

## Plant diversity and species richness of some Ljubljana Marsh grasslands under the influence of cutting and fertilizing management

### Pflanzen-Diversität und Arten-Reichtum einiger Wiesen im Leibacher Moor unter dem Einfluss von Mahd und Düngung

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**Key words:** grassland, cutting, fertilising, species richness, Marsh Horsetail, Ljubljana marsh.

**Schlagwörter:** Grünland, Mahd, Düngung, Arten-Vielfalt, Sumpf-Schachtelhalm, Ljubljana Moor.

**Summary:** Good grassland management usually improves herbage value, but on the other hand frequently decreases plant diversity and species richness in swards. We investigated this relationship at Ljubljana marsh meadows. In trials were established on *Arrhenatherion* type of vegetation. Cutting regimes were 2 cuts – with normal and delayed first cut, 3 and 4 cuts per year, fertiliser treatments were zero fertiliser – control, PK and NPK with 2 or 3 N rates. The results at 1<sup>st</sup> cutting in the 5<sup>th</sup> trial year were as follows: On both trials fertilising either with PK or NPK regarding all cutting regimes had no significant negative effect on plant diversity. In average 20 species were listed on unfertilised and fertilised swards respectively. At this low to moderate level of exploitation intensity, increased number of cutting had no significant negative effect on plant diversity as well (19 species at 2 cuts vs. 20 species at 3 or 4 cuts). On both trials PK fertilising increased the proportion of legumes in herbage within 2 and 3 cuts. The proportion of grasses in herbage increased at all fertilising treatments with increased cutting numbers. Fertiliser treatments reduced considerably the proportion of Marsh Horsetail (*Equisetum palustre*) in herbage on T1. This effect was even more pronounced at higher cut numbers. The proportion of *Equisetum palustre* in herbage was the highest in

unfertilised sward within 2 cuts (26.4%) and the lowest in NPK fertilised sward within 4 cuts (1.4%).

Zusammenfassung: Gute Grünlandbewirtschaftung steigert gewöhnlich die Futterproduktion reduziert aber die Arten-Vielfalt von Wiesenpflanzen. Das Verhalten der Arten wurde in Ljubljana-Moorwiesen untersucht. Der Versuch wurde an einem *Arrhenatherion*-Wiesen typ durchgeführt. Die Wiesen wurden zweimal jährlich geschnitten und zwar mit normalem und verzögertem ersten Schnitt, sodann 3 mal Schnitt und 4 Schnitte pro Jahr. Folgende Düngungsstufen wurden verglichen: keine Düngung - Kontrolle, PK und NPK mit 2- oder 3- maliger N Gabe. Die Resultate beziehen sich auf den ersten Schnitt des fünften Versuchsjahres. Die Düngung mit PK oder mit NPK in allen Schnitt-Nutzungen hatten keine negativen Effekte auf Arten-Vielfalt der Bestände. Im Durchschnitt wuchsen 20 Pflanzen-Arten auf gedüngten und ungedüngten Wiesen. Auch die Schnittnutzung hatte keine signifikant negativen Effekte auf die Artenvielfalt der Pflanzen (19 Arten in 2-Schnitt; 20 Arten im 3- und 4-Schnittnutzung). Der Anteil der Gräser stieg in allen Düngungsbehandlungen mit erhöhter Mahdfrequenz. Düngung reduzierte den Anteil des Sumpf-Schachtelhalms (*Equisetum palustre*) im Versuch T1. Dieser Effekt war noch gesteigert mit zunehmender Schnittfrequenz. Der Anteil des Sumpf-Schachtelhalms (*Equisetum palustre*) war auf ungedüngtem Wiesen mit 2 Schnitt-Nutzung (26.4%) am höchsten und bei NPK Düngung mit 4 Schnitt-Nutzung (1.4 %) am niedrigsten.

