Restoration trends of the Thau lagoon's water ecological status and phytoplankton communities in response to changes in anthropogenic nutrient inputs

Valérie Derolez[1]*, D. Soudant[2], B. Bec[3], M. Richard[1], F. Lagarde[1], C. Chiantella[1], N. Malet[4], C. Aliaume[2]

1) Ifremer LERLR, UMR MARBEC (IRD, Ifremer, Université de Montpellier, CNRS). Avenue Jean Monnet. CS30171 34203 Sète cedex. France
2) Ifremer VIGIES. Rue de l'Ile d'Yeu BP 21105. 44311 Nantes Cedex 03. France
3) Université de Montpellier, UMR MARBEC (IRD, Ifremer, Université de Montpellier, CNRS). Place Eugène Bataillon, 34095 Montpellier. France
4) Ifremer LERPAC/CO. Zoning Industriel Furiani, 20600 Bastia. France

***email: valerie.derolez@ifremer.fr**

Coast Bordeaux 2017

Shellfish farms in the Mediterranean Thau lagoon (France). R. Dupuy de la Grandière

CONTEXT

Thau lagoon (south of France) is one of the largest Mediterranean coastal lagoons (Fig. 1). **It supports many ecosystem services such as shellfish farming**, whose production reaches 10 000 tons a year. Since the 1960s, the increase of anthropogenic inputs, linked to the exponential growth of human population (Fig. 2), have resulted in contaminations of shellfish farming and the eutrophication of Thau lagoon, with significant ecological and socio-economic impacts (Mongruel *et al.* 2013). Since the 1970s and the late 2000s, the considerable efforts made to water depuration systems on the watershed have induced a **significant decrease of nutrient inputs** (Fig. 2), and have gradually led to **a good environmental status of the lagoon according to the Water Framework Directive (WFD)**. Dissolved Inorganic Phosphorus **(DIP) concentrations were reduced by 99% from 1972 to 2016**, moving from bad to high WFD ecological status (Fig. 3). Dissolved inorganic nitrogen, total phosphorus and nitrogen decreased and corresponded to high status from 1999 to 2016 (Derolez *et al.*, 2017).

Simultaneously with the restoration of the lagoon ecosystem, fishermen and shellfish farmers experienced changes in their professional activities related to recent residential and touristic attractiveness of the area. Facing difficulties in their economic sector, they also worry about **the potential limiting capacity of the ecosystem**.

