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Reviewing historical traditional knowledge for innovative conservation management: A re-evaluation of wetland grazing

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Abstract

Wetlands are fragile, dynamic systems, transient at larger temporal scales and strongly affected by long-term human activities. Sustaining at least some aspects of human management, particularly traditional grazing, would be especially important as a way of maintaining the "necessary" disturbances for many endangered species. Traditional ecological knowledge represents an important source of information for erstwhile management practices. Our objective was to review historical traditional knowledge on wetland grazing and the resulting vegetation response in order to assess their relevance to biodiversity conservation.

We studied the Pannonian biogeographic region and its neighborhood in Central Europe and searched ethnographic, local historical, early botanical, and agrarian sources for historical traditional knowledge in online databases and books. The findings were analyzed and interpreted by scientist, nature conservationist and traditional knowledge holder (herder) co-authors alike.

Among the historical sources reviewed, we found 420 records on traditional wetland grazing, mainly from the period 1720–1970. Data showed that wetlands in the region served as basic grazing areas, particularly for cattle and pigs. We found more than 500 mentions of habitat categories and 383 mentions of plants consumed by livestock. The most important reasons for keeping livestock on wetlands were grazing, stock wintering, and surviving forage gap periods in early spring or mid-late summer. Besides grazing, other commonly mentioned effects on vegetation were trampling and uprooting. The important outcomes were vegetation becoming patchy and remaining low in height, tall-growing dominant species being suppressed, litter being removed, and microhabitats being created such as open surfaces of mud and water.

These historical sources lay firm foundations for developing innovative nature conservation management methods. Traditional herders still holding wetland management knowledge could contribute to this process when done in a participatory way, fostering knowledge co-production.

Keywords: effect of livestock grazing, knowledge gap, knowledge co-production, traditional ecological knowledge, vegetation structure

1. Introduction

Wetlands contribute significantly to overall biodiversity and play a major role in the landscapes where they are found, acting as key carbon sinks and climate stabilizers of our planet (IUCN, 1993; Mitsch and Gosselink, 2000; Maitland and Morgan, 2002; Zedler and Kerscher, 2005). Being highly sensitive to external factors such as hydrological and pedological conditions, and owing to the fact that many of their functions and services proved useful to humans and were thus often overused, wetlands have become one of the most threatened ecosystems globally (Mitsch and Gosselink, 2000; Brinson and Malvárez, 2002; Zedler and Kerscher, 2005; Davidson, 2014).

Wetlands are dynamic and transient ecosystems. Wetland plant communities are influenced by water supply and climate and can change dynamically in space and time, both long-term and short-term (van der Valk, 1981; Mérő et al., 2015). Native herbivores, followed by domestic large herbivores, functioned as ecological keystone species influencing succession, plant species distribution and vegetation patterns in many wetland areas (Van der Valk, 1981; Zedler and Kercher, 2005). In previous centuries, wetlands were diversely and extensively used and managed not only through grazing, but also fishing, hunting and reed cutting (Mitsch and Gosselink, 2000; Zedler and Kercher, 2005; Poschlod, 2015). Owing to socio-economic changes (e.g. population growth, intensification of agriculture), many wetlands have been drained, while those that escaped are mainly altered and often no longer managed at all, especially in Europe (IUCN, 1993; Esselink et al., 2000; Brinson and Malvárez, 2002; Stammel et al., 2003).

Traditional (extensive) land use practices (e.g., grazing or mowing) harnessed the whole spectrum of habitat types around settlements, including wetlands (Poschlod, 2015), while, as a side-product, acted as essential ecological-anthropological disturbances, with major effects on plant communities (Bakker, 1989; Wallis DeVries et al., 1998; Marty, 2005; Hill et al., 2009) and overall species and (micro)habitat diversity (Mori, 2011; Mérő et al., 2015; Vadász et al., 2016). Appropriate grazing regimes may, for example, induce patchiness, lead to greater microhabitat diversity, alter habitat functioning (Davidson et al., 2017). At the same time, the absence of large herbivores leads to homogenization, as temperate wetland plant communities become dominated by tall-growing species such as *Phragmites*, *Typha*, and *Phalaris* (van der Valk, 1981; Esselink et al., 2000; Burnside et al., 2007; Lougheed et al., 2008), or to an increased abundance of non-native species (Marty, 2005), followed by an impoverishment, especially of flora (Hill et al., 2009; Manton et al., 2016; Davidson et al., 2017; Rannap et al., 2017). Biodiversity loss may alter and decrease the stability of ecosystem functions (Cardinale et al., 2012); therefore wetland conservation management for biodiversity purposes aims to minimize biodiversity losses or to reverse degradation in order to prevent or overcome ecosystem changes (Maitland and Morgan, 2002; Manton et al., 2016). It also aims to enhance habitat diversity (Vadász et al. 2016) and to maintain or recreate habitats e.g., for birds (Mérő et al., 2015; Manton et al., 2016), amphibians (Mester et al., 2015; Rannap et al., 2017), and Red-listed *Nanocyperion* species (Gugič, 2009; Hill et al., 2009). To achieve their goals, conservation strategies often maintain, reinstate or mimic past traditional management regimes (Mori, 2011; Duncan, 2012; Middleton, 2013; Babai et al., 2015) to provide the “necessary” disturbances.

Unfortunately, recent publications on wetland ecology rarely contain information on past traditional management practices (but see Stammel et al., 2003; Burnside et al., 2007; Molnár, 2014). Even less is known about the practical details of these traditional practices and their effects on wetland vegetation. Knowledge of traditional uses would certainly help when planning the proper conservation management of contemporary wetlands (cf. Middleton, 2016). For example, in order to meet biodiversity management or restoration targets, what type of livestock species and breeds should be deployed, in which seasons, and with what intensity?

Traditional land-use practices are often based on local traditional ecological knowledge (Berkes et al., 2000). This knowledge and practices still survive in some areas of Europe (e.g., in the post-communist member states of the European Union) (Babai et al., 2015; Varga et al., 2016; Hartel et al., 2016). Holders of this knowledge understand their living environment well; for example, they can recognize and name about half the native flora, ca. 100 local habitat types, and have a deep understanding of the ecological dynamics of the local landscape (Babai and Molnár, 2014; Molnár, 2014). Traditional ecological knowledge on grazing practices may be crucial when developing feasible and innovative management methods to ensure the maintenance of desired ecological conditions. Innovative methods are often rooted in the past and not only have ecological or conservational value, but also social, cultural and economic benefits (Hartel et al., 2016). Reviving past management practices may decelerate the abandonment of erstwhile management traditions and erosion of the related knowledge, and also bring in policy-relevant, innovative methods, such as outdoor pig rearing (Neugebauer et al., 2005; Hill et al., 2009) or re-designed silvopastoral or silvoarable agroforestry systems in agroforestry innovations (Hartel et al., 2016; Rois-Díaz et al. 2018). In some wetland areas, where traditional land uses still persist, a greater amount of this knowledge has survived; such areas include the Lonjsko Polje and Kopački Rit floodplains in Croatia, the Temes region and Bosut forest in Serbia, and the Hortobágy region in Hungary (Gugič, 2009; Tucakov, 2011; Molnár, 2014; Varga et al., 2016; Kiš et al., 2018, but see also Duncan, 2012; Ludewig et al., 2014, for examples from other European regions).

