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RESEARCH ARTICLE

Spatial and temporal description of the dystrophic crisis in Lesina lagoon during summer 2008

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Abstract

1 - Lagoons are vulnerable ecosystems often exposed to eutrophication due to anthropogenic activities. They are characterized by high vulnerability to climatic factors and biogeochemical impairment that, in some cases, can lead to dystrophic crisis.

2 - Here we analyze the short term temporal pattern of climatic, physical and chemical parameters during a dystrophic crisis occurred in Lesina lagoon in Summer 2008, focusing on the interactive effect of their variations.

3 - To this aim, we integrated meteorological data, satellite image analysis and local physical and chemical measurements in order to have a more detailed sight of processes that can give raise to a dystrophic crisis and to describe how the crisis evolves.

4 - Results show that an unusual change in main wind direction, sun radiation, and other meteorological parameters with respect to the previous years together with a temporal closing of tidal channel that assure the seawater inflow led to an hydrologic isolation of the western basin of Lesina lagoon occurred in summer 2008. The consequent unbalance in biogeochemical cycles produced a dystrophic crisis and a shift, in this area, from a macrophytes based system toward a phytoplankton based system.

5 - Since changes in climatic factors or in hydrologic regimes into the eutrophic lagoon probably already happened previously in different moments without giving rise to dystrophic event, the crisis was likely triggered by the co-occurrence of both factor variations.

6 - It is essential to understand the mechanistic linkages in space and time between man-made alterations of hydrologic and nutrient load regimes (that can be managed or controlled) and unpredictable climatic factors in the context of the individual ecosystem for managing transitional water ecosystems incurring in nutrient enrichment.

Keywords: Lesina lagoon, dystrophic crisis, eutrophication, climatic change

Introduction

"Eutrophication is a new word in the vocabulary of many sanitary engineers and scientists and is destined to become a part of the normal complement of words used by everyone concerned with the broad concept of water resources" wrote Sawyer early in 1966 on his "Basic Concepts of eutrophication". More than 40 years later this prediction seems to be realized if we look at the number of articles published on the scientific journals set included in the JSTOR database. More than 2200 articles were published in the last decade of the 20^{th} century dealing with "eutrophication" and the same number will be reached probably until the next year (Figure 1).

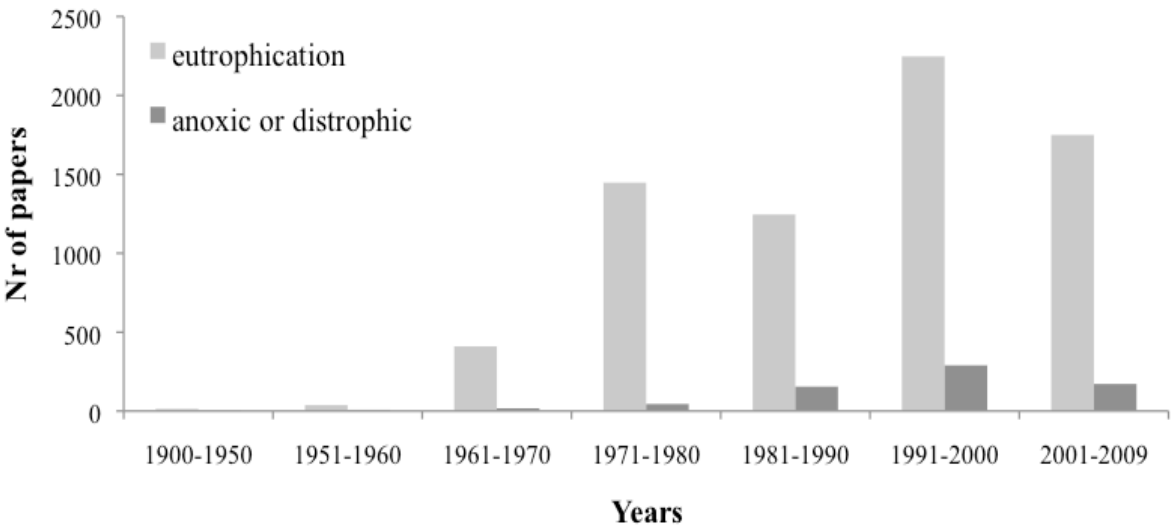

Figure 1. Number of articles published on scientific journals included in JSTOR database per decades from 1900 up to date. The gray columns line indicate the number of papers found using "eutrophication" as keyword. The black columns represents the results of "(anoxic event)OR(dystrophic event)AND(aquatic)"

Most of the aquatic ecosystems of varying characters worldwide receives regular inputs of a range of nutrients in varying quantities (Fareed and Ansari, 2005). Among them coastal systems in urbanized areas worldwide are becoming eutrophic as a result of increased nutrient loading from human activities. Anthropogenic nutrient enrichment is considered to be one cause of increased abundance of phytoplankton and macroalgae and accompanying changes in the structure and function of transitional ecosystems (Price *et al*. 1985; Rosenberg, 1985; Valiela *et al*. 1992). However "During the last 20 years the word eutrophication has been used more and more in the sense of the artificial and undesirable addition of plant nutrients to waters. This is to some extent an unfortunate change in emphasis since what is an un-desirable addition to one water may be desirable or harmless in another" (Lund, 1972). Nevertheless eutrophication describes a process that lead to a new trophic state (the eutrophic state) characterized by high productivity and biomass. This change in trophic state could make the ecosystem more sensitive to environmental changes but not necessarily unbalanced. Late in 2001 Pinckney and colleagues wrote "The term eutrophication describes a process rather than a trophic state". Nixon (1995) proposed to define eutrophication as "an increase in the rate of supply of organic matter to an ecosystem". As a matter of fact in the last 30 years an increasing number of published articles (Figure 1) pointed out the consequences of eutrophication as "Anoxic event" or "dystrophic event" more than eutrophication itself. In this article we suggest the terminological distinction between "eutrophication" (according to Nixon 1995), "hypoxia" (Dissolved oxygen <50%; Breitburg 2002), "anoxia" (Dissolved oxygen <3 mg/l; for instance D'Avanzo 1994) and "dystrophy" (white waters, sulphide diffusion in the water column, fish death; Valiela 1984) on the basis of water column and benthic respiration relative to production and of temporal duration of the event. Each one of these state could be considered a reversible stage of a temporal or spatial succession that drive the system toward the crisis.

