# Regulation of reed (*Phragmites australis*) by water buffalo grazing: use in coastal conservation

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## SUMMARY

Despite the beneficial effects of reeds on abiotic environmental resources (by trapping sediments) their tendency to form near-monocultures with only a small number of accompanying species limits biodiversity at the landscape scale. This is a problem in some habitats such as coastal saltmarsh grasslands which have the potential to host a range of rare species. To understand the influence of differing grazing regimes, we investigated the distribution of reed stands and of competing saltmarsh grassland on a 28 ha coastal island in the southern Baltic Sea. The water is brackish, and since 1989 the vegetation has been grazed by changing varieties and ages of cattle. Some changes in the distribution of *Phragmites* stands and saltmarsh grassland resulted from differences in grazing intensity, but the age and variety of cattle had little effect. In 2010 grazing by water buffalo at moderate stocking density was introduced. Reed stands diminished and saltmarsh grassland increased. This management has the potential to balance the conservation needs of birds (reduced nest losses from trampling) against those of vegetation.

**KEY WORDS:** phytodiversity; preservation of landscape; reed encroachment; wetland grazing

## INTRODUCTION

Reed stands are a usual stage in the natural succession of brackish coastal lagoons in the southern Baltic (Jeschke 1987). They have various important beneficial effects for wetland ecosystems (Venterink *et al.* 2002, Rejmánková 2011).

Under continuous grazing, reed stands are replaced by grazing-tolerant saltmarsh plants and undergo a shift towards the short saltmarsh grassland vegetation (Jeschke 1987, Bernhardt & Koch 2003) that is listed in Natura 2000 guidelines (Code 1330, Atlantic Salt Meadows) as worthy of protection. As well as being of botanical interest, short saltmarsh grassland vegetation has high potential for hosting ground-nesting birds, whose numbers have declined over recent decades (Thorup 2006). Furthermore, continuous grazing is a prerequisite for development of "Salzwiesentorf" (salt marsh peat), a typical coastal peat substrate in the southern Baltic. Unlike reed belts, salt meadow systems are able to accumulate peat until they are above the mean water level and, therefore, have the potential to sequester large amounts of carbon (Jeschke 1987, Ford *et al.* 2012). If continuous grazing ceases, however, short saltmarsh grassland vegetation is quickly overgrown by reed (Burnside *et al.* 2007). This re-encroachment results in a loss of biodiversity (Esselink *et al.* 2000, Burnside *et al.* 2007, Wanner 2009) and a loss of habitat function (Rannap *et al.* 2004). Controlling reed mechanically is expensive (Chambers *et al.* 1999) and in some cases, as at our study area, is not technically feasible. For this reason, grazing is often re-introduced where short saltmarsh grassland has previously been abandoned, but common cattle are successful at keeping reeds back only when grazing pressure is high (Vulink *et al.* 2000). On the other hand, high grazing pressure may threaten the nesting success of waders (Müller *et al.* 2007). Grazing pressure, which is determined mainly by stocking density, is limited by nature conservation restrictions (Oppermann & Luick 1999).

A possible remedy is to replace cattle with different grazing animals. In Germany, attention has recently turned to the water buffalo whose hooves and grazing behaviour in their native wetland habitat seem ideally suited to conservation (Georgoudis *et al.* 1999, Wiegleb & Krawczynski 2010, Wichtmann 2011, Sweers *et al.* 2013).

The aim of this study was to evaluate the potential of water buffalo grazing as a remedy for reed encroachment onto saltmarsh grassland in the southern Baltic region.


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## METHODS

### Site description

The coastal tidal island "Schmidts-Bülten" is part of the National Park "Vorpommersche Boddenlandschaft" and is situated in the "Bodstedter Bodden", a brackish coastal lagoon in the southern Baltic region 60 km north-east of Rostock (Mecklenburg - Western Pomerania, northern Germany; 54° 25′ N, 12° 38′ E, Figure 1). Meteorological data were obtained from two weather stations operated by the German Weather Service. The nearest weather station for precipitation is in the town of Zingst (4 km to the east), while the nearest location for temperature recordings is in the town of Barth (10 km to the south-east). Figure 2 shows a composite climate diagram for the period 1988 to 2012, made with R package "Climatol" (Guijarro 2011, R Development Core Team 2011). The mean annual air temperature is 9.0 °C and mean annual precipitation is 611 mm (German Weather Service 2012).

