**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; Májsky & 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 ($\mu S\ cm^{-1}$) | $O_2$ ($mg\ l^{-1}$) | $PO_4$–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 (*Ceratophyllum demersum*, 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 ( *Lemna trisulca*, occurring naturally)[1] |
| Illés Pond III (Created July 2009) | Sep. 2010 | 7.4 | 870 | | 1.0 | 0.10 | 0.05 | 0.5 | 65 (*Ceratophyllum demersum*, planted) |
| Illés Pond IV (Created July 2009) | May 2010 | 7.6 | 1,050 | 1.7 | 0.3 | 0.10 | 0.12 | 26.0 | 95 (*Chara* 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 (*Ceratophyllum demersum*, 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 |

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

[2] We 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) |

[1] The stored sample was damaged.
[2]Reference 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 ($\mu S\ cm^{-1}$) | $O_2$ ($mg\ l^{-1}$) | $PO_4$–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 (*Ceratophyllum demersum*, 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 (*Chara* 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 (*Ceratophyllum demersum*, 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 Gőgő-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 Gőgő-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 fising 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)


2008a


2008b


2009


2010


2011


2012

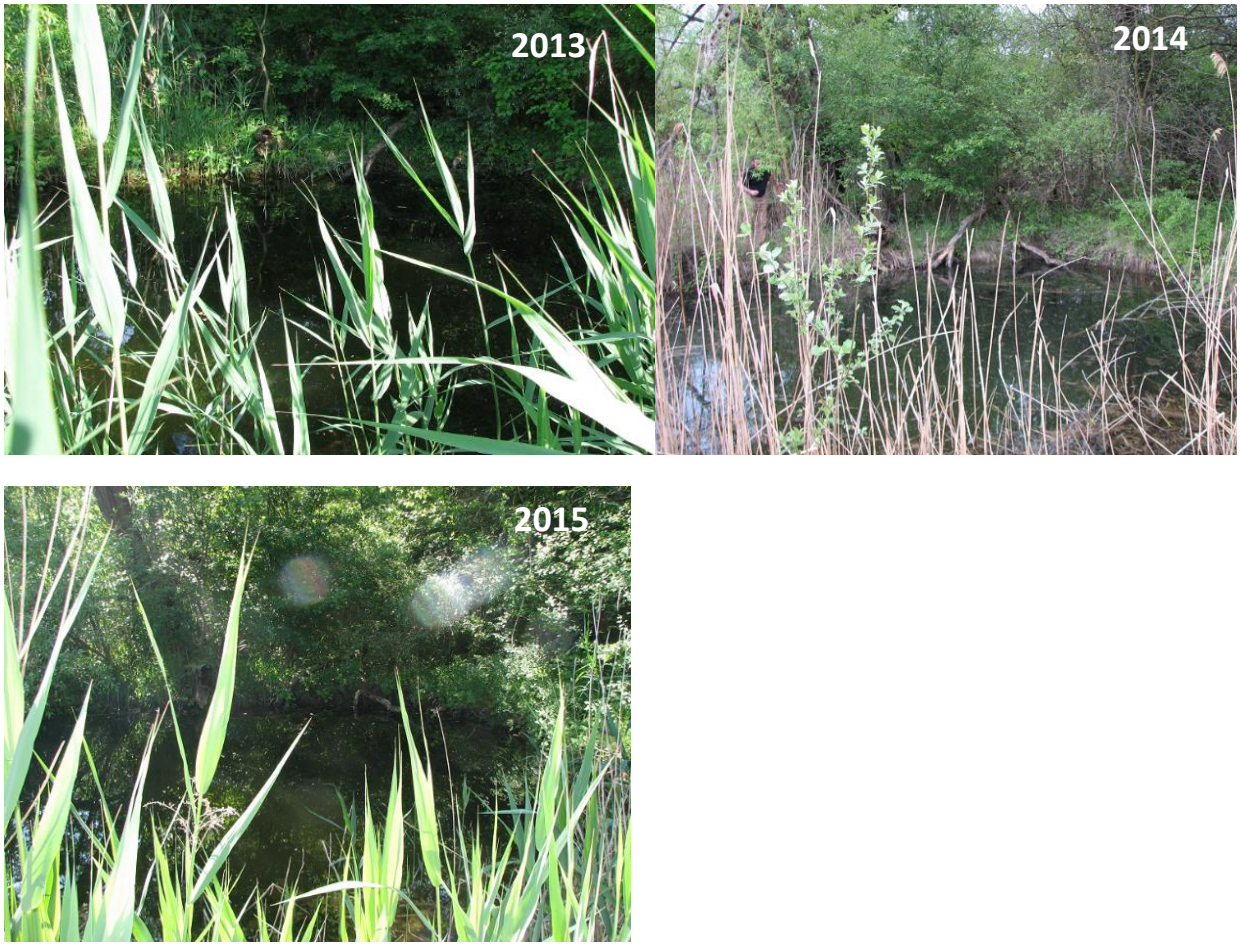


PLATE S20 Changes of alternative stable states in Illés Pond I during 2008–2015. Photographs were taken in summer, except in 2014 (spring). 2008a: the selected areas for creating surrogate habitats were dominated by *Solidago* species before ponds were established; 2008b, the creation of the pond; 2009–2011,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


(a)


(b)


(c)


(d)


(e)


(f)





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)

## References


GEYER, F. (1940) Der ungarische Hundsfisch *(Umbra lacustris* Grossinger). *Zeitschrift für Morphologie und Ökologie der Tiere*, 36, 745–811.

