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High frequency records of nutrients and algal biomass pigments for deciphering biogeochemical processes in the Loire River (France)

What are the physical and biological controls of water quality in the eutrophic River Loire?

The Loire River Basin

At station 3 :

- 110 000 km²
- 900 km
- 8 million people, concentrated along the Loire River
- Arable land = 30%, Forest land = 25%
- Average annual discharge = 860 $m^3.s^{-1}$

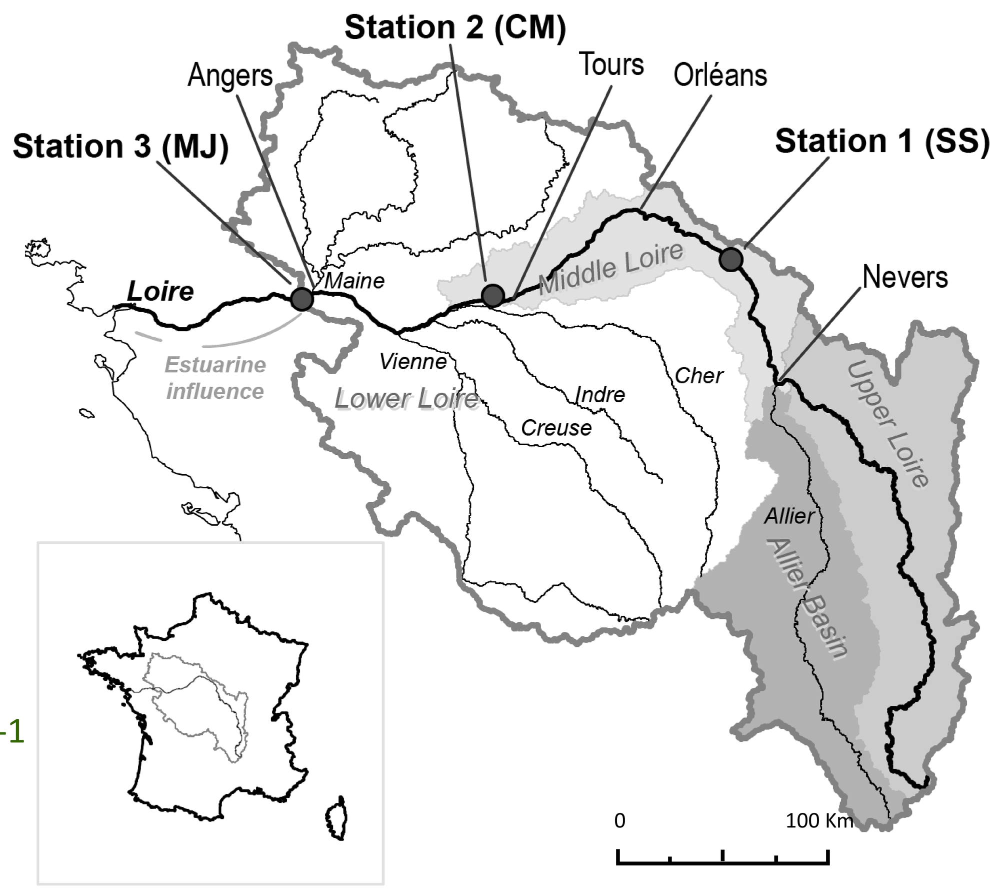

Fig. 1. Basin situation, location of sampling stations and of major cities.

In the 1980's, both the Middle and Lower Loire systems were found to suffer from extreme eutrophication[1] (summer Chl. *a* average > 150 $\mu g.L^{-1}$) because of high concentrations of bio-available nutrients in the Loire River. Controlling P inputs reduced significantly this imbalance[2].

Sampling

Three sampling sites (Fig. 1) in order to follow :

- Total Suspended Solids } everyday
- Total algal pigments (= Chl. a + pheopigments)
- Nitrate (NO_3)
- Dissolved Inorganic Phosphorus (DIP)
- Dissolved silica (DSi) } every 3 days

