



Original Articles

What are the most suitable indices to detect the structural and functional changes of benthic community after a local and short-term disturbance?



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ABSTRACT

A one-year experimental study was conducted in 2012–2013 to assess the physical and biological impacts of dumping dredge spoil composed of muddy fine sand (1 million m³) in a benthic zone with medium-grained sands in the eastern part of the Bay of Seine. Previous study showed that the impact is local and the benthic habitats show a high degree of resilience after a short dumping phase and the recovery of the community is observed just after cessation of the disturbance. Moreover, during the deposition phase, Impacted and Influenced zones can be distinguished from a Non-impacted zone. A combination of indices (BO2A, AMBI benthic indices) and modelling tools were applied to study the dumping dredge spoil impact. Results highlighted that these different indices allowed detecting the dumping operations effects. In addition, results from the AMBI et BO2A indices revealed that the system showed a high resilience after a short dumping phase. Lastly, the macrofauna and demersal fishes appear to be stimulated in the Influenced zone during the dumping phase, thus supporting the Intermediate Disturbance Hypothesis.

1. Introduction

The dumping of dredged materials represents one of the most important problems in coastal zone management and leads to major physical, sedimentological and biological disturbances (O'Connor, 1998; Essink, 1999; Marmin, 2013; Marmin et al., 2014). Moreover, many studies had dedicated on the environmental impact of dredging activities on coastal and estuarine environments (De Jonge et al., 2004; Van Raalte, 2006). Consequently, numerous studies have been conducted to investigate the effects of dumping on benthic macrofauna, i.e. resistance and resilience/recovery of benthic habitats subject to the pressure of dredge spoil deposition (Marmin et al., 2014, 2016; De Backer et al., 2014; Bolam et al., 2016).

The dredging of harbour entrances results mainly in a change of sedimentation patterns in deep scour zones due to the increase of vessel size (Marmin et al., 2014, 2016). In the case of harbours with intense international maritime traffic, the volumes of dredged materials sometimes amount to several millions of m³ per year, which are mainly disposed in authorized marine offshore zones such as in the eastern part of the Bay of Seine. In this area, the Kannik deposition zone is used for material dredged from Rouen harbour (4–4.5 million m³ per year) and the Octeville deposition zone for Le Havre harbour (2–2.5 million m³

per year) (Marmin et al., 2014, 2016; Pezy et al., 2017).

Located in the North Channel of the Seine estuary, the Kannik deposition zone has recently become saturated. Therefore, a new site called 'MACHU', located offshore from the estuary, has been authorized by the French State from 28 April 2017 for a period of 10 years and a maximum of 45 million m³ of deposited material. Numerous impact studies have been implemented since the beginning of the search for an alternative site for Kannik in the early 2010s (Marmin, 2013; Marmin et al., 2014, 2016). Among these studies, an experimental dumping operation was carried out in 2012–2013 to assess the impacts of the deposition of dredged sediments on the morpho-sedimentary features of the seabed and benthic communities using a Before-After-Control Impact approach (Marmin, 2013; Marmin et al., 2014, 2016; Pezy et al., 2017).

Pezy et al. (2017) used a combination of modelling tools to investigate the structure and functioning of the MACHU site, before and after the experimental dumping operations. Ecological Network Analysis (ENA) indices (Ulanowicz, 1986) were calculated summarizing ecosystem functional traits, giving indications about the evolution of ecosystem state after experimental dumping operations. Pezy et al. (2017) also reveal a high resilience (amount of disturbance a system can cope with and still remain in the same state, see Holling, 1973;

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Elmqvist et al., 2003) of the benthic habitat after a one-year dumping phase at the MACHU site. The MACHU experimental dumping site can be considered as a textbook case since we have a knowledge of both the exact period of dumping of dredged material and the volume deposited (Marmin et al., 2016).

The MACHU zone is composed of two distinct experimentation, the MASED site to study the sediments and morphology modifications and the MABIO site, to study the biological changes. We study here the short-term temporal changes of the MABIO site, during dumping operations from 2012 to 2013, applying a trophic web modelling tool. The resulting ENA indices (Pezy et al., 2017) are then compared with benthic indices used to identify the Ecological Status of benthic habitats of coastal water masses covered by the Water Framework Directive (Borja et al., 2000; Rombouts et al., 2013a; Van Hoey et al., 2010) or marine zones of the Marine Strategy Framework Directive (Rombouts et al., 2013b). Thus, our study has the following objectives: 1) to determine the short-term changes of benthic indices during the dumping period in three zones of the deposition site, i.e. the Impacted (zone of sediment deposition), Influenced (zone near the sediment deposition zone) and Non-impacted (zone outside the sediment deposition) zones; and 2) to characterize the trophic network properties of the MACHU site during experimental deposition in these three zones through a combination of modelling tools (Ecopath models and ENA indices).

2. Materials and methods

2.1. Study area and available data

The MACHU site is located in the eastern part of the Bay of Seine just off the mouth of the Seine estuary (Fig. 1) in water depths of ~12–20 m (Marmin et al., 2016; Pezy et al., 2017). The MACHU benthic habitat corresponds to a medium-to-fine sand *Ophelia borealis* community, but is influenced in its southern part by mixing between *Ophelia borealis* and *Abra alba-Lagis koreni* communities (Marmin, 2013).

