On the origin of cyanobacteria blooms in the Enxoé reservoir

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Introduction

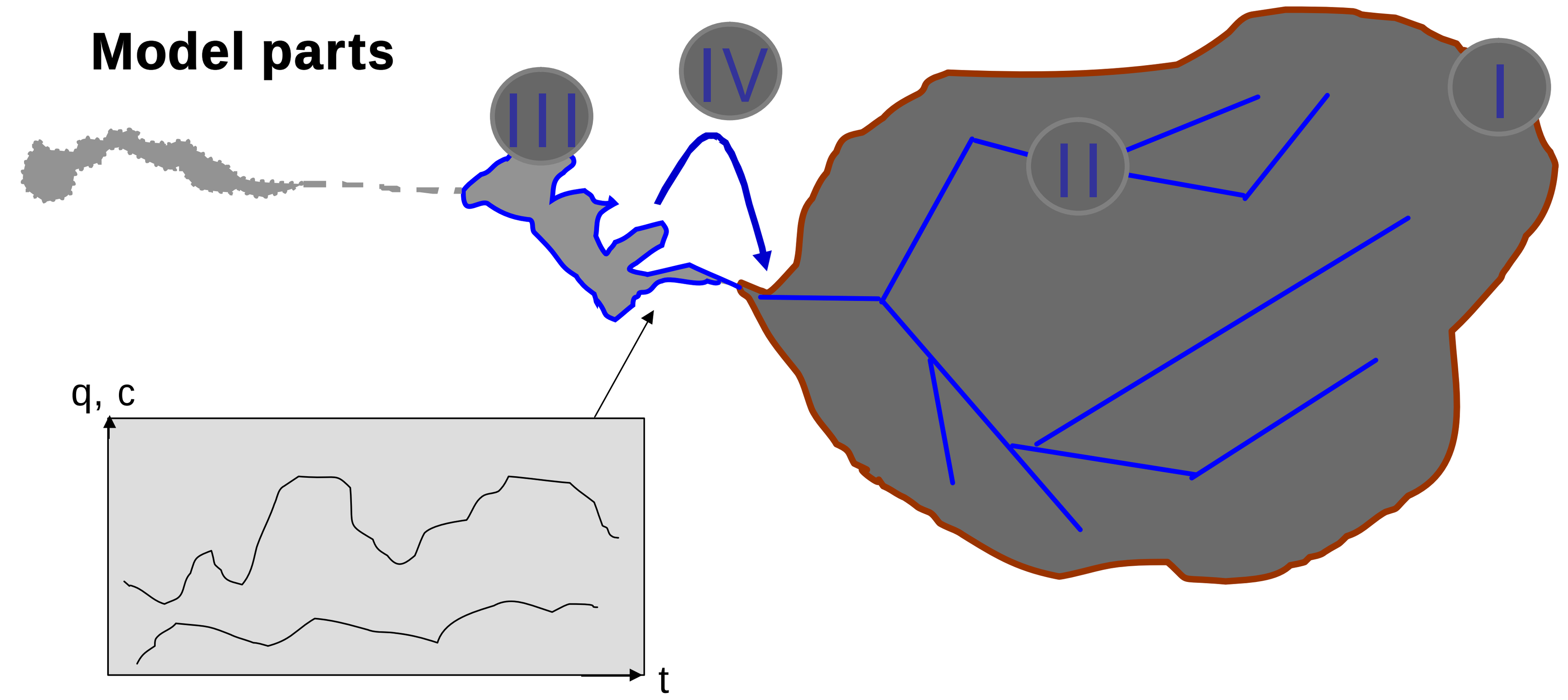
In the framework of AquaStress (an EU funded integrated project), a small reservoir (Enxoé) located in the South of Portugal was studied. The reservoir was built to supply water for human consumption, but it shows several water quality problems namely cyanobacteria blooms. In the last years and as a consequence of these problems, it was not possible to use it to supply water during the entire summer. In order to try to understand the possible causes of the problems and, hopefully, find proper solutions to solve them, an integrated study involving the catchment, the data available concerning the nutrient loads, the meteorology and the water quality and mathematical models was set up. This approach allowed the suggestion of some possible actions that may lead to improve the conditions within the reservoir.

Some major conclusions of data analysis put in evidence that there was a sudden change after the winter 2000/2001 floods, namely a rapid phosphorous enrichment and a rapid decrease of N:P ratio, bottom anoxia and presumably phosphorous release from sediments and permanent cyanobacteria dominance since the 2001/2002 floods.

The first modelling results also put in evidence that the model was not reproducing accurately the behaviour of the reservoir. The main cause for this is probably due to errors in the methods of the loads quantification, although a standard approach based on OSPAR guidelines that showed to be successful in other applications made in the north of Portugal is being used. The cyanobacteria dominance started only after the winter of 2000/2001, indicating that the big floods that occurred on that year and associated erosion, may be responsible for a major source of P for the reservoir. This source is possibly misrepresented by any estimate of loads.

