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Distribution and seasonality of the marine macrophytes from Antikyra Gulf (Viotia, Greece)

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Abstract

The Gulf of Antikyra (Viotia) with a bauxitic substrate was aggravated by waste discharged from an aluminium factory where Parnassos bauxite is treated.

Seasonal collections of macrophytes from stations selected inside the Antikyra Gulf were carried out. 85 species of macroalgae were collected totally, out of which 16 belonged to Chlorophyceae, 12 to Phaeophyceae and 57 to Rhodophyceae.

There is no obvious difference in the qualitative composition of the macroalgae as we move away from the area where the waste is being discharged. Moreover, the stations where depths are greater exhibit different qualitative composition that those with smaller depths.

The presence of phanerogams and especially that of Halophila stipulacea, the Lessepsian immigrant, encountered for the first time in the Korinthiakos Gulf, was also evident.

The biomass of the three phanerogams decreased in the order: Posidonia oceanica>Cymodocea nodosa>Halophila stipulacea. The biomass of C. nodosa and P. oceanica was higher in July, while that of H. stipulacea was lower in July and higher in March and September.

Keywords: Antikyra Gulf (Greece), Biomass, Distribution, Marine vegetation.

Introduction

Studies of the marine flora of Western Greece and of the narrow coasts of the Korinthiakos and Patraikos Gulfs, in particular, have not been extensively carried out (BITIS, 1988).

Some collections made at the beginning of the last century (BORY DE SAINT VINCENT, 1832; 1838) and then during recent decades (LEVRING, 1942; GIACCONE, 1968) have been reported within the framework of different oceanographic scientific researches.

Studies have also been conducted in the past 25-30 years and especially in the Korinthiakos Gulf. ANAGNOSTIDIS (1968) wrote some papers on the Gulf of Loutraki where he reports 19 species of algae. HARITONIDIS and TSEKOS (1976) focused their attention on the Gulf of Itea and of Nafpaktos, on the western coast of Greece. BITIS (1988) studied eight stations in the

Korinthiakos Gulf after seasonal collections during 1981-1982 and identified about 100 different taxa of macroalgae. In a paper by DIAPOULIS and HARITONIDIS (1987) 14 study areas on the West coast of Greece were included; from these 4 stations were near the Antikyra Gulf (Fig. 1); the closest site was that of Itea, where 60 species of macroalgae were found to exist.

The present paper, done in the framework of a broader research work, was financed by the EU and carried out with metal concentrations in macrophytes in the Antikyra Gulf (e.g. MALEA, 1992; HARITONIDIS & MALEA, 1995; MALEA & HARITONIDIS, 1999). This part refers to the systematic classification, distribution and seasonality of macrophytes in the Gulf of Antikyra. The substrate of this area is bauxitic and from 1986 factory waste (red mud) was discharged outside the Gulf, 2000m away from the coast and at a depth of 100m (Fig.1) (Technical Report of Air Environmental Committee of Aluminium Factory, 1986). The internal part of the Gulf was severely degraded. The concentrations of some metals in the macrophytes, the sediment and the seawater as well, were measured (e.g. MALEA, 1992; MALEA & HARITONIDIS, 1999).

The phanerogams *Cymodocea nodosa* (Ucria) Aschers and *Posidonia oceanica* (Linnaeus) Delile have been observed to develop among the macroalgae. Moreover, the Lessepsian immigrant *Halophila stipulacea* (Försk). Aschers, has for the first time been detected in the Gulf in great quantities and at depths of under 2m.

The present study is a contribution to the relatively poor knowledge of the marine flora of the Greek coasts and of the Korinthiakos Gulf in particular.