Traditional ecological knowledge is disappearing rapidly due to globalization and lifestyle changes (Biró et al., 2014). Considerable wetland-related knowledge was already lost, even from the living memory of elderly land users, after extensive wetlands throughout Europe were drained (cf. Middleton, 2016). However, ethnographers and local historians had documented “smaller or larger parts” of the knowledge and practices of past generations. This historical documentation could be utilized effectively by ecologists and conservationists. An ecological re-evaluation of these sources of historical traditional practices and traditional ecological knowledge may thus provide valuable understanding of how particular wetlands were managed centuries or several decades ago and the ways in which vegetation was affected by management (Gimmi et al., 2008; Szabó, 2013).

Traditional knowledge holders who are still active (e.g., traditional herders) could also help this re-evaluation process if this is pursued in a participatory way (Molnár et al., 2016; Kis et al., 2017).

Our objectives were to 1) reconstruct past grazing regimes and their effects on wetlands using historical sources of traditional knowledge from the past 300 years; 2) discuss the conservation relevance of these findings; and 3) evaluate the knowledge-base potential of historical traditional grazing practices for tradition-based but innovative conservation management methods of wetlands, adapted to the present socio-ecological environment.

2. Methods

2.1. Study area

We studied the Pannonian vegetation region (Fekete et al., 2016) and its neighborhood in the central region of the Carpathian Basin, in Central Europe (Fig. 1). The study area belongs to six countries (Hungary, Slovakia, Ukraine, Romania, Serbia, and Croatia). The climate is subcontinental, the mean annual temperature of Hungary is 10-11°C, and annual precipitation is between approx. 500-800 mm (Kocsis, 2018).

During the Holocene, the area was mostly covered by floodplain vegetation, with forest-steppe vegetation on loess and sand ridges, and inhabited in the early Holocene by native large herbivores (Magyari et al., 2010; Németh et al., 2017). A substantial part of the wide expanses of wetland consisted of floodplain oak forests and swamp forests, but extensive treeless wetlands may also have existed (Magyari et al., 2010; Fehér, 2018). For several millennia, the area was populated mostly by nomadic herding tribes. Later, according to medieval sources, the floodplains played a prominent role in the lives of local inhabitants (Belényesy, 2012).

In the 16th and 17th centuries, when the region was under Ottoman occupation, livestock represented a mobile form of wealth among people hiding from the enemy (Szűcs, 1977). Year-round, free-range cattle and pig husbandry that made intensive use of the wetlands continued to be an important source of income until the first half of the 19th century, thanks to the export of livestock to

Western Europe (Bellon, 1996). Most of the drainage of extensive wetlands (measuring up to several hundred thousand hectares in area) took place in the region between 1850 and 1900 (Andrásfalvy, 1975). The period saw parallel increases in the production of forage (maize, alfalfa) and in stockyard husbandry, which resulted in the substitution of breeds and the rapid decline of wetland husbandry (Andrásfalvy, 1975; Balassa, 1990). In recent decades, the practice among villagers of grazing their pigs on wetlands has been abandoned almost completely in each country. Wetland grazing, meanwhile, continues to the present day in several areas, mostly by cattle, with smaller quantities of sheep and pigs.

2.2. Literature search and analysis

When searching the literature for sources of historical traditional knowledge, we looked for information on the types of livestock and objectives of grazing in wetlands, grazed plant species, the activities of livestock and their effects on vegetation, as well as the main habitat types of grazed wetlands, including specific microhabitats. For the purposes of this study, we regarded wetlands as areas that are usually dominated by *Phragmites australis, Carex, Typha, Schoenoplectus* and *Glyceria* spp. and euhydrophyte species. Both online and printed historical sources were reviewed. The internet search was carried out in the Arcanum Digitheca Digital Library Online Database (http1) and in the Public Collection Library of the Hungaricana Online Database (http2) in June-October 2018. These databases store over 17 and 11 million pages, respectively, containing information on the entire study area, as it largely matches the territory of the erstwhile Austro-Hungarian Monarchy. We conducted our search using the Hungarian equivalents for the words "marsh, wetland, tussock, moor, reed, sedge, grazing, pasture, and wet pasture", namely the terms "mocsár, zsombék, láp, nád, sás, vizes hely, legel, legelő, vizes legelő, mocsaras legelő", and the local terms for cattle, cows, pig, swine, horse, sheep, goat, geese, buffalo, and herds of these livestock. We repeated this search also in the national languages of the other five countries in libraries and collections (ethnographic, local historical, early botanical and agrarian papers, encyclopedias and books). Additionally, we examined ethnographical and other books that were not available through the digital databases (approx. 6000 pages). Altogether 165 historical sources contained relevant information (see the complete reference list in the Supplementary Material).

We set up a digital database, into which we collated the records that mention wetland grazing, assigning them to different thematic columns. We separated any mentions of wet meadows from mentions of wetlands (including marshes, floodplains, water bodies and moors) dominated by *Phragmitetea*, *Caricetea* and *Lemnetea* plant communities, and did not process the former, as we focused on non-conventional grazing areas in wetlands. Grazer species mentioned only a few times, e.g., geese and buffalo, were omitted from our analysis (5 records). Analysis and interpretation of historical information was greatly facilitated by some particularly detailed documentation from the late 18th century, before the regulation of the rivers, consisting of hundreds of pages of travel diaries by the renowned botanist, Pál Kitaibel (Gombocz, 1945), and several hundred sheets of maps (scale: 1: 28 800) from the First Military Survey of the Habsburg Empire (http3). The localization of records was performed using ArcGIS version 10.1 (ESRI 2012). In the paper, the erstwhile condition of the wetlands and information about the details and effects of grazing are presented using quantitative summaries and original quotations. Local folk terms for plants and habitats have been replaced, respectively, by their Latin and/or English equivalents.

Analysis and interpretation of historical mentions was carried out by groups of co-authors (traditional knowledge holder herders, nature conservationists and scientists) to avoid misinterpretation and to detect unreliable or distorted information. Scientist and conservationist co-authors based their interpretations on their personal field experience and information from the literature, whereas herders used their own personal herding experience and knowledge inherited from family members and elders. Herder co-authors, for example, helped to define old plant names and information on livestock activity, while by remembering their grandparents' stories they helped decrease the knowledge gap caused by the shifting baseline syndrome (c.f. Soga and Gaston, 2018).