The study island, which currently extends to 28 ha, was originally part of a group of three islands that originated from sediment deposition caused by the inverted delta formation of the stream "Prerower Strom" (Jeschke & Lange 1992). The north-eastern island was dyked and has since been used for intensive grassland farming. The remaining two islands were joined together with material that accrued from suction dredging to preserve the shipping channel through the "Prerower-Strom". Dredged material was last dumped in the small southern bay of the island in 1988. This most recent dumping area is also the highest part of the island. The subsoil consists of sand that has washed ashore, and silt. Most parts of the island lie less than 30 cm above the mean water level, and no point in the whole area is more than 70 cm above mean sea level. The mean (1990–2010) high tide of the Bodstedter Bodden is 49 cm (Water- and Shipping Department Stralsund 2012), so most of the island is periodically inundated, mostly during the months of September to March. The brackish water is oligohaline with a concentration of 4.5 Practical Salt Units (PSU), while the salinity of the southern Baltic is 10.1 PSU at the inflow of the lagoon (Schubert *et al.* 2003).

Adjacent to the "artificial" mineral core of the island, areas of organic subsoil can be found. Because their hydrology is dominated by inundation, these areas form an inundation mire (Joosten & Succow 2001). The subsoil layer is a mosaic of "Salzwiesentorf" (salt marsh peat) and

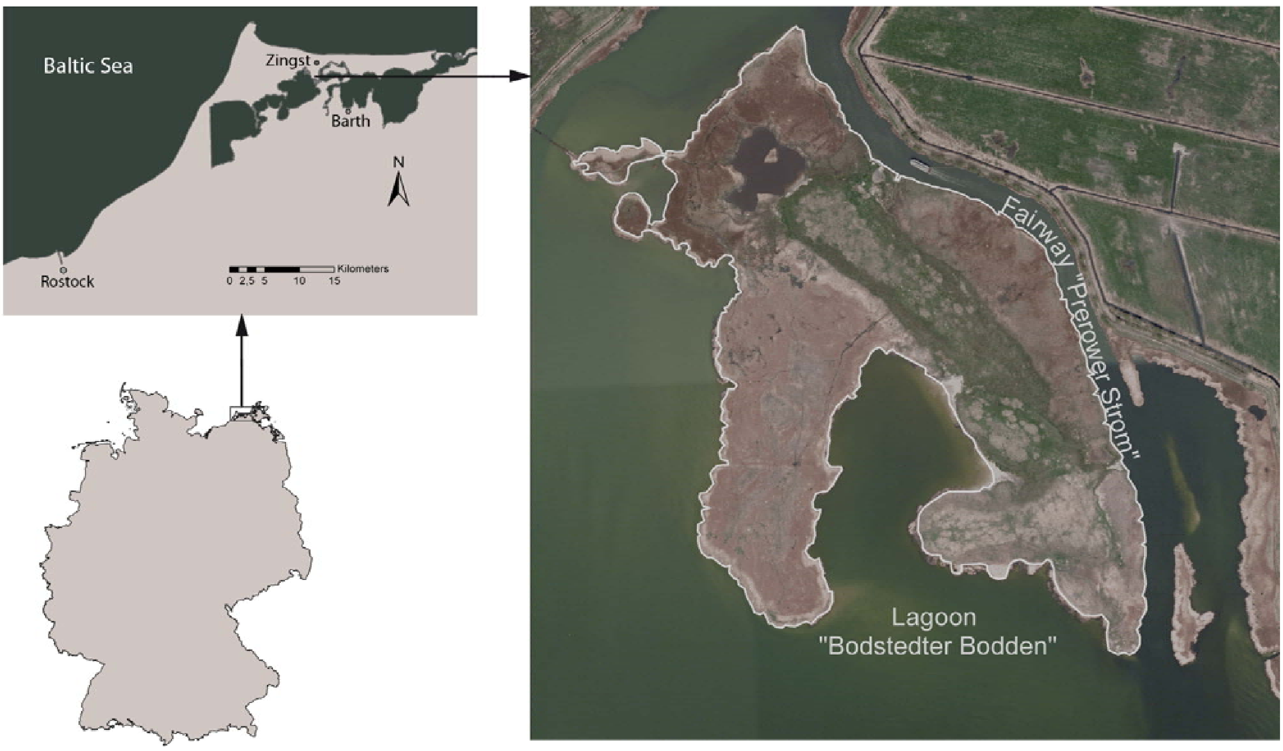


Figure 1. Location of the study site "Schmidts-Bülten" in the southern Baltic Sea. Lower left: position in Germany. Upper left: position inside the lagoon "Darß-Zingster Boddenkette". Right: aerial photograph of the island "Schmidts-Bülten".


