Assessment of eutrophication of French Mediterranean lagoons in relation to meteorological interannual variability

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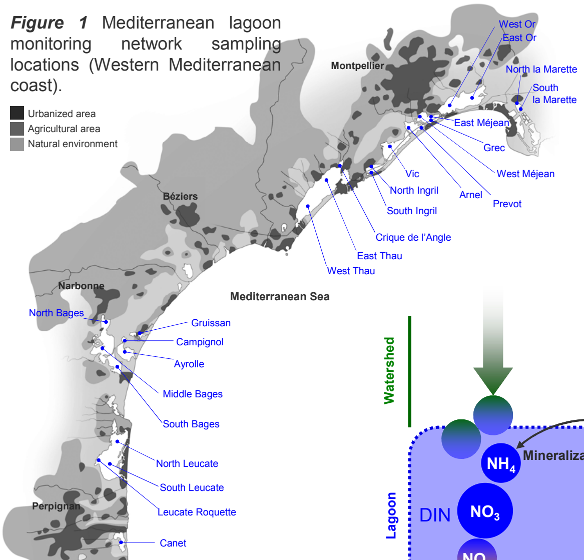

Figure 1 Mediterranean lagoon monitoring network sampling locations (Western Mediterranean coast).

INTRODUCTION

Since recent decades, nutrient-related eutrophication, originating from agricultural use of fertilizer and population enhancement, can be considered worldwide as the main disturbance for coastal lagoons. Since coastal lagoons are very shallow and enclosed, their functioning is tightly linked to meteorological conditions. **The aim of this study is to compare different rainfall levels and eutrophication response on coastal lagoons of the Languedoc-Roussillon** (Western Mediterranean coast), **subject to different nutrient loads from their watershed, in order to check the possibility to distinguish the effects of watershed management or rainfall conditions on water quality** (waste water treatment plant improvement, decrease of fertilizer spreading).

MATERIALS & METHODS

<u>Sampling</u> The French Mediterranean lagoon monitoring network (LMN) focuses upon eutrophication and is operated since 2000 on 21 coastal lagoons of the Languedoc-Roussillon (Daloz *et al.*, poster n°9.3, Fiandrino *et al.*, talk session 9). Several assessment tools were developed for each ecosystem compartment: water, sediments, phytoplankton, macrophytes and allowed to diagnose their biological trophic quality status (Laugier *et al.*, poster n°9.4).

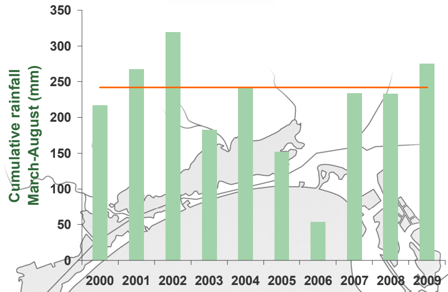

Figure 3 Cumulative rainfall (March-August) from 2000 to 2009 and their average on 20 years (red line).

Data collected monthly during the summer (June, July and August) from 2000 to 2009 were extracted form the LMN for 15 coastal lagoons (26 sampling stations) subject to different nutrient loads from their watershed (Fig. 1). Water column parameters were selected: total nitrogen (TN), phosphorus (TP), nitrogen and phosphorus dissolved inorganic forms, Chlorophyll-*a* (Chl-a) and turbidity (TU). Rainfall data were provided by Météo-France at Montpellier.

<u>Data analyses</u> [XLSTAT 2008.7.02 software] If several stations were sampled for a lagoon, the average concentrations parameters from summer 2000 to 2009 were compared with Kruskal-Wallis non-parametric test. When the difference was significant ($p < 0.05$), data collected at the different stations were considered separately, otherwise, they were averaged. For each of the parameters selected, linear regressions of average concentrations in summer *vs* cumulative rainfall levels were performed and Spearman correlation coefficients (r) were calculated. Several cumulative rainfalls levels (Sept-June, Jan-June, Feb-June, March-Aug …) and different periods (from 2000 to 2009, 2000-2005, 2000-2006, 2000-2007, 2000-2008) were tested, in order to highlight any change of eutrophication response to rainfall during the 10 years studied.

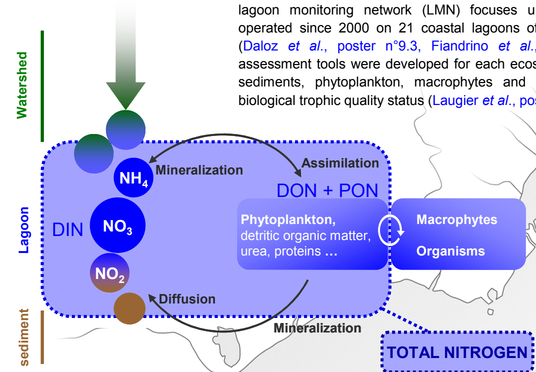

Figure 2 Nitrogen cycle

RESULTS & DISCUSSION

<u>**Rainfall *vs* eutrophication response**</u> From all the parameters tested, TN showed the strongest correlations with the cumulative rainfall levels. As it includes dissolved inorganic and organic forms of nitrogen, this parameter integrates causes (DIN dissolved inorganic nitrogen) and consequences (DON, PON: dissolved and particulate organic forms from biological fixation) of the eutrophication process (Fig. 2). For instance, TP integrates also inorganic and organic forms of phosphorus, however phosphorus is much more subject to mineralization from sediment than nitrogen, particularly in summer, which reduces the strength of the relationship with nutrient loads from the watershed and consequently with rainfall. The highest correlations between TN concentrations and rainfall were found for cumulative rainfall levels from March to August. During this period, total nitrogen integrates N from watershed inputs, N from organic forms assimilated by primary producers in the lagoon and N remaining as dissolved forms in the lagoon. Comparison of the March-August cumulative rainfall with their average on 20 years highlights the rainy (2001, 2002 and 2009), the dry years (2000, 2003 and 2005 to 2008) and the 2006 drought (Fig. 3).

