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Temporal and spatial distribution of physico-chemical parameters in an anoxic lagoon, Aitoliko, Greece

Author Details

Areti Gianni	Department of Environmental and Natural Resources Management, University of Ioannina, 2 Seferi Str., 30100 Agrinio, Greece
George Kehayias	Department of Environmental and Natural Resources Management, University of Ioannina, 2 Seferi Str., 30100 Agrinio, Greece
Ierotheos Zacharias (*Corresponding author*)	Department of Environmental and Natural Resources Management, University of Ioannina, 2 Seferi Str., 30100 Agrinio, Greece e-mail: izachari@cc.uoi.gr

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Abstract

Temporal and spatial distribution of physico-chemical and water quality parameters and their correlation with meteorological and hydrological data, was investigated for anoxic lagoons, in Greece. Monthly variations of parameters like temperature, salinity, dissolved oxygen, chlorophyll-*a*, total phosphorus *etc*., along the Aitoliko lagoon water column, were recorded and studied at 14 stations. Throughout the sampling period, in lagoon's water column three layers were determined: the surface low density layer (11.49-16.15), the layer with the steep density gradient and the deep dense (19.78-20.62) water below the depth of 20 m. The depth of the surface and pycnocline layers depends on seasonal surface salinity (20.53-22.43‰) and temperature (12.48-28.40°C) alterations. Lagoon's monimolimnion was extended, below the depth of 20 m and had constant temperature and salinity equal to about 13°C and 27‰ respectively. Meteorological conditions control temperature (R^2=0.845) and dissolved oxygen (R^2=0.576) monthly changes, in lagoon's epilimnion, while salinity seems to be related with the salt/fresh water budget into Aitoliko lagoon. Epilimnetic chlorophyll-*a* (3.29-14.89 $\mu g\ l^{-1}$) and total phosphorus (13.33-36.31$\mu g\ l^{-1}$) concentrations classify Aitoliko lagoon as a mesotrophic environment (40<TSI (Chl-a)<55, 40<TSI (TP)<60). The vertical distribution of dissolved oxygen in the water column was always of special interest. During the last decades the Aitoliko lagoon was reported as a permanent anoxic basin. The depth of the anoxic layer gradually decreased and reached 5 m depth during 2003-2004. In the present study, the anoxic layer was limited below the depth of 18 m during summer. The most interesting is the dissolved oxygen presence in lagoon's monimolimnion during January and February, 2007. In this study, for the first time, Aitoliko lagoon was reported as seasonal anoxic basin.

Key words

Aitoliko lagoon, Anoxia, Physico-chemical characteristics, Trophic state index

Introduction

Anoxia and hypoxia have been widely observed in many coastal regions over the last several decades. Anoxic/hypoxic zones have been commonly reported for waters around America, Africa, Europe, India, South-East Asia, Australia, Japan and China (Nixon, 1990; Diaz and Rosenberg, 1995; Wu, 1999). Major ecological problems, including mass fish mortalities, defaunation of benthic populations and decline in fisheries production are not uncommon in many parts of the world (Leonardos and Sinis, 1997; Fallesen, 2000; Lu and Wu, 2000; Baric *et al.*, 2003; Luther *et al.,* 2004; Gollock, 2005; Caskey, 2007; Dimitriou, 2010).

The most well-known hypoxic/anoxic areas are the Gulf of Mexico, Chesapeake Bay, North Sea, Black Sea and Baltic Sea (Diaz, 2001; Rabalais *et al.*, 2001; Turner *et al.*, 2005; Glazer *et al.*, 2006; Diaz and Rosenberg, 2008).

Around Greek coasts anoxic/hypoxic environments were increased during 80's. This increase is related with intensive human activities in coastal areas, which increased nutrient load into the marine ecosystems. It's mainly about, shallow, eutrophic, semi-closed basins, where seasonal stratification result to dissolved oxygen depletion in the bottom water layers. Benthic fauna disturbance and mass mortalities are usually observed during anoxic/hypoxic periods (Friligos and Zenetos, 1988; Theodorou, 1996; Arvanitidis *et al.*, 1999; Koutrakis *et al.*, 2004; Dougleraki *et al.*, 2006; Karaouzas, 2009).