In order to try to clarify these aspects it was decided to find similar data from other reservoirs in the neighbourhood (e.g. Monte Novo and Roxo) to validate the thesis that floods might be a triggering mechanism for cyanobacteria dominance. Also to solve the problem of boundary conditions for the reservoir model, a simple inverse model that computes the loads as a function of measurements of Phosphorus in the reservoir and exchanges between the water column and the sediments was used.

System of Models



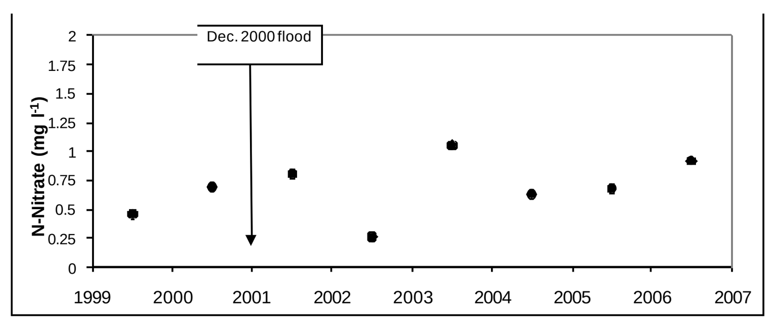
I: Catchment (SWAT)

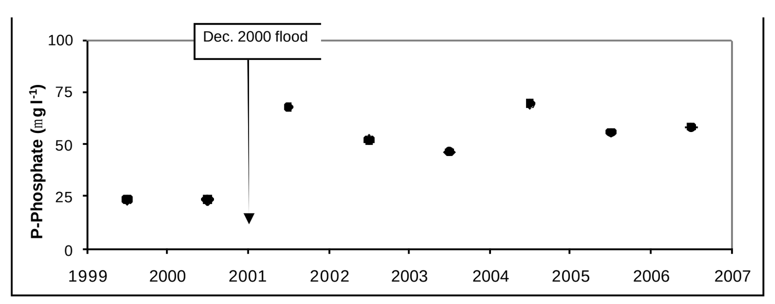
II: River Network (MOHID-LAND)

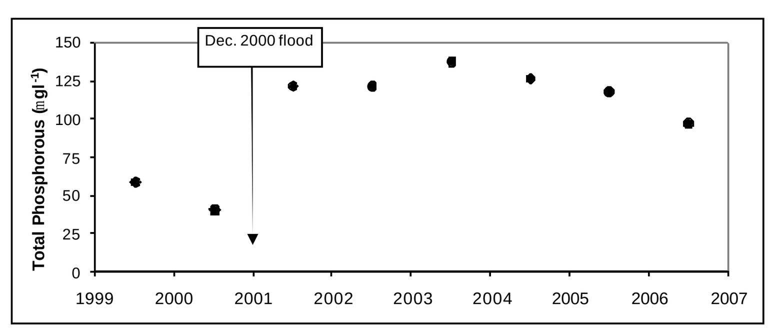
III: Reservoir (CE-QUAL-W2)

