Use of grazing and mowing to reduce the dominance of soft rush *Juncus effusus* in fen meadows in Scotland

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SUMMARY

Three years of differing management regimes to reduce the dominance of soft rush *Juncus effusus* were undertaken at Moss Town Fen on the north-east Aberdeenshire coast, Scotland, UK. The effectiveness of grazing and mowing combinations of increasing intensity were trialled, from ungrazed and unmown management to continuous grazing and annual mowing for three years. Sward height and density, and rush cover were surveyed to examine the effect of the management combinations. Forb, grass, bryophyte and bare ground cover were also monitored to understand whether the management treatments had any effect on these sward components. Continuous grazing with konik ponies and at least two years of mowing (either consecutively or with a gap year) reduced rush the most. The treatments had no consistent effect on forb, grass or bryophyte cover, which may be due to a time lag between the reduction in rush cover and the germination and growth of these sward components. Bare ground cover was low, at less than 1% in most of the treatments, negating any concern that the grazing intensity was having a negative impact on the delicate fen habitat. Anecdotal observations on waterfowl and lesser butterfly orchid *Platanthera bifolia* support the benefits of a grazing and mowing regime to reduce rush dominance. These results also identified that a cost saving could be made by slightly reducing the intensity of management regime.

BACKGROUND

Moss Town Fen is a 22 ha fen meadow, a rare and declining habitat in UK, in which wetland grades into dry grassland fields. It is part of the RSPB Loch of Strathbeg Nature Reserve, the largest dune loch in the UK on the east coast of Aberdeenshire (NK058591). The surrounding wetland is of international importance for its wildlife, particularly migrating waterfowl. It is a Special Protection Area under the Birds Directive 2009, RAMSAR site and Site of Special Scientific Interest. Until about 40 years ago, the fen was subject to a late cut of hay for winter livestock fodder and lightly grazed over winter. Since then management has been largely abandoned, resulting in willow *Salix* spp. scrub and rush *Juncus* spp., particularly soft rush *Juncus effusus*, dominance. Most of the willow scrub was removed in 2006-2007 as part of a wider habitat restoration project, leaving the area carpeted in soft rush. Rushes are an important component of fen vegetation, but the dominance of soft rush, and especially the dense mat of its litter, prevents other rush species, forbs, grasses and sedges from flourishing. Positive indicator species found at the site during surveys in 2005 and 2011, such as glaucous sedge *Carex flacca*, meadowsweet *Filipendula ulmaria*, marsh-bedstraw *Galium palustre*, marsh pennywort *Hydrocotyle vulgaris*, marsh cinquefoil *Potentilla palustris*, greater bird's-foot-trefoil *Lotus pedunculatus*, ragged robin *Silene flos-cuculi*, marsh violet *Viola palustris* and self heal *Prunella vulgaris*, are likely to decline with increasing dominance of soft rush. Lesser butterfly orchid *Platanthera bifolia* had also been recorded in low numbers within the fen vegetation.

Winter cutting of soft rush has also been found to increase numbers of breeding northern lapwing *Vanellus vanellus* and common redshank *Tringa totanus* chicks have been observed feeding within cut patches (Robson & Alcorn 2006). The number of common snipe *Gallinago gallinago* also increased after cutting soft rush and the initiation of a more intensive grazing regime (Holton & Alcorn 2006).

There is some uncertainty about how long it may take for rush management to be effective. Cutting two or three times per year can reduce rush vigour over a two year period, and stocking with high numbers of goats may eliminate rushes within three years (Shellswell *et al*. 2016). However, both these management regimes would have a detrimental impact on bird populations through disturbance, and may also affect forbs present within the sward by poaching and grazing of flowering stems. Thus, there is some evidence that ongoing management can reduce rush dominance, but little evidence regarding the most effective combination of cutting and grazing, taking into consideration the sensitivity of fen vegetation to poaching and overgrazing.