Aitoliko lagoon is a permanent anoxic basin in Western Greece and constitutes the northern part of an extensive wetland, which main part consists of Messolonghi lagoon. First reference for the anoxic Aitoliko lagoon was made in historical documentary of 18th century. Messolonghi/Aitoliko lagoonal system is of scientific interest since 50's (Hatzikakidis, 1951). Even though some studies, involved with the physico-chemical characteristics of Aitoliko lagoon, were conducted during these decades, the most recent were based on yearly cruises, in single stations (Psilovikos, 1995; Chalkias, 2006). Thus, the annual changes in hydrography of Aitoliko lagoon as well as the regional characteristics of anoxia in this area remain unexplored over the last decades.

The aim was to study the monthly variations of parameters like temperature, salinity, dissolved oxygen, pH and redox potential along lagoon's water. Water transparency as well as chlorophyll-*a* and total phosphorus concentrations, were also determined in Aitoliko lagoon.

Materials and Methods

Study area: Aitoliko lagoon is one of the 6 distinct lagoons, with different topographic and hydrological features, located in north-western part of Patraikos gulf (Western Greece). This wetland is of great ecological importance and is protected under the Ramsar and Natura 2000 conventions. The system is polluted from sewage from both Aitoliko and Messolonghi towns, as well as from the intensive agriculture in the neighboring area. It is a tectonically formed basin and is characterized as an a typical lagoon as its main axis is perpendicular to the shoreline. Its maximum length and width is 7.5 and 3 km, respectively. The area covered by Aitoliko lagoon is about 16 km^2 and its maximum depth is 27.5 m, whereas the maximum depth of the wider Messolonghi lagoon is about 2 m. The two lagoons are connected through narrow openings (mean depth ~1 m) under the bridges of Aitoliko island (Fig. 1).

Aitoliko lagoon receives fresh water from three main streams as well as from a pumping station, which is located near the connection channel with Messolonghi lagoon and drains an extended cultivated land of the catchment area.

Field monitoring, chemical and data analysis: Twelve monthly sampling cruises were organized from May 2006 to April 2007. Vertical profiles of temperature (T), electrical conductivity (EC), dissolved oxygen (DO), pH and oxidation-reduction potential (Eh) were measured *in situ*, in 14 stations (Fig. 1), using a Troll 9500 water quality multi-parameter instrument. Salinity (S) and density (σ-t) were calculated from temperature, conductivity and pressure data.

Water transparency (Tr) was determined in 5 stations (A_2, A_4, A_8, A_9, A_{14}), in a south-north traverse, using a Secchi disk.

Water samples were collected from the deepest station A_9, with 5 m vertical intervals, using a 2.5 l Hydrobios free flow sampler.

