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Halophytes at soda pans in northern Burgenland under the influence of soil conditions and conservation management

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We should not let our fears hold us back from pursuing our hopes. John F. Kennedy
sowie
Mathematik ist die Musik der Vernunft. James Joseph Sylvester

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Begeisterung ist der Anfang aller Wunder und der Atem der Seele. Hans Menzel

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Obstacles don't have to stop you. If you run into a wall, don't turn around and give up. Figure out how to climb it, go through it, or work around it. Michael Jordan

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Güte, Liebe, Mitgefühl und Sanftheit sind keine Dinge für Weichlinge. Sie sind Dinge, nach denen sich die Welt letztlich sehnt. Desmond Tutu

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Monika Minder

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Abstract

Soda pans of the Carpathian basin are shallow saline lakes with variable water levels. They are critically endangered habitats of European concern. Conservation management is trying to revive traditional grazing in order to preserve the specialised halophytic vegetation surrounding these soda pans. However, explicit effects of grazing on halophytes are unclear apart from changes in community structure by supressing otherwise dominant species like *Phragmites australis*. This study asks whether low intensity shifting grazing by cattle in the Seewinkel area in Austria affects community composition, halophyte presence, species richness and abundance when reed dominated patches are excluded. I conducted 176 vegetation relevés on randomly chosen salinity-influenced sites around 19 soda pans and took soil samples to further determine the influence of conductivity and nitrate on vegetation. Additionally, I monitored shares of bare soil and reed abundance on the twelve grazed and seven non-grazed pans. In an AIC_c-based model selection approach grazing *per se* never showed a relevant influence on halophytes, while share of bare soil turned out to be the main environmental driver. As expected, soil conductivity shaped community structure as well as the ratio of halophyte to glycophyte abundance. Salinity was a relevant factor increasing the presence of two halophytic model species *Puccinellia peisonis* and *Tripolium pannonicum* but decreasing presence of glycophytes. Soil nitrate increased glycophyte relative to halophyte abundance and the presence of reed. Reed cover still shaped plant communities, despite the pre-selection of study sites to exclude reed-dominated habitats. All models showed higher values of explained variance when the random effect of soda pan identity was considered, which indicates that other factors than the physical soil and vegetation characteristics measured here play an important role as well. Re-establishing connectivity between soda pans through grazing corridors might be crucial for future halophyte population persistence. I conclude that herded cattle grazing at the current intensity does not pose any threat to halophytes around soda pans in the Seewinkel region and might even be slightly intensified without adverse effects.

Keywords:
halophytes, soda pans, salt marsh, biodiversity loss, endangered species, endangered habitats, National Park Neusiedler See – Seewinkel, cattle grazing, sedentary herding

Abbreviations

acc. w_i	cumulative Akaike weight (sums up to 1 for all models in a candidate set)
AIC_c	Akaike information criterion corrected for small sample size
ΔAIC_c	delta values, i.e. difference to AIC_c-value of best-ranked model
dbRDA	distance-based Redundancy Analysis
ER	evidence ratio (expressing how much less likely $model_i$ is than the best-ranked model)
GLMM	generalised linear mixed model
HPLC	High-performance liquid chromatography
IQR	inter-quartile range
k	number of estimated parameters of a model
LMM	linear mixed model
ML	Maximum likelihood
PCV	proportion change in variance
R^2	Coefficient of determination, amount of variance ‘explained’ by a model
REML	restricted maximum likelihood (REML)
w_i	Akaike weight (probability of being best-ranked model)

Deutsche Zusammenfassung

Die Sodalacken des Karpathenbeckens sind flache, salzhaltige Seen mit wechselndem Wasserstand. Sie sind stark bedrohte Lebensräume von europäischer Bedeutung. Im Naturschutz-Management wird versucht das traditionelle Hutweidesystem wieder zu beleben, um die angepasste Halophyten-Vegetation rund um die Salzlacken zu erhalten. Allerdings sind die genauen Auswirkungen der Beweidung auf Halophyten noch unklar, mit Ausnahme des Einflusses auf die Artenstruktur durch Unterdrückung von sonst dominierenden Arten wie *Phragmites australis*. Diese Studie untersucht, ob auf Hutweiden im Seewinkel in Österreich die Artenzusammensetzung, das Vorkommen, die Artenvielfalt und Deckung von Halophyten beeinflusst werden, wobei schilf-dominierte Flächen ausgeschlossen wurden. Ich habe 176 Vegetationsaufnahmen auf zufällig ausgewählten, salz-beeinflussten Flächen an 19 Sodalacken durchgeführt und Bodenproben entnommen, um zugleich auch den Einfluss von Salzgehalt und Nitrat auf die Vegetation festzustellen. Zusätzlich habe ich den Anteil an offenem Boden und Schilfdeckung auf den zwölf beweideten und sieben nicht beweideten Lacken notiert. In einem AIC_c-basierten Modell-Auswahlverfahren zeigte Beweidung nie einen relevanten Einfluss auf Halophyten, während der Anteil an offenem Boden als Hauptumweltfaktor hervortrat. Wie erwartet, beeinflusste die Bodenleitfähigkeit sowohl die Struktur der Lackenvegetations-Gemeinschaften als auch das Verhältnis zwischen Halophyten- und Glykophyten-Deckung. Der Boden-Salzgehalt erhöhte das Vorkommen der zwei halophytischen Modell-Arten *Puccinellia peisonis* und *Tripolium pannonicum,* aber verringerte das Vorkommen von Glykophyten. Nitrat erhöhte das Verhältnis von Glykophyten-Deckung relativ zu Halophyten sowie das Vorkommen von Schilf. Schilfdeckung beeinflusste trotz der Vorauswahl der Untersuchungsflächen die Zusammensetzung der Pflanzengemeinschaften. Alle Modelle zeigten höhere Werte für erklärte Varianz, wenn der Zufallseffekt der Salzlacken-Identität mitberücksichtigt wurde, was darauf hindeutet, dass auch andere Faktoren als die hier gemessenen Boden und Vegetations-Charakteristika eine wichtige Rolle spielen. Eine Wiederherstellung der Verbundenheit der Salzlacken durch Beweidungskorridore könnte entscheidend sein für die zukünftige Erhaltung der Halophyten-Populationen. Ich folgere daher, dass das Hutweidesystem als solches keine Bedrohung für Halophyten der Sodalacken im Seewinkel darstellt und die derzeitige Beweidungsintensität ohne negative Folgen sogar etwas erhöht werden könnte.

Schlagwörter:
Halophyten, Salzlacken, Salzwiesen, Salzsümpfe, Verlust der Artenvielfalt, bedrohte Arten, bedrohte Lebensräume, National Park Neusiedler See – Seewinkel, Rinderbeweidung, Hutweiden

1. Introduction

Soda pans are astatic, alkaline wetlands, which lack surface water in summer, but are filled annually by precipitation during winter and show seasonally varying salinities (Williams 2002). Most soda pans occur in semi-arid climate zones around the world. As for freshwater lakes, a common trend in degradation of these ecosystems can be observed globally (Williams 2002). The soda pan area in northern Burgenland, Austria is the westernmost region of salt pans in Eurasia (Löffler 1982). The so-called Seewinkel is situated at the western edge of the Little Hungarian Plain (Kisalföld) and shows many botanical similarities with the Hungarian salines (Wendelberger 1951). About 80% of once existing soda pans in the Carpathian basin have been lost already through drainage and river regulations (Boros et al. 2013). The formation of the soda pan basins and the origin of the soda in northern Burgenland are still subject of scientific debate (Dober et Gritzmann 2014, Weiss 2015a, Gurresch et al. 2015), but any changes in hydrological conditions have been shown to strongly reduce soil salinity (Boros et al. 2013). At the bottom of soda pans, over thousands of years, sedimentation of calcite and clay minerals have formed a water-impermeable horizon, which acts as a barrier for both seeping rainwater and rising groundwater (Krachler et al. 2012). This soda pan ground must remain in touch with the underlying groundwater for staying water-impermeable and to ensure a continuous capillary rise of ions to upper soil layers (Krachler et al 2012).

While salt compositions of coastal salt-affected habitats are comparable to sea water (=neutral, sodium chloride dominated), continental salt-affected habitats often show differing, alkaline salt components and are dominated e.g. by sodium carbonate and sodium sulphate (Waisel 1972). Soda pans of the Carpathian basin show high chemical diversity (Boros et al. 2014). The biggest areas of sodic soils in Europe occur continentally in Hungary (Great Hungarian Plain, Alföld) and in Romania (Tóth et al. 2008). Two types of salt-affected soil can be distinguished: solonetz (black alkali soil) and solonchak (white alkali soil) (e.g. IUSS 2015). Solonchak soils accumulate highest salt concentrations in their uppermost layers and typically show white salt efflorescences during dry periods. Solonetz soils show a zone of highest concentration of salts in deeper layers and exhibit shrinkage cracks in summer. In northern Burgenland, most salt-affected soils are mixtures between those two soil types on a small spatial scale (Nelhiebel 1980), but solonchak dominates the soda pan basins and their surroundings (Festetics 1971).

Continental naturally salt-affected habitats are critically endangered throughout Europe and listed as protected habitats in the EU habitats directive. Two different habitat types are discriminated: Inland salt meadows (1340) and Pannonic salt steppes and salt marshes (1530) (EIONET 2014, Šefferová Stanová et al. 2008). Austrian reports to EU conservation authorities only mention the latter (Ellmauer et al. 1999). Of the five EU countries listing Pannonic salt steppes and salt marshes in their official reports, only Romania currently assigns favourable conservation status to its sites. The main reasons for endangerment are drainage and melioration of less salt-affected soils (i.e. the conversion into arable land), changes to more extreme ends of utilisation gradients, leading to either abandonment or intensification of once extensively managed meadows or pastures, as well as intensification of surrounding agricultural land with heavy use of fertilizers and pesticides (EIONET 2014, Török et al. 2011, Kohler et al. 1994).

Around 6% of the Earth's land surface is covered by salt affected soils and a considerable part of them occur within winter-cold steppe ecosystems, deserts and semi-deserts around the world (Grabherr 1997). On salt-affected soils, specialised halophytic (halos = greek for *salt*, philos = greek for *friend*) plants occur (e.g. Eliáš et al. 2013). Most halophytes are not literally salt-loving but have found ways to cope with salinity through different strategies to prevent salt-uptake, dilute salts within cellular tissues, shift excess salts to special plant organs or cell compartments, actively secrete them by salt glands, or outbalance the osmotic stress induced by salts within the plant individual or its environment by producing compatible solutes or by selective ion uptake (Flowers & Colmer 2015, Flowers & Colmer 2008, Albert 1975). While there are some eu-halophytic species, which truly need a certain soil salinity level to germinate and thrive, there are numerous species which only tolerate saline conditions. Multiple physiological as well as ecological classification systems have been proposed to describe this gradient of adaptations to saline conditions (Breckle 2018, Grigore et al. 2010, Grigore & Toma 2017). In the current study, all vascular plant species known for their main presence in saline habitats were included in analyses, regardless of their physiological preferences. This corresponds to two of the three types of halophytes Braun-Blanquet (1964) described: salt-requiring and salt-loving species, excluding merely salt-tolerant species.

Salt steppes and salt marshes show vegetation patterns reflecting not only the salt content of the soil, but also the type of salts involved, as well as the depth of the salt horizon (Molnár & Borhidi 2003). Wendelberger (1951) described the typical zonation of halophytic vegetation around Central European soda pans and Essl (2005) put together all relevant plant associations for the mapping of Pannonian salt steppes and salt marshes as Natura 2000 sites in Austria. Dítě et al. (2017) examined the current phytocoenological status of Carpathian soda pans. Differences in micro-relief in combination with annual changes in habitat conditions, especially in the extent of open water surface due to variation in precipitation, result in a shift in the location of characteristic phytocoenoses of soda pan shorelines and dominant species (Blab 1997, Boros et al. 2013, Lukács et al. 2015). Thus, alkaline marshes mostly exhibit a mosaic pattern, due to small-scale variation in salt accumulation in the soil and water supply (Valkó et al. 2014). Furthermore, the shorelines of many soda pans have been taken under cultivation, confining them to small remains of their potential size (Boros et al. 2013). Anthropogenic activities lead to disturbance and degradation of many halophytic phytocoenoses. This hampers identification of 'plant associations' in the field even further. This study therefore followed a different approach. I directly addressed halophytic species on randomly selected, potentially salt-influenced sites of equal size, instead of pre-selecting putatively "homogenous" vegetation patches along gradients in the field.

In non-saline environments, true halophytes mostly lack competitive power and are overgrown and outcompeted by other species (Ungar 1998). This might be due to their salt-exclusion strategies, which can be energy-intensive, but could also be caused by other factors, e.g. enhanced growth rates of highly-salt tolerant plants at higher salinity levels or later germination and shorter growing season length due to their well-adapted life cycles to their environments (Rozema & Schat 2013). *Phragmites australis* (Poaceae) (Cav.) Trin. ex Steudel (reed) has been shown to outcompete halophytic target species of conservation concern at the salt marshes around soda pans in Austria without proper management (Korner et al. 2008). In a grazing exclosure experiment, Török et al. (2014) documented that *P. australis* reached three- to twenty-times higher cover scores in fenced plots in Hungarian salt marshes, but yearly fluctuations were very high. Bart & Hartman (2002) found evidence that the loss of alkaline character facilitates reed invasion in tidal salt marshes. Furthermore, reed expansion is likely to be favoured by regular reed cut (Deák et al. 2015). Reed from alkaline habitats used to be economically valued because of its special structure (Valkama et al. 2008) and many reed beds on soda pans in Austria were commercially harvested in winter until recently (Kohler & Korner 2006). In these regularly harvested stands of reed other species are generally suppressed or even missing, because young reed forms a dense, uniform structure (Deák et al. 2014). Thus, reed-dominated areas of soda pan basins were excluded in this study.

For millennia one traditional form of land use of salt-influenced soils in the Carpathian basin has been extensive grazing since arable agricultural use was not profitable (Molnár et al. 2016). Shifting grazing or sedentary herding is a form of traditional grazing which involves herdsmen with herder dogs accompanying (in former times also mixed) herds of cattle, (horses), sheep, pigs (or geese) from barns in villages to daily grazing grounds (Kohler et al. 1994, Molnár 2014). Different feeding behaviours, activity levels, body size and mouth anatomies of grazing animals lead to different effects on vegetation (e.g. Tóth et al. 2018, van Klink et al. 2016, Rook et al. 2004, Menard et al. 2002, Olff & Ritchie 1998). In a study on coastal salt marshes, Nolte et al. (2014) found that size of homogenously grazed patches is smaller for cattle herds compared to horses, but mean canopy height is higher for cattle pastures, because cattles rip off vegetation with their tongues. Grazing of salt marshes leads to decreased vegetation height, reduction of mean vegetation cover resulting in a more open canopy and an increase of species richness, because annual plant species may sprout in the created open soil patches (Bakker & Ruyter 1981). Cattle grazing enhances growth of creeping and rosette-forming species and supresses tall growing species (Török et al. 2014). Grazing may also affect soil chemical conditions. By creating more open surface and compaction of soil through trampling, grazing animals can enhance soil salinity through increased evapotranspiration (di Bella et al. 2015, van Klink et al. 2015). However, productivity of the grazed ecosystems plays an important role as well (Bakker et al. 2006). Ren et al. (2012) even conclude that grazing effects are barely noticeable when differences in precipitation are very high. This present study focused on areas grazed by cattle that are guided by herdsmen and compared them to unmanaged soda pan grounds.

Soda pans in the Carpathian basin are hypertrophic systems (Szabó et al. 2017) but nitrogen uptake mostly exceeds input in aquatic ecosystems (Likens 2010). Soda pan waterbodies have unusually low nitrogen to phosphorus ratios (Boros et al. 2008) and saline soils around them often show limited amounts of nitrogen available to plants (Wollenweber & Zechmeister-Boltenstern 1989), because bacteria involved in N-cycling may immobilize large fractions within their biomass (Dendooven 2010). Inorganic nitrogen in the form of ammonia or nitrate is the only source of nitrogen in the soil that is available to plants (Wagner 2011). Microorganisms help halophytic species overcome nutrient deficiencies but only little specific information on nitrogen uptake of halophytes is available yet (Ruppel et al. 2013). Many halophytes show mycorrhiza, which has been shown to alleviate salinity stress and increase phosphorus uptake, but results on nitrogen metabolism are debated and only available for glycophytes under salt stress up to now (Porcel et al. 2012, Ruppel et al. 2013). Bacteria with genes encoding for dinitrogenase reductase (*nif*H) convert atmospheric nitrogen into ammonia and are screened for in microbiota assays (e.g. Szymańska et al. 2016). However, Mapelli et al. (2013) additionally tested for ammonia production of bacteria and found more than 90% of strains in *Salicornia* rhizosphere capable of it, even though only 5% of these rhizobacteria showed the *nifH* gene sequence. Several halophytes are nitrophilous species or known for their occurrence on ruderal sites, especially species of the family Chenopodiaceae (Wendelberger 1951, Albert & Popp 1977). Local nitrogen maxima may occur at the driftline of soda pans, where dead organic material accumulates or at dung sites of grazing animals, which are most frequently found at resting areas of cattle herds (Kohler et al. 1994, Molnár 2014), although decomposition of organic material can be hampered at high salinities (Dendooven 2010). Cattle urea probably is of minor relevance, because ammonia is highly volatile under the high pH conditions typical for sodic soils (Boros et al. 2008, Dendooven 2010). Grazing might also affect nitrogen availability by reducing soil net N-mineralization rates through reduced litter accumulation (van Wijnen et al. 1999). Due to the vicinity of agricultural land in many cases, the leaching of fertilizers into the soda basins probably plays a role as well (Krachler 1992). I focused on plant available soil nitrate in this study and looked for correlations between its concentration and the presence, species richness and abundance of halophytic species of conservation concern.

Current conservation management practices around soda pans in eastern Austria include traditional land-use techniques applied by herders like mowing or use of fire (Kohler & Korner 2006), but some traditional habits like manuring or cutting of draining ditches are banned now by National Park administrations or are strictly directed by EU regulations (Molnár et al. 2016). Experienced herders may adjust the herd's travelling speed and spread to current needs and force the animals to forage in certain areas (i.e. apply higher grazing pressure with less selective foraging), while completely sparing areas of special conservation concern. Herders also avoid unnecessary trampling of grassland areas (Molnár 2014). Therefore, the otherwise typical recommendations of livestock units per hectare for stationary conservation grazing systems are neither as easy to estimate for sedentary herding systems nor do they necessarily apply to them. While traditional Hungarian herding practices aim at animal well-being to increase weight gain and milk production as efficiently as possible, modern nature conservation targets may conflict with herders' perspectives (Molnár et al. 2016). Young halophytes of the soda pan basin (e.g. *Atriplex* or *Salicornia*) and salt marshes (e.g. *Juncus gerardii*) make good fodder plants for animals (Waisel 1972, Molnár 2014), but grazing grounds should always involve larger surroundings of soda pans to ensure that the grazers find nutrient rich vegetation throughout the year. Otherwise additional fodder might be necessary during the vegetation period, even for regional animal breeds (Ecsedi & Boros 2013a, compare Gilhaus & Hölzel 2016). An open attitude from herders and conservationists is needed to develop adaptive management strategies that simultaneously serve both interests (Molnár et al. 2016). In the focal region of this paper, grazing activities were set out in yearly adopted grazing management plans by the National Park administration, National Park rangers and conservationists together with the owners of the herds.

One main goal of the National Park Neusiedler See – Seewinkel is the perpetuation of traditional grazing. While proponents of grazing hypothesized that herding would favour halophytes despite the drastic reduction of soda pan area and soil salinization, critical voices raised concerns that grazing might have additional adverse effects on the already endangered species (Korner et al. 2008, Albert et al. 2016). However, no solid data were available to settle that debate. While other regional studies investigated the effect of grazing on distinctive vegetation communities or went deeper into the effects on *P. australis* and other dominating species by exclusion experiments (Korner et al. 2000, Korner et al. 2008, Euller et al. 2014) or by documenting detailed effects on soil nutrients (Steingruber 2013, Albert et al. 2016), this present study focuses specifically on the following four research questions:

(1) How strongly does the current conservation practice of low intensity shifting grazing by cattle influence species richness, abundance and species composition of halophytes as the main target of vegetation conservation aims on soda pan shores? (2) How does grazing affect the presence of two characteristic halophytic plant species of the Seewinkel, viz. *Puccinellia peisonis* (Poaceae) (Beck) Jav. and *Tripolium pannonicum* (Asteraceae) L.? (3) How do halophytes respond to variation in soil salinity, soil nitrate and bare soil area? (4) Does the abundance of *Phragmites australis* as the most problematic competitive species affect the presence, abundance or species composition of halophytes, and how is *P. australis* affected by soil conditions and grazing itself?

2. Material and Methods

2.1. Study region

The climate in the Seewinkel is subcontinental with around 600 mm precipitation per year and a mean annual temperature of 10 °C (NP Neusiedler See – Seewinkel 2019). Pollen and macrofossil records show that soda pans of the Danube-Tisza interflow in the Carpathian basin developed at the early postglacial period 13,000–10,000 years ago and have been continuously present since then (Sümegi & Boros 2013). Similar or even older ages are assumed for the soda pans in Austria (Krachler et al. 2012). Soda pan area as well as soda pan numbers in the Seewinkel have started to decline about 160 years ago through the construction of a system of drainage ditches, followed by shifts in agricultural use (Kohler et al. 1994). The irrigation of arable farmland surrounding soda pans as well as the construction of high-capacity community wells led to additional groundwater level lowering (Krachler et al. 2012). The water-retaining clay layer forming the bottom of soda pans shrinks and cracks open when the clay minerals dry and salts are then easily washed out by precipitation (Krachler 1992, Milleret 1999).

With this considerable habitat loss and land use change went hand in hand a change and loss of quality/diversity of the accompanying halophytic soda pan vegetation, specialised on alkaline soils. The Seewinkel region is known as a very species-rich area (Löffler 1982) and this holds true for halophytic plants as well, even though the species richness of Hungarian soda pans never was reached (Wendelberger 1951). Central European saline and sodic soils used to be treeless areas prior to the introduction of Russian olives (*Elaeagnus angustifolia*) from western and central Asia as windbreak species and nectar source for beekeeping in the 20th century (Ecsedi & Boros 2013a, Fischer et al. 2008). Common reed (*Phragmites australis*) and wood small-reed (*Calamagrostis epigejos*) now dominate many areas of former and current soda pans in the Seewinkel (Korner et al. 2008, Krachler et al. 2012). Salt barley (*Hordeum geniculatum*), a rare halophytic species of nitrate-rich, ruderal (highly disturbed) saline soils, even became extinct in Austria (Fischer et al. 2008). Many attempts to put a halt to this deteriorating trend include assigning different conservation status to the area (nature reserve, National Park, Ramsar site, Natura 2000, Unesco biosphere reserve, Unesco world heritage; Weiss 2015b). Various management techniques, such as retaining water by damming drainage ditches (Kohler and Korner 2006), and restoring former soda pan basins by applying soda to vegetation covered soils (Stojanovic 2006, Krachler et al. 2012) are currently implemented to conserve the ecological values of these rare habitats (Kohler et al 1994).

While at the beginning of the 20th century overuse of meadows by grazing in northern Burgenland was common (Kohler et al. 1994), numbers of grazing cattle continually declined in the last 60-70 years throughout the Carpathian basin due to intensification of agricultural practises (Varga et al. 2016). Like in many other European countries (e.g. Redecker et al. 2002), with the intentional political disruption of integrated agriculture (mixed farming) after the second world war (Bauer 1988), cattle grazing in Northern Burgenland could only survive because private initiatives or non-governmental organisations like the WWF started to rent land in the 1960s and continued or resumed sedentary herding as a means of nature conservation with specific management aims to achieve (Löffler 1986, Albert et al. 2016). Sedentery herding in the Seewinkel today relies on the expertise of Hungarian herders, since local farmers in Burgenland have lost this traditional knowledge. While mixed herds were traditional, nowadays (conservation) herds rather consist of single species, i.e. cattle. The grazing itinerary for cattle starts in April, lasting until November and shows fixed and opportunistic elements, following both pasture conditions and animal needs. Three different herds were grazing in my study area in summer 2007. One herd of Aberdeen Angus cattle was stationed at the Illmitzer Zicksee (grazing soda pans no. 39 and 40), one Fleckvieh cattle herd south of the Kirchsee (pan no. 41) in Illmitz, and another Fleckvieh cattle herd at the conservation zone Lange Lacke, which is the only continuously grazed area in the study region (soda pans no. 14, 23, 24, 25, 26, 48, 49, 85, 89). Livestock units were kept at around 0.5/ha (Steingruber 2013, Korner et al. 2008). Some areas were subject to additional management by mowing, but information available on this topic was too scarce at the time of the study design to be integrated on a fine-scale spatial level.

2.2. Study area and plot selection

The study area was defined within the National Park Neusiedler See – Seewinkel in northern Burgenland. In spring 2007, I selected eight to ten plots each on twelve grazed and seven ungrazed soda pans in an area of around 5800 ha spreading between municipal grounds of the villages of Podersdorf, Illmitz and Apetlon (central coordinates: ca. N 47°47' latitude and E 16°50' longitude). Selection criteria for soda pans were:

- open water area of more than 1 hectare during times of high water levels (Dick et al. 1994, Appendix 2);
- reed-dominated areas (*Phragmites australis*) do not surround the water area completely;
- shifting grazing occurred by cattle, if grazed at all by life-stock.

A stratified random sampling of the potentially salt-influenced area surrounding these soda pans was subsequently done by the following procedure. The salt-influenced area around each water body was estimated using a digital elevation model of the Seewinkel region (laserscan flights from Nov. 24th and 25th 2004; Attwenger & Chlaupek 2006). The shallowest part in the center of the respective soda pan served as an indicator for the position of the salt containing soil horizon. All areas situated up to 40 cm above that measured point per soda pan were considered. The altitudes of the lowest measured points ranged between 116 to 120.2 m a.s.l. (see Table A1 in Appendix). Salt-influence on vegetation can be seen up to 30 cm above the salt-containing soil horizon (Wendelberger 1951). In combination with an accuracy of the digital elevation model of ±4 cm in height (Herzig et al. 2002), the level of 40 cm was therefore chosen. The resulting focal area was digitized manually for each soda pan (shapefile by Böck 2004, based on Dick et al. 1994, supplement 3, additionally adjusted to water areas on real color orthophotos, Bgld GIS, from Sept. 17th, 2004). Grazed soda pan areas were identified in dialogue with the administration of the National Park Neusiedler See – Seewinkel, from grazing management plans and from interviews with the two herdsmen in summer 2006. Water bodies of soda pans, reed-dominated areas as well as non-grazed areas of grazed soda pans were excluded. All GIS-work was done with ArcMap (ESRI).
Within the resulting target areas 20 points were randomly selected per soda pan via XTools (ArcView, ESRI) and their x and y coordinates in Austrian Ferro East system (BMN M34) projection used for locating the sampling points in the field. Plots were named using soda pans numbers (Dick et al. 1994) and the sequential number of the random plot (column ID_Plot in tables below). Plots with numbers zero to nine were preferred for field work. Plots with higher numbers served as substitutes in case a plot could not be worked on, because it did not match above mentioned selection criteria in the field. Further in situ selection criterium was that the location was not situated in *Elaeagnus angustifolia* groves. Eight to ten of these points were worked on in summer and autumn 2007 (see Appendix Figure A1 for an orthophoto example and Table A1).