Materials and Methods

The Gulf of Antikyra (Fig. 1) into which the factory's wastes are discharged was chosen to be our study area. Bauxite from Mount Parnassos is treated in the factory. The red mud from the aluminium factory

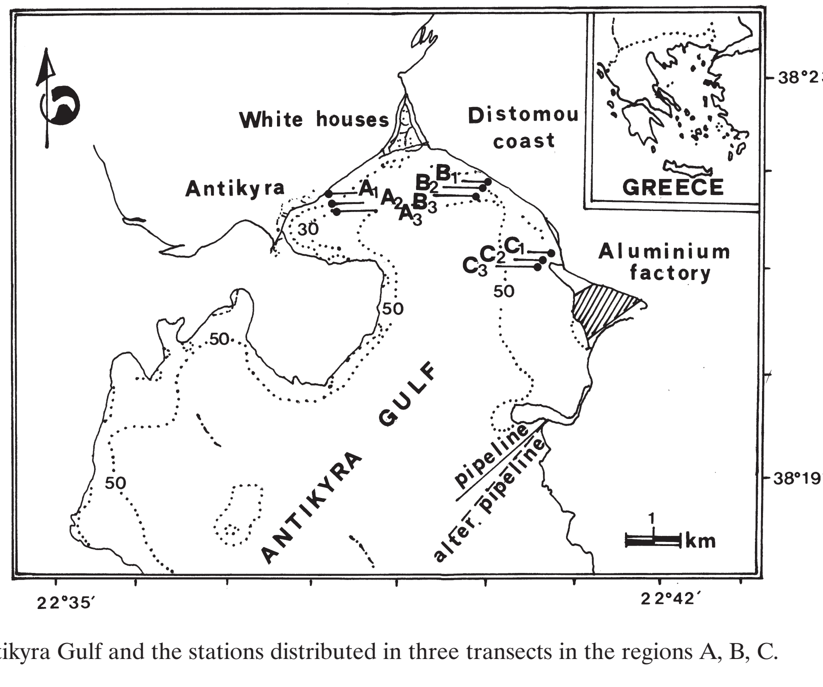

Fig. 1: Antikyra Gulf and the stations distributed in three transects in the regions A, B, C.

formed a new substrate-bottom which, when stirred, gave off a peculiar odour. Three stations with 3 different depths each were chosen from both hard and soft substrates. Region A covered stations A_1, A_2, A_3 with depths ranging from 1.5-2.0, 4.0-5.0 and 10.0m, respectively, region B stations B_1, B_2, B_3 with depths from 1.5-2.0, 3.5-4.0 and 9.5m, respectively and region C stations C_1, C_2, C_3 (25-50cm, 5-7 and 10-15m, respectively) (Fig. 1). Collections were made in December, March, July and September by means of a 25x25 cm iron frame, of a hammer and chisel so that all the material and the substrate as well could be collected into the net of the iron frame.

The material was then transported to the Institute of Botany in an Athylenglycol/ seawater solution (45/55v) for identification and was determined based on key-books and observations through a microscope. The nomenclature was mainly based on the floral lists of SOUTH & TITTLEY (1936), ATHANASIADIS (1987), RIBER *et al.,* (1992) and GALLARDO *et al.,* (1993).

The Sörensen index of qualitative similarity was determined in the vegetation of stations A, B, C and in each station between replicas 1, 2, 3, which correspond to different depths ($S={}^{2c}/a+b$ where c= the number of the common species, a, b= the number of species of the stations compared).

Results

The taxa of the macroalgae species were listed in Table 1 according to their distribution among the stations and their seasonal variation. The three marine phanerogams were preserved in the same manner. From the 85 species of macroalgae found in the Gulf 1/3 were epiphytes. In Figure 2 the seasonal variation of the number of the three classes of macroalgae was given.

Comparing (Sörensen index of qualitative similarity) the qualitative composition of macroalgae between stations A, B, C, showed that only stations B and C were dissimilar (S=0.349). The relative comparison done in each station as depth increased (between replicas 1→2→3) indicated that the stations with smaller depths presented different qualitative composition than those with larger depths. ($S_{A1\text{-}A3}=0.248$, $S_{A2\text{-}A3}=0.360$, $S_{B1\text{-}B3}=0.467$, $S_{C1\text{-}C2}=0.304$, $S_{C2\text{-}C3}=0.346$ and $S_{C1\text{-}C3}=0.300$).

