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Soft-bottom community responses in a marine area influenced by recurrent dumping activities and freshwater discharges

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ABSTRACT

The results of a 3 years monitoring program to assess the effects associated with recurrent dredged spoil disposal activity in a naturally stressed subtidal coastal area subjected to estuarine inputs are described. Changes observed through time in environmental and anthropogenic variables have been analyzed using cumulated sums and compared to macrobenthic community structure. Results revealed a scarce impact of the recurrent dumping activities, with faunal assemblages derived from the main "*Tellina-venus* community". The magnitude of estuarine influence appeared indeed greater on the soft-bottom community than the putative changes due to anthropogenic activities. Through a combination of high energetic conditions, structural changes were observed and ascribed to a flushing action of the highly channeled estuary. Finally, an exceptional flood was recorded over the monitoring period, resulting in a short-term spatial homogenization of the benthic community with an abundance burst of *A. alba*. Origins of this main new species are discussed.

1. Introduction

Assessing variability in biodiversity and identifying factors responsible for spatial patterns are central themes in marine ecology (Blanchet et al., 2014; Dutertre et al., 2013). In estuarine and coastal systems environmental drivers are influenced by both natural processes (e.g. water mass movements, sediment deposition) and anthropogenic activities such as land resource management, urbanization and dredging (Akoumianaki et al., 2013). Following the adoption of European Directives (Water Framework and Marine Strategy), ambitious objectives for the conservation and the restoration of the state of water bodies have been set. As a result, improving our knowledge of natural variability patterns on one hand (Claudet and Fraschetti, 2010; Schückel et al., 2015; Veiga et al., 2017) and human impacts on the other hand has become even more crucial for suitable marine management and conservation (Desroy et al., 2003; Claudet and Fraschetti, 2010; Marmin et al., 2016).

The benthic soft-bottom community is an important component of marine ecological systems since it is involved in nutrients cycling, pollutant metabolism and constitutes a food source for higher trophic levels (Snelgrove, 1998; Constable, 1999). In addition, benthic species are also known for their sensitivity to physical changes because of their relative immobility (Simonini et al., 2005; Taupp and Wetzel, 2013) suggesting that these organisms are good indicators for sediment disturbance (Seiderer and Newell, 1999; Van Hoey et al., 2010).

In coastal systems, sediment discharges due to high riverine inputs influence the soft-bottom organisms (Akoumianaki et al., 2006, 2013; Harris, 2014; Salen-Picard and Arlhac, 2002; Salen-Picard et al., 2003). The spread of turbid plumes plays a significant role in water quality (e.g. high concentrations of nutrients, fines particles) of extensive areas of the shelf adjacent to the river mouths (Chin-Leo and Benner, 1992; Govoni and Grimes, 1992; Lohrenz et al., 1990). Studies in coastal areas with high riverine inputs from major or smaller rivers, mainly suggested that the long-term impact sedimentary processes on benthic community is dependent upon a deposit distance gradients from the river mouth and/or the temporal variability in water and sediment discharge rates (Rhoads et al., 1985; Aller and Aller, 1986; Aller and Stupakoff, 1996; Moodley et al., 1998; Wijsman et al., 1999; Akoumianaki and Nicolaidou, 2007; Harmelin-Vivien et al., 2009). Regarding the occurrence of short-term effects of river inputs on benthic macrofauna, discrepancy is observed between results depending on the sampling design relative to the inshore/offshore gradients (Occhipinti-Ambrogi et al., 2005; Wheatcroft, 2006; Akoumianaki et al., 2013; Bonifácio et al., 2014). As already reported

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by Bonifácio et al. (2014), new studies based on appropriate spatial and temporal sampling design are therefore needed to improve the assessment of the effects of changes in riverine inputs on adjacent benthic macrofauna distribution.

Estuaries and marine coastal areas are also recognized as hotspots of human development and have therefore been under continuous pressures arising from anthropogenic development (Dauvin et al., 2006; Sánchez-Moyano and García-Asencio, 2010). In particular, to support navigation, trade and economic sustainability, both dredging and the dumping of dredged material are common practices around the world and are one of the most serious environmental concerns for coastal management (Bates et al., 2015; Moog et al., 2015; OSPAR, 2008; Van Dolah et al., 1984). The relocation of dredged material is one of the most important concerns in those activities (Harvey et al., 1998; Katsiaras et al., 2015; Tornero and Hanke, 2016), by causing environmental issues in coastal and marine areas, both physically and through contaminants (e.g. Bolam et al., 2006; Bolam and Rees, 2003; Cesar et al., 2014; Fredette and French, 2004). Several author's assessed the impacts of dumping activities in off-shore environments (Smith and Rule, 2001; Zimmerman et al., 2003; Simonini et al., 2005; Ware et al., 2010; Bolam et al., 2011; Bolam, 2012; Taupp and Wetzel, 2013; Cesar et al., 2014; Katsiaras et al., 2015; Marmin et al., 2016; Dauvin et al., 2018). However, numerous studies have highlighted the divergent results obtained and concluded to "site-specific" potential environmental effects of these perturbations pledging for a case-by-case evaluation (Bolam et al., 2006; Bolam and Rees, 2003; Harvey et al., 1998; Katsiaras et al., 2015; Simonini et al., 2005).

In this study, we investigated the relationship between macrobenthos community structure and distribution with abiotic natural and anthropogenic variables in a swell-exposed coastal area receiving freshwater discharges from the Adour River (Basque country, South-West France) and subjected to recurrent dumping activities. The aim of this study was to assess the level of impact of recurrent dumping activities carried out for decades in this coastal area subjected to freshwater discharges from a mountain-range river system with short water residence time. To our knowledge, the effects of recurrent dumping on the marine benthic community have not been widely studied (Bolam et al., 2011; Donázar-Aramendía et al., 2018) and the addition of natural drivers as freshwater discharges on this heavy stressed soft-bottom macrofauna has been studied even less (Naeem et al., 2012; Villnäs et al., 2013).

2. Material and methods

2.1. Study area and dumping activities

The study area is situated 3 km offshore in an open water area in front of the river mouth of the Adour estuary located on the French Basque coast (south west of France, Fig. 1).

Because of its location in the inner part of the Bay of Biscay and the small width of the continental shelf the French Basque coast is exposed to very energetic wave conditions. Waves predominantly come from the West-North West direction with a 10 s peak period and an average 2-m significant wave height (Augris et al., 2009). These wave climates together with estuarine inputs contribute to making the coastal opening of the Adour estuary a naturally stressed area.

The Adour River drains a watershed area of 16,800 km^2, which is a small extent compared with the three main French macrotidal estuaries Gironde, Loire and Seine (Etcheber et al., 2007). This estuary has been heavily modified and channeled over the last four centuries. It currently displays a narrow channel of 200 m width as its mouth (Stoichev et al., 2004). These transformations generate a strong current which drives a large amount of estuarine sedimentary inputs to the ocean (Maneux et al., 1999). Residence time for water and sediment is therefore very short suggesting a dominant transfer to the coastal area during the mean to the high flows (Monperrus et al., 2005; Petus, 2009). The mean annual river discharge is about 300 $m^3 \cdot s^{-1}$ (Stoichev et al., 2004). Flood periods observed occur mainly during the fall and winter, but sudden events can occur during spring (Dailloux, 2008). On average, three flood events above 1000 $m^3 \cdot s^{-1}$ annually occur: two during winter (in November/December and January/February) and one during spring, around April or May (Brière, 2005). Sediments transported through the estuary plumes have been recorded around 15 km off the mouth of the Adour as a large deposit of lenticular muds located at a depth of > 100 m-depth (Jouanneau et al., 2008). Fine deposited sediments are indeed generally resuspended by waves which prevents the formation of a permanent deposit (Jouanneau et al., 2008). The behavior of the plume is variable and depends on hydroclimatic forcings (i.e. freshwater discharge, wind and tide) characterized by a strong spatial and temporal variability (Petus, 2009).

The Adour estuary provides access to Bayonne harbor. In order to guarantee a minimum navigation depth, the local authority (Chambre de Commerce et d'Industrie de Bayonne Pays Basque (CCI BPB)) performs maintenance dredgings. For several decades, fine to medium sands with a variable mud content were hence extracted along the estuary and its mouth and dumped in three disposal areas. This study focused on the marine disposal site which has been constantly used for the past 30 years. Located in front of the Adour river mouth, this dumping area has a rectangular shape with a surface of 200 ha, located between −20 m and −35 m in depths (Fig. 1). For several decades and until the present study, these works were done without an empirical assessment of the effects on the soft-bottom communities neither at the dredging sites nor at the sites receiving the dredged materials.