2.3. Plant relevés

Vegetation surveys were conducted from 18th of June to 2nd of August 2007. On each sampling point, a 50 x 50 cm wooden frame divided into 25 (10 x 10 cm) cells by flexible cotton ropes (Traxler 1997, see Appendix Figure A2 for an example of plot documentation) was positioned at a random spot with its upper edge facing north. The plot area was marked to be able to retrieve it during soil sampling. Abundances of individual plant species were estimated as perpendicular projections of aerial parts on the ground (Allaby 2013), termed cover hereafter. Cover values were estimated in 0.1 %-intervals from 0–1 % and 0.5 %-intervals from 1–4 % per cell. Dry plant parts of the current vegetation period were added to estimate total cover values. Plant parts of individuals not rooting in the plot area, but craning into it, were also considered in cover values. Each species cover was estimated separately for each cell and summed up for the cover value of a species per plot. Applying this procedure, the sum of abundances of all observed species for a specific plot may well exceed 100%, because of overlapping leaves in multi-layered structures (compare Hansen & Snickars 2014, Wikström et al. 2016).

Bare soil values were estimated for the entire plot, not on cell basis. Estimations of the complementary residual area were used to achieve high precision also for values of open soil between 80 and 100% of plot areas (compare Gehlker 1977, cited in Traxler 1997).

Of all recorded species (plant names after Fischer et al. 2005), halophytic target species were selected using salt indicator figures from Borhidi (1995). Only species of class S5 or higher (alpha-mesohaline to hypersaline plants) were considered as true halophytes to ensure a linear relationship with soil salt content. On the other hand, glycophytes were defined as species with salt indicator figures of zero using Borhidi (1995) as well as Ellenberg et al. (1991) and Blab (1997) as additional references. This was done to check for all species that possibly comprise halotolerant ecotypes in the Seewinkel and exclude them from the group of glycophytes.

2.4. Cattle grazing impact

Cattle grazing intensity was primarily estimated in the field by determining the level of grazed vegetation for each plot. Four levels of grazed vegetation were defined: no (0), little (1), intermediate (2), or strong/heavy (3) cattle consumption of herbage. Additional aspects were considered as well:

- cattle footprints in the plot area
- cattle footprints in the surrounding area of the plot within a radius of 1 meter
- cattle feces on the plot area
- cattle feces on the surrounding area of the plot within a radius of 1 meter
- trampled vegetation

The single parameter of grazing influence used in the analyses is mainly based on the original four levels of grazed vegetation. Yet, the two levels “no herbivory” and “little grazing influence” were subsequently merged for grazed soda pans, because most plots showed signs of cattle grazing in one or more of the additional grazing aspects (see Table A7, Appendix). Two soda pans (25, 26) serving as additional feeding grounds in autumn, were included within this merged level “little grazing influence” as well. Six plots on ungrazed soda pans showed herbivory by wild animals (such as roe deer) but were treated like all other ungrazed plots in analyses.

2.5. Soil analysis

The objective of soil analysis was to measure actual salt-influence and nitrate concentrations at plots, to gain insights about their role in determining halophytic species occurrences. Soil sampling took place from October 16th to 21st 2007. For each plot one soil sample was taken next to the relevé area, at a spot that lay around halfway between the soda pan centre and its shore. Soil samples were taken using a metal drill (1 m length, 5 cm diameter, see Figure A3 in Appendix) or shovels for coarse-grained soils. Since accessible depths for soils with heavy gravel were not comparable, only top soil samples (0-10 cm) were considered in analyses. In case original plant relevé plots could not be recovered during soil sampling, spots with similar vegetation close by were sampled instead (12 plots).
Soil samples were transported in plastic bags each, together with coolers, weighed and stored in a cool place before transferring them to the laboratory. Soil samples were transferred to paper bags for drying in a drying cabinet at 105 °C. The dried soil was sieved (5 mm, 2 mm) for further processing. Water extracts of the sieved soil samples were prepared using around 1.5 g of dry soil with 15 ml of distilled water (MiliQ) in scintillation tubes. Exact soil net weights were noted and used to calculate per gram-values of the following measurements. To recover soluble soil materials, extracts were shaken for one hour at 140–200 revs/min, followed by a resting time of 30 min in upright position allowing for small particles to settle down. Conductivity as a measure of total salt ion content (Boros et al. 2014) was metered directly in the resulting crude soil extract (WTW LF330 Conductivity Meter, TetraCon325 Electrode, Texas Instruments). Extracts were filtered (Whatman 40-Filter) for a maximum of two hours and filtrates deep frozen at -18 °C.
HPLC measurements of nitrate in soil water extracts were done following standard protocols (DX500, Dionex, Vienna, Austria, Anion exchange column AS11, 250 mm, Dionex, using a linear KOH gradient from 2–30 mM in 6 min with a total run time of 10 min). Frozen filtrates of water extracts were melted at room temperature, shaken, centrifuged and required sample amounts taken out. Standards for nitrate were added to each HPLC measuring cycle in 12 dilutions (50 mg/l to 0.0244 mg/l). Retention time was 2.6 min for nitrate ions.
All lab work was done at the former Department of Terrestrial Ecosystem Research, Faculty of Life Sciences, University of Vienna, in spring and early summer 2008.

2.6. Statistical analyses

2.6.1. Overview

All analyses were done in the R environment (R Core Team 2018), using the packages *vegan* (Oksanen et al. 2016) for ordination and multivariate analyses, *lme4* (Bates et al. 2015) for mixed models, *MuMIn* (Barton 2016) and *AICcmodavg* (Mazerolle 2011) for model inference and selection as well as *car* (Fox & Weisberg 2011) for evaluating model fit.
Seven response variables were chosen to model the influence of grazing, soil conditions and competition on halophytes: 1. presence of halophytic target species 2. species richness (i.e. number) of halophytic target species 3. index of halophyte abundance (after Hansen & Snickars 2014) based on the cumulative cover of halophytic target species subtracted by the cumulative cover of glycophytes divided by the cumulative cover of all plant species on a plot, including not classified or indifferent species. 4. species composition of plots 5. presence of the endemic Pannonian halophytic plant species *Puccinellia peisonis* (Poaceae) (Beck) Jav. 6. presence of the halophytic plant species *Tripolium pannonicum* ssp. *pannonicum* (Asteraceae) L. 7. presence of the competitive species *Phragmites australis* (Poaceae) (Cav.) Trin. ex Steudel. Additionally, the presence of glycophytes was modelled to check if assumptions for the index

of halophyte abundance were matching the local conditions across my study sites, using the same parameters as above.

2.6.2. Methodical approaches and modelling parameters

For species richness and the index of halophyte abundance, linear mixed effects models (LMMs) were run using REML (Restricted maximum likelihood) estimations of model parameters (Bolker et al. 2008). Analysis of soda pan plant species composition was conducted through a partial distance-based redundancy analysis using function *capscale* (dbRDA; Legendre & Anderson 1999) based on Bray-Curtis distances (Odum 1950, Bray & Curtis 1957). For presence-absence data of halophytic target species, *P. peisonis*, *T. pannonicum, P. australis* and glycophytic non-target species binomial generalised linear mixed models (GLMMs) with logit-link functions were run. To account for the nested sampling design of grouped plots per soda pan, all univariate models were run as random intercept mixed effects models with soda pan identity as the random factor (Zuur et al. 2009). In the multivariate analysis of plant species composition, the effect of soda pan identity was removed before constraining with fixed variables (Oksanen 2015).

2.6.3. Response data preparation

Index of halophyte abundance was arc sine-transformed to achieve a Gaussian distribution (Bolker et al 2008). Cover of *P. australis* was excluded from the community table since it was used as a predictor for species composition in dbRDA. To approximate Bray-Curtis distances to Euclidean distances species abundance values were Hellinger-transformed prior to distance calculations (Legendre & Gallagher 2001).

2.6.4. Selection and preparation of predictor variables for regression models

The same set of predictor variables was chosen for all univariate and multivariate global models: soil conductivity, intensity of grazing, soil nitrate, reed cover and share of bare soil. Exception was the model for presence of *Phragmites australis*, for which reed cover values were excluded on the predictor side. Predictor variables were transformed to fit Gaussian distributions if necessary (see Table 1 in Results section) and checked for correlations. Prior to applying a logit-transformation, an increment was added to all zero values and subtracted from all one values, respectively, which was chosen to be half the amount of the difference between the smallest recorded value of the selected variate and zero (Warton & Hui 2011). Intensity of grazing was entered as a continuous variable in the models for easier interpretations of results.

2.6.5. Model validation and inference

To validate LMMs, Gaussian distributions of residuals of global models were checked. For GLMMs, plots of Pearson residuals and fitted values were inspected for anomalities in spread. Goodness of fit for (G)LMMs was asserted by calculating R^2 values and proportion change in variance following Nakagawa & Schielzeth (2013).

Model inference followed Burnham & Anderson (2002). Using an all-subset approach without any interaction terms a 95% confidence set of models was put together based on Akaike information criterion value corrected for small sample sizes (AIC_c). Predictor weights, model averaged parameter estimates, and unconditional confidence intervals were reported (Symonds & Moussalli 2011, Burnham et. al 2011) using function *modavgShrink* (package *AICcmodavg*). All predictors with variate weights of 0.9 or higher were considered as relevant and checked graphically by producing biplots and boxplots with simple regressions based on original values. To extract AIC_c-values and R^2-estimates all LMMs were refitted using ML (Zuur et al. 2009). Adjusted R^2 values accounting for different numbers of parameters in the models were calculated for (G)LMMs using *k* values of the *aictab* output.

For dbRDA (*capscale*) results function *ordistep* in the *vegan*-package was used to perform permutational pseudo (non-parametric) *F*-tests on stepwise reduced models and an adjusted R^2 value was obtained for the global model. Clarification of species results was achieved by showing only species with scores > |0.5| for at least one of the ordination axes and removing all other species with less distinctive ordination scores clustered at the origin.

3. Results

3.1. Overview of gathered data

I worked on 176 plots at 19 soda pans. Altogether, there were 67 plots on 7 ungrazed soda pans and 109 plots on 12 grazed soda pans. Of all grazed plots, 53 were little affected by grazing influence (level 1), 31 plots showed medium grazed vegetation (level 2) and 25 plots were heavily grazed (level 3).
Of the 131 recorded plants species in total, there were 14 halophytic target species and 63 glycophytes (see Tables A6 and A7 in Appendix). The plant community table with cover values for all recorded species is shown in Table A10 in Appendix.
Halophytic plant species were present in 142 of 176 plots. The number of halophytic target species per plot ranged from zero to six species with a mean of 1.7 species (±SD: 0.43–2.95) and highest values for plots with medium grazing intensity. Index of halophyte abundance showed a mean value of 0.30 (±SD: -0.36–0.96). *Puccinellia peisonis*, *Tripolium pannonicum* and *Phragmites australis* were present in 67, 91 and 75 of 176 plots, respectively. 85 plots harboured at least one glycophytic plant species.
Table 1 gives descriptive statistics for all modelled environmental influences on halophytes. Original values of soil conductivity and soil nitrate are listed in Table A9 (see Appendix) as well as reed (*P. australis*) cover values and bare soil values.

Table 1: Applied transformations to improve fit to Gaussian distributions and descriptive statistics (mean, median, interquartile range as well as range) for original values of predictor variables on 176 plots at 19 soda pans. IQR – inter-quartile range.

	Predictor				
	Conductivity in g/kg dry soil	**Grazing intensity**	**Nitrate in mg/l**	**Share of bare soil**	**Share of reed cover**
Applied transformation	4th root	4th root	4th root	logit	logit
Mean	3.52	1.08	24.24	0.22	0.03
Median	2.56	1	16.05	0.07	0
IQR	3.87	2	18.3	0.4	0.04
Range	0.62 –13.4	0–3	0–160.9	0–0.98	0–0.38

3.2. Mixed models for aggregate univariate responses

3.2.1. Modelling the presence of halophytic target species

The AICc-based model selection process revealed that only the fraction of bare soil showed relevant (and positive) effects on the occurrence of halophytic plants (Table 4 and Table 2). Neither grazing intensity nor soil conductivity were related to the presence of halophytes in my data set. Marginal R^2 values were rather low, indicating that bare soil was of low relevance (Table 2), but differences between individual soda pans (see conditional R^2 values) were high.

In all, the five selected predictors did not explain the presence of halophytes very well. AIC_c values of best-ranked models were rather close and the Akaike weight of the best ranked model very low (see Table 3 and Figure A4, Appendix).
Figure 1 illustrates this uncovered relationship through a bivariate logistic function. Plots with higher shares of bare soil had a significantly higher probability that halophytic plant species were present. The slope never reached zero, though, signalling that even plots without any open soil had a 70% chance of halophyte plant species occurrence. The most extreme outlier for absence of halophytes (plot showing 80% bare soil) was a dried-out soda pan bottom dominated by *Crypsis aculeata*. This typical soda pan species is rated S3 by Borhidi (1995) and therefore not part of the set of target species considered in this present study, but highly relevant in terms of conservation issues.

Table 2: Summary results of null and global GLMM for presence of halophytic target species on 176 plots at 19 soda pans. *b* – estimate of beta coefficient, CI – confidence interval assuming infinite degrees of freedom (t=1.96), VC – variance component, PCV – proportion change in variance, R^2_m – variance explained by fixed factors, R^2_c – variance explained by both fixed factors and random factor, AIC_c – AIC corrected for small sample size.

	Null model	Global model
Fixed effects:	*b* [95% CI]	*b* [95% CI]
Intercept	2.19 [1.00; 3.39]	2.48 [1.23; 3.73]
Conductivity	-	0.57 [-0.25; 1.39]
Grazing intensity	-	0.45 [-0.60; 1.50]
Bare soil	-	0.75 [0.09; 1.41]
Nitrate	-	-0.39 [-1.00; 0.23]
Reed cover	-	0.04 [-0.54; 0.61]
Random effect:	VC	VC
PanNo	3.778	3.582
Fixed factors	-	1.519
$PCV_{[PanNo]}$	-	5.19%
R^2_m	-	18.11%
R^2_c	-	60.80%
AIC_c	150.86	146.20

Table 3: AIC_c-based table for 95% confidence set of best-ranked models for presence of halophytic target species. *k* – number of estimated parameters of a model, ΔAIC_c – difference to AIC_c-value of best-ranked model, w_i – Akaike weight, acc. w_i – cumulative Akaike weight, ER – evidence ratio, C – soil conductivity, G – grazing intensity, S – bare soil, N – soil nitrate, R – reed cover.

	k	AIC_c	ΔAIC_c	w_i	acc. w_i	ER
S	3	141.04	0	0.19	0.19	
C+S	4	141.90	0.86	0.12	0.31	1.54
S+N	4	142.41	1.36	0.09	0.40	1.97
C+S+N	5	142.59	1.55	0.09	0.49	2.17
G+S	4	142.76	1.72	0.08	0.57	2.36
S+R	4	143.13	2.09	0.07	0.64	2.84
C+G+S	5	143.54	2.49	0.05	0.69	3.47
C+S+R	5	143.97	2.93	0.04	0.73	4.33
C+G+S+N	6	144.04	3.00	0.04	0.77	4.48
G+S+N	5	144.06	3.01	0.04	0.82	4.50
S+N+R	5	144.42	3.38	0.03	0.85	5.42
C+S+N+R	6	144.73	3.69	0.03	0.88	6.33
G+S+R	5	144.87	3.83	0.03	0.91	6.79
C+G+S+R	6	145.65	4.60	0.02	0.93	9.97
G+S+N+R	6	146.05	5.00	0.02	0.94	12.18
global model	7	146.20	5.15	0.01	0.96	13.13

Table 4: Variate weights based on all models in the candidate set for presence of halophytic target species. Model averaged estimates [± 95% confidence interval] based on 95% confidence set of best-ranked models. acc. w_i – cumulative Akaike variate weight, CI – confidence interval, Int – intercept, C – soil conductivity, G – grazing intensity, S – bare soil, N – soil nitrate, R – reed cover. Relevant predictors (variate weight >0.9) are highlighted in bold face.

	Int	C	G	S	N	R
acc. w_i		0.43	0.30	**0.95**	0.37	0.25
Estimate [± 95% CI]	2.43 [1.17; 3.69]	0.23 [-0.5; 0.95]	0.12 [-0.56; 0.79]	**0.84 [0.13; 1.55]**	-0.12 [-0.6; 0.35]	0 [-0.29; 0.29]

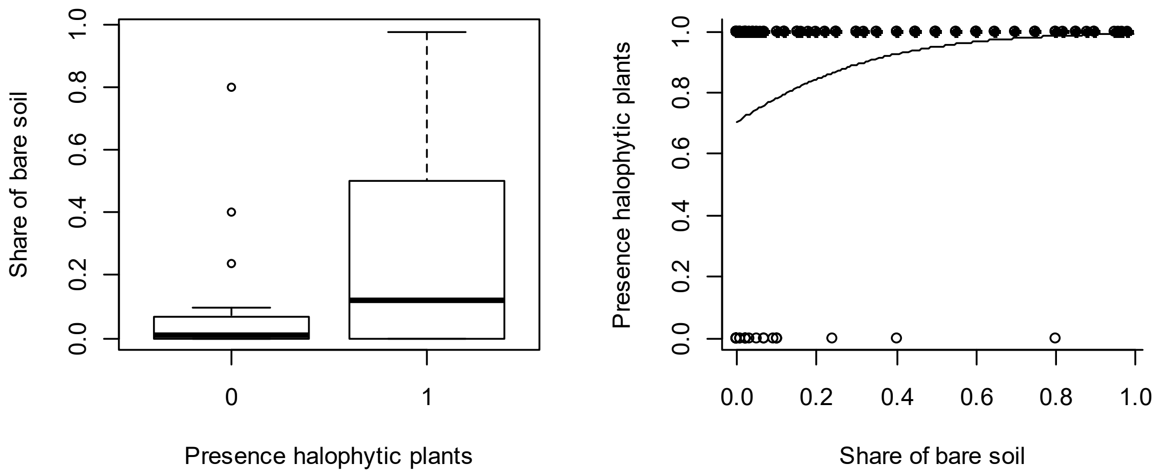

Figure 1: Probability of presence of halophytic target species on 176 plots on 19 soda pans relative to share of bare soil based on original predictor values in combination with simple logistic regression function. A boxplot further illustrates medians and spread of measured data.

3.2.1. Species richness of halophytic target plants

Again, neither grazing intensity nor soil conductivity were related to species richness of halophytes in the current study. Fraction of bare soil was the only relevant predictor with positive effects on the species richness of halophytic plants (Table 7 and Table 5). Marginal R^2 values were a little higher compared to the halophyte occurrence model, but bare soil was still of low relevance (Table 5). Differences between individual soda pans (see PCV) were reduced in the global model and the best-ranked model reached the highest Akaike weight of all models in this study (w_i=0.41, Table 6). Variate weights were relatively high as well, but none of the other predictors could explain species richness of halophytes very well on its own (Table 7).

Figure 2 illustrates this uncovered relationship through a simple linear regression. Most plots with 100% plant cover harboured at least one halophytic species, so the steepness of the slope was rather low, but still distinct.

Table 5: Summary of null and global LMM results for species richness of halophytes on 176 plots at 19 soda pans. *b* – estimate of beta coefficient, CI – confidence interval assuming infinite degrees of freedom (t=1.96), VC – variance component, PCV – proportion change in variance, R^2_m – variance explained by fixed factors, R^2_c – variance explained by both fixed factors and random factor, AIC_c – AIC corrected for small sample size.

	Null model	Global model
Fixed effects:	*b* [95% CI]	*b* [95% CI]
Intercept	1.70 [1.36; 2.05]	1.69 [1.41; 1.97]
Conductivity	-	0.25 [0.05; 0.44]
Grazing intensity	-	0.30 [0.02; 0.58]
Bare soil	-	0.31 [0.13; 0.50]
Nitrate	-	-0.04 [-0.23; 0.14]
Reed cover	-	-0.22 [-0.40; -0.03]
Random effect:	VC	VC
PanNo	0.460	0.289
Residuals	1.184	0.961
Fixed factors	-	0.406
$PCV_{[PanNo]}$	-	37.30%
$PCV_{[Residuals]}$	-	18.81%
R^2_m	-	24.52%
R^2_c	-	41.95%
AIC_c	563.18	528.32

Table 6: AIC_c-based table for 95% confidence set of best-ranked models for species richness of halophytic target species per plot. k – number of estimated parameters of a model, ΔAIC_c – difference to AIC_c value of best-ranked model, w_i...Akaike weight, acc. w_i – cumulative Akaike weight, ER – evidence ratio, C – soil conductivity, G – grazing intensity, S – bare soil, N – soil nitrate, R – reed cover.

	k	AIC_c	ΔAIC_c	w_i	acc. w_i	ER
C+G+S+R	7	526.39	0	0.41	0.41	
global model	8	528.32	1.93	0.16	0.56	2.62
C+S+R	6	528.54	2.15	0.14	0.70	2.93
G+S+R	6	530.48	4.08	0.05	0.76	7.69
C+S+N+R	7	530.63	4.23	0.05	0.81	8.29
C+G+S	6	530.67	4.27	0.05	0.85	8.46
C+G+S+N	7	531.42	5.03	0.03	0.89	12.37
S+R	5	532.25	5.85	0.02	0.91	18.63
G+S	5	532.59	6.20	0.02	0.93	22.20
G+S+N+R	7	532.63	6.23	0.02	0.94	22.53

Table 7: Variate weights based on all models in the candidate set for halophyte species richness. Model averaged estimates [± 95% confidence interval] based on 95% confidence set of best-ranked models. acc. w_i – cumulative Akaike variate weight, CI – confidence interval, Int – intercept, C – soil conductivity, G – grazing intensity, S – bare soil, N – soil nitrate, R – reed cover. Relevant predictors (variate weight >0.9) are highlighted in bold face.

	Intercept	C	G	S	N	R
acc. w_i		0.86	0.75	**1.00**	0.29	0.86
Estimate [± 95% CI]	1.69 [1.42; 1.97]	0.2 [-0.03; 0.44]	0.22 [-0.12; 0.56]	**0.34** **[0.13; 0.54]**	-0.01 [-0.12; 0.09]	-0.19 [-0.42; 0.03]

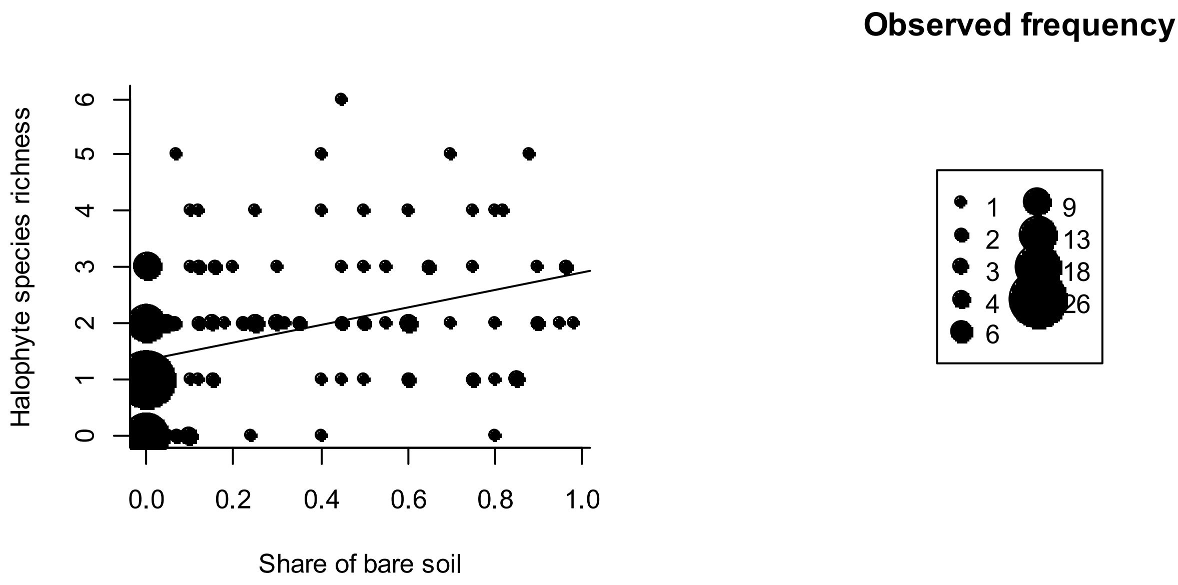

Figure 2: Halophyte species richness of 176 plots on 19 soda pans in relation to share of bare soil based on original values in combination with a simple linear regression. Symbol size varies with number of observations to display double or multiple overlapping data points.

3.2.2. Index of halophyte abundance

Halophyte abundance relative to glycophyte abundance (positive values up to 1 meaning halophytes dominate, negative values to -1 meaning glycophytes dominate) increased with rising soil conductivity and openness of grasslands and decreased with higher soil nitrate content (Figure 3). Grazing intensity and reed cover did not show a relevant effect on the index of halophyte abundance.

The AICc value of the global model was clearly lower than the criterion of the zero model and explained variance for fixed predictors (R^2m) was around 49% (Table 8). The 95% confidence set of candidate models is the shortest list in the study with two equal ranking best models with a rather high Akaike weight of 0.37. Model fit is mostly due to the low variation of glycophyte-dominated plots regarding soil conductivity and openness of patches (Fig. 3). Plots dominated by halophytes just showed a rather tight spread relative to soil nitrate. This effect did not appear in the occurrence model for halophytes alone. Occurrence of glycophytes was modelled separately to verify the above findings and showed a tendency for soil nitrate influence (see Appendix).

Table 8: Summary of null and global LMM results for halophyte abundance index for 176 plots at 19 soda pans. *b* – estimate of beta coefficient, CI – confidence interval assuming infinite degrees of freedom (t=1.96), VC – variance component, PCV – proportion change in variance, R^2_m – variance explained by fixed factors, R^2_c – variance explained by both fixed factors and random factor, AIC_c – AIC corrected for small sample size.

	Null model	Global model
Fixed effects:	*b* [95% CI]	*b* [95% CI]
Intercept	0.30 [0.09; 0.50]	0.30 [0.16; 0.43]
Conductivity	-	0.35 [0.27; 0.43]
Grazing intensity	-	-0.00 [-0.14; 0.13]
Bare soil	-	0.19 [0.12; 0.27]
Nitrate	-	-0.15 [-0.23; -0.08]
Reed cover	-	-0.06 [-0.14; 0.02]
Random effect:	VC	VC
PanNo	0.177	0.075
Residuals	0.346	0.171
Fixed factors	-	0.237
$PCV_{[PanNo]}$	-	57.42%
$PCV_{[Residuals]}$	-	50.48%
R^2_m	-	48.99%
R^2_c	-	64.57%
AIC_c	350.95	230.48

Table 9: AIC_c-based table for 95% confidence set of best-ranked models for index of halophytic abundance. *k* – number of estimated parameters of a model, ΔAIC_c – difference to AIC_c value of best-ranked model, w_i...Akaike weight, acc. w_i – cumulative Akaike weight, ER – evidence ratio, C – soil conductivity, G – grazing intensity, S – bare soil, N – soil nitrate, R – reed cover.

	k	AIC_c	ΔAIC_c	w_i	acc. w_i	ER
C+S+N	6	228.29	0	0.37	0.37	
C+S+N+R	7	228.29	0	0.37	0.75	
C+G+S+N	7	230.46	2.17	0.13	0.87	2.96
global model	8	230.48	2.19	0.13	1.00	2.99

Table 10: Variate weights based on all models in the candidate set for index of halophyte abundance. Model averaged estimates [± 95% confidence interval] based on 95% confidence set of best-ranked models. acc. w_i – cumulative Akaike variate weight, CI – confidence interval, Int – intercept, C – soil conductivity, G – grazing intensity, S – bare soil, N – soil nitrate, R – reed cover. Relevant predictors (variate weight >0.9) are highlighted in bold face.

