EVOLECO: EVOlution à Long terme des Ecosystèmes COtiers Pessac – Décembre 2017

Evaluer le risque d'hypoxie dans l'estuaire de la Gironde à partir d'observations multi-sites, pluriannuelles et à haute fréquence

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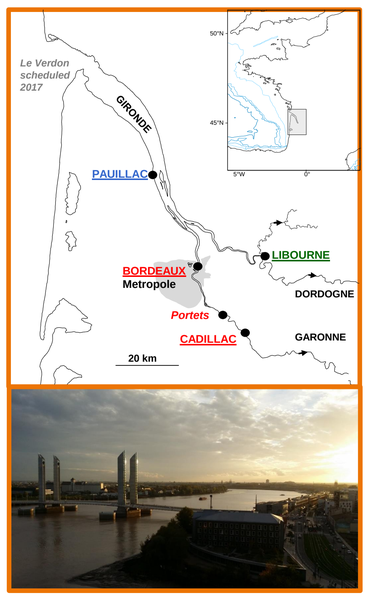
• Introduction:

Dissolved Oxygen (DO) concentration is critical for most of aquatic life. The number of low oxygen, hypoxic (< 2 mg L^{-1}) and anoxic (< 0 mg L^{-1}) zones in aquatic environments is increasing (Rabalais et al., Biogeosciences, 2010). Hypoxia now occurs in many areas where it did not occur before, including transitional areas. For this reason, DO is one of the chemical quality elements (CQE) that must be considered under the EU Water Framework Directive (WFD) to reach *good ecological status*.

The Gironde estuary, the largest estuary of the western Europa, had already presented episodic low dissolved oxygen (DO) content close to Bordeaux, a large urban area located on the tidal Garonne, its main tributary.

In addition, the Aquitaine Region (S.W. France) is regarded as one of the regions of France where global warming will be the most important, with an expected increase in temperature of 2 to 5 °C by 2021-2050. In addition, the population of Bordeaux Metropole is projected at nearly 1 million by 2030.

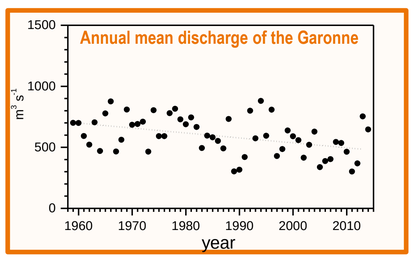
In such a context of long-term environmental changes and local pressures, the establishment of a permanent seasonal hypoxia is expected in the next decades, that could be problematic for downstream migration of juvenile fishes (eel, shad or salmon).



• The Gironde estuary under climatic and local pressures:

The Gironde fluvio-estuarine system (S-W France) formed by the confluence of the Garonne and Dordogne Rivers is:

- **the largest fluvial-estuarine system which drains to the Bay of Biscay in term of surface area (625 km^2) and mean annual discharge (600 m^3 s^{-1});**
- **characterised by a pronounced Turbidity Maximum Zone (TMZ) with suspended sediment concentration (SSC) in surface waters > 1 g L^{-1};**
- **an ecological corridor for emblematic migrating fishes (sturgeon; salmon).**



Since the last decades, the Gironde watershed experiences a trend in decreasing river flow, and a subsequent intensification of the turbidity maximum presence in the fluvial estuary (Jalón-Rojas et al., Hydrol. Earth Sys. Sci. 2015). Regionally, the Adour-Garonne basin has the largest structural water deficit in France (Mazzega et al., J. Hydrol., 2014). This decrease is explained by the large abstraction for hydroelectric dams and irrigation, but also by a change in precipitation intensity and frequency. The variability of the Garonne discharge is influenced by the North Atlantic Oscillation (NAO), a prevailing climate index in Western European (Chevalier et al., Hydrol. Sci. J., 2013).

➔ MAGEST: a continuous, real-time monitoring of the Gironde estuary:

Since 2004, MAGEST (MArel Gironde ESTuary) provides high-frequency (each 10 minutes), real-time measurements of key physical-chemical parameters, including dissolved oxygen, in the Gironde estuary (see map).