2.2. Sampling design and laboratory analyses

To assess dumping impact on the benthic soft-bottom communities, 6 sampling stations have been defined and seasonally investigated during 3 years, for a total of 12 sampling campaigns (called "C1" to "C12") between August 2014 and June 2017. The location of stations was chosen based on the bathymetry (directly impacted stations and the western control station located at −31 ± 1.2 m chart datum in average and both, indirectly impacted stations and the eastern control, at −21 ± 1.7 m chart datum in average), the dumping activities details and knowledge stem from dispersion plumes models (CASAGEC INGENIERIE, 2014). Two stations were placed in a directly impacted zone ("DIR") within the western most used part of the disposal area, divided into 8 boxes (Fig. 1). Another pair was located inside the dumped area, within the eastern part which has never been used since 2004 but could be affected by the turbid plumes due to dumping activities (indirectly impacted zone "IND"). The last two stations were situated in a control area outside the dumping area and its turbid plumes (reference stations "REF") at −22 and −30 m chart datum. The reference stations are slightly northern to the river mouth compared to those of the disposal area, located in the axis of the river. Nonetheless, all monitored stations were exposed to the influence of the Adour inputs according to the estuarine plume dynamic reported by Dailloux (2008).

During each sampling campaign, three replicates of sediment samples were collected in each station using a Van Veen grab (0.1 m^2). Grab contents were sieved through a 1 mm mesh size. Material retained on the sieve was directly fixed in ethanol (99.9%) for later identification to the lowest taxonomic level (predominantly species) and counted in the laboratory. The World Register of Marine Species (WORMS, 2017) was used to check and harmonize species names. For the sediment analysis, a very small sub-sample (around 0.3 L) of each collected grab was used for the determination of both organic matter content and grain size analyses.

Both stations located in the reference area (i.e. A15 and A20 in "REF") have not been sampled during the second and the third seasonal field campaigns (December 2014 and March 2015). For the C6 campaign (December 2015), no sediment data was also available (analytical issue at the laboratory).

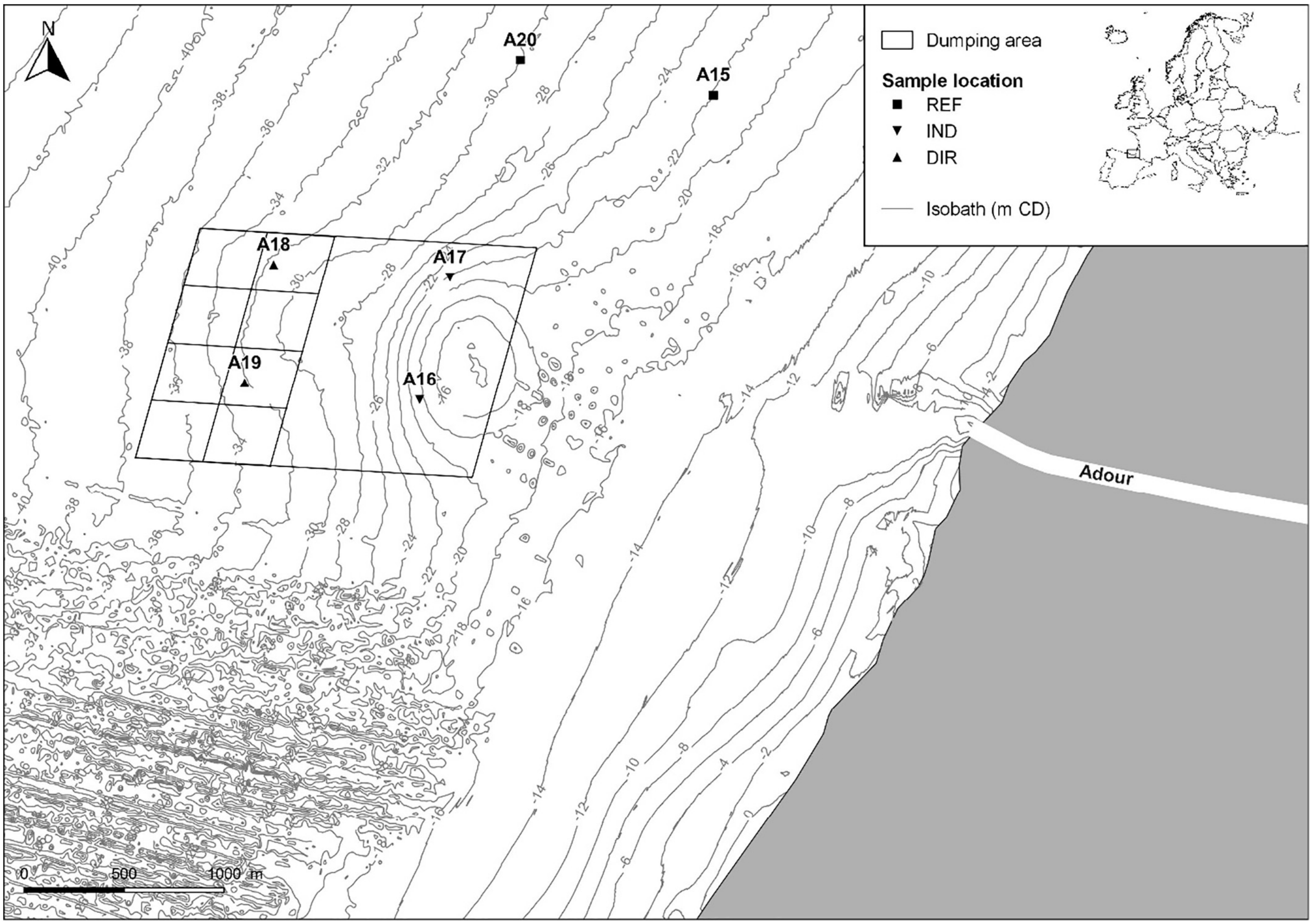

Fig. 1. Geographical location of the sampling station. The different impact levels ("IND" indirect impact, "DIR" direct impact and "REF" reference) were indicated by the same label on the map. The dumping area divides into disposal boxes was represented. Isobath values are indicated in meters.

2.3. Natural abiotic variables

2.3.1. Hydrodynamic conditions

2.3.1.1. Wave climate. Wave climate was determined for each station and between each field campaign from a SWAN operational model developed within the European project Littoral, Ocean and Rivers of Euskadi-Aquitaine (LOREA). Detailed model setup and validation results are further described in Dugor et al. (2010). The model boundaries are forced by HOMERE sea-states hindcast database, based on WAVEWATCH III model. Wind data are provided by the ECMWF (European Center for Medium-Range Weather Forecasts). A nesting strategy allows making the transition between offshore and coastal models over 3 successional grids: a regional grid, an intermediate grid and finally a local grid with a 20 m resolution. Four wave parameters were obtained in order to describe wave climate: mean significant wave height (Hs_{mean}), maximum significant wave height (Hs_{max}), mean bottom orbital velocity (Ubr_{mean}) and maximum bottom orbital velocity (Ubr_{max}). The wave climate characterization was carried out for the period preceding each sampling campaign. Daily values were also obtained throughout the study period (April 2014 to July 2017).

The three-dimensional ECOMARS model (Lasure and Dumas, 2008; Tolman, 2002), as performed by Dutertre et al. (2013) at a larger scale, was not used in this study. Resolution grid (3 km) was not adapted to represent hydrological variations within the sampled site, where directly and indirectly impacted stations were spaced from 900 m within the dumping area and from 1,6 km with the reference stations.

2.3.1.2. Estuarine inputs. To take into account estuarine influence, mean and maximal river discharges (Q_{mean}, Q_{max}) were retrieved between each field campaign from the French water information system database (http://www.hydro.eaufrance.fr/). Mean daily values were also extracted throughout the study period (April 2014 to July 2017).

