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The implication of oyster farming in increasing sedimentation rates in a macrotidal bay: the Marennes-Oléron Bay, France

Xavier BERTIN and Eric CHAUMILLON
Centre littoral de Géophysique, Université de La Rochelle, Avenue Michel Crépeau, 17042 La Rochelle cedex 1, France ; xavier.bertin@univ-lr.fr

Abstract: The Marennes-Oléron Bay is a 150 km^2 macrotidal bay, located in the middle of the French Atlantic coast, and constituting the first oyster farming domain in Europe. Historical bathymetric data have permitted to evidence the accretion of 120.10^6 m^3 of sediment since 1824, reducing by 20 % the water volume infilling the bay. The superimposition of sediment gain areas with oyster farm locations locally displays a good correlation and the sediment accreted within these areas reaches 30% of the whole sediment accreted in the bay since 1824. The consequences of this sediment infilling on the bay southern inlet are finally discussed.

Résumé : *Le rôle de l'ostréiculture dans l'augmentation du taux de sédimentation dans une baie macrotidale : la Baie de Marennes-Oléron.* La Baie de Marennes-Oléron est une baie macrotidale de 150 km^2, située au milieu de la façade atlantique française et qui constitue le premier domaine ostréicole en Europe. Des données bathymétriques historiques ont permis de montrer l'accrétion de 120.10^6 m^3 de sédiments dans la baie depuis 1824, diminuant son volume de remplissage en eau de 20%. La superposition du cadastre ostréicole avec les zones de gain sédimentaire montre localement une bonne corrélation et les sédiments accrétés sous les parcs à huître constituent 30% des sédiments accrétés dans la baie depuis 1824. Les conséquences de ce comblement sur le fonctionnement de l'entrée sud de la Baie sont abordées en conclusion.

Keywords : Sedimentation; Oyster farming; Macrotidal bay; Marennes-Oléron

Introduction

The Marennes-Oléron Bay is a 150 km^2 macrotidal bay located in the western coast of France. It constitutes the first oyster farming area of Europe, obviously justifying the necessity of understanding the hydro-sedimentary processes responsible for its morphological changes, in particular the high sediment accretion that occurs in several zones since the last decades. The importance of oyster farming in increasing sedimentation rates has already been pointed out in the study area by Sornin (1981) and locally quantified by Gouleau et al. (2000).

It is the purpose of this paper to demonstrate the secular morphological changes of the Marennes-Oléron Bay and to evidence the correlation between high sediment accretion zones and oyster farms. The consequences of Marennes-Oléron bay sediment infilling for rest of the study area are then briefly discussed.

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Methods

High quality bathymetric data are available on the study area from 1824. These data were extracted from the data bases of the Service Hydrographique et Océanographique de la Marine (S.H.O.M.) and the hydrographic office of La Rochelle (Direction Départementale de l'équipement de Charente Maritime). The different data sets have been georeferenced, including datum conversion (local geodesic system New Triangulation of France), reference marine level conversion and calculation of Lambert 2 planar coordinates. Digital elevation models (D.E.M.) were developed using Surfer software with a grid spacing ranging between 20 and 200 m, depending on the density of the original data. The final relative error does not exceed 10 m in position and 0.5 m in depth for data older than 1970 and 1 m and 0.1 m respectively after this date. The reliability of these data was checked by the rocky outcrops stability between each survey and has already permitted to demonstrate morphological evolutions in the study area (Chaumillon et al., 2002; Bertin et al., 2004 & 2005).

