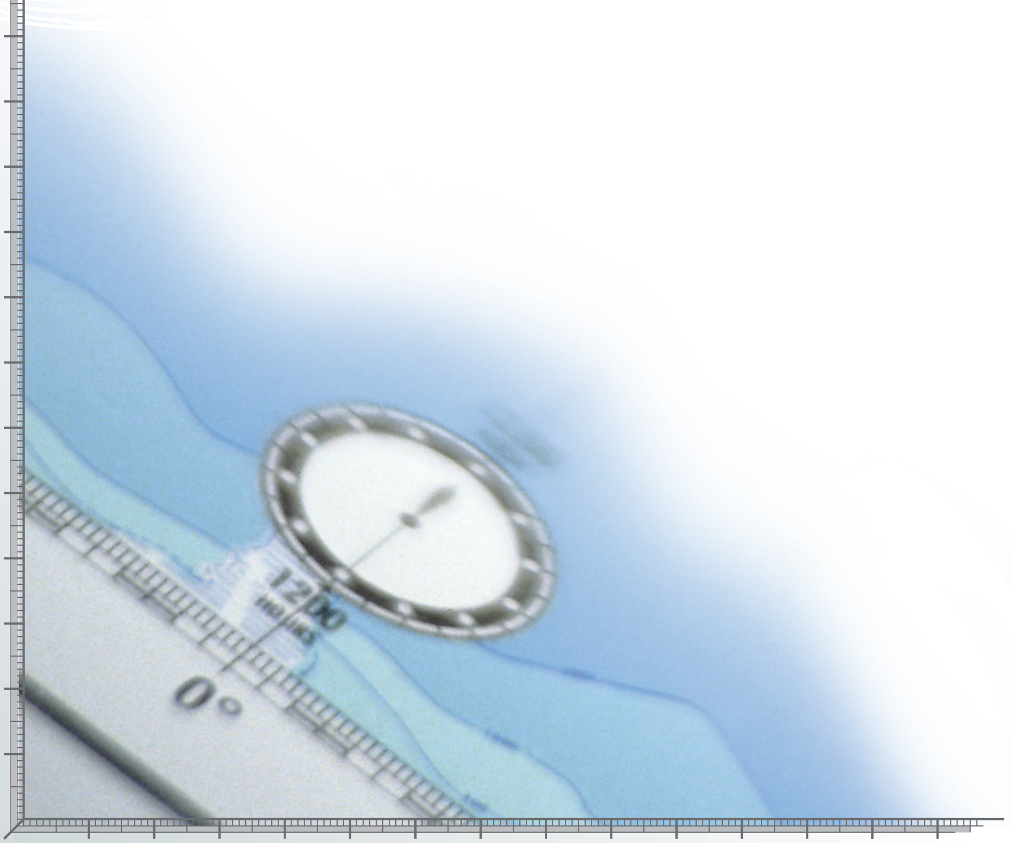
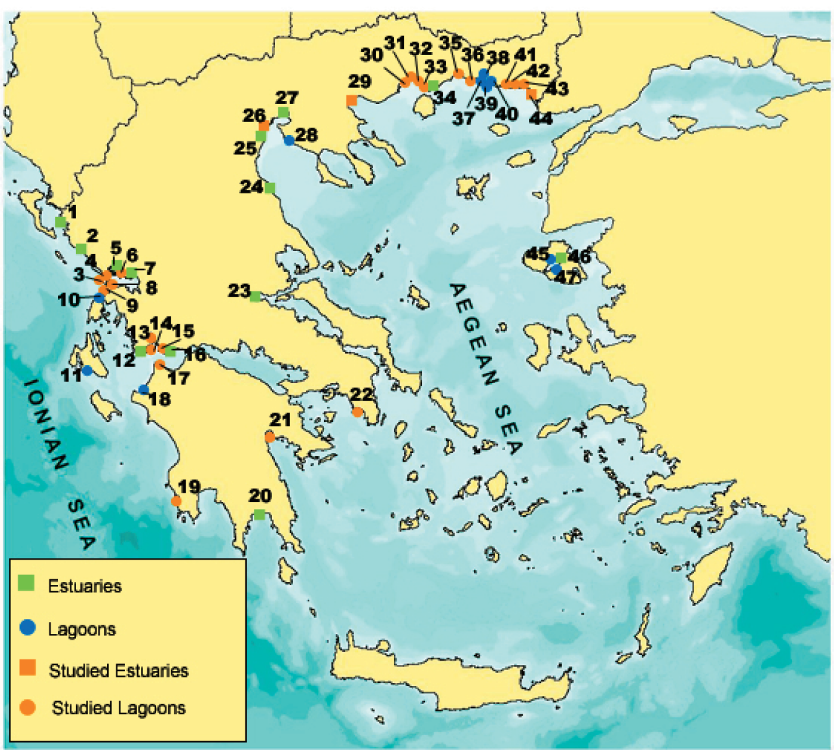
CHAPTER VI
BIOTA OF THE SEA BED



VI.1. LAGOONS

The most extensive lagoonal systems are located in western and northern Hellas (Figure VI.1). The most important are protected under the Ramsar convention and/or are part of the Natura 2000 network. Almost all are used for the extensive culture of fish (Table VI.1). The Hellenic lagoons are not all equally explored scientifically. More attention has been given to the lagoons of the Amvrakikos Bay, while the most comprehensive study was carried out in Gialova, in the southwest Peloponnisos.