In 2014, restoration of Moss Town Fen began through a programme of grazing and cutting to reduce the height and density of soft rush and allow the underlying forbs, rushes and sedges to expand. In the first year, mowing and grazing increased the structural diversity of the fen by decreasing the cover of rush and increasing the cover of forbs within the newly formed 'lawns' (Roland 2015, Hammond 2016). Here we report the effects of different combinations of grazing and cutting on soft rush and fen vegetation over a three year period.

ACTION

In 2014, seven konik ponies *Equus ferus caballus* were introduced to Moss Town Fen with the aim of increasing the herd to 20 (mares, foals and a stallion) by the summer of 2017. Areas of fen were either grazed or ungrazed for the entire three-year period from 2014-2016 (Figure 1).

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ISSN 1758-2067

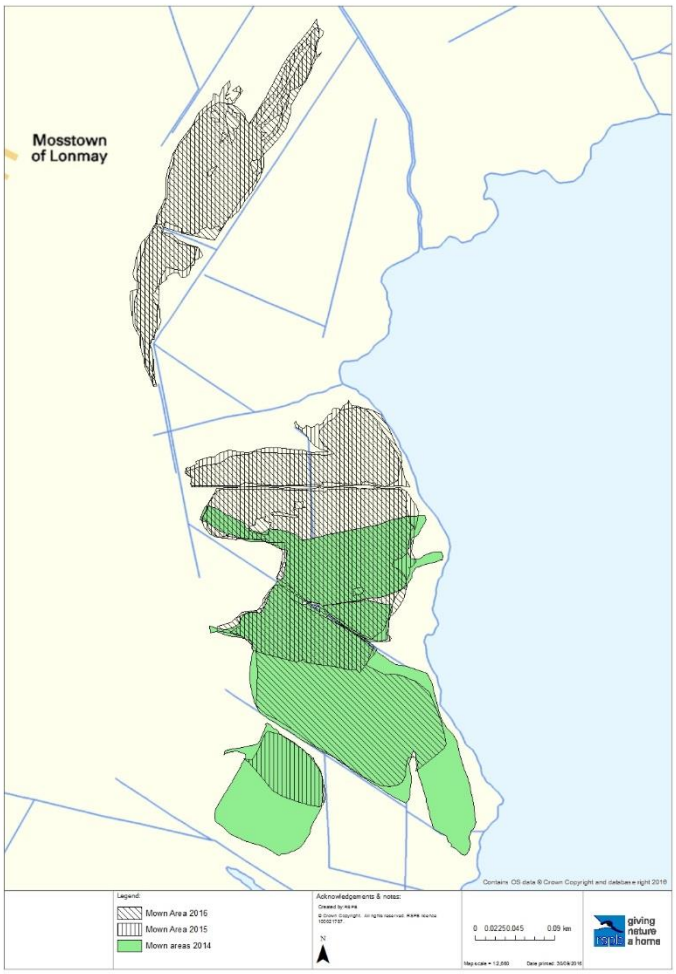

Figure 1. Map of Moss Town Fen, showing areas mown in 2014 (diagonal shading), 2015 (vertical shading), and 2016 (solid green).

A specialised tracked mower (Softrack) with low ground pressure (Figure 2) cut 6.2 ha (5.2 ha in the grazed area, and 1 ha within the ungrazed area) in July-August 2014. This area was mown again in 2015 and 2016, with an additional 1 ha in 2015 (increasing the cut area to 7 ha) and 2 ha in 2016 (increasing the cut area to 8 ha). The area cut increased each year as it was easier to mow in areas that had been previously cut. As the contractors were employed for a set amount of time this enabled them to move into uncut areas, expanding the management across the fen each year.

The mowing and grazing regime created a range of treatments across the units under management, with an ungrazed and unmown area acting as the control (Table 1). The number of grazing and mowing combinations was restricted by the size of compartments excluding or including the ponies, and the soft ground restricting access by the specialised mower.

Figure 2. Specialised mower cutting Moss Town Fen. The tracked wheels reduced ground pressure enabling the contractor to cut areas of the fen that would be too boggy for conventional machinery.