2.3.2. Sediment characterization

At each station, a sub-sample of each collected grab was used for sediment characterization. Data were treated as percentages for each grain size categories determined using a sieve shaker. The following sedimentary fractions were considered based on the classification of Wentworth (1922) modified by Folk (1954), Folk and Ward (1957) and Folk (1966): Gravel and pebble (Gr > 2 mm), very coarse sand (VCS: 1–2 mm), coarse sand (CS: 0.5–1 mm), medium sand (MS: 0.25–0.5 mm), fine sand (FS: 0.125–0.25 mm), very fine sand (VFS: 0.063–0.125 mm) and silt & clay (F < 0.063 mm). The diameter corresponding to the median grain size of sediment particles (D50) and the sorting index (So; Trask, 1930) were calculated using a MATLAB routine for each station and each field campaign. D50 was expressed in the phi (φ) scale originally developed by Krumbein (1934) in order to simplify statistical analyses. Organic matter content was estimated by loss of ignition (450 °C, 6H) and was also treated as percentage of sediments weight.

2.4. Dumping pressure variables

Based on measures of dredging pressure defined by De Backer et al. (2014a) and in order to characterize the dumping pressure at the different stations, three variables were defined and individually calculated for each sampled station at each field campaign: (i) the interval time (in days) "T" between the last time dumping and each different biosedimentary sampling periods; (ii) the number of effective dumping days "D" prior to each sampling campaign; (iii) the volume "V" of materials dumped (in m^3) on each monitoring stations between each field campaign. For the volume "V", daily values were also available throughout the study period (April 2014 to July 2017).

These disposal parameters have been calculated using an operational database provided by the local authority performing maintenance dredgings. This database contained details of the dumping volume per day and per disposal box To calculate dredging pressure at the biological sampling location, the dumping activities in the upper 4 boxes were considered affecting the station "A18" and the lower 4 boxes the station "A19". To integrate the turbid plume influence within the indirectly impacted area, 10% of the effective dumped volumes within the directly impacted area were considered. This percentage was consistent with knowledge stem from Boutin (2000) and the hypothesis used for numerical model (CASAGEC INGENIERIE, 2014).

2.5. Data analysis

2.5.1. Abiotic variables times series during the monitoring period

In order to describe general tendencies and to detect shifts through time, the series of natural and anthropogenic abiotic variables were analyzed using cumulative sums for each sampled station within each location (i.e. IND, DIR and REF) over the study period. This method consists in the cumulative sum of standardized deviations from a target specification, calculated as a running sum of data normalized to the dataset mean and standard deviation (Regier et al., 2019).

To complete this descriptive method, natural abiotic variables (seven fractions from silt and clay to gravels & pebbles, mean grain size, sorting index and organic matter content) were then tested on Euclidean distances using a permutational univariate analysis of the variance (PERMANOVA) to check for spatial between locations and temporal differences (Anderson, 2001a). This routine was chosen for univariate analyses because resulting sums of squares and F-ratios are exactly the same as Fisher's univariate F-statistic in traditional ANOVA and does not assume a normal distribution of errors (Anderson, 2005, 2001b; Donázar-Aramendía et al., 2018). PERMANOVA was performed with two crossed fixed factors: 'campaign' with twelve levels (C1 to C12) and 'location' with three impact levels (Reference "REF", Indirectly impacted "IND" and Directly impacted "DIR"). *P*-values were provided using unrestricted (9999) permutations (Anderson et al., 2008). When the number of possible permutations was restricted (< 100), *p*-values were drawn from Monte Carlo (MC) permutations, (Anderson and Robinson, 2003).

2.5.2. Macrobenthic community structure and their relationships with abiotic variables

The data set consisted in a matrix with 68 rows and 165 columns. Statistical analyses described below were therefore essentially based on descriptive methods.

The structure of the macrobenthic community was investigated using a Principal Coordinate Analysis (PCO; Anderson et al., 2008) based on the Bray-Curtis similarity index of fourth-root transformed abundance data (Clarke and Warwick, 2001). The abundance data used were the sum of the three replicates sampled at each station. This multivariate technique provided an overview of the structure and composition of the faunal community through time (12 seasonal field campaigns) for the different locations (i.e. IND, DIR and REF). SIMPER analysis was used to identify the species contributing most to any observed spatial or temporal pattern in the communities (Clarke, 1993). Each location was then characterized by its species richness (S), density of individuals (N), Shannon's diversity (H′) and Pielou's evenness index (J′). In addition, typical estuarine species were tracked in order to identify possible surviving estuarine species dumped in the area together with sediments. Typical estuarine species were defined as taxa regularly observed among French Atlantic estuaries (Blanchet et al., 2014).

The predefined PERMANOVA design was used to test for significant differences on the multivariate structure of the communities and on the biological univariate measures.

Relationships between the multivariate data cloud and environmental variables (grain size fractions, mean grain size, sorting index, organic matter content, wave climate, estuarine inputs and dumping pressure variables per station) were investigated through DISTLM analysis using BEST selection and AICc criterion, and visualized by a dbRDA plot. Before running the DISTLM analysis, collinearity among environmental variables was examined using Spearman rank correlation coefficients. If a linear dependency between variables was identified ($r \geq 0.9$, disregarding the sign of the coefficient) only one of the variables was retained in the analysis.

All previously described analyses were firstly performed on the whole dataset (sampling campaigns C1 to C12). When a temporal pattern due to natural disturbance was observed, a subset of data excluding this particular condition was defined and analyzed in more detail using the same routines as described above to focus on spatial and temporal differences in the community structure and their putitative relation to the dumping activities.

All analyses described here were carried out using the software package PRIMER v6 (Clarke and Gorley, 2006) with PERMANOVA add on software (Anderson et al., 2008).

3. Results

3.1. Abiotic variables dynamics during the monitoring period

3.1.1. Hydrodynamic conditions

The daily wave climate and Adour discharges are presented for the three monitored years in Fig. 2. The four wave parameters were similar for the whole studied area. Significant wave height values (Hs) ranged between summer minima around 0.2 m and reached winter maxima at 5.2 m. This seasonal dynamic was quite similar over years. Nonetheless, the second part of the monitored period (years 2016 and 2017) showed a stronger wave climate (Fig. 2a) (PERMANOVA, p-val < 0.05).

Regarding the Adour estuary water flow, low-water levels were generally observed between July and October with an average flow of about 120 $m^3 \cdot s^{-1}$, whereas in winter, between November and February, the mean monthly flow was 405 $m^3 \cdot s^{-1}$. The first part of the monitored period was clearly distinguished by the frequency and intensity of floods. More specifically the year 2014 was also characterized by a winter vicennial flood in January (25/01/2014: Q = 3287 $m^3 \cdot s^{-1}$, not shown on the Fig. 2b) followed by an exceptional flood in July (04/07/2014: Q = 1430 $m^3 \cdot s^{-1}$) at the beginning of the summer. During a low-water period this summer flood event constituted an exceptional phenomenon never again observed over the study period (Fig. 2b). The PERMANOVA results for wave climate and flow rate parameters indicated these temporal differences (p-val < 0.05) among sampling campaigns.

In further analyses of macrobenthic community and abiotic variables relationships, a subset of the data from C2 (Dec. 2014) to C12 (June 2017) excluding the exceptional summer flood event from C1 (Aug. 2014) has been analyzed in more detail to investigate for spatial and temporal differences in the macrobenthic communities and their putative relation with the dumping activities.