	Int	C	G	S	N	R
acc. w_i		**1.00**	0.26	**1.00**	**1.00**	0.50
Estimate [±95% CI]	0.3 [0.17; 0.43]	**0.34 [0.26; 0.42]**	0 [-0.06; 0.06]	**0.2 [0.12; 0.28]**	**-0.16 [-0.24; -0.08]**	-0.03 [-0.11; 0.05]

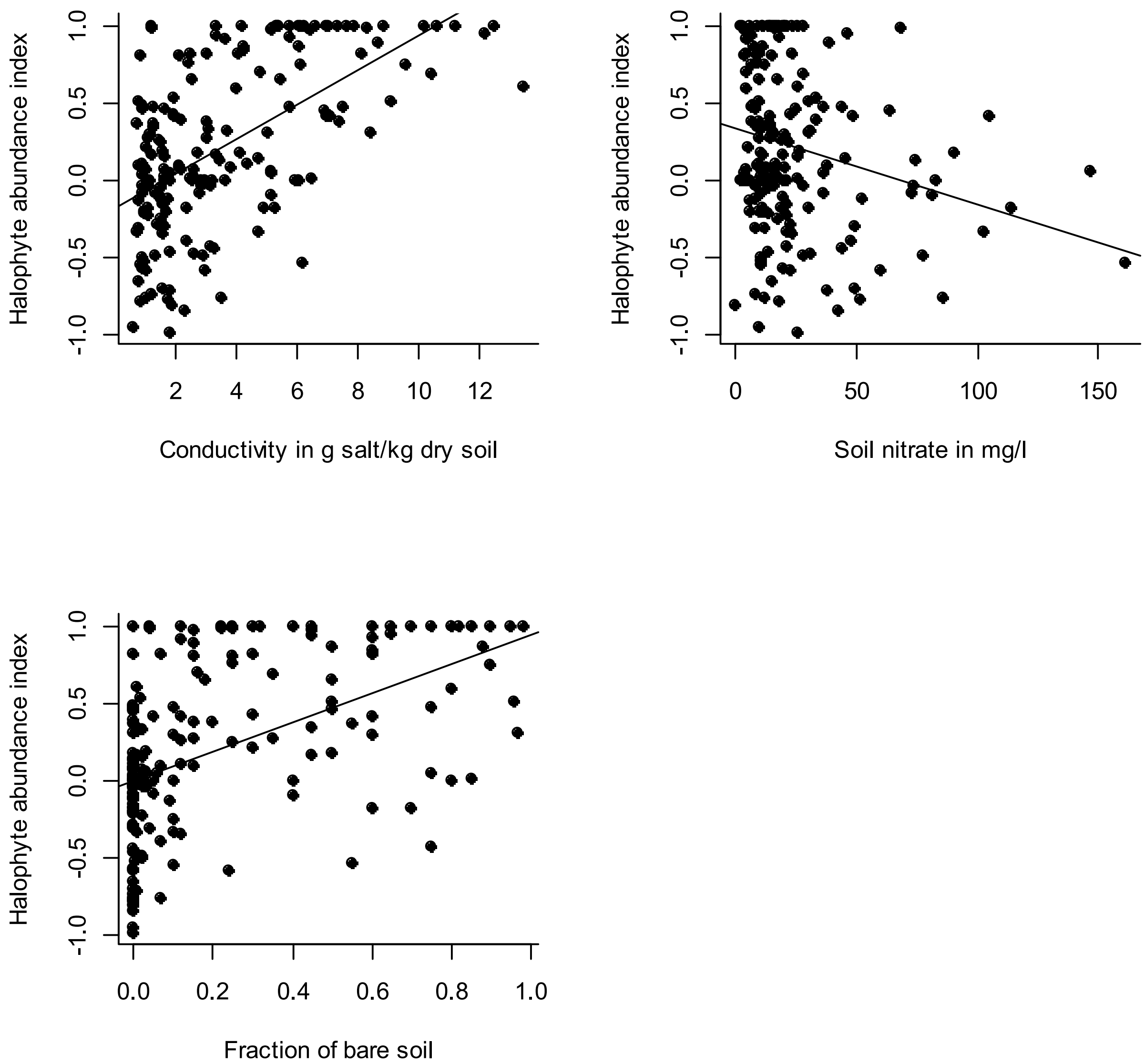

Figure 3: Index of halophyte abundance relative to the most relevant predictor variables (variate weight >0.9) revealed by an all-subset model averaging using AIC_c. Simple linear regressions for soil conductivity, soil nitrate and fraction of bare soil are based on original values (n=176).

3.3. Drivers of halophytic target species composition

3.3.1. Distance-based redundancy analysis (db-RDA) and permANOVA-based model selection

The first two constrained axes together explained 84% of constrained variability (cumulative proportion of CAP1 and CAP2, see Table 11). Overall, pan identity accounted for 23.9% of variation in soda pan species composition and the five site characters together only explained another 11.1% of variation, leaving 65% of variation unexplained by the model.

Table 11: Results for global model obtained by a db-RDA after removing the random effect of spatial clustering of 176 sites at 19 soda pans using five environmental variables (soil conductivity, grazing intensity, soil nitrate, bare soil and reed cover) as constraints.

	Inertia	Proportion
Total	74.56	1.000
Conditional	17.80	0.239
Constrained	8.28	0.111
Unconstrained	48.48	0.650

Accumulated constrained eigenvalues

Importance of components:	CAP1	CAP2	CAP3	CAP4	CAP5
Eigenvalue	4.979	2.004	0.511	0.494	0.292
Proportion Explained	0.601	0.242	0.062	0.060	0.035
Cumulative Proportion	0.601	0.843	0.905	0.965	1.000

Eigenvalues of the first 8 (out of 48) unconstrained axes

MDS1	MDS2	MDS3	MDS4	MDS5	MDS6	MDS7	MDS8
6.867	5.274	2.718	2.625	2.412	1.954	1.823	1.641

Stepwise model selection based on permutational non-parametric MANOVA showed highest influence for soil conductivity, whereas grazing intensity did not shape soda pan halophyte communities (Table 12). Reed cover and vegetation cover showed small but highly significant effects on plant species composition, while soil nitrate was not of clear relevance.

Table 12: Results of stepwise model selection starting with the global model for species composition (expressed as Bray-Curtis distances) using backward and forward selection. Given are AIC-like criterions and marginal effects of terms based on permutational MANOVA with 200 permutations.

	Df	"AIC"	*F*	*P*	
- Conductivity	1	737.52	**8.39**	**0.005**	**
- Grazing intensity	1	729.62	1.34	0.130	
- **Bare soil**	1	731.63	**3.11**	**0.005**	**
- Soil nitrate	1	730.50	2.11	0.010	**
- **Reed cover**	1	732.67	**4.02**	**0.005**	**
Drop Grazing intensity: C+S+N+R					
- Conductivity	1	737.02	**8.39**	**0.005**	**
- Soil nitrate	1	730.24	2.30	0.010	**
- **Bare soil**	1	731.30	**3.24**	**0.005**	**
- **Reed cover**	1	732.74	**4.52**	**0.005**	**
+ Grazing intensity	1	730.07	1.34	0.14	
				Signif. code: **…p<0.01	

Below, ordination plots illustrate relationships between site characters and soda pan halophyte plant communities (Fig. 4) and individual plant species (Fig. 5) in more detail, respectively. The first ordination axis depicted a gradient of soil salinity and vegetation cover (with high conductivity and low vegetation cover to the left), whereas the second axis predominantly reflected a gradient in reed cover (with negative values indicating high reed occurrence). Directions of intensity of grazing and soil nitrate are indicated with shorter arrows since they did not affect community composition substantially (see Table 12). Grazed (black symbols) and ungrazed plots (red symbols) did not form any distinct clusters. Plot scores showed a rather even spread for many soda pans due to the removal of pan identity as a random effect. However, most plots at pan 35 (open red triangles) formed a clustered group in a narrow zone close to the ordination origin (see Appendix Fig. A6 for an additional graph highlighting soda pans with biased plot spread).

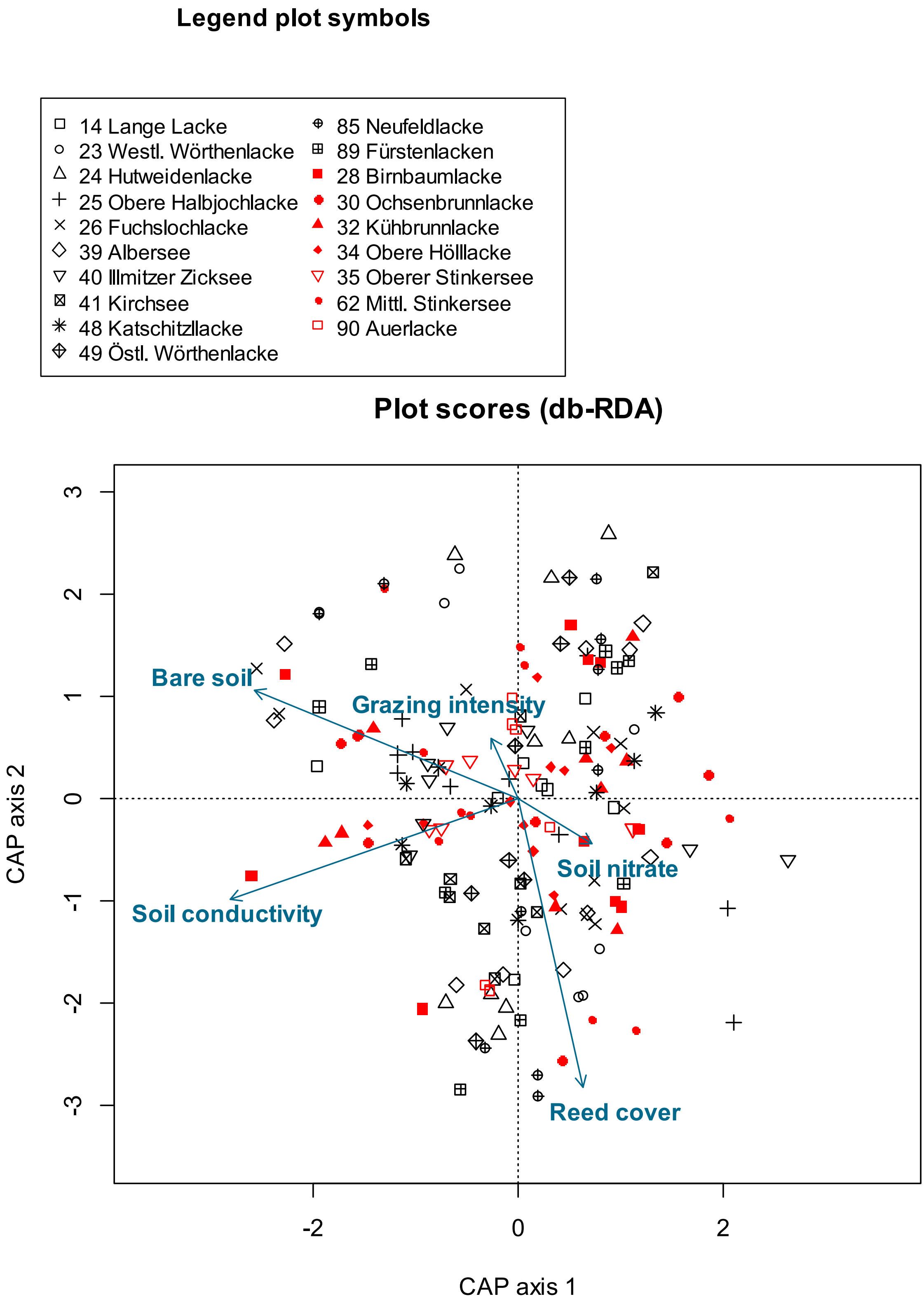

Figure 4: Biplot of halophytic plant species communities on 176 plots at 19 soda pans along the first two constrained axes of db-RDA ordination. Black symbols – grazed plots, red symbols – non-grazed plots. Blue arrows show direction of influence of environmental variables.

Figure 5 illustrates the position of the eight most distinct study species in the observed ecological gradients. Halophytes were separated from glycophytic and intermediate species along the gradient of vegetation cover and – in the opposite direction – the (potential) influence of soil nitrogen. *Puccinellia peisonis* was found on plots with high salinity but scarce vegetation cover and reed cover. These trends were also confirmed by the binomial species model for occurrence of *P. peisonis* (see 3.4.1). *Tripolium pannonicum* was mainly associated with soil salinity and was found on plots with less open vegetation cover. *Plantago maritima* and *Suaeda pannonica* preferred conditions with intermediate soil salinity and rather open vegetation, but little reed occurrence. *Festuca pseudovina* neither occurred on plots with scarce vegetation nor high conductivity. *Poa angustifolia* showed a very similar ordination result. *Agrostis stolonifera* and *Bolboschoenus maritimus* both displayed high affinity to reed, but *A. stolonifera* occurred on less saline plots with denser vegetation.

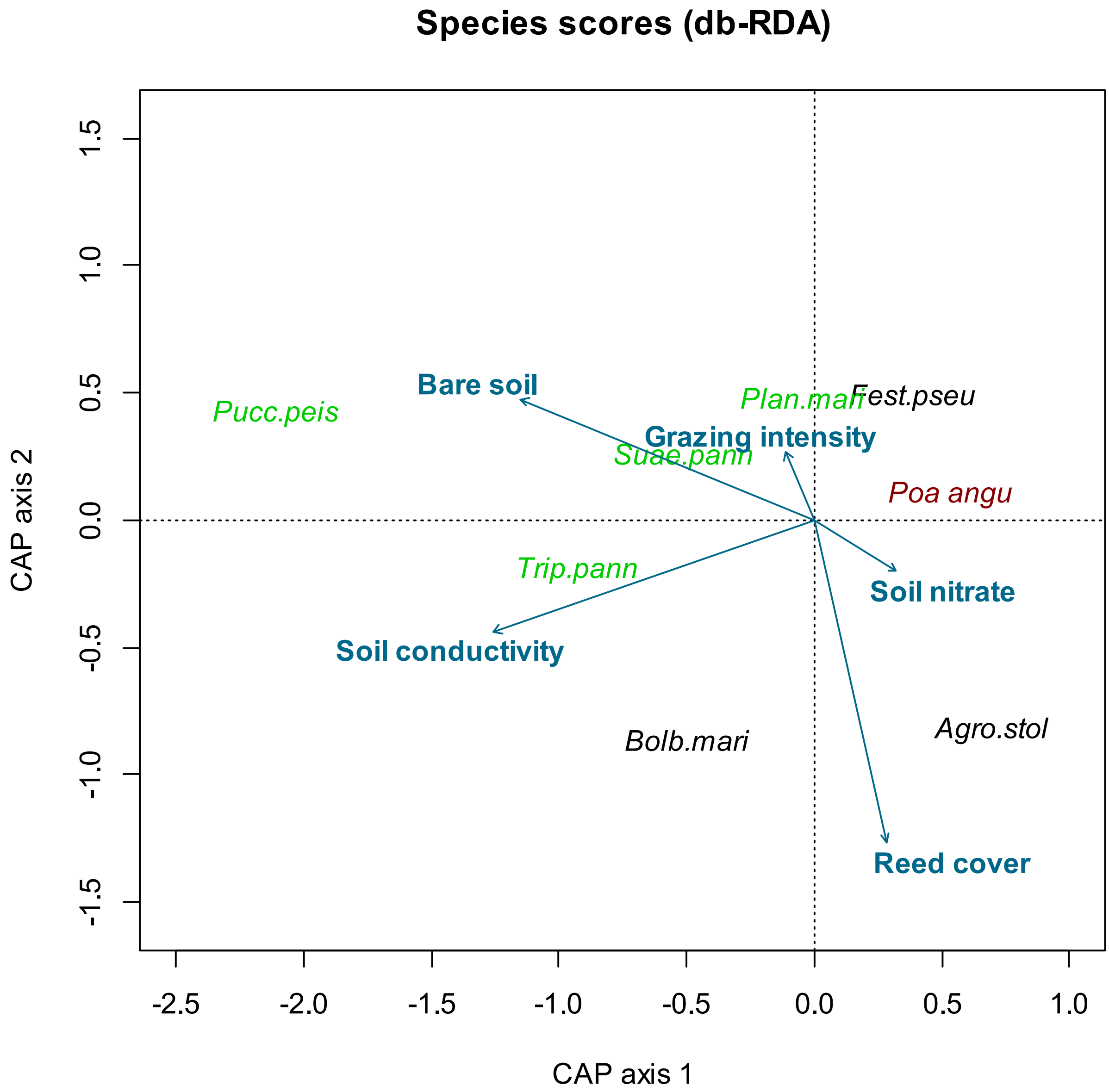

Figure 5: Biplot of most prominent soda pan plant species along the first two ordination axes obtained through a db-RDA on 176 plots on 19 soda pans. Blue arrows show direction of influence of environmental variables. For clarity, only species with scores >|0.5| for at least one of the axes are shown (see Table A5 in Appendix). Colors of species names indicate habitat preferences: green – halophytes, rated S5 or higher; red – glycophytes, rated S0; black – intermediate species (Borhidi 1995). *Agro.stol – Agrostis stolonifera*, *Bolb.mari – Bolboschoenus maritimus*, *Fest.pseu – Festuca pseudovina*, *Pla.mar – Plantago maritima*, *Poa angu – Poa angustifolia*, *Pucc.peis – Puccinellia peisonis*, *Trip.pann – Tripolium pannonicum*, *Suae.pann – Suaeda pannonica*.

3.4. Modelling the presence of individual target species

3.4.1. Modelling the presence of *Puccinellia peisonis*

The global model (Table 13) revealed that share of bare soil and soil conductivity showed relevant positive effects on the occurrence of *P. peisonis*. For soil conductivity, the turning point (50 % probability of presence for *P. peisonis*) lay at an intermediate value (~5 g salt/kg soil; Fig. 6). The same was true for bare soil values (turning point at ~40 % open soil), meaning that plots with higher shares of open soil had a significantly higher probability that *P. peisonis* formed part of their vegetation cover. Grazing intensity was not related to the presence of this endemic grass in my study. Reed cover showed negative tendencies towards the presence of *P. peisonis*. While the competing reed species *Phragmites australis* occurred in 75 plots, only 16 plots shared both species.

Table 13: Summary results of null and global GLMM for presence of *Puccinellia peisonis* on 176 plots at 19 soda pans. *b* – estimate of beta coefficient, CI – confidence interval assuming infinite degrees of freedom (t=1.96), VC – variance component, PCV – proportion change in variance, R^2_m – variance explained by fixed factors, R^2_c – variance explained by both fixed factors and random factor, AIC_c – AIC corrected for small sample size.

	Null model	Global model
Fixed effects:	*b* [95% CI]	*b* [95% CI]
Intercept	-0.55 [-1.01; -0.09]	-0.71 [-1.13; -0.29]
Conductivity	-	1.01 [0.50; 1.53]
Grazing intensity	-	0.22 [-0.20; 0.65]
Bare soil	-	0.71 [0.26; 1.16]
Nitrate	-	-0.48 [-0.95; -0.01]
Reed cover	-	-0.57 [-1.09; -0.06]
Random effect:	VC	VC
PanNo	0.497	0.055
Fixed factors	-	3.007
$PCV_{[PanNo]}$	-	88.93%
R^2_m	-	47.34%
R^2_c	-	48.21%
AIC_c	233.17	173.95

Table 14: AIC_c-based table for 95% confidence set of best-ranked models for presence of *Puccinellia peisonis*. *k* – number of estimated parameters of a model; ΔAIC_c – difference to AIC_c value of best-ranked model, w_i – Akaike weight, acc. w_i – cumulative Akaike weight, ER – evidence ratio, C – soil conductivity, G – grazing intensity, S – bare soil, N – soil nitrate, R – reed cover.

	k	AIC_c	ΔAIC_c	w_i	acc. w_i	ER
C+S+N+R	6	172.91	0	0.36	0.36	
C+S+R	5	173.88	0.97	0.22	0.57	1.62
global model	7	173.95	1.04	0.21	0.79	1.68
C+G+S+R	6	175.37	2.46	0.10	0.89	3.42
C+S+N	5	176.71	3.80	0.05	0.94	6.69

Table 15: Variate weights based on all models in the candidate set for presence of *Puccinellia peisonis*. Model averaged estimates [± 95% confidence interval] based on 95% confidence set of best-ranked models. acc. w_i – cumulative Akaike variate weight, CI – confidence interval, Int – intercept, C – soil conductivity, G – grazing intensity, S – bare soil, N – soil nitrate, R – reed cover. Relevant predictors (variate weight >0.9) are highlighted in bold letters.

	Int	C	G	S	N	R
acc. w_i		**0.98**	0.34	**0.97**	0.66	0.9
Estimate [± 95% CI]	-0.7 [-1.16; -0.24]	**1.01 [0.47; 1.54]**	0.08 [-0.27; 0.42]	**0.72 [0.22; 1.22]**	-0.32 [-0.9; 0.26]	-0.6 [-1.26; 0.05]

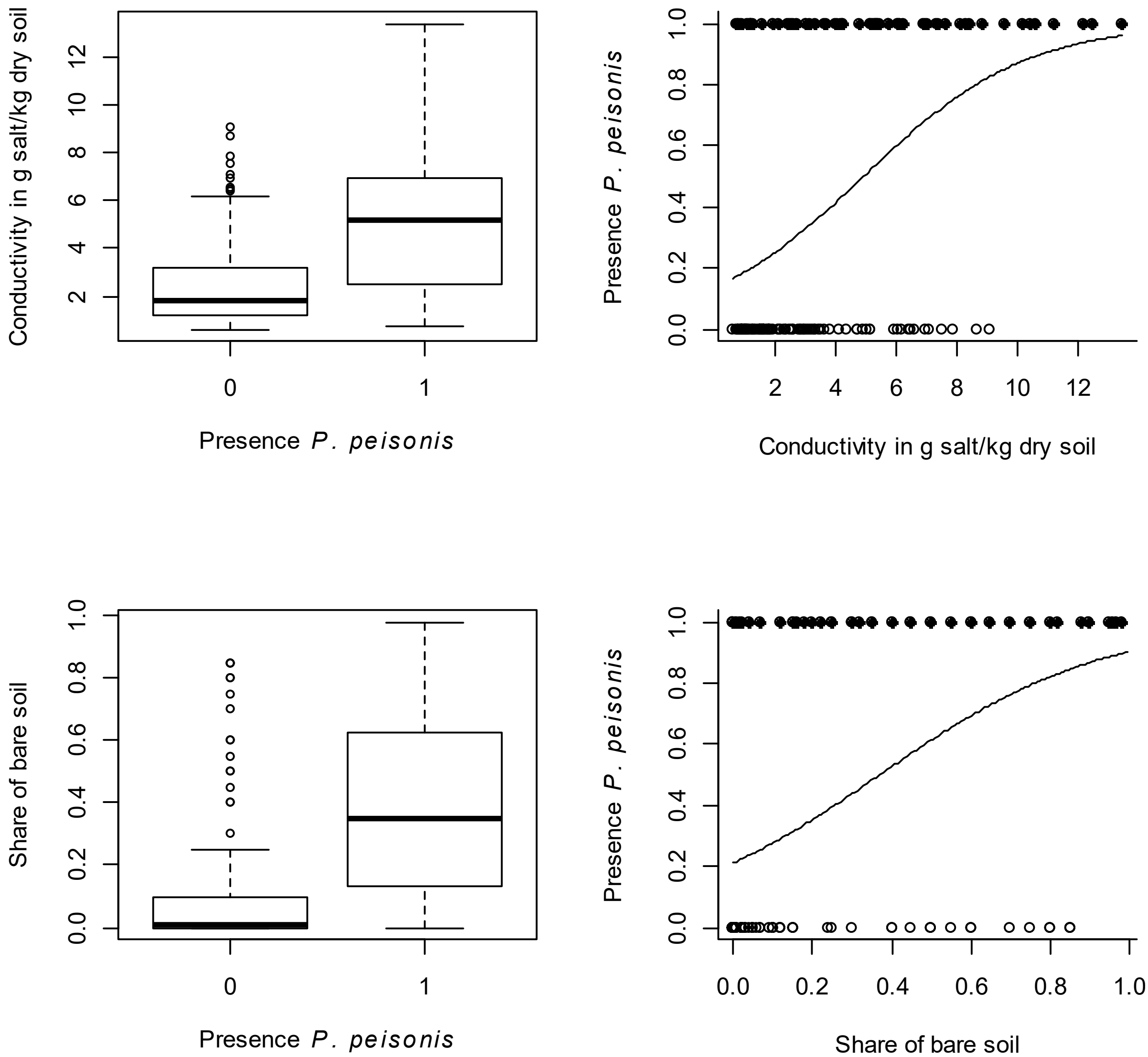

Figure 6: Probability of presence of *Puccinellia peisonis* on 176 plots at 19 soda pans relative to soil conductivity and share of bare soil. Biplots are combined with simple logistic regressions and based on original values of the most relevant predictor variables (variate weight > 0.9) revealed by an all-subset averaging using AIC_c. Boxplots further illustrate medians and spread of measured data.

3.4.2. Modelling the presence of *Tripolium pannonicum*

Tripolium pannonicum only showed a relevant relation to soil conductivity. Grazing intensity as well as all other tested predictors did not show any effect on the presence of *Tripolium pannonicum*. The effect of soil salinity was not very pronounced (see boxplots Fig. 7) and global model fit was not very convincing. The model showed the lowest R^2_m value of all models considered in this study (see Tables 16 and 22) and PCV was actually negative. Probability of presence for *T. pannonicum* ranged between 40 and 80% (Fig. 7) and 50% probability of presence was reached rather quickly, at a salinity value of 3g salt/kg dry soil.

Table 16: Summary results of null and global GLMM for presence of *Tripolium pannonicum* on 176 plots at 19 soda pans. *b* – estimate of beta coefficient, CI – confidence interval assuming infinite degrees of freedom (t=1.96), VC – variance component, PCV – proportion change in variance, R^2_m – variance explained by fixed factors, R^2_c – variance explained by both fixed factors and random factor, AIC_c – AIC corrected for small sample size.

	Null model	Global model
Fixed effects:	*b* [95% CI]	*b* [95% CI]
Intercept	0.05 [-0.42; 0.52]	0.07 [-0.44; 0.58]
Conductivity	-	0.70 [0.24; 1.17]
Grazing intensity	-	0.27 [-0.24; 0.79]
Bare soil	-	0.03 [-0.38; 0.45]
Nitrate	-	-0.25 [-0.67; 0.17]
Reed cover	-	0.21 [-0.21; 0.62]
Random effect:	VC	VC
PanNo	0.588	0.734
Fixed factors	-	0.569
$PCV_{[PanNo]}$	-	-24.83%
R^2_m	-	12.39%
R^2_c	-	28.37%
AIC_c	241.72	236.83

Table 17: AIC_c-based table for 95% confidence set of best-ranked models for presence of *Tripolium pannonicum*. *k* – number of estimated parameters of a model, ΔAIC_c – difference to AIC_c value of best-ranked model, w_i – Akaike weight, acc. w_i – cumulative Akaike weight, ER – evidence ratio, C – soil conductivity, G – grazing intensity, S – bare soil, N – soil nitrate, R – reed cover.

	k	AIC_c	ΔAIC_c	w_i	acc. w_i	ER
C	3	230.90	0	0.22	0.22	
C+G	4	232.10	1.19	0.12	0.34	1.81
C+N	4	232.32	1.41	0.11	0.45	2.02
C+R	4	232.73	1.83	0.09	0.54	2.50
C+S	4	232.99	2.09	0.08	0.61	2.84
C+G+N	5	233.46	2.56	0.06	0.67	3.60
C+N+R	5	233.67	2.76	0.06	0.73	3.97
C+G+R	5	233.89	2.98	0.05	0.78	4.44
C+G+S	5	234.21	3.31	0.04	0.82	5.23
C+S+N	5	234.43	3.53	0.04	0.86	5.84
C+G+N+R	6	234.69	3.79	0.03	0.89	6.65
C+S+R	5	234.77	3.86	0.03	0.92	6.89
C+G+S+N	6	235.59	4.68	0.02	0.94	10.38

Table 18: Variate weights based on all models in the candidate set for presence of *Tripolium pannonicum*. [± 95% confidence interval] based on 95% confidence set of best-ranked models. acc. w_i – cumulative Akaike variate weight, CI – confidence interval, Int – intercept, C – soil conductivity, G – grazing intensity, S – bare soil, N – soil nitrate, R – reed cover. Relevant predictors (variate weight >0.9) are highlighted in bold face.