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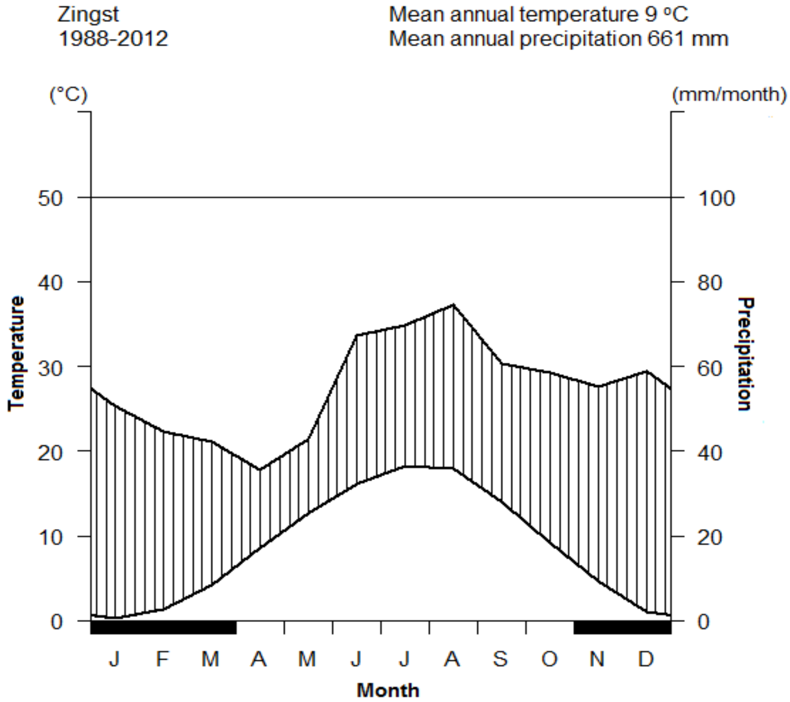


Figure 2. Walter climate diagram for the study site "Schmidts-Bülten" in the southern Baltic Sea, constructed from weather data collected in the nearby towns of Zingst (4 km to the east) and Barth (10 km to the south-east). The lower and upper curves represent temperature data from Barth (°C) and precipitation data from Zingst (mm), respectively. Frost days are indicated below the zero line (white: no frost days; black: more than ten frost days per month).

Table 1. Summary of land use history on the island Schmidts-Bülten in the southern Baltic from 1978 to 2012, listing periods with different kinds and ages of grazing animals from 1989 to 2012. LU = Livestock Unit. Grazing intensity is represented by 'Stocking density LU $ha^{-1}$', and intensity of grazing season by 'Grazing days LU $ha^{-1}$ $y^{-1}$'.

| Grazing period | Kind of animal | Stocking density LU $ha^{-1}$ | Grazing days LU $ha^{-1}$ $y^{-1}$ |
|---|---|---|---|
| 1978–1988 | Abandoned | - | - |
| 1989–1993 | Heifer | 2.0 | nearly 320 |
| 1994–2002 | Fattening cow | 1.4 | nearly 224 |
| 14/05–26/09/2003 | Suckling cow | 1.4 | 189 |
| 06/05–24/10/2004 | Suckling cow | 1.1 | 188 |
| 20/05–26/09/2005 | Suckling cow | 0.6 | 77 |
| 18/05–24/10/2006 | Highland cattle | 0.6 | 95 |
| 16/06–26/10/2007 | Highland cattle | 0.7 | 92 |
| 19/05–30/11/2008 | Highland cattle | 0.6 | 117 |
| 14/05–25/09/2009 | Suckling cow | 0.4 | 54 |
| 14/06–15/10/2010 | Water buffalo | 1.0 | 123 |
| 16/05–11/10/2011 | Water buffalo | 1.3 | 192 |
| 04/05–05/10/2012 | Water buffalo | 1.0 | 155 |