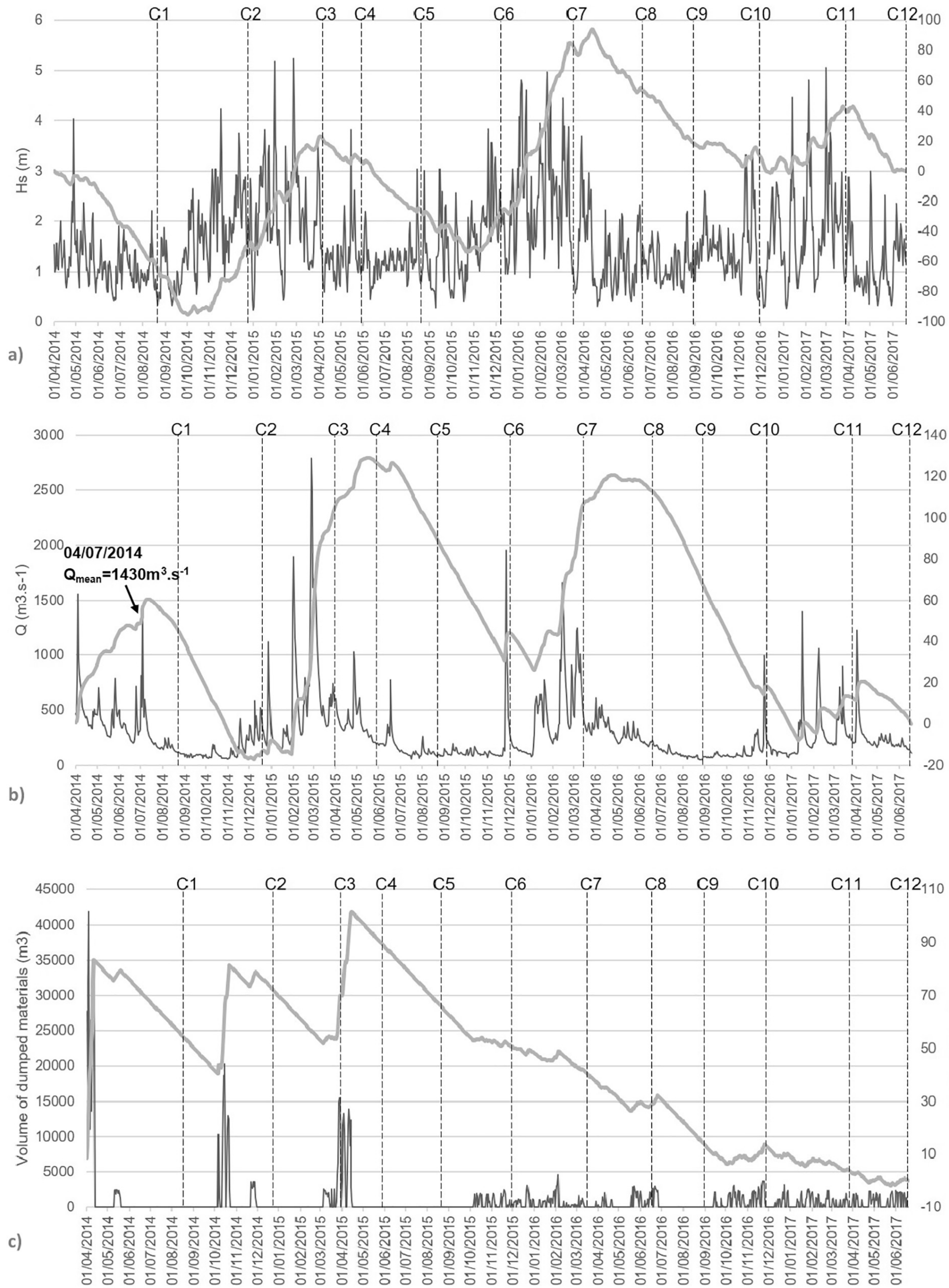

Fig. 2. Time series for abiotic variables (April 2014–July 2017): a) significant wave height (Hs), b) mean daily river discharge (Q) and c) volume of dumped materials on the directly impacted area. The light grey curves represent cumulated sums where increasing values correspond to period of higher-than-average values and decreasing values correspond to lower-than-average values. Labels "C1" to "C12" indicate the seasonal time points of sampling.

3.1.2. Sediment features

Throughout the monitoring period, sediment features were influenced by location. The PERMANOVA results showed significant spatial differences (p-val < 0.05) for most of the sediment parameters except gravel content and sorting index. Pairwise comparisons between impact groups revealed that the sediment composition of reference stations was significantly finer than those located within the dumping area. Sand with a low organic content were sampled over the disposal site (Fig. S1 in supplementary material). The western part (i.e. directly impacted location) generally displayed a coarser grain size than the eastern part (i.e. indirectly impacted location) due to a higher proportion of medium sand relative to fine sands (48% medium sands in average in "DIR" and 31% in average in "IND", see Fig. S1 in supplementary material).

Regarding variation during the survey, grain size remained similar through time except during the first field campaign C1 (Aug. 2014) following the summer flood event. Silt and clay, coarse sand and sorting index were significantly influenced by the temporal factor "Campaign" (resp. p-val = 0.0003, p-val = 0.0002 and p-val = 0.005). Pairwise comparisons between campaigns revealed significant differences between the first sampling campaign C1 (Aug. 2014) and most of the remaining campaigns (p-val < 0.05). Sediments during this campaign were significantly finer with a higher sorting index. Indeed silt and clay peaked 65% (± 3), 19% (± 16) and 15% (± 10) respectively within the REF, IND and DIR locations in August 2014 (C1). During the eleven remaining campaign these fines proportion reached respectively in average 12% (± 4), 1% (± 1) and 6% (± 7) for these 3 areas.

3.1.3. Dumping pressure

In term of dumping pressure, disposal activities changed over the monitoring period (Fig. 2c). Until September 2015 (between field campaigns C5-August 2015 and C6-December 2015), huge volumes of dredged materials were dumped by way of two massive operations executed during spring and fall. Mean volumes monthly dumped within the directly impacted zone ("DIR") were around 110,000 m^3.

Throughout the second part of the monitoring period, an important decrease of the dumped sediment volumes was observed but associated to an increase of dumping frequency. Small volumes (around 20,500 m^3 in average) have been monthly disposed within the directly impacted zone ("DIR"), excepted during summer (July and August).

3.2. Macrobenthic community structure and their relationships with abiotic variables

3.2.1. Features and variations of the macrobenthic community structure

A total of 165 species were found in the study area throughout the overall monitoring program (August 2014–June 2017). In terms of abundance, polychaetes, arthropods, echinoderms and molluscs ranked among the most common phyla. We did not find any dominant clade except for some increments of a particular species in all stations: In August 2014 (C1) a huge increase of bivalves abundance was observed due to *Abra alba* (total abundance of 2376 ind./m^2). Beside this first sampling campaign (C1), species with the maximum total abundance over time and locations were the echinoid *Echinocardium cordatum* (22 ind./m^2), the polychaetes *Owenia fusiformis* (15 ind./m^2), *Nephtys cirrosa* (14 ind./m^2), *Magelona mirabilis* (12 ind./m^2) and the malacostraca *Diastylis bradyi* (15 ind./m^2) and *Diogenes pugilator* (11 ind./m^2). The first two axes of the PCO Analysis together explained 33% of the variation of the data cloud (Fig. 3). This rather low percentage of explanation on the first two axes suggests that the overall variations within the data is not very high considering the reasonable size of the data (165 species × 68 stations). A low level of information extracted by the axes of a factorial analysis is either due to the high complexity of data (in our case many species × many stations) and/or to weak pattern within the data.

Two-way PERMANOVA (Table 1) indicated a significant interaction of Campaign × Location (p-val = 0.0083) during the monitoring period. These results indicated a different temporal pattern of change between, on the one hand the control area, and, on the other hand the disposal areas during the sampling campaigns. This was evidenced by the PCO-plot where the points corresponding to control area (REF) were located on the positive part of the first PCO axis disregarding sampling campaigns (Fig. 3). In contrast, points corresponding to both directly and indirectly impacted locations (DIR, and IND, Fig. 3) were mostly located on the negative part of the PCO-axis 1 except during the first sampling campaign (C1-August 2014). This showed that the composition of benthic communities did not follow the same pattern through time between, on the one hand, the control locations and, on the other hand the directly and indirectly impacted locations (Fig. 3, Table 1). When the first campaign was excluded from the analysis, the Campaign × Location interaction was no longer significant (Table 1). This means that the difference of temporal pattern of variation among the locations during the monitoring only differed due to the events leading to the situation of the sampling campaign C1 (August 2014). During this campaign (C1-August 2014) the benthic community appeared quite similar throughout the three locations. The SIMPER analysis results showed that the benthic communities were indeed characterized at C1 (August 2014) by the presence of *Abra alba* at all sampling locations with high abundance (713 ± 979 ind./0.3 m^2). In addition, the benthic communities during this C1 campaign (August 2014) were also characterized, though with lower respective contribution to dissimilarity among campaigns (SIMPER), by other phyla of muddy sands to sandy muds such as the polychaetes *Owenia fusiformis* (53 ± 52 ind./0.3 m^2) and *Lagis koreni* (4 ± 3 ind./0.3 m^2), the sea urchin *Echinocardium cordatum* (46 ± 39 ind./0.3 m^2), the brittle star *Ophiura ophiura* (8 ± 5 ind./0.3 m^2) and the amphipod *Ampelisca spinimana* (3 ± 2 ind./0.3 m^2). Finally, the community showed significantly higher density and species richness with lower evenness due to the dominance of *A. alba* (PERMANOVA on univariate community descriptors, Table 2 and Figs. S2 to S5 in supplementary material). From the second campaign (C2-December 2014), < 4 months later, the impacted stations plotted along the negative part of PCO axis 1 (Fig. 3). Density of *Abra alba* decreased drastically to an average density of 2 ± 5 ind./0.3 m^2 during the eleven remaining campaigns within the control area and even less within the disposal site.

