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Development of a Protocol for a Sustainable Blue Economy in the Coastal Zone: Case Study and Preliminary Results in a Coastal Industrial Area in the Eastern Mediterranean

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Abstract: During the last decade, growing demand has prevailed for environmental protection and the application of sustainability principles toward the coastal environment. As the coastal zone constitutes one of the first recipients of the impacts of climate change due to the rise in sea level, integrated coastal zone management arises as a significant tool for the study of vulnerable coastal ecosystems. In combination with ICZM, the use of indicators and ecosystem services analysis couples all of the information, leading to an integrated approach and opportunities for a sustainable blue economy in coastal ecosystems. The aim of the present study is to form a protocol for a sustainable blue economy in the coastal zone, which will investigate and define the current capacity and the boundaries of a coastal ecosystem with specific characteristics of industrial activity, cultural heritage, and a protected natural environment. The case study for this research is the Gulf of Elefsis, a special sea basin in the eastern Mediterranean, located a short distance from the Athens metropolitan area. The Gulf of Elefsis is characterized by a developed coastal zone, which includes intense industrial activity, the ancient historical sights of Elefsis, the environmentally protected wetland of lake Koumoundourou, the town of Elefsis, a trade port, and growing shipbuilding activity.

Keywords: sustainable blue economy; integrated coastal zone management; shipyard; industry; tourism

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1. Introduction

It is a fact that, nowadays, there is an immediate need to protect and strive for the sustainable development of marine environments. The sustainable blue economy has emerged in the last decade as a great driving force, leading the way for achieving sustainability in the marine environment [1]. Recently, the importance of the marine environment has started to be widely known and accepted, showing its great potential for blue growth [1]. This can be translated into the demand for a remarkable boost of economic and social development, combined with the creation of new job positions and new opportunities for business activities [2]. It is crucial to define the environment's threats. Otherwise, it is estimated that a significant part of blue investments will no longer be sustainable in 2030. This condition, if translated into numbers, is calculated to be equal to EUR 250 billion invested into unsustainable activities that will not be friendly to the environment within the European Union [3]. The notion of a blue economy has been used to protect the oceans and marine resources worldwide, while it has been interpreted in multiple different ways according to the preferences of each stakeholder due to the gap between the definition of blue economy and the information on the means of its attainment [4–6]. The whole concept is harmonized with the terms of sustainable development and green economy, applied to the gains derived from ocean activities [7]. When it comes to the definition of a sustainable blue economy, the United Nations report describes it as "an ocean-based economy that provides equitably distributed social and economic benefits for current and future generations, while restoring and protecting the intrinsic value and functionality of coastal and marine ecosystems" [8].

An important milestone on the road to a sustainable marine environment is the achievement of the sustainable development goals (SDG) related to blue economy activities, which are [9,10]:

- SDG 1: End poverty in all its forms everywhere;
- SDG 7: Ensure access to affordable, reliable, sustainable, and modern energy for all;
- SDG 8: Ensure opportunities for decent work and economic growth;
- SDG 9: Build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation;
- SDG 13: Take urgent action to combat climate change and its impacts;
- SDG 14: Conserve and sustainably use the oceans, seas, and marine resources for sustainable development;
- SDG 15: The protection of biodiversity by the reduction of population pressure;
- SDG 17: Partnerships of organizations and institutions at a global scale to achieve the goals.

This means that the activities that operate in the coastal zone should, in some way, contribute to the above-mentioned sustainable development goals. Another important step to sustainability in the marine environment is to capitalize on the advantages of digitalization in industry and tourism, as well as to mitigate the environmental footprint in all sectors that operate in the coastal zone. The goal for sustainable development in each sector is different and depends on the land use in each part of the coastal zone [2,3]. Different coastal areas demand different solutions in order to achieve sustainability according to their existing conditions [11]. For example, in the sectors of industry and tourism the environmental pressures are different, and sustainability can be achieved through the adoption of specific measures accordingly, such as stricter and continuous control of atmospheric emissions from the industrial plants and the installation of energy and water saving systems in hotels.

Integrated Coastal Zone Management

The coastal zone is one of the first areas to face the impacts of climate change, because of the rise in sea level. The Integrated Coastal Zone Management (ICZM) contributes to the confrontation of the problems that occur due to climate change, providing, at the same time, a way to avoid any differences that might appear related to land uses and the allotment of wealth and supplies [12]. The major tool used in ICZM approaches to engage and assess the level of integration, is the application of indicators [13].

The aim of the present paper is the formation of a protocol for a sustainable blue economy and the management of a developed coastal zone with intense industrial activity, cultural and environmental interest, and growing tourism potential. The protocol is based on two different methods, the application of which is expected to lead to matching results.

