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TROPHIC STATUS CHANGES IN THE VENICE LAGOON DURING THE LAST 40 YEARS

EVOLUZIONE DELLO STATO TROFICO DELLA LAGUNA DI VENEZIA NEGLI ULTIMI 40 ANNI

Abstract *- In the Venice lagoon nutrient concentrations increased significantly up to the end of the 1990s both in surface sediments and water column. Consequently, abnormal biomasses of thionitrophilic macroalgae colonised the lagoon contributing to their further increase. In the successive years, both macroalgal biomass and nutrient concentrations declined and the ecological status of the lagoon increased. These trophic changes are presented by analysing their variation both in the central lagoon since the 1980 and in the whole lagoon from the early 2000s.*

Key-words*: trophic status, nutrient concentrations, biomass changes, species dominance, Venice Lagoon.*

Introduction - Coastal areas and transitional systems, since the 2nd post-war period, were affected by strong changes in the trophic status, especially in the northern Adriatic Sea. Nutrients carried by rivers and/or surface runoff increased considerably, both in the water column and surface sediments, triggering phytoplankton and macroalgal blooms. Coastal waters of the Emilia-Romagna region, lagoons in the Po delta and the lagoon of Venice were affected by changes of trophic status, but with different trends. The lagoons and the coastal sea affected by the Po discharge are still eutrophic (Sfriso *et al.*, 2014a, 2016), whereas the Venice Lagoon is undergoing recovery.

Materials and methods - In this paper trophic status changes recorded in the last 40 years in the Venice Lagoon are analysed as the variations of nutrient concentrations in the water column and surface sediments and as changes of macroalgae biomass and production.

Results - The lagoon of Venice is one of the most studied coastal ecosystems. Nutrient data are available since the 1950s. The concentration of total phosphorus (TP) and total nitrogen (TN) in surface sediment increased by 18.9 and 1.9 times, respectively, from 1948 to 1983. In the successive years TP slightly decreased whereas TN decreased significantly. If the central lagoon is considered, by examining the same 34 stations and sediment sections (0-5 cm top layer), a strong Organic Phosphorus (OP: -49%) and Total Nitrogen (TN: -41%) decrease were recorded from 1987 to 2003 (Tab. 1). In 2011, the location of the stations was different, but OP was again ca. 41%, lower than in 1987, whereas TN decreased even by 71%. The decrements of the maximum values were even greater (Tab. 1). In the water column the highest differences were recorded for ammonium. In the industrial area of Porto Marghera, ammonium decreased from 3800 µM in 1962-64 to 1200 µM in 1970-72, 200 µM in 1976-77 and ca. 10-20 µM in 2011, whereas nitrates showed quite the same values.

Tab. 1 - Changes of Phosphorus and Nitrogen concentrations in surface sediments of the central basin of the Venice Lagoon. In 2011 the stations were placed in different locations.
Variazione delle concentrazioni di fosforo ed azoto nei sedimenti superficiali del bacino centrale della laguna Veneta. Nel 2011 le stazioni erano posizionate in località differenti.

	Total Phosphorus					Organic Phospohorus					Total Nitrogen				
	1987	1993	1998	2003	2011	1987	1993	1998	2003	2011	1987	1993	1998	2003	2011
	µg/cm³					µg/cm³					mg/cm³				
stations N°	34	34	34	34	31	34	34	34	34	31	34	34	34	34	31
Mean	386	361	375	358	383	104	67	59	53	62	1.21	1.14	0.93	0.71	0.35
STD	98	80	65	99	50	42	28	31	53	24	0.60	0.48	0.48	0.36	0.48
Min	227	184	257	201	281	49	27	16	2	13	0.22	0.33	0.10	0.09	0.04
Max	720	682	541	635	473	246	210	167	150	113	3.00	2.62	1.37	1.48	0.48
2003-1987	-7.3%					-49.0%					-41.3%				
2003-2011	≈					-40.4%					-71.1%				

Dissolved Inorganic Nitrogen (DIN) and Reactive Phosphorus (RP) concentrations, recorded in the whole lagoon in 2011 in 118 stations, were far below the mandatory values of the Ronchi-Costa decree (April 1998): 25 µM for DIN and 0.8 µM for RP. During surveys these limits have been exceeded only in few areas close to freshwater inputs or works to consolidate the salt marshes (Fig. 1).