The phanerogams *Cymodocea nodosa* and *Posidonia oceanica* grow in the Gulf at depths of a few centimeters to some meters. The occurrence of *Halophila stipulacea* raised the question of what course this immigrant had followed into the Korinthiakos Gulf.

In Table 2 the range, the mean value and the standard deviation of the biomass (g dry weight m^{-2}) of the three phanerogams, independently of stations and seasons, were given. The three phanerogams appeared to have greater biomass than the macroalgae and the biomass of the phanerogams decreased in the order: *Posidonia oceanica* > *Cymodocea nodosa* > *Halophila stipulacea.*

The seasonal variation of the biomass (g d w m^{-2}) of the seagrasses at the three stations, was given in Figure 3. The biomass of *Cymodocea nodosa* and of *Posidonia oceanica* was higher in July whereas that of *Halophila stipulacea* was lower in July and higher in March and September (Fig. 3). The reason why in certain cases Table 1 does not coincide with Figure 3 as concerns the presence of phanerogams (*P. oceanica, C. nodosa*) at certain seasons is attributed to the fact that different frames were used for the qualitative and quantitative study.

Discussion

It is obvious that the 85 taxa identified do not make up a detailed list of the entire marine flora of Antikyra Gulf (Table 1). It is, however, a notable distribution if we take into consideration that the collections covered all seasons of the year.

Table 1
The taxa of the macroalgae species listed according to their distribution among the stations and their seasonal variation, where A,B,C=sampling stations, I=winter, II=spring, III=summer, IV= autumn.

CHLOROPHYCEAE	
Dasycladales	
Acetabularia acetabulum (Linnaeus) Silva	II B_1 C_3
Dasycladus vermicularis (Scop.) Krasser	I A_2C_1-II B_2C_1-III C_1-IV B_2C_1, Sciophille
Anadyomenaceae	
Anadyomene stellata (Wulf.)	I $B_{1,2}C_{1,3}$-II$B_{1,2}$-III$A_{2,3}B_1C_3$-IV B_1C_2, Sciophile
Clarodophorales	
Cladophoraceae	
Chaetomorpha crassa Kütz	III C_3
C. linum (O.F. Müller) Kütz	II $A_3B_{2,3}$ C_1-III B_2C_1
Cladophora albida Kütz	I A_1B_2-II $A_3B_{1,2}C_1$-II B_2-IV $A_3B_{1,2}C_1$
C. pellucida (Hudson) Kütz	I A_2C_1-II B_3C_1
C. prolifera (Roth) Kütz	I B_3-II $A_3B_{2,3}$-III $A_1B_{1,2,3}C_{1,3}$-IV A_3C_3
Microdictyon sp.	I C_3-II $A_{1,2}$ Epiphyte
Rhizoclonium tortuosum (Dillw.) Kütz.	I A_2C_2 Epiphyte
Halimedales	
Codiaceae	
Codium bursa (Linnaeus)	I C_2-III $A_3B_{2,3}$
C. fragile (Sivr.) Hariot.	I A_1C_3
Udoteaceae	
Flabellia petiolata (Turra) Nizamuddin	II $B_{1,3}$-III $A_3B_{1,2}$-IV B_1 Sciophile, Epiphyte
Siphonocladales	
Valoniaceae	
Valonia macrophysa Kütz	II B_1-III A_3-IV B_1, Sciophile
Valonia utricularis (Roth) C. Ag.	II B_2 Sciophile
PHAEOPHYCEAE	
Fucales	
Cystoseiraceae	
Cystoseira crinita (Desf.) Borry	I C_3
C. compressa (Esper.) Gerloff & Nizamuddin	III C3
C. spinosa Sauvageau	II B_2
C. zosteroides (Turn.) C. Ag.	III $A_3C_{1,2}$-IV C_3
Dictyotales	
Dictyotaceae	
Dictyota dichotoma (Hudson) Lamour.	I $A_{1,2}B_3C_{2,3}$-II $A_{2,3}B_{1,2}C_1$-III $B_1C_{1,3}$-IV $C_{1,3}$
D. linearis (C.Ag.) Greville	I $A_2B_{1,2}C_{1,2,3}$-II $A_{2,3}B_{1,2,3}$-III B_1C_2-IV C_1, Epiphyte
Dilophus spiralis Montagne	I A_1B_3
Padina pavonica (L.) Lamouroux.	I A_1C_1-III $A_1B_1C_1$-IV B_1C_1
Ectocarpales	
Ectocarpaceae	
Ectocarpus sp.	II C_3 Epiphyte
Shacelariales	
Schacelariaceae	

