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Rapid improvement of grey dunes after shallow sod cutting

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Abstract

Grey dunes are an important habitat in Dutch coastal sand dunes, harbouring various Red Data Book flora and fauna species. However, during the last decades, dune grasslands belonging to this habitat have suffered from severe grass encroachment due to prolonged stabilisation, atmospheric pollution, and rabbit decline. In the Amsterdam Water supply Dunes shallow sod cutting was applied in 2002 on a small scale in dune grasslands of the syntaxa Taraxaco-Galietum veri and Phleo-Tortuletum ruraliformis, with high cover of the tall grass species *Calamagrostis epigejos* and *Elytrichia maritima*. In this article, we describe the first results of sod cutting, which was executed in order to recover dune grassland vegetation and the accompanying characteristic fauna species.
Soil and biomass were studied and permanent plots were used for vegetation survey and pellet counting of rabbits. In addition, several insect groups were monitored in pitfalls and plots, and along transects. The dune grasslands of the Taraxaco-Galietum veri show a strong increase of characteristic plant species and a recovery of rabbits, butterflies and grasshoppers. In the dune grasslands of the Phleo-Tortuletum ruraliformis vegetation responds more slowly to sod cutting, probably due to lower nutrient availability. Number of rabbits and the grasshopper *Oedipoda caerulescens* increased as well. The longer-term effects remain to be seen, but the results indicate that a rapid improvement of vegetation and fauna can be reached after shallow sod cutting of grass-encroached grey dunes.

1 Introduction

1.1 Grass encroachment

Until the 1980's large parts of the Dutch coastal sand dunes were covered by dune grasslands, belonging to the Koelerio-Corynephoretea (cf. Weeda et al. 1996). They are part of the grey dunes, which are considered a priority habitat according to the European Habitats Directive (Council of the European Commission 1992). In the last decades, grass encroachment caused fragmentation and a severe decline of the area of grey dunes in most Dutch coastal dune areas. This led to loss of biodiversity (Veer & Kooijman 1997) and a decline of vulnerable and endangered Red Data Book flora and fauna species, such as the plant species *Polygala vulgaris* and *Thymus pulegioides* and the butterfly species *Aricia agestis* and *Issoria lathonia*. They depend on a varied vegetation structure with moss patches and bare sand (Brouwer et al. 2005), and finally disappear due to the expansion of tall grasses.

Grass encroachment in coastal sand dunes in the Netherlands is enhanced by several reasons. Over many decades, site managers used to counteract wind dynamics and stabilised drifting sand and blow-outs by planting marram grass (*Ammophila arenaria*), shrubs, and coniferous forest (Van Til et al. 1999). The outbreak of myxomatosis in the 1950's and 1960's followed by rabbit haemorrhagic disease in the 1990's led to a collapse of the rabbit population. They usually play an important role in the maintenance of a short and open turf in many grasslands of the Koelerio-Corynephoretea (Weeda et al. 1996). Rabbit decline caused a strong decrease of small-scale dynamics in the grey dunes. Furthermore, prolonged high loads of nitrogen in the second half of the 20th Century contributed to growing nutrient availability in the generally poor grassland systems (Bobbink et al. 1998), and led to im-

proved conditions for competitive grass species such as *Calamagrostis epigejos*, *Elytrichia maritima* and *Ammophila arenaria* (Kooijman & Van der Meulen 1996, Kooijman et al. 1998).

In the Amsterdam Water supply Dunes (AWD) along the Dutch mainland coast the area of dune grasslands has decreased substantially since 1980, especially in the middle dunes, which are most sensitive for grass encroachment (Van Breukelen & Van Til 2005, Kooijman & Besse 2002). The effects of several nature conservation measures in dune grasslands were studied, such as mowing and haymaking, top soil removal and extensive cattle and sheep grazing (Veer & Kooijman 1997). However, these management tools do not always seem to contribute to a decline of grass encroachment and an increase in area of dune grassland, or are rather expensive. Mowing and haymaking has to be applied frequently and is a difficult measure in the undulating dune landscape. Top soil removal is an expensive measure, which sometimes promotes scrub expansion, especially of *Hippophaë rhamnoides*. Moreover, a transition in the vegetation structure from open to closed canopy has been determined within the dune grasslands under grazing management in the AWD (Van Breukelen & Van Til 2005). This closed vegetation is probably unfavourable for above-mentioned Red Data Book species.

