Does global warming favour the occurrence of recent blue mussel mortality events in France?

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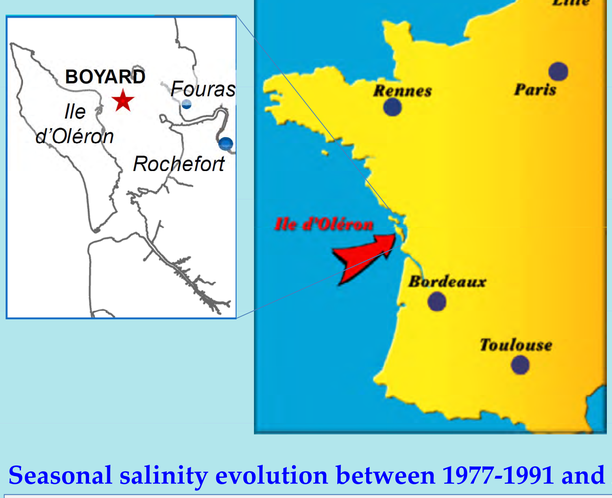
Here, we report findings of two independent studies carried out in the Pertuis Charentais for which a link might exist?

1- Climate change & Global warming : case of Marennes Oleron Basin



- **The present study focused on the hydroclimatic evolution of the Marennes-Oléron Bay (French Western Atlantic Coast) between two 15 years-long periods (1977-1991 and 2000-2014) linked to a strong seawater temperature increase in the 1990's (Soletchnik *et al.*, 2017) (Fig.1).**
- **Between these two studied periods, the annual median seawater temperature value rise of about 3°C endorsed the strong increase in higher temperature value frequency during the latest period (the annual mean temperature increase was 1,5°C in the northern part of the Bay at Boyard Station).**

Change in seawater temperature

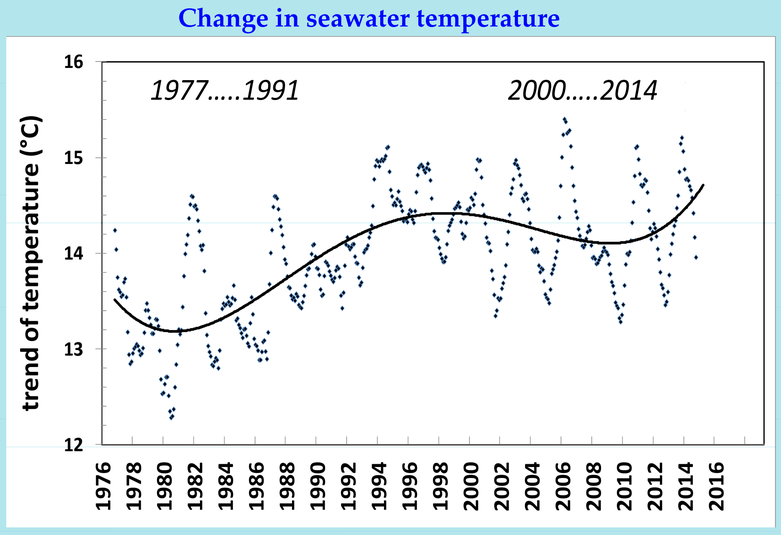


Figure 1. Evolution from 1977 to 2014 of the seawater temperature trend (monthly time scale) observed at Boyard Station (dotted line). The additive Census II model was used for time series decomposition (Statgraphic centurion XVI software, Shiskin 1957 from Béthoux et al, 1980). A polynomial model of order 4 (R^2 = 0.46) was then adjusted to median values (solid curve). (data source, Ifremer LERPC)

