Ocean & Coastal Management 121 (2016) 33–48

Contents lists available at ScienceDirect

Ocean & Coastal Management

journal homepage: www.elsevier.com/locate/ocecoaman

Management options for restoring estuarine dynamics and implications for ecosystems: A quantitative approach for the Southwest Delta in the Netherlands

Tom Ysebaert [a, b, *], Dirk-Jan van der Hoek [c], Rick Wortelboer [c, d], Jeroen W.M. Wijsman [a], Marijn Tangelder [a], Arno Nolte [d]

[a] IMARES – Wageningen UR, Institute for Marine Resources and Ecosystem Studies, PO Box 77, 4400 AB Yerseke, the Netherlands
[b] NIOZ Yerseke, Royal Netherlands Institute for Sea Research, PO 140, 4400 AC Yerseke, the Netherlands
[c] PBL Netherlands Environmental Assessment Agency, PO Box 303, 3720 AH Bilthoven, the Netherlands
[d] Deltares, PO Box 177, 2600 MH Delft, the Netherlands

ARTICLE INFO

Article history:
Received 20 April 2015
Received in revised form
3 November 2015
Accepted 6 November 2015
Available online xxx

Keywords:
Estuarine dynamics
Estuarine gradients
Management options
Management implications
Modeling
Habitat mapping
Intertidal habitat
Salinity
Hydrodynamics

ABSTRACT

The Delta Works, a series of dams and barriers constructed in the 1960's–1980's changed the estuarine landscape of the Rhine-Meuse-Scheldt delta (SW Netherlands) into more stagnant and disengaged freshwater, brackish water or saltwater lakes. The remaining tidal systems were adapted by building a storm surge barrier in the Oosterschelde and dike reinforcement works along the Westerschelde. The Delta Works brought protection against flooding, but at the same time resulted in environmental and socio-economic problems, such as degradation of ecological quality and ecosystem functioning, disruption of fish migration routes, water and sediment quality problems.

In this study we explore in an integrated, quantitative way the consequences of a number of management options for the Southwest Delta and their implications for the occurrence and distribution of aquatic and estuarine habitats, considering the mutual coherence between the water basins. Five scenarios were evaluated using a 1D hydraulic, water quality and primary production numerical model and GIS habitat mapping. Scenarios vary from small-scale interventions, such as changes in day-to-day management of hydraulic infrastructures or creation of small inlets in dams, feasible in the short term, to restoration of an open delta by removing dams and barriers, as a long term potential. We evaluate the outcomes in relation to the restoration of estuarine dynamics, as this is in policy plans proposed as a generic solution for the current ecological and environmental problems. Net water flow rates show more complex patterns when connectivity between water basins is increased and when sluice management is less strict. Estuarine transition zones and fish migration routes are partly restored, but only fully develop when basins are in open connection with each other. Area of intertidal habitats, tidal flats and tidal marshes, increases in each scenario, ranging between 7 and 83%, 1–56%, and 8–100% respectively, depending on scenario. Large scale infrastructural adaptations are needed to restore estuarine dynamics at large scale.

The use of a 1D numerical model allowed to quantify the effect of different management measures for all water basins simultaneously, but also has its limitations. The model does not resolve more complex processes such as vertical mixing and morphodynamic changes. This requires expert judgment and more detailed 3D modelling.

1. Introduction

The devastating flood of 1953 prompted the construction of a series of dams and barriers, the so-called Delta Works, in the Southwest Netherlands to protect the Rhine-Meuse-Scheldt delta (Southwest Delta) from North Sea floods (Fig. 1). To achieve the

* Corresponding author. IMARES – Wageningen UR, Institute for Marine Resources and Ecosystem Studies, P.O. Box 77, 4400 AB Yerseke, The Netherlands.
E-mail address: tom.ysebaert@wur.nl (T. Ysebaert).

http://dx.doi.org/10.1016/j.ocecoaman.2015.11.005

Fig. 1. The Southwest Delta (Netherlands) with the main water basins and the main hydraulic infrastructures related to the Delta Works. Numbers indicate locations for which model results are presented: 1) Brienenoord, 2) Puttershoek, 3) Bovensluis, 4) Haringvliet center, 5) Steenbergen, 6) Zoom center, 7) Dreischor, 8) Zijpe, 9) Lodijkse Gat, 10) Hammen Oost, 11) Soelekerkepolder, 12) Hansweert. Except for 4) and 6), locations coincide with current routine monitoring stations.

desired safety levels the coastline was shortened through damming the estuary mouths and through dike reinforcements. Although the Delta Works increased safety against flooding for the local population (Pilarczyk, 2012), the environmental drawbacks are becoming increasingly evident, such as the degradation of ecological quality and ecosystem functioning, disruption of fish migration routes, and water and sediment quality problems (Nienhuis et al., 2002; Smits et al., 2006; van Wesenbeeck et al., 2014). Many of these problems and undesirable side effects result from the impact of these infrastructural measures on the natural processes, such as an imbalance between geometry (e.g., depth, surface area), water flows and its constituents, a disrupted sediment balance and a lack of connectivity (Mulder and Louters, 1994; van Wesenbeeck et al., 2014). Furthermore, the Delta Works split up the estuary into individual water basins of different sizes. As the new ecosystems developed, the estuarine landscape with natural transitions between tidal fresh, brackish and saline waters was replaced by more stagnant and disengaged fresh water, brackish water or salt water lakes (e.g. Saeijs and Stortelder, 1982; Wijnhoven et al., 2010; Paalvast and van der Velde, 2014). Each water basin has specific environmental problems (Table 1) (van Wesenbeeck et al., 2014). These problems also have an impact on socio-economic sectors such as recreation and shellfish aquaculture. Finally, climate change has prompted a reconsideration of the long-term safety measures against flooding in the Netherlands. A general policy movement towards working with natural processes as opposed to hard engineering solutions has paved the way to combine solutions for safety with solutions for environmental problems (Smits et al., 2006; Verspagen et al., 2006; van Wesenbeeck et al., 2014).

Increased awareness of these problems has led to a shift in thinking on management of the Southwest Delta as reflected in integrated water management policy plans launched since the 1990s. Already in the “Vierde Nota Waterhuishouding” (Fourth Memorandum on Water Management) (1998), the policy objective