Application of the LOICZ biogeochemical model to C, N, P flux estimation in the coastal lagoon Pialassa Baiona (Ravenna, Italy)

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Southern European Coastal Lagoons: The Influence of River Basin-Coastal Zone interactions

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Fig. 1. The Pialassa Baiona lagoon and the adjoining harbour/industrial area (by Biserni, 1999).

Introduction

The Pialassa Baiona (Fig. 1) is a coastal lagoon located along the northern Adriatic coast of Italy. It is a Ramsar site included in the Regional Po River Delta park, furthermore it was designed as Special Protection Zone (Directive 79/409/EEC) and proposed as Site of Community Importance (Directive 92/43/EEC). Following the LOICZ (Land-Ocean Interaction in the Coastal Zone, IGBP Core Action) guidelines, an annual single box - single layer biogeochemical model to estimate the nutrients budget of the Pialassa Baiona has been applied referring to the year 2000. Although its inner complexity, the lagoon has been considered as a black box due to the lack of data necessary to estimate the internal fluxes.

Study area

Artificial embankments divide the lagoon into several shallow water ponds connected by branched channels converging to the shipway of the harbour. Altogether the area is 11.80 km^2, including the embankments. The average depth varies from 0.5 m in the shallow areas to 3 m in the channels with a tidal range variable from 0.3 to 1 m, excluding extreme events. Tidal regime cause large variations in the water levels and vast shallow areas emerge during low tides. On average, the water covers an area of 9.86 km^2 and the total water volume is estimated in approximately 8.89 million of m^3, equally shared between ponds and channels. The lagoon receives water inputs from five main channels that drain a watershed of 264 km^2, including urban (9%) and agricultural (87%) areas. The southern channel collects also the wastewater coming from urban and industrial treatment plants and from two power plants.

Data sources

Meteorological data for the study period were supplied by the Regional Agency for Environmental Protection (ARPA, Regione Emilia-Romagna). Potential evaporation flow was estimated by Hargreaves's equation (Hargreaves, 1975). Data concerning freshwater flow and nutrient concentration were obtained from Giaquinta (2001). Salinity and nutrients concentration of coastal waters were obtained from the annual report of the DAPHNE oceanographic division of the ARPA Emilia-Romagna (2001). Salinity and nutrients concentration of the system were provided by the Department of Public Health of the Local Health Service Agency (AUSL, Ravenna).

Water and salt balance

Runoff from the watershed and civil and industrial sewages was the main freshwater input (Tab. 1; Fig. 2). Groundwater flow was negligible compared to the other freshwater inputs and was assumed to be zero in the budget. Direct precipitation during study period was 574 mm, while the evaporation flow was estimated to be about twice that of precipitation (Tab. 1). A high unidirectional input of saltwater was provided by the cooling water of two power plants. To balance the water inputs a net water output of 1292 x 10^3 m^3 d^{-1} to the sea was estimated.

Considering the salinity gradient between the lagoon system and the sea and the other input of saltwater, the exchange flux was calculated at 1828 x 10^3 m^3 d^{-1} and the estimated average water residence time was about 3 days. This average time does not consider the water circulation within the ponds and channels. Water turnover requires only a tide cycle (about 12 hours) in the main channels and much more time in the with reduced water exchange and .

Tab. 1. Summary of the mean water flow, salinity (S), average concentration of nutrients (DIP, DIN) and respective fluxes of the different water sources.

Sources	Water Flow 10^3 m^3 d^{-1}	S psu	DIP mmol m^{-3}	DIN mmol m^{-3}	DIP Flux mol d^{-1}	DIN Flux mol d^{-1}
Runoff	113	0	10.74	499.87	1,218	56652
Treated sewages	97	0	39.38	746.78	3,809	72224
Atmosphere	18.5	0	0	97.00	0	1795
Evaporation	-36	0	0	0	0	0
Power plants	1099	30.32	2.58	49.97	2837	54927
Sea (residual)	-1292	29.14	1.70	35.07	-2190	-45302
Sea (exchange)	1828	/	/	/	-5588	-46824
Lagoon system	/	/	3.22	47.88	/	/
Sea	/	30.32	0.17	22.26	/	/

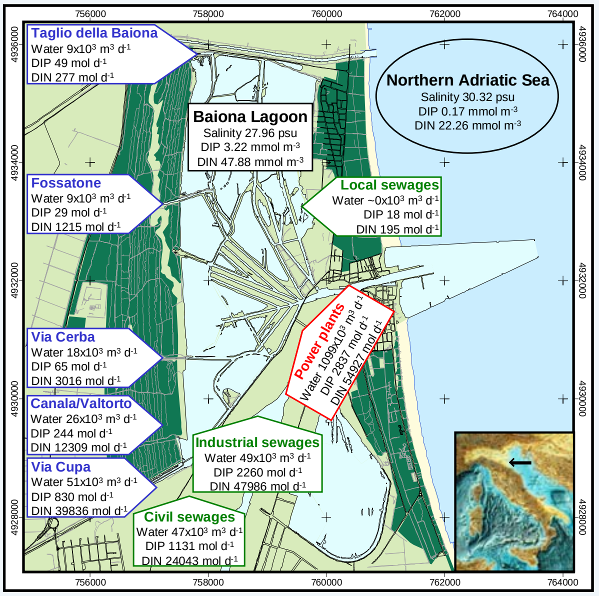

Fig. 2. Locations and details of water and nutrients inputs coming from runoff, sewages and power plants. Average salinity and nutrients concentrations of the lagoon and sea were indicated. Map grid is UTM 32T ED50.

