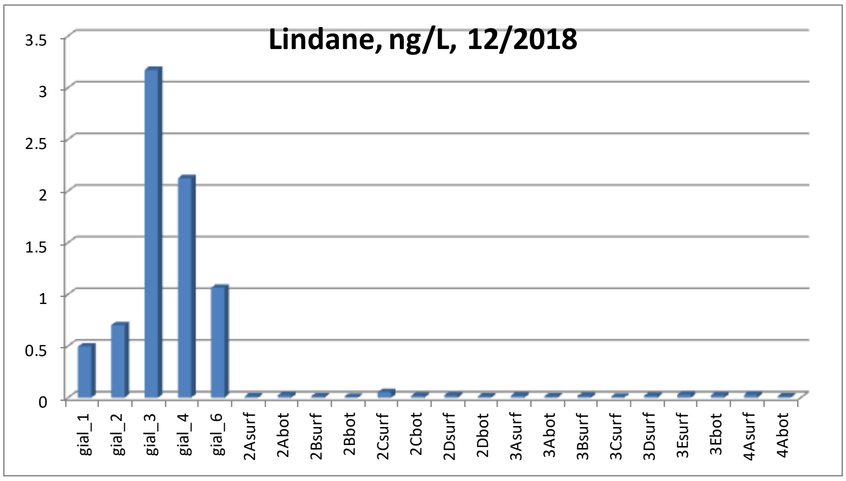

Figure 8.3 Lindane concentrations (ng/L) in marine and lagoon waters.

Phenols

The phenol concentrations measured in marine samples collected in December 2018 are shown in Figure 8.4. In all cases the concentrations were low indicating no significant influence from the olive oil wastewaters (Pavlidou et al., 2014).

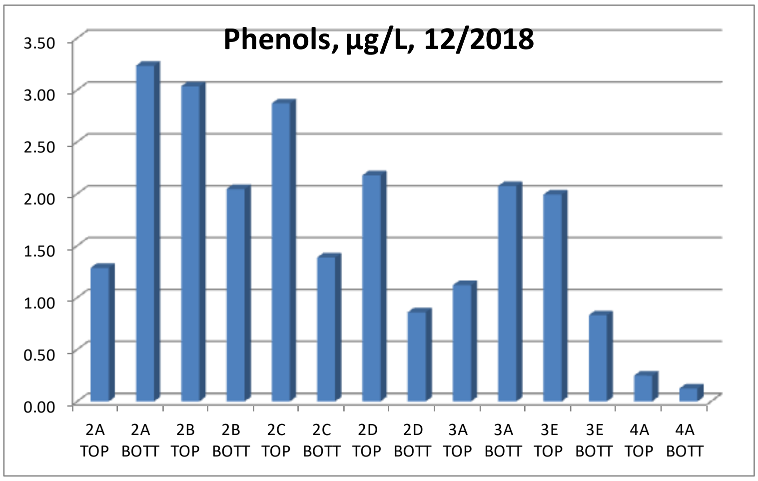

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Figure 8.4 Phenol concentrations (μg/L) in marine waters collected in December 2018.

The phenol concentrations measured in river water samples collected in December 2019 are shown in Figure 8.5. Again, in all cases the concentrations were low indicating no significant influence from the olive oil wastewaters (Lydakis et al., 2005). Much higher phenol concentrations were measured in Messinia rivers and streams during 2008-2011 (Pavlidou et al., 2014).

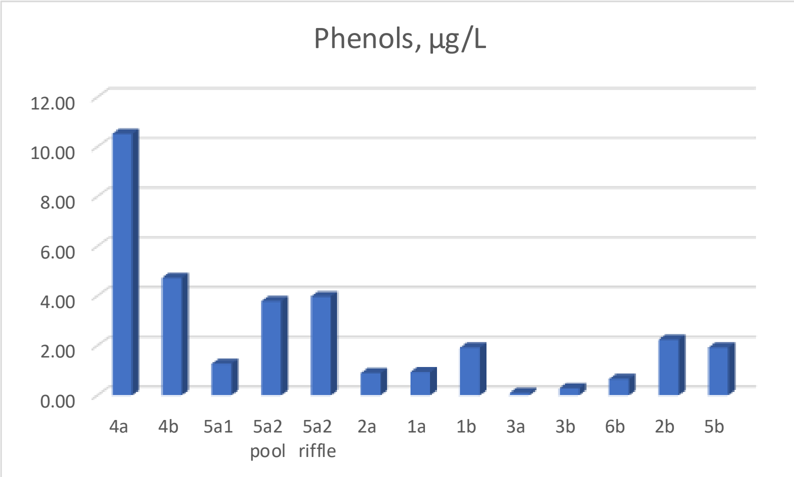

Figure 8.5 Phenol concentrations (μg/L) in river waters collected in December 2019.

8.3.2. Sediments

POLYCYCLIC AROMATIC HYDROCARBONS

Total Polycyclic aromatic hydrocarbon concentrations (The sum of the concentrations of all the compounds determined) in the various stations are given in Figure 8.6.

They varied from 43.3 ng/g to 180.2 ng/g (mean value 101 ng/g) in lagoon sediments and from 8.2 ng/g to 302.3 ng/g (mean value 87 ng/g) in marine sediments. These values are similar to those reported for the open north Aegean Sea (31-176 ng/g) (Hatzianestis et al., 1998) or the south Aegean Sea (14.7-161.5 ng/g) sediments (Gogou et al., 2000) and clearly lower than these measured in coastal zones (Botsou & Hatzianestis, 2012).

Depending on the sum of PAH concentrations, marine areas can be classified into four categories (Baumard et al., 1998): (a) unpolluted, 0–100 ng/g; (b) moderately polluted, 100–1000 ng/g; (c) highly polluted, 1000–5000 ng/g; and (d) very highly polluted, more than 5000 ng/g. According to this criterion most from the studied sediments are classified as unpolluted and only marine station 4A can be considered as moderately polluted.

In all cases, parent compounds with four or more aromatic rings, known to come from various combustion sources (pyrolytic PAH), were clearly predominant, accounting for more than 50% of the total PAH.

In all marine sediments a clear decreasing trend was observed from the open sea towards the coast.

