

The role of biota in fine sediment transport processes in the Markermeer: a synthesis

de Lucas Pardo Miguel¹, Thijs van Kessel¹ and Johan C. Winterwerp^{1,2}

¹ Marine and Coastal Management, Deltares, PO Box 177, 2600 MH, Delft, the Netherlands
E-mail: Miguel.deLucasPardo@deltares.nl

² Section of Environmental Fluid Mechanics, Civil Engineering and Geosciences, Delft University of Technology, PO Box 5048, 2600 GA, Delft, the Netherlands

The very turbid and ecologically deteriorated Lake Markermeer, in the Netherlands, has been subject of many studies over the last decades. A major contribution to the understanding of the lake's dynamics has been accomplished over the last four years, in the context of the PhD study of the first author. We provide an overview of the previous knowledge, as well as elaborate on our most important findings, aiming at the holistic picture of the lake's fine sediment dynamics.

The bed of the lake consists of a muddy layer that is subdivided into an oxic and easily erodible layer and an anoxic and more resistant layer below. Underneath these two layers, very stiff clayey old deposits are found.

Formerly, the turbidity of the lake was considered to be dominated by erosion and deposition of the oxic layer. We corroborated that hypothesis, but we also demonstrated that the oxic layer owes its characteristics not to its oxidized state, but to its bioturbated state. Moreover, we hypothesized that the muddy layer at the bed stems from historic bioturbation of the old deposits on the bed, and after the closure of the lake in 1975.

Furthermore, the turbidity in the water column was formerly regarded as a function of the suspended minerals only. We evaluated the influence of water column biota (algae) in the turbidity, showing that turbidity does not only depend on the amount of suspended minerals, but also on the type of algae present in the water column. In fact, some algae species were found to promote flocculation, whereas some other species inhibit flocculation due to large concentrations of algae yielding steric repulsion. Finally, biota was also found to be relevant for consolidation processes in the lake, accelerating consolidation due to tunnels and burrows created by the fauna. These tunnels result in an increased permeability of the bed, hence in a more rapid dewatering process. Summarizing, the role of biota in the Markermeer has been found to be dominant for the sediment sources (erosion), relevant for sediment transport (inhibition or promotion of flocculation), and relevant for the sediment sinks (consolidation).

During the investigation of these sediment transport processes, we measured a number of sediment transport parameters, either in the field or in the lab. These measurements were then used in a one dimensional modelling exercise. This exercise was performed with the 1DV version of the multi-layer bed module of Delft 3D. The model was coupled externally with Matlab, and thus we could introduce the effect of biota in the relevant sediment transport processes. Below are the main parameters that we measured in the lab and implemented in the model:

- Critical shear stress for erosion and erosion rate for the non-bioturbated anoxic layer and for the bioturbated oxic layer. These parameters were obtained by using a Gust erosion microcosm.
- Settling velocity. Measurements of the settling velocity were performed in the 5 metres large settling column at Delft University of Technology, and with a recently developed measuring chamber.
- Floc sizes were measured in the large scale settling column, with the Malvern Mastersizer used for the small scale flocculation experiments, and in the field with the recently developed floc camera.
- Bioturbation rates were measured by letting fauna bioturbate the bed for a certain time, while measuring the difference in erosion between a non-bioturbated and a bioturbated bed at the Gust erosion microcosm.
- Aggregation rates were measured from the flocculation experiments, from the increased size per time interval between measurements.

All these parameters were used in the sediment transport model, without further calibration. Only the rate at which the sediments in the oxic and bioturbated layer gain strength has to be calibrated for good model results. Our results compare reasonably well with the measurements of turbidity. The latter suggests that our measuring techniques and instruments provide reliable and useful data. Second, turbidity observations cannot be explained without the effect of biota, in particular without the effect of bioturbation. Other biotic effects were found to be relevant as well, as the effect of algae in the aggregation efficiency of flocs or in the settling velocity. Hence, the relevance of biota in Markermeer's fine sediment dynamics has also been established indirectly with the 1DV model.