3. Results

Among the historical sources we found 420 records pertaining to traditional wetland grazing in the past. The earliest records date from the 15th century, but the bulk of them were generated between 1720 and 1970. (Fig. 1). The livestock grazed on the wetlands were mostly cattle (208 mentions, 49%), pigs (149 mentions, 35%), horses (29), and sheep (34) (Fig. 1). The sources emphasized the importance of extensively kept breeds of animals, such as Hungarian grey cattle and certain breeds of pigs.

3.1. Habitat categories of grazed wetlands

In relation to wetland grazing, we found 508 mentions of habitat categories (Fig. 2). A total of 83 mentions were related to microhabitats (e.g., muddy patches) and 257 to habitat mosaics (e.g., large permanent wetlands). Vegetation types (dominated often by one or two wetland species) were mentioned in 168 cases, most frequently *Phragmites* and *Typha* beds.

3.2. Reasons for keeping livestock on wetlands

The sources often explicitly stated why livestock was kept on wetlands (253 mentions, Fig. 3). The most important reasons were grazing in general, stock wintering, and surviving forage gap periods in summer and early springtime. The livestock was usually tended by a herder, who monitored the movement of the herd, but we found no mention of grazing where the herder was constantly beside the herd. Management purposes were mentioned in eight cases e.g., cleaning marshy hayfields from litter by trampling and grazing or preserving other pastures from grazing by pigs.

In the case of pigs, the main objective was to make money by keeping the animals on wetlands. The removal of creatures (e.g., fish and their remains) left behind after floods was a rarely mentioned, but important objective: *"the fish stuck in the hollows of the floodplain were gobbled up by pigs."* (Oláh, 1540 in Andrásfalvy, 1975).

3.3. Timing and activity of livestock on the wetlands

We found 232 mentions in the records concerning the timing when livestock was kept on the wetlands (Fig. 4). Almost half of the mentions indicated the importance of stock wintering on wetlands. It was mentioned several times that cattle herds kept on conventional pastures were moved to large floodplain wetlands for winter (even distances of up to 200 km, see Mód, 2003). Wetlands in the region served as basic grazing areas, particularly for cattle and pigs, and in many places, these livestock grazed all year round on wetlands. It was also common for pigs to spend only certain periods on the wetlands in spring and summer. From autumn they were driven to nearby or more distant (up to 100-150 km, see Szabadfalvi, 1971) woodlands to fatten on acorns.

We found 388 cases describing livestock activity on wetlands, with grazing being the most frequently mentioned (Fig. 5). When activities of livestock were described, besides grazing, trampling, wallowing and uprooting were also commonly mentioned. Almost a sixth of all mentions referred directly to trampling, uprooting or wallowing (61). There were 19 accounts of livestock entering deeper water: *"From one grazing place to the next, they waded in waist-high water."* (Szűcs, 1942).

3.4. What plants were consumed by livestock on wetlands?

Regarding the types of vegetation consumed by livestock, we found 383 mentions, classified into 19 species or groups of species (Table 1). The most frequently mentioned plants were *Phragmites australis, Typha* spp., *Bolboschoenus maritimus, Schoenoplectus lacustris,* and *Carex* spp. For *Phragmites australis, Bolboschoenus maritimus,* and *Schoenoplectus lacustris*, the preference for young shoots or leaves was emphasized in mentions related to cattle: *"the cattle would take Bolboschoenus maritimus even from under the water until the plants grew old*." (Varga, 1994). Most commonly mentioned as the preferred forage were the young leaves and shoots of reeds as well as narrow-stemmed reeds, especially during summer droughts and in winter. Some mentions showed the importance of reed beds as winter pastures, which were prepared in summer: *“In July … the reeds were cut, even if they were not needed. The reed that sprouted in its place did not wilt by winter.”* (Andrásfalvy, 1975). In winter, the cattle would also suffice on dried plants or those withered from frost: *“Carex, Typha, Juncus, Eleocharis, and even the Phragmites provided good feed in winter.”* (Györffy, 1941).

With several plant species, the consumption of roots was of major significance (seven species were specified as being consumed by pigs, mostly in late winter, early spring) (Table 1). The sources often recorded (68 mentions)that pigs were fond of the underground parts of plants, such as the young tubers of *Bolboschoenus maritimus* (“[pigs] *did not like them so much after they had hardened”* (Havel et al., 2016)), the roots of *Carex and Phragmites*, the underground tubers of *Typha* species, and the sweet-tasting, young underground reed shoots (5-10 cm long). These were sometimes compared with the most valuable food source for pigs at the time, mast (acorn) feeding: *“they eat sweet reed shoots as greedily as they eat acorns in other places.”* (Bél, 1727). Pigs were also fond of the tender white parts at the base of the stem of *Typha* species and young reed leafs. Pigs relished the forage provided by wetlands and were also very fond of food of animal origin (e.g., worms, maggots, fish [including dead fish], frogs, carcasses of animals, birds’ eggs and chicks, snails, mice, snakes, larvae): *“The wetland pigs also cleaned up the carcasses, devouring the dead livestock…”* (Balassa, 1990).

On several occasions, sources emphasized how well-nourished wetland-grazed pigs were: *“They can eat good Typha tubers, plenty of Bolboschoenus, on which the pigs grow as fat as on mast.”* (Török, 1870). Certain wetland plants (e.g., *Trapa natans*, *Phragmites australis*) were once regarded as of full nutritional value, and not merely fed to livestock as a “last resort”: *“When the water caltrop [Trapa natans] is in its early stages of growth, pigs like it as much as acorns or maize […] It is as useful as mast, and makes them just as fat.”* (Szabóné Futó, 1974). Sources also mentioned some plants whose consumption could cause problems to the livestock, although we could only find information on this in connection with cattle, for pigs *"would eat everything"*. Cattle very much liked the young, sweet leaves of *Glyceria maxima*, for example, but overconsumption would make them bloated. When cattle consumed the muddy grass left over after a flood (Bodó, 1992), or the young shoots or roots of *Cicuta virosa*, which are easily turned up from loose soil, this could result in death (Sajó, 1905).

3.5. Effects of livestock on wetland vegetation

In 54 cases, sources provided explicit information on how cattle and pigs altered or otherwise impacted wetland vegetation (Fig. 6). One of the most important effects of cattle was that the wetland vegetation remained low in height: *"Even young, tender reeds were unable to grow if they were constantly grazed."* (Havel et al., 2016). In extreme drought, livestock was forced to graze on *Typha* spp. and *Schoenoplectus lacustris*, *"leaving the soil bare"* (Kitaibel 1800, in Gombocz, 1945). Grazing of *Carex elata* had a substantial impact on the structure of tussocky areas: *"Carex tussocks could easily be recognized despite being grazed bare, and from among them rose older and younger leaves of Aspidium Thelipteris."* (Borbás, 1881).