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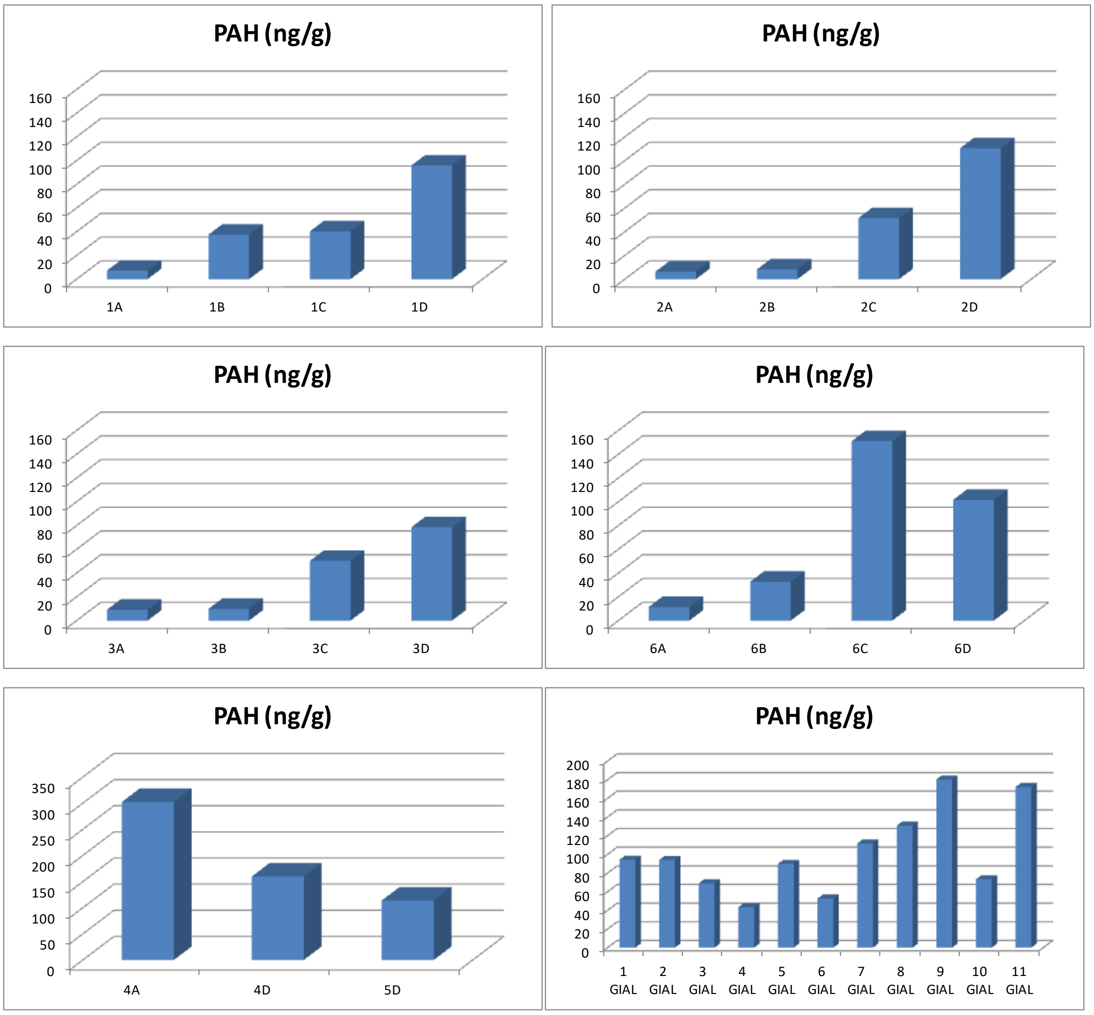
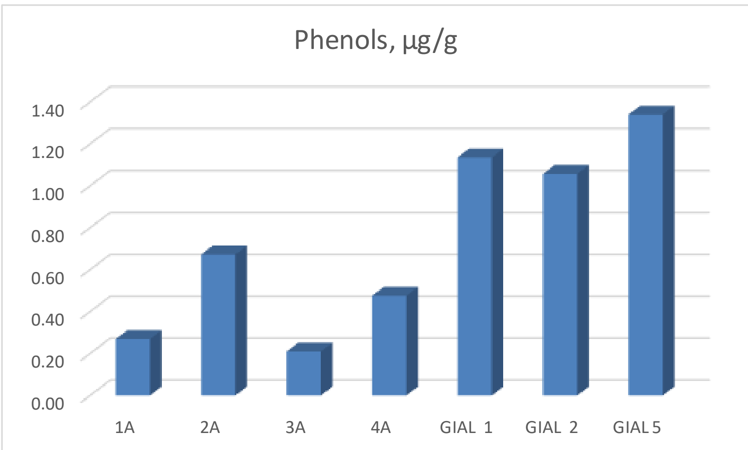


Figure 8.6 Total PAH concentrations (ng/g) in marine and lagoon sediments.

PHENOLS

Very low phenol concentrations were measured in all sediment samples (Figure 8.7). In lagoon samples phenol values were slightly higher than in marine samples, but in all cases remained < 1.5 μg/g indicating the absence of pollution



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 773782.

Figure 8.7 Phenol concentrations (μg/g) in marine and lagoon sediments.

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9. Assessment of the ecological quality of coastal and lagoon benthic communities

SARAH FAULWETTER, LAURA BRAY, NIKOLAOS KATSIARAS, NIKOLAOS PROVIDAKIS, KALLIOPI SIGALA, EMANUELA VOUTSINAS, GEORGE ARVANITAKIS, SOFIA REIZOPOULOU

9.1. Introduction

As a part of the environmental assessment in the coastal waters and in Gialova Lagoon in SW Messinia, a survey of the benthic ecosystem in relation to environmental conditions was performed. Benthic communities are commonly used for environmental quality assessment. Macrofaunal communities are not only considered a crucial component of the marine ecosystem, but also they respond reliably to both anthropogenic and natural stress (e.g. Pearson & Rosenberg, 1978). Thus, since most benthic organisms are primarily sedentary and directly depend on the environmental conditions in the sediment, they can be used as indicators to detect environmental impacts at a local scale. Macrofaunal communities are used as bioindicators in several National and European marine strategies [e.g. the Marine Strategy Framework Directive (MSFD) and the Water Framework Directive (WFD)]. Here, we present an assessment of the Ecological Quality Status of the benthic ecosystem as well as a community-based assessment of the study area and relate the results to the prevailing environmental parameters and conditions.

9.2. Materials & Methods

SAMPLE COLLECTION

Macrobenthos was collected from eleven stations: six deeper (12–67 m) coastal stations (COAS 2A, 2B, 2C, 3A, 3E, and 4A) and three stations in the lagoon (COGIA 1, 2, and 3). Two additional stations in the shallow subtidal (< 1 m) outside the lagoon (COAS 3F and 3G) were sampled to form a transect from the lagoon towards Station COAS 3E. Coastal stations were sampled from F/R “PHILIA” on 16 December 2018. A “Smith McIntyre” grab with a sampling surface of 0.1 m^2 and inspection flaps was used. Lagoonal stations and the two shallow-water stations outside the lagoon were sampled on 17 December 2018 from a small fishing boat or on-foot, using a hand-operated box corer with a sampling surface of 0.025 m^2. For acquiring benthic macrofauna data, two replicate samples were collected from each coastal station and three replicates from the lagoonal stations. Sediments were sieved using a metal sieve with a 0.5 mm mesh. Residues were stored in polypropylene containers, fixed with 4% formalin and stained with Rose Bengal. All relevant metadata, including habitat features, were recorded in field logs on site.

