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7 **Reviewing historical traditional knowledge for innovative conservation management:**

8 **A re-evaluation of wetland grazing**

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28

29 **Abstract**

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

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

41 Among the historical sources reviewed, we found 420 records on traditional wetland grazing,
42 mainly from the period 1720–1970. Data showed that wetlands in the region served as basic grazing
43 areas, particularly for cattle and pigs. We found more than 500 mentions of habitat categories and
44 383 mentions of plants consumed by livestock. The most important reasons for keeping livestock on
45 wetlands were grazing, stock wintering, and surviving forage gap periods in early spring or mid-late
46 summer. Besides grazing, other commonly mentioned effects on vegetation were trampling and
47 uprooting. The important outcomes were vegetation becoming patchy and remaining low in height,
48 tall-growing dominant species being suppressed, litter being removed, and microhabitats being
49 created such as open surfaces of mud and water.

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

53

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

56

57 **1. Introduction**

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

65 Wetlands are dynamic and transient ecosystems. Wetland plant communities are influenced by
66 water supply and climate and can change dynamically in space and time, both long-term and short-
67 term (van der Valk, 1981; Mérő et al., 2015). Native herbivores, followed by domestic large
68 herbivores, functioned as ecological keystone species influencing succession, plant species
69 distribution and vegetation patterns in many wetland areas (Van der Valk, 1981; Zedler and Kercher,
70 2005). In previous centuries, wetlands were diversely and extensively used and managed not only
71 through grazing, but also fishing, hunting and reed cutting (Mitsch and Gosselink, 2000; Zedler and
72 Kercher, 2005; Poschlod, 2015). Owing to socio-economic changes (e.g. population growth,
73 intensification of agriculture), many wetlands have been drained, while those that escaped are mainly
74 altered and often no longer managed at all, especially in Europe (IUCN, 1993; Esselink et al., 2000;
75 Brinson and Malvárez, 2002; Stammel et al., 2003).

76 Traditional (extensive) land use practices (e.g., grazing or mowing) harnessed the whole
77 spectrum of habitat types around settlements, including wetlands (Poschlod, 2015), while, as a side-
78 product, acted as essential ecological-anthropological disturbances, with major effects on plant
79 communities (Bakker, 1989; Wallis DeVries et al., 1998; Marty, 2005; Hill et al., 2009) and overall

80 species and (micro)habitat diversity (Mori, 2011; Mérő et al., 2015; Vadász et al., 2016). Appropriate
81 grazing regimes may, for example, induce patchiness, lead to greater microhabitat diversity, alter
82 habitat functioning (Davidson et al., 2017). At the same time, the absence of large herbivores leads to
83 homogenization, as temperate wetland plant communities become dominated by tall-growing species
84 such as *Phragmites*, *Typha*, and *Phalaris* (van der Valk, 1981; Esselink et al., 2000; Burnside et al.,
85 2007; Loughheed et al., 2008), or to an increased abundance of non-native species (Marty, 2005),
86 followed by an impoverishment, especially of flora (Hill et al., 2009; Manton et al., 2016; Davidson
87 et al., 2017; Rannap et al., 2017). Biodiversity loss may alter and decrease the stability of ecosystem
88 functions (Cardinale et al., 2012); therefore wetland conservation management for biodiversity
89 purposes aims to minimize biodiversity losses or to reverse degradation in order to prevent or
90 overcome ecosystem changes (Maitland and Morgan, 2002; Manton et al., 2016). It also aims to
91 enhance habitat diversity (Vadász et al. 2016) and to maintain or recreate habitats e.g., for birds
92 (Mérő et al., 2015; Manton et al., 2016), amphibians (Mester et al., 2015; Rannap et al., 2017), and
93 Red-listed *Nanocyperion* species (Gugič, 2009; Hill et al., 2009). To achieve their goals,
94 conservation strategies often maintain, reinstate or mimic past traditional management regimes
95 (Mori, 2011; Duncan, 2012; Middleton, 2013; Babai et al., 2015) to provide the “necessary”
96 disturbances.

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

104 Traditional land-use practices are often based on local traditional ecological knowledge
105 (Berkes et al., 2000). This knowledge and practices still survive in some areas of Europe (e.g., in the

106 post-communist member states of the European Union) (Babai et al., 2015; Varga et al., 2016; Hartel
107 et al., 2016). Holders of this knowledge understand their living environment well; for example, they
108 can recognize and name about half the native flora, ca. 100 local habitat types, and have a deep
109 understanding of the ecological dynamics of the local landscape (Babai and Molnár, 2014; Molnár,
110 2014). Traditional ecological knowledge on grazing practices may be crucial when developing
111 feasible and innovative management methods to ensure the maintenance of desired ecological
112 conditions. Innovative methods are often rooted in the past and not only have ecological or
113 conservational value, but also social, cultural and economic benefits (Hartel et al., 2016). Reviving
114 past management practices may decelerate the abandonment of erstwhile management traditions and
115 erosion of the related knowledge, and also bring in policy-relevant, innovative methods, such as
116 outdoor pig rearing (Neugebauer et al., 2005; Hill et al., 2009) or re-designed silvopastoral or
117 silvoarable agroforestry systems in agroforestry innovations (Hartel et al., 2016; Rois-Díaz et al.
118 2018). In some wetland areas, where traditional land uses still persist, a greater amount of this
119 knowledge has survived; such areas include the Lonjsko Polje and Kopački Rit floodplains in
120 Croatia, the Temes region and Bosut forest in Serbia, and the Hortobágy region in Hungary (Gugič,
121 2009; Tucakov, 2011; Molnár, 2014; Varga et al., 2016; Kiš et al., 2018, but see also Duncan, 2012;
122 Ludwig et al., 2014, for examples from other European regions).