## Introduction

In the last fifty years approximately 2700 km<sup>2</sup> by management abandoned Slovene grasslands culminated in forest vegetation. On the managed grasslands in Slovenia the three cut and two cut grasslands (karst and wet grasslands) dominate. The idea of draining Ljubljana marsh and changing it into arable land was highly appealing to various individuals as early as in the 16<sup>th</sup> century, by digging of drainage channels, pulling down of dams and later also pumping stations were built. The idea carried on until no less than 1980s. Insufficient money as well as the increasingly louder warnings by ecologists stopped this attempts. In the past the peat cutting on Ljubljana marsh expanded into a true industry. But the peat industry ran out much quicker than expected. The floor subsided, and water again returned to Ljubljana marsh. Agriculture on this area in spite of great efforts and investments, did not yield the expecting results. Great attempts were made in the past that Ljubljana marsh would become a landscape park. The Ljubljana marsh can be described as environment sensitive one. Approximately 75% of the Ljubljana marsh area (160 km<sup>2</sup>) is covered with semi-natural grasslands of the *Arrhenatherion* type. One of the major problems in fodder production with this type of grasslands is the massive appearance of Marsh Horsetail (*Equisetum palustre*). Good grassland management usually improves herbage value, but on the other hand frequently decreases plant diversity and species richness of swards. The second grasslands much smaller in area on Ljubljana marsh is the *Molinion* type of vegetation (ČOP et al., 1994; ČOP et al. 2004). Managing grasslands on this area has a relative long tradition. Many of

young farmers on Ljubljana marsh abandoned farm activities and were looking for other employment in the nearby Ljubljana city. The main reason for our work is to establish management strategies for Ljubljana marsh grassland fodder production with minimal negative effects on the environment. Relative moderate fertilizer treatments were used and also extensive cutting regimes were chosen in our trials. In this study we investigated the effects of cutting and fertilizer treatments on the botanical composition of grass sward, plant diversity and species richness.

## Materials and methods

Field trials were established in March 1999 on the semi-natural grassland of the Ljubljana marsh (lat. 45° 58' N, long 14° 28' E, alt. 295 m). The trial T1 is based on *Arrhenatherum elatius* grassland. The trial consists of the split-split design with four replications. The cutting regimes were main plots, and the four fertilizer treatments as subplots. The cutting regimes were: 2 cuts with a delayed first cut, 3 cuts and 4 cuts per year. Fertilizer treatment were 0 (Zero), PK (35 kg P + 133 kg K ha<sup>-1</sup> y<sup>-1</sup>); N<sub>(1)</sub> PK (50 kg N ha<sup>-1</sup> cut<sup>-1</sup> applied to first cut only + 35 kg P and 133 kg K ha<sup>-1</sup> y<sup>-1</sup>); N<sub>(c)</sub> PK (50 kg N ha<sup>-1</sup> cut<sup>-1</sup> applied to each of 2, 3 and 4 cuts + 35 kg P and 133 kg K ha<sup>-1</sup> y<sup>-1</sup>). The size of sub-plots was 2.5 X 4 m. The soil on the T1 plot was pH neutral (7.2), with low P and K content (ammonium lactate extraction; P = 0.9-2.2 mg, K = 7.7- 9.0 mg per 100 g of dry soil). The presented results are from the first cut of the fifth trial year (May 11 to June 25, 2003) and consist of portion of botanical groups (and *Equisetum palustre*) in herbage (Table 1), plant number and species richness (Table 2).

## Results and discussion

The grassland community on the trial consisted of approximately 30 plant species with *E. palustre* and *A. elatius* prevailing. After fertilizer use in the first year, the trial exhibited a change in species composition. The ratio of botanical groups (grasses, legumes, herbs and Marsh Horsetail (*Equisetum palustre*), measured at the fifth trial year (first cut), showed that the grass sward was less affected by cutting (three P < 0,003) than by fertilizer application (P < 0.001). On the trial T1, compared to control plots, the proportion of grasses in all fertilized swards increased. This was most evident under the four cut regime (Table 1). The intensification adopted in the trial, did not negatively affect sward plant diversity (Table 2), which was stable and relative high and highest within 4 cuts. Applying fertilizer decreased diversity in all treatments within 2 cuts and the 200 kg annual rate within 4 cuts. These results are partly in contrast to those in the literature, where negative relationship between fertilizer treatments and plant diversity were referenced (ELLENBERG 1952; NÖSBERGER et al. 1994, ZECHMEISTER et al. 2003). The plants may have adapted to human activities, that

have a relative long tradition on Ljubljana marsh area. During many years the genotypes of the plants may be affected and adapted to the relative long period of management, especially to the cutting regime. On the other hand unmanaged grasslands and meadows on Ljubljana marsh are very important for survival of other rare plants – like Snake’s head Fritillary (*Fritillaria meleagris*), many meadow orchids, such as Early Marsh Orchid (*Dactylorhiza incarnata*), Spotted Orchid (*Dactylorhiza maculata*), Marsh Orchid (*Orchis palustris*), at the European level endangered Fen Orchid (*Liparis loeselii*) and others. Also animals need unmanaged Ljubljana marsh grasslands and meadows – especially birds (migration and nesting in unmanaged natural grasslands).