	Int	C	G	S	N	R
acc. w_i		**1.00**	0.35	0.26	0.35	0.31
Estimate [± 95% CI]	0.06 [-0.48; 0.61]	**0.71 [0.26; 1.17]**	0.1 [-0.31; 0.51]	0.01 [-0.2; 0.22]	-0.07 [-0.37; 0.24]	0.04 [-0.21; 0.3]

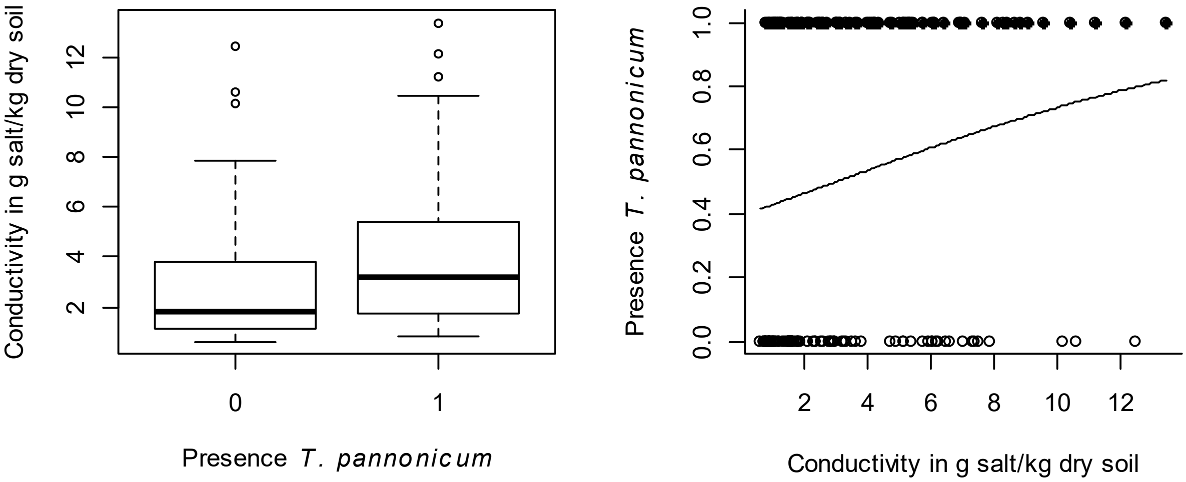

Figure 7: Probability of presence of *Tripolium pannonicum* on 176 plots at 19 soda pans relative to original values of soil conductivity in combination with simple logistic regression. A boxplot further illustrates medians and spread of measured data for the most relevant predictor variable (variate weight = 1) revealed by an all-subset model averaging using AIC_c.

3.4.3. Modelling the presence of *Phragmites australis*

Probability of presence for *P. australis* showed relevant effects of share of bare soil (negative influence) and soil nitrate (positive influence; Table 21). Grazing intensity as well as soil conductivity did not shape the presence of reed in my data set. R^2 values were very low again compared to the GLMM run for *P. peisonis*. Figure 8 shows that the negative relationship of reed and share of bare soil was not very pronounced. The turning point for the simple logistic regression for soil nitrate was at a low value of 25mg/l and boxplots showed that medians for occupied and non-occupied plots were within close range.

Table 19: Summary results of null and global GLMM for presence of *Phragmites australis* on 176 plots at 19 soda pans. *b* – estimate of beta coefficient, CI – confidence interval assuming infinite degrees of freedom (t=1.96), VC – variance component, PCV – proportion change in variance, R^2_m – variance explained by fixed factors, R^2_c – variance explained by both fixed factors and random factor, AIC_c – AIC corrected for small sample size.

	Null model	Global model
Fixed effects:	*b* [95% CI]	*b* [95% CI]
Intercept	-0.43 [-1.24; 0.38]	-0.41 [-1.16; 0.33]
Conductivity	-	0.31 [-0.22; 0.84]
Grazing intensity	-	-0.3 [-1.06; 0.46]
Bare soil	-	-0.76 [-1.24; -0.27]
Nitrate	-	0.7 [0.2; 1.21]
Random effect:	VC	VC
PanNo	2.51	1.895
Fixed factors	-	1.257
$PCV_{[PanNo]}$	-	24.50%
R^2_m	-	19.52%
R^2_c	-	48.93%
AIC_c	210.76	196.51

Table 20: AIC_c-based table for 95% confidence set of best-ranked models for presence of *Phragmites australis*. *k* – number of estimated parameters of a model, ΔAIC_c – difference to AIC_c value of best-ranked model, w_i – Akaike weight, acc. w_i – cumulative Akaike weight, ER – evidence ratio, C – soil conductivity, G – grazing intensity, S – bare soil, N – soil nitrate.

	k	AIC_c	ΔAIC_c	w_i	acc. w_i	ER
S+N	4	194.29	0	0.37	0.37	
C+S+N	5	194.98	0.70	0.26	0.64	1.42
G+S+N	5	195.69	1.41	0.19	0.82	2.02
global model	6	196.51	2.22	0.12	0.95	3.03

Table 21: Variate weights based on all models in the candidate set for presence of *Phragmites australis*. Model averaged estimates [± 95% confidence interval] based on 95% confidence set of best-ranked models. acc. w_i – cumulative Akaike variate weight, CI – confidence interval, Int – intercept, C – soil conductivity, G – grazing intensity, S – bare soil, N – soil nitrate, R – reed cover. Relevant predictors (variate weight >0.9) are highlighted in bold face.

	Int	C	G	S	N
acc. w_i		0.40	0.33	**0.97**	**0.96**
Estimate [± 95% CI]	-0.43 [-1.17; 0.3]	0.13 [-0.33; 0.59]	-0.1 [-0.62; 0.42]	**-0.68 [-1.18; -0.18]**	**0.7 [0.15; 1.25]**

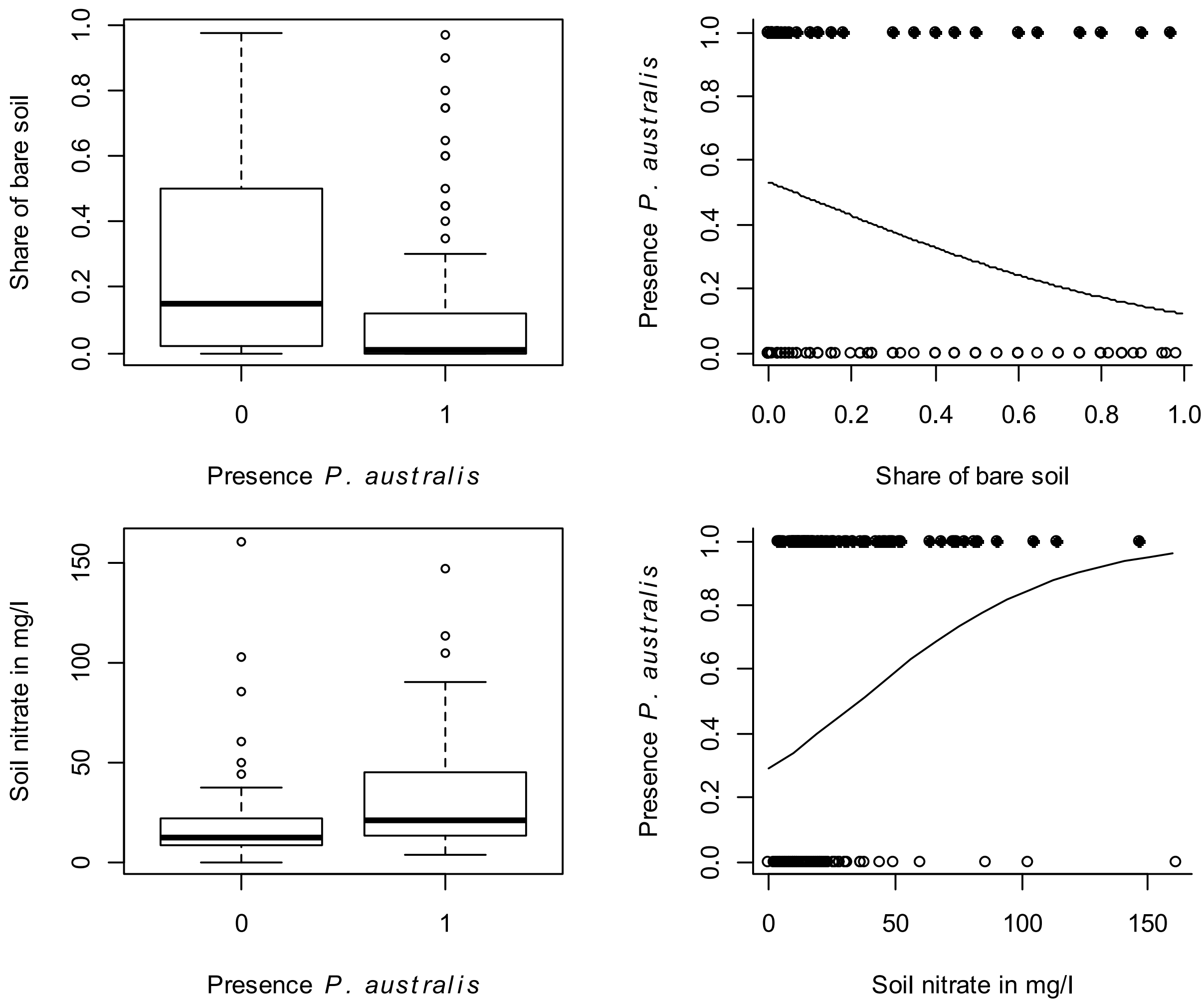

Figure 8: Probability of presence of *Phragmites australis* on 176 plots at 19 soda pans relative to share of bare soil and soil nitrate in combination with simple logistic regressions. Biplots are based on original values of the most relevant predictor variables (variate weight > 0.9) revealed by an all-subset averaging using AIC_c. Boxplots further illustrate spread of medians and measured data.

3.5. General résumé of model results

Table 22 summarizes the main findings from all global models described in the previous sections. Soil conductivity showed a strong effect on soda pan plant communities and shaped the presence of the two model species *P. peisonis* and *T. pannonicum*. Index of halophyte abundance was also explained by soil conductivity, but presence of halophytes was not. Cattle grazing never had a negative effect on halophytic plant species or communities on soda pans in any model. The fraction of bare soil revealed most relevant positive effects on halophytes and was negatively associated with reed cover and presence of glycophyte. Soil nitrate influenced the relation of halophytes to glycophytes negatively and favoured the presence of reed. Reed cover emerged as a relevant predictor for soda pan plant communities. Variation of response values explained by fixed terms (R^2_m) ranged from 9 to 60% in the models, with considerably stronger results when pan identity was included as a random effect (R^2_c; 25 to 70%).

Table 22: Synopsis of relevant effects for all halophyte study models, showing model-averaged estimates [± 95% confidence interval] and variance explained adjusted to the number of predictors in the global model with (adjR^2_c) and without (adjR^2_m) the random effect of soda pan identity. C – Soil conductivity, G – grazing intensity, N – soil nitrate, S – share of bare soil, R – reed cover. Relevant predictors (variate weight >0.9) are in given in bold letters. Results for the multivariate model for species composition are based on stepwise model selection and marginal effects of permutational MANOVA with 200 permutations.

	C	G	S	N	R	adjR^2_m	adjR^2_c
Presence halophytes	0.23 [-0.5; 0.95]	0.12 [-0.56; 0.79]	**0.84 [0.13; 1.55]**	-0.12 [-0.6; 0.35]	0 [-0.29; 0.29]	14.7%	59.2%
Species richness	0.2 [-0.03; 0.44]	0.22 [-0.12; 0.56]	**0.34 [0.13; 0.54]**	-0.01 [-0.12; 0.09]	-0.19 [-0.42; 0.03]	21.4%	39.5%
Index of halophyte abundance	**0.34 [0.26; 0.42]**	0 [-0.06; 0.06]	**0.2 [0.12; 0.28]**	**-0.16 [-0.24; -0.08]**	-0.03 [-0.11; 0.05]	46.9%	63.1%
Species composition	**0.005**	**0.130**	**0.005**	0.01	**0.005**	12.3%	36.2%
P. peisonis	**1.01 [0.47; 1.54]**	0.08 [-0.27; 0.42]	**0.72 [0.22; 1.22]**	-0.32 [-0.9; 0.26]	-0.6 [-1.26; 0.05]	45.2%	46.1%
T. pannonicum	**0.71 [0.26; 1.17]**	0.1 [-0.31; 0.51]	0.01 [-0.2; 0.22]	-0.07 [-0.37; 0.24]	0.04 [-0.21; 0.3]	8.7%	25.4%
P. australis	0.13 [-0.33; 0.59]	-0.1 [-0.62; 0.42]	**-0.68 [-1.18; -0.18]**	**0.7 [0.15; 1.25]**		16.2%	46.8%
Presence glycophytes	**-2.18 [-3.01; -1.35]**	0.35 [-0.44; 1.13]	**-0.8 [-1.46; -0.14]**	0.62 [-0.02; 1.26]	-0.02 [-0.31; 0.26]	60%	70.4%

4. Discussion

4.1 Effects of grazing and local site conditions on halophyte vegetation

A. Grazing

Grazing intensity neither was a relevant influence on halophyte presence, abundance or species richness nor on plant community composition at the randomly chosen plots around 19 soda pans in the Seewinkel in my data set. None of the different responses was shaped by grazing. These results imply that – at the low intensities applied by the National park conservation management – there is no harm done by grazing to halophytic communities at soda pans in the Seewinkel area.

Other studies did detect grazing induced shifts in community composition in alkali grasslands but were based on exclusion experiments (Euller et al. 2014, Török et al. 2014). In their long-time monitoring Euller et al. (2014) detected a shift in species composition of soda pans of selected grazed and ungrazed sites in the National Park from *P. australis* and *A. stolonifera* dominated associations to salt meadows with high shares of *J. gerardii* and *A. stolonifera*.

Considering the very small relevé areas of 0.25 m² in this study, and the fact that most halophytic plant associations are characterised by the dominance of a single species (Dítě et al. 2017), the maximum number of six halophytic plant species found per plot is very high. However, the single plot showing six halophytic plants harboured a mixture of rather rare species in the data set. These species also rarely occur together on small-scale areas (*Artemisia santonicum*, *Lepidium cartilagineum* and *Suaeda pannonicum*), thus this single observation is unique. Cattle grazing did shape halophyte species richness in other studies but all these focused on single certain types of alkaline grasslands (Török et al. 2018, Godo et al. 2017, Török et al. 2016).

While grazing affects overall plant cover by reducing above-ground plant biomass (e.g. Bakker et Ruyter 1981, Korner et al. 2008), halophytes profit from that effect or at least do not show negative reactions (Török et al. 2016, Gilbert and Fraser 2013, Dítětová et al. 2016).

Sedentary herding includes widely variable grazing intensities and effects with heavily trampled drifts, areas grazed only at certain times of the year and resting sites with frequent dung deposits (Molnár 2014). Tälle et al. (2016) found different effects for grazing in summer and autumn. Autumn-grazed soda pans did form a special case in my data set as well (data not shown), but I accounted this effect to soil properties (higher share of gravel) and decided to include them in the low intensity-grazing group. Another reason could be (unknown) high background effects of small native grazers in both grazed and ungrazed plots of my study. The exclosure of geese and hares showed significant effects on the abundance of vegetation in a salt marsh in the Netherlands (van Wijnen et al. 1999). Greylag geese are increasingly common breeding birds around Lake Neusiedl (Wendelin & Dvorak 2016) and contributed to herbivory on my study plots. The exclusion of reed-dominated areas in my study design may have biased my sample towards naturally grazed sites. It might therefore be interesting to disentangle effects of soil properties, natural grazers and time of cattle grazing around soda pans in a future research project.

While fenced grazing systems also show differing grazing intensities in relation to drinking troughs and occurrence of palatable species (Barcella et al. 2016), sedentary herding allows for a more directed grazing pressure but strongly relies on the abilities of the herder (Molnár 2014). Török et al. (2014) found differing grazing effects along a moisture gradient in alkali grasslands with lowest effects in dry and strongest effects in wet vegetation. The same study also found high between-site variability for mesophilous and dry alkali grasslands. Effects of grazing probably vary with soil salinity, because grazing affects competition, which varies with soil salinity by itself (Gilbert and Fraser 2013). Due to the random plot selection around soda pans in my study the sample included mesophilous and dry sites as well as non-saline and hypersaline spots. Hence, plots were differing in their soil moisture and salt content along a wide gradient. Since my sample captured a larger fraction of the environmental variance encountered around soda pans than many of the earlier studies on similar vegetation systems, I was able to demonstrate that there is no genuine overall negative effect of grazing – which might be contingent on certain site conditions only.

I preselected study sites by a priori excluding reed-dominated areas. This is probably the main reason for the insignificant influence of grazing on the presence of reed in my study, because effects of grazing on *P. australis* are well known (Török et al. 2014, Ecsedi & Boros 2013a, Korner et al. 2008). Maybe grazing pressure was too low or grazing intensities too heterogenic in my dataset. Successful suppression of *P. australis* can be achieved by cattle grazing in stocking rates of 1 animal per ha, a grazing level which was found to increase halophyte species richness in wet alkali grasslands (Török et al. 2014). Cattle especially like to feed on young reed sprouts in spring, but do not feed on older reed stands (Ecsedi & Boros 2013a). In the Seewinkel region, horses were more effective in reducing areas dominated by *P. australis*, due to their higher level of activity, i.e. trampling (Korner et al. 2008). However, Euller et al. (2014) found that only abundances of *Calamagrostis epigejos* and *Elymus repens* significantly decreased on grazed areas in the Seewinkel during 16 years of monitoring but could not observe a similar trend for *P. australis*. This result was based on plots showing at least 10% cover of *P. australis* in the first monitoring year, which may have been a too low threshold to detect any differences for reed. Comparison of paired plots with grazing exclusion did allow to uncover a significant increase of reed cover in the same monitoring project (Korner et al. 2008). A combination of initial mowing and follow-up cattle grazing proved very successful in reducing reed dominated areas (Kohler & Korner 2006).

B. Soil salinity

As expected, index of halophytic plant cover, presence of the two model-species *P. peisonis* and *T. pannonicum* as well as halophytic species composition were shaped by soil salinity. The index of halophytic abundance (-1 standing for 100% glycophytic cover, +1 meaning 100% halophytic abundance) comprises the opposite ends of the salinity gradient and therefore had to show a relevant effect of soil salinity. Glycophyte species show decreasing biomass and root to shoot ratios with increasing soil salinity, while halophyte species show constant (smaller) biomass and ratios across the salinity gradient, but their biomass is mostly significantly higher at zero salinity as well (Ungar 1998, Gilbert and Fraser 2013). The effect of soil salinity on species composition is well known and recently also has been specifically documented for Pannonic alkali grasslands (Dítě et al. 2017, Valkó et al. 2014).

Interestingly, the presence of halophytic plant species was not affected by soil salinity in my data set. This was probably due to the preselection of sampling sites, because only a small share of plots did not harbour any halophytes and occupied plots showed a wide variation in soil salinity in the current study. Species richness of halophytes did not show any relationship to soil salinity in my data set either. This is not surprising, since mono-dominant stands of annual species on dried out soda pan beds (*Suaedetum pannonicae*) prefer similar soil salinity levels as littoral associations (*Puccinellietum limosae*) shaped by several perennial halophytes (Dítě et al. 2017). However, grazed plots showed a lower mean salinity than non-grazed plots in my data set (data not shown). If grazed plots harboured more halophytic species at low salinities, this might have blurred an existing effect of soil salinity on halophyte species pres-

ence or richness or a crossover interaction effect could be responsible for this observation. I did not test for interaction effects in any model, so this question remains open.
Maybe the hypothesized correlation between soil salinity and elevation of plots around soda pans in my data set was not as strong as previously expected. Soils in the Seewinkel show small-scale heterogeneity due to varying depths of the salt-containing horizon. Ladányi et al. (2016) found high correlations between soil conductivity, pH and soda content of a soda pan in Hungary but did not detect significant correlations between alkalinity/salinisation and elevation. Surprisingly, Howison et al. (2015) could not detect significant correlations between soil salinity and elevation or inundation in a salt marsh in the Netherlands, either. The authors suspected that soils with low root to soil ratios show higher fluctuations in their salinity due to higher absorbance of moisture and ions. Maybe, field measurements of actual plot altitudes would have led to a stronger correlation (Valkó et al. 2014). Another aspect influencing soil conditions at a very small scale could be the active influence of halophytes increasing soil salinities themselves to outcompete glycophytes (Ungar 1998, Wendelberger & Richards 2017).

C. Share of bare soil

Occurrence of *T. pannonicum* was the only response not explained by share of bare soil. All other models showed positive (presence of halophytes and *P. peisonis* and to a lesser degree species richness and index of halophyte abundance) or negative (presence of glycophytes and *P. australis*) correlations with bare soil. *T. pannonicum* is a perennial species that can cope with a wide range of ecological conditions around soda pans. It usually thrives on open patches but can be found in rather dense reed stands as well (Krachler et al. 2012). The low competitive abilities of many halophytes (Ungar 1998), i.e. open site conditions are favourable, might be the main reason for the high relevance of bare soil in explained variance throughout all other models.Many target species of this study are halophytes of soda pan basins, which prefer high light intensity and need bare soil to germinate in case of annual species (Gul et al. 2013).
Plots with little soil salinity in my dataset probably harboured glycophytes as stronger competitors to halophytes. Glycophytes outcompete halophytes in salt-free conditions and halophytes outcompete glycophytes (to a smaller extent) only at high salinities but clipping strongly reduced these interaction effects in an experimental setting (Gilbert & Fraser 2013). Shares of bare soil do not exactly represent inverse general vegetation cover in the current dataset, because litter and cryptogams sometimes covered large areas. The only response taking competition by non-halophytes into consideration was index of halophyte abundance, which showed the least pronounced effect of open soil in this study, meaning that although higher ratios of halophytic abundance did occur on plots with higher shares of bare soil, this increase was only small. Halophytes also strongly compete interspecifically (Ungar 1998), which has a much stronger effect on halophyte biomass than natural grazing by geese and hares (Dormann et al. 2000). On the other hand, there are also indications for strong niche separation among halophytic species (e.g. Davy et al. 2011, Landschulz 2009). In some plots of the current data set, litter was barely present even though vegetation density of a plot was high. Hence, shares of bare soil represent light intensity at soil level only to a certain extent. Nevertheless, an astonishing 14.7% and 21.4% of variance of presence and species richness of halophytes in this study were explained by shares of bare soil alone.
Shares of bare soil did not correlate with grazing intensity in my data set (data not shown), even though grazing and trampling by cattle are known to create more open surface patches (di Bella et al. 2015, van Klink et al. 2015, Bakker & Ruyter 1981). The irrelevance of grazing intensity as a covariate for bare soil in the current analyses might be due to the exclusion of

reed dominated areas as study sites. However, Lukács et al. (2015) found that open soil patches can also be created through high precipitation, not merely by high soil salinity or trampling effects. These precipitation-induced changes in species richness and composition were more pronounced in wet saline grassland habitats than in dry ones but favoured halophytic plant cover only in *Puccinellia*-dominated grazed grasslands (Lukács et al. 2015). Given the high relevance for halophytes in the current investigation, it might be interesting to focus on the favouring conditions for shares of bare soil in a follow-up study in the Seewinkel area.

D. Soil nitrate

Soil nitrate reduced the ratio of halophytic to glycophytic species abundance in my data and enhanced the presence of reed, but did not affect halophytic presence *per se*, their species richness or community composition. Interestingly, the presence of glycophytes was not shaped by soil nitrate either. Salt-tolerant plants may show increased salinity tolerance with higher nitrate availability, thereby changing their competitive abilities. Valéry et al. (2017) and Leport et al. (2006) reported invasive spread of the native grass *Elymus athericus* in salt marshes of a French bay. Similar effects may be suspected for the spread of reed on soda pan basins in the Seewinkel. Aerial N-immissions in the Seewinkel (around 16 kg/ha) do not reach the critical load for the eutrophic fens (22.5kg/ha), yet (Obersteiner & Offenthaler 2008). However, groundwater in the Seewinkel area north of Illmitz is nitrate-rich with mean values above 50mg/l in three out of four measuring stations (BMLFUW 2016). Hence, agricultural sources of nitrate leaching into soda pan basins can be assumed to reinforce the issue. Steingruber (2013) reported between 8–52 and 8–40 mg nitrate per kg dry soil for salt fens and salt steppes in the Seewinkel area, respectively. In the present study, nitrate values were both considerably higher and lower (see Table 1). Lower values are probably due to differences in sampling methods: current soil samples were comprising top 10 cm of soil instead of just the uppermost 5 cm in Steingruber's analyses. Furthermore, Steingruber used fresh soil for his extracts, while samples had been dried for the current analyses. Higher nitrate values of the current dataset were mainly found on two soda pans in the close vicinity of agricultural areas (soda pans 34 and 49). Wollenweber & Zechmeister-Boltenstern (1989) found indications that halophytes prefer ammonia over nitrate as their N source. Schrama et al. (2013) also found increases in the ratio of ammonia to nitrate in clay soils of grazed salt marshes. Therefore, targeted NH_4^+-measurements rather than soil nitrate might have been more suitable to detect grazing effects on halophytes in my study. However, Steingruber (2013) consistently observed higher nitrate than ammonia values in his study.
Litter mineralisation is also a main source of nitrate in saline soils but can be reduced even by small grazers like geese and hares (van Wijnen et al. 1999). Goose droppings did not compensate this effect in the same study except in young successional stages of the exclosure experiment. Schrama et al. (2013) showed that low intensity cattle grazing in a salt marsh lowers N mineralization rates via soil compaction by trampling, which inhibits the breakdown of soil organic matter in anoxic soil conditions. The authors observed this effect only in clay soils of a salt marsh, but not in sandy soils. N-fixation in alkaline soils of the Seewinkel was positively correlated with sandy soils, but negatively correlated with loamy soils (Wollenweber & Zechmeister-Boltenstern 1989). Soil texture was not taken into consideration in analyses in my study but might explain further variation in the current dataset since soils in the Seewinkel are often mixtures of sand and loam in varying proportions.

E. Reed cover

The single, most sensitive response variable, which showed significant effects of reed cover despite the exclusion of reed dominated areas as study sites, was soda pan plant species composition. *Agrostis stolonifera* (the most common grass species in this study) and *Bolboschoenus maritimus* are well-known indicator species for soda pan degradation (Krachler et al. 2012) in the Seewinkel area. Both *A. stolonifera* and *B. maritimus* showed associations with high reed cover in my dataset (Fig. 5). These results reaffirm that monitoring based on soda pan plant communities may serve well as an early indicator for soda pan degradation. The negative influence of *P. australis* on halophytes have been well documented by other studies (Korner et al. 2008, Török et al. 2014). On the other hand, results of the current study could also indicate that the selected non-grazed sites were still well enough supplied with alkali salts to withstand reed dominance, like soda pans in optimal conditions (Ecsedi & Boros 2013a), since non-grazed plots showed higher mean soil salinity values than grazed ones (data not shown).

