

Habitat establishment, captive breeding and conservation translocation to save threatened populations of the Vulnerable European mudminnow *Umbra krameri*

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TABLE S1 Pre-stocking values of water quality parameters and coverage of macrophytes in Illés Ponds (Fig. 1) and their reference ranges based on literature data (Geyer, 1940; Sterbetz, 1963; Keresztessy, 1995; Povž, 1995a; Wanzenböck & Spindler, 1995; Májský & Hajdú, 2004; Sallai, 2005; Sekulić et al., 2013; Keckeis & Sehr, 2014; Pekárik et al., 2014; Sallai & Müller, 2014) and our measurements at various native habitats (sites 1–10, Table 1). Values in bold are outside the range of natural habitats.

	Date of sampling	pH	Conductivity ($\mu\text{S cm}^{-1}$)	O ₂ (mg l ⁻¹)	PO ₄ -P (mg l ⁻¹)	NH ₄ ⁺ (mg l ⁻¹)	NO ₂ ⁻ (mg l ⁻¹)	NO ₃ ⁻ (mg l ⁻¹)	% coverage of macrophytes (Dominant taxa)
Illés Pond I (Created July 2008)	May 2010	7.8	1,120	1.1	0.8	0.20	0.35	20.0	1 (<i>Ceratophyllum demersum</i> , planted)
Illés Pond II (Created July 2008)	June 2010	7.5	1,600	1.2	0.9	0.25	0.02	6.0	0.9 (<i>Lemna trisulca</i> , occurring naturally) ¹
Illés Pond III (Created July 2009)	Sep. 2010	7.4	870		1.0	0.10	0.05	0.5	65 (<i>Ceratophyllum demersum</i> , planted)
Illés Pond IV (Created July 2009)	May 2010	7.6	1,050	1.7	0.3	0.10	0.12	26.0	95 (<i>Chara</i> sp., occurring naturally)
Illés Pond V (Created Sep. 2010)	Aug. 2012	7.6	690	3.2	0.4	0.30	0.60	5.0	0 ²
Illés Pond VI (Created Sep. 2010)	Aug. 2011	n.a.	820	9.9	0.3	0.05	0.01	1.0	52 (<i>Ceratophyllum demersum</i> , planted)
Range of natural habitats		6.4–9.2	182–1,180	0.3–12.7	0.0–1.3	0.01–0.50	0.00–0.23	0.0–35.0	0–100

¹We observed a rapid increase in the abundance of cyanobacteria and sulphur bacteria during August.

²We observed planktonic algal bloom.

TABLE S2 Abundance and number of taxa of macroinvertebrates in samples collected in natural habitats of the European mudminnow *Umbra krameri* in Hungary (Fig. 1) in summer.

Sites	Date of sampling	Abundance of macroinvertebrates per sample (No. of taxa)
Pócos Pond A, site 8	June 2008	119 (12)
Pócos Pond B, site 9	June 2009	71 (17)
	June 2012	38 (12)
Ócsa Landscape Protection Area, site 3	June 2008	48 (9)
Gőgő-Szenke Stream, site 10a	June 2010	(27)*
Gőgő-Szenke Stream, site 10b	May 2009	134 (24)
Felső-Tápió Stream, site 4	June 2009	196 (19)
Hejő main channel, site 12a	June 2007	78* (16)*
Hejő main channel, site 12b	June 2007	43* (15)*
Pocsaji-láp Nature Reserve, site 13	June 2010	(26)
Zala-Somogy-Canal, site 14	June 2007	232* (19)*
Range		38–232 (9–27)
Mean		107 (18)

*Data from the Hungarian Ministry of Agriculture

TABLE S3 Pre-stocking abundance and number of taxa of macroinvertebrates in the artificially created Illés Ponds (Fig. 1). Values in bold are outside the range of natural habitats.

	Date of sampling	Abundance of macroinvertebrates per sample (No. of taxa)
Illés Pond I	June 2009	149 (18)
Illés Pond II	June 2012	38 (12)
Illés Pond III		Not available ¹
Illés Pond IV	May 2010	65 (18)
Illés Pond V	June 2012	323 (19)
Illés Pond VI	June 2011	98 (14)
Range of natural habitats ²		38–232 (9–27)
Mean value of natural habitats*		107 (17)

¹The stored sample was damaged.

²Reference values from Table S2

TABLE S4 Post-stocking values of water quality parameters and maximum % coverage of macrophytes in Illés Ponds during 2011–2013, and their reference ranges for natural habitats (Table S1). Values in bold are outside the range of natural habitats.

	Date of sampling	pH	Conductivity ($\mu\text{S cm}^{-1}$)	O ₂ (mg l^{-1})	PO ₄ -P (mg l^{-1})	NH ₄ ⁺ (mg l^{-1})	NO ₂ ⁻ (mg l^{-1})	NO ₃ ⁻ (mg l^{-1})	Max. % coverage of macrophytes (Dominant taxa)
Illés Pond I	Feb.–Aug. 2011	7.9–8.9	620–1,040	7.8–8.4	0.5– 1.8	0.05–0.15	0.07–0.17	13.0–25.0	0
Illés Pond II*	Feb.–Aug. 2011	7.3–8.5	600– 1,730	2.0–9.6	0.1– 3.0	0.05– 6.00	0.01–0.15	0.5–5.0	0
Illés Pond III	July, Aug. 2012; Mar. 2013	7.0–8.2	540–720	2.1–2.4	0.1–0.6	0.05–0.10	0.01–0.02	0.5–0.5	100 (<i>Ceratophyllum demersum</i> , planted)
Illés Pond IV	July, Aug. 2012; Mar. 2013	7.3–8.0	780–810	1.8–2.0	0.1–0.2	0.05–0.05	0.01–0.01	0.3–24.0	95 (<i>Chara</i> sp., occurring naturally)
Illés Pond V*	Mar., Aug. 2013	7.3–7.3	870–1,130		0.1–0.3	0.05–0.25		0.5–4.0	0
Illés Pond VI	July, Aug. 2012; Mar. 2013	7.3–7.4	830–980	2.1–2.8	0–1.0	0.10–0.10	0.01–0.02	0.5–1.0	75 (<i>Ceratophyllum demersum</i> , planted)
Range of natural habitats		6.4–9.2	182–1,180	0.3–12.7	0.0–1.3	0.01–0.50	0.00–0.23	0.0–35.0	0–100