This research project pursues the formation, at its final stage, of a decision-making tool that will be used to define the current capacity and boundaries of a coastal ecosystem with the above-listed characteristics. This will actually form the second part of the project in the next publication.

2. The Study Area

The case study for this research is the Gulf of Elefsis, a small and semi-enclosed bay presented in Figure 1, which is located north of the Saronic Gulf and includes a suburban town in the West Attica regional unit of Greece [14,15]. It is situated about 18 km northwest from the center of Athens, and is part of its metropolitan area. The Gulf of Elefsis covers an area of 68 m^2 and is characterized as shallow, with a maximum depth of 35 m [15]. The climate is characterized as subtropical, while the altitude is 1.41 m [16]. The Gulf of Elefsis presents an interesting geomorphology that consists of multiple basins, coastal formations, and drainage systems [15]. The Elefsis Gulf connects with the neighboring Saronikos Gulf through two small channels, leading to restricted water renewal and fostering the creation of anoxic conditions at greater depths during the warm months [17]. The water supply fluctuates between 240 m^3/s and 450 m^3/s [18], while the annual sedimentation rate is estimated to be between 0.5–0.8 cm [19].

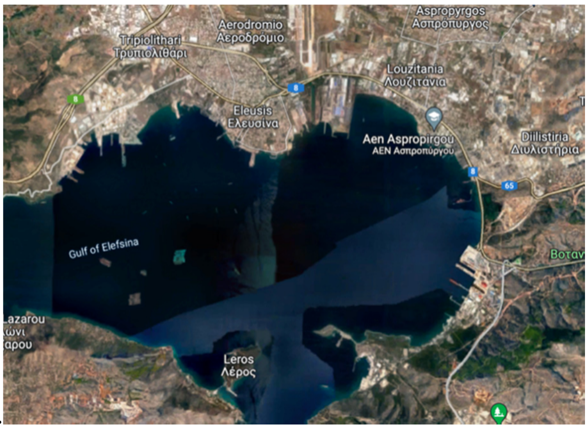

Figure 1. The map of Elefsis Gulf [14].

In recent decades, there has been a gradual and encouraging decline in the accumulation of metals at the bottom of the bay [20]. The coastal zone of Elefsis includes multiple ancient Greek historical sights and the naturally protected lake Koumoundourou. The main factors that stress the local ecosystem are:

- Shipbuilding: A leading industrial activity in the Elefsis Gulf. Shipyards are one of the major installations that operate in the coastal zone, contributing to a high extent to the local GDP. The increasing growth of the shipbuilding activities may impose greater pressure on the local ecosystem;
- Industry: The study area presents intense industrial activity along the coastal zone. Most of the pollution is concentrated in the northern part of the Gulf, which receives effluents from the industrial plants (e.g., oil refineries, shipyards, cement, and steelworks) and from the major industrial area of the Thriassio plain, a short distance from the sea [21,22]. Among the various industrial installations within the coastal zone of the Elefsis Gulf, both petroleum and cement industrial plants stand out. The prevalence of heavy metals in the Gulf of Elefsis is attributed to the intense industrial and shipbuilding activity [23]. An additional source of pollution in the past decades has been the outflow of urban wastewater from the plants servicing the city of Athens [21];
- Marine traffic: Being mainly a trade port, the Elefsis Gulf is one of the areas where most marine accidents with regard to pollution diffusion occur [24]. Especially regarding the marine traffic in the port of Elefsis, the mean annual activity in the last decade rose to 379 vessels, and to 530.930 tn of traded loads [25]. The occurrence of oil spills is one of the most common marine pollution incidents in the area [24];
- Tourism: The local tourism ecosystem is vulnerable against environmental and economic degradation. Indicators are used as the tools to define the coastal zone's capability to be transformed into a sustainable touristic destination, stabilizing the imbalance between tourism and industrial activity.

The Natural Environment of Lake Koumoundourou

Lake Koumoundourou is located in the northeastern part of the coastline of the Elefsis Gulf and is a naturally protected wetland and a protected archaeological site since 1974 according to Greek legislation, including a 50 m surrounding zone [26]. The avifauna of the wetland includes various species, the majority of which are gulls (about 30,000) and starlings [27]. The surface of the lake is 39 km^2, while the mean and the maximum depths are 1 m and 2.6 m (northeast), respectively [28,29]. From a geological perspective, Koumoundourou Lake is characterized as vulnerable due to its karstic composition [30]; in order to avoid its further deterioration, attention and special treatment are required [15,31]. Environmentally protected ecosystems, such as Koumoundourou lake, are important factors of climate regulation, as they make significant contributions to the microclimate around the urban environment [32]. Except for regulating ecosystem services, the wetland of Koumoundourou Lake also provides cultural ecosystem services, as it offers opportunities for recreation, education, and spiritual activities. All in all, the wetland of Koumoundourou Lake is considered to be a highly vulnerable transitional water body of special cultural importance [30].