Except during the first sampling campaign, there was a significant difference of benthic community composition among locations (PERMANOVA, significant Location effect, Table 1) which was mainly due to difference between on the one hand the control location, and, on the other hand, the directly and indirectly impacted location. This is illustrated by the difference in point coordinates along the first axis of the PCO between on the one hand, the stations from the control locations (REF, Fig. 3), and on the other hand, the directly and indirectly impacted stations (DIR and IND, Fig. 3). SIMPER analysis on the reduced subset excluding the first sampling campaign (C1-August 2014) showed the locations in impacted groups (DIR and IND) displayed few dominant species (i.e. 3 species contributing to 50% of the overall abundance). All species are characteristic for sandy bottoms (Table 3). Sharing three of the most contributive species of the impacted groups, the control group (REF) was related to slightly finer grain size. Among the sampled species within the dumping area, some typical estuarine invertebrates were recorded. Exclusively within the station A18 located at the northern part of the directly impacted location, the bivalve *Scrobicularia plana* and the polychaetes *Alkmaria romijni*, *Heteromastus filiformis* and *Streblospio shrubsolii* have occasionally been found in variable densities consisting in 3% to 23% of the total abundance (Fig. 4). Species richness and density were generally higher within the control area (REF) compared to dumping-impacted stations (IND, DIR) (PERMANOVA on univariate community descriptors, Table 2) with 26 ± 4 species per station and 103 ± 45 individuals.0.3-m^{-2} vs, on average, < 15 species per station and density level lower than 50 individuals.0.3-m^{-2} for potentially impacted stations (Table 3).

At the scale of each location, variations of benthic communities

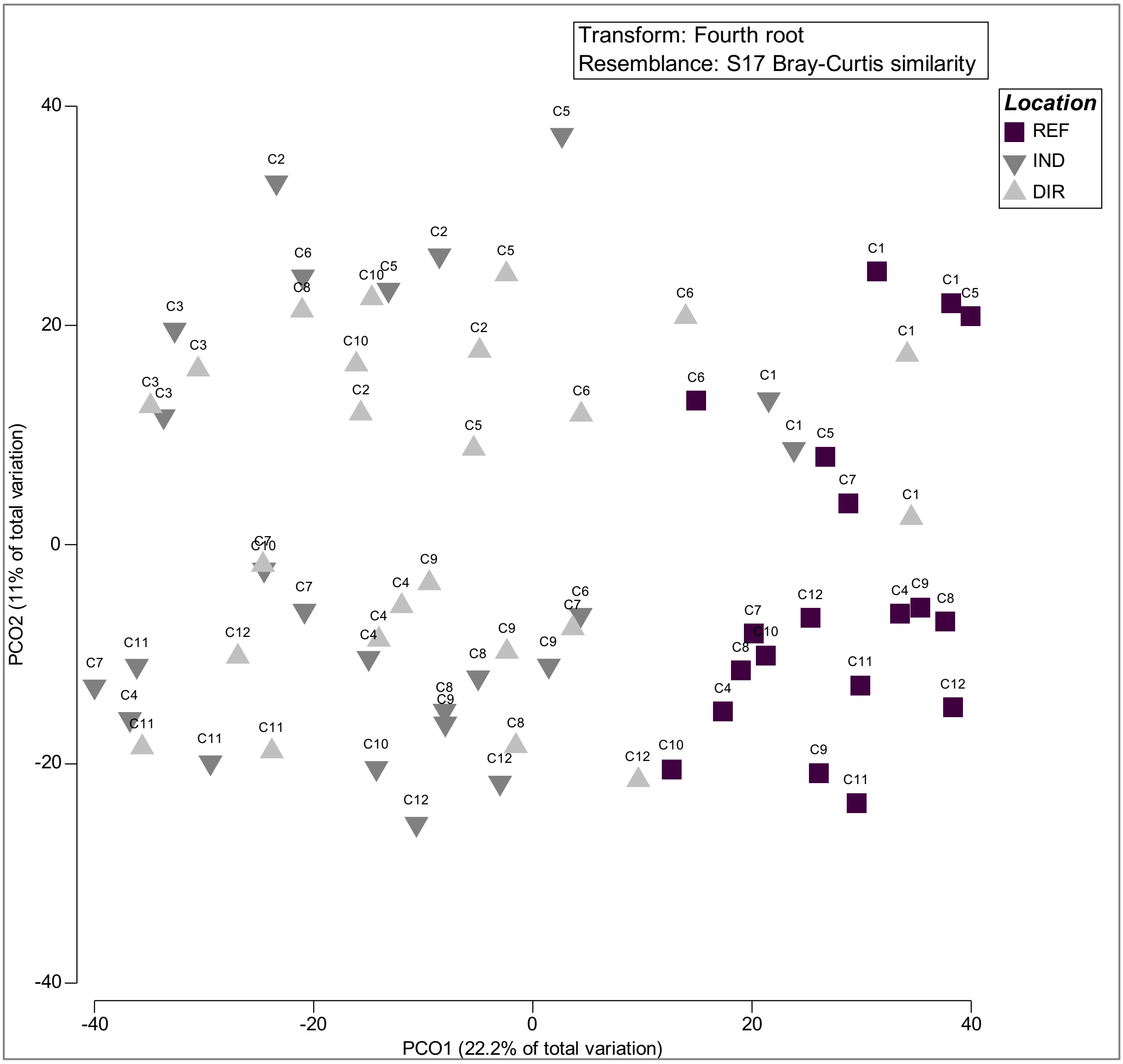

Fig. 3. PCO plot of stations at each time point from August 2014 ("C1") to June 2016 ("C12") regarding the different impact levels (IND indirect impact, DIR direct impact and REF reference). Labels indicate the seasonal time points of sampling. The analysis was based on Bray-Curtis similarity calculated from fourth-root transformed abundance values.

composition occurred during the survey (PERMANOVA, significant Campaign effect, Table 1), even when excluding the first sampling campaign. These temporal patterns of community were observed more closely for each location by plotting the coordinate of each time-point over the two first principal coordinates (PCO1 and PCO2, respectively Figs. S6 and S7 in supplementary material). For each location (i.e.: IND, DIR or REF), both stations generally followed the same pattern, suggesting that the observed variability affected the whole location and not only an individual station. Within control location (REF), community appeared mostly unchanged, restricted to the positive part of the PCO1 axis throughout the whole survey. Variability along the PCO1 axis was higher within the disposal area. Within both impacted locations ("DIR" and "IND"), similar patterns were observed for the C1 (August 2014) to C4 (June 2015) and C9 (August 2016) to C12 (June 2017) disregarding differences in dumping modalities, suggesting a seasonal pattern. At the scale of the whole study area, comparison of the general tendencies (i.e.

Table 1
Multivariate PERMANOVA of the Bray-Curtis similarity matrix based on fourth-root-transformed data for the whole dataset (C1 to C12) and the subset (C2–12).

Whole dataset: C1-C12	df	MS	Pseudo-F	P (perm)	Unique perms
Campaign	**11**	**5218.6**	**3.6988**	**0.0001**	9801
Location	**2**	**12,321**	**8.7331**	**0.0001**	9890
Campaign × location	**20**	**1778.8**	**1.2608**	**0.0179**	9745
Res	34	1410.9			
Total	67				

Subset: C2-C12	df	MS	Pseudo-F	P (perm)	Unique perms
Campaign	**10**	**4488.9**	**3.0732**	**0.0001**	9809
Location	**2**	**13,565**	**9.2871**	**0.0001**	9890
Campaign × location	18	1659.1	1.1358	0.1335	9753
Res	31	1460.7			
Total	61				

Table 2
: Univariate PERMANOVA results for the whole dataset (C1 to C12) and the subset (C2–12) based on Euclidean distance matrix of richness data (S), total abundance (N, ind./0.3 m^2), Shannon's diversity (H′) and Pielou's evenness (J′).