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

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

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

139

140 **2. Methods**

141 **2.1. Study area**

142 We studied the Pannonian vegetation region (Fekete et al., 2016) and its neighborhood in the
143 central region of the Carpathian Basin, in Central Europe (Fig. 1). The study area belongs to six
144 countries (Hungary, Slovakia, Ukraine, Romania, Serbia, and Croatia). The climate is subcontinental,
145 the mean annual temperature of Hungary is 10-11°C, and annual precipitation is between approx.
146 500-800 mm (Kocsis, 2018).

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

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

158 Western Europe (Bellon, 1996). Most of the drainage of extensive wetlands (measuring up to several
159 hundred thousand hectares in area) took place in the region between 1850 and 1900 (Andrásfalvy,
160 1975). The period saw parallel increases in the production of forage (maize, alfalfa) and in stockyard
161 husbandry, which resulted in the substitution of breeds and the rapid decline of wetland husbandry
162 (Andrásfalvy, 1975; Balassa, 1990). In recent decades, the practice among villagers of grazing their
163 pigs on wetlands has been abandoned almost completely in each country. Wetland grazing,
164 meanwhile, continues to the present day in several areas, mostly by cattle, with smaller quantities of
165 sheep and pigs.

166

167 **2.2. Literature search and analysis**

168 When searching the literature for sources of historical traditional knowledge, we looked for
169 information on the types of livestock and objectives of grazing in wetlands, grazed plant species, the
170 activities of livestock and their effects on vegetation, as well as the main habitat types of grazed
171 wetlands, including specific microhabitats. For the purposes of this study, we regarded wetlands as
172 areas that are usually dominated by *Phragmites australis*, *Carex*, *Typha*, *Schoenoplectus* and
173 *Glyceria* spp. and euhydrophyte species. Both online and printed historical sources were reviewed.
174 The internet search was carried out in the Arcanum Digitheca Digital Library Online Database
175 (<http1>) and in the Public Collection Library of the Hungaricana Online Database (<http2>) in June-
176 October 2018. These databases store over 17 and 11 million pages, respectively, containing
177 information on the entire study area, as it largely matches the territory of the erstwhile Austro-
178 Hungarian Monarchy. We conducted our search using the Hungarian equivalents for the words
179 “marsh, wetland, tussock, moor, reed, sedge, grazing, pasture, and wet pasture”, namely the terms
180 “mocsár, zsombék, láp, nád, sás, vizes hely, legel, legelő, vizes legelő, mocsaras legelő”, and the
181 local terms for cattle, cows, pig, swine, horse, sheep, goat, geese, buffalo, and herds of these
182 livestock. We repeated this search also in the national languages of the other five countries in
183 libraries and collections (ethnographic, local historical, early botanical and agrarian papers,

184 encyclopedias and books). Additionally, we examined ethnographical and other books that were not
185 available through the digital databases (approx. 6000 pages). Altogether 165 historical sources
186 contained relevant information (see the complete reference list in the Supplementary Material).

187 We set up a digital database, into which we collated the records that mention wetland grazing,
188 assigning them to different thematic columns. We separated any mentions of wet meadows from
189 mentions of wetlands (including marshes, floodplains, water bodies and moors) dominated by
190 *Phragmitetea*, *Caricetea* and *Lemnetea* plant communities, and did not process the former, as we
191 focused on non-conventional grazing areas in wetlands. Grazer species mentioned only a few times,
192 e.g., geese and buffalo, were omitted from our analysis (5 records). Analysis and interpretation of
193 historical information was greatly facilitated by some particularly detailed documentation from the
194 late 18th century, before the regulation of the rivers, consisting of hundreds of pages of travel diaries
195 by the renowned botanist, Pál Kitaibel (Gombocz, 1945), and several hundred sheets of maps (scale:
196 1: 28 800) from the First Military Survey of the Habsburg Empire (<http3>). The localization of records
197 was performed using ArcGIS version 10.1 (ESRI 2012). In the paper, the erstwhile condition of the
198 wetlands and information about the details and effects of grazing are presented using quantitative
199 summaries and original quotations. Local folk terms for plants and habitats have been replaced,
200 respectively, by their Latin and/or English equivalents.

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

209

210

211 **3. Results**

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

218

219 **3.1. Habitat categories of grazed wetlands**

220 In relation to wetland grazing, we found 508 mentions of habitat categories (Fig. 2). A total of
221 83 mentions were related to microhabitats (e.g., muddy patches) and 257 to habitat mosaics (e.g.,
222 large permanent wetlands). Vegetation types (dominated often by one or two wetland species) were
223 mentioned in 168 cases, most frequently *Phragmites* and *Typha* beds.

224

225 **3.2. Reasons for keeping livestock on wetlands**

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

233 In the case of pigs, the main objective was to make money by keeping the animals on wetlands.
234 The removal of creatures (e.g., fish and their remains) left behind after floods was a rarely

235 mentioned, but important objective: “*the fish stuck in the hollows of the floodplain were gobbled up*
236 *by pigs.*” (Oláh, 1540 in Andrásfalvy, 1975).