Increasing the frequency of cutting and the use of inorganic fertilizer improved the agronomic value of the managed grass sward. It also maintained plant diversity of the *Arrhenatherum* grassland (Table 3) on the level of the extensively used sward, which can be stated at least for this soil type, climate and vegetation. Management also drastically decreased the massive occurrence of the marsh horsetail (*Equisetum palustre*). Plants were named and determined after (MARTINČIČ et al. 1999) and (SELIŠKAR 1986).

Table 1: The proportion of botanical groups and *Equisetum palustre* (% of fresh matter herbage) in *Arrhenatherum elatius* grassland in year five, first cut, with respect to cutting regime and fertilizer application.

| Fertilizer          | cutting regime  | grasses | legumes | herbs | <i>E. palustre</i> |
|---------------------|-----------------|---------|---------|-------|--------------------|
| Zero                | 2cuts (delayed) | 55.8    | 0.5     | 43.7  | 26.4               |
| Zero                | 3 cuts          | 75.7    | 0.6     | 23.7  | 14.8               |
| Zero                | 4 cuts          | 73.0    | 0.3     | 26.7  | 10.3               |
| PK                  | 2cuts (delayed) | 75.5    | 1.9     | 22.6  | 7.6                |
| PK                  | 3 cuts          | 83.3    | 3.3     | 13.4  | 4.0                |
| PK                  | 4 cuts          | 82.3    | 0.5     | 17.2  | 2.5                |
| N <sub>(1)</sub> PK | 2cuts (delayed) | 85.2    | 1.9     | 12.9  | 6.6                |
| N <sub>(1)</sub> PK | 3 cuts          | 86.9    | 0.4     | 12.7  | 3.8                |
| N <sub>(1)</sub> PK | 4 cuts          | 87.5    | 0.6     | 11.9  | 1.4                |
| N <sub>(c)</sub> PK | 2cuts (delayed) | 82.3    | 0.7     | 17.0  | 7.5                |
| N <sub>(c)</sub> PK | 3 cuts          | 86.3    | 0.7     | 13.0  | 3.1                |
| N <sub>(c)</sub> PK | 4 cuts          | 92.9    | 0.0     | 7.1   | 1.6                |

Fertilizer treatment were 0 (Zero), PK (35 kg P + 133 kg K ha<sup>-1</sup> y<sup>-1</sup>); (N<sub>(1)</sub> PK (50 kg N ha<sup>-1</sup> cut<sup>-1</sup> applied to first cut only + 35 kg P and 133 kg K ha<sup>-1</sup> y<sup>-1</sup>); N<sub>(c)</sub> PK (50 kg N ha<sup>-1</sup> cut<sup>-1</sup> applied to each of 2, 3 and 4 cuts + 35 kg P and 133 kg K ha<sup>-1</sup> y<sup>-1</sup>).

Table 2: Shannon diversity index and species number in the *Arrhenatherum elatius* grassland in year five, first cut, with respect to cutting regime and fertilizer application.

|                     | Shannon diversity index <sup>†</sup> |       |                     |                     |                    | Species richness of plants investigated <sup>‡</sup> |     |                     |                     |         |
|---------------------|--------------------------------------|-------|---------------------|---------------------|--------------------|------------------------------------------------------|-----|---------------------|---------------------|---------|
|                     | Zero                                 | PK    | N <sub>(1)</sub> PK | N <sub>(c)</sub> PK | average            | Zero                                                 | PK  | N <sub>(1)</sub> PK | N <sub>(c)</sub> PK | average |
| 2 cuts<br>(delayed) | 1.92                                 | 1.42  | 1.43                | 1.52                | 1.57a <sup>§</sup> | 19                                                   | 15  | 14                  | 15                  | 16a     |
| 3 cuts              | 2.11                                 | 2.06  | 1.94                | 1.80                | 1.98b              | 22                                                   | 26  | 21                  | 20                  | 22b     |
| 4 cuts              | 2.35                                 | 2.16  | 2.18                | 1.70                | 2.10b              | 23                                                   | 21  | 23                  | 20                  | 22b     |
| Average             | 2.13b <sup>§</sup>                   | 1.88a | 1.85a               | 1.67a               | 1.88               | 21a                                                  | 21a | 19a                 | 18a                 | 20      |

