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MOWING IN AGRI-ENVIRONMENTAL SCHEMES (AES) AND RARE SPECIES OF *VERTIGO* SNAILS: HOPE FOR GRASSLANDS BUT A THREAT TO SNAILS

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ABSTRACT: Four *Vertigo* species are covered by special forms of protection under Annex II of the Habitats Directive. The habitats of these snails are currently rare in Europe. Since typical conservation practices are ineffective for this ecosystem, support mechanisms for measures maintaining biodiversity have been incorporated into agriculture in the form of agri-environmental schemes (AES). However, an inappropriately designed AES may threaten the survival of populations of globally endangered species such as *Vertigo moulinsiana* (Dupuy) as mowing and swath removal dates coincide with the snails' activity period in the upper parts of the mown plants, the majority of their population will be removed from the area along with the harvested swath. In addition, mowing instantaneously and radically alters the habitat's microclimate. The policy of mowing the total area thus leads to unprecedented habitat homogenisation across the landscape, especially when machine mowers are used. In the case of *V. moulinsiana*, the best approach would be not to mow the whole area but to leave a part unmown where these snails could live unhindered. Instead of machines, traditional mowing could be implemented, which entails cutting at a greater height above the sedge clump level. This would not destroy the tussock structure and would allow the habitat to recreate itself. In combination with the designation of unmown refuges, the effects of this approach could be quite beneficial to the snails.

KEY WORDS: protected snail species; mowing treatment; policy analysis; semi-natural grassland management

Over the past few hundred years, land use has been a key factor influencing biodiversity (VERA 2000). In the last century, agricultural practices were modernised and intensified, thereby much reducing the area of semi-natural grasslands. The loss and fragmentation of such habitats following management changes or abandonment has negatively impacted biodiversity, and many species that rely on this type of habitat are now rare and endangered (PÄRTEL et al. 2005, STOATE et al. 2009, DENGLER et al. 2014, JANSSEN et al. 2016). Preservation of semi-natural grasslands and their associated species is largely dependent on low-intensity management which maintains an open habitat and prevents secondary herb, shrub and tree succession (PÄRTEL et al. 2005, HALADA et al. 2011, VALKÓ et al. 2012, DENGLER et al. 2014).

Wetlands and grasslands were found to make up the greatest proportion of threatened terrestrial and freshwater habitats in Europe (JANSSEN et al. 2016), among them fens, floodplains, fen meadows and wet grasslands that have historically relied on extensive management. These are now under threat from both abandonment and conversion to arable land, intensive grassland or forest (VAN DIGGELEN et al. 2006, LAMERS et al. 2015, JANSSEN et al. 2016). No less serious, and often associated with agricultural intensification, are disturbances to the hydrological regime and anthropogenic eutrophication of these habitats (VAN DIGGELEN et al. 2006, JANSSEN et al. 2016). Therefore, protection of the remnants of these areas or their restoration is an urgent task requiring appropriate management (VAN DIGGELEN et al. 2006, LAMERS et al. 2015).

Several species of the genus *Vertigo* are closely associated with calcareous wetlands. Usually very tiny (shell height about 1.8–2.5 mm), they have a distinctive shell shape, with different numbers of whorls winding one above the other, so that the resulting

barrel-shaped form resembles an insect pupa. The following *Vertigo* species are covered by special forms of protection under Annex II of the EU Habitats Directive (Council Directive 92/43/EEC): *V. geyeri* Lindholm, 1925, *V. angustior* Jeffreys, 1830, *V. genesii* (Gredler, 1856) and *V. moulinsiana* (Dupuy, 1849). All four are included in the 2021 IUCN Red List of Threatened Species. At present, their calcareous wetland habitats are global conservation priorities, as they act as refugia for stress-tolerant species in the currently changing landscapes (Raney et al. 2014, Hájek et al. 2020).

These species often occur beyond protected areas, in species-rich wetlands and grasslands which are subject to agricultural management. Support mechanisms for measures intended to maintain the biodiversity of such areas have been incorporated into agriculture in the form of agri-environmental schemes (AES) (Batáry et al. 2015). These measures are supported across the European Union and rely on financial incentives for environmentally sensitive farming. Halting the decline in rare grassland species can be achieved through the protection of high-value habitats with their associated biodiversity, organic farming and environmentally beneficial extensive management like low-intensity pasture systems or mowing cycles appropriately adapted to the habitat and target species (Dengler et al. 2014, Batáry et al. 2015, Tälle et al. 2018).