MAGEST provides turbidity data to the SNO DYNALIT. DYNALIT

www.magest.u-bordeaux1.fr
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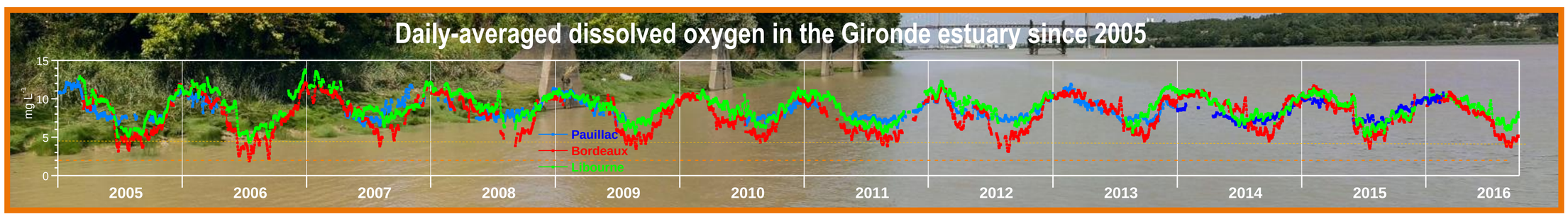
This network is funded by : AEAG; SMIDDEST; SMEAG; EPIDOR; EDF; GPMB; Bordeaux Metropole; IRSTEA; Université de Bordeaux; CNRS.

Assessing and managing the risk of hypoxia in transitional system is complex, because it is contextual with several processes (temperature, river discharge, turbidity, land use, city, climate change) acting over a wide range of temporal and spatial scales. A prerequisite to predict the evolution of DO in waters of a coastal system is to better understand DO dynamics in relation to natural and anthropic forcings.

Here we present a 12-years continuous record of dissolved oxygen in the Gironde fluvial-estuarine system to demonstrate the interest of high-frequency monitoring to better understand the factors controlling DO concentrations and for the development of manager's oriented tools.

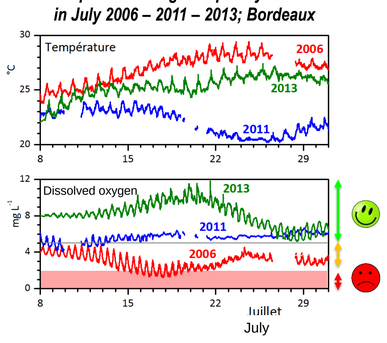


• Dissolved oxygen (DO) in the Gironde estuary:

The 12-yr DO record (see the above figure) in surface waters of the Gironde estuary shows :

- **a clear seasonal variation in daily-averaged DO with :**
  - **the highest DO in winter, between 8 and 12.5 mg.L^{-1}, at low water temperatures (< 10°C)**
  - **the lowest DO in summer, between 1.8 and 10 mg.L^{-1}, when waters are warm (20 – 28.5°C);**
- **the lowest values are always recorded at Bordeaux in the tidal Garonne in summer.**

Comparison of high-frequency records in July 2006 – 2011 – 2013; Bordeaux



The large variability in DO in July is explained by the meteorological context :

- 2006: among the driest years recorded by MAGEST and a 21-days heat wave in summer;

- 2011: the lowest Garonne discharge of the period but a rather wet and cool summer;

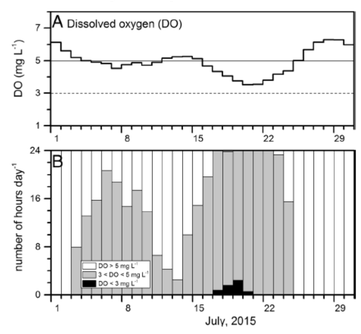
- 2013: the wettest year.

DO changes in July 2015 is detailed considering the daily mean, but also the number of hours per day during which DO was above or below the threshold of 5 mg L^{-1} *:

- **it is noticeable that, whereas from July 4 to 12, 2015, daily mean DO oscillates around 5 mg L^{-1}, raw DO concentrations are at least 8 h per day below 5 mg L^{-1}, and even few hours < 3 mg L^{-1} from July 18 to 21;**
- **only a high frequency monitoring is able to capture DO changes by recording all periods of the day and night and to produce reliable daily mean;**
- **a special care is required in the use of daily mean; it can conceal periods of time throughout the day below thresholds.**

** : the schema of development and management of Gironde waters (SAGE Estuaire de la Gironde) has an ambitious criteria of a minimum daily mean DO level of 5 mg L^{-1} in the tidal Garonne.*

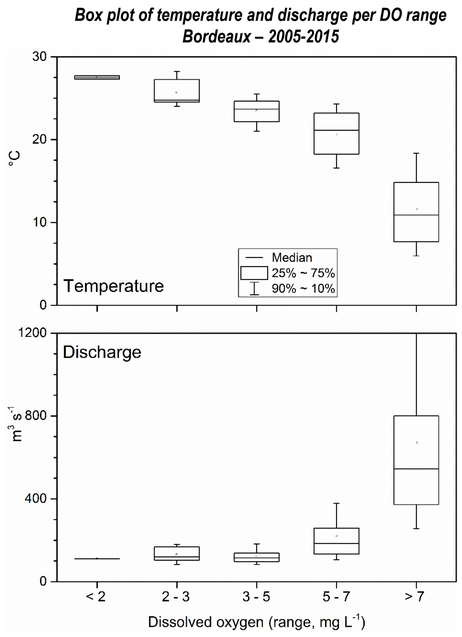
DO concentrations and number of hours per days in July 2015 - Bordeaux



• DO controlling factors in the Gironde estuary :

The threshold for dissolved oxygen adopted for the fluvial estuary is ambitious. But, considering the records since 2005 (see figure), a question is to which extent is this disposition realistic. For the period 2005-2016, the objective was reached only a single year (2011), that was characterized by an atypical summertime in term of fluvial discharge and temperature.