F. Variation among individual soda pans

Higher values of R^2_c (viz. including the random effect of soda pan identity) compared to R^2_m (displaying only variance explained by the five fixed predictors soil salinity, soil nitrate, share of bare soil, reed cover and grazing intensity) of all current study models indicate that presence of halophytes, their species richness and halophytic plant community composition were to a substantial extent also driven by other factors than the physical soil and vegetation characteristics measured here. Among these factors could be the composition of dominant salts, since the chemical diversity of soda pans of the Carpathian basin is unique worldwide and five of altogether twelve described subtypes were present in the current study selection (Boros et al. 2014, Ecsedi & Boros 2013b, see Table A1 in Appendix). The landscape context, e.g. vicinity to other soda pans or the extent of agricultural use of surrounding areas of a soda pan, differs between soda pans in the Seewinkel (Ecsedi & Boros 2013b, Krachler et al. 2012, Dick et al. 1994). Moreover, the land-use history of each soda pan, especially concerning groundwater supply (i.e. effects of drainage ditches and influences by high-capacity wells), is very specific (Ecsedi & Boros 2013b, Krachler et al. 2012, Dick et al. 1994). Fluctuations of water-levels have had strong effects on the region historically and probably still are the main factor for disparate vegetation trends in different years (Euller et al. 2014). Since soda pan sizes differ strongly (see Table A1 in Appendix), variations due to a simple species-area effect may be assumed as well (Hanski 1998). From a metapopulation ecology viewpoint (Hanski 1998), stochastic effects probably have much stronger impacts on halophytes in the Seewinkel nowadays than historically, because long-distance dispersal by cattle was possible when animal herds were regularly driven to markets as far as the city of Vienna (Horváth 2011). Today, the three sedentary cattle grazing areas in the Nationalpark Neusielder See-Seewinkel are operated separately without any interchange between the three herds and linking corridors between many soda pans have been lost due to the conversion of meadows to vineyards, other agricultural areas or fallow land (Kohler et al. 1994). Models on invertebrate zooplankton in soda pans of the Seewinkel showed higher explanatory power for loss in species richness over time when reduced habitat connectivity was considered in addition to area loss and changes in habitat quality (Horváth et al. 2019). These observations indicate that factors idiosyncratically associated with individual soda pans play an important role in shaping their biota and present a wide variety of opportunities for future research projects.

4.2 Responses of selected halophyte species to habitat conditions

Plant community composition on soda pans in the Seewinkel showed clear gradients at small spatial scales in relation to shares of bare soil, soil salinity and reed cover but was not noticeably shaped by intensity of grazing or soil nitrate (Fig. 5). Differences between halophytes and glycophytes were mainly visible along the gradient of vegetation cover. Surprisingly, soil salinity did not display the major direction of spread between halophytic and glycophytic species. One reason might be that plants with preferences for slightly saline soils (salt figures S2-S4 in Borhidi 1995) like *Agrostis stolonifera* and *Bolboschoenus maritima* or species occurring across wide salinity gradients like *Festuca pseudovina* were deliberately not defined as 'halophytic' target species in this study. Another explanation could be non-representative soil salinity values in my data set after an unusually rainy summer season (see Table A8 in Appendix). *S. pannonica* showed an unexpected ordination result with a preference for intermediate soil salinity, which does not concur with the literature (Dítě et al. 2017, Freitag et al. 1996). *Plantago maritima*, in contrast, was represented in the ordination plot as expected according to literature. It occurs on relatively open patches with less salt influence, at the flow line on the outskirts of soda pan basins in close association with *Festuca pseudovina* (Dítě et al. 2017, Korner et al. 2008). The similar position of *Festuca pseudovina* with the glycophyte *Poa angustifolia* in my dataset is probably due to misidentification in the field, because – unfortunately - the two species are easily confounded by floristic beginners like me. *Agrostis stolonifera* and *Bolboschoenus maritimus* were highly associated with reed cover, yet *B. maritimus* tolerated higher salinity values and occurred on more open plots in my dataset. *Bolboschoenus maritimus* is a typical species of slightly saline soils in soda pan beds (salt figure S3 in Borhidi 1995) but has shown spreading tendencies together with the salt-tolerating species *Agrostis stolonifera* on ungrazed, desalinated soda pans in the last decades (Krachler et al. 2012, Korner et al. 2008, Ladányi et al. 2016). *B. maritimus* contributes to the sedimentation of soda pans by trapping aerial dust (Ecsedi & Boros 2013a). In Austria, mowing of reed- or *Bolboschoenus*-dominated spots with a follow up of intensive grazing by cattle herds is usually recommended for conservation management (Krachler et al. 2012). Results of a CCA ordination in Valkó et al. (2014) for the four shared plant species show some common aspects: *P. limosa* is situated at the highly alkaline edge like its Austrian sister species, the local endemic *P. peisonis* in this study. *F. pseudovina* showed an indifferent behaviour in terms of soil conductivity, and *A. stolonifera* was found on locations with little conductivity in both studies. Interestingly, *T. pannonicum* showed a higher affiliation with high soil conductivity in my dataset.

The two focus species *P. peisonis* and *T. pannonicum* were the most common halophytic target plants in this study. *Puccinellia peisonis* was found on plots with high salinity but scarce vegetation cover and reed cover in the ordination plot. However, the logistic model did not confirm a relevant negative effect of reed on the occurrence of *P. peisonis*. This was probably due to the exclusion of reed patches as study sites and thus little shared plots, because ungrazed plots showed decreasing trends in *Puccinellia*-cover parallel to the expansion of reed in long-term monitoring in the Seewinkel (Korner et al. 2008). *Tripolium pannonicum* was mainly associated with soil salinity and was found on plots with less open vegetation cover in the ordination result and showed a broad spectrum of salinity tolerance in the logistic model (Fig. 7). Probability of presence (*T. pannonicum*) ranged between 40 and 80%, which indicates that *T. pannonicum* is better capable of coping with less saline soil conditions than *P. peisonis* but is more sensitive to, or less competitive at, very high soda concentrations in soil. *T. pannonicum* as well as *Puccinellia limosa*, a close relative of *P. peisonis*, both show mycorrhiza (Füzy et al. 2010), which enable halophytes to better deal with soil salinity (Dashtebani et al.

2014, Ruppel et al. 2013). *P. peisonis* and *T. pannonicum* were facilitated by grazing but showed greater precipitation-induced changes than changes due to conservation management in other studies (Korner et al. 2008, Lukács et al. 2015). *T. pannonicum* profits from high water levels, because it can build up high population levels quickly (Korner et al. 2008), *P. peisonis* shows decreased cover (Korner et al. 2008, Lukács et al. 2015). However, facilitation by grazing sometimes simply means less decrease in cover in managed than in unmanaged plots (Korner et al. 2008). For both species cessation of grazing has led to declines in cover within a few years (Korner et al. 2008, Dítětová et al. 2016). *Puccinellia maritima* is a shade-intolerant species in salt marshes (Howison et al. 2015) and this probably also holds true for *P. peisonis* in the Seewinkel area. Neither *P. peisonis* nor *T. pannonicum* showed a relation to soil nitrate in this study. The maritime variety or subspecies *T. pannonicum ssp./var. tripolium* (L.) Greuter showed bacteria with *nif*H genes in its roots and rhizosphere (Szymańska et al. 2016), enabling it to thrive independently from nitrate resources in the soil.

4.3 Methodological issues with halophyte vegetation assessment

In the present study, the metric to score low shifting grazing intensities combines very different influences (i.e. fraction of non-grazed areas, signs of trampling, indications of herbivory and amount of dung deposition). This combined metric should be tested independently in future studies, because the currently investigated grazing effect might be too heterogenic. On the other hand, indices summarising multiple aspects of land-use have been proven very useful in predicting general effects of management intensity on biodiversity (Blüthgen et al. 2012, Kahl & Bauhus 2014). Thus, a stepwise composition and subsequent analysis of a continuous grazing index could yield more meaningful results than the applied metric in this study, as well (Blüthgen et al. 2012). Plot size of the current study design was probably adequate to detect potential differences between grazed and non-grazed plots (compare Godo et al. 2017, Wanner et al. 2013), but results on the impact of grazing may have been refined with a more targeted selection of plots around soda pans, e.g. by stratifying plots in four different elevation levels around soda pan bottoms and/or using measurements of height above pan bottoms to confirm positions of plots in the field (compare Lukács et al. 2015). Estimation of general vegetation cover values would be highly recommendable, as they allow for correction of overly generous abundance values of single species and could be used as an alternative fixed predictor in models. Conducting just one relevé per plot at a rather dry time of the year led to difficulties to discriminate between leaves of the current vegetation period and remnants from past years for cover estimates. Since halophytic plant associations are shaped by early spring therophytes (Korner et al. 2008) and late flowering plants of soda pan basins in autumn (Bergmeier & Schaminée 2016), multiple sampling (spring, summer and autumn) would be recommendable for both vegetation and soil data, but would obviously increase the need for human resources. With wide amplitudes of soil salinities in soda pan basins throughout a year and differing soil water content between the random plots, the assumption of a linear relationship of soil salt content of a single sampling period and halophytic plant species occurrence may have been overly simplistic for the current data set. Nitrate detection by high pressure liquid chromatography (HPLC) is known to show interferences by chloride in samples (Wang et al. 2017). Colorimetric methods are more exact and should be used to confirm HPLC measurements of nitrate for future soil samples. Additional soil factors, which might play a role for halophytes around soda pans, but would require more time and resources to document, are depth of anoxic conditions (Schröder et al. 2002, Davy et al. 2011), length of spring inundation, duration of soil aridity in late summer as well as soil layer sequence or depth of a certain soil layer (Horvat et al. 1974). Lukács et al. (2015) recommend comparing wet and dry years for an in-depth comparison of a habitat assessment, because many halophyte species show highly fluctuating presence with different amount of precipitation leading to remarkable reductions of total cover in years of intense rainfall. Exclusion of mown grounds led to a very small variability for plots at soda pan 35 (see Appendix Fig. A6). Even though a recent study did not detect significant differences between grazing versus combined grazing and mowing on species richness in Hungarian grasslands (Vadász et al. 2016), a repetition of the study with more precise data on mowing activities would be eligible and could lead to higher proportions of explained variability in the models, since effects of grazing and mowing are highly contingent on grassland type (Tälle et al. 2016).

5. Consequences for conservation and management

My results indicate that the yearly adapted grazing management plans work fine in the National Park Neusiedler See – Seewinkel. The danger of overgrazing (viz. too high grazing intensity) is well known to the National Park management and taken into consideration by monitoring grazing effects yearly. Török et al. (2018) showed that species richness in wet alkali grasslands grazed by cattle decreased with higher than 1–2.5 animal units/ha. In dry *Artemisa*-steppes, halophyte shares peaked at 1 animal unit/ha (Török et al. 2016). Hence, animal units per hectare for the Seewinkel area (ca. 0.5 at the time of data collection) could probably be increased slightly. To reduce management costs, rotational grazing could be an option to allow for the inclusion of previously ungrazed soda pans without considerable negative consequences (Lagendijk et al. 2017).

Reducing reed dominated areas remains one main aim of conservation grazing around soda pans. To this end, a combination of mowing and grazing proved very successful in Austria (Kohler & Korner 2006). Ecsedi & Boros (2013a) describe additional pre-management options prior to the beginning of long-term grazing, that could be useful for Austrian National Park authorities as well. The Hungarian authors recommend trampling by herds of large herbivores (cattle, horses or water buffalos), domestic geese flocks or Mangalitza pig grazing, which are least efficient. A coastal study recommended water buffalos for reducing reed strongly while preserving high shares of nests of breeding birds (Sweers et al. 2013). Additionally, the reintroduction of grazing with sheep or mixed herds of cattle, donkeys, horses and sheep could be considered in Austria, because this ensures the best development of typical soda pan shores with very short vegetation (Ecsedi & Boros 2013a, citing Hungarian authors).

Soil nitrate showed unfavourable effects on halophytes via increased competition by less salt-tolerant species in my dataset. Hence, reducing soil nitrate amounts by reducing above-ground biomass through grazing would be favourable for halophyte conservation. This has been a main aim of conservation grazing in the Seewinkel ever since. However, Varga et al. (2016) highlighted that extensive grazing systems in the Carpathian basin used to include a high percentage of non-grassland grazing grounds to supplement animal feeding in times of drought or at the end of the vegetation period. Management authorities of nature protection areas should consider including non-target areas as additional grazing grounds for times of feed shortage when planning sedentary herding conservation projects. Additionally, appropriate resting areas should be designated where animal dung deposits do not pose threats to species of conservation concern.

As Deák et al. (2014) pointed out, a crucial point in the conservation of alkali marshes is to provide astatic water regime. Natural soda lakes are selfsustained ecosystems when water regimes are optimized again (EASME 2019). This is far from reality for most soda pans in Austria. It should rather alarm us to change the water usage patterns in the area, that grazing did not show any promoting effect on halophytes in my dataset. Rising groundwater levels would also be beneficial, because the most problematic invasive plant for pristine alkaline vegetation, *Eleagnus angustifolia*, cannot sustain permanent inundation. Conversely, *E. angustifolia* additionally lowers groundwater levels of disturbed soda pans, because of its high water demands and evapotranspiration (Ecsedi & Boros 2013a), thereby increasing already existing water supply problems.

5.1 Future prospects

Since ecological indicator values reflect the competitive situations of climatic and floristic regions, probably neither the applied Hungarian (Borhidi 1995) nor the additionally used Central European list (Ellenberg 1991) reflect the transitional situation in the Seewinkel precisely. Even though Blab (1997) laid the foundations for a regional assessment, a more comprehensive analysis of existing relevés on alkaline soils of the region could bring more clarity and reveal potentially existing local ecotypes of species.

Samples from sites with high amount of gravel showed higher halophytic cover (data not shown) than on sites with soil cores comprising loamy and sandy soils. All these samples were located at soda pans of the central Seewinkel, which are assumed to have a different genesis than soda pans close to Lake Neusiedl (Riedl 1965, Weiss 2015a) and were sampled with shovels. It might be an interesting point to try to get deeper soil samples for these sites as well and compare their soil salinity, soil water content and effect on halophytes in future research activities.

Dispersal strategies probably differ between halophytes of soda pans, as indicated for example by the unequal representation of perennial graminoid species and annual halophytes in seed banks in alkali grasslands (Valkó et al. 2014). Annual species are supposed to react quicker to changes in environmental parameters (Korner et al. 2008, Braun-Blanquet 1964) but perennial halophytic species must be apt to cope with wide varying site conditions (e.g. Valkó et al. 2014, Lukács et al. 2015). Thus, there might be differences in grazing responses between halophytes especially concerning connectivity effects, i.e. the use of grazing animals as dispersal vehicles. Since soda pan sizes as well as their connectivity have been drastically reduced (Horváth 2019), stochastic effects might lead to extinctions of halophyte species even if soda pan qualities could be restored to optimal local conditions (compare Hanski 1998). To my knowledge, this aspect of conservation grazing has not been considered in management decision of the National Park Neusiedler See-Seewinkel, yet. Since the sedentary herding systems around soda pans of the central Seewinkel and soda pans close to Lake Neusiedl are currently not connected by grazing corridors, re-establishing connectivity could be a crucial point for long-term persistence of halophyte populations worth investigating in detail.

Even though shares of bare soil were not correlated with grazing intensity in the current data set, trampling effects could influence soil salinity in the Seewinkel by creating more open surface and soil compaction as reported by coastal studies (di Bella et al. 2015, van Klink et al. 2015). Conversely, grazing animals might possibly reduce soil salinity via foliage uptake, similar to reductions in soil nitrogen through reduced litter accumulation (van Wijnen et al. 1999). Hungarian herders also report that cattle like to lick salt from barren solonchak soils showing salt efflorescences in summer (Molnár 2014). Even though both trampling effects and salt-uptake by cattle probably are only small in conservation grazing with low animal units per hectare, deteriorating soda pan grounds without any salt supply from deeper soil layers theoretically might be negatively affected by grazing and it could be interesting to try and quantify these antagonistic effects.

On the other hand, the quality of beef meat could be enhanced by halophyte feed. Feeding-experiments with *Atriplex*-hay in Italy showed that high shares of salt hay increased the intensity of flavour of lamb meat (Moreno et al. 2015). Salt uptake of grazing sheep is so high in coastal areas of the Atlantic that their meat takes on a special taste and is considered a delicacy in France ("pré-salé" lamb, Pearce et al. 2010). If similar effects could be proven for beef, sale interests and return of investments for farmers taking part in conservation grazing in the Seewinkel might be increased.

5.2 Comprehensive meaning of preserving soda pans in the Seewinkel

With respect to climate change (IPCC Report 2014), rising sea water levels will lead to expanded coastal flooding (Meeresatlas 2017) and huge agricultural areas will become salty due to droughts. Hence, the share of salt affected soils is very likely to increase globally (Flowers et Muscolo 2015). Many halophytes are currently in the focus of agricultural research as potential future cash crops. The maritime variety or subspecies *T. pannonicum ssp./var. tripolium* is handled as a very promising plant (Geissler et al. 2010), so it seems valuable to preserve populations of the closely related *Tripolium pannonicum ssp./var. pannonicum* in the Seewinkel. Moreover, most halophytic species in this study were probably used as food source in the Seewinkel area in former times (Machatschek 2010). Few studies on phylogenetics of halophytes are available up to now and even fewer consider inland, especially Pannonian sites (Weising & Freitag 2007, Lambracht et al. 2007, Prinz et al. 2010). Due to the special geographical situation, the Seewinkel area harbours continental halophytic species, some spreading from central Asia to Europe like *Lepidium cartilagineum*, coastal species with sometimes worldwide distributions like *Juncus maritimus*, but on the other hand also locally endemic species to the Pannonian plant region like *P. peisonis* (Löffler 1982). Considering the isolated distribution of salt-affected inland habitats in Europe (cf. Brandes 1999), it seems especially crucial to protect their few existing populations of highly adapted biota, which are all of high conservation concern, as evidenced by their Red List status (Niklfeld & Schratt-Ehrendorfer 1999).

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8. Appendix

Figure A1: Example of an orthophoto with 20 randomly selected points for soda pan 30 (Ochsenbrunnlacke) prior to field work. At 10 of these points, vegetation relevés and soil samples were taken (points 0 - 9).

Table A1: Soda pans with numbers and geographical names after Krachler et al (2012). Altitude of lowest measured point at soda pan center in meters above sea level (extracted from digital terrain model of the Seewinkel) and number of plots per soda pan in univariate and multivariate analyses of this study. Column "grazed" shows cattle grazing status in 2007. Values for soda pan area and composition of dominant salts are taken from Ecsedi & Boros (2013b).

Pan No	Geographical name	m a.s.l.	n	grazed	area (ha)	salts
14	Lange Lacke	116.98	8	yes	144.89	**Na, HCO_3 > SO_4**
23	Westliche Wörthenlacke	117.52	8	yes	51.12	**Na > Mg, HCO_3 > SO_4**
24	(Westliche) Hutweidenlacke	117.64	9	yes	3.95	**Na, HCO_3**
25	Obere Halbjochlacke	118,77	10	yes	29.43	**Na, HCO_3**
26	Fuchslochlacke	119,28	10	yes	28.52	**Na, HCO_3**
28	Birnbaumlacke	120.21	10	no	21.16	**Na > Ca > Mg > HCO_3 > SO_4**
30	Ochsenbrunnlacke	119.63	10	no	23.55	**Na, HCO_3**
32	Kühbrunnlacke	119.62	9	no	6.55	**Na, HCO_3**
34	Obere Hölllacke	116,75	10	no	6.89	**Na, HCO_3**
35	Oberer Stinkersee	116.45	10	no	56.82	**Na, HCO_3 > Cl**
39	Albersee	116.00	10	yes	12.23	**Na, HCO_3 > Cl**
40	Illmitzer Zicksee	116.00	8	yes	204.15	**Na, HCO_3 > SO_4**
41	Kirchsee	116.25	10	yes	12.51	**Na, HCO_3**
48	Katschitzllacke	117.52	8	yes	11.79	**Na, HCO_3 > SO_4**
49	Östliche Wörthenlacke	117.60	8	yes	39.11	**Na, HCO_3 > SO_4**
62	Mittlerer Stinkersee	116.56	10	no	8.61	**Na, HCO_3**
85	Neufeldlacke	117.59	10	yes	n.a.	n.a.
89	Fürstenlacken	117.88	10	yes	3.62	**Na, HCO_3 > SO_4**
90	Auerlacke	119.79	8	no	4.08	**Na, HCO_3**
		Total	176	19		

Figure A2: Example of the photo documentation of a plant relévé on plot 23_05 (plot number 5 on soda pan 23, Westliche Wörthenlacke). Grid size: 10 × 10 cm.

Figure A3: Soil sampling by metal drill on plot with ID 48_06. Soil cores were divided into three subsamples (top soil to 10 cm depth, 10 cm to 20 cm depth and 20 cm to 30 cm depth) and processed separately in the lab. Only the top soil layer was considered in statistical analyses.

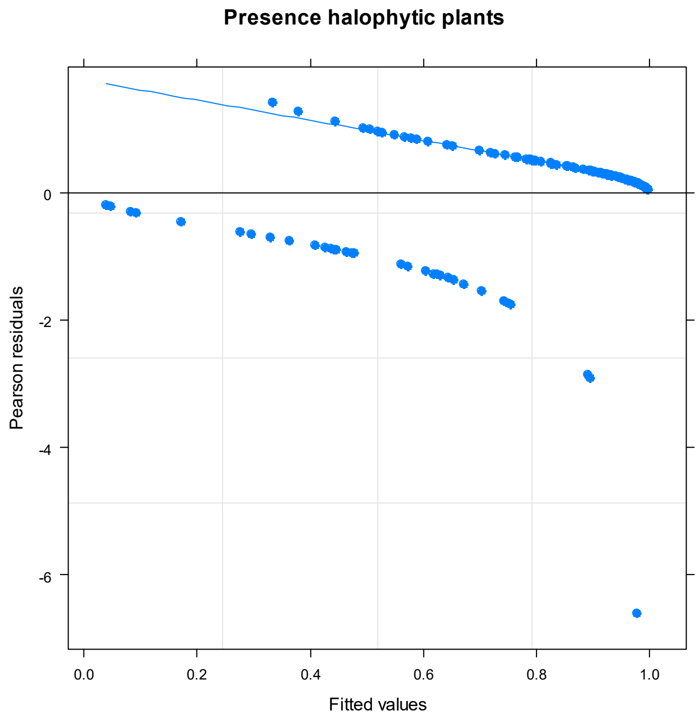

Figure A4: check for abnormalities of Pearson residuals and fitted values of global model for presence of halophytic plants.

8.1 Modelling the presence of glycophytes

Probability of presence for glycophytic plants was shaped by soil salinity and vegetation cover. Neither grazing intensity nor soil nitrate nor reed cover influenced presence of glycophytes in my data set. The global model for glycophytes showed the highest R^2_m (61.6 %, see Table A2) of all statistical models in this study. Figure A5 shows that both effects were very pronounced. Probability of presence for glycophytes was already lowered to 50% at 3.5g salt/ kg dry soil and 80 % vegetation cover. No clear turning point was visible for share of bare soil.

Table A2: Summary results of null and global GLMM for presence of glycophytic non-target species on 176 plots at 19 soda pans. *b* – estimate of beta coefficient, CI – confidence interval assuming infinite degrees of freedom (t=1.96), VC – variance component, PCV – proportion change in variance, R^2_m – variance explained by fixed factors, R^2_c – variance explained by both fixed factors and random factor, AIC_c – AIC corrected for small sample size.

	Null model	Global model
Fixed effects:	*b* [95% CI]	*b* [95% CI]
Intercept	-0.05 [-0.59; 0.47]	-0.46 [-1.18; 0.25]
Conductivity	-	-2.11 [-2.93; -1.30]
Grazing intensity	-	0.60 [-0.08; 1.29]
Bare soil	-	-0.84 [-1.44; -0.23]
Nitrate	-	0.71 [0.19; 1.23]
Reed cover	-	-0.11 [-0.63; 0.41]
Random effect:	VC	VC
PanNo	0.871	1.154
Fixed factors	-	7.127
$PCV_{[PanNo]}$	-	-32.49%
R^2_m	-	61.59%
R^2_c	-	71.57%
AIC_c	237.60	155.52

Table A3: AIC_c-based table for 95% confidence set of best-ranked models for presence of glycophytes. *k* – number of estimated parameters of a model; ΔAIC_c – difference to AIC_c value of best-ranked model, w_i – Akaike weight, acc. w_i – cumulative Akaike weight, ER – evidence ratio, C – soil conductivity, G – grazing intensity, S – bare soil, N – soil nitrate, R – reed cover.

	k	AIC_c	ΔAIC_c	w_i	acc. w_i	ER
C+G+S+N	6	153.53	0	0.36	0.36	
C+S+N	5	154.15	0.62	0.27	0.63	1.36
global model	7	155.52	2.00	0.13	0.76	2.72
C+S+N+R	6	156.11	2.58	0.10	0.86	3.63
C+G+S	5	158.07	4.54	0.04	0.90	9.68
C+S	4	158.14	4.61	0.04	0.94	10.02
C+G+N	5	159.80	6.27	0.02	0.95	22.99

Table A4: Variate weights based on all models in the candidate set for presence of glycophytes. Model averaged estimates [± 95% confidence interval] based on 95% confidence set of best-ranked models. acc. w_i – cumulative Akaike variate weight, CI – confidence interval, Int – intercept, C – soil conductivity, G – grazing intensity, S – bare soil, N – soil nitrate, R – reed cover. Relevant predictors (variate weight >0.9) are highlighted in bold face.

	Int	C	G	S	N	R
acc. w_i		**1.00**	0.57	**0.96**	0.90	0.26
Estimate [± 95% CI]	-0.47 [-1.23; 0.29]	**-2.18 [-3.01; -1.35]**	0.35 [-0.44; 1.13]	**-0.8 [-1.46; -0.14]**	0.62 [-0.02; 1.26]	-0.02 [-0.31; 0.26]

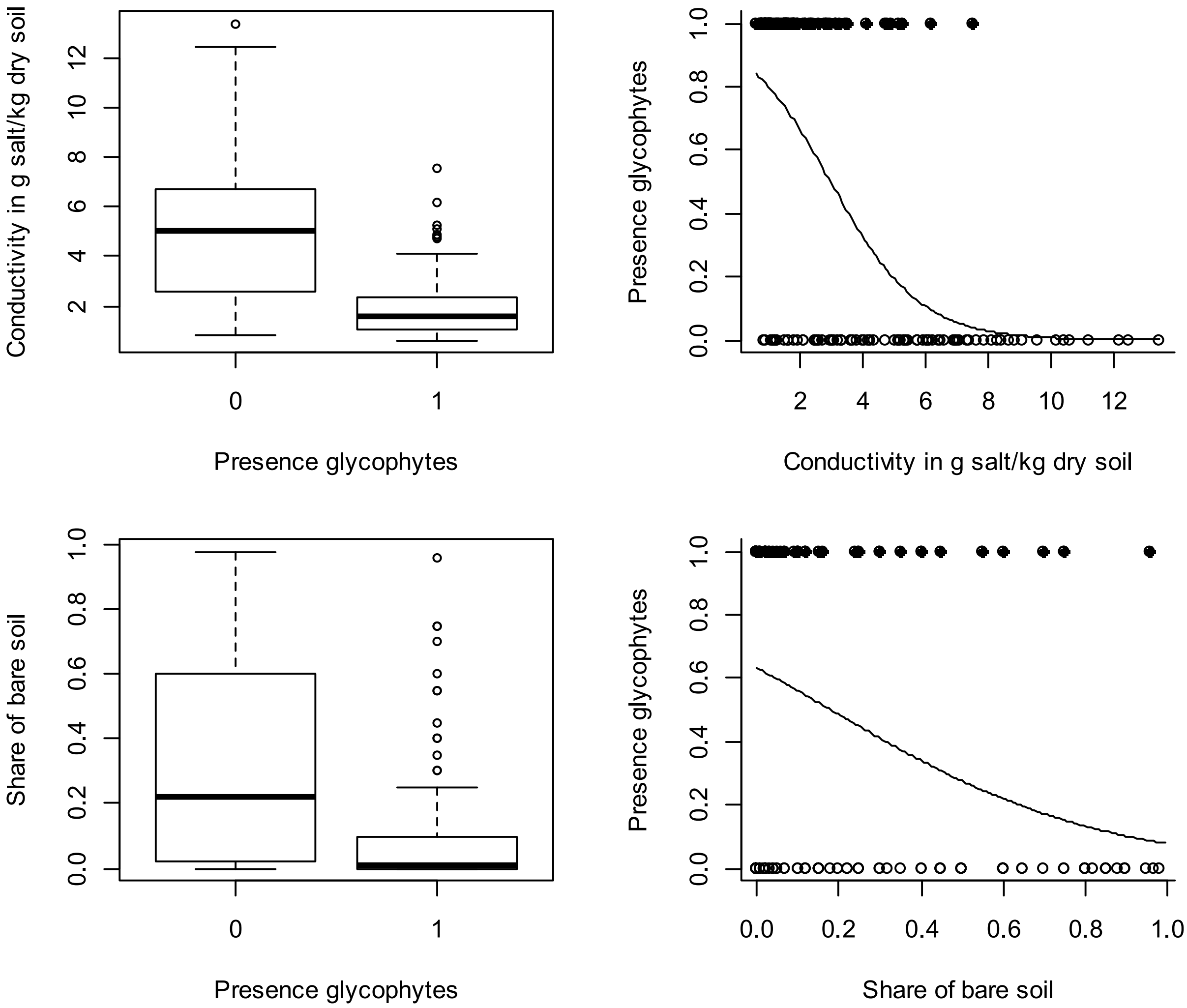

Figure A5: Probability of presence for glycophytes on 176 plots at 19 soda pans relative to soil conductivity and share of bare soil in combination with simple logistic regressions. Biplots are based on original values of the most relevant predictor variables (variate weight > 0.9) revealed by an all-subset averaging using AIC_c. Boxplots further illustrate spread of medians and measured data.