Another important impact of cattle was the creation of open surfaces of mud and water (Fig. 7): *"... all* [the cattle] *walked there, trampling even the Bolboschoenus maritimus, so that sometimes, it would not even emerge from the water [...] there was such a large expanse of clear water."* (Havel et al., 2016). *"This trampled and churned sea of mud provided an ideal home for swamp birds*." (Glück, 1903). Margittai (1939) mentions occurrences of *Elatine triandra "in puddles on the pasture, in the inner, muddy part of cattle footprints"*. Further spectacular effect of grazing by cattle was the emergence and maintenance of trails and paths by trampling. In the wake of cattle wandering between grazing areas, muddy and watery tracks with no vegetation would be formed. If such trails were untrampled by cattle for a longer period, *"the trails became overgrown by Phragmites, Carex and Stratiotes aloides and 'went blind'"* (Györffy, 1941).

One important effect of stock wintering was the removal and trampling of litter. This also assisted springtime revegetation: *"the grazing livestock especially cleared the interior of the wetlands* [in winter] *by eating the edible plants and trampling the rest down. Thus, the next year, 'the areas cleared in this way produced much better forage'."* (Bellon, 1996). Other sources also emphasized that grazed wetland vegetation would regenerate and rejuvenate more readily, and that young shoots were selected by the livestock: *"Whatever the livestock broke off gave rise later to three or four new shoots, which were subsequently grazed upon."* (Morvay, 1940). In some places, long-term cattle grazing completely transformed the wetland vegetation, leading to changes in the dominant plant species.

4. Discussion

4.1. Wetland grazing in the Pannonian region between 1720 and 1970

We managed to obtain a large number of historical records on wetland grazing of livestock in the Pannonian region and its immediate vicinity. These historical accounts enable us to form a reasonable, albeit incomplete image of past wetland grazing practices and their effects on vegetation. Unexpectedly, none of the sources gave a detailed discussion of the activities and effects of wetland grazing by livestock. Publications on livestock management from this period (e.g., Fándly, 1792) also lack detailed information on the relationship between grazing and wetland vegetation. Neither the18th, nor the 19th-century works on flora mention any differences or comparisons between the vegetation of grazed and ungrazed wetlands (e.g., Kitaibel 1793–1815, in Gombocz, 1945; Borbás, 1881). To bridge this knowledge gap, it is especially important to process the information that can be gathered from the non-botanical historical sources. An ecological re-evaluation of these historical sources would harness their potential from the perspective of wetland management through grazing for biodiversity conservation purposes.

Wetlands played an important role in the everyday life of societies living close to floodplains and other wetlands. In the Carpathian basin and in other European regions as well, animal husbandry was the main source of income in areas with relatively few arable fields (e.g., Cook and Moorby, 1993; Bellon, 1996; Poschlod, 2015). Grazing was probably pursued on almost all wetlands, even on the interiors of large wetlands (measuring several thousand hectares, Lovassy, 1931; Morvay, 1940; Györffy, 1941).

Specific husbandry systems were developed for optimal utilization of wetlands to achieve short- and long-term benefits. The ideal habitat for keeping pigs, for example, had grazing wetlands and mast forests in close proximity to each other (Belényesy, 2012), which mostly existed on extensive floodplains (Szabadfalvi, 1971; Gugič, 2009; Kiš et al., 2018). Until the beginning of the 19th century, extensive pig husbandry was based on mast feeding (Balassa, 1990; Szabó, 2013). Pigs also fed in wetlands, however, and in many cases, keeping pigs on wetland was nearly as profitable as keeping them in mast forests (Török, 1870; Szabadfalvi, 1971, Szabóné Futó, 1974). On the other hand, for cattle husbandry wetlands provided the means for survival in the subcontinental climate of the Pannonian region during extremities, like droughts that occurred almost every year (Varga et al., 2016). We found few mentions concerning the number of animals kept in wetlands, but from the sources it can be inferred that the number of pigs kept in such habitats was substantial in comparison with the present situation, exerting a significant impact on plant communities (Neugebauer, 2005; Poschlod, 2015; Varga, et al 2016). In a wetland near Mukachevo (Ukraine), for example, the density reached one pig per hectare – 6880 pigs on ca. 6-7000 ha (Szabadfalvi, 1971).

The spatio-temporally variable management systems of wetlands and entire landscapes through grazing led to the appearance and maintenance of heterogeneous habitats, leading to transitions between vegetation states (van der Valk 1981; Wallis de Vries et al., 1998; Bölöni et al., 2011; Mérő et al. 2015). Stronger grazing intensity often produced pioneer surfaces, kept vegetation in a transitional state, while a lack of grazing facilitated the succession processes of many wetland habitats (van der Valk, 1981; Hill et al., 2009), and their homogenization (Esselink et al., 2000; Burnside et al., 2007; Lougheed et al., 2008) .

Several management decisions helped to maintain wetland habitats in good condition and suitable for long-term grazing (e.g., the removal or, on the contrary, even the non-removal of reed or dry litter from a given area), and aided the exploitation of biomass in places that were otherwise inaccessible in summer (Bellon, 1996). Local regulations also helped to maximize the number of livestock that could be kept by a village (Bellon, 1996; Belényesy, 2012). Before river regulations and wetland drainage, wetlands were often set aside as reserves particularly for wintering, as haymaking and forage production were of lesser importance than nowadays (Györffy, 1941; Szűcs, 1977; Bellon, 1996; Belényesy, 2012). Transhumance to these reserve pastures was an important part of historic wetland management to maximize short- and long-term benefits and to balance forage availability on a regional scale (Szabadfalvi, 1971; Mód, 2003; Belényesi, 2012). Seasonal patterns of transhumance, including movement of sheep, pigs, cattle, and horses to floodplain wetlands during winter (Maior, 1911; Szabadfalvi, 1971; Mód, 2003) or for feeding animals (cattle or pigs) before taking them to market (Neugebauer et al., 2005), were similar to those known from other European landscapes (Poschlod, 2015; Costello and Svensson, 2018).

4.2. The effect of grazing on wetland vegetation between 1720 and 1970

Based on historical sources, livestock had an effect on wetland vegetation mainly due to their grazing, trampling, and uprooting behavior, thus reducing biomass and creating micro-habitats (cf. Esselink et al., 2002; Hill et al., 2009, Davidson et al., 2017). Among the obvious effects of grazing were reduced height of vegetation, lower biomass, and greater openness of vegetation. There were only a few species in the wetlands that were not consumed by livestock. Sources usually revealed different effects between cattle and pigs, with cattle being associated mostly with trampling, and pigs with uprooting. The effect of grazing could vary according to the season, partly because livestock would sometimes only spend specific periods of the year on the wetlands, and partly because they would consume certain species of plants only in particular phenological stages, such as after frost or withering, when the taste of several plants changed (e.g., *Carex* and *Typha* spp., Andrásfalvy, 1975), or in spring, when there were young, tender shoots of reed (Morvay, 1940; Györffy, 1941; Varga, 1994). Surfaces dislodged by digging pigs contributed to an increased richness of wetland microhabitats by creating patches of mud and puddles, whose importance for biodiversity has recently been demonstrated (Hill et al., 2009; Poschlod et al., 2002). Several sources stated that certain plant species were consciously reduced by grazing livestock, leading to the creation of pastures consisting of grasses and sedges (Lovassy, 1931; Morvay, 1940). Examples of this are also known from other European regions, although experience shows that grazing alone is sometimes insufficient to eliminate reeds or other species (Valkama et al., 2008).