Being enclosed, shallow areas, the lagoons are characterised by frequent fluctuations in environmental parameters on a daily and seasonal basis (Table VI.2). In this sense, coastal lagoons can be considered as harsh, naturally stressed environments. This natural instability discourages the settlement of many organisms, thus, the lagoons present a generally low number of species and low diversity. On the other hand, they are organically enriched areas, both as a result of river input and recycling of materials within the system. Hence, a large number of individuals and high biomass is attained.



1: Kalamas Est.
2: Acherontas Est.
3: Mazoma Lag. (*)
4: Tsopeli Lag. (*)
5. Louros Est.
6. Rodia Lag. (*)
7. Arachthos Est.
8. Logarou Lag. (*)
9. Tsoukalio Lag. (*)
10. Stenou Lefkadas Lag.
11: Koutavos Lag.
12: Acheloos Est.
13: Aitoliko Lag. (*)
14: Mesolongi Lag. (*)
15: Kleisova Lag. (*)
16: Evinos Est.
17: Araxos/Papas Lag. (*)
18: Kotychi Lag.
19: Gialova Lag. (*)
20: Evrotas Est.
21: Vivari Lag. (*)
22: Vouliagmeni Lag.
23: Spercheios Est.
24: Pineios Est.
25: Aliakmonas Est.
26: Axios Est.
27: Gallikos Est.
28: Epanomis Lag.
29: Strymonas Est.
30: Vassova Lag. (*)
31: Erateinou Lag. (*)
32: Agiasma Lag. (*)
33: Keramoti Lag. (*)
34: Nestos Est.
35: Porto Lagos Lag.
36: Fanari or Xsirolimni Lag. (*)
37: Karatza Lag.
38: Alyki Lag.
39: Ptelea Lag.
40: Elos Lag.
41: Laki Lag. (*)
42: Drana Lag. (*)
43: Monolimni Lag. (*)
44: Evros Est. (*)
45: Alyki Kallonis Lag.
46: Vouvaris Est.
47: Alyki Polychnitou Lag.

Figure VI.1: *Map of Hellas showing the main transitional coastal ecosystems (estuaries and lagoons). Asterisks indicate ecosystems for which detailed information exists and are treated in this work.*

Table VI.1 *Conservation status, exploitation and research carried out in Hellenic lagoons.*

LAGOONS		Amvrakikos Gulf					Patraikos Gulf		
		Ma	T	Ts	R	L	Me	A	P
Size (km)		1,6	1	16,5	13,5	25,7	100	26	3
Exploitation		AE, F	F, AE, ASI	F, AE, ASI	F, AE, ASI	F, AE, ASI	F, AE	F, AE	F, AB, AE
Conservation		R,N	R,N	R,N	R,N	R,N	R,N	R,N	N
Human impact								DC	DC
Parameters studied	Abiotic	*	***	***	***	***	***	***	***
	Plankton				**				
	Phytobenthos	*	**	**	**	**	**	**	**
	Zoobenthos	*	***	***	***	***	***	***	***
Source		NICOLAIDOU *et al.*, (2005)					REIZOPOULOU & NICOLAIDOU, 2004		

LAGOONS		Ionian Sea	Eastern Makedonia & Thraki					Evros Delta
		G	Va	E	Ag	Ke	F	
Size (km)		2.5	0,8	3,0	3,9	1,0	1,9	
Exploitation		F, AE	F, AE, AB	F, AE, AB	F, AE	F, AE	F	F
Conservation		N	R,N	R,N	R,N	R,N	R,N	R,N
Human impact		DC	SL	SL				
Parameters studied	Abiotic	***	*	*	*	*		***
	Plankton	**						
	Phytobenthos	*	**	**	**	**	*	**
	Zoobenthos	***						***
Source		KOUTSOUBAS *et al.*, 2000	ORFANIDIS *et al.*, 2000 & 2001					KEVREKIDIS & KOUKOURAS, 1988

Notes: (A=Aetoliko, Ag=Agiasma, E=Eratino, F=Fanari, G=Gialova, Ke=Keramoti, L=Logarou, Ma= Mazoma, Me=Mesolongi, P=Papas, R=Rhodia, T=Tsopeli, Ts=Tsoukalio, Va=Vassova),(F=Fisheries, AE=Extensive aquaculture, ASI=Semi-intens. aquaculture, SLW=Saltwork, AB=algal bloom, DC=dystrophic crisis, SL=sea grasses loss, OEN=organic enrichment), =RAMSAR, N=NATURA); * =occasional, ** =seasonal, *** =seasonal, more than one year.

Table VI.2 *Environmental and ecological characteristics of Hellenic lagoons.*

LAGOONS	Amvrakikos Gulf					Patraikos Gulf			
	Ma	T	Ts	R	L	K	Me	A	P
Depth (m)	1.0 – 2.0	0.2 – 1.5	1.6 – 5.2	2.9 – 5.2	0.7 - 1.0	0.20 – 2.0	0.20 – 2.0	0.30 – 30.0	0.20 - 1.5
S	23.0 – 27.0	21.0 – 38.0	14 – 36.5	5.0 - 35.0	15.8 - 48.6	23.0 – 41.0	37.0 – 45.0	18.5 - 23.5	20.0 – 42.5
T ˚C	9.0 – 13.0	8.0 – 29.0	8.6 – 30.0	8.9 - 29.1	9.1 – 28.1	20.5 – 21.6	24.5 - 27.9	15.5 -25.3	10.0 – 32.0
O_2 (mg/l)	4.8 – 6.8	2.8 – 9.8	4.6 – 10.6	3.5 – 10.8	4.5 – 12.1	5 – 6.7	4.2 – 7.9	4.5 – 7.3	1.2 – 9.3
Coarse %	–	6.7 – 66.3	6.3 – 79.0	12.0 – 77.5	6.4 – 32.0	19.9 – 35.6	2.0 – 76.8	9.1 - 11.1	23.0 - 98.0
Org. C %	–	0.6 – 2.7	1.3 – 5.1	1.2 - 5.0	2.2 - 3.5	1.6 - 3.6	0.9 - 5.1	2.4	2.9 – 5.6
No species (S)	8 – 39	5 – 45	4 – 29	3 – 17	11-31	11-14	9-42	0 - 12	0 - 44
Diversity (H')	2.1 – 3.5	1.3 – 3.7	1.9 - 3.3	0.8 – 3.0	0.4 - 3.3	2.2 – 3.3	2.7 – 4.1	1.2 – 2.3	1.7 – 3.7