1.2 Shallow sod cutting

In 2002, we started a research project as part of a nature conservation experiment, which was executed within the framework of the Dutch survival plan for forest and nature and subsidised by the Dutch government. Shallow sod cutting (5 cm top soil), a new measure in coastal sand dunes, was applied on a small scale in about 4 hectares of grass-encroached grey dunes at the locations Rozenwaterveld and 'infiltration area' in the AWD in October 2002. This measure is intermediate between mowing and top soil removal: it might be more sustainable than mowing and is less expensive than top soil removal.

Today, the Rozenwaterveld is, in many places, dominated by the grass *Calamagrostis epigejos* and the dwarf shrub *Rosa pimpinellifolia*. The dune grasslands belong to the Taraxaco-Galietum veri. In the infiltration area *Elytrichia maritima* has increased during the last decades, which caused grass encroachment in dune grasslands of the Phleo-Tortuletum ruraliformis. A monitoring plan was worked out, focussing on the recovery of the dune grassland vegetation and the return of characteristic fauna species.

1.3 Research methods

The research was executed in permanent plots of 6 m^2, in which the effects of sod cutting were studied on soil and biomass in the first year after the measure was applied. Vegetation relevés were made, using Londo's scale for permanent plots (Londo 1975). The development of the vegetation was analysed for structure and for ecological species groups (cf. Van der Meijden et al. 2000) of dune grasslands and ruderal vegetation, which is the result of grass encroachment. Mosses and lichens were added to this list of vascular plants, according to their distinctiveness in a local vegetation typology of the AWD (Van Til & Mourik 1999).

Rabbit (*Oryctolagus cuniculus*) activity was estimated by the amount of pellets produced in the permanent plots in four weeks, which can be used as a measure for the population density (Bankert et al. 2003). Butterflies were only studied at the Rozenwaterveld, as the flower-rich dune grasslands of the Taraxaco-Galietum veri harbour many (Red Data Book) species in comparison with the grasslands of the Phleo-Tortuletum ruraliformis of the infiltration area, which are poor in butterflies. Species were divided into an ecological group characteristic for open dune grasslands and another group with more preference for uniform vegetation structure (Wallis de Vries & Raemakers 2001). They were counted along transects of 50 metres nine times a year, in spring and summer. Numbers of individuals of different grasshopper species were counted in large plots three times in summer, during time intervals of ten minutes. Carabid beetles were caught once a week in pitfalls from March to October. Among the carabid beetles, various target species were distinguished for dune grasslands (cf. Turin 2000).

The monitoring was set up in a random block design (Lepš & Šmilauer 2003), with the treatments sod cutting, control (grass encroached; no management) and reference (remnants of dune grassland; target type). Vegetation, rabbits, and butterflies were also studied in the summer before the application of sod cutting. Data were statistically analysed after log transformation. In case of a normal distribution, ANOVA was applied (Anonymus 1999). Depending on whether there was (un)equality of error variances the additional tests Tamhene or Tukey HSD were used for multiple comparisons. If the data did not meet the conditions of a normal distribution, the non-parametric Kruskal-Wallis test was chosen.

2 Results

The soil survey of summer 2003 made clear that there was neither a significant rise in pH of the top soil shortly after sod cutting nor a significant decline in decalcification depth. The Rozenwaterveld has a lower pH (5.5) and a larger decalcification depth (6 – 15 cm) than the infiltration area (pH > 7; decalcification depth 0 – 2 cm). This is mainly caused by the difference in age of the dune sand: the Rozenwaterveld (RV) was formed in the 12th – 13th Century, whereas the infiltration area (IA) originates from the 18th – 19th Century (Jelgersma et al. 1970). Both living biomass and dead organic material show a strong, significant decline after sod cutting, resulting in a more favourable light climate for dune grassland species. Although the soil characteristics indicate that the sod cutting sites at the Rozenwaterveld are still sensitive for grass encroachment (Koojiman & Besse 2002), litter input and litter mineralisation have diminished, due to which nutrient availability has probably become low.

