ECOSYSTEM SERVICES AND SPATIAL PLANNING IN SENSITIVE AND VULNERABLE COASTAL AREAS: A CASE STUDY IN THE AEGEAN SEA

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ABSTRACT

Ecosystem services include natural processes and biotic resources that can significantly contribute to environmental sustainability and fulfill human life. Oxygen production, transformation of organic matter, waste assimilation, cleansing, biogeochemical processes supporting recycling of organic matter and detoxification of pollutants as well as highly valued landscapes and seascapes are among the most significant ecosystem services. In addition, protection, production, delivery of goods and services from the natural environment are highly valued by the community. In the marine environment biological resources (fisheries and aquaculture), installations for energy production based on renewable sources and recreational use of the coastal environment are the main benefits to humans from the point of view of biological services. Use of the coastal waters as a dispersion field for sewage and industrial effluents should also be valued as an ecosystem service. However, many of those activities are conflicting and therefore implementation of marine spatial planning practices should be adopted. This is particularly important in sensitive and vulnerable areas like the Aegean marine ecosystems and the Aegean Islands. In the present work, the main ecosystem services in the Aegean are reviewed and methods for spatial planning scenarios focusing on blue growth based on ecosystem services are proposed for the Northern and Southern Aegean Regions.

Keywords: marine spatial planning, multiple criteria analysis, ecosystem sustainability, the project THAL-CHOR

1. Introduction

As the human population these days exceeds seven billion people at a global scale, there is a tendency for over-exploitment of natural resources and activities focusing at development but sometimes a number of these activities conflict with each other. The impacts from the overexploitation of open-access resources and use of the natural system as a waste sink are not obvious from the basis of day-to-day environmental management. However, over a scale of decades, it becomes obvious that massive depletion of natural resources such as high quality potable water, clean air, mineral fuels, productive land, fisheries and biodiversity cannot be compensated by natural processes. This is why the trade-off between competing activities regarding individual and societal interests is becoming more evident (Daily, 1997). No management scheme can be successful on a long run if goods and services flowing from natural ecosystems are not appreciated by the society. With the exception of carbon dioxide permits, ecosystem services are not trade in formal markets and therefore they do not send price signals of quantitative shortages of goods or quality deterioration regarding their supply or condition. By the term “ecosystem services” we mean “conditions and processes through which natural ecosystems and the species that make them up, sustain and fulfill human life” (Daily, 1997). As the terrestrial environment is more or less at a point of saturation regarding human activities, the current tendency is towards development in the marine environment, known as “blue growth”. Technological exploitation innovations allow extraction of abiotic and biological resources at rates that could not have been thought of one or two decades ago. The European Union learning from lessons on the terrestrial environment has recently launched a Directive on Marine Spatial Planning, MSP (EU, 2014). The MSP Directive established the foundation for a sustainable use of the European Seas. However, European Seas differ in their physiography, type and intensity of human pressures as well as water quality conditions (Karydis and Kitsiou, 2014). Implementation of this Directive should take into account the particular characteristics of each marine area regarding coastal population, economic growth, environmental constraints and future trends. The Aegean Sea is characterized by sensitive and vulnerable marine ecosystems. These ecosystems on one hand provide valuable ecosystem services and benefits but on the other hand their sustainability requires very careful planning that should take into account both: possible impacts and at the same time the limited carrying capacity of the system. The objective of the present article is to review the environmental and societal situation prevailing in the Aegean Sea and try to set some criteria at a preliminary level on the type of activities that would be compatible to the special features of the Aegean marine environment.

2. Ecosystem services and benefits

Many authors tend to discriminate between ecosystem services and human benefits. By the term "ecosystem services" natural processes contributing to environmental quality are included, whereas what is known as "benefits" refer to "ecosystem's goods", useful to sustain human communities. Ecosystem services regarding the marine environment and coastal zone include: (a) water purification (b) mitigation of floods and droughts (c) detoxification and decomposition of wastes (d) maintenance of biodiversity (e) partial stabilization of climate – moderation of temperature extremes (f) moderation of wind force and waves and (g) provision of aesthetic beauty. Ecosystem benefits refer to seafood, marine recreational activities, biomass fuels, pharmaceutical products and their precursors.