<sup>†</sup>  $P = 0.006$  for cutting;  $P = 0.003$  for fertilizing; no cutting x fertilizing interaction

<sup>‡</sup>  $P = 0.001$  for cutting;  $P = 0.138$  for fertilizing; no cutting x fertilizing interaction

<sup>§</sup> Means within a column or row followed by the same letter are not significantly different at  $P = 0.05$  - Duncan's multiple range test.

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Table 3: Botanical survey of the *Arrhenatherum elatius* grassland trial T1 (after Braun-Blanquet method; Braun-Blanquet J. 1964) according to the cutting regime and fertilizing application (4<sup>th</sup> trial year)\*.

|                                  | 2 cuts (delayed) |     |                  |                  | 3 cuts |     |                  |                  | 4 cuts |     |                  |                  |
|----------------------------------|------------------|-----|------------------|------------------|--------|-----|------------------|------------------|--------|-----|------------------|------------------|
|                                  | Zero             | PK  | N <sub>1</sub> P | N <sub>k</sub> P | Zero   | PK  | N <sub>1</sub> P | N <sub>k</sub> P | Zero   | PK  | N <sub>1</sub> P | N <sub>k</sub> P |
| <i>Anthoxanthum odoratum</i>     |                  |     |                  |                  |        |     |                  | 1.1              | +1     | +1  | +1               | +1               |
| <i>Arrhenatherum elatius</i>     | 2.1              | 2.1 | 2.1              | 3.1              | +1     | 3.1 | 3.1              | 3.1              | +1     | 2.1 | 1.1              | 3.1              |
| <i>Dactylis glomerata</i>        | 1.1              | +1  | +1               | 1.1              | +1     | 1.1 | 1.1              | 1.1              | +1     | 1.1 | 1.1              | 1.1              |
| <i>Festuca pratensis</i>         | +1               | +1  |                  |                  | 1.1    | 1.1 | 1.1              | 1.1              |        | 1.1 | 1.1              | +1               |
| <i>Festuca rubra</i> agg.        | 2.1              | 1.1 | 1.1              | +1               | 2.1    | 1.1 | 1.1              |                  | 3.1    | 1.1 | 3.1              | +1               |
| <i>Helictotrichon pubescens</i>  |                  |     | +1               | +1               | 2.1    | 1.1 | 2.1              | 2.1              | 1.1    | 1.1 | 1.1              | 1.1              |
| <i>Holcus lanatus</i>            | +1               | 1.1 | 1.1              | +1               |        |     |                  |                  |        |     | +1               |                  |
| <i>Poa trivialis</i>             | +1               |     |                  |                  |        |     | +1               | +1               |        |     |                  | 1.1              |
| <i>Lathyrus pratensis</i>        | +1               | 1.1 | +1               | +1               |        | +1  |                  | +1               |        |     |                  |                  |
| <i>Medicago lupulina</i>         |                  | +1  |                  |                  |        |     |                  |                  |        | +1  |                  | +1               |
| <i>Trifolium pratense</i>        |                  | +1  |                  |                  | 1.2    | 1.2 | 1.2              |                  |        |     |                  | +1               |
| <i>Vicia cracca</i>              | +1               | +1  |                  | +1               | +1     | +1  | +1               | +1               |        | +1  | +1               | +1               |
| <i>Achillea millefolium</i> agg. | +1               | +1  | +1               | +1               | 1.1    | +1  | 2.1              | 1.1              | +1     | +1  | +1               | 1.2              |
| <i>Ajuga reptans</i>             |                  |     |                  |                  | +1     |     |                  |                  | +1     |     |                  | +1               |
| <i>Angelica sylvestris</i>       |                  | +1  |                  |                  |        | +1  | +1               |                  |        | +1  |                  |                  |
| <i>Calystegia sepium</i>         |                  | +1  | +1               | +1               |        |     | +1               |                  |        |     |                  |                  |
| <i>Campanula patula</i>          | +1               |     | +1               | +1               |        | +1  | +1               |                  |        | +1  |                  |                  |
| <i>Centaurea jacea</i>           | +1               | +1  | +1               | +1               | +1     | +1  | +1               | +1               | +1     | +1  | 1.1              | +1               |
| <i>Cerastium holosteoides</i>    |                  |     |                  |                  |        |     |                  | +1               |        |     | +1               | +1               |