Rush height and density: The sward height was measured in July 2017 at the peak of the growing season using a 1.5 m sward stick marked in 1 cm increments with a 10 cm diameter circular clear plastic disc on the end (Figure 3). A rough 'W' route was surveyed within each treatment area creating four relatively even survey legs. Each leg was then subdivided into roughly equal lengths by pacing (usually 15-25 paces) and at each sample point a set of measurements was taken (Table 1). Maximum height of the sward was measured by lowering the disc until it touched the highest flowering stem or leaf. The disc was then dropped and the height where it came to rest supported by the sward was used as a proxy for density.

Sward composition: In October 2017, 1 x 1 m quadrats subdivided into 10 x 10 cm squares were used to estimate the cover of bryophytes, grasses, rushes, forbs and bare ground using the Domin scale (Bannister 1966). *Sphagnum* and *Polytrichum* moss species were estimated separately. The Domin scale was converted to a percentage cover using the formula (Currell 1987):

$$Percentage\ cover = \frac{(Domin\ score)^{2.6}}{4}$$

Table 1. Number of 1 x 1 m quadrats sampled, and years of mowing for each treatment at Moss Town Fen. Number in brackets is the number of quadrats for sward composition where this differs from the sample size for rush height and density. Dashes represent management regimes that were not tested.

	Unmown	**One year of mowing 'Mown1'**	**Two consecutive years of mowing 'Mown2c'**	**Two alternate years of mowing 'Mown2a'**	**Three years of mowing 'Mown3'**
Ungrazed	40 (20)	20	20	-	-
years mown		*2014*	*2014, 2015*		
Grazed	40	20	40	40	40
years mown		*2014*	*2015, 2016*	*2014, 2016*	*2014, 2015, 2016*

ISSN 1758-2067

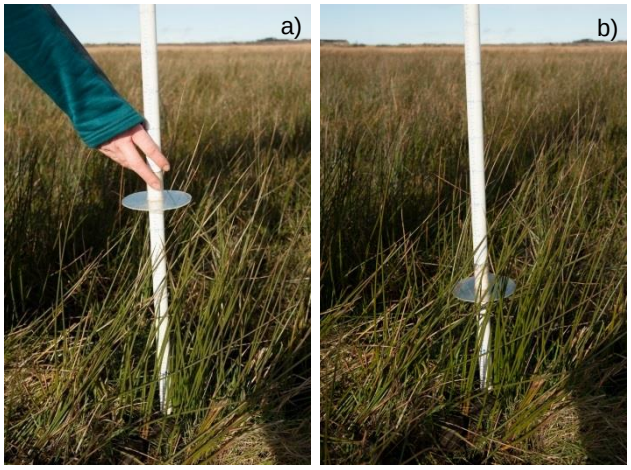

Figure 3. Sward stick: a) measuring the maximum height of sward, and b) with the disc lowered to measure supported height measurement, used as a proxy for rush density.

Data analysis: Analyses were undertaken in the programme R 3.1.1 (R Development Core Team 2014) using the package MASS (Venables & Ripley 2002). Generalised linear models (GLMs) were used for analysing the data. The response variables 'sward height' and 'sward supporting height' were assessed for normality and, after confirmation that the data followed this distribution, were analysed using a normal distribution. The response variables 'rushes', 'forbs', 'grasses', mosses separated into '*Sphagnum*' and '*Polytrichum*', and 'bare ground' percentage cover were arcsine transformed and analysed using a normal distribution. Mean and standard errors were calculated by back-transforming the test estimates.

The explanatory variables were Grazing (two levels) and Mowing (five levels) and GLMs were undertaken using forward addition of terms, including the interaction between the two explanatory variables. In all cases the interaction was found to be significant, and a combined explanatory variable for the eight treatments was created to look at the individual effects of each management. Post-hoc tests to assess for significant differences between means were undertaken using the package phia (Rosario-Martinez 2015) with the link=TRUE for the normal distribution.