Nutrient budgets

Civil and industrial treated waste water represents the main inorganic phosphorus (DIP) and nitrogen (DIN) inputs, followed by runoff from the watershed and cooling water from power plants (Tab.1; Fig. 2; Fig. 3). Atmospheric phosphorus inputs were assumed to be zero since no data on dry and wet deposition were available, while atmospheric nitrogen inputs were estimated from the average DIN concentration in the rainwater (Viaroli and Giordani, 2001).

Net phosphorus budget (ΔDIP) was low and reached values of -8.6 x 10^{-3} mmol m^{-2} d^{-1} equivalent to -84.95 mol d^{-1} on overall. Net nitrogen budget (ΔDIN) was high and reached values of -9.48 mmol m^{-2} d^{-1} equivalent to -93473 mol d^{-1}. Both annual mean phosphorus and nitrogen budgets were negative suggesting that the system acts as sink of both dissolved inorganic phosphorus and nitrogen.

Overall, the exports of nutrients to the sea accounts for 7778 mol d^{-1} of DIP and 92126 mol d^{-1} of DIN, corresponding to 88 tons y^{-1} and 472 ton y^{-1}, respectively. These values agree with estimates on theoretical bases by Marchetti and Verna (1992) for contribution to northern Adriatic eutrophication from the whole Candiano basin (including the harbour channels, the connected small Piomboni lagoon and their watersheds).

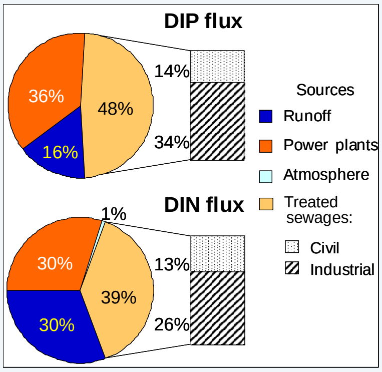

Fig. 3. Relative contribution of the different water inputs to the budgets of DIP and DIN.

Net system metabolism

Stoichiometric calculations based on the photosynthetic production were done considering both the Redfield ratio for phytoplankton (C:N:P=106:16:1) and the ratio for macroalgae (C:N:P=335:35:1; Atkinson and Smith, 1983). The latter seems more appropriate for the Pialassa Baiona, which is affected by seasonal blooms of macroalgae, mainly *Ulva* sp. Overall the lagoon can be considered as "autotrophic", with a net ecosystem metabolism (calculated as the difference between production and respiration) ranging between 0.91 and 2.89 mmol C m^{-2} d^{-1}, if stoichiometric calculations are based on phytoplankton or on macroalgae, respectively.

The difference between the observed and expected ΔDIN, based on the N:P ratio, was considered as the net ecosystem nitrogen fixation minus denitrification (nfix-denit). Negative values suggest that denitrification losses dominate over nitrogen fixation inputs (Tab. 2). The relative high values obtained can be explained by high benthic respiration rates. However, these results should be considered as preliminary since they do not take into account the heterogeneity of the lagoon system.

Hypothesis	NEM	ΔDIN_{exp}	nfix-denit
Phytoplankton	0.91	-0.14	-9.34
Macroalgae	2.89	-0.30	-9.18

Tab. 2. Results of the stoichiometric calculations (mmol m^{-2} d^{-1}).

References

ARPA Emilia-Romagna 2001 Eutrofizzazione delle acque costiere dell'Emilia Romagna - rapporto annuale 2000. Regione Emilia Romagna, Assessorato Agricoltura, Ambiente e svilupo sostenibile, 195 pages.

Atkinson, M.J. and Smith, S.V. 1983 C:N:P ratios of benthic marine plants. Limnology and Oceanography 28:568-574.

Corticelli, S., Piccoli, F. and Merloni, N. 1999 Carta della Vegetazione del Parco Regionale del Delta del Po. Servizio Cartografico e Geologico, Regione Emilia-Romagna, Bologna.

Giaquinta, S. 2001 Progetto di caratterizzazione del bacino del canale Candiano e revisione delle stazioni di monitoraggio. ARPA, Servizio Sistemi Ambientali, Sez. Ravenna, 53 pages.

Gordon, D.C. Jr, Boudreau, P.R., Mann, K.H. and Yanagi, T. 1966 LOICZ Biogeochemical Modelling Guidelines. LOICZ Reports and Studies 5, LOICZ, Texel, The Netherlands, 96 pages.

Hargreaves, G.H. 1975 "Moisture availability and crop production," Trans. Am. Soc. Agric. Eng. 18 (5):980-984.

Marchetti, R. and Verna, N. 1992 Quantification of the phosphorus and nitrogen loads in the minor rivers of the Emilia-Romagna coast (Italy). A methodological study on the use of theoretical coefficients in calculating the loads. Pages 315-336 in Vollenweider, R.A., Marchetti, R., and Viviani, R. (eds.) Marine Coastal Eutrophication, Elsevier, Amsterdam, 1310 pages.

Viaroli, P. and Giordani, G. 2001 Valli di Comacchio. Pages 46-49 in Dupra, V., Smith, S.V., Marshall Crossland, J.I. and Crossland, C.J. (eds) Coastal and Estuarine systems of the Mediterranean and Black Sea regions: carbon, nitrogen and phosphorus fluxes. LOICZ Reports and Studies 19, LOICZ, Texel, The Netherlands, 101 pages.