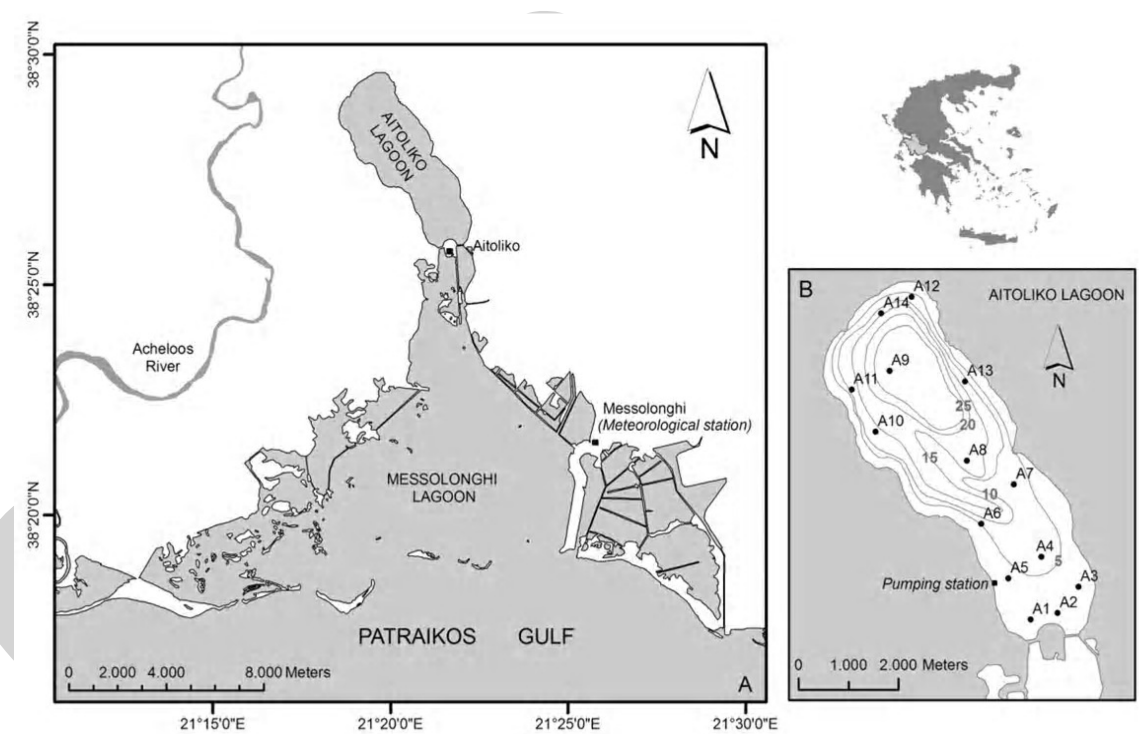

Fig. 1: (A) Map of the extended study area. (B) Sampling stations in Aitoliko lagoon

All the samples were brought to the laboratory in a portable fringe at 4°C.

Water samples were analyzed for chlorophyll-*a* (Chl-*a*) and total phosphorus (TP) determination. Chlorophyll-*a*, acetone extraction was done as soon as the samples were transferred to the laboratory and about 20 hrs later chlorophyll-*a* was determined using the trichromatic colorimetric method. Total phosphorus, after persulfate digestion of all the samples, was determined by the ascorbic acid method (APHA, 2005).

In order, to characterize Aitoliko lagoon, according to its trophic state, Carlson's trophic state index (TSI) was used (Carlson, 1977; U.S. EPA, 1998). It is the most widely used index, and it compares chlorophyll-*a*, Secchi transparency and total phosphorus concentrations.

TSI index for three different quality variables was calculated according to the equations:
TSI of Secchi depth (SD) = 60-14.41 in secchi depth (m)
TSI of Chlorophyll-*a* (CA) = 30.6+9.81 in chlorophyll-*a* ($\mu g\ l^{-1}$)
TSI of Total phosphorus (TP) = 4.15+14.42 in total phosphorus ($\mu g\ l^{-1}$)

For TSI (CA) and TSI (TP), the average epilimnetic concentrations of Chl-*a* and TP were used, while for the TSI (SD), the average value of the 5 sampling stations, were used. Finally, Carlson's TSI index, was calculated as the average value of TSI (SD), TSI (CA) and TSI (TP):

Carlson's TSI = (TSI(SD)+TSI(CA)+TSI(TP))/3

Results and Discussion

Throughout the sampling period, Aitoliko lagoon, presented surfacially homogenous, since no differences were observed between the surface values of the measured physico-chemical characteristics, in the 14 sampling stations. Only surface oxidation-reduction potential values, presented, significant spatial differences. Nevertheless, surface values of temperature, salinity, dissolved oxygen and pH varied monthly and seasonally. This temporal temperature, salinity and dissolved oxygen variability, was correlated with meteorological, hydrological and water quality data (Table 1).

In Table 2, are summarized per month the physico-chemical parameters, temperature, salinity and dissolved oxygen, the quality variables, chlorophyll-*a* and total phosphorus, the meteorological parameters, air temperature, rainfall and evaporation, as well as the monthly fresh water supply from the pumping station D_6. Meteorological data from a meteorological station situated in Messolonghi town was used.

As it was expected, monthly surface temperature variability in Aitoliko lagoon resulted from meteorological changes. Air temperature (R^2=0.845, n=11, p<0.01), is almost exclusively accountable for the temporal water temperature distribution in the surface layer of Aitoliko lagoon.