CONSEQUENCES

There was a difference in sward height, supporting height of the sward (density) and rush cover between different treatments (Figure 4, Table 2, 3). Sward height was highest in areas that were ungrazed and unmown, and lowest in areas that were mown in two or three years and also grazed (Figure 4a). The supportive height of the sward, as a proxy for vegetation density, was higher in ungrazed and unmown areas than in those which were grazed and mown in either one, two or three years (Figure 4b). Rush cover was reduced from 54% in ungrazed and unmown areas to 26% under 'Grazed and two consecutive years of mowing' (Figure 4c). Rush cover in areas that were either only mowed or grazed was not significantly different from the unmown and ungrazed control.

Although there were significant differences in forbs, grasses, *Sphagnum*, *Polytrichum* and bare ground between different management regimes, there was no discernible pattern consistent with grazing and mowing treatments (Table 2, Table 3).

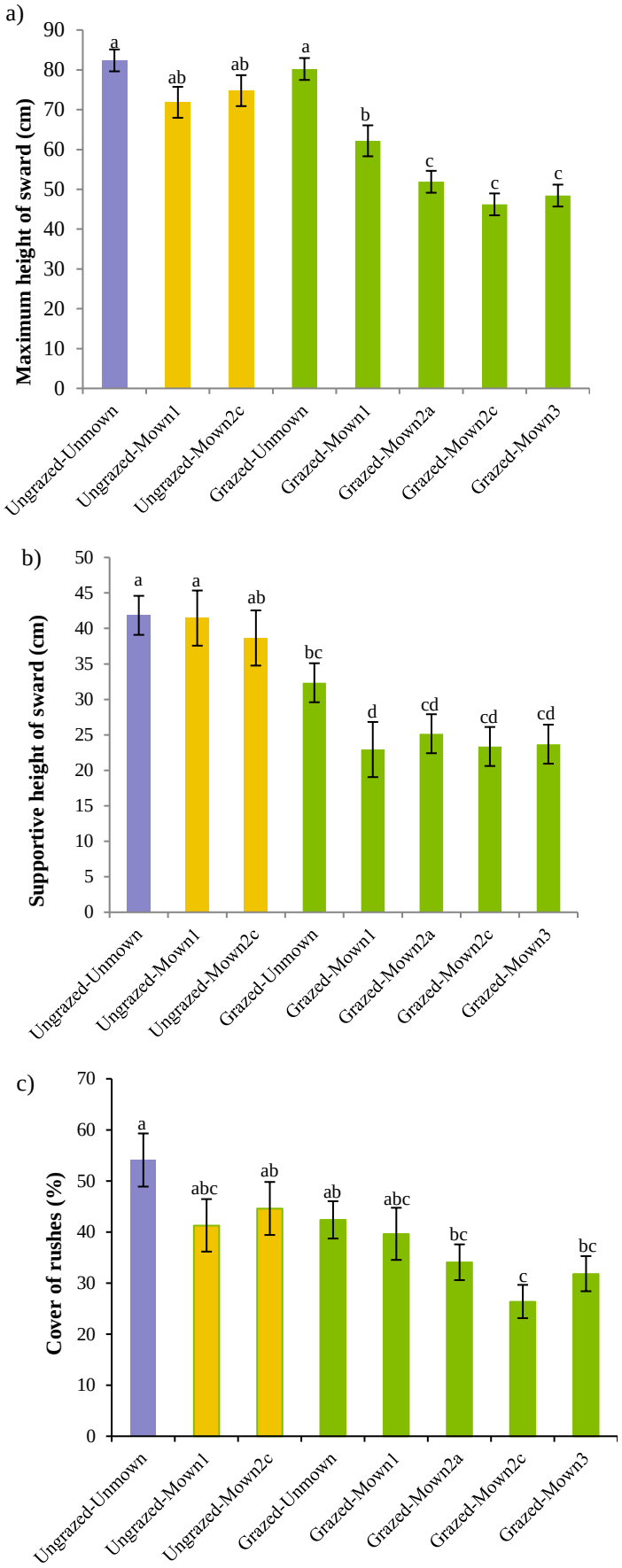

Figure 4. Effect of combinations of grazing and/or mowing at Moss Town Fen: a) maximum height of sward (± S.E.); b) supporting height of sward (± S.E.), as a proxy for rush density; c) rush cover (± S.E.). Different letters indicate significant differences between treatments. Sample sizes shown in Table 1.