Shallow lagoons are well represented in many coastlines and are often urbanized. These ecosystems are really vulnerable to eutrophication if nutrient inputs are high and water turnover times are low. In many shallow lagoons benthic macrophytes are dominant producers where sufficient irradiance reaches the bottom. In lagoons placed in urbanized areas, the increase in nutrient loading apparently promotes growth of phytoplankton and floating macroalgae at the expense of benthic rooted plants (Lee and Olsen 1985; Valiela *et al*. 1992, Duarte 1995). An increase in primary producers biomass often enhances the global secondary productivity and this process can be managed in order to obtain also some economic benefits. On the other hand an increase in global productivity reduces the resistance of these ecosystems to environmental stresses increasing the probability to undergo a dystrophic crisis caused by unbalanced production/respiration rates. The shift from benthic to pelagic primary production usually introduces large diurnal variations in oxygen conditions from high rates of photosynthesis during day followed by high respiration rates at night. High rates of respiration have caused widespread and recurrent anoxia and hypoxia in urbanized ecosystems (Officer *et al*. 1984; Parker and O'Reilly 1991, Sfriso *et al* 1992, Tsirtsis 2008). In addition, oxygen consumption within the sediment increases the deposition of easy degradable algal material on the sediment. In semi-enclosed basins with low water exchange such high rates of consumption may regularly cause anoxia in bottom water and sulphide emissions from the sediment to the water column resulting in dystrophic crisis with mass mortality of infauna and fish. Therefore deeper knowledge of the main driving forces in lagoons is required in order to set the cause-effect relationship that turns eutrophication in transient hypoxia or anoxia in order to prevent the shift of the internal metabolism toward a dystrophic crisis.

Several authors reported that the duration and intensity of seasonal and episodic hypoxia are heavily influenced by physical variables such as water temperature, freshwater inflow, tidal mixing, and wind events (Haas 1977; Taft *et al*. 1980; Pihl *et al*. 1991). Deviations in dissolved oxygen dynamics from the general temporal pattern in atypical events have been attributed to environmental variables such as temperature, irradiance, precipitation, tide, freshwater discharge, and wind (Beck and Bruland 2000). Extreme hypoxic events have often occurred in association with early morning low tide (Edwards *et al*. 2004), heavy cloud cover (D'Avanzo and Kremer 1994; D'Avanzo *et al*. 1996) and calm wind conditions, usually following a rain event (Gallegos *et al*. 1992; Lapointe and Matzie 1996).

In this study, we report a general description, in a short temporal scale, of the dynamics in hydrological and chemical factors in Lesina lagoon, a shallow lagoon in south

Italy, during a dystrophic crisis that occurred in summer 2008. Severe and prolonged hypoxia events in a well localized area of this lagoon took place starting few weeks after the extraordinary maintenance works on Acquarotta channel, one of the main exchange channel with the sea, and persisted for several weeks.

The objectives of our research were to I) highlight the strength of associations between the dystrophic event and some abiotic, physical environmental variables that influence biological production and respiration (i.e. water temperature, tide, precipitation, and wind), II) define the local variability in the intensity and spatial dynamics of dissolved nutrient cycling and primary producers biomass during severe hypoxia events, and III) use these results to enhance understanding of the combinations of variables that culminate in severe hypoxia, which may in turn lead to food web disruptions (e.g., changes in community structure, abundance, and mortality) in shallow transitional waters.

Materials and Methods

Study site

The Lagoon of Lesina (41.88°N and 15.45°E) is located along the southern Adriatic coast of Italy (Figure 2) and is characterised by shallow waters (0.7-1.5 m) and limited exchanges with the sea, features that it shares with many other Mediterranean lagoons.

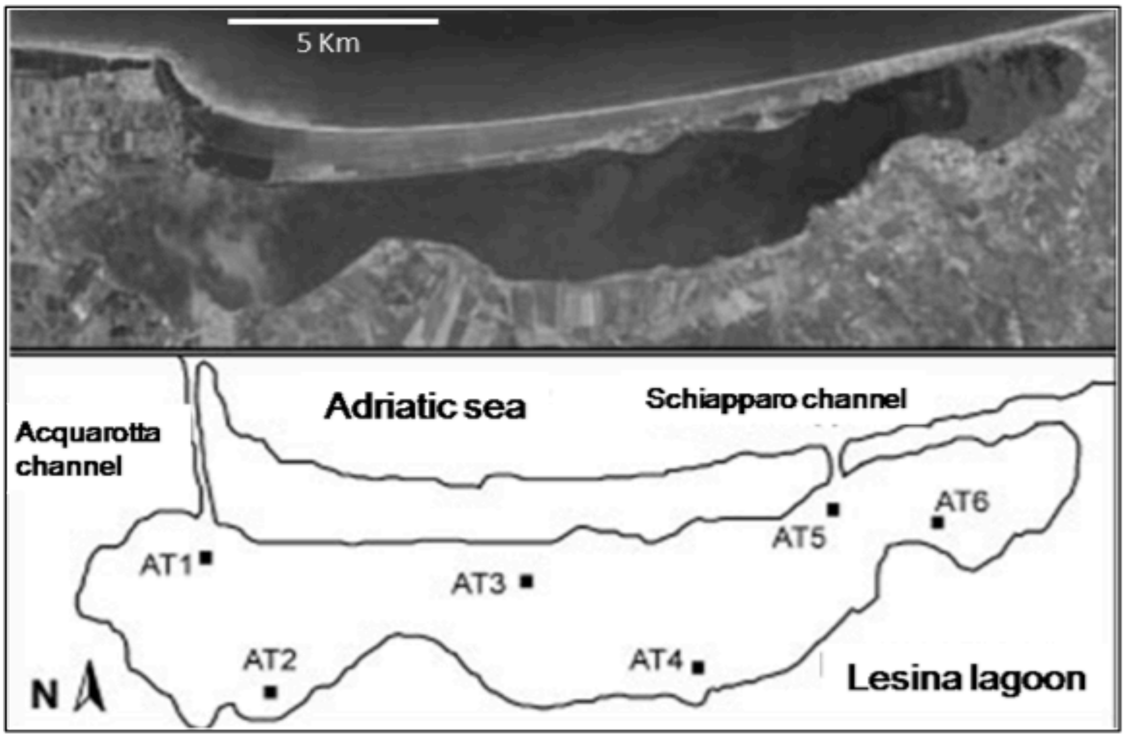

Figure 2. Sampling sites in the Lesina lagoon in the annual monitoring programme. During the dystrophic crisis AT2 station represented "impact" and AT3 station the "control"