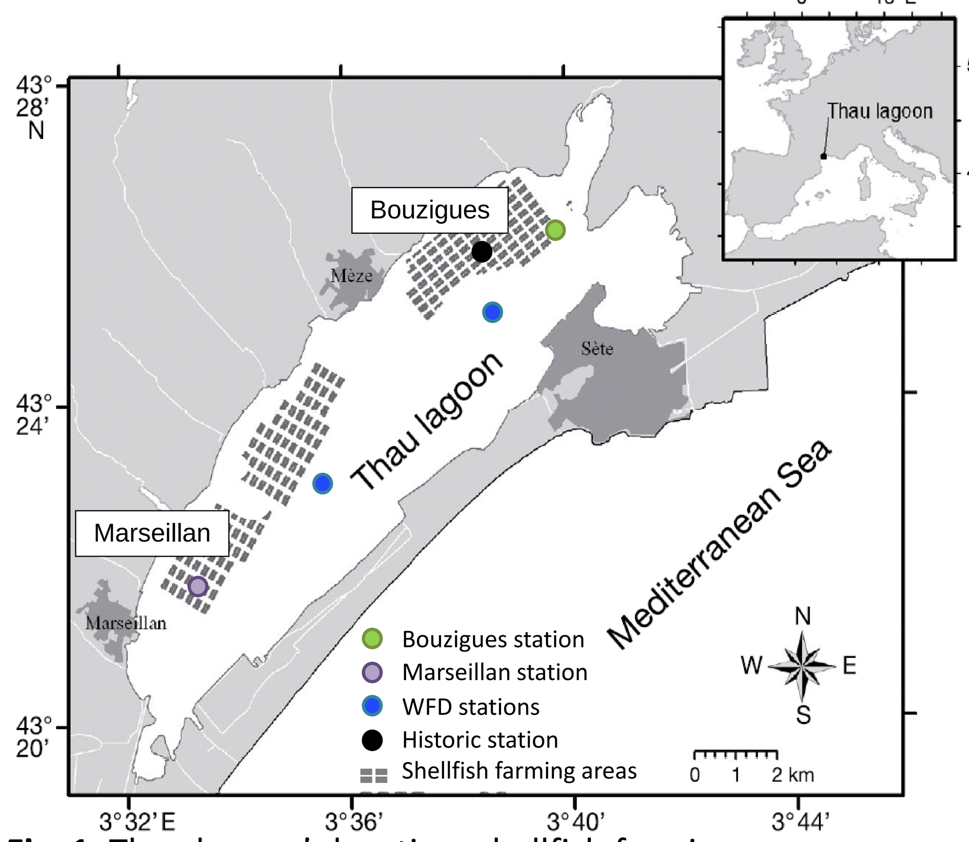


Fig. 1. Thau lagoon's location, shellfish farming areas and sampling stations.

SIGNIFICANT DECREASE OF NUTRIENT INPUTS

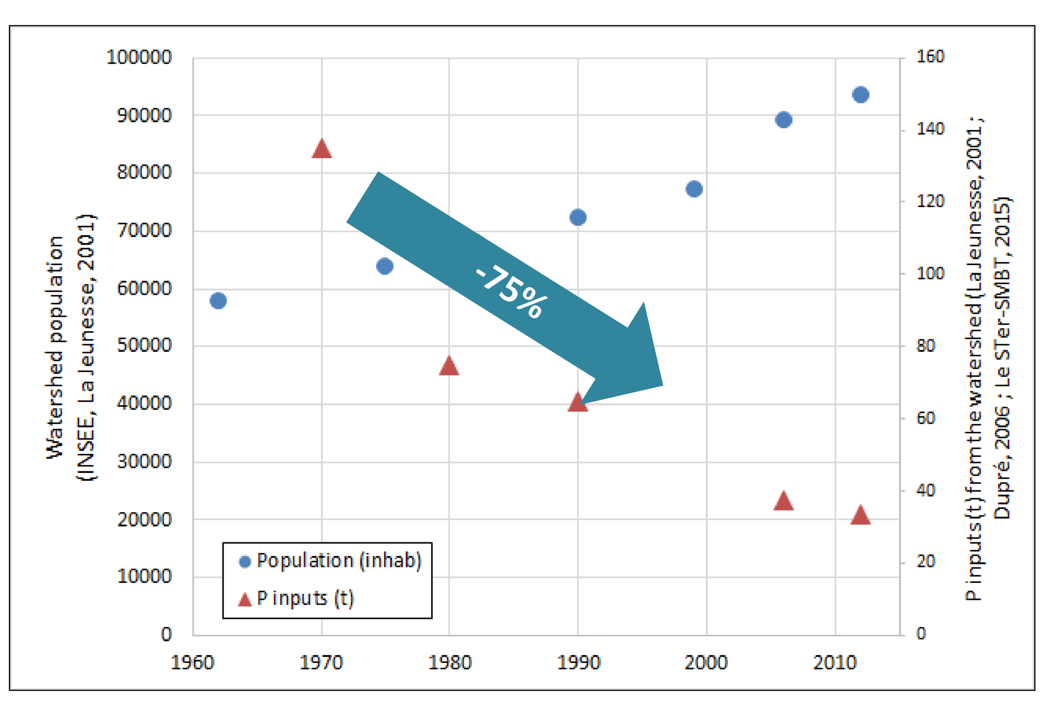


Fig. 2. Thau lagoon's population (inhabitants) and Phosphorus inputs (t/year) from the watershed from 1960 to 2012.