ISSN 1758-2067

Table 2. Average percentage cover of different components of the sward under different mowing and grazing treatments.

Treatment	Rushes	Forbs	Grasses	*Sphagnum*	*Polytrichum*	Bare ground
Ungrazed – Unmown	54.1	13.9	16.3	15.7	8.5	<0.1
Ungrazed – Mown1	41.4	12.4	25.4	18.3	7.9	<0.1
Ungrazed – Mown2c	44.6	23.2	4.6	5.6	17.6	<0.1
Grazed – Unmown	42.4	0.1	10.1	3.8	<0.1	0.1
Grazed – Mown1	39.6	0.1	41.4	9.3	<0.1	1.0
Grazed – Mown2a	34.0	13.5	25.7	14.2	9.7	1.1
Grazed – Mown2c	26.3	<0.1	10.4	14.0	<0.1	0.2
Grazed - Mown 3	31.8	8.7	21.3	21.5	6.5	0.2

DISCUSSION

It was surprising that the most intensive management, grazing continuously and mowing in all three years, did not result in a difference in sward height, density and rush cover compared with continuous grazing and mowing for two years, either consecutively or with a year break. The differences between these treatments are so small that it can be summarised that any combination of continuous grazing with at least two cuts significantly reduces rush cover. However, there is an economic difference, with mowing for three years costing considerably more than mowing for two years.

The increase in management intensity had no consistent observed effect on forb, grass, *Sphagnum* or *Polytrichum* cover (Table 3). This may be due to the dominance of soft rush creating a patchy distribution of other sward components, or environmental conditions, such as soil hydrology, which may particularly be associated with bryophyte cover closer to the Loch. In addition, the cover of forbs and grasses may have a delayed response, as there will be a time lag between the plants growing, flowering, producing and shedding seed and germination of seed. It was not expected that there would be sufficient recruitment of individual forbs during the three years of these management regimes to observe any significant changes, but future monitoring may observe a change in vegetation cover as the effects of the management are borne out.

There was concern that if the ponies preferentially grazed any particular treatments, this could lead to poaching and destruction of the delicate fen vegetation. However, bare ground cover was not high in any of the management treatments.

Anecdotally, the cut and grazed areas have been used by many snipe on migration (over 100 on one count) with four displaying males in 2017. This is double the number present before the management started. Counts of over 400 pink-footed geese *Anser brachyrhynchus* and curlew *Numenius arquata* feeding on migration have also been seen within the managed

Table 3. Results of GLM analysis of different measures of vegetation and bare ground under different mowing and grazing treatments. All treatment estimates are relative to the reference level of ungrazed-unmown areas.

