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THE FIRST ATTEMPTS OF PLANT REINTRODUCTIONS ON THE DRAVA RIVER IN CROATIA: EXPERIENCES WITH DWARF CATTAIL (*TYPHA MINIMA* FUNCK EX HOPPE)

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Reintroduction of key plant species to habitats where they became locally extinct contributes to the restoration of biodiversity and ecological functions of the natural ecosystem. The dwarf cattail (*Typha minima* Funck ex Hoppe) is a pioneer plant, adapted to newly formed gravel- and sand bars of free-flowing rivers, and it is an indicator species of rivers with natural hydro-morphological sediment dynamics and a changing riverbed. In the last decades, it has disappeared from known sites on the banks of the Drava River near Varaždin, Donja Dubrava and Legrad, and therefore its reintroduction was planned and carried out within the framework of the DRAVA LIFE project. Pieces of rooted rhizomes of the dwarf cattail originating from the upper sections of the Drava River in Austria were planted on three occasions (2018, 2019 and 2024) at selected locations near the Drava-Mura confluence. Monitoring revealed that most plants (83% from the total of 1285), did not survive long-term floods; they were buried by sediments or carried away by strong currents. From the 17% of plants that survived the floods, 9% were dug up by wild boars. Only about 8% of the plants survived until the end of the year in which they were planted. Despite the lower rate of success, the reintroduction of this species should be continued by planting rhizomes or seedlings in micro-locations with potentially more favourable conditions, such as newly restored Drava side arms, where the river dynamics is more moderate, and the newly created bare surfaces are potentially suitable habitats.

Key words: bulrush, hydro-morphological dynamics, pioneer, river restoration, sand bar, wild boar

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Reintrodukcija ključnih biljnih vrsta u staništa iz kojih su lokalno izumrle doprinosi obnavljanju bioraznolikosti i ekoloških funkcija prirodnih ekosustava. Patuljasti rogoz (*Typha minima* Funck ex Hoppe) je pionirska biljka adaptirana na novonastale šljunčane i pješčane sprudove slobodnotekućih rijeka te se smatra indikatorskom vrstom rijeka s prirodnom hidromorfološkom dinamikom sedimenata i promjenjivim koritom. Zadnjih desetljeća nestala je s poznatih nalazišta na obali rijeke Drave kod Varaždina, Donje Dubrave i Legrada te je u okviru projekta DRAVA LIFE planirana i provedena reintrodukcija. Komadi ožiljenih rizoma patuljastog rogoza podrijetlom iz gornjeg toka rijeke Drave u Austriji posađeni su u tri navrata (2018., 2019. i 2024. godine) na odabranim mjestima uz ušće Mure u Dravu. Praćenjem je utvrđeno da većina (83%) od ukupno posađenih 1285 biljaka nije preživjela dugotrajne poplave; zatrpane su nanosima ili odnešene jakom vodenom strujom. Od 17% biljaka koje su preživjele poplave, 9% su iskopale divlje svinje. Svega oko 8% biljaka je preživjelo do kraja godine u kojoj su posađene. Unatoč slabom uspjehu potrebno je nastaviti s reintrodukcijom ove vrste sadnjom rizoma ili klijanaca na mikrolokacijama s potencijalno povoljnijim uvjetima, kao što su novoobnovljeni rukavci Drave, gdje je hidromorfološka dinamika rijeke umjerenija, a novonastale neobrasle površine predstavljaju potencijalno pogodna staništa.

Ključne riječi: hidro-morfološke promjene, divlja svinja, pionirska vrsta, obnova rijeke, pješčani sprud

INTRODUCTION

Reintroduction of native plant species has become an important active management strategy increasingly integrated into conservation practice worldwide (e.g. Maunder, 1992; Ren *et al.*, 2014). However, in spite of huge number of species reintroduction projects, few studies have reported on the outcome of reintroduction efforts (Bottin *et al.*, 2007; Godefroid *et al.*, 2011; Müller, 2023). As reintroduction is recognized as a relatively high-risk, high-cost activity, disseminating information concerning reintroduction experiments is important to provide examples and case studies to define and update common standards and methodologies. Case studies, best practice and experiences of plant reintroductions are important to the plant conservation community; however, most often remaining in unpublished internal reports which are difficult to access (Godefroid & Vanderborght, 2011). Moreover, publications are biased towards the most successful experiments, since many failed attempts with negative results are less publishable or regarded as uninteresting. However, these cases can be highly informative for practitioners to avoid future problems (Godefroid *et al.*, 2011, 2025).