237

238 **3.3. Timing and activity of livestock on the wetlands**

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

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

253

254 **3.4. What plants were consumed by livestock on wetlands?**

255 Regarding the types of vegetation consumed by livestock, we found 383 mentions, classified
256 into 19 species or groups of species (Table 1). The most frequently mentioned plants were
257 *Phragmites australis*, *Typha* spp., *Bolboschoenus maritimus*, *Schoenoplectus lacustris*, and *Carex*
258 spp. For *Phragmites australis*, *Bolboschoenus maritimus*, and *Schoenoplectus lacustris*, the
259 preference for young shoots or leaves was emphasized in mentions related to cattle: “*the cattle*
260 *would take Bolboschoenus maritimus even from under the water until the plants grew old.*” (Varga,

261 1994). Most commonly mentioned as the preferred forage were the young leaves and shoots of reeds
262 as well as narrow-stemmed reeds, especially during summer droughts and in winter. Some mentions
263 showed the importance of reed beds as winter pastures, which were prepared in summer: “*In July ...*
264 *the reeds were cut, even if they were not needed. The reed that sprouted in its place did not wilt by*
265 *winter.*” (Andrásfalvy, 1975). In winter, the cattle would also suffice on dried plants or those
266 withered from frost: “*Carex, Typha, Juncus, Eleocharis, and even the Phragmites provided good*
267 *feed in winter.*” (Györffy, 1941).

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

281 On several occasions, sources emphasized how well-nourished wetland-grazed pigs were:
282 “*They can eat good Typha tubers, plenty of Bolboschoenus, on which the pigs grow as fat as on*
283 *mast.*” (Török, 1870). Certain wetland plants (e.g., *Trapa natans*, *Phragmites australis*) were once
284 regarded as of full nutritional value, and not merely fed to livestock as a “last resort”: “*When the*
285 *water caltrop [Trapa natans] is in its early stages of growth, pigs like it as much as acorns or maize*
286 *[...] It is as useful as mast, and makes them just as fat.*” (Szabóné Futó, 1974). Sources also

287 mentioned some plants whose consumption could cause problems to the livestock, although we could
288 only find information on this in connection with cattle, for pigs “*would eat everything*”. Cattle very
289 much liked the young, sweet leaves of *Glyceria maxima*, for example, but overconsumption would
290 make them bloated. When cattle consumed the muddy grass left over after a flood (Bodó, 1992), or
291 the young shoots or roots of *Cicuta virosa*, which are easily turned up from loose soil, this could
292 result in death (Sajó, 1905).

293

294 **3.5. Effects of livestock on wetland vegetation**

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

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

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

322

323 **4. Discussion**

324 **4.1. Wetland grazing in the Pannonian region between 1720 and 1970**

325 We managed to obtain a large number of historical records on wetland grazing of livestock in
326 the Pannonian region and its immediate vicinity. These historical accounts enable us to form a
327 reasonable, albeit incomplete image of past wetland grazing practices and their effects on vegetation.
328 Unexpectedly, none of the sources gave a detailed discussion of the activities and effects of wetland
329 grazing by livestock. Publications on livestock management from this period (e.g., Fándly, 1792)
330 also lack detailed information on the relationship between grazing and wetland vegetation. Neither
331 the 18th, nor the 19th-century works on flora mention any differences or comparisons between the
332 vegetation of grazed and ungrazed wetlands (e.g., Kitaibel 1793–1815, in Gombocz, 1945; Borbás,
333 1881). To bridge this knowledge gap, it is especially important to process the information that can be
334 gathered from the non-botanical historical sources. An ecological re-evaluation of these historical
335 sources would harness their potential from the perspective of wetland management through grazing
336 for biodiversity conservation purposes.

337 Wetlands played an important role in the everyday life of societies living close to floodplains
338 and other wetlands. In the Carpathian basin and in other European regions as well, animal husbandry

339 was the main source of income in areas with relatively few arable fields (e.g., Cook and Moorby,
340 1993; Bellon, 1996; Poschlod, 2015). Grazing was probably pursued on almost all wetlands, even on
341 the interiors of large wetlands (measuring several thousand hectares, Lovassy, 1931; Morvay, 1940;
342 Györfy, 1941).

343 Specific husbandry systems were developed for optimal utilization of wetlands to achieve
344 short- and long-term benefits. The ideal habitat for keeping pigs, for example, had grazing wetlands
345 and mast forests in close proximity to each other (Belényesy, 2012), which mostly existed on
346 extensive floodplains (Szabadfalvi, 1971; Gugič, 2009; Kiš et al., 2018). Until the beginning of the
347 19th century, extensive pig husbandry was based on mast feeding (Balassa, 1990; Szabó, 2013). Pigs
348 also fed in wetlands, however, and in many cases, keeping pigs on wetland was nearly as profitable
349 as keeping them in mast forests (Török, 1870; Szabadfalvi, 1971, Szabóné Futó, 1974). On the other
350 hand, for cattle husbandry wetlands provided the means for survival in the subcontinental climate of
351 the Pannonian region during extremities, like droughts that occurred almost every year (Varga et al.,
352 2016). We found few mentions concerning the number of animals kept in wetlands, but from the
353 sources it can be inferred that the number of pigs kept in such habitats was substantial in comparison
354 with the present situation, exerting a significant impact on plant communities (Neugebauer, 2005;
355 Poschlod, 2015; Varga, et al 2016). In a wetland near Mukachevo (Ukraine), for example, the density
356 reached one pig per hectare – 6880 pigs on ca. 6-7000 ha (Szabadfalvi, 1971).