The lagoon is about 24.4 km long, with a total area of 51.4 km^2; the catchment area is about 600 km^2. The lagoon is separated from the sea by a sand-bar about 18 km long characterized by typical Mediterranean coastal vegetation. Seawater enter the lagoon by two tidal channels: Acquarotta to the West, about 2 km long, and Schiapparo to the East, about 1 km long. Over the last ten years, rainfall (400-700 mm a year) has tended to be concentrated in autumn-winter. However, heavy rainfall events have also been recorded in spring. The hydrological regime is strongly influenced by continental freshwater inputs and by local meteorological conditions (winds and rains). The residence time of the waters is estimated to be about 70-100 days (Manini *et al*., 2002). The lagoon's main hydrological features, temperature and salinity follow a seasonal trend, with minimum values in winter and maximum values in summer. Temperatures generally range from 3 to 32 °C and salinity from 5 to 38 ppt. Fresh-water inputs, precipitation and the exchange efficiency of the tidal channels generate a well structured salinity gradient, which rises towards the West (Manini *et al*. 2002; Fabbrocini *et al*. 2005). Main freshwater inputs enter the basin along its southern edge. Roughly 80% of the annual freshwater budget is discharged into the eastern part of the lagoon (Roselli 2009). The partially treated waste waters of three municipalities with a total of 30000 inhabitants are discharged into the lagoon by the Elce channel (8000 inhabitants), the river Lauro and the Idrovora Lauro pumping station. Waters drained from nearby cultivated land (21000 ha) are discharged into the lagoon by the Lauro and Zannella watercourses and the Idrovora Pilla pumping station; the area surrounding the western end of the basin is used for intensive vegetable and wheat farming. In addition, there are three intensive fish farms along the coast which discharge wastewaters into the lagoon through small channels on the western side and through the Zannella channel on the eastern side. Finally there is a cattle farm situated on the western shore, near the Acquarotta channel. The macrophytobenthos community is composed by the rhizophytes *Ruppia cirrhosa* and *Nanozostera noltii*, mainly distributed in the Eastern and central parts of the basin. In the western area, variations in salinity and progressive nutrient enrichment over the last thirty years have led to a succession of uniform carpets of macro-algae, from *Gracilaria gracilis* to Cladophora sp., which have occasionally caused anoxic crises (Manini *et al*. 2003). The lagoon of Lesina is a nursery area for numerous fish and crustacean species of commercial value (Villani, 1998). Fishing and commercial activity associated to fisheries has an important economic role in local economy.

Sampling and analysis

Since february 2008 Lesina lagoon was included in a monitoring programme carried out by ARPA Puglia in collaboration with University of Salento, CNR-Ismar Lesina and CNR-Istituto per l'ambiente marino costiero of Taranto. Sampling was performed every 1 or 2 months (depending on the considered parameter) in 6 stations situated along the major axis of the lagoon (Figure 2). All sampling were conducted during tidal outflow. Water temperature (°C), salinity (ppt), dissolved oxygen (% saturation) and pH were measured, *in situ*, using a YSI 556 MPS multiprobe. Transparency was evaluated with a Secchi disk. Water samples were taken in triplicate at a depth of 30-50 cm, kept refrigerated and conveyed as soon as possible to the laboratories for subsequent analyses of dissolved nutrients, chlorophyll *a*, suspended particulate matter. Samples taken for phytoplankton cell counting and taxonomic assessment of phytoplankton community were immediately fixed by Lugol solution. Sediment samples were collected by means of an Ekman dredge (15x15cm) in order to analyse ORP, TOC and organic matter content. Three other sediment samples were immediately passed through a 1mm-mesh sieve, transferred to the laboratory, then fixed with formaldehyde 4% before the

determination of macrobenthos community structure.
Metereological data were acquired daily from a weather station belonging to "Consorzio per la Bonifica della Capitanata" located near the lagoon (41°51'32.83"N 15°17'29.49"E). Daily wind direction and velocity, irradiance, humidity, air temperatures and other meteorological parameters were obtained from an automated weather station placed near the lagoon. At the start of the dystrophic crisis the temporal scale of sampling was modified to a weekly scale (from 9.00 AM to 12.00 AM) in two sampling site: AT2 (impacted) placed in the centre of the dystrophy and AT3 (control) just outside the area interested, for a period ranging from the end of May to September 2008. In the same period satellite images of the lagoon were acquired in order to evaluate the spatial evolution of the dystrophic event. Dissolved nutrient concentrations (ammonium (NH_4^+), oxidised nitrogen (NO_2^- NO_3^-), nitrite (NO_2^-), soluble reactive phosphorus (SRP), soluble reactive silicate (SRSi), total nitrogen (TN) and total phosphorus (TP) were analysed using a Bran+Luebbe QuAAtro flow analyser according to Grasshoff *et al*. (1999). Chlorophyll *a* was estimated spectrofluorimetrically after pigment extraction in 90% acetone (Yentsch and Menzel 1963). In each samples the relative contribution to total biomass of different dimensional classes (picophytoplankton, nanophytoplankton and microphytoplankton) after differential filtration was also determined. The phytoplankton cells counting was realized following the Utermöhl method