Dwarf cattail or dwarf bulrush (*Typha minima* Funck ex Hoppe) (*Typhaceae* family) is a perennial herbaceous plant, native to Eurasia, while its distribution is limited to the rivers of the Alps and the Apennines and its forelands, the Danube River and to the rivers of the Balkans region and the mountains of central Asia (Walters & Cook, 1980). It grows on gravel- and sand bars on periodically flooded banks of rivers and in slow-flowing side arms of rivers, at an altitude up to 1200 metres above sea level (Hegi, 1980). The life form of dwarf cattail is helophyta-hydrophyta, meaning that this plant with submerged overwintering buds is adapted to living in aquatic environments (Soó, 1973). In the parts of its European range dwarf cattail grows in the community *Equiseto-Typhetum minimae* Br.-Bl. ap. Volk 1939 (e.g. Müller, 1991, 1995; Prunier *et al.*, 2010b). A further habitats where this species was observed is the *Salicetum*

eleagno-daphnoidis Moor 1958 and other willow-successional stages (e.g. *Salix alba - S. triandra* stage) which are formed on the sites without flooding on alpine rivers. These stages further develop and become the typical grey alder forest *Alnetum incanae* Lüdi 1921. Dwarf cattail occurs also in the *Calamagrostietum pseudophragmites* Kopecký 1968 community (Camenisch, 1996, 1999; Egger *et al*., 2007). In northern Croatia vegetation with domination of dwarf cattail and reed (*Phragmites australis*) was revealed more than 50 years ago on the sandbanks of the Drava River in the vicinity of Varaždin where these stands were described as *Phragmiti-Typhetum minimae* Trinajstić (1964) 1985 community, which is classified into the vegetation alliance *Phragmition*. The ecological series near the Drava River was illustrated and the ecological conditions of different habitats were described by Trinajstić *et al*. (1985). All gravel and sand banks closer to the running water were occupied by pioneer shrubs of the *Salicetum eleagno-purpureae*. Dwarf cattail preferably occupied sites between flowing and stagnant waters (Fig. 1). These stands occurred on sites with very high level of ground water on coarse sand, periodically inundated but permeable substrate, which prevented development of swamp (Trinajstić *et al*., 1985).

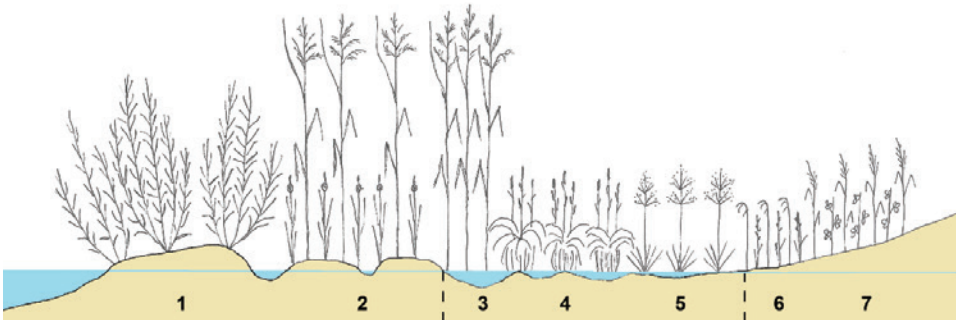


Fig. 1. Syndynamic sheme of vegetation with dwarf cattail near the Drava River in Croatia: 1. *Salicetum eleagno-purpureae*; 2. *Phragmiti-Typhetum minimae*; 3. *Scirpo-Phragmitetum*; 4. *Caricetum elatae*; 5. *Deschampsietum caespitosae*; 6. *Bromo-Cynosuretum cristati*; 7. *Ononido-Arrhenatheretum*; Redrawn upon Trinajstić *et al*. (1985)

According to the flagship species concept (Simberloff, 1998) dwarf cattail is a key species of the pioneer habitats, on newly formed islands of sandy sediments along slowly flowing arms of braided rivers, e.g. the Lech in Austria (Egger *et al*., 2007). It is one of the most sensitive indicator species for river floodplains with natural hydro-morphological dynamics of sediments and changing of riverbed (Müller *et al*., 2019). Outstanding but rare examples of the anabranching river type with dwarf cattail are the upper Loire and Allier in France and the Lech in Austria (Nanson & Knighton, 1996; Egger *et al*., 2007). Human impacts on rivers (e.g. channelization, construction of hydroelectric power plants (HPP) as well as gravel and sand extraction) in the last century altered vital hydro-morphological processes, reduced dynamics of river sediments, and affected natural floods, causing the massive decline of the species linked to pioneer habitats especially *Typha minima* and *Myricaria germanica* (Endress, 1975; Müller, 1991; Prunier *et al*., 2010a; Šafarek, 2012; Sitzia *et al*., 2021; Egger *et al*., 2023; Becker *et al*., 2025). Gravel and sand bars as pioneer habitat types

