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Temporal stability of a coarse sediment community in the Central Eastern English Channel Paleovalleys

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ABSTRACT

The natural variation of the benthic community of eastern Channel paleovalleys was investigated over a four-year period in the context of an aggregate extraction licence for the French side of the English Channel. Six surveys were conducted: twice a year (mid-April: pre-recruitment and the end of August: post-recruitment) in 2007, 2009 and 2010. The area showed similar features of community structural parameters, to other coarse sediment areas in the eastern English Channel. This area also presented an outstanding constancy over time. The baseline obtained allows the identification of cause-effect relationships between the impact of aggregate dredging and environmental changes and also highlights the consequences of dredging on key ecological attributes. The long-term biological recovery rate will thereby be easier to assess. The use of this baseline is discussed in terms of implications for future management of the study area.

1. Introduction

The management of marine offshore areas in the eastern English Channel implies considering the growth in aggregate extractions sites and of marine renewable energy devices developments (Dauvin and Lozachmeur, 2006; Dauvin, 2012; James et al., 2011). Within this context, it has been strongly recommended to establish baseline surveys for environmental impact assessment as part of a framework of ecosystem based management (ICES, 2005). Compiling baseline data entails monitoring natural variation of the environment prior to impact, to set reference data in order to gather conclusive evidence of potential adverse effects of human activities at sea such that appropriate mitigation measures can be taken (Hardman-Mountford et al., 2005; ICES, 2005). Some authors recognise that baseline studies are currently lacking as so, clearly establish achievement of the restoration status of gravel extraction site in England (Barrio-Froján et al., 2008, 2011; Boyd et al., 2005). However they are currently considered more often in other marine areas as in the recent construction of offshore wind farms in Germany (Köller et al., 2006) and in Belgium (Degraer et al., 2011), for the implementation of tidal energy conversion devices in Scotland (Shields et al., 2009) and with gravel extraction sites in the eastern English Channel (The East Channel Association, 2011; www.siegma.fr).

The eastern English Channel is a shallow sea presenting a large network of paleovalleys, partly filled with coarse sediment, up to several metres in some areas (Dingwall, 1975; Gupta et al., 2007). It represents a great resource for industry and aggregate extraction and it is becoming a marine economic management challenge on the French side of the eastern English Channel. Indeed, marine resources represent only 1% of the national aggregate production in France (Sutton and Boyd, 2009) but the delivery of three exploration licences to aggregate companies for three sites initially called *Charlemagne*, *Saint Nicolas* and *Côte d'Albâtre* in the Eastern English Channel predict a change in the French habits in the next few years (Dauvin and Lozachmeur, 2006; http://wwz.ifremer.fr/drogm/).

Aggregate extraction induces physical disturbance on the seafloor, therefore environmental changes are assessed through benthic communities living in close relationship with the substrate (Dauvin, 1993; Hall, 1994). Organisms forming these benthic communities are commonly used as bio-indicators for the ecological status of marine areas because they respond rapidly to environmental stress (Dauvin, 1993). This particular attribute is essential in environmental monitoring because any irregular variations in their structure make it possible to detect damaging levels of human activities in marine ecosystems. Aggregate extraction impacts on marine ecosystems have been thus described through numerous scientific publications relating to the Eastern English Channel and the North Sea (Barrio-

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Froján et al., 2011; Boyd et al., 2005; Cooper et al., 2007a; Desprez, 2000; Desprez et al., 2010; Newell et al., 1999, 2004). These studies have shown that there is a strong relationship between sediment characteristics, particularly of the relative sand and gravel proportions, and the benthic communities settling there.

Impacts are schematised within two main scenarios, which describe the evolution of the benthic community after the dredging has ceased (Boyd et al., 2005): (i) the substrate changes from sandy gravel to gravelly sand or (ii) the substrate remains unchanged. In the first case, there is a change in the benthic community, from a gravel community to a sand community, generally with lower biomass. Recovery will be quicker in the second case, when the sediment characteristics (e.g., sediment type, topography and hydrodynamics) remain unchanged. However, each site presents unique physical and biological characteristics (i.e., site-specificity), and these characteristics must be studied prior to dredging to anticipate the potential impacts of dredging on the local benthic communities (Barrio-Froján et al., 2008; Boyd et al., 2004; Foden et al., 2009).

A relevant baseline gives description of benthic community structure prior to disturbance. As part of this, it is however important to include temporal replication because there is a wide range of natural fluctuations that affect the benthic community structural parameters (i.e., species composition, abundance, diversity, and biomass) (Gentil and Cabioch, 1997; Glémarec, 1979). In temperate waters, winter seasonal stress causes a pattern in macrobenthic communities, which display a maximum abundance at the end of the summer and early autumn and a minimum abundance at the end of the winter and early spring (Armonies, 2000; Dauvin et al., 2004; Ibanez et al., 1993; Van Hoey et al., 2007). Beyond this seasonal cycle, macrobenthic communities can also show less predictable large variations, which can be due either to physical parameter variability (e.g., severe winters, sediment changes) and/or to biological variability (e.g. strong recruitment) (Cooper et al., 2007; Davoult et al., 1998; Desroy et al., 2007; Gentil et al., 1985; Ghertsos et al., 2000; Ibanez et al., 1993; Maurer et al., 1979; Ropert and Dauvin, 2000). It is thus more difficult to detect the signal of a human-induced disturbance when an ecosystem presents strong "noise" due to its natural seasonal and pluriannual variation.