Box plot of temperature and discharge per DO range Bordeaux – 2005-2015



The classification of the different DO ranges according to temperature and discharge shows that the lowest DO concentration are always observed for the lower fluvial discharge. Below 150 m^3 s^{-1}, the risk is high to record DO below 5.0 mg L^{-1}.

Considering temperature, the link between deoxygenation and water temperature is even more obvious. With increasing temperature, there is a gradual and inexorable decrease in DO concentration.

A warm summer (> 25°C) always results in DO below < 5 mg L^{-1}. By contrast, a dry summer is not always related to low oxygen, as observed in 2011.

But the combination of a warm and dry summer, amplified by urban inputs, is likely to result in hypoxia.

• In conclusion:

The real time, high-frequency MAGEST monitoring is an essential tool for understanding the changes in dissolved oxygen of the Gironde transitional waters, from tidal to seasonal and multiannual timescales. It is also of valuable interest for the development of manager's oriented-tools and the follow-up of DO objectives in the Gironde estuary.

Regarding the risk of hypoxia in the Gironde estuary, summer is the most critical period due to the combination of warm water, low fluvial discharge, high particle load and urban input. For the next decades, the climatic projections for the Garonne watershed anticipate an increase of temperature (> + 2°C) and a decrease in mean annual runoff. Such changes are not favourable to maintain dissolved oxygen above the threshold of 5.0 mg L^{-1} in summer.

At the different of the North Sea for example where the decreased nutrient loadings could function as mitigation tool to counteract the effect of rising temperature (Meire et al, Biogeosci. 2012), the triggers are limited in the case of the Gironde estuary for preventive management strategies. As it is not possible to prevent temperature rise, the only factor that could potentially be controlled is the Garonne discharge.

Résumé

- **Au cours des dernières décennies, l'hypoxie s'est développée dans les eaux côtières, notamment à cause de l'eutrophisation liée aux activités anthropiques. L'estuaire de la Gironde est caractérisé par une zone de turbidité maximum, avec une charge particulaire de plusieurs grammes par litre, empêchant ainsi la pénétration de la lumière et la production primaire. Cependant, de fortes désoxygénations ont déjà été mesurées dans sa section fluviale.**
- **L'évaluation du risque d'hypoxie sur un si vaste estuaire est complexe et exige des observations fiables afin de comprendre l'importance relative des différentes pressions agissant sur une large gamme d'échelles spatiales et temporelles. Ici, nous montrons l'intérêt du réseau MAGEST d'observation haute-fréquence, pluriannuelle et multi-sites, qui enregistre depuis 2005, la température, la salinité, la turbidité et l'oxygène dissous dans les eaux de surface.**
- **A l'échelle de l'année, la température est le principal facteur de contrôle de l'oxygénation, suivi par le débit et la turbidité. À l'échelle saisonnière, la variabilité de l'oxygène dissous résulte d'interactions complexes entre les différents facteurs environnementaux (température, écoulement fluvial, turbidité, cycles de marée, rejets urbains). En ce qui concerne le risque d'hypoxie dans l'estuaire fluvial, l'été est la période la plus critique en raison de la combinaison d'eaux chaudes, de débits faibles et d'une charge particulaire élevée. Les changements régionaux en cours (augmentation de la température et de la population, diminution du débit) suggèrent l'établissement d'une hypoxie estivale chronique dans les prochaines décennies.**

For more informations:

Jalón-Rojas I., Schmidt S., Sottolichio A. (2015). Turbidity in the fluvial Gironde Estuary (S.-W. France) based on 10-year continuous monitoring: sensitivity to hydrological conditions. Hydrological and Earth System Sciences 19, 2805-2819.

Schmidt S., Bernard C., Escalier J.-M., Etcheber H., Lamouroux M. (2016) Assessing and managing the risks of hypoxia in transitional waters: a case study in the tidal Garonne River (South-West France). Environmental Science and Pollution Research. doi: 10.1007/s11356-016-7654-5.

Schmidt S., Etcheber H., Sottolichio A., Castaing P. (2016). Le réseau MAGEST : bilan de 10 ans de suivi haute-fréquence de la qualité des eaux de l'estuaire de la Gironde. Mesures haute résolution dans l'environnement marin côtier, Edts Schmitt F. & Lefevre A., Presses du CNRS.