LAGOONS	Ionian Sea	Eastern Makedonia & Thraki			Evros Delta				
	G	V	E	F	C	La	Mo	D	I
Depth (m)	0.3 – 1.2	0.2-4	0.2-3	0.2-2	0.15 – 0.40	0.05 –0.5	0.30 – 0.85	0.2 – 0.85	0.2 – 0.95
S	13 – 60	26.1-34.6	19.3-34.2	34-55.9	4.0 – 25.0	0.1 – 6.8	0.3 – 5.7	0.8 – 8.7	24.0 – 36.0
T ˚C	14-31	2-31.5	2-31.5	9-31.4	12.6 – 24.5	6.7 – 25.9	1.8 – 28.5	2.0 – 34.0	3.4 – 26.9
O_2 (mg/l)	4.5 – 9.1	4.2-22	4.3-15.2	5.4-15.1	–	5.3 – 13.7	6.1 – 18.0	10.3 – 15.6	5.3 – 8.4
Coarse %	14.5-94.7	–	–	–	147 – 208*	63 – 153*	94-176*	79 – 164 *	63 – 104 *
Org. C %	0.2-5.0	1.1-3.8	2-3.9	0.20 – 1.95	0.37 – 1.32	0.31 – 1.66	0.15 – 2.20	0.10 – 2.03	0.86 – 2.54
No species (S)	22-87	1-10 ***	1-7***	1-5***	12 – 23	7 – 12	6 – 12	2 – 8	4 – 8
Diversity (H')	1.9-3.4	0-2.3 (e)	0-1.95(e)	0-0.99 (e)	1.5 – 3.1	0.8 – 1.7**	0.7 – 2.2**	1.2 – 1.8**	0.5 – 1.3

Notes: Number of species based on different total sample size. Shannon-Wiener diversity based on $\log_2$ except where ** :loge ***: benthic macrophytes,(Aetoliko, Ag=Agiasma, C=Coast, D=Drana, E=Eratino, F=Fanari, G=Gialova, I=Isolated shallows, K=Klissova, Ke=Keramoti, L=Logarou, La=Laki, Ma= Mazoma, Me=Mesolongi, Mo=Monolimni, P=Papas, R=Rhodia, T=Tsopeli, Ts=Tsoukalio, Va=Vassova); =Median diameter (φ) .

PLANKTON

The phytoplankton, in terms of species composition (Table VI.3), is poorer than neritic phytoplankton. It is frequently enriched by benthic diatoms, which, due to the small depth of the lagoons, are put in suspension by the wind. In addition, neritic species enter passively from the sea and remain in the lagoon for a period of time. Thus, in the most enclosed lagoons, for example, in Rodia of Amvrakikos, cryptophytes are the most abundant genera. Where communication with the sea is greater, as in Logarou, the dominant species belong to the diatoms. In semi-enclosed lagoons, such as Gialova, the diatoms are rather few, restricted to the marine channels, while dinoflagellates are quite well represented especially in the innermost part of the lagoon.

The abundance of phytoplankton varies not only between lagoons and seasons but also between stations in the same lagoon. Maximum concentrations are observed at the end of winter/beginning of spring. Total phytoplankton abundance usually ranges between $3x10^4$ to $2x10^6$ cells/l but concentrations of up to $4.4x10^7$ cells/l, belonging mostly to nanoplankton, have been reported under slightly polluted conditions. Such blooms tend to be monospecific and localised.

In the mesozooplankton, densities as low as a few individuals per m^3 to approximately 4 500 indiv/m^3 have been observed. Copepods are the dominant group. In the inner parts of the lagoons the zooplankton consists of brackish water copepod species, accompanied or replaced (depending on the season), by euryhaline species such as larvae of barnacles, molluscs, decapods and polychaetes. In the outer parts, euryhaline species are dominant, accompanied by meroplanktonic larvae and benthic amphipods. Close to the sea, typically marine species enter the lagoons with the currents. Micro-zooplankton in coastal lagoons is represented mostly by ciliates with densities varying from 0.1 to 50 X 10^6 indiv/m^3, according to prevailing environmental conditions, season and distance from the point of communication with the sea.

In general, qualitative and quantitative variability in lagoonal plankton is attributed to variability of environmental conditions, such as salinity and nutrient concentrations, which arise from fresh water input from land and mixing with sea water.

PHYTOBENTHOS

Benthic vegetation in lagoons consists of a small number of species and associations (sensu the ‘Zürich-Montpellier School’). The following five associations are considered most important:

1) Association with *Ruppia cirrhosa* and/or *Ruppia maritima*. *Ruppia* is a cosmopolitan genus, characteristic of many coastal brackish waters and inland salt-water habitats, with enormous tolerance to salinity fluctuations (range ca. 3 to 101 psu).
2) Association with *Zostera noltii* with relatively restricted distribution, mostly in the lagoons of the Amvrakikos Bay (Figure VI.2).