The ever more widespread implementation of AES is perceived by many as offering hope for the biodiversity of European grasslands (Fox et al. 2006). However, it has often been reported (Balmer & Erhardt 2000, Anthes et al. 2003, Kleijn & Sutherland 2003, Johst et al. 2006, Kleijn et al. 2006, Batáry et al. 2015) that such hopes with regard to AES may be misplaced if grassland management regulations do not meet the requirements of endangered species or, more generally, if they ignore basic ecological knowledge about how species persist in the managed landscapes (Konvicka et al. 2008). An inappropriately designed AES can threaten populations of globally endangered species such as minute land snails, whose survival is highly dependent on the conservation status of their habitats. Among these, *V. moulinsiana* is the species most endangered by AES. It occupies wetland habitats overgrown with *Typha* spp., *Iris* spp., *Glyceria* spp., *Carex* spp. and *Phragmites* spp., and with standing water at ground level (Killeen 2003, Lipińska 2010, Lipińska et al. 2011, 2012, Lipińska & Ćmiel 2016). Unlike other endangered *Vertigo* species, *V. moulinsiana* can be found high up on the vegetation at certain times of the year (Książkiewicz-Parulska 2019). In spring, these snails occur low down, on the previous year's decayed stems and the leaves of monocotyledons (Killeen 2003), but in summer and autumn, according to various studies, they climb to heights of 30–50 cm (Pokryszko 1990), 1 m (Myzyk 2011), more than 2 m (Killeen 2003) or even several metres above the ground (Cameron et al. 2003). Apart from seasonal differences, the heights at which the snails occur most likely depend on local habitat and microclimatic conditions. Probably because of the climbing behaviour of *V. moulinsiana*, the species is not found in regularly mown or intensively grazed areas. The sites of this species should therefore be protected against mowing, grazing and trampling (Killeen 2003). The introduction of cutting programmes in areas where this has not yet been done is mentioned by Killeen (2003) as one of the factors that could adversely affect Desmoulin's whorl snail populations.

Unfortunately, to limit succession on semi-natural grasslands, AES require these to be mown once or twice a year, with mandatory material (swath) removal within two weeks of the mowing (MRRW 2019). As the mowing and swath removal times coincide with the snail's activity period in the upper parts of the plants to be mown, the majority of their population will be removed from the area along with the harvested swath.

Biomass removal by mowing implies the loss of nutrients. This is beneficial for maintaining the biodiversity and species composition of semi-natural grasslands as it limits competition from tall, nutrient-demanding species (Tälle et al. 2014). Nevertheless, mowing instantaneously and radically alters the habitat's microclimate, especially after the swath has been removed. The negative impact of mowing on rare invertebrate species is known (Konvicka et al. 2008), since this procedure, even if part of a purportedly "environmentally friendly" agri-environmental programme, may extinguish their populations. Crucially, the offer of financial subsidies motivates farmers to manage as much land as possible, including large areas that would otherwise lie fallow. Moreover, a rigorous enforcement policy is applied, imposing financial penalties, for example, on farmers who do not cut the total area unit declared (MRRW 2019). In response, farmers mow every possible patch of land, including uneven, hard-to-reach terrain, forest edges and vegetation at the foot of trees (Konvicka et al. 2008). Such a policy thus leads to the unprecedented homogenisation of habitat conditions across the landscape (Konvicka et al. 2008). In the case of habitat of *V. moulinsiana*, this can gradually reduce the height of sedge tussocks until they disappear altogether (Lipińska unpublished). The habitat being altered and unified in this way, the number of snails decreases not only as a result of their removal along with the swath, but also because of the unsuitable conditions of the new habitat. Książkiewicz (2014) described the destruction

of vegetation and litter by heavy equipment at a site of *V. moulinsiana*. Repeated machine mowing of the same habitat patches will probably have a negative effect on *V. moulinsiana*: the snails may not survive in constantly disturbed plots (Książkiewicz 2014). A similar situation was described by Killeen (2003), where much of *V. moulinsiana* habitat in the UK was lost or rendered unsuitable as a result of the regular cutting of sedge and the tidying of river banks, with no space for plants to recover.

