Monitoring and predictive modelling of estuarine benthic macrofauna and their relevance to resource management problems

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Practical considerations in estuarine management, as well as prediction of the consequences of global change on coastal protection, urgently require a better understanding and better modeling of estuarine ecosystems as influenced by ecological, physical, chemical and morphological processes. Recent Dutch examples of such questions are: the impact of enhanced dredging in the Schelde estuary, the impact of sea level rise on the Wadden Sea and Delta area, concerns about the loss of salt marsh habitats, etc. Benthic communities are good indicators of biotic integrity and reflect the present state of the estuarine ecosystem. The analysis of benthic infauna is a key element of many marine and estuarine monitoring programs. In the Dutch Delta area (SW-Netherlands) there is a relatively long tradition on estuarine macrozoobenthos monitoring, such as implemented e.g. in the BIOMON program. This program was designed to detect long-term trends in the average density, biomass and species composition of large parts of different systems (e.g. Schelde estuary, Oosterschelde, Grevelingen), in order to obtain insight in the natural development of estuarine and coastal areas and the anthropogenic influences on these systems. Running now for over a decade, these programs, together with other field campaigns, provide a unique data set on benthic macrofauna (e.g. for the Schelde estuary over 5000 samples are available at the moment). Until recently these data were hardly processed and used for further analysis. However, such data sets offer the opportunity to analyze and predict patterns in occurrence of benthic macrofauna in a much more profound way. Recently, within a cooperation between decision makers (Rijkswaterstaat, Directie Zeeland), advisers (RIKZ) and scientists (NIOO-CEMO), the possibilities and limitations of using these data sets for the predictions of benthic macrofauna at scales relevant to resource management problems are evaluated. In our approach we use different statistical methodologies to quantify, model and predict patterns at different spatial and temporal scales, going from patterns on a single tidal flat to inter-estuary comparisons and from monthly patterns to decennial trends. Several examples are shown that illustrate the use of these data, going from simple classification techniques to more sophisticated predictive modeling: Changes and shifts in benthos communities are shown for a land reclamation area of Rotterdam harbour in the Haringvliet-delta using classification techniques. Ordination analysis on the saline lake Grevelingen, a former estuary, showed long-term changes in macrobenthic community structure as a consequence of changes in salinity, light penetration, etc. This case study will be dealt with in more detail in a separate contribution. In the Schelde estuary, a detailed study was performed to unravel the use of environmental data in predicting benthic macrofaunal species distributions at different spatial scales (from a single tidal flat to the whole estuary). Statistical techniques such as geostatistics, hierarchical analysis and logistic regression were applied. At these different scales a distinct relation between the environment (e.g. salinity, sediment characteristics) on the one hand and macrofaunal species distributions on the other hand was observed. As a consequence, predictions of macrofaunal distributions can be made quite successful from environmental data within the Schelde estuary. An inter-estuary comparison between the Schelde estuary and Oosterschelde revealed that predictive models should also incorporate system-wide properties of estuarine systems, such as primary production and suspended matter concentrations, in order to perform in a more generic way. The results clearly show their use in making more sensible long-term decisions about matters having direct environmental effects. The results also provide information on how the design of monitoring programs could be improved or optimized, depending on the questions asked. As such, a more synergetic and flexible approach is urgently necessary, in which decision makers, advisers and scientists communicate in a more efficient way.