have become very rare in Europe and are among the most endangered ecosystems. Therefore, the habitat with dwarf cattail was declared as a priority natural habitat of Community interest (Annex I of the European Union Habitats Directive (Council of the European Communities, 1992); Natura 2000 Habitat type code: 7240* Alpine pioneer formations of Caricion bicoloris-atrofuscae. Corine Biotope Code: 54.33 Riparian formations with dwarf cattail of the hilly level of the Alpine and peri-Alpine regions (Devillers *et al.*, 1991). This species is also listed on the Appendix I of the Convention on the Protection of European Wildlife and Natural Habitats (Bern Convention; Council of Europe, 1979). General causes of threats are hydro technical interventions, building of power plants, accumulations and dams, or melioration of the area. According to the IUCN classification the major threats are melioration and flooding of riparian areas and marshes; and habitat loss (Nikolić *et al*., 2005), as well as dams and water management/use; and agricultural and forestry effluents (Stamenković & Kovačić, 2014). It is listed as endangered in Switzerland (Moser *et al*., 2002), where only three natural populations survived (Camenisch, 1999). Larger populations only survive in France (Werner, 1998, 2010). In other European countries, the species is either extirpated (Germany) or restricted to small populations (Austria) (Müller, 1991, 2007; Csencsics *et al*., 2008; Till-Bottraud *et al*., 2010). In Hungary, it is recently considered to be extinct (Király, 2009).

In Croatia, dwarf cattail was critically endangered (Nikolić *et al*., 2005), statutorily strictly protected species and it is on the list of endangered plants for which action plans need to be developed, according to the document of National Strategies and Action Plan for the Protection of Biodiversity and Landscape Diversity of the Republic of Croatia (Official Gazette, 1999). According to the last extinction risk assessment carried out in 2014, this species is considered regionally extinct (Stamenković & Kovačić, 2014). In the Flora Croatica Database (FCD; Nikolić *et al*., 2024), based on ZA Herbarium and publications from 19th and 20th century, this species occurred in Varaždin surroundings, left bank of the Drava River, Drnje, Donja Dubrava and Legrad surroundings (Trinajstić *et al*., 1985), Kopačevo - Kopački rit (Panjković, 1990), Varaždin, Donji Miholjac (Drava bank), Kopački rit (Drava bank) (Šegulja & Topić, 1993–1994). The occurrence of this species in Croatia was not confirmed after 1994 (Csiky & Purger 2008; Stamenković & Kovačić, 2014; Nikolić *et al*., 2024). Despite our thorough survey during the last decade, from 2016, the occurrence of dwarf cattail was not proved on previously known localities where it was an abundant plant, thus we consider this species as regionally extinct in Croatia. According to the dwarf cattail assessment in Red Book of Vascular Flora of Croatia, its reintroduction to the nature is difficult or impossible because of lack of habitats, active measures of its protection have not been taken in Croatia (Lovašen-Eberhardt, 1994; Nikolić *et al*., 2005). Several countries undertook specific conservation efforts, such as Austria (Müller, 2007) or Switzerland (Camenisch, 1996), and in the course of several reviewed river restoration projects, dwarf cattail is stated as a target species to be reintroduced where possible. The long-term conservation of this species requires both the restoration of regularly disturbed, sparsely vegetated river margins and the reintroduction of plants with appropriate origin (Galeuchet *et al*., 2002; Galeuchet & Holderegger, 2005). A population genetics study to find suitable source populations for future reintroductions of the plant species of conservation importance performed by Csencsics *et al*. (2010) determined

the genetic structure of dwarf cattail (n=15, 2n=30). They also found a small genetic variability both within and between populations.

In Croatia there is a lack of action focused on conservation implementation; moreover, this is the first attempt of the reintroduction of plant species. Dwarf cattail has been extinct from its natural habitats; therefore the goals of DRAVA LIFE project were habitat management and the reintroduction of this species on several locations in the middle section of the Drava River.

The aim of our paper was: 1) to document how successful the dwarf cattail reintroduction in the Drava River in Croatia has been so far, 2) to determine supposed causes of reintroduction outcome and 3) to make suggestions which can support success in future attempts based on our experiences.