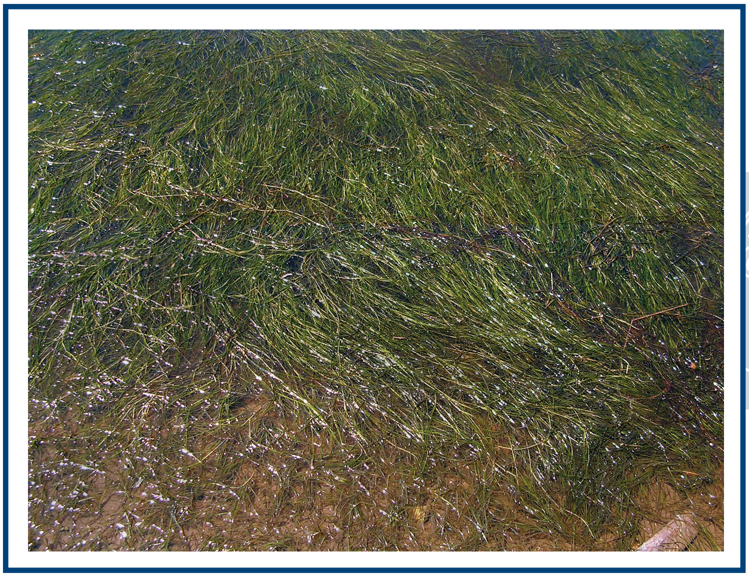


Figure VI.2:
Dense Zostera in an Ionian lagoon.

Table VI.3 *The most important lagoonal species.*

	Plankton	Phytobenthos	Zoobenthos	Fish
Phytoplankton	*Cryptomonas* sp.	*Ceramium diaphanum* (Lightfoot) Roth	*Abra ovata* (Philippi, 1836)	*Anguilla anguilla* Linnaeus, 1758
	Cylindrotheca closterium (Ehrenberg)	*Ceramium flaccidum* (Kützing) Ardissone	Actiniaria	*Aphanius fasciatus* Nardo, 1827
	Goniodoma sphaericum Murray & Whitting, 1899	*Chaetomorpha aerea* (Dillwyn) Kützing	*Armandia cirrosa* (Philippi, 1861)	*Atherina boyeri* Risso, 1810
	Gymnodinium heterostriatum Kofoid & Swezy	*Chondria tenuissima* (Goodenough &Woodward) C. Agardh	*Cerastoderma glaucum* (Poiret, 1789)	*Blenius* sp.
	Oxyrrhis marina Dujardin	*Cladophora liniformis* Kützing	Chironomidae	*Chelon labrosus* Risso, 1826
	Prorocentrum scutellum Schroder	*Cladophora* spp.	*Corophium orientale* Schellenberg 1928	*Dicentrarchus labrax* Linnaeus, 1758
	Protoperidinium depressum (Bailey)	*Cymodocea nodosa* (Ucria) Aschers	*Cyclope neritea* (Linnaeus)	*Diplodus annularis* Linnaeus, 1758
	Rhizisolenia fragilissima Bergon	*Cystoseira barbata* C. Agardh	*Gammarus aequicauda* (Martynov, 1931)	*Diplodus puntazzo* Cetti, 1777
	Rhodomonas sp	*Ectocarpus* sp.	*Hediste diversicolor* (O.F. Müller, 1776)	*Diplodus sargus* Linnaeus, 1758
	Scrippsiella trochoidea (Stein)	*Enteromorpha linza* (Linnaeus) J. Agardh	*Heteromastus filiformis* (Claparede, 1864)	*Diplodus vulgaris* Linnaeus, 1758
Zooplankton	*Acartia clausi* Giesbrecht, 1889	*Enteromorpha* spp.	*Idotea baltica* (Pallas 1772)	*Gobius* sp.
	A. discaudata (Giesbrecht, 1881)	*Gracilaria bursa-pastoris* (Gmelin) Silva	*Iphinoe serrata* (Norman, 1867)	*Knipowitschia caucasica*
	A. latisetosa (Kritschagin, 1873)	*Herposiphonia secunda f. tenella* (C. Agardh) Wynne	*Loripes lacteus* (Linnaeus, 1758)	*Lithognathus mormyrus* Linnaeus, 1758
	Calanipeda aquaedulcis (Kritschagin, 1873)	*Hypnea musciformis* (Wulfen) Lamouroux	*Microdeutopus gryllotalpa* (A. Costa, 1853)	*Liza aurata* Risso, 1826
	Centropages kroyeri Karawaev, 1895	*Polysiphonia elongata* (Hudson) Sprengel	*Mytilaster minimus* (Poli, 1795)	*Liza ramada* Risso, 1826
	Clausocalanus furcatus (Brady, 1883)	*Ruppia cirrhosa* (Petagna) Grande	*Naineris laevigata* (Grube, 1855)	*Liza saliens* Risso, 1810
	Oithona nana Giesbrecht, 1892	*Ruppia maritima* Linnaeus	*Nephtys hombergi* (Savigny, 1820)	*Mugil cephalus* Linnaeus,1758
	O. plumifera Baird, 1843	*Ulva rigida* C. Agardh	Oligochaeta	*Salpa salpa* Linnaeus, 1758
	Paracalanus parvus (Claus, 1863)	*Ulva* sp.	*Streblospio shrubsolii* (Buchanan, 1890)	*Solea vulgaris* Quensel, 1806
	Temora stylifera (Dana, 1849)	*Zostera noltii* Hornem	*Tanais cavolinii* (Milne Edwards, 1828)	*Sparus aurata* Linnaeus, 1758