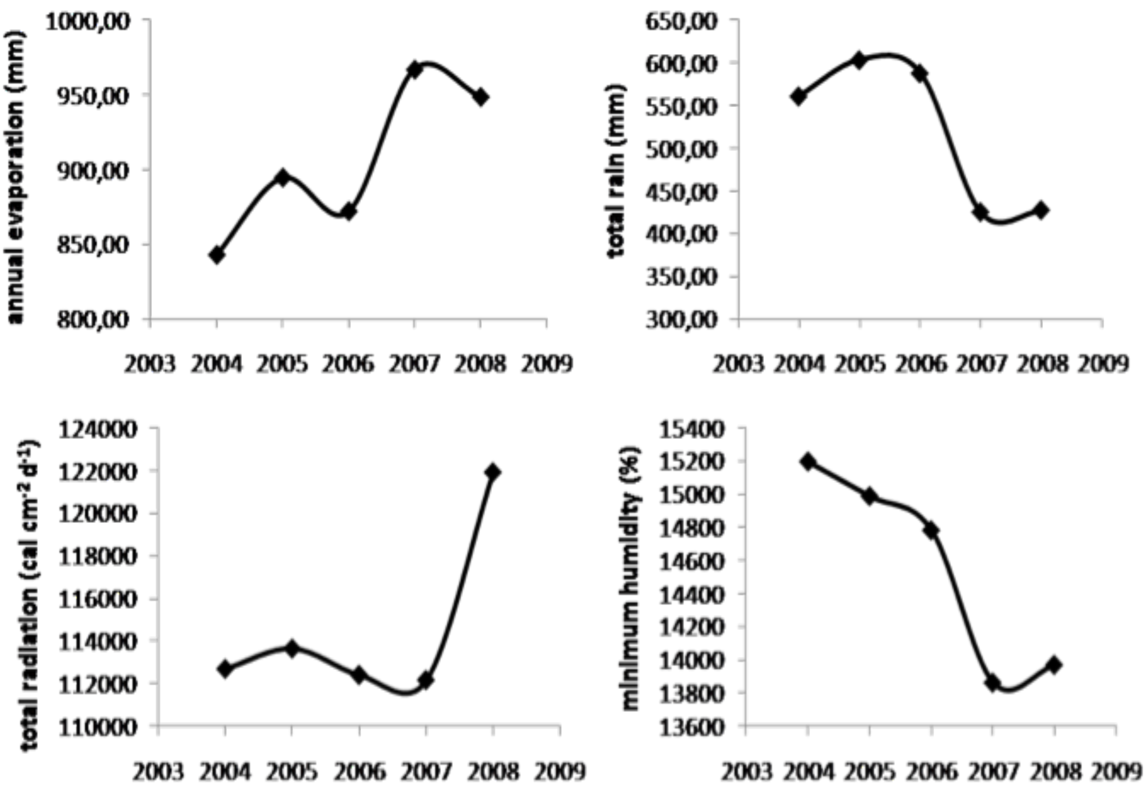

Figure 3. Annual time course of main meteorological parameters. Data for evaporation, total rain and total radiation are expressed as sum; minimum humidity is presented as average.

(1958). Nano-and micro-plankton cells were also identified by using various taxonomic guide.

Suspended particulate matter was concentrated using fibre-glass Whatman GF/F filters, dried to determine the quantity of total suspended matter (TSM) and subsequently burned in a muffle furnace in order to estimate the organic fraction (POM), in accordance with the methods set out in Strickland and Parsons (1968).

Benthic samples, fixed with 4% buffered Formaldehyde solution, were sorted and selected from the sediment matrix under stereomicroscopes; each specimen was identified by dichotomous keys and measured.

Satellite images of Lesina lagoon in the period from June to September were obtained by Landsat 7 ETM. The extension of the area involved in the dystrophic crisis was calculated by means of image analysis utilizing a freeware version of ImageJ (ver.1.42q Wayne Rasband National Institute of Health USA).

Results

Patterns of variation of meteorological data along a 5 years period before the crisis event is shown in Figure 3. During 2008 the total annual incoming radiation and evaporation