Table 1 (continued)

Sphacelaria tribuloides Meneghini	I $B_2C_{2,3}$
S. plumula Zanardini	I C_2
Chordariales	
Chordariaceae	
Cladosiphon mediterraneus Kütz.	I C_1-IIIB_1
RHODOPHYCEAE	
Bangiales	
Bangiophyceae	
Bangia atropurpurea (Roth) C. Ag.	I C_3 Epiphyte
Porphyra leucosticta Thuret	I C_2-III B_2C_3, Epiphyte
Nemalionales	
Liagora viscida C. Ag.	I $A_1B_{1,2}C_1$-II B_1-IV C_2
Gelidiales	
Gelidiaceae	
Gelidium crinale (Turn.) Gaillon	I $A_{1,2}B_{2,3}C_1$-II B_1C_1-III $A_{1,3}B_{1,2,3}$
G. spinosum (Gmel.) *Silva v. spinosum*	III B_1
Pterocladionella capillacea (Gmel.) Santelices et Hommersand	I A_2C_3
Kallymeniaceae	
Kallymenia reniformis J. Ag.	II A_2
Peyssonneliaceae	
Peyssonnelia polymorpha (Zanard.) Schmitz.	IV C_3, Sciophile
P. rubra (Grev.) J.Ag.	I $A_{1,2}B_2C_3$, Sciophile
Corallinales	
Corallinaceae	
Corallina elongata Ellis et Solander	I B_2C_1-II B_1C_1-III A_1B_1-IV C_2
Jania rubens (L.) Lamour.	I $A_{1,2}B_{1,2}C_{2,3}$-II $A_3B_1C_1$-III $A_1B_1C_1$-III $A_1B_1C_1$-IV $B_{1,3}C_{1,2}$, Epiphyte
Lithophyllum incrustans Phil.	I $A_1B_2C_3$-II B_1
Phymatolithon lenormandii (Aresch.) Foslie	I A_2-II B_1
Hydrolithon callithamnoides (Foslie) Serio	I A_2B_2
Hydrolithon farinosum (Lamouroux.) Penrose et Champerlain	I $A_{1,2}$, Epiphyte
Neogoniolithon mamillosum (Hauck) Setchell et Mason	III $B_{1,2}$
Rhodomeniales	
Rhodymeniaceae	
Botryocladia botryoides (Wulf.) Felfmann	I $B_{2,3}$-II B_2-III B_1C_3, Epiphyte
Champiaceae	
Champia parvula (C.Ag.) Harvey	I B_2-II B_1-III B_1-IV C_3
Gastroclonium clavatum (Roth) Ardissone	I B_3-II B_1
Gigartinales	
Phyllophoraceae	
Gymnogongrus griffithsiae (Turn.) Mart.	III A_1C_3

Table 1 (continued)

