



Long term anthropogenic changes and ecosystem service consequences in the northern part of the complex Rhine-Meuse estuarine system



Peter Paalvast^{a,*}, Gerard van der Velde^{b,c}

^a Ecoconsult, Asterstraat 19, 3135 HA Vlaardingen, The Netherlands

^b Radboud University Nijmegen, Institute for Water and Wetland Ecology, Department of Animal Ecology and Ecophysiology, Heyendaalseweg 135, 6525 AJ Nijmegen, The Netherlands

^c Naturalis Biodiversity Center, P.O. Box 9517, 2300 RA Leiden, The Netherlands

ARTICLE INFO

Article history:

Available online 27 February 2014

ABSTRACT

Around 0 AD, the Rhine-Meuse estuary in the southwest of the Netherlands was a typical coastal plain estuary. Drainage of peatland and land subsidence behind the dunes later caused the sea to penetrate into the land. Most of the peat was eroded, and by 1000 AD the so-called Delta area had turned into a landscape of large estuaries and intertidal zones. Rotterdam developed from a small fishing village on the banks of the tidal river “Nieuwe Maas” from the 14th century onwards into the largest seaport of Europe in 2013. The Rotterdam harbour area situated in the northern part of the Delta area includes the former Europoort harbour, and is nowadays known as Rijnmond. The hydrology of the area is controlled by the drainage regime of the sluices in the Haringvliet barrier that was constructed as part of the “Delta Works” project to protect the southwest of the Netherlands against storm surges. The sluices are opened at slack tide to discharge river water to the sea and are always closed at flood tide.

As a baseline study for environmental and ecological reconstruction and development, we describe in detail the loss of intertidal soft sediment ecotopes due to land reclamation, harbour development and river training works (straightening of the navigational channel) in the tidal rivers, and the expansion of hard substrate ecotopes (quay walls, groynes, training walls, riprap, concrete, stones etc.) in the Rijnmond area in the 19th and 20th centuries. Within 135 years, more than 99% of the original 4 775 ha of characteristic pristine soft sediment estuarine ecotopes have disappeared. In the same period, 338 ha of hard intertidal substrate zone was constructed. Such trends can also be observed in harbour areas elsewhere, and have ecological and environmental consequences for estuarine areas in particular.

Restoration of soft substrate estuarine ecotopes can be achieved by opening the Haringvliet Sluices at both ebb and flood tide, which would restore large-scale estuarine dynamics to the northern part of the Rhine-Meuse estuarine system. This will have a highly favourable effect on many ecosystem services. The Dutch division of the World Wildlife Fund has launched a new proposal for a safer and more attractive South-West Delta area. It comprises the reopening of the sea inlets such as the Haringvliet by removing the barriers, and building climate-proof dikes in combination with natural wetlands. In case of storm surges, the hinterland could be protected with a new generation of barriers that do not hamper the free transport of sediment, tides and animals. Based on 30 ecosystem services or subservices, it was calculated that opening the Haringvliet inlet would lead to an increase in Total Economic Value (TEV) of at least 500 million Euro per year. The costs of removing old barriers and the construction of new ones was not included in the calculations.

© 2014 Elsevier Ltd. All rights reserved.

* Corresponding author. Tel.: +31 107537549.

E-mail address: peter.paalvast@gmail.com (P. Paalvast).

1. Introduction

1.1. General introduction

All over the world, coasts have been shaped after the Ice Ages, as sea levels rose during the Holocene. During this period, several estuaries were formed along the newly developing coasts of North-West Europe, through flooding of existing river valleys. This type of estuary, which is common in temperate regions, is called drowned river valley estuaries or coastal plain estuaries; they are often shallow and filled up with sediments, resulting in extensive mud flats and salt marshes (Dyer, 2002; McLusky and Elliott, 2004). In these new areas, islands could develop through heavy sedimentation of material transported from the river catchment areas. In addition, sediment from the sea, the coastal environment and erosion of the banks can also play a role in sedimentation processes and the distribution of sediment types in estuaries. Estuaries are further characterized by salinity fluctuations and gradients, where sea water and river water meet, as well as tidal and turbidity (suspended matter, flocculation) fluctuations and gradients. Coarse-grained sediment is deposited as bars near the mouth of the estuary, while finer-grained sediment penetrates upstream (Viles and Spencer, 1995). These processes originally led to ecologically valuable pristine estuarine wetlands developing as dynamically functioning ecosystems with high biodiversity and production (Barnes, 1974).

Estuaries have long been used by humans for various purposes. In the Netherlands, for example, the use of estuaries went through several phases in historical times (de Jonge, 2009). First people settled on the higher parts of the estuary, as there was less risk of flooding there, and they also built artificial dwelling mounds or terps to protect their homes against storm surges. The next step was to stabilize water courses by means of dikes or levees to protect homesteads and land against flooding. The next phase saw salt marshes as well as freshwater marshes being reclaimed and converted into polders for use as agricultural land. Later on, structures were built to prevent erosion of the littoral borders and the harbours and industrial sites, and further land reclamation followed. Harbours were made more accessible by dredging the water courses to deepen them. The consequences of this dredging activity have been widely studied, for example in the Ems (de Jonge, 1983, 2000; Schuttelaars et al., 2013; de Jonge and de Jong, 2002) and Elbe estuaries (ARGE-ELBE, 2001; Fickert and Strotmann, 2007). The most recent phase has featured the creation of artificial sandy plains outside the former estuaries to enable the construction of marine harbours which can receive the largest ships.

