

**Ecosystem based design rules for sand extraction sites**

Maarten de Jong (Arcadis, the Netherlands), Martin Baptist (IMARES the Netherlands), Bas Borsje (TU Twente + Deltares, The Netherlands) and Daan Rijks (Boskalis, the Netherlands)

Corresponding author: Maarten de Jong (Arcadis)

**Abstract:**

For Maasvlakte 2 (MV2), a seaward harbour extension of the Port of Rotterdam, 220 million m<sup>3</sup> of sand was extracted in a 15 km<sup>2</sup> large area with water depths of 20 m and sand extraction depths up to 20 m. We studied the ecological effects and compared these with other sand extraction case-studies with intermediate and shallow extraction depths on the Dutch continental shelf (DCS).

We observed significant short-term changes in faunal species composition and sediment characteristics in the 40 m deep MV2 borrow pit. Biomass of macrozoobenthos and demersal fish biomass increased on average 10 to 20-fold in the deep areas 2 years after extraction. Macrozoobenthos and demersal fish distribution correlated with sediment and hydrographic characteristics and time after cessation of sand extraction. Ecological and bed shear stress data were combined and transformed into Ecosystem-based design (EBD) rules which can be used in the design phases of future borrow pits in order to simultaneously maximize the sand yield and decrease the surface area of direct impact.

The EBD rules can be applicable in other regions than the DCS depending on the extraction depth, hydrodynamic regime, and the supply of suspended matter. For areas outside Europe, ecological data for comparable deep sand extraction sites may be necessary. In general, the EBD rules can help to even make large-scale and deep sand extraction sustainable by mitigating or preventing related processes with potential negative impacts.

**Keywords:** deep sand extraction, macrozoobenthos, hydrodynamics, ecosystem

**Corresponding author:** Maarten de Jong, Arcadis, Hanzelaan 286, PO box 137, 8000 AC Zwolle, the Netherlands

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