Gracilariacneae	
Gracilaria bursa-pastoris (Gmel.) Silva	I C_1
Gr. longa, Gargiulo de Masi et Tripodi	IV A_3
Ceramiales	
Ceramiaceae	
Antithamnion sp.	I A_1, Epiphyte
Callithamnion corymbosum (Smith) Lyngbye	I A_1C_1
Seirospora interrupta (Smith) Schmitz	I A_2-II C_1
Wrangelia penicillata (C.Ag.) C. Ag.	I $C_{1,2}$
Gulsonia nodulosa (Ercegovic) J. Feldmann & G. Feldmann	II B_2
Spyridia filamentosa (Wulf.) Harvey	I $C_{1,2}$
Ceramium diaphanum (Light.) Roth	I $A_{1,2}C_3$-II A_2
C. echionotum J. Ag.	I C_1
C. rubrum (Hudson) C. Ag.	I $B_{2,3}$
C. ciliatum (Ellis) Ducl.	I $B_{1,2}$
C. diaphanum (Light.) Roth	I $A_1B_2C_2$-II $A_{1,2}$-III B_1-IV C_3 Epiphyte
Anotrichium barbatum (C. Ag.) Nageli	I A_2B_3
Delesseriaceae	
Nitophyllum punctatum (Stack.) Greville	I C_3-II $B_{1,2}$
Dasyaceae	
Dasya hutchingsiae Harvey in Hooker	I $A_{1,2}B_{1,3}$
D. punicea, Meneghini in Zanardini	III B_3-IV C_2, Epiphyte
Eupogodon planus (C. Ag.) Kütz.	I $B_{2,3}$C3-III B_1C_1
Rhodomelaceae	
Laurencia obtusa (Huds.) Lamouroux	I $A_{1,2,3}B_{1,2,3}C_{2,3}$-II $A_3B_{1,2}C_1$-III $A_{1,3}B_{1,2,3}C_{1,3}$-IV $A_2B_{1,2}C_{1,2,3}$
Osmudea truncata (Kütz) Nam.	I $A_{1,2}$-III A_1B_1-III A_2
Chondrophycus papillosus (C. Ag.)	I A_1-II $A_{1,2}B_1$-III A_2
Digenea simplex (Wulf.) C. Ag.	I $C_{2,3}$
Dipterosiphonia rigens (Schousboe ex C.Ag) Falkenberg	I $A_{1,2}C_{1,2,3}$-II $B_{2,3}$-III $B_{1,2,3}$-IV $C_{2,3}$, Epiphyte
Herposiphonia secunda (C.Ag.) Ambr.	I $A_{1,2}B_2$-II B_1-III $A_1B_{1,2,3}C_1$-IV $A_3B_1C_1$, Epiphyte
Polysiphonia furcellata (C.Ag.) Harvey	I B_3
Pterosiphonia pennata (C.Ag) Sauvageau	I B_3-II B_1
P. sertularoides (Grat.) J. Ag.	I B_2
P. denudata (Dillwyn) Greville	I B_3-III A_3B_1-IV A_3
Pterosiphonia complanata (Clem.) Falkenb.	I A_2B_3-II $A_{2,3}B_{2,3}$-III $A_3B_{2,3}$-IV $A_3B_{2,3}$
Rytiphloea tinctoria (Clemybuil) C.Ag.	II B_3
Osmundata volubilis (Linnaeus) J.Ag.	I A_2B_3-II $A_3B_{2,3}$-III $A_3B_3C_3$-IV A_3B_3, Sciophile
Acanthophora najadiformis (Del.) Papanfuss	II A_3
Chondria capillaris (Huds.) Wynne	I $A_1B_2C_2$-II $A_{1,2}$-III B_1-IV C_3
MARINE PHANEROGAMS	
Cymodocea nodosa (Ucria) Aschers.	I $A_2B_2C_{1,2}$-II $A_{1,2}B_3C_2$-III $A_{1,2,3}B_{2,3}C_1$-IV $A_{1,2,3}B_3C_1$
Halophila stipulacea (Försk) Aschers.	I $A_{1,2,3}B_3$-II $A_{1,2,3}B_{2,3}$-III$A_{1,2,3}B_{2,3}$-IV $A_{1,2,3}B_{2,3}$
Posidonia oceanica (L.) Delile	I $B_{2,3}C_{1,2}$-II $A_{2,3}B_3C_3$-III $A_3B_{2,3}$-IV $A_3B_3C_{2,3}$

Macroalgae from the three classes identified, included 16 Chlorophyta among which were a few Bryopsidophyceae; they were present at all stations occurring less in region C and declining in number of species from summer to autumn (Table 1, Fig. 2).