LABORATORY ANALYSES

Fixed macrofauna samples were washed under tap water, and organisms were collected from the sediment residues, sorted to main taxonomic groups, and preserved in 70% ethanol. Entire organisms or fragments bearing the head were identified to species level and their abundance was counted. In cases where identification to species level was not possible, due to poor preservation condition or unclear literature, taxa were assigned to a higher taxonomic level and classified into morphospecies. Juveniles were recorded separately.

9.3. Statistical analyses

BENTHIC COMMUNITIES AND RELATIONSHIP WITH ENVIRONMENTAL VARIABLES

Macrofauna data from the replicate samples were standardised to densities (abundances/m^2) and averaged per station. Colonial organisms and meiofaunal taxa (e.g. bryozoa, nematodes, copepoda, foraminifera) were excluded from the analyses, juveniles were included as their numbers were generally low.

The diversity of macrofauna communities was investigated by calculating the following indices: Species richness (S), Abundance (N), Pielou’s Evenness (J’) and Shannon-Wiener Diversity (H’) with log base 2.

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To assess relatedness of sampling stations based on their benthic communities, data were first log(x+1) transformed to reduce the effect of extreme abundances. The similarity between stations was calculated using the Bray-Curtis similarity index and visualized through a non-metric multidimensional scaling (MDS) plot.

The influence of the following abiotic parameters on the biotic communities was tested: depth, granulometry, temperature, salinity, total and organic carbon in the sediment, total nitrogen in the sediment, nitrate (NO_2), nitrite (NO_3), nitrate+nitrite (NO_2+NO_3), ammonium (NH_4), silicate (SiO_4), phosphate (PO_4), total dissolved nitrogen (TDN) and chlorophyll-α in the water column.

The similarity of the stations based on their abiotic characteristics was visualized through Multidimensional Scaling. Data were normalized prior to analysis and the similarity between stations was calculated using the Euclidian distance measure. Variables were fitted to the MDS using the *envfit* function of the *vegan* package in R and displayed as vectors on the MDS plot to identify those variables responsible for differentiating the stations.

To assess which environmental factors play a role in structuring the benthic communities, a Permutational Analysis of Variances (PERMANOVA) was performed on the log(x+1)-transformed community data, testing the factor “lagoon / deep coastal / shallow coastal” and the factor “sediment type” (characterization of sediment according to Folk, 1954), without interactions. A BIO-ENV analysis was performed using the normalized abiotic data in order to identify those abiotic variables that best match the multivariate community patterns.

Ecological Quality

The Ecological Quality Status of the stations was estimated using two different indices, BENTIX (Simboura & Zenetos, 2002) and the Multivariate AMBI (M-AMBI) (Muxika et al., 2007). The BENTIX index is used in national assessments of the coastal environment (e.g. in the WFD), whereas the M-AMBI is more suited for environments with low species richness, e.g. lagoons, and is used for transitional water bodies in Greece under the WFD.

Correlations of the BENTIX / M-AMBI results with the abiotic variables were calculated through a Spearman’s Rank Correlation.

All analyses were done in R (R Core Team, 2018), except for the calculation of M-AMBI which was done using the AZTI software (https://ambi.azti.es/).

9.4. Results & Discussion

Benthic communities and relationship with environmental variables

In total, 14999 individuals/m² belonging to 326 taxa were recorded at the deeper coastal stations, 1689 individuals/m² belonging to 12 taxa at the shallow coastal stations (COAS 3F and 3G) and 202667 individuals/m² belonging to 26 taxa at the lagoonal stations. Annelida was the most abundant phylum at most stations, except for Stations COAS 2A, 2B, 3F and 3G, where arthropods (crustaceans) were most abundant, and Station COAS 3A, where molluscs dominated.

Diversity differed strongly among stations (Table 9.1), with lagoonal and shallow-water stations near the lagoon showing a low species richness and low diversity (Shannon-Wiener). The lagoonal stations also presented high abundances, resulting, as expected, in a low evenness (Pielou’s index), whereas all the coastal stations were characterised by very evenly distributed communities. The near-lagoon shallow water stations were the least species-rich and showed the lowest abundances. Station COAS 4A showed by far the highest species richness and diversity. This station is deepest and characterised by a biogenic habitat (maerl), which is considered a priority habitat of high value for biodiversity due to its structural heterogeneity.

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The analysis of the community structure by means of multidimensional scaling revealed a clear separation of the lagoonal stations from the coastal stations, with the shallow-water coastal stations being placed in an intermediate position (Fig. 9.1A). This is confirmed by the PERMANOVA analysis, which found both the factor “lagoon / coastal (shallow) / coastal (deep)” and the sediment type to have highly significant effect on the community structure ($F = 5.1497$, $p < 0.001$ / $F = 2.2179$, $p < 0.001$, respectively).

The deeper coastal stations show a clear depth gradient, with the deepest station COAS-4A showing the lowest resemblance to the other coastal stations. Thus, the benthic communities clearly reflect the environmental conditions with a gradual transition from the lagoonal waters towards the deeper coastal sites. This strong differentiation of the stations based on their benthic community composition reflects the strong differentiation of the stations based on their environmental characteristics, and indeed, the MDS pattern obtained from the set of environmental variables shows an almost identical pattern (Fig. 9.1B).

Table 9.1 Diversity and ecological quality indices

Station	Species richness (S)	Mean abundance/ m² (N)	Shannon-Wiener (H' log_2)	Pielou's (J')	BENTIX value	M-AMBI value
COAS 2A	50	1003.33	5.04	0.89	4.39	0.7
COAS 2B	64	965	5.79	0.97	4.54	0.78
COAS 2C	84	1418.33	6.13	0.96	4.16	0.81
COAS 3A	61	1400.83	5.42	0.91	3.57	0.72
COAS 3E	46	913.33	5.16	0.93	4.5	0.66
COAS 3F	9	533.33	2.98	0.94	3.11	0.42
COAS 3G	5	355.56	2	0.86	5.6	0.34
COAS 4A	152	2680.83	6.78	0.94	4.54	0.97
COGIA 1	18	26837.04	1.94	0.47	2.05	0.19
COGIA 2	12	17980.74	1.86	0.52	2.02	0.21
COGIA 3	14	23658.52	2.11	0.55	2.06	0.25