IMPROVEMENT OF WATER WFD ECOLOGICAL STATUS

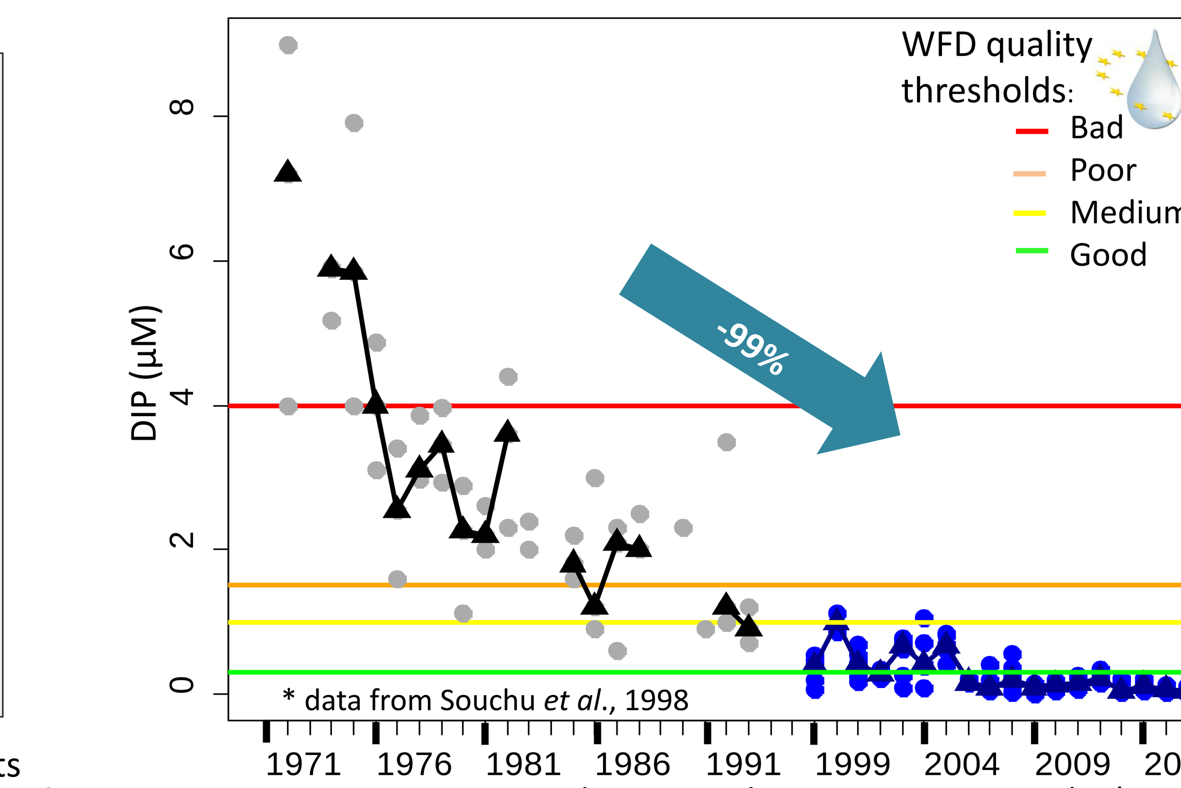


Fig. 3. DIP concentrations measured in water during summer months (triangles: median values) at **historic station** from 1972 to 1993* and at **WFD's stations** from 1998 to 2016.

AIMS OF THE STUDY

Data on phytoplankton communities of Thau lagoon were analysed in order:

1) **to highlight the changes in the biomass, abundance and composition of phytoplankton in Thau lagoon, in response to the reduction of nutrient inputs since the late 20th century**;
2) **to compare results collected on two stations to highlight a potential spatial heterogeneity.**

MATERIALS & METHODS

PHYTOPLANKTON MONITORING

- Sampling twice a month, since 1994 at **Bouzigues station** and since 2009 at **Marseillan station** (Fig. 1) (REPHY, 2017).
- Microphytoplankton cells counts: Utermöhl microscopy method (AFNOR, 2006).
- Chlorophyll-*a* concentration by monochromatic spectrophotometry (Aminot & Chaussepied 1983; Aminot & Kérouel, 2004).

DATA TREATMENT AND STATISTICAL ANALYSES

- Variance stabilizing **log transformations** were applied to variables: base is *e* for chlorophyll-*a*, *10* for cell counts and Myzozoa/Ochrophyta ratio. All species counted in Myzozoa were dinoflagellates (*resp.*Ochrophyta=diatoms).
- **Dynamic Linear Models (DLM)** (West and Harrison, 1997; Harvey *et al.*, 1998; Taylor *et al.*, 2007), decomposing an observed time series into: the deseasonalized trend, the seasonality and the residuals as a white noise. DLM were composed of second order polynomial trend and a two harmonic trigonometric seasonal components.

