Large dunes hosting hotspots of biodiversity: Testing proxies of occurrence and habitat change

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ABSTRACT: The interaction of geomorphological and ecological landscape elements is complex. In the case of dunes, not only their shape and dimensions design the habitat, but also the way in which the morphology interacts with the currents. The resulting sedimentary processes will further depend on the in situ sediments, but also on the geological substratum in terms of longevity of biological communities. However in soft substrata, hotspots of biodiversity are mostly observed where coarse substrates combine with deposition of fine-grained sediments. The influx of such fines can originate both from natural and human-induced sources.

In this study, hotspots of biodiversity in dune fields are revisited to define new proxies for the prediction of occurrence, and potential habitat changes. Therefore, several databases are combined: primarily related to geology and sediments, but also to sediment dynamics, including results from cumulative sediment plume dispersal models. The ultimate goal is to facilitate stratification and prioritization of areas that require monitoring of good environmental status (Europe's Marine Strategy Framework Directive).

1. INTRODUCTION

Bedforms as benthic habitats are studied increasingly as acquisition and analyses of acoustic data improve in capturing, visualizing and quantifying benthic and terrain variables on various scales. However, feedback mechanisms between geomorphology and benthos are not always clear (Van Lancker et al., 2012) and complexity increases where the benthos-landscape relationship is also affected by humans.

Based on results from research-oriented seabed mapping and measurements along the Belgian part of the North Sea (BPNS), in combination with large geological and sediment transport databases, new proxies are tested for the prediction of high-biodiversity bedform areas. Additionally, it is aimed at identifying areas with a high potential of habitat change. Such studies are critical within Europe's Marine Strategy Framework Directive, targeting good environmental status of marine waters by 2020. Cost-efficient monitoring programmes are needed covering impacts of all anthropogenic stressors. The BPNS is a good laboratory for such studies since it is one of world's busiest continental shelf areas, including 30-yrs of active disposal of dredged material and extraction of aggregates, as well as more than 150-yrs of bottom disturbing fisheries.

2. METHODS

1.1 Study area

The BPNS is a siliciclastic macro-tidal environment (range of 4.5 m), comprising several groups of sandbanks. Depths range from 0 to - 50 m Mean Lowest Low Water at Spring (MLLWS). Mean grain-sizes range from fine to medium sands varying along a subtle gradient. Sediment transport is mainly driven by tidal currents (max. 1.5 m s^{-1}), though wind-induced currents may have a direct effect on sediment resuspension and bedform morphology. Bedform patterns are simple to complex, with varying rates and directions of migrating sand dunes (on average 20 m yr^{-1} and oscillating) with heights being on average 4-6 m in the offshore zone (Lanckneus et al., 2001). Human activities on the BPNS influence natural sediment fluxes, for example through dispersion and deposition of plumes originating from the disposal of dredged material, marine aggregate extraction, wind mill farms, or fishing activities.

1.2 Methodology

Results from very-high resolution acoustic seabed mapping are revisited to spot dense occurrences of species aggregations (following Van Lancker et al., 2012). This imagery was mostly derived from multibeam echosounders (RV Belgica Kongsberg EM1002/95 kHz; EM3002D/300 kHz; RV Simon Stevin Kongsberg EM2040/300 kHz), and contains both depth and backscatter data. At some biodiversity hotspots areas data were also available from current and backscatter profiling (Acoustic Doppler Current Profiling, ADCP) in the water column, in combination with vertical profiling of oceanographic parameters and water sampling.

Information on geology, sediments and their dynamics is now revisited systematically in a research network building a 4D voxel-based resource model of the Belgian and southern Netherlands part of the North Sea up to -30m below the seabed (Van Lancker et al., subm.). Focus was on the compilation of long-term datasets and model hindcasts to reflect spatial and temporal variation. For biological validation, several case study areas existed with sufficient ground-truthing and where the link with the physical habitat was studied (e.g. Degraer et al., 2008; Rabaut et al., 2009; Houziaux et al., 2012). Complementary information is available through international data portals (e.g. EMODnet-Biology; http://www.emodnet-biology.eu/).

3. RESULTS

The first part of the study focused on synthesizing the knowledge on where biodiversity increases were depicted in association with bedforms. Simplified, such zones were found: (1) in the lee side of topzones of sandbanks, in combination with large to very-large dunes, and (2) along dune areas where complex sediment transport pathways prevail (e.g. shear zones). In both cases the trapping of an additional naturally or anthropogenically-induced influx of fine-grained sediment was critical. Along those areas sediment distribution is often highly patchy and varying in composition, with a coarser geological substratum.

For this study, key databases that are further exploited relate to: (1) grain-size distribution curves, to maximize parameterization of sediment heterogeneity, and allowing for detailed change detection; and (2) hydrodynamics and sediment transport for which a 16-year hindcast modelling was performed (Francken et al., 2014), from which parametrization of bedload convergence zones is targeted. Additionally, results from cumulative plume dispersion models will be used and confronted to the other datasets.

In the mapping exercises, focus is on the construction of probability models of the underlying parameters. So far, data grids are mostly produced statically, where only one parameter (e.g. mean, percentiles) is mapped. On the contrary, probability mapping includes a measure of interpolation-related uncertainty by making 100 interpolations on each dataset, hence reflecting heterogeneity in the underlying data. Finally, results are confronted with bathymetric datasets to find relationships with occurrences of dune fields. Ultimately, the goal is to find a predictor that can be applied on existing digital terrain models, and that, in combination with intensity maps of human activities, can be used to stratify and prioritize areas for further monitoring of good environmental status of marine waters (Europe's Marine Strategy Framework Directive).

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