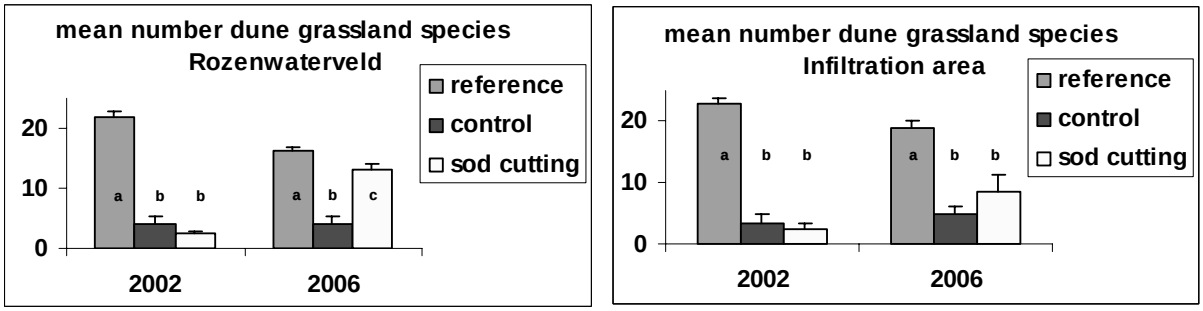

Figure 1: Mean number of dune grassland species per plot at the Rozenwaterveld and in the infiltration area shortly before (2002) and four years after shallow sod cutting (2006). Error bars represent standard error. Significant differences between treatments (sod cutting, control, and reference) are indicated with different letters.

Analysis of the species composition of the vegetation for the period 2002 – 2006 (Fig. 1) illustrates that there was no significant difference in number of dune grassland species between sod cutting and control plots shortly before treatment in 2002 in both areas. The number in the reference (dune grassland) plots was significantly higher. In 2006, the fourth year after sod cutting, dune grassland species such as *Viola curtisii*, *Erodium cicutarium* ssp. *dunense*, *Lotus corniculatus*, *Saxifraga tridactylites* and *Phleum arenarium* have returned. Their average number has increased significantly in both areas (RV: 13 species; IA: 9 species) in comparison with 2002 (RV: 3 species; IA: 2 species). Nevertheless, at the Rozenwaterveld and in the infiltration area the number was still significantly lower than in the reference situation (RV: 16 species; IA: 19 species). In the infiltration area there was in 2006 not yet a significant difference with the control plots (5 species), while at the Rozenwaterveld mean species number was significantly higher in comparison with the control plots (4 species). The coverage of dune grassland species in moss and herb layer after four years was still very low (RV: 17 %; IA: 2 %) compared with the reference plots (RV: 95 %; IA: 88 %).

The mean coverage of the tall grass species *Calamagrostis epigejos* decreased significantly at the Rozenwaterveld from 41 % in 2002 to 4 % in 2006. *Rosa pimpinellifolia*, which often shows a strong

increase in grass-encroached sites, diminished significantly in coverage (from 68 % to 28 %) and height (from 40 cm to 15 cm). The vegetation structure has become very diverse with a mosaic of bare sand (25 %), moss patches, low grass and herbs and dwarf shrubs. In the infiltration area, mean cover of *Elytrichia maritima* decreased significantly from 70 % to 5 %, although it reaches higher density at some steep slopes where the sod-cutting machine was not very effective. The vegetation development is generally slower, which has resulted in a still high cover of bare sand (50 %).