Marine ecosystem services and benefits are driven by complex natural cycles. The sun is the major source of energy but there are also delicate interactions between land and the marine environment. Natural processes operate on very different spatial and time scales. Biogeochemical cycles are global and induce the movements of carbon, nutrient compounds (such as nitrogen and phosphorus compounds) and trace metals through the whole ecosystem including the marine environment from surface to the bottom, the atmosphere and the terrestrial environment. On the contrary, life cycles of marine bacteria can take place and be completed within a drop of seawater. Between these two spatial extreme cycles, various other processes materialize. Different processes are also characterized by different rates. For example the biogeochemical cycle of carbon is faster than that of phosphorus by a few orders of magnitude and life cycles of microorganisms are usually much faster than the carbon cycle. If natural cycles are disrupted, rapid changes can threaten human welfare and finally civilization. Humanity is now at the doorstep of this possibility and therefore any activities should be the result of thoughtful and careful planning by putting extra weight on ecosystems' sustainability. This can become possible in spatial planning where there is still "vital space" for designing human activities.

3. The physiography of the Aegean sea

The Aegean Sea is the third major sea in the Eastern Mediterranean having a volume of 7.4×10^4 km^3. Water exchanges between the Aegean and the adjacent seas take place in the South Eastern with the Levantine Sea through the Kasos, Karpathos and Rhodos Straits; the South Western part of the Aegean communicates with the Ionian Sea through the Elafonisos, Kithira and Antikithira Straits. The Northern Aegean Sea communicates with the Black Sea through the Bosporus Strait, the Marmara Sea and the Strait of Dardanelles. The Aegean Sea is characterized by the large number of Islands (more than 2000), many gulfs and an irregular coastline. External plateaus of Thermaikos, Samothraki, Limnos and Cyclades being the largest, alternate with deep basins: the North Aegean Trough (1600m), the Chios Basin (1160 m) and the Cretan Sea are the most noteworthy (Stergiou *et al.*, 1997).

The main water masses circulating in the Aegean Sea are the Black Sea Water (BSW), the Levantine Intermediate Water (LIW), the modified Atlantic Water (AW) and the Eastern Mediterranean Deep Water (EMDW). The BSW enters the Aegean through the Strait of Dardanelles and the average flux is estimated to be about 200 km^3y^{-1} (Tixeront, 1970). BSW moves westward towards the Greek mainland and then follows a southward route forcing a cyclonic route circulation pattern that prevails in the northern and western Aegean. The LIW is generated in the Levantine area: LIW is characterized by high salinity and enters the Southern Aegean through the Cretan Arc and it is detected as subsurface water mass (30 - 200 m). The Atlantic Water mass characterized by low salinity enters the Mediterranean Sea through Gibraltar and flows into the Eastern Mediterranean through the Strait of Sicily. Part of the AW mass enters the Aegean through the Cretan Passage. The EMDW is formed in winter mainly by the mixing of the deep and cold Adriatic water and to a lesser extent by the mixing of the deep Cretan water masses. The Aegean Sea hydrological regime strongly influenced by winter meteorological conditions forms well oxygenated, dense water masses that eventually slide to the deepest basins of the Northern Aegean Trough (Theocharis and Georgopoulos, 1993).

The Aegean climate is mainly the climate of the Eastern Mediterranean Sea characterized by windy, mild, wet winters and relatively calm, hot dry summers (EEA, 1999). It is the result of a combination between subtropical (Southern Mediterranean) and mid-latitude weather systems (Northern Mediterranean). However, the Aegean climate is influenced by the topography and the shift between land and sea (Livadas, 1976). Maximum cloudiness, humidity and rainfalls are observed in December whereas the minima are observed in July and August. River run offs in the Aegean amount to $18{,}800 \times 10^6$ m^3 but as evaporation exceeds precipitation, the Aegean is characterized like the rest of the Mediterranean, as a concentration basin. During the summer a low pressure system located in the Levantine Basin combined with high pressure systems located in the Balkan Peninsula generate seasonal winds known as Etesians (meltemia). During winter, spring and autumn, the Aegean Sea is influenced by highly cyclonic storms and the prevailing winds are extremely variable.

4. The Aegean sea: an oligotrophic regime

The main water mass of the Aegean Sea is characterized as an oligotrophic system (Karydis and Kitsiou, 2012). Nutrient concentrations are about 12 times lower compared to nutrient concentrations in the Atlantic Ocean. Nutrient concentrations in the Northern Aegean have been reported by Ignatiades (2005). The concept of the oligotrophic regime is also supported by low primary productivity measurements (Ignatiades *et al.*, 1995). Mesotrophic and eutrophic waters appear along the coastal zone of some Aegean areas due to the presence of cities or estuaries; numerous eutrophic hot-spots are located in the coastal zones of Macedonia, Thrace, Thessaly and Asia Minor. The Southern Aegean Sea is more oligotrophic than the Northern Aegean. It has been pointed out a long time ago (McGill, 1961) that nutrient concentrations in the Southern Aegean Sea were eight times lower than nutrient concentrations in the Alboran Sea and three times lower than those of the Ionian Sea. Nutrient values have been reported by Ignatiades (1998) characterizing extreme oligotrophy. The N/P ratio ranged between 18 and 24. This range compared with the N/P Redfield ratio which is 16, indicates phosphorus limitation. Accordingly, chlα values strengthened the view regarding the oligotrophic character of the Southern Aegean Sea.