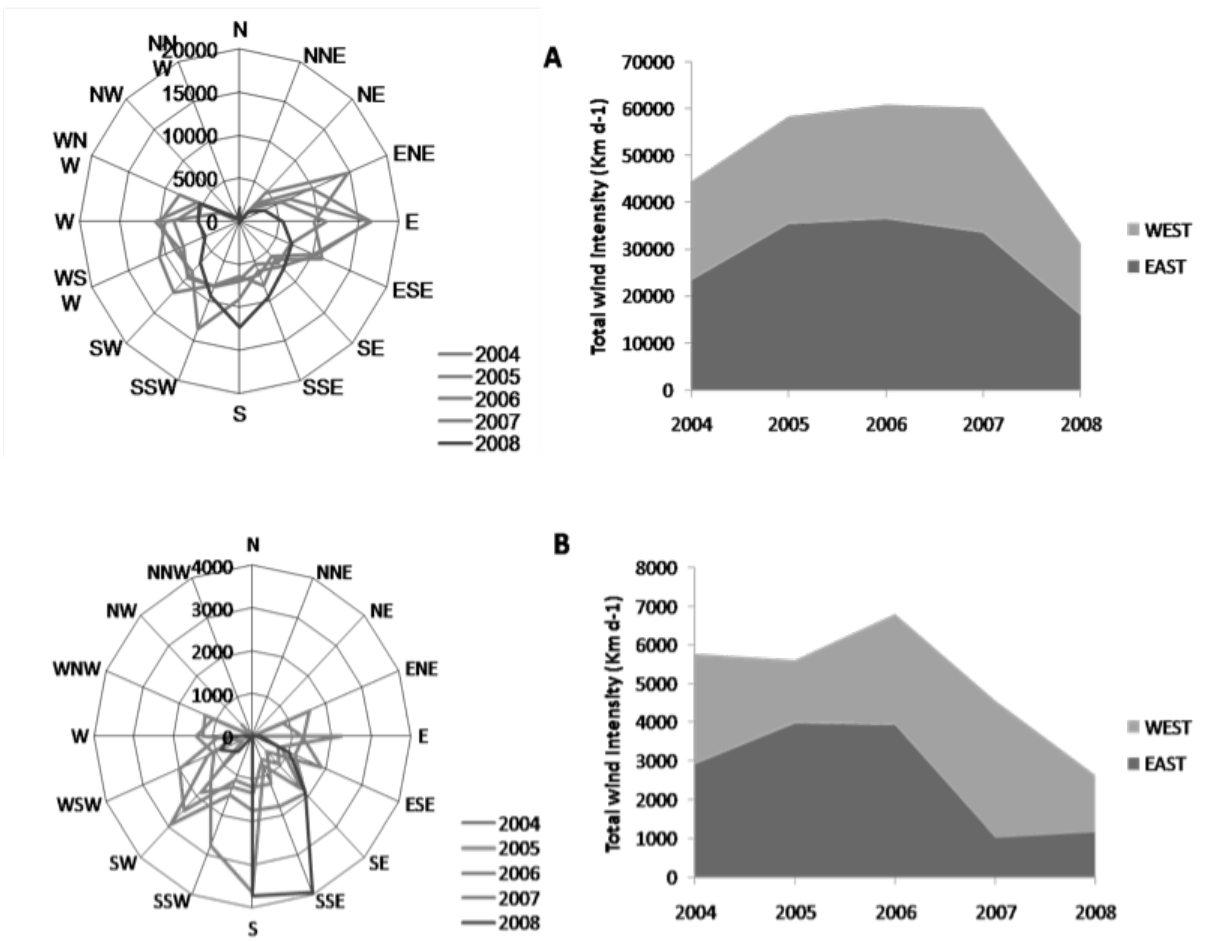

Figure 4. Annual (A) and period limited "May-June" (B) distribution of wind intensity (left) in the windrose. Graph on the right represent the annual comparison of the total intensity of the winds blowing from West (WSW, W and WNW) and East (ESE, E and ENE)

showed an increase with respect to the previous years while total rain and humidity presented a marked reduction. According with these data it is plain that the 2008 year was a dryer year. Another important climatic factor analyzed was the intensity of the wind which, together with tides, can drive the water exchange in the lagoon. In 2008 there was a considerable reduction in intensity of the wind blowing from the sector East (ESE, E and ENE) and West (WSW, W and WNW) (Figure 4a) even though no differences in total annual intensity were found with respect to the previous years. This reduction seemed more considerable in the period of two months just before the dystrophic crisis (May-June)(Figure 4b).
An image analysis of satellite photographs was run in order to estimate the area affected by the dystrophic crisis (Figure 5). Calculations showed a sharp increase of the area interested by dystrophy reaching soon a maximum surface of 4,2 Km^2 and a more gradual return to normality during the next month. More than 42% of the area of the entire western basin of the lagoon was affected by dystrophy. The phenomenon involved mainly the area in front of the city of Lesina and its waste water discharging and reached a mean radius of 1.2 km expanding in the western basin northward up to the sand-bar.
Physical and chemical parameters in water were strongly influenced by the dystrophic crisis. In AT2 station transparency declined immediately reaching values as low as 30 cm whereas in control station AT3 light reached always the bottom of the lagoon. At the same time salinity increased faster in AT2 station with respect to AT3 (Figure 6). Measurements of the total suspended solids showed an increase in turbidity as the difference in salinity between the two station increase (Figure 7). Large fluctuations of dissolved oxygen and pH occurred during

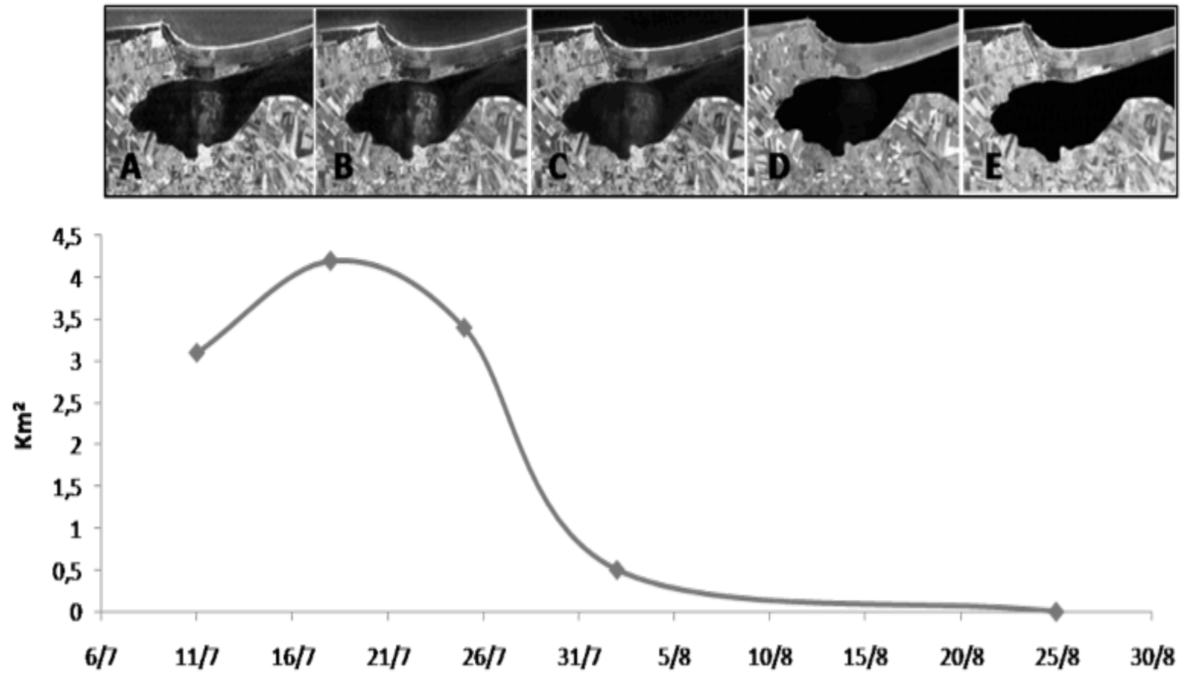

Figure 5. Time course of the area interested by the dystrophic crises as calculated from satellite image analysis.