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reed peat (Paulson & Raskin 1994). For an unrecorded number of decades prior to 1978, the island was grazed almost continually in summer. In 1978 it was abandoned for ten years, which resulted in severe reed encroachment. After this, the island was grazed intensively by heifers at a stocking rate of two livestock units per ha (LU $ha^{-1}$) from May to October each year from 1989 to 1993. This was followed (until 2002) by stocking with fattening cows at a rate of 1.4 LU $ha^{-1}$ (Table 1). In 2003, 2004 and 2005 the island was grazed by suckling cows at rates of 1.4, 1.1, and 0.6 LU $ha^{-1}$, respectively. Between 2005 and 2008 the usual suckling cows (Fleckvieh cattle × Limousin) were replaced with Highland cattle (expected to thrive on low-quality forage, Matthes *et al.* 1991) and the island was predominantly grazed at only 0.6 LU $ha^{-1}$. The following year it was again grazed at 0.6 LU $ha^{-1}$, but this time by suckling cows.

As a result of the severe reed encroachment that followed these treatments, parts of the island lost their status as actively managed agricultural areas, and with it their entitlement to EU subsidies. Furthermore, the National Park Authority had made a vegetation survey of 24 plots on the island in August 1993 (Paulson & Raskin 1994) and now insisted that, for conservation reasons (National Park Authority 2002), reed encroachment should be returned to that previous state. Therefore, in 2010, the farmer intensified grazing to 1.0–1.3 LU $ha^{-1}$ and replaced the suckling cows with water buffalo, again grazing seasonally from May to October. This practice has continued until the present day (2013).

## METHODS

In October 2011 and 2012 we recorded reed distribution on the island by ground survey using a D-GPS device (Leica GX 1230). We also used aerial photography to reconstruct changes in reed distribution over the period investigated. From these data, the reed area disturbed by the water buffalo was calculated using ArcGIS 10.

We created a reed encroachment index (REI) to merge the information about reed-covered area with the observed characteristics of the reed stands:

$$REI = \frac{(0.8 \times t) + (0.6 \times i) + (0.4 \times s) + (0.2 \times d)}{A_t} \times 100$$

where $t$ = tall stand area; $i$ = intermediate stand area; $s$ = short stature area; $d$ = disturbed stand area; and $A_t$ is the total area of reed.

We also resurveyed (in August 2012) the 24 vegetation plots recorded by Paulson & Raskin (1994), relocated from their map. Species composition was determined at each plot as percentage cover values in 5 × 5 m squares. Paulson & Raskin (1994) recorded on the Braun Blanquet scale, and their data were transformed to cover (%) using Jurasinski's (2012) factors (r=0.1 %; +=1 %; 1=5 %; 2= 15 %; 3=37.5 %; 4=62.5 %; 5= 87.5 %).

## RESULTS

### Patterns of reed distribution

In 1993 distinct reed stands were located in various places, mainly on the margins of the island (Figure 3). Nevertheless, reed could be found as a sparsely distributed short form in all areas of the island. In 2005 aerial photography showed dense reed stands in the northern part and on the south-western promontory of the island (Figure 3). The area covered by reed stands had increased from 2.2 ha to 18.4 ha. In 2007 an area of 4.3 ha can be identified as having been mown (Figure 3). Between 2010 and 2012 the water buffalo were able to disturb 7.1 ha of dense reed stand (Figure 3). In the areas that had been disturbed earliest, the reed was approximately 30 cm tall, but was already undergrown by *Agrostis stolonifera* and *Juncus gerardii*. In the following year these areas were grazed again, resulting in the development of short vegetation.

### Development in species composition

Between 1993 and 2012, the greatest increase in cover on the 24 plots was found for *Phragmites australis*. Cover of *Juncus gerardii* and *Trifolium repens* also increased (Figure 4). On the other hand, cover of *Elymus repens*, *Puccinellia maritima* and *Puccinellia distans* decreased by more than 5 %.