5. Human activities in the aegean region

The population of the area under study (N. Aegean, S. Aegean and the Region of Crete) is about 1,000,000 habitats (National Statistical Service of Greece, Census 2011) and the total area about 15,000 km^2. Data on the population and the area of the three regions are given in Table 1. The primary sector in the Aegean Islands includes crop farming, animal husbandry, fisheries and aquaculture. The farming land is split into small plots where olive groves and vineyards are cultivated using traditional methods. There is also fruit cultivation and horticulture. Due to limited water resources only a small part of the cultivated areas is irrigated. As the Aegean Islands differ as far as their area, geomorphology, population and natural resources are concerned, their economic activities vary in intensity and they are usually highly specialized.

Aquaculture and fisheries activities although contribute a small fraction to the National Gross Product (NGP) are characterized by a rather high added value. Aquaculture is focused in the production of sea bass and sea bream. The fishing fleet in Greece encompasses about 16,000 fishing vessels, most of them operating in the Aegean Sea. The majority of the vessels are small boats, fishing in the coastal zone and only a few hundred are trawlers.

The secondary sector covers activities that include small units for manufacturing natural products, salt fields, quarries and small construction companies. The construction outbreak in the Aegean Islands during the 1980s and 1990s increased the tendency for urbanization, a fact that eventually induced changes in the spatial planning of the coastal environment. The tertiary sector, concerning services, supports the employment of a remarkable percentage of human manpower of the Aegean Islands. The percentage of employments in tourist activities is almost 55%, whereas in the primary sector is only 20% and the secondary sector about 26% indicating the dynamic character of the tertiary sector in the area. Tourism represents a principal activity in the area under study, since some of the Aegean Islands are the most classic tourist destinations of Greece such as Rhodes, Kos, Mykonos and Malia. In addition, there are areas such as Gennadi, Lindos and Elounda trying to develop luxury tourism with all inclusive services. Furthermore, in many areas in the North Sea (like Chios, Samos and Ikaria) and the smaller islands of the Cyclades (as Anafi, Donoussa, Koufonissia) tourism is at the stage of development. These areas due to their particular physical characteristics are ideal for the adoption of mild and alternative forms of tourism, such as marine fishing tourism, diving and cruising.

Table 1: Area and Population in the three Aegean regions under study (National Statistical Service of Greece, Census 2011).

Region	Area (km^2)	Population
Northern Aegean	3,836	199,231
Southern Aegean	2,714	190,988
Crete	8,335	623,065
Total	14,885	1,013,284

6. Threats for the marine life in the Aegean and conservation framework

There are many threats on the quality of marine ecosystems and ecosystem services from industrial effluents, sewage outfalls, coastal construction projects, coastal erosion, species invasions and overexploitation of marine resources. Landings of fish and other invertebrates have dropped significantly after an increase in catches in 1980s. Loss of habitats has also been observed and it may partly explain the loss of diversity. Invasions of alien species and increasing frequency of Harmful Algal Blooms (HABs) are emerging threats to the marine environment of the Aegean. Nutrient enrichment in the coastal marine system comes from sewage effluents, either treated or untreated, as well as from farming activities. Retention of sediment material by dams and extraction from riverbeds for sand and gravel is also a serious environmental threat as it disrupts the sedimentary balance and causes coastal erosion (DiMento and Hickman, 2012). The relations between human activities and ecosystem services in the Aegean are given in Table 2. It is obvious that a number of human activities have a negative impact on ecosystem services, therefore implementation of marine spatial planning (MSP) practices should be adopted. In this framework, the project 'Cross-Border Cooperation for the development of Marine Spatial Planning' referred as THAL-CHOR aims at developing a methodology for MSP and then using this methodology for pilot implementation in selected areas in Cyprus and Greece for preparing both countries for the imminent implementation of the EU Directive on MSP. In Greece, the study area is the coastal zone of three Greek regions in the Aegean Sea that is the Northern Aegean Region, the Southern Aegean Region and the Region of Crete (Karydis, 2014).