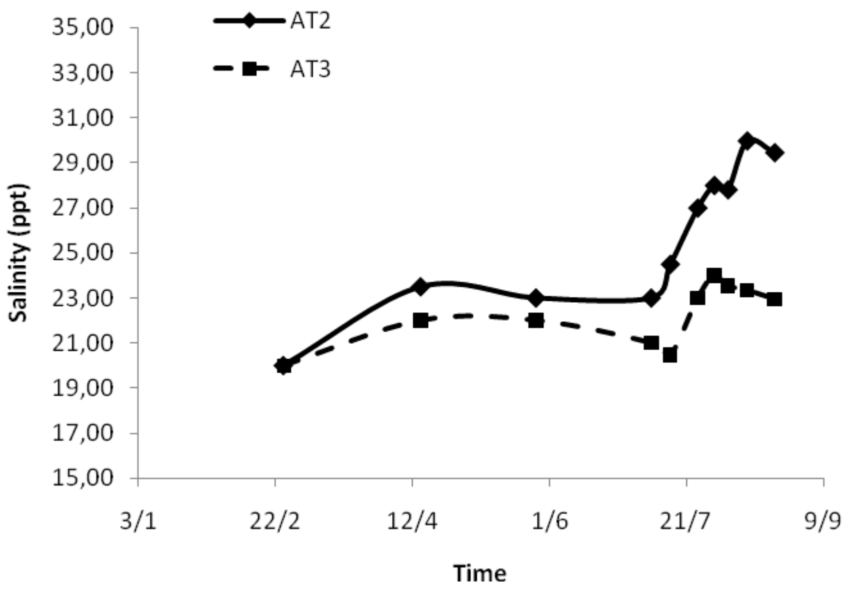

Figure 6. Salinity time course in AT2 and AT3 stations during the dystrophic crisis

that period (Figure 8). pH tended to decrease in both stations but, in the impacted one, pH values showed a marked oscillatory trend with lower values throughout the crisis. Dissolved oxygen concentration, usually in supersaturation, fell down to severe hypoxic conditions, reaching values as low as 2 mg l^{-1}. Although all the measurements were made nearly in the same conditions of insolation and in the same hours in the morning, measured values varied largely during the dystrophic crisis reaching finally stable values at

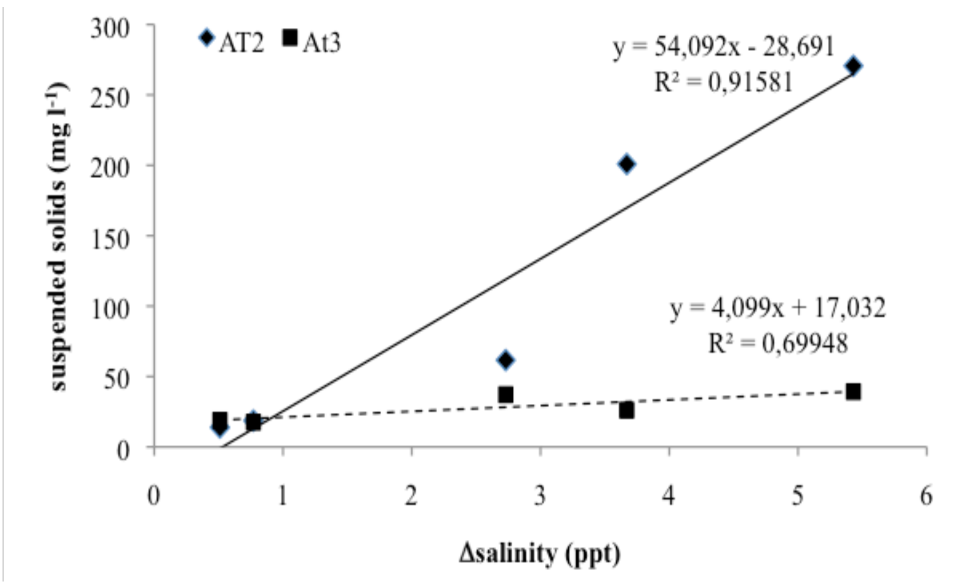

Figure 7. Suspended solid concentrations in AT2 and AT3 stations refferred to the difference in salinity between the two stations (ΔSalinity= AT2Salinity-AT3 salinity)

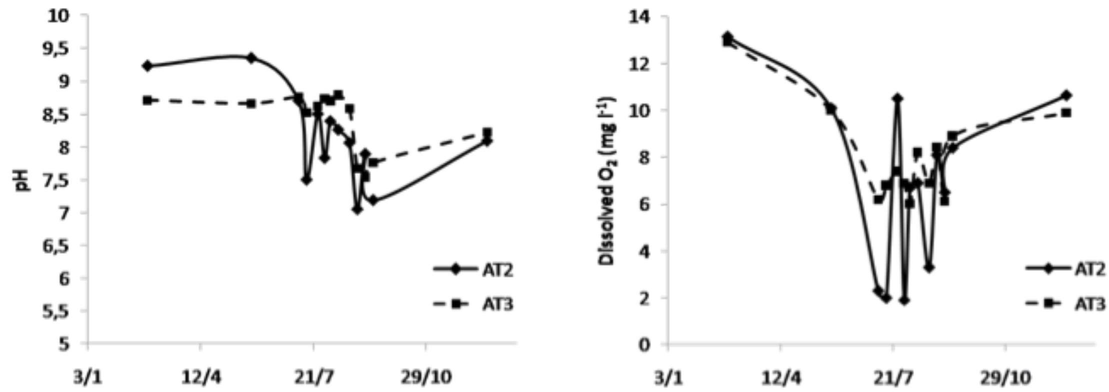

Figure 8. Variations in pH and dissolved oxygen values during the dystrophic crisis in the water column of AT2 and AT3 stations.

the end of August. Hypoxia, as expected, drove the water chemical characteristics. Reduced forms of nitrogen prevailed on the oxidised ones (Figure 9), inorganic dissolved phosphorous varied abruptly whereas total phosphorous showed higher concentration in the impacted station all over the sampling time. The effect of these changes on the biotic component was quite direct. The time course of phytoplankton biomass expressed as chlorophyll *a* is presented in Figure 10. In AT2 chlorophyll *a* concentration rose early in a peak of more than 180 mg m^{-3}, then decreased before presenting a second smaller peak after 5 weeks. Values of chlorophyll *a* in AT3, on the contrary, remained nearly stable during the entire period, ranging from 0.3 to 5.9 mg m^{-3}. The phytoplankton biomass resulted correlated with several physical and chemical parameters in water. Table 1 list