Judging from these accounts, our opinion is that the structure and species composition of the vegetation of wetlands close to settlements was fundamentally transformed by grazing, while in wetlands further away from settlements, grazing had a significant effect. Past folk names for wetlands attest to the diversity of wetlands and describe the main types of vegetation (cf. Molnár, 2014; Fehér, 2018). Sources indicate that dominant plant species of wetlands in the past were largely the same as today (e.g., Lovassy, 1931; Kitaibel in Gombocz, 1945). Mud vegetation was not described in the sources, only muddy surfaces, but in the lists of wetland species compiled by Kitaibel (in Gombocz, 1945), there is a remarkably large number of species that require trampling and are avoided by grazing livestock (e.g., *Ranunculus lateriflorus, Mentha pulegium, Alisma* spp., *Eleocharis palustris, Gratiola officinalis*). Undesirable plants in the past were mostly the poisonous species (alien invasive species were not yet present). We could find no information about the poisonous species being destroyed (although this is common practice in the Carpathian region, Babai and Molnár, 2014), whereas dense reed beeds were substantially and deliberately reduced by targeted grazing (cf. Lovassy, 1931; Valkama et al., 2008).

4.3. The current conservation relevance of historical wetland grazing

Historical sources often explicitly mention livestock effects that are of potential relevance to contemporary wetlands conservation (e.g., reduction of tall species, creation and maintenance of patches of mud and open water). It was surprising that, despite significant grazing density, the sources did not mention degraded wetlands (compared with degraded overgrazed grasslands and forests, which are mentioned frequently in historical sources, e.g., Borbás, 1881; Kitaibel in Gombocz, 1945). Apart from during the extreme droughts of 1790s and 1863 , when the livestock were driven 200-250 km in search of wetlands to graze on (Morvay, 1940; Szabadfalvi, 1971; Mód, 2003), there were no mentions to suggest that grazing wetlands became exhausted and degraded. There may be one reason for this, that majority of the benefits of the wetlands were incidental, secondary comparing to the benefits from forests or grasslands, whose degradation affected local communities more seriously. Additionally, wetland dynamic occurs in shorter cycles. Consequently, degradation of wetlands (e.g. changing species composition) was considered a natural phenomenon, and local communities didn’t perceive these trends as harmful.

Despite the potential for wetland management, recent botanical and conservation-oriented synthetic works in our region rarely, if at all, mention grazing in wetlands (Bölöni et al., 2011; Haraszthy, 2014). We argue that the effect of past grazing (especially pigs) was possibly far more significant in wetlands than is generally thought by botanists and conservationists (see also Poschlod, 2015; Szigetvári, 2015). It seems that this field of study is also prone to the shifting baseline syndrome (cf. Vera, 2009; Soga and Gaston, 2018). Most of today’s generation of botanists and conservationists have never seen pigs grazing in wetlands. Large-scale wetland grazing of pigs is not part of their worldview because the open vegetation of wetlands previously trampled and uprooted by pigs has grown back in recent decades, and the structure and species composition of such wetlands is entirely different (cf. Neugebauer et al., 2005; Hill et al., 2009; Szigetvári, 2015). A lack of scientific knowledge and understanding of traditional grazing systems often leads to erroneous management recommendations, as shown by the personal experience of some of the authors of this paper, who have previously recommended avoiding grazing in wetland areas, which they later found to be dependent of this particular disturbance.

Grazing livestock were shifted away from wetlands in the 1970s and 1980s to prevent "degradation"; i.e., the creation of muddy, trampled patches (Havel et al., 2016; Szigetvári, 2015). Meanwhile, it is obvious that ungrazed wetlands differ in nature from grazed wetlands (Lougheed et al., 2008; Bölöni et al., 2011; Molnár, 2014; Mérő et al., 2015; Mester et al., 2015), and many features from the past grazed wetlands would be beneficial to conservation even nowadays (Neugebauer et al. 2005; Poschlod, 2015). The decrease in species richness of ungrazed and thus closed-vegetation wetlands is considerable (Lougheed et al., 2008; Mester et al., 2015). From a conservation perspective, species-rich wetlands require disturbance by large grazing livestock (Bakker, 1989; Neugebauer et al. 2005; Mérő et al., 2015). Wetland plant species have, for millennia, adapted to grazing (the wild herbivores of the early Holocene were gradually replaced by domestic livestock). Wetlands, therefore, should be grazed, and in the proper manner, which begs the question of how they should be grazed.

4.4. The need for innovative conservation management regimes through knowledge co-production

The historical information showed that livestock grazed in the wetlands, not only during the growing season but also in winter. Wetland-fattened livestock was highly valued at market (e.g., Morvay, 1940). Breeds of livestock were kept that were well adapted to wetland grazing (e.g., they could swim well and tolerate cold weather and diseases) (cf. Andrásfalvy, 1975; Balassa, 1990; Bellon, 1996). It may be stated that nowadays the livestock breeds, the herders and the social environment that sustained such historical wetland grazing practices no longer exist. In the 21st century, however, there is an increasing demand for nature-friendly farming and extensive free-range animal husbandry, which often results in entirely extensive grazing practices (Flade et al., 2006; Duncan, 2012; Varga et al., 2016; Costello and Svensson, 2018). An opportunity exists to develop innovative wetland-grazing regimes that function as appropriate conservation management practices. Such innovations are fully compliant with the new conservation paradigm, whose objective is to reintroduce, restore or diversify certain natural and anthropological disturbances (Mori, 2011; Middleton, 2013; Vadász et al., 2016; Hartel et al. 2016). Innovation can be aided not only by the historical information described above, but also by the surviving (though often neglected) traditional ecological knowledge, in which regard Central Europe is in a privileged position and of regional significance (Molnár and Berkes, 2018). Some of the traditional knowledge holders are middle-aged and thus still use and adapt their knowledge and graze their herds in the remnant wetlands (Molnár et al., 2016; Kis et al., 2017). For example, in the Hortobágy National Park (a UNESCO World Cultural Heritage Site for its herding traditions), modern-day herders distinguish between 15 wetland types and are familiar with their species (e.g., knowledge of *Phragmites*, *Typha latifolia* and *T. angustifolia*, *Carex acutiformis*, *Schoenoplectus lacustris* and *Trapa natans* is above 95%, that of *Phalaris arundinacea*, *Eleocharis* spp. and *Bolboschoenus maritimus* is above 80%, and that of *Glyceria maxima* is also 55%, Molnár, 2014). Traditional grazing practices are not banned in these reserves, but are rather seen as acceptable and essential for maintaining the optimal ecological conditions of wetlands for many threatened species (http4), like in some UNESCO Biosphere Reserves in Germany and France (Flade et al. 2006; Duncan, 2012; Ludewig et al., 2014).

