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"Make me a willow cabin at your gate": Legislation and implementation of tidal forest restoration at estuarine upstream sites

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ABSTRACT

The restoration of estuarine habitats provides diverse ecological functions and services, e.g., vegetated foreshores reduce current speeds and attenuate waves and may enhance nursery grounds for fish and other estuarine organisms and estuarine water purification. A set of legislation regulates the conservation, usage and restoration of European estuaries. The European Habitats Directive (HD) protects biodiversity on species and habitats level and today most of the European estuaries are designated as protected Natura 2000 sites. In tidal freshwater wetlands at locations of large ports (e.g., Antwerp, Hamburg, London, Rotterdam) integrative management to maintain natural structures paralleled by ecosystem restoration with respect to flood risk reduction and harbour activities is challenging. This led to the Hamburg strategy for improving the conservation status under the HD and measures are implemented along the Elbe estuary. Alluvial forests listed as priority habitats (HD annex I) are fragmented, and tidal softwood forests comprising willows must be restored. In our case study, autochthones plant material was collected and cultivated, and used for initial plantings on a former floodplain meadow. Two years after planting, the basket, crack and purple willow reached heights of 3 m and more, whereas the number of white and almond willows was largely decreased, and numerous willows were affected by competing herbaceous vegetation. The careful selection of restoration sites including ecological hydrology providing bar ground for less competitive willows combined with the use of acclimated autochthonous *Salix* may enhance the restoration success of tidal floodplain forests at estuarine upstream sites.

1. Introduction

Members of the *Salicaceae* plant family have provided multiple values for civilisations for millennia. Light-weight woven willow baskets for gathering food and storing supplies made them one of the first manufactured articles (Kuzovkina et al., 2008). During the Elizabethan era the playwright Shakespeare (1601/1602) in "Twelfth night, or what you will" let Viola answer "make me a willow cabin at your gate …" to create an arbour for protection and room for retreat. Today, these trees and shrubs benefit societies in the rehabilitation of degraded land, restoration of forests, bioenergy production and mitigation of climate change (Isebrands and Richardson, 2014). Plantations have been extensively applied as windbreaks and shelterbelts, e.g. in North American Prairie Province's shelterbelt programs, in the Chinese Three North Shelterbelt program with more than 20 million ha *Salicaceae* plantations (Carle and Ma, 2005). Borsje et al. (2011) proposed to build willow floodplains to reduce wave overtopping of dykes on the large scale in an ecosystem approach.

Building with Nature (BwN) is an innovative approach to infrastructural demands by making optimum use of natural ecosystem functions. Natural systems sustainability and adaptability are important attributes in times of rapid societal and environmental change. Hydraulic infrastructure development and operation in the BwN approach include natural components to achieve adaptability to changing environmental conditions and to reach societal demands (de Vriend et al., 2014). To make optimum use and moreover create new opportunities, BwN measurements shall be evolved and applied via exchange among experts, problem owners and with the participation of the stakeholders (Temmerman and Kirwan, 2015). Facilitating coastal protection by using species that trap sediment and damp waves (e.g. oyster beds, mussel beds, willow floodplains and marram grass) (Borsje et al., 2011) is an example of BwN in hydraulic engineering. Species known for their capacity to modify their physical environment and its abiotic and biotic conditions by their structure and activity are called ecosystem engineering species (EES) (e.g. Jones et al., 1994). In the intertidal, reef-building bivalve species reduce current velocities and damp waves and thereby trap sediment (e.g. van Leeuwen et al., 2010). In salt marshes, EES plants serve in coastal protection by wave

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reduction on a landscape scale (Möller et al., 2015). Hydrological models showed the resilience of mangroves to catastrophic disturbance and reduced 90% in tsunami wave flow pressure for a 100-m wide tropical forest belt (Alongi, 2008). In a review on the value of estuarine and coastal ecosystem services (Barbier et a. 2011), marshes, mangroves, nearshore reefs, seagrass beds, sand beaches and dunes were all included, but not willow floodplains forests. However, willow floodplains reduced the overtopping of dykes at Norwaard polder close to the tidal freshwater wetlands of the National Park De Biesbosch, NL. White willows (*Salix alba*) served as EES due to the ability to grow during flooding periods, resistance to extreme storms and high resprouting capacity in an innovative dyke scheme that combines lowered height of the dyke and construction costs with maintaining landscape attractiveness and conservation value (Borsje et al., 2011). Although in western Europe and eastern North America tidal freshwater wetlands were historically locations of huge human settlements and large ports (Antwerp, Hamburg, London, New Orleans and Washington DC) these locations have experienced less attention compared to mangroves and salt marshes (Baldwin et al., 2009). Large tidal freshwater wetlands are restricted to lowland estuaries (e.g. Chesapeake Bay, Elbe, Scheldt, Thames) in former river valleys (McLusky and Elliott, 2004), large river mouths in microtidal environments (e.g. Mississippi), or „tidal river estuaries“ with high discharge and low salt water intrusion (e.g. Amazon, Rio de la Plata).