### Type of grazing animal and change in reed encroachment

We assessed the effect of the type of grazing animal on the annual change in reed stand area (Figure 5). The 'basic line' indicates no annual change in reed area and vitality, as expressed by the REI. The use of suckling cows at a medium stocking rate even resulted in an increase of the REI. The change to Highland cattle in combination with a decreased stocking rate had little potential to reverse reed encroachment. On the other hand, grazing by water buffalo at moderate livestock densities was found to reduce the area occupied by *Phragmites australis*.


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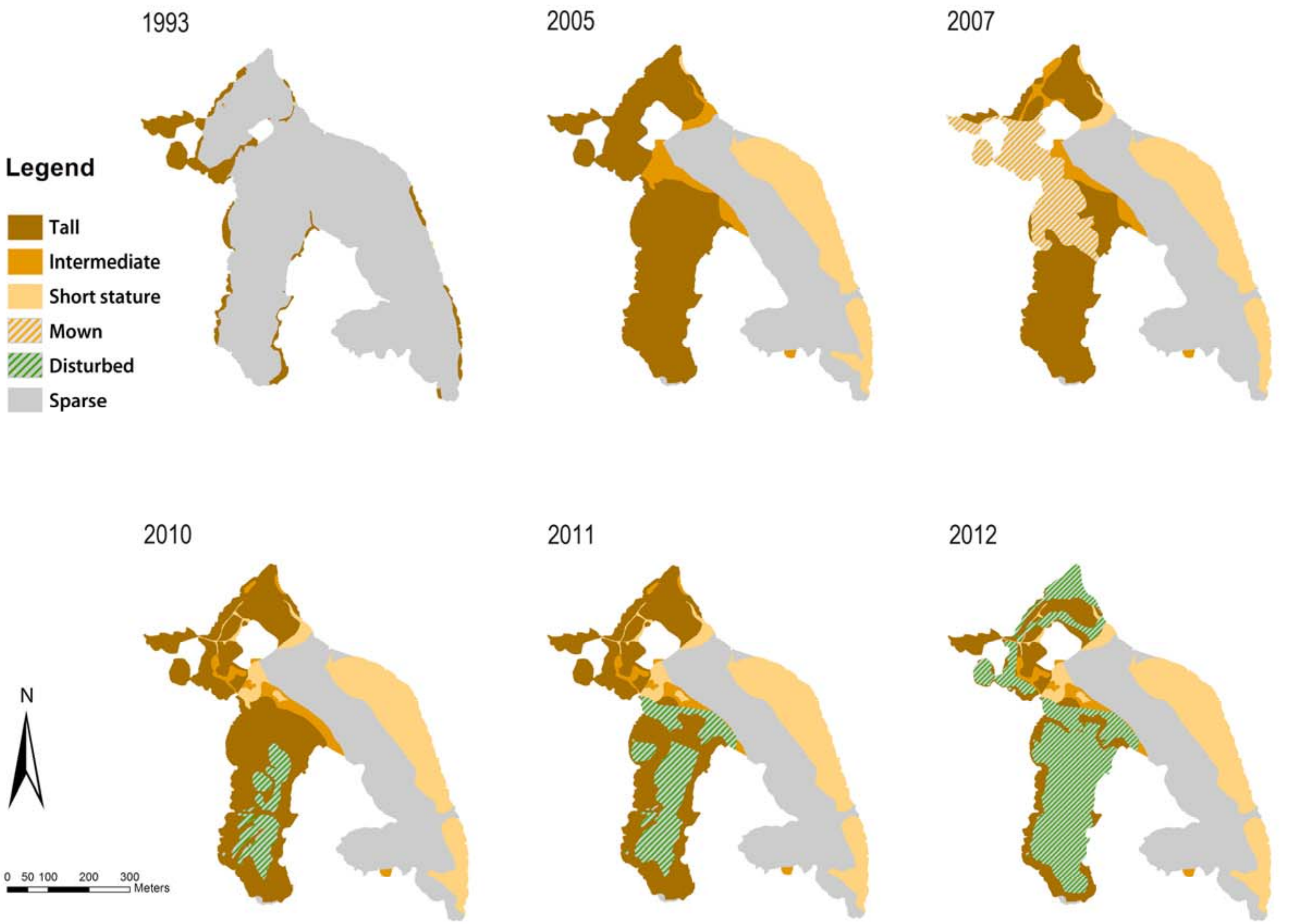


Figure 3. Reed distribution over the period 1993–2012. 1993 data based on the vegetation survey by Paulson & Raskin (1994). Data for 2005, 2007 and 2010 inferred from aerial photography. Data for 2011 and 2012 measured with D-GPS. Tall = man-height; Intermediate = waist-high; Short stature = ankle-high; Mown = hand-mown; Disturbed = trampled down; Sparse = infrequent shoots.