A special feature of the study area is the coexistence of great cultural heritage, heavy industrial activity, and tourism, all in the same coastal zone, while there is an emerging need and great demand for the installation of new industrial activities.

3. The IES Protocol

In order to define and examine the ecosystem boundaries, an ecosystem-based management approach with the creation of a protocol under the prism of ICZM was attempted. The protocol is based on a three-step analysis, while its name originates from the acronym Indicators Ecosystem Services (IES), as its major components are the indicators and the ecosystem services. Through this protocol, we analyzed how and to what extent do the existing activities comply with the sustainable blue economy.

The first step of this approach is an indicator-based analysis. The indicator setting process is the fundamental element of this approach and starts with the selection of a goal, which has to be based on the fundamentals of sustainable development. Afterwards, the indicator that refers to the goal is defined, followed by the selection of a specific unit that measures the indicator, as it is presented in Figure 2. This indicator setting process is applied to the coastal ecosystem, and a corresponding table was formed. The resulting table includes all the characteristic parameters that describe the coastal ecosystem, such as financial, social, natural, cultural, and environmental parameters, transfusing a holistic approach to this analysis. The creation of a table containing the appropriate indicators for the study of a coastal ecosystem, with the specific characteristics of industry, cultural heritage, and protected environment, is the first added value of the research.

Figure 2. The indicator setting process.

The second step of this approach is an ecosystem services analysis through a pressure analysis model; the structure of the Driver Pressure State Impact Response (DPSIR) model is presented in Figure 3 below [33]. The application of the DPSIR analysis model issues an organized perspective to the analysis of polyparametric ecosystems [34]. The ecosystem services are the benefits that humans derive from the ecosystem and result from the ecological processes that contribute to social wellbeing [35,36]. The concept of ecosystem services is increasingly being used to assess the potential impact of changes in human behavior on the environment [37]. The analysis of the ecosystem services through the DPSIR starts with those ways in which the drivers put pressure on the ecosystem, which accordingly affects the state of the natural resources. Subsequently, the impacts of the pressures on the coastal ecosystem, as well as the possible responses that stakeholders may take into account in order to face those impacts on the ecosystem and its services, are described. The use of the ecosystem services context transfuses a holistic approach to the analysis of the coastal ecosystem.

The above two steps (indicators and ecosystem services) operate as being supplementary to each other, improving the level of integration in the management process. In the final step of the protocol, a map for each approach with the quantification and the visualization of the data derived will be constructed. The geospatial map derived from the indicator-based analysis will be similar to the depiction which occurs from the ecosystem services approach. Both maps will be part of the next publication of this research project and will be presented therein.

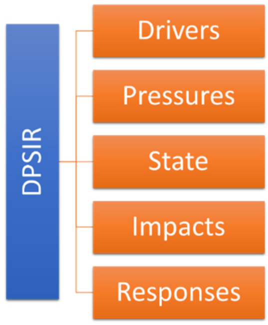

Figure 3. The DPSIR analysis model.

The application of the protocol will be brought out through three major steps, as described in Table 1 below.

Table 1. The steps of the IES protocol.

Step	Description
1	Creation of a table with goals and their indicators.
2	Creation of a list of the ecosystem services and the implementations of the DPSIR model.
3	Mapping of the results from the previous steps.

4. Implementation of the IES Protocol in the Coastal Zone of the Elefsis Gulf: Preliminary Results

After an extended study of the coastal zone of Elefsis and its parameters, the most characteristic indicators have been outlined. A major component of the indicators from the study area is the goal that they represent, as this expresses the current needs of the Elefsis Gulf and is based on sustainable blue economy principles. Typical examples of these goals are the demand for environmental health, sustainable coastal economics, social wellbeing, and the preservation of natural and cultural identity. The units that express and measure the indicators are presented in Table 2.

Table 2. The indicators in the study area.