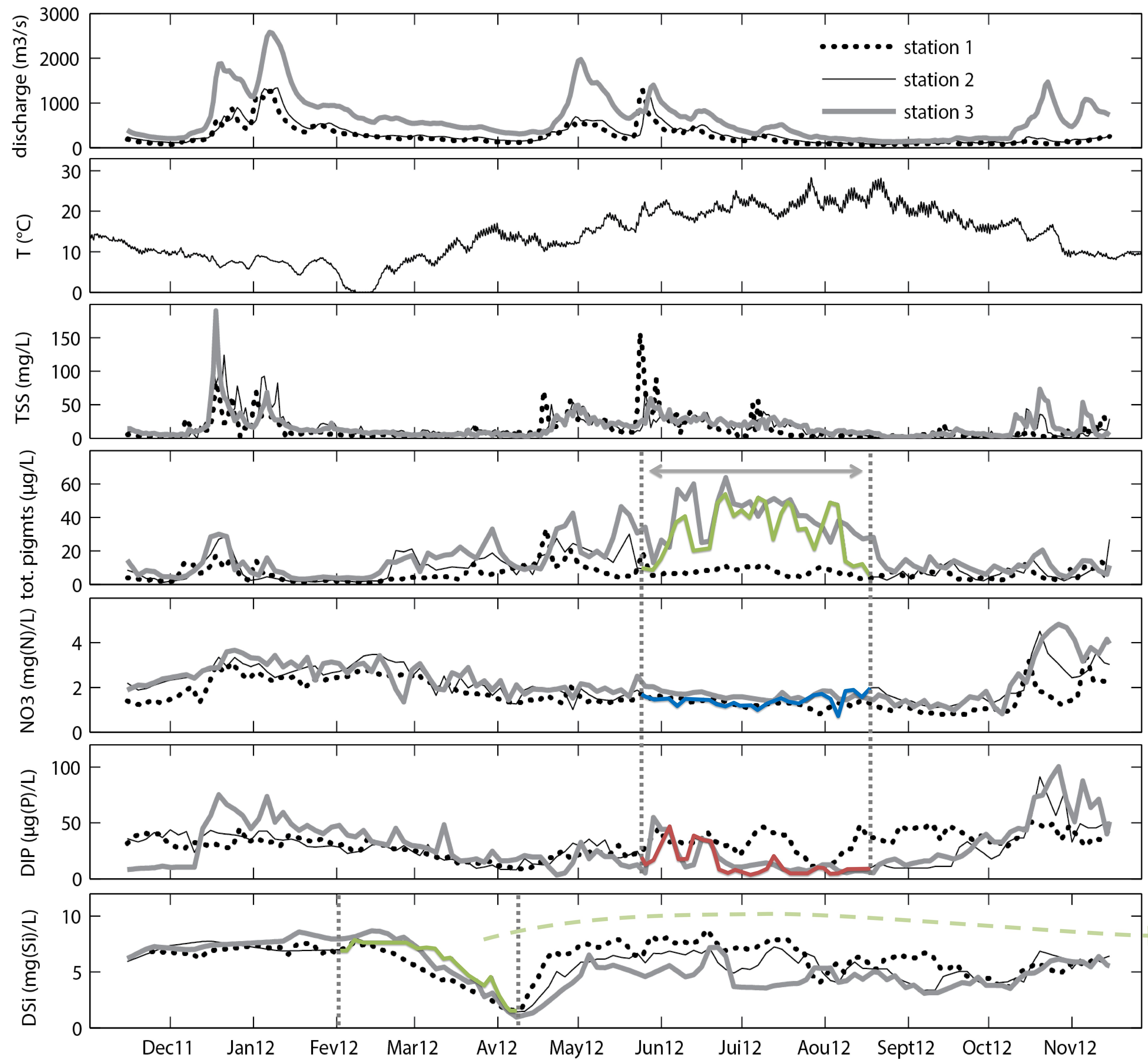

Fig. 2. Survey results during the year Nov 2011 – Nov 2012 at three stations.