Table 2
Number of samples (n), range, mean value (MV), standard deviation of biomass (g dry weight m^{-2}) in different macrophyte species, independently of seasons and stations.

	n	*Range*	*MV*	*sd*
Cymodocea nodosa	16	6.080.-253.600	106.428	67.634
Halophila stipulacea	14	5.600-131.040	36.184	37.756
Posidonia oceanica	13	11.360-611.200	248.502	257.298

The Phaeophyceae observed were relatively less than those expected in this kind of substrate (calcifiets, granitic) and geographical level (12 species), the small rocky surface available probably being the cause of this.

Red algae were present in even greater numbers than usual in areas of the configuration (see above). A lot were found as epiphytes on larger red or brown algae and on the phanerogams *Cymodocea nodosa* and *Posidonia oceanica* as well. The lack of epiphytes on the leaves of *Halophila stipulacea* was also characteristic.

Fifty seven species of red algae were detected in the Gulf of Antikyra. A smaller number of taxa of all classes of macroalgae was observed in region C. Most of the red algae occur at greater depths and also at lower seawater temperature (winter) (LUNING, 1990). The same was observed in the Antikyra Gulf (Table 1, Fig. 2).

Species which are characterized as skiophilous are also of great interest. Despite the fact that there are not many rocks in the area the number of skiophilous must be attributed to the opaqueness of the seawater. The dense community of *Posidonia* also constituted another reason for the presence of skiophilous species.

Red algae were seen to prevail in number throughout the year particularly in winter (Table 1, Fig. 2). The same observation has been made by HARITONIDIS (1978). Seasonal dominance was not evident in the other classes (Clorophyceae and Phaeophyceae). The ratio Rhodophyceae/Phaeophyceae (R/P) was 4.5; this ratio characterizes the tropical type of marine flora (FELDMANN, 1937; HARITONIDIS, 1978; DIAPOULIS & HARITONIDIS, 1987).

The nearby Itea station was considered to be the right station for comparison with those of our study, because they have similar bauxitic substrate and also the part of Itea has been used for the shipment of crude, heavy bauxite. The higher values of the R/P ration observed at the Antikyra Gulf in comparison to those of the nearby Itea station are due to the fact that our study area is an enclosed Gulf with greater depths than that of Itea.

The different qualitative composition of the macroalgae observed between stations B and C does not lead to any conclusion linked to the distance from waste discharge of the factory, as each of the above stations is similar to the most remote station A. Relative studies on the concentrations of 10 metals in the seawater have shown that these metals are uniformly distributed in the Gulf of Antikyra (MALEA & HARITONIDIS, 1996). Only Al and Fe concentrations in the sediment were observed to present significantly local variation with maximum values at stations B3 and C3, respectively and minimum at a station located near the coast, at the point where the waste pipe reaches the sea (MALEA, 1992).

The discrepancies among stations at higher and lower depths is probably influenced by the fact that as depth increases the sediment becomes finer. It is worth mentioning that with the increase of depth the mean Al concentrations in the substrate also statistically increased (MALEA, 1992).

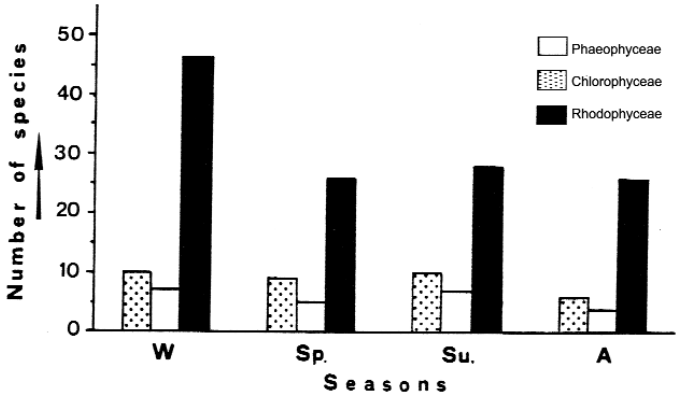

Fig. 2: Seasonality variation of the number of macroalgae in Antikyra Gulf. (W: winter, Sp: Spring, Su: Summer, A: Autumn)