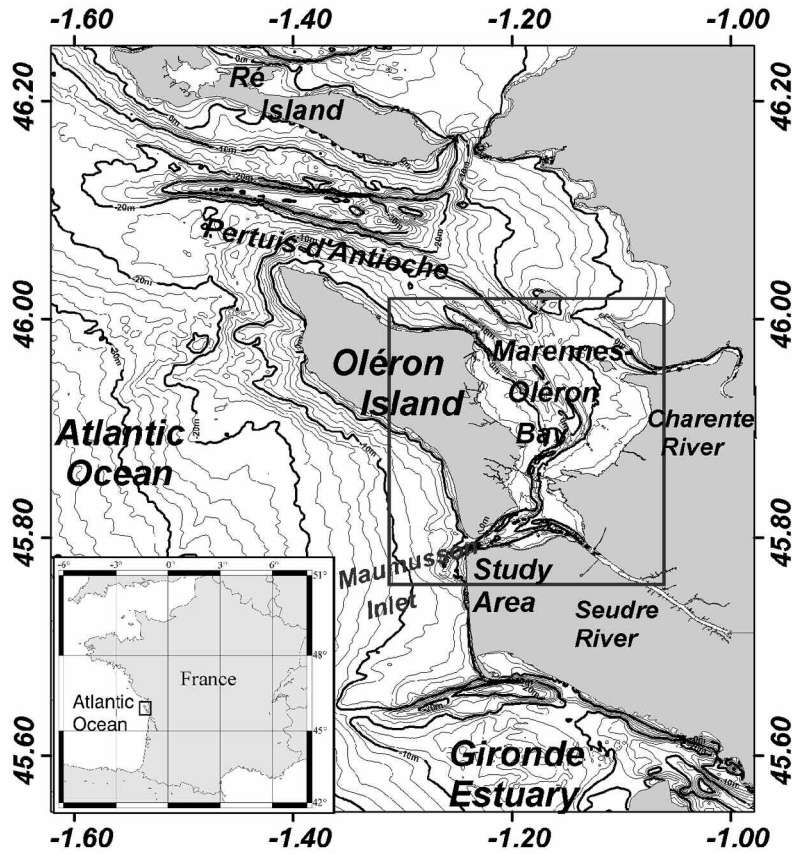

Figure 1. General location of the study area. Bathymetric interval is 2 m and isobath lines are bolded every 10 m.

Figure 1. Zone d'étude. Isobathes tous les 2 m et isobathes en gras tous les 10 m.

Physical settings

The Marennes-Oléron Bay is located on the French Atlantic coast (Bay of Biscay), between Oléron Island to the west and the continental shoreline to the east (Fig. 1). This macrotidal bay has two connections with the Atlantic Ocean: (1) a tidal inlet to the south (Maumusson Inlet, Bertin et al., 2004 & 2005); (2) a drown incised valley to the north (Pertuis d'Antioche; Weber et al., 2004). A main central channel separates wide intertidal zones which constitute 60% of this 150 km^2 embayement.

The study area is dominated by tides ranging from less than 2 m during neap to more than 6 m during spring tides (macrotidal), inducing tidal currents up to 2 m.s^{-1} at the southern entrance of the bay (Maumusson Inlet, Fig. 1). Other hydrodynamic forcing factors include wind waves and attenuated swells that penetrate the bay through its two entrances (Maumusson Inlet and Pertuis d'Antioche, Fig. 1).

Sedimentation rates have been estimated on the eastern mudflat of the bay with ^{210}Pb method (Gouleau et al., 2000). The values range between 0.97 cm.yr^{-1} on the mudflat lower part and 0.26 cm.yr^{-1} on upper part.

Historical morphological changes

The volume calculation between 1824 and 2004 D.E.M. (Fig. 2) clearly evidences that accretion is dominant in the sediment budget of Marennes Oléron Bay over the last 181 years: + 120.10^6 m^3. The average corresponding sedimentation rate of 0.55 cm.yr^{-1} has been estimated, which is consistent with previous geochemical measurement on the eastern mudflat (Gouleau et al., 2000). This sediment infilling has led to a decrease in the water volume of the tidal bay (W.V.B.) since 1824, being in the order of 20% for a spring tide. Sediment gain occurs in four types of area: (1) Close to connections with the ocean (Pertuis d'Antioche to the North and Maumusson Inlet to the south, Figs 1 & 2) associated with a progradation of the shoreline; (2) In the lower part of intertidal areas, particularly in the southern and eastern parts of the bay, where maximum accretion reached up to 3 m; (3) In the central tidal channel, located at the northern part of the bay, where sedimentary