Whole dataset: C1-C12						Subset: C2-C12					
	df	MS	Pseudo-F	P (perm)	Unique perms		df	MS	Pseudo-F	P (perm)	Unique perms
N						N					
Campaign	**11**	**3.8398**	**19.363**	**0.0001**	9941	**Campaign**	**10**	**0.67696**	**4.9057**	**0.0003**	9944
Location	**2**	**4.5171**	**22.778**	**0.0001**	9950	**Location**	**2**	**4.5932**	**33.285**	**0.0001**	9949
Campaign × location	20	0.26526	1.3376	0.2109	9927	Campaign × location	18	0.20089	1.4558	0.1789	9922
Res	34	0.19831				Res	31	0.13799			
Total	67					Total	61				
S						S					
Campaign	**11**	**0.50315**	**8.1547**	**0.0001**	9933	**Campaign**	**10**	**0.36895**	**5.7493**	**0.0001**	9942
Location	**2**	**2.2196**	**35.973**	**0.0001**	9951	**Location**	**2**	**2.4271**	**37.821**	**0.0001**	9952
Campaign × location	20	0.087379	1.4162	0.1904	9927	Campaign × location	18	0.073044	1.1382	0.3673	9929
Res	34	0.061701				Res	31	0.064173			
Total	67					Total	61				
H′						H′					
Campaign	**11**	**0.89503**	**6.645**	**0.0001**	9929	**Campaign**	**10**	**0.40031**	**3.3708**	**0.004**	9960
Location	**2**	**1.1759**	**8.7303**	**0.0005**	9962	**Location**	**2**	**1.4985**	**12.618**	**0.0003**	9952
Campaign × location	20	0.20801	1.5443	0.1222	9922	Campaign × location	18	0.11448	0.96393	0.5174	9921
Res	34	0.13469				Res	31	0.11876			
Total	67					Total	61				
J′						J′					
Campaign	**11**	**0.11668**	**8.5723**	**0.0004**	9922	Campaign	10	0.019208	1.6378	0.1294	9948
Location	2	0.0020872	0.15335	0.8671	9947	Location	2	0.0068015	0.57994	0.5833	9951
Campaign × location	20	0.016728	1.229	0.2583	9904	Campaign × location	18	0.011336	0.9666	0.498	9923
Res	34	0.013611				Res	31	0.011728			
Total	67					Total	61				

increase or decrease of time points position along the axis PCO1) showed similarity within the three locations (Fig. S6 in supplementary material), as confirmed by the non-significant interaction of Campaign × Location on the reduced subset excluding the first sampling campaign (C1-August 2014, Table 1). Distinctions appeared between control area ("REF") and disposal site ("DIR" and "IND") during the lowest (weak river discharge and wave: C4-C5 and C8-C9, see Fig. 2) and the strongest hydrodynamic conditions (C6-C7 and C10-C11). The dumping area community appeared on the median part of the PCO1 axis through low energetic conditions and on the negative part during high energetic conditions. Over these time periods, dredged materials were regularly dumped in small volumes.

3.2.2. Relationships between macrobenthic community structure and abiotic variables

The medium sand (0.25–0.5 mm) content, the median grain size, the number of effective dumping days prior to each biological sampling and the bottom orbital velocities (mean and maximal) were excluded from the analysis because of collinearity. The combination of predicting variables that best explained the variation (21.6%, DISTLM/BEST) in

Table 3
: Characterization of the first field campaign C1 (August 2014) and the a priori defined groups by species contributing to the 'within group' similarity based on SIMPER analysis of fourth-root-transformed species abundance data. Also number of samples, average species richness (S), average density (N), average Pielou's evenness (H) and average mean grain size ± SD for each group are represented.

Location	C1 – August 2014 (Average sim. = 52%)	REF (Average sim. = 42%)	DIR (Average sim. = 33%)	IND (Average sim. = 37%)
Typifying species contributing to average Bray-Curtis similarity (SIMPER cut-off at 70%)	*Abra alba* (16%) *Owenia fusiformis* (9%) *Echinocardium cordatum* (8%) *Ophiura ophiura* (7%) *Ampelisca spinimana* (5%) *Nephtys* sp. (5%) *Lagis koreni* (5%) *Tritia reticulata* (4%) *Processa* sp. (3%) *Diastylis* sp. (3%) *Mactra stultorum* (3%) *Glycera alba* (3%)	*Magelona mirabilis* (10%) *Echinocardium cordatum* (8%) *Fabulina fabula* (7%) *Ampelisca brevicornis* (7%) *Diastylis bradyi* (6%) *Euspira nitida* (5%) *Tritia reticulata* (4%) *Glycera alba* (4%) *Mactra stultorum* (4%) *Nephtys hombergii* (3%) *Abra alba* (3%) *Owenia fusiformis* (3%) *Tellimya ferruginosa* (3%) *Ophiura ophiura* (3%)	*Nephtys cirrosa* (26%) *Magelona mirabilis* (14%) *Diogenes pugilator* (14%) *Echinocardium cordatum* (10%) *Diastylis bradyi* (6%)	*Nephtys cirrosa* (26%) *Diogenes pugilator* (17%) *Diastylis bradyi* (10%) *Gastrosaccus sanctus* (8%) *Echinocardium cordatum* (7%) *Tritia reticulata* (7%)
Average N (ind/0.3 m^2) ± SD	883 ± 929	103 ± 45	41 ± 16	37 ± 13
Average S ± SD	27 ± 5	26 ± 4	14 ± 5	13 ± 4
Average J' ± SD	0.38 ± 0.21	0.83 ± 0.08	0.81 ± 0.10	0.85 ± 0.05
Average mean grain size (μm) ± SD	131 ± 88	150 ± 10	250 ± 40	220 ± 30
Number of samples	6	18	22	22

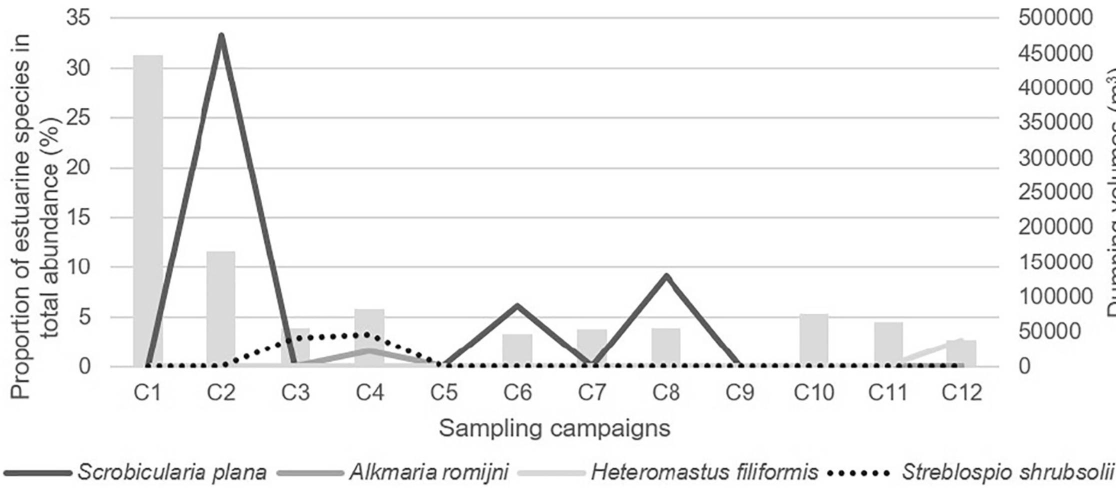

Fig. 4. Proportion (%) of estuarine species within the station A18 located at the northern part of the directly impacted location throughout the 12 seasonal campaigns "C1-August 2014" to "C12-June 2017". Histograms showed dumping volumes on A18 between each field campaign.

the biological multivariate data cloud of the whole dataset (C1–C12), were silt and clay content, very fine sand, fine sand, mean significant wave height, mean river flow and sorting index (Fig. 5a). Benthic communities from each location (DIR, IND and REF) were identifiable as clusters of points having similar symbols on the dbRDA plot.

Excluding the first field campaign (C1-August 2014), the variation in the multivariate data cloud was best explained (24,4%) by the same combination of predicting variables except sorting index replaced by the number of effective dumping days "D" (Fig. 5b).