3) Association with *Cymodocea nodosa*, a characteristic angiosperm of several Hellenic coasts and of saline lagoons. A recent attempt to limit fresh water inflow into the lagoons, as a measure against eutrophication, increased their water salinity and may also have favoured the growth of this species
4) Association with the algae *Cystoseira barbata, Gracilaria bursa-pastoris, Cladophora liniformis* and *Ulva* spp. These species dominate in eutrophicated lagoons or basins within lagoons.
5) Association with *Lamprothamnion papulosum.* The Charophyceae, to which *L. papulosum* belongs, are regarded as a class of the Chlorophyta, despite their highly distinctive thallus and reproductive organs. The association is recorded only in the Amvrakikos Gulf lagoons.

The dominant phytobenthic species are shown in Table VI.3. The diversity and biomass change in space and time. In the Vassova lagoon the diversity tends to decrease and the biomass to increase towards the inner fresh water sources. The diversity is higher during summer in the inner parts and in autumn close to the outlet due to the growth of tropical affinity species. Biomass values are maximal during winter to spring in the inner parts, possibly due to higher loads of nutrients.

MEIOFAUNA

Meiobenthos has been studied only in the Gialova lagoon, where 18 meiofaunal taxa were found with nematodes and copepods being the most abundant. Densities ranged from 17 to over 2 000 individuals per 10 cm^2. The distribution pattern of the meiofaunal community varied both across the lagoon and over the seasons. On the basis of the spatial differences a meiofaunal coenocline [1], correlated with the degree of isolation, was observed, composed of mainly two zones: one defined by the area close to the marine channel and the other the more isolated area in the inner lagoon. The meiofaunal distribution pattern, however, was not clearly correlated to a single environmental variable; apart from purely physical and chemical characteristics it was also associated with food supply.

ZOOBENTHOS

Macrozoobenthos is the ecosystem component most studied in Hellenic lagoons. The most abundant species are shown in Table VI.3.

Four main groups of benthic invertebrates are found in coastal brackish water lagoons, depending on their hydrologic and trophic status: i) *fresh water* species, represented by chironomid larvae and oligochaetes, found in areas remote from the sea with increased fresh water input; ii) *euryhaline brackish water* species, which are the most widely distributed and highly abundant species; iii) *marine* species preferring shallow sheltered areas; and iv) *opportunistic* species, commonly found in abundance in organically enriched areas. Most species are common to all lagoons. What differs is their relative abundance, which varies according to season and the life cycle of the dominant species.

It is worth mentioning the dominance of the mud snail *Ventrosia maritima*, found exclusively in extremely isolated areas of the Evros Delta. This mud snail was only known from the Black Sea. However, utilising DNA sequencing and phylogenetic analyses, the occurrence of this species was recently ascertained in the Evros Delta. *Ventrosia maritima* is a typical lagoonal species. To our knowledge, the life cycle, population dynamics and productivity of this species have not been described yet.

The most important variable shaping species composition and macrobenthic community structure is the degree of communication with the sea, or *confinement*, described by GUELORGET & PERTHUISOT (1992) as the time required for a lagoon to renew its marine elements. Six zones, as described in the model, have been found in Hellenic lagoons: Zone I, which is a continuation of the sea, with strictly marine species; Zone II, where the more stenohaline marine species are missing; Zone III, with mixed species; Zone IV, with strictly brackish water species; Zone V with only vagile fauna and freshwater (hypohaline) or evaporitic (hyperhaline) species and finally; Zone VI, which shows almost total colonisation of substratum by Cyanobacteria. Some or all of the zones are present in each lagoon, as shown in Figure VI.3 for the lagoon Gialova. The limits of the zones may show seasonal shifts

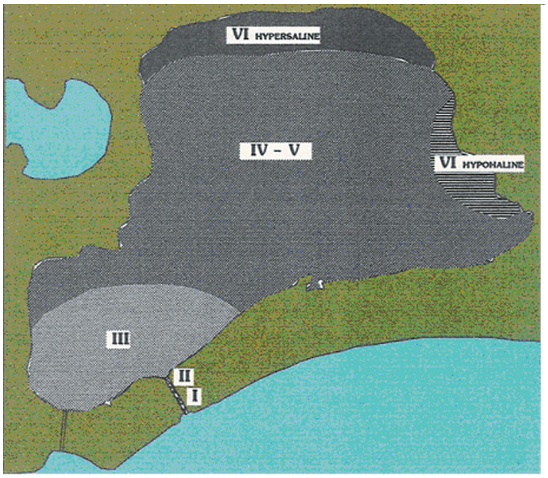
[1] Definition coenocline: a figure representing the distributions of all species as a function of evnironmental gradients.

indicating the dynamic character of the lagoonal environment.

The degree of confinement affects community diversity. There is a negative correlation between confinement and diversity (Figure VI.4). The lowest diversity is observed in enclosed lagoons, most isolated from the marine environment, while in lagoons with an important marine element and good water circulation, diversity is high. Such differences in diversity may be observed in the same lagoon, where the inner parts show the lowest diversity and the canals of communication with the sea the highest.