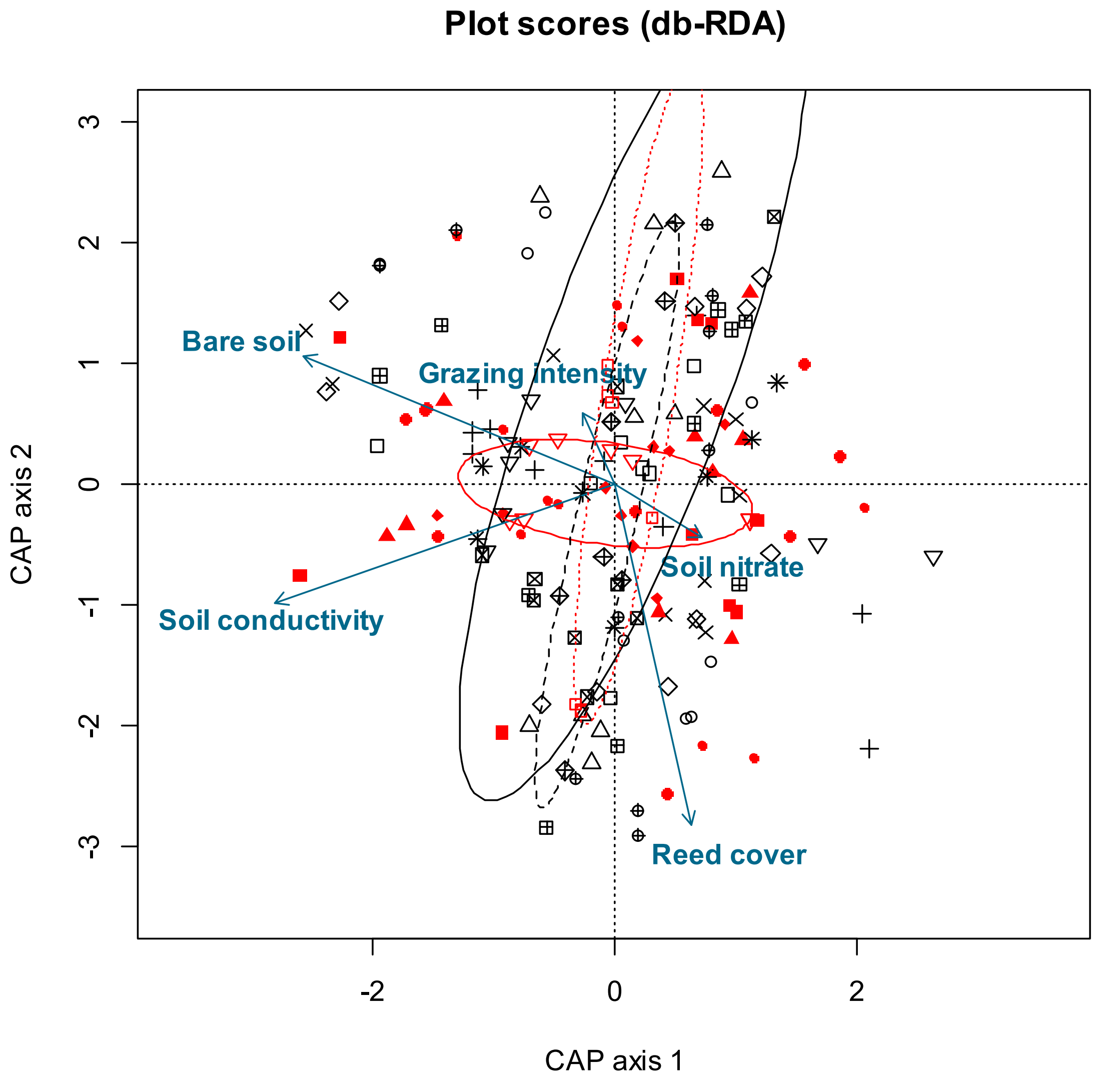

Figure A6: Biplot of halophytic plant species communities in 118 plots at 16 soda pools along first two ordination axes of dbRDA ordination. Ellipses highlight pools with special clustering of plots along the ordination axes (35, 41, 49, 90; see text for details). Black symbols – grazed plots, red symbols – non-grazed plots. Blue arrows show direction of influence of environmental variables. Soil cond. – Soil conductivity.

Table A5: Scores of relevant species at soda pan plant communities with a value of ~|0.5| for at least one of the first two constrained axes in db-RDA. Halophytic target species are highlighted in bold letters.

Species name	CAP1	CAP2
Agrostis stolonifera	0.695	-0.811
Bolboschoenus maritimus agg.	-0.504	-0.851
Festuca pseudovina	0.383	0.495
Plantago maritima	-0.050	0.490
Poa angustifolia	0.529	0.110
Puccinellia peisonis	-2.109	0.431
Suaeda pannonica	-0.515	0.261
Tripolium pannonicum	-0.930	-0.184

Table A6: 14 halophytic target plant species (occurring only rarely on non-saline soils according to Ellenberg 1991, thus considered ecologically "obligatory halophytes") in alphabetical order (species names after Fischer et al. 2005), their affinity to saline soils (SB; Borhidi 1995) in numbers between 5 (alpha-mesohaline) and 8 (euhaline) and information on their habitat, life form/life span and red list classification (Fischer et al. 2008). Red list classifications (column R): 1 – threatened with extinction, 2...critically endangered, 3 – endangered, 4 – potentially endangered, (s) – scattered (Niklfeld et al. 1999).

Species name	SB	Habitat	life form /life span (Raunkiaer)	R
Artemisia santonicum	5	salt steppes	chamaephyte-hemicryptophyte, perennial	3
Carex distans	5	moist to wet, also saline meadows	hemicryptophyte, perennial	3
Cirsium brachycephalum	5	swampland, fens, ditches; esp. on slightly saline soils	hemicryptophyte, biennial to perennial	2
Juncus gerardii	5	saline, moist to wet meadows, soda pan margins	geophyte, perennial	3
Lepidium cartilagineum	8	salt steppes (white alkali soil); obligatory halophyte	hemicryptophyte, perennial	3
Matricaria chamomilla	6	saline meadows/pastures	therophyte	- (s)
Plantago maritima	7	mostly on strongly saline, wet to periodically moist turfs	hemicryptophyte, perennial	3
Plantago tenuiflora	8	Wet, temporarily inundated saline turfs	therophyte	1
Puccinellia peisonis	7	sandy soda soils, soda pan margins, white alkali soil	hemicryptophyte, perennial	3
Scorzonera cana	5	Ruderal semi-dry grasslands and dry meadows, waysides	hemicryptophyte, perennial	-
Spergularia maritima	8	moist salt steppes; saline clay-soils	hemicryptophyte, perennial	3
Suaeda pannonica	8	temporarily wet saline sites, soda pans, saline mud soils (esp. habitats rich in soda)	therophyte	3
Triglochin maritimum	6	Moist to wet, (slightly) saline meadows	hemicryptophyte, perennial	3
Tripolium pannonicum	7	saline meadows	hemicryptophyte, perennial	3

Table A7: Glycophytes listed with salt figure S0 in Borhidi (1995) as well as Ellenberg et al. (1991) and Blab (1997). Species names after Fischer et al. (2005) in alphabetical order.

Allium vineale	Epilobium tetragonum ssp. tetragonum	Poa angustifolia
Arenaria serpyllifolia	Equisetum arvense	Poa compressa
Arrhenatherum elatius	Erigeron annuus	Polygala comosa
Avenula pubescens	Erigeron canadensis	Polygala vulgaris
Calamagrostis epigejos	Euphorbia cyparissias	Portulaca oleracea
Calystegia sepium	Falcaria vulgaris	Potentilla verna agg.
Carex otrubae	Festuca pratensis	Rubus caesius
Carex riparia	Festuca rupicola	Rumex palustris
Centaurea jacea	Fragaria viridis	Sanguisorba minor
Centaurea stoebe	Galium aparine	Saxifraga tridactylites
Cichorium intybus	Galium verum	Scirpoides holoschoenus
Cirsium canum	Lactuca serriola	Sedum sexangulare
Convolvulus arvensis	Linaria vulgaris	Senecio erraticus
Cuscuta epithymum	Lycopus europaeus	Serratula tinctoria
Cynodon dactylon	Melilotus albus	Teucrium chamaedrys
Dactylis glomerata	Mentha aquatica	Thesium linophyllon
Daucus carota	Mentha sp.	Thesium ramosum
Deschampsia cespitosa	Molinia caerulea	Thymus pannonicus agg.
Echium vulgare	Pastinaca sativa	Tilia/Acer seedling
Elymus hispidus	Picris hieracioides	Trifolium campestre
Epilobium tetragonum ssp. lamyi	Plantago lanceolata	Valeriana officinalis

Table A8: Mean monthly precipitation for Apetlon for the period 1991-2010 (source: Krachler et al 2012, Appendix II) and monthly precipitation (in mm) in 2007 for four climate stations close to the survey area in northern Burgenland (data derived from Hydrographie Österreich 2018).

Month	Apetlon 1991-2010	Apetlon 2007	Illmitz 2007	Frauenkirchen 2007	Podersdorf 2007
January	29.3	38.9	39.6	36.4	34.8
February	23.9	34.9	33.5	37.9	30.6
March	46.5	89.0	81.2	78.9	68.7
April	43.9	0.0	0.0	0.5	0.0
May	62.3	74.7	83.0	62.1	62.3
June	74.5	25.7	19.4	34.5	46.3
July	75.3	52.4	39.4	49.2	45.0
August	68.1	141.7	100.1	60.0	104.5
September	65.5	155.1	137.6	142.2	121.9
October	45.7	71.2	65.4	64.1	53.4
November	51.6	36.2	27.1	36.8	30.5
December	45.7	47.9	37.7	37.3	30.0
Total	632.5	767.7	664.0	639.9	628.0

Table A9: GPS location (BMN M34 projection, Austrian Ferro East System; in meters) and environmental parameters of plots. ID_Plot – identification number for study sites starting with soda pan number followed by number of random plot, GPS_x – GPS-value for latitude (easting), GPS_y – GPS-value for longitude (northing), a – accuracy of GPS location in m, Cond – soil conductivity in g salt/kg dry soil; NO3 – soil nitrate in mg/l, d – depth of soil sample in cm, Soil – share of bare soil, Reed – cover *Phragmites australis*, GrIn – intensity of cattle grazing (0 – no, 1 – little, 2 – medium, 3 – strong), ViGr – grazed vegetation (0 – no, 1 – little, 2 – medium, 3 – heavily), Fec – plot area covered with cattle feces, FecPc – Pieces of cattle feces surrounding the plot area within a radius of 1 meter, Ftpr – plot area with visible cattle footprints in percent, FtprPc – number of cattle footprints surrounding the plot area within a radius of 1 meter, t – are there signs of trampled vegetation on the plot? y – yes/blank – no.

ID_Plot	GPS_x	GPS_y	a	Cond	NO3	d	Soil	Reed	GrIn	ViGr	Fec	FecPc	Ftpr	FtprPc	t
14_01	789415	291622	5	4.795	4.6	0-10	0.16	0	3	3	0	1	0.14	19	
14_03	789391	291341	5	1.021	5	0-10	0.3	0	3	3	0	1.5	0.11	17	
14_04	791415	291544	4	2.718	10.2	0-10	0.5	0	2	2	0	4.5	0.06	9	
14_05	789506	291292	5	1.786	3.6	0-10	0.06	0	3	3	0	0	0.16	16	
14_06	790301	291181	4	1.686	9.8	0-10	0	0.04	2	2	0	0	0	0	y
14_07	789519	291044	5	1.845	0	0-10	0	0	1	0	0	0	0	0	
14_08	789447	291726	5	5.268	11.3	0-10	0	0.19	1	0	0	0	0	0	y
14_09	791444	291739	4	2.519	10	0-10	0.5	0	2	2	0	1	0.08	6	
23_00	789951	292581	4	0.795	9.8	0-10	0.96	0	1	1	0	1.5	0.12	20	
23_04	789983	293360	6	1.954	33.6	0-10	0.02	0.02	3	3	0.008	7	0.08	16	
23_05	790219	293291	5	2.872	2.7	0-10	0.4	0	1	1	0	0	0.45	40	
23_06	789781	292864	5	10.57	20.2	0-10	0.65	0	1	0	0.016	2	0.08	40	
23_07	790069	293314	4	2.359	47.9	0-10	0.07	0	2	2	0	0	0.19	28	
23_08	790271	292569	5	1.115	16	0-10	0	0.02	1	1	0	0	0.07	47	y
23_09	790209	293353	5	2.905	77.6	0-10	0.01	0.05	1	0	0	0	0.14	20	
23_14	790411	292778	5	1.245	9	0-10	0.45	0.02	1	0	0.003	1	0	0	
24_00	790105	292369	5	1.584	11.9	0-10	0	0	1	1	0.008	3	0	0	
24_01	790072	292384	5	1.242	14	0-10	0.01	0.05	2	2	0	4	0.06	7	
24_04	790179	292424	7	2.154	4.3	0-10	0	0.13	2	2	0	0	0	0	
24_05	790052	292279	4	2.496	14.7	0-10	0	0.2	1	0	0	0	0	0	
24_06	790174	292358	5	1.603	2.2	0-10	0	0	1	0	0	0	0	0	
24_08	790172	292184	4	0.983	5.7	0-10	0	0.11	2	2	0	0	0	0	
24_09	790062	292255	5	2.618	10.8	0-10	0	0.06	1	0	0	0	0	0	
24_10	790333	292424	4	0.734	12.9	0-10	0.55	0	3	3	0	3	0.1	50	
24_17	790071	292349	4	1.242	36.3	0-10	0.75	0	2	2	0	2	0.04	6	
25_00	787902	294320	4	6.122	6.6	0-10	0.9	0	1	0	NA	NA	NA	NA	
25_01	788127	294146	4	0.799	9.1	0-10	0.15	0	1	0	NA	NA	NA	NA	
25_03	788584	294114	5	4.17	2.6	0-10	0.3	0	1	0	NA	NA	NA	NA	
25_04	788299	294096	4	5.75	5.5	0-05	0.9	0	1	0	NA	NA	NA	NA	
25_05	787956	294581	4	1.002	12.2	0-10	0	0	1	0	NA	NA	NA	NA	
25_06	787885	294334	4	4.211	11.1	0-07	0.5	0	1	0	NA	NA	NA	NA	
25_07	787882	294518	4	1.52	52.3	0-10	0	0.08	1	0	NA	NA	NA	NA	
25_08	788548	293993	4	5.305	2.3	0-10	0.75	0	1	0	NA	NA	NA	NA	
25_09	788455	293940	4	0.917	7.5	0-10	0	0	1	0	NA	NA	NA	NA	
25_17	787924	294304	4	1.071	9.4	0-10	0.35	0	1	0	NA	NA	NA	NA	
26_00	789327	294777	5	1.337	28.3	0-10	0.02	0	1	0	NA	NA	NA	NA	
26_01	788908	294903	5	2.162	33.4	0-10	0	0.03	1	0	NA	NA	NA	NA	
26_02	790164	294583	4	1.196	16.1	0-10	0.25	0	1	1	NA	NA	NA	NA	
26_03	788758	294344	4	0.892	7.8	0-10	0.03	0	1	0	NA	NA	NA	NA	
26_04	789801	295132	5	1.635	49.4	0-10	0	0.21	1	0	NA	NA	NA	NA	
26_05	788812	294720	5	1.836	38.2	0-10	0.01	0.1	1	0	NA	NA	NA	NA	
26_06	789214	295127	5	1.563	23.7	0-10	0.12	0.02	1	0	NA	NA	NA	NA	
26_07	789818	295046	5	1.121	15	0-10	0.6	0	1	0	NA	NA	NA	NA	
26_08	789135	294981	4	1.367	22.4	0-10	0	0.02	1	0	NA	NA	NA	NA	
26_09	789010	294949	4	5.159	3.3	0-10	0.45	0.02	1	0	NA	NA	NA	NA	
28_01	789445	297762	5	1.519	21.5	0-05	0.25	0	0	0	NA	NA	NA	NA	
28_03	790158	297993	6	0.806	7.8	0-10	0.04	0	0	0	NA	NA	NA	NA	
28_04	789866	297474	5	1.111	21.1	0-10	0	0	0	0	NA	NA	NA	NA	
28_05	790117	298001	5	1.101	21.1	0-10	0.02	0.01	0	0	NA	NA	NA	NA	
28_06	789581	297810	5	3.009	6.5	0-10	0.2	0	0	0	NA	NA	NA	NA	
28_07	789927	297960	5	3.99	4.5	0-10	0.8	0	0	0	NA	NA	NA	NA	
28_08	789452	297739	4	1.167	20.6	0-05	0.1	0	0	0	NA	NA	NA	NA	
28_09	789755	297579	6	1.204	11.1	0-05	0.8	0	0	0	NA	NA	NA	NA	
28_18	789735	297408	5	0.623	9.4	0-10	0	0	0	0	NA	NA	NA	NA	
28_19	789396	297747	5	2.125	20.3	0-10	0	0	0	0	NA	NA	NA	NA	

ID_Plot	GPS_x	GPS_y	a	Cond	NO3	d	Soil	Reed	GrIn	ViGr	Fec	FecPc	Ftpr	FtprPc	t
30_00	788106	297240	4	3.613	4.5	0-10	0.12	0	0	2	NA	NA	NA	NA	
30_01	788162	296966	5	5.191	3.3	0-10	0.22	0	0	0	NA	NA	NA	NA	
30_02	788412	297305	6	5.739	17.9	0-05	0.6	0	0	3	NA	NA	NA	NA	
30_03	788022	297134	5	0.955	10.6	0-10	0.01	0	0	0	NA	NA	NA	NA	
30_04	788578	297096	7	1.281	14.3	0-10	0	0.02	0	0	NA	NA	NA	NA	
30_05	788155	297324	4	0.99	13.7	0-10	0	0	0	0	NA	NA	NA	NA	
30_06	788057	297113	4	0.919	9.6	0-10	0	0	0	1	NA	NA	NA	NA	
30_07	788063	297038	7	1.039	10.5	0-10	0.02	0	0	0	NA	NA	NA	NA	
30_08	788339	297306	4	6.443	25.5	0-10	0.85	0	0	0	NA	NA	NA	NA	
30_09	788199	297290	4	2.436	8.7	0-07	0.25	0	0	0	NA	NA	NA	NA	
32_00	791025	294919	4	0.925	11.8	0-10	0	0.29	0	0	NA	NA	NA	NA	
32_01	790783	295122	5	1.815	13.4	0-10	0	0.21	0	0	NA	NA	NA	NA	
32_03	790816	295047	4	2.457	9.7	0-10	0.6	0	0	0	NA	NA	NA	NA	
32_04	790832	295004	5	0.808	6.2	0-10	0.09	0	0	0	NA	NA	NA	NA	
32_05	790767	295117	5	1.775	51.6	0-10	0	0.06	0	0	NA	NA	NA	NA	
32_06	791083	295011	5	0.837	3.6	0-10	0.15	0	0	0	NA	NA	NA	NA	
32_07	791074	295077	5	1.579	20.9	0-10	0	0.02	0	0	NA	NA	NA	NA	
32_08	791027	295177	6	1.661	25.5	0-10	0.02	0.03	0	0	NA	NA	NA	NA	
32_09	790963	295248	6	3.023	4.2	0-10	0.3	0.01	0	0	NA	NA	NA	NA	
34_00	785653	298610	6	3.819	12.7	0-10	0	0.09	0	0	NA	NA	NA	NA	
34_01	785807	298844	5	5.142	147	0-10	0.03	0.1	0	0	NA	NA	NA	NA	
34_02	785798	298759	5	6.965	105	0-10	0.05	0.14	0	0	NA	NA	NA	NA	
34_03	785836	298830	6	3.45	74.2	0-10	0	0.25	0	0	NA	NA	NA	NA	
34_04	785612	298601	6	1.531	17.5	0-10	0.1	0.05	0	0	NA	NA	NA	NA	
34_05	785427	298975	5	1.343	72.7	0-10	0	0.03	0	0	NA	NA	NA	NA	
34_06	785824	298866	5	2.869	73.8	0-10	0.02	0.09	0	0	NA	NA	NA	NA	
34_08	785738	298693	5	4.108	90.5	0-10	0	0.07	0	0	NA	NA	NA	NA	
34_09	785758	298793	5	13.4	25.5	0-10	0.01	0.04	0	0	NA	NA	NA	NA	
34_19	785546	298698	5	3.009	14.3	0-10	0.15	0	0	0	NA	NA	NA	NA	
35_00	784797	297728	5	5.367	14.4	0-10	0.7	0	0	1	NA	NA	NA	NA	
35_01	784183	296663	5	6.236	25.9	0-10	0.6	0	0	0	NA	NA	NA	NA	
35_02	784695	297108	6	7.325	16.1	0-10	0.25	0	0	0	NA	NA	NA	NA	
35_03	784461	296969	5	3.31	21.3	0-10	0.85	0	0	0	NA	NA	NA	NA	
35_04	784126	297197	5	6.101	17.3	0-10	0.04	0	0	0	NA	NA	NA	NA	
35_05	784364	297623	4	6.575	16.9	0-10	0.8	0	0	0	NA	NA	NA	NA	
35_06	784800	297290	4	12.44	20	0-10	0.98	0	0	0	NA	NA	NA	NA	
35_07	784311	297452	5	7.861	28.1	0-10	0.85	0	0	0	NA	NA	NA	NA	
35_08	784795	297646	4	5.338	28.1	0-10	0	0	0	0	NA	NA	NA	NA	
35_09	784235	296649	5	6.076	18.1	0-10	0.95	0	0	0	NA	NA	NA	NA	
39_00	782872	293154	6	3.317	19.9	0-10	0.01	0.05	3	3	0.14	9	0	0	
39_01	782871	293420	5	5.729	43.7	0-10	0	0.11	2	2	0	7	0	0	
39_03	782651	293222	5	1.657	15.4	0-10	0	0.09	3	3	0.04	2	0	0	
39_04	782976	292851	5	0.847	18.4	0-10	0	0.01	1	1	0.07	0	0	0	
39_05	782870	293166	6	1.649	17.4	0-10	0.02	0.08	3	3	0.008	4	0	0	
39_06	782627	292939	5	5.039	16.1	0-10	0	0.17	3	3	0.04	4	0	0	
39_07	782964	292890	5	0.772	14.8	0-10	0	0.01	2	2	0	4	0	0	
39_08	782828	293449	5	8.269	68.6	0-10	0.04	0.02	3	3	0.04	8	0.01	15	
39_09	782847	293474	5	1.932	14.3	0-10	0.12	0.01	2	2	0.04	8	0	0	
39_19	782791	292800	5	12.17	45.9	0-10	0.65	0.03	3	3	0	6	0	10	
40_00	784366	292189	4	8.849	23.4	0-10	0.82	0	3	3	0	0	0	7	
40_02	784022	291853	4	0.722	21.1	0-10	0.01	0.04	1	0	0	0	0	0	
40_04	784548	292385	5	0.915	8.3	0-10	0	0	1	1	0	0	0	0	
40_05	784851	292524	5	3.355	7	0-10	0.45	0	2	2	0	1	0.08	15	
40_06	784821	292850	4	7.599	13.8	0-10	0.4	0	2	2	0	2	0.08	19	
40_08	784350	292181	5	5.409	15	0-10	0.4	0	2	2	0	0	0	3	
40_09	784306	293050	4	10.19	19.5	0-10	0.32	0	3	3	0.06	7	0.04	14	
40_17	783487	292510	4	11.21	13.9	0-10	0.22	0	2	2	0	2	0.2	70	
41_00	783875	291501	4	1.484	19.6	0-10	0	0	3	3	0	1	0	1	
41_01	783723	291241	4	3.686	31.1	0-10	0.01	0	1	0	0	2	0.12	14	
41_02	783785	291373	5	5.456	17	0-10	0.18	0.01	1	0	0	0	0.36	80	
41_03	783763	291191	5	10.42	28.1	0-10	0.35	0.01	1	0	0	3	0.12	25	
41_04	783747	291343	5	3.064	10.5	0-10	0.02	0.01	1	0	0	0	0.2	55	
41_05	783951	291302	5	2.953	10.9	0-10	0.8	0.02	1	0	0	0	0.08	11	
41_06	783827	291289	5	2.61	12.2	0-10	0.02	0.03	1	0	0	0	0.2	52	
41_07	783630	291231	5	1.028	11.1	0-10	0	0	1	1	0	1	0	0	
41_08	783772	291146	5	9.092	30.4	0-10	0.5	0	1	1	0	0	0.09	33	
41_09	783907	291443	5	4.345	16.4	0-10	0.12	0.05	2	2	0.025	0.5	0.05	9	
48_03	790522	292294	5	0.916	10.2	0-10	0.02	0	2	2	0.02	2	0.05	12	