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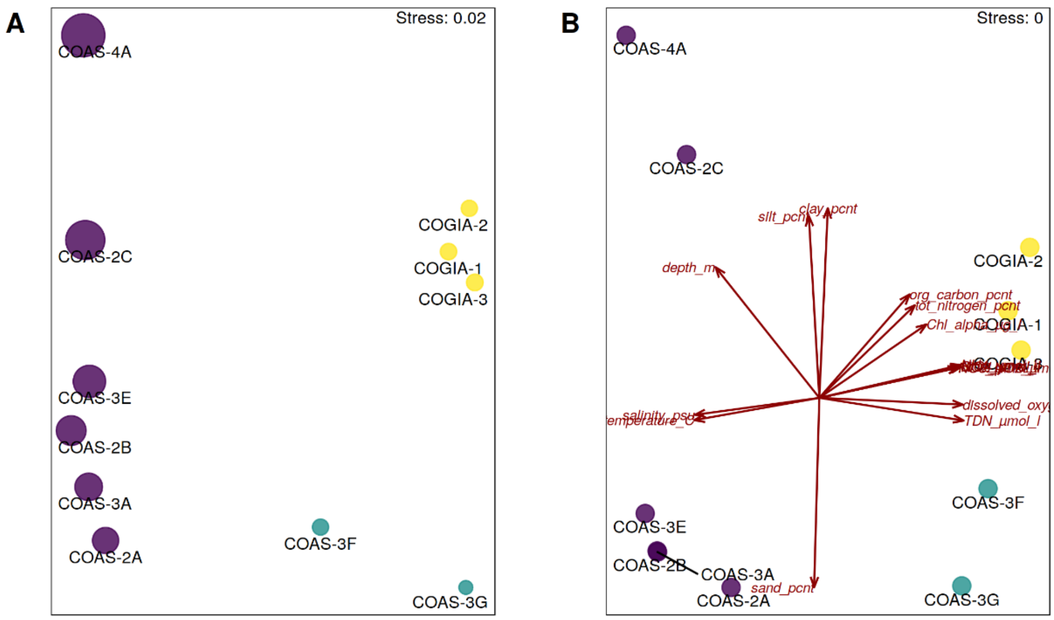

Figure 9.1 A) MDS based on species densities, point sizes indicate depth. B) MDS based on abiotic va*riables with fitted vectors of environmental variables as overlay. Point colours indicate* station characterization: yellow = lagoon, green = shallow water near lagoon, purple = coastal

Fitting the environmental variables onto the MDS plot reveals that sediment characteristics and depth are the two major vectors differentiating stations COAS 2C and 4A from the remaining stations. Salinity and temperature as well as nutrient load, physicochemical and geomorphological characteristics separate the coastal stations from the lagoon system, with lagoonal stations showing higher values in chlorophyll-α, dissolved oxygen, NH_4, NO_2, NO_2+NO_3, organic carbon, SiO_4, TDN, total carbon, total nitrogen and NO_3, and lower values of temperature and salinity than the deeper coastal stations. The shallow-water stations are characterised by high values of dissolved oxygen (due to wave action) and TDN, while their measurements of NH_4, NO_2 NO_3, NO_2+NO_3 and SiO_4 show intermediate values between coastal and lagoonal stations. Concerning salinity and temperature, the shallow-water stations do not show a gradient – the station closest to the lagoonal mouth shows similar temperatures and salinity values to the lagoonal stations, the station further towards the sea is characterized by a marine temperature and salinity regime.

The BIO-ENV analysis confirmed likewise that the combination of temperature, salinity, dissolved oxygen, total dissolved nitrogen and the percentage of sand was highly correlated with the pattern of the community structure ($p = 0.935$).

The benthic communities therefore reflect clearly the differences of the trophic status of the confined lagoon and the coastal area. Within the lagoon, stations do not differ based on their environmental characteristics and no confinement pattern from the opening to the more central parts of the lagoon can be observed. This is again reflected in the benthic communities which do not differ between the lagoonal stations. In the coastal area, on the other hand, depth and sediment characteristics seem to be the major factors structuring the benthic assemblages.

9.5. Ecological quality

The coastal stations in the study area present a GOOD or HIGH ecological status, indicating that the coastal area is not deteriorated from the surrounding anthropogenic activities. Contrarily, the lagoonal stations are classified as POOR or BAD, indicating that the ecosystem is strongly affected from anthropogenic stressors, especially from nutrient enrichment. The shallow stations near the lagoon show a POOR to MODERATE status, possibly in part due to the natural disturbance induced from the wave action and turbulence, but, as they also show a rather high nutrient load compared to the deeper coastal stations, anthropogenic disturbances cannot be excluded (Fig. 9.2). The two ecological quality indices (BENTIX/M-AMBI) applied in the study area show congruent results for most stations, however, the M-AMBI in the present study appears to be a more suitable tool to assess the quality for coastal environments with low species richness.

The Spearman's rank correlations of the two ecological quality indices with the environmental variables show that the BENTIX index is significantly ($p < 0.05$) negatively correlated with the nutrient load in the study area (NH_4: R = -0.69, p = 0.019; NO_2: R = -0.73, p = 0.011; NO_2+NO_3: R = -0.63, p = 0.038; SiO_4: R = -0.66, p = 0.031; total nitrogen in sediment: R = -0.65, p = 0.031). The M-AMBI index, on the other hand, is negatively correlated with nutrients chlorophyll-α and oxygen, but positively correlated with depth, salinity and temperature (Chl-α: R = -0.69, p = 0.019; depth: R = 0.82, $p < 0.005$; dissolved oxygen: R = -0.86, $p < 0.005$; NH_4: R = -0.87, $p < 0.005$; NO_2: R = -0.74 , p = 0.0093; NO_3: R = -0.88 , p = 0.0093; NO_2+NO_3: R = -0.92, $p < 0.005$; PO_4: R = 0.8 , $p < 0.005$; salinity: R = 0.87 , $p < 0.005$; SiO_4: R = -0.95 , $p < 0.005$; TDN: R = -0.72, p = 0.017; temperature: R = 0.91, $p < 0.005$).