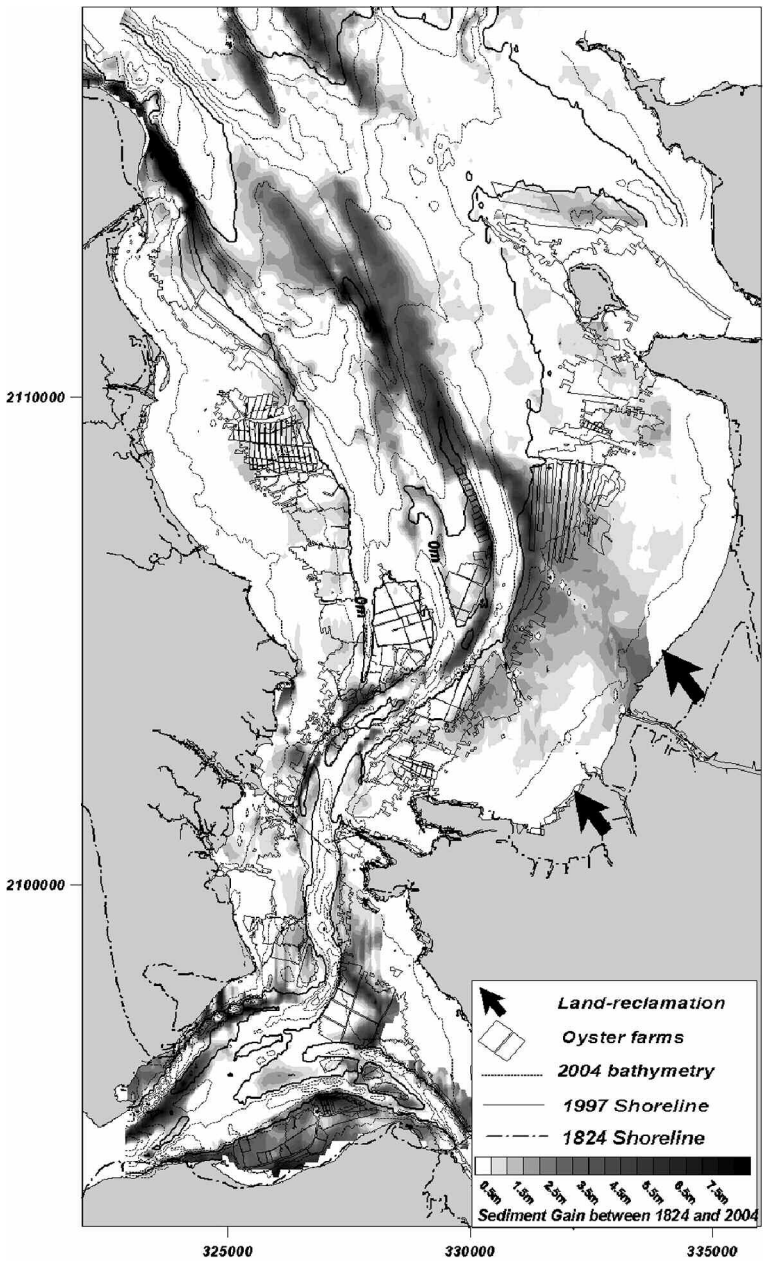

Figure 2. Superimposition of sediment gain areas since 1824 and oyster farms, locally showing a good correlation. Bathymetric interval is 2 m for the 2004 bathymetry.

Figure 2. Superposition des zones d'engraissement depuis 1824 et des concessions ostréicoles, montrant localement une bonne corrélation. Isobathes tous les 2 m pour la bathymétrie de 2004.

accretion attained 10 m since 1824; (4) In areas where land reclamation has occurred like at the eastern mudflat shoreline.

Discussion

The mean sedimentation rate to be found in the Marennes-Oléron bay is very high regarding values computed from other lagoons in the world (Fig. 3). High sedimentation rates are usually explained by fast relative sea level rise (Nichols, 1989; Oertel et al, 1992) and/or a deltaic coastal setting (Nichols, 1989). Because of the non-deltaic setting of the study area and the moderate sea level rise rate of 1-2 $mm.yr^{-1}$ the western coast of France is subjected to for the two last centuries (Wöppelmann, 1997), neither of these two hypotheses could be retained for explaining high sedimentation rates in the Marennes-Oléron Bay. On the contrary, the main difference between the Marennes-Oléron Bay and other lagoons in the world is the exceptional development of aquaculture (mainly oyster farming). Henocque (2003) estimated the Marennes-Oléron Bay to be overstocked since 1985 by 100,000 tons of cultured oysters deployed over 3,600 ha of leasing grounds.