Table - 1: Results for spatial, monthly and seasonal differences in the measured physico-chemical variables, during the study period

Source of variable	Variable	df	F - ratio	P
Station	S	13	0.19	ns
	T	13	0.008	ns
	DO	13	0.031	ns
	Eh	13	2.963	*
	pH	13	0.517	ns
Month	S	10	258.579	*
	T	11	6113.533	*
	DO	11	412.861	*
	Eh	11	36.446	*
	pH	11	42.867	*
Season	S	3	29.580	*
	T	3	281.387	*
	DO	3	83.559	*
	Eh	3	21.284	*
	pH	3	32.867	*

* Indicates significant differences (p<0.05), ns = not significant, S = Salinity, T = Temperature, DO = Dissloved oxygen, Eh = Oxidation-reduction potential

Dissolved oxygen concentrations was limited from epilimnetic temperature (R^2=0.576, n=12, p<0.01) while it amplified by the increase in the amount of algal as measured by chlorophyll-*a* (R^2=0.734, n=11, p<0.01).

Salinity monthly variability could not be explained by the changes in the available meteorological data of the study area. It seems that hydrological processes control the seasonal variability of the surface salinity in Aitoliko lagoon. The available hydrological data are not enough to ensure this hypothesis, thus the study of the fresh /salt water budget in Aitoliko lagoon is essential in order to explain salinity changes in this basin.

Aitoliko lagoon, during the sampling period was permanent stratified and stratification was mainly controlled by salinity while temperature played secondary role. Throughout the sampling period, in lagoon's water column three layers were discriminated: the surface low density layer, the layer with the steep density gradient and the deep dense water below the depth of 20 m (Table 3). The depth of the surface and pycnocline layers depends on seasonal salinity and temperature alterations.

A permanent halocline was present in lagoon's water column throughout the sampling period (Table 3). Its thickness as well as the surface layer depth was seasonally varied. During summer surface layer was limited (up to the 6 m depth) and was characterized of mean salinity values of 20.61‰ while at winter months was extended up to the depth of 12 m and its salinity increased to 21.64‰ (Table 4).

Vertical temperature distribution indicated a wide surface layer (0-15 m), with mean values of about 12.5°C, during winter months. In late spring, the seasonal thermocline was formed; the surface layer was limited in the upper 5 m and its temperature