MATERIAL AND METHODS

Morphological features and ecology of dwarf cattail

Dwarf cattail is a wetland plant, with the leaves arranged only in the basal part. The leaves are linear, narrow, 1–3 (5) mm in width, up to 30 centimetres in length, and always shorter than the stem (Király, 2009). On the top of the stem, large numbers of tiny female and male flowers form a dense, separate spike of similar length. Female flowers form a dense, short cylindrical-oval spike, barely longer than broad (up to 4.5 cm). The seeds are minute, 0.2 mm long with fine hairs. When ripe, the spikes disintegrate into a cottony fluff from which the seeds are dispersed by wind (Király, 2009; Nikolić, 2019). It flowers in May and June, sometimes from April to August. Germination of seeds is 90% successful in the first period after ripening, however, it rapidly decreases, and after one year a seed loses its germination ability (Camenisch, 1996). Germination experiments revealed a very low mean germination rate of 15.6%, with a range of 0–90%. After seed storage for 480 hours, no germination was observed (Baur *et al*., 2017). A finer texture sediment can favour seed germination and vegetative expansion, while coarse sediment is unsuitable and may prevent colonisation (Prunier *et al*., 2010a; Popoff *et al*., 2021b). Transport of propagules happens via water (hydrochory) by drifting of rhizome pieces and by wind (anemochory), and this vector can transport seeds upstream and downstream. Vegetative propagation takes place by a short, thick (5–8 mm) rhizome, which grows up to 20 cm deep under the ground and usually forms large, dense patches. In monitored populations in Austria individuals of dwarf cattail up to three years old developed only sterile shoots. Reproductive shoots developed after four years, and the number of inflorescences increased, but after 11 years started to decrease (Csencsics & Müller, 2015). Dwarf cattail is especially dependent on high soil moisture content, with an average of 39 Vol-% humidity (Baur *et al*., 2017). Being an oligotrophic species, it grows in cool and pure waters, on a substrate which is relatively poor in nutrients, acidic or neutral. Commonly, it grows on clay, loam and sand substrate. It is a heliophyte, light-loving plant adapted to full sun, but it can tolerate partial shade. The importance of light conditions for growth is shown; declines in shoot density were found at > 50% canopy coverage by *Salix* shrubs. Through its low competitiveness, this species disappears within 10-50 years from sites without floods where the succession continues rapidly (Soó, 1973).

Plant material used for reintroduction

Pieces of rooted rhizomes of the dwarf cattail originating from the upper sections of the Drava River in Carinthia (Austria) (Fig. 2) were planted during reintroduction on the Drava in Croatia, since propagule material should originate from a nearby, closest existing population to preserve threatened genotypes (Flöss & Keel, 2004). Those source populations of dwarf cattail have been successfully resettled after its disappearance from the area in Austria. After several trials, the initial plantation was established on the Nature 2000 site Upper Drava (Baur *et al*., 2015). According to these experiences, using rooted plants gives better results than rhizome fragments (Camenisch, 1996, 1999; Müller, 2023). During transport, the roots of these plants should be protected from desiccation and mechanical damage. Planting was performed with hand tools and watered in the first weeks. According to the IUCN guidelines for reintroductions (IUCN, 1998), the optimum number of individuals to reintroduce should be a trade-off between the impact on the source population and reducing the risk of the founder population failing to establish because of random effects on a small population and lack of genetic diversity. Since a reintroduction involves the removal of individuals from a source population, the impact on the source population in the upper section of the Drava River should be assessed. A higher number of plants and repeated reintroductions will increase the success (Godefroid *et al*., 2011). Experiences from the reintroduction project of this species in Switzerland suggested that for such action, a period of several years is needed and a high number of plants should be used (Flöss & Keel, 2004). The larger the population, the higher the genetic diversity, and therefore, large populations should be established, with more than one thousand individuals. A population with less than ten shoots can be considered risky. If there is little genetic variation in the source material used for reintroduction, there is a potential risk of a lack of adequate genetic variation to enable survival and adaptation in the face of environmental changes. A low genetic variation leads to a reduced fertility (Csencsics & Müller, 2015). We used ca. 500 pieces of rhizome in the first two attempts and ca. 285 for the third one. These numbers were estimated as optimal based on experiences from previous actions of reintroduction.



Fig. 2. Dwarf cattail in the upper section of the Drava River near the village of Kleblach in Austria, April 2024. (Photo by G. Egger)