4. Discussion

Identifying factors responsible for spatial and temporal patterns in macrofaunal assemblages are a central theme in marine benthic ecology (Blanchet et al., 2014; Dutertre et al., 2013). Especially discriminating natural and anthropogenic variables that shape soft-bottom community structure has become an issue of concern to adopt relevant management and conservation strategies (Dutertre et al., 2013). Our study assessed the level of impact of recurrent dumping activities carried out for several decades in a wave exposed coastal area subjected to estuarine discharges from a mountain range river system with short water residence time (Point et al., 2007). Within the study area, our results suggested that the magnitude of estuarine influence appeared greater on the soft-bottom communities than the putative changes due to dumping activities. Our study is unfortunately not consistent with the BACI model (Underwood, 1994) since it is based on the comparison on control vs potentially impacted stations and, unfortunately does not include a "Before"-"After" approach in addition to the "Control"-"Impact" approach. Until very recently, in France, most offshore dumping activities have unfortunately been conducted without sound scientific approach that aim at evaluating the impact of those activities on benthic organisms. Only, within the implementation of the European

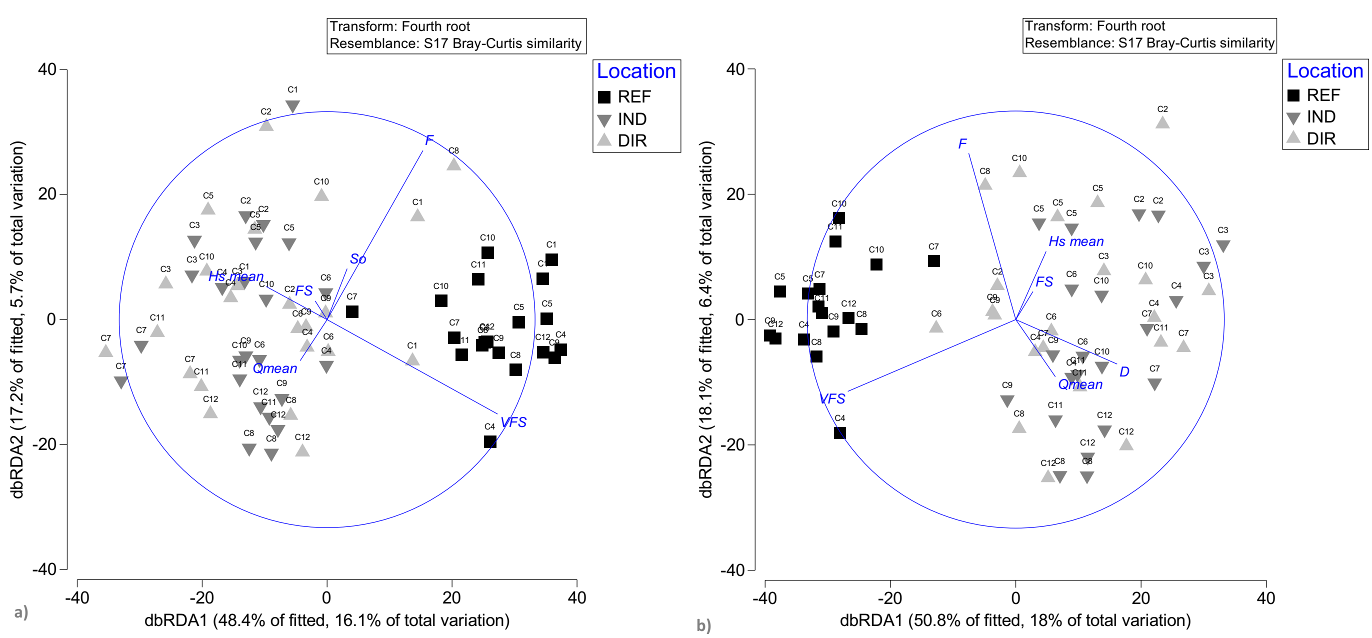

Fig. 5. Distance-based redundancy (dbRDA) plots based on Bray–Curtis similarities from fourth-root-transformed species abundance data at the sampling locations (IND, DIR and REF). Overlaid are the retained environmental variables best explaining the observed variance based on a BEST-model with AICc selection criterion ("VFS" very fine sands fraction, "F" silt and clay content, "Qmean" average flow rate, "Hsmean" mean significant wave height, "FS" fine sand, "So" sorting index and "V" materials dumped volume) per station between each sampling campaign. The plot on the left (a) illustrating the analysis ran on the full dataset (C1 to C12) and the plot on the right (b) represented the analysis ran on the reduced dataset (C2 to C12).

Water Framework Directive, the improvement of our knowledge of human impacts is become critical for marine management and conservation (Marmin et al., 2016). The study of the impact of many of these activities that have occurred for decades is therefore restricted to a “Control”-“Impact” approach (Marmin, 2013).

4.1. Short-term effects of an exceptional summer flood event

The first campaign took place one month after an exceptional summer flash flood event (July 2014) which induced important changes of both physical and biological natures. Although the swell was stronger during the second part of the monitored period, this wave climate is regularly reported along the Basque coast (Augris et al., 2009). In August 2014, sediment were dominated by fine particles, while the coarse sand proportion was particularly low. These poorly sorted sediments suggested high variability of near-surface sediment grain-size (Pridmore et al., 1990; Turner et al., 1995). Such habitat disturbance at the scale of the whole study area was never observed again during the following three years of monitoring. This observation suggested that despite seasonal flood occurring every winter, a summer flood could indeed produce an important deposit in the near coastal area linked to important solid flow during a low-hydrodynamic period (minimal wave height and river discharge) where both the riverine flush action ability (Bárcena et al., 2012) and wave actions are reduced. This physical modification of surface sediments resulted in a spatial homogenization of the benthic communities throughout the whole study area which was observed during this first sampling campaign. Communities were characterized by a bloom of the bivalve *Abra alba*, known to live in organic matter enriched sediment (Marmin, 2013; De Backer et al., 2014b). This settlement could be explained either by (i) a post-summer flood recruitment (i.e. one month and a half between the summer flood and the sampling campaign) or (ii) a passive redistribution of the species by hydrodynamic transport. As reported by Bachelet and Cornet (1981) who addressed the life cycle of *Abra alba* in the Southern part of the Bay of Biscay, recruitments indeed take place from April to November. However, in the latter study, small organisms were not retained due to the 1-mm mesh size sieve used. Furthermore, during the current study, a high density of individual with a length up to 10 mm was observed in August 2014. Considering the highest growth speed (around 37.10^{-3} mm/day) reported for *A. alba* juveniles by Bachelet and Cornet (1981), other processes should explain the presence of such large organisms. Vallet (1993) has reported that *Abra alba* could regulate its position in the water column by opening their valves to different extents. Thus, this mollusc could play an active part in settling-drifting mechanisms and in the control of its position in the water column. This has been demonstrated in juveniles of other bivalve species (see de Montaudouin, 1995). Olivier et al. (1996) demonstrated an active and/or passive redistribution of subtidal benthoplanktonic species. Forêt et al. (2018) observed a response of bivalve recruits to a “trophic migration trigger”. Patterns of secondary migrations result from a close physico-biological coupling involving hydrodynamics factors, but also eco-ethological responses modulated by physiological processes related to the trophic environment. In the megatidal environment such as the Bay of Seine (Olivier et al., 1996; Olivier and Retière, 1998) or the archipelago of Chausey (Forêt et al., 2018), the species drifting was correlated to critical bed shear stress caused by tidal current and potentially amplified by swell. *Abra alba* presence cannot be linked to an estuarine origin within the mesotidal and highly energetic study environment (Augris et al., 2009). Indeed, no *Abra alba* community has been observed within the subtidal or intertidal Adour estuarine habitat (Cottet et al., 2007; Blanchet et al., 2009, 2011, 2013, 2017a, 2017b, 2018a, 2018b; Garcia et al., 2010; Humbert et al., 2019). A marine origin could be therefore suggested. Nonetheless, due to the apparent lack of knowledge on benthic subtidal soft-bottom community along the Basque coast, this origin cannot be confirmed (Foulquier et al., 2020).