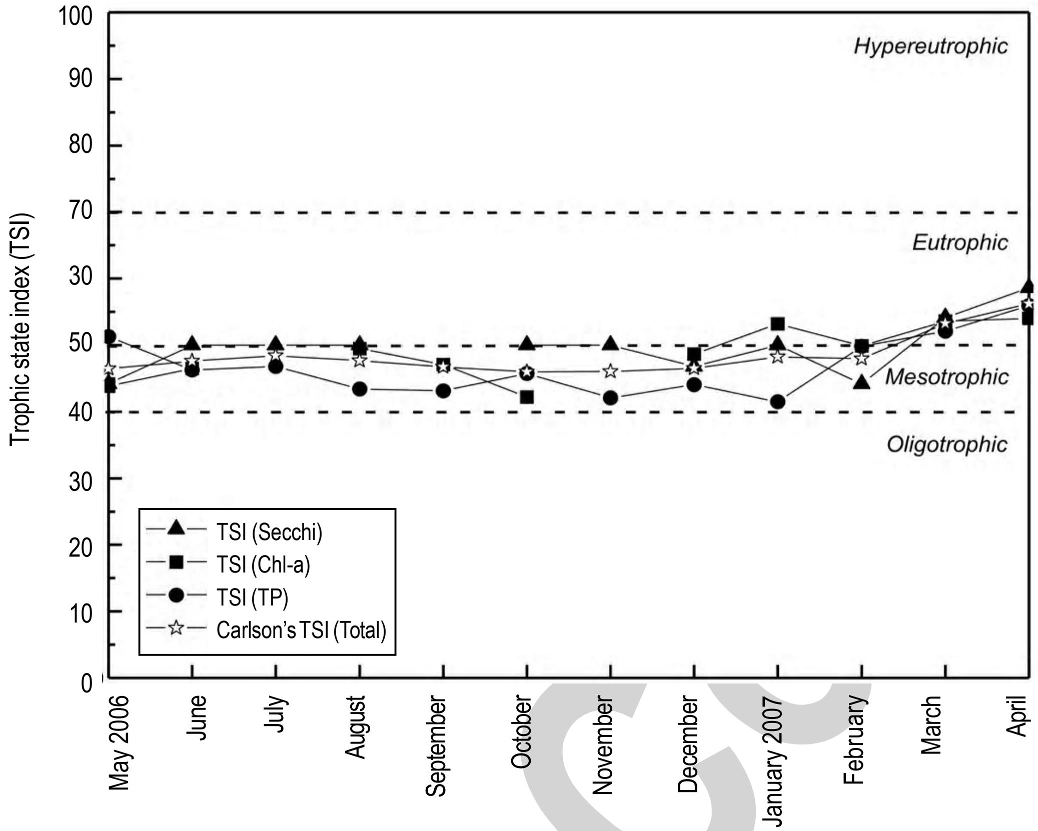

Fig. 2: Trophic state index (TSI) in Aitoliko lagoon throughout the sampling period, based on Secchi depth, chlorophyll-a and total phosphorus

inceased to 19.32°C. This stratification pattern remained during summer while in late autumn the seasonal thermocline was destroyed.

Straightly related to above mentioned salinity and temperature alterations, lagoon's epilimnion was limited (about 6 m deep), from late spring and during summer months. At the same time, Aitoliko lagoon water column was characterized by an extended strong metalimnion (from 6 to 20 m depth). In winter, time surface layer extended (up to 12 m wide - depth) metalimnion's thickness was reduced and density alterations were less sharp through the autumn thermal overturn.

Lagoon's monimolimnion was extended, throughout the sampling period, below the depth of 20 m and had constant temperature and salinity equal to about 13°C and 27‰, respectively (Table 3). The recorded bottom water temperature was about 2-3°C, lower than the value reported for the period 1951-2004 (Hatzikakidis, 1951; Psilovikos, 1995; Chalkias, 2006), while monimolimnion's salinity did not decline from the values reported from Psilovikos (1995).

Salinity spatiotemporal distribution constitutes an evidence of the interaction between Messolonghi and Aitoliko lagoons. From June until October 2006, high salinity water was found at the upper metalimnion. This abnormal vertical salinity distribution was noticed in the entire lagoon's extent and was ascribed to salt water inflows from Messolongi lagoon. This saltier water mass flowed as a bottom current near the connection channel between the two lagoons and when it achieved the same density as the surrounding water was interleaved into the interior of Aitoliko lagoon. Spatial and temporal differences in salinity values of this layer were noticed. Highest salinity values were always characterized sill's area, while in the interior of the Aitoliko lagoon, salinity was decreased, through vertical advection. In June 2006, the maximum salinity of this layer into Aitoliko lagoon was about 21‰, while increased during autumn months. These temporal differences resulted from the seasonal changes in the salinity of Messolongi lagoon. The depth at which this layer appeared inside Aitoliko lagoon varied during the sampling period as well. In June 2006, it extended from 4 to 10 m depth, while in October, 2006 from about 7 to 13 m depth.

In Aitoliko lagoon, the dissolved oxygen vertical distribution and the depth of oxic/anoxic interface was always of spatial interest. Epilimnion was well oxygenated and usual presented values over the saturation concentration due to eutrophication and high primary productivity (Hatzikakidis, 1951; Psilovikos, 1995, Chalkias, 2006). In 1951, oxygen concentration sharply decreased at the upper metalinmion and was undetectable below 14 and 19 m during summer

Table - 2: Temperature (T), Salinity (S), Dissolved oxygen (DO), Chlorophyll-*a* (Chl-*a*) and Total phosphorus (TP) in the surface layer of Aitoliko lagoon. Air temperature (AT), Rainfall (RF) and Evaporation (E) in Messolonghi meteorological station