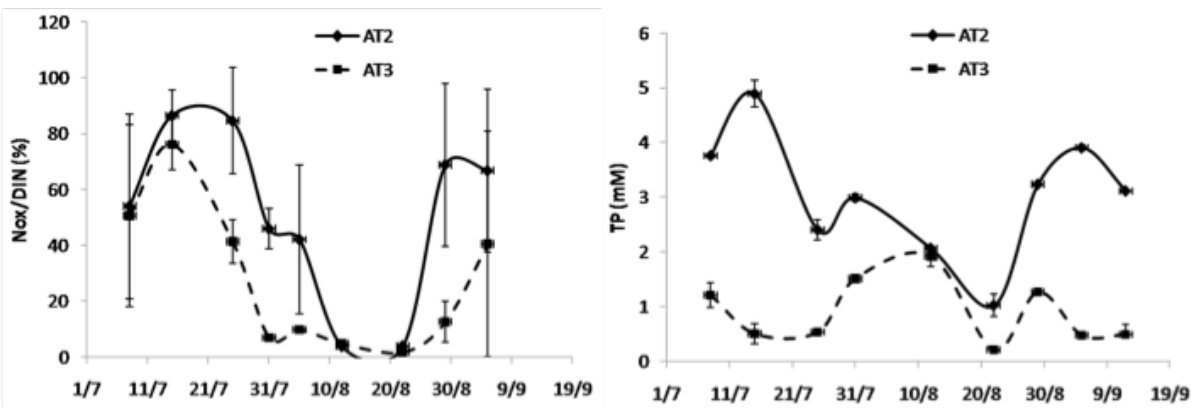

Figure 9. Fluctuations of dissolved Nox percentages and Total phosphorus in the water column in AT2 and AT3 sampling stations.

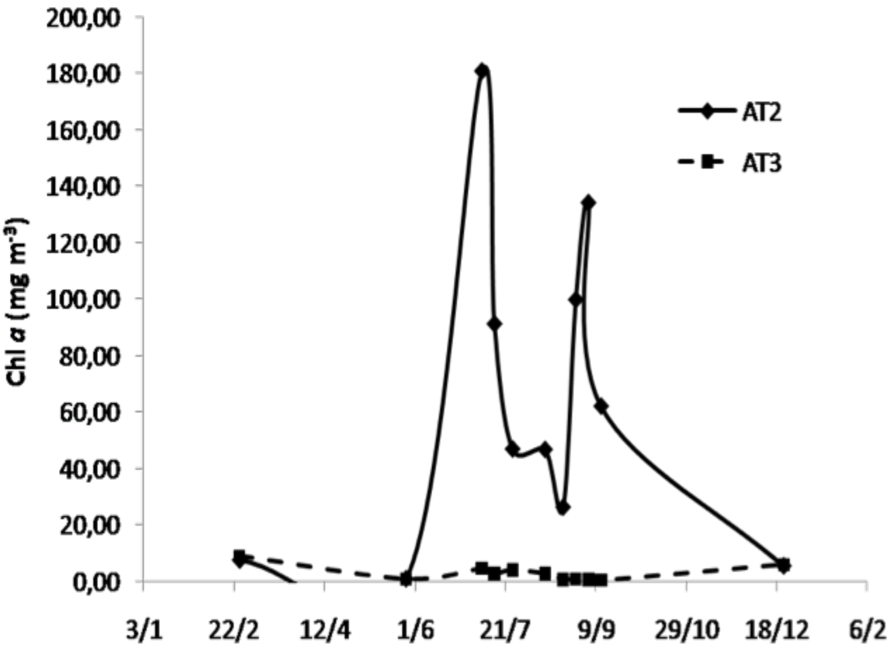

Figure 10. Chlorophyll *a* concentrations in the water column of AT2 and AT3 sampling stations during the dystrophic crisis.

the significant correlation found between chlorophyll *a* concentration and the principal dissolved nutrients (D'Adamo, 2009 personal communication). It is noteworthy that correlation between chlorophyll a and dissolved oxygen was negative; also negatives were the correlation with different forms of nitrogen and silicon whereas the correlation

Table 1 - List of significant relationship between chlorophyll *a* concentrations and physical or chemical parameters in the water column (Specchiulli 2009, next in this issue) during the dystrophic crisis.

parameter	relationship	P
O_2 (mg l^{-1})	-63,82 Ln(O_2)+147.17	<0.01
NH_4^+ (μM)	-18.88 Ln(NH_4^+)+29.66	<0.01
Total nitrogen (μM)	-30.91Ln(TN)+109,72	<0.01
Total organic nitrogen (μM)	-31.43Ln(TON)+106.31	<0.01
DIP(μM)	133.22(DIP)+7.14	<0.05
Total phosphorous (μM)	31.12(TP)-14.84	<0.01
Si (μM)	-23.44(Si)+98.41	<0.01

between chlorophyll *a* and phosphorous was positive. No significant correlation were found between chlorophyll and total nitrogen or TOC in sediments even though evidence could be found about a strong influence of TOC on water column chemistry (Specchiulli, 2009).

Discussion

In this work a temporal description of a dystrophic crisis in a Mediterranean lagoon is presented making use as well of satellite image analysis. Satellite imagery is now widely used to examine spatial and temporal trends in several ecosystems (Focardi *et al*. 2006) and it was proposed as a tool for monitoring the spatial distribution of phytoplankton biomass in the surface layer as an additional approach in eutrophication surveillance (Specchiulli *et al*. 2008). In our work satellite images return a clear description of the temporal evolution of the crisis. At the beginning of June the area covered by dystrophy rose suddenly to cover more than 4 Km^2 (a large part of the western basin) and decreased very slowly till the end of August. Dystrophy took place mainly in the area surrounding the city of Lesina and its waste water discharging and no horizontal sliding or water mixing was observed during the period revealing, practically, a hydrological isolation of the western basin of the lagoon. Probable factors that triggered the dystrophic crisis were analyzed. Focus on meteorological data revealed the importance of climatic changes in dystrophic crisis rising either in Lesina lagoon or in different Mediterranean lagoon. In many Mediterranean lagoons, in fact, eutrophication is an emerging problem that need pressing scientific and operational answers in order to manage them avoiding to result in dystrophic crisis. Generally the interaction of several environmental and anthropogenic factors is required to cause a dystrophic crisis. Among them meteorological factors like temperature, daily sun radiation, rainfall, wind intensity and tide can act directly on primary producers or indirectly influencing the hydrological conditions into the lagoon (residence time and tide mixing) (Reynolds 1984). On the other hand the man-made nutrient enrichments by sewage and fertilizers can create the optimal conditions for macrophytes overgrowing or algal blooms that drive the system toward an unbalance in dissolved oxygen availability, starting the phase sequence coming from hypoxia and anoxia to dystrophy.