Goal	Indicator	Measurement
Natural&cultural identity	Area of protected land	Area in km^2
	Alterations in protected habitats and species	Number and population of species
Coastal economy	Employment	Employment percentage in each sector
	Port traffic	Number of vessels
		Volume of goods
	Intensity of tourism	Number of overnight stays
Climate change	Sea level rise	Stormy days
Environmental health	Atmospheric pollution	Concentration of micropollutants
	Oil pollution	Volume of oil spills
Carbon footprint	Energy consumption	Kw consumed by each sector
Sustainable use of land	Built up land	Area built in km^2
Water quality	Ecological and chemical status	Measured by the responsible authorities
	Bathing water	According to the EU Directive
	Nutrients in coastal water	Concentrations of P and N
Social wellbeing	Local and cultural identity	Participation in festivals and social events
		Museum's visitors
Public health and security	Crime	Number of recorded incidents
	Provision of public health	Number of health infrastructures

With the application of step 2, the ecosystem services and the pressures of the Elefsis Gulf have been analysed through the DPSIR model, as presented in Figure 4 Box A presents the drivers and the pressures they put onto the coastal ecosystem, such as industry and urbanization, while box B presents the ecosystem's present state, expressed by the chemical and ecological status of the water bodies of Elefsis, as well as the air quality. Box D describes the impacts those pressures have on the coastal ecosystem and the way they affect the associated ecosystem services. A characteristic example is the impact of environmental degradation, which affects a series of supporting cultural and regulating ecosystem services, such as biodiversity, pollution control, and recreation. Box C presents the responses that could help with the confrontation of the pressures and the restoration of the coastal ecosystem, such as the enactment of stricter regulations on environmental pollution, the information given to the local communities, and the allowance of financial incentives for the reduction in carbon footprint from local industries and businesses. All the parameters of the DPSIR model interact with each other and are closely interlinked, as it is presented by the arrows between the boxes A to D.

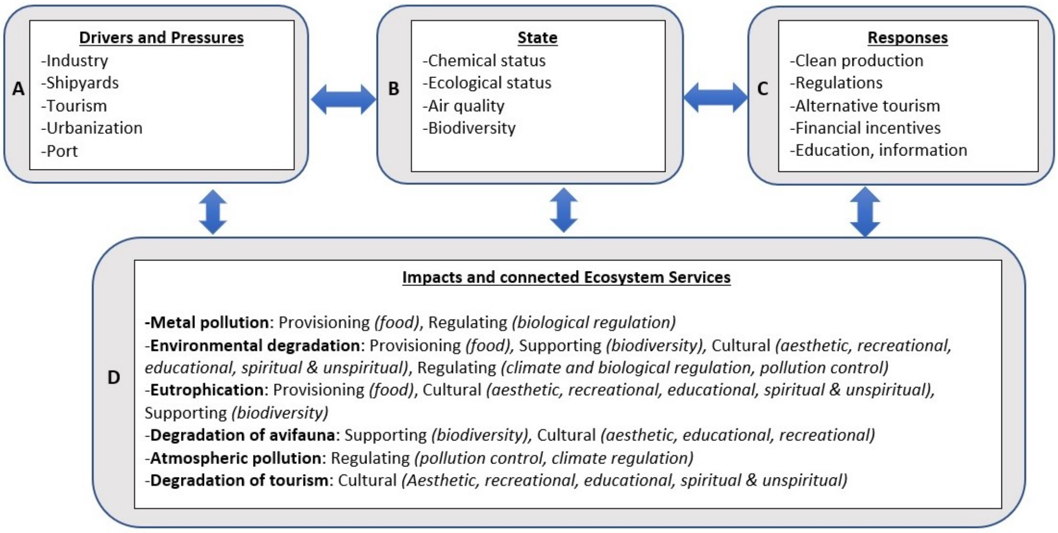

Figure 4. The ecosystem services analyses through the DPSIR model.

As for the results of step 3, the expected outcome is the creation of two similar maps from the two protocol approaches. The maps will include data related to the indicators, such as the number of overnight stays in touristic infrastructures and the concentration of pollutants and nutrients in the water, marine traffic, atmospheric emissions, and area of built-up land. The geospatial map from step 1 will present the distribution of the indicators in the coastal zone of the Elefsis Gulf. The map from step 2 will depict the present state of the ecosystem services in the study area.

5. Conclusions

The road to a sustainable blue economy is long and starts from the coastal zones, where most of the anthropogenic activities are concentrated. The development of a protocol for a sustainable blue economy in coastal zones is an important step for the preservation of the coastal environment. The IES protocol aims to form a useful ecosystem analysis tool based on the approach of indicators and ecosystem services. The Gulf of Elefsis is an area of special scientific interest, as it combines the parameters of culture, industry, and environment in just a small geographical space. Urbanization, shipbuilding and repair, marine traffic, and intense industrial activity seem to place significant environmental pressures on the Gulf of Elefsis and have been analyzed through the IES protocol. The added value of the IES protocol includes the creation of a table of indicators for areas such as these and also the matching of the results of the two approaches in the mapping stage. A further investigation of these pressures in the Gulf of Elefsis is expected to provide more specific results on the ecosystem's boundaries and capacity, leading to the creation of a useful decision-making tool for the local authorities and other stakeholders.

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