Study area

After wide consultations with local and international experts on the target species, thorough study of literature, and field research on the entire Drava section in Croatia conducted during the summer and autumn of 2017, five sites have been selected for the reintroduction of dwarf cattail. The sites selected (Tab. 1-3) were near the Drava-Mura confluence (near those of former occurrence of dwarf cattail before becoming extinct) in the middle section of the Drava River, with moderate fluvial hydro-morphological dynamics (Šafarek, 2012), where sand bars provide suitable conditions, and the water regime seem to be favourable for dwarf cattail. These sites are also exposed to periodic heavy flooding, which relocates the substrate and resets the succession to vegetation-free bare gravel and sand banks, though the water flow is not so fast and strong and does not destroy the whole habitat, thus planted individuals should persist. We supposed that the sites fulfil the main criteria needed for the establishment of new populations: bare surfaces on fine-grained (silt, silt-sand mixture) deposits, poor in nutrients, humid and occasionally flooded sites. The sand sediments and fine gravel are substrates with favourable moisture conditions for the growth of dwarf cattail. In slowly flowing side arms or standing water beside of gravel and coarse sand, fine sand, silt and clay are deposited (Drescher, 2016). The research of geomorphology and hydrology on gravel and sand bars of the Drava River performed by Andrási & Kiss (2013), and Kiss & Andrási (2014) showed that in the past decades, conditions have been dramatically changed, and the most significant alterations were recorded on the upstream section of the Drava River, where hydroelectric power plants were built. These changes are in relation with the decrease in water level in the main riverbed and the lack of natural floods and deposits, both due to the operation of the HPP. Therefore, on the upper section of the Drava River, which is more exposed to the effects of HPPs, we could not find potential sites for reintroduction, and we presumed that the extinction of dwarf cattail is a consequence of human impacts on the Drava River.

Methods applied during reintroduction

The methods that we applied were selected based on experiences from previous reintroductions conducted in other European countries, especially in Austria, described in the literature and particularly according to the suggestions related to the conditions necessary for the survival of a viable population of this species. In the three years prior to the reintroduction of dwarf cattail (2015, 2016, 2017), the water level and water flow of the Drava River were low in March and April, therefore, the reintroduction was planned for this early spring period. According to the literature, the best time for the reintroduction of this species is the early spring (Flöss & Keel, 2004), after spring frosts but before the foliation. Therefore, the planting of dwarf cattail was carried out in early spring, at the end of March, except in 2024 when the planting was performed in May due to persistent high waters. Since the planting has been carried out only in the potentially suitable sites, in spring during a very short period (several days), no negative impact on other target species and habitats of the ecological network Natura 2000 site was expected.

In 2018, at the Forjanov siget site near Donja Dubrava (Fig. 3), the plants were planted in two groups of 50 individuals with about 50 meters between them and at dif-

ferent altitudes. At the Čićoka site near Legrad, the individuals of dwarf cattail were planted in smaller groups (25 each) but only a few meters apart. At the Ciglana site near Legrad, the pieces of rhizome were planted in two groups about 50 m apart at different altitudes. At the Đelekovec site (Lubenovac), the plants were planted in two groups about 100 m apart, but the difference in altitude was more than 2 m. During the second year of reintroduction in 2019, we reduced the planting sites and placed more plants in each site. In 2024, due to high water levels, we had to look for a new site (Šoderica) where, according to our estimates, the planting conditions were optimal, given the circumstances. We applied the following procedure to inventory and impact checks: In the field, the border lines of the planted area were measured by GPS and data transferred to GIS and marked in map on a scale 1: 2000.



Fig. 3. Planting of dwarf cattail on a sand bar at Forjanov siget site near Donja Dubrava in March 2018. (Photo by J. J. Purger)

After-monitoring plan

Some of the previous experiences suggest that reintroduced populations require regular inventory checks and monitoring (Camenisch, 1996, 1999). Outcome assessment and continued management are important since monitoring allows progressive improvement of understanding and, therefore, the development of more accurate models. Control of success of action of reintroduction was followed on three levels: by determining the presence/absence of plant individuals, by estimation, or by counting the number of shoots, and by measuring the height of individuals within the 1 m^2 sampling plots. As even the most detailed habitat assessments may not capture the full range of environmental variation during the lifespan of individuals, the loss of reintroduced individuals at some sites or in some years should be expected. In case of mortality of some reintroduced individuals, identifying the causes accurately and precisely can be critical in assessing progress and indicating the challenges facing the establishing population.

Causes of reintroduction outcome

Among the main factors which can potentially prevent the establishing of reintroduced plants are those connected with hydro-morphology, e.g, river regulation, extraction of gravels, hydro power plants, groundwater, and riverbed deepening.

These threatening effects could not be easily eliminated, though in the DRAVA LIFE project, other actions, e.g. restoration are in accordance with these aims. On the other hand, the potential danger of mechanical damage, trampling on sites where the target species was planted can be prevented by informing local people and by compiling a guide for tourists. The negative effects of shading and competitors during vegetation succession can also be eliminated by clearing the shading shrubs and trees.

The estimation of the success of the reintroduction proposed by Flöss & Keel (2004) was adapted to our project, and we formulated two goals: 1. To successfully establish two populations; 2. To successfully establish one population with at least 50 individuals. The action of reintroduction can be considered very successful - if both goals will be realized; successful - if one of our goals will be realized, and not successful - if neither of our goals will be realized.