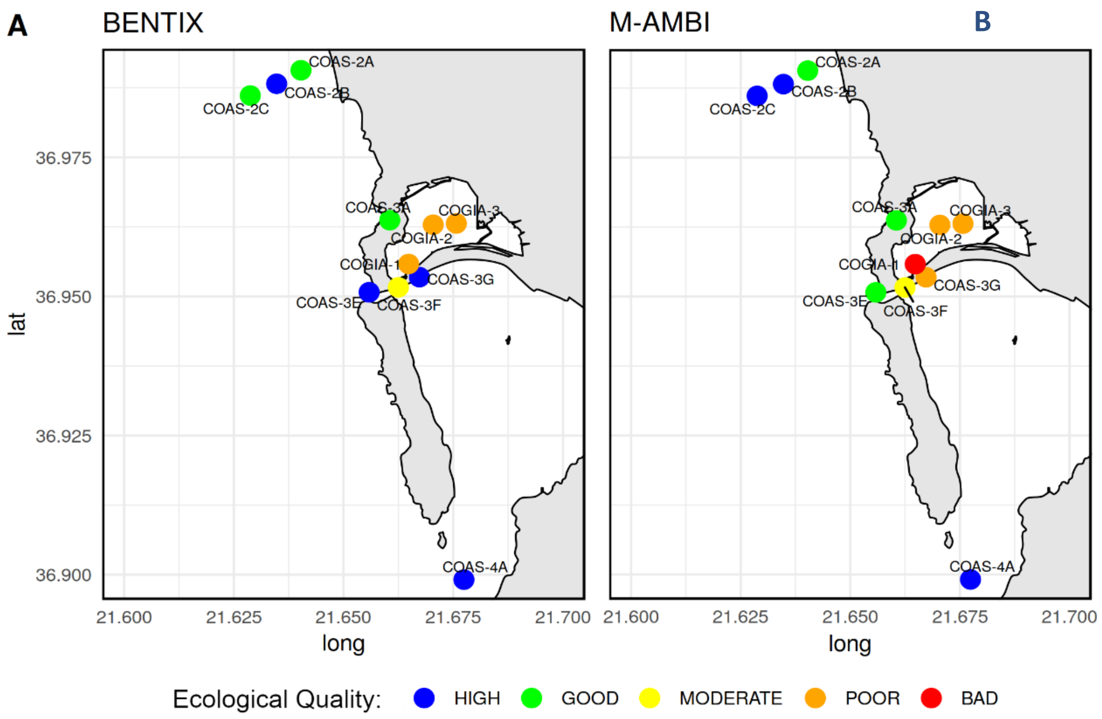

Figure 9.2 Ecological status of each station shown on the map of the area. A: BENTIX, B: M-AMBI

9.6. Conclusions

The results of the present study show a quality gradient, reflected by the composition and structure of the benthic communities, from the lagoon towards the coastal environment, in accordance with the observed nutrient and organic loads mostly originating from the local agricultural activities. The Gialova Lagoon has a restricted connectivity to the sea and thus water renewal is limited. Together with the high nutrient input from the watersheds of the area, this results in a severely impacted environmental status of the lagoon.

In addition, the lagoon acts as a sink between land and sea, retaining the nutrients and organic loads, and forms a buffer to the coastal ecosystem. This situation calls for careful managerial decisions, since on the one

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hand the quality status of the lagoon, which is a Natura 2000 site, could be improved by facilitating water exchange with the sea, on the other hand, this would cause an increased influx of nutrients and possibly other pollutants into the nearby coastal waters. The assessment of pressure drivers on the benthic ecosystem of the case study area has been published as 'Open Access' by Bray[2] et al. (2022).

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10. Marine litter on beaches of the SW Peloponnese

HELEN KABERI AND CHRISTINA ZERI

10.1. Introduction

Marine litter -any anthropogenic persistent, manufactured or processed solid material discarded, disposed of or abandoned in the marine and coastal environment- is globally acknowledged as a major societal challenge of our times due to its significant environmental, economic, social, political and cultural implications (Galgani et al., 2010). Marine litter is a human pressure, not only to marine habitats and species, but also to ecosystem services, with important implications for human welfare (Werner et al., 2016). An increasing body of evidence highlights the tremendous impacts of marine litter to economic sectors, such as tourism and recreation, fisheries and aquaculture, maritime transport and navigation; as well as to infrastructure and services for individuals, local communities and enterprises (Vlachogianni, 2018).
The present study aims to assess the amounts, composition and sources of marine macro-litter on beaches of the SW Peloponnese.

10.2. Materials and Methods

The beach litter surveys were carried out in November 2018 on three beaches of the SW Peloponnese: Romanos beach close to Costa Navarino Resort, Voidokilia beach and Divari beach on the northern coast of Navarino Bay (Fig. 10.1). All the beaches receive a great number of tourists during summer.

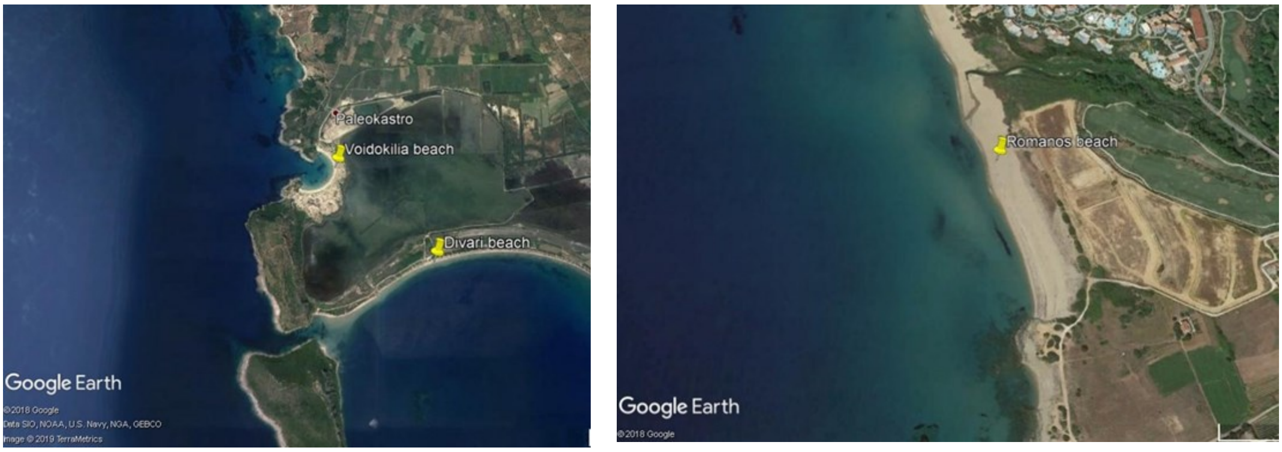

Figure 10.1 The three sampling sites for beach litter

All surveys performed followed the approach described by the EU MSFD TG10 "Guidance on Monitoring of Marine Litter in European Seas" (Galgani et al., 2013) with some modification related to the size of the sampling unit. The survey sites were selected taking into consideration the following criteria: i) they had a minimum length of 100 meters in order to allow a fixed 100-metre stretch to be surveyed; ii) they were characterized by low to moderate slope (~1.5-4.5°); iii) they had clear access to the sea (not blocked by breakwaters or jetties); iv) they were easily accessible to survey teams; and v) they were ideally not subject to cleaning activities.
During the surveys, all macroscopic beach litter items larger than 2.5 cm in the longest dimension were collected and counted, ensuring the inclusion of caps, lids and cigarette butts. In each survey, a predefined

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sampling unit was used, corresponding to a fixed section of a beach covering the area defined by a 100-metre stretch of beach along the strandline.

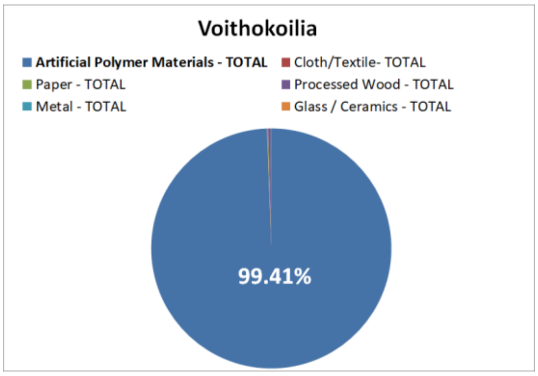
10.3. Results and Discussion

The results of the total litter density are summarized in Table 1 and compared with the recommended baseline values of UNEP (2015).