Pre-stocking monitoring of Illés Ponds II and V revealed poor water quality and therefore these ponds were not stocked with European mudminnow, although we continued to monitor them.

TABLE S5 Post-stocking abundance and number of taxa of macroinvertebrates in the artificially created Illés Ponds. Values in bold are outside the range of natural habitats.

	Date of sampling	Abundance of macroinvertebrates per sample (No. of taxa)
Illés Pond I	June 2012	150 (14)
Illés Pond II ¹	May 2015	52 (8)
Illés Pond III	June 2012	73 (18)
Illés Pond IV	June 2012	62 (15)
Illés Pond V ¹	May 2015	104 (7)
Illés Pond VI	June 2012	98 (14)
Range of natural habitats ²		38–232 (9–27)
Mean value of natural habitats ²		107 (17)

¹ Illés Ponds II and V were not stocked with European mudminnow but their monitoring continued.

² Reference values from Table S2



PLATE S1 The European mudminnow *Umbra krameri* is categorized as Vulnerable on the IUCN Red List on the basis of its restricted and fragmented habitat. (credit: Csaba Posztós)



PLATE S2 One of the greatest threats to the survival of the European mudminnow is the invasive Chinese sleeper *Perccottus glenii*, which has colonized almost the entire Carpathian Basin. (credit: Zoltán Sallai)



PLATES S3 & S4 Pollution (left) and the resulting hypertrophication (right) at one of the habitats of the European mudminnow, the Gögő-Szenke Stream. During the vegetation period the water surface is covered by a thick layer of common duckweed *Lemna minor*, which was dredged on the bank during spring and autumn 2010. (credits: Sándor Tatár)



PLATE S5 Saving European mudminnows from Gógó-Szenke Stream in spring 2010. (credit: Sándor Tatár)



PLATE S6 Fish breeding vessel containing 172 individuals of 1-day-old European mudminnow larvae. (credit: Sándor Tatár)



PLATE S7 10-day-old larva that has been feeding for 2 days. (credit: Posztós Csaba)



PLATE S8 Captive-bred European mudminnows. (credit: Tamás Müller)



PLATE S9 Creation of Illés Pond I in Szada Pilot Area (July 2008). (credit: Sándor Tatár)



PLATE S10 Planting of aquatic macrophytes in a surrogate habitat. (credit: Sándor Tatár)



PLATES S11 & S12 Stocking of captive bred crucian carp *Carassius carassius* and weatherfish *Misgurnus fossilis* to test survival in new habitats. (credits: Sándor Tatár)



PLATE S13 The first stocking of European mudminnow in Szada Pilot Area (31 May 2010). (credit: Sándor Tatár)



PLATE S14 Stocking of mudminnow by local students in Szada Pilot Area. (credit: Tamás Müller)



PLATE S15 Captive-bred mudminnows before stocking. (credit: Sándor Tatár)



PLATE S16 Reinforcement of natural population by stocking of captive-bred mudminnows in Csupics Island (June 2012). (credit: Sándor Tatár)



PLATE S17 Electric fishing in Illés Pond I. (credit: Sándor Tatár)



PLATE S18 Three generations together in the Illés Ponds: saved parent fish, captive-bred and released individuals, and offspring born in the new habitat. (credit: Sándor Tatár)



PLATE S19 In 2011 the densely vegetated Illés Pond III had a considerable natural progeniture. (credit: Sándor Tatár)





PLATE S20 Changes of alternative stable states in Illés Pond I during 2008–2015. Photographs were taken in summer, except in 2014 (spring). 2008a: the selected areas for creating surrogate habitats were dominated by *Solidago* species before ponds were established; 2008b, the creation of the pond; 2009–2011, dominance of *Cladophora* sp.; 2012, cyanobacterial dominance (turbid state); 2013–2015, submerged macrophyte (*Utricularia vulgaris*) dominance (clear state). (credits: Sándor Tatár)





PLATE S21 Alternative stable states in surrogate habitats of Szada Pilot Area. (a & b) Clear state with dominance of submerged macrophyte *Ceratophyllum demersum* (Illés Pond III, VI). (c & d) Clear state with *Utricularia vulgaris* (Illés Pond I). (e & f) Clear state with *Chara* sp. (Illés Pond IV, VII). (g) Cyanobacterial dominance (turbid state; Illés Pond II). (h) Sulphur and iron bacterial dominance, with turbid surface (Illés Pond VIII). (i) Dominance of *Cladophora* sp., with low density of phytoplankton (Illés Pond V). (j) Dominance of floating plants, with low density of phytoplankton (*Lemnetum trisulcae* association) in Illés Pond II. (credits: Sándor Tatár)

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