In 2002, mean number of rabbits at the Rozenwaterveld were significantly higher (25 per hectare) in the reference plots in comparison with the control sod cutting plots (≤ 1 per hectare). In the period 2002 – 2006 rabbits showed a significant increase and remarkable recovery after sod cutting (Fig. 2). Mean number increased from less than 1 rabbit per hectare to 61 per hectare. The plots in the infiltration area had a large variety (Fig. 2), which explains that there was no significant difference between all treatments. Nevertheless, the mean number of rabbits had become significantly higher four years after sod cutting (0 vs. 60 per hectare). Besides, in both areas there was also an increase in rabbit numbers in the control plots, which can be explained by the likewise growing numbers in the reference sites.

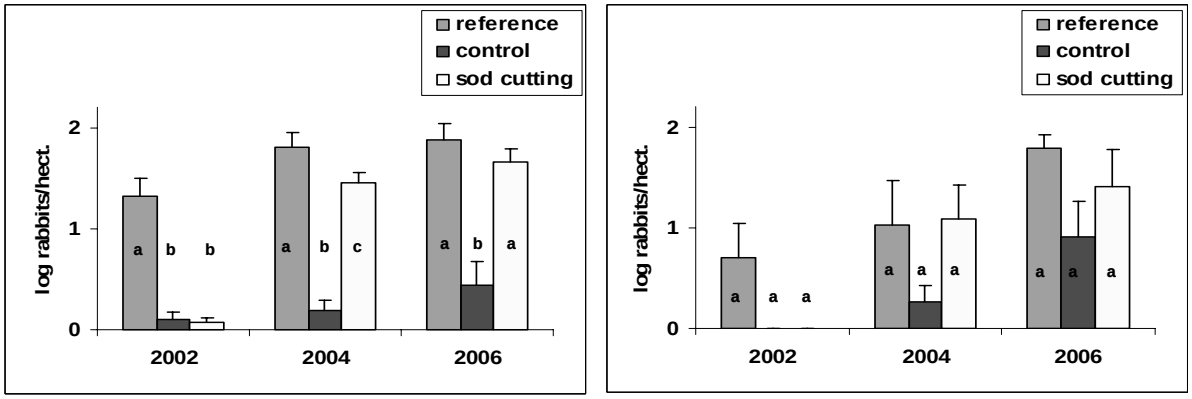

Figure 2: Mean number of rabbits (log rabbits per hectare) at the Rozenwaterveld (left) and in the infiltration area (right) shortly before (2002), two years (2004) and four years after shallow sod cutting (2006). Error bars represent standard error. Significant differences between treatments (sod cutting, control, and reference) are indicated with different letters.

Four grasshopper species were found at the Rozenwaterveld, which are characteristic for dune grassland (Kleukers et al. 1997; Table 1), among which the Red Data Book species *Oedipoda caerulescens*. At the Rozenwaterveld, there was a significant increase from 2003 to 2005 for all species, and in the third year after sod cutting (2005), they all had significantly higher numbers in comparison with the control sites. There was no significant difference with the reference situation. In the infiltration area, *Oedipoda caerulescens*, the only species which was investigated here, also showed a significant increase after sod cutting.

Table 1: Mean number of individuals of grasshopper species characteristic for dune grasslands at the Rozenwaterveld in the third year after sod cutting (2005). Statistical analysis was performed with Kruskal-Wallis test).

Species	Reference	Control	Sod cutting	Significance
Chortippus mollis	58	25	63	$p < 0.01$
Myrmeleotettix maculatus	77	1	113	$p < 0.01$
Oedipoda caerulescens	7	0	20	$p < 0.01$
Chortippus brunneus	101	43	122	$p < 0.05$

Carabid beetles were studied at the Rozenwaterveld in the first year after sod cutting (2003). The dune grasslands of the Taraxaco-Galietum veri seemed to be rather species-poor. Mean number of species and mean number of individuals were significantly higher in the reference plots (10 species, 65 indiv.) in comparison with sod cutting (5 species, 19 indiv.) and control plots (5 species, 24 indiv.). This difference was especially caused by larger numbers of common species such as *Calathus fuscipes*. There was no significant difference found between sod cutting and control plots. Shallow sod cutting had not yet contributed to the return of target species such as *Amara lucida*, *Harpalus neglectus,* and *Notiophilus germinyi*.