The average density recorded during this first sampling campaign was also abnormally high, sixteen times superior to the average densities obtained within the eleven remaining field campaigns. This was in accordance with the results of Salen-Picard et al. (2003) who found an increase in abundance of many species at receiving site of terrestrial inputs following flooding events. They assumed the increase in food supply (e.g. organic matter content in terrestrial inputs) due to the high flow rates was the cause of such peaks in macrofauna abundance. As reported by Akoumianaki et al. (2013), the distribution of the dominant species throughout the whole study area during this field campaign succeeding an exceptional flooding event point to the stirring effect of hydrodynamic conditions. Indeed, our results showed that the faunal patterns post-summer flood were related to huge input of terrestrial sediment during a low-energetic period. The observed highest sorting index throughout the whole study area, following a major sediment discharge, suggests that macrofauna structure is influenced by sediment resuspension and current-driven transport of species (Akoumianaki et al., 2013). Following van Hoey et al. (2007), our study suggest that year-to year variations due to local events induce more variations in benthic communities composition than seasonal variations.

4.2. Recurrent dumping activity effects on soft-bottom benthic community

To investigate for spatial and temporal differences in the assemblages and their putative relation to the dumping activity, a subset of the data excluding the first sampling campaign described above was analyzed in more detail. Within this subset, our results pointed out some spatial differences between impacted and control area suggesting a possible dumping operations effect. Contrary to other studies which reported an average decrease of sediment grain size after disposal operations (Zimmerman et al., 2003; De Backer et al., 2014b; Marmin et al., 2016), the fine particles content as well as fine sands tended to decrease from the reference stations to the most impacted stations. During the dumping operation, the smallest particles are dispersed in the water column while the sandy fraction of dredged sediment with a higher density are deposited at the bottom (Alzieu et al., 1999; Walther et al., 2014).

In terms of macrofauna composition, dumping activities may cause the short-term presence of typical estuarine species within the directly impacted location. These species, such as the bivalve *Scrobicularia plana*, were occasionally found as an important but transitory component of the community (23% of the total abundance), have been rapidly replaced by other species. Interspecific competition with local marine species or unsuitable substrata could explain the settlement absence for theses weak competitive euryhaline species (Conde et al., 2011).

The difference in community composition along locations were not very strong and the three locations shared many species in common (52% between REF and IND, 43% between DIR and IND and 38% between DIR and REF). Nevertheless, the potentially impacted areas exhibited lower diversity indices than the reference area and a species composition that included an higher occurrence of species linked to clean sandy substrata. At the scale of the whole study area, both impacted and reference areas consisted in different assemblages derived from the main “*Tellina-Venus* community” as described by Borja and Collins (2004) along sublittoral bottoms of the Spanish Basque Coast. This community consisted in an indistinguishable mixture of the *Tellina tenuis* Lusitanian-boreal community (Stephen, 1930) associated with mixed sediments, dominated by sand and mud (Cornet et al., 1983) and the *Venus fasciata* community, typical of sandy bottoms in 20–40 m water depth described by Ford (1923), Thorson (1957) and Cabioch (1961). Given the values taken by the structural parameters (abundance and species richness) in comparison with the average values defined by Borja and Collins (2004), this community would appear as slightly impoverished within the dumping area. This apparent subtle effect of recurrent dumping activity could be ascribed to the body-size of the sampled organisms. Indeed, individual were essentially small body-size species with a short life cycle, "r-strategists" species as defined by Pianka (1970), McCall (1976), Rees and Dare (1993), Holt et al. (1995). A study focusing on larger organisms with longer life span ("K-strategists" species) would probably have resulted in a clearer signal (Newell et al., 1998; Bolam and Rees, 2003; Bolam et al., 2006). In addition, our conclusions regarding possible marginal dumping effect on macrobenthos are unfortunately not sustained by a complementary "before-after" approach at the different locations. Lacking this kind of approach, one cannot exclude that the small differences observed in community composition and diversity between potentially impacted stations and reference stations naturally occurred before spoil disposal activities. The knowledge of natural variability as discussed in the following paragraph provides elements to discuss the relevance of the location of the control stations.

4.3. Variability due to a naturally highly stressed area

Other studies carried out in high energy environment, such as Roberts and Forrest (1999), Smith and Rule (2001), Simonini et al. (2005) and Bolam et al. (2011), found also scarce indication of impact on in macrofaunal community structure in their respective spoil-disposal areas. Throughout the study area, multiple sources of natural disturbance are combined and mingled with the putative effects of recurrent dumping activities. Over the monitoring period, the control and the impacted locations followed globally the same temporal pattern. Difference among locations were evidenced during the lowest and the highest energic condition periods. During low wave energy conditions, this difference could suggest an impact of dredge spoil disposal, observed as a change over time of the dumping area community with a different pattern when compared to control area (Underwood, 1994; De Backer et al., 2014b; De Backer et al., 2017; Donázar-Aramendía et al., 2018). Nonetheless, this change within the impacted area was linked to an increase of abundance and number of species and a species composition similar to the reference stations over the monitoring period. Conversely, through a combination of seasonal high energy conditions (wave and river discharge), structural parameters drastically decreased within the impacted area. Therefore, a flushing action (Bárcena et al., 2012) due to the location of the dumping area directly in front of a highly channeled estuarine mouth could be hypothesized to explain the lower diversity along the axis of the river and the coarser substrata observed. Stations of control and impacted areas, located at the same depth, showed the same wave climate. Wave-orbital motions are likely to be able to penetrate down to the bed and resuspend sediments (Komar and Miller, 1975; Barthe and Castaing, 1989). In front of the river mouth, these resuspended sediment by wave action were probably then flushed by the river flow. A combined effect of wave resuspension and flushing action could therefore appear in front of the river mouth. As established above, hydrodynamic drivers distinguished the faunal community structure located in front of the mouth of the river over the monitoring period. These results are consistent with the recent study carried out in the near-shore area where hydrodynamic conditions appeared as key descriptors for the local distribution of soft-bottom communities (Foulquier et al., 2020).

4.4. Recovery ability in a natural highly stressed environment

Recovery ability from natural or anthropogenic disturbances seems site specific and depends on several factors (Newell et al., 1998; Bolam and Rees, 2003; Bolam et al., 2006; Marmin, 2013). Some experimental studies which tested the effects of different type and intensity of disturbances (e.g. dredged sediment disposal, raking and organic enrichment) on sublittoral and intertidal marine benthic communities suggest that the recovery time after a perturbation can be very variable from one ecosystem to another (Marmin, 2013; Powilleit et al., 2006; Whomersley et al., 2010). This recovery time can range from a few months (Diaz, 1994; Smith and Rule, 2001) to several years (Harvey et al., 1998). Whomersley et al. (2010) pointed out that communities frequently disturbed by sediment movement or naturally rich in organic material would be expected to contain species able to survive in such environments and may therefore show greater resilience in the face of further physical disturbance. In the same way, Bolam and Rees (2003) argued that 9 months were sufficient for highly exposed communities to return to their pre-disturbance structure. Our result showed very short recovery time after the exceptional summer flood event. Indeed, approximately four months after the perturbation, a shift was observed in the species assemblage, from an *A. alba* enriched sandy mud assemblage towards a *Tellina-venus* muddy sand assemblage, clearly related to the decrease in fine particles. This new community structure was then observed during the eleven remaining campaigns.

5. Conclusions

Congruent with other published studies in natural highly stressed environment, the present contribution supports a scarce impact of dredge spoil disposal on in macrofaunal community structure. As expected, this study confirms the greater magnitude of hydrodynamic drivers on the subtidal soft-bottom communities than the putative changes due to anthropogenic activities. As reported by Bolam et al. (2011), the dynamic nature of the study area, highly exposed to natural hydrodynamic stressors, ultimately makes difficult to discretize the different drivers. A flushing action of river added to the general wave climate is hypothesized in the present study to explain the spatial and temporal variability of the benthic community. Through an exceptional summer discharge event, this river influence extended to a large coastal area causing a short-term change leading to an homogeneisation of the soft-bottom benthic community into an *Abra alba* sandy mud community. Finally, the present study suggests an important role of these natural hydrodynamic conditions in post-disturbance recovery. Further studies, however, are needed to estimate precisely the time recovery length of the benthic community in this natural highly stressed environment.

CRediT authorship contribution statement

Clémence Foulquier: Conceptualization, Methodology, Formal analysis, Investigation, Writing - original draft, Visualization, Funding acquisition. **Julien Baills:** Software. **Hugues Blanchet:** Validation, Writing - review & editing. **Frank D'Amico:** Supervision, Project administration. **Didier Rihouey:** Conceptualization, Resources, Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://

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