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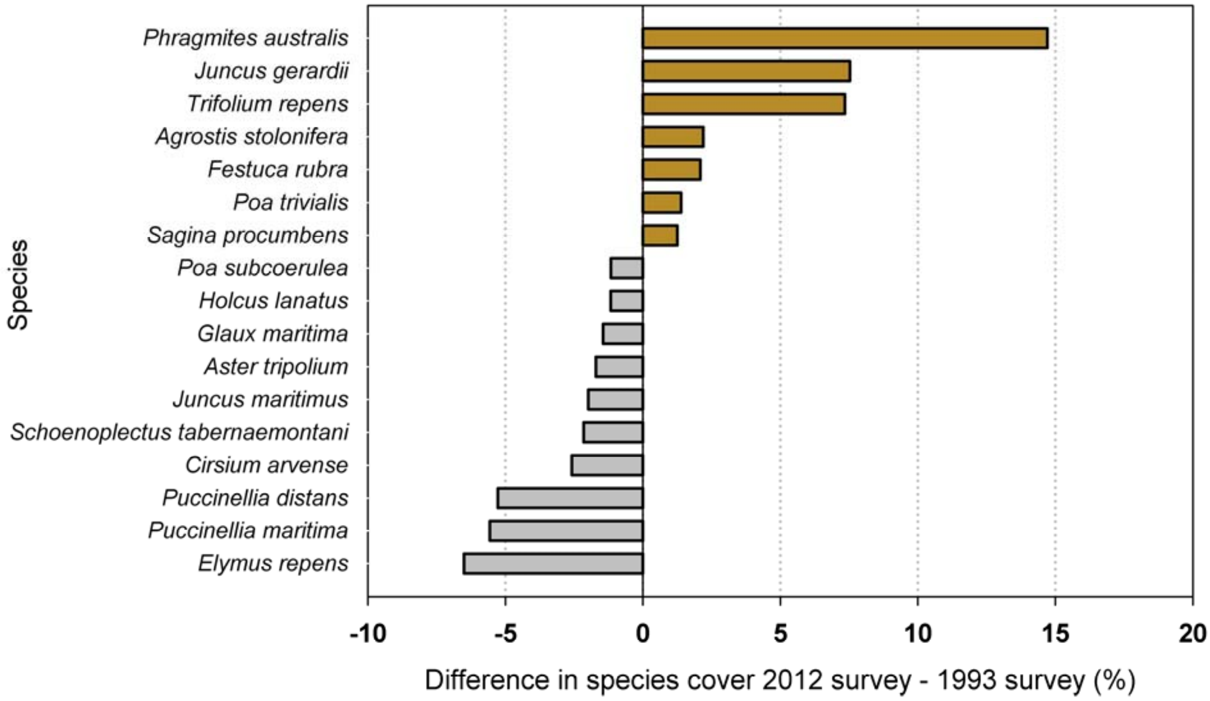


Figure 4. Changes in cover of plant species on plots at Schmidts-Bülten, between surveys carried out in 1993 (Paulson & Raskin 1994) and 2012. On the y axis: species; on the x axis: difference in % cover (2012 - 1993), mean of 24 plots. Grey colour: species cover decreased from 1993 to 2012; ochre colour: species cover increased from 1993 to 2012.