The infiltration area was investigated in the second year after sod cutting (2004). The open dune grasslands of the Phleo-Tortuletum ruraliformis were found to be more species-rich (reference: 13 species). They harboured more target species such as *Masoreus wetterhalli*, *Harpalus anxius,* and *Amara curta*. Nevertheless, the differences between sod cutting, control and reference plots were mostly not significant. Only the number of pioneer species (e.g. *Cicindela hybrida* ssp. *hybrida* and *Harpalus servus*) was significantly higher after sod cutting.

Several butterflies were found at the Rozenwaterveld that are characteristic for dune grasslands, among which Red Data Book species such as *Issoria lathonia*, *Fabriciana niobe,* and *Aricia agestis* occured. In 2002, before sod cutting, mean number of dune grassland species and individuals per transect of 50 metres was significantly lower in the sod cutting (1 species, 2 indiv.) and control plots (1 species, 1 indiv.) in comparison to the reference plots (5 species, 18 indiv.). In the third year, 2005, both mean numbers of species and individuals were significantly higher in the sod cutting plots (4 species, 11 indiv.) in comparison with the control situation (1 species, 2 indiv.; see figure 3). The same goes for the Red Data Book species, which seem to profit from sod cutting. There was no significant difference between sod cutting and reference plots (5 species, 13 indiv.). Mean number of the butterfly species that prefer ruderal vegetation (mainly *Maniola jurtina* and *Thymelicus lineola*) was significantly lower after sod cutting in 2005 (2 indiv.), compared with the untreated control situation (10 indiv.).

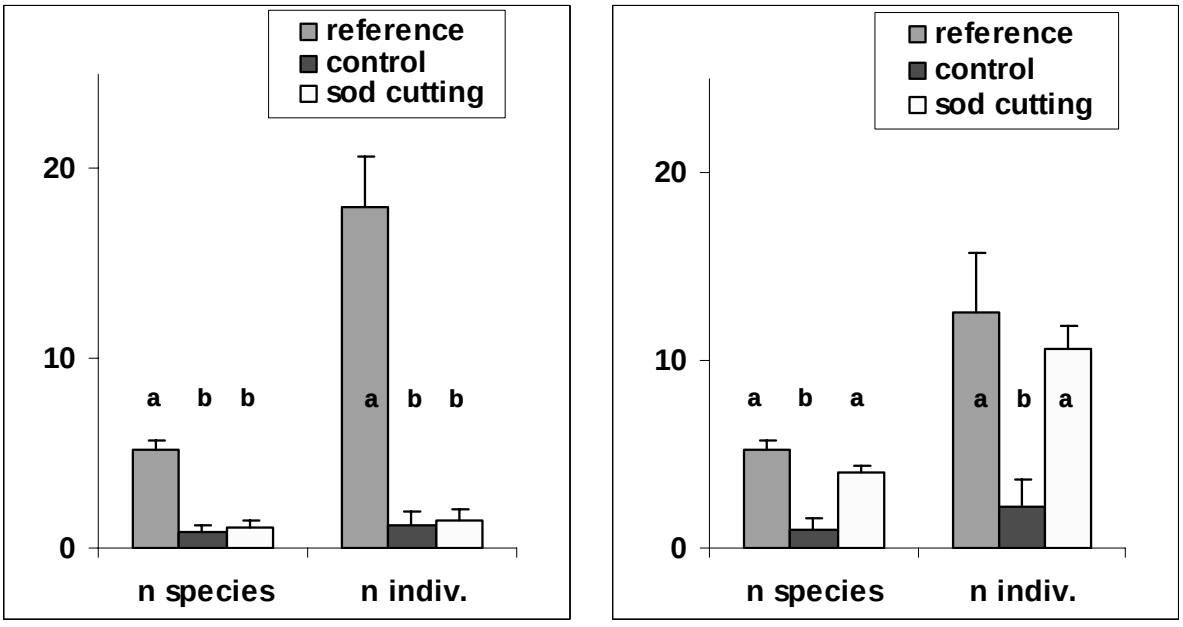

Figure 3: Mean number of species and individuals of dune grassland butterflies at the Rozenwaterveld shortly before (2002) and three years after shallow sod cutting (2005). Error bars represent standard error. Significant differences between treatments (sod cutting, control, and reference) are indicated with different letters.