Year/Month	S (‰)	T (°C)	DO (mg l^{-1})	AT (°C)	RF (mm month^{-1})	E (mm month^{-1})	Chl-*a* (μg l^{-1})	TP (μg l^{-1})	D_6 discharge (m^3 month^{-1})
2006									
May	18.74±0.23	22.39±0.26	9.63±0.24	21.44±4.68	0	96	3.84±2.64	26.29±5.47	817200
June	19.27±0.37	28.39±0.52	6.53±0.97	24.30±5.70	0	96	5.06±5.05	18.59±2.97	908000
July	20.39±0.36	27.32±0.39	7.69±0.44	26.36±4.48	25	102		19.25±5.71	908000
August	22.17±0.52	29.50±0.29	6.68±0.42	26.49±5.47	0	141	6.86±6.86	15.25±5.24	908000
September	22.38±0.22	23.34±0.21	7.36±0.47	18.60±3.67	55.20	84	5.36±3.71	14.90±1.64	998000
October	22.48±0.08	19.02±0.37	6.66±0.45	11.92±4.83	80.60	88	3.26±2.97	17.86±4.86	1135000
November		15.15±0.18	12.93±0.41	11.27±3.72	81.20	105		13.89±3.47	1634400
December	21.68±0.28	13.64±0.29	12.94±0.16	11.04±4.94	82.00	172	6.29±4.793	15.91±5.17	1498200
2007									
January	21.68±0.29	11.51±0.17	13.25±0.28	10.68±3.50	83.80	177	10.04±4.79	13.33±3.8	1089600
February	21.56±0.25	12.30±0.13	11.55±0.32	12.66±3.64	35.80	166	7.14±2.02	23.72±4.84	908000
March	21.18±0.15	14.52±0.28	11.75±0.23	16.35±4.48	4.00	112	10.42±5.60	27.81±1.38	817200
April	21.68±0.11	21.03±0.38	14.21±1.18				14.89±8.71	36.31±5.48	635600

Values are mean ±S.D for T, S, DO, AT, Chl-a and TP. Values are sums for RF, E and D_6 discharge

Table - 3: Temperature (°C), Salinity (‰), Density (σ-t), Dissolved oxygen (mg l^{-1}) and Eh (mV) vertical distribution in the deepest sampling station (A_9), throughout the sampling period

Depth (m)	Temperature (°C)	Salinity (‰)	Density (σ-t)	Dissolved oxygen (mg l^{-1})	Eh (mV)
0	29.58-12.00	22.41-18.87	16.27-10.56	14.09-7.29	210-(-87)
2	29.38-11.07	22.47-18.85	16.61-10.56	13.53-7.04	214-(-89)
4	28.99-11.19	22.77-18.67	16.65-11.70	14.01-6.61	214-(-95)
6	26.29-11.30	23.39-19.29	16.71-12.37	16.76-1.56	204-(-103)
8	22.69-11.08	24.04-19.88	16.97-14.52	15.28-0.64	167-(-185)
10	18.94-11.06	24.44-20.19	17.55-14.94	12.16-0.49	130-(-231)
12	15.73-11.43	24.03-20.71	17.59-15.55	11.78-0.38	95-(-253)
14	14.91-12.73	24.37-22.04	18.19-16.72	10.91-0.23	53-(-270)
16	14.57-13.23	25.45-23.35	18.96-17.70	9.50-0.13	49-(-284)
18	13.74-13.36	25.94-24.85	19.39-18.52	6.24-0.03	40-(-307)
20	13.44-12.14	26.56-25.93	19.94-19.38	4.10-0.01	35-(-309)
22	13.15-12.65	27.34-26.41	20.48-19.78	3.52-0.00	33-(-315)
24	13.13-12.86	27.53-26.51	20.62-19.84	2.98-0.00	32-(-323)
26	13.13-12.95	27.56-26.58	20.63-19.87	2.54-0.00	31-(-329)
28	13.12-12.97	27.55-26.62	20.62-19.90	1.37-0.00	30-(-331)

Values are maximum and minimum

and winter months, respectively. (Hatzikakidis, 1951). Throughout 1995 oxic/anoxic interface was recorded at the depth of 7 m (Psilovikos, 1995) while in the period 2003-2004 the anoxic layer had its maximum extent, from the depth of 4 m to the lagoon's bottom (Chalkias, 2006).