RESULTS

In early spring of 2018, rooted plants of dwarf cattail, originated from the upper section of the Drava River in Austria, were planted on Forjanov siget and on selected sites near the Drava-Mura confluence (Čićoka, Ciglana and Lubenovac). The results of planting performed in 2018 (Tab. 1) showed that 68 plants (14%) survived after three months, while only 32 (6%) remained after nearly five months (Fig. 4). For almost three months after reintroduction, the gravel and sand bars were inaccessible due to unusually high water level and water discharge. The average of surface water discharge of the Drava River was higher every month in the first half of 2018 than the average for the last ten years (2015-2024), and the water discharge was extremely high in April and May 2018 (Fig. 4).

Tab. 1. Results of reintroduction of dwarf cattail during 2018.

Donja Dubrava (Forjanov siget)			**Planting**	**Control 1**	**Control 2**
Latitude °N	Longitude °E	Altitude m	30.03.2018	30.06.2018	21.08.2018
46.308944	16.838592	130	50	25	12
46.308422	16.838606	129	50	5	5
Total			100	30	17
Legrad (Čićoka)			**Planting**	**Control 1**	**Control 2**
Latitude °N	Longitude °E	Altitude m	30.03.2018	30.06.2018	12.08.2018
46.301472	16.874953	130	25	0	0
46.301447	16.874956	130	25	4	0
46.301419	16.874939	130	25	4	4
Total			125	8	4
Legrad (Ciglana)			**Planting**	**Control 1**	**Control 2**
Latitude °N	Longitude °E	Altitude m	30.03.2018	30.06.2018	12.08.2018
46.300389	16.874836	128	25	4	0
46.300383	16.874878	128	25	3	0
46.300354	16.875045	128	25	4	0
46.300450	16.874847	128	25	11	11
46.300333	16.875956	127	25	2	0
46.300353	16.875933	127	25	1	0
46.300328	16.875847	127	25	2	0
46.300303	16.875878	127	25	2	0
46.300303	16.875869	127	25	1	0
Total			225	30	11
Đelekovec (Lubenovac)			**Planting**	**Control 1**	**Control 2**
Latitude °N	Longitude °E	Altitude m	30.03.2018	30.06.2018	20.08.2018
46.279655	16.883195	131	25	0	0
46.280514	16.883468	128	25	0	0
Total			50	0	0

The second attempt of reintroduction was carried out on March 22, 2019. Approximately 500 dwarf cattail individuals were removed from the upper section of the Drava River in Austria (wider Greifenburg area, Carinthia) and on the same day transported to the reintroduction site in Croatia. They were planted at three sites (Tab. 2). During the first control, 132 vital individuals (26%) were counted (Tab. 2). During the second control, the number of surviving individuals (n = 60) was much smaller, only 12% of planted individuals (Fig. 4). Unfortunately, an unexpected event further reduced the success of our interventions, since most established plants on Forjanov siget were dug out by wild boars (*Sus scrofa*) and after a while, they dried out during autumn. At other sites, most of the plants were destroyed by high water levels, carried away by strong flood events or buried under a thick layer of sediment. Because of that, in the third control only a small number of plants survived (Fig. 5). We were unable to follow the further development of these plants for almost two years due to COVID-related restrictions. After that, during a survey in 2023, the dwarf cattail was not found in any locality where it had been reintroduced.