Due to its shallow depth, the Lesina lagoon is strongly influenced by atmospheric events and terrestrial inputs but no dystrophic crisis were reported in it in recent past, with the exception of very localized and short temporal anecdotic described events. Indirect evidence were produced about localized previous anoxic events (Manini 2003) but a detailed description is not available. In 2008 an increase in evaporation and in sun radiation and a decrease in rain and humidity lead probably to an anticipation in summer temperatures. The contemporary closing of the Acquarotta channel, which prevented the input of freshly oxygenated seawater into the lagoon, and the reduction in intensity of the winds blowing along the longer geographical axis of the lagoon caused probably a strong increase in water residence time of the western basin and prevented the mixing waters intake. An early divergence in physical factors such as salinity between AT2 station, in the middle of the dystrophic area, and AT3 station (control) occurred indicating a possible hydrologic isolation of the western basin from the rest of the lagoon. Not a clear vertical stratification was however measured, probably due to the very low depth of the sub-basin. Without a supply of oxygenated water by seawater flushing neither dilution effects, reductive processes started likely soon to overcome the oxidative ones. An overgrowth of *Gracilaria gracilis* (Cecere 2009, personal communication) was reported in May 2008 in the same area just few weeks before the dystrophic crisis. Early observation stated that the standing stock of Gracilaria sp. can reach values as high as 20 $Kg_{fresh\ weight}$ m^{-2} (Francavilla and Trotta, 2007) in the western basin of Lesina lagoon. No observations are available on the physiological status of *Gracilaria gracilis* at the beginning of the dystrophic crisis but a mechanism similar to that described in D'Avanzo 1994 could be invoked, with respiratory demand of the entire macrophyte stock overcoming the productivity carried out only by the thick algal canopy actively photosynthesizing. However high values of TOC and TN were found in sediments before and during the crisis, suggesting a trigger effect by the organic matter in sediments (Specchiulli 2009).

Soon after suspended solids and water turbidity increased sharply resulting in a shadowing effect on sediments. With no light reaching the bottom, a shift from a macrophytes-dominated system to a phytoplankton-dominated system was observed. The phosphorus released as a result of the decomposition of macroalgal biomass was promptly re-used by phytoplankton (Gomez *et al*., 1998). As a matter of fact chlorophyll *a* concentration, usually ranging from 0.5 to 9.0 mg m^{-3} (Roselli *et al*. 2009), peaked soon in the early June ruling over the local biogeochemical patterns of nutrients. The linkage between nutrient release and hypoxia/anoxia dynamics is often complex and non-linear in transitional water systems (Cloern, 2001). Anyway the extraordinary bloom of phytoplankton gave rise to large fluctuations in physical parameters like dissolved oxygen and pH producing an unbalance in the water column metabolism. The following decrease in chlorophyll *a* concentration is probably due to unsustainable biomass of phytoplankton. At the same time the equilibrium between the different chemical forms of dissolved nitrogen shifted toward the reduced species, whereas dissolved inorganic phosphorous cycling was probably enhanced. No trend in phosphorous uptake were recognizable but a substantial increase in total phosphorous was measured, probably most of this retained in floating biomass. The role of phytoplankton in the water column chemistry is also highlighted by the several significant correlations between chlorophyll *a* content and chemical parameters. The negative correlation with dissolved oxygen is coherent with dystrophy, because total respiration could overwhelm the production. Negative correlations with the different forms of nitrogen and silicon could be due to an active uptake of nitrogen from phytoplankton (mainly diatoms: Vadrucci *et al*. 2009) whereas the direct dependence of biomass with dissolved inorganic phosphorus suggest a significant release of this nutrient by sediment, probably due to the change in red-ox conditions, and a prompt exploitation by phytoplankton. A slightly and not significant positive correlation between dissolved phosphorous in water and TOC in sediment seems to confirm this hypothesis but more data are required for a statistical inference.

Conclusions

Lesina lagoon is a non-tidal, autotrophic (Manini *et al*. 2002) and eutrophic lagoon (Roselli *et al*. 2009). It receives a continuous environmental pressure consisting in a nutrient load deriving from agricultural, zootechnical and fish farming activity and from waste water discharge. The two channels connecting it with the sea play a very important role in flushing the lagoon and maintaining the quality of waters. Due to the artificial origin of the tidal channels of the Lagoon of Lesina, it is important to avoid their periodical silting up, in order to improve tidal dilution and the flow of nutrients, thereby minimising the effects of accumulation (Newton and Mudge, 2005; Coelho *et al*., 2007) and preserving the nursery function of these ecosystems. For this reason in summer 2008 extraordinary maintenance works in Acquarotta channel were started. The contemporary alterations in meteorological conditions, mainly the reduction in West and East oriented winds and an increase in temperatures, sun radiation and evaporation enhanced the biogeochemical processes leading to the dystrophic crisis. It could be suppose that local hypoxic events are not uncommon at sediment-water interface in Lesina lagoon during every summer but in 2008 the co-occurrence with critical meteorological conditions represented the key factor. The interactions between anthropogenic and climatic factor was obviously complex but a better knowledge of the local interactions of factors that control the phytoplankton productivity and its composition is essential to understanding, predicting, and ultimately managing eutrophication in a climatic changing world. Invariably, even nearby transitional water system do not exhibit identical physical (residence time, stratification), chemical (nutrient supply, cycling rates), and biological (community composition, microbial associations, grazing) characteristics.

Global warming is expected to cause unpredictable changes in frequency and intensity of precipitation, wind and radiation both in global and in local scales. Hence it is essential to understand the mechanistic linkages in space and time between man-made alterations of hydrologic and nutrient load regimes (that can be managed or controlled) and climatic factors (normally uncontrollable) in the context of the individual ecosystem. A better cooperation among research and government control institutes seems therefore necessary to develop best realistic, ecologically sustainable and cost-effective strategies for management transitional water ecosystems.

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