RESULTS

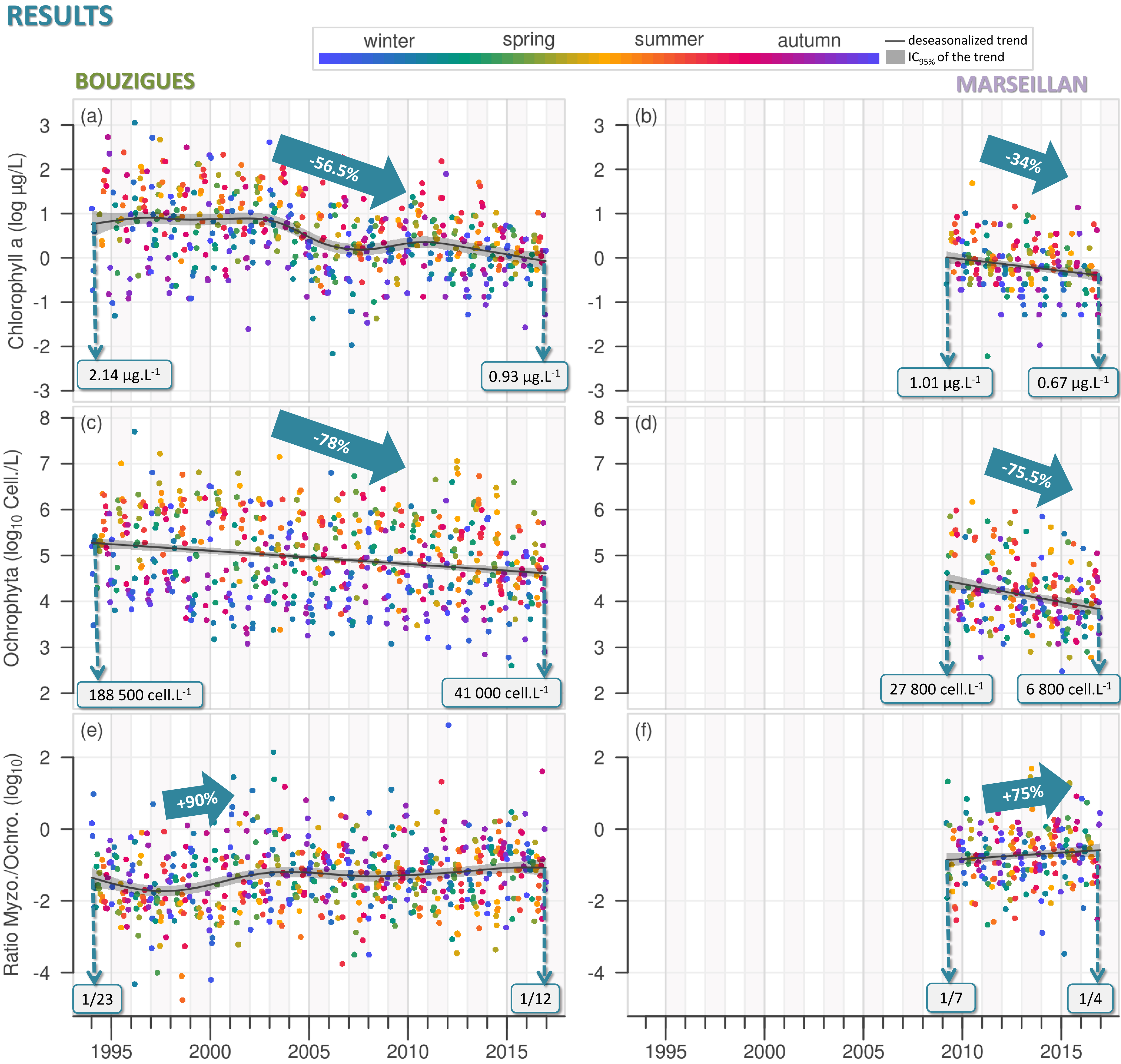


Fig. 4. **a)-b)** Chl-*a* biomass (log µg.L^{-1}), **c)-d)** Ochrophyta abundances (log$_{10}$ cell.L^{-1}) and **e)-f)** Myzozoa/Ochrophyta ratio (log$_{10}$) from 1994 to 2016 at **Bouzigues station** (left panel) and at **Marseillan station** (right panel).