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

364 Several management decisions helped to maintain wetland habitats in good condition and
365 suitable for long-term grazing (e.g., the removal or, on the contrary, even the non-removal of reed or
366 dry litter from a given area), and aided the exploitation of biomass in places that were otherwise
367 inaccessible in summer (Bellon, 1996). Local regulations also helped to maximize the number of
368 livestock that could be kept by a village (Bellon, 1996; Belényesy, 2012). Before river regulations
369 and wetland drainage, wetlands were often set aside as reserves particularly for wintering, as
370 haymaking and forage production were of lesser importance than nowadays (Györffy, 1941; Szűcs,
371 1977; Bellon, 1996; Belényesy, 2012). Transhumance to these reserve pastures was an important part
372 of historic wetland management to maximize short- and long-term benefits and to balance forage
373 availability on a regional scale (Szabadfalvi, 1971; Mód, 2003; Belényesi, 2012). Seasonal patterns
374 of transhumance, including movement of sheep, pigs, cattle, and horses to floodplain wetlands
375 during winter (Maior, 1911; Szabadfalvi, 1971; Mód, 2003) or for feeding animals (cattle or pigs)
376 before taking them to market (Neugebauer et al., 2005), were similar to those known from other
377 European landscapes (Poschlod, 2015; Costello and Svensson, 2018).

378

379 **4.2. The effect of grazing on wetland vegetation between 1720 and 1970**

380 Based on historical sources, livestock had an effect on wetland vegetation mainly due to their
381 grazing, trampling, and uprooting behavior, thus reducing biomass and creating micro-habitats (cf.
382 Esselink et al., 2002; Hill et al., 2009, Davidson et al., 2017). Among the obvious effects of grazing
383 were reduced height of vegetation, lower biomass, and greater openness of vegetation. There were
384 only a few species in the wetlands that were not consumed by livestock. Sources usually revealed
385 different effects between cattle and pigs, with cattle being associated mostly with trampling, and pigs
386 with uprooting. The effect of grazing could vary according to the season, partly because livestock
387 would sometimes only spend specific periods of the year on the wetlands, and partly because they
388 would consume certain species of plants only in particular phenological stages, such as after frost or
389 withering, when the taste of several plants changed (e.g., *Carex* and *Typha* spp., Andrásfalvy, 1975),

390 or in spring, when there were young, tender shoots of reed (Morvay, 1940; Györfly, 1941; Varga,
391 1994). Surfaces dislodged by digging pigs contributed to an increased richness of wetland
392 microhabitats by creating patches of mud and puddles, whose importance for biodiversity has
393 recently been demonstrated (Hill et al., 2009; Poschlod et al., 2002). Several sources stated that
394 certain plant species were consciously reduced by grazing livestock, leading to the creation of
395 pastures consisting of grasses and sedges (Lovassy, 1931; Morvay, 1940). Examples of this are also
396 known from other European regions, although experience shows that grazing alone is sometimes
397 insufficient to eliminate reeds or other species (Valkama et al., 2008).

398 Judging from these accounts, our opinion is that the structure and species composition of the
399 vegetation of wetlands close to settlements was fundamentally transformed by grazing, while in
400 wetlands further away from settlements, grazing had a significant effect. Past folk names for
401 wetlands attest to the diversity of wetlands and describe the main types of vegetation (cf. Molnár,
402 2014; Fehér, 2018). Sources indicate that dominant plant species of wetlands in the past were largely
403 the same as today (e.g., Lovassy, 1931; Kitaibel in Gombocz, 1945). Mud vegetation was not
404 described in the sources, only muddy surfaces, but in the lists of wetland species compiled by
405 Kitaibel (in Gombocz, 1945), there is a remarkably large number of species that require trampling
406 and are avoided by grazing livestock (e.g., *Ranunculus lateriflorus*, *Mentha pulegium*, *Alisma* spp.,
407 *Eleocharis palustris*, *Gratiola officinalis*). Undesirable plants in the past were mostly the poisonous
408 species (alien invasive species were not yet present). We could find no information about the
409 poisonous species being destroyed (although this is common practice in the Carpathian region, Babai
410 and Molnár, 2014), whereas dense reed beds were substantially and deliberately reduced by targeted
411 grazing (cf. Lovassy, 1931; Valkama et al., 2008).