During the present study, the surface layer was saturated and often super-saturated in dissolved oxygen throughout the sampling period. This surface well oxygenated layer was 5 m deep during summer and spring, while in winter months its depth increased in 10 m. From this depth onwards, oxycline was extended, with its lower limit to be depended on season as well. During summer, anoxic layer was extended from 17-18 m depth up to the bottom of Aitoliko lagoon. Its thickness gradually decreased during the autumn months, and finally in December 2006, was limited below the depth of 24 m. January and February 2007, lagoon's monimolimnion was oxygenated. In January 2007, 3 mg l^{-1} dissolved oxygen was recorded in 20 m depth, while oxygen concentration was gradually decreased with depth, and values equal to about 1 mg l^{-1} characterized the maximum sampling depths. In February 2007, 3 mg l^{-1} of DO were measured at 25 m and values slightly lower than 1 mg l^{-1} were recorded in water sediment interface. In March and April, 2007 the anoxic layer was well developed below the depth of 20 m.

Our measurements demonstrate the anoxic layer limitation below the depth of 18 m during summer, but the most interesting is its absence during January and February 2007, since dissolved oxygen equal to 1 mg l^{-1}, just above lagoon's bottom, was measured (Table 3). Thus, the permanent anoxic Aitoliko lagoon (Hatzikakidis, 1951; Psilovikos, 1995; Chalkias, 2006) is reported, for first time, as seasonal anoxic. It would be really interesting and usefull to

Table - 4: Density (σ-t), salinity (‰), temperature (^oC), dissolved oxygen (mg l^{-1}), Eh (mV) and pH in the surface layer of Aitoliko lagoon during the sampling period

	Density (σ-t)	Salinity (‰)	Temperature (^oC)	Dissolved oxygen (mg l^{-1})	Eh (mV)	pH
Spring	13.88±1.86	20.53±1.57	19.32±4.20	11.86±2.29	53.56±77.72	8.48±0.25
Summer	11.49±0.92	20.61±1.46	28.40±1.09	6.97±0.63	58.05±25.69	
Autumn	14.89±0.83	22.43±0.07	19.17±4.10	8.98±3.44	30.77±88.88	7.89±0.04
Winter	16.15±0.18	21.64±0.07	12.48±1.08	12.58±0.90	146.38±60.64	7.93±0.37

Values are mean ± S.D.

Table - 5: Mean epilimnetic values for chlorophyll-*a* and total phosphorus (TP) in station A_9 during the sampling period. Secchi depth (m) values are mean values from A_2, A_4, A_8, A_9, A_{14} stations

	May 2006	June	July	August	September	October	November	December	January 2007	February	March	April
Water quality variable												
Chlorophyll-*a* (µg l^{-1})	3.84±2.64	5.06±5.05		6.86±6.86	5.36±3.71	3.26±2.97		6.29±4.79	10.04±4.79	7.14±2.02	10.42±5.60	14.89±8.71
Total P (µg l^{-1})	26.29±5.47	18.59±2.97	19.25±5.71	15.25±5.24	14.90±1.64	17.86±4.86	13.89±3.47	15.91±5.17	13.33±3.8	23.72±4.84	27.81±1.38	36.31±5.48
Secchi depth (m)	3±0.3	2±0.3	2±0.1	2±0.2	2±0.2	2±0.2	2±0.2	2.5±0.2	2±0.2	3±0.4	1.5±0.1	1±0.1

Values are mean ± S.D.

investigate the hydrodynamic mechanism under which the permanent anoxic Aitoliko lagoon was converted to a seasonal anoxic environment as well as the impact of this change on the hydrochemical and biological processes.

During this study, hydrogen sulfide concentrations in Aitoliko lagoon didn't determine. Nevertheless, its presence below the depth of 15 m was sensible, throughout the sampling period, through its characteristic odor. Hydrogen sulfide in mM order of magnitude were reported from Hatzikakidis (1951) and Psilovikos (1995), including in this way Aitoliko lagoon in the environments with the highest H_2S concentrations.