KECKEIS, H. & SEHR, M. (2014) Vorkommen und Verteilung des Hundsfisches (*Umbra krameri*, Walbaum, 1792) im Fadenbach im Bereich Mannsdorf an der Donau bis Witzelsdorf. *Wissenschaftliche Reihe Nationalpark Donau-Auen*, 36, 1–67.

KERESZTESSY, K. (1995) Recent fish faunistical investigations in Hungary with special reference to *Umbra krameri* Walbaum, 1792 (Pisces: Umbridae). *Annalen des Naturhistorischen Museums in Wien*, 97, 458–465.

MÁJSKY, J. & HAJDÚ, J. (2004) *Program Záchrany Blatniaka Tmavého (Umbra krameri Walbaum, 1792)*. Správa CHKO Dunajské luhy. [In Slovak].

PEKÁRIK, L., HAJDÚ, J. & KOŠČO, J. (2014) Identifying the key habitat characteristics of threatened European mudminnow (*Umbra krameri* Walbaum 1792). *Fundamental and Applied Limnology*, 184, 151–159.

POVŽ, M. (1995a) Discovery, distribution, and conservation of mudminnow *Umbra krameri* Walbaum, 1792, in Slovenia (Pisces: Umbridae). *Annalen des Naturhistorischen Museums in Wien*, 97, 478–485.

SALLAI, Z. (2005) A lápi póc (*Umbra krameri*) magyarországi elterjedése, élőhelyi körülményeinek és növekedési ütemének vizsgálata a kiskunsági Kolon-tóban. In *A Puszta* (ed. T. Barna), pp. 113–172. Nimfea Természetvédelmi Egyesület, Túrkeve, Hungary. [In Hungarian]

SALLAI, Z. & MÜLLER, T. (2014) A lápi póc. In Veszélyeztetett lápi halak megóvása (lápi póc, réticsík, széles kárász) (ed. T. Müller), pp. 11–84. Vármédia Print Kft, Gödöllő, Hungary. [In Hungarian].

SEKULIĆ, N., MARIĆ, S., GALAMBOS, L., RADOŠEVIĆ, D. & KRPO-ĆETKOVIĆ, J. (2013) New distribution data and population structure of the European mudminnow *Umbra krameri* in Serbia and Bosnia and Herzegovina. Journal of Fish Biology, 83, 659–666.

STERBETZ, I. (1963) Adatok a lápi póc (*Umbra krameri* WALBAUM) és a tarka géb (Proterorhinus marmoratus PALLAS) kárpát-medencei elterjedéséhez. Vertebrata Hungarica, 5, 15–18. [In Hungarian]

WANZENBÖCK, J. & SPINDLER, T. (1995) Rediscovery of *Umbra krameri* WALBAUM, 1792, in Austria and subsequent investigations. *Annalen des Naturhistorischen Museums in Wien*, 97, 450–457.