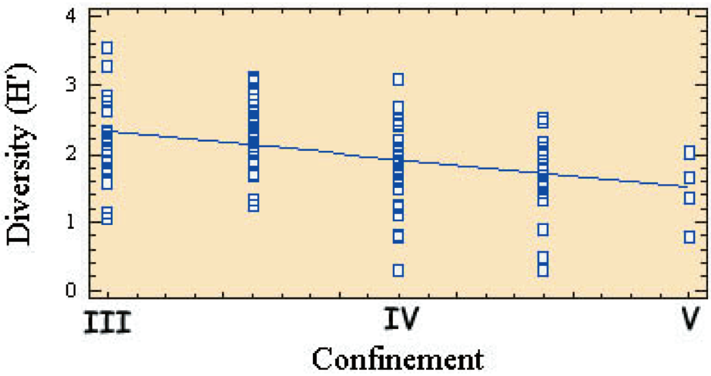
FISH FAUNA

The most common and abundant fish species are shown in Table VI.3. Lagoonal fish species can be divided in three different categories: i) *typical lagoonal species*, which complete their whole life cycle in lagoons, occupying the innermost part of the lagoonal systems where salinity, temperature, dissolved oxygen as well as other environmental variables present a severe fluctuation; ii) *migratory marine/estuarine species*, which reproduce in the sea, but which spend a period of their life in brackish waters and are found in the inner parts of the



Source: *DOUNAS & KOUTSOUBAS, 1996.*

Figure VI.3:
Biological zonation in the Gialova lagoon according to the scheme proposed by GUELORGET & PERTHUISOT (1992).



Source: *REIZOPOULOU & NICOLAIDOU, 2004.*

Figure VI.4:
Regression of diversity against confinement (based on data from the lagoons of Amvrakikos, Mesolongi, Papas, Vivari and Gialova).

lagoons, but only during the most stable period from spring to autumn; and iii) *marine species* which are normally distributed in the sea and are occasionally or accidentally found in the lagoons, in the narrow zone influenced by the sea.

In accordance with other biotic components of the lagoonal system, fish fauna is characterised by spatial and temporal variability, both in terms of numbers of species and individuals. There is a general tendency of the most rich fish fauna, both in terms of species numbers and density, to exist from spring to autumn, while during the winter very few species and low densities are observed.

Most lagoons in Hellas are used for the extensive culture of various fish species, the majority of which belong to the migratory marine/estuarine species. Mean annual production varies significantly depending on the size of the lagoon while differences are also observed in the fish catch composition.

MODELLING

The European Regional Seas Ecosystem Model (ERSEM), initially designed for the open sea, has been usefully applied to the Gialova lagoon with minimum modifications. Model results depicting the seasonal variation of nutrients and Chl-a in the water column, as well as three benthic functional groups (suspension feeders, deposit feeders and benthic carnivores), have been validated with *in situ* data. The modelled pelagic ecosystem exhibits a microbial food web, characterised by competition for nutrients between bacteria and phytoplankton, which is broadly in agreement with the observations made. The heterotrophic biomass is larger than the autotrophic biomass and there is a strong benthic-pelagic coupling in the model, as would be expected in a shallow system rich in detrital material. The seasonal variations in the benthic flux of nutrients are tightly coupled to the phytoplankton nutrient demand and hence to the supply of detritus to the sediments. The benthic recycling of nutrients (especially silicate) helps to maintain the modelled diatom population, which is indicated by the higher diatom biomass in the near-bed layer. The likely effect of a technical intervention (river input) increasing the fresh water nutrient inputs on the lagoonal ecosystem functioning has also been investigated. Detailed annual carbon fluxes and benthic fauna biomasses have been calculated before and after the river input, and importance of external physical/chemical forcing on the pelagic system and its subsequent effect on the benthic system has also been investigated. Model experiments indicate the shift of the ecosystem from nitrate limitation to predator control with external inputs. Model experiments also show a significant increase in the amount of carbon entering the benthic system through the activity of filter feeders when river inputs are implemented. The sensitivity analysis performed on model responses to different river nutrient fluxes and silt concentrations has highlighted the potential utility of a model as an operational tool to support environmental management decisions.

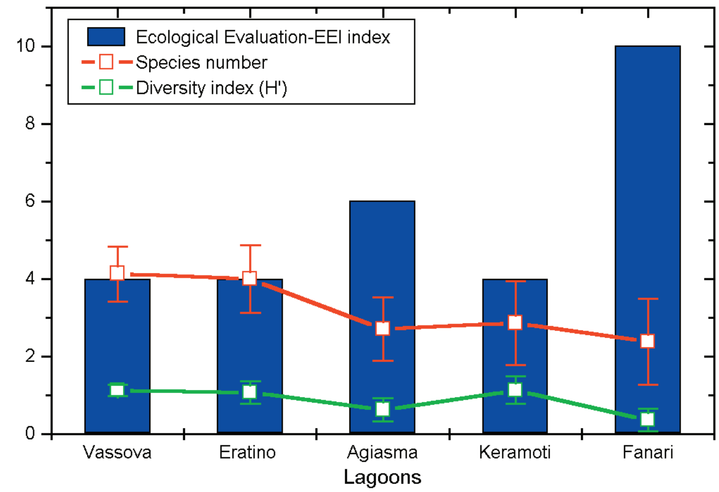
POLLUTION

Lagoons are nutrient rich areas as a result of input of nutrients by rivers and recycling between sediment and water column facilitated by their shallowness. A nutrient excess and hydrological change, often accelerated by human intervention, in the lagoons, result in a non-linear and self-accelerating chain reaction, commonly called eutrophication. It starts with an increase in growth (organic production) and a shift in dominance of primary producers from angiosperms to opportunistic seaweeds, and culminates in a *dystrophic crisis* with extensive algal blooms, severe anoxia and mass mortalities of both fish and invertebrate fauna. Such events are not uncommon in some Hellenic lagoons such as Papas, Aetoliko, Gialova and Vassova where some areas become completely defaunated, especially during summer. The sedentary infauna is affected more than the vagile organisms, such as Crustacea and Fish, which are able to migrate. Recovery is generally rapid, as organisms soon recolonise the affected areas. The Papas lagoon, for example, which was affected by a summer dystrophic crisis with extensive mortality of fish and benthic invertebrates, recovered the same autumn. This was also true for Gialova.