| <i>Cirsium oleraceum</i>         |                  | +1  | +1               |                  |        |     | +1               |                  |        |     | +1               |                  |
| <i>Convolvulus arvensis</i>      | +1               | +1  | +1               | +1               |        | +1  | +1               |                  |        | +1  |                  | +1               |
| <i>Cruciata glabra</i>           |                  | +1  | +1               | +1               |        | +1  |                  |                  |        | +1  |                  |                  |
| <i>Daucus carota</i>             | +1               |     | +1               | +1               | +1     |     |                  | +1               |        |     |                  |                  |
| <i>Equisetum palustre</i>        | 3.1              | 1.1 | 1.1              | +1               | 3.1    | 1.1 | +1               | +1               | 3.1    | +1  | +1               | +1               |
| <i>Erigeron annuus</i>           |                  |     |                  |                  |        |     | +1               | +1               |        | +1  |                  |                  |
| <i>Galium mollugo</i>            | 1.1              | 2.1 | 2.1              | 2.1              | 1.2    | 2.1 | 1.1              | 2.1              | 1.1    | +1  | +1               | 1.1              |
| <i>Glechoma hederacea</i>        |                  |     |                  | +1               |        | +1  |                  |                  |        |     |                  | +1               |
| <i>Leontodon hispidus</i>        | +1               |     |                  |                  | +1     | +1  |                  |                  | +1     | +1  |                  |                  |
| <i>Leucanthemum ircutianum</i>   | +1               | +1  | +1               | +1               | +1     | +1  | +1               | +1               | +1     | 1.1 | 2.1              | +1               |
| <i>Lythrum salicaria</i>         | +1               | +1  |                  | +1               | +1     |     | +1               |                  |        |     |                  |                  |
| <i>Silene latifolia</i>          |                  | +1  |                  | +1               | +1     | +1  | +1               | +1               |        |     |                  |                  |
| <i>Mentha aquatica</i>           | +1               | +1  |                  |                  |        | +1  |                  |                  | +2     |     |                  | +2               |
| <i>Mentha longifolia</i>         |                  |     | +1               | +1               |        |     |                  | +1               |        |     |                  |                  |
| <i>Pastinaca sativa</i>          | +1               | +1  | +1               | +1               | +1     |     | +1               | +1               |        |     |                  |                  |
| <i>Pimpinella major</i>          | +1               | +1  | +1               |                  |        |     |                  |                  |        | +1  | +1               |                  |
| <i>Plantago lanceolata</i>       | +1               |     |                  |                  | 1.1    | +1  | 1.1              | 1.1              | 1.1    | +1  | +1               | +1               |
| <i>Ranunculus acris</i>          | +1               | +1  |                  |                  | 1.1    |     | 1.1              | 1.1              | +1     | +1  | +1               | +1               |
| <i>Ranunculus repens</i>         | +1               | +1  | +1               | +1               | +1     | +1  | +1               | +1               | +1     | +1  | +1               | +1               |
| <i>Rumex acetosa</i>             |                  |     |                  |                  |        |     | +1               | +1               | +1     |     | +1               |                  |
| <i>Taraxacum officinale</i>      |                  |     |                  |                  |        |     |                  | +1               | +1     | +1  |                  | +1               |
| <i>Verbascum</i> sp.             |                  |     |                  | +1               |        | +1  | +1               |                  | +1     |     |                  |                  |
| <i>Veronica persica</i>          | +1               |     |                  | +1               |        |     | +1               |                  | +1     | +1  | +1               | +1               |
| Total number                     | 28               | 28  | 23               | 28               | 25     | 28  | 29               | 29               | 28     | 26  | 24               | 27               |

\*Species that cover less than 1%, appeared in one or two treatments only, are not included in the table.

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Fig. 1: The river Ljubljanica crossing Ljubljana Marsh.

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