As described above, the activities of agri-environmental schemes may, in some cases, actually lead to habitat deterioration and endanger certain valuable species. Some alternatives, i.e. intensive grazing or leaving the area to natural succession, are also unacceptable as conservation measures. The right solution would appear to be to adapt the AES to local habitat conditions. For example, slight modifications of mowing regimes, easily implementable in agri-environmental policy schemes, can boost invertebrate abundance, potentially also benefitting insectivorous vertebrates (van Klink et al. 2019). Therefore, one needs to appropriately prioritize conservation goals and focus on the species/communities of greatest concern by applying an individual approach.

In the case of *V. moulinsiana*, the best solution would be not to mow the whole area but to leave unmown refuges where these snails could live unhindered (this scenario is applied to meadows and pastures, but not to large sedge beds and reed sweetgrass beds, which are mostly *V. moulinsiana* habitat). Mowing regimes which leave particular zones uncut have been recommended before in the case of other invertebrates (Braschler et al. 2009, Dover et al. 2010, Cizek et al. 2012, Lebeau et al. 2015). The benefits of refuge zones were demonstrated by Lebeau et al. (2015) with quantitative evidence of a higher density of grassland butterflies after mowing. According to AES requirements, such a refuge zone is designated each year in a different place. However, with the help of expert assessment, based on the already extensive and widely available knowledge about the habitat requirements of *V. moulinsiana* (Pokryszko 2004, Zając 2004, Lipińska et al. 2012, 2020), it would be perfectly possible to designate the sites this species prefers and leave them unmown in subsequent years. An important supportive measure for the designation of unmown refuges could also be to simply shake the cut swath manually in order to shake off the snails from the stems so that some of them fall back to the ground and remain at the site. But even so, it would be crucial to leave unmanaged patches in order to maintain the appropriate living conditions for these snails. However, the implementation of this procedure does not seem realistic, and in fact it is hard to imagine how such shaking could be effectively carried out over a large area. In addition, Myzyk (2011) stated in the context of *V. moulinsiana* that "shaking snails out of the vegetation gave satisfactory results only in the spring", that is, before the mowing period. Moreover, in summer and autumn such a beating technique may not be very effective because of the sticky mucus that glues the snails to the substrate, as a result of which most snails remain on the vegetation, and fresh increments of juveniles often become damaged (Myzyk 2011).

Another potential solution, i.e. leaving the swath on part of the mown plot, would not physically remove all the snails from that area and allow them to live on the regrowing vegetation. However, leaving the mown material in place can also have a negative impact on the habitat, because the supply of nutrients will alter the water and soil chemistry (Tälle et al. 2014 and references therein, Banaszuk et al. 2016). This approach also rests on the assumption that the vegetation will indeed regrow unchanged. Unfortunately, machine mowers cut low, close to the ground, seriously affecting the habitat structure and plant species composition (Kotowski et al. 2013, Banaszuk et al. 2016). In the habitat of *V. moulinsiana*, many plant species, like sedges, form tussocks, the structure of which develops during the course many growing seasons (Peach & Zedler 2006, Lawrence & Zedler 2011). As mowing destroys these tussocks, the regrowing vegetation will have a different structure: this reduces the microtopography and, consequently, the number of rare species (Rydin et al. 2006, Valkó et al. 2012). This is especially important in relation to fens, where the microtopography contributes to their unique botanical diversity (Kotowski et al. 2013).

Raising the mowing height to c. 10 cm above the sedge clump level would lessen the damage to the sedge tussock structure. This could also be achieved by an individual approach tailored to the habitat at the site, namely, by abandoning machine mowing in favour of traditional manual mowing, which would not destroy the tussock structure and would allow the habitat to recreate itself. Indeed, it was found that the traditional treatment had no substantial adverse effect on the sedges (Kołos & Banaszuk 2018). In combination with leaving unmown refuges, the effects of this approach could be quite beneficial to the snails. As the snail's basic requirement is the presence of wetlands, with sites unshaded by tall plants, management should aim to maintain these conditions (Killeen 2003). Killeen (2003) also described the positive effects of rotational mowing, either annually, biennially, three-yearly or four- to five-yearly, with some areas left unmown (Killeen 2003). The effects of mowing on *V. angustior* and *V. moulinsiana* were described by Książkiewicz (2014), who emphasised the harmful effect of machine mowing and, like Killeen (2003), suggested that extensive land