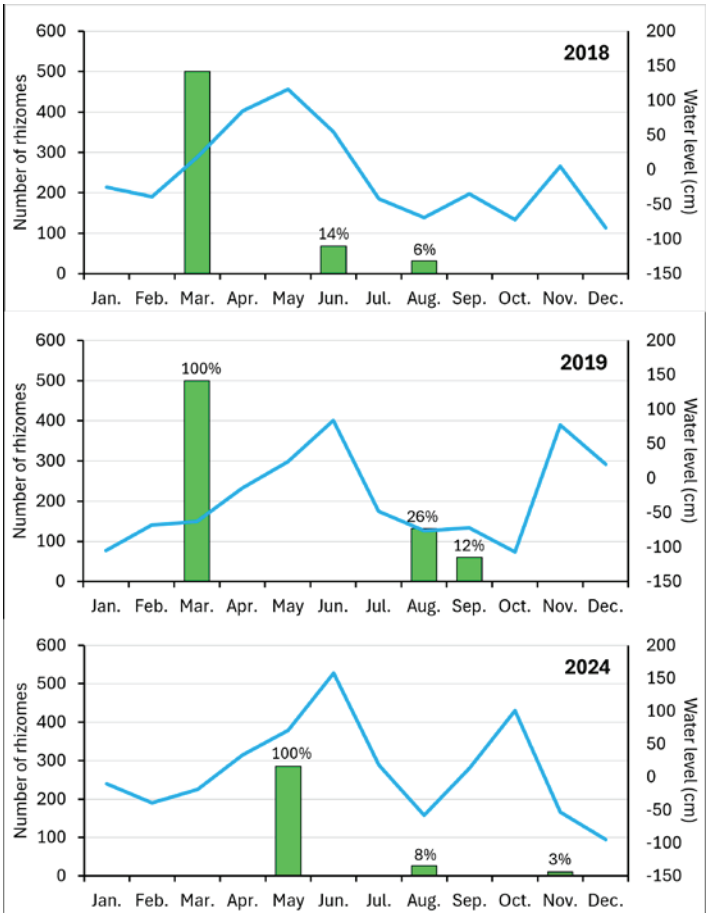


Fig. 4. The success of the reintroduction of dwarf cattail (green bars) and the average water level of the Drava River (blue line).

Tab. 2. Results of reintroduction of dwarf cattail on three sites in 2019.

Donja Dubrava (Forjanov siget)			**Planting**	**Control 1**	**Control 2**
Latitude °N	Longitude °E	Altitude m	22.03.2019	01.08.2019	05.10.2019
46.308711	16.837592	128	100	60	0
46.309086	16.838711	130	50	14	12
46.308978	16.838536	130	50	8	5
46.309064	16.838692	130	50	20	18
Total			250	102	35
Legrad (Sabolićev siget)			**Planting**	**Control 1**	**Control 2**
Latitude °N	Longitude °E	Altitude m	22.03.2019	01.08.2019	05.10.2019
46.297722	16.877978	128	50	20	20
46.298150	16.879019	129	50	7	2
46.297839	16.878389	128	50	0	0
Total			150	27	22
Đelekovec (Lubenovac)			**Planting**	**Control 1**	**Control 2**
Latitude °N	Longitude °E	Altitude m	22.03.2019	01.08.2019	05.10.2019
46.280150	16.883408	130	25	0	0
46.280211	16.883436	129	25	0	0
46.280219	16.883442	129	25	0	0
46.280603	16.883139	127	25	3	3
Total			100	3	3



Fig. 5. Dwarf cattails during the summer control in August 2019. (Photo by J. J. Purger)

An additional attempt of reintroduction was performed in the spring of 2024. We acquired pieces of dwarf cattail rhizome (Tab. 3), which were collected in the upper section of the Drava River in Austria, then transported and stored in a cool room until

the planting on the Drava in Croatia. In the third reintroduction attempt, out of 285 plants, 24 survived for three months (8%), and 10 plants for five months (3%). During the control in August of the same year, at two sites, all plants were destroyed by wild boars, and in third site, some of the plants survived. More than half of the surviving plants disappeared after the high waters in October (Fig. 6). In the first half of 2024, the water level and water discharge were much higher than the last 10-years average, and their values in June and October were extremely high (Fig. 4).

According to the results of monitoring, out of the total of 1285 plants, most of the plants (83%) did not survive long-term floods; they were buried by sediments or carried away by strong water currents. From the 17% of plants that survived the floods, 9% were dug up by wild boars. Only about 8% of the plants survived until the end of the year in which they were planted.

Tab. 3. Results of reintroduction of dwarf cattail in 2024.

Legrad (Šoderica)			**Planting**	**Control 1**	**Control 2**
Latitude °N	Longitude °E	Altitude m	05.05.2024	09.08.2024	09.11.2024
46.258032	16.919700	122	12	0	0
46.257930	16.920045	122	44	0	0
46.257599	16.920348	123	50	10	3
46.257686	16.920411	122	69	2	2
46.257268	16.919233	124	110	10	5
Total			285	24	10



Fig. 6. Dwarf cattails after the autumn flood in November 2024. (Photo by J. J. Purger)

DISCUSSION

Our attempts to reintroduce dwarf cattail on the Drava River in Croatia have demonstrated a very low plant survival rate. Within the first 3-4 months, less than a quarter of the reintroduced plants survived. Based on these results, the reintroduction effort was unsuccessful, since we could not achieve our aims to establish at least one new viable population. Despite the poor success of the attempt of reintroduction, our observations and conclusions provide valuable insight for the planning and implementing of future plant reintroduction projects (Godefroid *et al*., 2011).