Variable	Treatment	Estimate (S.E.) [1]	
Maximum sward height	Grazed-Unmown	-2.16 (3.89)	
	Ungrazed – Mown2c	-7.60 (4.76)	
	Ungrazed – Mown1	-10.53 (4.76)	*
	Grazed – Mown1	-20.20 (4.76)	***
	Grazed - Mown2a	-30.49 (3.89)	***
	Grazed - Mown2c	-36.16 (3.89)	***
	Grazed – Mown3	-33.95 (3.89)	***
Supportive sward height	Grazed-Unmown	-1.80 (3.46)	
	Ungrazed – Mown2c	1.98 (4.24)	
	Ungrazed – Mown1	-4.08 (4.24)	
	Grazed – Mown1	-8.93 (4.24)	*
	Grazed - Mown2a	-11.51 (3.46)	**
	Grazed - Mown2c	-13.31 (3.46)	***
	Grazed – Mown3	-12.99 (3.46)	***
Rush cover	Grazed-Unmown	-6.76 (3.67)	
	Ungrazed – Mown2c	-5.47 (4.24)	
	Ungrazed – Mown1	-7.40 (4.24)	
	Grazed – Mown1	-8.37 (4.24)	*
	Grazed - Mown2a	-11.67 (3.67)	**
	Grazed - Mown2c	-16.49 (3.67)	***
	Grazed – Mown3	-13.04 (3.67)	***
Forb cover	Grazed-Unmown	-20.34 (3.00)	***
	Ungrazed – Mown2c	6.94 (3.46)	*
	Ungrazed – Mown1	-1.24 (3.46)	
	Grazed – Mown1	-20.62 (3.46)	***
	Grazed - Mown2a	-0.31 (3.00)	
	Grazed - Mown2c	-21.35 (3.00)	***
	Grazed – Mown3	-4.69 (3.00)	
Grass cover	Grazed-Unmown	-5.29 (3.50)	
	Ungrazed – Mown2c	-11.42 (4.05)	**
	Ungrazed – Mown1	6.46 (4.05)	
	Grazed – Mown1	16.24 (4.05)	***
	Grazed - Mown2a	6.69 (3.50)	
	Grazed - Mown2c	-4.98 (3.50)	
	Grazed – Mown3	3.65 (3.50)	
Sphagnum cover	Grazed-Unmown	-12.03 (3.13)	***
	Ungrazed – Mown2c	-9.65 (3.62)	**
	Ungrazed – Mown1	1.99 (3.62)	
	Grazed – Mown1	-5.61 (3.62)	
	Grazed - Mown2a	-1.16 (3.13)	
	Grazed - Mown2c	-1.33 (3.13)	
	Grazed – Mown3	4.32 (3.13)	
Polytrichum cover	Grazed-Unmown	-16.05 (2.82)	***
	Ungrazed – Mown2c	7.85 (3.26)	*
	Ungrazed – Mown1	-0.66 (3.26)	
	Grazed – Mown1	-16.08 (3.26)	***
	Grazed - Mown2a	1.21 (2.82)	
	Grazed - Mown2c	-16.66 (2.82)	***
	Grazed – Mown3	-2.21 (2.82)	
Bare ground	Grazed-Unmown	0.77 (1.17)	
	Ungrazed – Mown2c	-0.50 (1.36)	
	Ungrazed – Mown1	-0.33 (1.36)	
	Grazed – Mown1	4.74 (1.36)	***
	Grazed - Mown2a	4.97 (1.17)	***
	Grazed - Mown2c	1.32 (1.17)	
	Grazed – Mown3	1.64 (1.17)	

[1] *represents $p < 0.05$, ** $p < 0.01$, *** $p < 0.00$

ISSN 1758-2067

areas, and neither species used Moss Town Fen prior to starting the grazing and mowing management. The number of lesser butterfly orchid spikes increased substantially, from 11 in 2014 and 10 in 2015, to 51 in 2016 and 26 in 2017. Lesser butterfly orchids take several years from germination to flowering, so it seems likely that the grazing and cutting has allowed this species enough room to flower and potentially set seed, expanding the population over time. The decline in 2017 is thought to be related to overall environmental conditions, as in general 2017 was a poor year for the orchid across the reserve and at other nearby sites.

In conclusion, the restoration regime at Moss Town Fen, involving continuous grazing plus mowing for at least two years out of three, will be expanded to the rest of the site over time where conditions allow. It is hoped that only very limited cutting will be required once rush dominance has been reduced and the fen will be maintained in good condition solely through grazing. This trial of different grazing and cutting regimes has provided sufficient evidence to forecast costs and apply for grants to facilitate this work, enabling a better degree of budget management at the nature reserve and better informed future ecological and cost-effective management.

ACKNOWLEDGEMENTS

Thank you to AMW contracting for undertaking the mowing for all three years. Thanks also to all the staff and volunteers at the Loch of Strathbeg, particularly Derren Fox and Lorna Dow. Part of this work was generously funded by the Heritage Lottery Fund as part of the Save Our Magnificent Meadows project.

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ISSN 1758-2067