management could be advantageous for both species only when the site was divided into patches that would be mown alternately in consecutive years. The slow recovery of snails follows the slow regeneration of plants. When a break of several years between mowing episodes is made, significant numbers of snails are lost when the sedge is cut, but many drop off onto the ground and crawl up on to stems of the vegetation (Killeen 2003). The introduction of less frequent mowing cycles, for example every 4–5 years at the beginning of August, as proposed by Kołos & Banaszuk (2018), is also worth considering. These authors showed that annual management could favour the colonisation by large numbers of seedlings of *Alnus glutinosa*, thereby accelerating succession (Kołos & Banaszuk 2018). In Poland, numbers of *Vertigo* snails usually peak in August (Książkiewicz et al. 2012, Lipińska et al. 2012, 2020) and, in the case of *V. moulinsiana*, the snails then stay high up in the vegetation. In combination with leaving the refuges unmown, replacing machine mowing with manual mowing and possibly shaking off the snails before swath removal, mowing at a higher level may prove to be a good solution.

While the approaches described above are the most realistic and feasible, the existing management regulations for areas where endangered *Vertigo* snails occur will need to be amended if they are to be put into practice. In addition, the legislation will have to be altered to allow for a thorough preliminary check on whether mowing is actually necessary at a given place and time; it should not be assumed that this procedure is always appropriate. If there are no visible signs of succession and the ecosystem appears to be undisturbed, it may be enough to monitor the area and apply land management measures only where necessary. But the most important conclusion is that an individual approach should be taken to each area. There are no one-size-fits-all solutions when it comes to protecting ecosystems. Mowing may be effective in hampering the establishment of trees and shrubs in sedge-dominated wetlands (Sundberg 2012), but at the same time it reduces the heterogeneity of the microhabitat by destroying the sedge tussock structure, which is necessary for the survival of other organisms (Peach & Zedler 2006, Kotowski et al. 2013), and can also lead to the transformation of this habitat towards managed meadow communities (Kozub et al. 2018). Active protection treatments should therefore be adapted to the target species of plants and animals most in need of protection in a given area. For example: mowing high above the ground may be beneficial to *Vertigo* snails but insufficient to suppress the expansion of tall vascular plants and *Sphagnum* mosses that threaten competitively weaker and rare fen-specialised bryophytes (Singh et al. 2019, Záleská et al. 2021). In the same way, mowing abandoned land designated for biodiversity protection in a broad sense is not always beneficial for snail protection.

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REFERENCES

Anthes N., Fartmann T., Hermann G., Kaule G. 2003. Combining larval habitat quality and metapopulation structure: the key for successful management of pre-alpine *Euphydryas aurinia* colonies. Journal of Insect Conservation 7: 175–185. https://doi.org/10.1023/A:1027330422958

Balmer O., Erhardt A. 2000. Consequences of succession on extensively grazed grasslands for Central European butterfly communities: Rethinking conservation practices. Conservation Biology 14: 746–757. https://doi.org/10.1046/j.1523-1739.2000.98612.x

Banaszuk P., Kamocki A. K., Zarzecki R. 2016. Mowing with invasive machinery can affect chemistry and trophic state of rheophilous mire. Ecological Engineering 86: 31–38. https://doi.org/10.1016/j.ecoleng.2015.10.005

Batáry P., Dicks L., Kleijn D., Sutherland W. J. 2015. The role of agri-environment schemes in conservation and environmental management. Conservation Biology 29: 1006–1016. https://doi.org/10.1111/cobi.12536

Braschler B., Marini L., Thommen G. H., Baur B. 2009. Effects of small-scale grassland fragmentation and frequent mowing on population density and species diversity of orthopterans: a long-term study. Ecological Entomology 34: 321–329. https://doi.org/10.1111/j.1365-2311.2008.01080.x

Cizek O., Zamecnik J., Tropek R., Kocarek P., Konvicka M. 2012. Diversification of mowing regime increases arthropods diversity in species-poor cultural hay meadows. Journal of Insect Conservation 16: 215–226. https://doi.org/10.1007/s10841-011-9407-6

Cameron R. A. D., Colville B., Falkner G., Holyoak A., Hornung E., Killeen I. J., Moorkens E. A., Pokryszko B. M., Proschwitz T., Tattersfield P., Valovirta I. 2003. Species accounts for snails of genus *Vertigo* listed in Annex II of the Habitat Directive: *V. angustior*, *V. genesii*, *V. geyeri* and *V. moulinsiana* (Gastropoda: Pulmonata: Vertiginidae). Heldia 5: 151–170.