The estuarine management to maintain natural structures and functions paralleled by restoring degraded habitats with respect to both ecological and socio-economic needs is challenging (Boerema and Meire, 2016; Bouma et al., 2013; Elliott et al., 2016). Estuaries at the interface among riverine and marine ecosystems are closely linked to major population centres, and as such vulnerable to anthropogenic induced hazards (Lotze et al., 2006; Barbier et al., 2011) and hazards due to both extreme events and climate change (Jennerjahn and Mitchell, 2013). More than a dozen types of natural up to anthropogenic hazards to the estuarine environment are detailed by Elliott et al. (2014) including concerns regarding engineering to protect the coastline against these hazards which may result in a degraded ecosystem contravening nature conservation laws. Jennerjahn and Mitchell (2013) highlight in their syntheses on „Pressures, stresses, shocks and trends in estuarine ecosystems" the necessity to manage estuarine ecosystem recovery being beneficial for the ecosystem as well as for the stakeholders. Solutions to protect and create valuable wetland habitats, e.g. via measures like plantings to form sediment traps or controlled flooded areas are proposed (Temmerman et al., 2013).

Measures within estuarine and coastal systems have to be conform with the sets of European legislation, including the Floods Directive (Floods Directive, 2007; 2007/60/EC) as a framework to reduce negative consequences of flooding on the human population, and the Water Framework Directive (WFD; 2000/60/EC) that firstly defines quality by using several biological elements together with physical-chemical elements to access good ecological status at the ecosystem level. However, the WFD is limited for coastal water extending up to the outer limit of transitional waters and covers only a limited part of the European marine waters (Borja, 2005). In 2008, the Marine Strategy Framework Directive (MSFD, Directive, 2008/56/EC) was approved for protecting preserving and restoring the quality of the marine environment across Europe. However, the MSFD generally does not cover transitional waters (Boyes et al., 2016) and thus is not applicable to the estuarine environment. Apart from the aforementioned, the European Habitats Directive (European Habitats Directive, 1992; 92/43/EEC) and Wild Birds Directive (BD; 2009/147/EC) aim to protect biodiversity on both the species and habitats level. Most of the European estuaries are designated as Natura 2000 sites, a legally binding system of protected areas in EU member states. Within Natura 2000 sites both habitat types (HD annex I) and species (HD annex II; BD Annex I; migrating bird species in important wetlands Art. 4, Parag. 2 BD) are listed, for which the conservation and restoration of a good conservation status are

Fig. 1. Highly altered Elbe estuary in the state of Hamburg/GER with fragmented protected habitat types according to the Habitats Directive.

intended). Estuaries as a whole are protected (habitat type 1130) and tidal freshwater stretches may be facultatively designated as habitat type 1130 (EU-Interpretation-Manual). According to the HD, an estuary (1130) is a complex habitat, which may contain further habitat types such as Mudflats and sandflats (1140), Atlantic salt meadows (1330), Inland dunes with open grasslands (2330), Alluvial forests (91EO), Hardwood alluvial forests (91F0) and others. Furthermore, an estuary is representing an important habitat for species listed in the HD (e.g. twaite shad and harbour porpoise) and species listed in the BD (e.g. common tern and redshank) as well as for endemic species (e.g. *Oenanthe conioides* in tidal freshwater wetlands along the Elbe estuary).

Along the Elbe, the whole estuarine stretch except the Hamburg harbour and other industrial sites are protected via the Natura-2000 network (Fig. 1). Impact assessments regarding the conservation objectives must be carried out for planning's which may affect a Natura 2000 site considerably, (Article 6, Parag. 3 HD). For each Natura 2000 site management plans must be set up (Article 6, Parag. 1 HD), the conservation status of habitats and species must be monitored (Article 11 HD), and a report regarding significant measures and results has to be submitted to the EU-Commission every 6 years (Article 17 HD). Although the macrotidal Elbe along with the Scheldt estuary is drastically changed due to human impact both still comprise the main tidal freshwater wetlands at estuarine upstream sites in Europe (Struyf et al., 2009). However, according to the third National Report of the EU Habitats Directive for the period 2007–2012 most of the habitats and species are assessed as being in an unfavourable conservation status in Germany (Ellwanger et al., 2014). Thus, for many of the European habitats and species the restoration of a good conservation status is indicated, which also applies to the European protected habitats and species along the Elbe estuary.

Eleven habitat types listed in annex I (HD) are an integral part of the estuarine ecosystem for which conservation objectives are mandatory. The Hamburg Ministry of Environment and Energy developed a Fauna-Flora-Habitats-Strategy (FFH-Strategy) to restore the favourable conservation status of habitats in Hamburg according to the HD directive (FFH-Strategie, 2015; http://www.hamburg.de/ffh-strategie/) including a methodology of habitat profiles and measures (Michalczyk et al., 2016). The measures to improve the conservation status of habitats along the Elbe estuary are determined in the Integrated Management Plan for the Elbe estuary which is legally based on the HD and BD (Integrated Management Plan for the Elbe Estuary, 2012; http://www.natura2000-unterelbe.de/links-Gesamtplan.php). The IBP is consent of the neighbouring federal states, the Federal Administration for Waterways and Navigation and the Hamburg Port Authority and was developed in participation with stakeholders. Tidal forests, categorized as alluvial forests 91E0 (HD), are target habitats (*Salician albae*) due to their specific characteristics in the estuarine environment. At estuarine upstream sites in the state of Hamburg, these habitats are generally assessed as in bad conservation status due to fragmentation, change of floodplain hydrology, morphology and land use, and immigration of invasive species. Concrete measures to improve the conservation status are determined in the FFH-Strategy: Tidal softwood forest will be restored via succession on estuarine islands in the area Mühlenberger Loch/Neβsand (1), and habitat restoration via extension of foreland by