There are few quantitative studies about natural variability in coarse sediment communities in the eastern English Channel because this type of sediment had been difficult to sample before widespread adoption of the use of the Hamon grab. Coarse sediment is almost by its definition hard and the organisms present are at high dispersion rate (Dauvin, 1979, 1988a, 1988b; Eleftheriou and Holme, 1984). Currently, most of the studies of this type of sediment concern aggregate extraction sites that are already in dredging operation. Thus, before this economic activity in France becomes a major source of disturbance, it is worthwhile to establish baseline records for the benthic communities in the eastern English Channel paleovalleys, especially in their central part for which there are very little quantitative data. In 2007, the company possessing the *Charlemagne* exploration licence carried out a benthic monitoring of the site to compile a reference state on the basis of a biannual sampling survey (pre- and post-recruitment). The site was renamed 'PER Manche Orientale' because it currently has the status of *Permis Exclusif de Recherche* (exclusive permission to research or exploration licence) by a ministerial order of the 26th of January 2006. For an undetermined period, this site is in the administrative investigation stage, pending an authorisation to start aggregate extraction. In collaboration with the *LOG* research laboratory of Wimereux, this period has provided a good opportunity to continue monitoring, using the same sampling protocol in 2009 and 2010 as in 2007 to obtain temporal replication of the 2007's baseline data.

In the present study, we analyse spatial and temporal trends in sediment characteristics and benthic assemblage structure over a four-year period (2007–2010). We aim at identifying the natural variation in the coarse sediment macrofauna communities of Channel paleovalleys thanks to our baseline surveys and thus improve knowledge on the benthos in this marine habitat. In the context of the delivery of an aggregate extraction licence for the French side of the eastern English Channel, we also discuss about the implications of this work for future benthic monitoring on the PER Manche Orientale area.

2. Materials and methods

2.1. Study sites

Designated as PER Manche Orientale, the area lies to the north of the Bay of Seine, in the central eastern English Channel paleovalleys. Spring tide current velocity in the area is about 2.5 to 3 knots (SHOM, 2003). Surface and bottom temperature are similar throughout the year, indicating an absence of thermocline. However, there is high amplitude seasonal variation: temperature varying from about 8 °C in winter to 17 °C in summer (Carpentier et al., 2009).

The area was divided into two smaller zones designated as the 'aggregate extraction area' in Fig. 1, which were delimited according to the quality of mineral resources suitable for industrial extraction (i.e., sand and gravel). The 2007 reference state report showed that there is moderate fishing activity (survey of fishermen), the nearest commercial fishing harbours being at long distance and the commercial species densities being quite low (benthic and pelagic surveys) (GIEGMO, unpublished data). Zone A is approximately 12 NM north-east of Barfleur Point and zone C is 23 NM north-west of Antifer Cape (Fig. 1). Zone B was part of the initial exploration licence which was then abandoned for technical reasons. Also, parts of the site are at their closest 53 NM from Cherbourg, 43 NM from Port-en-Bessin and 60 NM from Le Havre, the three main commercial fishing harbours in the Bay of Seine. Zone A covers 43 km², with a mean depth of 42 m below chart datum, and Zone C is 26 km², with a mean depth of 48 m.

2.2. Sample collection

Six surveys were carried out: twice a year (mid-April: pre-recruitment and at the end of August: post-recruitment) in 2007, 2009 and 2010. All surveys were conducted from the RV *Côtes de la Manche*, except the first survey in June 2007, which was lead from the RV *Côtes d'Aquitaine*. During the baseline study, a total of eleven stations were sampled in the PER Manche Orientale during each survey. In 2007, sampling was conducted to establish a benthic reference state. These preliminary surveys, conducted in June and August, showed that the macrofauna was similar throughout the PER Manche Orientale area, and no sub-communities could be described. This was why we moved the sampling sites within zone A in 2009 and 2010, in order to homogenise the sampling grid in the perspective of conducting long-term benthic monitoring. The final sampling grid for the baseline study corresponded to six sampling stations in zone A and five in zone C for each survey (see table in Fig. 1).

The sampling technique described below, i.e. the choice of the grab, number of replicates and sieving mesh size, follows the IFREMER monitoring protocol for gravel extraction sites (wwz.ifremer.fr/drogm/Ressources-minerales/Materiaux-marins/Protocoles/). Sediment and macrofauna samples were collected with a 0.25 m² Hamon grab, which is considered as effective in coarse sediment (Dauvin, 1979; Eleftheriou and Holme, 1984). This grab was specified in the prefectural order of the 13th of September 2006 granting the exploration licence to the aggregate company. One replicate was used for sediment characterisation and two replicates were used for macrofauna analyses (i.e., 0.5 m²).

A subsample from the sediment grab was analysed for particle size distribution. First, sediment was first wet sieved over a 50 μm mesh. The sieved sediment fraction (<50 μm) was kept still and left to