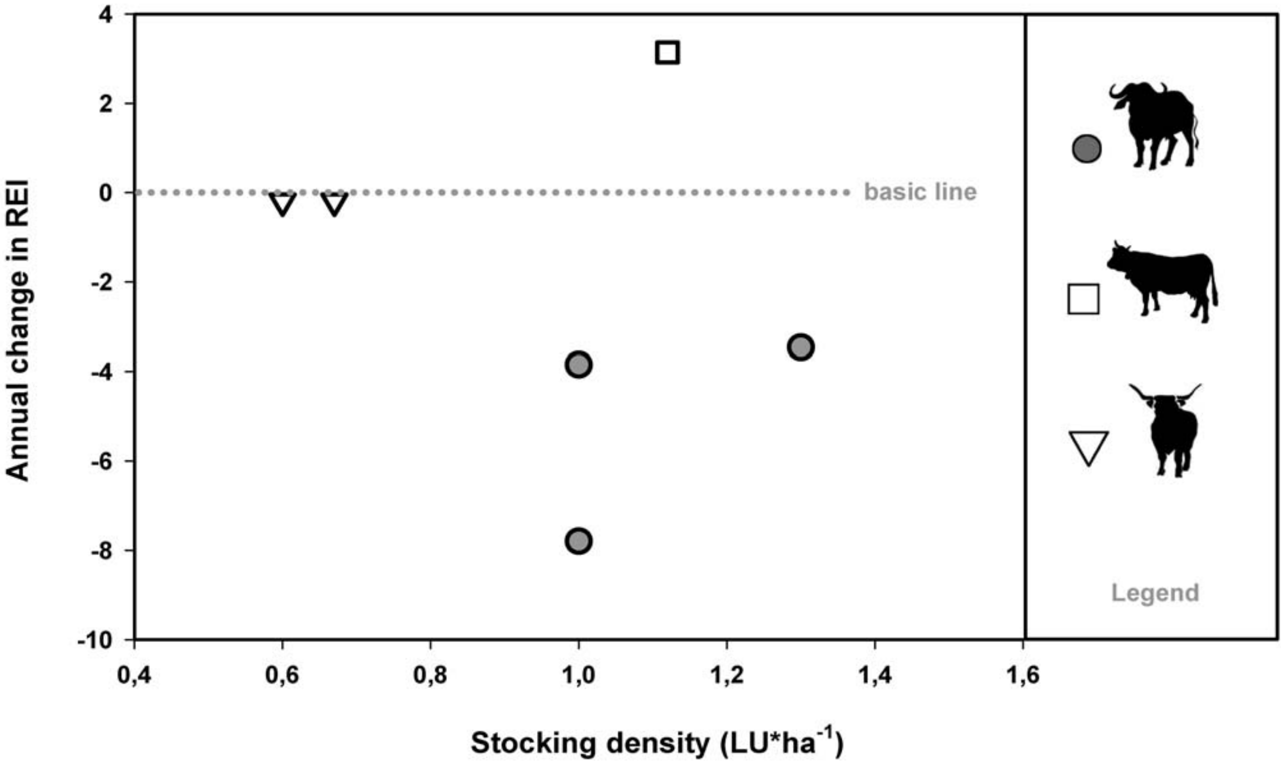


Figure 5. Annual change in reed encroachment index (REI) in relation to stocking density and kind of grazing bovidae (basic line – no annual change in reed area and vitality). Circle = water buffalo; square = suckling cow; triangle = Highland cattle.


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**DISCUSSION**

Grazing has repeatedly been recognised as an indispensible management tool in preserving the multiple ecological functions of saltmarsh grasslands in the southern Baltic region (Jeschke 1987, Jutila 2001, Bernhardt & Koch 2003, Burnside *et al.* 2007, Wanner 2009, Sammul *et al.* 2012). However, a balance has to be struck between the ability of reed to rapidly re-encroach on wetland areas (Haslam 1972) and the fact that other aspects of nature conservation call for cattle stocking densities and grazing intensities to be restricted (Müller *et al.* 2006, Pakanen *et al.* 2011).