The MACHU site was subject to experimental dumping operations in 2012–2013 along two disposal transects: 1 million m³ of dredge spoil

sediment were deposited between 13 May 2012 and 15 December 2012 on the MASED transect, while 1 million m³ were deposited on a rectangular area ~100 ha (1400 m × 700 m) between 16 April 2012 and 21 February 2013 on the MABIO transect (Fig. 1) (Marmin, 2013; Marmin et al., 2016). The present study covers only the MABIO dumping site, which was more intensely sampled for macrofauna and fish during dumping operations from April 2012 to February 2013. Dumping took place in four phases (or periods), with about 250,000 m³ deposited per season: spring (16 April–14 May 2012: 228,100 m³), summer (1–26 July 2012: 274,500 m³), autumn (10 October–7 November 2012: 226,600 m³) and winter (24 January–21 February 2013: 270,300 m³) amounting to a total of 999,800 m³ (Marmin et al., 2016). At the end of the dumping operations, only 50% of the initial volume of dredge spoil material remained at the deposition site, attaining a maximum height of 2 m in the centre of the deposition zone (Marmin et al., 2016).

Macrofauna was sampled using a 0.1 m² Van Veen grab at seven dates during the overall disturbance period (May, June, July, October and November 2012; January and March 2013), i.e. just after the end of the first deposition phase and just after the end of the annual deposition phase. Three replicates (sieved on a 1-mm mesh size) were recorded at each of the six stations, spaced at regular intervals of 500 m along a transect named AK4. The Non-impacted zone corresponds to stations AK4A and AK4F located at each extremity of the transect, the Impacted zone corresponds to the central stations AK4C and AK4D, and the Influenced zone corresponds to stations AK4B and AK4E (Fig. 1). After sieving, the retained material was fixed with 10% formaldehyde solution, sorted and the species identified at the lower level of taxonomy, then the biomass (Ash Free Dry Weight, AFDW) was determined for each species at each station (Marmin, 2013).

The fish and cephalopods were collected with a bottom otter trawl (with an opening width of 8 m) at night (for optimize the sampling of flatfish which are more active during the night) on seven dates during the overall disturbance period (May, June, July, October and November 2012; January and March 2013). At each of these dates, three hauls were carried out in the Non-impacted zone (R1, R2 and B4), two hauls in the Influenced zone (B2 and B3) and three replicate hauls in the

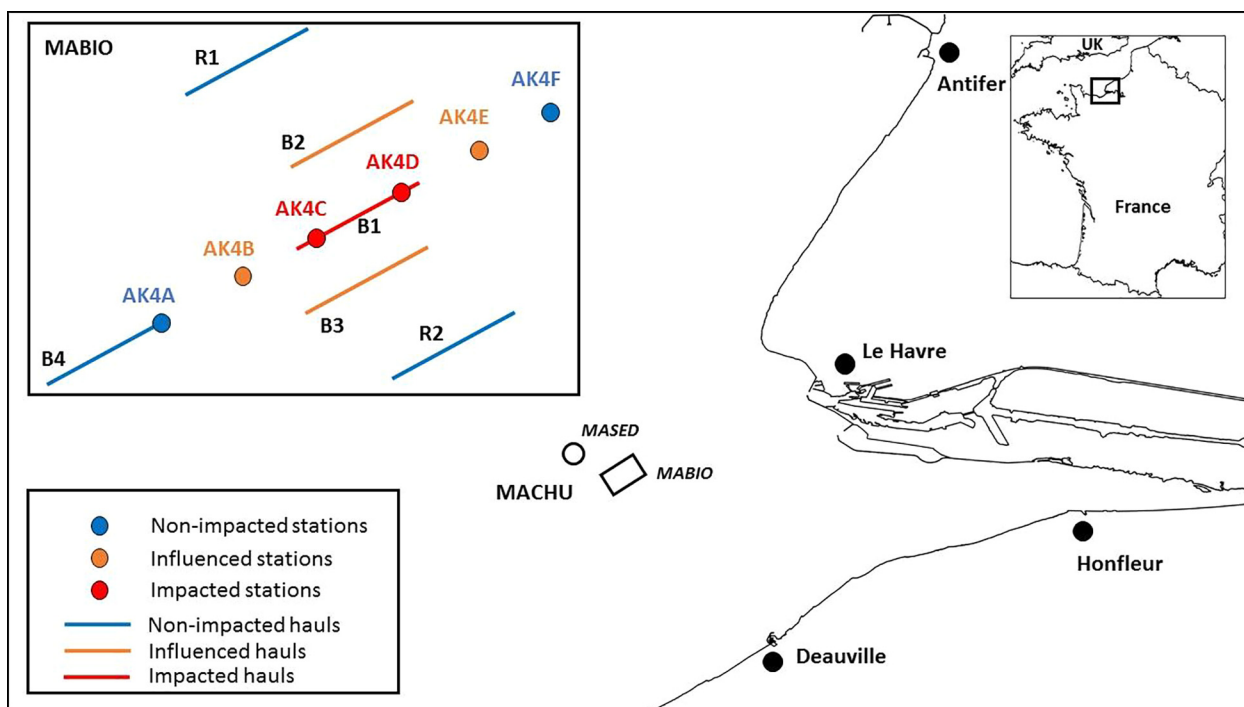


Fig. 1. Location of the MACHU dumping site in the eastern part of the Bay of Seine, with focus on the three sampling zones (Non-impacted, Influenced, and Impacted) of the experimental MABIO site.

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