Seasonal salinity evolution between 1977-1991 and 2000-2014 periods

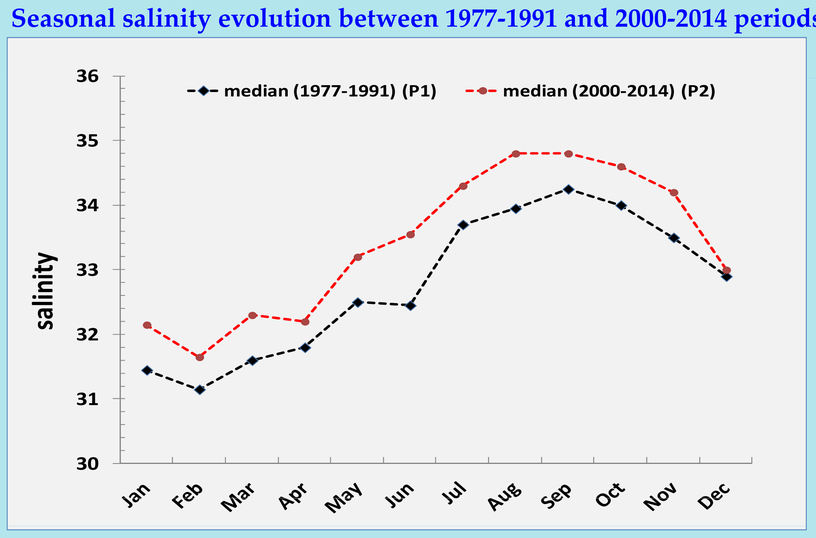


Figure 2. Seasonal median salinity values compared between 1977-1991 and 2000-2014 periods. Confidence ranges fixed at 95% for each median were based on order statistics of each sample (Statgraphic centurion XVI). Red and blue surface curves showed these confidence ranges for both studied periods (Boyard Station). (data source, Ifremer LERPC)

From non-parametric statistical analysis (Kruskal Wallis test, Statgraphic centurion XVI), a salinity time series comparison was realized between the two periods for each month of the year. Results showed (Fig.2)

- **Whatever the considered month, median salinity values were always higher during the latest period (2000-2014) (from +0,1 to +1,1 PSU in December and June, respectively) ;**
- **The significant differences (5% threshold) in salinity values observed in March, May months and the autumn season (September, October and November months) delimited the summer season (June, July and August months) characterized by a stronger salinity value increase (1% threshold) ;**
- **At the annual scale, the salinity value difference between the two studied periods was +0.58 (from 32.9 to 33.48 PSU). It showed the « marinization » phenomenon of the Marennes-Oléron Bay coastal ecosystem.**

Conclusion: At local scale of Marennes-Oleron bay, our forty-year *in situ* time series data show that hydroclimatic conditions have significantly changed , as in the Bay of Biscay (Michel *et al.*, 2009).

2- Biological changes, coincidence or consequence?

Decrease in Phytoplankton diversity

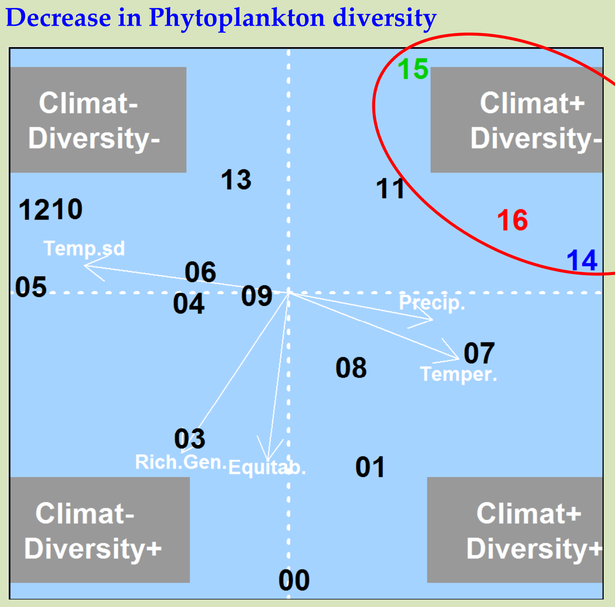
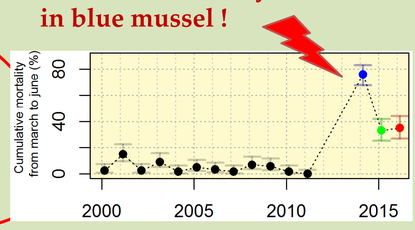


Figure 3: Results for the compromise of the Partial Triadic Analysis (PTA); from 2000 to 2016, years in color correspond to years with high level of mortality.

Increased mortality in blue mussel !



From 2000 to 2016 (warmer trend years), data analysis based on phytoplankton diversity indices and general climatic descriptors (atmospheric temperatures and cumulative rainfall) categorizes the years according 4 typologies. Surprisingly, a group of 3 years is associated with high level of mortality. This group is characterized, in winter and spring, by weather rather hot and rainy, and diversity indices rather low (Fig.3).