4.5. Improving wetland conservation management

Our review provided numerous examples of historical traditional practices and traditional ecological knowledge representing lessons on wetland grazing. This, together with the substantial traditional ecological knowledge held by present-day herders, and with the desire among nature conservationists for better management, lays firm foundation for innovation and knowledge co-production. Experience has shown that together, scientific and traditional types of knowledge are capable of generating insights that were previously lacking from both systems (Molnár et al., 2016). For developing innovative wetland conservation methods, we recommend giving consideration to the following criteria:

- As is the case with grasslands (cf. Vadász et al. 2016), wetlands should also be grazed at varying intensities in a mosaic pattern, with both over- and under-grazed areas (http4).
- The application of grazing periods that last different lengths of time may help facilitate greater regulation of intensity and control the effects on vegetation (cf. Cornelissen et al., 2014).
- Late autumn grazing may be of importance for nature conservation, for example, by decreasing litter cover.
- Besides ancient breeds (e.g., Mangalitsa pig, Hungarian grey cattle), certain modern breeds (e.g., Limousine cattle, Merino sheep, Yorkshire pig) may also be suitable for wetland grazing.
- It is worth devoting particular attention to pig grazing, although there is relatively limited active experience of this management type (but see Poschlod et al., 2002; Neugebauer et al., 2005; Gugič, 2009; Hill et al., 2009).
- It would be beneficial to summarize results achieved to date by European experimental ecological research into wetland grazing (e.g. Neugebauer et al., 2005; Mester et al., 2015; http4). Wilderness experiments also provide numerous lessons on year-round extensive wetland grazing (e.g. Vera, 2009; Cornelissen et al., 2014; http5).
- 21st-century technology may also prove valuable, e.g., temporary electric fences on the "outside" of wetlands (that is, the opposite side to where the herders are present).
- It is worth involving and giving leading roles to herders who are familiar both with the livestock and local wetland habitats and have substantial experience ("conservation herders", Molnár et al., 2016). A herder can plan forage regeneration, and with timed grazing or mowing and adapted herd size, grazable biomass can often be increased during springtime or periods of drought (Kis et al., 2017). As part of innovative development, present-day herder experience should be placed under "creative tension" with the help of historical sources to test whether it is possible for herders to revive extinct management components (primarily in the case of pigs), as numerous practical elements of past wetland grazing have been lost.

5. Conclusions

On the one hand, the effect of grazing on wetland vegetation is obvious (vegetation became patchy and remained low in height, tall-growing dominant species were suppressed, litter was removed, and microhabitats like open surfaces of mud and water were created), but on the other hand, grazing can be done in many ways, resulting in just as many effects on vegetation, about which little is known. Therefore, a wide range of experiments should be conducted, which will require the involvement of nature conservationists, herders, and researchers alike.

The historical sources have demonstrated that grazing is often beneficial with regard to the conservation of wetlands. It would therefore be worthwhile experimenting boldly. At the same time, the image of wetlands that have been trampled and “colored” with livestock excrement is often hard to reconcile with the present-day conservation worldview. This is very similar to how things were in the past: the lake *“is heavily grazed, but in places its flora is beautiful nonetheless!”* wrote Ádám Boros in 1957, when he discovered great diversity in the vegetation of a lake where traditional grazing was done intensively (Boros 1912–1972). It would therefore be important to carry out research that takes the long-term historical perspective into account, as a way of overcoming the shifting baseline syndrome in the conservation management of wetlands.

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http5: Pentezug Wild Horse Reserve, Hungary, http://www.hnp.hu/en/szervezeti-egyseg/conservation/oldal/pentezug-wild-horse-reserve [last accessed on 22.11.2018]

Figures

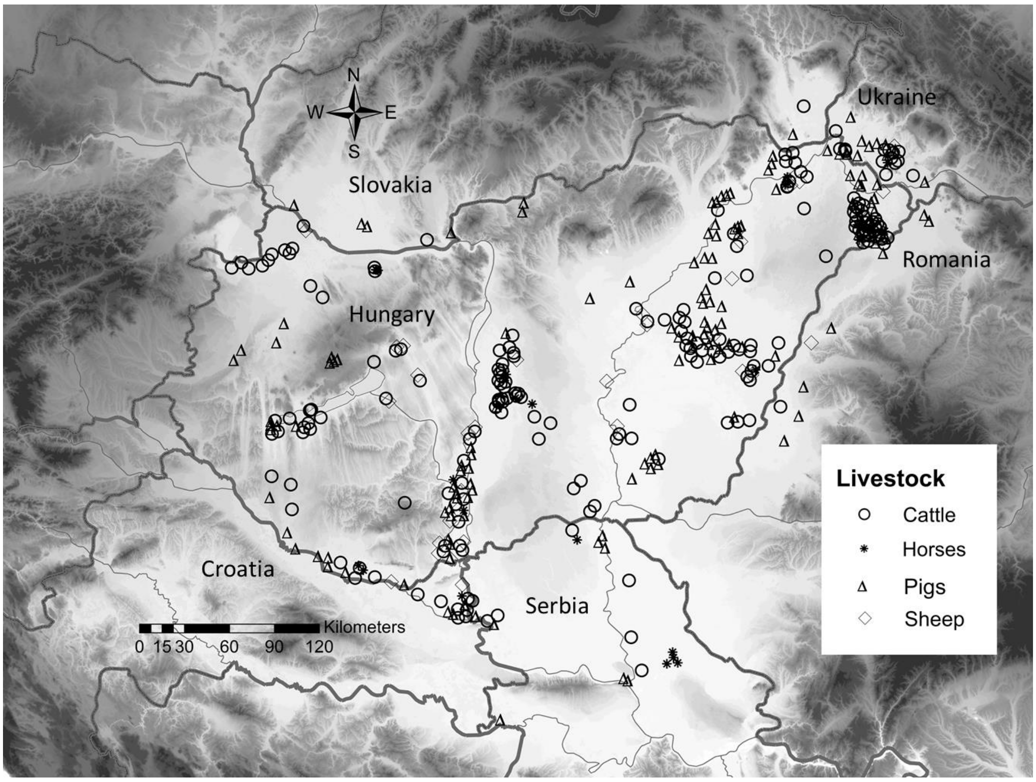

Fig. 1. Map of the study area in the Carpathian Basin, Central Europe. Symbols indicate localities of historical mentions of wetland grazing by domestic livestock. Country borders: thick grey lines, main rivers: thin grey lines (source: Natural Earth). Source of base map: ASTER-DEM, USGS, 2009