Dengler J., Janisová M., Török P., Wellstein C. 2014. Biodiversity of Palaearctic grasslands: a synthesis. Agriculture, Ecosystems and Environment 182: 1–14. https://doi.org/10.1016/j.agee.2013.12.015

Diggelen R. van, Middleton B., Bakker J. P., Grootjans A. P., Wassen M. J. 2006. Fens and floodplains of the

temperate zone: present status, threats, conservation and restoration. Applied Vegetation Science 9: 157–162. https://doi.org/10.1111/j.1654-109X.2006.tb00664.x

Dover J. W., Rescia A., Fungariño S., Fairburn J., Carey P., Lunt P., Dennis R. L. H., Dover C. J. 2010. Can hay harvesting detrimentally affect adult butterfly abundance? Journal of Insect Conservation 14: 413–418. https://doi.org/10.1007/s10841-010-9267-5

Fox R., Asher J., Brereton T., Roy D., Warren M. 2006. The state of butterflies in Britain and Ireland. Nature Bureau, Newbury, UK.

Hájek M., Horsáková V., Hájková P., Coufal R., Dítě D., Němec T., Horsák M. 2020. Habitat extremity and conservation management stabilise endangered calcareous fens in a changing world. Science of the Total Environment 719: 134693. https://doi.org/10.1016/j.scitotenv.2019.134693

Halada L., Evans D., Romão C., Petersen J.-E. 2011. Which habitats of European importance depend on agricultural practices? Biodiversity and Conservation 20: 2365–2378. https://doi.org/10.1007/s10531-011-9989-z

Janssen J. A. M., Rodwell J. S., Criado M. G., Arts G. H. P., Bijlsma R. J., Schaminee J. H. J. 2016. European red list of habitats. Part 2. Terrestrial and freshwater habitats. European Union.

Johst K., Drechsler M., Thomas J., Settle J. 2006. Influence of mowing on the persistence of two endangered large blue butterfly species. Journal of Applied Ecology 43: 333–342. https://doi.org/10.1111/j.1365-2664.2006.01125.x

Killeen I. J. 2003. Ecology of Desmoulin's Whorl Snail. Conserving Natura 2000 Rivers Ecology Series No. 6. English Nature, Peterborough.

Kleijn D., Sutherland W. J. 2003. How effective are European agri-environment schemes in conserving and promoting biodiversity? Journal of Applied Ecology 40: 947–969. https://doi.org/10.1111/j.1365-2664.2003.00868.x

Kleijn D., Baquero R. A., Clough Y., Diaz M., De Esteban J., Fernandez F., Gabriel D., Herzog F., Holzschuh A., Johl R., Knop E., Kruess A., Marszall E. J. P., Steffan-Dewenter I., Tscharntke T., Verhulst J., West T. M., Yela J. L. 2006. Mixed biodiversity benefits of agri-environment schemes in five European countries. Ecology Letters 9: 243–254. https://doi.org/10.1111/j.1461-0248.2005.00869.x

Klink R. van, Menz M. H. M., Baur H., Dosch O., Kühne I., Lischer L., Luka H., Meyer S., Szikora T., Unternährer D., Arlettaz R., Humbert J.-Y. 2019. Larval and phenological traits predict insect community response to mowing regime manipulations. Ecological Applications 29: e01900. https://doi.org/10.1002/eap.1900

Kołos A., Banaszuk P. 2018. Mowing may bring about vegetation change, but its effect is strongly modified by hydrological factors. Wetlands Ecology and Management 26: 879–892. https://doi.org/10.1007/s11273-018-9615-x

Konvicka M., Benes J., Cizek O., Kopecek F., Konvicka O., Vitaz L. 2008. How too much care kills species: Grassland reserves, agri-environmental schemes and extinction of *Colias myrmidone* (Lepidoptera: Pieridae) from its former stronghold. Journal of Insects Conservation 12: 519–525. https://doi.org/10.1007/s10841-007-9092-7

Kotowski W., Jabłońska E., Bartoszuk H. 2013. Conservation management in fens: Do large tracked mowers impact functional plant diversity? Biological Conservation 167: 292–297. https://doi.org/10.1016/j.biocon.2013.08.021