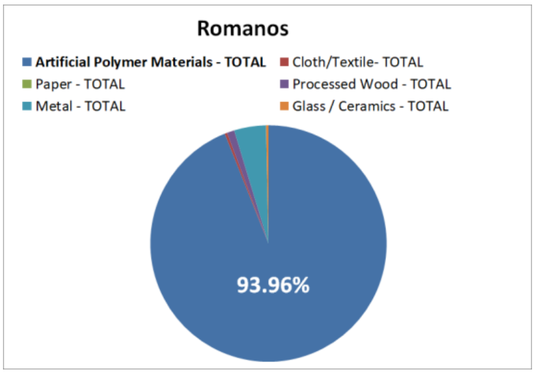
Table 10.1 Litter density (items/100m) on the beaches of SW Peloponnese.

Beach	Items/100 m	recommended baseline value (UNEP, 2015) items/100 m
Voidokilia	3239	450-1400
Romanos	596	
Divari	746	

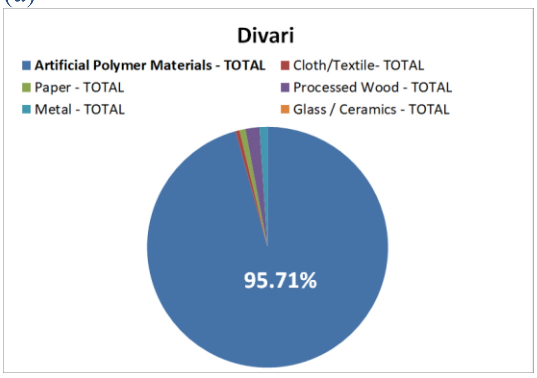
It is clear that the litter density at the Voidokilia beach exceeds the recommended baseline values.
The qualitative composition of the litter items shows that the abundance of plastics is far higher, as it is systematically found above 90% (Figure 10.2).



(a)



(b)



(c)

Figure 10.2 Percentage composition of beach litter on (a) Voidokilia, (b) Romanos, and (c) Divari beaches, in November 2018.

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Detailed analysis of the individual categories of artificial polymer-plastic waste showed that plastic pieces (2.5 - 50 cm) (MSFD-G79 code), polystyrene pieces (2.5 - 50 cm) (MSFD-G82 code) and cigarette butts (MSFD code - G27) are found in all cases in the largest abundances while otherwise there is considerable variation between the three beaches.

The attribution-by-litter type method is usually used to determine the potential sources of marine litter (Tudor and Williams, 2004). This method is based on the assumption that certain marine litter items are typically or widely used by particular sectors (e.g. tourism) or are released into the environment via well-defined pathways (e.g. sewage outlets). The item-to-source attribution scheme applied here, followed the approach described by Veiga et al. (2016). The sources of marine litter are classified into eight major categories: (1) shoreline, including poor waste management practices, tourism and recreational activities; (2) fisheries and aquaculture; (3) shipping; (4) fly-tipping; (5) sanitary and sewage-related; (6) medical related; (7) agriculture; (8) non-sourced.

However, many litter items cannot be directly connected to a particular source. Some items can have a number of potential sources and pathways of entry. For example, plastic drinks bottles can be left on beaches by tourists locally, thrown overboard by merchant shipmen, disposed of improperly in-land and washed into the sea through storm water overflows. They can also enter the sea via rivers and, because they are buoyant, can be easily transported into a given area by water currents and prevailing winds. On the other hand, the source and way of release of some litter items, especially fragments, is impossible to identify.

In the case of the SW Peloponnese beaches, pieces of plastic/polystyrene (excluding the net fragments) were the most common item of beach litter; however, their source is difficult to be assessed. Cigarette butts were the second most frequent litter item found on Voidokilia and Divari beaches, attributed to the first sources category, the shoreline i.e. improper disposal of cigarette butts by beach-users and visitors to the coast.

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11. Integrating the assessment of existing environmental stresses and human activities in SW Messinia

Erasmia Kastanidi, Aristomenis P. Karageorgis

11.1. Introduction

Coastal areas exhibit some of the most complex dynamics in terms of coupled social-ecological systems and uncertainties in terms of future scenarios (Jozaei, 2020) as they are the spaces where the land meets and the sea and where human communities can be dependent on the land and/or the sea. As a result, it is not surprising that conventional environmental and natural resource management approaches are limited in their ability to respond to these complex dynamics (Benson and Craig, 2014; Carpenter et al., 2019), often lacking in their inclusion of social concerns and values (Sharma and Norton, 2005) or failing to provide an integrated assessment and understanding of the environmental and biological stresses. SW Messinia and the watershed represent such a system providing a range of livelihoods and values to local communities. The area has been selected as case study in COASTAL because of the apparent land-sea interaction taking place, and the well-developed relationships between local authorities and the tourist industry. However, a comprehensive examination of the environmental status of both the coastal and inland areas was not available, as was the case with the other selected case studies. Within COASTAL, a separate task was foreseen, to support the collection, analysis, and assessment of multi-parametric environmental measurements and information that would be used for modeling exercises. The present D33 Deliverable collates all data collected during field works (12 coastal campaigns and 2 marine cruises) that lasted up to winter 2021. The report focuses on the environmental stresses and integrated assessment in view of a coastal SES cannot be complete without a connection to the human activities and the use of the data for building and validating the system dynamics models for the case are of SW Messinia (COASTAL D13 & D14).

11.2. Human Activities

The study area includes the town of Pylos and numerous small villages and has a total population of 10,444 inhabitants (2011). In terms of human activities the study area is a typical example of rural Greece, where the economy has been traditionally based on farming and small scale food manufacturing (olive oil) and where now it is transitioning towards tourism following global trends and the new images of rural spaces (Papadopoulos & Hatdjimichalis, 2008). Farming activities in SW Messinia have mainly been olive groves and olive oil production is the local food manufacturing industry, with a total of 30 olive oil mills, located mainly on along the two main rivers, and olive cultivation covering 75% of the total arable land. The industry also includes a number of pomace processing units as well as bottling and standardization plants. The olive oil produced in the area has gained a PDO (Protected Destination Origin) recognition through the extension of the Kalamata Protected Designation of Origin (PDO) olive oil to the rest of the region of Messinia[3]. The olive groves, which are scattered on the sloppy landscape, along with maquis and garrigues give it its characteristic features. The presence of sandy beaches and in particular Voidokilia Beach, which is often featured in lists of best European beaches (Guardian, 2019) acts as the big tourist attraction pole in the area but the tourism sector is seeking to also explore the rural images for tourism expansion. However, tourism expansion goes hand in hand with infrastructure development (hotels, roads and airports; Fig. 11.1) increasing pressures on the agricultural land which has a land use rate of almost 20% per year (calculated for the years 2000 to 2021 through spatial analysis).