The primary cause of reintroduction failure appears to be abiotic factors, particularly the extremely dynamic hydro-morphological conditions on the site. Many plants were washed away by strong currents or buried under sediment deposits. Results of geomorphological and hydrological studies conducted in recent decades, supported by quantitative data, confirm that rapid changes in fluvial morphology, sediment transport, and hydrologycal characteristics of the Drava River have been driven by human activities, such as river regulation and operation of hydroelectric power plants (e.g. Bonacci *et al*., 1992; Bonacci & Oskoruš, 2010; Kiss *et al*., 2011; Kiss & Andrási, 2011, 2015; Kiss & Balogh, 2015). Following the construction of the reservoirs and dams with hydropower plants (HPPs) (Varaždin, Čakovec and Dubrava) the water levels of the Drava River changed, became lower and at the same time the duration of floods (the number of flood days) decreased. Kiss (2014) even reconstructed river morphology changes and island development over 125-year period (1882 – 2007) on the Drava River near Donja Dubrava (215-225 rkm). This series of evidence of hydro-morphological changes caused by river engineering works (e.g. dams, groins, grade control structures) help explain the disappearance of some rare keystone species in the last decades from the gravel- and sand bars. Similar experiences were reported by Whisenant (1999). Further supporting evidence suggests that the recent retraction of dwarf cattail distribution is primarily due to river regulation and diminished morpho-dynamic activity, which would normally create open patches suitable for germination and development of seedlings (Baur *et al*., 2017; Grabher & Aschauer 2017). The channelization and regulation over the last century have severely degraded the structure, diversity, and ecological function of riparian habitats (Bejarano *et al*., 2018; Popoff *et al*., 2021b).

Biotic factors may have also contributed to reintroduction failure. Wild boar activity that further hindered success of reintroduction was confirmed in the case of DRAVA LIFE related study where, in the months following the reintroduction activities, after floods, the rooting activity of wild boars caused the destruction of plants and effected the further losses on all sites. Similar impacts were reported by Whisenant (1999) and Arrington *et al*. (1999).

The outcome of our reintroduction effort underscores the obvious need to harmonize actions of species reintroductions with broader river restoration initiatives that aim to re-establish near-natural hydrodynamic processes of the Drava River (Šafarek, 2012). While earlier river restoration efforts focused mainly on physical (hydrological and geomorphological) aspects, more recent nature conservation strategies fully involve ecological criteria, including restoring habitat heterogeneity and, biodiversity (Nienhuis *et al*., 2002). The ecological functionality of the riverine ecosystem should be increased by river restoration and improved hydropower dam operation management. Reintroduction of sensitive indicator species, as dwarf cattail should be closely integrated with such efforts, particularly in areas where habitat quality can support their long-term survival.

Effective reintroduction requires continuous monitoring to assess reproductive success, including collecting field data on propagules production, seedling survival, and establishment to reproductive age. Dwarf cattail may not flower for several years under suboptimal conditions, sometimes requiring up to four years to develop from seedlings to flowering stage (Csencsics & Müller, 2015). In contrast, environmental hydro-morphological changes in the Drava riverbed are fast and rapid, often preventing long-term population establishment.

The effects of fluvial dynamics are much smaller in side branches compared to the main riverbed; therefore, future reintroduction efforts should be focused on newly restored side branches of the Drava River (Grđan & Kereša, 2003; Parrag & Lóczy 2019). Moreover, the newly exposed bare surfaces following river restoration could serve as suitable colonization sites for pioneer species, such as dwarf cattail (Purger & Csiky, 2013; Schletterer *et al*., 2024).

However, the overharvesting of individuals from the few natural habitat (e.g. upper section of the Drava River in Austria) could threaten the survival of that population. Therefore, the success of the reintroductions could be improved by propagation of plants from seeds in nursery – established in Croatia or Hungary – may offer a more sustainable source for future reintroductions (Gorbunov *et al*., 2008, Popoff *et al*., 2023a; Purger, 2024). The use of data loggers to monitor environmental variables at both nursery and reintroduction sites is recommended to guide adaptive management (Wild *et al*., 2019). Additionally, the testing of wild animal deterrents (e.g. repellents) should be considered to protect young plants from biotic disturbances such as wild boar rooting, particularly post flood (Schlageter & Haag-Wackernagel, 2012).

Knowledge of the complex effects of abiotic and biotic pressures and applying lessons learned from past attempts, is essential for improving future reintroduction success of dwarf cattail (e.g. Popoff *et al*., 2021b). The failure of dwarf cattail reintroduction reflects the incomplete restoration of riverine ecosystems along the Drava. Improving habitat conditions through enhanced river dynamics and sediment processes could support not only survival of dwarf cattail, but also promote broader riparian biodiversity. The successful establishment of this sensitive species would serve as a strong indicator of restored river dynamics and ecological integrity as well as natural values of the Drava River.

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