412

413 **4.3. The current conservation relevance of historical wetland grazing**

414 Historical sources often explicitly mention livestock effects that are of potential relevance to
415 contemporary wetlands conservation (e.g., reduction of tall species, creation and maintenance of

416 patches of mud and open water). It was surprising that, despite significant grazing density, the
417 sources did not mention degraded wetlands (compared with degraded overgrazed grasslands and
418 forests, which are mentioned frequently in historical sources, e.g., Borbás, 1881; Kitaibel in
419 Gombocz, 1945). Apart from during the extreme droughts of 1790s and 1863 , when the livestock
420 were driven 200-250 km in search of wetlands to graze on (Morvay, 1940; Szabadfalvi, 1971; Mód,
421 2003), there were no mentions to suggest that grazing wetlands became exhausted and degraded.
422 There may be one reason for this, that majority of the benefits of the wetlands were incidental,
423 secondary comparing to the benefits from forests or grasslands, whose degradation affected local
424 communities more seriously. Additionally, wetland dynamic occurs in shorter cycles. Consequently,
425 degradation of wetlands (e.g. changing species composition) was considered a natural phenomenon,
426 and local communities didn't perceive these trends as harmful.

427 Despite the potential for wetland management, recent botanical and conservation-oriented
428 synthetic works in our region rarely, if at all, mention grazing in wetlands (Bölöni et al., 2011;
429 Haraszthy, 2014). We argue that the effect of past grazing (especially pigs) was possibly far more
430 significant in wetlands than is generally thought by botanists and conservationists (see also Poschod,
431 2015; Szigetvári, 2015). It seems that this field of study is also prone to the shifting baseline
432 syndrome (cf. Vera, 2009; Soga and Gaston, 2018). Most of today's generation of botanists and
433 conservationists have never seen pigs grazing in wetlands. Large-scale wetland grazing of pigs is not
434 part of their worldview because the open vegetation of wetlands previously trampled and uprooted
435 by pigs has grown back in recent decades, and the structure and species composition of such
436 wetlands is entirely different (cf. Neugebauer et al., 2005; Hill et al., 2009; Szigetvári, 2015). A lack
437 of scientific knowledge and understanding of traditional grazing systems often leads to erroneous
438 management recommendations, as shown by the personal experience of some of the authors of this
439 paper, who have previously recommended avoiding grazing in wetland areas, which they later found
440 to be dependent of this particular disturbance.

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

453

454 **4.4. The need for innovative conservation management regimes through knowledge co-** 455 **production**

456 The historical information showed that livestock grazed in the wetlands, not only during the
457 growing season but also in winter. Wetland-fattened livestock was highly valued at market (e.g.,
458 Morvay, 1940). Breeds of livestock were kept that were well adapted to wetland grazing (e.g., they
459 could swim well and tolerate cold weather and diseases) (cf. Andrásfalvy, 1975; Balassa, 1990;
460 Bellon, 1996). It may be stated that nowadays the livestock breeds, the herders and the social
461 environment that sustained such historical wetland grazing practices no longer exist. In the 21st
462 century, however, there is an increasing demand for nature-friendly farming and extensive free-range
463 animal husbandry, which often results in entirely extensive grazing practices (Flade et al., 2006;
464 Duncan, 2012; Varga et al., 2016; Costello and Svensson, 2018). An opportunity exists to develop
465 innovative wetland-grazing regimes that function as appropriate conservation management practices.
466 Such innovations are fully compliant with the new conservation paradigm, whose objective is to

467 reintroduce, restore or diversify certain natural and anthropological disturbances (Mori, 2011;
468 Middleton, 2013; Vadász et al., 2016; Hartel et al. 2016). Innovation can be aided not only by the
469 historical information described above, but also by the surviving (though often neglected) traditional
470 ecological knowledge, in which regard Central Europe is in a privileged position and of regional
471 significance (Molnár and Berkes, 2018). Some of the traditional knowledge holders are middle-aged
472 and thus still use and adapt their knowledge and graze their herds in the remnant wetlands (Molnár et
473 al., 2016; Kis et al., 2017). For example, in the Hortobágy National Park (a UNESCO World Cultural
474 Heritage Site for its herding traditions), modern-day herders distinguish between 15 wetland types
475 and are familiar with their species (e.g., knowledge of *Phragmites*, *Typha latifolia* and *T.*
476 *angustifolia*, *Carex acutiformis*, *Schoenoplectus lacustris* and *Trapa natans* is above 95%, that of
477 *Phalaris arundinacea*, *Eleocharis* spp. and *Bolboschoenus maritimus* is above 80%, and that of
478 *Glyceria maxima* is also 55%, Molnár, 2014). Traditional grazing practices are not banned in these
479 reserves, but are rather seen as acceptable and essential for maintaining the optimal ecological
480 conditions of wetlands for many threatened species (http4), like in some UNESCO Biosphere
481 Reserves in Germany and France (Flade et al. 2006; Duncan, 2012; Ludewig et al., 2014).