[3]https://op.europa.eu/en/publication-detail/-/publication/a974b890-424a-11e5-9f5a-01aa75ed71a1/language-en

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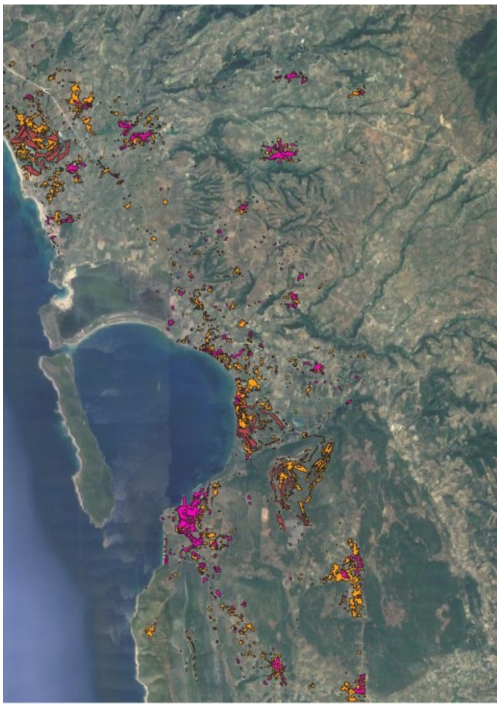

Figure 11.1 Aerial view of MAL II Case study area showing built up land in 2000 (pink areas) and in 2020 (Orange areas), as well as the site of the two golf courses that were created in the same period.

The area also has a small but important fishing community, as the Gialova Lagoon is considered an important breeding and spawning ground for many commercially important fish species and it is managed as an extensive aquaculture space. The town of Pylos is the largest settlement in the area with a total of 2,767 residents (ELSTAT, 2011), which also includes the small harbor of Pylos. The area also has many important archaeological and modern history sites and monuments both on land and underwater. These include several castles and fortresses with archaeological findings that range to the Early Helladic Era (3000-2000 BC) to modern history urban buildings[4]. The area also has a number of caves and two of present archaeological evidence of their use during the Late Neolithic Period (5300 – 4500 BC) as occasional pastoralism grounds relative to the nomadic livestock breeding practices of the time.

Within this region is an important bird area of Europe, Gialova Lagoon. It is the southernmost stopover of birds migrating from the Balkans to Africa, giving shelter to 270 bird species, some listed on the IUCN red list. It is also an important breeding area for fish while the sandy areas around Gialova provide a unique habitat for the endangered African chameleon. A Natura 2000 area which has suffered from lack of consistent management efforts, as well as drainage and land use change and which, as the results from this EIA show is the most degraded ecosystem of the region (CHAPTER 9, this report).

11.3. Environmental Assessment and System Dynamics modeling

Field data can be applied to derive regionalized functional relationships between key variables, which can be used in models. Chapters 1 through to 10 of this report collect all the data obtained as a result of the environmental assessment of the water bodies (rivers, coastal waters and Gialova lagoon) of the case study area.The field data were used to estimate several indices that provide the ability to score the environmental status of each water body and support problem identification, the potential causes, and if required, suggestions for remediation. Connecting and using the data in the model was not a straightforward process

[4] http://wwk.kathimerini.gr/kath/7days/1994/10/02101994.pdf

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as the model was built to simulate dynamic processes linked to current human actions, whereas the data recorded provided knowledge of current conditions that could have been related to past actions (Such as the legacy issues reported by MAL3). Temporal and spatial scale mismatches have been reported by others in relation to analyzing social –ecological interactions in systemic approaches (Glaser and Glaeser, 2014, Cumming et al 2006). However, the results from the benthic analysis in coastal, transitional and inland waters has enabled us to identify which are the long term pressures in the environment and which can be charaterised as seasonal. The specific hydrological features in the area (Chapter 3) and especially the effect of the open sea do not allow high concetrations of agricultural runoff on olive mill effluents to remain in the coastal waters hence they do not appear to have long term effects, with the exception of Gialova lagoon (analysed in detail in Chapters 6 and 9).

Most importantly, the report has clarified that the most important stress to the local ecosystems is that caused during draught periods and the lack of freshwater in the lagoon, and at the mouths of the streams, as well as upstream (Chapter 2). This is not to undermine other issues such as the effluents from the olive mills or wastewater, but these issues seem to have a temporal or seasonal effect on the ecosystems, which was not modeled, given the annual timestep chosen for assessing overall issues in timescales compatible with the rest of the needs of the project. In addition, recent policy changes affecting the procedures of olive oil extractions are expected to further reduce the impact of the effluents in the streams, thus these have not been included as the goals of the projected included the effect of future policy changes (COASTAL D05 and D11). On the other hand, the stress caused by the lack of freshwater is noticeable on an annual basis and especially for the lagoon it could even cause a collapse in the fishing activities if additional measures, including the restoration of freshwater flows are not taken or are delayed. Figure 11.2 shows the modeled effect on the lagoon fisheries if measures are delayed (SSP2 and SSP4) and if taken in time (SSP1). A more detailed analysis is included in COASTAL deliverable D20.

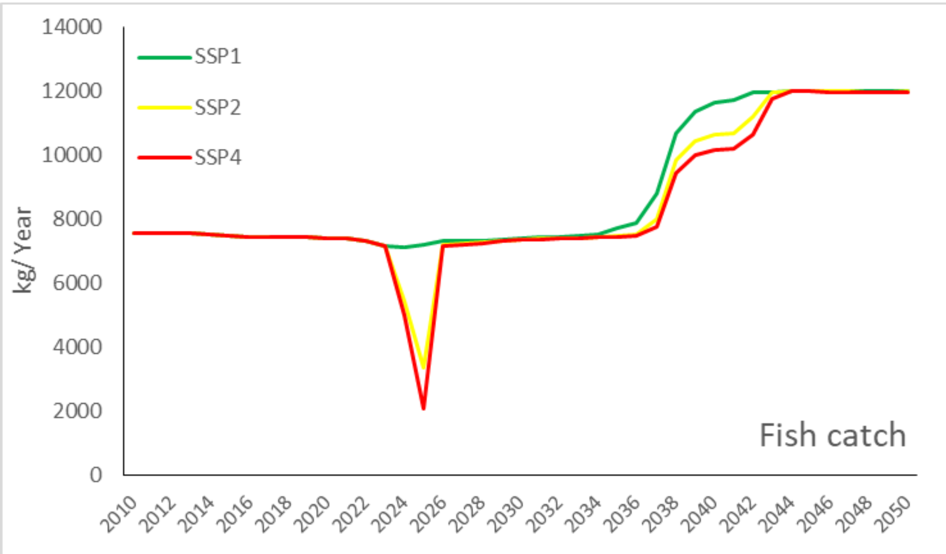

Figure 11.2 Scenario outputs of the lagoon fisheries.