The degree of pollution in Hellenic lagoons has been assessed by an array of methods, including Abundance-Biomass-Comparison (ABC) curves and plotting of Geometric Abundance Classes, which are widely used for pollution assessment in the marine environment. However, due to the naturally stressed condition of the lagoons, these methods were ineffective as was the application of the Shannon-Wiener diversity index. Thus, two new indices were proposed, one is the Ecological Evaluation Index (EEI), based on macrophytes, algae and angiosperms. The other, the Index of Size Distribution (ISD) is based on the size distribution of macrobenthic animals.

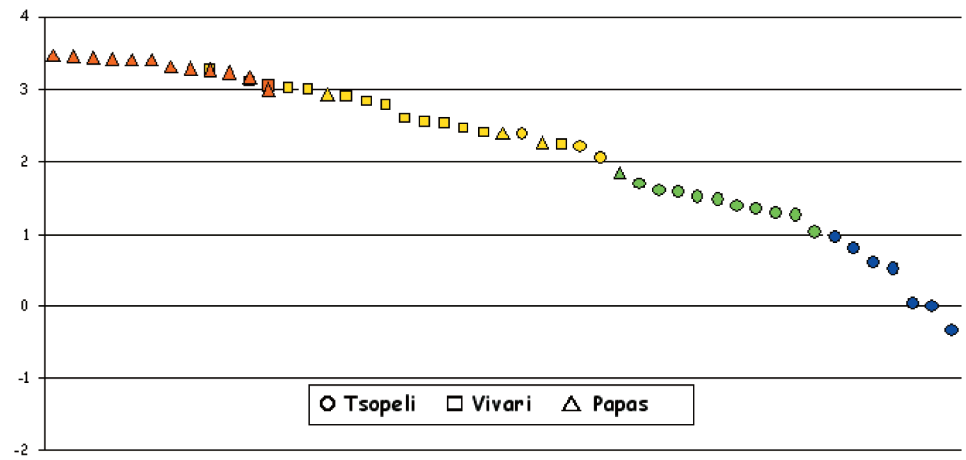
The EEI is described in detail in Chapter VIII. Its application in five Hellenic lagoons and the comparison with diversity indices, considered inappropriate for ecological assessment, is shown in Figure VI.5.

The ISD is based on the observation that with increasing organic load the community size structure changes. Due to the dominance of small size opportunistic species and the decline of large-bodied specimens (mainly suspension-feeders and carnivores), smaller and fewer size classes are present, thus, size class distribution is skewed towards the smaller size classes. The value of skewness of the curve is used as a measure of environmental quality. It has the advantage of a good discrimination power and not requiring a high taxonomic expertise. Application of the index in three Hellenic lagoons is shown in Figure VI.6.



Source: *ORFANIDIS et al., 2001.*

Figure VI.5:
Ecological Evaluation Index (EEI) in comparison to diversity indices in five Hellenic lagoons. High EEI values correspond to the less affected lagoons. Line bars indicate 95% confidence intervals.



Source: *REIZOPOULOU & NICOLAIDOU, 2005.*

Figure VI.6:
ISD (Index of Size Distribution) in three Hellenic lagoons. Higher values correspond to the most disturbed lagoon, Papas and smaller to the less affected, Tsopeli.

CONCLUSIONS

The research carried out so far in Hellenic lagoons confirms the variability of the environment, demonstrated also for other coastal lagoons in the Mediterranean. Differences exist not only among lagoons but also within the same lagoon, both in space and time. The degree of communication with the sea affects most of the other environmental variables, playing a prominent role in shaping the biological communities. Inflow of fresh water is also very important in the differentiation of biota. However, neither of the above has been directly quantified so far. The zoning of confinement is based on the end result the species distribution rather than the causative factor the water circulation and exchange. An independent evaluation of confinement, based on physical predictors rather than on the fauna, might provide a better understanding of its role. The input of fresh water and the contributed organic matter and nutrients of natural or human origin, would give a clearer picture of the terrestrial influence.

Finally, it is demonstrated that variability between and within lagoons concerns mostly the dominance of species and not the presence of different sets of species. Changes in the dominance of species could be caused not only by natural and/or anthropogenic variability in the physical environment, but also by biological interactions such as competition and predation. Giving more emphasis to the autecology of the dominant species would give a better insight into the dynamics of the lagoonal communities.

H.C.M.R

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INTRODUCTION

This report provides a general assessment of the Hellenic Seas. It was envisaged as a collection of information, providing background comprehensive facts for the broader scientific community and European citizens.