482

483 **4.5. Improving wetland conservation management**

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

- 492 ▪ As is the case with grasslands (cf. Vadász et al. 2016), wetlands should also be grazed at
493 varying intensities in a mosaic pattern, with both over- and under-grazed areas ([http4](#)).
- 494 ▪ The application of grazing periods that last different lengths of time may help facilitate greater
495 regulation of intensity and control the effects on vegetation (cf. Cornelissen et al., 2014).
- 496 ▪ Late autumn grazing may be of importance for nature conservation, for example, by decreasing
497 litter cover.
- 498 ▪ Besides ancient breeds (e.g., Mangalitsa pig, Hungarian grey cattle), certain modern breeds
499 (e.g., Limousine cattle, Merino sheep, Yorkshire pig) may also be suitable for wetland grazing.
- 500 ▪ It is worth devoting particular attention to pig grazing, although there is relatively limited
501 active experience of this management type (but see Poschlod et al., 2002; Neugebauer et al.,
502 2005; Gugič, 2009; Hill et al., 2009).
- 503 ▪ It would be beneficial to summarize results achieved to date by European experimental
504 ecological research into wetland grazing (e.g. Neugebauer et al., 2005; Mester et al., 2015;
505 [http4](#)). Wilderness experiments also provide numerous lessons on year-round extensive
506 wetland grazing (e.g. Vera, 2009; Cornelissen et al., 2014; [http5](#)).
- 507 ▪ 21st-century technology may also prove valuable, e.g., temporary electric fences on the
508 “outside” of wetlands (that is, the opposite side to where the herders are present).
- 509 ▪ It is worth involving and giving leading roles to herders who are familiar both with the
510 livestock and local wetland habitats and have substantial experience (“conservation herders”,
511 Molnár et al., 2016). A herder can plan forage regeneration, and with timed grazing or mowing
512 and adapted herd size, grazable biomass can often be increased during springtime or periods of
513 drought (Kis et al., 2017). As part of innovative development, present-day herder experience
514 should be placed under “creative tension” with the help of historical sources to test whether it
515 is possible for herders to revive extinct management components (primarily in the case of
516 pigs), as numerous practical elements of past wetland grazing have been lost.
- 517