ID_Plot	GPS_x	GPS_y	a	Cond	NO3	d	Soil	Reed	GrIn	ViGr	Fec	FecPc	Ftpr	FtprPc	t
48_04	790402	292024	4	7.515	7	0-10	0.1	0	2	2	0.06	3.5	0.11	34	
48_05	790499	292086	4	2.091	15	0-10	0.25	0	2	2	0	2.5	0.07	3	
48_06	790473	292442	4	4.061	23.2	0-10	0.07	0	2	2	0	1	0.05	8	
48_07	790481	292150	4	1.933	22.3	0-10	0.3	0	2	2	0	0	0.21	79	
48_08	790449	292092	4	4.228	9.3	0-10	0.6	0	3	3	0	0	0.13	80	
48_09	790427	292152	4	1.073	18.5	0-10	0.7	0	2	2	0	2	0.05	28	
48_20	790301	292021	4	1.456	18.9	0-10	0.12	0	2	2	0	0	0.1	32	
49_01	790891	292984	4	0.897	10.4	0-10	0.05	0	1	0	0	1	0.08	0	
49_02	790961	293737	7	4.903	114	0-10	0.6	0.08	3	3	0	3	0.08	18	
49_03	790868	293023	4	1.489	13.7	0-10	0	0.01	1	0	0	0	0	0	
49_04	790561	293524	5	5.121	81.6	0-10	0.4	0.14	1	1	0	0	0.18	50	
49_05	790631	293566	5	3.491	85.6	0-10	0.07	0	3	3	0.005	5	0.16	52	
49_06	790629	293610	4	2.964	60	0-10	0.24	0	3	3	0	4	0.2	70	
49_07	790727	293619	4	6.166	161	0-10	0.55	0	2	2	0	4	0.3	90	
49_08	791019	293611	5	4.737	103	0-10	0.1	0	2	2	0	2	0.08	15	
62_02	784038	296574	4	4.723	45.3	0-10	0	0.18	0	0	NA	NA	NA	NA	
62_03	784088	296673	6	5.903	82.9	0-10	0.02	0.38	0	0	NA	NA	NA	NA	
62_04	783997	296809	4	2.627	31.2	0-10	0.01	0.08	0	0	NA	NA	NA	NA	
62_05	784022	296544	5	9.562	12.1	0-10	0.9	0	0	0	NA	NA	NA	NA	
62_08	784149	296636	5	5.164	36.3	0-10	0.75	0.12	0	0	NA	NA	NA	NA	
62_09	783929	296489	4	6.992	9.1	0-10	0.45	0	0	0	NA	NA	NA	NA	
62_10	784007	296639	4	8.427	30.5	0-10	0.97	0.08	0	0	NA	NA	NA	NA	
62_13	784224	296563	4	8.114	8	0-10	0	0.07	0	1	NA	NA	NA	NA	
62_18	784032	296540	4	6.407	4.7	0-10	0.15	0	0	0	NA	NA	NA	NA	
62_19	784222	296579	5	6.869	63.4	0-10	0	0.19	0	1	NA	NA	NA	NA	
85_00	789689	292272	4	1.614	24.8	0-10	0.5	0.11	1	0	0	2	0.12	50	
85_01	789880	292596	4	1.554	49.3	0-10	0	0	2	2	0.015	0.5	0.08	10	
85_02	789770	292649	5	2.515	9.8	0-10	0	0.33	1	0	0	3	0	0	
85_03	789542	292585	5	6.057	7.4	0-10	0.88	0	1	0	0	0	0	0	
85_05	789841	292284	5	0.907	19.2	0-10	0	0	1	0	0	0	0	0	
85_06	789842	292318	4	1.134	11.8	0-10	0	0.16	1	0	0	0	0	0	
85_07	789877	292589	4	1.016	22.4	0-10	0	0	2	2	0	0	0	0	
85_08	789757	292529	7	1.759	7.8	0-10	0	0	1	0	0	0	0	0	
85_11	789603	292383	4	1.221	11.1	0-10	0.45	0	2	2	0.015	7	0.6	200	y
85_16	789806	292476	5	1.184	7.8	0-10	0	0	1	0	0	0.5	0	0	
89_00	791103	293373	5	7.379	9.9	0-10	0.15	0	2	2	0.02	2	0	9	
89_01	791278	292948	4	7.066	48.8	0-10	0.6	0.08	3	3	0	1.5	0.18	55	
89_02	791254	293062	4	1.545	26.8	0-10	0.03	0	3	3	0.005	4	0	0	
89_03	791117	293408	5	6.939	10.9	0-10	0.12	0	3	3	0.004	3	0.055	30	
89_04	791279	292947	4	3.167	21.2	0-10	0.75	0.16	2	2	0	0	0.2	50	
89_05	791179	293394	5	2.35	30.5	0-10	0	0	2	2	0	0	0	0	
89_06	791241	292984	4	8.668	38.8	0-10	0.15	0.05	3	3	0	1	0.14	30	
89_07	791161	293363	5	2.129	37.5	0-10	0.07	0	3	3	0	0	0.05	7	
89_08	791370	292990	5	2.775	36.5	0-10	0	0	3	3	0.09	6	0.02	0	
89_09	791024	293216	5	3.169	28.2	0-10	0	0	3	3	0.01	1.5	0	0	
90_00	791722	294664	4	0.824	10.7	0-12	0.1	0	0	0	NA	NA	NA	NA	
90_02	791402	294729	4	3.251	43.6	0-10	0	0	0	0	NA	NA	NA	NA	
90_03	791538	294762	4	2.274	42.3	0-10	0	0.05	0	0	NA	NA	NA	NA	
90_04	791690	294771	4	1.826	19.5	0-10	0.02	0.08	0	0	NA	NA	NA	NA	
90_05	791539	294801	4	1.799	25.8	0-10	0	0	0	0	NA	NA	NA	NA	
90_07	791421	294641	4	6.061	5.5	0-10	0.05	0	0	0	NA	NA	NA	NA	
90_08	791577	294549	4	3.65	4.8	0-10	0.1	0.11	0	0	NA	NA	NA	NA	
90_09	791431	294593	4	3.176	4.3	0-10	0.02	0	0	0	NA	NA	NA	NA	

Table A10: Plant species cover per plot. Plots are named using soda pans numbers (Dick et al. 1994) and the sequential number of the random plot. Species names follow Fischer et al. (2005).

	14_01	14_03	14_04	14_05	14_06	14_07	14_08	14_09	23_00	23_04	23_05	23_06	23_07	23_08	23_09	23_14	24_00	24_01	24_04	24_05	24_06
Achillea millefolium agg.				0.028						0.013			0.109				0.002				
Agrostis stolonifera		0.394	0.147	0.252	0.232		0.145	0.178			0.740		0.103	0.287	0.308	0.145	0.016	0.077	0.152	0.163	0.295
Allium vineale																	0.005				
Arenaria serpyllifolia																					
Arrhenatherum elatius																					
Artemisia santonicum																					
Atriplex prostrata (s.lat.)	0.002						0.006									0.009			0.030	0.010	
Avenula pubescens																					
Bolboschoenus maritimus agg.	0.202						0.353				0.069			0.027		0.010	0.033		0.363	0.089	0.615
Bromus hordeaceus				0.003						0.004											
Bupleurum tenuissimum										0.134											
Calamagrostis epigejos					0.080	0.593	0.073														
Calystegia sepium															0.184	0.012					
Carex distans							0.079	0.166									0.025	0.284			
Carex divisa																					
Carex flacca					0.042																
Carex otrubae													0.074								
Carex riparia															0.259						
Carex sp.																					
Carex stenophylla																					
Centaurea jacea																					
Centaurea stoebe													0.264								
Centaurium littorale			0.274																		
Cerastium holosteoides					0.024																
Cerastium pumilum																					
Chenopodium chenopodioides																					
Chenopodium glaucum																					
Cichorium intybus																					
Cirsium arvense																					
Cirsium brachycephalum						0.051															
Cirsium canum							0.182														
Convolvulus arvensis																					
Crypsis aculeata	0.032																				
Cuscuta epithymum		0.149																			
Cynodon dactylon									0.004				0.040				0.384				
Dactylis glomerata				0.013													0.075				
Daucus carota					0.019								0.042		0.006						
Deschampsia cespitosa																					
Echium vulgare				0.007																	
Elaeagnus angustifolia																					
Eleocharis uniglumis																					
Elymus hispidus													0.134								
Elymus repens														0.035			0.065	0.160			

	14_01	14_03	14_04	14_05	14_06	14_07	14_08	14_09	23_00	23_04	23_05	23_06	23_07	23_08	23_09	23_14	24_00	24_01	24_04	24_05	24_06
Epilobium tetragonum ssp. lamyi							0.014														
Epilobium tetragonum ssp. tetragonum																			0.008		
Equisetum arvense																					
Erigeron annuus																					
Erigeron canadensis							0.027														
Euphorbia cyparissias																					
Euphorbia palustris																					
Falcaria vulgaris																					
Festuca arundinacea													0.302								
Festuca pratensis																					
Festuca pseudovina		0.015						0.011									0.247				
Festuca rupicola																					
Fragaria viridis																					
Galium aparine																					
Galium verum				0.05													0.036				
Hordeum jubatum																					
Inula britannica									0.006							0.006	0.015	0.111		0.169	
Juncus articulatus																					
Juncus gerardii		0.108		0.094				0.109		0.253							0.127	0.004			
Juncus ranarius											0.027										
Lactuca saligna																					
Lactuca serriola																					
Lepidium cartilagineum												0.138									
Linaria vulgaris																					
Lolium perenne								0.002	0.01	0.061											
Lotus corniculatus																					
Lotus maritimus													0.017								
Lotus tenuis	0.04	0.107	0.038	0.197	0.039			0.085		0.021	0.213		0.007	0.085	0.002	0.199	0.044	0.172			
Lycopus europaeus														0.028	0.003						
Lythrum hyssopifolia																					
Matricaria chamomilla									0.049							0.019					
Medicago lupulina										0.177							0.011				
Melilotus albus					0.17																
Melilotus dentatus																					
Mentha aquatica													0.005		0.09						
Mentha pulegium																					
Mentha sp.																					
Molinia caerulea																					
Odontites vulgaris										0.073			0.069		0.015		0.006	0.002			
Ononis spinosa				0.034	0.318								0.108				0.033				
Pastinaca sativa																	0.002				
Picris hieracioides																					
Plantago lanceolata																	0.01				
Plantago major													0.011	0.021	0.016			0.036			
Plantago maritima									0.032			0.058									

	14_01	14_03	14_04	14_05	14_06	14_07	14_08	14_09	23_00	23_04	23_05	23_06	23_07	23_08	23_09	23_14	24_00	24_01	24_04	24_05	24_06
Plantago tenuiflora																					
Poa angustifolia				0.003	0.003				0.011												
Poa compressa																					
Polygala comosa																					
Polygala vulgaris																					
Polygonum aviculare s. lat.									0.05												
Portulaca oleracea																					
Potentilla anglica (P. reptans x P. erecta)					0.197	0.022															
Potentilla anserina					0.099									0.028	0.085						
Potentilla verna agg.																					
Puccinellia peisonis	0.432		0.009				0.01	0.004	0.032	0.122		0.284									
Pulicaria dysenterica					0.031								0.132		0.011						
Ranunculus sp.																					
Rubus caesius																					
Rumex palustris	0.004						0.007				0.005										
Rumex stenophyllus																					
Samolus valerandi															0.076						
Sanguisorba minor																					
Saxifraga tridactylites																					
Schoenoplectus pungens			0.321					0.011													
Schoenoplectus tabernaemontani																					
Scirpoides holoschoenus																					
Scorzonera cana																					
Sedum sexangulare																					
Senecio erraticus				0.02																	
Serratula tinctoria																					
Silene multiflora																					
Sonchus arvensis			0.015				0.004							0.013		0.045					
Spergularia maritima	0.115															0.002					
Suaeda pannonica																					
Taraxacum bessarabicum																					
Teucrium chamaedrys																					
Thesium linophyllon																					
Thesium ramosum																					
Thymus pannonicus agg.																					
Tilia/Acer seedling																					
Trifolium campestre																					
Trifolium fragiferum	0.139			0.409			0.049														
Trifolium pratense													0.005								
Triglochin maritimum																					
Tripolium pannonicum	0.417	0.263	0.163	0.057			0.005	0.245		0.211				0.01		0.231		0.031	0.057	0.004	
Typha angustifolia																					
Valeriana officinalis																					
Veronica scutellata																					

	24_08	24_09	24_10	24_17	25_00	25_01	25_03	25_04	25_05	25_06	25_07	25_08	25_09	25_17	26_00	26_01	26_02	26_03	26_04	26_05	26_06
Achillea millefolium agg.						0.342												0.004			0.006
Agrostis stolonifera		0.168	0.113	0.061					0.092		0.142		0.016		0.017	0.155	0.006	0.269	0.223	0.089	0.05
Allium vineale																					
Arenaria serpyllifolia						0.015															
Arrhenatherum elatius																					
Artemisia santonicum																					
Atriplex prostrata (s.lat.)																0.005					
Avenula pubescens																					
Bolboschoenus maritimus agg.	0.016	0.135		0.005														0.028			
Bromus hordeaceus			0.001															0.052			
Bupleurum tenuissimum																					
Calamagrostis epigejos											0.087				0.181						
Calystegia sepium																					
Carex distans	0.005								0.007		0.006					0.572					0.135
Carex divisa																					
Carex flacca																					
Carex otrubae	0.1																				
Carex riparia																					
Carex sp.	0.019																				
Carex stenophylla																					
Centaurea jacea																					0.128
Centaurea stoebe																					
Centaurium littorale																					
Cerastium holosteoides															0.178						
Cerastium pumilum				0.013	0.047	0.088				0.052			0.005	0.132							
Chenopodium chenopodioides																					
Chenopodium glaucum																					
Cichorium intybus																					
Cirsium arvense									0.003		0.058										
Cirsium brachycephalum																					
Cirsium canum																				0.003	
Convolvulus arvensis																					
Crypsis aculeata																					
Cuscuta epithymum									0.335					0.081					0.364		
Cynodon dactylon			0.036																		
Dactylis glomerata			0.009																		
Daucus carota									0.359		0.043				0.225	0.054			0.005	0.165	0.209
Deschampsia cespitosa																					
Echium vulgare													0.003								
Elaeagnus angustifolia															0.01						
Eleocharis uniglumis																					
Elymus hispidus																					
Elymus repens	0.206			0.005																	

	24_08	24_09	24_10	24_17	25_00	25_01	25_03	25_04	25_05	25_06	25_07	25_08	25_09	25_17	26_00	26_01	26_02	26_03	26_04	26_05	26_06
Epilobium tetragonum ssp. lamyi																					
Epilobium tetragonum ssp. tetragonum																					
Equisetum arvense																					
Erigeron annuus														0.003		0.013		0.006			
Erigeron canadensis													0.017	0.006							
Euphorbia cyparissias																					
Euphorbia palustris																					
Falcaria vulgaris											0.012										
Festuca arundinacea																					0.13
Festuca pratensis																					
Festuca pseudovina			0.145	0.101											0.006			0.008			
Festuca rupicola																					
Fragaria viridis																					
Galium aparine																					
Galium verum	0.003								0.525									0.002			0.16
Hordeum jubatum																					
Inula britannica		0.161		0.004														0.277	0.01		
Juncus articulatus																					
Juncus gerardii			0.013	0.017																	
Juncus ranarius																					
Lactuca saligna																					
Lactuca serriola																				0.004	
Lepidium cartilagineum																					
Linaria vulgaris																					
Lolium perenne				0.024																	
Lotus corniculatus																					
Lotus maritimus									0.144		0.199				0.033				0.036		0.166
Lotus tenuis	0.019			0.022									0.091		0.216			0.017	0.248		0.009
Lycopus europaeus											0.014										
Lythrum hyssopifolia																					
Matricaria chamomilla																					
Medicago lupulina				0.013		0.108															
Melilotus albus																					
Melilotus dentatus											0.058										
Mentha aquatica																					
Mentha pulegium																					
Mentha sp.																					
Molinia caerulea																					
Odontites vulgaris				0.032	0.008						0.008		0.039	0.019		0.034			0.119		0.002
Ononis spinosa																					
Pastinaca sativa																				0.354	
Picris hieracioides															0.04						0.003
Plantago lanceolata																					
Plantago major																					

	24_08	24_09	24_10	24_17	25_00	25_01	25_03	25_04	25_05	25_06	25_07	25_08	25_09	25_17	26_00	26_01	26_02	26_03	26_04	26_05	26_06
Plantago maritima			0.237	0.127																	
Plantago tenuiflora																					
Poa angustifolia																					0.029
Poa compressa																					
Polygala comosa																					
Polygala vulgaris																					
Polygonum aviculare s. lat.					0.019					0.005				0.027				0.002			
Portulaca oleracea																					
Potentilla anglica (P. reptans x P. erecta)																					
Potentilla anserina																					
Potentilla verna agg.				0.013																	
Puccinellia peisonis			0.002	0.079	0.093	0.074	0.584	0.212		0.341		0.366	0.102	0.092			0.269				
Pulicaria dysenterica									0.064		0.01										
Ranunculus sp.																					0.006
Rubus caesius																					
Rumex palustris																					
Rumex stenophyllus																					
Samolus valerandi																					
Sanguisorba minor																					
Saxifraga tridactylites																					
Schoenoplectus pungens																					
Schoenoplectus tabernaemontani																					
Scirpoides holoschoenus																					
Scorzonera cana																					
Sedum sexangulare																					
Senecio erraticus															0.005						
Serratula tinctoria																					
Silene multiflora																					
Sonchus arvensis											0.451		0.08			0.332			0.019	0.01	
Spergularia maritima																					
Suaeda pannonica							0.001	0.037		0.002		0.016									
Taraxacum bessarabicum									0.008												
Teucrium chamaedrys																					
Thesium linophyllon																					
Thesium ramosum																					
Thymus pannonicus agg.			0.001																		
Tilia/Acer seedling																					
Trifolium campestre																		0.015			
Trifolium fragiferum			0.006																		
Trifolium pratense									0.038												0.062
Triglochin maritimum																					0.006
Tripolium pannonicum		0.013		0.069	0.129		0.017		0.002	0.023	0.013	0.004	0.171	0.13		0.007	0.053			0.004	
Typha angustifolia																					
Valeriana officinalis																0.028					
Veronica scutellata																					

	26_07	26_08	26_09	28_01	28_03	28_04	28_05	28_06	28_07	28_08	28_09	28_18	28_19	30_00	30_01	30_02	30_03	30_04	30_05	30_06	30_07
Achillea millefolium agg.										0.039		0.038									0.126
Agrostis stolonifera	0.084	0.5		0.018	0.377	0.16	0.145	0.197		0.089			0.337			0.017		0.216	0.086	0.097	0.042
Allium vineale																					
Arenaria serpyllifolia																					
Arrhenatherum elatius		0.048																			
Artemisia santonicum																					
Atriplex prostrata (s.lat.)																					
Avenula pubescens																					
Bolboschoenus maritimus agg.								0.305	0.112												
Bromus hordeaceus					0.049	0.118				0.105			0.3								0.019
Bupleurum tenuissimum																					
Calamagrostis epigejos							0.02														
Calystegia sepium																					
Carex distans																					
Carex divisa																					
Carex flacca							0.055														
Carex otrubae																					
Carex riparia																					
Carex sp.																					
Carex stenophylla																	0.022			0.318	
Centaurea jacea																					
Centaurea stoebe																					
Centaurium littorale																					
Cerastium holosteoides																					
Cerastium pumilum	0.14			0.001	0.002																0.003
Chenopodium chenopodioides																					
Chenopodium glaucum																					
Cichorium intybus																					
Cirsium arvense		0.013					0.02														
Cirsium brachycephalum								0.061													
Cirsium canum																					
Convolvulus arvensis																					
Crypsis aculeata									0.014												
Cuscuta epithymum																					
Cynodon dactylon																					
Dactylis glomerata												0.101									
Daucus carota		0.001					0.02														
Deschampsia cespitosa																					
Echium vulgare												0.018									
Elaeagnus angustifolia							0.005														
Eleocharis uniglumis																					
Elymus hispidus												0.123					0.147				
Elymus repens						0.109													0.057		

	26_07	26_08	26_09	28_01	28_03	28_04	28_05	28_06	28_07	28_08	28_09	28_18	28_19	30_00	30_01	30_02	30_03	30_04	30_05	30_06	30_07
Epilobium tetragonum ssp. lamyi																					
Epilobium tetragonum ssp. tetragonum																					
Equisetum arvense																					
Erigeron annuus																					
Erigeron canadensis					0.016																
Euphorbia cyparissias																					
Euphorbia palustris																					
Falcaria vulgaris																					
Festuca arundinacea							0.045														
Festuca pratensis		0.087																			
Festuca pseudovina	0.031			0.436						0.102			0.212						0.345		
Festuca rupicola																	0.435				0.053
Fragaria viridis																					
Galium aparine																					
Galium verum		0.004																			
Hordeum jubatum																					
Inula britannica				0.001	0.09	0.138	0.055			0.019			0.01						0.07	0.071	0.008
Juncus articulatus																					
Juncus gerardii																					
Juncus ranarius																					
Lactuca saligna																					
Lactuca serriola																					
Lepidium cartilagineum																					
Linaria vulgaris																					
Lolium perenne																					
Lotus corniculatus				0.004		0.044	0.369														
Lotus maritimus		0.042																			
Lotus tenuis	0.279																				
Lycopus europaeus																					
Lythrum hyssopifolia																					
Matricaria chamomilla																					
Medicago lupulina										0.071											
Melilotus albus																					
Melilotus dentatus																					
Mentha aquatica																					
Mentha pulegium																					
Mentha sp.																					
Molinia caerulea																					
Odontites vulgaris	0.036	0.003			0.006		0.078			0.01				0.054	0.008		0.03		0.006		0.053
Ononis spinosa				0.005																	
Pastinaca sativa		0.059																			
Picris hieracioides		0.033																			
Plantago lanceolata																					
Plantago major																					
Plantago maritima				0.116						0.143							0.121		0.005	0.072	0.207

	26_07	26_08	26_09	28_01	28_03	28_04	28_05	28_06	28_07	28_08	28_09	28_18	28_19	30_00	30_01	30_02	30_03	30_04	30_05	30_06	30_07
Plantago tenuiflora											0.023										
Poa angustifolia					0.227		0.196					0.536							0.165	0.034	0.149
Poa compressa																					
Polygala comosa																					
Polygala vulgaris																					
Polygonum aviculare s. lat.																					
Portulaca oleracea																					
Potentilla anglica (P. reptans x P. erecta)																					
Potentilla anserina																					
Potentilla verna agg.																					
Puccinellia peisonis	0.051		0.586					0.017	0.163		0.355			0.545	0.456	0.124					
Pulicaria dysenterica																					
Ranunculus sp.																					
Rubus caesius																					
Rumex palustris																					
Rumex stenophyllus								0.017													
Samolus valerandi																					
Sanguisorba minor																					
Saxifraga tridactylites																					0.02
Schoenoplectus pungens																					
Schoenoplectus tabernaemontani																					
Scirpoides holoschoenus																					
Scorzonera cana				0.036						0.026	0.005		0.067				0.035			0.024	0.062
Sedum sexangulare																					
Senecio erraticus																					
Serratula tinctoria																					
Silene multiflora																			0.024		
Sonchus arvensis																		0.048			
Spergularia maritima																					
Suaeda pannonica																					
Taraxacum bessarabicum																					
Teucrium chamaedrys																					
Thesium linophyllon																					
Thesium ramosum																					
Thymus pannonicus agg.																					
Tilia/Acer seedling																					
Trifolium campestre																					
Trifolium fragiferum																					
Trifolium pratense																					
Triglochin maritimum																					
Tripolium pannonicum	0.191		0.022		0.003			0.228	0.015	0.012	0.002		0.012	0.015	0.022	0.09	0.004	0.161			
Typha angustifolia																					
Valeriana officinalis																					
Veronica scutellata																					

	30_08	30_09	32_00	32_01	32_03	32_04	32_05	32_06	32_07	32_08	32_09	34_00	34_01	34_02	34_03	34_04	34_05	34_06	34_08	34_09	34_19
Achillea millefolium agg.						0.117										0.005					
Agrostis stolonifera					0.086	0.036		0.064	0.32	0.144	0.037	0.45	0.4	0.14	0.24	0.142	0.395		0.076	0.02	0.27
Allium vineale																					
Arenaria serpyllifolia																					
Arrhenatherum elatius																					
Artemisia santonicum																					
Atriplex prostrata (s.lat.)																					
Avenula pubescens																					
Bolboschoenus maritimus agg.					0.015	0.059					0.096	0.015	0.005	0.255	0.01			0.007		0.314	
Bromus hordeaceus																					
Bupleurum tenuissimum																0.001					
Calamagrostis epigejos				0.161												0.085	0.07	0.069			
Calystegia sepium																			0.168		
Carex distans												0.05			0.113	0.024		0.122	0.305		
Carex divisa																					
Carex flacca																					
Carex otrubae																					
Carex riparia				0.072			0.466														
Carex sp.																					
Carex stenophylla																					
Centaurea jacea																					
Centaurea stoebe																					
Centaurium littorale															0.005	0.002		0.038			
Cerastium holosteoides																					
Cerastium pumilum		0.111											0.03								
Chenopodium chenopodioides																					
Chenopodium glaucum																					
Cichorium intybus																					
Cirsium arvense				0.005			0.089		0.017	0.065											
Cirsium brachycephalum													0.005					0.01			
Cirsium canum																					
Convolvulus arvensis																					
Crypsis aculeata	0.301																				
Cuscuta epithymum															0.001	0.009					
Cynodon dactylon																					
Dactylis glomerata						0.068												0.01			
Daucus carota									0.012	0.002											
Deschampsia cespitosa																					
Echium vulgare										0.008											
Elaeagnus angustifolia																					
Eleocharis uniglumis																					
Elymus hispidus																					
Elymus repens			0.146	0.114		0.183	0.065										0.015				0.032

	30_08	30_09	32_00	32_01	32_03	32_04	32_05	32_06	32_07	32_08	32_09	34_00	34_01	34_02	34_03	34_04	34_05	34_06	34_08	34_09	34_19
Epilobium tetragonum ssp. lamyi																					
Epilobium tetragonum ssp. tetragonum																					
Equisetum arvense																					
Erigeron annuus																					
Erigeron canadensis		0.002																			
Euphorbia cyparissias																					
Euphorbia palustris																					
Falcaria vulgaris						0.002															
Festuca arundinacea													0.004								
Festuca pratensis																					
Festuca pseudovina																					
Festuca rupicola																					
Fragaria viridis																					
Galium aparine							0.261		0.069												
Galium verum															0.042	0.021		0.005			
Hordeum jubatum																					
Inula britannica			0.003			0.023															
Juncus articulatus																					
Juncus gerardii			0.236																		
Juncus ranarius																					
Lactuca saligna										0.146											
Lactuca serriola																					
Lepidium cartilagineum																					
Linaria vulgaris				0.044																	
Lolium perenne																					
Lotus corniculatus																		0.002			
Lotus maritimus																0.013	0.08	0.098			0.004
Lotus tenuis						0.012		0.048	0.02	0.002											
Lycopus europaeus				0.011																	
Lythrum hyssopifolia																					
Matricaria chamomilla																					
Medicago lupulina																					
Melilotus albus																					
Melilotus dentatus																0.001					
Mentha aquatica																					
Mentha pulegium																					
Mentha sp.																		0.015	0.004		
Molinia caerulea																					
Odontites vulgaris		0.006				0.005							0.013			0.004	0.002				
Ononis spinosa																	0.115				
Pastinaca sativa																					
Picris hieracioides																					
Plantago lanceolata																					
Plantago major																			0.02		
Plantago maritima														0.035							

	30_08	30_09	32_00	32_01	32_03	32_04	32_05	32_06	32_07	32_08	32_09	34_00	34_01	34_02	34_03	34_04	34_05	34_06	34_08	34_09	34_19
Plantago tenuiflora																					
Poa angustifolia			0.206																		
Poa compressa																					
Polygala comosa																					
Polygala vulgaris																0.001		0.054			
Polygonum aviculare s. lat.		0.015																			
Portulaca oleracea																					
Potentilla anglica (P. reptans x P. erecta)																					
Potentilla anserina																0.005			0.081		
Potentilla verna agg.																					
Puccinellia peisonis		0.306			0.292			0.226			0.26									0.002	
Pulicaria dysenterica									0.01							0.001					
Ranunculus sp.																0.003	0.015				
Rubus caesius																					
Rumex palustris																					
Rumex stenophyllus																					
Samolus valerandi																					
Sanguisorba minor																					
Saxifraga tridactylites																					
Schoenoplectus pungens																					
Schoenoplectus tabernaemontani																					
Scirpoides holoschoenus																					
Scorzonera cana																					
Sedum sexangulare																					
Senecio erraticus																					
Serratula tinctoria																					
Silene multiflora						0.017															
Sonchus arvensis									0.033	0.037			0.137		0.038	0.008			0.055		0.008
Spergularia maritima																					
Suaeda pannonica	0.002																				
Taraxacum bessarabicum																0.001					
Teucrium chamaedrys																					
Thesium linophyllon																					
Thesium ramosum																	0.014				
Thymus pannonicus agg.																					
Tilia/Acer seedling																0.005					
Trifolium campestre																					
Trifolium fragiferum																					
Trifolium pratense																	0.005				
Triglochin maritimum																					
Tripolium pannonicum		0.118			0.158			0.22	0.004	0.087	0.395		0.038	0.35	0.021		0.02		0.005	0.555	0.118
Typha angustifolia																					
Valeriana officinalis																					
Veronica scutellata																					