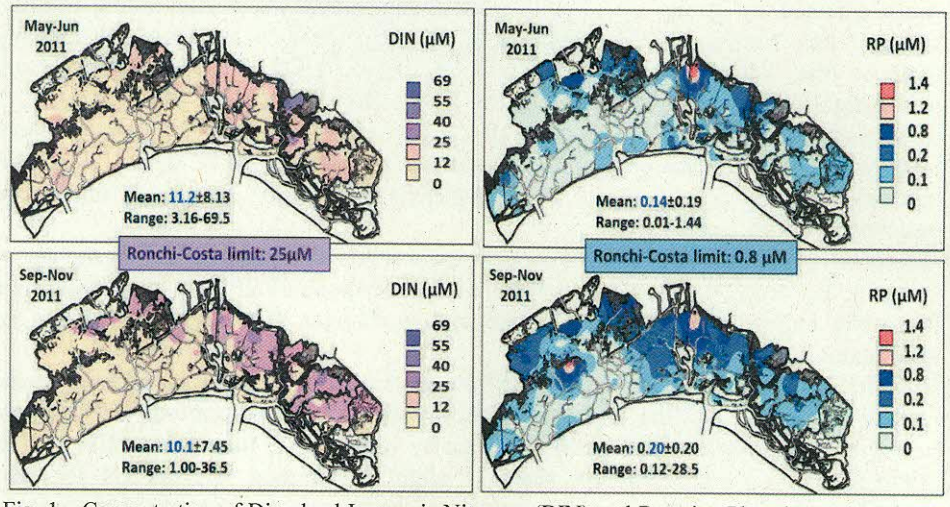

Fig. 1 - Concentration of Dissolved Inorganic Nitrogen (DIN) and Reactive Phosphorus (RP) in the lagoon of Venice in spring and autumn 2011.
Concentrazioni di Azoto Inorganico Disciolto (DIN) e Fosforo Reattivo (RP) nella laguna di Venezia in primavera ed autunno 2011.

The recovery of lower trophic status can be better appreciated by examining the changes of some parameters measured in late spring since the 1980s in ca. 60 stations in the central basin, where a larger data set is available (Fig. 2). Reactive phosphorus decreased from 0.76 to 0.19 µM between 1987 and 2011 and increased to 0.24 µM in 2014. DIN showed the highest values in 1993 after the macroalgal decline and decreased up to 5.89 µM in 2014. The macroalgal biomass in 1987 showed the highest

value (Sfriso and Facca, 2007). In the whole central lagoon the standing crop was ca. 0.6 million tonnes of fresh biomass, with a mean value of 4.78 kg fwt m^{-2}. The lowest value was recorded in 1998 (ca. 0.11 kg fwt m^{-2}. The mean biomass increased to 1.04 kg fwt m^{-2} in 2014, the most rainy of the last 25 years. Dissolved oxygen, water pH and water transparency changed accordingly. Water dissolved oxygen and pH were strongly affected by the abnormal macroalgal production, especially Ulvaceans. Then they decreased as the biomass decreased. Water transparency was strongly related to the clam-fishing activities which reached the peak values between the 1995 and 2010.