518 **5. Conclusions**

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

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

534

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547

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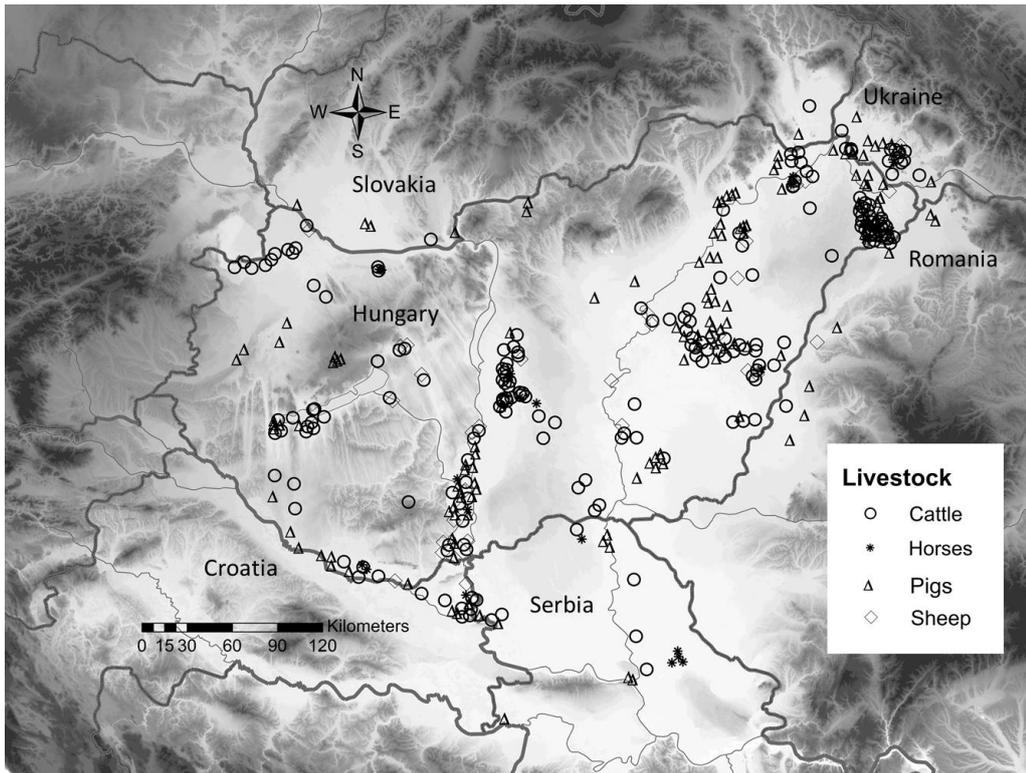
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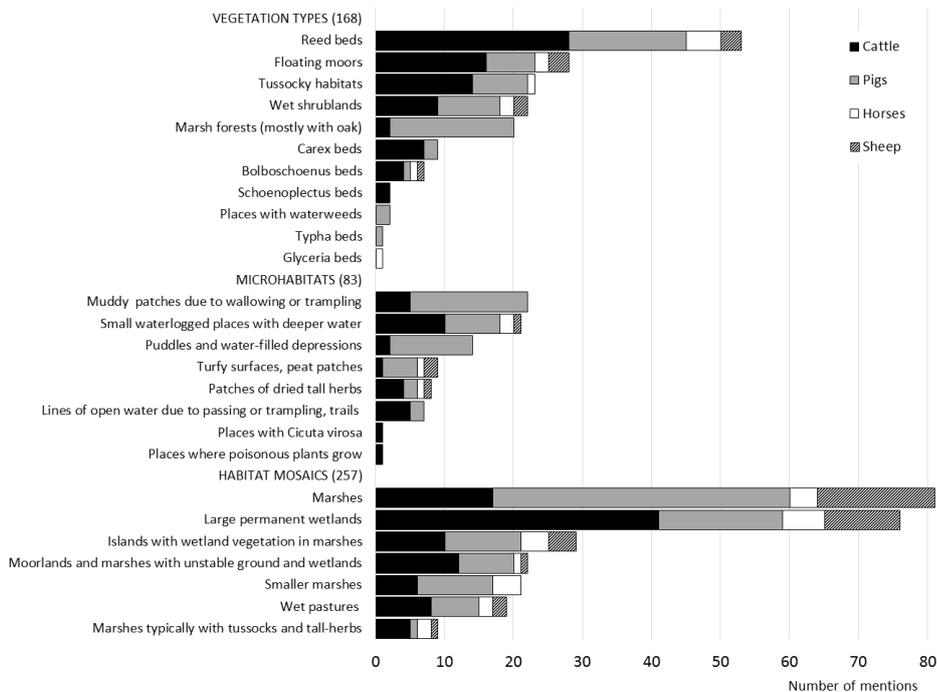
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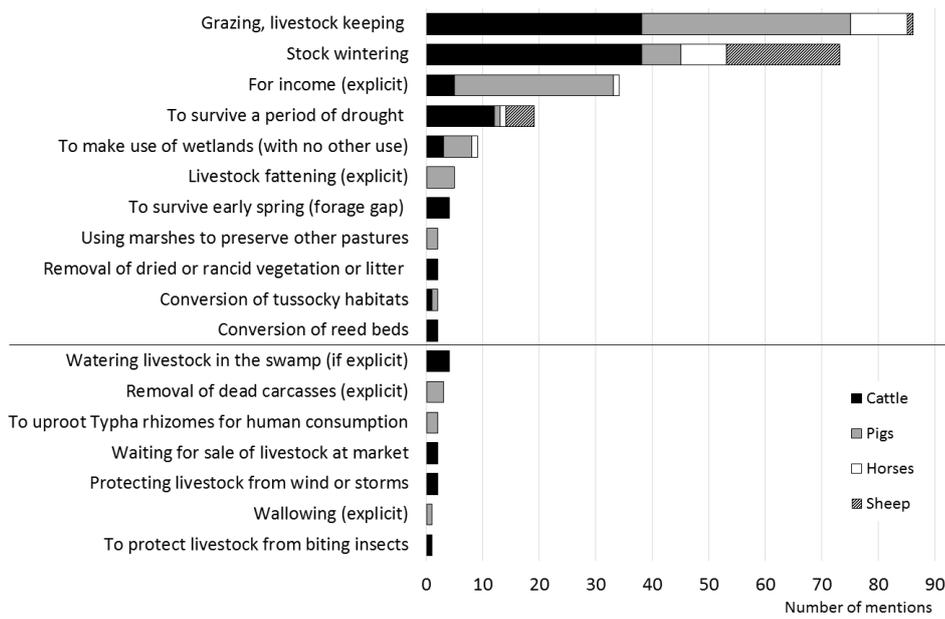
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786 **Fig. 1.** Map of the study area in the Carpathian Basin, Central Europe. Symbols indicate localities of
 787 historical mentions of wetland grazing by domestic livestock. Country borders: thick grey lines, main
 788 rivers: thin grey lines (source: Natural Earth). Source of base map: ASTER-DEM, USGS, 2009
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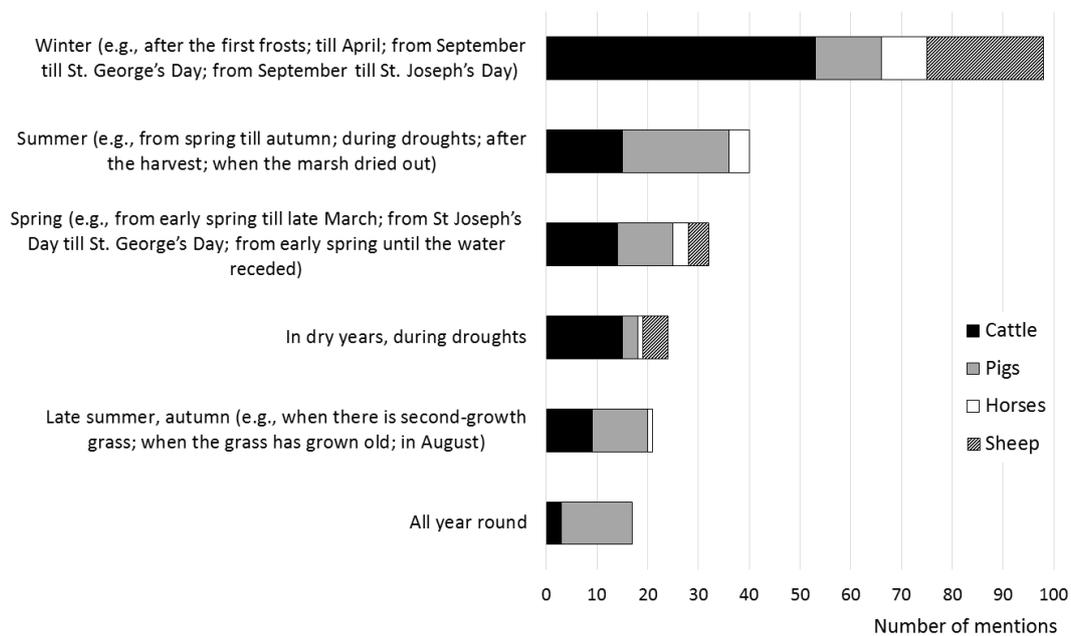
791 **Fig. 2.** Habitat categories of grazed wetlands, as mentioned in the historical sources