	35_00	35_01	35_02	35_03	35_04	35_05	35_06	35_07	35_08	35_09	39_00	39_01	39_03	39_04	39_05	39_06	39_07	39_08	39_09	39_19	40_00
Achillea millefolium agg.														0.094							
Agrostis stolonifera											0.382	0.366	0.307	0.003	0.31	0.159			0.032		
Allium vineale																					
Arenaria serpyllifolia																					
Arrhenatherum elatius																					
Artemisia santonicum																					
Atriplex prostrata (s.lat.)																					
Avenula pubescens														0.093							
Bolboschoenus maritimus agg.											0.018	0.034									
Bromus hordeaceus																					
Bupleurum tenuissimum																					
Calamagrostis epigejos																					
Calystegia sepium																					
Carex distans														0.05	0.006		0.09		0.111		
Carex divisa																					
Carex flacca															0.035		0.051				
Carex otrubae																					
Carex riparia																					
Carex sp.																					
Carex stenophylla													0.279						0.003		
Centaurea jacea																			0.057		
Centaurea stoebe																					
Centaurium littorale																					
Cerastium holosteoides																					
Cerastium pumilum																					
Chenopodium chenopodioides																0.007					
Chenopodium glaucum																					
Cichorium intybus																					
Cirsium arvense																					
Cirsium brachycephalum												0.075									
Cirsium canum																					
Convolvulus arvensis																					
Crypsis aculeata																					
Cuscuta epithymum													0.012						0.015		
Cynodon dactylon														0.311			0.415				
Dactylis glomerata														0.022					0.017		
Daucus carota																					
Deschampsia cespitosa																					
Echium vulgare													0.002								
Elaeagnus angustifolia																					
Eleocharis uniglumis																					
Elymus hispidus																					
Elymus repens											0.031				0.087						

	35_00	35_01	35_02	35_03	35_04	35_05	35_06	35_07	35_08	35_09	39_00	39_01	39_03	39_04	39_05	39_06	39_07	39_08	39_09	39_19	40_00
Epilobium tetragonum ssp. lamyi																					
Epilobium tetragonum ssp. tetragonum																					
Equisetum arvense																					
Erigeron annuus																					
Erigeron canadensis																					
Euphorbia cyparissias																					
Euphorbia palustris																					
Falcaria vulgaris																					
Festuca arundinacea																	0.033		0.104		
Festuca pratensis																					
Festuca pseudovina																			0.094		
Festuca rupicola														0.131			0.332				
Fragaria viridis																					
Galium aparine																					
Galium verum														0.004							
Hordeum jubatum																					
Inula britannica																					
Juncus articulatus																					
Juncus gerardii																					
Juncus ranarius																					
Lactuca saligna																					
Lactuca serriola																					
Lepidium cartilagineum																					
Linaria vulgaris																					
Lolium perenne																					
Lotus corniculatus																					
Lotus maritimus															0.082				0.066		
Lotus tenuis											0.023		0.007		0.013				0.032		
Lycopus europaeus																					
Lythrum hyssopifolia																					
Matricaria chamomilla																					
Medicago lupulina																					
Melilotus albus																					
Melilotus dentatus																			0.003		
Mentha aquatica																					
Mentha pulegium																					
Mentha sp.																					
Molinia caerulea																					
Odontites vulgaris													0.03				0.055				
Ononis spinosa																	0.079				
Pastinaca sativa																					
Picris hieracioides																					
Plantago lanceolata														0.015							
Plantago major																					
Plantago maritima															0.01				0.26		0.125

	35_00	35_01	35_02	35_03	35_04	35_05	35_06	35_07	35_08	35_09	39_00	39_01	39_03	39_04	39_05	39_06	39_07	39_08	39_09	39_19	40_00
Plantago tenuiflora																					
Poa angustifolia														0.109							
Poa compressa																					
Polygala comosa														0.013			0.004				
Polygala vulgaris																					
Polygonum aviculare s. lat.																					
Portulaca oleracea																					
Potentilla anglica (P. reptans x P. erecta)														0.055							
Potentilla anserina																					
Potentilla verna agg.																					
Puccinellia peisonis	0.254	0.034	0.225		0.65		0.187		0.59	0.007		0.019						0.5		0.335	0.218
Pulicaria dysenterica																					
Ranunculus sp.																					
Rubus caesius																					
Rumex palustris																					
Rumex stenophyllus																					
Samolus valerandi																					
Sanguisorba minor														0.04							
Saxifraga tridactylites																					
Schoenoplectus pungens																					
Schoenoplectus tabernaemontani																					
Scirpoides holoschoenus														0.263			0.105				
Scorzonera cana																					
Sedum sexangulare																					
Senecio erraticus																					
Serratula tinctoria																					
Silene multiflora																					
Sonchus arvensis											0.152		0.042								
Spergularia maritima																					
Suaeda pannonica	0.069	0.211	0.419	0.168		0.206	0.05	0.257	0.01	0.072										0.264	0.067
Taraxacum bessarabicum																					
Teucrium chamaedrys																					
Thesium linophyllon																					
Thesium ramosum																					
Thymus pannonicus agg.																					
Tilia/Acer seedling																					
Trifolium campestre																					
Trifolium fragiferum																					
Trifolium pratense																					
Triglochin maritimum																					
Tripolium pannonicum					0.032				0.16		0.124	0.367	0.071			0.148		0.539	0.088	0.01	0.017
Typha angustifolia																					
Valeriana officinalis																					
Veronica scutellata																					

	40_02	40_04	40_05	40_06	40_08	40_09	40_17	41_00	41_01	41_02	41_03	41_04	41_05	41_06	41_07	41_08	41_09	48_03	48_04	48_05	48_06
Achillea millefolium agg.		0.252						0.285										0.063			
Agrostis stolonifera	0.002	0.113							0.419	0.181	0.132	0.285		0.516	0.064	0.312	0.471			0.003	
Allium vineale																					
Arenaria serpyllifolia																		0.011			
Arrhenatherum elatius																					
Artemisia santonicum			0.134	0.002															0.19		0.061
Atriplex prostrata (s.lat.)		0.006								0.028	0.032	0.011	0.006			0.004					
Avenula pubescens																					
Bolboschoenus maritimus agg.									0.064	0.032	0.061	0.134		0.04		0.007	0.337				
Bromus hordeaceus		0.008	0.002																		
Bupleurum tenuissimum			0.005																		0.004
Calamagrostis epigejos	0.009																				
Calystegia sepium																					
Carex distans	0.083							0.014											0.01	0.032	
Carex divisa	0.011																				
Carex flacca															0.128						
Carex otrubae																					
Carex riparia																					
Carex sp.																					
Carex stenophylla															0.075			0.214	0.017	0.004	0.046
Centaurea jacea	0.128																				
Centaurea stoebe								0.019							0.177						
Centaurium littorale																					
Cerastium holosteoides																					
Cerastium pumilum																					
Chenopodium chenopodioides																					
Chenopodium glaucum													0.013								
Cichorium intybus																					
Cirsium arvense																					
Cirsium brachycephalum																					
Cirsium canum																					
Convolvulus arvensis																					
Crypsis aculeata													0.481								
Cuscuta epithymum																					
Cynodon dactylon								0.355										0.403			
Dactylis glomerata																					
Daucus carota	0.001																				
Deschampsia cespitosa																					
Echium vulgare																					
Elaeagnus angustifolia																					
Eleocharis uniglumis																					
Elymus hispidus	0.122																				
Elymus repens								0.007							0.074						

	40_02	40_04	40_05	40_06	40_08	40_09	40_17	41_00	41_01	41_02	41_03	41_04	41_05	41_06	41_07	41_08	41_09	48_03	48_04	48_05	48_06
Epilobium tetragonum ssp. lamyi																					
Epilobium tetragonum ssp. tetragonum																					
Equisetum arvense	0.003																				
Erigeron annuus																					
Erigeron canadensis																					
Euphorbia cyparissias																					
Euphorbia palustris																					
Falcaria vulgaris																					
Festuca arundinacea	0.351							0.025							0.075						
Festuca pratensis																					
Festuca pseudovina								0.498							0.351			0.141	0.425	0.01	0.06
Festuca rupicola																					
Fragaria viridis																					
Galium aparine																					
Galium verum	0.017							0.003							0.005						
Hordeum jubatum																					
Inula britannica																	0.003				0.032
Juncus articulatus																					
Juncus gerardii								0.157													
Juncus ranarius																					
Lactuca saligna																					
Lactuca serriola																					
Lepidium cartilagineum			0.016																0.032		0.009
Linaria vulgaris																					
Lolium perenne																					
Lotus corniculatus																					
Lotus maritimus																					
Lotus tenuis	0.023	0.025	0.01					0.043	0.003							0.015	0.134			0.085	0.003
Lycopus europaeus																					
Lythrum hyssopifolia																					
Matricaria chamomilla																					
Medicago lupulina	0.002							0.136													
Melilotus albus																					
Melilotus dentatus																					
Mentha aquatica																					
Mentha pulegium																					
Mentha sp.																					
Molinia caerulea																					
Odontites vulgaris	0.042		0.017												0.007				0.002	0.006	0.02
Ononis spinosa								0.022							0.084						
Pastinaca sativa	0.024																				
Picris hieracioides																					
Plantago lanceolata																		0.026			
Plantago major																					
Plantago maritima		0.178	0.116	0.01	0.04			0.027							0.005			0.009	0.161	0.316	0.232

	40_02	40_04	40_05	40_06	40_08	40_09	40_17	41_00	41_01	41_02	41_03	41_04	41_05	41_06	41_07	41_08	41_09	48_03	48_04	48_05	48_06
Plantago tenuiflora																					
Poa angustifolia	0.122																				
Poa compressa															0.037						
Polygala comosa																					
Polygala vulgaris																					
Polygonum aviculare s. lat.		0.006																			
Portulaca oleracea																					
Potentilla anglica (P. reptans x P. erecta)																				0.004	
Potentilla anserina	0.03																				
Potentilla verna agg.																					
Puccinellia peisonis			0.224	0.278	0.308	0.493	0.538		0.046	0.019	0.083			0.02						0.067	0.369
Pulicaria dysenterica																					
Ranunculus sp.																					
Rubus caesius																					
Rumex palustris																					
Rumex stenophyllus																					
Samolus valerandi																					
Sanguisorba minor																					
Saxifraga tridactylites																					
Schoenoplectus pungens																					
Schoenoplectus tabernaemontani																					
Scirpoides holoschoenus																					
Scorzonera cana																					
Sedum sexangulare																			0.002	0.001	
Senecio erraticus																					
Serratula tinctoria																					
Silene multiflora																					
Sonchus arvensis																					
Spergularia maritima																0.028					
Suaeda pannonica			0.001	0.006	0.035	0.002															
Taraxacum bessarabicum								0.003													
Teucrium chamaedrys																					
Thesium linophyllon															0.002						
Thesium ramosum																					
Thymus pannonicus agg.																					
Tilia/Acer seedling																					
Trifolium campestre																					
Trifolium fragiferum																					
Trifolium pratense																					
Triglochin maritimum																					
Tripolium pannonicum		0.168	0.01	0.297	0.09		0.354		0.175	0.446	0.439	0.213		0.02		0.319	0.11			0.073	0.056
Typha angustifolia																					
Valeriana officinalis																					
Veronica scutellata																					

	48_07	48_08	48_09	48_20	49_01	49_02	49_03	49_04	49_05	49_06	49_07	49_08	62_02	62_03	62_04	62_05	62_08	62_09	62_10	62_13	62_18
Achillea millefolium agg.		0.015		0.018	0.002					0.01											
Agrostis stolonifera					0.08			0.318	0.093	0.08	0.155	0.229	0.675	0.12	0.533					0.092	
Allium vineale																					
Arenaria serpyllifolia			0.015		0.003																
Arrhenatherum elatius																					
Artemisia santonicum		0.055		0.069	0.13																
Atriplex prostrata (s.lat.)	0.001												0.03								
Avenula pubescens																					
Bolboschoenus maritimus agg.						0.09		0.196					0.329	0.385			0.033		0.019	0.039	
Bromus hordeaceus				0.028																	
Bupleurum tenuissimum				0.015																	
Calamagrostis epigejos																					
Calystegia sepium																					
Carex distans				0.045		0.032															
Carex divisa						0.211															
Carex flacca									0.098	0.264											
Carex otrubae						0.13															
Carex riparia																					
Carex sp.					0.105						0.085	0.139									
Carex stenophylla				0.105			0.194														
Centaurea jacea												0.012									
Centaurea stoebe									0.026	0.042											
Centaurium littorale																					
Cerastium holosteoides																					
Cerastium pumilum																					
Chenopodium chenopodioides																0.036			0.021		0.02
Chenopodium glaucum			0.007																		
Cichorium intybus																					
Cirsium arvense												0.072									
Cirsium brachycephalum								0.011			0.003										
Cirsium canum						0.023						0.018									
Convolvulus arvensis																					
Crypsis aculeata			0.038													0.001			0.032		
Cuscuta epithymum	0.032																				
Cynodon dactylon															0.542						
Dactylis glomerata																					
Daucus carota																					
Deschampsia cespitosa									0.183	0.019	0.304	0.226									
Echium vulgare																					
Elaeagnus angustifolia																					
Eleocharis uniglumis								0.099			0.047										
Elymus hispidus															0.009						
Elymus repens					0.101	0.006	0.101														

	48_07	48_08	48_09	48_20	49_01	49_02	49_03	49_04	49_05	49_06	49_07	49_08	62_02	62_03	62_04	62_05	62_08	62_09	62_10	62_13	62_18
Epilobium tetragonum ssp. lamyi																					
Epilobium tetragonum ssp. tetragonum																					
Equisetum arvense																					
Erigeron annuus																					
Erigeron canadensis																					
Euphorbia cyparissias																					
Euphorbia palustris												0.058									
Falcaria vulgaris																					
Festuca arundinacea						0.084				0.01		0.04									
Festuca pratensis																					
Festuca pseudovina				0.355	0.31		0.337		0.028												
Festuca rupicola																					
Fragaria viridis																					
Galium aparine																					
Galium verum																					
Hordeum jubatum																					
Inula britannica			0.007	0.009	0.006		0.115		0.006												
Juncus articulatus						0.03			0.007												
Juncus gerardii			0.01								0.002										
Juncus ranarius																					
Lactuca saligna																					
Lactuca serriola																					
Lepidium cartilagineum																					
Linaria vulgaris																					
Lolium perenne																					
Lotus corniculatus																					
Lotus maritimus																					
Lotus tenuis	0.063	0.014					0.009														
Lycopus europaeus						0.005		0.041	0.01		0.025	0.018									
Lythrum hyssopifolia			0.05																		
Matricaria chamomilla			0.003																		
Medicago lupulina																					
Melilotus albus																					
Melilotus dentatus																					
Mentha aquatica																					
Mentha pulegium			0.107																		
Mentha sp.								0.072	0.041	0.001	0.077	0.019									
Molinia caerulea									0.367	0.376											
Odontites vulgaris				0.014			0.001														
Ononis spinosa																					
Pastinaca sativa																					
Picris hieracioides																					
Plantago lanceolata				0.019																	
Plantago major											0.003										
Plantago maritima		0.033		0.217	0.128		0.052														

	48_07	48_08	48_09	48_20	49_01	49_02	49_03	49_04	49_05	49_06	49_07	49_08	62_02	62_03	62_04	62_05	62_08	62_09	62_10	62_13	62_18
Plantago tenuiflora																					
Poa angustifolia					0.36		0.095														
Poa compressa																					
Polygala comosa																					
Polygala vulgaris																					
Polygonum aviculare s. lat.	0.032	0.031	0.14																		
Portulaca oleracea			0.058																		
Potentilla anglica (P. reptans x P. erecta)																					
Potentilla anserina									0.009	0.001	0.124	0.093									
Potentilla verna agg.																					
Puccinellia peisonis	0.083	0.101														0.001	0.006	0.438	0.023	0.206	
Pulicaria dysenterica						0.017		0.048	0.005	0.04	0.024	0.025									
Ranunculus sp.						0.012															
Rubus caesius																					
Rumex palustris			0.125																		
Rumex stenophyllus																					
Samolus valerandi																					
Sanguisorba minor																					
Saxifraga tridactylites																					
Schoenoplectus pungens																					
Schoenoplectus tabernaemontani										0.003											
Scirpoides holoschoenus																					
Scorzonera cana																					
Sedum sexangulare				0.031																	
Senecio erraticus																					
Serratula tinctoria									0.189	0.125	0.131	0.037									
Silene multiflora																					
Sonchus arvensis																					
Spergularia maritima			0.024																		
Suaeda pannonica			0.013													0.121			0.042		0.655
Taraxacum bessarabicum																					
Teucrium chamaedrys				0.025																	
Thesium linophyllon																					
Thesium ramosum																					
Thymus pannonicus agg.																					
Tilia/Acer seedling																					
Trifolium campestre																					
Trifolium fragiferum	0.002			0.023	0.003				0.004												
Trifolium pratense																					
Triglochin maritimum																				0.075	
Tripolium pannonicum	0.07	0.122	0.031										0.196			0.001			0.002	0.643	0.023
Typha angustifolia								0.095													
Valeriana officinalis																					
Veronica scutellata																					

	62_19	85_00	85_01	85_02	85_03	85_05	85_06	85_07	85_08	85_11	85_16	89_00	89_01	89_02	89_03	89_04	89_05	89_06	89_07	89_08	89_09
Achillea millefolium agg.			0.059			0.047		0.021				0.006					0.022			0.066	0.026
Agrostis stolonifera	0.398	0.02	0.109	0.701	0.004	0.004	0.75	0.059	0.288		0.321		0.227	0.053		0.099	0.021	0.052	0.452	0.079	0.244
Allium vineale																					
Arenaria serpyllifolia			0.008																		
Arrhenatherum elatius																					
Artemisia santonicum					0.006																
Atriplex prostrata (s.lat.)													0.062			0.175					
Avenula pubescens																					
Bolboschoenus maritimus agg.		0.039		0.049			0.025		0.325				0.031			0.001					
Bromus hordeaceus			0.011																		
Bupleurum tenuissimum			0.014		0.046									0.031					0.002		0.008
Calamagrostis epigejos																					
Calystegia sepium																					
Carex distans																					
Carex divisa								0.167													
Carex flacca																					
Carex otrubae											0.294					0.064					
Carex riparia																					
Carex sp.						0.053											0.03				0.1
Carex stenophylla												0.302					0.103		0.109	0.034	
Centaurea jacea														0.063			0.008			0.004	
Centaurea stoebe								0.041			0.023										
Centaurium littorale																					
Cerastium holosteoides																					
Cerastium pumilum																					
Chenopodium chenopodioides																0.008					
Chenopodium glaucum																					
Cichorium intybus						0.054															
Cirsium arvense		0.005																			
Cirsium brachycephalum																					
Cirsium canum																					
Convolvulus arvensis						0.021															
Crypsis aculeata													0.032			0.002					
Cuscuta epithymum											0.008										
Cynodon dactylon			0.62			0.267		0.227			0.412										
Dactylis glomerata						0.297															
Daucus carota											0.006										
Deschampsia cespitosa																					
Echium vulgare																					
Elaeagnus angustifolia																					
Eleocharis uniglumis																					
Elymus hispidus																					
Elymus repens						0.012								0.239			0.053		0.076		0.085

	62_19	85_00	85_01	85_02	85_03	85_05	85_06	85_07	85_08	85_11	85_16	89_00	89_01	89_02	89_03	89_04	89_05	89_06	89_07	89_08	89_09
Epilobium tetragonum ssp. lamyi																					
Epilobium tetragonum ssp. tetragonum																					
Equisetum arvense																					
Erigeron annuus																					
Erigeron canadensis																					
Euphorbia cyparissias								0.007													
Euphorbia palustris																					
Falcaria vulgaris																					
Festuca arundinacea						0.019											0.007			0.121	
Festuca pratensis																					
Festuca pseudovina						0.485						0.003		0.13			0.4			0.105	0.03
Festuca rupicola																					
Fragaria viridis						0.064															
Galium aparine																					
Galium verum						0.069					0.42			0.01							
Hordeum jubatum									0.093												
Inula britannica			0.038					0.002			0.004			0.079			0.006		0.136	0.003	
Juncus articulatus																					
Juncus gerardii														0.27					0.052		
Juncus ranarius																					
Lactuca saligna			0.003																		
Lactuca serriola																					
Lepidium cartilagineum												0.007			0.023						
Linaria vulgaris																					
Lolium perenne		0.003						0.065		0.02											
Lotus corniculatus																					
Lotus maritimus						0.006															
Lotus tenuis		0.005	0.022		0.002						0.058		0.004	0.384			0.003		0.049	0.527	0.555
Lycopus europaeus							0.005														
Lythrum hyssopifolia																					
Matricaria chamomilla		0.494			0.01																
Medicago lupulina			0.049		0.003					0.007				0.054							
Melilotus albus																					
Melilotus dentatus																					
Mentha aquatica																					
Mentha pulegium																					
Mentha sp.																					
Molinia caerulea																					
Odontites vulgaris																	0.006				
Ononis spinosa																					
Pastinaca sativa																					
Picris hieracioides																					
Plantago lanceolata						0.023		0.069													
Plantago major		0.298		0.052																	
Plantago maritima					0.156					0.022		0.004		0.051	0.488		0.109	0.062	0.028	0.119	0.161

	62_19	85_00	85_01	85_02	85_03	85_05	85_06	85_07	85_08	85_11	85_16	89_00	89_01	89_02	89_03	89_04	89_05	89_06	89_07	89_08	89_09
Plantago tenuiflora																					
Poa angustifolia			0.145					0.155												0.232	0.25
Poa compressa																					
Polygala comosa																					
Polygala vulgaris																					
Polygonum aviculare s. lat.					0.028					0.374											
Portulaca oleracea																					
Potentilla anglica (P. reptans x P. erecta)																					
Potentilla anserina		0.021																			
Potentilla verna agg.																					
Puccinellia peisonis	0.436		0.008		0.306					0.054		0.178			0.178						0.009
Pulicaria dysenterica																					
Ranunculus sp.																				0.002	
Rubus caesius																					
Rumex palustris									0.228							0.281					
Rumex stenophyllus																					
Samolus valerandi																					
Sanguisorba minor						0.059															
Saxifraga tridactylites																					
Schoenoplectus pungens																					
Schoenoplectus tabernaemontani																					
Scirpoides holoschoenus																					
Scorzonera cana																					
Sedum sexangulare																					
Senecio erraticus																					
Serratula tinctoria																	0.289				
Silene multiflora																					
Sonchus arvensis		0.068		0.012		0.01			0.34												
Spergularia maritima																					
Suaeda pannonica																					
Taraxacum bessarabicum																				0.01	0.018
Teucrium chamaedrys																					
Thesium linophyllon																					
Thesium ramosum																					
Thymus pannonicus agg.																					
Tilia/Acer seedling																					
Trifolium campestre																					
Trifolium fragiferum		0.011						0.043			0.021									0.041	
Trifolium pratense																					
Triglochin maritimum																					
Tripolium pannonicum	0.044				0.023				0.046				0.303		0.142	0.006		0.705			0.025
Typha angustifolia																					
Valeriana officinalis																					
Veronica scutellata									0.113												

	90_00	90_02	90_03	90_04	90_05	90_07	90_08	90_09			90_00	90_02	90_03	90_04	90_05	90_07	90_08	90_09
Achillea millefolium agg.	0.396									Epilobium tetragonum ssp. lamyi								
Agrostis stolonifera	0.003			0.098		0.424	0.11	0.545		Epilobium tetragonum ssp. tetragonum								
Allium vineale										Equisetum arvense								
Arenaria serpyllifolia										Erigeron annuus								
Arrhenatherum elatius										Erigeron canadensis								
Artemisia santonicum										Euphorbia cyparissias								
Atriplex prostrata (s.lat.)			0.005							Euphorbia palustris								
Avenula pubescens										Falcaria vulgaris								
Bolboschoenus maritimus agg.						0.401	0.169	0.454		Festuca arundinacea								
Bromus hordeaceus										Festuca pratensis								
Bupleurum tenuissimum										Festuca pseudovina								
Calamagrostis epigejos			0.559		0.43					Festuca rupicola								
Calystegia sepium										Fragaria viridis								
Carex distans										Galium aparine			0.084					
Carex divisa										Galium verum								
Carex flacca										Hordeum jubatum								
Carex otrubae										Inula britannica				0.238				
Carex riparia		0.74								Juncus articulatus								
Carex sp.			0.063							Juncus gerardii								
Carex stenophylla										Juncus ranarius								
Centaurea jacea	0.006									Lactuca saligna								
Centaurea stoebe										Lactuca serriola								
Centaurium littorale										Lepidium cartilagineum								
Cerastium holosteoides										Linaria vulgaris								
Cerastium pumilum										Lolium perenne	0.057							
Chenopodium chenopodioides										Lotus corniculatus								
Chenopodium glaucum										Lotus maritimus								
Cichorium intybus										Lotus tenuis								
Cirsium arvense		0.45			0.003					Lycopus europaeus								
Cirsium brachycephalum										Lythrum hyssopifolia								
Cirsium canum										Matricaria chamomilla								
Convolvulus arvensis										Medicago lupulina								
Crypsis aculeata										Melilotus albus								
Cuscuta epithymum										Melilotus dentatus		0.165						
Cynodon dactylon	0.207									Mentha aquatica								
Dactylis glomerata	0.151									Mentha pulegium								
Daucus carota			0.006		0.016					Mentha sp.								
Deschampsia cespitosa										Molinia caerulea								
Echium vulgare										Odontites vulgaris								
Elaeagnus angustifolia										Ononis spinosa								
Eleocharis uniglumis										Pastinaca sativa								
Elymus hispidus										Picris hieracioides								
Elymus repens	0.018									Plantago lanceolata	0.013							

	90_00	90_02	90_03	90_04	90_05	90_07	90_08	90_09
Plantago major								
Plantago maritima								
Plantago tenuiflora								
Poa angustifolia	0.192							
Poa compressa								
Polygala comosa								
Polygala vulgaris								
Polygonum aviculare s. lat.								
Portulaca oleracea								
Potentilla anglica (P. reptans x P. erecta)								
Potentilla anserina								
Potentilla verna agg.								
Puccinellia peisonis								
Pulicaria dysenterica					0.018			
Ranunculus sp.								
Rubus caesius					0.79			
Rumex palustris								
Rumex stenophyllus								
Samolus valerandi								
Sanguisorba minor								
Saxifraga tridactylites								
Schoenoplectus pungens								
Schoenoplectus tabernaemontani								
Scirpoides holoschoenus								
Scorzonera cana								
Sedum sexangulare								
Senecio erraticus								
Serratula tinctoria								
Silene multiflora								
Sonchus arvensis		0.338	0.002					
Spergularia maritima								
Suaeda pannonica								
Taraxacum bessarabicum								
Teucrium chamaedrys								
Thesium linophyllon								
Thesium ramosum								
Thymus pannonicus agg.								
Tilia/Acer seedling								
Trifolium campestre								
Trifolium fragiferum								
Trifolium pratense								
Triglochin maritimum								
Tripolium pannonicum								
Typha angustifolia								
Valeriana officinalis								
Veronica scutellata								