<u>Lagoon response</u> Comparing the relationship between TN in water and rainfall reveals different lagoon response types facing eutrophication and rainfall inputs (Table 1):

1- Lagoons highly connected to the sea and moderately eutrophicated (Fig. 4a): the stations showing the highest correlation coefficients (Thau, Ayrolle) are located downstream from rivers or nutrient point sources.

2- Palavasien lagoons (Fig. 4b): lagoons poorly connected to the sea, showing no significant relationship for rainfall calculated from 2000 to 2009, but significant or stronger relationships for rainfall calculated from 2000 to 2006. TN levels simulated with the regression parameters obtained for the 2000-2006 period (dotted lines) are overestimated. These observations highlight a change in functioning of the lagoons, probably due to the deviation of a wastewater treatment plant outlet towards the sea in December 2005 (Castel *et al.* 1996).

3- Lagoons highly eutrophicated (Fig. 4c): these lagoons show very low or no significant correlation. TN comes essentially from the large nutrient stock of the sediment and from important permanent inputs from the watershed, that could blur the relationship.

Group	Lagoon stations	Periods	n	r
1	Thau *Crique de l'Angle*	2000-2009	9	0,95
	West & East Thau	2000-2009	9	0,76
	North, Middle & South Bages	2000-2009	9	0,48
	South, North Leucate & *Roquette st.*	2000-2009	9	0,55
	Ayrolle	2000-2009	9	0,66
	Gruissan	2000-2009	9	0,50
2	Palavasien lagoons: North & South Ingril	2000-2009	9	0,47
		2000-2006	7	0,86
	Vic	2000-2009	9	0,03
		2000-2006	7	0,61
	Prévost	2000-2009	9	0,19
		2000-2006	7	0,82
	Arnel	2000-2009	9	0,61
		2000-2006	7	0,92
	South Méjean	2000-2009	9	0,03
		2000-2006	7	0,57
	West Méjean	2000-2009	9	0,22
		2000-2006	7	0,89
	Grec	2000-2009	9	0,07
		2000-2005	6	0,60
3	Canet	2001-2008	7	ns
	Or	2000-2009	9	ns
	North & South La Marette	2003-2009	7	ns
	Campignol	2000-2009	9	0,48

Signification levels: ns; P < 0,05; P < 0,01; P < 0,001

Table 1 TN concentration *vs* cumulative rainfall, (March-August) linear regression results (r = correlation coefficient, colors indicate the signification level). Blue arrows indicate a stronger relationship. Lagoons response types were divided in three groups.

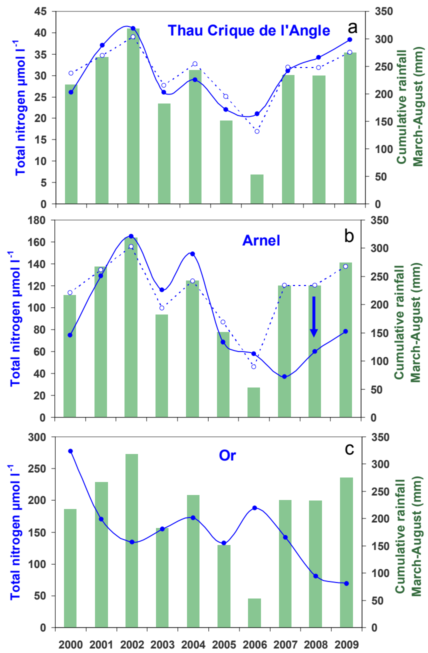

Figure 4 Measured TN (solid blue line), simulated TN concentration with regression parameters for the 2000-2006 period (dotted blue line) and cumulative rainfall levels from 2000 to 2009.

CONCLUSION

This study focused only on rainfall, excluding the other meteorological parameters (temperature, wind, light intensity…) which may affect eutrophication response of the lagoons. Moreover, the monitoring sampling strategy was not adapted to the analysis of rainfall effects (monthly and punctual sampling on the summer period). **However, our results allowed us to identify total nitrogen as an integrative parameter of eutrophication level in the lagoons, which may highlight the impact of rainfall conditions or the effect of lower nutrient loads related to watershed management.** It remains difficult to assume exactly the part of water quality improvement related to watershed management or meteorological conditions. With the LMN set of data, we showed that relationships between TN and cumulative rainfall can highlight different types of lagoon responses. The modelling of lagoon eutrophication could be tested for the types identified in this study and at a regional scale.

Fiandrino A *et al.* (2009) Bages-Sigean lagoon restoration: an example of science and management cooperation. European Conference on Coastal Lagoon Research. Oral session 9
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Castel J *et al.* (1996) Eutrophication gradients in coastal lagoons as exemplified by the Bassin d'Arcachon and the Étang du Prévost. Hydrobiologia 329: 1573-5117