- **After oyster spat crisis that farmers faced from 2008-2012 (Pepin *et al.*, 2014), mussel farming of Charente-Maritime and Vendée has experienced an unprecedented crisis since spring of 2014.**
- **Mass mortality events of blue mussel (*M. edulis*) have affected livestock areas, decimating up to 100% of production in some farming areas (Polsenaere *et al.*, 2017).**
- **In this context, the MORBLEU research project (DPMA-Ifremer agreement) was initiated to explore potentially aggravating factors, associated or correlated with mortality of mussels.**
- **Here, the work is to support the hypothesis that these episodes could be linked to an evolution of microbial communities (water column and mussel microbiota).**

Change in microbial balance

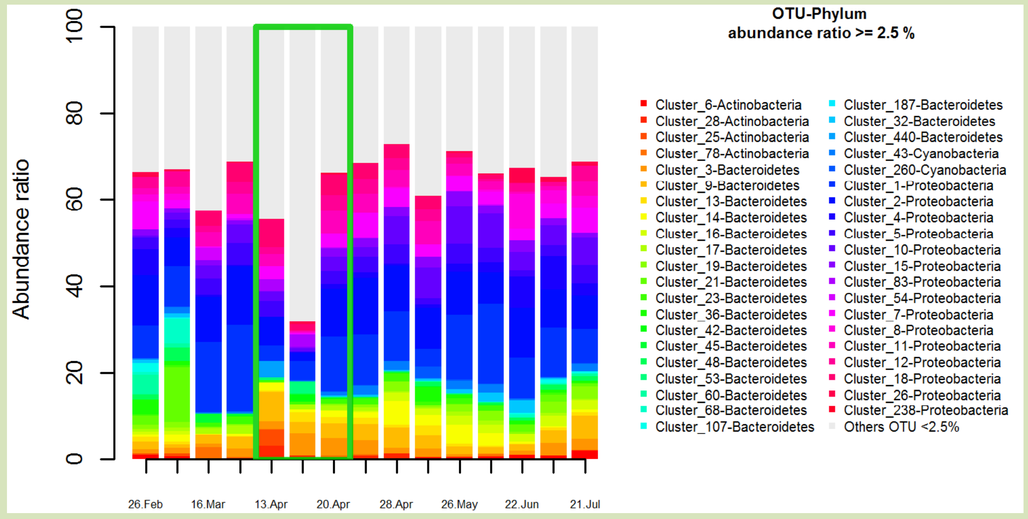


Figure 4: Winter and spring evolution of relative abundance of OTUs (operational taxonomic unit, 16S rRNA gene prokaryote metabarcoding) and classes of bacteria at the Filière station in 2015. Green frame indicates initiation of mussels mortalities.

Since 2015, a monitoring of bacterial communities (through an NGS metabarcoding approach) is conducted on three stations from Pertuis sounds. It confirmed that this period of initiation of mortality phenomenom is also marked by changes in bacterial equilibrium. A decrease in most dominant taxa (abundance ratio > 2.5%) is observed in favor of less present specie (Fig.4).

Conclusion:

- **Although there is a simultaneity between certain events of the microbial dynamics (imbalances) and the first spring mussels mortalities, no causal link is currently established.**
- **Our observations contribute to the hypothesis of a microbial origin (pathogenic bacteria) responsible for the spring mortality of mussels, among those advanced since the emergence of the phenomenon.**
- **Whatever the temporal window of observation (seasonal, or medium-term historical), a link between the evolution of microbial balances and the spring mortality of mussels gets clear.**
- **If causal links existed, in addition to the fact that an organism or a group could be identified as responsible for mortality (seasonal dimension), the emergence of this phenomenon could have its origin in the evolution of Microbial communities of shellfish ecosystems under the action of more global constraints such as warming change.**
- **The holistic approach carried out in the MORBLEU project will contribute to describe potential links between dynamic equilibrium of the planktonic microbial communities, and "health" of mussel livestocks.**

Data sources : Mussel mortality: Remoula and Mytilobs recordings (Ifremer Networks / Quadrige) ; Meteorology (atmospheric temperature and precipitation): Chassiron station (Météo-France / Synop) ; Phytoplankton abundances from the REPHY network (Ifremer / Quadrige); eDNA metabarcoding (NGS) of prokaryotic plankton (16S rRNA gene) analyzed as part of the MORBLEU 2015 project (Fig.4)(Pepin *et al.*, 2017).
Data processing : The diversity indices (Richness and Equitability) are calculated on the basis of the aggregated phytoplankton abundances at the genus level. The years 2000 to 2016 are discriminated by a partial triadic analysis based on environmental variables (climate and diversity): matrix (years X variables) repeated from February to June, forming the cube of data analyzed.

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