In 1993, at the beginning of the investigated period, reed distribution was concentrated on the margins of the island. However, Paulson & Raskin (1994) reported that reed was present in a short form all over the island. This form might be attributable to the period of intensive grazing (2 LU $ha^{-1}$) from 1989 to 1993. In 1988 the whole island was documented as covered by reed. During the period 1994–2004, the island was grazed at the reduced stocking rate of 1.4 LU $ha^{-1}$, which by 2005 had led to distinct reed encroachment in the northern part and on the south-western promontory of the island. In 2007 an attempt to mow part of the island as a first step towards controlling reed encroachment failed. A regime of mowing or burning in winter and grazing in spring was also suggested by Rannap *et al*. (2004). After the mowing or burning, young reed shoots which have very good fodder values (Duncan & D´Herbes 1982) emerge and are grazed by cattle (Haslam 1972, van Deursen & Drost 1990). In our case, however, this effect was not seen owing to the low stocking density in 2008. Fresh fodder from plant species that are more attractive to grazing animals (*Lolium perenne*, *Trifolium repens*) is available on the higher areas of the island, especially in spring. After the introduction of water buffalo as grazing animals, a total reed area of 1.8 ha was disturbed in 2010. These disturbed areas have the potential for transformation into short saltmarsh grassland. The process of transition can be described in two steps. Firstly, the animals walk paths through the dense reed stands, and at the margins of these paths gaps are created. The gaps permit the growth of an understorey of *Agrostis stolonifera* and *Juncus gerardii*. In the following year, these grazing-resistant plants and the young shoots of the previously trampled reed are grazed again. This process is repeated on adjacent areas, and the transition area grows. A similar process of reed transition is described by Vulink *et al.* (2000), where *Poa trivialis* formed the understorey. The trampling of the animals, as they move through the reeds and browse young shoots, suppresses the vigour of the plants by damaging the upper rhizome (Haslam 1972, confirmed by Vulink *et al.* 2000).

Changes in the pattern of species composition underline the fact that previous grazing activities took place mainly on the higher areas of the island. Areas where *Phragmites australis* cover increased were under-used, while in intensively used sub-areas the grazing-sensitive *Elymus repens* (Bauer 1989) decreased and the grazing-resistant and light-demanding *Trifolium repens* increased (Frame *et al.* 1998). The same pattern of palatability-related grazing pressure on inhomogeneous vegetation was reported by Köster *et al.* (2004) for an area of coastal saltmarsh grassland in Estonia.

As the development of the reed encroachment index (REI) demonstrates, water buffalo reduced the area covered by reed each year (Figure 5) even at a medium stocking rate of 1 LU $ha^{-1}$, while suckling cows at a comparable stocking rate were not able to prevent reed encroachment. Thus, water buffalo may be able to maintain the habitat function of the island for waders while not excessively endangering nesting success by high stocking density (Pakanen *et al.* 2011). However, when water buffalo grazing started in 2010, reed encroachment was much higher than it was in 1993 (Figure 3). This might explain the intense increase in cover of *Phragmites australis* at the vegetation plot scale indicated by Figure 4, despite the recent effects of water buffalo grazing.

The fact that water buffalo started to transform dense reed stands, at a stocking density similar to or lower than that of the cattle previously used, may confirm their greater attraction to wetland plants as suggested by Georgoudis *et al.* (1999), Wiegleb & Krawczynski (2010) and Wichtmann (2011), and indeed indicates that the natural behaviour of water buffalo makes them particularly suitable for landscape management in saltmarsh grasslands. On stormy or very hot days, both we and the farmer observed that the entire herd would move into the reed belt and stay there for hours.

Other authors report similar success in reed displacement with common cattle at a high grazing intensity (Vulink *et al.* 2000) or in combination with “initial measures” such as mowing or burning (Rannap *et al.* 2004). However, high stocking densities frequently conflict with other principles of nature conservation (Müller *et al.* 2006) and may result in trampling damage or encourage poaching (Trimble & Mendel 1995). The necessary grazing pressure for areas of inhomogeneous vegetation may be achievable only through a stocking density that would be unacceptably high for other nature conservation reasons, and this was probably the case for our study site in 1993.


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Reed stands tend to be situated on bare ground with little understorey vegetation (Haslam 1972), low shear strength and, therefore, low bearing capacity, especially in wet areas. With this in mind, trampling damage during this type of restoration management seems unavoidable, and may have negative consequences for the peat layer. However, if a dense and grazing-resistant sward is established, the bearing capacity may increase sufficiently to minimise trampling damage.

We conclude that water buffalo can potentially reconcile the interests of landscape preservation and avian conservation, given suitable stocking densities and management. Further research should focus on the mechanisms of reed repression by sward-scale interactions between land use and environment. This should create possibilities for further adaptation of the grazing regime to the requirements of nature conservation, whilst ensuring that landscape preservation goals are also met.

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