In addition to the protected areas in the Aegean region there are international conventions, agreements and European Union Directives that apply to all the marine water, the seabed as well as the terrestrial coastal waters. The Barcelona Convention (BARCON) enforced in1976 has been the first legal framework for protecting the quality of Mediterranean, hence Aegean Waters. What is known as the Barcelona System is accompanied by seven protocols regarding, inter alia, marine pollution in general, dumping, pollution from oil and other harmful substances, pollution from land based sources, a protocol on protected areas, pollution from exploration and exploitation of the continental shelf, the transboundary pollution protocol and the protocol on the Integrated Coastal Zone Management. The Mediterranean Action Plan (MAP), the policy instrument of BARCON was replaced in 1995 by the Plan for the protection of the Marine Environment and the Sustainable Development of Coastal Areas. A framework of European policies is also focusing on good ecosystem health. Although the Directives have not been planned explicitly for protecting ecosystem services, they form a useful tool towards this direction as they are concerned with environmental protection, coastal management and marine strategy; the Pan European Ecological Network includes the European Union Natura 2000 and the Emerald Network of the Bern Convention. The Marine Strategy Framework requires Good Environmental Status by the Member States. Habitats along coastal wetlands are protected through the Ramsar Convention. The last European legislative framework on Marine Spatial Planning provides the guidelines to ensure that good environmental quality and socio-economic benefits can be mutually satisfied.

Table 2: Potential relations between human activities and ecosystem services in the Aegean.

		Human Activities in the Aegean Marine Environment										
		Fisheries	Aquaculture	Maritime	Marine Recreation	Swimming Beaches	Harbor facilities	Desalination units	Sand Extraction	Geothermal Energy	Wind Energy	Sewage Processing
Ecosystem Services	Water purification	O	P	N	O	0	N	N	O	O	O	P
	Mitigation of extreme events	N	N	O	O	O	O	N	N	N	O	N
	Detoxification of wastes	O	P	O	O	O	N	O	O	P	O	P
	Maintenance of biodiversity	N	O	N	O	O	O	N	O	N	N	N
	Decomposition of wastes	O	P	O	O	O	N	O	O	N	O	P
	Provision of aesthetic values	O	N	O	O	O	N	O	N	O	N	O

0: no effect; N: negative effect; P: positive effect

7. Towards a sustainable environment based on good spatial planning

To maintain high quality of ecosystem services and benefits a number of steps in strategic spatial planning should be taken. These include: (a) clear and feasible objectives (b) spatial definition of areas of particular interest in terms of vulnerability and environmental pressures (c) a set of environmental data (d) a set of socio-economic data (e) identification of environmental threats (f) identification of conflicts between human activities and environmental values and (g) development of policy proposal to mitigate the impacts. To achieve the last target apart from the legislative toolbox a good compliance monitoring program is necessary to ensure that both pollutants and ecosystem's impacts are well below the level that would threaten sensitive and vulnerable marine ecosystems. Good spatial planning should consider the conflicts on a quantitative basis; this can be helpful in ranking potential threats and setting management priorities. The latter could be investigated using Multiple Criteria Analysis (MCA).

MCA methods focus on the evaluation of choice possibilities based on selected criteria. They have the advantage of considering simultaneously information expressed in both metric and non-metric form and assigning weights to criteria according to their importance (Nijkamp and Voogd, 1986). Their purpose is to identify differences among a number of choice possibilities based on criteria derived from conflicting objectives by combining a ranking algorithm and a criteria weighting method (Kitsiou and Karydis, 2011). MCA has been successfully applied for assessing sea water quality in coastal zones, an important prerequisite in decision making and coastal management (Moriki and Karydis, 1994) as well as in strategic urban planning (Schetke *et al.*, 2012). Nowadays, it has been established as an important tool in environmental management, policy analysis and physical planning (Ananda and Herath, 2009).

In marine spatial planning application of MCA is very effective if it runs in the framework of a Geographical Information System (GIS), since visualization of the datasets in appropriate scales as well as further Spatial Analysis can be easier performed. Therefore, the development of integrated GIS-MCA systems represents an important component of spatial planning (Jinag and Eastman, 2000). GIS-MCA has provided useful results especially in small scale approaches. Such an example is the methodology developed for the multi-dimensional evaluation and ranking of coastal areas in the Island of Rhodes based on specific scenarios, as an early warning system regarding impact from human activities on marine environmental quality in coastal areas is important for guiding decision-making and planning (Kitsiou *et al.*, 2002). However, good spatial planning has a number of prerequisites which should be considered in the framework of appropriate methodological approaches in order to generate sound alternative outcomes and quantitative indicators to an extent that different objectives could be realized; MCA-GIS can therefore be a good support system for maintaining high quality ecosystem services and benefits.

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