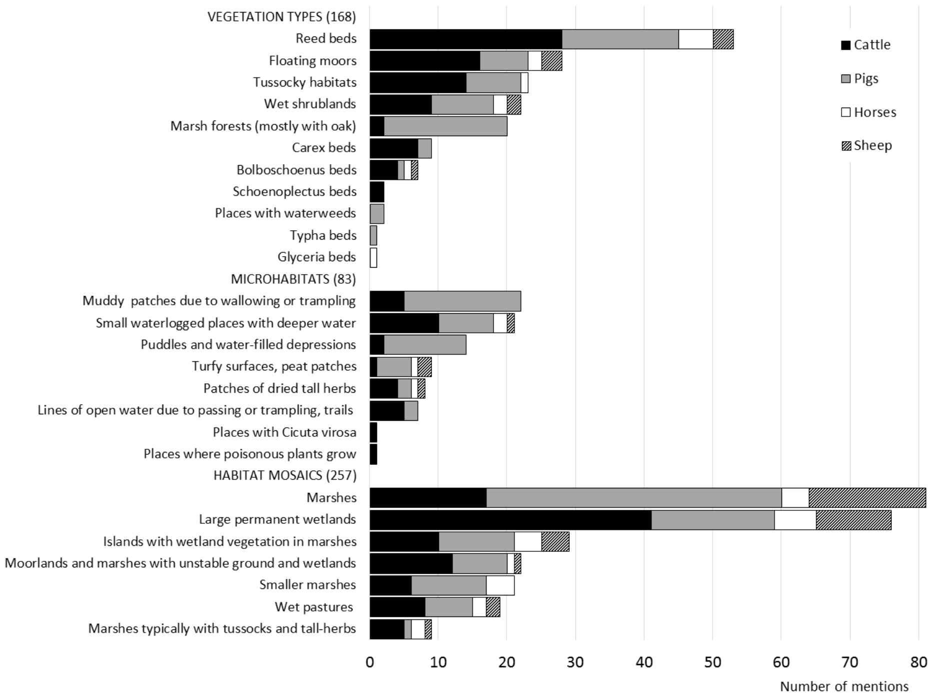

Fig. 2. Habitat categories of grazed wetlands, as mentioned in the historical sources

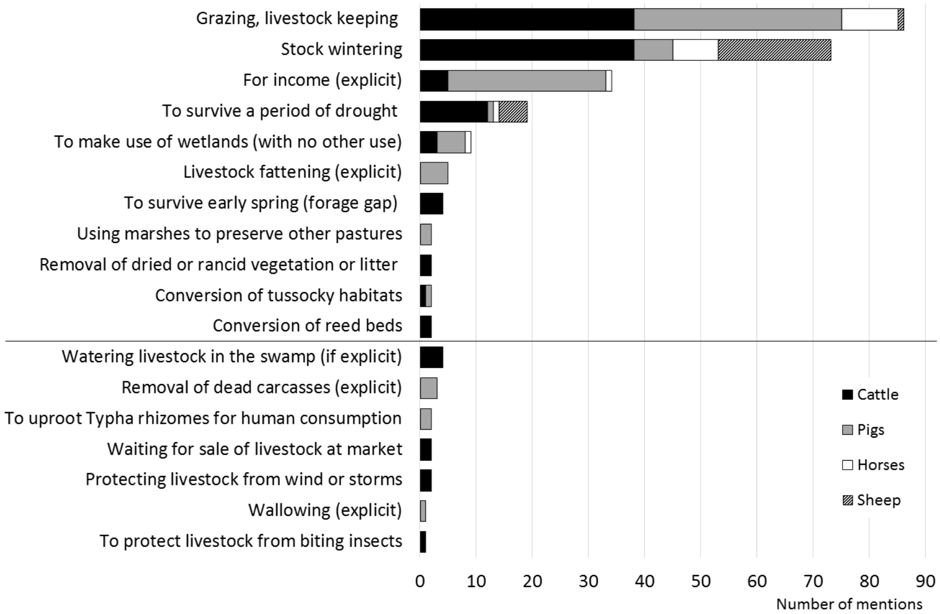

Fig. 3. Reasons for grazing and, below the line, other reasons for keeping livestock on wetlands, as mentioned explicitly in the historical sources

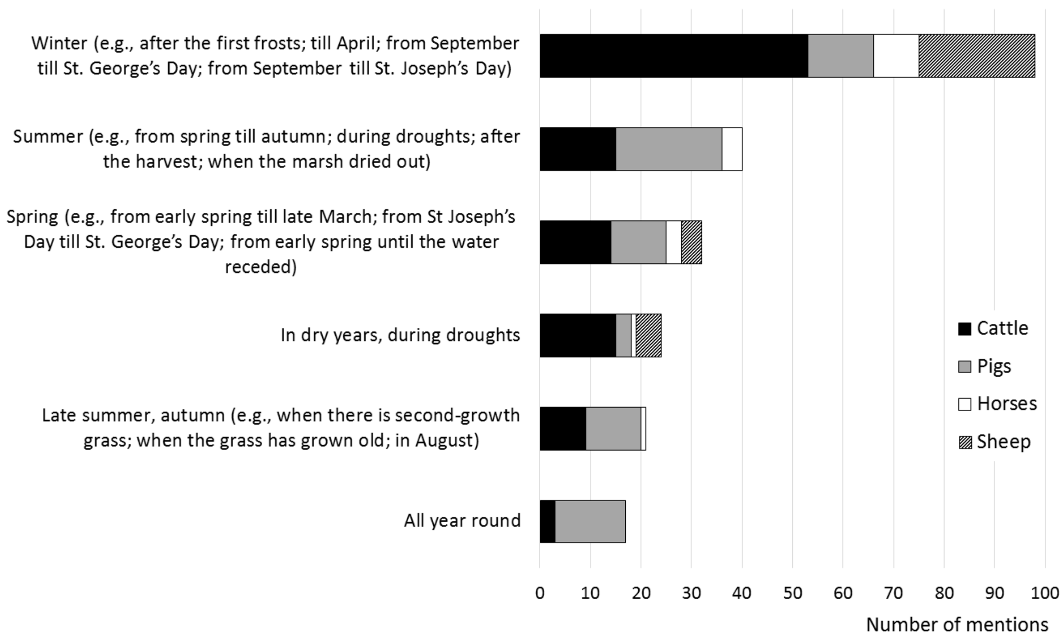

Fig. 4. Timing of presence of livestock on wetlands, as mentioned explicitly in the historical sources