Other data used in the analysis included data on **nitrogen concentration** in rivers and streams which were used to make the calculations of the different type of N-loads in the catchment (Build up land, olive orchards and other crops) together with published and local farmers data (Berg et al, 2018; Gkisakis et al, 2020) on the differences in fertilizer application between conventional, integrated and organic farming practices as suggested by other researchers for alleviating scale mismatch issues (Herse et al, 2020). The effect of nitrogen input in the lagoon was also included in the System Dynamics model built, recognizing that accumulated input of increasing nitrogen concentrations could have impacts on the ecosystem (Chapter 9).

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Similar to the nitrogen concentrations, data on marine litter on the beaches of SW Peloponnese were used to identify issues associated with the current capacity of the waste management efforts, especially in relation to the high seasonality of tourism. Similarly to the nutrient concentrations, the differences in temporal scales between the occurance of the effect (during high peak season in summer) and the modeling timescale (annual) made it difficult to use the measured data. However, the findings were used for informing the Policy and Business Roadmap action measures on waste management capacities in beaches and the built up areas of the region, including the hotels.

11.4. Conclusions

A social-ecological systems approach along the land-sea continuum, as applied in COASTAL, combines the knowledge gained from the social and natural sciences, with the knowledge of those living and working with this interconnectedness. Combining data collection in small streams, transitional waters (Gialova Lagoon, Natura 2000 site), and the coastal area, together with local knowledge during the same period has increased the understanding of ecological and social interactions and our ability to assess the causes and effects of the anthropogenic activities. Issues relating to scale mismatches, both with respect to the modelling efforts and between the social and natural components of the system can be an issue where substancial time series of data are not available. Still valuable information in relation to the degradation of ecosystem services (e.g. fish provision, water circulation and purification, support of biodiversity), derived from these integrated assessments can be connected to past and current anthropogenic activities using stakeholder knowledge.

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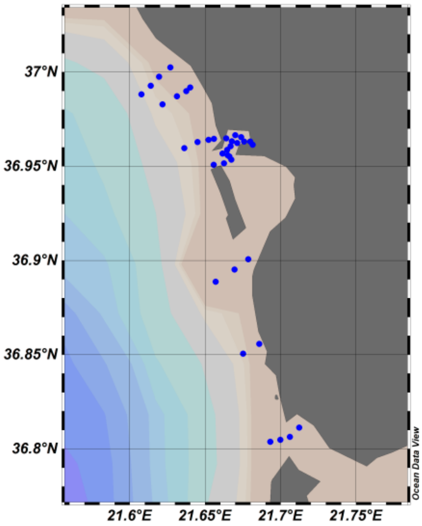
12. DATA

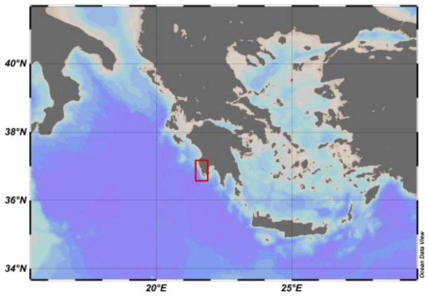
In the frame of COASTAL Project, the Institute of Oceanography/HCMR coordinated the Multi-Actor Lab for the SW Messinia case study. In this area (SW Messinia) five research cruises in three periods were conducted, as shown in the next Table 13.1.

Table 13.1 Sampling cruises in the SW Messinia

Platform	Cruise Name	Start Date	End Date
Fishing vessel	COASTAL_1B	17/10/2018	17/10/2018
Philia RV	COASTAL_2A	16/12/2018	16/12/2018
Fishing vessel	COASTAL_2B	17/12/2018	17/12/2018
Philia RV	COASTAL_3A	22/03/2019	23/03/2019
Fishing vessel	COASTAL_3B	24/03/2019	24/03/2019

The specific geographic area and the stations are shown in the following images:





Cruise Summary Reports

HNODC/IO/HCMR (the Hellenic NODC, belonging to the IO of HCMR) with the cooperation of the Chief Scientists of the cruises created a Cruise Summary Report (CSR) file for each cruise.

Subsequently the five CSR files were submitted to SeaDataNet (SDN) and were uploaded to the SDN CSR Catalogue:

https://seadata.bsh.de/Cgi-csr/retrieve_sdn2/start_sdn2.pl (old version managed by BSH, German; search by ‘Responsible Laboratory’, ‘Country’ = ‘Greece’ and ‘Institute’=’HCMR/IO’).

or https://csr.seadatanet.org/ (upgraded version, managed by IFREMER, France; search by ‘Collate centre=’HCMR/HNODC).

Quality Assurance

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement N° 773782.

HNODC collected the data sets and metadata information of these cruises from the responsible laboratories. Data were delivered to HNODC in excel format, and have been subjected to quality control by the responsible scientists.

Data format: Initially data were transformed to ODV SDN format according to SDN Standards (https://www.seadatanet.org/Standards/Data-Transport-Formats).

26 ODV data files containing 242 stations were created whereas every measured parameter was mapped to the appropriate SDN Common P01 Vocabulary term (https://vocab.seadatanet.org/search).

The data files compliance to the ODV SDN format was checked by SDN Octopus software (https://www.seadatanet.org/Software/OCTOPUS).

The following Table 13.2 summarises the results per Parameter Group (P03 vocabulary)

Table 13.2 Results per Parameter Group according to P03 vocabulary for COASTAL sampling in SW Messinia

Parameter Group	Parameters	Stations	Files
Nutrients, chlorophyll, dissolved oxygen, carbon, nitrogen, phosphorus in water	13	45	5
Metals, carbon, nitrogen, mineralogy in sediment	30	35	3
Metals, carbon, nitrogen, mineralogy in sediment cores	30	2	1
Particulate matter	1	43	5
Hydrocarbons (PAHs, PCBs) in water	47	41	4
Hydrocarbons (PAHs) in sediment	33	37	4
Zooplankton biomass	1	28	2
Zoobenthos taxonomic abundance	2	11	2
Total	**157**	**242**	**26**

Quality Control: Finally, the ODV files were inserted into ODV software for further quality control by the Data Centre (HNODC) according to the SDN protocol (https://www.seadatanet.org/Standards/Data-Quality-Control).

Making data FAIR

Metadata were uploaded to the SDN infrastructure to enable the data discovery and access according to the FAIR principles. To this end, an ISO 19115/19139 xml file, named Common Data Index (CDI) was created for every station allowing the data discovery, access and download at station level granularity. The data access is regulated by the license of the data. Currently, the COASTAL data are labeled as restricted and downloading is not permitted.

242 CDIs containing the metadata of each station were created using MIKADO software (https://www.seadatanet.org/Software/MIKADO) and submitted through standard procedures to SDN (https://www.seadatanet.org/Metadata/How-to-contribute/Data-CDI).

Data and metadata were additionally checked at the HNODC local server by RM, the automated manager of SDN (https://www.seadatanet.org/Software/Replication-Manager) before the final upload of the metadata at the central SDN CDI catalogue.

Metadata could be found at the following URL:

https://cdi.seadatanet.org/search/welcome.php?query=1624&query_code={CB446520-3372-4741-8D97-07074040D499}