CHLOROPHYLL-*A*

BOUZIGUES

- Levels of **Chl-*a* concentrations decreased by 56.5%**: from 2.14 µg.L^{-1} in 1994 to 0.93 µg.L^{-1} in 2016 (Fig. 4a).
- Maximum levels were reached during summer. Another bloom of lower magnitude was observed during spring until 2005.

MARSEILLAN

- From 2009 to 2016, levels of Chl-*a* concentrations were on average **1.5 times lower at Marseillan than at Bouzigues. Chl-*a* decreased by 34%**: from 1.01 µg.L^{-1} in 2009 to 0.67 µg.L^{-1} in 2016 (Fig. 4b).

DIATOMS (OCHROPHYTA)

BOUZIGUES

- Levels of **diatom abundances decreased by 78%**: from 188 500 cell.L^{-1} in 1994 to 41 000 cell.L^{-1} in 2016 (Fig. 4c).

MARSEILLAN

- From 2009 to 2016, levels of diatom abundances were on average **3.6 times lower at Marseillan than at Bouzigues**.
- Levels of **diatom abundances decreased by 75.5%**: from 27 800 cell.L^{-1} in 2009 to 6 800 cell.L^{-1} in 2016 (Fig. 4d).

RATIO DINOFLAGELLATES/DIATOMS

BOUZIGUES

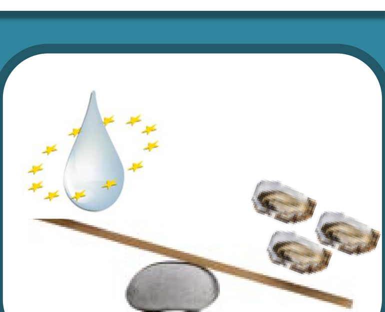
- **Diatoms were dominant** (ratio <1) (Fig. 4e).
- Diatom abundances were 23 times (in 1994) to 12 times (in 2016) higher than the abundances of dinoflagellates.
- The ratio was mainly driven by diatom abundances, as **abundances of dinoflagellates remained stable** (~4 000 cell.L^{-1}).

MARSEILLAN

- The ratio was **higher at Marseillan than at Bouzigues**.
- Diatom abundances were 7 times (in 2009) to 4 times (in 2016) higher than the abundances of dinoflagellates (Fig. 4f).
- **Abundances of dinoflagellates decreased by 55%**, from 3 800 cell.L^{-1} in 2009 to 1 700 cell.L^{-1} in 2016.

CONCLUSION AND PERSPECTIVES

The mitigation actions carried out on the watershed of Thau lagoon since two decades have induced a modification of phytoplankton communities. Our results highlighted **a decrease of chlorophyll-*a* concentrations and of diatom abundances**. They also evidenced a **spatial heterogeneity of phytoplankton communities**. To address the issue of the potential limiting capacity of the ecosystem, further analyses focusing on species composition and integrating the important part of biomass represented by nano- and pico-phytoplankton (Bec *et al.* 2005) need to be performed. Ecosystem modeling and multidisciplinary approaches will also be required to address the issues raised by stakeholders in the Thau lagoon (CAPATHAU program 2017-2018).



REFERENCES: AFNOR (2006) NF EN 15204; Aminot & Chaussepied (1983) CNEXO ed.; Aminot & Kérouel (2004) Ifremer & MEDD ed.; Aminot & Kérouel (2007) Quae ed.; Bec et al. (2005) J. Plankton Res. 27:881-894; Collos et al. (2009) J. Sea Res. 61:68-75; Derolez et al. (2017) OBSLAG report (http://archimer.ifremer.fr/doc/00386/49744/); Harvey et al. (1998) Adv. Econom. 13:103-143; La Jeunesse (2001) PHD Thesis - Université d'Orléans, France ; Mongruel et al. (2013) J. Env. Manag. 118:55-71; REPHY (2017) SEANOE database (http://doi.org/10.17882/47248); Souchu et al. (1998) Mar. Ecol. Prog. Ser. 164:135-146; Taylor et al. (2007) Env. Model. & Software 22:797-814; West & Harrison (1997) Springer ed. **ACKNOWLEDGEMENTS:** REPHY, AERMC, Région Occitanie, Cépralmar, SMBT.