IV: Inverse Model

Data Analysis





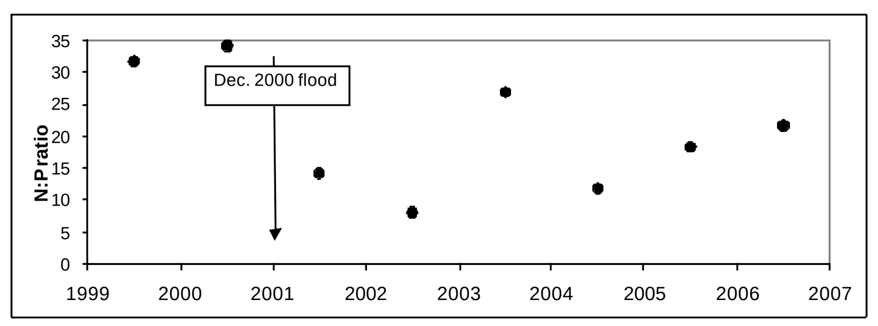


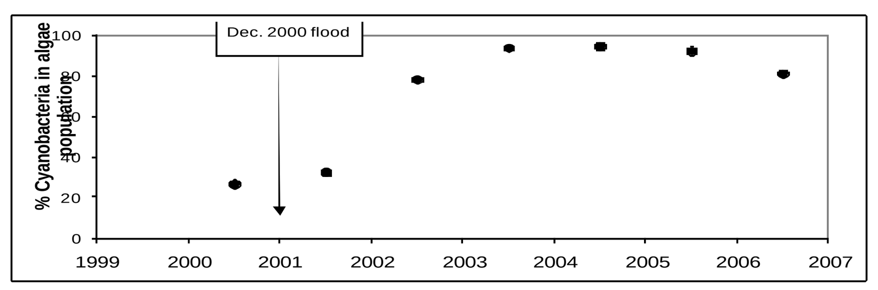
It is shown the relative abundance of cyanobacteria. Apparently a large increase in relative abundance occurred only in 2002 and not in 2001 when the Phosphorous concentration started to increase and the N:P ratio decreased. This might be a consequence of an increase in Nitrate also in 2001 that is not detectable in data because it has been consumed by diatoms and chlophytes. It is important to note that relative abundances of cyanobacteria close to 100% mean that, not only cyanobacteria is the dominant group of the phytoplanktonic population, but also, that they dominate during the entire year, which is far from a typical pattern of algae succession in a temperate lake.

The first remarkable feature present in the data is the large increase observed in Phosphate and Total Phosphorous after the floods of December 2000. This increase is not clear in Nitrate concentration. Clearly there seems to be a relation between P concentration and precipitation.

The fact that Nitrate concentration in the reservoir seems to be correlated to a minor extent with precipitation is reflected on the N:P ratios (by mass) calculated using the inorganic forms of N and P – that is, Nitrate, Nitrite, Ammonia and Phosphate. Actually, Figure 5 shows a substantial decrease in N:P ratio after the floods of December 2000. This decrease in N:P ratio, reflects the increase in P that was not accompanied by an increase in N.

Under these conditions, i. e. the reduction of the N:P ratio it is expected that cyanobacteria start to dominate the phytoplankton population at least in some periods of the year.





Correlations between a few water quality indicators measured at Enxoé reservoir between 1998 and 2006.

	Cyanobacteria relative abundance	*TP*	*P-Phosphate*	*N-Nitrate*	*Chlorophyl*	*Minimun Hipolimnium Depth*	*N:P*
Cyanobacteria relative abundance		***0.66***	***0.40***	*0.02*	***-0.88***	***0.61***	*0.28*
TP			***0.82***	*0.23*	*-0.50*	***-0.63***	***-0.56***
P-Phosphate				*0.22*	*0.32*	*0.10*	***-0.64***
N-Nitrate					*-0.06*	*0.10*	*-0.14*
Chlorophyl						*-0.33*	*-0.28*
Min. Hipo. Depth							***0.66***
N:P							

Discussion

The analysis of data obtained in the reservoir shows many important aspects of the behaviour of the reservoir. The reservoir is relatively young since the operations started in 1998. On the first years of operation it was observed a regular pattern with a typical algae succession and phosphorus levels in agreement with the neighbouring reservoirs. The winter of 2000/01 was particularly wet. The first response observed in the reservoir is the increase in phosphorus concentrations. However the change in phytoplankton population is not seen before 2002 which might be an indicator of an indirect consequence of the floods of December 2000. A possible explanation is that during the 2000/01 floods a large amount of organic material and nutrients adsorbed to sediments reach the reservoir. In the following months both phosphorus and nitrogen were consumed by primary producers. This increase in primary production was composed of successive peaks of cyanobacteria, clorophytes, dinofalgellates and diatoms, conveying the presence of phosphorus, nitrogen and silica in the reservoir. However at a certain time, both silica and nitrogen became the limiting factor in the reservoir. On the other the excess of phosphorus adsorbed to particulate material settled at the bottom and remained in the reservoir. Finally the oxidation of the large amounts of organic matter consumed the available oxygen available. The reservoir became anoxic, particularly in deeper layers, and the conditions for phosphorus remobilization were created. The dominance by cyanobacteria seen after March 2002 reflects essentially this excess of phosphorus.

This conceptual model could be confirmed by using a model of the reservoir. In the absence of flow rates and concentrations measured at inflowing rivers it is usual to use a model to estimate nutrient production in the catchment. This model can be simply an estimate following the OSPAR Guidelines or an implementation of a more complex scheme like SWAT. None of these approaches have produced reasonable results because clearly the upstream boundary condition is misrepresented. Presently an inverse model scheme that uses the data in the reservoir to estimate an upstream boundary condition for phosphorous that is used to calibrate the catchment model is being developed. The problem with the upstream boundary condition for the reservoir model is that the amounts of nutrients are overestimated in dry years and underestimated in wet years. It seems reasonable to admit that in semi-arid regions like Alentejo with highly variable precipitation and runoff, a large amount of the organic material and nutrients produced in the watershed are not transported downstream. This is particularly evident in dry years but might be valid even in years with precipitation close to the average values. This means that a large proportion of this material accumulates in the watershed and only in very wet years with intense floods is removed and transported into downstream reservoirs. Often this occurs in a very short period of time. This could explain why the available catchment models (like SWAT) overestimate loads in dry years and underestimate them in wet years as the model misrepresent erosion processes. More important, this could explain what happened at Enxoé after the floods of December 2000.

Acknowledgements

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