3 Discussion and conclusion

The results of this project show clearly that both vegetation and fauna of grey dunes start to recover after shallow sod cutting of grass-encroached dune grasslands. Large-scale sod cutting is often considered unfavourable, especially for the fauna (Brouwer et al. 2005). The success of this project can be explained by the small-scale application and the shallowness of the measure, and the presence of still species-rich remnants of the original habitat in the vicinity. Besides, the development within a few years towards a diverse vegetation structure with bare sand and moss patches has probably contributed to the quick improvement of the insect fauna, especially at the Rozenwaterveld.

There is however a difference between the two areas. The more rapid response of the vegetation at the Rozenwaterveld in comparison with the infiltration area might be explained by several reasons. First of all the organic top soil is thicker and has not been removed completely by shallow sod cutting, as a result of which the deeper part of the soil seed bank (5 – 10 cm) is still present. Research in the AWD made clear that seeds from several dune grassland species might be present in this layer, such as *Veronica officinalis*, *Aira praecox* and *Thymus pulegioides* (Bekker & De Vries 2001). In the infiltration area the organic layer is generally less than 5 cm thick, so here the seed bank has been completely removed. Besides, at the Rozenwaterveld rabbits are present in much higher numbers and have expanded their activity more quickly into the sod cutting sites. They contribute to the dispersion of grassland species by pellets (Malo & Suarez 1996, Cosijns et al. 2005). Finally, sod cutting at the Rozenwaterveld did not lead to a change in pH of the topsoil. The intermediate pH of 5.5 (IA: pH > 7) together with the larger decalcification depth of approximately 9 cm (IA: 0 cm) and the higher organic matter content of the remaining top soil (RV: 2.6 %; IA: 0.9 %) probably provides much better conditions for germination, establishment and growth.
The question is whether the fauna species are able to settle down definitively, or whether we observed temporary visitors. Although oviposition was not studied, the establishment at the sod cutting sites of plant species on which caterpillars of several butterfly species of the Red Data Book depend, such as *Aricia agestis* (*Erodium cicutarium* ssp. *dunense*) and *Issoria lathonia* (*Viola curtisii*), is hopeful. Many grasshopper species characteristic of grey dunes forage on different (small) grass species, which also appear after sod cutting. However, carabid beetles do not respond quickly to the conservation measure applied, although they are considered as good colonisers (Turin 2000).

The results of vegetation and butterflies illustrate remarkable differences in number of dune grassland species and individuals throughout the years, considering the reference plots. These differences are probably caused by fluctuations in weather conditions. The year 2002 started wet, while spring 2006 was very dry, resulting in the absence of various annuals, such as *Cerastium semidecandrum* and *Erophila verna*. This explains the lower number of dune grassland species found in the summer of 2006 (Fig. 1). The butterflies show decreasing numbers over a much longer period. Even in years with good weather conditions (2005) the situation is getting worse in comparison with previous good years (e.g. 2002; Fig. 3). The underlying reasons are not yet clear, although the situation for the butterflies characteristic of dune grasslands is generally deteriorating on a regional scale (Wallis De Fries 2004).

Whether the measure is sustainable at the Rozenwaterveld and whether the improvement will continue in the infiltration area remains to be seen. Gradually it becomes clear that rabbits play an indispensable role in the recovery of the grey dunes. Fortunately, the overall trend of rabbits in the AWD has changed from stable and low in the period 1995 – 2003 to a strong increase in recent years (CBS, 2006), especially in sites where nature conservation measures are applied. They keep the vegetation short by grazing and open by burrowing, so the light climate becomes and remains favourable for critical flora and fauna species and competitive grass species are suppressed. Further research on vegetation and fauna will be necessary to monitor future developments.

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