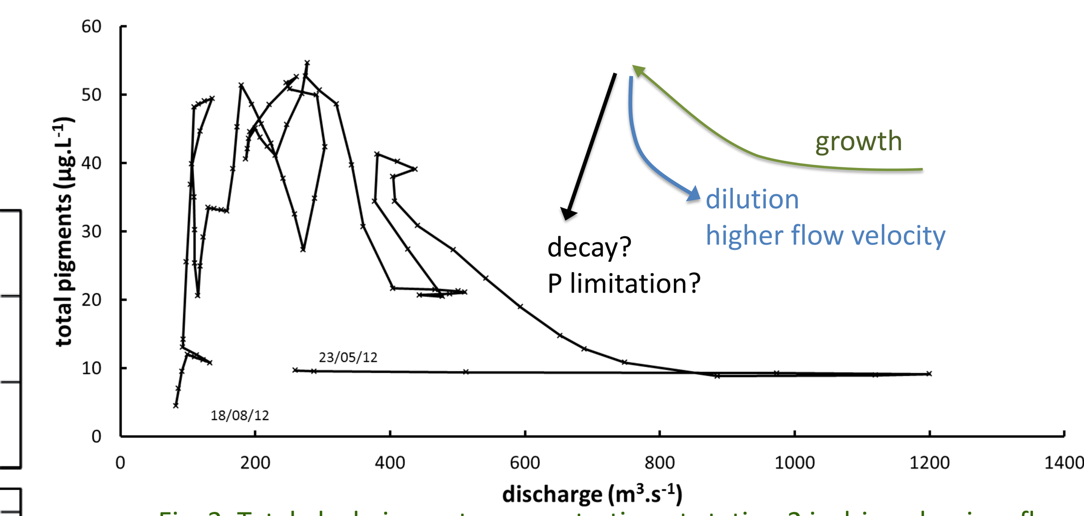

Fig. 3. Total algal pigments concentration at station 2 is driven by river flow.

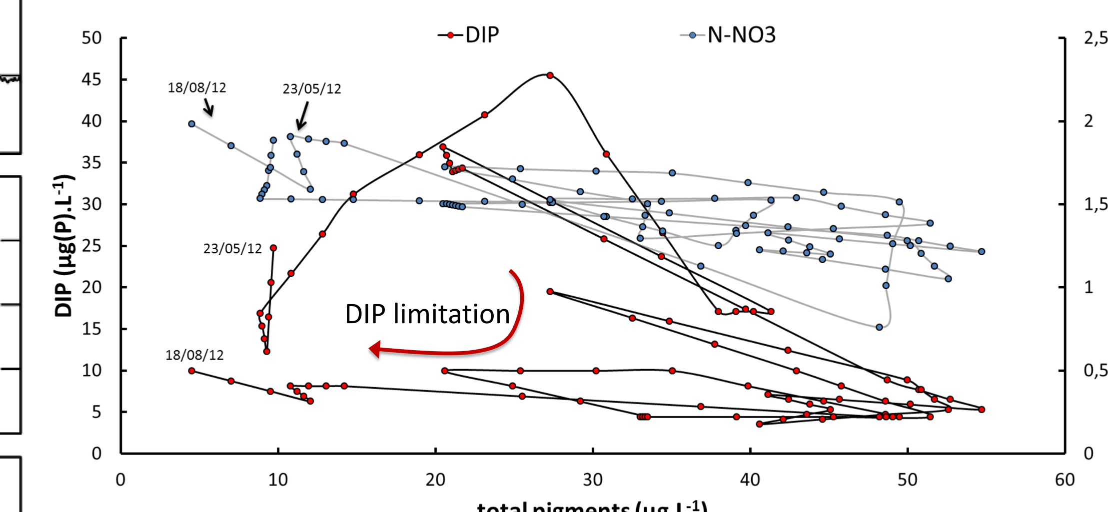

Fig. 4. Nutrients at station 2. DIP is limiting the algal development.

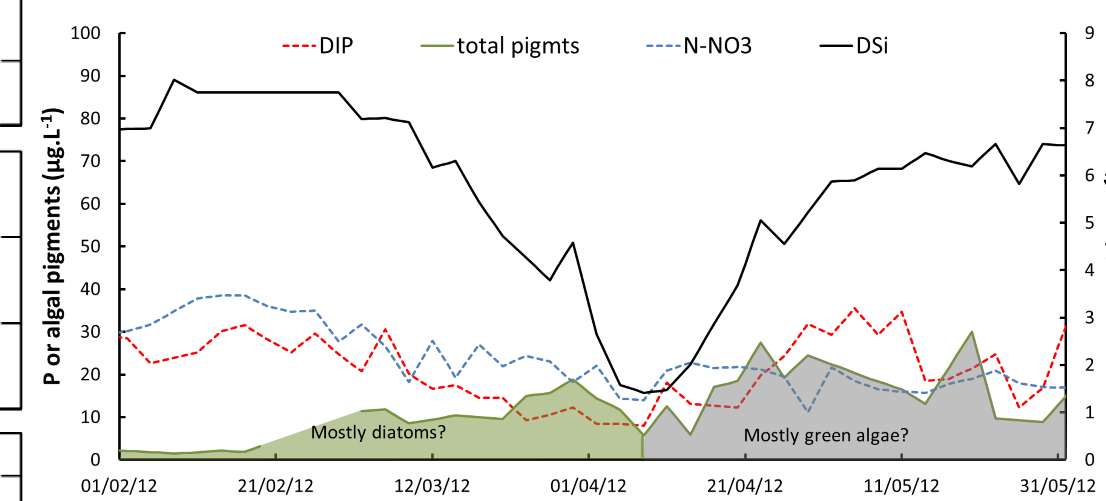

Fig. 5. Phytoplankton population dominance at station 2.