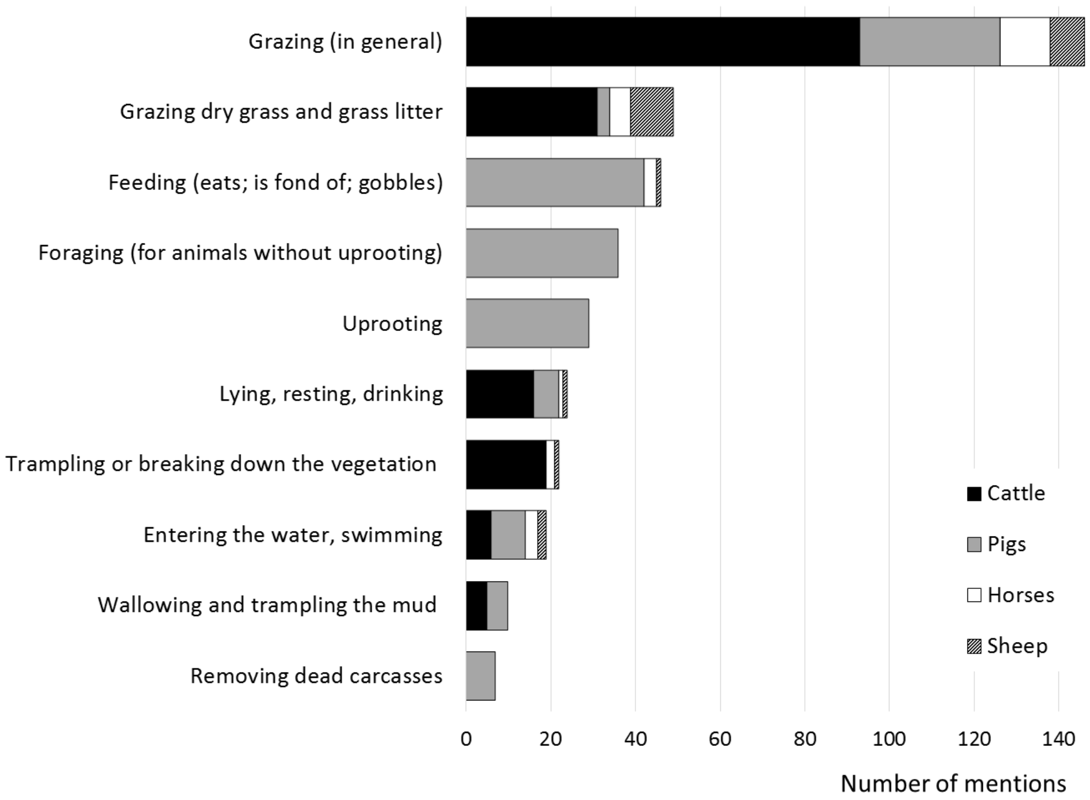

Fig. 5. Activity of livestock on wetlands, as mentioned explicitly in the historical sources

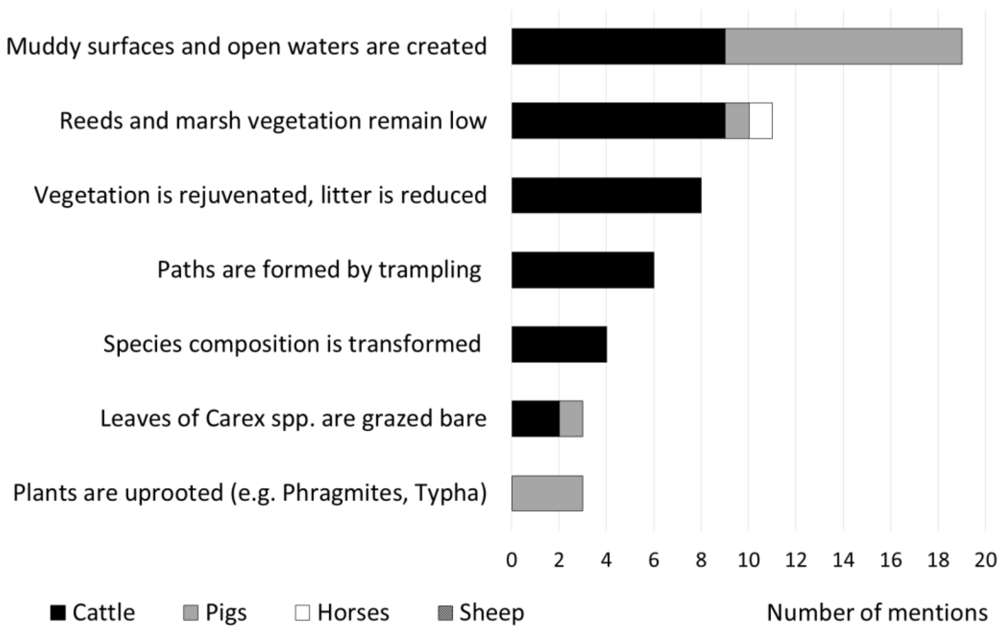

Fig. 6. Effect of domestic livestock on wetland vegetation, as mentioned in the historical sources

Fig. 7. Above: Impacts of grazing include the creation of open water surfaces, the maintenance of vegetation at low height, thus decreasing the dominance of *Phragmites australis* and *Typha angustifolia*, and creating breeding and migrating bird habitats with open water surfaces (Hortobágy National Park, Hungary, photos: Zsolt Molnár). Below: Traditional pig grazing in the Bosut forest (Serbia). Pasturing practices with modern pig breeds provide habitats for *Hottonia palustris*, *Ludwigia palustris* and *Marsilea quadrifolia*, which are Red-listed species in many Central European countries (photos: Ábel Molnár and Viktor Ulicsni)

Graphical Abstract

Table 1. Plant species and plant parts consumed by livestock on wetlands, as documented in the historical sources. “Root” refers to underground parts, such as roots, rhizomes and tubers.

Plant species / parts	**Cattle**	**Pigs**	**Horses**	**Sheep**	**Total**
Reeds – total (*Phragmites australis)*	34	16	5	1	56
young reeds	26	2	4	1	33
reed roots and underground shoots		14			14
Sedges – total (*Carex riparia, C. acutiformis, C. acuta* etc.)	19	9	4	4	36
young sedges		1	2		3
sedge roots		6			6
Bulrushes – total (*Typha latifolia, T. angustifolia)*	6	21		5	32
young bulrushes		2			2
mealy bulrush roots		19		2	21
Bolboschoenus maritimus – total	9	10			19
young shoots of *B. maritimus*	4				4
tubers of *B. maritimus*		9			9
Wetland plants in general – total	3	21			24
young wetland plants	2	3		1	6
roots of wetland plants		16			16
Schoenoplectus lacustris – total	4	5		2	11
young shoots of *S. lacustris*	2	1			3
roots of *S. lacustris*		1		1	2
Carex elata – total	5				5
young leaves of *C. elata*	1				1
Grasses in general (including dry grass)	6	4	4	3	17
Dry grass, grass litter	14	2	1	2	19
Glyceria maxima	4	1	4		9
Eleocharis palustris, E. uniglumis	7				7
Juncus effusus, J. conglomeratus	3				3
Agrostis stolonifera	2				2
Unripe fruits of *Trapa natans*		7			7
Chenopodiaceae spp.		2			2
Thistles (*Cirsium* spp., *Carduus* spp.)		2			2
Willow and poplar twigs, shoots and catkins (*Salix* spp. and *Populus* spp.)	3	1	2		6
Acorus calamus			1		1
Triglochin palustris	1				1
Phalaroides arundinacea	1				1
Marsh fern roots (*Thelypteris palustris*)		1			1
Sow thistle roots (*Sonchus* spp.)		1			1
Water weed and its roots		2			2
Total	156	178	27	22	383