Kozub Ł., Goldstein K., Dembicz I., Wilk M., Wyszomirski T., Kotowski W. 2019. To mow or not to mow? Plant functional traits help to understand management impact on rich fen vegetation. Applied Vegetation Science 22: 27–38. https://doi.org/10.1111/avsc.12411

Książkiewicz Z. 2014. Impact of land use on populations of *Vertigo moulinsiana* (Dupuy, 1849) and *Vertigo angustior* (Jeffreys, 1830) (Gastropoda: Pulmonata: Vertiginidae): Ilanka River Valley (W. Poland). Folia Malacologica 22: 277–282. https://doi.org/10.12657/folmal.022.019

Książkiewicz Z., Lipińska A., Zając K., Barga-Więcławska J. A. 2012. Poczwarówka zwężona *Vertigo angustior*. In: Makomaska-Juchiewicz M., Baran P. (eds). Monitoring gatunków zwierząt. Przewodnik metodyczny. Część II. GIOŚ, Warszawa, pp. 482–503.

Książkiewicz-Parulska Z. 2019. Vertical migrations in two hygrophilous species of micro-snails in relation to time of the year and habitat type. Invertebrate Biology 138: e12253. https://doi.org/10.1111/ivb.12253

Lamers L. P. M., Vile M. A., Grootjans A. P., Acreman M. C., Diggelen R. van, Evans M. G., Richardson C. J., Rochefort L., Kooijman A. M., Roelofs J. G. M., Smolders A. J. P. 2015. Ecological restoration of rich fens in Europe and North America: from trial and error to an evidence-based approach. Biological Reviews 90: 182–203. https://doi.org/10.1111/brv.12102

Lawrence B. A., Zedler J. B. 2011. Formation of tussocks by sedges: effects of hydroperiod and nutrients. Ecological Application 21: 1745–1759. https://doi.org/10.1890/10-1759.1

Lebeau J., Wesselingh R. A., Van Dyck H. 2015. Butterfly density and behaviour in uncut hay meadow strips: Behavioural ecological consequences of an Agri-Environmental Scheme. PLoS ONE 10 (8): e0134945. https://doi.org/10.1371/journal.pone.0134945

Lipińska A. M. 2010. Poczwarówka jajowata *Vertigo moulinsiana* – rzadki gatunek ślimaka chroniony Dyrektywą Siedliskową. Chrońmy Przyrodę Ojczystą 66: 482–490.

Lipińska A. M., Ćmiel A. M. 2016. Habitat structure effects on the distribution and abundance of the rare snail *Vertigo moulinsiana* (Dupuy 1849). Journal of Conchology 42: 79–83.

Lipińska A. M, Ćmiel A. M., Kwaśna D., Myzyk S., Zając K., Zając T. 2020. The role of microhabitat and water

level in regulating small-scale distribution, seasonal abundance and overwintering success of the protected snail *Vertigo moulinsiana* in a natural wetland. Polish Journal of Ecology 68: 229–241. https://doi.org/10.3161/15052249PJE2020.68.3.004

LIPIŃSKA A. M., GOŁĄB M. J., ĆMIEL A. M. 2011. Occurrence of Desmoulin's whorl snail *Vertigo moulinsiana* (Dupuy 1849) in the Nida Wetlands (South Poland): interactive effects of vegetation and soil moisture. Journal of Conchology 40: 1–5.

LIPIŃSKA A., KSIĄŻKIEWICZ Z., ZAJĄC K., BARGA-WIĘCŁAWSKA J. A. 2012. Poczwarówka jajowata *Vertigo moulinsiana*. In: MAKOMASKA-JUCHIEWICZ M., BARAN P. (eds). Monitoring gatunków zwierząt. Przewodnik metodyczny. Część II. GIOŚ, Warszawa, pp. 463–481.

MRRW 2019. Przewodnik po działaniu rolno-środowiskowo-klimatycznym PROW 2014–2020 (Guide to agri-environment climate measure RDP 2014–2020). Ministerstwo Rolnictwa i Rozwoju Wsi, Warszawa. Available online at https://www.gov.pl/web/rolnictwo/materialy-informacyjne1 (accessed 10 January 2022).