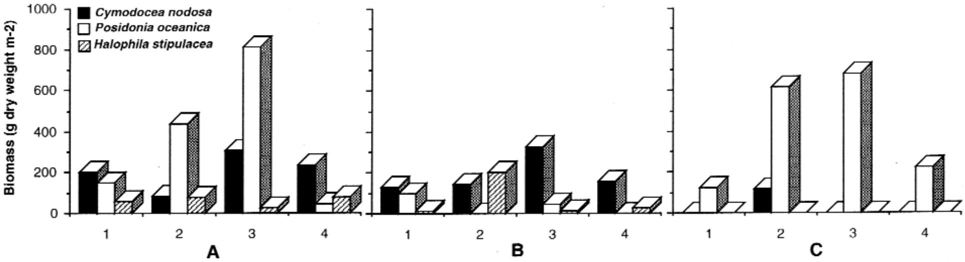

Fig. 3: Seasonal variation of the biomass (g dry weight m^{-2}) of the three phanerogams at A, B, C stations. Seasons: 1: December, 2: March, 3: July, 4: September.

The variation of the *Posidonia oceanica* biomass and of *Cymodocea nodosa* in this study was in accord with the life cycles of these species. The greatest production of new leaves of *P. oceanica* was observed to occur at the end of summer and in autumn (WITTMANN, 1984; PERGENT & PERGENT-MARTINI, 1991). The leaves were longer after the period of maximum growth (April-June) and before their loss in September-October (PANAYOTIDIS & GIRAUD, 1981). According to PEDUZZI and VUKOVIČ (1990) in late autumn and early winter the leaves of *C. nodosa* were narrower and smaller; the biomass of the leaves gradually increased from March until July-August (maximum values) and became lower in winter. Wahbeh (1984, 1988) suggested that the biomass of *Halophila stipulacea* had its maximum values early, in March.

Halophila stipulacea grows in the Gulf of Antikyra at depths ranging from 2 to 15m. This phanerogam which originated from the Indian Ocean and moved into the eastern Mediterranean Sea has for the first time been identified in southern Crete, Rhodes, the Peloponnese and Sounio (GIACCONE, 1968; LIPKIN, 1975; HARITONIDIS & DIAPOULIS, 1990). The species was detected for the first time in the Antikyra Gulf in 1985 (MALEA & HARITONIDIS, 1989; HARITONIDIS & DIAPOULIS, 1990; MALEA, 1992). Although it is a thermophile species from the Indian Ocean it has advanced northwards, where temperatures drop to 12°C. In 1994 it was located on the coasts of the

Pagasitikos Gulf (HARITONIDIS *et al.,* 1994). *Halophila stipulacea* is a phanerogam of great interest because of its tolerance to low temperatures.

In conclusion

a. 85 taxa were identified in the Antikyra Gulf, including 57 Rhodophyceae, 12 Phaophyceae and 16 Chlorophyceae with many skiophilous among them.
b. The ratio R/P= 4.5 characterizes this area as tropical.
c. There is no obvious difference in the qualitative composition of the macroalgae as we move away from the area into which the wastes are being discharged. However, the stations where depths are greater exhibit different qualitative composition than those with smaller depths.
d. The Lessepsian immigrant *Halophila stipulacea* develops inside the Gulf of Antikyra and has probably drifted through from the western side of the Patraikos Gulf.
e. The biomass of the phanerogams decreased in the order *Posidonia oceanica* > *Cymodocea nodosa* > *Halophila stipulacea* and was greater than that of the macroalgae. The biomass of *C. nodosa* and *P. oceanica* was higher in July, while that of *H. stipulacea* was lower in July and higher in March and September.

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