The figure 2 locally evidences a strong correlation between high sediment accretion zones, located in intertidal lower parts, and the position of oyster farms. This supports the idea that oyster farming installations increase the sedimentation of fine particles, by creating obstacles to tidal currents, and to a smaller extend to the wind waves, favouring their decantation. In addition, Sornin (1981) has shown that oysters directly contribute to sedimentation by filtering fine sediments and rejecting them in the form of cohesive feces balls. These hypotheses are supported by geochemical measurement, showing higher sedimentation rates within lower mud flats and close to oyster parks (Gouleau et al., 2000). The contribution of oyster farming to the overall sedimentation in the bay is very critical to quantify, among others because tidal bay and lagoons naturally experienced sediment accretion during sea-level high stand periods (Freitas et al., 2002). Nevertheless, the volume of sediment accreted under oyster farms since 1824 has been estimated to 35.10^6 m^3, that approximately constitutes 30% of the sediment accreted in the bay since 1824.

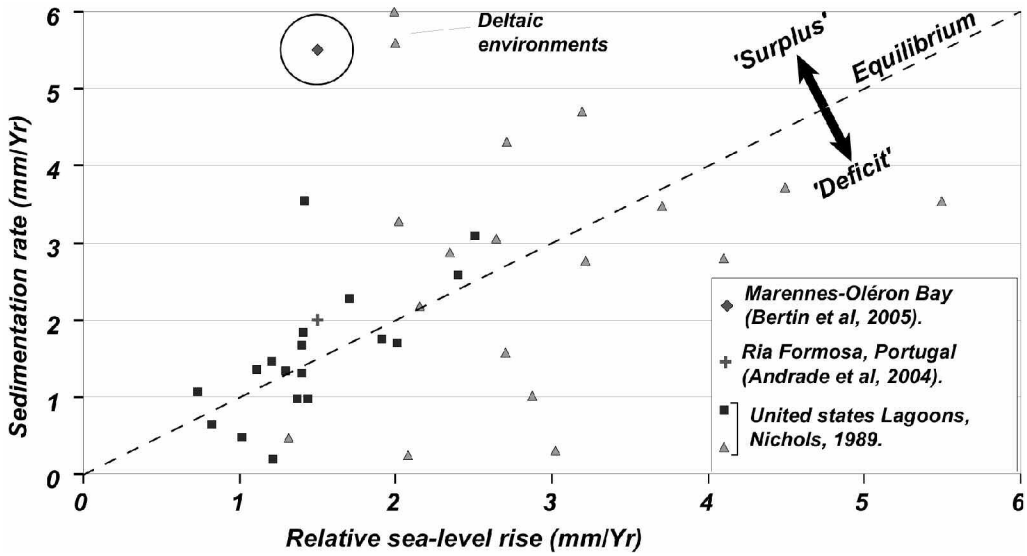

Figure 3. Relative sea-level rise versus sedimentation rates in lagoons and tidal bays, modified after Nichols (1989).

Figure 3. Augmentation relative du niveau de la mer en fonction des taux de sédiment dans les lagunes et les baies soumises à marée, modifié d'après Nichols (1989).

Conclusion

The secular sediment infilling of the Marennes-Oléron Bay has led to a 35% decrease in tidal prism at its southern inlet (Bertin et al, 2005). This has probably significantly altered the water replacement in the bay, which is a key-data regarding aquaculture concerns. Furthermore, Bertin et al (2004 & 2005) have demonstrated that this major tidal prisms change has stroked the inlet morphology, causing its shoaling and downdrift shifting, itself causing severe erosion at the northern adjacent shoreline. Marennes-Oléron Bay constitutes an original semi-enclosed environment, where oyster farming is very developed and is suspected to significantly contribute to the high sediment infilling of the bay, striking the equilibrium of its southern entrance and at a century time-scale menacing aquaculture in the bay if the southern inlet shoals up to the closure.

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