Coastal and estuarine wetlands in North West Europe were settled by humans during the Neolithic Age. Major land management interventions such as ditched drainage systems and reclamation of salt marshes started during the Roman era (Rippon, 2000; Healy and Hickey, 2002) in particular in the south of Great Britain and the Netherlands. Systematic reclamation by means of embankment, resulting in large-scale loss of coastal and estuarine habitats, started in the 12th century (Wolff, 1992, 1993; Rippon, 2000) and continued until the second half of the 20th century. Airoidi and Beck (2007) give a comprehensive overview of the historical development of coastal wetlands in Europe, and they estimate an overall loss of more than 50% of the original surface area, with peak losses of over 80% in many regions. They estimated that between 1960 and 1995, one kilometre of European coastline a day was developed for human purposes alone. Land reclamation and dredging are considered to be more destructive to the estuarine ecosystem than the input and discharge of pollutants, as they lead to the disappearance of

vital sedimentary habitats by coastal squeeze and changes in the hydrodynamic situation and associated sedimentation patterns (Doody, 2004; Hughes and Paramor, 2004; McLusky and Elliott, 2004).

1.2. Losses of estuarine ecotopes in the Netherlands

Large areas of moorland, swamp forest and salt marsh were reclaimed in the Netherlands between the 12th century and the second half of the 20th century (Wolff, 1993). The world's largest intertidal system, the "Wadden Sea" (Waddenzee in Dutch), which stretches along the coasts of the northern Netherlands, northwest Germany and west Denmark, has frequently been altered by humans since its origin 7 500 years ago. The large-scale habitat transformations over the last 1 000 years have had a major impact on its functioning as an ecosystem (Lotze et al., 2005), and during the last century in particular, human exploitation has transformed the intertidal areas from an internally regulated and spatially heterogeneous system to an externally regulated and spatially homogenous system (Eriksson et al., 2010).

Two projects carried out in the Netherlands during the 20th century greatly reduced the size of the Rhine-Meuse estuary. The damming of the large northern inlet formerly known as the Zuiderzee (Fig. 1) was decided upon after a storm surge in 1916 had breached many dikes and inundated large areas around its shores (de Jonge, 2009). The 30 km long dike separating the Zuiderzee from the Wadden Sea was completed in 1932, and changed a 3 700 km² estuarine area into a freshwater lake (de Jonge & de Jong, 1992). After the 1953 storm surge, which breached the dikes in 89 places in the south-west of the Netherlands, with the loss of 1836 lives, a huge flood protection scheme known as the Delta Project was proposed in the Delta Act, which was adopted by the lower chamber of the Dutch Parliament in 1957 and by the upper chamber in 1958 (Stuvel, 1956, 1961). The implementation of the Delta Project shortened the coastline by 700 km and resulted in the closure of most of the inlets of the Rhine-Meuse estuary by means of dams and sluices, and in the case of the Eastern Scheldt inlet and the Nieuwe Waterweg canal, by means of a storm surge barrier. An area of 890 km², comprising deep tidal water (446 km²), shallow water (97 km²), sand and mud flats (188 km²), salt and brackish marshes (94 km²), extensive reed and rush beds (40 km²) and tidal willow coppices (tidal forest) (25 km²) was lost or no longer part of the estuary (Wolff, 1992; Eertman, 1997; Paalvast et al., 1998a,b). If these numbers are added to the losses due to land reclamation (3 500 km²) over the last 1 000 years before the Delta Project, the total loss of estuarine ecotopes in the 5 300 km² Delta Area is 83%, including the Western Scheldt inlet which was not closed. In 2011, less than 7% of the total area of the Rhine-Meuse estuary was left, relative to the 1950 situation. As entrances to the harbours of Antwerp and Rotterdam, the Western Scheldt inlet and Nieuwe Waterweg canal remained open, and only these waterways can be regarded as estuaries nowadays. From 1970, the Nieuwe Waterweg canal (excavated in the second half of the 19th century) was the only open connection left between the North Sea and the catchment areas of the rivers Rhine and Meuse.

1.3. Historical flood defence systems

The first dikes were protected against wave attack by rows of wooden piles (open-pile permeable groyne), which continued to be used until the years 1731/32, which saw massive destruction of the piles by the shipworm *Teredo navalis* (Vrolijk et al., 1860). This

Download English Version:

<https://daneshyari.com/en/article/8061554>

Download Persian Version:

<https://daneshyari.com/article/8061554>

[Daneshyari.com](https://daneshyari.com)