This is the first report of its kind, regarding the Hellenic marine and coastal waters. It is an initiative of the Institute of Oceanography of the Hellenic Centre for Marine Research (HCMR). Research Institutes and Universities across Hellas have joined forces to produce this report. The efforts to coordinate and compile the work, by different institutions, gave very encouraging results

The literature review on all issues examined for the Hellenic Seas with links to climate changes, biodiversity, sustainable development, socio-economic aspects was undertaken using electronic databases and all available sources. All forms of literature were exploited (the most recent information, historical data and the grey literature) and are included in the reference sections at the end of each chapter. In addition, abstracts from conferences have been used where no other relative information was available.

The aim of the report is to offer a common frame of reference, to underline the current state of the marine environment and the related environmental problems, identify the gaps of knowledge and, based on trends, highlight the areas where action is needed.

How to read the report

The report focuses on eight major environmental problems/issues. Homogeneity throughout the chapters was not feasible mainly because of data availability. Issues for which there is lot of data are presented like reviews/reports, whereas issues for which studies are limited are treated like essays based on a few case studies. Each chapter is accompanied by a list of references to the major sources of information.

Chapter I gives the geological setting of the area. It presents a **description** of the Hellenic Seas, gives synoptically the history and mechanisms of their formation and provides some sedimentological details.

Chapter II pertains to **air-sea-land interaction**. The air-sea interaction of the Eastern Mediterranean is examined in three steps: the regional weather and climate systems are described first, followed by wind waves and tides and finally the resulting short and long-term atmospheric fluxes (pollutants and particulate matter) into the sea.

Chapters III and IV describe the **physical and chemical characteristics** and illustrate some short and long term trends in the development of these features Arial distribution of the above parameters is depicted in thematic maps and in compiled tables. Hazardous substances (**heavy metals and PCBs**) are presented in the chemistry section (Chapter IV. Hydrography-chemistry and biology of the water column are addressed separately in coastal and deep seas).

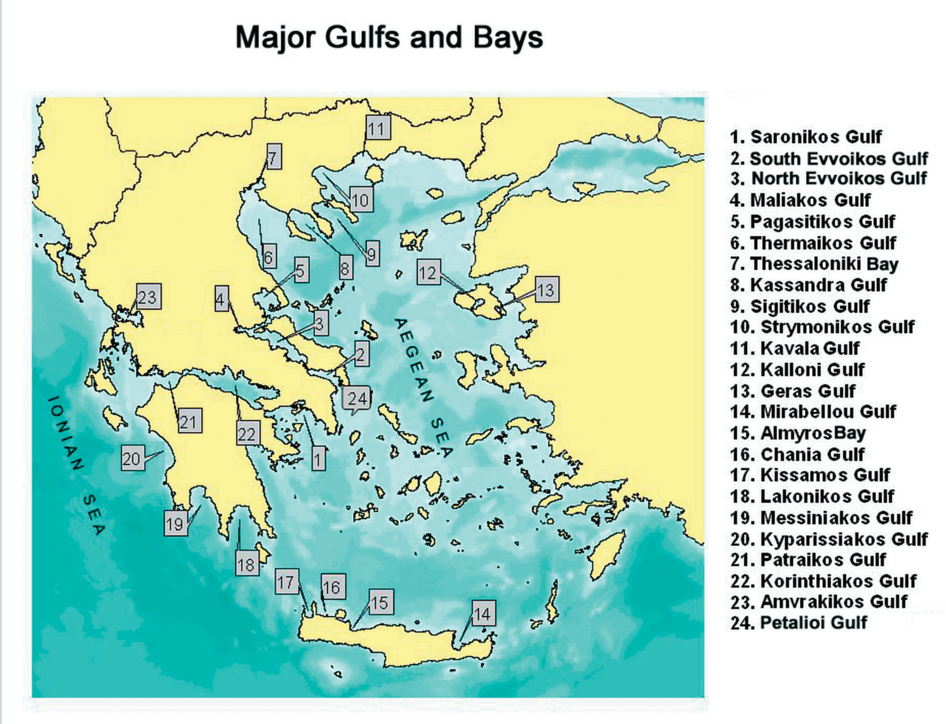
The **biology** section (Chapters V and VI) examines separately the pelagic (microbial, phytoplankton, zooplankton) and the benthic ecosystems/communities. However, in the lagoonal ecosystems both communities are presented together.

Biological resources (Chapter VII) are treated separately although the impact of fishery/aquaculture activities in the ecosystem is presented under the anthropogenic activities section.

Chapter VIII refers to **anthropogenic stress**. Coasts are treated as fragile natural systems that have economical, social and cultural significance for mankind. Anthropogenic pressures pertain to changes in coastal morphology, hydrology, eutrophication, biodiversity (introduction of Non Indigenous Species), ecological quality status, and ecosystem changes from fisheries and aquaculture.

The editors adopted the rules of ELOT (Hellenic Organisation of Standardisation) for writing-translating the names of localities. (Greece is written as Hellas throughout this volume). Exceptions are the transliteration of Aigaio and Kritikon which are named as Aegean and Cretan Sea, respectively.

A map including the main localities (Gulfs and Bays) addressed in the following chapters is presented below. A detailed map of Lagoons is provided in Figure VI.1 (Chapter VI), while a bathymetric map of the Hellenic Seas and location of major morphological features is presented in Figure I.4 (Chapter I).



It is believed that the publication of the report provides an important step forward on the coupling of the physics with the chemistry and biology of the region, a precious tool for the protection and sustainable use of our fascinating small ocean, the eastern Mediterranean Sea.

As the Hellenic Seas are probably the only place in the Mediterranean Sea that pristine conditions can be found, we foresee this report also playing the role of a baseline/reference issue so that future publications can make use of all this compiled information and assessment of the Hellenic marine environment.