In Aitoliko lagoon, water column pH was high and varied from 7.7 to 8.7 in surface waters due to photosynthesis, while in the sulfide rich layer, pH was always between 7.0 and 7.5. This pH, vertical distribution, is typical in anoxic environments and does not differ from the values reported in the past for Aitoliko lagoon (Hatzikakidis, 1951; Chalkias, 2006). The high epilimnetic pH values, reflect biogeochemical processes, such as photosynthesis and respiration, while hypolimnetic pH decrease is due to organic matter decomposition, low dissolved oxygen and high sulfide concentrations.

Oxidation reduction potential is related to pH and oxygen concentration, pH increase and dissolved oxygen decrease have as result the redox potential value decrease. Most redox reactions are carried out by bacteria, which gain energy from converting substances to thermodynamically favoured state as dissolved oxygen and redox potentials change. Redox changes are important to primary production in natural ecosystems. In the study area, during the sampling period, the surface layer was characterized by high Eh values (up to 214 mV). Oxycline layer was reflected on Eh measurements with steep decrease on oxidation reduction potential values. The anoxic hypolimnion presented low Eh values (up to -331 mV) during the period May 2006-November 2006 (Table 3). Dissolved oxygen increase in Aitoliko lagoon monimolimnion, during January and February, 2007 is reflected in the increased Eh values in this layer from December 2006 to March 2007.

Chlorophyll-*a* is the most appropriate parameter to follow the growth of both algae and *Cyanobacteria*, in a coastal environment. Its load is a good indicator of the number of algae present in waters (Räike *et al.*, 2003). In Aitoliko lagoon, during the sampling period, chlorophyll-*a* values presented a positive trend reaching its maximum values 14.78 $\mu g\ l^{-1}$ in April, 2007. The most likely explanation for the increase in the chlorophyll abundance is an increase in nutrients, the food for algae. Total phosphorus concentrations, presented a positive trend throughout the sampling period as well. In April 2007, the measured TP concentration was equal to 36.31 $\mu g\ l^{-1}$. (Table 5). Nutrients in water are essential for phytoplankton growth. The more the nutrients, greater is the potential for growth. The nutrients have to be present in the right amounts and if one nutrient is lacking then the growth can be retarded (Grzetic and Eamprag, 2010).

Transparency was recorded using a Secchi disk. The readings can be affected by algae and by suspended solids in the water. Plankton scatters light, hence a basin which is less transparent tends to have more plankton and be more productive. The Aitoliko lagoon had low transparency throughout the sampling period (always lower than 3 m), and therefore, is generally regarded a productive one. The higher the amounts of algae present in the waters, the lower is the water transparency. The lower value for lagoon's transparency (1m) was recoded in April 2007, when chlorophyll-*a* and total phosphorus reached their maximum concentrations.

An excellent indicator of the eco-chemical status of any coastal basin would be its trophic state, described by the trophic state index (the Carlson TSI). The trophic state index is based on the belief that the degree of eutrophication is primarily related to increased nutrient concentrations - phosphorus in particular. An increase in phosphorus concentration is expected to increase the amount of algae as measured by chlorophyll-*a*. Simultaneously, water transparency declines.

For TSI of chlorophyll-*a* and TSI of total phosphorus the average epilimnetic concentrations were used, while for TSI of transparency the average value of the five sampling stations, were used (Table 5).

The obtained results for TSI show constant rising trends for all three parameters. The first parameter, TSI for Secchi depth had a minimum value of 44 and a maximum value of 59. The second parameter, TSI for total phosphorus had a minimum value of 42 and a maximum one of 56, while the third parameter, the TSI for chlorophyll-*a* had a minimum value of 42 and a maximum of 54. The positive trend of TSI values for Secchi depth, Chlorophyll-*a* and total phosphorus, indicating the rise from mesotrophic to eutrophic in Aitoliko lagoon trophic state, during the sampling period (Fig.2). Specifically, Aitoliko lagoon was classified as mesotrophic environment from May 2006 until February 2007; while in the spring months March and April 2007 lagoon was characterized as eutrophic. It seems that nutrient inflows in the basin are stable as Aitoliko lagoon keeps this trophic character during the last decades.

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