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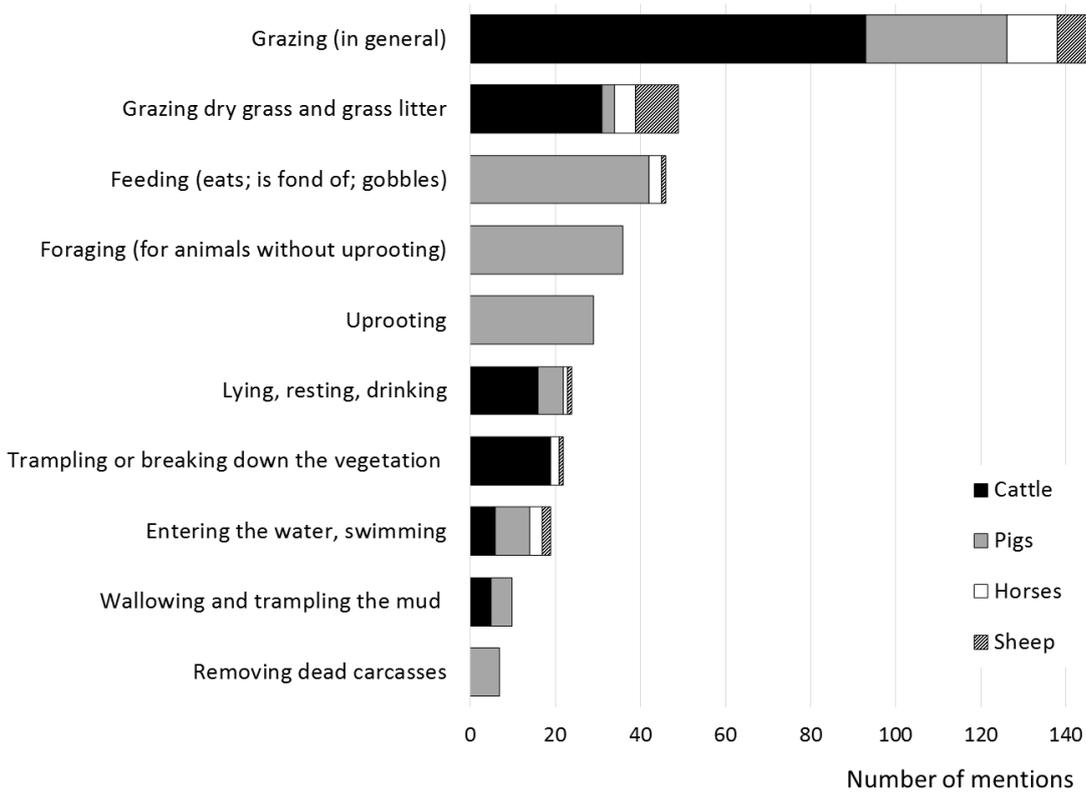
794 **Fig. 3.** Reasons for grazing and, below the line, other reasons for keeping livestock on wetlands, as
 795 mentioned explicitly in the historical sources

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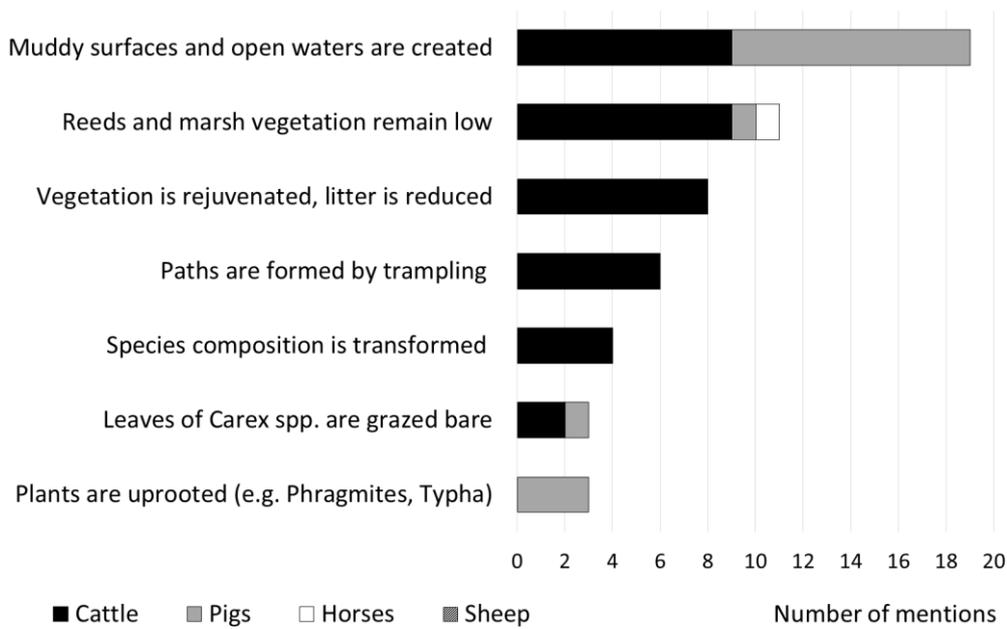
798 **Fig. 4.** Timing of presence of livestock on wetlands, as mentioned explicitly in the historical sources



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

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



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

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816 **Graphical Abstract**



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

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