MYZYK S. 2011. Contribution to the biology of ten vertiginid species. Folia Malacologica 19: 55–80. https://doi.org/10.2478/v10125-011-0004-9

PÄRTEL M., BRUUN H. H., SAMMUL M. 2005. Biodiversity in temperate European grasslands: origin and conservation. Grassland Science in Europe 10: 1–14. https://portal.research.lu.se/ws/files/5528474/625284.pdf

PEACH M., ZEDLER J. B. 2006. How tussocks structure sedge meadow vegetation. Wetlands 26: 322–335. https://doi.org/10.1672/0277-5212(2006)26[322:HTSSMV]2.0.CO;2

POKRYSZKO B. M. 1990. The Vertinigidae of Poland (Gastropoda: Pulmonata: Pupilloidea) - a systematic monograph. Annales Zoologici 43: 134–257.

POKRYSZKO B. M. 2004. *Vertigo moulinsiana* (Dupuy, 1849) Poczwarówka jajowata. In: GŁOWACIŃSKI Z., NOWACKI J. (eds). Polska Czerwona Księga Zwierząt. Bezkręgowce. Instytut Ochrony Przyrody, PAN, Kraków, pp. 324–325.

RANEY P. A., FRIDLEY J. D., LEOPOLD D. J. 2014. Characterizing microclimate and plant community variation in wetlands. Wetlands 34: 43–53. https://doi.org/10.1007/s13157-013-0481-2

RYDIN H., JEGLUM J. K., HOOIJER A. 2006. The biology of peatlands. Oxford University Press, Oxford. https://doi.org/10.1093/acprof:oso/9780198528722.001.0001

SINGH P., TĚŠITEL J., PLESKOVÁ Z., PETERKA T., HÁJKOVÁ P., DÍTĚ D., PAWLIKOWSKI P., HÁJEK M. 2019. The ratio between bryophyte functional groups impacts vascular plants in rich fens. Applied Vegetation Science 22: 494–507. https://doi.org/10.1111/avsc.12454

STOATE C., BÁLDI A., BEJA P., BOATMAN N. D., HERZON I., VAN DOORN A., DE SNOO G. R., RAKOSY L., RAMWELL C. 2009. Ecological impacts of early 21st century agricultural change in Europe – a review. Journal of Environmental Management 91: 22–46. https://doi.org/10.1016/j.jenvman.2009.07.005

SUNDBERG S. 2012. Quick target vegetation recovery after restorative shrub removal and mowing in a calcareous fen. Restoration Ecology 20: 331–338. https://doi.org/10.1111/j.1526-100x.2011.00782.x

TÄLLE M., BERGMAN K.-O., PALTTO H., PIHLGREN A., SVENSSON R., WESTERBERG L., WISSMAN J., MILBERG P. 2014. Mowing for biodiversity: grass trimmer and knife mower perform equally well. Biodiversity Conservation 23: 3073–3089. https://doi.org/10.1007/s10531-014-0765-8

TÄLLE M., DEÁK B., POSCHLOD P., VALKÓ O., WESTERBERG L., MILBERG P. 2018. Similar effects of different mowing frequencies on the conservation value of semi-natural grasslands in Europe. Biodiversity and Conservation 27: 2451–2475. https://doi.org/10.1007/s10531-018-1562-6

VALKÓ O., TÖRÖK P., MATUS G., TÓTHMÉRÉSZ B. 2012. Is regular mowing the most appropriate and cost-effective management maintaining diversity and biomass of target forbs in mountain hay meadows? Flora – Morphology, Distribution, Functional Ecology of Plants 207: 303–309. https://doi.org/10.1016/j.flora.2012.02.003

VERA F. W. M. 2000. Grazing ecology and forest history. CABI Publishing, Oxford, UK. https://doi.org/10.1079/9780851994420.0000

ZAJĄC K. 2004. Poczwarówka jajowata *Vertigo moulinsiana*. In: ADAMSKI P., BARTEL R., BERESZYŃSKI A., KEPEL A., WITKOWSKI Z. (eds). Gatunki zwierząt (z wyjątkiem ptaków). Poradniki ochrony siedlisk i gatunków Natura 2000 - podręcznik metodyczny. Ministerstwo Środowiska, Warszawa. T. 6, pp. 158–161.

ZÁLESKÁ T., HOLÁ E., KUČERA J., GRILL S., ŠMILAUER P., ŠTECHOVÁ T. 2021. Mowing and disturbance increase survival rates of three rare moss species of fen meadows. Folia Geobotanica 56: 167–177. https://doi.org/10.1007/s12224-021-09398-4

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