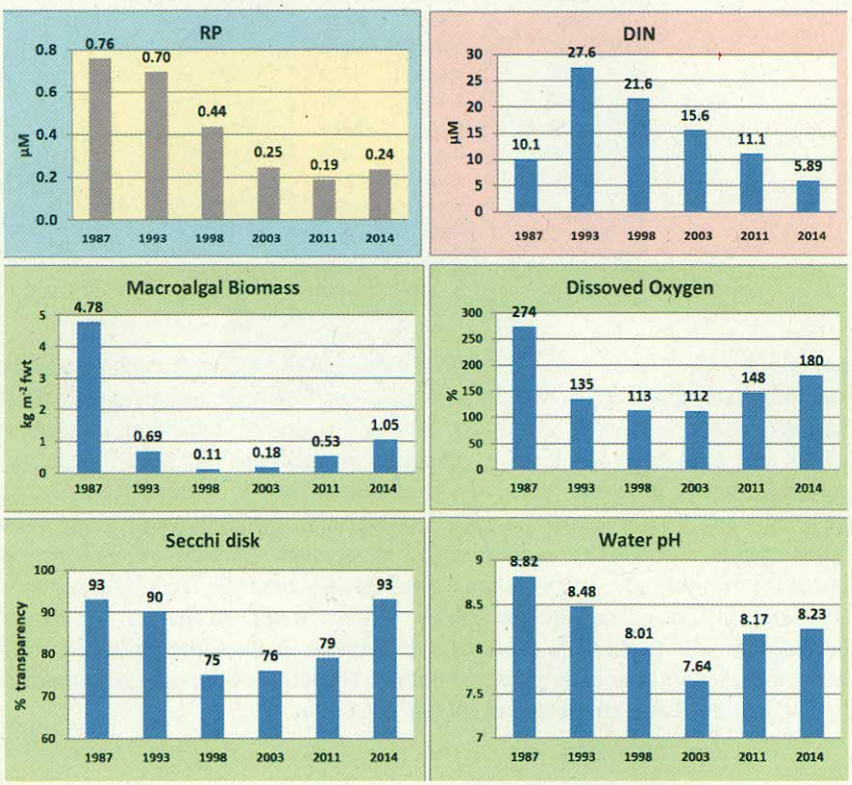

Fig. 2 - Changes of some environmental parameters in the central Venice Lagoon from 1987 to 2014. *Variazione di alcuni parametri ambientali nel bacino centrale della laguna di Venezia dal 1987 al 2014.*

At present, aquatic angiosperms and sensitive macroalgae are recolonizing the lagoon and the ecological status is increasing, especially in the central and northern basins which suffered the most serious anthropogenic impacts. The assessment of the ecological status with the Macrophyte Quality Index (MaQI, Sfriso *et al.*, 2014b) greatly improved from 2011 to 2014. In that period, by taking into account the 11 water bodies of the lagoon, the Ecological Quality Ratio (EQR) increased from 0.464 to 0.502 (+0.038) with a significant increase, especially in the water bodies EC (+0.223) and ENC2 (+0.177) that changed from Moderate to Good (Tab. 2) (Sfriso, 2014).

Tab. 2 - Comparison of MaQI EQR in the 11 water bodies and in 3 lagoon fishing ponds of the Venice Lagoon: 2011 and 2014.
Confronto dell'EQR del MaQI negli 11 corpi idrici e in 3 valli da pesca della laguna veneta: 2011 e 2014.

MaQI EQR changes			
Water bodies	2011	2014	Difference
EC	0.408	0.631	0.223
ENC1	0.698	0.769	0.071
ENC2	0.479	0.656	0.177
ENC3	0.417	0.483	0.066
ENC4	0.520	0.490	-0.030
PC1	0.317	0.292	-0.025
PC2	0.325	0.350	0.025
PC3	0.317	0.317	0.000
PC4	0.317	0.338	0.021
PNC1	0.330	0.350	0.020
PNC2	0.261	0.250	-0.011
Zappa valley	0.250	0.250	0
Dogà valley	0.850	0.850	0
Cavallino valley	1	1	0
Total	0.464	0.502	0.038

Conclusions - The Venice Lagoon from 1950s to 1980s suffered strong anthropogenic impacts which triggered an abnormal macroalgal proliferation and extensive dystrophic conditions. Then, from early 1990s, the biomass of thionitrophilic macroalgae rapidly declined and nutrient concentrations changed accordingly. At present the lagoon is oligo-mesotrophic in great part of its surface and is recolonizing by aquatic angiosperms and sensitive macroalgae. Although the introduction of many alien taxa, the macrophyte biodiversity is increasing. At present, ca. 350 different macroalgae colonize the lagoon but Ulvaceans are abundant only near the river (Marzenego, Dese, Siloncello) outflows and in the areas where water exchange is reduced by anthropogenic factors, such as artificial salt marshes. In fact, the reduction of nutrient inputs and the high water exchange with the sea (ca. 60% of the total water content) are the best guarantee for a quick environmental recovery.

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