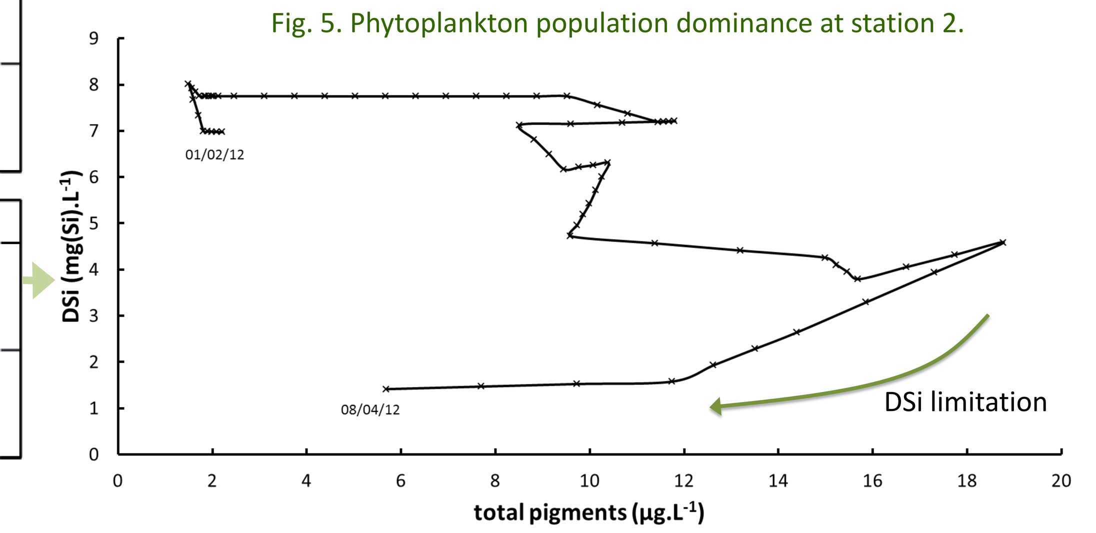

Fig. 6. Algal biomass reached DSi limitation in April at station 2.

What's controlling algal growth?

Water temperature

- Algal pigments started to rise when T > 10°C.

River Flow

- Phytoplankton biomass **growth is favored during low flows** (low velocity = high travel time) but a five-year flood occurred in May/June 2012 (Fig. 2)
- **Dilution** and an increased **water velocity** are more likely to be the limit of phytoplankton growth than higher levels of TSS (Fig. 3).

Suspended solids

- Although high levels of TSS should reduce the light penetration, this spring flood (50 $mg.L^{-1}$ at peak) did not limit the algal activity.
- TSS originates mostly from soil erosion processes during significant hydrological events. In summer, it is composed of detrital matter and of particulate organic matter (up to 50%).

Nutrients

- Nutrients are seasonal: maximum is reached in winter (bared soil weathering processes), minimum in summer (primary activity uptake).
- The Loire system is under **P-limitation**: DIP reached very low concentrations by the end of August at stations 2 and 3 (≈ 5 µg $P.L^{-1}$) while NO_3 remained at the same level around 1.3 mg $N.L^{-1}$ (Fig. 4).
- DSi concentrations dropped down in March/April concomitantly with the rise of algal biomass (Fig. 5). Although terrestrial vegetation could also be partly responsible, this uptake is certainly the signal of diatoms growth favored by stable and low hydrology (covariation of nutrients), until it reached the **Si-limitation** (Fig. 6).

Hypothesis to be confirmed

- Riparian denitrification, macrophytes and periphyton are removing nitrate in the alluvial channel. Given the Redfield ratios and a C/Chl. *a* ratio = 37[3], the seasonal amplitude of nitrate corresponds to an algal production of 350 µg(Chl. *a*).L^{-1}, five times the observation. Denitrification and the N-uptake by fixed vegetation are potential processes responsible for this nitrate loss.
- *Corbicula* clams are also responsible for a lower phytoplankton biomass. This specie invaded the Loire River in the 1990's[4], concomitantly with the algal biomass decline[2]. Unfortunately, the possible impact on the Loire phytoplankton biomass has not been assessed yet.

References

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4. Brancotte, V., & Vincent, T. (2002). L'invasion du réseau hydrographique français par les mollusques *Corbicula Spp*. Modalité de colonisation et rôle prépondérant des canaux de navigation. *Bull. Fr. Pêche Piscic.*, 325–337.